UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,917,304 B1
DATED : July 12, 2005
INVENTOR(S) : Barabara L. Jones et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title page,
Item [56], **References Cited**, add:
-- OTHER PUBLICATIONS
3G TS 23.127 1.0.0 (1990-10) 3rd Generation Partnership project; Technical Specification Group Services and System Aspects; Virtual Home Environment/Open Service Architecture --.

Column 7,
Line 51, "Packer-switching" should be -- packet-switching --.

Column 8,
Line 5, "(NVB)" should be -- (NVH) --.
Line 47, "claim" should be -- data --.
Line 48, "best" should be -- host --.

Signed and Sealed this

Sixth Day of September, 2005

Jon W. Dudas

JON W. DUDAS
Director of the United States Patent and Trademark Office

JUL 29 2005
PATENT & TRADEMARK OFFICE

09/402262 **Attorney Docket: 444200 (14,442)** CofC

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Patentee: Snap-on Equipment Limited

Title: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

Patent No.: 6,917,304 B1

Issue Date: July 12, 2005

Date: July 27, 2005

Certificate
AUG 05 2005
of Correction

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REQUEST FOR CERTIFICATE
OF CORRECTION UNDER RULE 322

Sir:

Enclosed herewith is a duplicate of a proposed "Certificate of Correction," entry of which is requested. It is believed that a Certificate of Correction is needed since errors were made in the References Cited and in the claims.

Respectfully submitted,

Harold V. Stotland
SEYFARTH SHAW LLP
Attorneys for Assignee
55 E. Monroe Street - 42nd Floor
Chicago, Illinois 60603-5803
312-346-8000

AUG 08 2005

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO: 6,917,304 B1

DATED: July 12, 2005

INVENTOR(S): Barbara L. Jones et al

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Item [56] References Cited

Add other publications --**3G TS 23.127 1.0.0 (1990-10) 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Virtual Home Environment/Open Service Architecture**--.

Column 7

Claim 4, line 51; "**packer-switching**" should be --**packet-switching**--.

Column 8

Claim 9, line 5; "**(NVB)**" should be --**(NVH)**--.

Claim 16, line 47; "**claim**" should be --**data**--.

Claim 16, line 48; "**best**" should be --**host**--.

MAILING ADDRESS OF SENDER:

Patent No. 6,917,304

Harold V. Stotland
SEYFARTH SHAW LLP
55 E. Monroe Street - 42nd Floor
Chicago, Illinois 60603-5803

AUG 0 8 2005

APPLICANT: Snap-on Equipment Limited

PATENT NO.: 6,917,304

ISSUE DATE: July 12, 2005

ENTITLED: **WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM**

CERTIFICATE OF FIRST CLASS MAILING

DATE OF DEPOSIT: **July 27, 2005**

I hereby certify that the attached paper (along with any paper referred to as being attached or enclosed) is being deposited with the United States Postal Service First Class Mail on the date indicated above and is addressed to CERTIFICATE OF CORRECTIONS BRANCH, Commissioner for Patents, Box 1450, Alexandria, VA. 22313-1450.

Consuelo Henry
(Name of person mailing paper)

(Signature of person mailing paper)

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail

Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

or Fax (703) 746-4000

OIPE
MAY 0 9 2005
PATENT & TRADEMARK OFFICE

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

27717 7590 02/11/2005

SEYFARTH SHAW
55 EAST MONROE STREET
SUITE 4200
CHICAGO, IL 60603-5803

05/10/2005 GWORDOF2 00000003 09402262

01 FC:1501 1400.00 OP

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (703) 746-4000, on the date indicated below.

Carolyn Wilson	(Depositor's name)
Carolyn Wilson	(Signature)
May 6, 2005	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/402,262	02/28/2000	BARBARA L. JONES	14.442	5719

TITLE OF INVENTION: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$0	$1400	05/11/2005

EXAMINER	ART UNIT	CLASS-SUBCLASS
DANG, HUNG Q	2635	340-870110

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Seyfarth Shaw LLP
2 ____
3 ____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Snap-on Equipment Limited

(B) RESIDENCE: (CITY and STATE OR COUNTRY): King's Lynn, Norfolk, United Kingdom

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are enclosed:

☒ Issue Fee

☐ Publication Fee (No small entity discount permitted)

☐ Advance Order - # of Copies ____

4b. Payment of Fee(s):

☒ A check in the amount of the fee(s) is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☒ The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number 19-1351 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27. ☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

The Director of the USPTO is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.
NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature Harold V. Stotland Date 5/6/05

Typed or printed name Harold V. Stotland Registration No. 24,492

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

SEYFARTH SHAW LLP
ATTORNEYS

Writer's direct phone
312-269-8971
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55 East Monroe Street
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312-346-8000
fax 312-269-8869
www.seyfarth.com

ATLANTA BOSTON CHICAGO HOUSTON LOS ANGELES NEW YORK SACRAMENTO SAN FRANCISCO WASHINGTON, D.C. BRUSSELS

May 6, 2005

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

CUSTOMER NO. 27717

Re: Snap-on - Matter No. 444200
Application for Patent for: WIRELESS MULTIPLEX
DATA TRANSMISSION SYSTEM
Application No. 09/402,262

Sir:

Transmitted for filing herewith are Issue Fee Transmittal form, check in the amount of $1,400 in payment of the issue fee and return postcard.

Please charge any additional fees or credit any overpayment to Deposit Account No. 19-1351.

Sincerely yours,

SEYFARTH SHAW LLP

Harold V. Stotland

HVS:cw
CH1 10895160.1

CERTIFICATE OF MAILING

I hereby certify that, on 5/6/05, this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Mail Stop Issue Fee, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Carolyn Wilson

Issue Classification	Application No. 09/402,262	Applicant(s) JONES ET AL.	
	Examiner Hung Q Dang	Art Unit 2635	

ISSUE CLASSIFICATION

ORIGINAL		CROSS REFERENCE(S)							
CLASS	SUBCLASS	CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)						
340	855.3	370	538						
INTERNATIONAL CLASSIFICATION		73	117.3						
G01V	3/34								
	/								
	/								
	/								
	/								

Hung Dang 2/2/05
(Assistant Examiner) (Date)

MICHAEL HORABIK
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2600
2/7/05
(Primary Examiner) (Date)

J Williams 2/8/05
(Legal Instruments Examiner) (Date)

Total Claims Allowed: 21

O.G. Print Claim(s)	O.G. Print Fig.
1	1

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1		31		61		91		121		151		181
2	2		32		62		92		122		152		182
3	3		33		63		93		123		153		183
	4		34		64		94		124		154		184
4	5		35		65		95		125		155		185
5	6		36		66		96		126		156		186
6	7		37		67		97		127		157		187
7	8		38		68		98		128		158		188
8	9		39		69		99		129		159		189
9	10		40		70		100		130		160		190
10	11		41		71		101		131		161		191
11	12		42		72		102		132		162		192
12	13		43		73		103		133		163		193
13	14		44		74		104		134		164		194
14	15		45		75		105		135		165		195
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17	19		49		79		109		139		169		199
18	20		50		80		110		140		170		200
19	21		51		81		111		141		171		201
20	22		52		82		112		142		172		202
21	23		53		83		113		143		173		203
	24		54		84		114		144		174		204
	25		55		85		115		145		175		205
	26		56		86		116		146		176		206
	27		57		87		117		147		177		207
	28		58		88		118		148		178		208
	29		59		89		119		149		179		209
	30		60		90		120		150		180		210

UNITED STATES DEPARTMENT OF COMMERCE
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NOTICE OF ALLOWANCE AND FEE(S) DUE

27717 7590 02/11/2005

SEYFARTH SHAW
55 EAST MONROE STREET
SUITE 4200
CHICAGO, IL 60603-5803

EXAMINER	
DANG, HUNG Q	
ART UNIT	PAPER NUMBER
2635	

DATE MAILED: 02/11/2005

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/402,262	02/28/2000	BARBARA L. JONES	14.442	5719

TITLE OF INVENTION: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$0	$1400	05/11/2005

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (Rev. 12/04) Approved for use through 04/30/2007.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail** **Mail Stop ISSUE FEE**
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P.O. Box 1450
Alexandria, Virginia 22313-1450
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CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

27717 7590 02/11/2005

SEYFARTH SHAW
55 EAST MONROE STREET
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CHICAGO, IL 60603-5803

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Certificate of Mailing or Transmission

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(Depositor's name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/402,262	02/28/2000	BARBARA L. JONES	14.442	5719

TITLE OF INVENTION: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1400	$0	$1400	05/11/2005

EXAMINER	ART UNIT	CLASS-SUBCLASS
DANG, HUNG Q	2635	340-870110

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 ____________
2 ____________
3 ____________

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are enclosed:

☐ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies ____________

4b. Payment of Fee(s):

☐ A check in the amount of the fee(s) is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The Director is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number ____________ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

☐ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.
☐ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

The Director of the USPTO is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.
NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature ____________ Date ____________

Typed or printed name ____________ Registration No. ____________

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/402,262	02/28/2000	BARBARA L. JONES	14.442	5719

27717 7590 02/11/2005

SEYFARTH SHAW
55 EAST MONROE STREET
SUITE 4200
CHICAGO, IL 60603-5803

EXAMINER	
DANG, HUNG Q	
ART UNIT	**PAPER NUMBER**
2635	

DATE MAILED: 02/11/2005

Determination of Patent Term Extension under 35 U.S.C. 154 (b)

(application filed after June 7, 1995 but prior to May 29, 2000)

The Patent Term Extension is 0 day(s). Any patent to issue from the above-identified application will include an indication of the 0 day extension on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Extension is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571) 272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (703) 305-8283.

PTOL-85 (Rev. 12/04) Approved for use through 04/30/2007.

Notice of Allowability	**Application No.** 09/402,262	**Applicant(s)** JONES ET AL.	
	Examiner Hung Q Dang	**Art Unit** 2635	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *12/14/2004*.

2. ☒ The allowed claim(s) is/are *1-3,5-15 and 17-23*.

3. ☒ The drawings filed on *01 October 1999* are accepted by the Examiner.

4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
   1. ☒ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

6. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
   1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO-1449 or PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application (PTO-152)
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☒ Examiner's Statement of Reasons for Allowance
9. ☐ Other _____.

DETAILED ACTION

1. This communication is in response to applicant's claims amendment received on 12/14/2004. The amended claims 1, 6-10, 12, 13, 18-20, 23 and the cancellation of claims 4 and 16 have been entered.

Response to Arguments

2. Applicant's arguments with respect to claims 1 and 13 have been fully considered and are persuasive. The rejections of claims 1 and 13 have been withdrawn.

The objections of claims 6-12 and 18-23 have been withdrawn.

Allowable Subject Matter

3. Claims 1-3, 5-15 and 17-23 are allowed.

Regarding claim 1, the prior arts of record fail to teach or disclose a method for wireless transmission of data in digital and/or analogue format through a communication channel from at least two data sensors to a data processing means as claimed in claim 1. Said method comprises the step dividing said communication channel into asymmetrical sub-channels, whereby the data carrying capacities of said sub-channels are unequal; and the data rate required for data transmission from said local sensors are different between said at least two sensors; and allocating data from said local data sensors to respective ones or groups of said sub-channels in accordance with the data carrying capacities of said sub-channels.

Regarding claim 13, the prior arts of record fail to teach or disclose an apparatus for wireless transmission of data in digital/analog format through a communication channel from at least two local data sensors to a data processing means; said apparatus comprises a multiplexer adapted to asymmetrically subdivide said communication channel into sub-channels, wherein said sub-channels having unequal data carrying capacities. Said apparatus also comprises a control means adapted to allocate data from said local sensors to said sub-channels in accordance with different data rate requirements from said local sensors.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Hung Q Dang whose telephone number is (571) 272-3069. The examiner can normally be reached on 9:30AM-6PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Michael Horabik can be reached on (571) 272-3068. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

HD

MICHAEL HORABIK
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2600

Michael Horabik

Attachment A

ALLOWANCE HOT LIST

Appl. No. 09/402262 Prepared by Williams
Examiner-TC Dang-2635 Date 2/8/05

JACKET:

YES NO Primary Examiner box complete.
YES NO Issuing Classification complete.

PTO-892/1449:

YES NO Examiner's initials or cross-through lines supplied for each item cited by applicant.
YES NO Date(s) supplied/complete on all PTO-1449/892 sheets. (Month and year required.)

SPEC:
YES NO Brief Description of Drawings includes description of each figure in drawings.
YES NO Continuing data is mentioned in 1st paragraph. (Can be an insert.)

CLAIMS:

YES NO Claims listed on Notice of Allowability match allowed claims and/or index of claims.
YES NO Claims correctly numbered in index.
(No duplicate or missing claim numbers.)
(No incorrect dependencies.)

CRFE:
YES NO If necessary (biological sequence listing).

NOTICE OF ALLOWABILITY:

YES NO Either Box No. 3 (drawings accepted) or Box No. 8 (corrected drawing request) has been checked.

Issue Classification	Application No. 09/402,262	Applicant(s) JONES ET AL.	
	Examiner Hung Q Dang	Art Unit 2635	

ISSUE CLASSIFICATION

ORIGINAL		CROSS REFERENCE(S)							
CLASS	SUBCLASS	CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)						
340	855.3	370	538						
INTERNATIONAL CLASSIFICATION		73	117.3						
G01V 3/34									
/									
/									
/									
/									

Hung Dang 2/2/05
(Assistant Examiner) (Date)

J Williams 2/8/05
(Legal Instruments Examiner) (Date)

MICHAEL HORABIK
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2600
2/7/05
(Primary Examiner) (Date)

Total Claims Allowed: 21

O.G. Print Claim(s): 1

O.G. Print Fig.: 1

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1		31		61		91		121		151		181
2	2		32		62		92		122		152		182
3	3		33		63		93		123		153		183
	4		34		64		94		124		154		184
4	5		35		65		95		125		155		185
5	6		36		66		96		126		156		186
6	7		37		67		97		127		157		187
7	8		38		68		98		128		158		188
8	9		39		69		99		129		159		189
9	10		40		70		100		130		160		190
10	11		41		71		101		131		161		191
11	12		42		72		102		132		162		192
12	13		43		73		103		133		163		193
13	14		44		74		104		134		164		194
14	15		45		75		105		135		165		195
	16		46		76		106		136		166		196
15	17		47		77		107		137		167		197
16	18		48		78		108		138		168		198
17	19		49		79		109		139		169		199
18	20		50		80		110		140		170		200
19	21		51		81		111		141		171		201
20	22		52		82		112		142		172		202
21	23		53		83		113		143		173		203
	24		54		84		114		144		174		204
	25		55		85		115		145		175		205
	26		56		86		116		146		176		206
	27		57		87		117		147		177		207
	28		58		88		118		148		178		208
	29		59		89		119		149		179		209
	30		60		90		120		150		180		210

Index of Claims	**Application No.** 09/402,262	**Applicant(s)** JONES ET AL.
	Examiner Hung Q Dang	**Art Unit** 2635

√	Rejected	–	(Through numeral) Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

Final	Original	2/2/05	Final	Original	Date	Final	Original	Date
1	1	=		51			101	
2	2	=		52			102	
3	3	=		53			103	
	~~4~~	~~=~~		54			104	
4	5	=		55			105	
5	6	=		56			106	
6	7	=		57			107	
7	8	=		58			108	
8	9	=		59			109	
9	10	=		60			110	
10	11	=		61			111	
11	12	=		62			112	
12	13	=		63			113	
13	14	=		64			114	
14	15	=		65			115	
	~~16~~			66			116	
15	17	=		67			117	
16	18	=		68			118	
17	19	=		69			119	
18	20	=		70			120	
19	21	=		71			121	
20	22	=		72			122	
21	23	=		73			123	
	24			74			124	
	25			75			125	
	26			76			126	
	27			77			127	
	28			78			128	
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	39			89			139	
	40			90			140	
	41			91			141	
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	43			93			143	
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	46			96			146	
	47			97			147	
	48			98			148	
	49			99			149	
	50			100			150	

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RECEIVED
CENTRAL FAX CENTER
DEC 14 2004

Facsimile Transmission

Date: December 14, 2004

RECIPIENT	GROUP ART UNIT	FAX NO.
Examiner John Hung Q. Dang	2635	703-872-9306

FROM: Harold V. Stotland **DIRECT FAX:** (312) 739-6986

PHONE: (312) 269-8971

RE: Snap-on Incorporated
Matter No. 444200
Patent Application for:
WIRELESS MULTIPLEX DATA
TRANSMISSION SYSTEM
Filed: February 28, 2000
Serial No. 09/402,262

File No: 25493-444200 **Number of Pages, Including Cover:** 10

ENCLOSURE:

Amendment

MESSAGE:

Transmitted herewith for filing, by facsimile, is an Amendment in the above-captioned application.

Please charge any additional fees or credit any over-payment incident to the filing of this document to Deposit Account No. 19-1351.

IF YOU DO NOT RECEIVE ALL THE PAGES, PLEASE PHONE (312) 269-8971 AS SOON AS POSSIBLE.

CH1 10829957.1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Barbara L. Jones, et al.

Title: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

Serial No.: 09/402,262

Filing Date: February 28, 2000

Seyfarth Shaw Docket No. 444200

Date: December 14, 2004

CUSTOMER NO. 27717

RECEIVED
CENTRAL FAX CENTER
DEC 14 2004

Examiner: Hung Q. Dang

Group Art Unit: 2635

Confirmation No. 5719

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

AMENDMENT

Dear Sir:

In response to the Office Action dated October 4, 2004, please amend the above-captioned application as set forth below.

This response includes amendments to claims 1, 6-10, 12, 13, 18-20 and 23 and cancellation of claims 4 and 16, as set forth in the Listing of Claims, beginning at page 2, and Remarks, beginning at page 7.

Certificate of Transmission

I hereby certify that on 12/14/04 this document is being facsimile transmitted to the Patent and Trademark Office (fax #703-872-9306).

Irene Feizulov

CH1 10803605.1

LISTING OF CLAIMS

1. (Currently amended) A method of wireless transmission of data in digital and/or analogue format through a communications channel ~~(72)~~ from at least two data sensors ~~(14, 16)~~ to a data processing means ~~(24)~~, said method comprising the step of division of said channel into sub-channels and transmitting said data from said data sensors respectively through said sub-channels accordingly;

characterized by

a) said step of division of said communications channel being effected asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) the data rate required for data transmission from said local sensors differing substantially between said at least two sensors; and

c) allocating data from said local data sensors to respective ones or groups of said sub-channels in accordance with the data carrying capacities of said sub-channels.

2. (Original) A method according to claim 1 characterized by said step of division being effected on a frequency basis.

3. (Original) A method according to claim 1 characterized by said step of division being effected on a time-division basis.

4. (Cancelled)

5. (Original) A method according to claim 1 characterized by said step of division being effected by packet-switching of data from said local data sensors, and interleaving said data packet with an unsymmetrical packet distribution.

6. (Currently amended) A method according to any one of claims 1 to 3 and 5 characterized by said data processing means comprising a host PC ~~(24)~~ having a series of virtual

serial ports, and said method comprising allocating each of said sub-channels to a corresponding one of said virtual serial ports.

7. (Currently amended) A method comprising to ~~any one of claims 1 to~~ claim 6 characterized by said local sensors comprising automotive diagnostic and/or servicing sensors and said wireless transmission of data being effected at radio frequencies.

8. (Currently amended) A method according to ~~any one of claims 1 to~~ claim 7 characterized by at least one of said local sensors (14) also providing a primary data-processing function.

9. (Currently amended) A method according to ~~any one of claims 1 to~~ claim 8 characterized by said local sensors comprising vibration sensor means ~~(104)~~ adapted to sense machine vibration, and said method comprising transmitting said data therefrom.

10. (Currently amended) A method according to claim 9 characterized by the step of using as said sensors, sensors ~~(104)~~ adapted to provide vibration data permitting noise vibration harshness (NVH) analysis of the data.

11. (Original) A method according to claim 10 characterized by at least three of said sensors being such NVH sensors, and the method comprising employing said sensors at three-dimensionally spaced locations to identify the location or co-ordinates of a source of vibration.

12. (Currently amended) A method according to claim 9 ~~or claim 10~~ characterized by said vibration sensor means further comprising three-dimensional location sensing means ~~(106)~~ and the method comprising the step of using said sensor to sense vibrations at three dimensionally-spaced locations in sequence, and using said three-dimensional location sensing means to identify the location or co-ordinates of said three spaced locations so as to identify the location or co-ordinates of a source of vibration.

13. (Currently amended) Apparatus for wireless transmission of data in digital and/or analogue format through a communications channel ~~(12)~~ from at least two local data sensors ~~(14, 16)~~ to a data processing means ~~(24)~~, the apparatus comprising a multiplexer ~~(62)~~ adapted to effect division of said communications channel into sub-channels, and a transmitter ~~(34)~~ adapted to transmit said data through said sub-channels accordingly;

characterized by

a) said multiplexer being adapted to divide said communications channel asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) control means ~~(40)~~ adapted to allocate data from said local data sensors to respective ones or groups of said communications sub-channels in accordance with substantially different data rate requirements from said local sensors.

14. (Original) Apparatus according to claim 13 characterized by said multiplexer being adapted to effect said multiplexing on a frequency basis.

15. (Original) Apparatus according to claim 13 characterized by said multiplexer being adapted to effect said multiplexing on a time-division basis.

16. (Cancelled)

17. (Original) Apparatus according to claim 13 characterized by said multiplexer being adapted to effect packet-switching of data from said local sources and to interleave said data packets with an unsymmetrical packet distribution.

18. (Currently amended) Apparatus according to any one of claims 13 to 15 and 17 characterized by said data processing function comprising a host PC ~~(24)~~ having a series of virtual serial ports, and said control means being adapted to allocate each of said sub-channels to a respective one of said virtual ports.

19. (Currently amended) Apparatus according to ~~any one of claims 13 to~~ claim 18 characterized by at least one of said local sensors ~~(14)~~ being adapted to provide a primary data-processing function.

20. (Currently amended) Apparatus according to claim 19 characterized by said local sensors comprising vibration sensor means ~~(104)~~ adapted to sense machine vibration whereby said apparatus can transmit said vibration data from said vibration sensing means.

21. (Original) Apparatus according to claim 20 characterized by said local data sensors comprising sensors adapted to provide vibration data permitting noise vibration harshness (NVH) data for analysis thereof.

22. (Original) Apparatus according to claim 21 characterized by said local data sensors comprising at least three or more such NVH sensors whereby said sensors can be located at three-dimensionally spaced locations to provide data enabling identification of the location or co-ordinates of the source of a vibration in a machine.

23. (Currently amended) Apparatus according to claim 20 ~~or claim 21~~ characterized by said vibration sensor means further comprising three-dimensional location sensing means ~~(106)~~ whereby said vibration sensor means can sense vibrations at three-dimensionally-spaced locations in sequence and said three-dimensional location sensing means can identify the co-ordinates or locations of said three locations so as to enable identification of the location or co-ordinates of a source of vibration.

24. (Withdrawn) A method for vibration analysis of a machine or other article comprising:

a) providing a vibration sensor (104);

b) causing said sensor to sense vibrations;

c) analyzing signals produced by said sensor;

characterized by

d) providing said sensor with three-dimensional location sensing means (106);

e) causing said vibration sensor to be mechanically coupled to the machine or other article to sense vibrations at three-dimensionally-spaced locations and using said three-dimensional location sensing means to determine the co-ordinates of said three locations; and

f) identifying the location or co-ordinates of a source of vibration accordingly.

25. (Withdrawn) Apparatus for vibration analysis of a machine or other article comprising:

a) a vibration sensor (104) adapted to sense vibrations at chosen locations; and

b) analysis means (124) adapted to analyze signals produced by said sensor;

characterized by

c) said vibration sensor being adapted to be mechanically coupled to the machine or other article and further comprising three-dimensional location sensing means (106);

d) whereby said single sensor can be caused to sense vibrations at three-dimensionally spaced locations at which said three-dimensional location sensing means can identify the co-ordinate locations thereof whereby the corresponding co-ordinate of a source of vibration can be determined.

REMARKS

It is noted that claims 24 and 25 are withdrawn from consideration as directed-elected subject matter.

Claim 6-12 and 18-23 are objected to as being in improper multiple dependent form. The claims have been amended so as to eliminate any improper multiple dependency.

Claims 4 and 16, which are rejected under 35 U.S.C. §112, have been cancelled.

It is noted with appreciation that claims 5 and 17 have been indicated to contain allowable subject matter. However, the recasting of those claims in independent form is being deferred, pending consideration of this Amendment, which is believed to overcome the rejections of the base independent claims.

Claims 1-3 and 13-15 are rejected under 35 U.S.C. §103 as being unpatentable over patent no. 4,738,133 to Breckel et al. in view of patent no. 5,509,013 to Adachi et al. The rejection is respectfully traversed.

Breckel et al. teaches wireless transmission of analog data from plural sensors over a single communication link by time-divisional multiplexing, although it discloses that frequency-division multiplexing could also be used. There is no mention of transmission speeds or data carrying capacities.

Adachi et al. discloses a multiplexer control system for controlling the multiplexing of data from pre-existing channels with different transmission speeds. The system utilizes time-division multiplexing and operates so that data channels having higher transmission speeds are more frequently multiplexed than data channels having lower transmission speeds. There is no disclosure of whether the data sources are sensors or whether or not they have different data rate requirements.

In the Adachi et al. system, if, for example, a communication channel is broken down into blocks each having 64 time slots, high data rate input channels would be allocated proportionally more of those 64 slots in each block than would low data rate input channels. But there is no indication in Adachi et al. of identifiable sub-channels to which specific sources can be assigned. Thus, e.g., Adachi et al. does not disclose that each input channel will always be assigned to the same slot numbers in each block.

The examiner contends that it would have been obvious to combine the teachings of Breckel et al. and Adachi et al. On the contrary, it is submitted that this would not have been obvious to one of ordinary skill in the art. Breckel et al. deals with data from sensors which apparently have the same data rates. Applicants' claims require a division of a communication channel "asymmetrically whereby the data carrying capacities of said sub-channels are unequal" and "allocating data from said local data sensors to respective of ones or groups of said sub-channels in accordance with the data carrying capacities of said sub-channels." Even assuming that Adachi et al. teaches asynchronous subdivision of a communication channel into sub-channels having different data-carrying capacities, there would be no point in utilizing such an arrangement in combination with the Breckel et al. system, wherein data is transmitted from sensors having the same data rates.

Thus, it is believed that the claims patentably distinguish from the cited references.

Claims 2 and 14 require that the channel be divided on a frequency basis. There is no suggestion in Adachi et al. as to how its system could be utilized in a frequency division multiplexing arrangement. This affords an additional reason for the allowance of claims 2 and 14.

For all of the foregoing reasons it is believed that, as amended, each of the claims 1-3, 5-15 and 17-23 is patentable over the cited art, and, accordingly, allowance of those claims is respectfully asked.

Respectfully submitted,

Seyfarth Shaw LLP
Attorneys for Assignee
55 East Monroe Street
Suite 4200
Chicago, Illinois 60603-5803
312-346-8000

By Harold V. Stotland

Harold V. Stotland, Reg. No. 24,492

Application or Docket Number
09/402262

PATENT APPLICATION FEE DETERMINATION RECORD
Effective November 10, 1998

CLAIMS AS FILED - PART I

FOR	NUMBER FILED (Column 1)		NUMBER EXTRA (Column 2)	SMALL ENTITY TYPE RATE	FEE	OR	OTHER THAN SMALL ENTITY RATE	FEE
BASIC FEE					380.00	OR		$840
TOTAL CLAIMS	29	minus 20=	* 9	X$ 9=		OR	X$18=	$162
INDEPENDENT CLAIMS	4	minus 3 =	* 1	X39=		OR	X78=	$78
MULTIPLE DEPENDENT CLAIM PRESENT			yes	+130=		OR	+260=	$260
				TOTAL		OR	TOTAL	1340

* If the difference in column 1 is less than zero, enter "0" in column 2

CLAIMS AS AMENDED - PART II

12-14-04

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	* 23	Minus	** 29	= /	X$ 9=		OR	X$18=	
Independent	* 4	Minus	*** 4	= /	X39=		OR	X78=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+130=		OR	+260=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	X$ 9=		OR	X$18=	
Independent	*	Minus	***	=	X39=		OR	X78=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+130=		OR	+260=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	X$ 9=		OR	X$18=	
Independent	*	Minus	***	=	X39=		OR	X78=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+130=		OR	+260=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

FORM PTO-875

Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

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Alexandria, Virginia 22313-1450
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/402,262	02/28/2000	BARBARA L. JONES	14.442	5719

27717 7590 10/04/2004

SEYFARTH SHAW
55 EAST MONROE STREET
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CHICAGO, IL 60603-5803

EXAMINER	
DANG, HUNG Q	
ART UNIT	**PAPER NUMBER**
2635	

DATE MAILED: 10/04/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No.	Applicant(s)
	09/402,262	JONES ET AL.
	Examiner	Art Unit
	Hung Q Dang	2635

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *06 July 2004*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1-25* is/are pending in the application.

4a) Of the above claim(s) *6-12 and 18-25* is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-4 and 13-16* is/are rejected.

7)☒ Claim(s) *5 and 17* is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☒ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *28 February 2000* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☒ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)

3) ☒ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date 3,7.

4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

5) ☐ Notice of Informal Patent Application (PTO-152)

6) ☐ Other: _____.

DETAILED ACTION

1. This communication is in response to applicant's response received on 7/16/2004. Applicant's election of claims 1-23 have been entered.

2. Claims 24-25 are withdrawn from further consideration pursuant to 37 CFR 1.142(b) as being drawn to a nonelected group, there being no allowable generic or linking claim. Election was made **without** traverse in the reply filed on 7/16/2004.

Claim Objections

3. Claims 6-12 and 18-23 are objected to under 37 CFR 1.75(c) as being in improper form because a multiple dependent claim cannot depend from any other multiple dependent claim. See MPEP § 608.01(n). Accordingly, claims 6-12 and 18-23 have not been further treated on the merits.

Claim Rejections - 35 USC § 112

4. The following is a quotation of the first paragraph of 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

5. Claims 4 and 16 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the enablement requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention. To be specific, the claim limitation in claims 14 and 16 "step of division being

adapted to effect said division on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time overlap between channels is permitted" is not clearly understood and the specification (page 6, lines 12-22) does not clearly provide support for said claimed limitation.

Claim Rejections - 35 USC § 103

6. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

7. Claim 1 is rejected under 35 U.S.C. 103(a) as being unpatentable over Breckel et al. U.S. Patent 4,738,133 in view of Adachi et al. U.S. Patent 5,509,013.

Regarding claim 1, Breckel et al. teaches a method of wireless transmission of data in analog format through a communication channel from at least two local data sensors (Figure 1, units 1, 2 or 3) to a data processing means (Figure 1, unit 5), said method comprising the step of division of said channel into sub-channels and transmitting said data from said data sensors respectively through said sub-channels accordingly (column 2 lines 24-31);

However, Breckel et al. does not specifically teach said sub-channels having unequal data carrying capacities and data rates; and allocating data from said local data sensors to respective ones of said sub-channels in accordance with the data carrying capacities of said sub-channels.

Adachi et al. discloses a transmission system having a multiplexer for providing many sub-channels (these are considered to be sub-channels of a single channel) having different data transmission speeds to suit economical demands (column 1, lines 10-18). One skilled in the art would recognize that data transmission speed is proportionally related to data carrying capacity. High data speed would result in high data transmission. High data capacity would also result in high data transmission since both data carrying capacity and data rate are time dependent. One skilled in the art would also recognize that allocating more data to be transmitted through a high data transmission speed/capacity channel and less data to be transmitted through a low data transmission speed/capacity channel would have been obvious and logical in order to efficiently and optimally transmit different amount of data through different sub-channels simultaneously.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to provide different data transmission speeds/data carrying capacities to the sub-channels disclosed by Breckel et al., as evidenced by Adachi et al., in order to efficiently and optimally transmit different amount of data from the sensors (1, 2 and 3) to the receiver (5) disclosed Breckel et al., as explained above.

Claim 13 is rejected for the same reasons as claim 1.

Regarding claims 2 and 14, Breckel et al. also teaches the division of said sub-channels being effected on a frequency basis (column 2, lines 26-29).

Regarding claims 3 and 15, Breckel et al. also teaches the division of said sub-channels being effected on a time-division basis (column 2, lines 20-22).

Allowable Subject Matter

8. **Claims 5 and 17** are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

The prior arts of record fail to teach or disclose a method of wireless transmission of data as claimed in claim 1, wherein the step of division of said sub-channels being effected by packet-switching of data from said local data sensors, and interleaving said data packet with an unsymmetrical packet distribution.

Conclusion

9. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Hung Q Dang whose telephone number is (571) 272-3069. The examiner can normally be reached on 9:30AM-6PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Michael Horabik can be reached on (571) 272-3068. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).

tcl)

MICHAEL HORABIK
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2600

Notice of References Cited

Application/Control No.	09/402,262
Applicant(s)/Patent Under Reexamination	JONES ET AL.
Examiner	Hung Q Dang
Art Unit	2635
	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
	A	US-4,738,133	04-1988	Breckel et al.	73/117.3
	B	US-5,509,013	04-1996	Adachi et al.	370/538
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Form PTO-1449 (Rev. 2-32)	U.S. Department of Commerce Patent & Trademark Office	Atty. Docket No. Q57274	Serial No. 09/468,227

INFORMATION DISCLOSURE STATEMENT
(Use several sheets if necessary)

Applicant: Lieve Maria Marcella Rosemarijn BOS, et al.

Filing Date: December 20, 1999

Group: ~~2734~~ 2635

OIPE JC68 FEB 1 1 2000 PATENT & TRADEMARK OFFICE

U.S. PATENT DOCUMENTS

Examiner Initial		Document Number	Date	Name	Class	Sub-Class	Filing Date (if appropriate)

FOREIGN PATENT DOCUMENTS

		Document	Date	Country	Class	Sub-class	Translation Yes/No

OTHER DOCUMENTS (Including Author, Title, Date, Pertinent Pages, Etc.)

HD		3G TS 23.127 1.0.0 (1999-10) 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Virtual Home Environment/Open Service Architecture

EXAMINER: [signature] DATE CONSIDERED: 9/7/04

EXAMINER: Initial if citation considered, whether or not citation is in conformance with MPEP 609; draw line through citation if not in conformance and not considered. Include copy of this form with next communication.

FORM PTO-1449 (Modified) LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	ATTY. DOCKET NO. 14,442	SERIAL NO. 09/402,262
	APPLICANT Barbara L. Jones et al.	
	FILING DATE Herewith	GROUP 2635

OIPE JAN 0 3 2000 PATENT & TRADEMARK OFFICE

REFERENCE DESIGNATION **U.S. PATENT DOCUMENTS**

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
HD	AA	4738133	4/88	Breckel et al.			
HD	AB	4787053	11/88	Moore			
HD	AC	4831558	5/89	Shoup et al.			
HD	AD	4831560	5/89	Zaleski			
HD	AE	5070536	12/91	Mahany et al.			
HD	AF	5132968	7/92	Cephus			
HD	AG	5193000	3/93	Lipton et al.			
HD	AH	5260944	11/93	Tomabechi			
HD	AI	5345599	9/94	Paulraj et al.			
HD	AJ	5363370	11/94	Abiven			
HD	AK	5446735	8/95	Tobagi et al.			

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUB-CLASS	TRANSLATION YES	TRANSLATION NO
HD	AL	18143	12/88	AU				
HD	AM	4106572	9/92	DE				
HD	AN	4131341	11/92	DE				
HD	AO	268492	5/88	EP				
HD	AP	483549	5/92	EP				

OTHER ART (Including Author, Title, Date, Pertinent Pages, Etc.)

	AR	
	AS	
	AT	

EXAMINER [illegible signature]	DATE CONSIDERED 9/7/04

E&D-FORM 1449 (April 1994)

FORM PTO-1449 (Modified) **LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT** (Use several sheets if necessary)	ATTY. DOCKET NO. 14,442	SERIAL NO. 09/402,262
	APPLICANT Barbara L. Jones et al.	
	FILING DATE Herewith	GROUP 2635

REFERENCE DESIGNATION **U.S. PATENT DOCUMENTS**

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
HD	BA	5 4 4 8 7 5 9	9/95	Krebs et al.			
HD	BB	5 4 8 1 4 8 1	1/96	Frey et al.			
HD	BC	5 5 0 9 0 1 3	4/96	Adachi et al.			
HD	BD	5 5 1 5 3 7 8	5/96	Roy, III et al.			
HD	BE	5 5 2 8 5 0 7	6/96	McNamara et al.			
HD	BF	5 5 4 1 8 4 0	7/96	Gurne et al.			
HD	BG	5 5 4 4 0 7 3	8/96	Piety et al.			
HD	BH	5 6 0 2 7 4 9	2/97	Vosburgh			
HD	BI	5 6 2 2 1 7 0	4/97	Schulz			
HD	BJ	5 6 4 2 3 5 3	6/97	Roy, III et al.			
	BK						

OIPE JAN 0 3 2003 PATENT & TRADEMARK OFFICE

FOREIGN PATENT DOCUMENTS

		DOCUMENT NUMBER	DATE	COUNTRY	CLASS	SUB-CLASS	TRANSLATION YES	TRANSLATION NO
HD	BL	5 1 5 7 2 8	12/92	EP				
HD	BM	6 8 5 3 9 0	12/95	EP				
HD	BN	2 2 9 5 0 7 0	5/96	UK				
HD	BO	8 9 0 9 5 2 2	10/89	WO				
	BP		/					

OTHER ART (Including Author, Title, Date, Pertinent Pages, Etc.)

	AR	
	AS	
	AT	

EXAMINER [signature] | DATE CONSIDERED 9/7/04

E&D-FORM 1449 (April 1994)

2634

SEYFARTH SHAW LLP
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OIPE JUL 06 2004 PATENT & TRADEMARK OFFICE

OIPE JUL 07 2004 PATENT & TRADEMARK OFFICE CANCELLED

July 2, 2004

CUSTOMER NO. 27717

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Re: Snap-on Incorporated
Matter No. 444200
Patent Application for:
WIRELESS MULTIPLEX DATA
TRANSMISSION SYSTEM
Filed: February 28, 2000
Serial No. 09/402,262

RECEIVED
JUL 0 9 2004
Technology Center 2600

Dear Sir:

Transmitted herewith for filing is a Response to Restriction Requirement in the above-captioned application, sent with Certificate of Mailing thereon.

No additional fee is necessitated.

Please charge any additional fees or credit any over-payment incident to the filing of this document to Deposit Account No. 19-1351.

Sincerely yours,

SEYFARTH SHAW LLP

J. Terry Stratman

J. Terry Stratman

JTS:ifm

CH1 10725868.1

BRUSSELS WASHINGTON, D.C. SAN FRANCISCO SACRAMENTO NEW YORK LOS ANGELES HOUSTON CHICAGO BOSTON ATLANTA

#13 Election/Respons
4/19/04

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of	)	CUSTOMER NO. 27717
Barbara L. Jones et al.	)	
Serial No. : 09/402,262	)	Group Art Unit: 2634
Filed: February 28, 2000	)	Examiner: Hung Q. Dang
Title: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM	)	Confirmation No. 5719
Seyfarth Shaw Docket No. 444200	)	
Date: July 2, 2004	)	

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

RESPONSE TO RESTRICTION REQUIREMENT

Dear Sir:

This is in response to the Office Action dated June 10, 2004, in which the examiner requires restriction to one of the following groups of claims:

Group I, claim(s) 1-23, drawn to a method for wireless transmission of data in digital and/or analogue format through a communication channel from at least two local data sensors to a data processing means, classified in class 340. subclass 870.11.

Group II, claim(s) 24-25, drawn to a specific method for vibration analysis of a machine or other article, classified in class 73, subclass 1.82.

Certificate of Mailing

I hereby certify that, on July 2, 2004, this correspondence is being deposited with the U. S. Postal Service, as First Class Mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Irene Feizulov

Irene Feizulov

CH1 10725124.1

Applicants here elect claims 1-23 of Group I for purposes of examination on the merits in this application.

Respectfully submitted,

Seyfarth Shaw LLP
Attorneys for Assignee
55 East Monroe Street
Suite 4200
Chicago, Illinois 60603-5803
312-346-8000

By Jerry Stratman

am

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/402,262	02/28/2000	BARBARA L. JONES	14.442	5719

27717 7590 06/10/2004

SEYFARTH SHAW
55 EAST MONROE STREET
SUITE 4200
CHICAGO, IL 60603-5803

EXAMINER	
DANG, HUNG Q	
ART UNIT	**PAPER NUMBER**
2635	12

DATE MAILED: 06/10/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary	Application No. 09/402,262	Applicant(s) JONES ET AL.	
	Examiner Hung Q Dang	Art Unit 2635	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 1 MONTH(S) FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on 28 February 2000.

2a)☐ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) 1-25 is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☐ Claim(s) _____ is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☒ Claim(s) 1-25 are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application (PTO-152)
6) ☐ Other: _____.

DETAILED ACTION

Election/Restrictions

1. A telephone call was made to Harold V. Stotland on 6/7/2004 to request an oral election to the above restriction requirement, but did not result in an election being made.

Applicant is advised that the reply to this requirement to be complete must include an election of the invention to be examined even though the requirement be traversed (37 CFR 1.143).

2. Restriction is required under 35 U.S.C. 121 and 372.

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1.

In accordance with 37 CFR 1.499, applicant is required, in reply to this action, to elect a single invention to which the claims must be restricted.

Group I, claim(s) 1-23, drawn to a method for wireless transmission of data in digital and/or analogue format through a communication channel from at least two local data sensors to a data processing means, classified in class 340, subclass 870.11.

Group II, claim(s) 24-25, drawn to a specific method for vibration analysis of a machine or other article , classified in class 73, subclass 1.82.

The inventions are distinct, each from the other because of the following reasons:

Inventions of group I and II are related as subcombinations disclosed as usable together in a single combination. The subcombinations are distinct from each other if they are shown to be separately usable. In the instant case, invention of group I has separate utility because the data transmission system of group I does not require the specific type of data (vibration data) of group II; and the vibration data in group II does not need to be transmitted using the method of group I. See MPEP § 806.05(d).

Conclusion

3. Because these inventions are distinct for the reasons given above and have acquired a separate status in the art as shown by their different classification, and the search required for group I is not required for group II and vice versa, therefore, restriction for examination purposes as indicated is proper.

Applicant is reminded that upon the cancellation of claims to a non-elected invention, the inventorship must be amended in compliance with 37 CFR 1.48(b) if one or more of the currently named inventors is no longer an inventor of at least one claim remaining in the application. Any amendment of inventorship must be accompanied by a request under 37 CFR 1.48(b) and by the fee required under 37 CFR 1.17(i).

4. Any inquiry concerning this communication or earlier communications from the examiner should be directed to Hung Dang whose telephone number is 703-305-

1836. The examiner can normally be reached on Monday through Friday from 8:30AM to 5:00PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Michael Horabik, can be reached on (703) 305-4704. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9314.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is (703) 305-3900.

Hung Dang
6/7/2004
H.D.

HD

MICHAEL HORABIK
SUPERVISORY PATENT EXAMINER
TECHNOLOGY CENTER 2600

2635

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of	
Barbara L. Jones, et al.	Group Art Unit: 2635 #11
Serial No.: 09/402,262	Examiner: Michael Horabik
Filed: February 28, 2000	Confirmation No. 5719
Title: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM	Customer No. 27717
Seyfarth Shaw Docket: 444200	
Date: April 1, 2004	

Mail Stop Status
Director of the US Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

REQUEST FOR INFORMATION

Sir:

Please inform us when you will issue an action in this application.

Respectfully submitted,

Seyfarth Shaw LLP
Attorneys for Assignee
55 East Monroe Street
Suite 4200
Chicago, Illinois 60603-5803
312-346-8000

By ______________________
Harold V. Stotland (24,492)

UNITED STATES DEPARTMENT OF COMMERCE
Patent and Trademark Office
ASSISTANT SECRETARY AND COMMISSIONER
OF PATENTS AND TRADEMARKS
Washington, D.C. 20231

#10

CHANGE OF ADDRESS/POWER OF ATTORNEY

FILE LOCATION 26C1 SERIAL NUMBER 09402262 PATENT NUMBER

THE CORRESPONDENCE ADDRESS HAS BEEN CHANGED TO CUSTOMER # 27717

THE PRACTITIONERS OF RECORD HAVE BEEN CHANGED TO CUSTOMER # 27717

THE FEE ADDRESS HAS BEEN CHANGED TO CUSTOMER # 27717

ON 04/04/03 THE ADDRESS OF RECORD FOR CUSTOMER NUMBER 27717 IS:

SEYFARTH SHAW
55 EAST MONROE STREET
SUITE 4200
CHICAGO IL 60603-5803

AND THE PRACTITIONERS OF RECORD FOR CUSTOMER NUMBER 27717 ARE:

22419 22792 24142 24492 25165 37196 39210 44860 45721

RECEIVED
APR 1 4 2003
Technology Center 2600

PTO INSTRUCTIONS: PLEASE TAKE THE FOLLOWING ACTION WHEN THE CORRESPONDENCE ADDRESS HAS BEEN CHANGED TO CUSTOMER NUMBER: RECORD, ON THE NEXT AVAILABLE CONTENTS LINE OF THE FILE JACKET, 'ADDRESS CHANGE TO CUSTOMER NUMBER'. LINE THROUGH THE OLD ADDRESS ON THE FILE JACKET LABEL AND ENTER ONLY THE 'CUSTOMER NUMBER' AS THE NEW ADDRESS. FILE THIS LETTER IN THE FILE JACKET. WHEN ABOVE CHANGES ARE ONLY TO FEE ADDRESS AND/OR PRACTITIONERS OF RECORD, FILE LETTER IN THE FILE JACKET.
THIS FILE IS ASSIGNED TO GAU 2664.

~~2731~~
2664

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Barbara L. Jones et al.)
)
Serial No.: 09/402,262)
)
Filing Date: February 28, 2000) Group Art Unit: 2731
)
For: WIRELESS MULTIPLEX DATA)
TRANSMISSION SYSTEM)
)
Date: May 2, 2001)

Director - U.S. Patent and Trademark Office
Washington, D.C. 20231

CHANGE OF CORRESPONDENCE ADDRESS

Sir:

It is requested that the address and other information for the captioned matter be changed to:

Harold V. Stotland
Seyfarth Shaw
42nd Floor
55 East Monroe Street
Chicago, Illinois 60603-5803
telephone number: 312-269-8971
fax number: 312-269-8869
e-mail: hstotland@seyfarth.com

Respectfully submitted,

By: ______________________
Harold V. Stotland,
An Attorney for Assignee

NL

OIPE
APR 0 2 2001
PATENT & TRADEMARK OFFICE

442
2731

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

#9

In re Application of:	Barbara L. Jones, et al.	)	
Serial No.:	09/402,262	)	
Filing Date:	February 28, 2000	)	Group Art Unit: 2731
For:	WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM	)	
Date:	March 30, 2001	)	

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Technology Center 2600

Director - U.S. Patent and Trademark Office
Washington, D.C. 20231

CHANGE OF CORRESPONDENCE ADDRESS

Sir:

It is requested that the address and other information for the captioned matter be changed to:

Harold V. Stotland
Seyfarth Shaw
42nd Floor
55 East Monroe Street
Chicago, Illinois 60603-5803
telephone number: 312-269-8971
fax number: 312-269-8869
e-mail: hstotland@seyfarth.com

Respectfully submitted,

By: [signature]
Harold V. Stotland,
An Attorney for Assignee

HA

OIPE
MAR 27 2000
JC24
PATENT & TRADEMARK OFFICE

731

09402

#8

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

RECEIVED
APR 24 2000
TC 2700 MAIL ROOM

Applicant: Jones et al

Title: WIRELESS DATA TRANSMISSIONS

Serial No.: 09/402262

Filing Date: October 1, 1999

Date: March 17, 2000

Commissioner of Patents
and Trademarks
Washington, D.C. 20231

CHANGE OF CORRESPONDENCE ADDRESS

SIR:

It is requested that the address and other information for the captioned matter be changed to:

Harold V. Stotland
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42nd Floor
55 East Monroe Street
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fax number: 312-269-8869
e-mail: hstotland@seyfarth.com

Respectfully submitted,

By:
Harold V. Stotland,
An Attorney for Assignee

U.S. APPLICATION NO.	FIRST NAMED APPLICANT		ATTY. DOCKET NO.
09/402262	JONES	B	14,442

HAROLD V STOTLAND
EMRICH & DITHMAR
300 SOUTH WACKER DRIVE
SUITE 3000
CHICAGO, IL 60606

INTERNATIONAL APPLICATION NO.	
PCT/GB98/00866	
I.A. FILING DATE	PRIORITY DATE
03 APR 98	03 APR 97

DATE MAILED: 22 MAR 2000

NOTIFICATION OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C. 371 AND 37 CFR 1.494 OR 1.495

1. The applicant is hereby advised that the United States Patent and Trademark Office in its capacity as ☐ a Designated Office (37 CFR 1.494), ☒ an Elected Office (37 CFR 1.495), has determined that the above identified international application has met the requirements of 35 U.S.C. 371, and is **ACCEPTED** for national patentability examination in the United States Patent and Trademark Office.

2. The United States Application Number assigned to the application is shown above and the relevant dates are:

28 FEB 2000	28 FEB 2000
35 U.S.C. 102(e) DATE	DATE OF RECEIPT OF 35 U.S.C. 371 REQUIREMENTS

A Filing Receipt (PTO-103X) will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE "FILING DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371(C) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN ABOVE.** *The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363).* Once the Filing Receipt has been received, send all correspondence to the Group Art Unit designated thereon.

3. ☐ A request for immediate examination under 35 U.S.C. 371(f) was received on and the application will be examined in turn.

4. The following items have been received:
   - ☒ U.S. Basic National Fee.
   - ☒ Copy of the international application in:
     - ☐ a non-English language.
     - ☒ English.
   - ☒ Translation of the international application into English.
   - ☒ Oath or Declaration of inventors(s) for DO/EO/US.
   - ☐ Copy of Article 19 amendments. ☐ Translation of Article 19 amendments into English.
     The Article 19 amendments ☐ have ☐ have not been entered.
   - ☒ The International Preliminary Examination Report in English and its Annexes, if any.
   - ☒ Copy of the Annexes to the International Preliminary Examination Report (IPER).
     - ☒ Translation of Annexes to the IPER into English.
     The Annexes ☒ have ☐ have not been entered.
   - ☐ Preliminary amendment(s) filed ______ and ______.
   - ☒ Information Disclosure Statement(s) filed 03 JAN 2000 and ______.
   - ☐ Assignment document.
   - ☒ Power of Attorney and/or Change of Address.
   - ☐ Substitute specification filed ______.
   - ☐ Verified Statement Claiming Small Entity Status.
   - ☒ Priority Document.
   - ☐ Copy of the International Search Report ☒ and copies of the references cited therein.
   - ☐ Other:

Applicant is reminded that any communication to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above. (37 CFR 1.5)

Paulette Kidwell, Paralegal
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FORM PTO-1390 (REV 11-98) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 14,442

U.S. APPLICATION NO. (If known, see 37 CFR 1.5): 09/402262

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB98/00866	3 April 1998 (04/03/1998)	3 April 1997 (04/03/1997)

TITLE OF INVENTION
WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

APPLICANT(S) FOR DO/EO/US
Jones, Barbara L. and Smith, Paul

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [ ] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (unsigned)
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [ ] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information: Form PCT/IB/308 dated 8 October, 1998 (10/08/98)
    International Search Report
    Written Opinion
    Response to Written Opinion
    International Preliminary Examination Report
    and Annexes

I Hereby Certify That This Correspondence Is Being Deposited With The United States Postal Service As Express Mail No. EL 453 823 906 US Addressed To: Assistant Commissioner for Patents, Washington, D.C 20231 On 10/1/99

Date. 10/1/99

U.S. APPLICATION NO (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/402262	PCT/GB98/00866	14,442

17. [X] The following fees are submitted:

	CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$970.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$840.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$760.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$670.00**		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) **$96.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 840	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	25 - 20 =	5	X $18.00	$ 90	
Independent claims	4 - 3 =	1	X $78.00	$ 78	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	$ 260	
TOTAL OF ABOVE CALCULATIONS =				$ 1,268	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also by filed (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$ 1,268	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$ 1,268	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$ 1,268	
				Amount to be: refunded	$
				charged	$

a. [X] A check in the amount of $ 1,268 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ____________ in the amount of $____________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 05-1060. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

Stotland, Harold V.
Emrich & Dithmar
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PCT INTERNATIONAL RECEIVED

SIGNATURE

Harold V. Stotland

NAME

24,492

REGISTRATION NUMBER

WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

This invention relates to a method and apparatus for wireless transmission of data through a communications channel comprising at least two local data sensors and a data processing function to receive data from the local sensors. A non-limiting example of the application of the method is in the field of automotive diagnostic equipment and related automotive service equipment. A particularly practical application of the invention is to noise vibration harshness (NVH) analysis of automotive and other machines to enable two or three-dimensional location pinpointing of vibration sources, for example in automotive warranty investigations and indeed in many other machine applications. Further examples of the application of the invention arise in relation to business operations for the wireless transmission of data, for example, across a room.

The invention also provides a method and apparatus for vibrational analysis of a machine or other article permitting three-dimensional positional co-ordinate identification of a source of vibration.

In this specification and the claims, references to local data sensors are to be interpreted in accordance with the following, namely that the sensors may transmit raw data for subsequent processing or one or more of these may incorporate some degree of primary data processing whereby the data received at the main processor is partially or totally pre-processed or indeed raw data.

In the field of automotive diagnostics and servicing there has been for a good many years a requirement for a step forward in terms of the transmission of diagnostic and servicing data from data sensors to a data processing function which operates to analyse and/or display the corresponding data for use by a person carrying out servicing and/or diagnostic functions on a motor vehicle. Conventionally, the data is transmitted from the data sensors to the data processing function via conventional conductors or cables which impose obvious inconveniences and limitations on the convenient operation of the equipment. Attempts have been made to reduce these drawbacks in several ways. Firstly, various proposals have been made to simplify the use of cable connectors as such. For example, one proposal in this regard provides for a system in which a boom-mounted data-handling sub-unit is conveniently manoeuvrable to a location close to the automotive sensors and is thus linked to them by relatively short cable connections. This arrangement undoubtedly does reduce somewhat the inconvenience of the cable connection systems but by no means eliminates it.

Various attempts have been made to achieve effective wireless transmission of data between automotive data sensors and a corresponding data-processing and/or display function but these have been relatively unsuccessful. The main shortcoming of such prior proposals has been the sheer volume of data, and the composite nature of the data (such as a mixture of data types eg digital and analogue). A further factor among the shortcomings of these prior proposals is also the composite nature of the data bandwidths to be transmitted. Such data needs to be transmitted and has conventionally been handled by a harness of 12 or more conduction cables. By adopting conventional wireless transmission systems for such data communication there is immediately a problem of excessive bandwidth requirements arising from the fact that some at least of the data sensors for this automotive application produce high data rates necessitating corresponding band widths to accommodate them. This does not apply to all the sensors. Comparable considerations apply to certain business applications where data is transmitted across a room or other relatively short transmission route.

Accordingly, we have identified a requirement for a method and apparatus for the wireless transmission of data through a communications channel from at least two local data sensors with optional primary data processing, to a data processing function, offering improvements in relation to prior proposals in this field, notably in relation to the bandwidth requirement and/or related functions attendant on the simultaneous transmission of data from a multiplicity of such local sensors.

There is disclosed in EP 0 483 549A2 (IBM CORP) a control method and apparatus for a wireless data link, for example, from a handheld workstation which is bidirectionally coupled to a base station through an infrared carrier. A robust control channel is provided separate from a data channel. The modulators employ on/off pulsing, multi-carrier modulation or direct sequence spread spectrum (DSSS) modulation. Each mobile unit is assigned an identifier or address and the system claims to overcome the problem of establishing and maintaining high bandwidth communication by separating the control channel from the data channel whereby the control channel bandwidths can be made significantly smaller.

In WO 89/09522 there is disclosed a method for allocating bandwidths in a broadband packet switching network using a set of parallel packet channels that act as a single data link connection between packet switches. Bandwidth is initially allocated to particular channel groups (at initial circuit set-up

times) and to individual channels within the groups (at transmission times) so as to increase throughput and reduce packet loss. For bursty traffic, the use of channel groups reduces the packet loss by several orders of magnitude.

EP 0 515 728A2 relates to a wireless indoor relay system. AU-A-18143/88 relates to a wireless data transmission link and notably a protocol for establishing a duplex link between first and second data link devices.

Other known references include:

GB 2295070
EP 0483549
EP 0268492
US 5509013
US 5448759
US 5363370

US 4,738,133 discloses a system for wireless transmission of multiplexed data from a plurality of transducers.

US 5,509,013 discloses a multiplexer control system for multiplexing the data from a plurality of input channels having different transmission speeds.

DE 4106572 discloses a system for contact-free measurement of object oscillations by directing laser light onto the object and detecting reflected light at plural spaced sensing heads so as to locate the point on the object from which the reflections are emanating.

According to the invention there is provided a method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors with optional primary data processing and a data processing function, as defined in the accompanying claims.

In a described embodiment, there is provided a method and apparatus in which the step of multiplexing division of the communications channel is effected asymmetrically, whereby the data carrying capacities of the sub-channels are unequal. Likewise in the embodiment, the data rates required for data transmission from the local sensors

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differs substantially between the at least two sensors. Likewise also in the embodiment, the step of allocating data from the local data sensors to the data transmission sub-channels is effected in accordance with the data-carrying capacities of these sub-channels. In this way there is achieved within a

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communications channel, the economical use of the available bandwidth whereby the allocation of bandwidth corresponds with the band width requirements of the individual data sensors. Thus, in the case of a sensor sensing data relating to ignition events which occur at a relatively high speed and thus require a corresponding significant allocation of bandwidth for satisfactory transmission, such is provided, whereas in the case of a sensor sensing alternator voltage (to take a simple example) the required that transmission rate is smaller by many orders of magnitude and likewise the corresponding bandwidth requirements.

Whereas prior proposals in relation to data transmission for automotive and related systems (in which data sensors produce substantially differing data rates) have ignored or overlooked these differing data rate requirements, with the result that the use of equal bandwidth sub-channels has led to a non-utilisation of sub-channel bandwidths for significant numbers of sensors whereby the overall utilisation of data transmission capacity allocated to the communications system has been very far from perfect.

In accordance with the embodiments of the invention, the use of a system in which data is fed via a "multiplexing" control system which allocates data to sub-channels in accordance with the actual data rate requirement of the individual data flow, each such data flow is thereby far more closely matched to the available capacity of its sub-channel and the twin evils of sub-channel under-utilisation and under-capacity (for a given data flow) are thereby avoided.

In one significant embodiment, the multiplex control system divides the communications channel on a frequency basis and allocates the data streams from the sensors to the frequency sub-channels accordingly.

In another important embodiment, the multiplexing control system divides the data communication channel on a time-division basis and likewise divides the data streams accordingly.

The reference above to "multiplexing" has been adopted to draw attention to the fact that references in this specification and in the claims to "multiplexing" are intended not to be limited strictly to non time-overlap or signal-chopping systems (such as would be obtained with a distinct signal-chopping technique). The term "multiplexing" in this description and the claims includes the provision of multiplexing systems which are adapted to effect multiplexing on an interdigitated and non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted. The data allocation systems for data-division between available channels can be readily designed accordingly by the technically skilled person so as to, in this way, more readily meet the technical parameters imposed on the system, as described below.

In a yet further embodiment, the multiplexing system achieves its channel division on a packet-switching basis and the interleaved data packets are distributed on an unsymmetrical basis.

In the embodiment, there is provided a radio frequency data rate of 1 to 4 Mb (megabits) per second. The multi-channel system can accommodate the requirements eg for the transmission of data for operating an oscilloscope system for engine analysis.

While the described embodiments utilise radio frequency transmission, the principles of the invention may well be applicable outside radio frequencies.

An important aspect of the invention relates to

vibrational analysis of machines and other articles and products and systems. In accordance with this aspect of the invention a vibration sensor, for example an NVH (noise vibration harshness) sensor is mechanically coupled to the machine or other article to three-dimensionally locate a source of vibration in a machine or system. Such a sensor may be just one of the local sensors in the wireless transmission system of the other embodiments, or it may be provided with its own cable or other transmission channel for its vibration signals.

In order to three-dimensionally locate a source of vibration, the vibration signals are monitored at three or more positionally-defined locations of the sensor. In the preferred embodiment the sensor is provided with its own three-dimensional location or co-ordinate-defining system (utilising spaced infra-red sensors), so that the sensor's location at any given time is readily defined. Alternatively, the sensor may be caused to sense at three known locations, or three sensors may be provided, one each at three such locations.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Fig 1 shows a functionality block diagram for a high speed RF data link, including both the frequency multiplexing system (of Figs 2 and 3) and the time-division multiplexing system (of Figs 4 and 5 hereof);

Figs 2 and 3 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as it applies to a frequency multiplexing system;

Figs 4 and 5 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as they apply to a time-division multiplexing system; and

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Fig 6 shows a three-dimensional representation of a further embodiment in which a local vibration sensor has its own three-dimensional imaging or location system whereby the single sensor can rapidly positionally locate a source of vibration.

As shown in Fig 1, a system 10 for wireless transmission of data through a communications channel 12 between local data sensors 14, 16, 18, 20 and 22, and a data-processing function or personal computer 24, to receive data therefrom, comprises the following main elements.

Firstly, as regards the local data sensors 14 to 22, as shown these comprise an engine tester 14, a gas bench 16, a scanner 18 and auxiliary sensors indicated as Aux 1 and Aux 2. These sensors are intended to be representative of the entire range of automotive sensors which are currently utilised for diagnostic and servicing processes, including for example vibration sensors (for RPM testing) ignition and alternator ripple sensors (likewise for RPM measurement), emissions analysis sensors, battery analysis sensors and the like.

Indicated at 26 is the remote receive/transmit unit to which the individual sensors 14 to 22 are connected. The duplex (transmit/receive) operating characteristics of this unit arise from the need for the return transmission of data from the data processing function 24 for set-up purposes.

Broadly, the system comprises antennae 28, 30 connected to receive/transmit functions 32 and 34 within remote unit 26. Likewise, a receive/transmit unit or function 36 is provided for PC 24. A receive buffer 38 and a controller 40 serve to interconnect the transmit and receive functions 34, 32 to a series of RS-232 interfaces 42 to 50, each connected to its respective one of the local sensors 14 to 22.

Interfaces 42, 44, 46, 48 and 50 are serial interfaces providing for serial communication between the sensor and the receive/transmit function 32, 34 via buffer 38 and controller 40. Interface 42 is a high speed serial interface. Interfaces 44, 46, 48 and 50 are RS-232 interfaces. Interfaces 44, 46 are designated in Fig 1 as "UART1" and "UART2", referring to their function as universal asynchronous receiver/transmitter devices (or interfaces) for serial transmission of data. Receive buffer 38 and controller 40 provide data processing functions relevant to the inflow and outflow of data for the duplex operating characteristics of system 10 as will be more fully described below in relation to Figs 2, 3, 4 and 5. Accordingly, the details of these aspects of the system 10 will now be described further with reference to Figs 2, 3, 4 and 5.

As shown in Figs 2 and 3, the RX buffer 38 and controller 40 provide data processing/signal conditioning functions to be more fully described below.

As shown in Fig 2, inputs from the individual sensors 14 to 22 are indicated at 52 and 54 which are marked "Sensor 1" and "Sensor 16" to indicate that the system can accommodate 16 individual inputs.

The main function of controller 40 is to provide a multiplexing function whereby communication channel 12 is divided into 16 sub-channels on a frequency basis, these channels being of unequal band width and being allocated according to band width (more band width for greater band width requirement) to the individual data channels 1 to 16.

Interfaces 42 to 50 in Fig 1 provide the signal conditioning function indicated in Fig 2 at 56. The functions of controller 40 are shown as divided into functions 58, 60 and 62, namely voltage frequency conversion, secondary (low frequency) frequency conversion and sub-channel combination respectively. Each function operates in relation to all 16 sub-channels.

The sub-channel combination function at 62 produces a serial data stream which is fed to the RF transmitter function 34 and thus to the helical or other suitable antenna 28.

A further function of controller 40 is to append the relevant sub-channel number to each sub-channel of raw data so that this data stream can be routed to the relevant virtual serial port of PC 24 after radio transmission between antennae 28 and 30.

In this embodiment, the multiplexing sub-division of the data communication channel is provided on a frequency basis, whereas in the embodiment of Fig 4 the multiplexing is effected on a time-division basis.

As shown in Fig 3, RX buffer 38 provides the related inverse functions for signals received via antenna 28 and receiver functions 32. These functions are indicated at 64 and 66 and 68 and correspond, respectively, with the functions 62, 60 and 58 respectively in Fig 2. No further description is therefore deemed necessary.

In operation, data from sensor 14 to 22 (or indeed from the 16 sensors indicated in Fig 2) is processed in accordance with the functions 56, 58, 60 and 62 as shown in Fig 2. The data streams are allocated to the 16 sub-channels indicated diagrammatically at 64 in Fig 2. The allocation is effected in accordance with the known data rate requirements of the individual sensors, according to their known uses. In general terms, the band width of each sub-channel is matched to comfortably accommodate the data rate requirements of its respective data stream, but without the over-provision which tends to occur in certain cases with conventional use of conventional data transmission equipment.

Turning now to the time-division embodiment of Fig 4, parts corresponding to those described above in relation to Figs 2 and 3 are numbered accordingly in Fig 4.

In Fig 4, the signal conditioning function 56 corresponds to that provided by the serial interfaces 42 to 50 in Fig 1. However, in this embodiment the controller function 40 differs from that of Fig 2 in being a time-division based function (utilising a 16-way switch function 66 to provide the time-based multiplexing function corresponding to the frequency-based multiplexing of Figs 2 and 3). A 12 bit analogue-to-digital conversion function 68 processes data from switch function 66 and is linked to a microcontroller 70 (an asynchronous PIC 16C54 communications element) coupled to RF transmitter 34. Microcontroller 70 provides at 72 a control signal to switch 66 in accordance with the time-based multiplexing function which controls the sub-channel data capacities in accordance with the required data rates of the sensor input. A related control function 74 is provided to ADC converter 68.

As shown in Fig 5, the data processing function 24 in Fig 1 receives data via antenna 30 and receiver 36 through a decoding function 76 shown in Fig 5 and comprising a microcontroller 78 corresponding to microcontroller 70 which feeds data via a digital-to-analogue converter 80 to workstation of PC 24. The microcontroller 78 produces a channel message 82 for the workstation enabling same to allocate the decoded data stream to respective virtual serial ports set up in the PC for data analysis and display purposes.

This embodiment allocates data streams to respective data channels on the same principle described above but on a time-division basis instead of a frequency-division basis.

In a further embodiment, not shown, in which a packet-switching data transmission technique is employed, the allocation of data streams to packets is effected asynchronously in accordance with the matching of data rate to sub-channel capacity discussed above, thereby producing the corresponding asymmetrical interleaving of the data packets.

In the frequency-multiplexed embodiment of Figs 2 and 3, a modification may be employed whereby spread spectrum frequency division is utilised thereby reducing or eliminating the requirement to label the sub-channels by means of identifying data.

Amongst other modifications which could be made in the above embodiment are the following. Firstly, it is to be understood that the local sensors may be adapted to produce analogue signals or digital signals. Usually, analogue signals will be produced and conversion to digital will be effected in the data-processing stage. Nevertheless, it may be beneficial for certain applications or in the future to employ sensors producing digital signals, and in some cases both digital and analogue-type sensors could be employed, these transmitting their data through their respective sub-channels. Secondly, it is to be understood that while the invention has been discussed and defined by reference to specific sub-channels and the allocation of data from sensors to respective ones of these, it is to be understood that a sensor producing a high data-rate may for that purpose have allocated to it a number of sub-channels or thus a group of sub-channels accordingly.

Turning now to the embodiment of Fig 6, this shows a system 100 for vibrational analysis of an automotive vehicle 102 to enable three-dimensional location or co-ordinate-identification of a source of vibration. Thus, the apparatus of Fig 6 may be employed for rapidly enabling location of squeaks or rattles or more serious vibrational symptoms.

For this purpose there is provided a local vibration sensor 104 which forms one local sensor of an embodiment of the invention described above and thus is provided with a link (not shown) to the wireless transmission system of the preceding embodiments. Alternatively, the sensor 104 may be provided with its own dedicated vibrational analysis system (not shown) in the case where it is desired to use it as a stand-alone system.

Incorporated as part of the local vibration sensor unit 104 is a three-dimensional location positional transmitter 106 having three spaced-apart infra-red light emitting diodes (LEDs) 108, 110, 112.

Transmitter 106 forms part of a three-dimensional optical localisation system 114. Such systems are available from Image Guided Technologies Inc of Boulder, Colorado, USA. Technology of this kind is described in US 5,622,170 (Schulz/Image Guided Technologies Inc).

System 114 comprises a moveable three-dimensional positional receiver 116 having infra-red LEDs 118, 120, 122 adapted to communicate with the LEDs 108, 110, 112. Receiver 116 communicates with personal computer 124 and with a positional interface 126 and a sensor interface 128, performing decoding functions.

The three-dimensional optical localisation system 114 enables the co-ordinate location of vibration sensor 104 at any given time to be readily identified.

As a result, the single sensor 104 can be monitored at three or more locations while its vibration signals are likewise monitored in accordance with the procedures of the preceding embodiments, enabling the source of a vibration signal within vehicle 102 to be identified in terms of its co-ordinate location.

CLAIMS

1 A method of wireless transmission of data in digital and/or analogue format through a communications channel (72) from at least two local data sensors (14, 16) to a data processing means (24), said method comprising the step of division of said channel into sub-channels and transmitting said data from said data sensors respectively through said sub-channels accordingly;

characterised by

a) said step of division of said communications channel being effected asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) the data rate required for data transmission from said local sensors differing substantially between said at least two sensors; and

c) allocating data from said local data sensors to respective ones or groups of said sub-channels [being effected] in accordance with the data carrying capacities of said sub-channels.

2 A method according to claim 1 characterised by said step of division being effected on a frequency basis.

3 A method according to claim 1 characterised by said step of division being effected on a time-division basis.

4 A method according to any one of claims 1 to 3 characterised by said step of division being adapted to effect said division on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time overlap between channels is permitted.

5 A method according to claim 1 characterised by said step of division being effected by packet-switching of data from said local data sensors, and interleaving said data packet with an unsymmetrical packet distribution.

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6 A method according to any one of claims 1 to 5 characterised by said data processing means comprising a host PC (24) having a series of virtual serial ports, and said method comprising allocating each of said sub-channels to a corresponding one of said virtual serial ports.

7 A method according to any one of claims 1 to 6 characterised by said local sensors comprising automotive diagnostic and/or servicing sensors and said wireless transmission of data being effected at radio frequencies.

8 A method according to any one of claims 1 to 7 characterised by at least one of said local sensors (14) also providing a primary data-processing function.

9 A method according to any one of claims 1 to 8 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration, and said method comprising transmitting said data therefrom.

10 A method according to claim 9 characterised by the step of using as said sensors, sensors (104) adapted to provide vibration data permitting noise vibration harshness (NVH) analysis of the data.

11 A method according to claim 10 characterised by at least three of said sensors being such NVH sensors, and the method comprising employing said sensors at three-dimensionally spaced locations to identify the location or co-ordinates of a source of vibration.

12 A method according to claim 9 or claim 10 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106) and the method comprising the step of using said sensor to sense vibrations at three dimensionally-spaced locations in

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sequence, and using said three-dimensional location sensing means to identify the location or co-ordinates of said three spaced locations so as to identify the location or co-ordinates of a source of vibration.

13 Apparatus for wireless transmission of data in digital and/or analogue format through a communications channel (12) from at least two local data sensors (14, 16) to a data processing means (24), the apparatus comprising a multiplexer (62) adapted to effect division of said communications channel into sub-channels, and a transmitter (34) adapted to transmit said data through said sub-channels accordingly;

characterised by

a) said multiplexer being adapted to divide said communications channel asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) control means (40) adapted to allocate data from said local data sensors to respective ones or groups of said communications sub-channels in accordance with substantially different data rate requirements from said local sensors.

14 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a frequency basis.

15 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a time-division basis.

16 Apparatus according to any one of claims 13 to 15 characterised by said multiplexer being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted.

AMENDED SHEET

17 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect packet-switching of data from said local sources and to interleave said data packets with an unsymmetrical packet distribution.

18 Apparatus according to any one of claims 13 to 17 characterised by said data processing function comprising a host PC (24) having a series of virtual serial ports, and said control means being adapted to allocate each of said sub-channels to a respective one of said virtual ports.

19 Apparatus according to any one of claims 13 to 18 characterised by at least one of said local sensors (14) being adapted to provide a primary data-processing function.

20 Apparatus according to claim 19 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration whereby said apparatus can transmit said vibration data from said vibration sensing means.

21 Apparatus according to claim 20 characterised by said local data sensors comprising sensors adapted to provide vibration data permitting noise vibration harshness (NVH) data for analysis thereof.

22 Apparatus according to claim 21 characterised by said local data sensors comprising at least three or more such NVH sensors whereby said sensors can be located at three-dimensionally spaced locations to provide data enabling identification of the location or co-ordinates of the source of a vibration in a machine.

23 Apparatus according to claim 20 or claim 21 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106)

whereby said vibration sensor means can sense vibrations at three-dimensionally-spaced locations in sequence and said three-dimensional location sensing means can identify the co-ordinates or locations of said three locations so as to enable identification of the location or co-ordinates of a source of vibration.

24 A method for vibration analysis of a machine or other article comprising:

a) providing a vibration sensor (104);

b) causing said sensor to sense vibrations;

c) analysing signals produced by said sensor;

characterised by

d) providing said sensor with three-dimensional location sensing means (106);

e) causing said vibration sensor to be mechanically coupled to the machine or other article to sense vibrations at three-dimensionally-spaced locations and using said three-dimensional location sensing means to determine the co-ordinates of said three locations; and

f) identifying the location or co-ordinates of a source of vibration accordingly.

25 Apparatus for vibration analysis of a machine or other article comprising:

a) a vibration sensor (104) adapted to sense vibrations at chosen locations; and

b) analysis means (124) adapted to analyse signals produced by said sensor;

characterised by

c) said vibration sensor being adapted to be mechanically coupled to the machine or other article and further comprising three-dimensional location sensing means (106);

d) whereby said single sensor can be caused to sense vibrations at three-dimensionally spaced locations at which said three-dimensional location sensing means can identify

the co-ordinate locations thereof whereby the corresponding co-ordinates of a source of vibration can be determined.

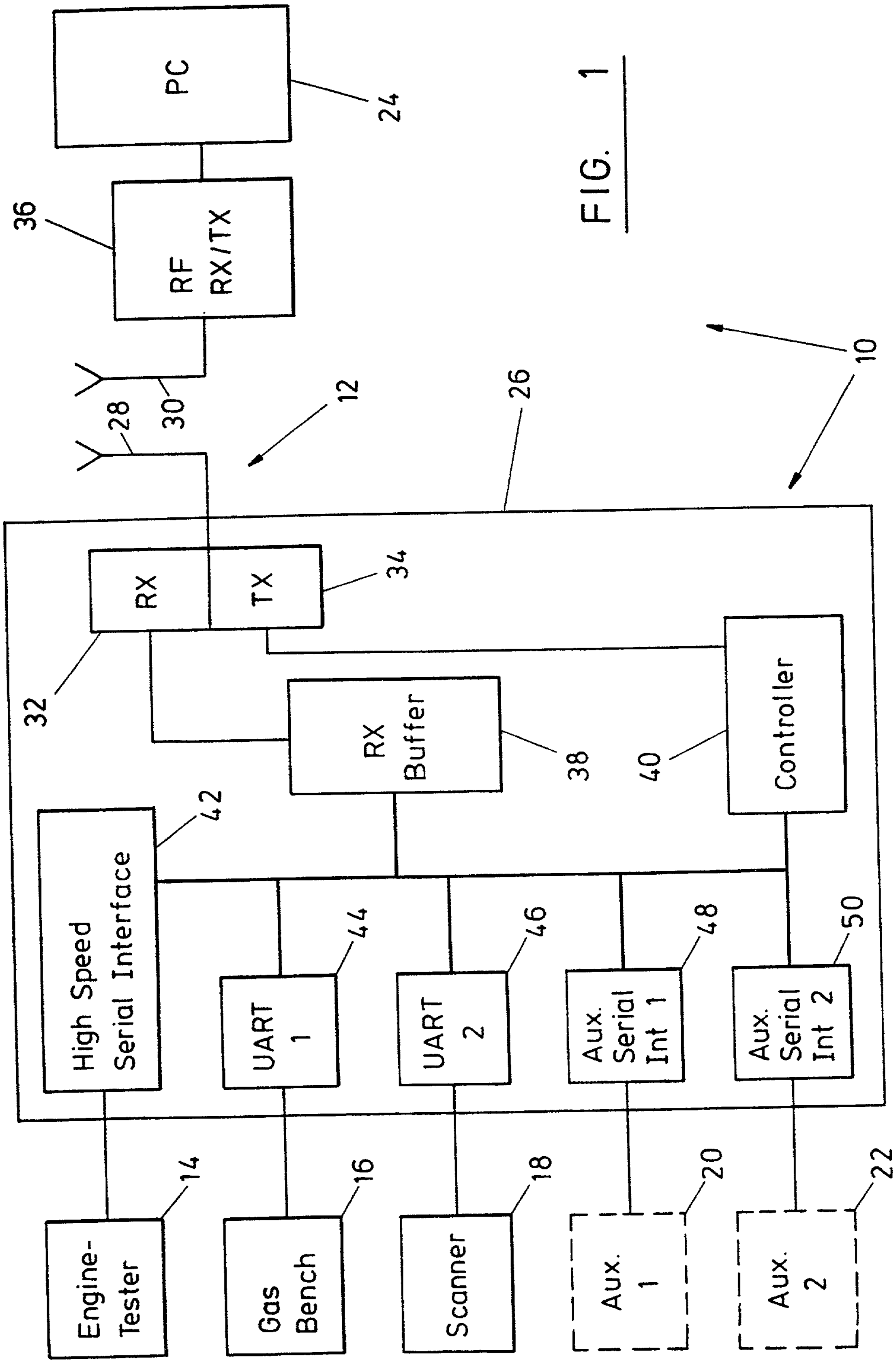
PC
24
RF
RX/TX
36
30
28
12
26
10
RX
TX
32
34
RX
Buffer
38
40
Controller
High Speed
Serial Interface
42
UART
1
44
UART
2
46
Aux.
Serial
Int 1
48
Aux.
Serial
Int 2
50
Engine-
Tester
14
Gas
Bench
16
Scanner
18
Aux.
1
20
Aux.
2
22

FIG. 1

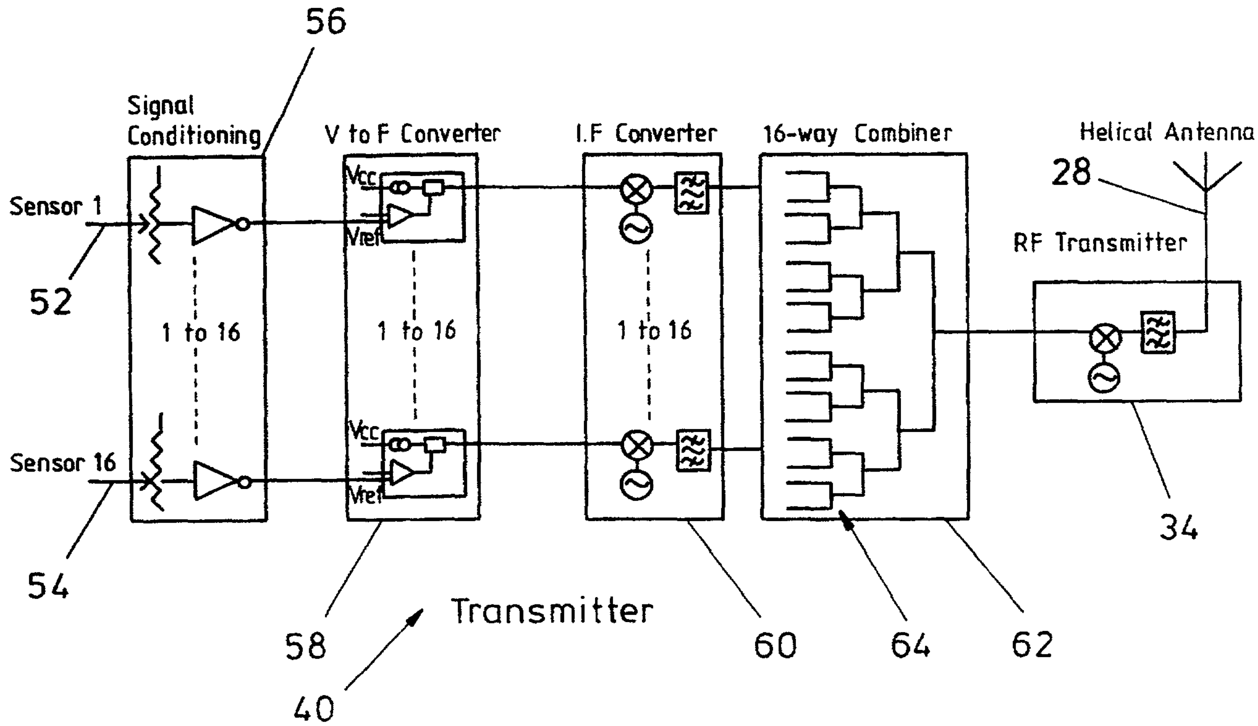
56
Signal Conditioning
V to F Converter
I.F Converter
16-way Combiner
Helical Antenna
28
Sensor 1
Vcc
Vref
RF Transmitter
52
1 to 16
1 to 16
1 to 16
Sensor 16
Vcc
Vref
34
54
Transmitter
58
60
64
62
40

FIG. 2

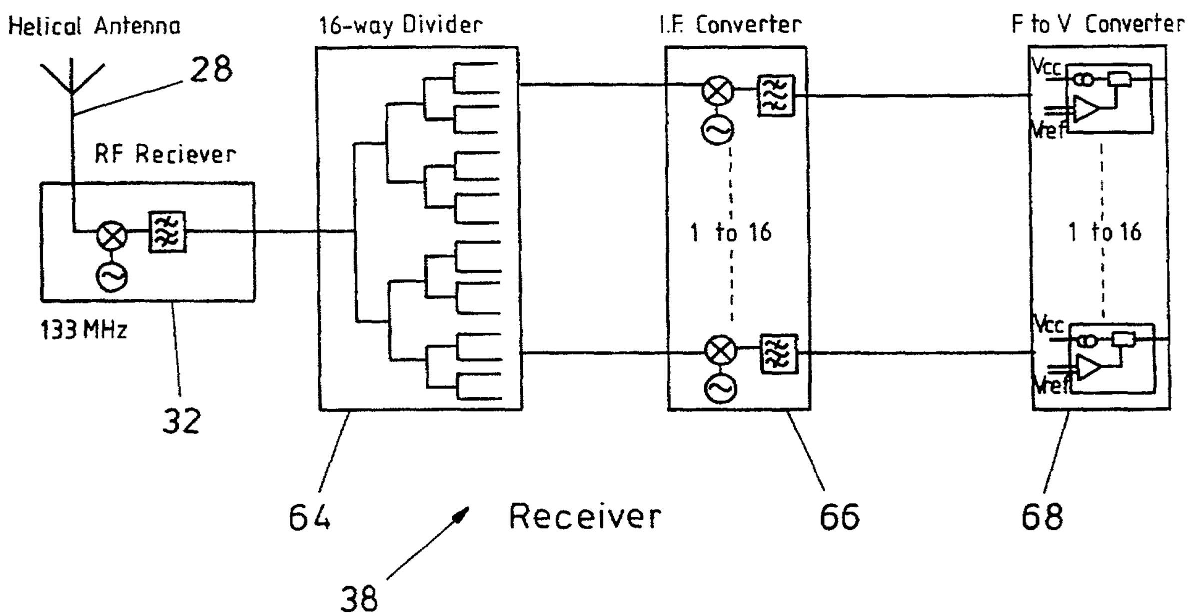
Helical Antenna
16-way Divider
I.F Converter
F to V Converter
28
Vcc
Vref
RF Reciever
1 to 16
1 to 16
133 MHz
Vcc
Vref
32
64
Receiver
66
68
38

FIG. 3

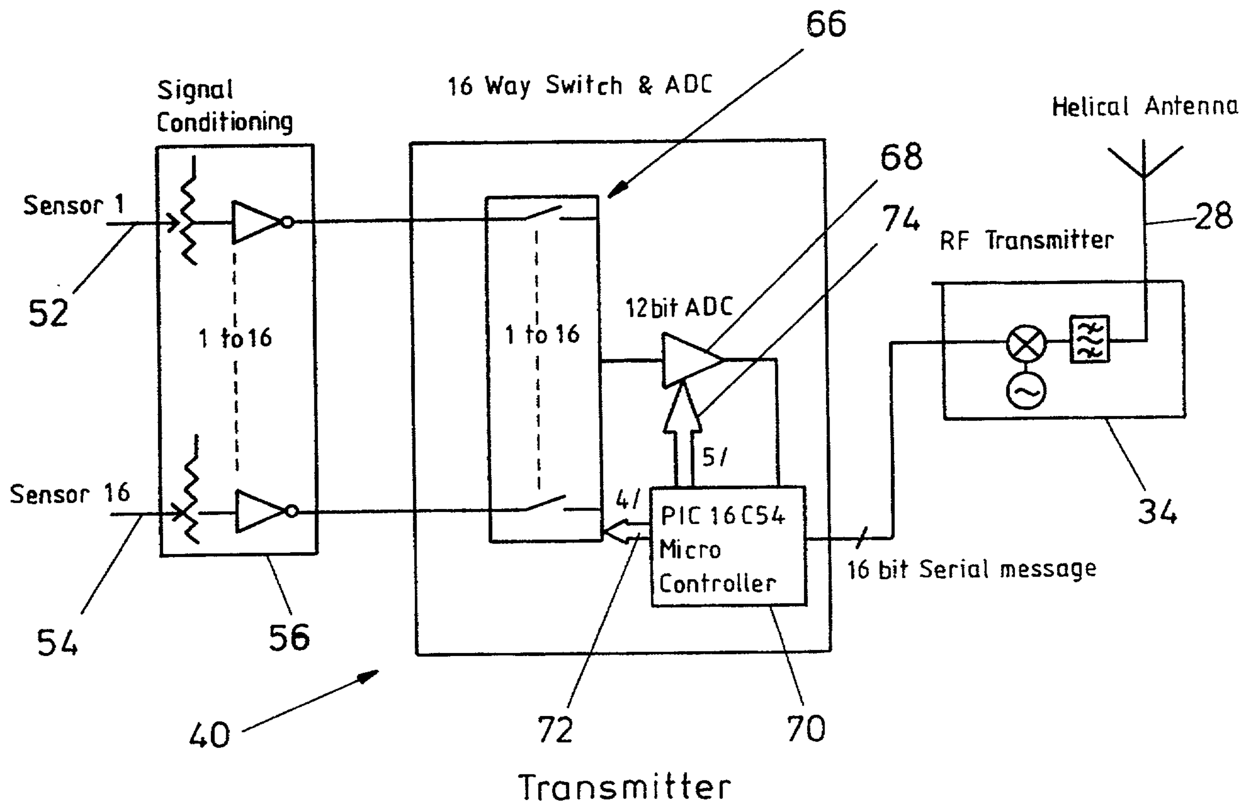
66
Signal Conditioning
16 Way Switch & ADC
Helical Antenna
68
74
28
Sensor 1
RF Transmitter
52
1 to16
1 to 16
12bit ADC
5/
Sensor 16
4/
PIC 16C54 Micro Controller
34
16 bit Serial message
54
56
40
72
70
Transmitter

FIG. 4

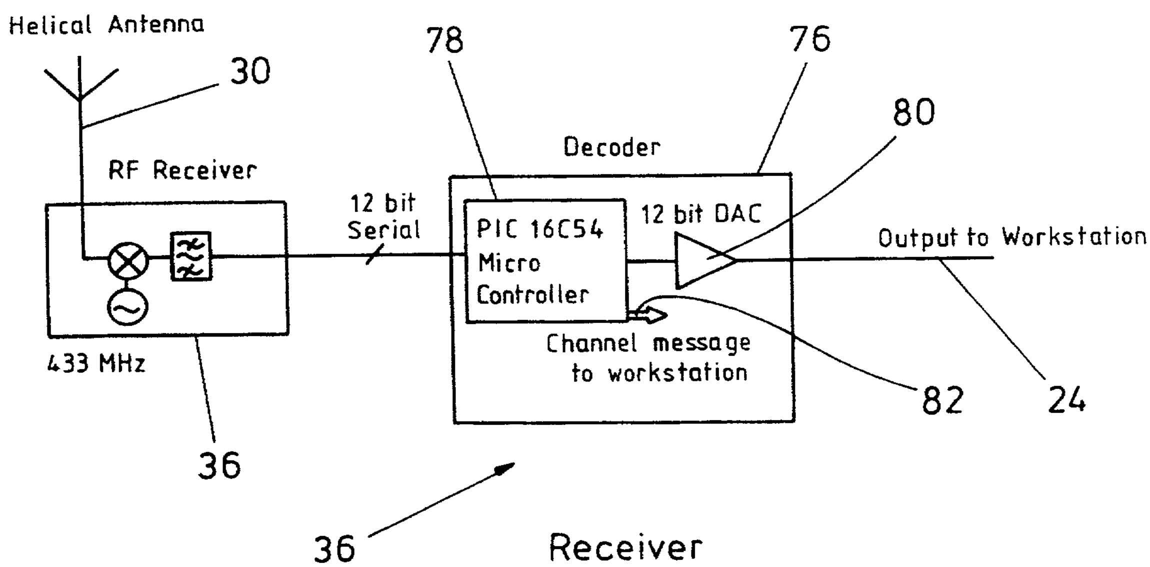
Helical Antenna
30
78
76
80
Decoder
RF Receiver
12 bit Serial
PIC 16C54 Micro Controller
12 bit DAC
Output to Workstation
433 MHz
Channel message to workstation
82
24
36
36
Receiver

FIG. 5

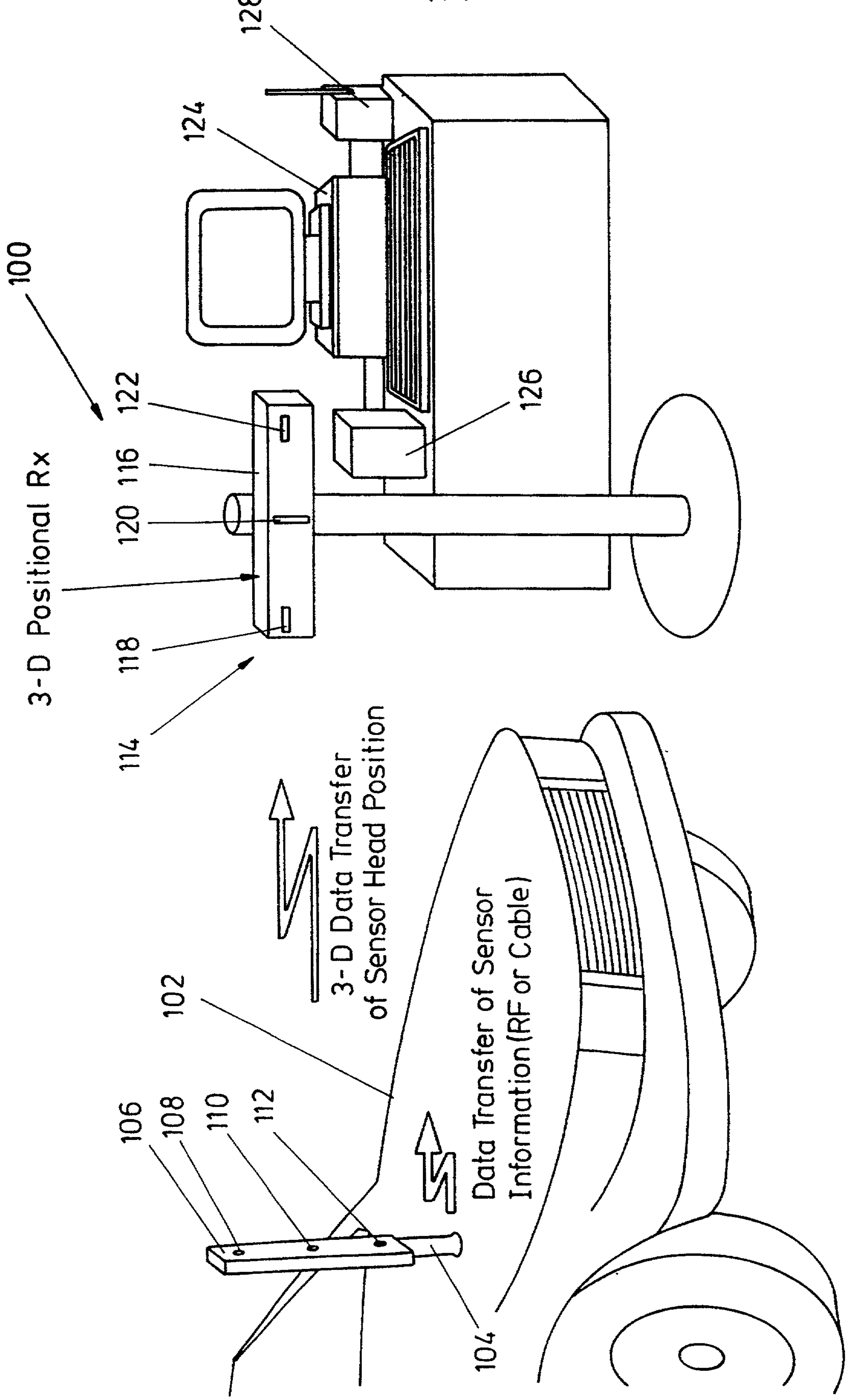
100
3-D Positional Rx
122
116
120
118
114
124
128
126
3-D Data Transfer
of Sensor Head Position
Data Transfer of Sensor
Information (RF or Cable)
102
106
108
110
112
104

FIG. 6

Please type a plus sign (+) inside this box → [+]

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Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

[X] Declaration Submitted with Initial Filing OR [ ] Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	14,442
First Named Inventor	Jones, Barbara L.
COMPLETE IF KNOWN	
Application Number	/
Filing Date	
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

(Title of the invention)

the specification of which

[ ] is attached hereto

OR

[X] was filed on (MM/DD/YYYY) 04/03/1998 as United States Application Number or PCT International Application Number PCT/GB98/00866 and was amended on (MM/DD/YYYY) 04/17/1999 (If applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
9706797.9	GB	3 April 1997 (04/03/1997)	[ ]	[ ]	[X]
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]

[ ] Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)

[ ] Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)
PCT/GB98/00866	3 April 1998 (04/03/1998)	

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☐ Customer Number → Place Customer Number Bar Code Label here
OR
☒ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Stotland, Harold V.	24,492		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

Direct all correspondence to: ☐ Customer Number or Bar Code Label OR ☒ Correspondence address below

Name	Harold V. Stotland				
Address	Emrich & Dithmar				
Address	300 South Wacker Drive, Suite 3000				
City	Chicago	State	IL	ZIP	60606
Country	U.S.A.	Telephone	312-663-9800	Fax	312-663-9822

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])			Family Name or Surname		
Barbara L.			Jones		
Inventor's Signature	Barbara L. Jones			Date	
Residence: City	Norfolk	State	Country U.K. GBX	Citizenship	U.K.
Post Office Address	37 Hall Orchards, Middleton, King's Lynn				
Post Office Address					
City	Norfolk	State	ZIP PE32 1RY	Country	U.K.

☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

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Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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DECLARATION

ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 1 of 1

Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])	Paul			Family Name or Surname	Smith		
Inventor's Signature	P. Smith					Date	
Residence: City	Norfolk	State		Country	U.K. GBX	Citizenship	U.K.
Post Office Address	Sunnyside, Main Road, Brookville,						
Post Office Address	Methwold, Thetford						
City	Norfolk	State		ZIP		Country	U.K.
Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])				Family Name or Surname			
Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
City		State		ZIP		Country	
Name of Additional Joint Inventor, if any:	☐ A petition has been filed for this unsigned inventor						
Given Name (first and middle [if any])				Family Name or Surname			
Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
City		State		ZIP		Country	

Burden Hour Statement: This form is estimated to take 0.4 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

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Patent and Trademark Office
Address: ASSISTANT COMMISSIONER FOR PATENTS
Box PCT
Washington, D.C. 20231

FEB 28 2000

U.S. APPLICATION NO.	FIRST NAMED APPLICANT		ATTY. DOCKET NO.
09/402262	JONES	B	14,442

STOTLAND HAROLD V
EMRICH & DITHMAR
300 SOUTH WACKER DRIVE
SUITE 3000
CHICAGO, IL 60606

INTERNATIONAL APPLICATION NO.	
PCT/GB98/00866	
I.A. FILING DATE	PRIORITY DATE
03 APR 98	03 APR 97

DATE MAILED: 17 DEC 1999

NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

RECEIVED
DEC 22 1999
EMRICH & DITHMAR

1. The following items have been submitted by the applicant or the IB to the United States Patent and Trademark Office as
   - ☐ a Designated Office (37 CFR 1.494),
   - ☒ an Elected Office (37 CFR 1.495):

- ☒ U.S. Basic National Fee.
- ☒ Copy of the international application in:
  - ☐ a non-English language.
  - ☒ English.
- ☒ Translation of the international application into English.
- ☐ Oath or Declaration of inventors(s) for DO/EO/US.
- ☐ Copy of Article 19 amendments.
- ☐ Translation of Article 19 amendments into English.
- ☒ The International Preliminary Examination Report in English and its Annexes, if any.
- ☒ Translation of Annexes to the International Preliminary Examination Report into English.
- ☐ Preliminary amendment(s) filed ________________ and ________________.
- ☐ Information Disclosure Statement(s) filed ________________ and ________________.
- ☐ Assignment document.
- ☐ Power of Attorney and/or Change of Address.
- ☐ Substitute specification filed ________________.
- ☐ Verified Statement Claiming Small Entity Status.
- ☒ Priority Document.
- ☒ Copy of the International Search Report ☒ and copies of the references cited therein.
- ☐ Other:

2. The following items MUST be furnished within the period set forth below in order to complete the requirements for acceptance under 35 U.S.C. 371:
   - ☐ a. Translation of the application into English. Note a processing fee will be required if submitted later than the appropriate 20 or 30 months from the priority date.
     - ☐ The current translation is defective for the reasons indicated on the attached Notice of Defective Translation.
   - ☐ b. Processing fee for providing the translation of the application and/or the Annexes later than the appropriate 20 or 30 months from the priority date (37 CFR 1.492(f)).
   - ☐ c. Oath or declaration of the inventors, in compliance with 37 CFR 1.497(a) and (b), identifying the application by the International application number and international filing date.
     - ☒ The current oath or declaration does not comply with 37 CFR 1.497(a) and (b) for the reasons indicated on the attached PCT/DO/EO/917.
   - ☒ d. Surcharge for providing the oath or declaration later than the appropriate 20 or 30 months from the priority date (37 CFR 1.492(e)).

3. Additional claim fees of $__________ as a ☐ large entity ☐ small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due. See attached PTO-875.

ALL OF THE ITEMS SET FORTH IN 2(a)-2(d) AND 3 ABOVE MUST BE SUBMITTED WITHIN ONE MONTH FROM THE DATE OF THIS NOTICE OR BY ☐ 21 OR ☒ 31 MONTHS FROM THE PRIORITY DATE FOR THE APPLICATION, WHICHEVER IS LATER. FAILURE TO PROPERLY RESPOND WILL RESULT IN ABANDONMENT.

The time period set above may be extended by filing a petition and fee for extension of time under the provisions of 37 CFR 1.136(a).

4. Translation of the Annexes MUST be submitted no later that the time period set above or the annexes will be cancelled. Note processing fee will be required if submitted later than 30 months from the priority date.
5. ☐ The Article 19 amendments are cancelled since a translation was not provided by the appropriate 20 (37 CFR. 494(d)) or 30 (37 CFR 1.495(d)) months from the priority date.

Applicant is reminded that any communication to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above. (37 CFR 1.5)

A copy of this notice MUST be returned with this response.

Enclosed:
☒ PCT/DO/EO/917 ☐ Notice of Defective Translation
☐ PTO-875

Paulette Kidwell, Paralegal
Telephone: 703-305-3656

FORM PCT/DO/EO/905 (December 1997)

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522 Rec'd PCT/PTO 2 8 FEB 2000

PCT/ #3

EMRICH & DITHMAR
ATTORNEYS AND COUNSELORS
SUITE 3000
300 SOUTH WACKER DRIVE
CHICAGO, ILLINOIS 60606, USA
TEL: 312-663-9800
FAX: 312-663-9822

PATENTS, TRADEMARKS, COPYRIGHTS
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AND RELATED LITIGATION

PAUL L. BROWN
JAMES J. HILL
HAROLD V. STOTLAND
HARRY M. LEVY
J. TERRY STRATMAN
ROBERT R. CALIRI
THOMAS E. HILL
HOWARD S. FUHRMAN
WILLIAM J. HALLIHAN
JONATHAN J. KRIT

February 24, 2000

Asst. Commissioner for Patents
BOX MISSING PARTS
Washington, D.C. 20231

CERTIFICATE OF MAILING

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner of Patents, Washington, D.C. 20231 on

2-24-00
Date of Deposit

Aerce Lans
Signature

2-24-00
Date of Signature

Re: Snap-on Equipment Limited
File 14,442
Patent Application for:
WIRELESS MULTIPLEX DATA
TRANSMISSION SYSTEM
Serial No. 09/402,262

Sir:

Applicants hereby petition under 37 CFR §1.136(a) for an extension of time to respond to the Notification of Missing Requirements under 35 USC 371 dated December 17, 1999 for two months from January 17, 2000 to March 17, 2000, together with our check in the amount of $510.00 (fee for Declaration $130.00 and $380 two-month extension).

Transmitted for filing herewith is an executed Declaration, Power of Attorney and Correspondence Address in response to Notification of Missing Requirements under 35 USC 371 dated December 17, 1999(copy enclosed).

Please charge any additional fees or credit any overpayment to Deposit Account No. 05-1060.

Sincerely yours,

Harold V. Stotland

Harold V. Stotland

HVS:cw

03/06/2000 UWALKER 00000112 09402262

01 FC:198 510.00 OP

Please type a plus sign (+) inside this box → [+]

PTO/SB/01 (12-97)
Approved for use through 9/30/00. OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

[X] Declaration Submitted with Initial Filing OR [ ] Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	14,442
First Named Inventor	Jones, Barbara L.
COMPLETE IF KNOWN	
Application Number	/
Filing Date	
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

(Title of the invention)

the specification of which

[ ] is attached hereto

OR

[X] was filed on (MM/DD/YYYY) 04/03/1998 as United States Application Number or PCT International Application Number PCT/GB98/00866 and was amended on (MM/DD/YYYY) 04/17/1999 (If applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
9706797.9	GB	3 April 1997 (04/03/1997)	[ ]	[ ]	[X]
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]

[ ] Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)

[ ] Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

OIPE JC73 FEB 28 2000 PATENT & TRADEMARK OFFICE

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Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE
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DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number *(if applicable)*
PCT/GB98/00866	3 April 1998 (04/03/1998)	

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☐ Customer Number [ ] → *Place Customer Number Bar Code Label here*
OR
☒ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Stotland, Harold V.	24,492		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

Direct all correspondence to: ☐ Customer Number or Bar Code Label [ ] OR ☒ Correspondence address below

Name	Harold V. Stotland				
Address	Emrich & Dithmar				
Address	300 South Wacker Drive, Suite 3000				
City	Chicago	State	IL	ZIP	60606
Country	U.S.A.	Telephone	312-663-9800	Fax	312-663-9822

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])				Family Name or Surname			
Barbara L.				Jones			
Inventor's Signature	Barbara L. Jones					Date	
Residence: City	Norfolk	State		Country	U.K. GBX	Citizenship	U.K.
Post Office Address	37 Hall Orchards, Middleton, King's Lynn						
Post Office Address							
City	Norfolk	State		ZIP	PE32 1RY	Country	U.K.

☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

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DECLARATION

ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 1 of 1

Name of Additional Joint Inventor, if any: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
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PATENT APPLICATION #7

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

Lieve Maria Marcella Rosemarijn BOS, et al. Attorney Docket Q57274

Appln. No.: 09/468,227 Group Art Unit: 2734

Filed: December 20, 1999 Examiner: Not yet assigned

For: A TERMINAL TO EXECUTE A TERMINAL APPLICATION

INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.97 and 1.98

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

In accordance with the duty of disclosure under 37 C.F.R. § 1.56, Applicants hereby notify the U.S. Patent and Trademark Office of the document which is listed on the attached Form PTO-1449 and which the Examiner may deem relevant to patentability of the claims of the above-identified application.

One copy of each of the listed documents is submitted herewith.

The present Information Disclosure Statement is being filed before the mailing date of the first Office Action on the merits, and therefore no Statement under 37 C.F.R. § 1.97(e) or fee under 37 C.F.R. § 1.17(p) is required.

The submission of the listed documents is not intended as an admission that any such document constitutes prior art against the claims of the present application. Applicants do not waive any right to take any action that would be appropriate to antedate or otherwise remove any listed document as a competent reference against the claims of the present application.

Respectfully submitted,

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Date: February 11, 2000

2734

PATENT APPLICATION #6

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

OIPE FEB 11 2000 PATENT & TRADEMARK OFFICE

In re application of

Lieve Maria Marcella Rosemarijn BOS, et al.

Appln. No.: 09/468,227

Filed: December 20, 1999

Attorney Docket Q57274

Group Art Unit: 2734

Examiner: Not yet assigned

RECEIVED FEB 17 2000 Group 2700

For: A TERMINAL TO EXECUTE A TERMINAL APPLICATION

SUBMISSION OF PRIORITY DOCUMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Submitted herewith is a certified copy of the priority document on which a claim to priority was made under 35 U.S.C. § 119. The Examiner is respectfully requested to acknowledge receipt of said priority document.

Respectfully submitted,

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Enclosures: **CERTIFIED COPY OF EUROPEAN PATENT APPLICATION NO. 99403045.0**

Date: February 11, 2000

09/468,227
Q57274
1871

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FEB 11 2000
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Bescheinigung

Certificate

Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

99403045.0

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 99403045.0
Demande n°:

Anmeldetag:
Date of filing: 06/12/99
Date de dépôt:

Anmelder:
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Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
A terminal to execute a terminal application

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
/

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

A TERMINAL TO EXECUTE A TERMINAL APPLICATION

The present invention relates to a terminal to execute a terminal application as described in the preamble of claim 1, the terminal application to be executed by such a terminal as described in the preamble of claim 4, a carrier of such a terminal application as described in the preamble of claim 6, a method realized by such a terminal as described in the preamble of claim 7 and a communication network comprising such a terminal, such a terminal application as described in the preamble of claim 8.

Such a terminal with terminal capabilities and terminal applications means coupled thereto to interact with the terminal capabilities and to execute thereby a terminal application is especially known in communication networks referred as a Universal Mobile Telecommunication Systems UMTS. For such an UMTS network the concept of Virtual Home environment is defined. A Virtual home environment is defined as a concept for personal service environment portability across network boundaries and between terminals. The concept of the Virtual Home environment is such that users are consistently presented with the same personalized features, User Interface customization and services in whatever network and whatever kind of terminal, wherever the user may be located. The Virtual Home Environment is seen as a key mechanism for convergence of fixed and mobile terminals, for public and private networks and operators and for telecommunication and data communication systems.

A terminal, either fixed terminal or mobile terminal, for use in such a virtual home environment comprises terminal capability means where for here below a non-exhaustive list of examples is provided:

- a Wireless Application Protocol WAP client that communicates via a WAP gateway with a WEB server in the Internet or other terminals. WAP specifies an application framework and network protocols for wireless devices such as mobile phones, pagers and personal digital assistants. The network protocols specify a way of transporting data between an Internet Protocol IP network and mobile terminals. The application framework enables the creation of Internet like services; and

- a Wireless Telephone Application WTA client that communicates with a WTA server in the network. WTA specifies an application framework that extends the WAP architecture with telephony services. It is a collection of telephony specific extension for call and feature control mechanisms that make advanced Mobile Network Services available to users. In contrast with classical client–server architecture e.g. WAP where the client continuously communicates with the server for the execution of the services actually running on the server, WTA adopts a terminal centric approach. WTA services run in the WTA client on the mobile terminal, which only communicates with the WTA server for maintenance and reconfiguration reasons; and

- a Java execution environment such as e.g. a Java card. A JavaCard is a recent evolution in the area of smart-cards with an enhanced architecture that has a Java Card Virtual Machine JCVM on top of its native Operating System OS and allows to develop applications written in Java programming language; and

- a User Service Identity Module USIM module that comprises e.g. an authentication algorithm and a ciphering key, a card identification, a user identification, network and service related data and UMTS SIM applications i.e. USIM applications; and

- a SIM Application Tool-kit provides mechanisms which allow applications that exist on the USIM to interact and to operate with any part of the mobile equipment of a mobile terminal.

It has to be remarked that according to the virtual home environment definitions a User Service Identity Module that identifies a user can be comprised in as well a fixed terminal as a mobile terminal. Such a USIM card comprises terminal capability means but might as well comprise terminal applications means with a terminal application.

The above mentioned terminal capabilities are realizing terminal capability features whilst being supported by terminal bearers such as e.g. short message service SMS, circuit switched data and Generic Packet Radio Service. It has to be mentioned that a particular manufacturer develops these terminal capability features and terminal bearers. In this way the terminal capability features and terminal bearers are technology dependent according to the choices of a manufacturer.

The known kind of terminals further comprises a terminal application means to interact with one or more of the terminal capabilities in order to execute a terminal application.

A terminal application provides to a user of a terminal a particular service such as e.g. 'a call forwarding application according to the user's preferences' or 'a voice message application' or 'personal banking applications', etc. It has to be remarked that such a terminal application is a hardware module or, more commons, a software module. Such a software module terminal application is information e.g. logic and data that can be stored at production time on e.g. a read only memory of the terminal, but on the other hand, it might as well be downloaded from a service provider in the telecommunication network on e.g. an accessible memory of the terminal during operational use of the terminal. It has to be remarked that such a terminal application is usual designed according to a higher programming language level.

A terminal application means comprises at least part of the data concerning the present application and an application execution environment. In this way the execution environment, under the support of the associated terminal capability means, executes the data of the application e.g. a WAP application means executes a particular WAP application by interacting with the associated WAP client.

It has to be remarked here that since the terminal capability means is technology dependent according to a certain manufacturer, that also the related application is developed towards this technology of this manufacturer. Indeed, in order to be executed by the terminal application means that interacts with the terminal capability means the terminal application must be designed according to the same interfaces. This means that an application signal that is transmitted by the terminal capability means is received and understood by the terminal application means that executes an application being developed according to the same manufacturer preferences as the one used for the terminal capability means, and vice versa.

A problem outstanding with such kind of terminals is that in the event when a third party service provider develops a terminal application for use on a terminal, that the application must be written for different underlying technologies preferred and used by different manufacturers of terminals. Indeed, a terminal application developed according to preferences of a first manufacturer is not able to cooperate via the terminal application means with a terminal capability means being developed according to preferences of a second manufacturer.

Furthermore, two different terminal applications applied on a same terminal are not able to interact with each other when being designed for different kind of terminal capability means.

An object of the invention is to provide a terminal for use in a communication network that executes a terminal application such as the above known terminal but which has not the above mentioned drawback of the requirement of development of different terminal application designs for execution of a this terminal application by interacting with different terminal capability means of possible different manufacturer's underlying technology.

This is realized by the terminal of claim 1 that executes the terminal application of claim 4 on the carrier of claim 6, that realizes the method of claim 7 and that is comprised in the communication network of claim 8.

Indeed, by comprising in the terminal according to the invention at least one terminal capability server means being coupled between the terminal application means and one or more of the plurality of terminal capability means, the terminal is adapted to translate a first application signal from the terminal capability means into a first predefined application open signal and to provide this first predefined application open signal to the terminal application means and the terminal is further adapted to translate a second predefined application open signal from the terminal application means into a second application signal and to provide this second application signal to the terminal capability means. Furthermore, by defining the first predefined application open signal and the second predefined application open signal independent of an underlying technology of the plurality of terminal capability means, a third party service provider is enabled to write only one terminal application for use on different kind of terminals with different underlying technologies being preferred and used by different kind of manufacturers. Indeed, when the manufacturers of different type of technologies comprise a terminal capability server means in its terminal, that is designed to translate technology dependent application signals into predefined application open signals similar to the first predefined application open signal and to translate predefined application open signals similar to the second predefined application open signal into technology dependent application signals, these manufacturers encourage third party service providers to develop services once that can be deployed on any kind or any type of terminal. These predefined application open signals are defined and agreed between the different manufacturers independent of their own technology specific aspects.

A further advantage of such kind of approach is the fact that one terminal application that is executed by a terminal application means can interact with different terminal capability means being developed with different underlying technologies such as e.g. a particular WAP application that interacts with a WAP client that is developed by one manufacturer and with another kind of terminal capability means such as a WTA client being developed by another manufacturer.

It has to be explained that the carrier of claim 6 can be realized by the terminal itself e.g. a memory element at the terminal application means, or by a third party service provider in order to be downloaded by a user or by a physical link between one of the network elements when e.g. being downloaded or just being transported.

A further feature, that is described in claim 2, is that the first predefined open signal and the second predefined open signal are defined in correspondence to information of a predefined network open service architecture interface. This will become more clear in the following paragraph.

Such predefined network open service architecture interface is e.g. described by the third Generation Partnership Project, Technical Specification Group Services and System Aspects, Virtual Home environment / Open Service Architecture with reference 3G TS 23.127 version 1.0.0 and available for the public at by 650 Route des Lucioles – Sophia Antipolis, Valbonne – France and via the World Wide Web at http://www.3gpp.org and in October, 1999. This document describes an Open Service Architecture. It is mentioned that the Open Service Architecture OSA defines an architecture that enables operator and third party applications to make use of network functionality through an open standardized interface i.e. the OSA Interface. Open Service Architecture provides the glue between applications and service capabilities provided by the network. In this way applications become independent from the underlying network technology. The applications constitute the top level of the Open Service Architecture OSA. This level is connected to the Service Capability Servers via the Open Service Architecture interface. The Service Capability Servers map the Open Service Architecture interface onto the underlying telecom specific protocols and are therefore hiding the network complexity from the applications.

Applications can be network/server centric applications or terminal centric applications. Terminal centric applications reside in the terminal e.g. a Subscriber Identity Module SIM application toolkit application called shortly SAT application. Network/server centric applications are outside the core network and make use of service capability features offered through the Open Service Architecture. It has to be remarked that applications may belong to the network operator domain although running outside the core network. Outside the core network means that the applications are executed in Applications Servers that are physically separated from the network entities.

A third party service provider is with such an predefined network open service architecture enabled to write once a network application that makes use of network functionality according to an network independent way. Such a network application is e.g. a call conference application on a call conference application server as e.g. described in the above-mentioned document in Chapter 9, Annex – Example of use of OSA (informative). Herein, a user A desires to have a call conference with a user B and a user C. The network application requests the Camel Service Capability Server to set up a call according to the call forwarding preferences of user A. The call conference service settings of user A are known by e.g. interacting via the terminal of user A that comprises terminal capability means which are developed by different manufacturers. In this way, the third party service provider still needs to write different applications towards these different underlying technologies of different terminals. According to the example, the procedure of the call set up is ordered via a WAP communication. This WAP communication can be implemented by a WAP terminal application that interacts with a WAP client on the terminal of user A i.e. a terminal capability means of the terminal that communicates with a WAP server in the network. The WAP terminal application asks for instance via the terminal display to the user the different call conference parties upon which user A enters e.g. the user identification numbers of user B and user C and itself. The WAP terminal application is executed on the WAP terminal application means by interacting with the WAP terminal capability means, which is technology dependent. The present invention brings an improvement to such kind of service network applications which interact also with terminals by comprising the terminal capability server means CS in the terminal to translate the technology dependent application signals into technology independent open application signals. However, by defining the predefined application open signals in correspondence to information of such a predefined network open service architecture interface the flexibility towards the third party service providers is further improved. Indeed, since the network application is provided here by a third service provider, it is preferred that the user A takes contact, not with its home service provider of its home network, but directly with the service provider that the service provides. Therefor the application at the terminal of user A needs to know e.g. the identification information of this third party service provider which is defined according to the predefined network open service architecture. This is realized by the terminal of claim 2 and by the terminal application of claim 5. It has to be remarked that the above mentioned identification information is only cited as an example, and that the information of the present invention, in correspondence to a predefined network open service architecture interface, is not limited to only identification information of a third party service provider.

A final feature of he present invention is described in claim 3. This is the fact that not only the interchanged signals between a terminal application means and a terminal capability means are terminal technology independent or are comprising information in accordance to a predefined network open service architecture interface information. It is also preferable that different terminal capability means are adapted to interact, either directly or indirectly via a terminal capability server means, according to predefined independent application open signals or according to signals comprising information of predefined network open service architecture. It has to be explained that as an example a SIM Application Tool-kit generates commands for the USIM of e.g. a mobile terminal, towards other parts of the mobile equipment. According to the present invention, such a command can comprise an identification reference of a terminal application on a terminal application means or an identification reference of a third party service provider in order to initiate e.g. a short message towards this third party service provider.

It should be noticed that the term 'comprising', used in the claims, should not be interpreted as being limitative to the means listed thereafter. Thus, the scope of the expression 'a device comprising A and B' should not be limited to devices consisting only of components A and B. It means that with respect to the present invention, the only relevant components of the device are A and B.

Similarly, it is to be noted that the term 'coupled', also used in the claims, should not be interpreted as being limitative to direct connections only. Thus, the scope of the expression 'a device A coupled to a device B' should not be limited to devices or systems wherein an output of device A is directly connected to an input of device B. It means that there exists a path between an output of A and an input of B which may be a path including other devices or means.

The above and other objects and features of the invention will become more apparent and the invention itself will be best understood by referring to the following description of an embodiment taken in conjunction with the accompanying figure that represents a telecommunication network in a virtual environment that comprises a terminal according to the present invention. Referring to the figure the working of the terminal in accordance with the other network elements will be explained by means of a functional description of the functional blocks shown therein. Based on this description, implementation of the functional blocks will be obvious to a person skilled in the art and will therefore not be described in detail. In additional, the principle working of the terminal regarding the invention will be described in further detail by means of three principle examples.

The communication network comprises a terminal T, a third party service provider 3rdSP and a visited mobile network VN. For this particular embodiment it is preferred to choose a mobile terminal. However, it has to be explained that the scope of the invention is not limited to mobile terminals and might be as well a fixed terminal. In order to explain the present invention by means of an example that is described in a later paragraph wherein the terminal is located in a visited i.e. not its home mobile network, a limited number of functional blocks of this visited mobile network will be shortly described.

The mobile network comprises, according to the definitions of the network open service architecture of the above mentioned document of 3GPP a service capability server SCS; a Customized Application for Mobile Network enhanced Logic Camel CML i.e. the required functionality to provide a mobile network a service of an intelligent network; a short message server SMS and a mobile switching center MSC. The service capability server SCS comprises a Camel service capability server CML-SCS on top of the Camel CML and a short message service capability server SMS-SCS on top of the short message server SMS.

It has to be remarked that these network elements are only mentioned in order to better explain the advantages of the present invention and that therefor these functional blocks are not described in further detail.

The terminal comprises four terminal capabilities CAP1, CAP 2, CAP3 and CAP4, four terminal application means APP1, APP2, APP3 and APP4 with four terminal applications app1, app2, app3 and app4, and one capability server CS.

It has to be understood that the applications app1, app2, app3 and app4, which are to be executed by the terminal application means, APP1, APP2, APP3 and APP4 are at least partly stored at the terminal application means, APP1, APP2, APP3 and APP4. How and when the applications are stored or eventual downloaded from the network goes beyond the scope of the invention. The aim is the fact that the logic and data, shortly called data information, concerning the execution of the applications is at least partly present at the application means and that this data information is to be used by the application means in order to provide a service to the user of the mobile terminal.

The terminal T comprises terminal equipment TE and an USIM.

The terminal equipment TE comprises as well terminal capabilities as terminal application means i.e. the terminal capabilities CAP1, CAP2, CAP4 and the terminal application means APP1 and APP2. The terminal equipment TE further comprises e.g. basic equipment of the mobile terminal to execute basic functionality for the mobile terminal such as e.g. setting up a communication.

The USIM is comprised to identify the user of the terminal and to personalize the terminal to this user. Furthermore by inserting the USIM in this terminal T the user informs the communication network the fact that he desires to communicate via this mobile terminal. The USIM comprises as well terminal capabilities CAP3 and CAP4 as two terminal application means APP3 and APP4.

It has to be remarked that in this way the terminal capabilities CAP4 is comprised in the USIM an in the terminal equipment TE. This will become more clear in a further paragraph wherein the terminal capabilities CAP is implemented with a SAT which indeed partly covers both functional blocks.

The four capabilities CAP2, CAP2, CAP3 and CAP4 are coupled via the capability server CS to one or more of the terminal application means APP1, APP2, APP3 and APP4. In this way APP2 is coupled via the capability server CS to capability CAP1 and capability CAP2.

It has to be remarked that the terminal capability server CS is preferred to be a centralized capability server. However, the terminal capability server CS can be distributed in the terminal towards the different terminal capabilities. In this way capability CAP 1 could have its own capability server and also capability CAP2 could have its own capability server. Furthermore, these two dedicated capability servers could on their turn be coupled to a centralized terminal capability server (not shown).

The terminal capability server CS is comprised to translate technology dependent application signals e.g. S1 received from one of the terminal capabilities CAP1, CAP2, CAP3 and CAP4 into technology independent open application signals e.g. SO1 and to provide these technology independent open application signals to one or more of the terminal application means APP1, APP2, APP3 and APP4. Further more the terminal capability server CS is comprised to translate technology independent open application signals e.g. SO2 received from one of the terminal applications means APP1, APP2, APP3 and APP4 into technology dependent application signals e.g. S2 and to provide these technology dependent application signals to one or more of the terminal capabilities CAP1, CAP2, CAP3 and CAP4. Since the terminal capability server CS is a centralized block it is preferred to show this translation in both directions by means of the two double arrows in the figure. The technology independent open application signals are called predefined application open signals e.g. SO1 and SO2. It has to be remarked that the predefined terminal application open signals are predefined according to a cooperation between different manufacturers of different type of terminals, whereby functionality such as basic terminal functions but also functions regarding the terminal capabilities are determined and defined in a uniform way. The determined functions are translated into these predefined application open signals and vice versa.

Furthermore, for this particular embodiment it is preferred to further determine the predefined application open signals in accordance with the information of a predefined network open service architecture interface according to the above mentioned information of 3GPP. However, it has to be remarked that this accordance is elementary for the present invention. This will become more clearly in a further paragraph.

A first example that will be described to explain the principle working and the advantages of the present invention concerns an application based on a call forwarding application. Presume that the terminal capability CAP1 is a wireless telephone application WTA client capability that supports the terminal application app1 i.e. a wireless telephone application WTA. A first manufacturer develops the WTA terminal capability and also the WTA application. Presume that the terminal capability CAP2 is a short message terminal capability SMS that is developed by a second manufacturer. The terminal application means APP1 comprises in this way a call forwarding application app1. This means that the user is enabled to install its own call forwarding preferences and to forward received communications to another e.g. telephone number. Presume that a third party service provider wants to develop an application that provides a service similar to the call forwarding application but furthermore wants to provide to its user clients the extra service of automatically generating a short message to a predefined identification number. According to prior art terminals this third party service provider needs to contact the first manufacturer and the second manufacturer to gather the knowledge of the underlying technology for the terminal capabilities CAP1 and CAP2. However, according to the present invention the terminal T comprises the capability server CS to translate the technology dependent application signals such as S1 into predefined application open signals such as SO1. In this way, the third party service provider is enabled to develop the 'call forwarding with short message application' e.g. app2 without prior knowledge of the technology used by the first manufactures of the WTA terminal capability and the second manufacturer of the SMS terminal capability.

Even more, when the third party service provider wants to offer this service to a second user that uses a second terminal (not shown) with its installed WTA and SMS terminal capabilities of some other manufacturers, no redesign of the application is required as long that the terminal comprises a terminal capability server CS according to the present invention.

A second example that will be described to explain a further advantage of the present invention concerns the application on the USIM i.e. app3 and app4. Presume that the application app3 on the terminal application means APP3 provides a service to the user that relates to its banking account i.e. its overall expenses over a predetermined period. The service provider of the bank provides at regular time moments by means of a short message the expenses made during the actual month. The information is also stored in the application means APP3 for eventual later inquiry. Furthermore, presume that the application app4 on the terminal application means APP4 provides a service to the user that relates to its expenses at its food store over a predetermined period. The preferred service provider of the food store keeps track of the expenses of the clients which are desiring such a service and furthermore provides on a regular base the expenses made in the food store during the actual month. The information is also stored in the application means APP4 for eventual later inquiry. Although that both applications are located at the USIM and that both application means APP3 and APP4 are interacting with the terminal capability CAP3 on the USIM, according to prior art situations, both applications app3 and app4 being developed by different service providers are not aware of each other and the information concerning the other application. However, due to the presence of the terminal capability server CS according to the present invention and in particular that part of the terminal capability server for the USIM related terminal capabilities CAP3, the terminal application means APP3 and APP4 are interacting with capability CAP3 according to a uniform way that is transparent to the user. Hereby it is enabled to provide information from one

USIM application to the other USIM application. Even a service provider that is different from the bank service provider and the food store service provider is enabled to develop in a technology independent way a further application that e.g. calculates the percentage of the food store expenses versus the overall expenses during the actual month (not shown).

Furthermore, the extra application can be improved by automatically sending a short message to a second user of the identical banking account in order to give this second user a warning when a predefined amount of expenses is reached by one or the other application. In the event when terminal capability CAP4 is a SAT functional block, upon request of the USIM, CAP4 commands the short message terminal capability means e.g. CAP 2 to generate automatically a short message towards the second user.

Even more, the application is further developed to additionally transmit a detailed list of the expenses, but only in the event when this second user is actually using a terminal with high display capabilities. Therefore, it is preferred to interrogate first, according to the extra application, the actual user profile of this second user by interacting with the home network capabilities. When, however this user profile network application is managed by a third party service provider outside the core network, it is necessary to inquiry this third party service provider and to known its identification references. Therefore the predefined application open signals are defined in accordance with a predefined network open service architecture information whereby e.g. this information can be requested to the network according to a standardized way.

The capabilities of the actual terminal (not shown) in use by the second user can be requested also directly to this terminal i.e. via the virtual home identification of the second user. Due to the presence of a capability server CS at this actual terminal of the second user the capabilities of this terminal are requested to the terminal directly in a way that is totally transparent for the second user himself.

The third example concerns a terminal application app1 i.e. a WTA application on terminal application means APP1 that provides the service of listening to voice messages. It explains however the interaction of a terminal according to the present invention with a network that supports open service architecture.

The terminal application means APP1 interacts with the terminal capability CAP1 i.e. a WTA client in order to execute the 'voice message application'. Presume that a third party service provider 3rdSP offers the application to the network of keeping track and storing voice messages. Herewith the 3rd service provider 3rdSP provides also the terminal application for the end-users of providing the voice messages upon request of the user. Furthermore, this 3rd party service provider wants to offer an extra service towards its users that are roaming in a visited network VN with a Camel version 1 VS1 that does not support interaction with a user using announcement voice prompting and information collection via in-band interaction. The extra service concerns the translation of the voice message into text TXT and the transmission of this text TXT message that is indeed supported by the Camel version 1 VS1. Now, when a user of the terminal T is roaming in a visited network VN and desires to listen to its voice messages, the user selects on the terminal the voice mail application app1. Furthermore, when the user wants to listen to one of its received voice messages, the application app1 interrogates, via the terminal capability server CS and under the support of the terminal capability CAP1 the installed Camel version VS of the visited network VN. This is shown with the request message Req(VS). Due to the accordance of the predefined application open signals, used by the terminal capability server CS, with the information of the 3GPP network open service architecture, the terminal is enabled to request the network for its Camel version. The visited network VN reacts by providing to the terminal is Camel version VS1, which is however too low and not adapted to request the 3rd service provider 3rdSP for the voice message. Upon reception of the Camel version VS1 by the terminal application means APP1, via the terminal capability CAP1 and the terminal capability server CS, the application app1 is further executed by the terminal application means APP1. In the event when the Camel version should have been a higher version e.g. Version 2 or Version 3, the terminal T could have asked, via the mobile network to the 3rd party service provider 3rd SP for transmission of the voice message. This is shown with a dotted line Req(V). However, due to the lower version V1, the application app1 requests for text transmission via the terminal capability server CS and the short message terminal capability CAP2, from the terminal T, via the mobile short message service functionality SMS and the short message service - network service capability server SMS-SCS to the third party service provider 3rdSP. This is shown with Req(TXT). Upon reception of this request the 3rdSP transforms the voice message into texts and transmits the text TXT to the terminal T via the mobile switching center MSC.

While the principles of the invention have been described above in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention, as defined in the appended claims.

CLAIMS

1. A terminal (T) for use in a communication network, said terminal (T) comprising a plurality of terminal capability means (CAP1, CAP2, CAP3, CAP4) to realize a plurality of terminal capability features and coupled thereto a terminal application means (APP1; APP2; APP3; APP4) to interact with one or more of said plurality of terminal capability means (CAP1, CAP2, CAP3, CAP4) and to execute thereby a terminal application (app1; app2; app3; app4), **characterized** in that said terminal (T) further comprises at least one terminal capability server means (CS) coupled between said terminal application means (APP1; APP2; APP3; APP4) and to at least one of said plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4), said terminal capability server means (CS) being adapted to translate a first application signal (S1) received from said at least one of said plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4) into a first predefined application open signal (SO1) and to provide said first predefined application open signal (SO1) to said terminal application means (APP1; APP2; APP3; APP4) and also being adapted to translate a second predefined application open signal (SO2) received from said terminal application means (APP1; APP2; APP3; APP4) into a second application signal (S2) and to provide said second application signal (S2) to said at least one of said plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4), said first predefined application open signal (SO1) and said second predefined application open signal (SO2) being independent of an underlying technology of said plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4).

2. The terminal according to claim 1, characterized in that said first predefined application open signal (SO1) and said second predefined application open signal (SO2) are defined in correspondence to a predefined network open service architecture interface information.

3. The terminal (T) according to any one of claim 1 and claim 2, characterized in that at least two of said plurality of terminal capability means

(CAP1; CAP2; CAP3; CAP4) are interacting with each other by means of capability signals comprising information in accordance with any one of said first predefined application open signal (SO1) and said second predefined application open signal (SO2) and a predefined network open service architecture interface information.

4. A terminal application (app1; app2; app3; app4) to be executed by a terminal application means (APP1; APP2; APP3; APP4) of a terminal (T) according to any previous claim, **characterized** in that said terminal application (app1; app2; app3; app4) is adapted to be executed according to received and transmitted open signals (SO1, SO2, ...) similar to any one of said first predefined application open signal (SO1) and said second predefined application open signal (SO2) and being independent of an underlying terminal technology of said plurality of terminal capability means (CAP1; CAP 2; CAP3; CAP4).

5. The terminal application (app1; app2; app3; app4) according to claim 4, characterized in that said terminal application (app1; app2; app3; app4) comprises data in correspondence to a predefined network open service architecture interface.

6. A carrier for a terminal application (app1; app2; app3; app4), **characterized** in that said carrier is adapted to carry a terminal application (app1; app2; app3; app4) according to any one of claim 4 and claim 5.

7. A method to execute a terminal application (app1; app2; app3; app4) by a terminal (T) comprising the step of realizing a plurality of terminal capability features by a plurality of terminal capability means (CAP1, CAP2, CAP3, CAP4), and interacting by a terminal application means (APP1; APP2; APP3; APP4) with at least one of said plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4), and thereby executing by said terminal application

means (APP1; APP2; APP3; APP4) a terminal application (app1; app2; app3; app4), **characterized** in that said method further comprises the steps of by at least one terminal capability server means (CS) :

translating a first application signal (S1) received from said at least one of said plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4) into a first predefined application open signal (SO1), and

providing said first predefined application open signal (SO1) to said terminal application means (APP1; APP2; APP3; APP4), and

translating a second predefined application open signal (SO2) received from said terminal application means (APP1; APP2; APP3; APP4) into a second application signal (S2), and

providing said second application signal (S2) to said at least one of said plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4); and

said first predefined application open signal (SO1) and said second predefined application open signal (SO2) being independent of an underlying technology of said plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4).

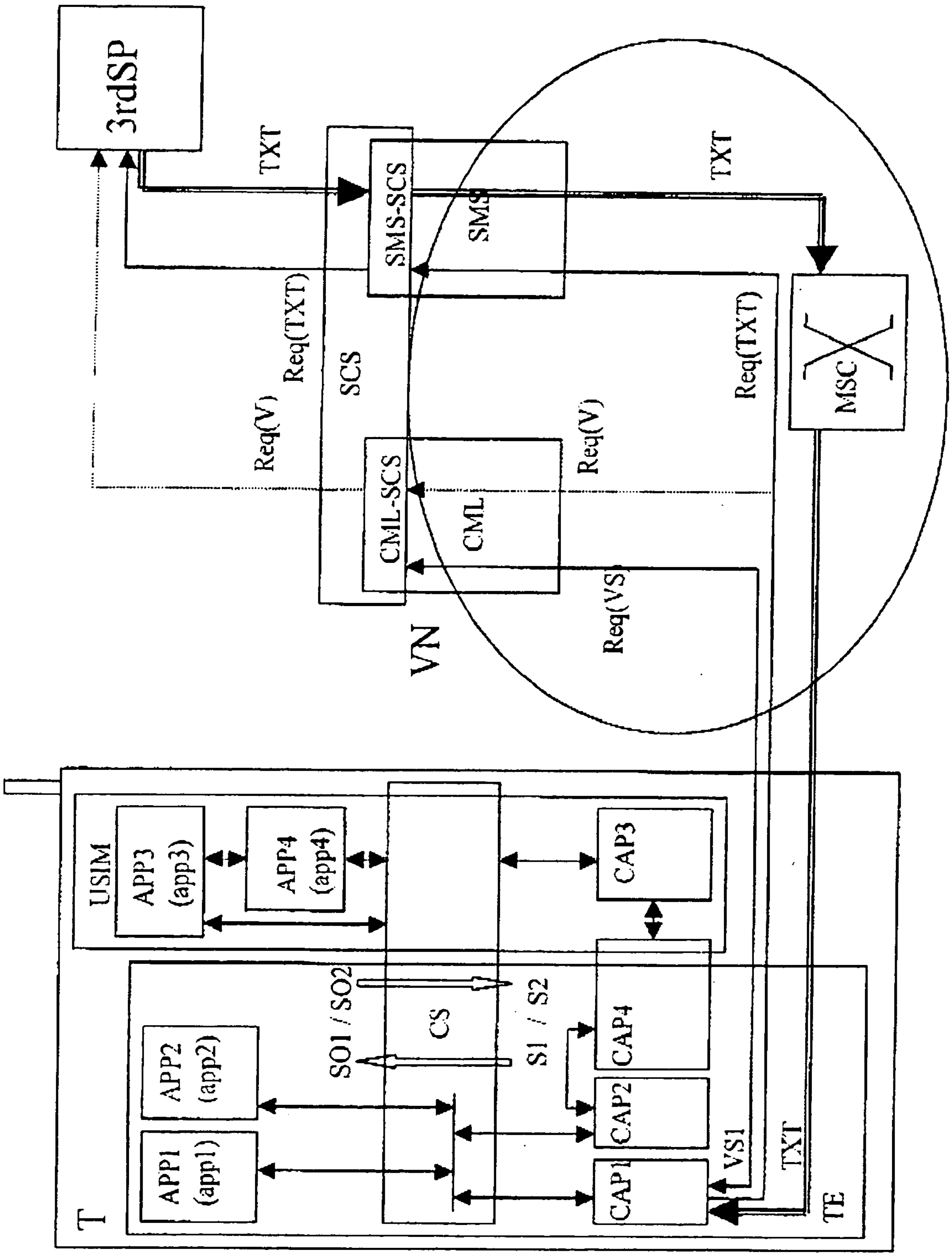
8. A communication network, **characterized** in that said communication network comprises at least one of a terminal (T) according to any one of claim 1 to claim 3, a terminal application (app1; app2; app3; app4) according to any one of claim 4 and claim 5 and a carrier according to claim 6.

ABSTRACT

A TERMINAL TO EXECUTE A TERMINAL APPLICATION

The present invention relates to terminal (T) for use in a communication network. The terminal (T) comprises a plurality of terminal capability means (CAP1, CAP2, CAP3, CAP4) to realize a plurality of terminal capability features. Terminal application means (APP1; APP2; APP3; APP4) are coupled to the terminal capability means to interact with one or more of the plurality of terminal capability means (CAP1, CAP2, CAP3, CAP4) and to execute thereby a terminal application (app1; app2; app3; app4). The terminal (T) further comprises at least one terminal capability server means (CS) coupled between the terminal application means (APP1; APP2; APP3; APP4) and to at least one of the plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4). The terminal capability server means (CS) is adapted to translate a first application signal (S1) received from at least one of the plurality of terminal capability means (CAP3) into a first predefined application open signal (SO1) and to provide the first predefined application open signal (SO1) to the terminal application means (APP1; APP2; APP3; APP4). The terminal capability server mens (CS) is also adapted to translate a second predefined application open signal (SO2) received from the terminal application means (APP1; APP2; APP3; APP4) into a second application signal (S2) and to provide the second application signal (S2) to at least one of the plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4)-. The first predefined application open signal (SO1) and the second predefined application open signal (SO2) are defined independent of an underlying technology of the plurality of terminal capability means (CAP1; CAP2; CAP3; CAP4). (Figure).

- 1/1 -


3rdSP
TXT
SMS-SCS
SMS
TXT
Req(TXT)
Req(TXT)
SCS
Req(V)
Req(V)
CML-SCS
CML
MSC
Req(VS)
VN
USIM
APP3
(app3)
APP4
(app4)
CAP3
SO1 / SO2
CS
S1 / S2
APP2
(app2)
APP1
(app1)
CAP4
CAP2
CAP1
VS1
TXT
TE
T

Figure

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Re: Snap-on Equipment Limited
File 14,442
Patent Application for:
WIRELESS MULTIPLEX DATA
TRANSMISSION SYSTEM
Serial No. 09/402,262

Sir:

Transmitted for filing herewith is an Information Disclosure Statement, PTO form 1449 and references cited therein.

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Harold V. Stotland

HVS:cw

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: Barbara L. Jones and Paul Smith

Title: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

Serial No.: 09/402,262

Date: December 30, 1999

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Washington, D.C. 20231

Sir:

Applicants' assignee's undersigned attorneys, who prepared the above-identified application, are aware of the references listed on the attached Form PTO-1449, copies of which are enclosed herewith, and which are relevant to said application.

Respectfully submitted,

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312-663-9800

By: [signature]

FORM 1

LODGED AT SUB-OFFICE
22 JUN 1987
Melbourne

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

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22 [illegible]
Melb[illegible]

APPLICATION FOR A STANDARD PATENT

~~I~~/We, DATAPLEX PTY. LTD.

of 28 John Street, Lilydale, Victoria 3140, Australia.

hereby apply for the grant of a standard patent for an invention entitled

WIRELESS DATA TRANSMISSION LINK

which is described in the accompanying provisional/~~complete~~ specification.

~~Details of basic application(s):~~

Number of basic application	Name of Convention country in which basic application was filed	Date of basic application

FEE STAMP TO VALUE OF
$ 60 ATTACHED

My/our address for service is care of CLEMENT HACK & CO., Patent Attorneys, 601 St. Kilda Road, Melbourne, 3004, Melbourne, Victoria, Australia.

DATED this 22nd day of June 1987.

DATAPLEX PTY. LTD.

CLEMENT HACK & CO.

Neil Hack

To: The Commissioner of Patents.

PF/App/ 2/81

(12) PATENT ABSTRACT (11) Document No. AU-A-18143/88
(19) AUSTRALIAN PATENT OFFICE

(54) Title
WIRELESS DATA TRANSMISSION LINK

(51)4 International Patent Classification
H04B 009/00 H04B 007/24

(21) Application No. : 18143/88 (22) Application Date : 22.06.87

(23) Filing Date of Complete Specification : 20.06.88

(43) Publication Date : 22.12.88

(60) Related to Provisional(s) : PI2590

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DATAPLEX PTY. LTD.

(72) Inventor
NAME NOT GIVEN

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GRIFFITH HACK & CO. MELBOURNE

(57) Claim

1. A method of establishing a wireless data transmission link between a first data link device and a second data link device, the method comprising:

(a) establishing a duplex link between said first data link device and said second data link device by

(i) transmitting an identification electromagnetic signal from said first data link device, then

(ii) receiving said identification electromagnetic signal at said second data link device, then

(iii) recognizing if said identification electromagnetic signal is intended for said second data link device, then

(iv) transmitting an acknowledging electromagnetic signal from said second data link device, then

(v) detecting said acknowledging electromagnetic signal at said first data link device, and only then

(b) commencing data transfer.

AUSTRALIA

Form 10

PATENTS ACT 1952

COMPLETE SPECIFICATION

(ORIGINAL)

FOR OFFICE USE

Short Title:

Int Cl

Application Number:

Lodged:

Complete Specification—Lodged:

Accepted:

Lapsed:

Published:

Priority:

Related Art:

TO BE COMPLETED BY APPLICANT

Name of Applicant: DATAPLEX PTY. LTD.

Address of Applicant: 28 John Street, Lilydale, Victoria, 3140.

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Melbourne, Victoria 3004,
Australia.

Complete Specification for the invention entitled: WIRELESS DATA TRANSMISSION LINK

The following statement is a full description of this invention, including the best method of performing it known to me:—

PF/CP1F/2/80

WIRELESS DATA TRANSMISSION LINK

The present invention relates to a method and apparatus for establishing a wireless data transmission link, and relates particularly but not exclusively to such for use between a first data apparatus and a second data apparatus.

Conventional remote data capturing and transferring systems have distinct limitations since they typically employ radio techniques or run physical cables for the duration of the data dump. Using physical cables is a slow and inefficient technique, whereas a radio link requires expensive licensing and must accommodate to the limitations of an already crowded spectrum. In view of the above disadvantages, both of these known techniques are undesirable in a low power, short distance, high speed application of the kind outlined below.

The present invention was developed with a view to providing an improved wireless data transmission link which would allow high speed data transfer while substantially reducing the problems associated with the prior art techniques.

According to one aspect of the present invention there is provided a method of establishing a wireless data transmission link between a first data link device and a second data link device, the method comprising:

(a) establishing a duplex link between said first data link device and said second data link device by

(i) transmitting an identification electromagnetic signal from said first data link device, then

(ii) receiving said identification electromagnetic signal at said second data link device, then

(iii) recognizing if said identification electromagnetic signal is intended for said second data link device, then

(iv) transmitting an acknowledging electromagnetic signal from said second data link device, then

(v) detecting said acknowledging electromagnetic signal at said first data link device, and only then

(b) commencing data transfer.

Most preferably the method includes increasing the power of the electromagnetic transmission when the data is transferred whereby data transmission errors can be minimized.

According to a further aspect of the present invention there is provided a data link device for establishing a wireless data transmission link between a first data apparatus and a second data apparatus, each of said first data apparatus and said second data apparatus having a respective data link device, the device comprising:

a transmitter and a receiver, said transmitter having transmitting means for transmitting an identification electromagnetic signal, said receiver having receiving means for receiving an acknowledging electromagnetic signal transmitted from the data link device at the other data apparatus upon receipt of said identification signal thereat; and

control means for allowing data transfer only when said acknowledging signal is received.

Most preferably the control means controls power increasing means for increasing the transmitting power of said transmitting means when said acknowledging signal is received, whereby data transmission errors can be minimized in a data transfer mode.

According to a still further aspect of the present invention there is provided apparatus for establishing a wireless data transmission link between a base station and a mobile station, the apparatus comprising:

at the base station a transmitter/receiver;

at the mobile station a receiver/transmitter;

said base station having means for transmitting an identification electromagnetic signal for detection by said mobile station when in proximity thereto, said mobile station having means for transmitting an acknowledging electromagnetic signal upon identifying said identification signal by a signal identifying means, said base station having an acknowledging signal detecting means for detecting said acknowledging signal and control means for allowing data transfer only when said acknowledging signal is detected.

Most preferably said base station of the apparatus is provided with transmission power increasing means for increasing transmission power and wherein said control means is responsive to said acknowledging signal detecting means detecting said acknowledging signal so that data can then be transmitted from said base station to said mobile station at said increased transmission power whereby data transmission errors can be minimized.

A preferred embodiment of the prevent invention relates to a mobile, typically vehicularly mounted, infrared optical data link which allows digital data to be transmitted between a fixed base station such as a gate house or loading dock and a mobile station such as a vehicle. A particular advantage of this embodiment is that it enables vehicle performance, orders, delivery and other information collected by the driver and/or salesman to be stored in a portable computer onboard the vehicle, which information can be rapidly transferred to a central computer when that vehicle returns to the depot. Conversely, despatch information such as routes to take, deliveries to make and calls to complete, can be transferred quickly from the base station computer to the terminal in the vehicle. Employing a wireless data transmission link in this situation greatly reduces the paper work involved using conventional methods, and improves the turn around time of the delivery vehicles.

In order that the invention can be more clearly understood a preferred embodiment will now be described with reference to the accompanying drawings. Although the following description will be given with reference to an infrared optical data link, it will be apparent that the present invention is not limited to optical wave lengths but may alternatively employ other parts of the electromagnetic spectrum such as for example radio frequencies or microwave frequencies. The invention is particularly advantageous for establishing a wireless data transmission link between a fixed site and a mobile site, however it may be used equally successfully between two fixed sites or two mobile sites. Furthermore, although the following description is given with reference to a wireless data transmission link between a central computer and a mobile computer terminal, the link may be employed between any two data apparatus which are suitable for capturing, storing, and/or processing information in digital format. Throughout the specification the term "duplex" is used to describe the operation of transmitting and receiving apparatus at either end of the transmission link, and covers both half duplex and full duplex operation. In the accompanying drawings:

Figure 1 illustrates schematically a preferred embodiment of the apparatus for establishing a wireless data transmission link between a base station and a mobile station;

Figure 2 is a circuit diagram of a preferred embodiment of a data link device used in the apparatus of Figure 1;

Figure 3 is a further circuit diagram illustrating the internal logic of IC1 in Figure 2; and

Figure 4, Figure 5, Figure 6 and Figure 7 are timing diagrams for the circuit illustrated in Figure 3.

Referring to Figure 1 there is illustrated schematically a preferred form of the apparatus for establishing a wireless data transmission link between a base station 10 and a mobile station 12. The base station 10 is typically at a fixed site and comprises a first data link device 14 connected via a switching means 16 to a first data apparatus 18. Data apparatus 18 is typically a central computer, such as an IBM personal computer, which may be linked to a larger general purpose computer having the main data base or accounting, delivery and invoicing information stored therein. Switching means 16 is responsive to the first data link device 14 to activate an indicating means 20 for indicating that a data transmission link has been established and that data transmission is taking place or is about to take place. Indicating means 20 may typically consist of a visible light and/or audible alarm located where it can be seen or heard by the driver of the mobile station 12 as he approaches the base station 10.

Mobile station 12 comprises a second data apparatus 22 connected to a second data link device 24. The second data apparatus 22 typically consists of a mobile computer terminal such as a hand held terminal, a portable computer, a lap-top computer or a purpose-built unit. The data link devices 14 and 24 are substantially identical and will be described in greater detail below. Control software, resident in both the mobile and fixed computers or terminals, preferably controls the data link devices and optionally the application and system software in the host computers and/or terminals. The control software may be configured by the user and typically controls the sequence of steps used to establish a duplex data transmission link. The method of establishing a duplex wireless data transmission link between the first data link device 14 and the second data link device 24 will now be described with reference to Figure 1.

At initialization, the fixed site central computer 18 raises Request To Send (RTS) when the system is up and running and ready to exchange data with a mobile station. Each data link device is adapted to transmit a low power electromagnetic signal whenever RTS is up. Furthermore, the computer or terminal attached to a particular data link device will also constantly repeat a short message, perhaps only one character long, which identifies that computer or terminal, whenever RTS is up. Consequently, whenever a data link device is transmitting in a low power or search mode, it will be transmitting an identification electromagnetic signal determined by the attached computer or terminal. Preferably the radiated field pattern from the data link device is restricted to a controlled beam shape so that the possibility of secure data being intercepted by third parties is minimized. Under software control the fixed site computer may either raise RTS just for the time of sending each character or raise RTS for the entire duration of the search and message transfer phase.

When a mobile station 12 enters the radiated field of the first data link device 14, the second data link device 24 of the mobile station 12 will receive the identification electromagnetic signal and after a short time interval will raise data carrier detect (DCD) to the second data apparatus 22. Received data (RD) identifying the fixed computer of the data apparatus 18 at the base station 10 is passed to the mobile terminal 22 of the mobile station 12 by the second data link device. On receipt of DCD and RD, the mobile terminal 22 checks whether the base station identifier is a valid address, and assuming both a valid address and the need to transmit data, the mobile terminal 22 will raise its own RTS which will cause the second data link device 24 to transmit a carrier, either low or high power depending on the state of DCD, and containing either a steady mark or mobile station identification under software control from the mobile computer terminal. Transmit data (TD) identifying the mobile terminal 22 is passed to the second data link device 24 to be transmitted to the first data link device 14 as an acknowledging electromagnetic signal. The presence of both RTS and DCD at the second data link device 24 causes it to send clear to send (CTS) to the mobile terminal 22.

At the base station 10, the radiated field from the mobile station 12, including the acknowledging electromagnetic signal, will be detected by the first data link device 14 and the simultaneous presence of RTS and DCD at the first data link device 14 causes it to grant CTS to the fixed computer 18. Switching means 16, located between the first data link device 14 and the first data apparatus 18 of the base station 10, is adapted to respond to the CTS signal to activate the visible or audible indicating means 20 informing the driver of the mobile station 12 to stop the vehicle since it is in an acceptable position for reliable data transfer. The driver must stop immediately the indicating means 20 is activated and should not move off until data transfer has concluded as evidenced by the indicating means 20 being extinguished.

In the event that the mobile station 12 is not correctly positioned, either to receive the radiated electromagnetic signal from the base station 10, or to transmit an electromagnetic signal to the base station 10 in order to establish the duplex transmission link with an acceptable low data error rate, the control software can be arranged to alternately raise and lower RTS to the data link device 14 or 24. This will have the effect of alternately raising and lowering CTS at the base station 10 causing the indicating means 20 to be alternately activated and deactivated by the switching means 16. The flashing light of indicating means 20 informs the driver than an unacceptably high data error rate exists in the data transmission link and that he will need to reposition the vehicle.

The data link devices 14 and 24 are configured so that the simultaneous presence of both RTS and DCD at both the base station and the mobile station will cause both devices to transmit at full power.

Using the above method a full duplex wireless data transmission link is established initially at low power, then increased automatically to full power to improve the signal to noise ratio and thus reduce the error rate during data transfer. Although the background error rate will be low because of the transmission link signal strength is well above the detection threshold, there will always be the possibility of some errors arising. Therefore block checking in the control software using a cyclic redundancy check is recommended to ensure end to end data integrity.

After the data has been transferred successfully, either end of the transmission link can drop RTS. If the mobile terminal 22 drops RTS, the mobile transmitter will be turned off and the base station indicating means 16 will be extinguished since the first data link device 14 will no longer provide CTS to the fixed computer 18. It will be recalled that the necessary condition for CTS to be granted by a data link device is the presence of both RTS and DCD. Once the indicating means 20 is extinguished, the mobile station 12 is free to leave the area. Alternatively, if the fixed computer 18 at the base station 10 drops RTS, again the switching means 16 will extinguish the indicating means 20 since CTS is no longer present. As the mobile station 12 moves away, the base station 10 software waits for a short period, for example 10 seconds, before raising RTS again and waiting for the next vehicle. The structure and operation of a preferred embodiment of the data link device will now be described in greater detail with reference to Figures 2 to 7 of the accompanying drawings.

For reasons of economy, performance, data security and ease of licensing, the preferred signalling means for the data link device is infrared energy, however visible light, microwave, RF and any other wireless communication technique can be used.

Referring to Figure 2 there is shown a circuit diagram of a preferred embodiment of a data link device that may be used in the apparatus of Figure 1. The data link device of Figure 2 comprises a transmitter 40 having transmitting means 42, a receiver 44 having receiving means 46 and a control means 48. In this embodiment the information content in the transmitted infrared radiation is transmitted using Pulse Width Modulation (PWM) in accordance with the data sent from the data apparatus connected to the device. The transmitting means 42 of the transmitter 40 comprises an array of infrared light emitting diodes (IREDs) shown in Figure 2 as LED1, LED2, LED3 and LED4. The LEDs are pulsed with two pulse widths of either 1.628 or 13.021 microseconds. A short pulse signals a data mark or 1, for the OFF condition and a long pulse signals a space or 0, for the ON condition. These pulse widths are digitally controlled by the control means 48. The timing ratio of 1:8 is chosen to allow unambiguous discrimination at the receiver 44 of a corresponding data link device, even with considerable pulse width smearing in the receiver electronics. The pulse amplitude to the transmitting means 42 is varied from low current, when in the low power search mode, to full current when in the high power data transfer mode of the data link device.

The receiver 44 comprises an optical filter (not shown) located in front of the receiving means 46 to reduce interference from visible light sources such as daylight, fluorescent and incandescent light globes, and discharge lamps. The receiving means 46 consists of an infrared PIN diode detector D1. Receiving means 46 is followed by a stable fixed gain amplifier which has its frequency response controlled to minimize gain at low frequencies to ensure rejection of mains powered stray light sources and to maximise response to the desired signal. A tracking comparator U1C is used to detect any signal greater than a predetermined threshold value and convert this into a digital logic signal whose pulse width replicates the transmitted pulse width. This digital logic signal, (Rx In to IC1) is also monitored by comparator U1D which comprises a proximity, or signal or carrier detect section 50. The time constants and discharge resistor values of the carrier detect section 50 are selected so that approximately 100 milliseconds of signal must be present at the input of U1D before the DCD line into IC1 is enabled. This ensures that short noise bursts are not passed to the data output RD line as the mobile station 12 moves around and encounters stray noise sources.

The fixed gain amplifier of the receiver 44 includes a field affect transistor (FET) Q1 which provides impedance matching for the electrical signal produced by the PIN diode detector D1 in order to provide maximum power transfer. Source bypass capacitor C2 reduces the gain of the FET at low frequencies by retaining high gain at the desired frequencies. Transistor Q3 provides a shaped response fixed gain amplification and has low gain outside the desired frequency range. Transistor Q2 is operated from a regulated +5 volt supply and serves to set the reference bias voltage of the comparator U1C at 100 millivolts, as well as delivering a controlled gain of 10 to the desired signal. The voltage at the junction of resistors R12 and R14 is averaged by resistor R13 and capacitor C13 and fed to the inverted input of comparator U1C. The desired signal (Rx SIG) is a fast positive-going pulse at the collector of transistor Q2 and this is passed directly to the non-inverting input of the comparator U1C. Providing the pulse amplitude of the signal exceeds the comparator threshold, set by the steady collector current through resistor R14, comparator U1C will fire and produce a digital representation of the received signal at its output.

The logic for the pulse width and amplitude encoder of the transmitter 40 and the decoder of the receiver 44, together with the gating of RTS, CTS and DCD is all contained in the control means 48. Preferably the control means 48 comprises an integrated circuit IC1 which embodies the digital logic of the data link device using flip flops and various gate circuits. Advantageously all of the digital logic embodied in IC1 can be configured using a single erasable programmable logic device chip of the kind manufactured by Altera Corporation.

The data link device requires a single voltage source in the range 8 to 16 volts and an onboard power supply to generate the regulated +5 volts for the logic and the +/-8 volts for the RS232 computer interface (Industry Standard V.24). Data and control information from the computer or terminal connected to the data link device, enters and leaves the device via a cable with a small connector at industry standard V.24 signal levels directly to and from integrated circuit U4 which is a CMOS line driver/receiver chip. Power enters through the same cable via a reverse voltage protection diode D2 to an energy storage and voltage smoothing capacitor C8. The nominal +10 volts DC is regulated down to a stable +5 volts by voltage regulator VR11. The negative supply rail for the V.24 driver chip U4 is generated by integrated circuit U3. The data link device includes a crystal oscillator 54 which operates continuously at a multiple of the data rate to ensure accurate timing information and repeatability between devices with no manufacturing or set-up adjustments. IC1 drives the crystal oscillator and its internal counter/divider chains at all times that power is supplied. The configuration and operation of the control means 48 will now be described with reference to Figures 3 to 7.

Referring to Figure 3 there is shown a further circuit diagram illustrating the internal logic of IC1 including the transmitter encoder section and the receiver decoder section of the control means 48. The transmitter encoder section comprises a pair of up/down counters 60 for controlling the width of transmitted pulses in accordance with the binary state of the transmit data (TD) line at the input of the transmitter encoder section. Whenever RTS is raised, pulses representing the binary state of the TD line are passed to the low power IRED array driver Q4 via the low power output line LO out. If the incoming TD line goes to the space condition, a fast reset pulse (TD reset) is generated within the transmitter encoder section to reset the transmit counters 60 (see Figure 4). This enables centre sampling of the TD bits and synchronisation of the remote receiver. At the centre sample time, the TD pulser section 62 sends the pulse width representation of the TD line to both the low and high power output driver sections 64. The TD pulser section 62 comprises a D flip flop with space and mark pulse width signals and appropriate gating. RTS must be present before the pulse width representation of the TD line is sent to the output driver sections 64 from the TD pulser section 62. When RTS goes high, output pulses on the Lo out line are enabled to the low power driver transistor Q4 (See Figure 2). Resistor R21 in Figure 2 limits the pulse amplitude to the transmitter IRED array when in the low power search mode. If both RTS and DCD are present, output pulses are enabled on both the Lo out and Hi out lines of the output driver sections 64 into both the low and high power driver transistors Q4 and Q5 respectively in Figure 2 which comprise a transmission power increasing means 52. AND gate 65 in Figure 3 provides for the ANDing of RTS and DCD to switch the data link device from the lower power search mode to the high power data transfer mode. A further AND gate 66 is provided to AND RTS and DCD and provide the Clear To Send signal CTS. Resistors R22 and R23 in Figure 2 together with other stray internal resistances in the IREDs and transistors, limit the peak current to the IRED array. High power pulse drive is handled by transistor Q5. Electrical energy for the IRED array is supplied by capacitor C9, and resistor R24 serves to limit noise from the transmitter 40 passing back into the power supply circuitry.

The receiver decoder section of the control means 48 illustrated in Figure 3 also includes a pair of updown counters 68. Counters 68 are controlled by a clock signal from the crystal oscillator and comprise part of a pulse width detector which outputs a 1 to the received data (RD) line whenever the incoming pulses are narrow, and a 0 whenever the pulse width is wide. Incoming pulses are fed from the output of comparator U1c in Figure 2 to the Rx In line of the control means 48 in Figure 3. As with the transmitter encoder section, the receiver decoder section also generates a reset pulse (Rx reset) whenever the incoming Rx In line goes to the spaced condition. This enables the receiver decoder section to determine whether the incoming pulses are narrow or wide. The decision point is set at 6.510 microseconds. Narrow pulses can be stretched from their correct 1.628 microseconds, or wide pulses can be shortened from their correct 13.021 microseconds, by a considerable margin before data errors can occur (see Figures 6 and 7). In the absence of DCD, the RD line output is clamped to the mark or 1 state so that spurious pulses appearing on the Rx In line do not appear on the RD output line of the receiver encoder section of IC1.

The above described embodiment of the data link device is particularly advantageous because the data error rate can be reduced to very low levels by the novel technique of first radiating a low power search mode signal which is increased to full power when another data link device is detected nearby. Furthermore, unlike a simple modem link, clear to send (CTS) is not granted to the computer or terminal connected to the device until the data transmission link is established in both directions. False triggering of the proximity or data carrier detect section 50 is avoided since a repetitive signal resembling the correct wave form must be present for a few thousand cycles before the DCD line goes high to the control means 48. Wave length filtering before the receiver 44 reduces stray interference, and careful shaping of the receiver amplifier frequency response characteristics ensures immunity to most noise sources encountered as the mobile station 12 moves around its normal route.

The life time of the transmitting means 46 is significantly improved by using the lower power search mode at all times while another data link device is not detected. The transmitting means 46 of the data link device will have over 10 years service life assuming 10 trips per day, 360 days per year and 8 kilobytes of data per transfer. Interestingly, even if RTS is low and the device transmitter is off, the presence of another transmitter nearby transmitting an electromagnetic signal at the correct frequency will cause DCD to go high which could be used by the system software to control the device transmitter.

The above described embodiment of the data link device enables the data transmission link to operate at the base band frequency, and the information content (mark or space) is conveyed by using Pulse Width Modulation, which enables the transmitter 40, the receiver 44 and the control means 48 to be of relatively simple construction. However the invention is not limited to this type of base band system and may be embodied using frequency, phase or some other form of modulation requiring more complex receiver and transmitter circuits. Furthermore, the control means 48 in the preferred embodiment is advantageously embodied in the integrated circuit IC1. However, the required digital encoding, decoding and driving may be done equally successfully using a circuit constructed from discrete components.

It will be obvious to persons skilled in the electronics and other related arts that numerous alterations and modifications can be made to the apparatus, method and device, other than those specifically described, without departing from the basic concepts of the invention. All such modifications and alterations are to be considered within the scope of the invention, the nature of which is to be determined from the foregoing description and the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of establishing a wireless data transmission link between a first data link device and a second data link device, the method comprising:

(a) establishing a duplex link between said first data link device and said second data link device by

(i) transmitting an identification electromagnetic signal from said first data link device, then

(ii) receiving said identification electromagnetic signal at said second data link device, then

(iii) recognizing if said identification electromagnetic signal is intended for said second data link device, then

(iv) transmitting an acknowledging electromagnetic signal from said second data link device, then

(v) detecting said acknowledging electromagnetic signal at said first data link device, and only then

(b) commencing data transfer.

2. A method as claimed in Claim 1, wherein said step of transmitting an identification electromagnetic signal from the first data link device comprises transmitting a low power electromagnetic signal in a lower power search mode.

3. A method as claimed in Claim 1 or Claim 2, wherein said step of transmitting an acknowledging electromagnetic signal from said second data link device comprises transmitting a lower power electromagnetic signal.

4. A method as claimed in any one of Claims 1 to 3, wherein said first data link device is provided at a base station of fixed location and said second data link device is provided at a mobile station.

5. A method as claimed in Claim 4, further comprising the step of indicating to a person at the mobile station that a duplex link has been established after said step of detecting the acknowledging electromagnetic signal at the first data link device.

6. A method as claimed in any one of the preceding claims, wherein said step of commencing data transfer comprises increasing the transmitting power of both said data link devices in a data transfer mode whereby data transmission errors can be minimized.

7. A data link device for establishing a wireless data transmission link between a first data apparatus and a second data apparatus, each of said first data apparatus and said second data apparatus being provided with a respective data link device, the device comprising:

a transmitter and a receiver, said transmitter having transmitting means for transmitting an identification electromagnetic signal, said receiver having receiving means for receiving an acknowledging electromagnetic signal transmitted from the data link device at the other data apparatus upon receipt of said identification signal thereat; and,

control means for allowing data transfer only when said acknowledging signal is received.

8. A data link device as claimed in Claim 7, wherein said control means controls power increasing means for increasing the transmitting power of said transmitting means when said acknowledging signal is received whereby, in use, data transmission errors can be minimized in a data transfer mode.

9. A data link device as claimed in Claim 7 or Claim 8, wherein said transmitting means comprises an array of infra-red light emitting diodes and said receiving means comprises an infra-red detector.

10. A data link device as claimed in Claim 9, wherein said control means further comprises a transmitter encoder section and a receiver decoder section for encoding and

decoding a transmitted or received infra-red electromagnetic signal respectively, whereby, in use, the information content of the infra-red electromagnetic signal can be transmitted using a pulse width modulation technique.

11. An apparatus for establishing a wireless data transmission link between a base station and a mobile station, the apparatus comprising:

at the base station a transmitter/receiver;

at the mobile station a receiver/transmitter;

said base station having means for transmitting an identification electromagnetic signal for detection by said mobile station when in proximity thereto, said mobile station having means for transmitting an acknowledging electromagnetic signal upon identifying said identification signal by a signal identifying means, said base station further having an acknowledging signal detecting means for detecting said acknowledging signal and control means for allowing data transfer only when said acknowledging signal is detected.

12. An apparatus as claimed in Claim 11, wherein said base station is provided with transmission power increasing means for increasing the transmitting power of said base station transmitter, and wherein said control means is responsive to said acknowledging signal detecting means detecting said acknowledging signal so that data can be transferred from the base station to the mobile station at said increased transmission power in a data transfer mode whereby data transmission errors can be minimized.

13. A method of establishing a wireless data transmission link substantially as herein described with reference to and as illustrated in the accompanying drawings.

14. A data link device substantially as herein described with reference to and as illustrated in the accompanying drawings.

15. An apparatus for establishing a wireless data transmission link substantially as herein described with reference to and as illustrated in the accompanying drawings.

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By Its Patent Attorneys:

CLEMENT HACK & CO.
Fellows Institute of Patent Attorneys
of Australia.

decoding a transmitted or received infra-red electromagnetic signal respectively, whereby, in use, the information content of the infra-red electromagnetic signal can be transmitted using a pulse width modulation technique.

11. An apparatus for establishing a wireless data transmission link between a base station and a mobile station, the apparatus comprising:

at the base station a transmitter/receiver;

at the mobile station a receiver/transmitter;

said base station having means for transmitting an identification electromagnetic signal for detection by said mobile station when in proximity thereto, said mobile station having means for transmitting an acknowledging electromagnetic signal upon identifying said identification signal by a signal identifying means, said base station further having an acknowledging signal detecting means for detecting said acknowledging signal and control means for allowing data transfer only when said acknowledging signal is detected.

12. An apparatus as claimed in Claim 11, wherein said base station is provided with transmission power increasing means for increasing the transmitting power of said base station transmitter, and wherein said control means is responsive to said acknowledging signal detecting means detecting said acknowledging signal so that data can be transferred from the base station to the mobile station at said increased transmission power in a data transfer mode whereby data transmission errors can be minimized.

13. A method of establishing a wireless data transmission link substantially as herein described with reference to and as illustrated in the accompanying drawings.

14. A data link device substantially as herein described with reference to and as illustrated in the accompanying drawings.

15. An apparatus for establishing a wireless data transmission link substantially as herein described with reference to and as illustrated in the accompanying drawings.

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By Its Patent Attorneys:
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Fellows Institute of Patent Attorneys
of Australia.

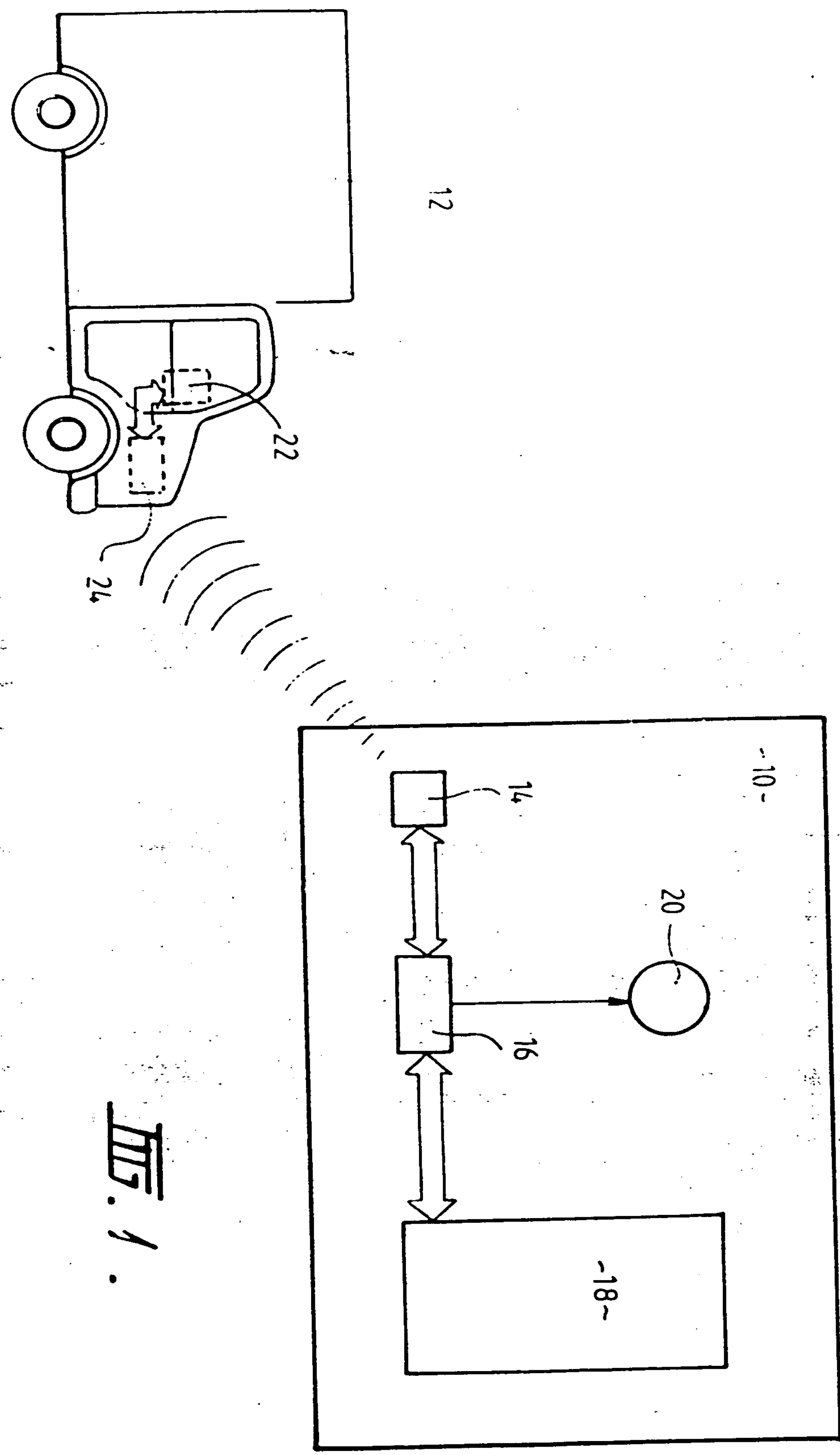


FIG. 1.

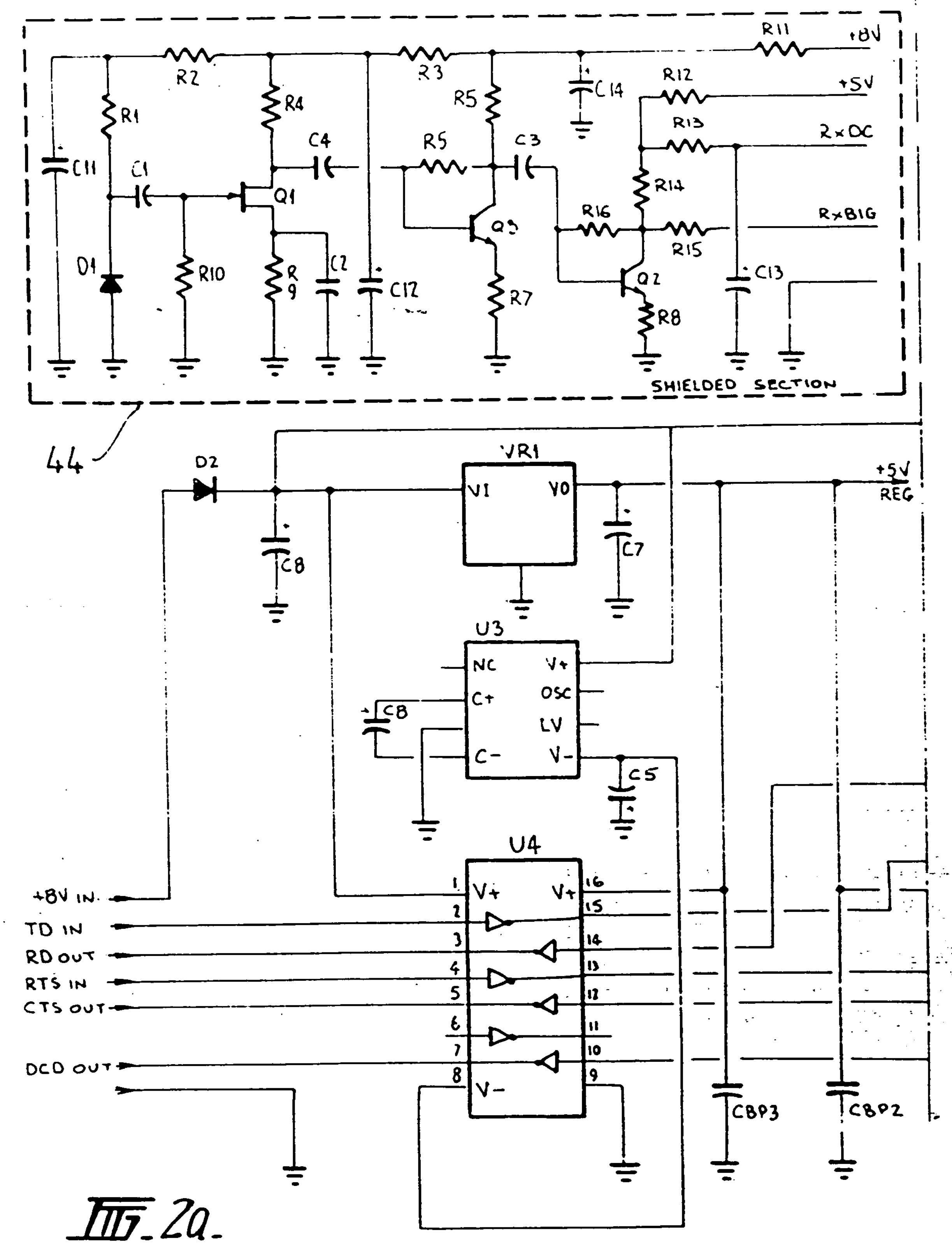
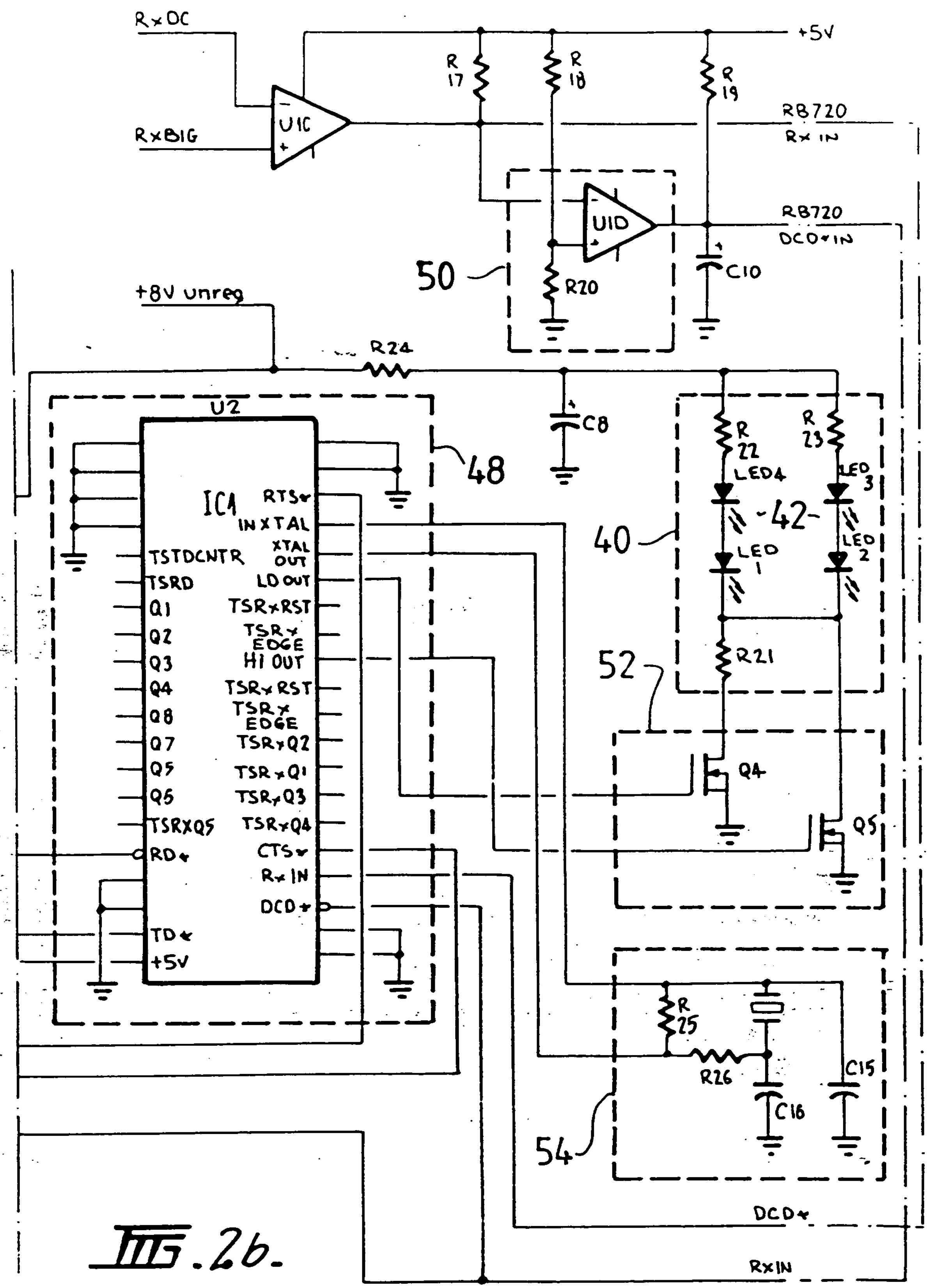
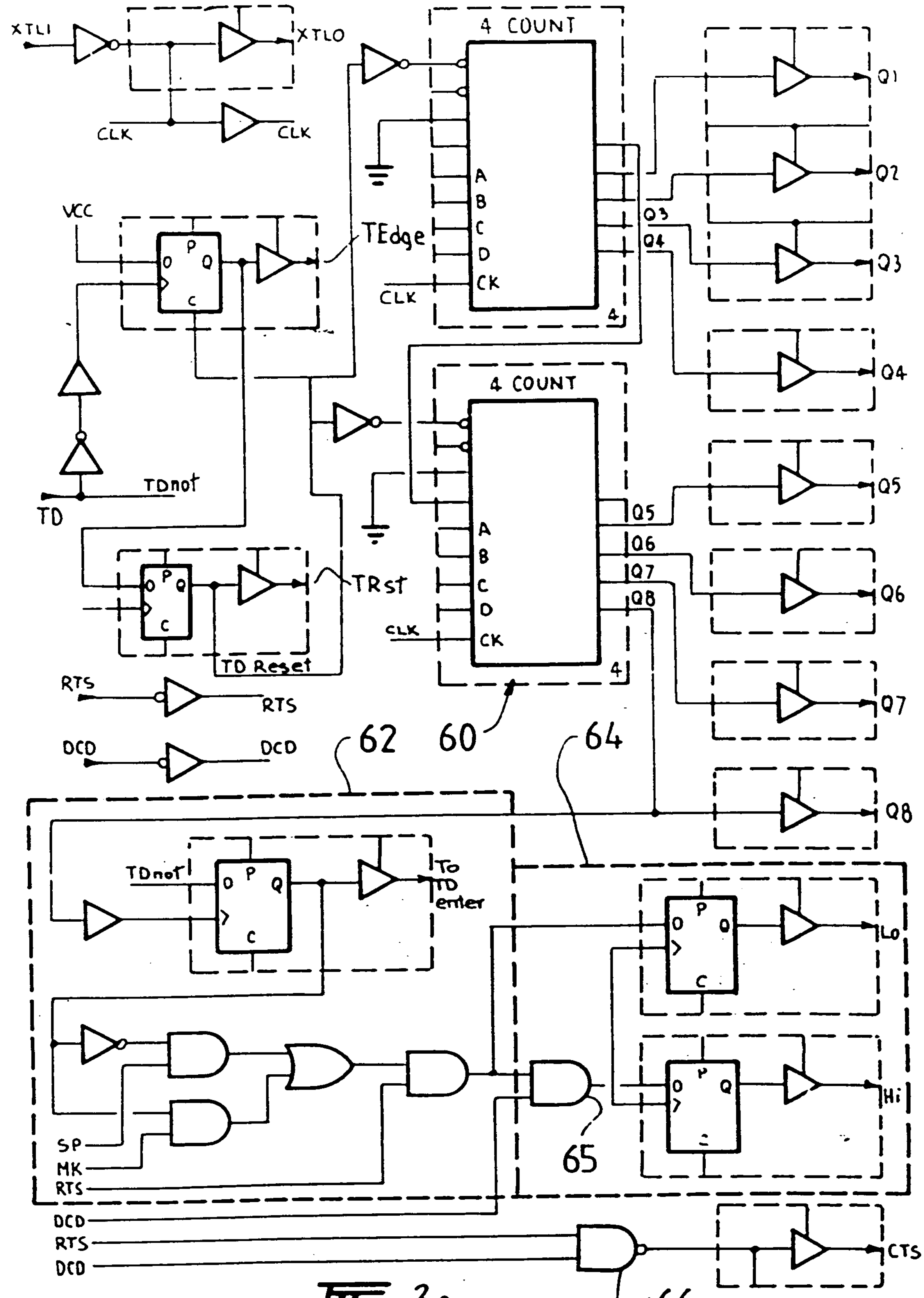

R11
+8V
R2
R3
R12
+5V
C14
R1
R4
R5
R13
RxDC
C11
C1
C4
C3
Q1
R14
R16
RxBIG
D1
R10
R9
C2
C12
Q3
R7
R15
Q2
C13
R8
SHIELDED SECTION
44
D2
VR1
VI
VO
+5V REG
C8
C7
U3
NC
V+
C+
OSC
LV
C-
V-
C5
U4
+8V IN
TD IN
RD OUT
RTS IN
CTS OUT
DCD OUT
V+
V-
CBP3
CBP2

FIG. 2a.



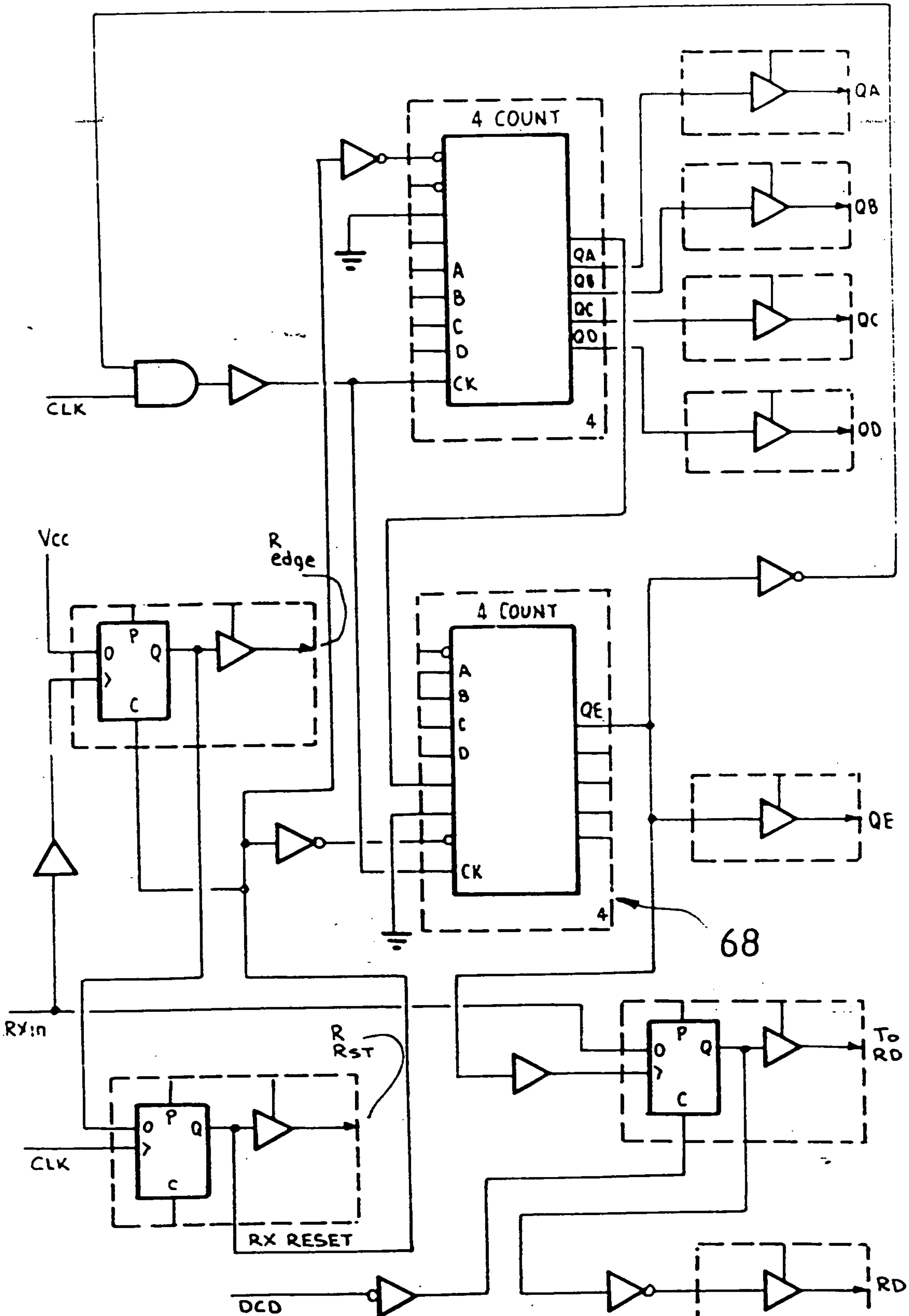
RxDC
RxBIG
U1C
+5V
R 17
R 18
R 19
RB720
Rx IN
U1D
RB720
DCD IN
C10
50
R20
+8V unreg
R24
U2
C8
48
IC1
RTS
IN XTAL
XTAL OUT
TSTDCNTR
TSRD
LD OUT
Q1
TSRxRST
Q2
TSRx EDGE
Q3
HI OUT
Q4
TSRxRST
Q8
TSRx EDGE
Q7
TSRxQ2
Q5
TSRxQ1
Q6
TSRxQ3
TSRXQ5
TSRxQ4
RD
CTS
Rx IN
DCD
TD
+5V
R 22
R 23
LED4
LED 3
-42-
LED 1
LED 2
40
R21
52
Q4
Q5
R 25
R26
C15
C16
54
DCD
RxIN

FIG. 2b.



XTLI
XTLO
CLK
CLK
4 COUNT
A
B
C
D
CK
CLK
4
Q1
Q2
Q3
Q3
Q4
Q4
VCC
P
Q
C
TEdge
TDnot
TD
TRst
TD Reset
4 COUNT
Q5
Q6
Q7
Q8
Q5
Q6
Q7
Q8
RTS
RTS
DCD
DCD
62
60
64
TDnot
To TD enter
Lo
Hi
65
SP
MK
RTS
DCD
RTS
DCD
CTS
66

FIG. 3a.



4 COUNT
A
B
C
D
CK
QA
QB
QC
QD
4
QA
QB
QC
QD
CLK
Vcc
R
edge
P
Q
C
4 COUNT
A
B
C
D
QE
CK
4
QE
68
RXin
R
RST
CLK
RX RESET
To
RD
DCD
RD

FIG. 36.

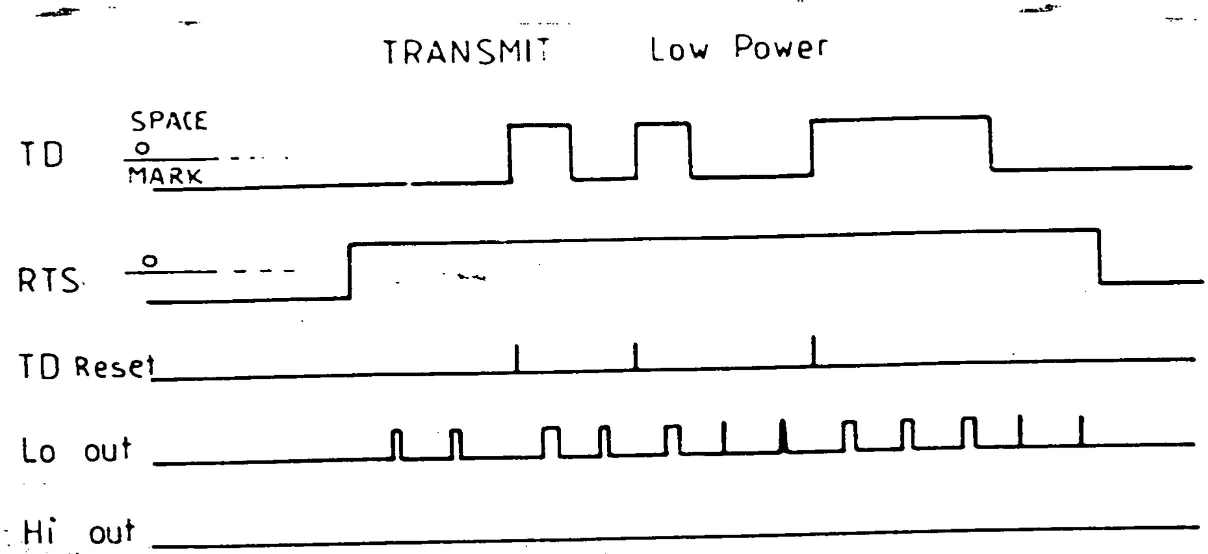

TRANSMIT Low Power
TD
SPACE
0
MARK
RTS
0
TD Reset
Lo out
Hi out

FIG. 4.

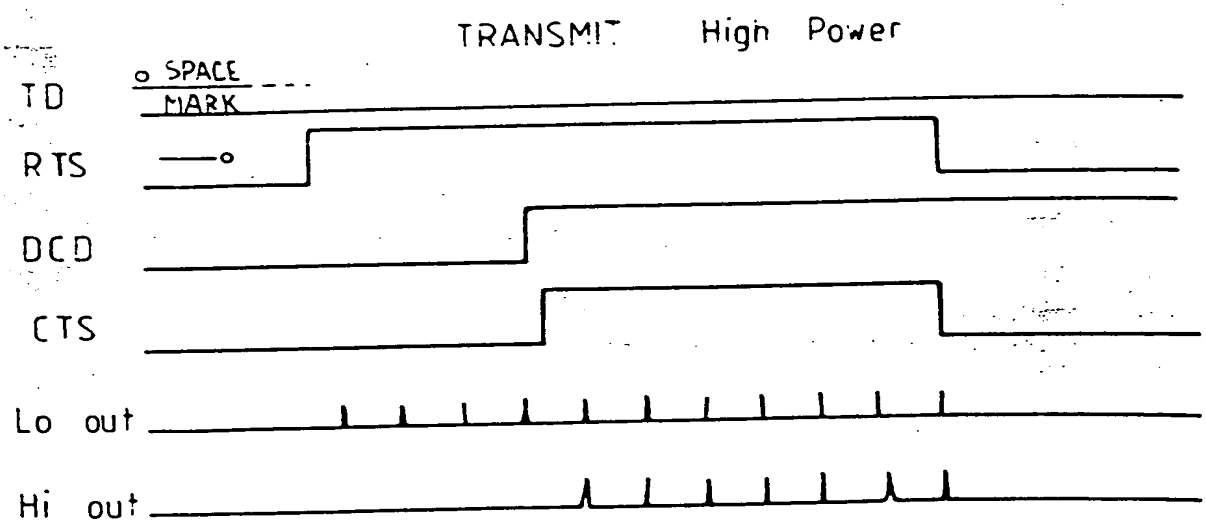

TRANSMIT High Power
TD
0 SPACE
MARK
RTS
0
DCD
CTS
Lo out
Hi out

FIG. 5.

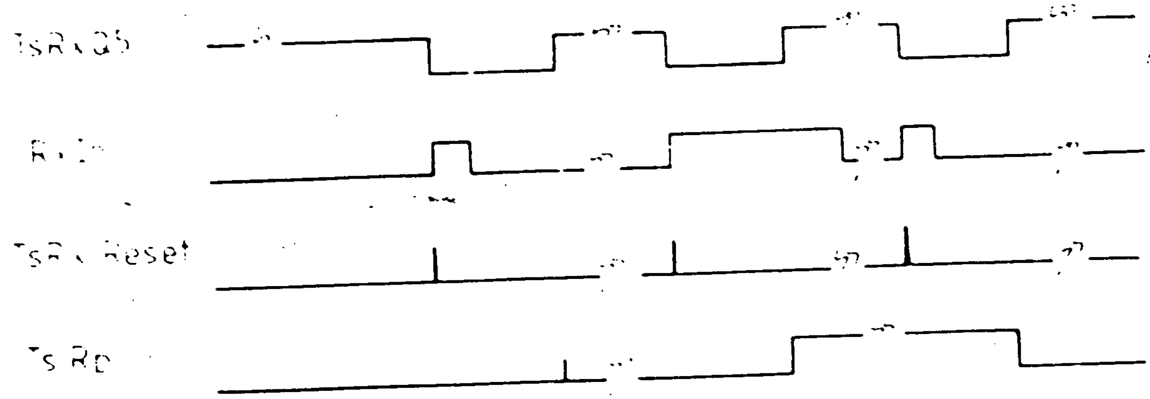


FIG. 6.

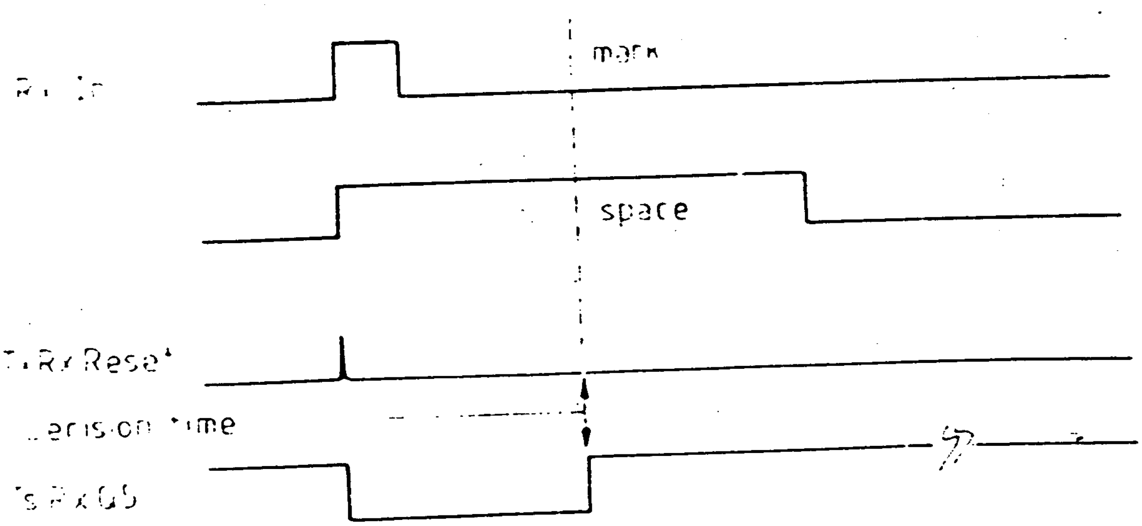


FIG. 7.

BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

(12) Offenlegungsschrift

(10) DE 41 06 572 A 1

(51) Int. Cl.⁵:
G 01 H 9/00
B 23 Q 17/12
G 01 S 17/58
// G01P 13/00, G01B 11/16, G01M 7/02

(21) Aktenzeichen: P 41 06 572.7
(22) Anmeldetag: 1. 3. 91
(43) Offenlegungstag: 3. 9. 92

DE 41 06 572 A 1

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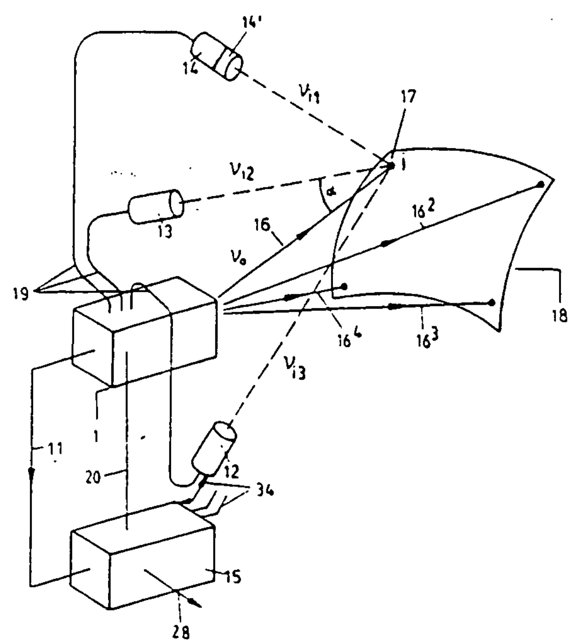
Prüfungsantrag gem. § 44 PatG ist gestellt

(54) Vorrichtung zum berührungslosen Messen von Objektschwingungen mit einem Laserstrahl

(57) Vorrichtung zum berührungslosen Messen von Objektschwingungen mit einem Laserstrahl (16), der mit einer die Einstrahlrichtung ($\vec{e}_{i0}$) bestimmenden Strahlablenkeinrichtung (7) nacheinander auf unterschiedliche Meßorte (17) des Meßobjekts (18) gerichtet ist, mit einem vom Meßobjekt (18) herrührendes Streulicht des Laserstrahls (16) aufnehmenden Meßkopf (12), der an einen Empfänger (24) angeschlossen ist, mit einem frequenzverschobenen Referenz-Laserstrahl (6), der in dem Empfänger (24) dem Streulicht des Meßobjekts (18) überlagert ist, und mit einer an den Empfänger (24) angeschlossenen Auswertungseinrichtung (15).

Um Meßorte (17) eines Meßobjekts (18) hinsichtlich ihrer in drei Raumrichtungen erfolgenden Bewegungen ausmessen zu können, ist die Vorrichtung so ausgebildet, daß zum Messen der in drei Raumrichtungen (x, y, z) erfolgenden Bewegungen des Meßobjekts (18) an einem Meßort (17) insgesamt drei vom Meßobjekt (18) herrührendes Streulicht des Laserstrahls (16) aufnehmende Meßköpfe (12, 13, 14) außerhalb der Einstrahlrichtung ($\vec{e}_{i0}$) des Laserstrahls (16) ortsfest in einer den Meßort (17) nicht aufweisenden Anordnungsebene angeordnet und an den Empfänger (24) angeschlossen sind, und daß eine die Relativlage des Meßorts (17) auf dem Laserstrahl (16) ermittelnde Ortsbestimmungseinrichtung (14') vorhanden ist.



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Beschreibung

Die Erfindung bezieht sich auf eine Vorrichtung zum berührungslosen Messen von Objektschwingungen mit einem Laserstrahl, der mit einer die Einstrahlrichtung bestimmenden Strahlablenkeinrichtung nacheinander auf unterschiedliche Meßorte des Meßobjekts gerichtet ist, mit einem vom Meßobjekt herrührendes Streulicht des Laserstrahls aufnehmenden Meßkopf, der an einen Empfänger angeschlossen ist, mit einem frequenzverschobenen Referenz-Laserstrahl, der in dem Empfänger dem Streulicht des Meßobjekts überlagert ist, und mit einer an den Empfänger angeschlossenen Auswertungseinrichtung.

Um Anlagen und Maschinen optimal konstruieren zu können, ist es erforderlich, das dynamische Verhalten der mechanischen Strukturen möglichst genau zu kennen. Es ist also erforderlich, das Steifigkeitsverhalten bzw. die charakteristischen Schwingungsformen einer Maschinenkonstruktion möglichst genau beschreiben bzw. ermitteln zu können. Für diese Ermittlung sind Meßverfahren erforderlich, mit denen die Bewegung eines Objektpunktes erfaßt werden kann, z. B. die Bewegung eines Objektpunktes durch eine Maschinenschwingung.

Es ist möglich, dreidimensionale Bewegungen eines Objektpunktes mit mechanischen Sensoren zu erfassen, die beispielsweise als Weg-, Geschwindigkeits- oder Beschleunigungsaufnehmer eingesetzt werden. Die Sensoren werden an ausgewählten Meßorten am Meßobjekt befestigt. Die mechanische Befestigung erfolgt üblicherweise durch Kleben oder Schrauben, so daß eine Änderung eines Meßorts stets mit einem entsprechenden Änderungsaufwand verknüpft ist. Infolge der mechanischen Befestigung kann mit den angesprochenen berührenden Sensoren nicht an bewegten Bauteilen gemessen werden. Die Sensoren verfälschen infolge ihrer eigenen Masse insbesondere an leichten Bauteilen die Schwingungsformen des Meßobjekts. Die Sensoren bilden ein Masse-Feder-System, dessen Steifigkeit und Masse die Bandbreite des Sensors begrenzen. Letztlich ist nicht auszuschließen, daß die Meßergebnisse durch gegenseitige Beeinflussung verfälscht werden, wenn der Sensor Objektbewegungen in drei Dimensionen mißt, also bei sogenannten Triax-Sensoren.

Allgemein bekannt sind flächenabtastende Laser-Doppler-Schwingungsanalysesysteme, mit denen eine berührungslose Geschwindigkeitsmessung von Objektpunkten von schwingenden Bauteilen möglich ist.

Aus der DE-Z: Technisches Messen 1984, S. 394 ff. ist eine Vorrichtung mit den eingangs genannten Merkmalen bekannt, bei der mit Hilfe eines frequenzverschobenen Referenz-Laserstrahls ein Geschwindigkeitssignal v(t) eines mit dem Laserstrahl bestrahlten Meßortes des Meßobjekts durch die Auswertungseinrichtung ermittelt wird. Der Laserstrahl wird über zwei gesteuerte Ablenkspiegel, die Teil der die Einstrahlrichtung bestimmenden Strahlablenkeinrichtung sind, auf das Meßobjekt fokussiert. Das zurückgestreute Licht wird auf demselben Wege gesammelt und gelangt gemeinsam mit dem Referenzstrahl auf einen Fotodetektor. Dessen Signal wird von der Auswertungseinrichtung zur Ermittlung der gesuchten Geschwindigkeitsfunktion verwertet. Bei der bekannten Vorrichtung ist die Beobachtungsrichtung der Einstrahlungsrichtung des Laserstrahls stets exakt entgegengesetzt gerichtet. Der bekannte Meßkopf nimmt also stets nur dasjenige reflektierte Streulicht des Laserstrahls vom Meßobjekt auf, welches genau entgegengesetzt der Einstrahlungsrichtung des Laserstrahls vom Meßobjekt herrührt. Mit der bekannten Vorrichtung kann also nur entsprechend der Einstrahlrichtung des Laserstrahls gemessen werden, also in nur einer einzigen Richtung, so daß die Messung sozusagen eindimensional ist. Dadurch können zwar Schwingungsprofile von unterschiedlichen Meßorten des Meßobjekts erstellt werden, beispielsweise also von Schwingungen eines eingespannten Bleches, jedoch ohne daß dabei die spezielle Ausbildung des Meßobjekts hinsichtlich des Abstands seiner Meßorte von der messenden Vorrichtung erfaßt werden kann.

Demgegenüber liegt der Erfindung die Aufgabe zugrunde, eine Vorrichtung mit den eingangs genannten Merkmalen so zu verbessern, daß die berührungslose und damit trägheitslose Messung der Objektschwingungen von Meßorten eines Meßobjekts in den drei Raumrichtungen ermöglicht wird, wobei die Formgestaltung des Meßobjekts erfaßt werden kann.

Diese Aufgabe wird dadurch gelöst, daß zum Messen der in drei Raumrichtungen erfolgenden Bewegungen des Meßobjekts an einem Meßort insgesamt drei vom Meßobjekt herrührendes Streulicht des Laserstrahls aufnehmenden Meßköpfe außerhalb der Einstrahlrichtung des Laserstrahls ortsfest in einer den Meßort nicht aufweisenden Anordnungsebene angeordnet und an den Empfänger angeschlossen sind, und daß eine die Relativlage des Meßorts auf dem Laserstrahl ermittelnde Ortsbestimmungseinrichtung vorhanden ist.

Für die Erfindung ist zunächst die Erkenntnis wichtig, daß die Einstrahlrichtung des Laserstrahls unabhängig von der Beobachtungsrichtung sein muß, unter der der jeweilige Meßort beim Abtasten des Meßobjekts mit dem Laserstrahl ausgemessen wird. Dieser Ausmessung dienen drei an unterschiedlichen Stellen relativ zum Meßobjekt angeordnete Meßköpfe, die jeweils auf das Meßobjekt ausgerichtet sind und das von diesem herrührende Streulicht des Laserstrahls aufnehmen. Für die Anordnung der Meßköpfe ist von Bedeutung, daß sie nicht koplanar mit dem Meßobjekt bzw. mit dem Meßort angeordnet sind. Die von den Meßköpfen aufgespannte Ebene darf also den Meßort nicht mit umfassen. Es stehen für die Beobachtung des Meßobjekts drei Meßsignale zur Verfügung, die infolge der ortsfesten Anordnung der Meßköpfe nur von den Änderungen der Streuung des Laserlichts am Meßort abhängig sind, so daß mit diesen Meßsignalen durch die Auswertungseinrichtung Informationen über die Bewegungen des Meßobjekts am Meßort in allen drei Raumrichtungen gewonnen werden können. Es ist also nicht erforderlich, an dem untersuchten Meßobjekt mechanische Strukturen zu befestigen, so daß die Einfachheit der Messung und die Flexibilität bei dem Einsatz der Meßvorrichtung erheblich verbessert werden können. Es kann an bewegten Meßobjekten gemessen werden und Verfälschungen des Meßergebnisses durch eine endliche Masse von Sensoren auf das dynamische Verhalten des Meßobjekts werden ausgeschlossen. Insbesondere leichte Strukturen können infolgedessen trägheitslos und damit störungsfrei vermessen werden. Die rein optische Vermessung ermöglicht eine sehr hohe Meßbandbreite in allen drei Raumrichtungen.

Von weiterer Bedeutung ist die Ortsbestimmungseinrichtung, die es erlaubt, die Relativlage des Meßorts in Bezug auf die Meßvorrichtung zu bestimmen. Infolgedessen ist nicht nur eine einfache Messung der Schwingungsbewegung eines Meßorts eines Meßobjekts möglich, sondern zugleich auch die einfache Erfassung des

Meßorts im Raum bzw. in Bezug auf den Laserstrahl.

In der Regel wird es von Vorteil sein, wenn alle Meßköpfe spitzwinklig zum Laserstrahl auf das Meßobjekt gerichtet sind. Alle Meßköpfe beobachten das Meßobjekt von einer Seite bzw. von einem halbkugeligen Raumbereich her. Die Ausrichtung der Meßköpfe kann dabei an die Beobachtungsaufgabe angepaßt werden, indem die Winkel der Beobachtungsrichtungen der Meßköpfe zum Laserstrahl anforderungsgemäß eingestellt werden.

Eine einfache Übermittlung der von den Meßköpfen gelieferten Signale an den Empfänger wird dadurch erreicht, daß jeder Meßkopf mit einem Lichtleiter an den Empfänger angeschlossen ist. Die Lichtleiter sind so flexibel, daß sie jeder Anordnung der Meßköpfe folgen können und zugleich gewährleisten, daß Signalverlust ausgeschlossen ist.

Die Vorrichtung ist des weiteren so ausgestaltet, daß ein Meßkopf einen das vom Meßobjekt herrührende Streulicht des Laserstrahls aufnehmenden positionsempfindlichen Detektor als Ortsbestimmungseinrichtung aufweist. Mit Hilfe dieses Detektors kann die Relativlage des Meßorts auf dem Laserstrahl bestimmt werden, so daß der Meßkopf in sehr vorteilhafter Weise nicht nur für die Beobachtung des Meßorts in Bezug auf Objektschwingungen des Meßobjekts eingesetzt wird, sondern zugleich auch ein Signal liefern kann, mit dem die Lage des Meßorts des Meßobjekts zu bestimmen ist.

Um die Meßvorrichtung baulich zweckmäßig ausbilden zu können, wird sie so gestaltet, daß die Meßköpfe an einem Gestell angeordnet sind, mit dem die auf das Meßobjekt bezogenen Beobachtungsrichtungen der Meßköpfe einstellbar sind. Hierdurch wird eine bauliche Integration der Meßköpfe in die Vorrichtung ermöglicht, was die Anpassung der Meßvorrichtung an unterschiedliche Meßaufgaben erleichtert, insbesondere an unterschiedlich ausgebildete und angeordnete Meßobjekte.

Im vorgenannten Sinne ist es vorteilhaft, wenn die Meßköpfe von der Auswertungseinrichtung steuerbare Einstelleinrichtungen aufweisen. Mit Hilfe der von der Auswertungseinrichtung bestimmten Meßergebnisse kann über die steuerbaren Einstelleinrichtungen eine optimale Positionierung der Meßköpfe in Anpassung an die Meßobjekte erreicht werden.

Die Vorrichtung ist so ausgebildet, daß die die Einstrahlrichtung bestimmende Strahlablenkeinrichtung und/oder die Ortsbestimmungseinrichtung von der Auswertungseinrichtung steuerbar sind. Das ist im Sinne einer schnellen Steuerung der Vorrichtung zur Anpassung an eine schnelle Meßdatenverarbeitung von Vorteil, wie sie für komplizierte Formen und für hochfrequente Schwingungsvorgänge erforderlich ist.

Von Vorteil ist es, wenn jeder Meßkopf einen Empfänger aufweist, dem der frequenzverschobene Referenz-Laserstrahl über einen Lichtleiter zugeleitet ist, und daß das Ausgangssignal des Empfängers der Auswertungseinheit über einen weiteren Lichtleiter zugeleitet ist. In diesem Fall werden Koppelverluste des in der Regel schwachen Streulichts in einen Lichtleiter vermieden, die aufträten, wenn das Streulicht vom Meßkopf mit einem Lichtleiter zu einem Empfänger geleitet werden müßte. Eine derartige Vermeidung von Koppelverlusten könnte sich in gewissen Anwendungsfällen der Meßvorrichtung positiv auswirken.

Die Erfindung wird anhand der Zeichnungen erläutert. Es zeigt

Fig. 1 eine Darstellung zur grundsätzlichen Erläuterung physikalisch bedeutsamer Größen für die Schwingungsbeobachtung eines Meßorts eines Meßobjekts,

Fig. 2 eine schematische Darstellung einer erfindungsgemäßen Vorrichtung in Bezug auf ein Meßobjekt,

Fig. 3 eine der **Fig.** 2 ähnliche Darstellung in baulicher Konkretisierung eines Teils ihrer Komponenten, und

Fig. 4 eine blockschaltbildartige Darstellung eines Sender/Empfängers der Vorrichtung der **Fig.** 2, 3.

In **Fig.** 1 wird schematisch ein Meßobjekt **18** dargestellt, das in Einstrahlrichtung $\vec{e}_{i0}$ mit einem Laserstrahl bestrahlt wird, der das gesamte Meßobjekt **18** punkt- oder zeilenweise abtastet. Dementsprechend gibt es auf dem Meßobjekt **18** eine Vielzahl von Meßorten **17**, die allgemein mit i bezeichnet sind, wobei $i = 1 \ldots N$ ist, wobei N eine durch die Größe des Meßobjekts **18** und/oder durch die auszuwählende Anzahl von Meßorten **17** bestimmte ganze Zahl ist.

Am Meßort **17** findet eine Bewegung des Meßobjekts **18** statt, nämlich eine Schwingung mit der zeitabhängigen Geschwindigkeit $\vec{v}_i = \vec{v}_i(t)$ im Raum. Diese Schwingung wird beobachtet, und zwar in der Beobachtungsrichtung $\vec{e}_{ij}$. Die Beobachtung erfolgt also in einer Richtung, die von der Einstrahlrichtung abweicht. Zur Beobachtung der Bewegung des Meßobjekts **18** am Meßort **17** wird das in die Beobachtungsrichtung gestreute Licht des Laserstrahls benutzt. Dieses Streulicht erfährt infolge der Bewegung des Meßobjekts eine Frequenzverschiebung. Diese Dopplerverschiebung ist abhängig von der Eigengeschwindigkeit des Meßobjekts **18**, von der Einstrahlrichtung $\vec{e}_{i0}$ und von der Beobachtungsrichtung $\vec{e}_{ij}$. Die Frequenz υ_{ij} bestimmt sich aus der Frequenz υ_0 des Laserlichts gemäß der zu **Fig.** 1 angegebenen Formel, in der c die absolute Lichtgeschwindigkeit bedeutet und j die Anzahl der Beobachtungseinrichtungen. Bei $j = 1, 2, 3$ wird das Streulicht dreier verschiedener Raumrichtungen beobachtet, so daß dementsprechend drei Vektorkomponenten der Geschwindigkeit $\vec{v}_i$ bestimmt werden können, aus denen die drei Raumkomponenten der gesuchten zeitabhängigen Geschwindigkeit $\vec{v}_i$ nach allgemeinen geometrischen Beziehungen berechnet werden können.

Fig. 2 veranschaulicht außer der mit **Fig.** 1 übereinstimmenden Darstellung eines Meßobjekts **18** in schematischer Darstellung einen Sender/Empfänger **1**, der mit einem Laserstrahl **16** das Meßobjekt **18** abtastet. Die Meßköpfe **12** bis **14** sind so vor dem Meßobjekt **18** angeordnet, daß sie mit dem Laserstrahl **16** stets einen spitzen Winkel α bilden. Hiervon kann jedoch auch abgewichen werden, wenn die Form oder das Schwingungsverhalten des Meßobjekts **18** dies erfordern. Der Laserstrahl kann die Extremlagen **16**, **16**^{2}, **16**^{3} und **16**^{4} einnehmen. In dem durch diese Extremlagen bestimmten Bereich können alle Meßorte **17** mit den Kennzahlen $i = 1$ bis N abgetastet werden, wobei die jeweiligen Meßorte **17** frei wählbar sind und im Sinne einer lückenlosen Abtastung oder im Sinne des diskreten Meßortes **17** bestimmt werden. Dementsprechend liegen unterschiedliche Einstrahlrichtungen $\vec{e}_{i0} = \vec{e}_{10}$ bis $\vec{e}_{N0}$ vor. Diese Einstrahlrichtungen werden von einer Strahlablenkeinrichtung **7** bestimmt und sind in **Fig.** 4 durch ein Strahlenbündel **8** symbolisiert.

Zur Beobachtung des Meßortes **17** bzw. aller anderen Meßorte sind drei Meßköpfe **12** bis **14** vorhanden, die auf das Meßobjekt **18** gerichtet sind. Sie nehmen von dem Meßobjekt **18** herrührendes Streulicht des Laserstrahls **16** auf. Die Meßköpfe **12** bis **14** sind über Lichtleiter 19 mit dem Sender/Empfänger 1 verbunden, so daß das von ihnen aufgenommene Laserstreulicht mit dem Lichtleiter 19 an den Empfänger 24 des Sender/Empfängers 1 weitergeleitet werden kann. Die dort gewonnenen Daten werden über eine Datenleitung 11 einer Auswertungseinheit 15 zugeleitet, von der das Meßergebnis über eine Meldeleitung 28 beispielsweise an eine nicht dargestellte Anzeigeeinrichtung abgegeben wird.

Das Laserlicht des Laserstrahls 16 soll die Frequenz ν_0 haben. Infolge der Bewegung des Meßorts 17 erfolgt eine Dopplerverschiebung in Abhängigkeit von der Schwingung des Meßorts 17 mit der Kennzahl i. Dementsprechend sind die Frequenzen des Streulichts in den drei Beobachtungsrichtungen der Meßköpfe 12, 14 frequenzverschoben und weisen die Frequenzen ν_{i1}, ν_{i2} und ν_{i3} auf. Diese Frequenzverschiebungen enthalten an sich bereits die erforderliche Information über den Schwingungsvorgang am Meßort 17. Die Frequenzverschiebungen sind jedoch sehr klein, so daß zu ihrer Auswertung im Sender/Empfänger 1 das sogenannte Heterodyn-Verfahren benutzt wird, bei dem eine definierte Frequenzverschiebung eines Referenz-Laserstrahls benutzt wird, um die geschwindigkeitsproportionale Doppler-Frequenzverschiebung zur Bestimmung des gewünschten Geschwindigkeitssignals $\vec{v}(t)$ zu benutzen. Insoweit wird auf **Fig.** 4 Bezug genommen, in der der Sender/Empfänger 1 mit seinen beiden Komponenten Sender 29 und Empfänger 24 blockschaltbildartig dargestellt ist.

Im Sender 29 wird mit einem Laser 2 ein Laserstrahl 3 erzeugt, der einer frequenzverschiebenden Einheit 4 zugeleitet wird. Die frequenzverschiebende Einheit 4 ist beispielsweise eine sogenannte Bragg-Zelle. Diese Einheit 4 erzeugt neben dem nicht frequenzverschobenen Laserstrahl 5 einen frequenzverschobenen Laserstrahl 6, der über Strahlführungsplatten 9, 9' einem Empfangsmodul 10 zugeleitet wird. Der nicht frequenzverschobene Laserstrahl 5 gelangt in die Strahlablenkeinheit 7, welche den Laserstrahl 16 auf die gewünschten Meßorte 17 lenkt. Der Ablenkung dienen in der Strahlablenkeinheit 7 vorhandene, nicht näher dargestellte Schwenkspiegel, die von der gewünschten Ablenkung entsprechend gesteuerten Stellmotoren so verschwenkt werden, daß der Laserstrahl 16 die gewünschte Richtung hat. Das kann beispielsweise durch Winkelgeber kontrolliert werden, so daß die Einstrahlrichtungen $\vec{e}_{i0}$ zu allen Zeitpunkten des Meßvorgangs bekannt sind. Dabei werden die Daten der Strahlablenkeinheit 7 über eine Datenleitung 20 an die Auswertungseinheit 15 übertragen.

Der Empfangsmodul 10 erhält über die Lichtleiter 19 das Streulicht der Meßköpfe 12 bis 14 zugeführt, wobei jeweils das Streulicht eines der Meßköpfe mit einem Anteil des frequenzverschobenen Laserstrahls 6 überlagert wird, indem es durch eine teildurchlässige Platte 9' gemeinsam mit dem Referenzstrahl auf einen Empfänger des Empfangsmoduls 10 gestrahlt wird, beispielsweise auf einen Fotoempfänger. Es sind insgesamt also drei Empfangsmodule 10 für die drei Meßköpfe 12 bis 14 vorhanden. Das Signal des Fotoempfängers jedes Moduls 10 wird über die Datenleitung 11 dem Auswertungssystem 15 zugeführt, welches die Schwingungsanalyse für die Meßorte 17 übernimmt. Es versteht sich, daß die Analyse der Bewegung eines Meßobjekts 18 an mehreren Meßorten 17 entsprechend getaktet erfolgen muß, wozu entsprechend schnelle Hardwarekomponenten einzusetzen sind. Die Auswertung ist insoweit herkömmlich.

In **Fig.** 3 ist das Meßobjekt 18 in Bezug auf ein Koordinatensystem 23 dargestellt, in Bezug auf welches die Schwingung des Meßobjekts 18 an einem Meßort 17 bestimmt wird. Die z-Achse fluchtet dabei mit der Normalrichtung 30 des Sender/Empfängers 1, der etwa auf die Mitte des Meßobjekts 18 ausgerichtet ist. Für die Meßköpfe 12 bis 14, von denen lediglich die beiden Meßköpfe 13, 14 dargestellt sind, ist ein Gestell 25 vorhanden, an dem die Meßköpfe 13, 14 verstellbar sind. Ein Gestellarm 22 ist vertikal in x-Richtung angeordnet und ein Gestellarm 31 ist horizontal in y-Richtung angeordnet. Beide Gestellarme 22, 31 sind vertikal zur z-Richtung. Beide Gestellarme 22, 31 weisen Längsnuten 32 auf, mit denen die Meßköpfe 13, 14 mit Schiebestützen 33 in gewünschter Weise angeordnet und befestigt werden können. Dementsprechend sind Beobachtungsrichtungen 26, 27 bezüglich eines Meßorts 17 vorhanden. Diese Beobachtungsrichtungen werden so gewählt, daß eine möglichst optimale Auswertung gegeben ist. Die Ausrichtung der Meßköpfe 13, 14 kann also beispielsweise so erfolgen, daß ein möglichst großer Anteil von Streulicht eingefangen wird, oder daß die Beobachtungsrichtungen 26, 27 mit den Hauptschwingungsrichtungen des Meßorst 17 übereinstimmen.

Zur Bestimmung der Koordinaten der Meßorte 17, der jeweiligen Einstrahlrichtung $\vec{e}_{i0}$ und der Beobachtungsrichtung $\vec{e}_{ij}$ wird das Koordinatensystem 23 mit seinen Koordinaten x, y, z herangezogen. Für die Bestimmung des Meßorts 17 kann davon ausgegangen werden, daß dieser stets in Einstrahlrichtung $\vec{e}_{i0}$ liegt. Die Koordinaten des Meßortes 17 sind: (x_i, y_i, z_i). Die Koordinaten eines Meßkopfes sind: (x_j, y_j, z_j). Die letztgenannten Koordinaten der Meßköpfe 12, 13, 14 können konventionell bestimmt werden, beispielsweise durch Ortsmelder an den Gestellarmen 22, 31. Auch die Anordnung des Sender/Empfängers 1 relativ zum Koordinatensystem wird konventionell festgelegt.

Es kann eine nicht dargestellte Ortsbestimmungseinrichtung verwendet werden, durch die die Lage des Leuchtflecks des Laserstrahls 16 auf dem Meßobjekt relativ zum Koordinatensystem 23 mit mechanischen Meßmitteln gemessen wird. Die Koordinaten der Meßorte 17 können aber auch mit Hilfe der Lasertriangulation bestimmt werden. In beiden Fällen können die die Meßorte 17 betreffenden Meßwerte an die Auswertungseinheit 15 übermittelt und dort gespeichert werden. Für jedes Meßobjekt 18 kann dann allein durch Identifizierung der Einstrahleinrichtung $\vec{e}_{i0}$ die durch Schwingungen ungestörte Ausgangslage eines Meßorts 17 berücksichtigt werden.

Eine besonders vorteilhafte Bestimmung der Koordinaten eines Meßorts 17 ergibt sich durch Beobachtung des Leuchtflecks des Laserstrahls 16 und Abbildung auf einem ortsempfindlichen Detektor, der als Ortsbestimmungseinrichtung 14' in einen Meßkopf 14 eingebaut ist. In diesem Fall wird das reflektierte Licht nicht nur zur Bestimmung der entsprechenden Schwingungskomponente ausgenutzt, sondern zugleich auch zur Bestimmung des Meßorts 17. In **Fig.** 3 ist angedeutet, daß die Übermittlung dieser Meßgröße auch über eine separate Signalleitung 34 direkt an die Auswertungseinheit 15 erfolgen kann. Der in einer solchen Leitung schematisch dargestellte Doppelpfeil deutet an, daß mit Hilfe der Auswertungseinheit 15 auch eine Einstellung der Meßköpfe 12 bis 14 mittels einer nicht dargestellten Einstelleinrichtung möglich ist, die von der Auswertungseinrichtung 15 steuerbar ist, wodurch eine neue Einstellung der Beobachtungsrichtung dieser Meßköpfe erfolgen kann.

Sind die Koordinaten (x_i, y_i, z_i) für i = 1 bis N bekannt, wie auch die Koordinaten (x_j, y_j, z_j) für j = 1, 2 und 3, so können mit Hilfe allgemein bekannter mathematischer Regeln die Vektoren $\vec{e}_{i0}$, für i = 1 bis N und $\vec{e}_{ij}$ für i = 1 bis N und j = 1, 2, 3 berechnet werden, so daß die in **Abb. 1** angegebene Beziehung $\vec{v}_i$ für i = 1 bis N aufgelöst werden kann. Die Geschwindigkeitsvektoren $\vec{v}_i$ sind die gesuchten Meßgrößen.

In den Figuren ist nicht ausgeführt, daß der Empfänger **24** bzw. der Empfangsmodul **10** auch im Meßkopf **12**, **13**, **14** angeordnet sein könnte. In diesem Falle müßte der frequenzverschobene Referenz-Laserstrahl **6** zur Überlagerung mit dem Streulicht des Meßortes über eine entsprechend gekippte Platte **9'** durch den Lichtleiter **19** in den Meßkopf bzw. in den dort befindlichen Empfangsmodul **10** geleitet werden, dessen verstärktes elektrisches Signal der Auswertungseinheit **15** über einen nicht dargestellten weiteren Lichtleiter zugeführt wird.

Patentansprüche

1. Vorrichtung zum berührungslosen Messen von Objektschwingungen mit einem Laserstrahl, der mit einer die Einstrahlrichtung bestimmenden Strahlablenkeinrichtung nacheinander auf unterschiedliche Meßorte des Meßobjekts gerichtet ist, mit einem vom Meßobjekt herrührendes Streulicht des Laserstrahls aufnehmenden Meßkopf, der an einen Empfänger angeschlossen ist, mit einem frequenzverschobenen Referenz-Laserstrahl, der in dem Empfänger dem Streulicht des Meßobjekts überlagert ist, und mit einer an den Empfänger angeschlossenen Auswertungseinrichtung, **dadurch gekennzeichnet,** daß zum Messen der in drei Raumrichtungen (x, y, z) erfolgenden Bewegungen des Meßobjekts **(18)** an einem Meßort **(17)** insgesamt drei vom Meßobjekt **(18)** herrührendes Streulicht des Laserstrahls **(16)** aufnehmende Meßköpfe **(12, 13, 14)** außerhalb der Einstrahlrichtung ($\vec{e}_{i0}$) des Laserstrahls **(16)** ortsfest in einer den Meßort **(17)** nicht aufweisenden Anordnungsebene angeordnet und an den Empfänger **(24)** angeschlossen sind, und daß eine die Relativlage des Meßorts **(17)** auf dem Laserstrahl **(16)** ermittelnde Ortsbestimmungseinrichtung **(14')** vorhanden ist.
2. Vorrichtung nach Anspruch 1, dadurch gekennzeichnet, daß alle Meßköpfe **(12, 13, 14)** spitzwinklig zum Laserstrahl **(16)** auf das Meßobjekt **(18)** gerichtet sind.
3. Vorrichtung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß jeder Meßkopf **(12, 13, 14)** mit einem Lichtleiter **(19)** an den Empfänger **(24)** angeschlossen ist.
4. Vorrichtung nach einem oder mehreren der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß ein Meßkopf **(12, 13, 14)** einen das vom Meßobjekt **(18)** herrührende Streulicht des Laserstrahls **(16)** aufnehmenden positionsempfindlichen Detektor als Ortsbestimmungseinrichtung **(14')** aufweist.
5. Vorrichtung nach einem oder mehreren der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß die Meßköpfe **(13, 14)** an einem Gestell **(25)** angeordnet sind, mit dem die auf das Meßobjekt **(18)** bezogenen Beobachtungsrichtungen **(26, 27)** der Meßköpfe **(13, 14)** einstellbar sind.
6. Vorrichtung nach einem oder mehreren der Ansprüche 1 bis 5, dadurch gekennzeichnet, daß die Meßköpfe **(13, 14)** von der Auswertungseinrichtung **(15)** steuerbare Einstelleinrichtungen aufweisen.
7. Vorrichtung nach einem oder mehreren der Ansprüche 1 bis 6, dadurch gekennzeichnet, daß die die Einstrahlrichtung ($\vec{e}_{i0}$) bestimmende Strahlablenkeinrichtung **(7)** und/oder die Ortsbestimmungseinrichtung **(14')** von der Auswertungseinrichtung **(15)** steuerbar sind.
8. Vorrichtung nach einem oder mehreren der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß jeder Meßkopf **(12, 13, 14)** einen Empfänger **(24)** aufweist, dem der frequenzverschobene Referenz-Laserstrahl **(6)** über einen Lichtleiter **(19)** zugeleitet ist, und daß das Ausgangssignal des Empfängers **(24)** der Auswertungseinheit über einen weiteren Lichtleiter zugeleitet ist.

Hierzu 3 Seite(n) Zeichnungen

Nummer: DE 41 06 572 A1
Int. Cl.^{5}: G 01 H 9/00
Offenlegungstag: 3. September 1992

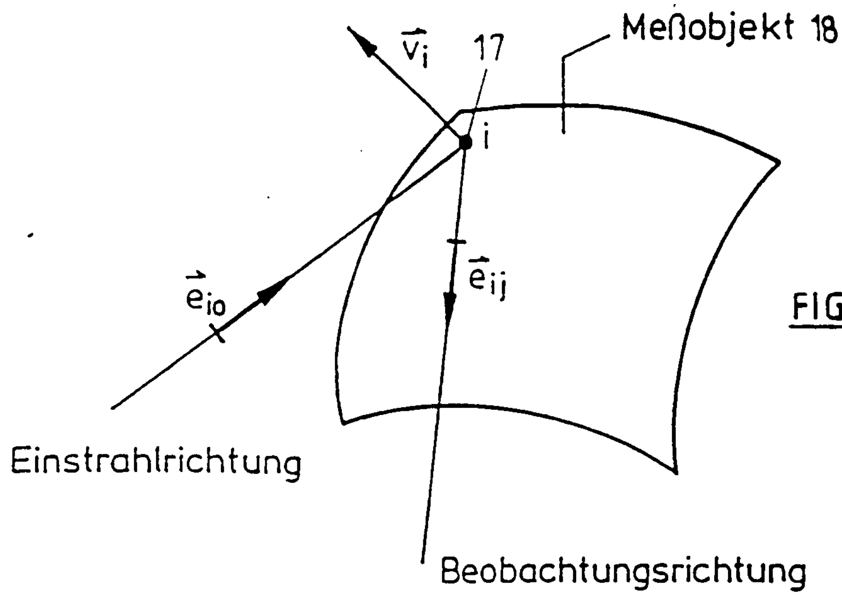
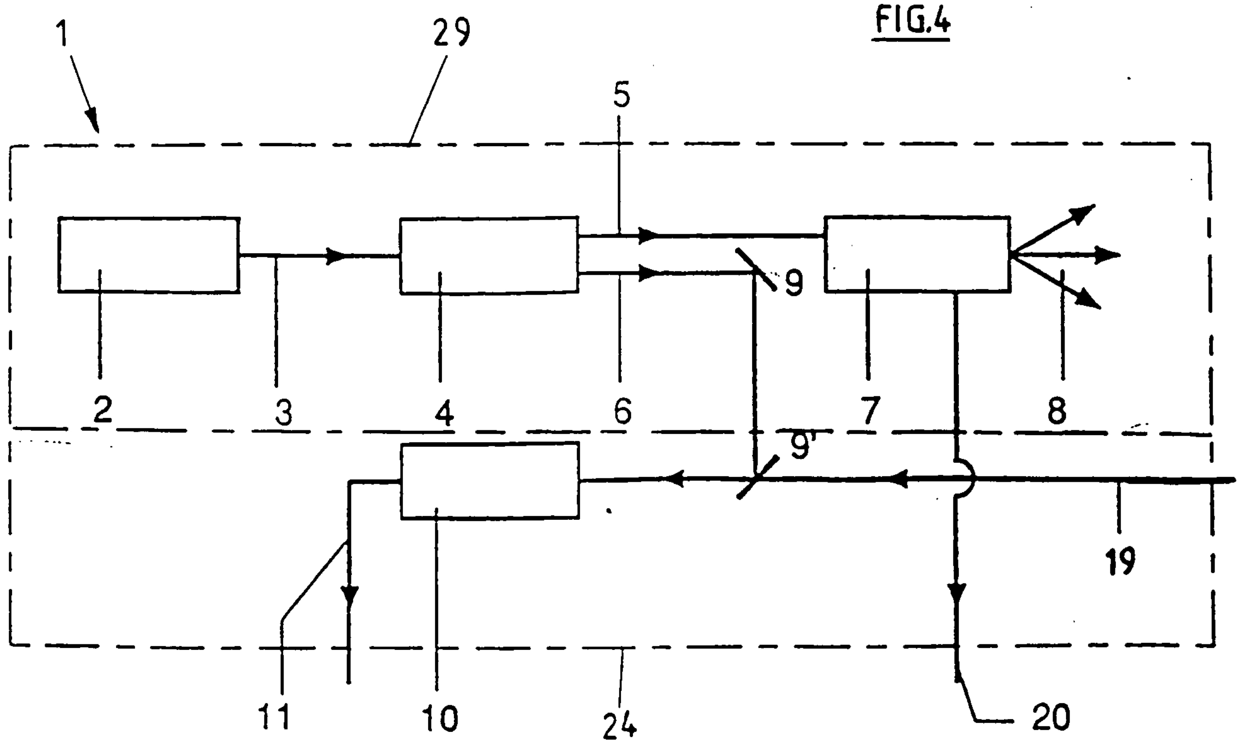


FIG.1

$$\vec{v}_i = \vec{v}_i(t) \quad , \quad i = 1 \ldots N$$

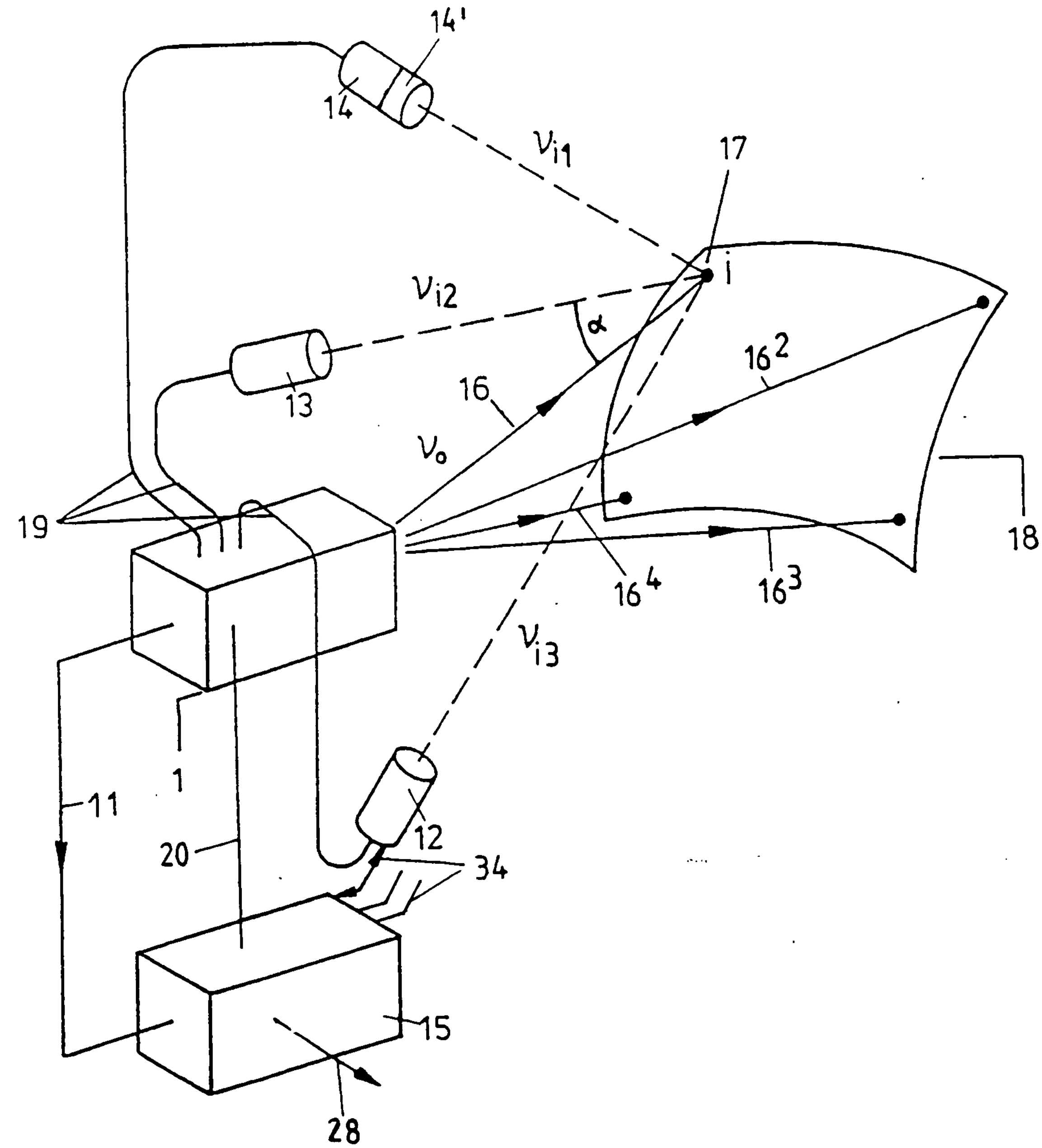
$$\nu_{ij} = \nu_o \left(1 + \frac{\vec{v}_i}{c} \cdot (\vec{e}_{ij} - \vec{e}_{io})\right) \quad , \quad j = 1, 2, 3$$

FIG.4



Nummer: DE 41 06 572 A1
Int. Cl.⁵: G 01 H 9/00
Offenlegungstag: 3. September 1992

FIG.2



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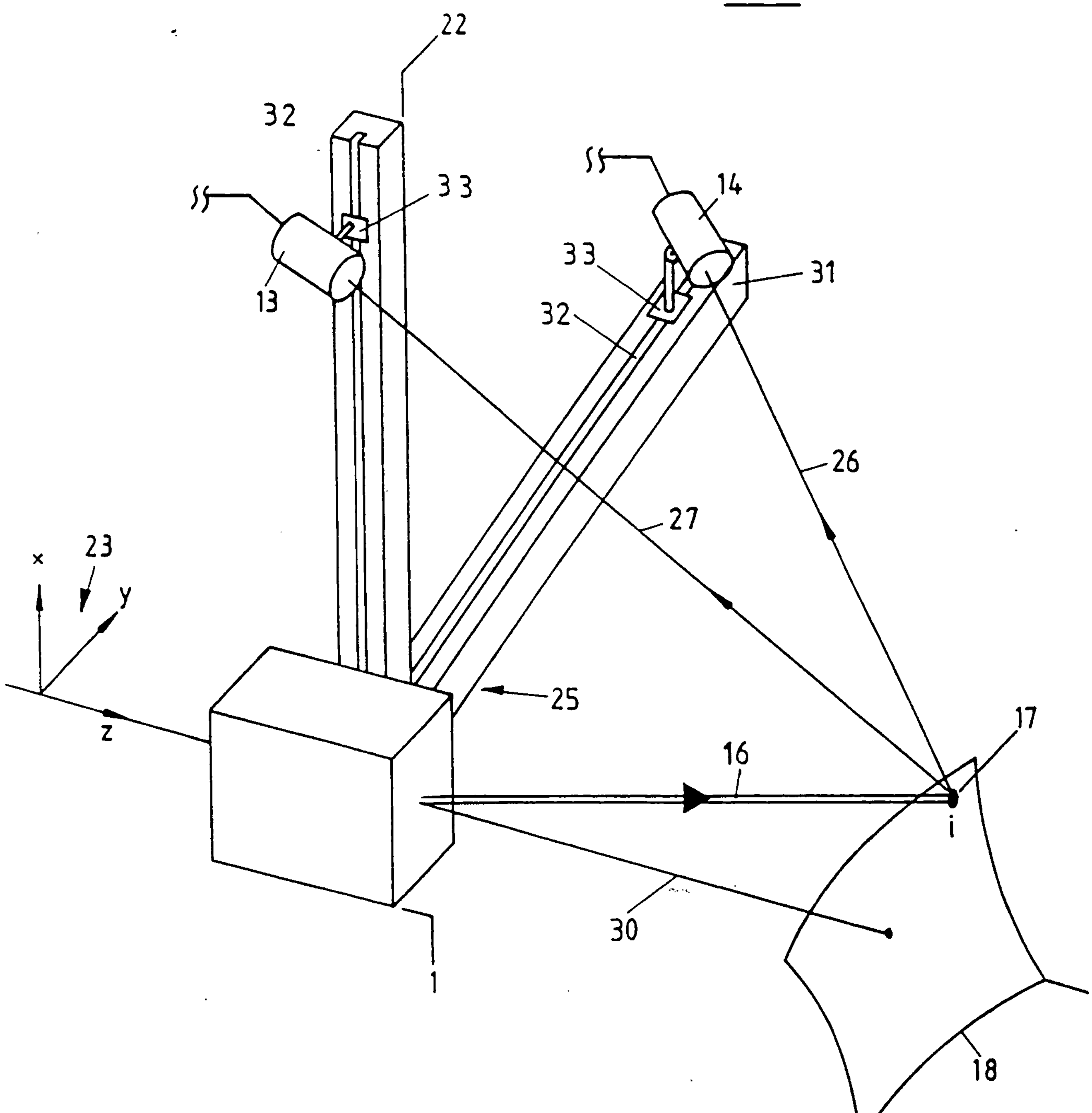
Offenlegungstag: 3. September 1992

FIG. 3



(19) BUNDESREPUBLIK DEUTSCHLAND

DEUTSCHES PATENTAMT

(12) Offenlegungsschrift

(10) DE 41 31 341 A 1

(51) Int. Cl.5: G 08 C 15/00

(21) Aktenzeichen: P 41 31 341.0
(22) Anmeldetag: 20. 9. 91
(43) Offenlegungstag: 26. 11. 92

DE 41 31 341 A 1

Mit Einverständnis des Anmelders offengelegte Anmeldung gemäß § 31 Abs. 2 Ziffer 1 PatG

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Prüfungsantrag gem. § 44 PatG ist gestellt

(54) Einrichtung zur radiofrequent-drahtlosen Übertragung von Meßdaten von einem Fahrzeug

(57) Eine Einrichtung zur radiofrequent-drahtlosen Übertragung von Meßdaten von einem Fahrzeug wird beschrieben. Sie erlaubt eine zeitgemultiplexte Übertragung einer Vielzahl von Meßkanälen vom fahrenden Fahrzeug aus mit hoher Störsicherheit. Dazu umfaßt die Einrichtung fahrzeugseitige Mittel zur getrennten Erzeugung und gemeinsamen Abstrahlung mehrerer jeweils mit nur einem Meßsignal modulierter Träger. Der ortsfeste Teil der Einrichtung umfaßt einen trägerfrequenten Teiler mit einer nachgeschalteten, entsprechenden Vielzahl von schmalbandigen Empfängern, deren Ausgänge in koinzidentem Takt mit den Schaltphasen eines fahrzeugseitigen Kanalumschalters entsprechenden Signalausgängen zugeordnet werden. Die Koinzidenz wird durch Zeit- bzw. Frequenznormale sowohl im fahrzeugseitigen als auch ortsfesten Teil der Einrichtung sichergestellt. Beide Normale werden vorzugsweise von einem Normalzeitsender drahtlos kontrolliert, so daß eine genaue Kanalzuordnung empfangbarer Daten selbst nach einem erfolgten Abriß der Datenübertragung nie verlorengehen kann.

DE 41 31 341 A 1

Beschreibung

Die Erfindung betrifft eine Einrichtung zur radiofrequent-drahtlosen Übertragung von Meßdaten von einem Fahrzeug nach dem Oberbegriff des Anspruchs 1.

Systeme zur radiofrequent-drahtlosen Übertragung von Meßdaten von Fahrzeugen sind bekannt. So ist es beispielsweise bekannt, eine Vielzahl von fortlaufend sich ändernden Daten zu digitalisieren und in serielle Datenpakete umzusetzen und aus einer Vielzahl solcher Datenpakete einen seriellen Datenstrom zu erzeugen, mit letztwelchem dann ein AM-, FM- oder PM-Sender moduliert wird, und auf der Seite eines entsprechenden Empfängers mittels einer umgekehrt verlaufenden Disassemblierung eines entsprechend demodulierten Signals die einzelnen Daten und deren Zeitverläufe wiederzugewinnen. Vielfach werden dabei auch störungsunterdrückende PCM-Techniken angewandt.

Diese Systeme weisen jedoch einige Nachteile auf. Die seriell-vielkanalige Übertragung bedingt zunächst hohe Modulationsfrequenzen. Infolgedessen belegt das modulierte Hochfrequenzsignal, d. h. der Träger und die je nach Modulationsart und Übertragungsgenauigkeit mehr oder weniger vollständig mitzuübertragenden Seitenbänder, ein relativ breites Frequenzband. Treten innerhalb dieses Frequenzbandes selektive Übertragungsstörungen auf, sind im Ergebnis alle Datenkanäle betroffen und insoweit in der Regel immer alle empfangsseitig wiedergewinnbaren Meßdaten entsprechend verfälscht. Da entsprechende Übertragungsstrecken um so breitbandiger vorgesehen werden müssen, je mehr Meßdaten und/oder je genauer solche übertragen werden sollen und vorgenannte Störungen um so wahrscheinlicher werden, je größer die Übertragungsbandbreite gewählt wird, gibt es für den Störabstand solch herkömmlicher Übertragung eine auch mit hohem technischem Aufwand nicht überschreitbare, natürliche Grenze, sofern die Sendeleistung aus energetischen Gründen nicht (beliebig) hoch gewählt werden kann. Dieser Fall liegt aber bei den meisten Anwendungen vor, bei denen Meßdaten von einem bewegten Objekt, etwa einem Fahrzeug, übermittelt werden sollen. Bei PCM-Übertragung kommt hinzu, daß eine auch nur geringfügige Störung des Datenrahmencodes zur Fehlübertragung sämtlicher Daten führt.

Es ist Aufgabe der Erfindung, eine Einrichtung zur radiofrequent-drahtlosen Übertragung von Meßdaten von einem Kraftfahrzeug zu schaffen, welche eine störungsarme vielkanalige Übertragung von Meßdaten erlaubt.

Diese Aufgabe wird bei einer erfindungsgemäßen Einrichtung nach der Gattung des Anspruchs 1 gelöst.

Diese Einrichtung erlaubt in vorteilhafter Weise eine extrem störungsarme Übertragung von Meßdaten, indem zum einen nicht Kanaldaten, sondern mit Kanaldaten schmalbandig modulierte Träger ("Trägerkanäle") sequentiell gemultiplext übertragen und empfangen werden und andererseits sowohl sende- als auch empfangsseits der Kanalbezug durch eine echtzeitgesteuerte Kanalaufschaltung bzw. -abfrage erfolgt. Der Echtzeitbezug, und dadurch die exakte Kanalzuordnung, kann dabei mittels eines sowohl im Sender als auch im Empfänger vorhandenen Normalzeitempfänger sichergestellt werden.

Vorteilhafte Weiterbildungen sind nach Lehre der darauf rückbezogenen Ansprüche 2 bis 9 gegeben.

Dabei erlaubt die gemäß dem abhängigen Anspruch 4 und folgenden ausgebildete Einrichtung eine optimale Anpassung an wechselnde Übertragungsbedingungen und -strecken.

Zwei Ausführungsbeispiele der Erfindung sind in der Zeichnung dargestellt und nachfolgend erläutert. Es zeigt

Fig. 1 das Funktionsblockschaltbild des fahrzeugseitigen Teils einer Einrichtung zur radiofrequent-drahtlosen Übertragung von Meßdaten von einem Fahrzeug;

Fig. 2 das Funktionsblockschaltbild des ortsfesten Teils einer Einrichtung zur radiofrequent-drahtlosen Übertragung von Meßdaten von einem Fahrzeug;

Fig. 3 das Funktionsblockschaltbild eines erweiterten fahrzeugseitigen Teiles einer solchen Einrichtung, die zusätzlich z. B. die Möglichkeit einer bedarfsangepaßt intelligenten Datenreduktion bietet.

Der fahrzeugseitige Einrichtungsteil gemäß **Fig.** 1 umfaßt mehrere Meßkanäle **11.1** ... **11.m** bis **12.1** ... **12.m**, die zu n Gruppen **10.1** bis **10.n** zusammengefaßt sind; der Einfachheit halber sind hier nur zwei Gruppen **10.1** und **10.n** figürlich gezeigt. Die Ausgänge der Meßkanäle sind an einen m-kanaligen Meßstellenumschalter **13** geführt, welcher den eingangsseitigen Gruppenfächer n aufweist. Dessen m Ausgänge sind auf die Modulationseingänge je eines sehr schmalbandigen FM/PM-Quarzoszillators **14.1** ... **14.m** geführt. Die Ausgänge **15.1** ... **15.m** sind an ein Summiermittel **16**, etwa in Form eines breitbandigen Power-Combiners geführt, dem eine Leistungsverstärkerstufe **17** mit Antenne **18** folgt.

Zur Anwahl der Schaltverbindungen zwischen den Meßkanälen **11.1** ... **12.m** und den FM/PM-Quarzoszillatoren **14.1** ... **14.m** ist der Meßstellenumschalter **13** über einen Steuerpfad **22** mit einer Echtzeitlogik **21** verbunden, die entsprechende Schaltbefehle echtzeitverkettet erzeugt und ausgibt. Hierfür enthält diese ein Frequenz- bzw. Zeitnormal, das von einem Normalzeitempfänger **20**, welcher von einer Normalzeit-Empfangsantenne **19** gespeist wird (z. B. in Form einer Empfangsspule), durch ein Echtzeit-Kontrollsignal gesteuert werden kann. Ein in diesem Zusammenhang geeigneter Normalzeitsender ist z. B. der Normalzeitsender DCF 77.

Die einzelnen FM/PM-Quarzoszillatoren werden nur mit geringem Hub moduliert, so daß die Abstände ihrer Mittenfrequenzen z. B. nur das Fünffache des maximalen Modulationshubes betragen können. Grundsätzlich kann die Zahl der FM/PM-Quarzoszillatoren **14.1** ... **14.m** — und insoweit die Zahl m der Meßstellen pro Gruppe — beliebig groß sein.

Der ortsfeste Einrichtungsteil gemäß **Fig.** 2 umfaßt u. a. eine Antenne **23**, einen nachfolgenden Bandpaßverstärker **24**, welcher nur das durch die Sendefrequenzen des Einrichtungsteils gemäß **Fig.** 1 belegte Frequenzband passieren läßt, eine Frequenzweiche **25** mit Ausgängen **26.1** ... **26.m**, sowie m an letztere angeschlossene Schmalbandempfänger **27.1** ... **27.m**. Die Ausgänge besagter m Empfänger sind an einen m-kanaligen Meßkanalumschalter **28** mit einem Ausgangsgruppenfächer von n, hier veranschaulicht mit n = 2, geführt, der Kanalausgänge **33.1** ... **34.m** speist.

Entsprechend dem Einrichtungsteil gemäß **Fig.** 1 steht der Meßkanalumschalter **28** über einen Steuerpfad **32** mit einer Echtzeitlogik **31** in Verbindung, die ebenfalls ein Frequenz bzw. Zeitnormal enthält und entsprechende Schaltbefehle insoweit echtzeitverkettet erzeugt und ausgibt, um damit die Schaltverbindungen zwischen den Ausgängen der m Schmalbandempfänger und den Meßkanalausgängen **33.1** ... **34.m** zu steuern. Auch das Zeitnormal der Echtzeitlogik **31** kann vorteilhafterweise von einem Normalzeitempfänger 30, welcher von einer Normalzeit-Empfangsantenne 29 gespeist wird (z. B. in Form einer Empfangsspule), durch ein Echtzeit-Kontrollsignal gesteuert werden.

Die Einrichtung funktioniert wie folgt.

Die beiden Logiken **19** und **29** geben an ihren Ausgängen zeitlich koinzidente, und insoweit zu jeder Zeit in eindeutiger Weise den Gruppen **10.1** ... **10.n** exakt zugeordnete Einstellbefehle an den Meßstellenumschalter **13** bzw. den Meßkanalumschalter **28** ab. Nach Maßgabe dieser Einstellbefehle werden die Umschalter **13** und **28** in zyklischer Weise synchron betätigt, und zwar unabhängig davon, ob Störungen welcher Art auch immer oder gar ein Abreißen der drahtlosen Datenübertragung zwischen Antennen **18** und **23** stattfindet. Diese Funktion ist bei Gleichlauf der Echtzeitlogiken **21** und **31** gewährleistet. Werden zur Erhöhung der Stabilität zusätzlich Normalzeitempfänger **20** und **30** vorgesehen, sind entsprechende separate Antennen **19** und **29** vorzugsweise so realisiert, daß sie im Fernfeld eines Normalzeitsenders bei jeder beliebigen Position einen ausreichenden Pegel an die die Empfänger **20** und **30** abgeben.

Eine selektive Störung, etwa aufgrund einer vorübergehenden frequenzselektiven Auslöschung oder aber einer Träger-Überdeckung durch ein externes Störsignal, stört insoweit nur vorübergehend einen oder allenfalls wenige nahe beieinander liegende Kanäle, während die Datenübertragung über die restlichen Kanäle ungestört bleibt. Da die Umschalter **13** und **28** echtzeitverkettet und insoweit synchron in einander entsprechende Schaltstellungen gesteuert werden, bleibt auch bei längerer vollständiger Unterbrechung der Übertragung — etwa wenn der fahrzeugseitige Sendeteil der Einrichtung vorübergehend außer Reichweite des ortsfesten Empfangsteils gerät — eine sende- und empfangseitig exakte Kanalzuordnung erhalten. Dies gilt insbesondere auch bei Kontrolle der Echtzeitlogiken **21** und **31** durch Normalzeitempfänger **20** bzw. **30**, da in der Regel Normalzeitsender innerhalb eines im Vergleich zur Übertragungsstrecke viel größeren Raumes gleichmäßig empfangen werden können.

Es gibt Anwendungsfälle, bei denen die vorerwähnte zyklische Kanalzuweisung in festem Raster stört, etwa wenn einem augenblicklich sich ändernden Meßwert in einem nicht vorhersehbaren Kanal eine erhöhte Bedeutung zukommt und deshalb eine augenblicklich zu erhöhende Meßgenauigkeit oder höhere Abtastrate im betreffenden Meßkanal erwünscht ist.

Eine Übertragungseinrichtung mit gemäß **Fig. 3** weitergebildetem fahrzeugseitigem Teil wird auch solchen Anforderungen gerecht.

Sie stützt sich auf einen Mikrocomputer **35** mit EPROM und RAM-Bereichen **38** bzw. **39** sowie auf einen Analog/Digital-Konverter **36** mit einer Vielzahl von Eingängen, an welche Meßstellen **11.1** bis **11.m** anschließbar sind. Es kann sich hierbei also auch um einen die vorgenannten Teile einstückig umfassenden Single-Chip-Mikro-Controller mit on-chip EPROM handeln.

Eine von einem Zeitnormal angetriebene Taktaufbereitungsstufe **21'** ist mit dem Mikrocomputer **35** verbunden und liefert an diesen ein echtzeitverkettetes Taktsignal. Der Speicher des Mikrocomputers **35** ist vorzugsweise in einen als Festwertspeicher fungierenden EPROM-Bereich **38** und einen als Arbeitsspeicher fungierenden RAM-Bereich **39** aufgeteilt. Außerdem ist ein bidirektional betreibbarer Ein-/Ausgangsport **37** vorgesehen. Wenigstens ein Ausgang ist mit einer auf eine Sendeantenne **42** wirkenden Sendeeinrichtung **40** verbunden, die aus einem vorzugsweise gemäß **Fig. 1** konfigurierten Mehrkanalsender **40.1** und einem Modulator **40.2** besteht. Sofern es sich um einen digitalen Modulator handelt, kann dieser z. B. ein schnell ladbares Schieberegister mit verschiedenen Oszillatoren zugeteilten Segmenten umfassen und/oder ebenfalls mit der Taktaufbereitungsstufe **21'** verbunden sein, wie durch gestrichelte Linien **45.1** und **45.2** angedeutet.

Des weiteren ist eine besondere Befehlsempfangseinrichtung **41** mit Antenne **43** vorgesehen. Sie besteht aus einem eigentlichen Empfänger **41.1** und einer Auswertstufe **41.2**, aus der der Mikrocomputer **35** über den Ein-/Ausgangsport **37** einen empfangenen Befehl abholen kann. Das Frequenznormal der Taktaufbereitungsstufe **21'** kann sinngemäß von einem Normalzeitempfänger **20**, dem von einer Empfangsantenne **19** hochfrequente Normalzeitsignale zugeführt werden, kontrolliert werden. Schließlich können noch Mittel oder Wege **44** vorgesehen sein, um am fahrzeugseitigen Teil der Einrichtung direkt, z. B. manuell, Befehle einzugeben bzw. ein laufendes Übertragungsprogramm zu verändern oder auszuwechseln.

Die so fortgebildete Einrichtung funktioniert insgesamt wie folgt.

Die an Meßstellen **11.1** ... **11.m** anstehenden Signale werden vom Mikrorechner nach Maßgabe wenigstens eines im EPROM **38** abgelegten Programms zyklisch eingelesen, digitalisiert, seriell gewandelt und entweder uni-seriell oder parallel-seriell an den Modulator **40.2** übertragen, je nachdem, wie der Modulator **40.2** beschaffen ist und wie viele Kanäle im Sinne von **Fig. 1** der Sender **40.1** aufweist.

Wesentlich ist, daß der Mikrorechner 35 auf drahtlose Anforderung seitens einer ortsfest kooperativen Empfangseinrichtung außer aktuellen Meßwerten auch wenigstens einen Verifikationsdatensatz zur Übertragung bringen kann, welcher z. B. die augenblickliche oder künftige Sequenz der Abfrage der Meßstellen **11.1** bis **11.m** und deren Bezug zur Normalzeit beschreibt.

Auf diese Weise kann im ortsfesten Einrichtungsteil jedem empfangenen Augenblickswert eindeutig der augenblicklich gültige Kanal zugeordnet werden. Hierfür kann der figürlich nicht dargestellte ortsfeste Teil der Einrichtung ebenfalls mit einem entsprechenden Mikrorechner ausgestattet sein, welcher von einem in gleicher Weise gewonnenen, normalzeitverketteten Taktsignal angetrieben wird.

Vermöge der Echtzeitverkettung können auch bei vorübergehend vollständiger Unterbrechung der Übertragung hernach wieder empfangbare Signale sofort und eindeutig den richtigen Kanälen zugeordnet werden, d. h., auch bei sehr geringem Signal-Rauschabstand.

Zur Reduktion der Übertragungsbandbreite zum ortsfesten Teil der Übertragungseinrichtung können im Mikrorechner **35** zusätzlich entweder Einzelmeßwerte miteinander verknüpft werden (etwa Drehzahl · Drehmoment = Leistung), oder es können Daten vorverarbeitet werden (z. B. Lastkollektive), oder es können laufend jeweils nur relevante oder kohärente Daten (z. B. nur Änderungen einer Meßgröße bzw. zusammengehörige Daten) übertragen werden. In welcher Art und Weise die Datenreduktion jeweils geschehen soll, bestimmen beispielsweise im EPROM **38** abgelegte Programm-Module. Auch die Übertragungsgeschwindigkeit des seriellen Datenstromes kann so aus dem EPROM software-gestützt den aktuellen Erfordernissen angepaßt werden.

Beispielsweise kann so bei der Verknüpfung zusammengehöriger Daten durch einen entsprechenden Funkbefehl seitens des ortsfesten Teils der Übertragungseinrichtung ein im RAM 39 abgewickelter Verknüpfungsalgorithmus verändert, aktualisiert bzw. ausgewechselt werden.

Über die Empfangseinrichtung **41** können vermittels eines kooperierenden Befehlssenders in einem als "Leitstation" wirkenden Teil der Einrichtung Befehle an den Mikrorechner **35** übertragen werden, etwa zur Auswahl geeigneter Programm-Module zur Datenreduktion, zur Anpassung der Übertragungsgeschwindigkeit, zur Änderung der Zahl bzw. Auswahl der Meßstellen, zur Umbelegung von Frequenzen, wenn der Sender **40.1** als Vielkanalsender gemäß **Fig.** 1 ausgelegt ist, oder zur Wiederholung einer Messung. Oder es kann während der Übertragung ein aus dem EPROM **38** geladenes Standard-Übertragungsprogramm modifiziert oder komplett ersetzt werden. Beispielsweise kann auch die Sequenz der Abfrage der Meßstellen verändert werden, wenn z. B. die Auswertung im ortsfesten Teil der Einrichtung ergibt, daß eine Erhöhung der Signalauflösung oder der Meßrate bezüglich eines speziellen Kanals wünschenswert ist.

Entsprechende Befehle können in der ortsfesten "Leitstation" entweder programmgesteuert generiert oder von Hand eingegeben werden. Es versteht sich von selbst, daß im Zuge einer solchen Anwendung die Empfangseinrichtung **41** und der Ein-/Ausgabeport **37** auch dazu mitbenutzt werden können, um Informationen an den Fahrer des entsprechenden Fahrzeugs kodiert zu übermitteln.

Patentansprüche

1. Einrichtung zur radiofrequent-drahtlosen Übertragung von Meßdaten von einem Fahrzeug, bestehend aus einem fahrzeugseitigen, sendenden Teil und einem ortsfesten, empfangenden Teil, wobei in beiden Teilen Mittel zur zeitgemultiplexten Zuordnung von Daten und Kanälen vorhanden sind, **dadurch gekennzeichnet,**
   — daß im fahrzeugseitigen und ortsfesten Teil Schalt- und Steuermittel zur Zuweisung von Datensignalen zu Kanälen (13, 21) bzw. von Kanälen zu Datensignalen (28, 31) vorhanden sind, die besagte Zuweisungen auch bei Unterbrechung der Übertragungsstrecke zwischen beiden Teilen im Gleichtakt aufrechterhalten, und daß besagte Schalt- und Steuermittel hierfür wenigstens ein autonomes Zeit- bzw. Frequenznormal (in 21, 31) beinhalten.

2. Einrichtung nach Anspruch 1, dadurch gekennzeichnet,
   — daß besagte Schalt- und Steuermittel je einen Normalzeitempfänger (20, 30) umfassen, welcher auf ein die logische Kanalzuweisung zeitlich beeinflussendes Element (21, 31; 21') im Sinne einer Steuerung oder Nachregelung einer Zeitgröße wirkt.

3. Einrichtung nach Anspruch 1, dadurch gekennzeichnet,
   — daß der fahrzeugseitige Teil eine Mehrzahl von modulierbaren Oszillatoren (14.1 ... 14.m) umfaßt, deren Signale einem Summiermittel (16) zuführbar und wenigstens mittelbar über eine gemeinsame Antenne (18) abstrahlbar sind und daß jedem der Oszillatoren als Modulationssignal jeweils nur das Signal eines Meßkanals zeitabschnittsweise zuführbar ist, und daß der ortsfeste Teil eine Frequenzweiche (25) und eine dieser nachgeschaltete Mehrzahl von schmalbandigen Empfängern (27.1 ... 27.m) umfaßt, deren demodulierte Ausgangssignale jeweils zeitabschnittsweise individuellen Meßkanalausgängen (33.1 ... 34.m) aufschaltbar sind.

4. Einrichtung nach Anspruch 1, dadurch gekennzeichnet,
   — daß der fahrzeugseitige Teil einen Mikrorechner (35) und einen Analog/Digitalwandler (36) mit einer Mehrzahl von Eingängen umfaßt, von letztwelchen jeder mit einem festen Meßkanal (11.1 ... 11.m) dauernd verbunden ist, daß sie ferner eine besondere Empfangseinrichtung (41) umfaßt, über welche wenigstens Befehlssignale vom orts-festen Teil empfangbar, auswertbar und über einen Ein-/Ausgabeport (37) an den Mikrorechner (35) übertragbar sind.

5. Einrichtung nach den Ansprüchen 3 und 4, dadurch gekennzeichnet,
   — daß die zur Modulation einer Mehrzahl von Oszillatoren vorgesehenen Mittel (40.2) im wesentlichen digitale sind.

6. Einrichtung nach Anspruch 5, dadurch gekennzeichnet,
   — daß besagten im wesentlichen digitale Mitteln (40.2) zur Modulation einer Mehrzahl von Oszillatoren außer digitalisierten Daten über wenigstens einen Pfad (45.1, 45.2) auch noch wenigstens ein echtzeitverkettetes Taktsignal vom Mikrorechner (35) oder von besagten Schalt- und Steuermitteln (21'; 21', 20, 19) zuführbar ist.

7. Einrichtung nach Anspruch 4, dadurch gekennzeichnet,
   — daß dem Mikrorechner (35) in einem Festwertspeicher (38) abgelegte Programm-Module zur Datenreduktion zugeordnet sind, welche durch besagte Befehlssignale in den RAM-Bereich (39) des Mikrorechners ladbar bzw. dort modifizierbar bzw. dort durch andere Programme überschreibbar sind.

8. Einrichtung nach Anspruch 4, dadurch gekennzeichnet,
   — daß im Mikrorechner (35) zur Verringerung radiofrequenten Signalbandbreite ein Programm abwickelbar ist für
   — eine Verknüpfung der Daten einzelner Kanäle miteinander, bevor die Modulation erfolgt, und/oder
   — eine Vorverarbeitung von Daten im fahrzeugseitigen Teil, und/oder
   — die Auswahl relevanter Daten für die Übertragung, und/oder
   — die Übertragung kohärenter Daten.

9. Einrichtung nach Anspruch 4, dadurch gekennzeichnet,
   — daß über die besondere Empfangseinrichtung (41) wenigstens einer der folgenden Befehle empfangbar und zu deren Ausführung an den Mikroprozessor (35) übertragbar ist:
   — Veränderung der Übertragungsgeschwindigkeit;
   — Veränderung der Zahl bzw. Auswahl von

Meßstellen;
– Veränderung der Abfragesequenz der Meßstellen;
– Umbelegung von Übertragungs-Trägerfrequenzen;
– Wiederholung wenigstens einer Messung;
– Abgabe einer Information an den Fahrzeugführer.

Hierzu 1 Seite(n) Zeichnungen

Nummer:
Int. Cl.^{5}:
Offenlegungstag:

DE 41 31 341 A1
G 08 C 15/00
26. November 1992

Fig. 1

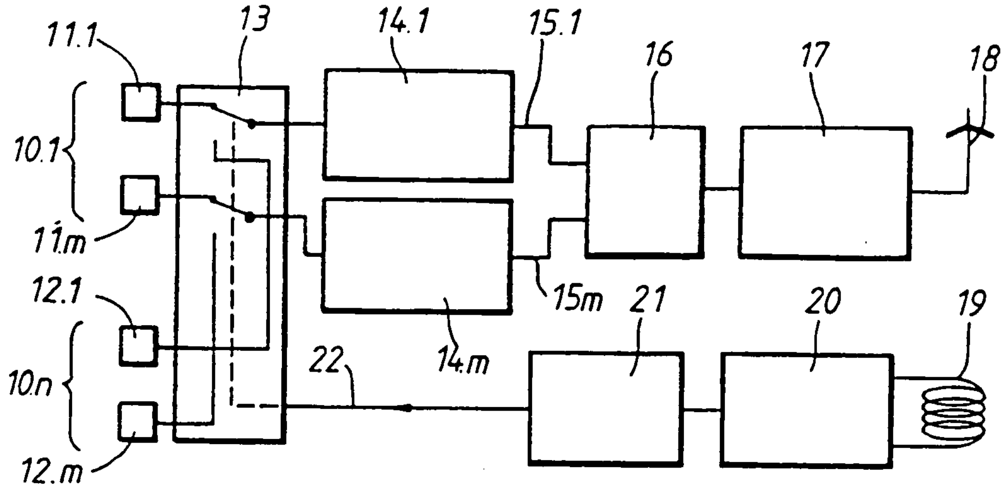


Fig. 2

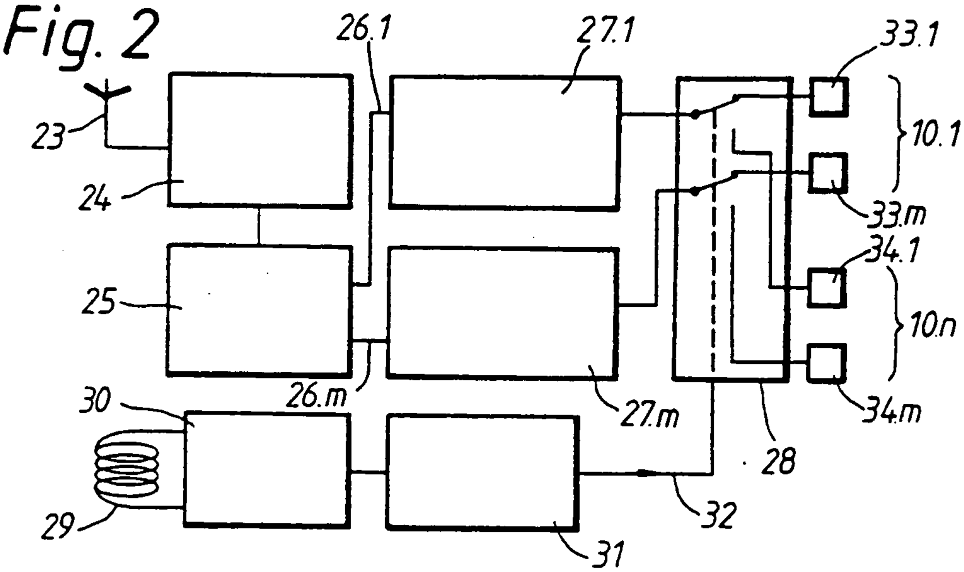
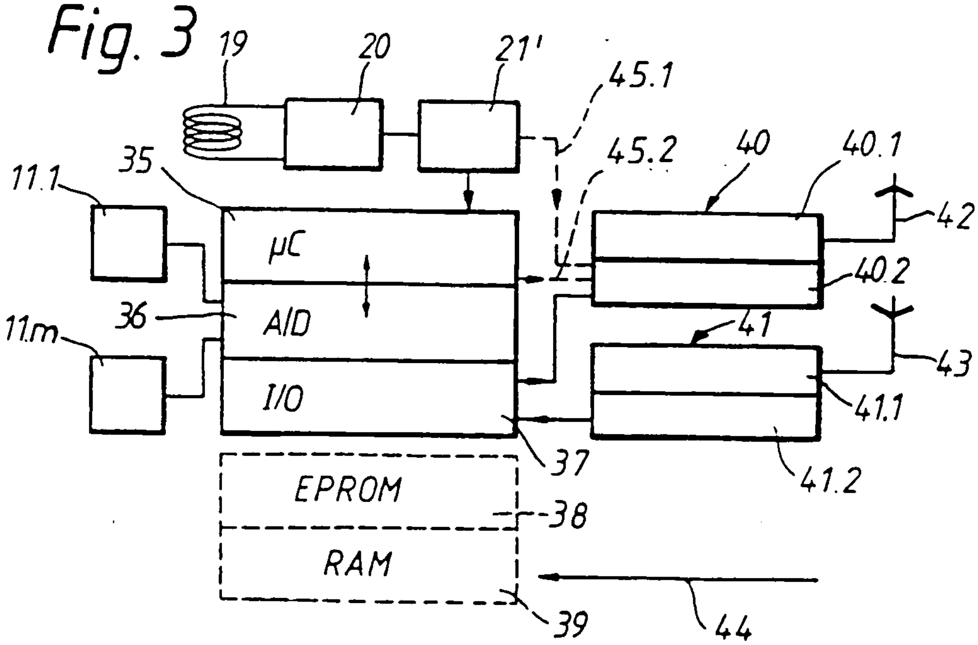


Fig. 3



See columns 1, 4 & 5.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 268 492 A2**

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 87310247.9

(51) Int. Cl.[4]: **G 08 C 15/04**

(22) Date of filing: 19.11.87

(30) Priority: 20.11.86 US 934238

(43) Date of publication of application: 25.05.88 Bulletin 88/21

(84) Designated Contracting States: BE CH ES FR GB IT LI

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(54) A common bus multimode sensor system.

(57) A multinode noise immune sensor system that transmits AC power and returning sensor signals from remote units through a coaxial cable. An isolation transformer and an integrated circuit type pin programmable bus interface are also used. A carrier is provided by a ripple counter producing a frequency divided signal compared to a fixed reference frequency, where the result of the comparison controls a voltage-controlled oscillator, which produces a signal which is applied to the coaxial cable. Receivers at the end of the coaxial cable are each tunable to a designated carrier frequency and each decode the respective encoded signal.

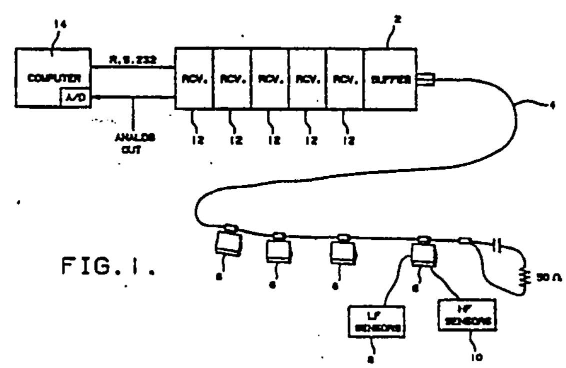

FIG. 1.

EP 0 268 492 A2

Description

A COMMON BUS MULTINODE SENSOR SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention is directed to a common bus multinode sensor system that allows multiple remote units to simultaneously transmit over the common bus using frequency division multiplexing and, more particularly, to a system that provides power to the remote units via the bus and allows low speed digital, low frequency analog signals and high frequency analog signals to be transmitted over the bus to receivers which demodulate the analog signals and decode the digital signals.

Description of the Related Art

Closed loop communication systems for facilities such factories and nuclear power plants require the capability of transmitting digital, low frequency analog and high frequency analog signals from a plurality of spaced apart points to a central location through an environment full of electromagnetic noise. Such systems typically require that the communication medium such as a twisted wire pair, coaxial cable or optical light guide be spread out through a very large complex requiring a media up to two kilometers in length. Prior art methods of providing such closed loop networks typically provide synchronous data transmission over a transmit channel and a receive channel. These systems poll each remote unit separately and, as a result, operate using a time division multiplexing scheme. The use of time division multiplexing does not allow plural sensors to be sampled simultaneously. The prior art systems also require power supplies at each remote unit producing ground loop problems as well as requiring that extra power wires be provided to the remote units.

SUMMARY OF THE INVENTION

The present invention provides a communications system that allows slow speed digital as well as low frequency and high frequency analog signals to be simultaneously transmitted for a plurality of sensors. Preferably, the communications system sends power remote units over a common bus, provides a remote unit that can interface plural types of sensors, provides separate communication channels for each remote unit, allows plural low speed analog signals to be multiplexed, provides a low cost remote unit that takes advantage of medium scale integration, allows asynchronous data collection, allows each remote unit to be flexibly assigned different channel frequencies for communication, and allows easy addition of remote units.

The invention in its broad form resides in a common bus multinode sensor system for at least one sensor to convey a sensor signal, comprising a power supply, a communication cable coupled to and carrying said power supply, remote sensor means, coupled between said cable, and said sensor, characterized by means providing a carrier and for frequency-division multiplexing the sensor signal onto said cable and receiving power from said cable; and receiver means, coupled to said cable, for demultiplexing the frequency division multiplexed sensor signal.

Described hereinafter is a multinode system that transmits power down a common bus coaxial cable typically using an alternating current power source. Each remote unit connected to the coaxial cable converts the alternating current power to direct current power for an integrated circuit bus interface. The interface is externally pin programmable to provide a carrier at a frequency for a channel assigned to the remote unit thereby providing each remote unit with an individual identity. When plural low frequency analog signals are to be transmitted over the common bus, an on-chip multiplexer multiplexes the signals to an off-chip, external analog-to-digital converter. The analog-to-digital converter loads an on-chip parallel-to-serial out-shift register that applies each bit of the digitized signal serially to an on-chip Manchester encoder. The encoder modifies the input voltage of an on-chip voltage-controlled oscillator operating at the carrier frequency. The modulated frequency oscillator signal is applied to the coaxial cable. Receivers at the end of the coaxial cable can be tuned to the designated carrier frequencies to demodulate and then decode the encoded signal at any time. If a high frequency analog signal is supplied, it is used to directly modify the voltage applied to the voltage-controlled oscillator; that is, the carrier frequency is modulated by the high frequency signal and the receiver operating at the carrier frequency demodulates the signal. The integrated circuit is arranged so that the digital circuitry is generally isolated from and on the opposite side of the chip from the analog circuitry so noise immunity is enhanced. The digital and analog circuitry have separate power supplies. The circuit is arranged in a carrier so that critical lead wire runs are held to a minimum.

BRIEF DESCRIPTION OF THE DRAWINGS

A more detailed understanding of the invention can be had from the following description of a preferred embodiment, given by way of example and to be studied in conjunction with the accompanying drawing, wherein

Figure 1 illustrates a multinode system in accordance with the present invention;

Figure 2 illustrates the components of one of the remote units 6 of Fig. 1;

Figure 3, including Figs. 3A and 3B, illustrates the ripple counter 32 and decoder 38 of Fig. 2;

Figure 4 illustrates one of the reset flip-flops of Fig. 3;

Figure 5 illustrates the details of the phase/frequency comparator 34 of Fig. 2;

Figure 6 illustrates the details of the oscillator 42 of Fig. 2;

Figure 7, including Figs. 7A and 7B, illustrates the details of the timing counters 40 of Fig. 2, including timing signal buffers;

Figure 8 illustrates one of the D flip-flops of Fig. 7;

Figure 9 illustrates one of the asynchronous set D flip-flops of Fig. 7;

Figure 10 depicts the details of the analog multiplexer 46 of Fig. 2;

Figure 11, including Figs. 11A and 11B, illustrates the details of the latch 50 and shift register 52 of Fig. 2;

Figure 12 illustrates the details of the single bit latches of Fig. 11;

Figure 13 depicts the dual input D flip-flop of Fig. 11;

Figure 14, including Figs. 14A and 14B, depicts the timing diagram for the integrated circuit 30, particularly illustrating the timing relationship to the external analog-to-digital converter 48 of Fig. 2;

Figure 15 illustrates the details of the Manchester encoder 54 of Fig. 2;

Figure 16, including Figs. 16A and 16B, illustrates the timing of the Manchester encoder 54 for example data;

Figure 17 illustrates the details of the loop filter amplifier 58 of Fig. 2;

Figure 18 illustrates the details of the voltage-controlled oscillator 36 of Fig. 2;

Figure 19 illustrates a typical level shift circuit which allows the inputs to the integrated circuit 30 of Fig. 2 to match the signal requirements of the circuit 30;

Figure 20 illustrates a composite mask of the integrated circuit 30 of the present invention;

Figure 21, including Figs. 21A and 21B, depicts the layout of the mask;

Figure 22 illustrates the components of the buffer 2 and receivers 12 of Fig. 1;

Figure 23 is a conceptual block diagram of the process performed by the microcomputer 660 of Fig. 22;

Figure 24, including Figs. 24A-24F, illustrates the process of Fig. 23 in greater detail;

Figure 25 illustrates the details of the frequency synthesizer update subroutine called from Fig. 24;

Figure 26 illustrates the details of the send subroutine called from Fig. 24;

Figure 27, including Figs. 27A and 27B, illustrates the functions performed by the interrupt routine of the microcomputer 660 of Fig. 22; and

Figure 28, including Figs. 28A-28C, illustrates the interrupt routine in greater detail.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention provides an improved sensor system that allows up to 128 remote sensor units to asynchronously and simultaneously transmit data over a common coaxial cable to a distantly located receiver and computer and receive power via the same cable. A buffer board 2, as illustrated in Fig. 1, preferably supplies alternating current power to a coaxial cable 4 which has remote units 6 attached thereto; however, the power supplied could be direct current. The cable can be a standard 1/4 or 1/2 inch 50 ohm cable. Each of the remote units 6 converts the alternating current power carried by the coaxial cable 4 to direct current to power an analog serial bus interface and other node components. The interface integrated circuit can sample low frequency sensors 8, encode the sensor signals and transmit same over the coaxial cable 4 on a designated frequency channel. Each remote unit 6 is assigned a different carrier frequency. The interface can also transmit signals from a high frequency sensor 10 over the cable 4 in the designated channel. The frequency division multiplexed signal produced by each remote sensor unit 6 is demodulated by an appropriate receiver 12 which can be tuned to the designated channel frequency. If the sensor signals have been encoded, the respective receiver 12 also decodes the sensor signals and supplies same to the computer 14. The computer 14 would normally be a sophisticated, high speed process control-type machine; however, a simple IBM PC is acceptable. If the high frequency sensor signal is transmitted by the remote unit 6, the respective receiver 12 produces same as analog output signal.

As illustrated in Fig. 2, a common transformer 26 couples the alternating current, at, for example, 28 volts and 60 Hz, to a power supply 28 which converts the alternating current into positive and negative direct current supplied to an analog serial bus interface integrated circuit 30. The transformer 26 also provides isolation preventing the failure of a single node from knocking out the entire system. The power supply is a common power supply which will convert a 60-cycle, 28-volt signal into plus 5 volt, minus 5 volt and ground direct current sources and supply at least 100 milliwatts, the minimum necessary for the interface 30, but preferably at least one watt so that other circuits and sensors can be adequately powered. It is also possible to construct a simple power supply from two diodes, two capacitors and three terminal regulators available from National Semiconductor as described in the National Semiconductor Linear Databook, 1982, in the application hints on pages 1-20.

The interface 30 includes a ripple counter 32 which receives a multibit frequency designation word from programming pins external to the chip 30. The multibit frequency designation word designates the carrier frequency assigned to the particular remote unit 6. The ripple counter 32 is reloaded with the frequency selection word from the external pins each time the decoder 38 detects a count of zero. The phase/frequency comparator 34 compares the ripple counter carry-out signal to a reference frequency of approximately 44.7 kilohertz from timing counters 40. The timing counters 40 also produce timing signals for other devices on the chip 30. The timing counters 40 are driven by an oscillator 42 connected to an external oscillator crystal 44 such as a TV crystal which oscillates at approximately 3.5 megahertz. The ripple counter 32, decoder 38, phase/frequency comparator 34, voltage-controlled oscillator 36, timing counters 40 and oscillator 42 create a programmable frequency synthesizer that operates off of a crystal reference such as the TV crystal.

The timing counters 40 also control the multiplexing of low frequency analog sensors 22 by an analog multiplexer 46. The analog multiplexer 46 provides the analog signals from one of the sensors 22 to an external analog-to-digital converter 48 available from G.E. Intersil as a 7109 converter. the sample rate of the converter 48 is controlled by a timing signal from the timing counters 40. When the analog-to-digital converter 48 has converted the selected analog signal, the digital value thereof is stored in latch 50. When the prior contents of shift register 52 have been shifted out, the contents of latch 50, as well as a two-bit address from the analog multiplexer 46, are loaded in parallel into the shift register 52. The two-bit address from the multiplexer 46 indicates which of the four analog signals is currently being sampled. The shift register 52 then serially outputs its contents to a Manchester encoder 54. The Manchester encoder 54 modifies the voltage produced by a filter 56 applied to the voltage-controlled oscillator 36. The chip 30 also includes a loop filter amplifier 58, is used for filtering out high frequency components.

During operation, the phase/frequency comparator 34 drives the voltage produced by the filter 56 upward whenever the voltage-controlled oscillator 36 is producing a frequency lower than the carrier frequency and drives the voltage downward whenever the voltage-controlled oscillator frequency is higher than the carrier frequency, and tends to track the carrier frequency designated by the inputs to the ripple counter 32. As a result, the Manchester encoder 54 is frequency shift keying the signal produced by the volage-controlled oscillator 36 by raising or lowering the voltage produced by the filter 56 in dependence upon the signal output by the Manchester encoder 54. The output of the voltage-controlled oscillator 36 is coupled to the coaxial cable 4 through a transformer 60. The transformer should be a high frequency transformer capable of operating in the 6 to 12 megahertz frequency range. Such a transformer can be constructed by winding several turns of wire around a ferrite core and providing an isolation resistor of 5k ohms.

As can be seen from the above discussion, the interface chip 30 encodes the analog signals and modulates a carrier frequency therewith. As a result, it is possible for the chip 30 to sample and transmit the values for four low frequency analog sensors 22. If a high frequency analog input signal, such as a signal from a piezosensor (up to 20 kHz with a dynamic range of 70 dB), is to be transmitted, the high frequency signal directly modulates the voltage produced by filter 56 so that the output of the voltage-controlled oscillator 36 is a carrier frequency modulated by the high frequency analog input signal. When a signal with a frequency higher than 20 kHz is being transmitted, it will occupy more than a single channel of bandwidth; as a result, it is necessary to leave adjacent channels empty.

It is also possible for the chip 30 to interface the values from digital sensors by substituting the outputs of the digital sensors for the input signals from the analog-to-digital converter 48. In this manner, at least 13 binary sensors can be sampled every 133 milliseconds. Thus, the interface chip 30 of Fig. 2 is capable of operating in at least four different modes: (1) low frequency analog; (2) high frequency analog; (3) digital data from one or more digital sensors; and, (4) digital data from the external A/D 48.

The ripple counter 32, as illustrated in Figs. 3A and 3B, is driven with a clock signal from the voltage-controlled oscillator 36. The clock signal passes through three buffers 62-66 (Fig. 3A) where the lettering next to each buffer (2X) indicates the sizing of the transistors in the buffer. The ripple counter 32 down-counts the contents thereof where each set/reset flip-flop is clocked by the output from the previous stage. As the counter 32 is down-counted, the output from the last stage flip-flop 82 (Fig. 3B) is applied to the phase/frequency comparator 34. When the content of the counter 32 equals zero, all of the carryout (CO) lines are at a 0 logic level, resulting in the outputs of the NOR gates 84-90, which are part of decoder 38 producing a logic 1 level. When all of the inputs of NAND gate 92 (Fig. 3B) of the decoder 38 are high, set/reset flip-flop 94 produces a load signal at the next clock signal which loads counter flip-flops 68-82 with the frequency selection count supplied from the external chip pins through inverters 130-160 and NAND gates 98-128.

Figure 4 illustrates the details of construction of each of the set/reset flip-flops 68-82 of Fig. 3. A T-switch 170 (transmission switch) supplies a NAND gate 172 with the D input. The gate 172 also receives the reset signal and a signal from switch 174. The switches 170 and 174 are activated with the clock signal. The gate 172 outputs to both switch 178 and gate 176. The set input is connected to gate 176 and gate 182. Gate 182 receives an input from either switch 178 or gate 182. Gate 182 produces an output through buffers 186 and 188 and supplies a signal to gate 184. Gate 184 also receives the reset input.

The output from the counter 32 is applied to the phase/frequency comparator 34 of Fig. 5, along with a reference signal from the timing counter 40. The compared signals are applied to the clock inputs of the set/reset flip-flops 208 and 210 through signal buffers 200-206. When the flip-flops are being clocked at a constant ratio with respect to each other, the NAND 212 resets each flip-flop at the same ratio. When the outputs of the flip-flops are being clocked at the same ratio, the transistors 214 and 216, on the average, produce a constant voltage level at the junction therebetween. Whenever one flip-flop is being clocked at a changing frequency as compared to the other flip-flop, the average voltage produced by transistors 214 and 216 changes. Whenever the counter signal is slowing down, as compared to the reference signal, the output voltage produced by the phase/frequency comparator 34 rises. The rise in the output voltage, after a delay, causes the output voltage produced by the filter 56 to rise, thereby causing the voltage-controlled oscillator 36 to move to a higher frequency. Whenever the ratio is falling, that is, the decoder signal is rising in frequency with respect to the reference signal, the voltage produced by the frequency phase/comparator 34 falls, thereby slowing the voltage-controlled oscillator 36.

The oscillator 42 of Fig. 6 is connected to the oscillator crystal 44 which is off the chip 30 and which can be a TV crystal available from CTI as Model PTI1633. The crystal signal is supplied through buffers 220-228 to the input of the timing counters 40. In addition, the output of the oscillator 42 is supplied external to the chip 30 through a buffer 230 and transistor 232 and 234. The numbers adjacent to transistors 232 and 234 indicate the sizing of the transistors necessary to produce an acceptable output that can be monitored by external circuits.

The timing counters 40 include synchronous D flip-flops 240-268 and asynchronous set D flip-flops to 270-278, as illustrated in Figs. 7A and 7B. The flip-flops have buffers and NAND gates 272-290 connected thereto which provide appropriate signal levels and set the division rate for each stage. The first stage (Fig. 7A), including flip-flops 240-246, is a divide-by-sixteen stage; the second stage, including flip-flops 248-252, is a divide-by-five stage; the third stage, including flip-flops 254-258, is a divide-by-six stage; the fourth stage, including flip-flops 270-278, is a divide-by-thirty-one stage; and the last five stages (Fig. 7B), including flip-flops 260-268, are each divided by two stages. The outputs of the last four stages are applied to NAND gates 292-298 to produce the clock signals for the circuits as indicated. (See also the timing diagram of Fig. 14.) The outputs produced by the NAND gates 292-298, as well as the flip-flops, are buffered by buffers 300-324, so that appropriate signal driving levels can be provided. In addition, the outputs of the high byte enable 294 and low byte enable 292 gates are provided through buffers 326 and 328 and transistors 330-336 to the external pins of the chip 30.

Figure 8 illustrates the construction of the D flip-flops 240-268. The D flip-flops each include a T-switch 340 receiving the D input. The switch 340 supplies buffer 342 which is also supplied by switch 346. The output of buffer 342 is applied to buffer 348 and switch 350. The output of switch 350 is supplied to output switch 354 which is fed back through buffer 356 to switch 352.

Figure 9 illustrates the construction of the asynchronous set D flip-flops 270-278. The asynchronous set D flip-flops each have a construction very similar to the flip-flop of Fig. 8. T-switch 360 receives the D-input and supplies buffer 362 which is also fed by switch 364 via NAND gate 366. The gate 366 receives the set input which is also applied to gate 372. Gate 372 receives another input from switch 368 and produces an output that is fed back through buffer 374 and switch 370.

One of the outputs from the timing counters 40 is provided to the 4 to 1 analog multiplexer 46 illustrated in Fig. 10. The timing signal provided to the multiplexer 46 is oscillating at a frequency of 7.517 Hz, producing windows approximately 133 ms wide, resulting in a complete cycle every 532.1 ms for four conversions. The timing counter signal is applied to D flip-flops 380 and 382 which control NAND gates 384-390. The gates 384-390 produce switching signals which control T-switches 392-398 through buffers 400-414. The multiplexer 46 also provides an address to the shift register 52 which indicates which analog input is currently being output. One bit of the address is produced by exclusive OR gate 416 while the other bit is produced by flip-flop 382. That is, the grey code of the multiplexer is converter to a two-bit binary address output. The address signals are buffered by buffers 418-424 which indicate appropriate sizing. The address supplied to shift register 52 is also supplied as an output of the chip 30 through transistors 426-432. If one of the inputs to the analog multiplexer 46 is connected to ground and/or to a predetermined voltage, the system can provide automatic calibration.

When the A/D converter 48 has converted a single analog input sample, the sample is loaded into the latches 440-464 illustrated in Figs. 11A and 11B one byte at a time. That is, the timing counter 40 provides a low byte enable signal to latches 440-454 which loads the low byte of the sample and a high byte enable signal which subsequently loads the upper five bits of the conversion into latches 456-464. When the latches 456-464 have been loaded, register load signals from the timing counters 40 load the contents of the latches 440-464, as well as the address bits from the multiplexer 46, into dual input D flip-flops 466-500. Once the flip-flops 466-500 are loaded, a clock signal, at a frequency of 120.28 Hz, from the timing counters 40 clocks the contents of the flip-flops 466-500 serially to the Manchester encoder 54.

The details of construction of each of the single bit latches 440-464 of Fig. 11 are illustrated in Fig. 12. Each single bit latch includes a T-switch 510 receiving the input and supplying same to a buffer 514. The output of buffer 514 is fed back through buffer 516 and switch 512.

The details of construction of each of the dual input D flip-flops 466-500 of Fig. 11 are illustrated in Fig. 13. The dual input flip-flops receive one input through a T-switch 520 and the other input through switch 522. Both switches 520 and 522 supply switch 524. The output of switch 524 is applied to switch 528 and fed back through buffer 530 and switch 526. The outputs are produced by switch 532 through buffers 536 and 538. Switch 534 feeds back the inverted output.

The timing associated with the sampling by the analog-to-digital converter 48, loading of the sample into the latches 440-464, transfer from the latches 440-464 to the shift register flip-flops 466-500, and the clocking of the samples serially to the encoder 54 is illustrated in Fig. 14. The top waveform indicates the clocking of the bits from the shift register 52 into the encoder 54 where the number within the waveform indicates the particular data bit being clocked. After the high byte and low bytes have been enabled (Fig. 14A), the digital-to-analog converter 48 begins an integration period followed by a deintegration period (Fig. 14B). During the deintegration period, the shift register 52 is loaded with the previous sample stored by the latch 50. This load enable corresponds to a dead period in the serial transmission of the shift register bits to the encoder 54. Near the end of the deintegration period, a valid data period starts during which the high and low bytes from the converter 48 are stored in the latch 50. Before a new integration cycle occurs, a delay is seen at the A/D converter 48 when using the RUN/HOLD as the clock. The delay period is approximately 113 microseconds after the low byte is latched and the multiplexer 46 is clocked.

The serial bits from the shift register 52 are applied to an exclusive OR gate 550 in the Manchester encoder 54, illustrated in Fig. 15. The other input of the gate 550 receives a 120 hertz timing signal from timing counters 40. the output of gate 550 is applied to a D flip-flop 552, the construction of which is illustrated in Fig. 8. The clock signals for D flip-flop 552 and D flip-flop 554 are supplied from the timing counters 40 through buffers 556 and 558 at 240 Hz. The output of flip-flop 552 is applied to an output line through buffers 560 and 562 and T-switch 564. The output of flip-flop 554 is applied through buffers 566 and 568 controls the switch 570 is applied to and one control input of T-switch 564.

Figure 16 illustrates the timing diagram for the Manchester encoder 54. As can be seen from the timing diagram, the Manchester encoder 54 produces a signal that is on the average, zero volts. Such a signal is very important when a carrier frequency is being modulated and controlled by a voltage-controlled oscillator. The use of the Manchester encoder 54 ensures that, on the average, the encoded signal produces the carrier frequency.

Figure 17 illustrates the loop filter amplifier 58 where, once again, the sizing of the transistors 580 and 582 is illustrated by the sizing numbers adjacent thereto.

The filter 56 can be ordinary 3 pole, or if higher accuracy is required, a 5-pole filter which will produce a time constant of approximately 40 seconds allowing the voltage-controlled oscillator 36 to receive a very steady input signal. One of ordinary skill in the art can provide an appropriate filter by reviewing. a filters designs book on phase-locked loops such as the Phase Locked Loop chapter of the Motorola MECL Data Book, 1982.

The voltage-controlled oscillator 36 is a standard ring-type oscillator, as illustrated in Fig. 18. The ring-type oscillator consists of cascade-connected P (592 and 594) and N (590) transistors producing eleven inverter stages where the output of the transistor in the final stage is connected back to drive the input of the first stage. The output of the ring oscillator is buffered by buffers 596-602 to increase its signal level before being applied to the transformer 60 of the coaxial cable 4. The buffers, once again, indicate transistor sizing. An auxiliary output is provided through buffer 604 which is connected to an external pin of chip 30 for connection to the ripple counter 32. the voltage-controlled oscillator 36 produces greater than 60 dB signal-to-noise. Each channel is 44.7 kHz wide, allowing 128 channels within one octave and thereby eliminating harmonic distortion considerations. The voltage-controlled oscillator 36 is not hard-wired back to the ripple counter 32 so that an external voltage-controlled oscillator can be used, if desired.

To allow the present invention to interface conveniently with other devices which use zero to five volts while still maintaining plus five to minus five-volt logic within the chip, level shift circuits are provided between each input pin and the internal chip circuits and between the internal chip circuit and each output pin. An example of a level shift circuit is illustrated in Fig. 19 where, once again, the appropriate transistor sizings are indicated. Each level shift circuit includes transistors 610-624 and buffer 626.

Figures 20 and 21, including 21A and 21B, illustrate the mask and layout, respectively, of the integrated circuit analog serial bus interface chip 30, where Fig. 20 illustrates the mask layout and Fig. 21 illustrates the relationship between the various circuits and between the circuits and the exterior chip connections. As can be seen in Figs. 21A and 21B, the ripple counter 32 is located (Fig. 21A) in the upper left-hand corner associated with side IV and with the phase locked loop bonding tabs which set the frequency of the frequency synthesizer. Below the ripple counter 32 is the decoder 38 (Fig. 21B) followed by the phase/frequency comparator 34. The voltage-controlled oscillator 36 is generally located in the lower left-hand corner and is surrounded by power supply lines, as illustrated in Fig. 20, so that the analog output signal produced by the voltage-controlled oscillator 36 will be relatively free of the noise generated by the digital circuitry on the chip. This physical isolation is also provided to loop filter 58 which is below the voltage-controlled oscillator 36. The voltage-controlled oscillator 36 and amplifier 58 are powered by analog power supply bonding tabs located along the bottom side (side III) of the chip while the digital circuitry has its own power supply tabs located on sides II and IV. The separation of the power supply bonding tabs reduces noise coupled to the network.

In the center of the chip, running vertically, are the timing counters 40. The timing counters 40 are located centrally because they must provide timing signals throughout the chip. The central location minimizes the length of high and low frequency signal runs within the chip. In the center of the timing counters 52 is a 10 kHz line running from one count stage at the bottom to a count stage at the top. The 10 kHz signal line is shielded on both sides by power supply lines. The oscillator 42 driving the chip is located above the timing counters 40.

The latch 50 is located between the folded shift registers 52 so that each shift register will receive its data from the closest latch. The two bits of the shift register 52 which receive the address from the analog multiplexer 46 (Fig. 21B) are located adjacent to the multiplexer 46. The output of the shift register 52 is buffered through buffers 630 and coupled to the Manchester encoder 54 located next to the end of the register 52 where the serial bits emerge. The analog multiplexer 46 is located in the bottom right corner of the chip. The location in the corner allows the inputs to enter and the output to exit the chip without the need for signal crossover lines; this arrangement reduces noise coupled from the chip 30. ON the right side of the chip are level shift circuits 632 which match the input signals from the analog-to-digital converter 48 with the signal level of the chip 30.

As can be seen from the pin layout in Figs. 21A and 21B, all digital signals are generally on the upper half of the chip while all analog signals are on the lower half-of the chip. This arrangement, once again, isolates noise sensitive analog signal lines from the noise creating digital signal input lines. The high frequency inputs for the oscillator crystal 44 are located at the top (side I) as far from the channel signal (output #2, side III) produced by the voltage-controlled oscillator 31. The lead tabs each have notches which divide each tab into two portions. Each portion is large enough to accept a lead, so that if a bonding error occurs the bonder can try again. The chip is oriented in its chip carrier with sides I and III toward the narrow side of the carrier to minimize the length of the analog signal lines, thereby increasing noise immunity.

The chip 30 is created using a standard CMOS process, the details of which are available from a plurality of sources, including:

Modern MOS Technology
Dewitt G. Ong, McGraw Hill, 1984.

The Physics of Semiconductor Devices
D. M. Sze, Wiley & Sons, 1984.

Microelectronics-Processing & Device Design
Roy A. Colclaser, Wiley & Sons, 1980.

VLSI Technology
S. M. Sze, McGraw-Hill, 1983.

Integrated Circuit Fabrication Technology
David J. Elliot, McGraw-Hill, 1982.

One of ordinary skill in the art can create a chip with a layout, as illustrated in Fig. 21 from the teachings of the above-listed books incorporated by reference herein.

As mentioned previously with respect to Fig. 1, the coaxial cable 4 is typically supplied with 60-cycle, 28-volt alternating current from a power supply in buffer 2, as illustrated in Fig. 22. A transformer 640 converts the 120-volt, 60-cycle signal into the signal which is coupled to the coaxial cable 4 through inductors 642 and 644 of 51 pico henrys each. The returning frequency division multiplexed signal from the remote units 6 is coupled through a capacitor 646 and an ordinary radio frequency transformer 648. The signal is then passed through a six to twelve megahertz bandpass filter 650 after which is it amplified by an amplifier unit 652 which comprises series coupled HA-2540 and HA-5002 amplifiers available from Harris. The buffer board also includes a crystal oscillator 654 which is tuned to a reference of 3.579 MHz and a divide-by-10 circuit which divides the reference frequency by a factor of 10.

Each receiver 6, as illustrated in Fig. 22, includes a microcomputer 660 which controls a frequency synthesizer 662 to synthesize the carrier frequency of the remote unit to which the receiver corresponds. The frequency synthesizer 662 includes a programmable frequency divider which converts the crystal oscillator signal to the appropriate carrier frequency. The frequency synthesizer 662 includes a frequency synthesizer Model MC145156 from Motorola, a divider Model MC3393 from Motorola and voltage-controlled oscillator Model C1648 from Motorola and a filter which is a 40 megahertz standard design lowpass filter designed to remove high frequency noise from the synthesized carrier signal. The synthesized carrier signal is mixed in mixer 664, such as an SL6440 From Plessey, with the modulated carriers for the various receivers provided by amplifier 652. The mixed signal is provided to a crystal filter 666 operating at a frequency of 21.4 megahertz. The crystal filter 666 selects only the channel of interest and attenuates all others. The output from the crystal filter 666 is applied to an FM detector 668 such as a CA3089 available from RCA. The FM detector demodulates and removes the carrier leaving either. the Manchester encoded signal or the high/low frequency analog signal transmitted by the respective remote unit 6.

If an analog signal is being transmitted by the remote unit 6, the demodulated signal is passed through a programmable attenuator 670, made with a resistor network and an analog multiplexer, such as an MC14052. The gain controlled analog signal is then applied to an amplifier 672, such as an LM 386-4 available from National Semiconductor, before the signal is output. If the Manchester encoded signal is the signal transmitted by the corresponding remote unit 6, comparators 674, such as an LM139 available from National Semiconductor, are used to determine the state of the transmitted signal and provide same to microcomputer 660. The microcomputer is preferably an 8731, available from Intel with appropriate ROM memory for storing a control program.

Figure 23 illustrates conceptually the operation of the microcomputer 660 of Fig. 22. The routine of Fig. 23 monitors a communication link to the computer 14 for commands therefrom and is interrupted by an interrupt timer to perform detection of encoded bits transmitted to the receiver 12 from the associated remote unit 6. The interrupt routine is discussed, in general, with respect to Fig. 27 and, in more detail, with respect to Fig. 28. After a power-on reset occurs 700 and the microcomputer 660 is initialized 702, the microcomputer 660 retrieves 704 the receiver frequency from the bus to computer 14 and loads 706 the frequency synthesizer 662 with the appropriate frequency designation word. Next, the processor 660 sets 708 the interrupt timer to 200 microseconds. That is, at the end of 200 microseconds the processor will examine the comparators 674 to determine whether a start bit has been received from the Manchester encoder 54 of the respective remote unit 6. The microcomputer 660 then enters into a loop wherein the bus from computer 14 is periodically examined to determine if a command has been received from the computer 14. The commands include tasks associated with updating 712 the synthesizer frequency, sending 714 the last encoded word, sending 716 the last four encoded words, sending 718 the last sixteen encoded words, sending 720 the current frequency and sending 722 a self-test.

At the beginning of the control routine, as illustrated in Fig. 24A during the power on reset function, the address for the input from the computer 14 bus is stored 730, after which the count register (TCON), interrupt enable register (IE), interrupt priority register (IP), serial count register (SCON) and program status word register (PSW) are initialized 732. Next, the microcomputer 660 begins monitoring the bus to computer 14 to determine whether a frequency word for this particular microcomputer (receiver) has been received. The first step is to examine 734 the receive interrupt flag to determine whether it has been set, indicating that the frequency word has been received. If the receive/interrupt flag has been set, then the microcomputer 660 examines 736 the most significant bit to determine whether it is a 1. If it is not a 1, the receive interrupt flag is set 738 to 0 and the microcomputer 660 continues examining words. If the most significant bit is a 1, then the microcomputer determines 740 whether the word is addressed to itself and then determines 742 whether the word is a frequency designation word. If it is a frequency designation word, the receive interrupt flag is set 744 to 0 followed by a check 746 to determine whether there has been another receive interrupt. If an interrupt has not occurred, then the most significant bit of a valid frequency (0-127) must always be zero. This serves as an additional check to make sure that the data is valid before the synthesizer is loaded. Once the microcomputer 660 has determined that the received word is the frequency designation word, the frequency is stored in the buffer for the frequency synthesizer. P3.5 and P3.6 (Fig. 24B) are microcomputer 660 output lines used to load data serially into the synthesizer 662. Next, the synthesizer update routine is called 752. This routine loads the designated frequency into the frequency synthesizer 662 and will be discussed in more detail with respect to Fig. 25. Once the frequency has been set, various flags and counters are set 754, after which the interrupt timer is set 756 to 200 microseconds. Next, the interrupt enable flag is set and the timer count register is started 758.

The loop depicted in Fig. 23 is illustrated in more detail in Figs. 24C and 24F. The program enters into a loop during which the receive interrupt flag is checked 760 (Fig. 24C) to determine whether a word has been received. If a word has been received, the interrupt flag is set 762 to 0 zero followed by a determination 764 as to whether the word is addressed to this receiver. If the word is addressed to this receiver, a check 766 is made to determine whether the most significant bit is 1. If the most significant bit is 1, the flag which indicates that a communication has been received is set 768 to 0. Next, a check 770 is made to determine whether the word is a frequency update command; and if so, the receiver enters a loop in which the receive interrupt flag is checked 772 until a word has been received. The receive interrupt flag is then set 774 to 0, after which the most significant bit is examined 776 (Fig. 24D) to determine whether it is 0. If so, it indicates that a correct frequency specification word has been received and the frequency is loaded 778 into the frequency synthesizer variable. The interrupt timer is then disabled 780 and the counter is disabled 782. Next, the synthesizer update subroutine is called 784 to update the frequency produced by the synthesizer 662. After the frequency update, the appropriate pointers and flags are updated 786 followed by the setting 788 of the interrupt timer to 200 microseconds. Once the interrupt timer has been set, the timer is enabled 790 and the timer count register is also enabled 792.

If the word received was not a frequency update word, then the processor determines 794 (Fig. 24E) whether a valid request has been received and, if so, executes the appropriate function. If an invalid request has been received 796, the bad word is just ignored.

If a command for sending words is detected, an array counter is set 798-802 to the appropriate value. The starting address (X) of the word of words to be transmitted is then stored 802 and the process enters a loop (Fig. 24F) during which the word of words are transmitted. During this loop, the send subroutine is called 812 and will be discussed in more detail with respect to Fig. 26.

If one of the other commands has been detected, the appropriate word is loaded 816 (Fig. 24F) and 818 into the transmit buffer or the appropriate self-test flag is set 820 to 0. If the transmission of the frequency or self-test is required, the program status word bit for enabling the bus is set 822 to 0 after which the call subroutine is executed 824. When the last word has been transmitted, the transmit interrupt flag will be set to 1 and the receiving communication flag will be set 828 to 1. Next, the program status word bit is updated 830 to set the bus connection between the microcomputer 660 and the common bus to a high impedance state. The bus connection between the computer 34 and microcomputer 660 is a tristate bus in which the bus connection can be set to a high impedance state whenever the microcomputer 660 is not accessing the bus.

Figure 25 illustrates the details of the subroutine which loads the frequency synthesizer 662 with the appropriate frequency designation word. First, the gain bits for the synthesizer are set 842 followed by the setting 844 of the indicated bits. P3.7 is the data output and P3.6 is the frequency synthesizer 662 clock. Step 844 clocks a 0 into the most significant bit of the synthesizer 662. Next, the bit pattern for the designated output frequency is retrieved 846 from a look-up table which includes 128 words where each word corresponds to the frequency of a possible channel to be received by the receiver 6. The look-up table, which correlates frequency or channel number with synthesizer bit pattern, can be created by one of ordinary skill in the art. Next, the microcomputer 660 enters a loop. During this loop using P3.7 as the output port and P3.6 as the clock, the loop shifts 858 the data to the left and by comparing 850 the word to 32767, determines if the next data bit to the synthesizer should be a 1 or 0. That is, if the word is greater than the constant, the output bit is set 854 to 1; otherwise, it is set 851 to 0. When the appropriate frequency is loaded, the microcomputer 660 latches 862 the new frequency by toggling the appropriate bit of the program status word. The processor then waits 80 milliseconds to allow the synthesizer to switch to the new frequency before returning 866.

Figure 26 depicts the details of the send subroutine in which the transmit interrupt flag is checked 872 to determine whether it is a 1 indicating that the bus is not occupied. If the bus is not occupied, the transmit interrupt flag is set to 0, indicating that the bus is occupied and the contents of the buffer are loaded into the transmitter. The contents of the variable XMIT is loaded into a buffer named SBUF and the buffer proceeds to shift out the word. Once the contents of the buffer are transmitted, the routine returns 878.

The interrupt routine, illustrated conceptually in Figs. 27A and 27B, begins by determining 892 (Fig. 27B) whether the start bit flag is set. If the flag is set, a determination is made 894 (Fig. 27A) concerning whether the bit being detected is the start bit. The start bit is detected by one of the comparators 674 outputting a signal indicating the input signal is high and the other of the comparators indicating that the input signal is low. That is, the start signal is between the high and low values, as depicted in Fig. 16A. If the start bit is being detected, the width counter is incremented 896 followed by the setting 898 of the interrupt timer to 200 microseconds, an interval that allows an accurate determination of the width and end of the start bit. That is, while the start bit is being detected, the width of the start bit is being measured by the interrupts. If the start bit is not being detected, determination is made 900 as to whether the start bit has a zero width. If so, the interrupt timer is set 898 to 200 microseconds and the microcomputer will continue to look for a start bit of non-zero width. If the start bit has a non-zero width, a determination is made 902 whether the start bit is of the correct width. If the correct width has not yet been detected, the the timer is once against set to 200 microseconds and another interrupt is awaited. If the start bit is of the correct width, the start bit flag is reset 904 and the timer between interrupts is set 906 to a longer period of 2.6 milliseconds. The 2.6 millisecond interval should cause an interrupt in the middle of the first data bit. A start bit is preferably 8.31 milliseconds wide and each data bit is 8.31 milliseconds wide.

If the start bit flag is not set and an interrupt has occurred, the microcomputer shifts 908 (Fig. 27B) in the data bit. The value of a data bit can be determined by examining the output produced by only one of the comparators. The microcomputer 660 then determines 910 whether this is the last bit of the word, and if not, sets the interrupt timer to the interval between data bits (8.31 milliseconds). If the bit is the last bit of the word, then the word is stored 914 and the start bit flag is set 916, followed by the setting of the timer for the deadband interval between the end of the last bit and the beginning of the start bit of the next encoded word.

Figs. 28A and 28B illustrate the interrupt routine of Fig. 27 in greater detail whereby the flags, status bits, etc., are examined. First, the register bank pointer to the bank, which is used for storing the incoming word, is set 930 (Fig. 28A) to 1, followed by disabling 932 of the timer counter register. Then the start bit flag, as previously discussed, is examined 934, followed by a comparison 936 of the indicated input bits. These bits indicate whether a start bit level is detected. If the start bit counter value is greater than 39, the value of the self-test word is examined 940 (Fig. 28C). If the value of the self-test word is not 7F, the self-test counter is incremented by one, followed by a setting 946 of the start bit counter to 0. A value of 7F indicates 128 start bits have not been detected. The bit counter indicates which bit of an encoded word is presently being input. When the start bit counter is less than 39, it is examined 948 to determined whether the start bit counter is greater than or equal to 24. If not, the start bit counter is examined 950; and if it is 0, another self-test check is performed; otherwise, the start bit counter is set 946 to 0. If the start bit counter is greater than or equal to 24, the program status bit indicated is set 952 to 1, followed by the setting 954-958 of various flags and values to 0. The interrupt timer is also set 960, followed by setting the program status word bit indicated to zero. If the start bit has been detected, the start bit counter is examined 962 (Fig. 28A) to determine whether it is at its maximum value. If not, the start bit counter is incremented 964, followed by the setting 966 (Fig. 28B) of the interrupt timer at the value for continuing to examine the start bit.

If the start bit flag is not equal to 1, the program status bit for setting the strobe high is set 968 (Fig. 28A) to 0. Next, the data word is shifted 970 left, by one, followed by a check 972 of the input data bit indicated to determined whether the incoming bit is a 1 or a 0. If the incoming bit is equal to 1, a 1 is added 974 (Fig. 28B) to the data word. If the incoming bit status word bit is equal to 0, a 0 is added 976 to the data word. Block 976 is intended to equalize the program delay associated with adding in block 974.

Next, the bit counter is incremented 978, followed by setting 980 the test point I/O bit indicated to 0. If the bit counter is determined 982 to be equal to 15, then the end of the word has been detected and the array pointer for storing the word is updated 984. If the array pointer is equal to 17, then the last word in the array available for storing incoming data has been filled and the pointer must rotate back to the beginning of the array by setting 988 the array pointer back to 0. Once a valid array pointer has been determined, the data is stored 990 in the appropriate location of the incoming buffer. The interrupt timer is then set 992 to 4.1 milliseconds to detect the next incoming data bit. If the bit counter is not equal to 15, then the interrupt timer is set 994 to a value appropriate for detecting the next data bit. Once the interrupt timer has been set to the proper value, the counter is enabled 996, followed by the setting 998 of the register bank to 0.

The many features and advantages of the invention are apparent from the detailed specification, and thus it is intended by the appended claims to cover all such features and advantages of the invention which fall within the true spirit and scope thereof. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation illustrated and described; and, accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.

Claims

1. A common bus multinode sensor system for at least one sensor (8/10 or 22/24) to convey a sensor signal, comprising

a power supply (640);

a communication cable (4), coupled to and carrying said power supply;

remote sensor means (6), coupled between said cable (4), and said sensor, characterized by:

means providing a carrier and for frequency-division multiplexing the sensor signal onto said cable and receiving power from said cable; and

receiver means (12), coupled to said cable, for demultiplexing the frequency division multiplexed sensor signal.

2. A system as recited in claim 1, wherein said remote sensor means (6) comprises:

programmable carrier frequency means (32-42) for providing a carrier to said cable at a carrier frequency in dependence on an external input; and

modulation means (56) for frequency modulating the carrier with the sensor signal.

3. A system as recited in claim 2, wherein said carrier frequency means comprises:

reference frequency means for providing a reference frequency;

a counter (32) counting in accordance with the external input and providing a divided count frequency;

a phase/frequency comparator (34), operatively connected to said counter and said reference frequency means (42), for comparing the divided count frequency to the reference frequency and providing a voltage indicative of the comparison; and

a voltage-controlled oscillator (36), operatively connected to said phase/frequency comparator (34) and said cable (4), producing the carrier at a frequency dependent on the voltage.

4. A system as recited in claim 3, wherein said modulation means (56) comprises a filter, operatively connected to said phase/frequency comparator (34), the sensor and said voltage-controlled oscillator, for averaging the voltage produced by said phase/frequency comparator and for combining the averaged voltage with the sensor signal and providing the combination to said voltage-controlled oscillator (36).

5. A sensor system as recited in claim 2, coupled to several sensors producing several sensor signals and said remote sensor means further comprises multiplexing means for time division multiplexing the sensor signals.

6. A system as recited in claim 5, wherein said remote sensor means further comprises encoding means (48, 54) for encoding the multiplexed sensor signals.

7. A system as recited in claim 6, wherein said encoding means comprises:

an analog-to-digital converter (48) operatively connected to said multiplexing means and converting the analog signals into digital data; and

an encoder operatively connected to said analog-to-digital converter and said modulation means, and encoding the digital data and applying the data to said modulating means for modulating the carrier.

8. A system as recited in claim 1, wherein said receiver means (12) comprises:

synthesis means (662) for producing a mixing frequency; and

mixing and detection means (644, 666, 668) for combining the frequency division multiplexed sensor signal and the mixing frequency, and producing a frequency division demultiplexed signal.

9. A system as recited in claim 1, wherein said remote sensor means encodes the sensor signal, and said receiver means includes decoder means for decoding the encoded sensor signal.

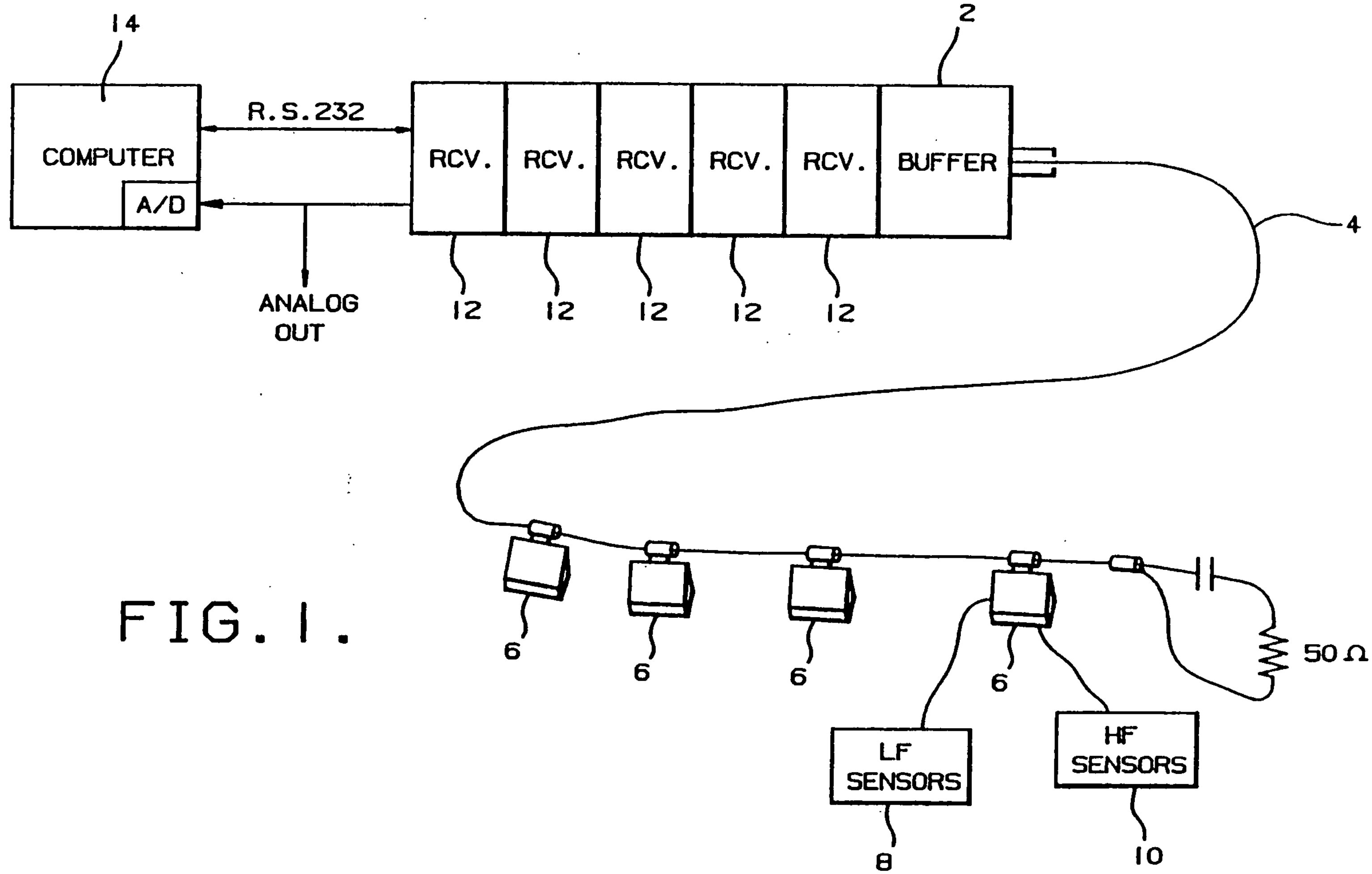
14
COMPUTER
A/D
R.S.232
ANALOG
OUT
RCV.
RCV.
RCV.
RCV.
RCV.
BUFFER
2
12
12
12
12
12
4
6
6
6
6
LF
SENSORS
8
HF
SENSORS
10
50 Ω

FIG. 1.

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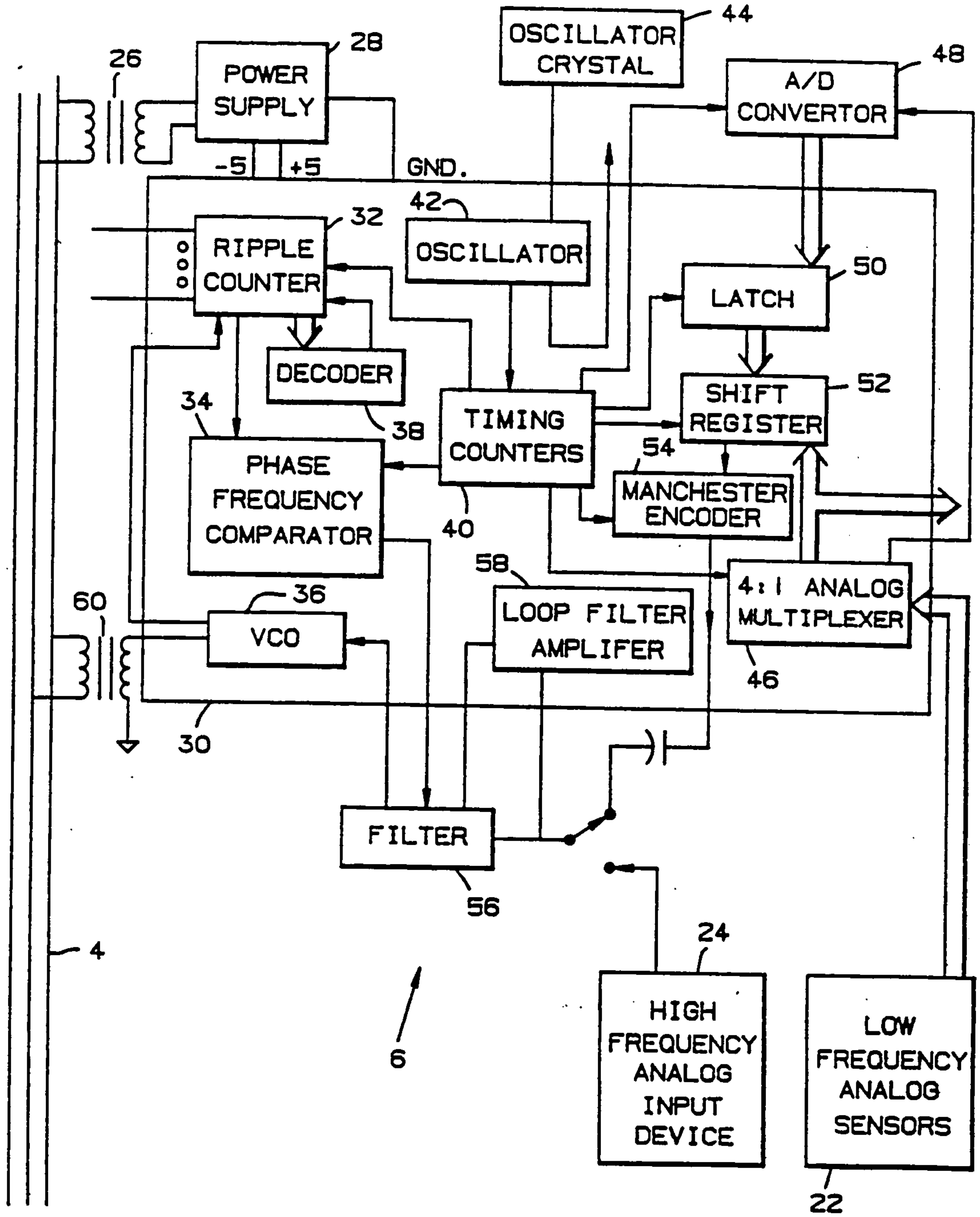


FIG. 2.

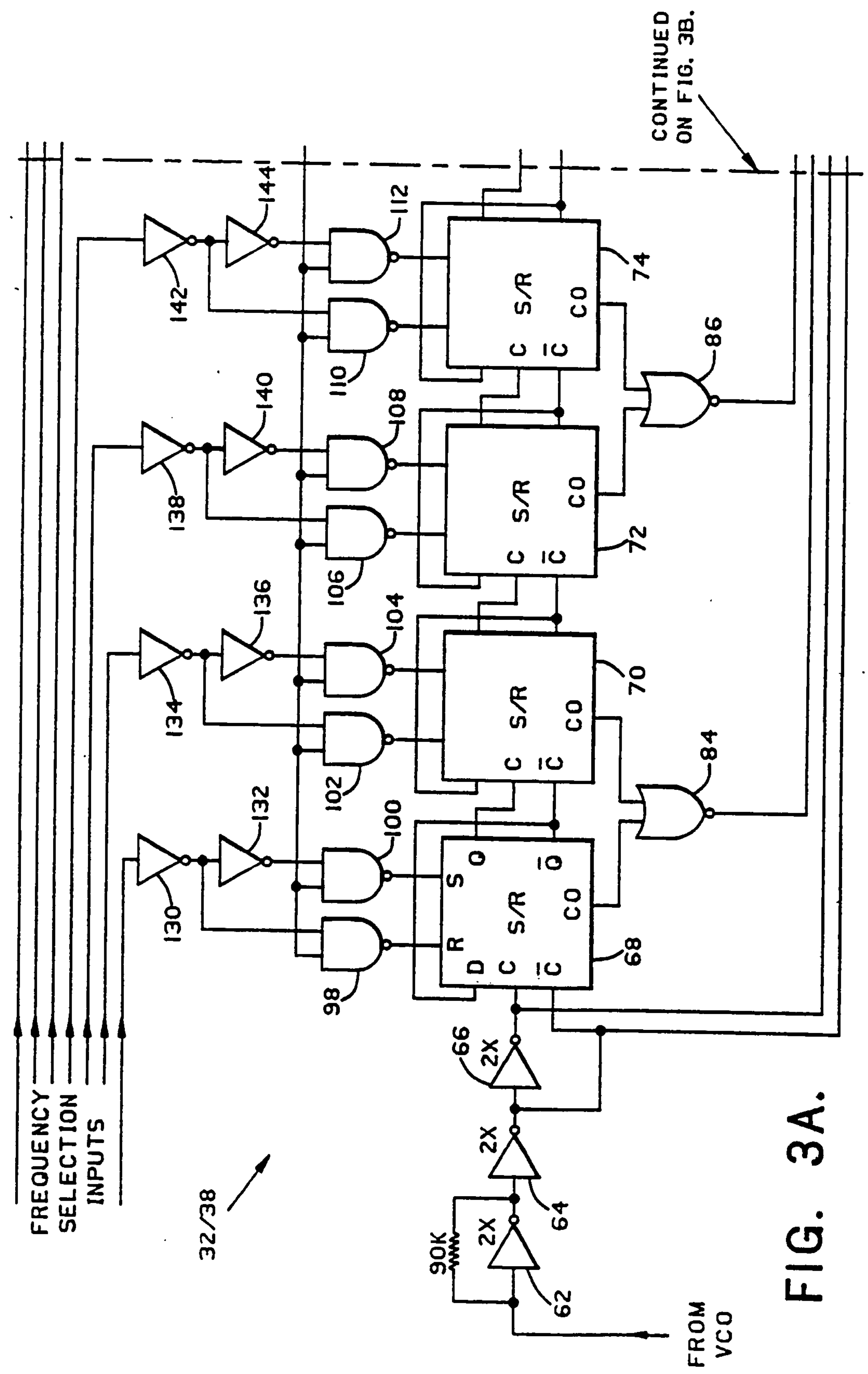

CONTINUED ON FIG. 3B.
FREQUENCY SELECTION INPUTS
32/38
FROM VCO
90K
2X
2X
2X
62
64
66
68
70
72
74
84
86
98
100
102
104
106
108
110
112
130
132
134
136
138
140
142
144
S/R
S
R
D
C
C̄
Q
Q̄
CO

FIG. 3A.

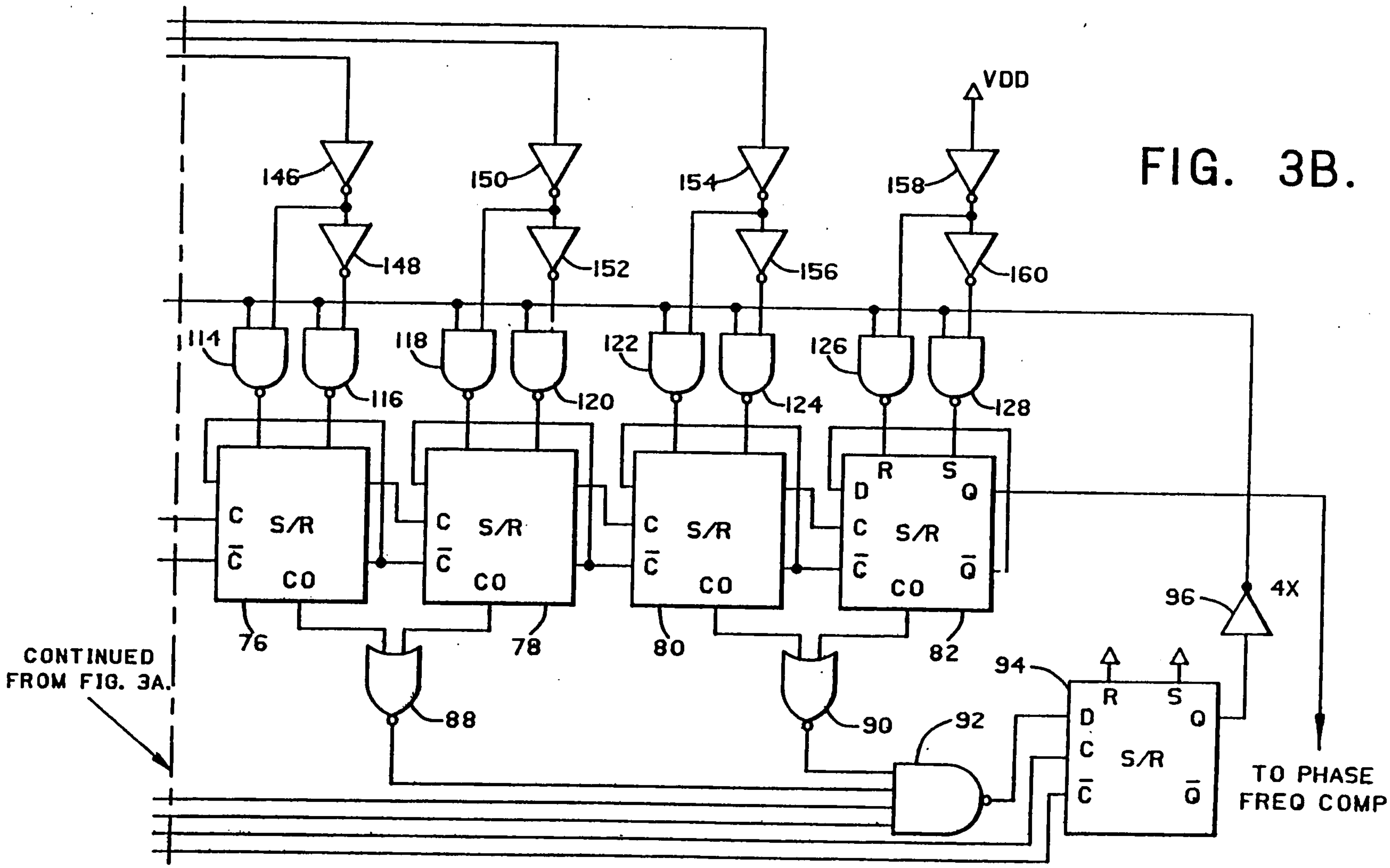
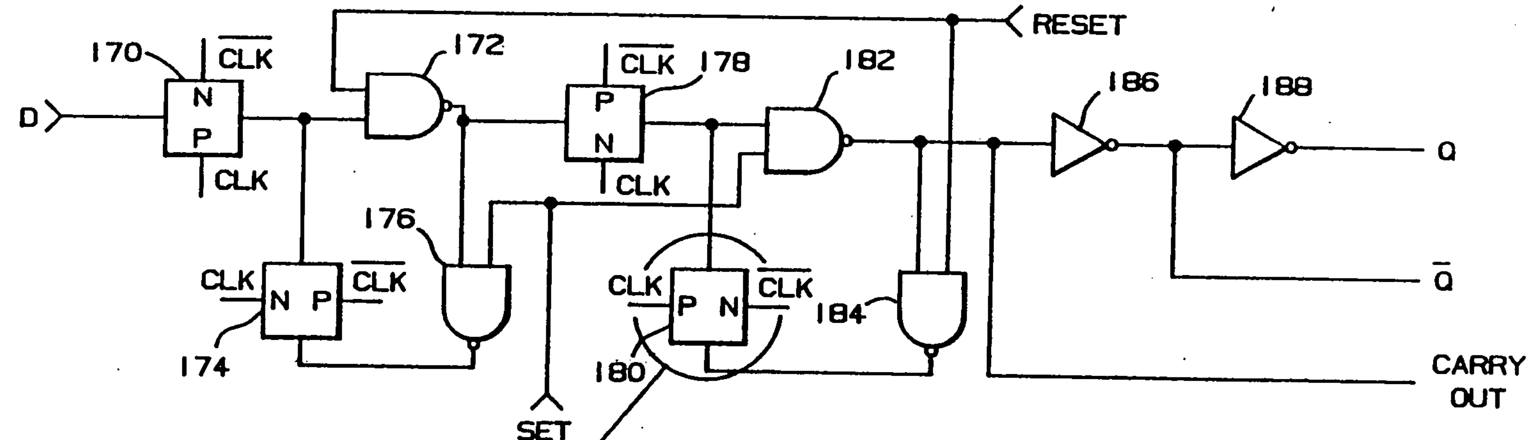
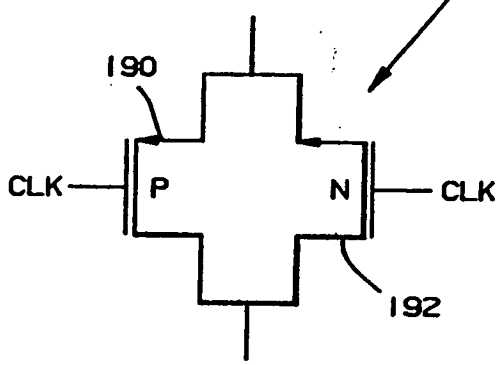

VDD
146
148
150
152
154
156
158
160
114
116
118
120
122
124
126
128
C
C̄
S/R
CO
D
R
S
Q
Q̄
76
78
80
82
88
90
92
94
96
4X
TO PHASE
FREQ COMP
CONTINUED
FROM FIG. 3A.

FIG. 3B.

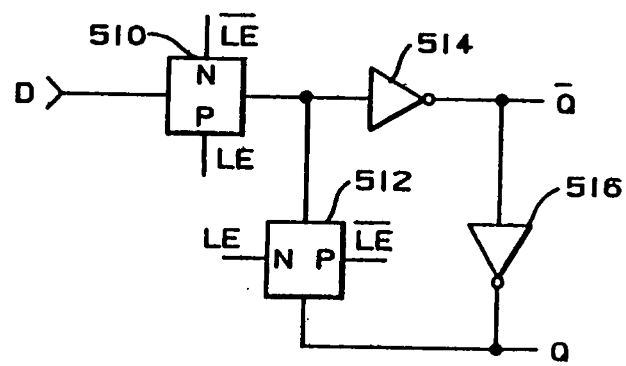


D
170
CLK
CLK
N
P
172
174
CLK
N P
CLK
176
RESET
CLK
178
P
N
CLK
182
SET
CLK
P N
CLK
180
184
186
188
Q
Q
CARRY
OUT



190
CLK
P
N
CLK
192

FIG. 4.



510
LE
N
P
LE
D
514
Q
512
LE
N P
LE
516
Q

FIG. 12.

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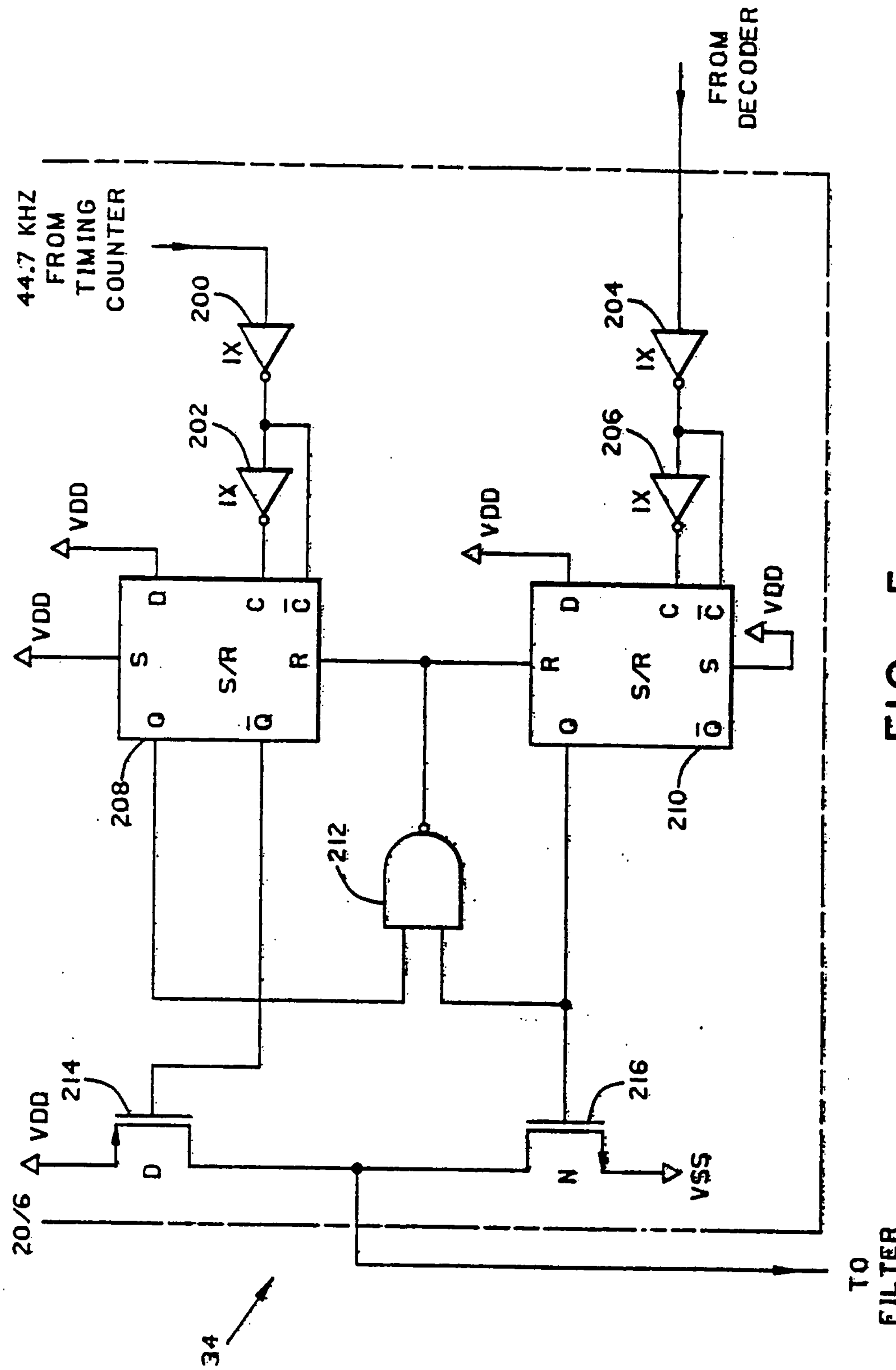


FIG. 5.

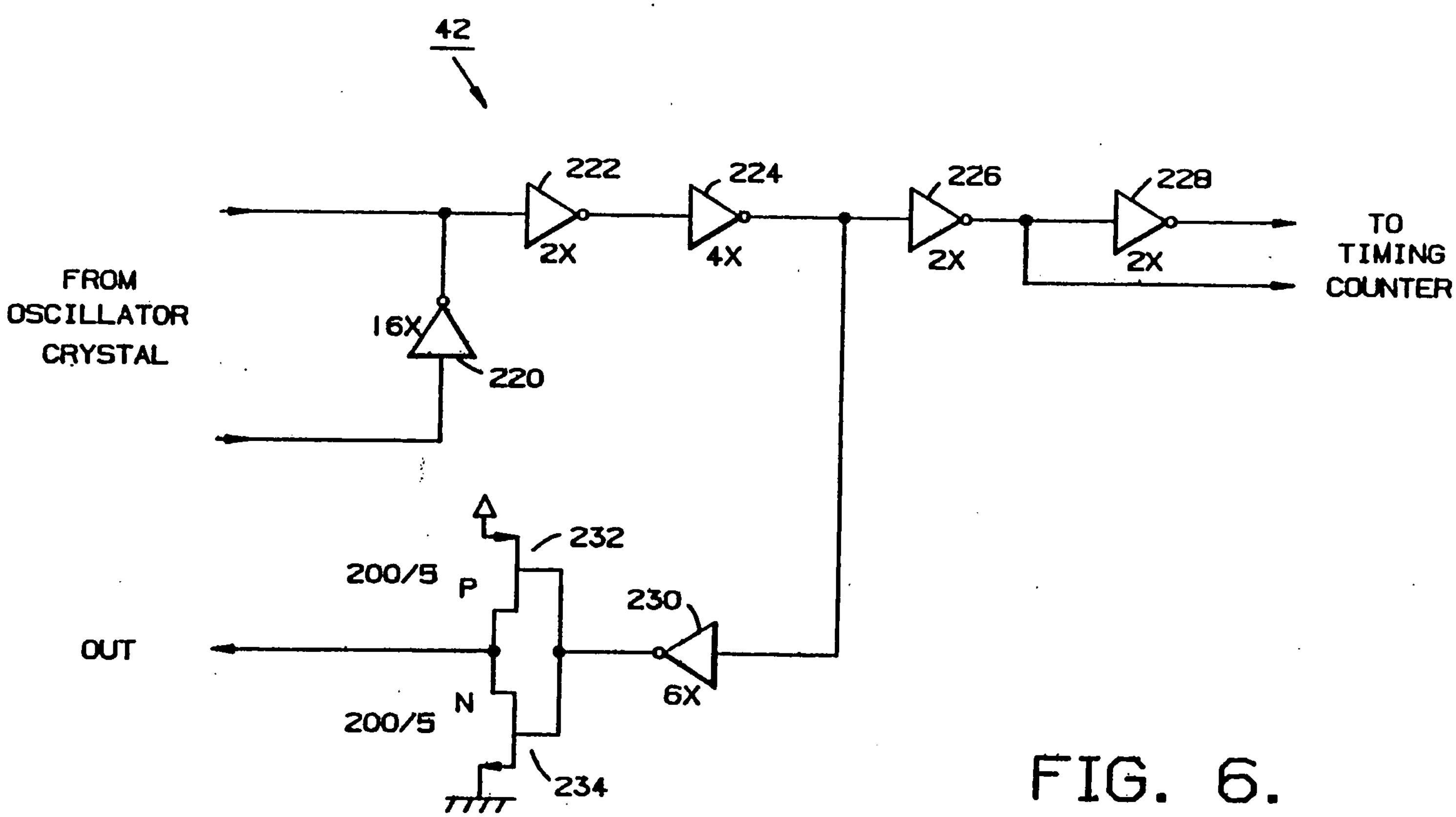

42
222
224
226
228
2X
4X
2X
2X
TO
TIMING
COUNTER
FROM
OSCILLATOR
CRYSTAL
16X
220
232
200/5
P
230
OUT
6X
N
200/5
234

FIG. 6.

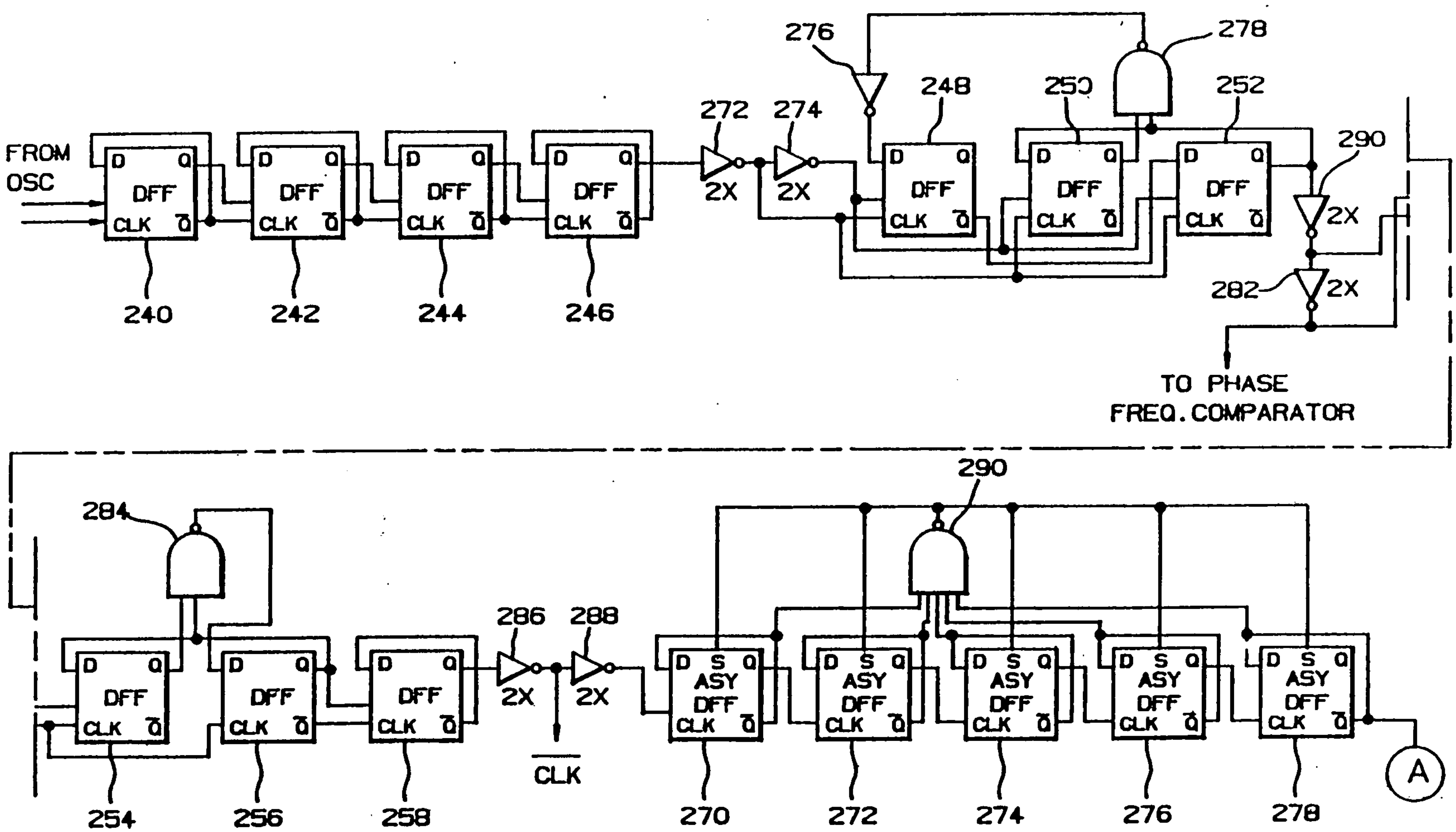
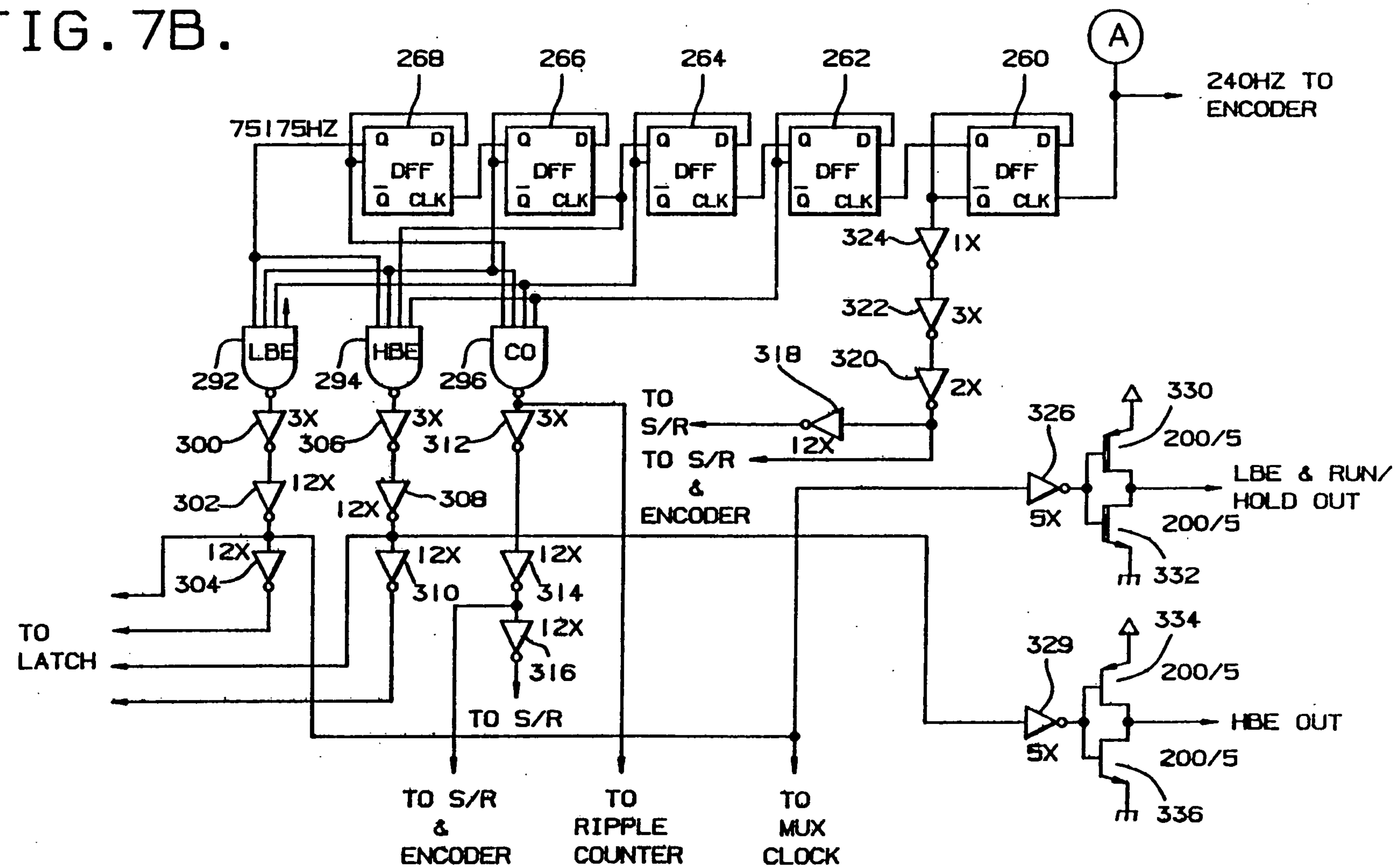

FROM OSC
DFF
D
Q
CLK
240
242
244
246
248
250
252
272
274
276
278
2X
290
282
TO PHASE FREQ.COMPARATOR
284
254
256
258
286
288
CLK
ASY DFF
S
270
272
274
276
278
290
A

FIG. 7A.

FIG. 7B.


268
266
264
262
260
A
240HZ TO ENCODER
75175HZ
Q D DFF Q̄ CLK
324
1X
322
3X
320
2X
318
12X
TO S/R
TO S/R & ENCODER
LBE
HBE
CO
292
294
296
300
306
312
3X
302
308
12X
304
310
314
316
TO S/R
TO LATCH
TO S/R & ENCODER
TO RIPPLE COUNTER
TO MUX CLOCK
326
329
5X
330
332
334
336
200/5
LBE & RUN/ HOLD OUT
HBE OUT

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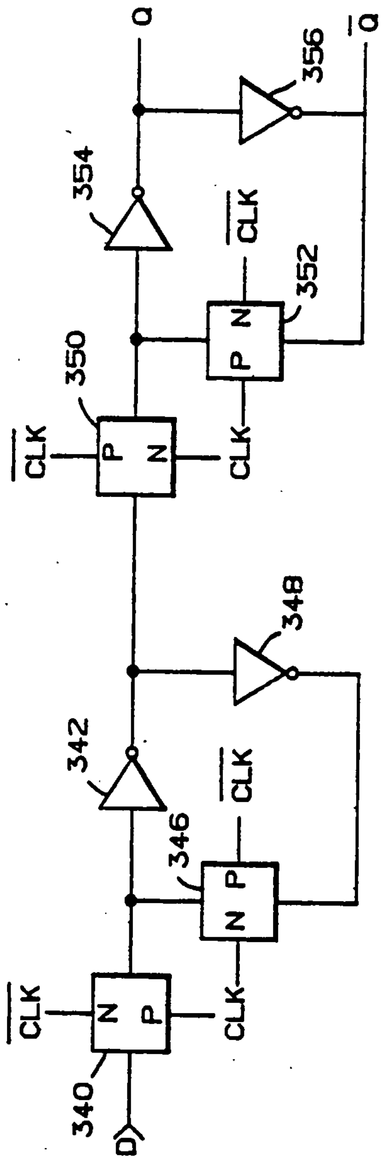

FIG. 8.

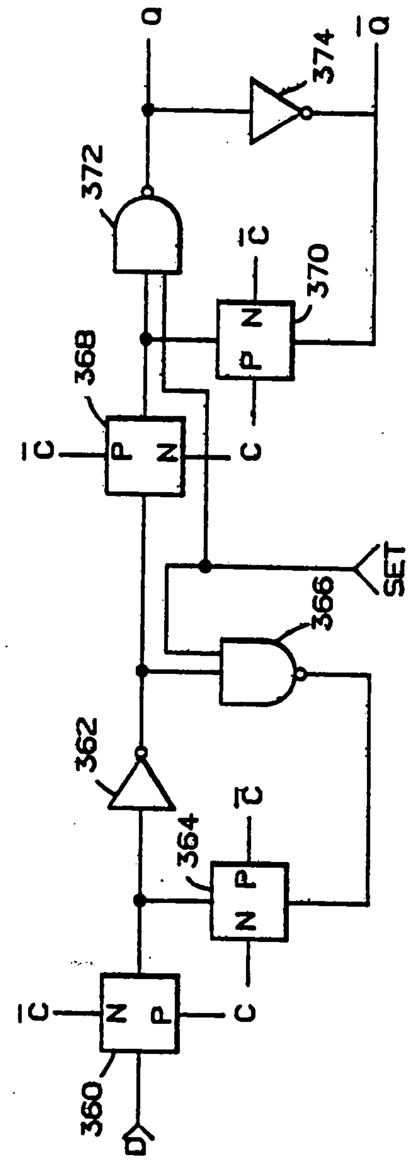

FIG. 9.

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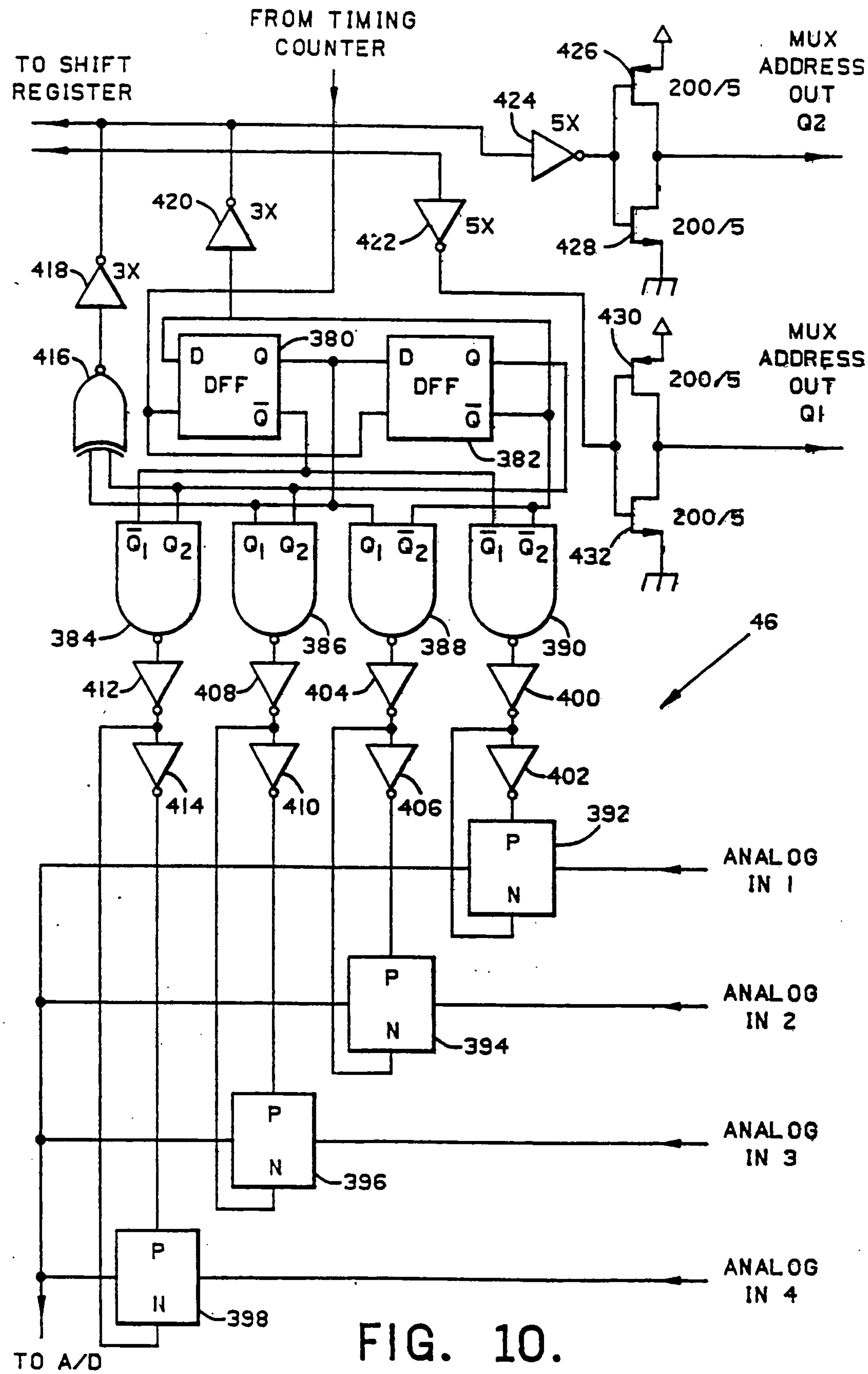


FIG. 10.

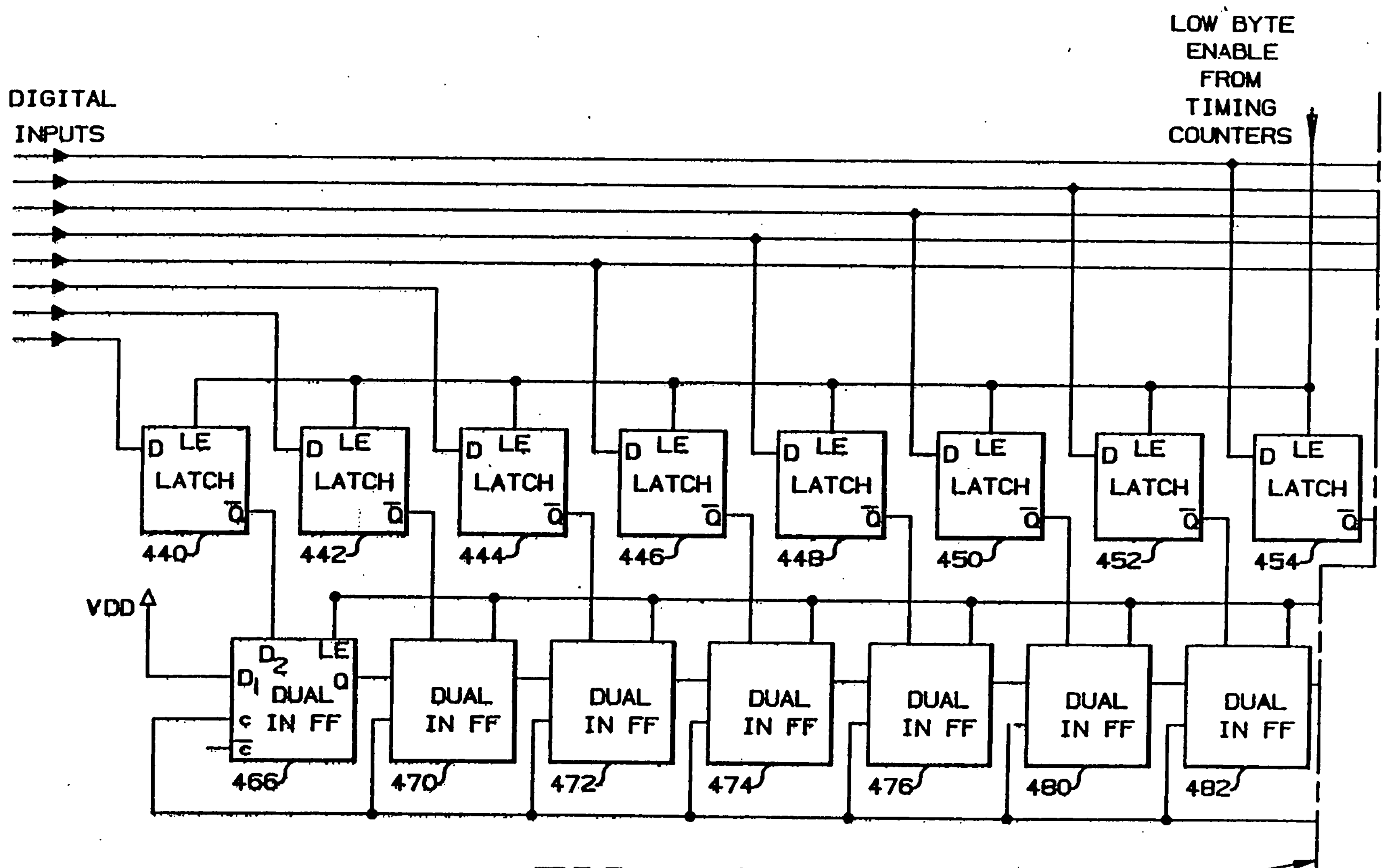


FIG. 11A.

CONTINUED ON FIG. 11B.

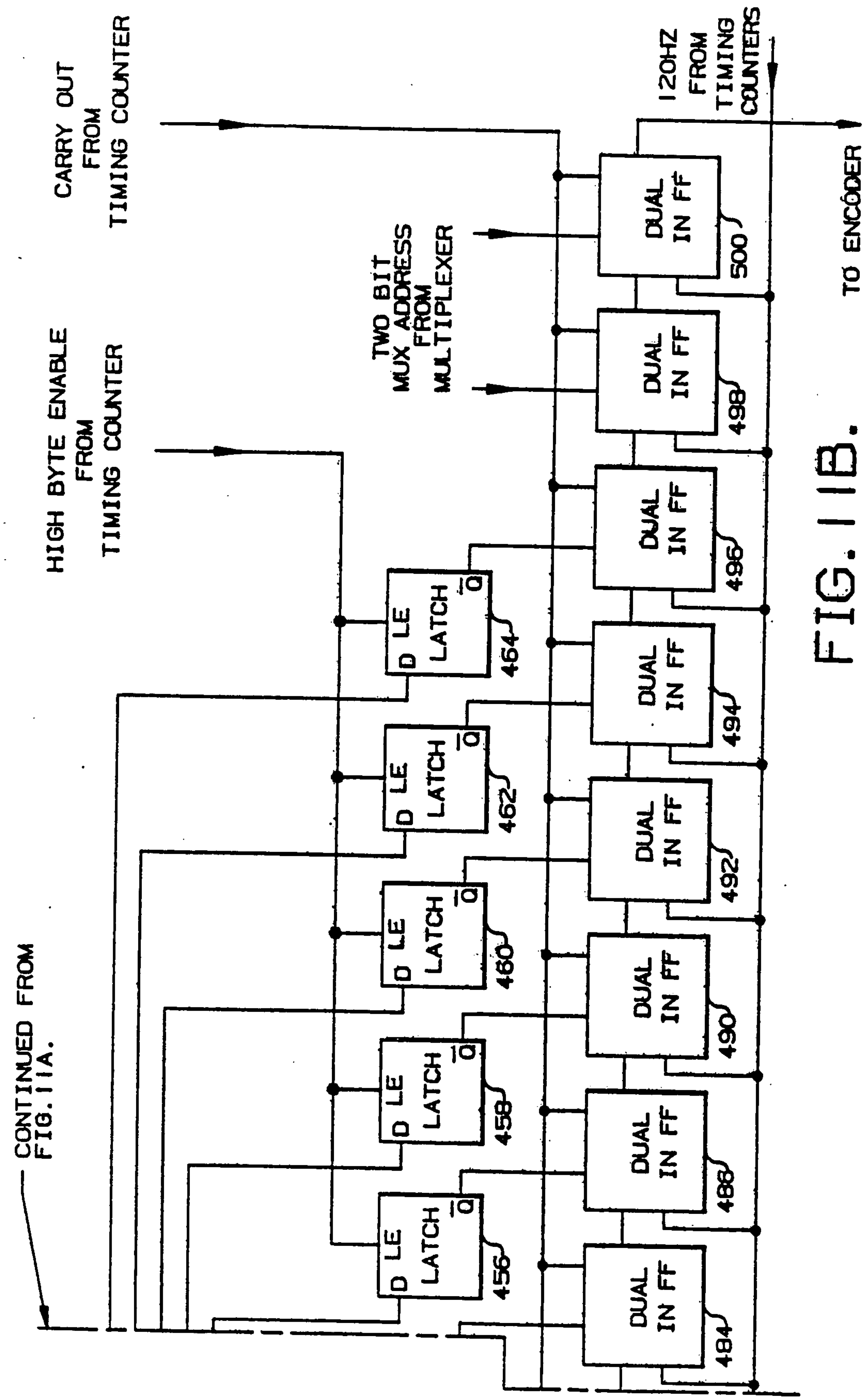
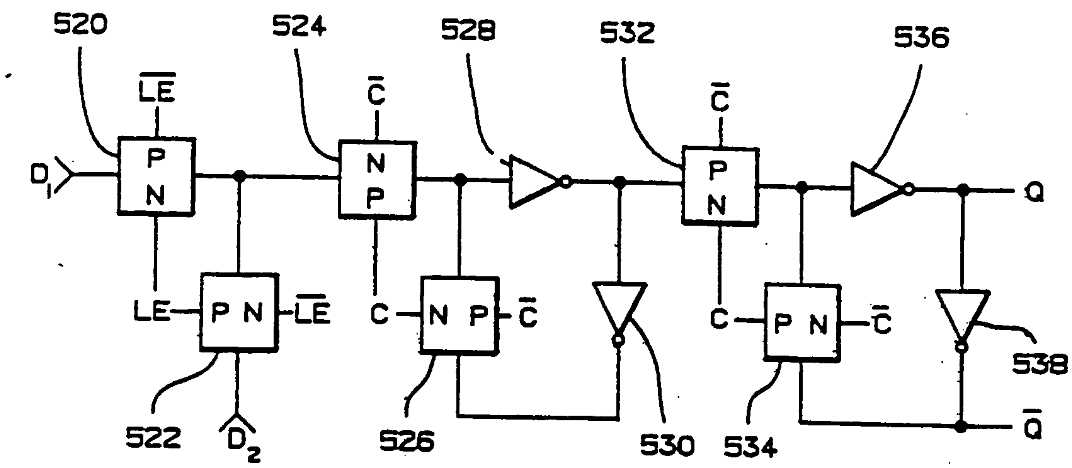
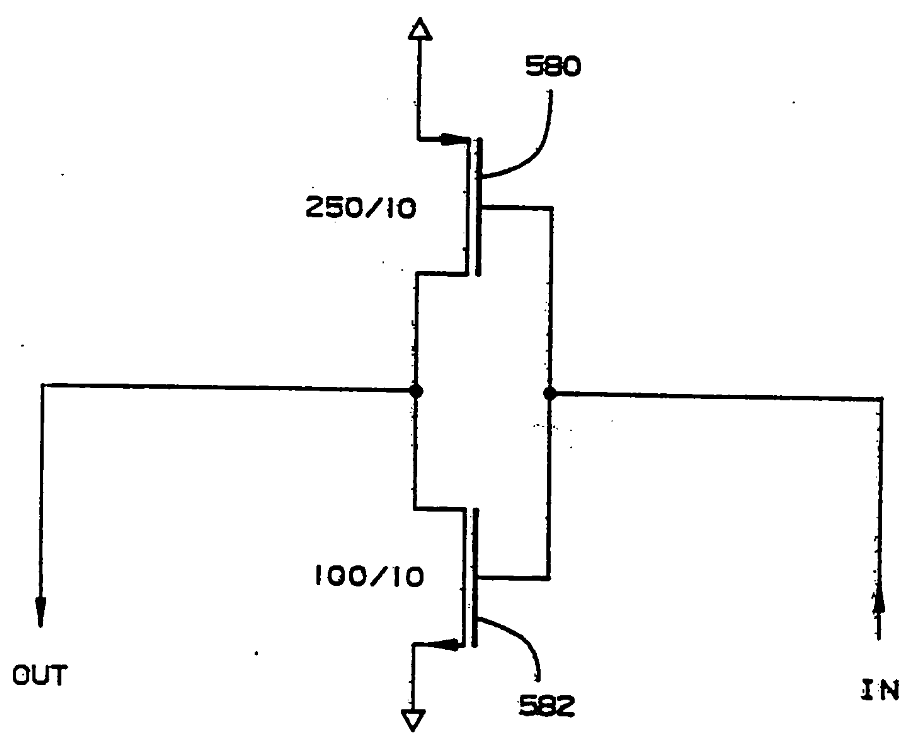

CARRY OUT FROM TIMING COUNTER
HIGH BYTE ENABLE FROM TIMING COUNTER
TWO BIT MUX ADDRESS FROM MULTIPLEXER
120HZ FROM TIMING COUNTERS
TO ENCODER
CONTINUED FROM FIG.11A.
D LE LATCH $\overline{Q}$
456
458
460
462
464
DUAL IN FF
484
488
490
492
494
496
498
500

FIG. 11B.



520
524
528
532
536
$\overline{LE}$
$\overline{C}$
$\overline{C}$
D_1
P
N
N
P
P
N
Q
LE
P N
$\overline{LE}$
C
N P
$\overline{C}$
C
P N
$\overline{C}$
538
522
D_2
526
530
534
$\overline{Q}$

FIG. 13.



580
250/10
100/10
OUT
582
IN
58

FIG. 17.

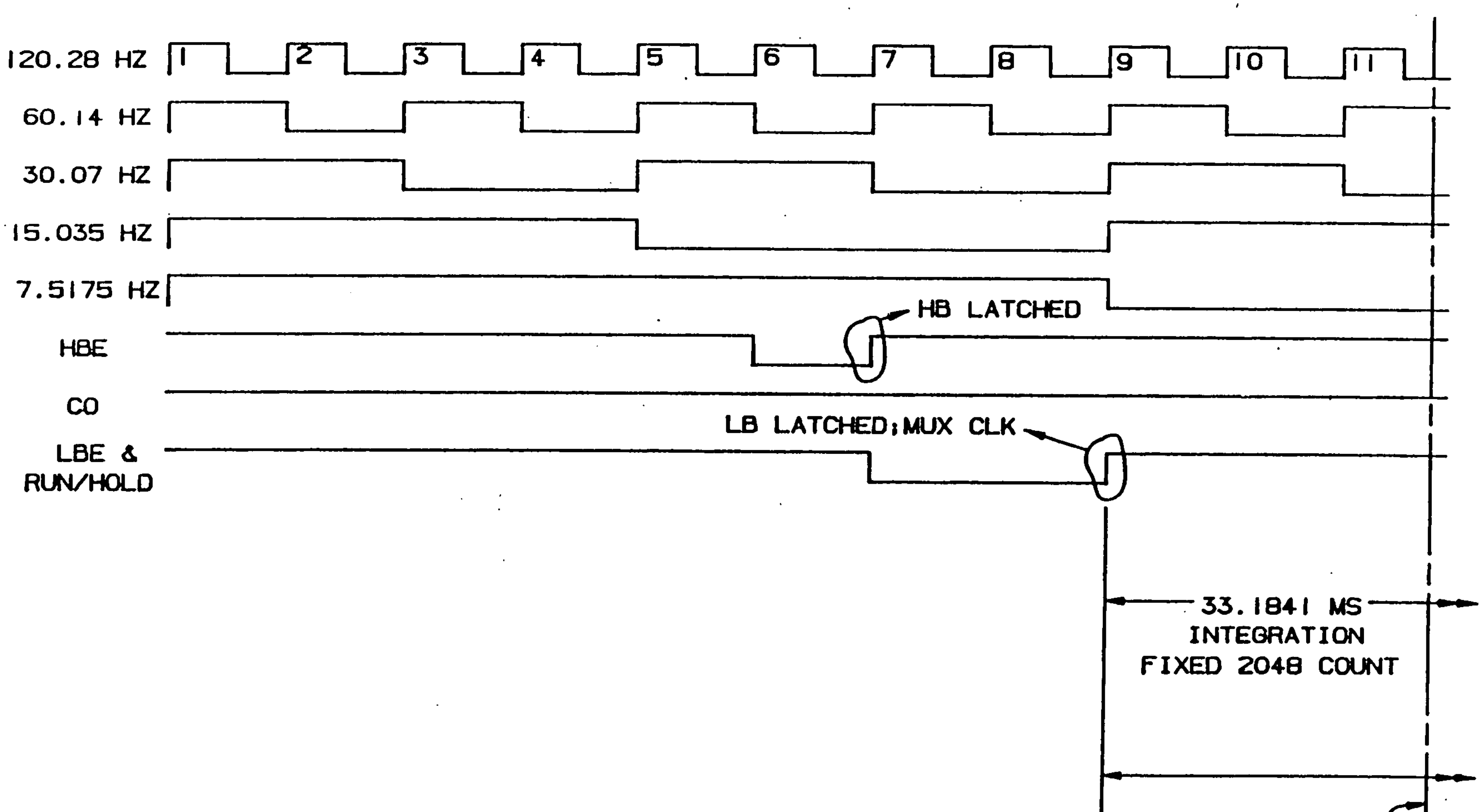


FIG. 14A.

CONTINUED ON FIG. 14B.

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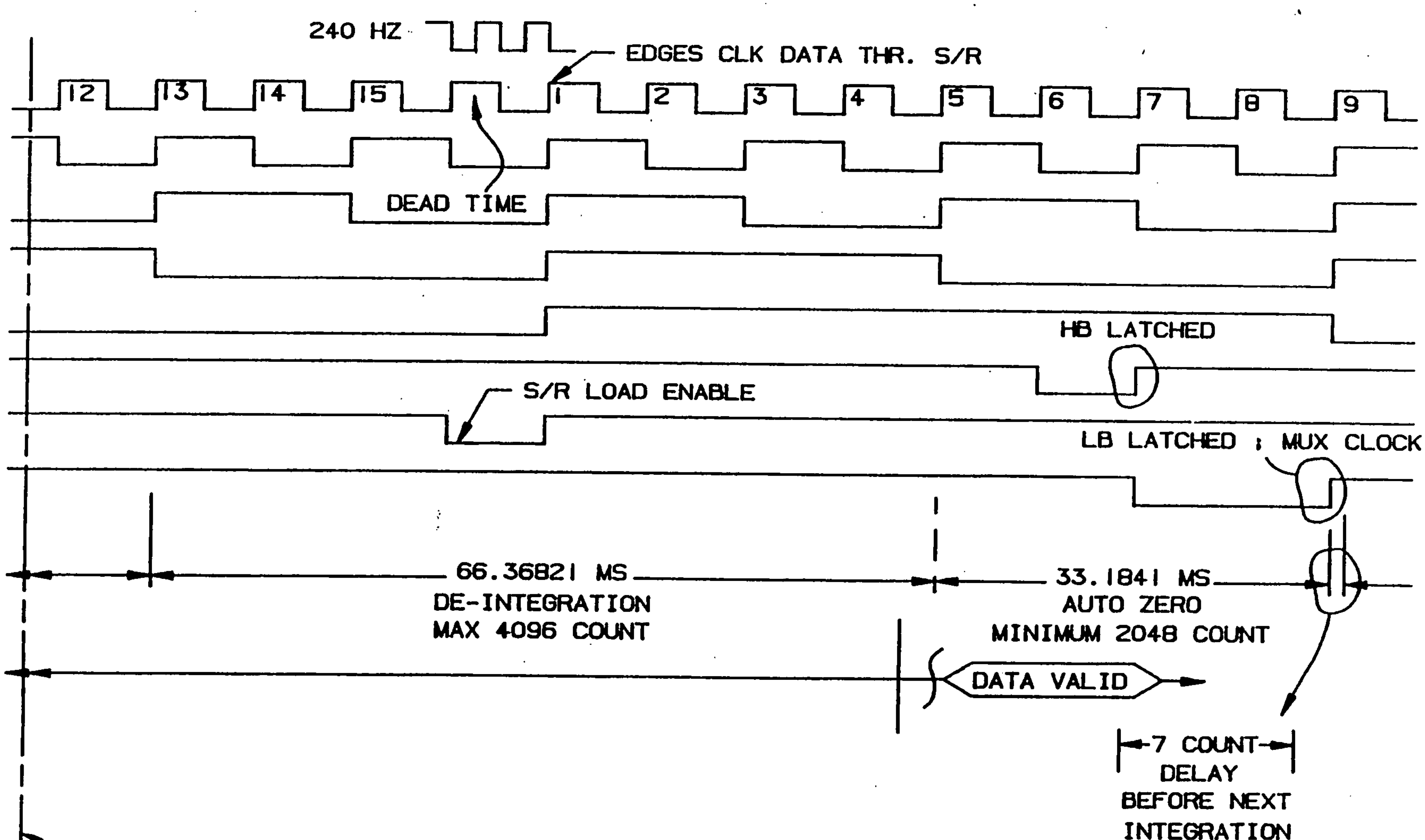

CONTINUED FROM FIG. 14A.

FIG. 14B.

CONVERSION=113.422 μS

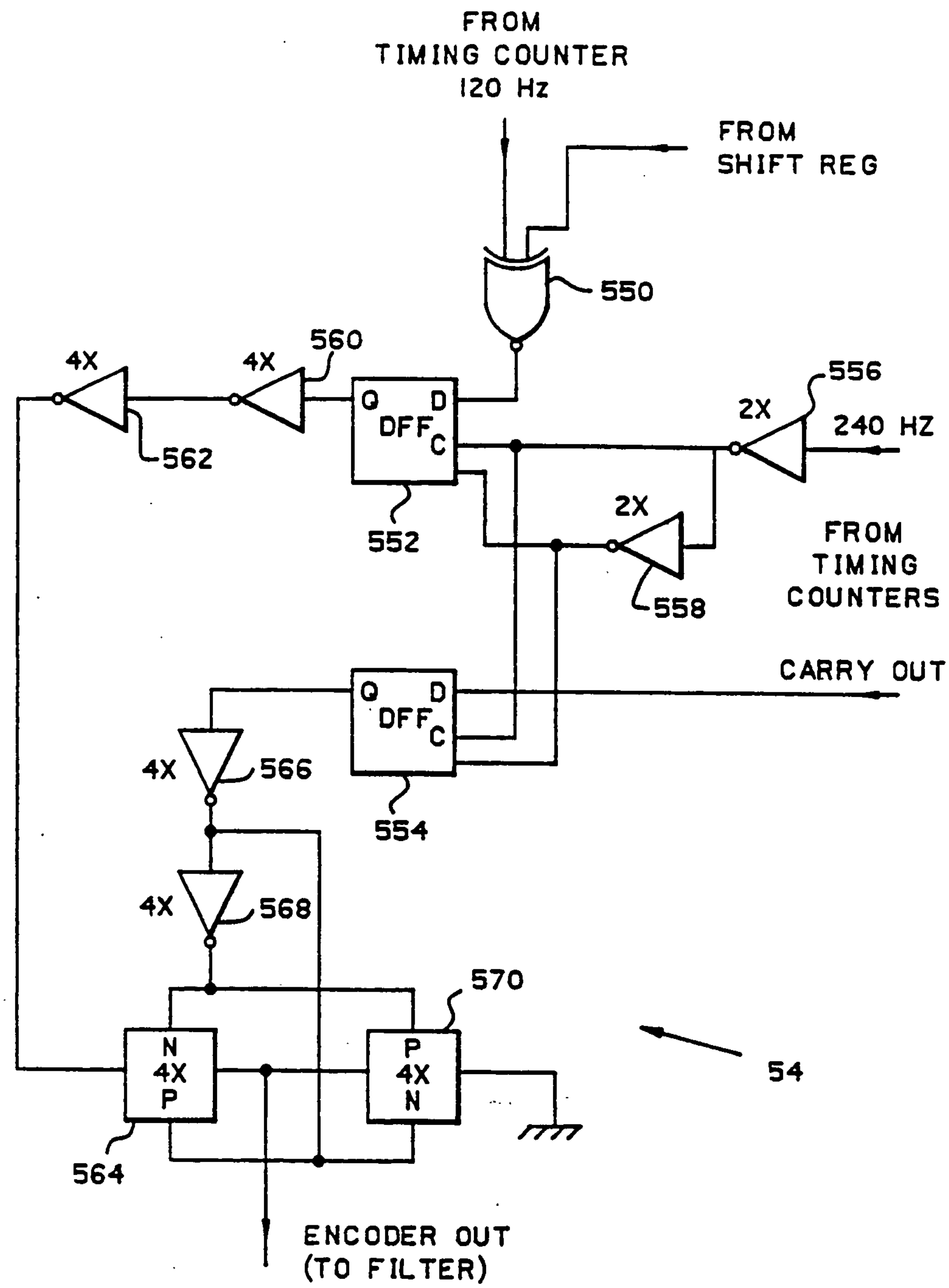
FROM
TIMING COUNTER
120 Hz
FROM
SHIFT REG
550
4X
4X
560
Q
D
DFF
C
556
2X
240 HZ
562
552
2X
558
FROM
TIMING
COUNTERS
CARRY OUT
Q
D
DFF
C
4X
566
554
4X
568
570
N
4X
P
P
4X
N
54
564
ENCODER OUT
(TO FILTER)

FIG. 15.

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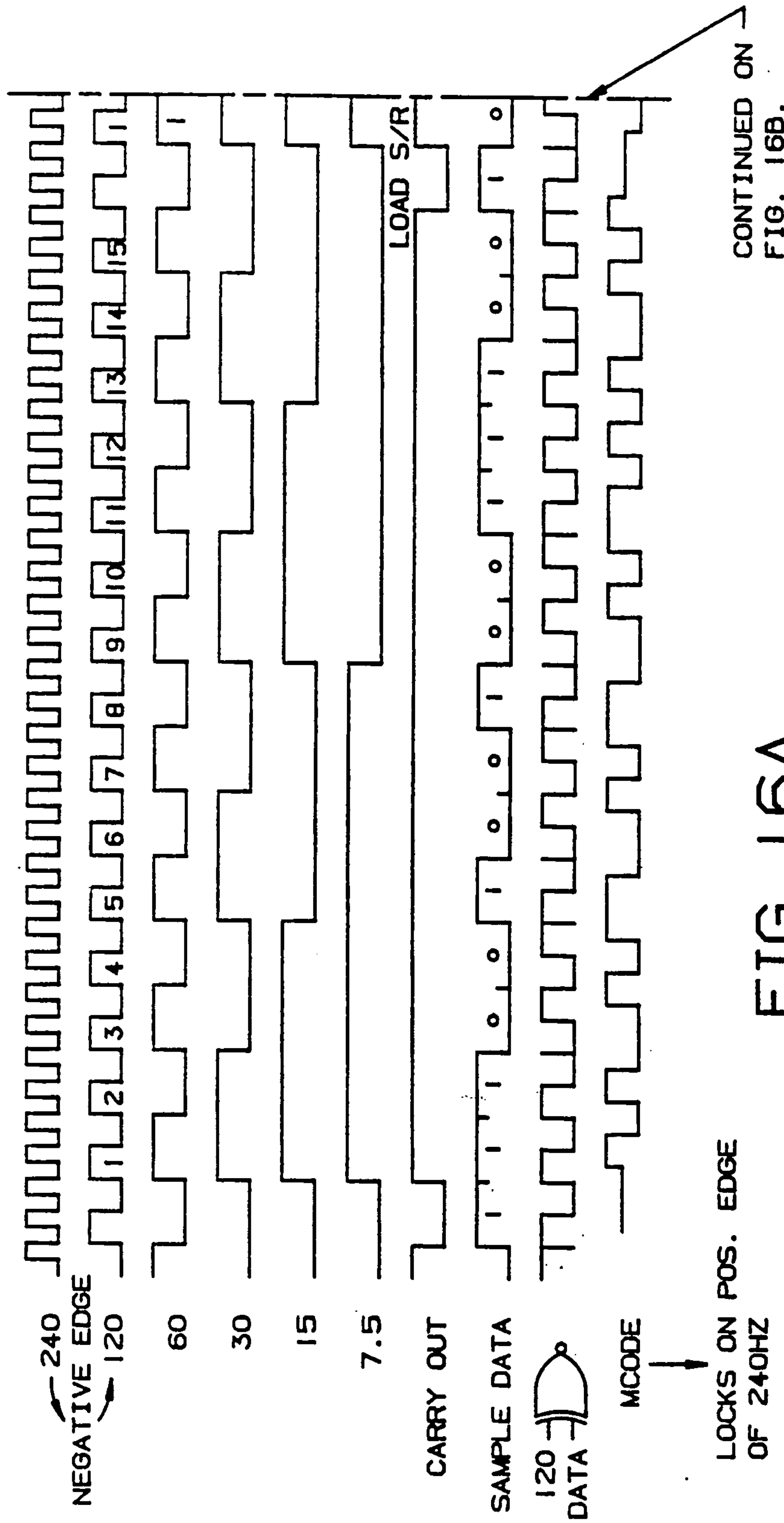


FIG. 16A.

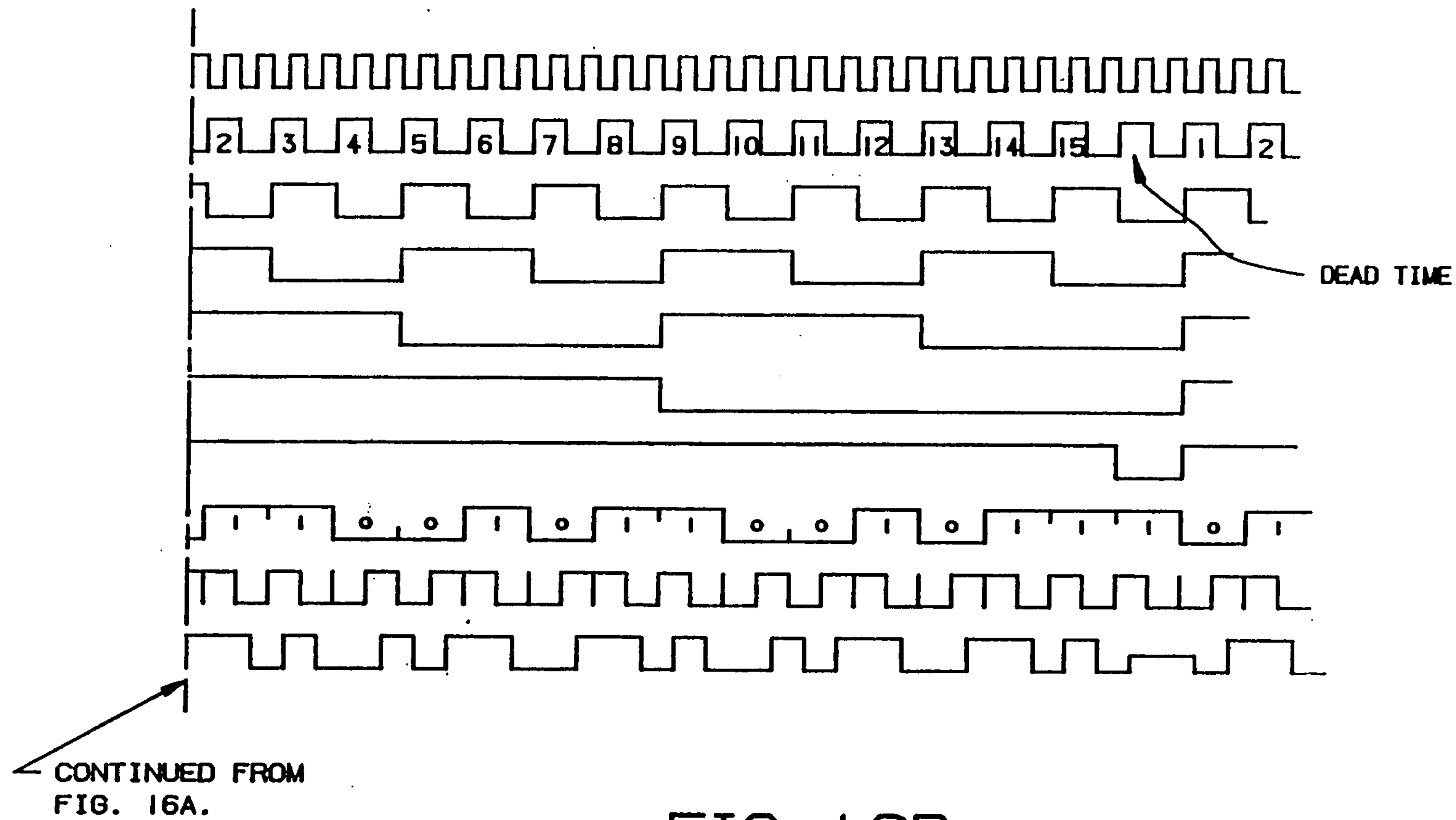
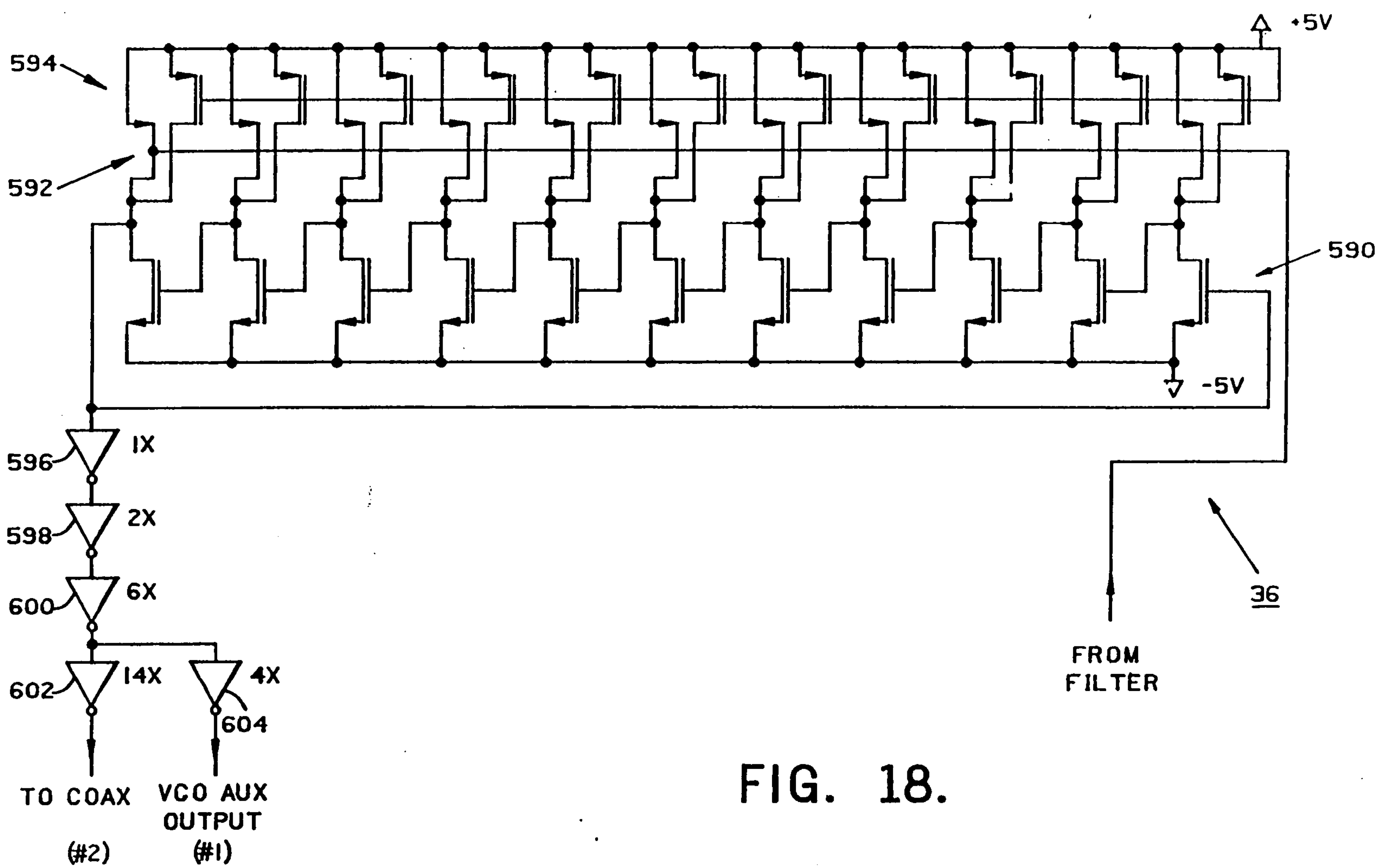


FIG. 16B.



594
592
+5V
590
-5V
596
1X
598
2X
600
6X
602
14X
4X
604
TO COAX
(#2)
VCO AUX
OUTPUT
(#1)
FROM
FILTER
36

FIG. 18.

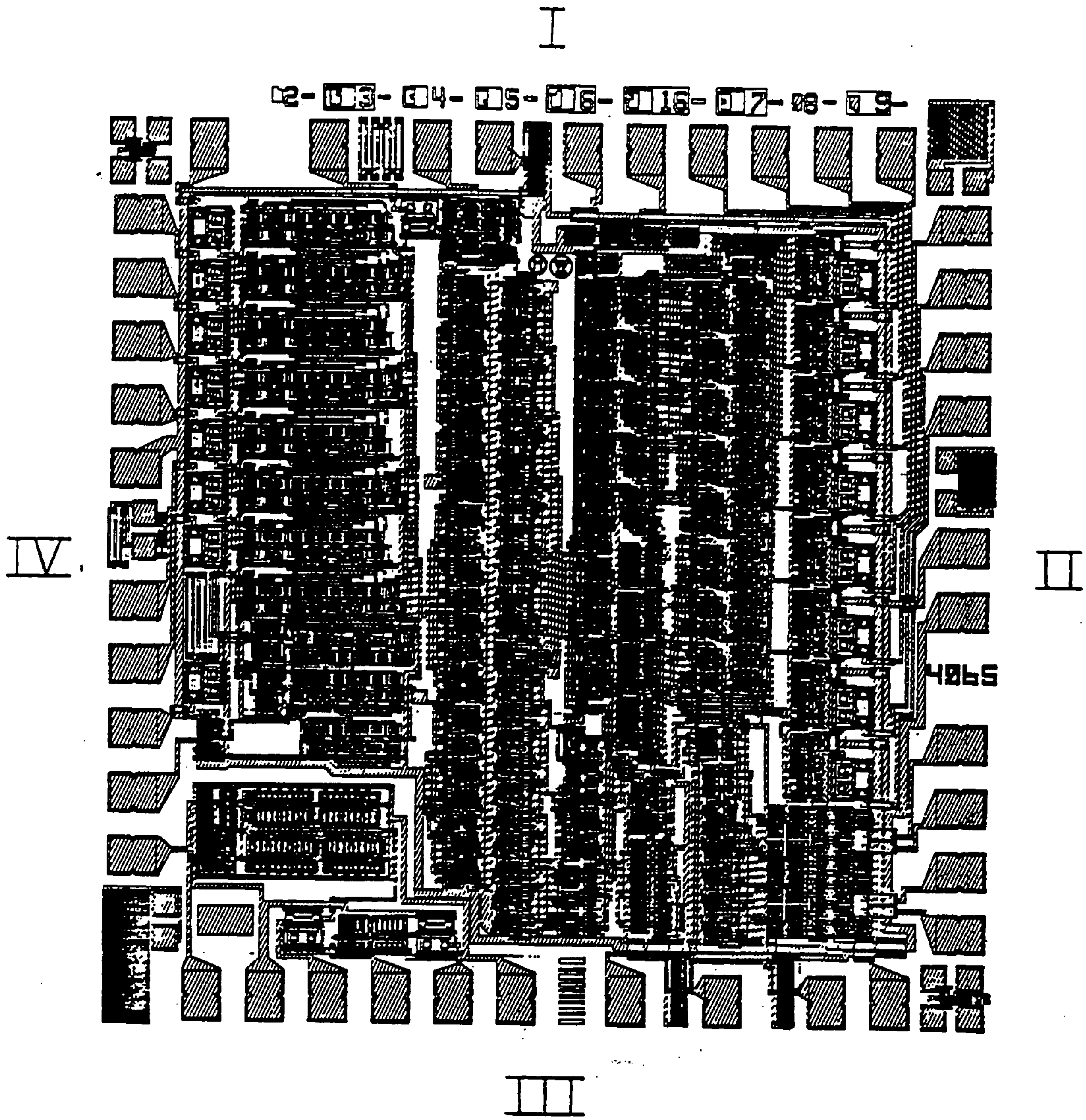
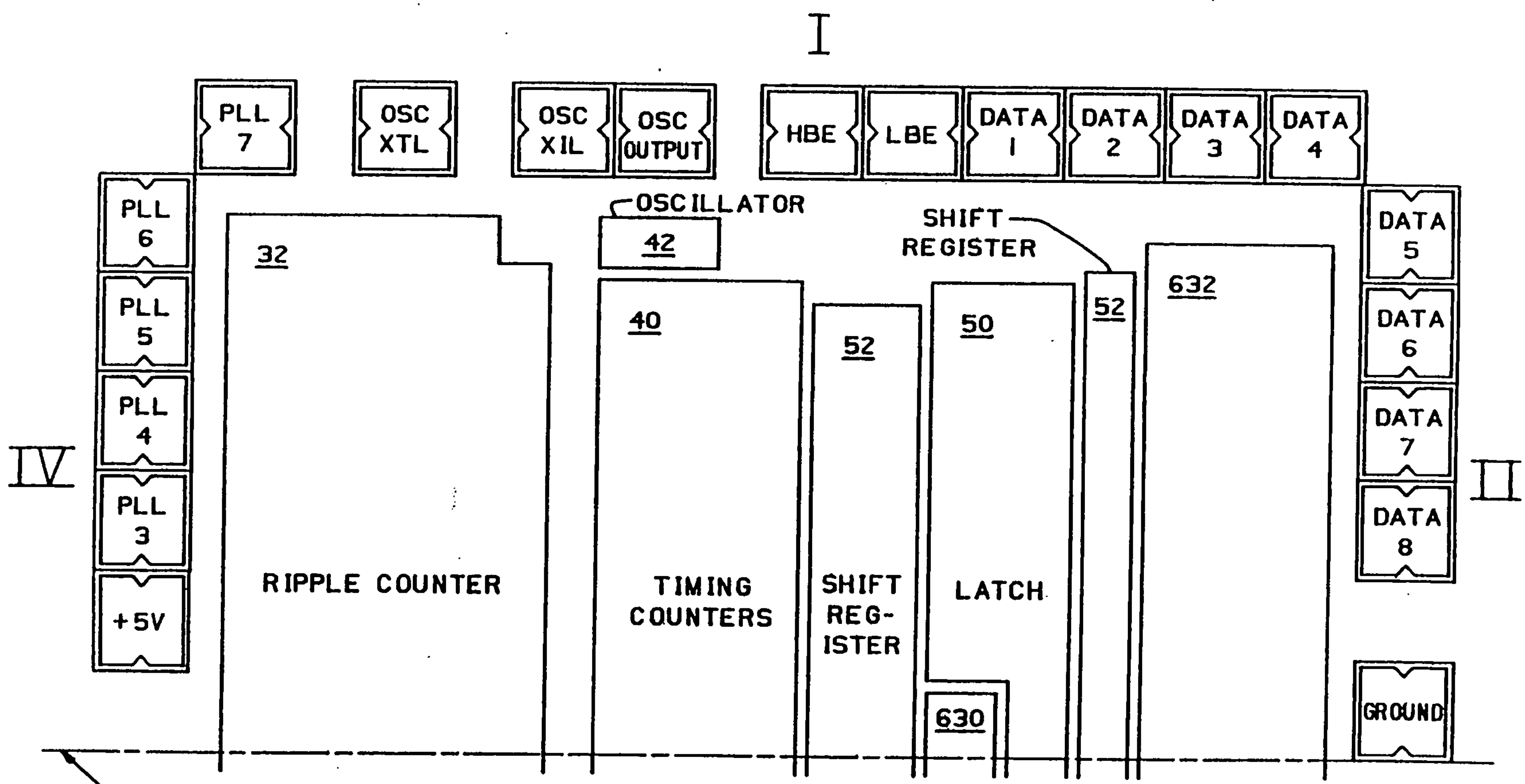


FIG. 20.



CONTINUED ON FIG. 21B.

FIG. 21A.

CONTINUED FROM FIG. 21A.

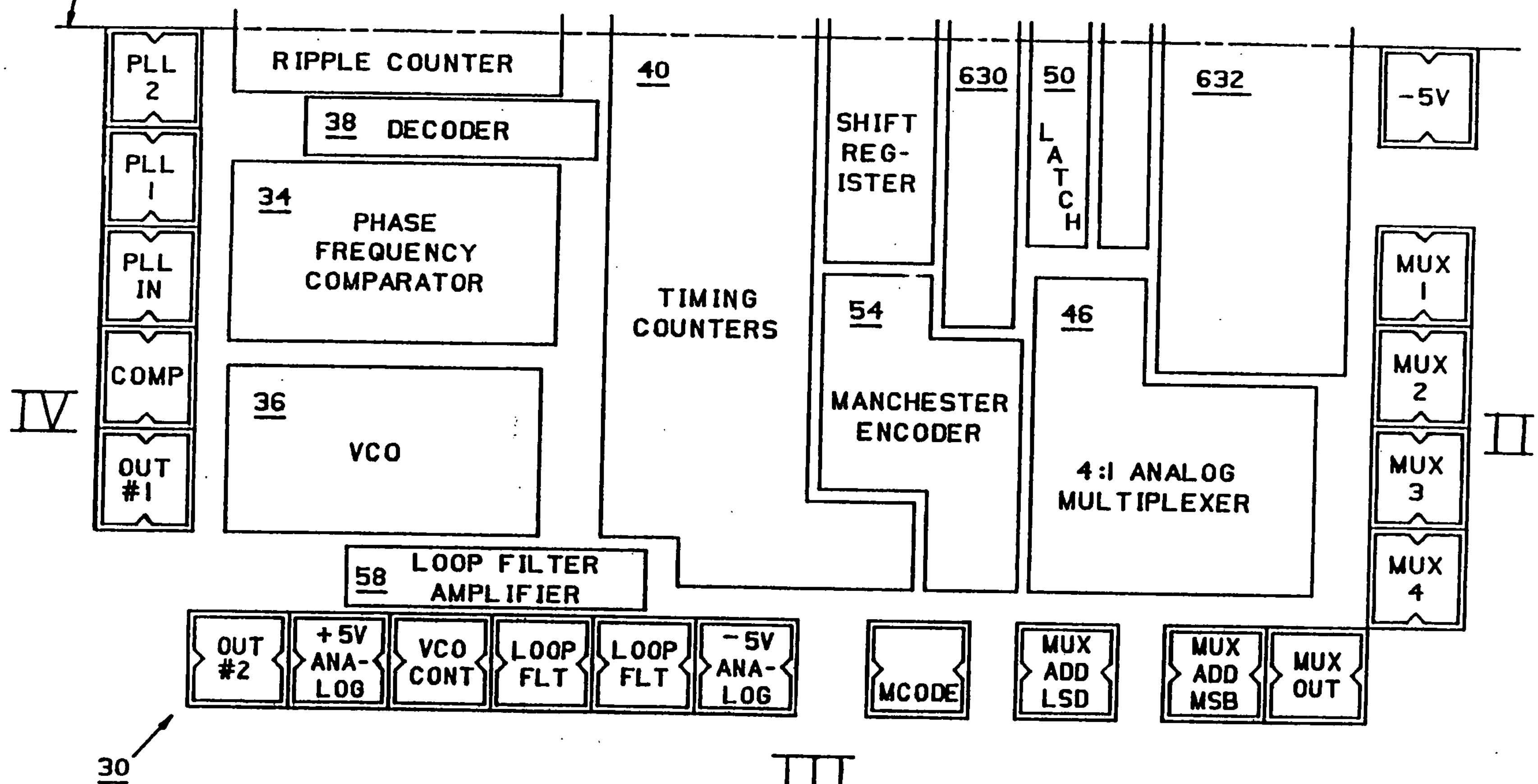


FIG. 21B.

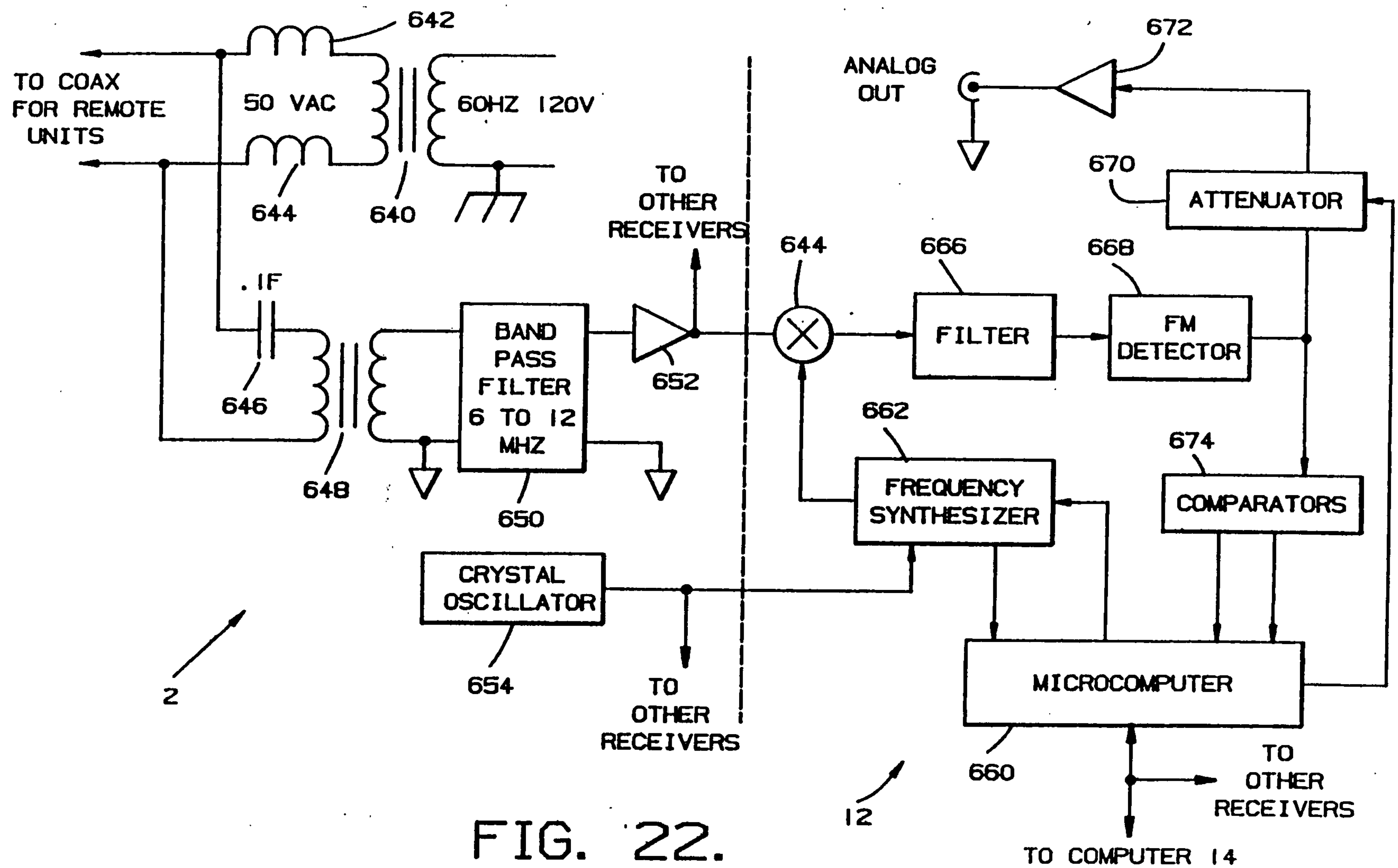
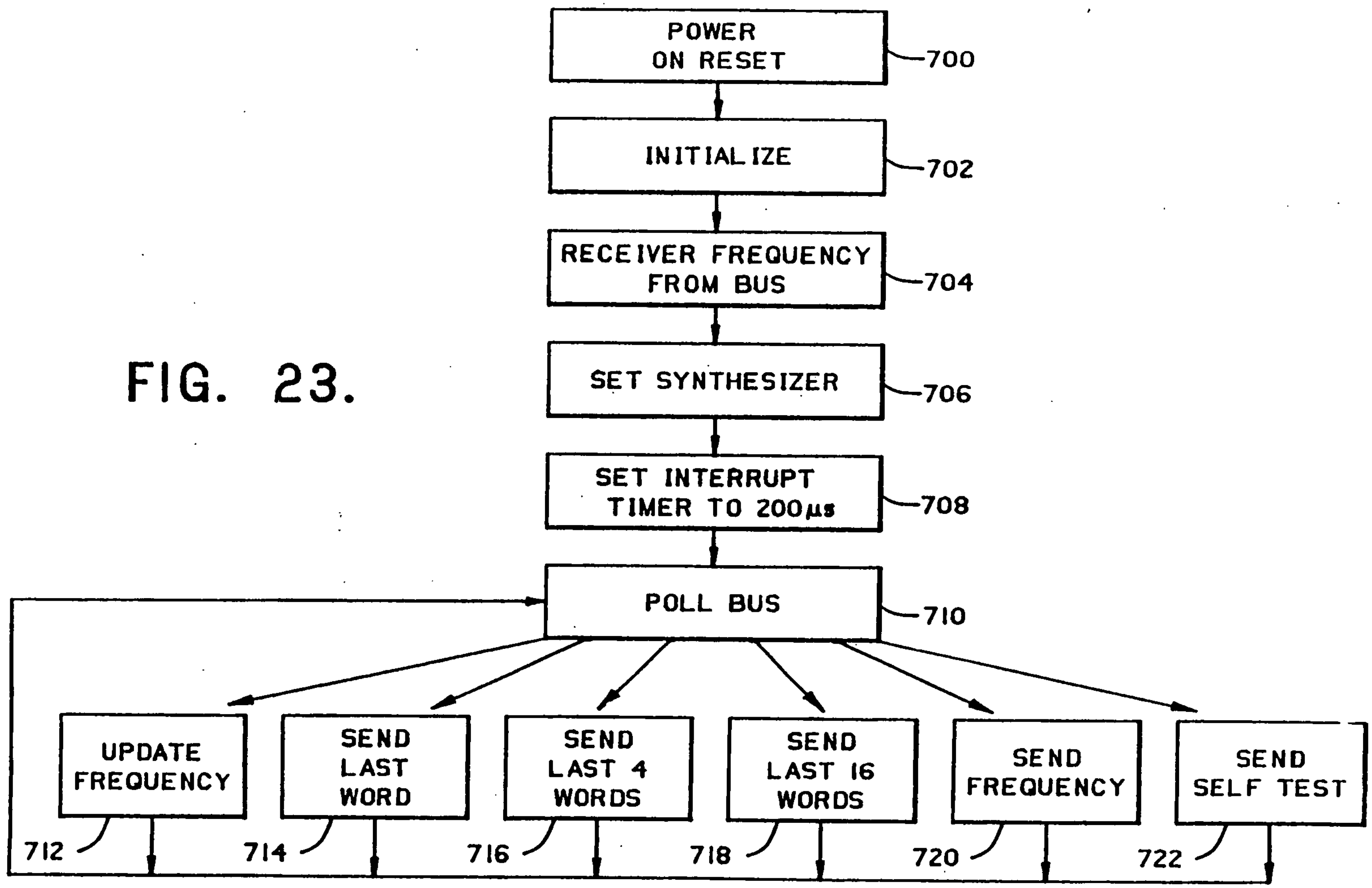

642
TO COAX
FOR REMOTE
UNITS
50 VAC
60HZ 120V
644
640
TO
OTHER
RECEIVERS
.1F
646
BAND
PASS
FILTER
6 TO 12
MHZ
652
648
650
CRYSTAL
OSCILLATOR
654
TO
OTHER
RECEIVERS
2
644
666
668
FILTER
FM
DETECTOR
ANALOG
OUT
672
670
ATTENUATOR
662
FREQUENCY
SYNTHESIZER
674
COMPARATORS
MICROCOMPUTER
660
12
TO
OTHER
RECEIVERS
TO COMPUTER 14

FIG. 22.

FIG. 23.


POWER ON RESET
700
INITIALIZE
702
RECEIVER FREQUENCY FROM BUS
704
SET SYNTHESIZER
706
SET INTERRUPT TIMER TO 200µs
708
POLL BUS
710
UPDATE FREQUENCY
712
SEND LAST WORD
714
SEND LAST 4 WORDS
716
SEND LAST 16 WORDS
718
SEND FREQUENCY
720
SEND SELF TEST
722

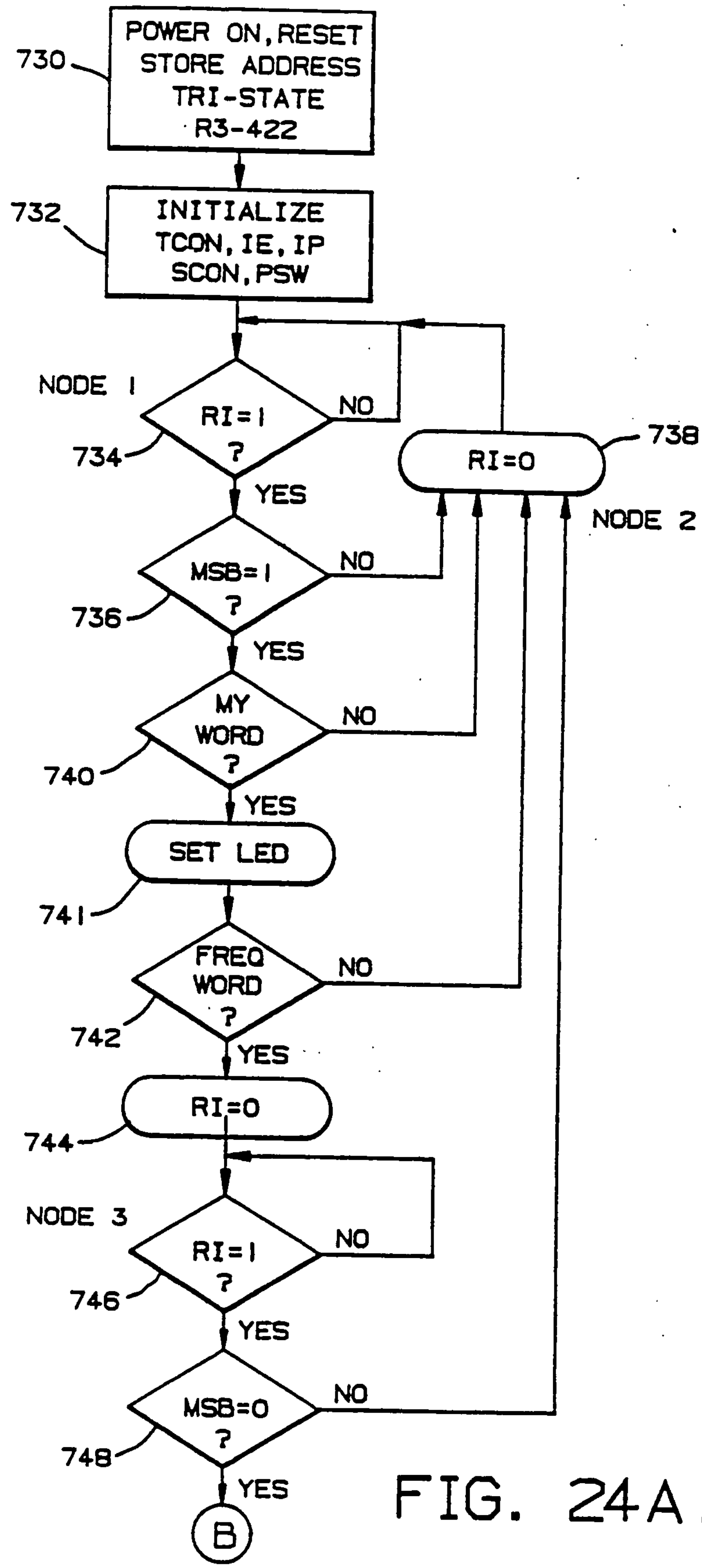

POWER ON, RESET
STORE ADDRESS
TRI-STATE
R3-422
730
INITIALIZE
TCON, IE, IP
SCON, PSW
732
NODE 1
RI=1
?
734
NO
YES
RI=0
738
NODE 2
MSB=1
?
736
NO
YES
MY
WORD
?
740
NO
YES
SET LED
741
FREQ
WORD
?
742
NO
YES
RI=0
744
NODE 3
RI=1
?
746
NO
YES
MSB=0
?
748
NO
YES
B

FIG. 24A.

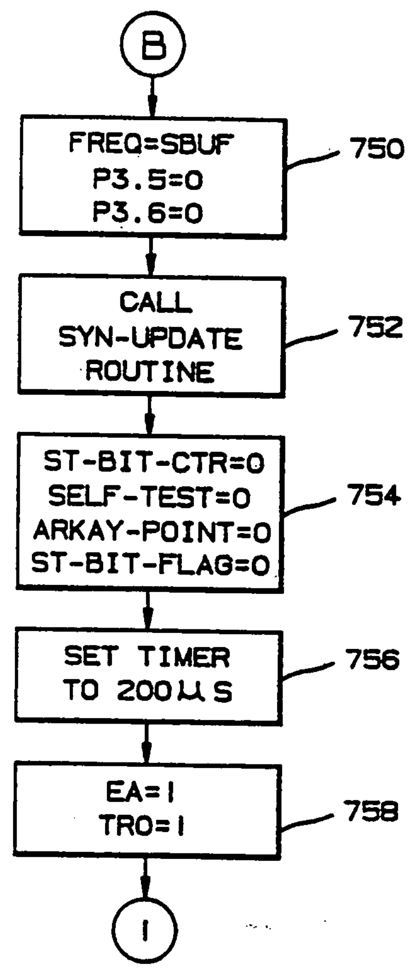

B
FREQ=SBUF
P3.5=0
P3.6=0
750
CALL
SYN-UPDATE
ROUTINE
752
ST-BIT-CTR=0
SELF-TEST=0
ARKAY-POINT=0
ST-BIT-FLAG=0
754
SET TIMER
TO 200μS
756
EA=1
TR0=1
758
1

FIG. 24B.

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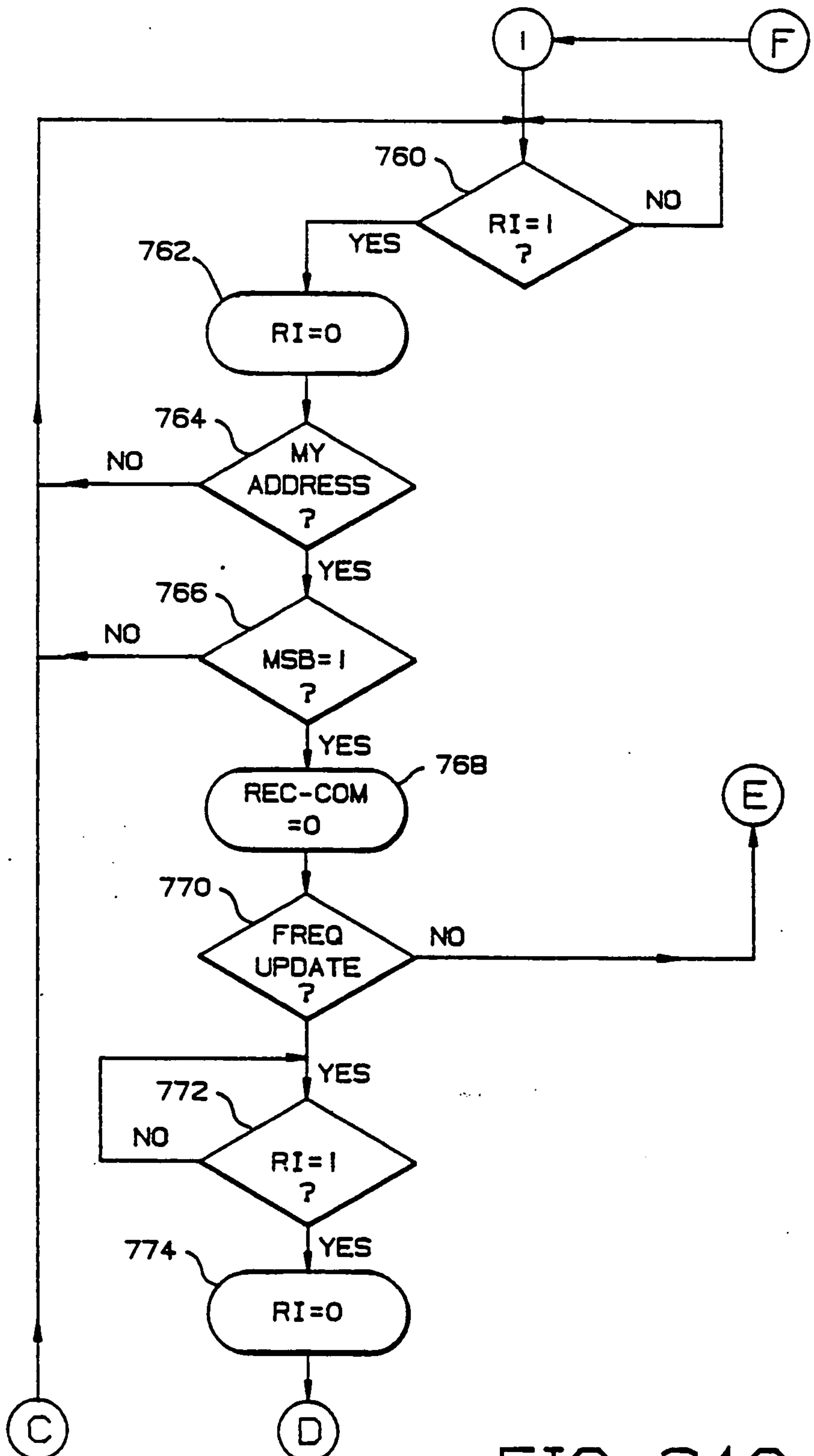

FIG. 24C.

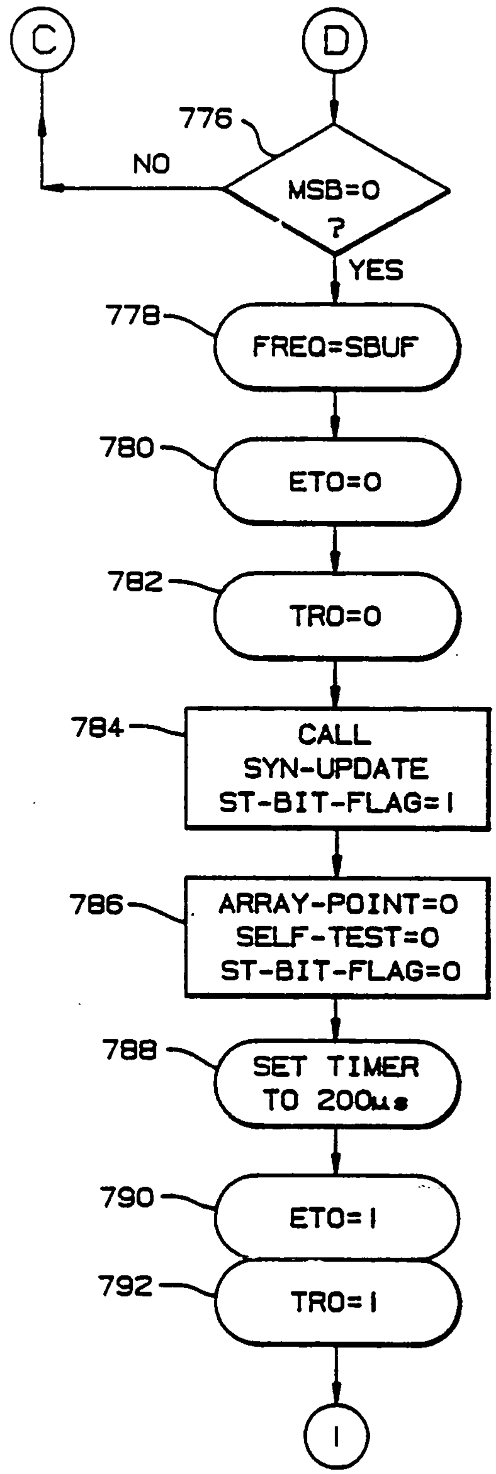
C
D
776
NO
MSB=0
?
YES
778
FREQ=SBUF
780
ETO=0
782
TRO=0
784
CALL
SYN-UPDATE
ST-BIT-FLAG=1
786
ARRAY-POINT=0
SELF-TEST=0
ST-BIT-FLAG=0
788
SET TIMER
TO 200us
790
ETO=1
792
TRO=1
I

FIG. 24D.

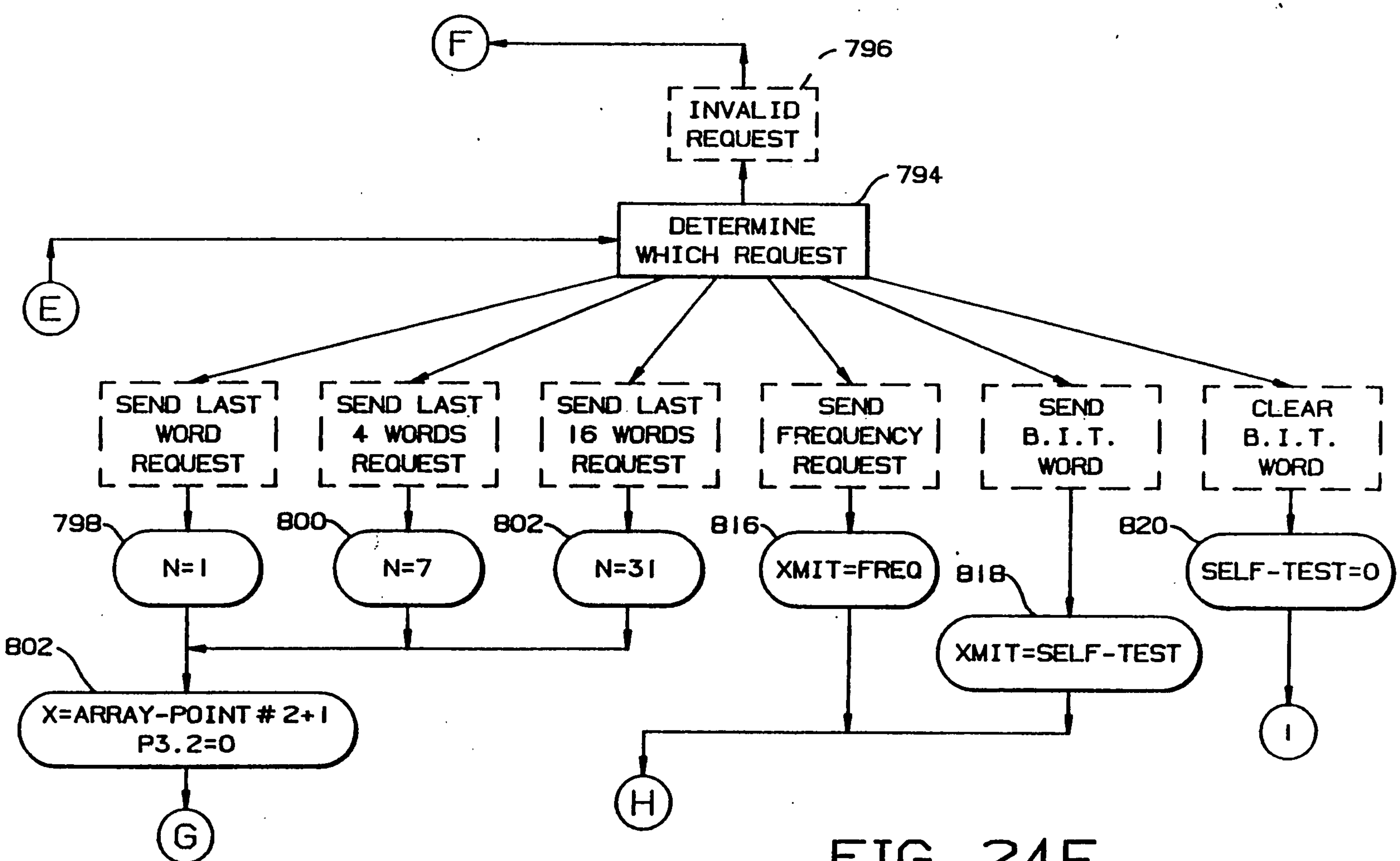
796
INVALID REQUEST
794
DETERMINE WHICH REQUEST
SEND LAST WORD REQUEST
SEND LAST 4 WORDS REQUEST
SEND LAST 16 WORDS REQUEST
SEND FREQUENCY REQUEST
SEND B.I.T. WORD
CLEAR B.I.T. WORD
798
N=1
800
N=7
802
N=31
816
XMIT=FREQ
818
XMIT=SELF-TEST
820
SELF-TEST=0
802
X=ARRAY-POINT # 2+1
P3.2=0
E
F
G
H
I

FIG. 24E.

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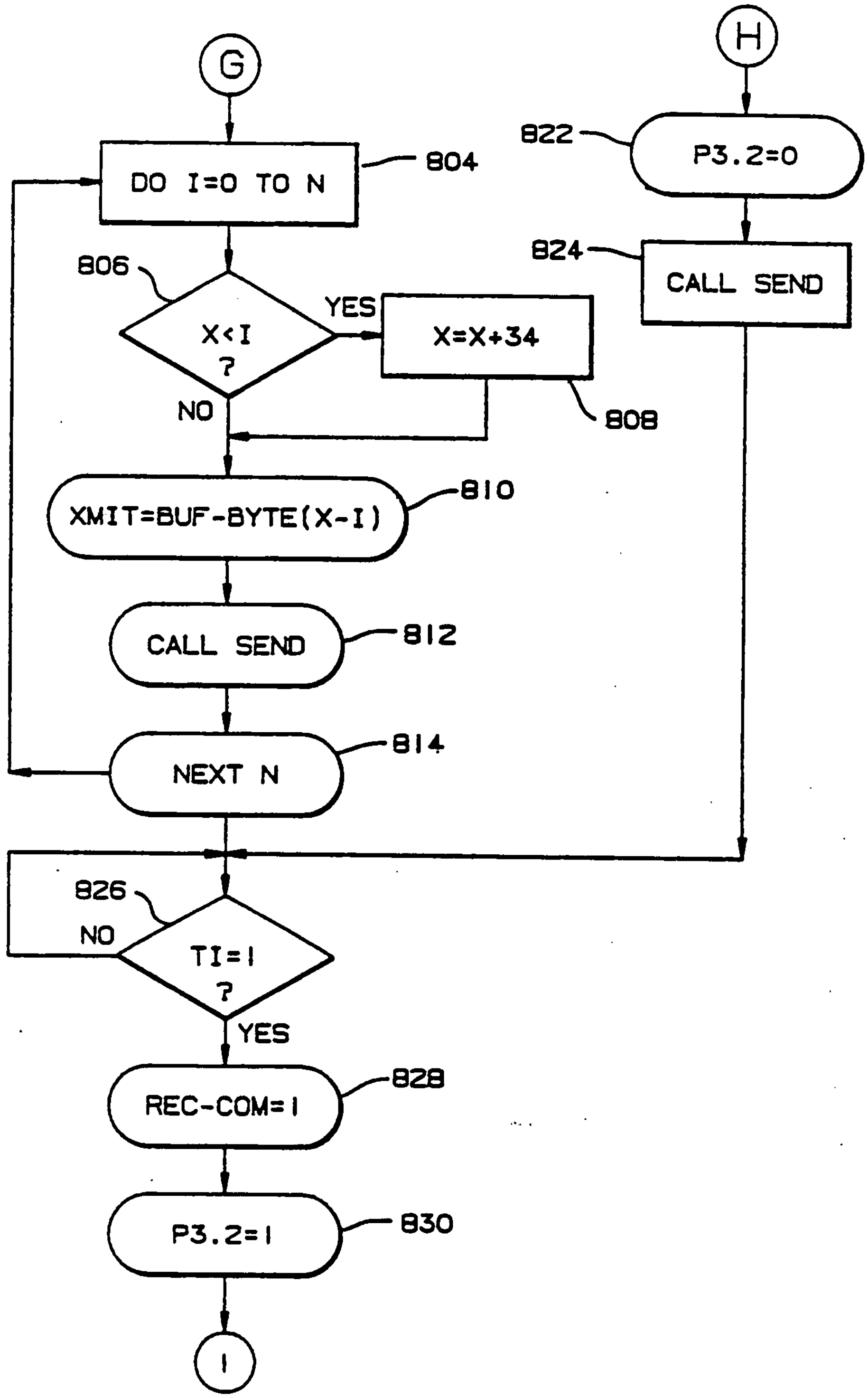

FIG. 24F.

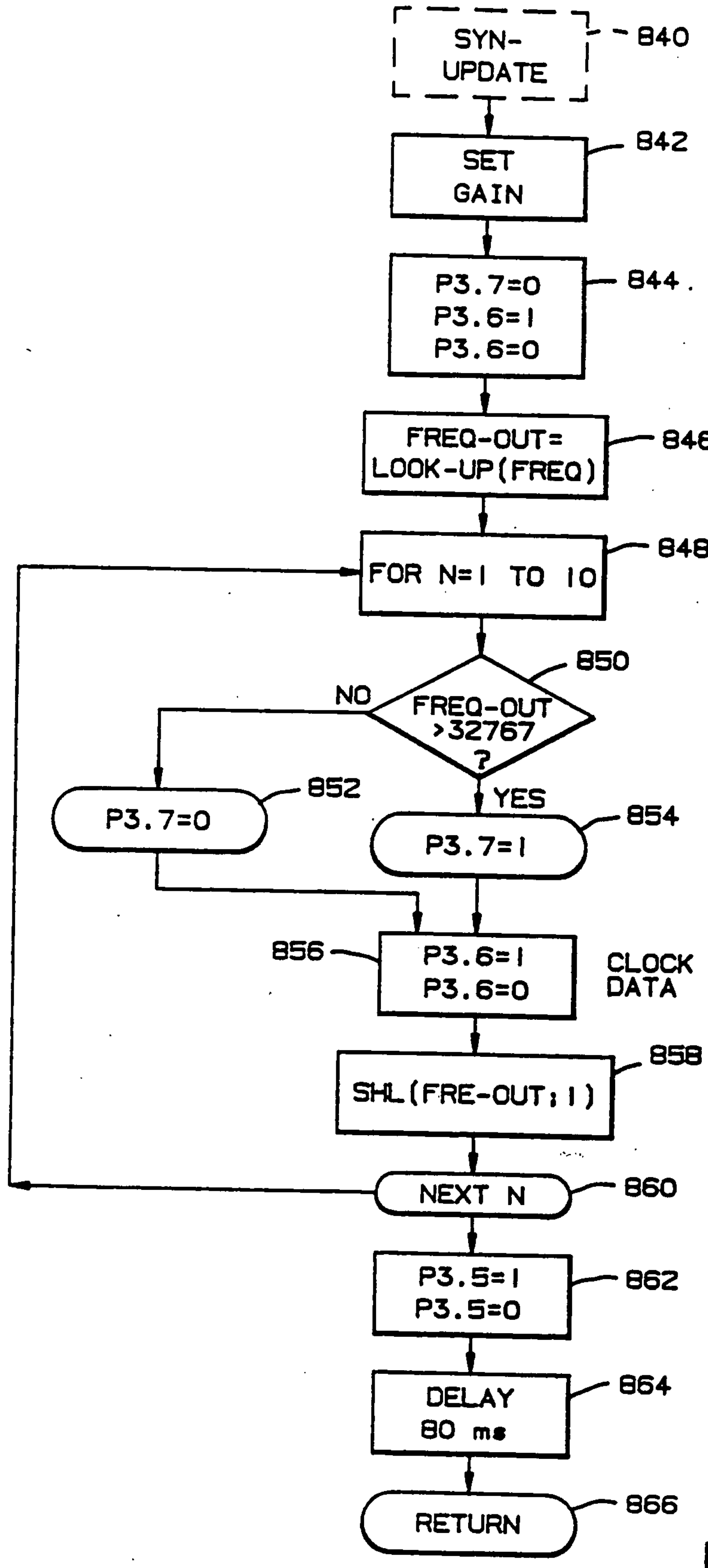
SYN-
UPDATE
840
SET
GAIN
842
P3.7=0
P3.6=1
P3.6=0
844
FREQ-OUT=
LOOK-UP(FREQ)
846
FOR N=1 TO 10
848
FREQ-OUT
>32767
?
850
NO
YES
P3.7=0
852
P3.7=1
854
856
P3.6=1
P3.6=0
CLOCK
DATA
SHL(FRE-OUT;1)
858
NEXT N
860
P3.5=1
P3.5=0
862
DELAY
80 ms
864
RETURN
866

FIG. 25.

0268492

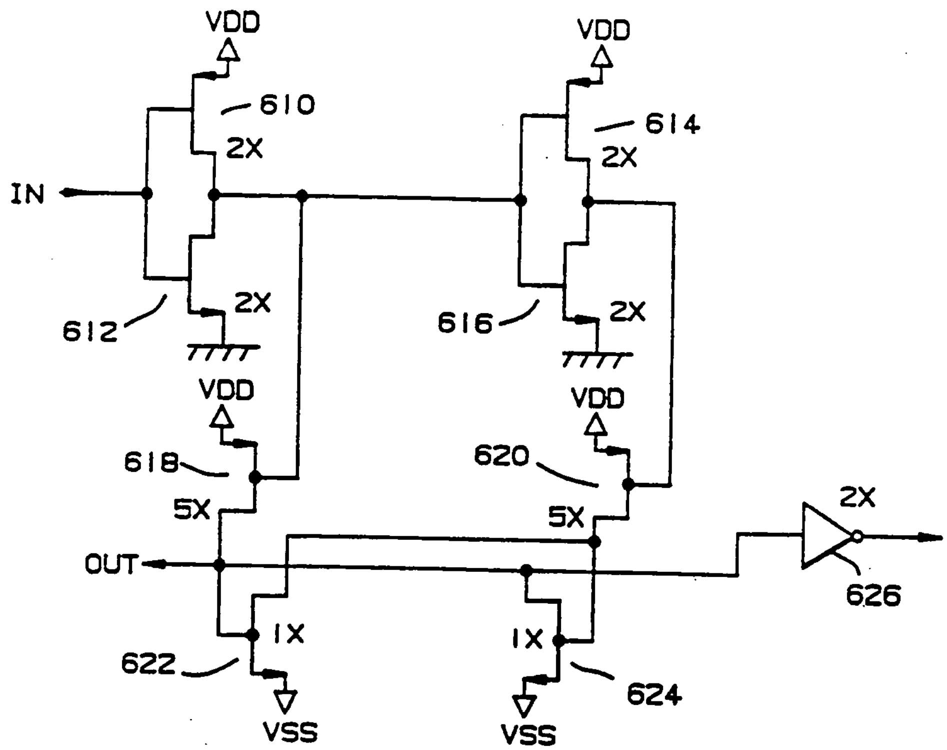

FIG. 19.

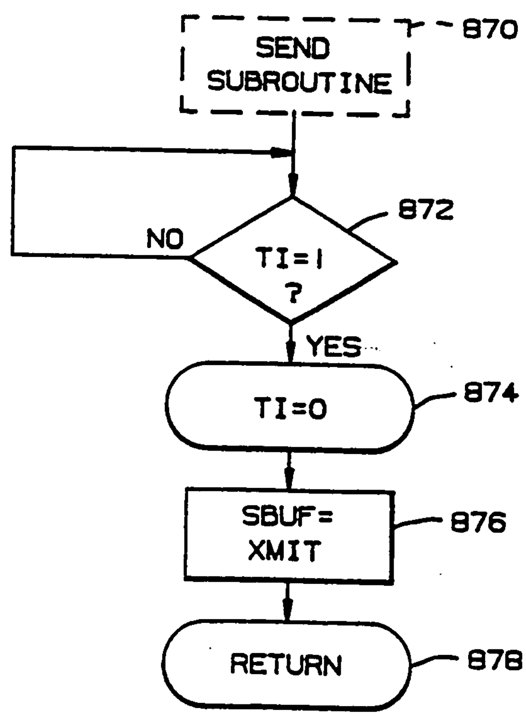

FIG. 26.

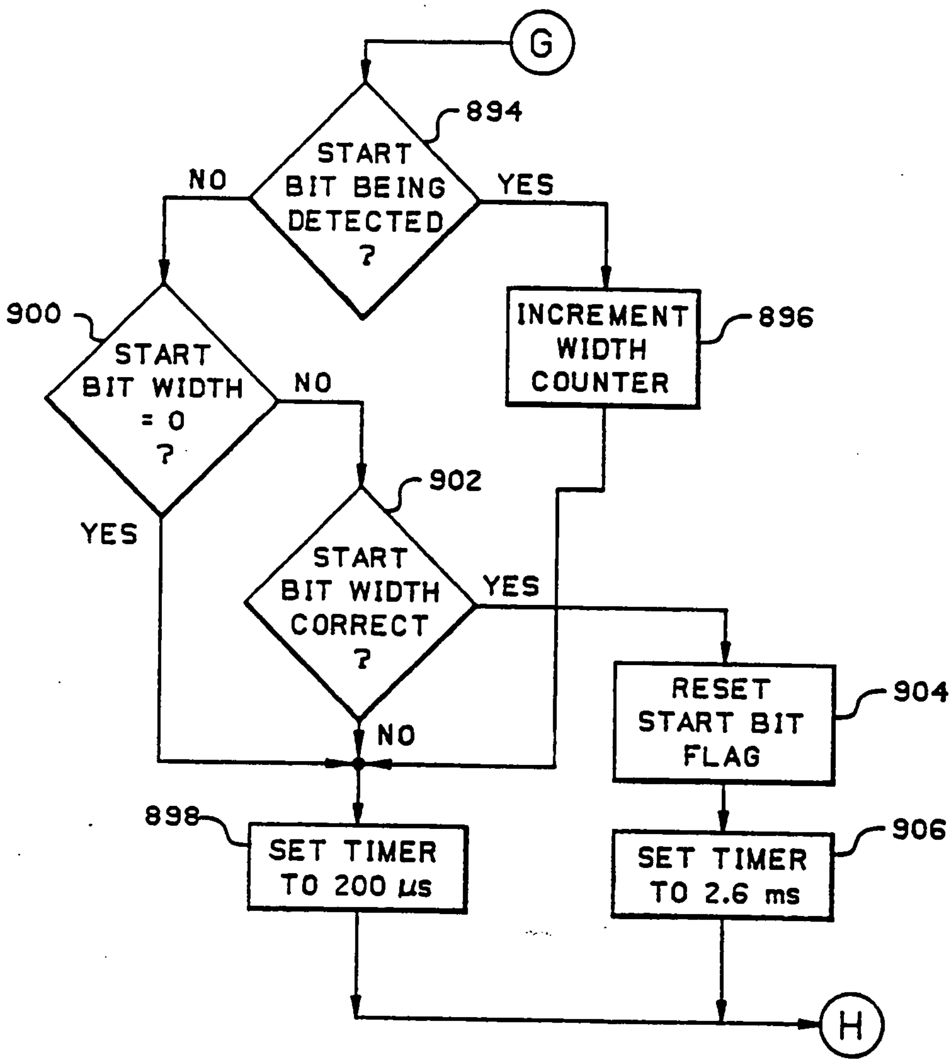
G
START BIT BEING DETECTED ?
894
NO
YES
INCREMENT WIDTH COUNTER
896
900
START BIT WIDTH = 0 ?
NO
YES
902
START BIT WIDTH CORRECT ?
YES
NO
RESET START BIT FLAG
904
898
SET TIMER TO 200 μs
SET TIMER TO 2.6 ms
906
H

FIG. 27A.

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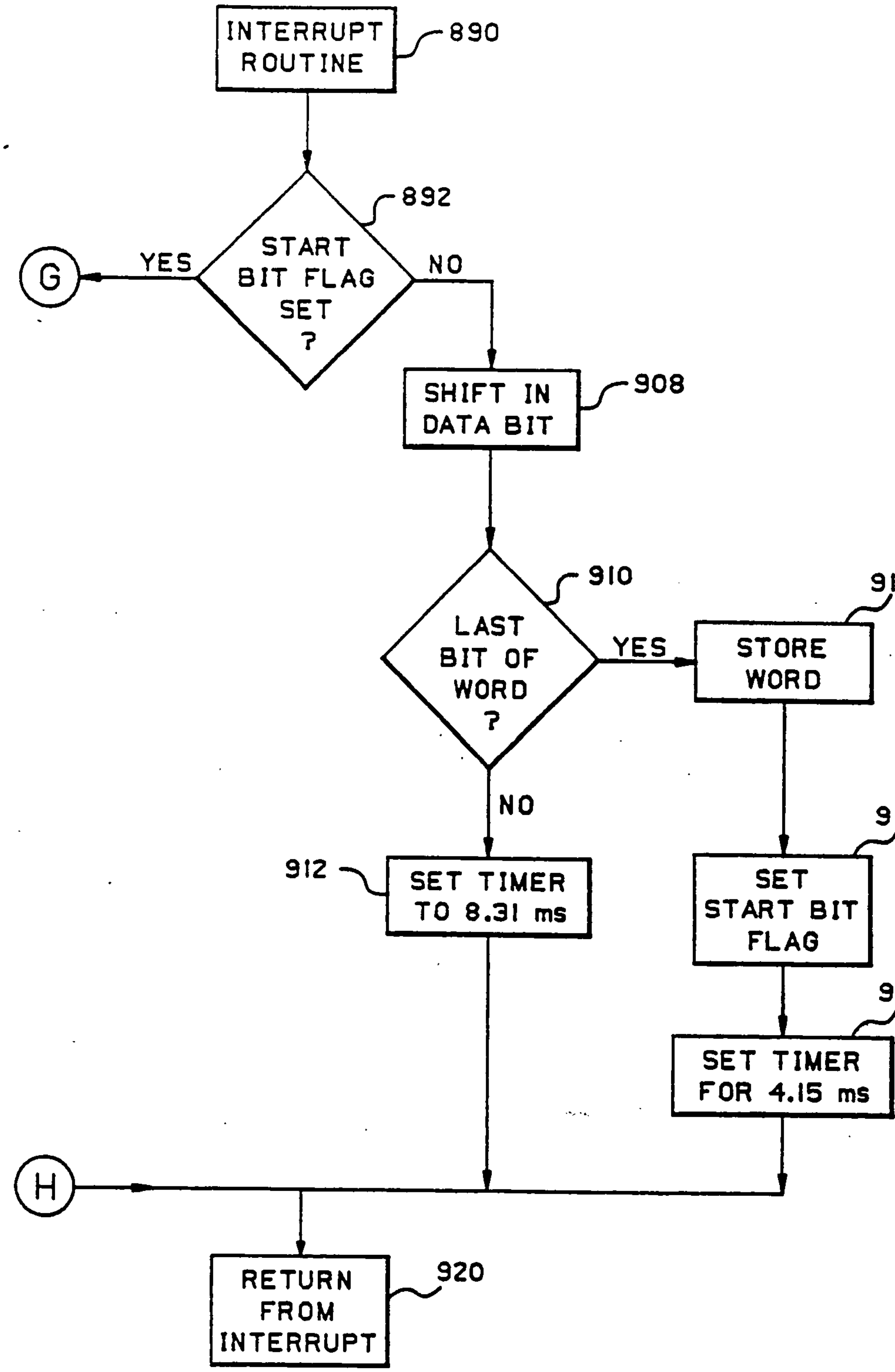
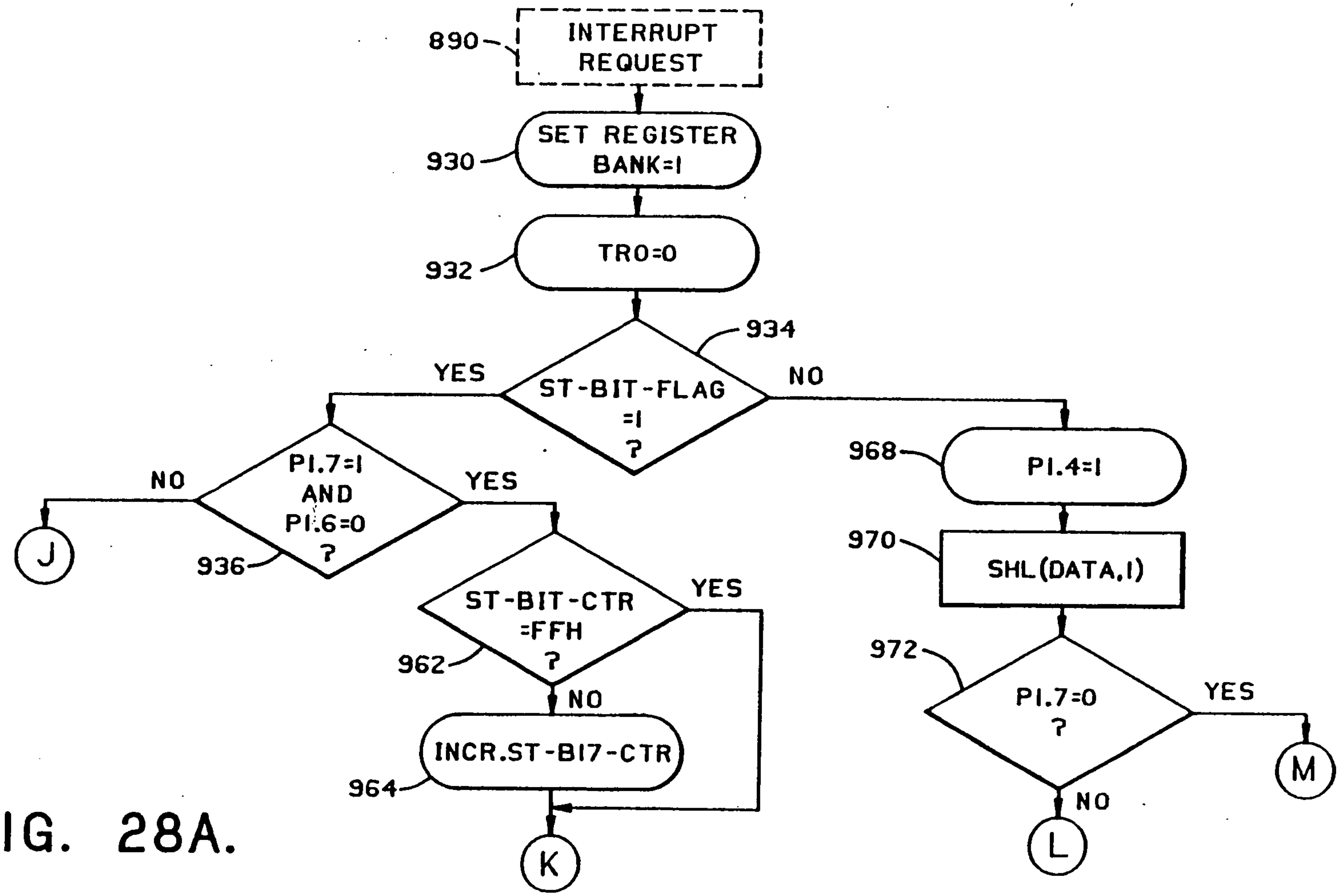


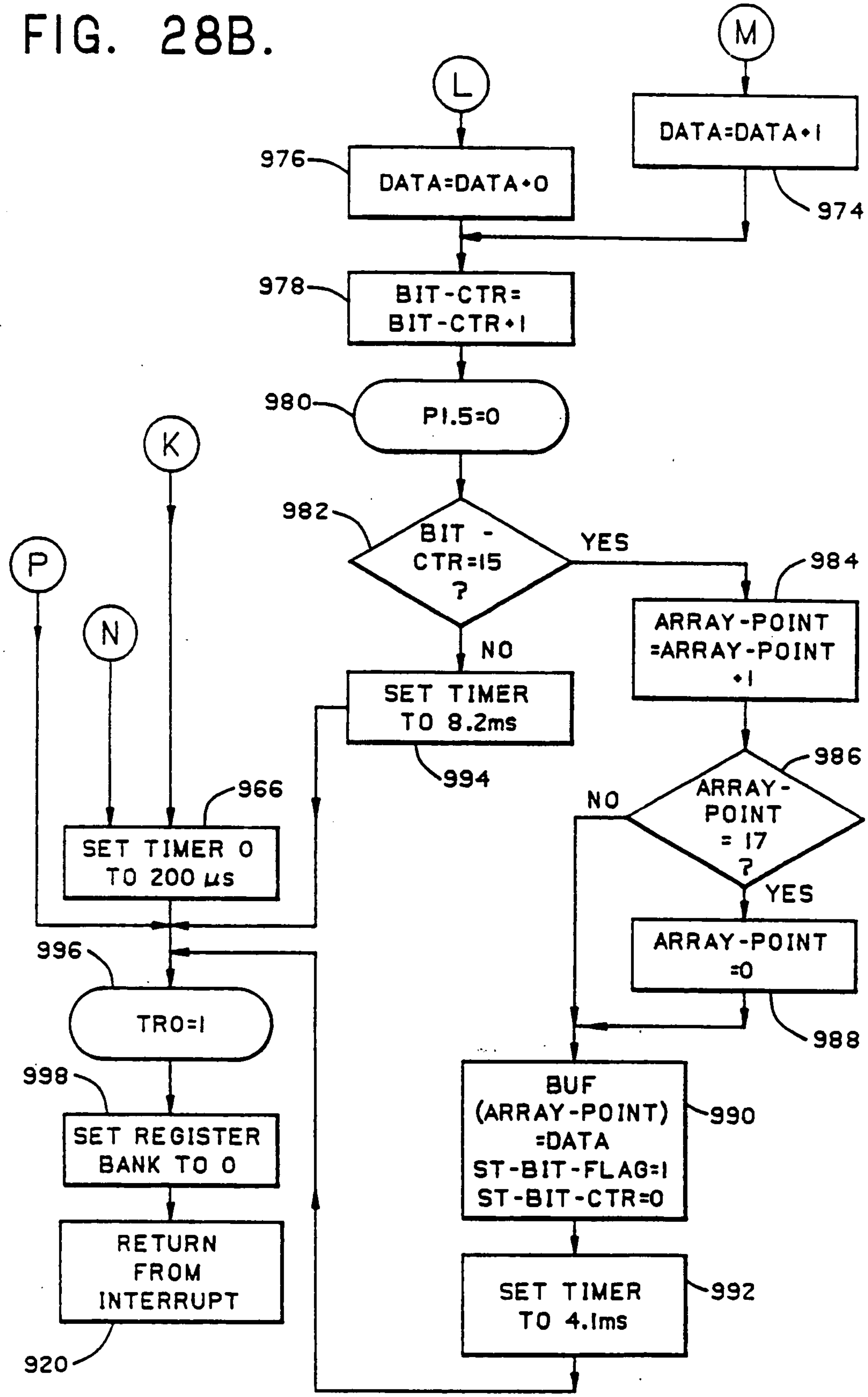
FIG. 27B.



INTERRUPT REQUEST
890
SET REGISTER BANK=I
930
TRO=0
932
ST-BIT-FLAG =I ?
934
YES
NO
PI.7=I AND PI.6=0 ?
936
NO
YES
J
ST-BIT-CTR =FFH ?
962
YES
NO
INCR.ST-BI7-CTR
964
K
PI.4=I
968
SHL(DATA,I)
970
PI.7=0 ?
972
YES
NO
M
L

FIG. 28A.

FIG. 28B.


L
M
DATA=DATA+1
974
976
DATA=DATA+0
978
BIT-CTR=
BIT-CTR+1
980
P1.5=0
K
982
BIT -
CTR=15
?
YES
984
P
N
NO
ARRAY-POINT
=ARRAY-POINT
+1
SET TIMER
TO 8.2ms
994
986
966
NO
ARRAY-
POINT
= 17
?
SET TIMER 0
TO 200 µs
YES
996
ARRAY-POINT
=0
TRO=1
988
998
BUF
(ARRAY-POINT)
=DATA
ST-BIT-FLAG=1
ST-BIT-CTR=0
990
SET REGISTER
BANK TO 0
RETURN
FROM
INTERRUPT
SET TIMER
TO 4.1ms
992
920

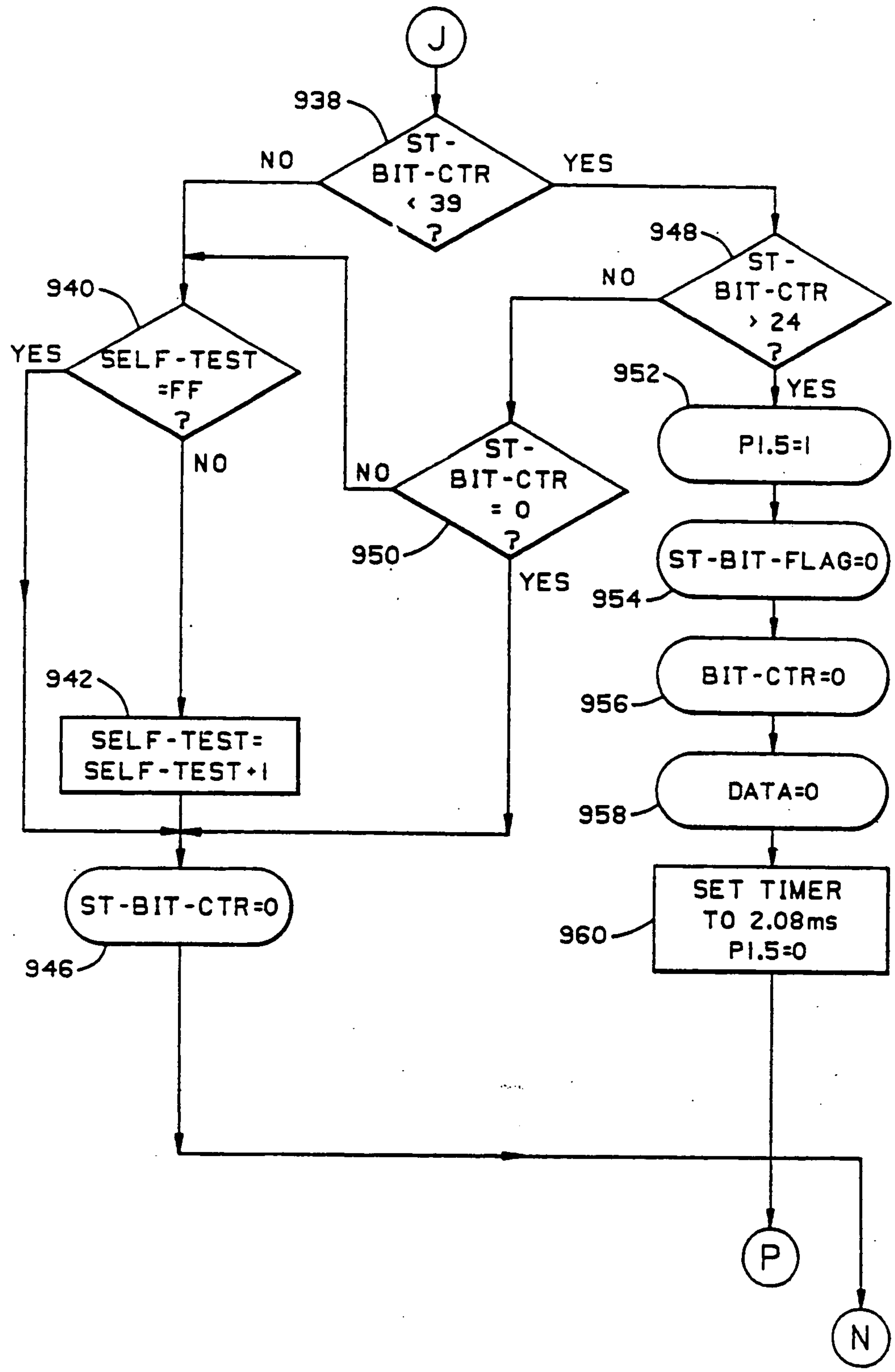

J
938
ST-BIT-CTR < 39 ?
NO
YES
948
ST-BIT-CTR > 24 ?
NO
YES
940
SELF-TEST =FF ?
YES
NO
950
ST-BIT-CTR = 0 ?
NO
YES
952
P1.5=1
954
ST-BIT-FLAG=0
956
BIT-CTR=0
958
DATA=0
960
SET TIMER TO 2.08ms P1.5=0
942
SELF-TEST= SELF-TEST+1
946
ST-BIT-CTR=0
P
N

FIG. 28C.

See c[illegible]umns 4,5,6,7.

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 483 549 A2**

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **91117072.8**

(22) Date of filing: **07.10.91**

(51) Int. Cl.[5]: **H04B 10/10**, H04B 10/22

(30) Priority: **29.10.90 US 605586**

(43) Date of publication of application: **06.05.92 Bulletin 92/19**

(84) Designated Contracting States: **DE FR GB**

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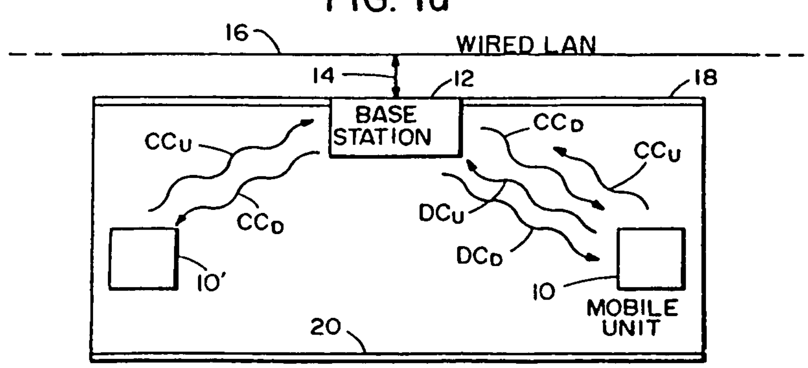
(54) **Control method and apparatus for a wireless data link.**

(57) Methods and apparatus for operating an optical communications system having at least two communicating entities (10,12). In accordance with a method of the invention a first step transmits communication link control information from a first entity to a second entity over a first optical channel having a first data bit rate. Responsive to the transmitted communication link control information, a second step of the method transmits data information from the second entity to the first entity over a second optical channel having a second data bit rate that is greater than the first data bit rate. The first optical channel is preferably a relatively low-bandwidth diffuse transmission infrared radiation channel. The second optical channel is preferably a relatively high-bandwidth infrared channel. One of the entities is a network adapter coupled to a wired network. The network adapter is preferably ceiling mounted. The other entity may be a mobile data processor. A plurality of mobile data processors may be served by one network adapter.

FIG. 1a



EP 0 483 549 A2

FIG. 1b

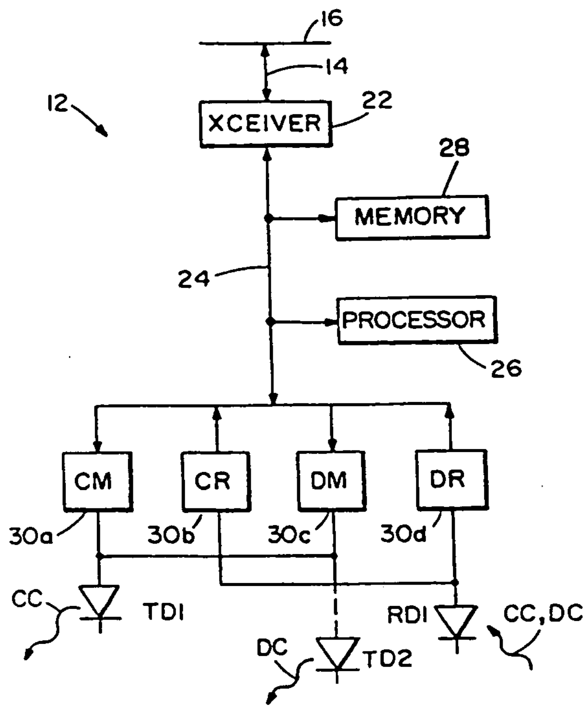
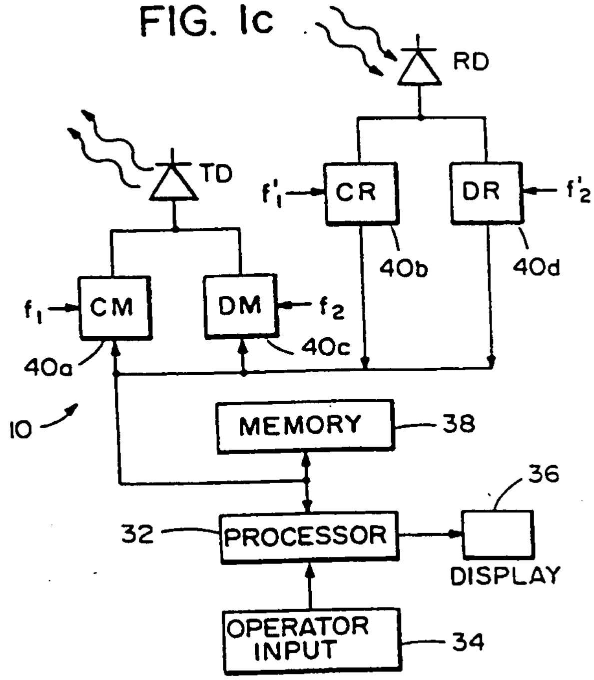

16
14
12
XCEIVER
22
28
MEMORY
24
PROCESSOR
26
CM
CR
DM
DR
30a
30b
30c
30d
CC
TD1
RD1
CC,DC
DC
TD2

FIG. 1c


RD
TD
f'1
CR
DR
f'2
40b
40d
f1
CM
DM
f2
40c
40a
10
MEMORY
38
36
32
PROCESSOR
DISPLAY
OPERATOR INPUT
34

This invention relates generally to data communication apparatus and method and, in particular, to a wireless communication system that employs a high speed data channel and a separate, lower speed diffuse transmission control channel for communicating information between one or more remote stations and a base station. In a preferred embodiment the remote stations are mobile, handheld workstations bidirectionally coupled to the base station(s) through an infrared radiation signal carrier.

A wireless data link provides a reliable, robust, and efficient means of transporting blocks of data from a mobile or handheld data processing workstation to a header or base station. The base station may be attached to a wired Local Area Network (LAN), such as an Ethernet network, and forms a connection into the LAN. The mobile workstation may employ standard, high-level network protocols, such as TCP/IP, to access the LAN. From the point of view of an operating system and application, programs running on the workstation transport over the wireless link occurs transparently.

Such a mobile wireless link, particularly one that employs infrared (IR) light as a communication medium, presents a communications reliability problem that is distinct from the problem of data transmission errors occurring at the bit level. As the mobile workstation is moved, or as optically opaque objects in the environment of the workstation move, the reception of optical signals transmitted between the mobile unit and the one or more base stations may be interrupted, strongly reduced by "shadowing" or corrupted by multi-path effects. Such an optical wireless link cannot therefore be treated as a reliable medium and specific provisions must be made for dealing with the inherent unreliability.

It is particularly desirable to avoid deadlock situations such as might arise when a connection is lost during a transaction. These can be resolved by timeout mechanisms, but this technique becomes burdensome if disconnection events occur frequently.

Problems related to signal processing and clock and bit recovery become progressively worse as the bandwidth of the wireless link is increased. This is due at least in part to admitting more noise into the receiver as a band-limiting filter is made wider and is also due to a need to compensate for inter-symbol interference as the data bit width approaches the rms delay spread of the multiple paths.

In IBM Technical Disclosure Bulletin, Vol. 20, No. 7, December 1977 F. Closs et al. describe the use of diffuse transmission of infrared signals for wireless communications between a controller and a plurality of terminals. Indirect links rely on infrared radiation that is diffusely scattered from walls and ceilings. The use of different wavelengths or different carrier frequencies is disclosed for separating channels.

In IBM Technical Disclosure Bulletin, Vol. 24, No. 8, page 4043, January 1982 F. Gfeller describe general control principles of an infrared wireless network incorporating multiple ceiling mounted transponders that couple a host/controller to multiple terminal stations. A downlink infrared channel operates at 200 kHz and an uplink infrared channel operates at 400 kHz. Access to the uplink channel is controlled by a Carrier Sense Multiple Access/Collision Detection (CSMA/CD) method.

In commonly assigned U.S. Patent 4,402,090, issued August 30, 1983, F. Gfeller et al. describe an infrared communication system that operates between a plurality of satellite stations and a plurality of terminal stations. A host computer communicates with the terminal stations via a cluster controller and the satellite stations, which may be ceiling mounted. Communication with the terminal stations is not interrupted even during movement of the terminal stations. In a disclosed embodiment a carrier frequency for the infrared link is 100 kHz and a data speed is 50 k Bit/s. Wired communication between the satellite and the cluster controller occurs at 1 M Bit/s.

What is not taught by the prior art is the provision of a robust control channel that is separate from a data channel. The utility of such a separate control channel becomes apparent from propagation studies of infrared links operating at high bandwidths (> 10 M Bits/s). These studies indicate that it may be difficult to sustain a continuously reliable link at such high bandwidths. Thus, if a control dialogue is also communicated over such a high-speed link frequent disconnections of the mobile workstation from the network can be expected to occur, resulting in an excessive overhead due to re-establishing the connection.

However, relatively low bandwidth links (< 50 k Bits/s) have been found to be extremely robust. That is, diffuse infrared propagation renders low bandwidth links less susceptible to loss of data.

It is therefore an object of the invention to provide a reliable and efficient infrared data communications network.

It is another object of the invention to provide an optical communication system that includes a separate control channel that has a lower bandwidth than a data channel.

It is a further object of the invention to provide an infrared communication system with a diffuse propagation channel for implementing a low-bandwidth control channel that is separate from a higher-bandwidth data transmission channel.

The foregoing and other problems are overcome and the objects of the invention are realized in advantageous manner by methods and apparatus for operating an optical communications system having at least two communicating entities as laid down basically in the independent claims.

In accordance with a method of the invention a first step transmits communication link control information from a first entity to a second entity over a first optical channel having a first data bit rate. Responsive to the transmitted communication link control information, a second step of the method transmits data information from the second entity to the first entity over a second optical channel having a second data bit rate that is greater than the first data bit rate.

The first optical channel is preferably a relatively low-bandwidth diffuse transmission infrared radiation channel. The second optical channel is preferably a relatively high-bandwidth infrared channel. One of the entities is a network adapter coupled to a wired network. The network adapter is preferably ceiling mounted. The other entity may be a mobile data processor.

In accordance with an embodiment of the invention the second optical channel transmits with a modulation spectrum within a range of approximately 400kHz to approximately 10MHz. That is, the second optical channel may be a high speed line-of-sight channel. The first optical channel transmits with a modulation spectrum within a range of approximately 2kHz to approximately 300kHz and relies on diffuse transmission from walls and ceilings within the environment to achieve a robust and reliable control channel that is separate from the higher speed and inherently less reliable data channel.

The above set forth and other features of the invention are made more apparent in the ensuing Detailed Description of the Invention when read in conjunction with the attached Drawing, wherein:

Fig. 1a is a block diagram showing a plurality of mobile units communicating with a base station;

Fig. 1b is a block diagram of the base station of Fig. 1a;

Fig. 1c is a black diagram of the mobile unit of Fig. 1a;

Fig. 2 shows a plurality of overlapping base station communication cells;

Fig. 3 shows a plurality of base stations disposed in separate rooms and not having overlapping coverage areas; and

Fig. 4 shows one embodiment of a transmission packet that is suitable for communicating command and data information between the mobile units and a base station.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1a depicts an embodiment of the invention wherein a mobile workstation, or data processing unit 10, is in bidirectional communication with a network adapter, or base station 12, over an optical radiation communications channel. The base station 12 is coupled via a connector 14 to a wired local area network (LAN) 16. As shown the base station 12 is disposed within or adjacent to a ceiling 18 and the mobile unit 10 is carried or is otherwise transported over a floor 20. Of course, the mobile unit 10 may be used in a stationary manner if desired. Ceiling mounting is not required for the base station 12 so long as there exists a substantially uncluttered transmission path between the base station 12 and the associated mobile unit or units 10.

In accordance with the invention communication between the mobile unit 10 and the base station 12 is accomplished through two discrete optical channels. Specifically, there is provided a relatively low-bandwidth, for example 50 k Bits/s, command channel (CC) and a relatively higher-bandwidth, for example 1 M Bit/s or higher, data channel (DC). An uplink command channel (CC_U), uplink being from the mobile unit 10 to the base station 12, has a carrier frequency or wavelength that is offset from a downlink command channel (CC_D), downlink being from the base station 12 to the mobile unit 10, by an amount sufficient to prevent collisions between uplink and downlink command messages. Similarly, an uplink data channel (DC_U) has a carrier frequency or wavelength that is offset from a downlink data channel (DC_D) by an amount sufficient to prevent collisions between uplink and downlink data messages.

The communications channels are carried via an infrared (IR) data link having a preferred wavelength of approximately 1.4 microns, although presently available optical devices readily provide for operation within the range of approximately 750 nanometers to approximately 1000 nanometers. In accordance with the invention the command channel is carried by a diffuse transmission lower bit-rate channel while the data channel is conveyed by a line-of-sight higher bit-rate channel. This permits the control channel of a mobile unit 10, including one that is just coming within range of a base station 12, to establish communication with the base station 12 and also possibly through a network to a host system, before reliable communication becomes feasible on the higher frequency data channel. The result is the provision of a reliable and efficient infrared data communications network, which is one expressed object of the invention.

Referring to Fig. 1b there is shown a simplified block diagram of the base station 12. The base station 12 is coupled to the LAN 16 via the connector 14. Connector 14 is coupled to a network adapter transceiver 22 which in turn is coupled to an internal bus 24. The base station 12 includes a processor 26 that is bidirectionally coupled to a memory 28 that stores program-related and other data, including packets of data transmitted to or received from the mobile units 10. Processor 26 also communicates with a plurality of modulators and receivers, specifically a control modulator 30a, a control receiver 30b, a data modulator 30c and a data receiver 30d. These IR modulators and receivers have inputs coupled to suitable infrared emitting or receiving devices such as laser diodes, LEDs and photodetectors. In the illustrated embodiment the control modulator 30a and the data modulator 30c both have an output coupled to a transmit diode 1 (TD1). In an alternate embodiment described below the data modulator 30c is not coupled to the TD1 but is instead coupled to a second transmit diode (TD2).

Referring now to Fig. 1c there is shown in block diagram form the mobile unit 10. Mobile unit 10 includes a processor 32 coupled to an operator input device 34 and also coupled to an operator display device 36. Operator input device 34 may be a keyboard or any suitable data entry means. Similarly, operator display device 36 may be a flat panel alphanumeric display or any suitable display means. Also coupled to processor 32 is a memory 38 that stores program-related data and other data, such as packets of information received from or intended to be transmitted to the base station 12 and also an identification of the mobile unit 10. Also coupled to processor 32 are a plurality of command and data modulators and receivers 40a-40d. In Fig. 1c it can be seen that the command modulator 40a (uplink) is provided with a first frequency f_1 while the command receiver 40b (downlink) is provided with a second frequency f_1' that is offset from f_1. Similarly, it can be seen that the data modulator 40c (uplink) is provided with a first frequency f_2 while the data receiver 40d (downlink) is provided with a second frequency f_2' that is offset from f_2. The data receivers of Figs 1b and 1c include demodulators and filters and operate in a conventional manner to extract the modulated bit stream from the received optical signals. Similarly, the modulators of Figs. 1b and 1c operate in a conventional manner to modulate the optical output in accordance with a transmitted bit stream.

In the embodiment of Fig. 1c both the command and data uplink information is transmitted via one transmit LED (TD) while the downlink command and data information is received by one receive photodetector (RD). If desired, separate transmit LEDS and receive photodetectors could be used for separately transmitting and receiving the control and the data information.

The wired LAN 16 may conform to any suitable network configuration. One suitable network protocol is known as TCP/IP, as described in detail in "Internetworking with TCP/IP Principles, Protocols, and Architectures" by Douglas E. Comer, Prentice Hall, New Jersey, 1988.

By example, the high bandwidth downlink data channel may operate at a wavelength of 900 nm and the uplink data channel may operate with a wavelength of 750 nm. Maximum output optical power for both is one Watt for a range of approximately five meters at a bit rate of from one to 10 Mbits/sec. The respective modulators may employ on-off pulsing, multi-carrier modulation or direct sequence spread spectrum modulation (DSSS), with the receivers including corresponding demodulating circuitry. DSSS is described in "Spread Spectrum in Communications", by Marvin K. Simon, Computer Science Press, Rockville, MD (1985).

Also by example, the low bandwidth downlink control channel may operate at a wavelength of 900 nm and the uplink control channel may operate with a wavelength of 750 nm. Output power for both is 10 mW for a range of 10 meters at a bit rate of 50 Kbits/sec. Manchester coding may be employed to obtain a DC null and modulation is preferably on-off although other techniques may also be employed.

Fig. 2 illustrates a plurality of the base stations 12 each of which is coupled to a wired LAN 16 which in turn is coupled to a host data processing system 50. The base stations 12 are disposed such that substantially symmetrical optical fields (42a-42d) associated with each are overlapping. Thus, it can be seen that certain of the plurality of mobile units 10 are contained wholly within a single one of the fields while the mobile unit 10a is disposed within an overlapping region 44 between the fields 42a and 42b. The mobile unit 10c is disposed within a region not covered by any of the base stations 12. During use, the mobile units 10 can be expected to move about within a given region and to travel from one region to another.

Fig. 3 illustrates another embodiment wherein the plurality of base stations 12 are each disposed within a separate enclosure or room (46a, 46b). In this embodiment there is no overlap between base station fields. So long as a mobile unit is within a room it is in communication with the associated base station 12. However, for those mobile units 10d which are illustrated to be within a hallway communication may be possible if properly aligned with a doorway or other opening into the enclosed area served by the base station 12.

Communication is preferably achieved by Time Division Multiple Access (TDMA) technique wherein a plurality of slots make up a frame. The frames are repeatedly transmitted and a given mobile unit 10 is assigned one or more specific slots within which to transmit or receive information. Fig. 4 illustrates one suitable slot 48 format that is similar to that disclosed in the before mentioned commonly assigned U.S. Patent 4,402,090. Specifically, a slot delimiter or synchronization (SYNC) field 48a is followed by a destination address field 48b and a source address field 48c. For an uplink message the destination address would be that of a base station 12 while the source address would be that of the transmitting mobile unit 10. In this regard each of the mobile units is assigned an identifier or address that typically corresponds to a network address. The mobile unit 10 addresses may be hardwired or otherwise preassigned. Preferably, the addresses are dynamically assigned when communication is established between the network and the mobile unit 10.

A next slot 48 field is a length field 48d which gives the length in bytes of the following data field 48e. For a command slot the data field will typically be substantially smaller than a data field 48e associated with a data slot. Following the data field 48e is a data integrity field, typically a CRC field 48f. A further slot delimiter is provided by a trailer field 48g. It should be realized that this format is exemplary only and that a number of suitable formats can be devised. For example, similar results can be achieved through the use of the before mentioned DSSS modulation.

Each slot on the wireless link may be a repacketized frame of the wired network protocol, for example, TCP/IP. The destination address field 48b is the address of the base station 12, possibly but not necessarily its' IP address. The source address field 48c is either the base station 12 address (downlink) or the mobile unit 10 address (uplink), also possibly but not necessarily the mobile unit's IP address.

In the optical communication system of the invention all wireless communication is between the base station 12 and the mobile units 10. There is no direct communication between the mobile units 10. The slotted TDMA method is employed for transmission in each direction. Frames of slots 48 are passed to or from mobile units 10 which are allocated specific slots according to an arbitration scheme performed by the base station 12.

The mobile wireless network thus far described must provide both media access control and data link control.

Media access control relates to arbitration among the group of mobile units 10 for uplink access to the wireless medium of the infrared data link. Control requirements are asymmetric with respect to the uplink and the downlink channels. In the system of the invention the uplink and downlink are carried on separate optical wavelengths, thus avoiding collision.

Typical control events that are conveyed between the mobile unit 10 to the base station 12 upon the lower bandwidth CC_U channel may include, but are not limited to, the following.

a) Establishment of connection with the base station 12, that is, becoming a member of the base unit's mobile unit group.

b) Authentication of the mobile unit's identity.

c) Request for access to the medium, when the mobile unit 10 has one or more slots to transmit. This involves an arbitration performed by the base station 12 among those members of the associated mobile unit group having slots to transmit. These mobile units may also be referred to as "active members".

d) Deletion of access to the medium at the end of a transmission or if the mobile unit 10 "disappears" or disconnects.

e) Control of optical power or of data transmission rates to accommodate a close approach to the base station 12 by the mobile unit 10 or to permit lowered transmission rates when the signal path is shadowed. By example, it may be desirable to reduce transmitted power within a certain radius of the base station 12 in order to prevent overdriving the CR 30b.

f) Allocation of slot 48 for the uplink data transmission.

g) Re-transmission of uplink slots found to have transmission errors.

h) A request to the mobile unit 10 to temporarily suspend transmission.

i) A request to the mobile unit 10 to discard any data that remains to be transmitted.

In regard to downlink control events it is noted that there is no requirement for downlink media access control, since only the base station 12 uses the downlink channel, whereas the uplink channel must be shared by all of the mobile units within the associated group. It is assumed that the base station 12 avoids transmitting slots to mobile units which are not members of the base unit's group. That is, the base station 12 will only transmit to mobile units 10 with which the base station 12 has an established link. For the downlink path therefore, the mobile unit 10 need only recognize slots 48 having the mobile unit's address within the field 48b.

Other downlink control events that are conveyed from the base station 12 to the mobile unit 10 upon the CC_D channel may include, but are not limited to, the following.

a) Notification of an intention to transmit to a specific mobile unit 10 (n) slots of information.

b) Notification of the end of the transmission.

Uplink responses to these control events from the mobile unit 10 to the base station 12 include the following.

a) Acknowledgement of the receipt of a slot.

b) A request for re-transmission of a slot.

c) A request for a temporary suspension of data transmission due to, for example, a buffer full condition.

d) A request for a more rapid transmission of slots. A base station 12 response to this uplink control event may be to allocate more time slots 48 within a frame to the requesting mobile unit 10.

e) A request for a less rapid transmission of slots. A base station 12 response to this uplink control event may be to allocate fewer time slots 48 within a frame to the requesting mobile unit 10.

The above mentioned uplink and downlink control events and responses are substantially independent of the wireless network implementation. For example, the control messages could be carried in the same bit stream as the packets of data. However, when high bandwidth data channels are required the inherent unreliability of such a high bandwidth channel makes the inclusion of control information on the channel disadvantageous for the reasons previously discussed.

In summary, the wireless optical network taught by the invention overcomes the problem of establishing and maintaining high-bandwidth communication via an unreliable medium by separating the control channel from the data channel. In that the control channel requires a much smaller bandwidth than the data channel the propagation problems mentioned above are avoided. The control channel bandwidth can be made significantly smaller because, at most, one control message per data slot is required with the required control message being, at most, but a few hundred bits as compared to several thousand for a typical TCP/IP frame. Also, by employing a slotted TDMA transmission method with preassigned slots control messages are only required to initially establish a transmission and, thus, the number of control messages per transmitted slot may be less than one.

Other advantages made possible by the teaching of the invention include but are not limited to the following.

The low-bandwidth diffuse IR optical link may have greater range or sensitivity whereas the broad-band data channel optics are preferably made directional and require line-of-sight access to the base station 12 in order to maximize the received signal strength and to reduce multi-path propagation problems. As such, the communication link establishment process may be begun early in the approach of the mobile unit 10 to the base station coverage region. For example, in Fig. 2 the mobile unit 10e may begin the link establishment procedure at the indicated position while not yet within but approaching the data coverage region 42d of the associated base station 12.

Also, the longer-range diffuse IR control channel enables the control channel to maintain contact as the mobile unit 10 moves out of range of the base station 12, thereby permitting a more controlled handoff mechanism.

A handoff procedure is disclosed in copending and commonly assigned U.S. Patent Application Serial No. 07/605,720, filed 29 October 1990, entitled "Handoff Method and Apparatus for Mobile Wireless Workstations" by Colin Harrison (IBM's Docket No. YO990-053).

Another advantage of the use of the separate low-bandwidth control channel is that it enables the mobile units 10 and the base station 12 to maintain contact temporarily even though the data channel is lost due to a momentary obstruction. This substantially reduces the communication overhead involved in losing a connection and then reestablishing it. This latter problem may be one of the limiting features of a wireless mobile network and is avoided if possible.

Furthermore, the control channel transmission rate can remain fixed while the data channel transmission rate may increase due to advances in network adapters and components. Thus, adapters with different data link speeds are enabled to coexist within a network.

The separate control channel can also be employed as a simplified connection method for low-cost, low-bandwidth devices, such as simple printers, where the additional cost for high-bandwidth data channel devices may not be justified. In Fig. 1 the unit 10' may be such a printer that communicates with the wireless network only through the low-bandwidth CC_U and CC_D channels. Of course, a printer may be fixed in a given position within a base station 12 coverage area and not moved about, although no such restrictions are placed upon printer position.

Preferably the data channels occupy the modulation spectrum above 400kHz and extend up to 1-10 MHz. The control channels occupy the modulation spectrum from approximately two kHz to approximately 300 kHz. In the embodiment of Fig. 3 the control and data channel signals are separated after the photodetector RD by electrical filtering. Each channel has its own receiver. Due to the lower bandwidth the control channel receiver (CR 40b) is less complex than the data channel receiver (DR40d). However, the data channel control logic is less complex than that of the control channel since only address recognition is required.

In operation, a mobile unit 10 seeking a base station 12 transmits a request for connection on the control channel by using maximum optical power. Since the control channel is separate from the data channel, this asynchronous transmission does not interfere with uplink data transmission that may be in progress between the base station 12 and another mobile unit 10, although it may interfere with ongoing uplink control signals being generated by another mobile unit 10.

The access mechanism for the uplink control channel is preferably a relatively simple ALOHA protocol of a type known in the art. This permits asynchronous requests for connection by an approaching mobile unit 10 to be handled in the same manner as requests from the existing group members. To improve the "fairness" of the ALOHA access under near/far conditions, the mobile units 10 have controllably variable power levels for the control signal transmission.

After the new mobile unit 10 is added to the base station 12 group the newly added member of the group is enabled to exchange control messages with the base station 12 using the uplink and downlink control channels.

The downlink control channel is broadcast to all mobile units within the group and the control slot 48 address field 48b enables only the addressed mobile unit(s) to identify their control messages. The downlink data channel is also broadcast to all mobile units within the group and the corresponding data slot 48 address field 48b enables only the addressed mobile unit(s) to identify their data streams.

The newly added mobile unit 10 synchronizes with the data link slot sequence by being assigned one slot number by the base station via the control channel. Thereafter the mobile unit 10 is expected to internally keep track of slot numbers, although it can request to be assigned a slot any number of times. The uplink and downlink paths employ the same set of slot numbers. A mobile unit 10 which has been authorized to use the uplink path waits for the beginning of its' authorized slot before sending data. A mobile unit 10 which has been instructed, via the control channel, to expect one or more packets of data from the downlink waits for the specified slot to occur and then begins to capture the information conveyed by that slot. A mobile unit can thus receive and transmit using a single assigned control or data slot.

The base station 12 buffers within the memory 28 data received from the wired network or from the uplink data channel. Data packets are transmitted in the order received within specified priority levels. The base station 12 refrains from transmitting except when it has data or control information to broadcast.

Implementation of the diffuse command channel in the receiver and transmitter of the mobile unit 10 and base station 12 depends strongly on the optical collection mechanisms employed for the high-speed data channel. The data channel preferably has some directionality associated therewith to overcome multi-path effects and to increase light collection. If optical devices such as lenses or mirrors are employed, which tend to reduce the acceptance angles of the transmitters and detectors, insufficient diffuse infrared light may be produced or received when a line-of-sight relationship does not exist between the mobile unit 10 and the base station 12.

To overcome this problem it is desirable to employ for the diffuse control channel separate infrared transmitters and detectors that do not use optical devices to narrow the field of view. The two channels (control and data) then have separate receivers. Preferably the control channel receiver (30b or 40b) uses a bandpass filter to exclude ambient light noise below 300 kHz and the data channel signals above 1 MHz. The data channel receiver (30d or 40d) uses a bandpass filter from approximately 400 kHz up to, for example, 20 MHz.

Since the control channel transmission rate is relatively low (50 k Bit/s) the associated receiver and clock recovery requirements are relatively simple; although a finite state machine or similar means may be required to achieve real-time link control. Since the data channel transmission rate is high, for example 10 M Bit/s, the associated receiver and clock recovery requirements are more complex. However, the data channel requires only a relatively simple finite-state machine or similar means to recognize the associated address. If separate infrared emitters, such as TD1 and TD2, are employed it is preferable to include bandlimiting filters to match the characteristics of the associated receivers. In this case it is also desirable to employ different wavelengths for the control and data links. This results in a total of four wavelengths for implementing the wireless link, that is, two each for the uplink and the downlink paths.

If the acceptance angles of the transmitters and detectors are not too narrow it may be preferable to connect the two receivers to the same detector and the two transmitters to the same emitter, as depicted in Fig. 1c.

Other advantages made possible by the teaching of the invention include the following.

In that the collision resolution of media access takes place in the control channel, and since the mobile unit 10 and the base station 12 agree on data channel slot usage, slots in the data channel are never wasted by collisions. In principle every data channel slot can be effectively used, thus achieving the highest efficiency.

On leaving the coverage region of a base station 12 the mobile unit 10 is enabled to signal its departure on the command channel to the base station 12, rather than simply "disappearing". This gives the base station 12 an opportunity to begin buffering or redirecting frames addressed to the departing mobile unit 10. Details of this procedure are disclosed in the aforementioned commonly assigned U.S. Patent Application Serial No. 07/605,720, filed 29 October 1990, entitled "Handoff Method and Apparatus for Mobile Wireless Workstations" by Colin Harrison (IBM's Docket No. YO990-053).

Furthermore, the separation of the control channel from the data channel enables network adapters having various data channel transmission and receive rates to coexist. The control channel, having standardized transmission and receive rates, provides a means for the mobile unit 10 and the base station 12 to determine the data transmission rate.

It is noted that control functions associated with the command and data channels, and also other logic required to operate the wireless link, may be implemented in software executed by the processors 26 and 32. Alternately special purpose logic may be incorporated to realize these functions or some combination of these approaches may be employed. For some applications the processor and modulator and receiver circuits may all be implemented within a suitably programmed digital signal processor integrated circuit.

Although the invention has been described thus far in the context of separately employed uplink and downlink channels having differing propagation characteristics it should be realized that various permutations of same are also within the scope of the teaching of the invention.

For example, in a situation where the data channel is inoperable due to, for example, an obstruction within the line-of-sight between the base station 12 and a mobile unit 10, data transmission can be made to "fall-back" to the diffuse transmission channel. Although the transmission rate may be appreciably slower, the link to the LAN 16 is not broken. Such a fall-back situation can be readily signalled from the base station 12 to the mobile unit 10 via a downlink control channel event after which the mobile unit 10 interprets subsequent diffuse channel receptions as data instead of command information.

As another example, for an application where uplink data transmissions are expected to be infrequent and of short duration the high speed uplink channel can be eliminated altogether and all uplink traffic, both command and data, is conveyed by the low speed diffuse channel. One such application is where the primary source of uplink data is expected to be keystrokes generated by an operator of the mobile unit 10. For this case the high bandwidth uplink channel may be eliminated without significantly impacting response time or other user-noticeable system functionality.

Thus, while the invention has been particularly shown and described with respect to a preferred embodiment thereof, it will be understood by those skilled in the art that changes in form and details may be made therein without departing from the scope and spirit of the invention.

Claims

1. A method of operating an optical communications system having at least two communicating entities, comprising the steps of:

   transmitting communication link control information from a first entity to a second entity with a first optical channel having a first data bit rate; and

   responsive to the transmitted communication link control information, transmitting data information from the second entity to the first entity with a second optical channel having a second data bit rate that is greater than the first data bit rate.

2. Method as set forth in Claim 1 wherein the first optical channel is a diffuse transmission infrared radiation channel and wherein the second optical channel is a line-of-sight infrared radiation channel.

3. Method as set forth in Claim 1 or 2, further comprising the steps of receiving the transmitted data information with the first entity and retransmitting the received data information from the second entity to a conductor coupled to a communications network.

4. Method as set forth in Claim 1, 2 or 3, further comprising the steps of:

transmitting communication link control information from the second entity to the first entity with the first optical channel; and

responsive to the transmitted communication link control information, transmitting other data information from the first entity to the second entity with the second optical channel, the step of transmitting the other data information including the initial steps of receiving the other data information from the network with the first entity; and buffering the received other information within the first entity.

5. Method as set forth in anyone of the preceding Claims, wherein the second optical channel transmits with a modulation spectrum within a range of approximately 400kHz to approximately 10MHz and wherein the first optical channel transmits with a modulation spectrum within a range of approximately 2kHz to approximately 300kHz.

6. Method as set forth in anyone of the preceding Claims, wherein the first and the second optical channels each employ a TDMA technique having a repetitively transmitted data frame comprised of a plurality of slots, each slot comprising a plurality of fields including a data field.

7. Method as set forth in Claim 6 wherein the step of transmitting communications link control information includes a step of transmitting an identification of at least one slot that is assigned to the second entity for transmitting the data information therein.

8. An optical communication system comprising at least one network adapter means coupled to a network, said network conforming preferably to a TCP/IP protocol, and at least one data processing means optically coupled through a wireless link to the network adapter means, wherein the network adapter means and the data processing means each comprise means for transmitting and receiving information with one another through a first, diffuse transmission infrared radiation channel at a first bit rate, and wherein the network adapter means and the data processing means each further comprise means for transmitting and receiving information with one another through a second infrared radiation channel having a second bit rate that is greater than the first bit rate.

9. An optical communication system as set forth in Claim 8 wherein the network adapter means and the data processing means each comprise means for transmitting and receiving wireless link control information with one another through the first, diffuse transmission infrared radiation channel, and wherein the network adapter means and the data processing means each also comprise means for transmitting and receiving data information with one another through the second infrared radiation channel having the second bit rate.

10. An optical communication system as set forth in Claim 8 or 9 wherein the second infrared radiation channel transmits with a modulation spectrum between approximately 400kHz to approximately 10MHz and wherein the first, diffuse transmission infrared channel transmits with a modulation spectrum within the range of approximately 2kHz to approximately 300kHz.

11. An optical communication system as set forth in Claim 8, 9 or 10, wherein the network adapter means and the data processing means each comprise means for transmitting and receiving wireless link control information with one another through the first, diffuse transmission infrared radiation channel with a slotted TDMA protocol, and wherein the network adapter means and the data processing means each also comprise means for transmitting and receiving data information with one another through the second infrared radiation channel also with the slotted TDMA protocol.

12. An optical communication system as set forth in Claims 8, 9, 10 or 11, wherein the network adapter means and the data processing means each comprise means for buffering data information transmitted to or received from the wireless link.

13. An optical communication system as set forth in anyone of the Claims 8 to 12 and comprising a plurality of network adapter means each coupled to the network, each network adapter means being operable for communicating with one or more associated data processor means.

14. An optical communication system as set forth in Claim 8 or anyone of the Claims 9 to 13, wherein the data processing means includes a single infrared transmitting means for transmitting both the first, diffuse transmission infrared radiation channel and also the second infrared radiation channel.

15. An optical communication system as set forth in Claim 8 or anyone of the Claims 9 to 13, wherein the data processing means includes a first infrared transmitting means for transmitting the first, diffuse transmission infrared radiation channel and further includes a second infrared transmitting means for transmitting the second infrared radiation channel.

16. An optical communication system as set forth in Claim 8 or anyone of the Claims 9 to 15, wherein the data processing means includes a single infrared receiving means for receiving both the first, diffuse transmission infrared radiation channel and also the second infrared radiation channel.

17. An optical communication system as set forth in Claim 8 or anyone of the Claims 9 to 15, wherein the data processing means includes a first infrared receiving means for receiving the first, diffuse transmission infrared radiation channel and further includes a second infrared receiving means for receiving the second infrared radiation channel.

18. In a wireless infrared link communication system comprising at least one network adapter means coupled to a network and a plurality of data processing means optically coupled through the wireless infrared link to the network adapter means, a method of communicating between the network adapter means and each of the data processing means comprising the steps of:

transmitting and receiving communication control information through a first, diffuse transmission infrared radiation channel having a first bandwidth; and

responsive to received communication control information, transmitting and receiving data information with one another through a second infrared radiation channel having a second bandwidth that is higher than the first bandwidth.

19. In a wireless infrared link communication system comprising at least one network adapter means coupled to a network and a plurality of mobile data processing means optically coupled through the wireless infrared link to the network adapter means, a method of establishing communication between the network adapter means and one of the mobile data processing means, comprising the steps of:

before the mobile data processing means comes within operable communication range of a first infrared data transmission channel,

transmitting and receiving communication control information through a second, diffuse transmission infrared radiation channel; the control information including information for enabling the mobile data processing means to be assigned to an active group associated with the network adapter means; and

after the mobile data processing means comes within operable communication range of the first infrared data transmission channel,

transmitting and receiving data information between the network adapter means and the mobile data processing means through the first infrared data transmission channel.

20. Method as set forth in Claim 18 or 19, further comprising the steps of buffering within the network adapter means data information received from the network or from one of the data processing means.

21. Method as set forth in Claim 18, 19 or 20, further comprising a step of communicating with one or more of the data processing means only with the diffuse transmission infrared radiation channel.

22. Network adapter means for use in coupling a wired network to a wireless communication medium, comprising:

means for coupling to the wired network; and

means for coupling to the wireless medium, including first means for transmitting and receiving modulated optical radiation having a first bandwidth having diffuse propagation characteristics associated therewith, and further including second means for transmitting and receiving modulated optical radiation having a second bandwidth that is greater than the first bandwidth.

23. Data processing means for use with a wireless communication medium, comprising:

means for coupling data processing means to a wireless communication medium, including first means for transmitting and receiving modulated optical radiation having a first bandwidth having diffuse propagation characteristics associated therewith, and further including second means for at least receiving modulated optical radiation having a second bandwidth that is greater than the first bandwidth.

24. Network adapter means as set forth in Claim 22 or 23, wherein the first means and the second means each operate within a range of optical wavelengths greater than approximately 700 nm.

25. Network adapter means as set forth in Claim 22, 23 or 24, wherein the second means includes means for transmitting or receiving optical radiation with a modulation spectrum within a range of approximately 400kHz to approximately 10MHz and wherein the first means includes means for transmitting with a modulation spectrum within a range of approximately 2kHz to approximately 300kHz.

FIG. 1a

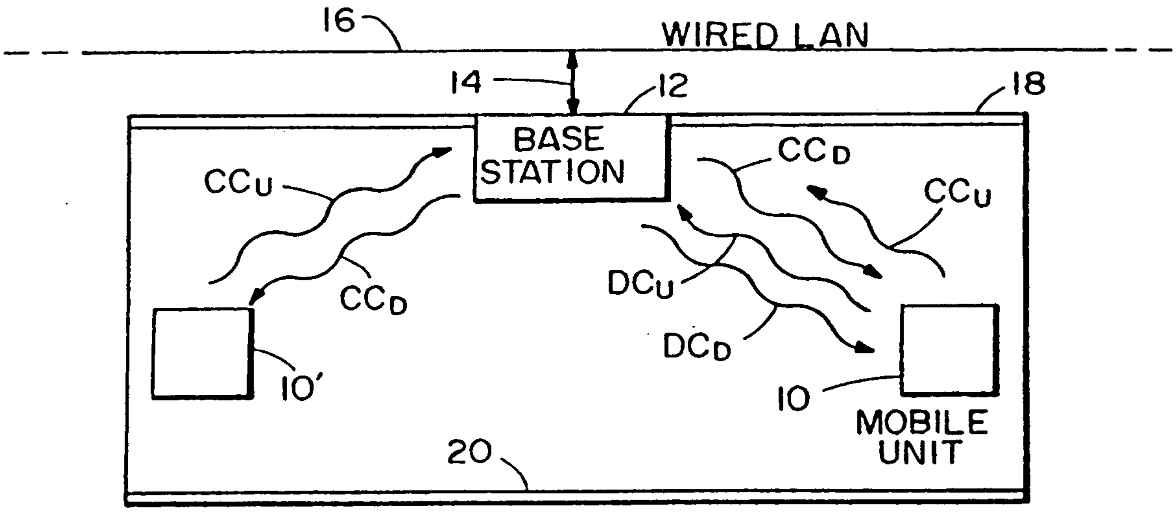

16
WIRED LAN
14
12
18
BASE STATION
CCu
CCD
CCD
CCu
DCu
DCD
10'
10
MOBILE UNIT
20

FIG. 2

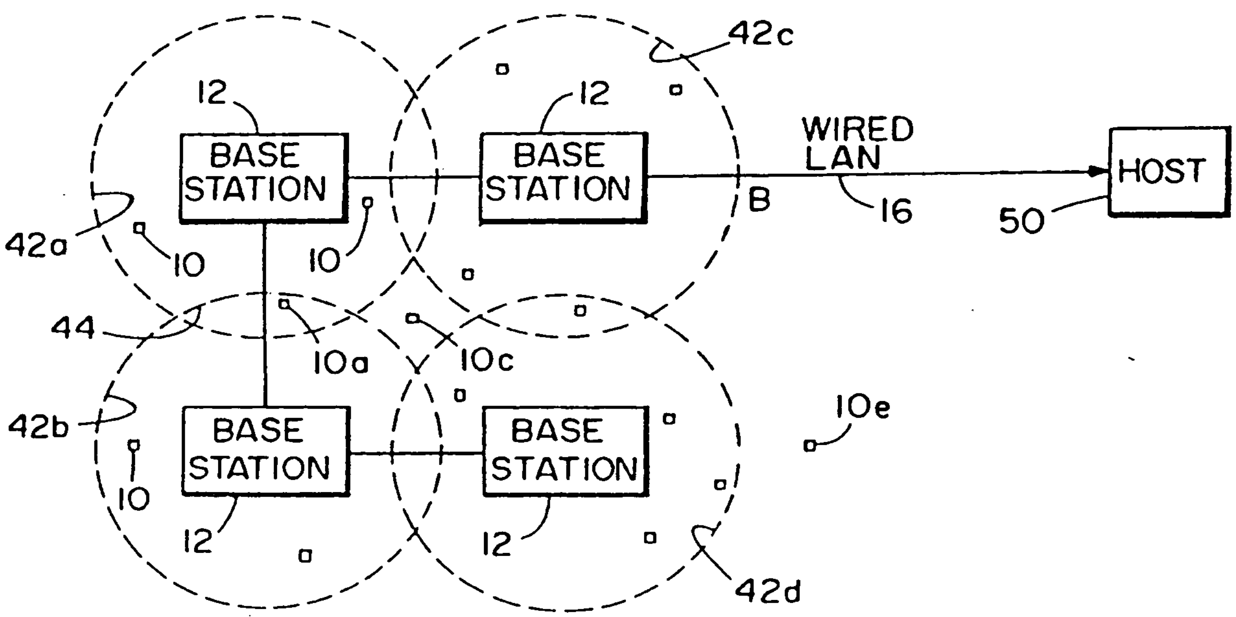
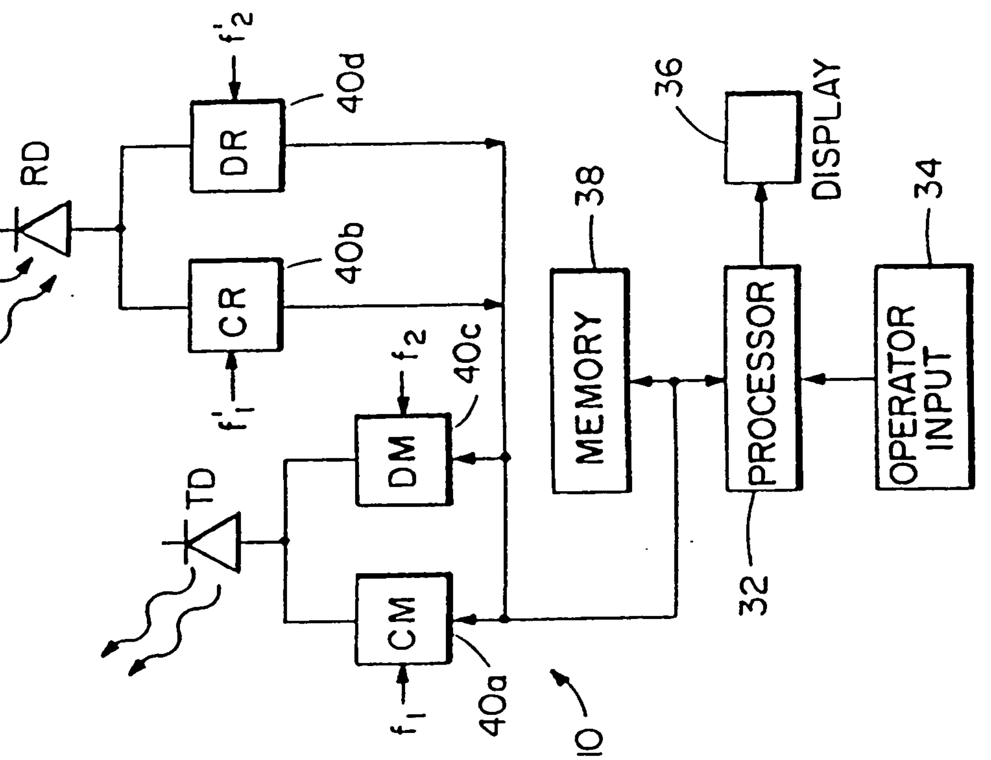
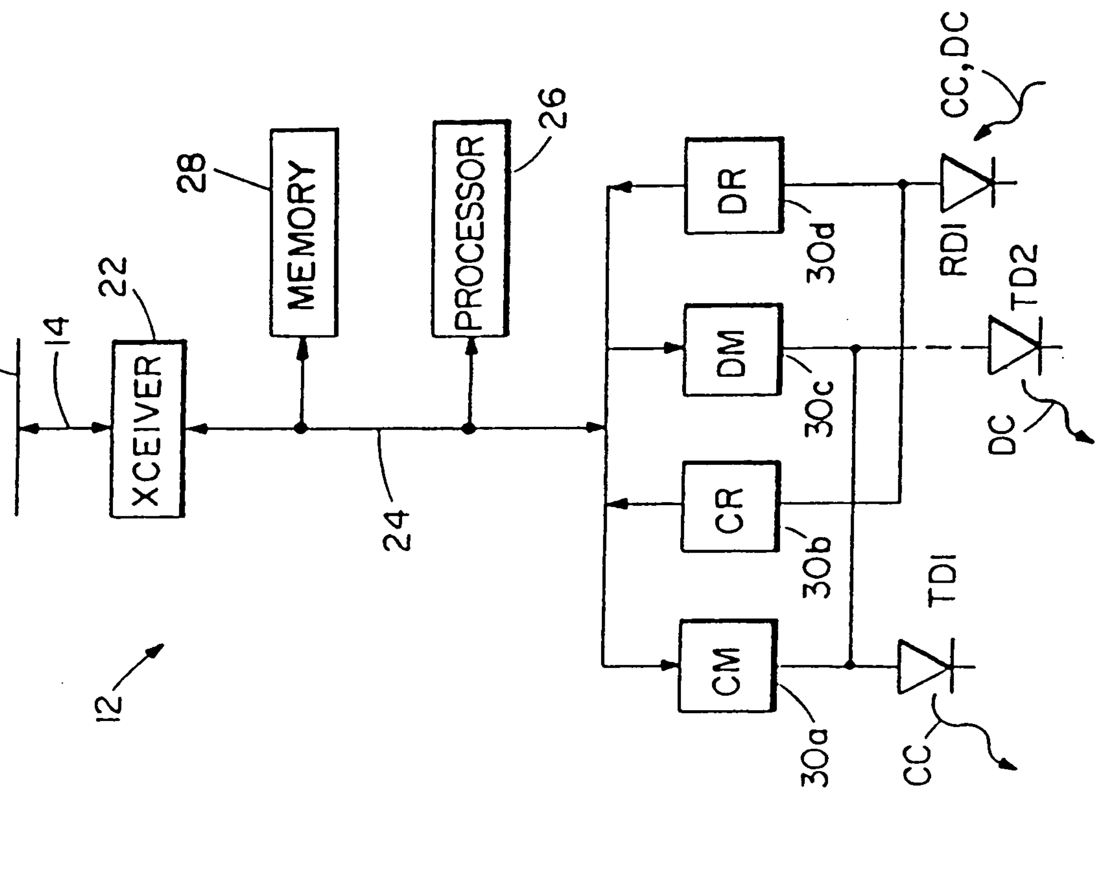

42c
12
12
BASE STATION
BASE STATION
WIRED LAN
HOST
B
16
50
42a
10
10
44
10a
10c
42b
BASE STATION
BASE STATION
10e
10
12
12
42d

FIG. 1c



RD
TD
DR
CR
DM
CM
40a
40b
40c
40d
10
MEMORY
38
PROCESSOR
32
DISPLAY
36
OPERATOR INPUT
34

FIG. 1b



12
16
14
XCEIVER
22
24
MEMORY
28
PROCESSOR
26
CM
CR
DM
DR
30a
30b
30c
30d
TD1
TD2
RD1
CC
DC
CC, DC

FIG. 3

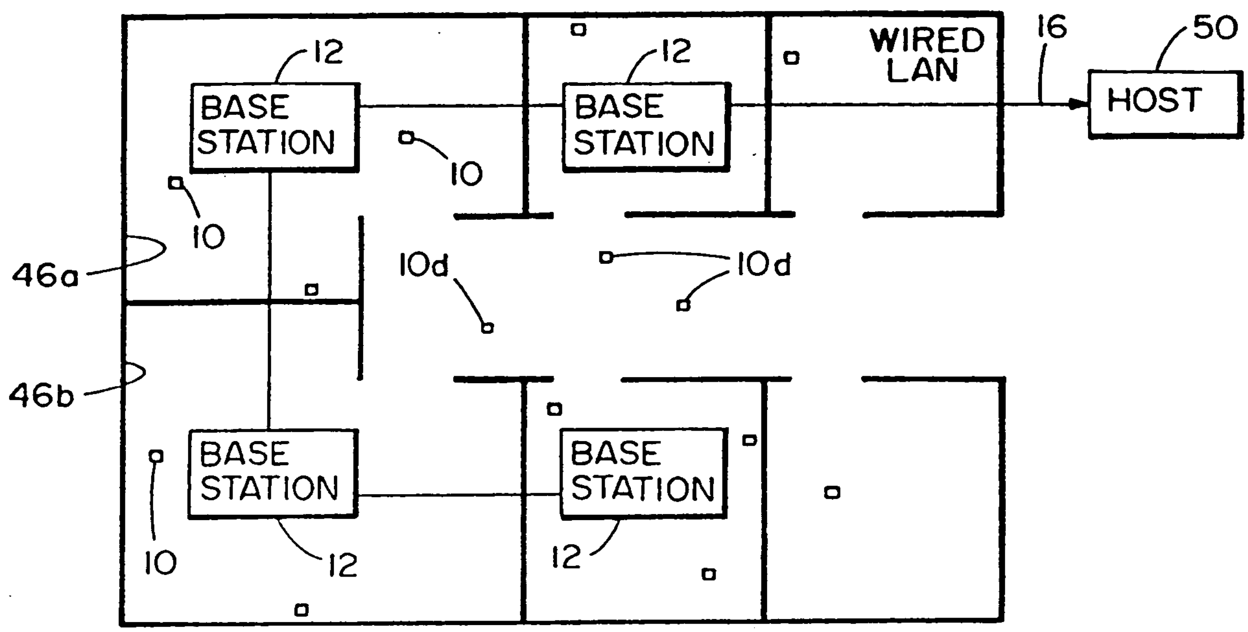
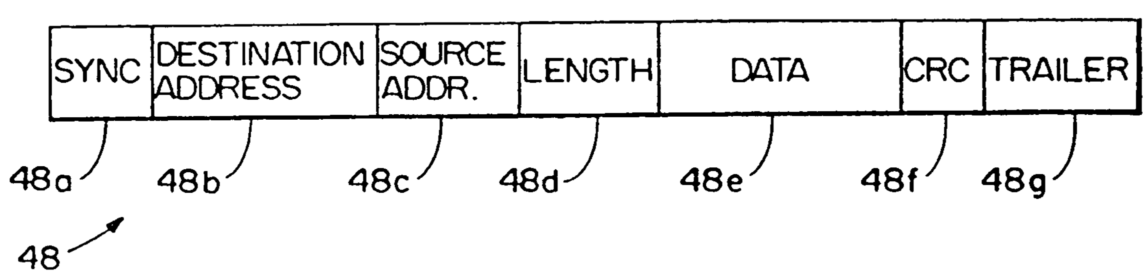

BASE STATION
12
BASE STATION
12
WIRED LAN
16
50
HOST
10
10
10d
10d
46a
46b
BASE STATION
BASE STATION
10
12
12

FIG. 4


SYNC
DESTINATION ADDRESS
SOURCE ADDR.
LENGTH
DATA
CRC
TRAILER
48a
48b
48c
48d
48e
48f
48g
48

(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 515 728 A2**

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **91117115.5**

(51) Int. Cl.[5]: **H04B 10/10**

(22) Date of filing: **08.10.91**

(30) Priority: **31.05.91 US 708433**

(43) Date of publication of application: **02.12.92 Bulletin 92/49**

(84) Designated Contracting States: **DE FR GB**

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(54) **Wireless indoor data relay system.**

(57) This invention removes the requirement of cable interconnection for local area networks (LANs) by wireless relay stations suitable for very high data rates by operation at high carrier frequencies where signal reflection and absorbtion by walls is total or requires undesirable high omnidirectional RF power transmissions. The LAN can be deployed without special installation requirements when operated with indoor transponders (U.S.Pat.4,975,926). In the preferred embodiment relay stations communicate with IR light beams, and wall and ceiling propagation blockage is overcome by low power RF structure couplers.

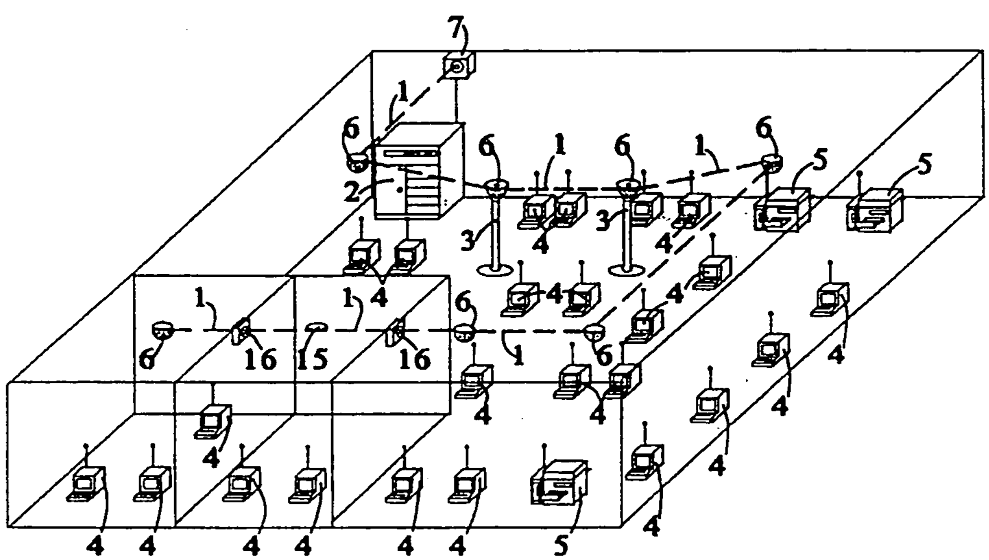

FIG. 1

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Field of Invention

The present invention relates in general to communication systems and is particularly directed to improve practicality and utility of wireless indoor communication between workstations or other devices by means of infrared and other electromagmagnetic radiation over a local area network (LAN) or as a stand-alone system over a limited local area.

Description of Prior Art

U.S. Pat. No. 4,975,926 issued to G. Knapp on Dec.4, 1990 describes a wireless, high data rate, indoor communication system. The system discussed uses transponders for in line-of-sight communication to workstations. The transponders perform signal amplification, processing and distribution. All transponders are interconnected by cables.

The problem remaining in the prior art is to provide an optical or radio communication system which eliminates all cable connections and prevents signal blockage or severe attenuation by certain building structures, i.e. walls and ceilings, which is inherent to high electromagnetic carrier frequencies that are needed for accommodation of large signal bandwidths.

Summary of Invention

The foregoing problem in the prior art is solved to a large extent with the present invention by providing a tether-free operation for the transponders. More specifically, transponders are interconnected by radio waves and IR light beams throughout a building. The IR light beams are guided through unobstructed areas of ceilings, elevator shaft walls, staircase center spaces, skylight openings, etc.. Single or multiple beams form network data links to and from transponders equipped with network data link relay sections. Structure couplers extend, by low power radio wave coupling through non-metallic walls and ceilings, the wireless interconnection from a single room to rooms and building floors.

A preferred embodiment uses infrared (IR) lightwaves within each room of a building which permits simpler and less expensive designs than microwave and millimeter-wave embodiments, and such design avoids regulatory restraints by governments. Relay sections are equipped with IR transmitters, receivers and narrow beam width antennas. Manual beam alignment is aided by a visible light beam of equal beam width and direction. Rotational freedom of the antenna system provides precise aiming.

Brief Description of Drawings

FIG.1 is a typical office floor plan with transponders attached to ceiling or attached to floor stands. The dashed line represents the invisible IR network data link.

FIG.2 is a transponder for attachment to a ceiling or a floor stand with protective cover for the unused a.c. power terminals or socket. Two IR network data relay sections are mounted for a 90 degree directional change of the IR beams.

FIG.3 is a transponder for placement on a wall. A structure coupler is mounted behind the transponder sections and is in contact with the wall for pick up of RF signals from the opposite side of the wall.

FIG.4 is a hanging transponder for ceilings with line-of-sight obstructions.

FIG.5 is a detailed view of a relay section with a swivel eye for manual antenna alignment.

FIG.6 is the block diagram of a pair of relay sections connected as a complete data relay station.

FIG.7 is the block diagram of two structure couplers with a room dividing wall shown in center.

FIG.8 is a pair of structure couplers with exposed radio antennas for communication through a wall.

Detailed Description of the Preferred Embodiments

Before describing in detail the particular improvements over U.S. Pat.4,975,926 with the present invention, it should be understood that the present invention resides in a novel transponder to transponder wireless communication link for any indoor network which employes conventional, electrical radio frequency (RF), and optical communication circuits and components or techniques as explained in detail in U.S. Pat.4,975,926. Accordingly, the structure, arrangement and operation of these known techniques, circuits and components have been illustrated here only in simplified drawings and block diagrams, however, specific details that are pertinent to the present invention are shown and explained in sufficient detail to be readily understandable to those skilled in the art.

In accordance with the present invention, the wireless indoor transponder data relay system shown in FIG.1 illustrates the preferred embodiment. For the demonstration of the concept an office floor plan with a small, three room LAN is shown. The inbound and outbound signal cables interconnecting the transponders of U.S. Pat.4,975,926 are by this invention replaced with IR light beams 1. A computer 2 is serving the LAN, all workstations 4 and laser printers 5. A wall mounted relay section 7 translates the hard-wire signal connection from the computer 2 to an inbound and outbound data link by IR beams 1. Transponders 6, shown also in FIG.2, are equipped with two relay sections 7 containing two IR transmitter/receiver pairs. Each relay section 7, shown as FIG.5, contains one receiver with antenna system 8 and one transmitter with antenna system 9. The transponder in FIG.4 has a different mounting provision, which is designed for locations where obstruction by ceiling ducts or other objects would interrupt the light beams normally located directly under the ceiling. The transponder version of FIG.2 is a plug-in unit with a.c. power connection by power connector 10 or Edison socket 11. The unused power connection is protected by cover 12 In FIG.1 two transponders 6 are attached with their Edison sockets to two floor stands 3, while the remaining transponders 6 are plugged into ceiling mounted a.c. power outlets. The preferred transponder embodiment has a mounting plate 13 carrying eight (8) upper sections. Typically, two blank section panels 14 are replaced with two relay sections 7. FIG.2 depicts an effective 90 degree turn of the IR beams by mounting the second section 7 at the third mounting position from the first relay section 7. Common is the "straight through" configuration with two relay sections 7 separated by 180 degrees, as shown in FIG.4. This transponder configuration permits the removal of a transponder for maintenance, as shown in FIG.1, with only the empty power outlet 15 left on the ceiling. Structure couplers 16 bridge the missing transponder with their IR beams 1. Service interruption will only occur in the center room and not in the adjacent rooms.

If transponders cannot be placed on ceilings or walls, floor stands 3 are used. The swivel eye assembly 38 contains the receiver antenna assembly 8, the transmitter antenna assembly 9 and the alignment light 28 with reflector 17. The receiver antenna assembly 8 carries a hood 22 to prevent direct ambient light to enter, a lens 24 with IR detector 25 and an input optical bandpass filter 23 for room light rejection and selection of the link specific wavelength. The transmitter antenna assembly 9 contains a light emitting diode (LED) with lens for transmission of a narrow modulated IR light beam to the next relay section 7. The swivel eye assembly 38 provides 23 degrees of freedom in any forward direction for alignment of the IR beam 1 to the adjacent transponder 6 or structure coupler pair 16. Alignment is aided by the alignment spot light 17 in projecting a visible light spot equivalent to the beam pattern of emitter assembly 9. On-Off control for the spot light bulb 28 is provided by switch 19.

Downlink transponder sections 18 provide inbound and outbound LAN connections to the workstations on the floor. Details of 18 are in U.S. Pat. 4,975,926.

FIG.6 is the block diagram of the transponder relay system. Two relay sections 7 are interconnected by interface connectors 39a and cables 39b, as shown. The upper interface carries the inbound signal and the lower interface carries the outbound LAN signal. IR receiver 20 and IR transmitter 21 can be, in their simplest configuration, amplifiers. The preferred embodiment of the receiver antenna system 8 is comprised of a hood 22 serving as mounting tube for the IR filter 23, lens 24 and detector 25. The detector 25 can be a photo diode, a photo transistor, a photo multiplier tube, etc. The lens can be implemented by a reflector or a more complex, multi-element optical system. When designed as a microwave antenna system, typically required will be a microwave lens or reflector, a low noise preamplifier, a frequency down converter and a diode detector.

The emitter assembly 9 can be a light emitting diode (LED), a laser diode, a conventional laser, or a microwave transmitter with antenna. The preferred embodiment shows a LED with a lens as part of its protective encapsulation.

The inbound and outbound downlink signal interface to the downlink transponder sections 18 are provided by connectors 26. A power supply 27 provides power to the transmit/receive electronics and the incandescent lamp 28 of the alignment spot light 17.

A pair of relay sections 7, as shown in FIG.6, may be used for guiding the signals around obstructions by two cables 39b or by placing the cables through holes in walls or ceilings. In many cases this may not be possible or desireable. As part of this invention the cables 39b, normally located between the relay sections 7, are removed and replaced with two radio couplers 30, as shown in FIG.7. The radio couplers 30 are separated by the width of the wall 31, ceiling or other structure. Each coupler contains a coupling transmitter 32 with carrier generator, modulator and other commonly used circuits for retransmission of the inbound or outbound signals present at the IR receiver 20 output, which are the recovered and amplified signals from the antenna systems 8. The coupling receiver 33 of each radio coupler 30 receives the RF transmission from the coupling transmitter 32 of the inbound or outbound link and is located on the other side of the wall in juxtaposition. The coupling receivers 33 amplify, demodulate the RF signals and recover the digital data by any of the well known radio communication circuits from the RF signal originally transmitted by transmitters 32 on the opposite side of the structure (wall 31). In the preferred embodiment the recovered data is retransmitted with IR by emitter 9 from the relay sections 7 via interface connectors 39a.

The coupling receiver antennas 34 and coupling transmitter antennas 35 may be designed in many configurations and are highly frequency dependent. In the preferred embodiment, as shown in FIG.8, a horn antenna and a microstrip patch antenna are used with close approximation to the wall for maximum near-field RF coupling. The receiver antenna 34 is dual-polarized to reduce losses caused by reflections in the wall structure and has a large aperture for RF wall scatterings. For penetration of the structure, and to minimize RF leakage to the outside, a high-gain, small aperture transmitter antenna 35 is used. The radio coupler 30 is tightly RF radiation sealed and has RF gaskets 36 between the wall (not shown in FIG.8) and the coupler housing for prevention of RF leakage and to minimize RF wall emissions by scattering. The wall transponder in FIG.3 is combined with a radio coupler 30. Two wall transponders of this type, mounted on opposite sides of a wall, provide wireless room to room LAN inbound/outbound connections and provide broadcast transmissions to workstations on both sides of a dividing wall.

It is to be understood that the above-described embodiments are simply illustrative of the principles of the invention. Various other modifications and changes may be made by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof. For example, as shown in FIG.3, the wall transponder equipped with downlink transponder sections 18 for IR wireless broadcast to workstations and equipped with a structure coupler 30, can be modified by replacement of all downlink transponder sections with one omnidirectional RF antenna as a means for downlink transmission to workstations with RF instead of IR, thereby, avoiding the need for higher RF transmitter power on the opposite side of the wall or ceiling.

Claims

1. An indoor wireless communication system to relay local area network (LAN) information from one relay station to another relay station by means of narrow beam electromagnetic radiation serving a plurality of transponders by a plurality of relay stations, each comprising:

   at least one receiving means for receiving a modulated signal representative of the received inbound digital data;

   at least one transmitting menas for transmitting a modulated signal representative of the said received inbound digital data.

2. An indoor signal relay system according to claim 1 wherein at least one second receiving means and at least one second transmitting means has been added to each relay section for multiple link communication by the LAN, comprising:

   of at least one receiving means for receiving a modulated signal representative of the received outbound digital data;

   of at least one transmitting means for transmitting a modulated signal representative of the said received outbound digital data.

3. An indoor wirless signal relay system according to claim 1 or 2,

   wherein coarse aiming of at least one said inbound receiving means together with at least one said outbound transmitting means are simultaneously positioned by a mounting means; and

   wherein coarse aiming of at least one said outbound receiving means together with at least one said inbound transmitting means are simultaneously positioned by a mounting means.

4. An indoor wireless signal relay system according to claim 3, wherein

   aiming of at least one said inbound receiving means and aiming of at least one said outbound transmitting means are simultaneously controlled by a beam alignment means; and

   aiming of at least one said outbound receiving means and aiming of at least one said inbound transmitting means are commonly controlled by said beam alignment means.

5. An indoor wireless signal relay system according to claim 3, wherein

   each said beam alignment means is assisted by a spot light means projecting a light pattern of approximately equal or smaller dimensions to that of the said antennas.

6. An indoor wireless signal relay system according to claim 2, wherein

   each inbound link operates at a different frequency; and

   wherein each outbound link operates at a frequency different from any of the inbound link frequencies.

7. An indoor wireless signal coupling relay system wherein for each inbound and outbound signal connectivity through a wall or ceiling is maintained by near-field electromagnetic coupling of low power signal modulated Radio Frequency (RF), comprising:

   an RF coupling inbound transmitter antenna placed in close proximity to a wall or ceiling for transmission of inbound signal modulated RF to the opposite side of said wall or ceiling and its reception by the RF coupling inbound receiver antenna located on said opposite side of wall or ceiling,

an RF transmitter for operation of said RF coupling inbound transmitter antenna, including:

an RF carrier generating means matching the said RF coupling inbound transmitter antenna,

a modulating means for modulation of an inbound RF carrier with inbound signals which are obtained from at least one inbound receiving means,

an RF coupling outbound receiver antenna which is placed in close proximity to said wall or ceiling for reception of outbound signal modulatad RF carrier transmissions from the opposite side of said wall or ceiling which are transmitted by the said RF coupling outbound transmitter antenna;

an RF receiver for receiving of said outbound signal modulated RF from said RF coupling outbound receiver antenna, including:

a low noise amplifying means for low level RF amplification,

a demodulating means for demodulation of received said outbound signal modulated RF, and

a recovery means for recovery of said outbound signals,

an RF coupling outbound transmitter antenna placed in close proximity to a wall or ceiling for transmission of signal modulated RF to the opposite side of said wall or ceiling and its reception by the RF coupling outbound receiver antenna located on said opposite side of wall or ceiling,

an RF transmitter for operation of said RF coupling outbound transmitter antenna, including:

an RF carrier generating means matching the said RF coupling outbound transmitter antenna,

a modulating means for modulation of an outbound RF carrier with outbound signals which are obtained from at least one outbound receiving means,

an RF coupling inbound receiver antenna which is placed in close proximity to said wall or ceiling for reception of inbound signal modulated RF carrier transmissions from opposite side of said wall or ceiling which are transmitted by the said RF coupling inbound transmitter antenna;

an RF receiver for receiving of said outbound signal modulated RF from said RF coupling inbound receiver antenna including:

a low noise amplifying means for low level RF amplification,

a demodulating means for demodulation of said inbound signal modulated RF, and

a recovery means for recovery of said inbound signals.

8. An indoor wireless signal coupling relay system according to claim 7, wherein the RF carrier detection power by the said RF coupling inbound receiver antenna is indicated by a signalling means, and the RF carrier detection power by the said RF coupling outbound receiver antenna is indicated by a signalling means, comprising:

a threshold means for each detected RF carrier to establish the best coupling proximity of the said RF coupling inbound and outbound transmitter antennas which are placed on opposite sides of said wall or ceiling by sensing the highest RF carrier power levels received,

a signalling means for each detected RF carrier for indication when said highest RF carrier power levels have been detected by the said threshold means for fixing the location of best signal reception for the signal coupling relay system on either side of the wall or ceiling.

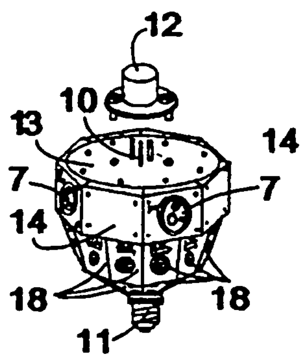


FIG. 2

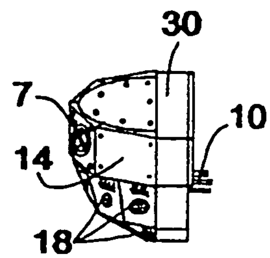


FIG. 3

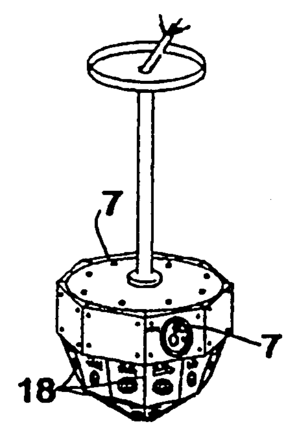


FIG. 4

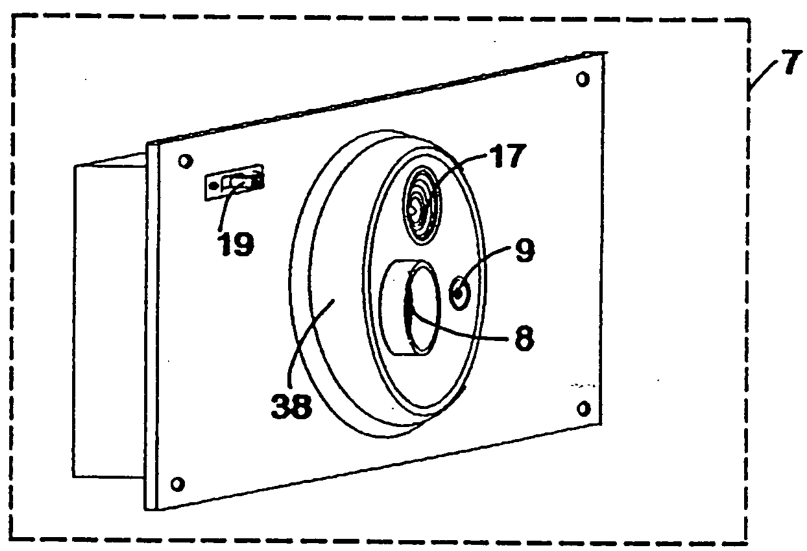
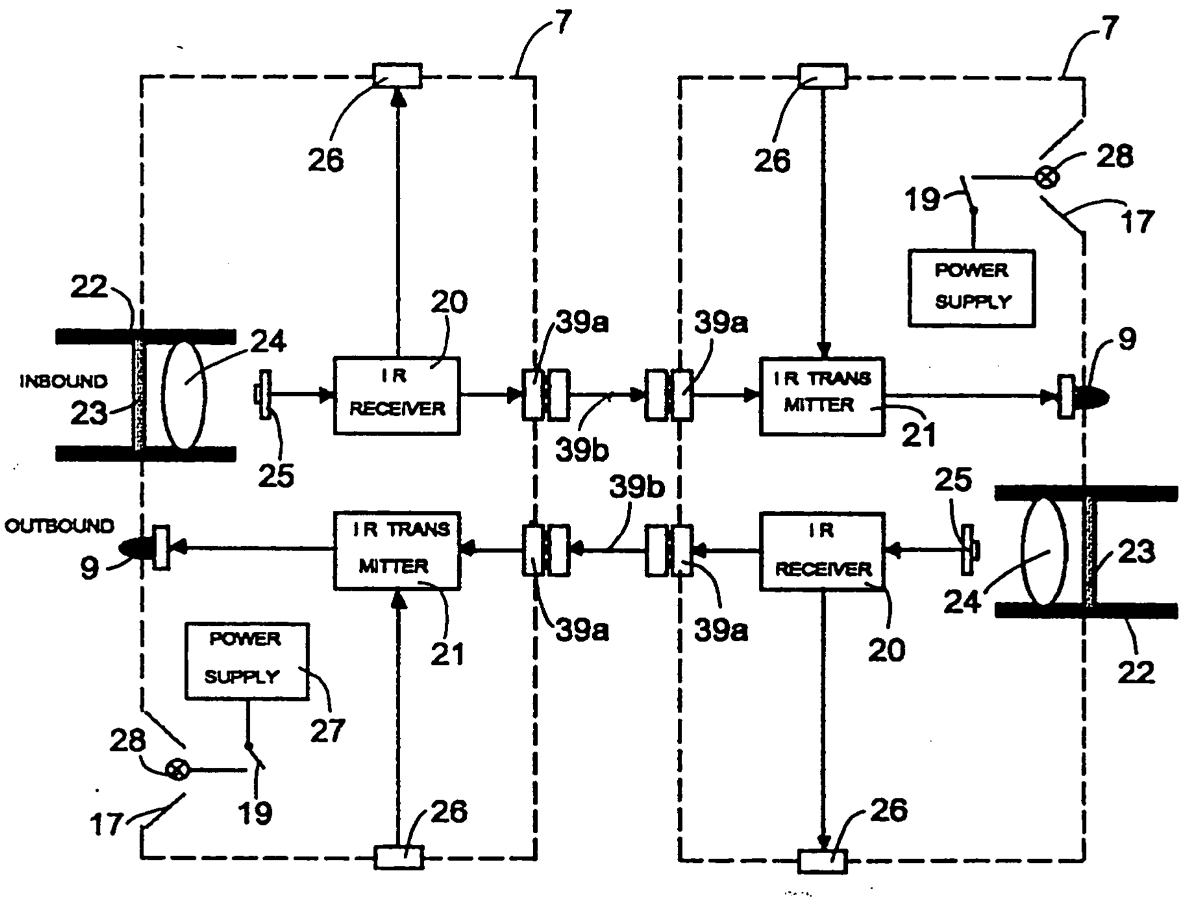


FIG. 5


7
7
26
26
28
19
17
POWER SUPPLY
22
20
39a
39a
9
24
INBOUND
I R RECEIVER
I R TRANS MITTER
23
25
39b
21
39b
25
OUTBOUND
I R TRANS MITTER
I R RECEIVER
9
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39a
39a
POWER SUPPLY
21
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28
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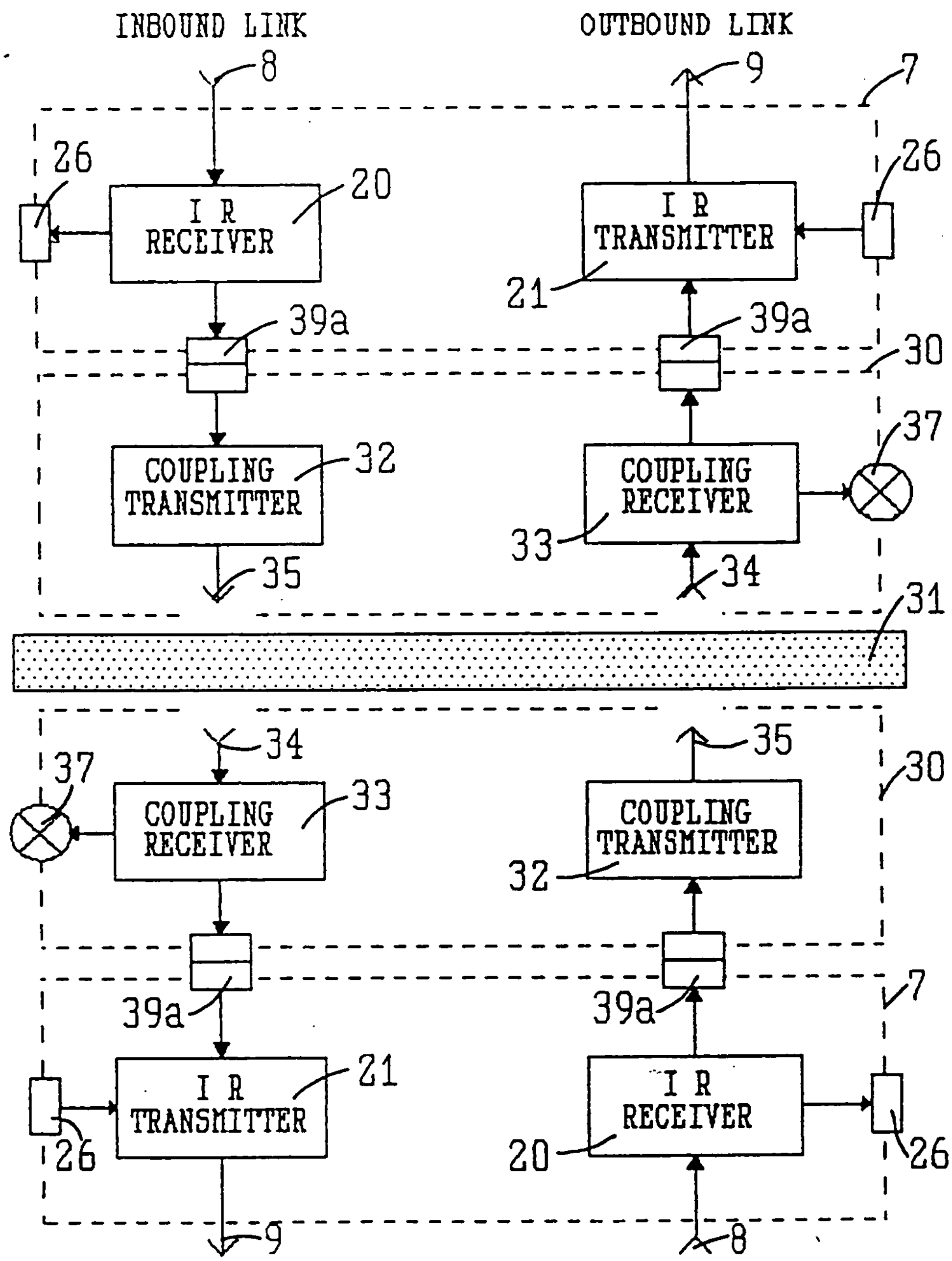
26
26

FIG. 6


INBOUND LINK
OUTBOUND LINK
8
9
7
26
20
I R
RECEIVER
I R
TRANSMITTER
26
21
39a
39a
30
COUPLING
TRANSMITTER
32
COUPLING
RECEIVER
37
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34
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COUPLING
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COUPLING
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FIG. 7

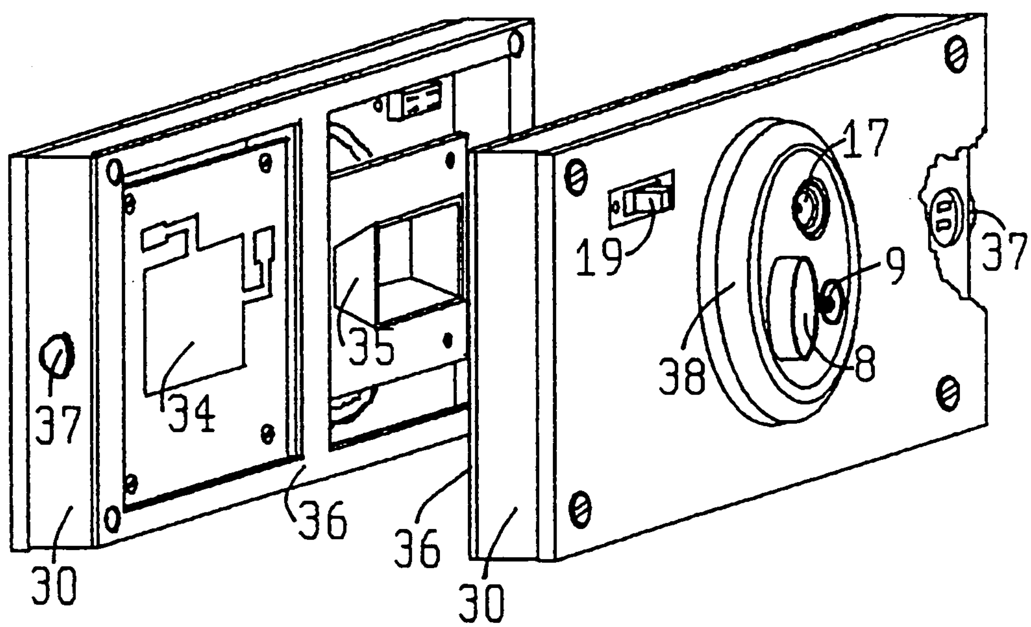

FIG. 8

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European Patent Office
Office européen des brevets

(11) Publication number: **0 685 390 A1**

EUROPEAN PATENT APPLICATION

(21) Application number: 95110844.8

(22) Date of filing: 13.05.93

(51) Int. Cl.6: B64G 1/22, G01P 15/08, G01H 9/00

This application was filed on 11 - 07 - 1995 as a divisional application to the application mentioned under INID code 60.

(30) Priority: **14.05.92 JP 121989/92**
14.09.92 JP 244625/92

(43) Date of publication of application:
06.12.95 Bulletin 95/49

(60) Publication number of the earlier application in accordance with Art.76 EPC: **0 569 994**

(84) Designated Contracting States:
DE FR GB IT

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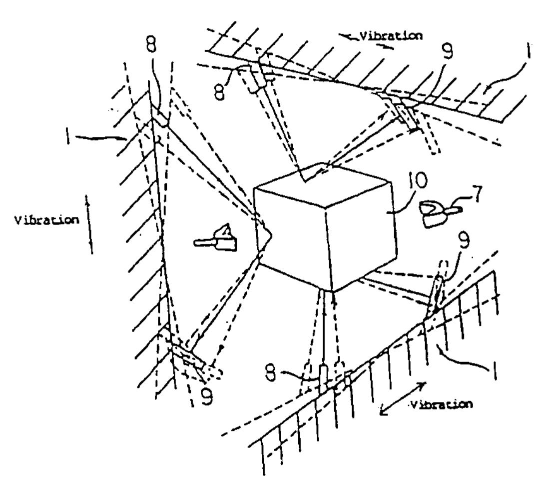
(54) **Vibration sensors for use in micro-gravity environment.**

(57) A vibration sensor (2) comprises a reflector (10) or a transparent refractor (30) disposed as floating in a micro-gravity space, output means (8) fixed to a vibrating body (1) for emitting energy towards the reflector (10) or transparent refractor (30), and a receiver (9, 29) fixed to the vibrating body (1) for receiving energy sent from the reflector (10) or transparent refractor (30) and measuring the nature of vibrations of the vibrating body (1) on the basis of movement of the reflected or permeated energy.

Fig. 6



EP 0 685 390 A1

BACKGROUND OF THE INVENTION:

1. Field of the Invention:

The present invention relates to vibration measuring sensors for measuring vibrations of an instrument used in a micro-gravity environment, such as a space station, an artificial satelite, a space vehicle, a micro-gravity environment system or the like to establish a counter-measure, and also relates to detection of positions and scales of collision of a meteoroid-debris colliding against these space stations.

2. Description of the Prior Art:

Recently, various experiments and communication services have been offered by means of space missions of space stations, space shuttles and the like. As one of the most important problems of this space mission, maintenance of a micro-gravity (μ - G: for instance 1 x 10^{-5}G or less) environment is pointed out.

However, in some cases, the micro-gravity environment is destroyed by vibrations or the like generated due to various causes. Also, sensors for accurately detecting arbitrary vibrations such as vibration energy, a frequency, an amplitude or the like as is the case with the meteoroid/debris collisions, are not present.

In order to maintain this micro-gravity environment, it is desirable to grasp the factors of vibrations destroying the micro-gravity environment and to take a counter-measure for reducing the vibrations. However, in the prior art such counter-measures were not taken. Also, in an assembly of complicated systems such as a space station or the like, it is difficult to grasp a source of generation of vibrations including the collision vibrations of meteoroid/debris.

Furthermore, it is the real status of the art that a procedure for grasping various vibrations under a μ - G (micro-gravity) environment has not yet been established. For instance, a vibration (acceleration) sensor in the prior art measures a vibration (acceleration) by measuring a movement of a vibrator supported by a spring and a material having an inherent damping characteristic such as a damper. However, such sensor involves a problem that it is limited in a frequency or the like of detectable vibrations and it cannot accurately detect vibrations under a micro-gravity environment.

Such type of problems are also the same even in a micro-gravity environment system equipped on the ground or in an airplane.

A vibration factor analyzing system for use in a micro-gravity environment comprises:

vibration sensors disposed in (a linear array, a matrix-like array or the like) on a vibrating body (a space station or the like) held in a micro-gravity environment:

analyzing means for collecting vibration data detected by the aforementioned vibration sensors and analyzing vibration spectra;

a neural network section for specifying a vibration source on the basis of the vibration spectra analyzed by the above-mentioned analyzing means;

actuators disposed on the above-mentioned vibrating body; and

a fuzzy control section responsive to vibration energy and a vibration source specified by the aforementioned neural network section for controllably driving the above-mentioned actuators so as to reduce harmful vibrations and/or eliminating the factors of vibrations.

With the vibration factor analyzing system for use in a micro-gravity environment having the above-described construction, the system itself can achieve optimum driving of the actuators for reducing vibrations or analytic elimination (stoppage) and reduction (lowering of a rotational speed or the like) of the vibration factors (meteoroid/debris collision vibration sources; motors, pumps, etc.) by collecting vibration data and judging. In addition, its performance including an analyzing capability can be improved by itself by again taking in the result of control and learning in the neural network section and the fuzzy control section to be ready for next occurrence of vibrations. This system makes it possible to grasp factors for destroying a micro-gravity environment and to establish a counter-measure against them.

An object of the present invention is to provide detector means which can accurately detect vibrations under a micro-gravity environment.

In order to achieve the above-mentioned object, the vibration sensor for use in a micro-gravity environment according to the present invention comprises:

a reflector disposed as floating in a micro-gravity space (surrounded by vacuum or arbitrary gas) and consisting of a polyhedron having an arbitrary number of surfaces (1 - ∞ surfaces (= sphere)) reflecting predetermined energy such as laser beams, light, electromagnetic waves, sound waves and the like having various frequencies according to known characteristics;

output means fixed to a vibrating body (a space station structure or the like) for irradiating the above-mentioned reflector with the aforementioned predetermined energy; and

receiving means fixed to the above-mentioned vibrating body for receiving reflection energy reflected from the above-mentioned reflector and measuring the natures (acceleration, amplitude, frequency, etc.) of vibrations of the above-mentioned vibrating body on the basis of variations of the aforementioned reflection energy.

The above-described vibration sensor for use in a micro-gravity environment according to the present invention does not employ members for supporting a vibrator such as a spring, a damper and the like as used in the conventional vibration sensor, but keeps a reflector consisting of a polyhedron having an arbitrary number of surfaces in an unvibrating condition floating in a zero-gravity environment. And while the output means for irradiating the reflector with energy and the receiving means vibrate jointly with the vibrator, the reflector does not vibrate. Accordingly, minute acceleration/amplitude/gravity and the like can be detected by measuring variations of received energy by the receiving means. Since the reflector is not supported, a range of measurement for the nature (acceleration, amplitude, frequency, etc.) of the detected vibration is not subjected to limitation.

Also, another micro-gravitational vibration sensor according to the present invention comprises a transparent refractor disposed as floating in a micro-gravity space and having known characteristics, an irradiator disposed on one side of the same transparent refractor and fixed to a structure whose vibrations are to be detected for irradiating with light rays, and a light receiver disposed on the other side of the above-mentioned transparent refractor as opposed to the same irradiator and fixed to the above-mentioned structure for receiving the light rays radiated by the irradiator via the transparent refractor. Here, the term "refractor" includes a lens and a prism.

In this micro-gravity vibration sensor, while the irradiator and the light receiver would vibrate jointly with the structure when the structure vibrates because they are fixed to the structure, the transparent refractor would not vibrate because it is floating in a micro-gravity space.

The light rays radiated from the above-mentioned irradiator make incidence to the transparent refractor, then permeate through the transparent refractor after having been subjected to refraction and convergence corresponding to a curved surface configuration, a polyhedron configuration or a configuration consisting of a combination of planes and curved surfaces of the transparent refractor, and are received by the light receiver. However, in the event that the above-described structure is vibrating, since the transparent refractor is held stationary, a light receiving position on a light receiving surface of the above-described light receiver is displaced from the light receiving position in the case where the above-mentioned structure is held stationary by the amount corresponding to the vibration of the structure and the characteristics of the refractor.

The displacement of the light receiving position on the light receiving surface of the above-mentioned light receiver is input to a computer, and the computer having this displacement input calculates an acceleration, an amplitude, a frequency and the like of the structure by making use of the characteristics of the refractor which are determined by the known configuration of the transparent refractor, and outputs them.

With the above-described construction and operation, a vibration sensor which can detect even a minute vibration of a structure under a micro-gravity environment, can be realized.

In addition according to the present invention, the above-described vibration sensor is provided with active vibration-suppressing means for making a reflector or a transparent refractor held stationary in a zero-gravity space, and thereby movements of the reflector or the transparent refractor are suppressed within a predetermined range.

The above-mentioned and other objects, features and advantages of the present invention will become more apparent by reference to the following description of a number of preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS:

In the accompanying drawings:

Fig. 1(a) is a front view showing a space station;

Fig. 1(b) is a cross-section view taken along line A-A in Fig. 1(a) as viewed in the direction of arrows;

Fig. 2 is a flow diagram showing flows of functions of data processing;

Fig. 3 is a flow diagram of a system software for realizing the data processing shown in Fig. 2;

Fig. 4 is a diagram showing one example of initial threshold values;

Fig. 5 is a perspective view showing a fixed state of a reflector mirror of a vibration sensor according to a first preferred embodiment of the present invention;

Fig. 6 is a perspective view showing a working state of a vibration sensor according to the first preferred embodiment of the present invention;

Fig. 7 is a schematic view of a vibration sensor according to a second preferred embodiment of the present invention, Fig. 7(a) being a schematic view showing the state where a lens is fixed, and Figs. 7(b) and 7(c), respectively, are schematic views showing a mode of operation;

Fig. 8 is a cross-section view partly cut away and partly in block form of a vibration sensor according to a third preferred embodiment of the present invention, in which a reflector is kept fixed;

Fig. 9 is a cross-section view partly cut away and partly in block form of the vibration sensor according to the third preferred embodiment of the present invention, which shows a working state of the vibration sensor: and

Fig. 10 is a flow chart showing an operation sequence of the vibration sensor according to the third preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

In the following, a number of preferred embodiments of the present invention will be described in greater detail with reference to the drawings.

As shown in Fig. 1, onto an outer peripheral surface of an airframe of a space station 1 and on the inboard thereof are stuck a large number of vibration sensors (three-dimensional acceleration sensors) 2 in a matrix array at predetermined intervals.

The respective vibration sensors 2 serve to detect vibrations of the airframe of the space station 1, the detected vibration data are collected in a DIU (Data Interface Unit) sampling unit 4 via transmission paths 3 consisting of coaxial cables, twist cables, optical fibers, or the like, and they are fed to a computer 5 via this DIU sampling unit 4.

The computer 5 detects a scale and factors of destruction of a micro-gravity (μ - G) on the basis of the data transmitted from the respective vibration sensor. Furthermore, in order to offset the detected vibrations, the computer 5 selects actuators 6 provided on the airframe, and drives the selected one. If necessary, the computer 5 performs elimination of the factors (vibration generation sources) or reduction of the factors. The computer 5 grasps the result of driving of the actuator 6 and the result of elimination or reduction of the factors by continuous vibration detection data sent from the vibration sensors 2.

The flow of a series of system analysis by means of the computer 5 is shown in Fig. 2.

In a block (a) in Fig. 2, initial threshold values of vibration are set for the respective vibration sensors 2 on the basis of various standards, for instance, on the basis of the regulation of NASA (National Aeronautics and Space Administration).

Next, as shown in a block (c), vibrations generated by important causes of generation of harmful vibrations such as operations by crews, driving of various motors, joining of a space shuttle, collision of meteoroid/debris and the like are detected by the vibration sensors 2, and spectral distributions thereof are calculated. Then, the produced spectral distribution and the initial threshold values are superposed as shown in block (b), and composite data are obtained.

The composite data produced in the block (b) are stored in a memory represented by a block (d). In a block (e), a principal factor of the vibrations is extracted as by comparing the vibration spectra with the initial threshold values. Practically, among the composite data, spectra at the protruding portions are detected, and the principal factors of the vibrations having the respective spectra are specifically determined. This block (e) is constructed of neural networks formed in a software fashion.

In order to reduce the vibrations caused by the principal factor which were determined in the block (e), selection of actuators 6 that is effective for offsetting the harmful vibrations is effected and an amount of control for the selected actuator is calculated in a block (f). In addition, in the event that the harmful vibrations cannot be reduced to a predetermined level or lower only by driving the actuator 6, commands for adjusting the movements of crews and the operations of instruments serving as the factors, are issued.

On the basis of the calculation in the block (f), a block (g) outputs commands for selection of the actuators, adjustment of a control amount and operation control of the instruments serving as the factor of the harmful vibrations, and a command for adjusting the movements of crews and the operations of instruments serving as the factors. This block (g) is constructed of fuzzy logics.

On the basis of the commands sent from the block (g), in a block (h), a control signal is actually sent to the actuator 6 to control the actuator 6. Also, the block (g) selects and controls the actuator 6 so as to reduce vibrations expected to arise according to a programmed schedule through feed-forward control based on mission schedule data. In addition, a necessary alarm is output.

The results of these series of control are analyzed by making them once more pass through a software corresponding to the block (f) and a block (g), and they are stored as data in the block (d). In other words, after the actuator 6 was driven, vibrations of an airframe area again detected by the vibration sensors 2, thus the factors are detected, and selection of an actuator 6 which is effective for offsetting harmful vibrations as well as calculation of a control amount are effected. Furthermore, commands for selection of an actuator, adjustment of a control amount and operation control of the instruments serving as the factors of harmful vibrations, are issued, and they are reserved as data in the block (d).

By comparing the data stored in the block (d) with the initial threshold values and the factors, compensative operations (control amount and the like) to be set in the block (f) are reset so that further effective control may be effected for the harmful vibrations to be generated by the respective factors next time. In other words, learning is caused. With regard to meteoroid debris vibrations, they are classified as special vibrations and stored as data, and also commands are sent to crews of a space station or a space shuttle or to the ground station.

Fig. 3 shows flows and constructions of a software for this system. In Fig. 3, a section-A shows a data input portion, in which detection of vibration data by the vibration sensors 2 are effected, and which inputs, checks and arranges data representing the status of the vibration source within the system such as a mission schedule (traveling programs and docking of a space shuttle), a motor or the like.

A section-B is a neural network routine, in which spectral analysis and vibration mode analysis are carried out, and classification of the factors as well as preparation of a threshold value curve are effected. In addition, the section-B investigates data fed back from a section-C as will be described later, prepares (calculates) a new threshold value curve and causes the data to be stored in a memory device.

A section-C is a fuzzy reasoning routine, in which a degree of working of an alarm or an actuator is judged on the basis of the factor analysis in the neural network portion of the section-B and the threshold value curve, and the data are reserved. Furthermore, in the section-C, operations of the source of the factors of vibrations are adjusted on the basis of the result of judgement (for example, a rotational speed of a motor or a pumping is lowered.), and/or a control amount of an actuator for use in active control is set, and further, an alarm is issued. In addition, in the section-C, the actuator 6 or the like is controlled so as to reduce vibrations expected to occur according to a programmed schedule by feed-forward control on the basis of the mission schedule data input in the section-A.

With the above-described construction, owing to the learning and predicting functions of the software forming the neural network section and the fuzzy section, even with respect to a space environment which cannot be verified at the time of development of this system on the ground, an accumulation of data after launching to the space can be applied to the system as empirical values, and so, a system performance is improved in the cosmic space. Also, even in a micro-gravity environment system installed on the ground or in a airplane or the like, it is possible to specifically determine and reduce causes of generation of harmful vibrations which destroy the micro-gravity environment.

Now, one example of a construction and an operation of a vibration sensor 2 used in the above-described embodiment will be described in detail.

The vibration sensor according to the illustrated embodiment is composed of a reflection mirror (reflection plates) 10 consisting of a polyhedron having an arbitrary number of surfaces (one surface to ∞ surfaces (sphere)), a laser irradiator 8 for irradiating the reflection mirror 10 with light, a laser beam receiver 9 for receiving a laser beam reflected by the reflection mirror 10, and further a support mechanism 7 for supporting the reflection mirror 10. The laser irradiator 8, the laser beam receiver 9 and the support mechanism 7 are fixed to an airframe of the space station 1.

Fig. 5 shows the state where the reflection mirror 10 is fixed by means of the support mechanism 7.

It is to be noted that in the case of disposing a plurality of laser irradiators 48, it is made possible to dispose them so that the frequencies or wavelengths (colors) of the emitted laser beams may be different, and thereby erroneous reading by light receivers 49 are obviated.

Fig. 6 shows a working state of this vibration sensor 2 under a micro-gravity environment. A supporting mechanism 7 holes the reflection mirror 10 floating in a zero-gravity space. At this time, the surroundings of the reflector mirror 10 could be either vacuum or any arbitrary gas, and the reflector mirror 10 is held in a non-support/non-vibration state.

However, owing to enclosure of gas and active vibration-suppressing (loudspeaker, microphone, etc.) functions, it is possible to detect vibrations while carrying out three-dimensional position control of the reflector mirror 3 by moving the reflector mirror 10 within a predetermined range in the initial stage or in a continuous or intermittent manner and by applying deviation of detected waves caused by natural vibration within gas or rotation of the reflector mirror 10 simultaneously to a control filter.

It is to be noted that the gas and active vibration-suppression can be selectively made operable (in use) or inoperable.

The laser beam emitted by the laser irradiator 8 is reflected by the reflector mirror 10, and received by the laser beam receiver 9. It is possible to improve a detection capability for vibrations by inserting any arbitrary number of separate reflection mirrors in the optical path extending from the irradiator 8 via the reflection mirror 10 up to the laser beam receiver 9 and thereby elongating the optical path. The laser beam receiver 9 detects an amplitude, a frequency and the like of the vibration of the received laser beam. The laser beam receiver 9 detect the amplitude and the frequency of the vibration on the basis of movement of the received laser beam. The vibration data detected in the laser beam receiver 9 are transmitted to the computer 5, analyzed therein and used for control and the like of the above-mentioned actuators 6.

While a system in which a laser beam is emitted from a laser irradiator 8, then reflected by a reflection mirror 10 and received by a laser beam receiver 9 was described in the above-mentioned preferred embodiment, the present invention is not limited to such system, but any arbitrary energy such as light (visible light, invisible light) having various frequencies, electromagnetic waves, sound waves or the like could be employed.

A second preferred embodiment of a vibration sensor according to the present invention is shown in Fig. 7. The vibration sensors 22 according to this preferred embodiment shown in Fig. 7 are arrayed in multiple at a predetermined interval in a matrix-like array on a structure such as a space station 1 or the like as shown in Fig. 1, they are connected to a computer 5 via a DIU (Data Interface Unit) sampling unit 4 to measure vibrations of the structure, and the computer 5 controls the actuators 6 to suppress vibrations of the structure.

In the preferred embodiment shown in Fig. 7, a vibration sensor 22 comprises a laser irradiator 28, a laser beam receiver 29 disposed in opposition to the same irradiator 28, composed of charge-coupled devices (CCD) or the like and fixed to a structure, a lens 30 or a prism 33 consisting of a polyhedron having an arbitrary number of surfaces disposed between the same laser beam receiver 29 and the above-mentioned laser irradiator 28, made of predetermined material and having predetermined curvature or curved surface configurations, and a supporting device 27 provided so as to be detachable from and attachable to the same lens 30 or prism 33 and fixed to the structure.

In the above-described vibration sensor, in the case of measuring vibrations of a structure under a micro-gravity environment, at first, starting from the state where the supporting device 27 supports a lens or a prism 33 as shown in Fig. 7(a), the support of the lens 30 or prism 33 by the supporting device 27 is released as shown in Fig. 7(b), and the lens 30 or prism 33 is held floating in a space. This is possible owing to the fact that the space is a micro-gravity space.

If a laser beam is emitted from the laser irradiator under the above-mentioned condition, then the laser beam makes incidence to the lens 30 or prism 33, in the lens 30 or prism 33 the laser beam is subjected to refraction and convergence corresponding to the characteristics determined by the curved surface configuration or the configuration of the polyhedron of the lens 30 or prism 33, and penetrates therethrough, and it is received by the laser beam receiver 29. The respective laser beam receivers 29 having received the laser beam output the laser beam reception data, the respective laser beam reception data are collected in a DIU sampling unit 4 via transmission paths 3 consisting of coaxial cables, twist cables, optical fibers, or the like as shown in Fig. 1, and they are transmitted to a computer 5 via this DIU sampling unit 4.

In the event that the above-described structure vibrate, while the laser irradiator 28 and the laser beam receiver 29 vibrate jointly with the structure, since the lens 30 or prism 33 is held floating in the space and is kept stationary, a receiving position of the laser beam emitted by the laser irradiator 28 on the beam receiving surface of the laser beam receiver 29 would vary in a mode corresponding to the characteristics determined by the vibration of the structure and the configuration of the lens 30 or prism 33.

With regard to the receiving position of a laser beam on the receiving surface of the laser beam receiver 29, as shown in detail in Figs. 7(b) and 7-(c), a displacement in the Y-axis direction is represented by a variable Y_1, a displacement in the Z-axis direction is represented by a variable Z_1, and a displacement in the X-axis direction is represented by a variable X_1 which is obtained by converting a variable of an image area $\beta - \alpha$ into a distance.

The above-described variables representing the displacements in the directions of X-, Y- and Z-axes, are input to the computer 5 via the DIU sampling unit 4, and since the characteristics of the lens 30 and prism 33 are known, the computer 5 calculates the acceleration, amplitude, frequency and the like of the vibration of the structure by making use of these known characteristics, displays them, and also performs control of the actuators 6 necessitated for suppression of vibrations.

Through the above-mentioned procedure, a vibration sensor capable of detecting a minute vibration of a structure under a micro-gravity environment, has been realized.

It is to be noted that while the above-described preferred embodiment concerns a vibration sensor making use of a laser beam, it can be modified to a vibration sensor making use of light, electromagnetic waves or sound waves having any arbitrary frequency by replacing an oscillator and an oscillation receiver which can emit and receive light, electromagnetic waves or sound waves having any arbitrary frequency, for the above-mentioned laser irradiator and laser beam receiver, and substituting members capable of refracting, converging and allowing to penetrate the respective waves for the lens or prism. In addition, in the case where a plurality of laser irradiator 8 are provided, it is preferable that the frequencies or wavelengths (colors) of the irradiating laser beams can be set differently so as to obviate erroneous reading by the laser beam receivers 9.

Also, the illustrated system can perform detection of vibrations while it is carrying out three-dimensional position control of the lens 30 and prism 33 by moving the lens 30 and prism 33 within a predetermined range in the initial stage or in a continuous or intermittent manner and applying deviations of the detected waves caused by natural vibration or rotation within gas of the lens 30 or prism 33 simultaneously to a control filter, owing to enclosure of gas and active vibration suppression (loudspeaker, microphone, etc.) functions.

Here, the enclosure of gas and active vibration suppression and the like could be such that selection of an operable (used) state and an inoperable (unused) state is possible.

Furthermore, it is possible to elongate or change an optical path and thereby improve a detection capability for vibrations by inserting any arbitrary number of reflection mirrors or separate lenses or prisms in the path extending from the irradiator 8 via the lens 30 or prism 33 up to the laser beam receiver 29.

Next description will be made on a third preferred embodiment of the vibration sensor according to the present invention with reference to Figs. 8 to 10.

The vibration sensor according to this preferred embodiment is composed of a reflector 50 consisting of a polyhedron having any number of surfaces (1 to ∞ surfaces (sphere)), a laser irradiator 48 for irradiating the reflector 50 with laser beam, a planar laser beam receiver 49 constructed of CCD's so as to receive a laser beam reflected by the reflector 50, and further, a support mechanism 47 for holding the reflector 50. The laser irradiator 48, the laser beam receiver 49 and the supporting mechanism 47 are fixed to an airframe of a space station 1.

Fig. 8 shows the state where the reflector 50 is fixed by means of the supporting mechanism 47.

It is to be noted that in the case of providing a plurality of laser irradiators 48, it is made possible to differently set the frequencies, wavelengths or colors of the emitted laser beams so that erroneous reading by the laser beam receiver 49 may be obviated.

Fig. 9 shows a working state of this vibration sensor 2 under a micro-gravity environment. Although illustration is omitted, the supporting mechanism 47 is separated from the reflector 50 as gently attracted towards the inner surface of the laser beam receiver 49 by means of a support structure driver 57, and holds the reflector 50 in the condition of floating in a zero-gravity space. At this time, the surroundings of the reflector 50 could be either vacuum or any arbitrary gas, and the reflector 50 is held in a non-support non-vibration state.

However, in the case of carrying out the following treatment, the illustrated system is possible to detect vibrations while performing three-dimensional position control of the reflector 50 by moving the reflector 50 within a predetermined range in the initial stage or in a continuous or intermittent fashion with the aid of enclosure of gas and active vibration-suppressing (loudspeaker, microphone, etc.) functions and simultaneously applying a deviation of detected waves caused by natural vibration in gas or rotation of the reflector 50 to a control filter.

It is to be noted that with regard to gas, active vibration-suppressing and the like, it is possible to select either to operate (use) or not to operate.

Laser beams emitted from the laser irradiators 48 are reflected by the reflector 50, and received by the laser beam receivers 49. It is to be noted that it is possible to improve a vibration detecting capability by inserting any arbitrary number of separate reflector mirrors in the path extending from the irradiator 48 via the reflector 50 up to the laser beam receiver 49 and thereby elongating the optical path. The laser beam receiver 49 detects an amplitude, a frequency and the like of the vibration of the received laser beam. The laser beam receiver 49 detects an amplitude and a frequency of a vibration on the basis of movement of the received laser beam. The vibration data detected by the laser beam detector 49 are sent to a computer 5, then analyzed, and used for control or the like of the above-described actuators 6.

A sensor body frame 51 is fixed to a space station structure 1 and supports the laser irradiators 48 and the like.

A laser irradiator power supply controller 52 controls electric power fed to the respective laser irradiators 48, frequencies of the emitted laser beams and the like.

A laser beam reception data sampling unit 53 processes the data of vibration loci of laser beams emitted from the respective laser irradiators 48, then reflected by the reflector 50 and received on the laser beam receiving surface of the laser beam receiver 49, and transmits the processed data to the CPU 54.

The CPU 54 consists of function coupling means as shown in Fig. 10, and it performs the following operations.

At first, a detection start command is received from a command bus 58. The detection start command is transmitted to a support command generator 72 after it has been confirmed by scheduling means 71 that the command fulfils a necessary condition and a time condition, and then a support release command is issued to a support structure drive controller 56. In response to this command, the support structure drive controller 56 calculates a support release speed. a timing and the like and instructs these to a support structure driving device 57. hence support of the reflector. 50 by the support mechanism 47 is released. and the reflector 50 is caused to float in a zero-gravity space.

Next, under the floating condition of the reflector 50. laser beam irradiation for the purpose of calibration is instructed from the scheduling means 71 to a laser beam emission controller 73. In response to this instruction, after a detailed process such as selection of the laser irradiators 48 has been clarified, the laser beam emission controller 73 instructs to a laser irradiator power supply controller 52, and the same laser irradiator power supply controller 52 allots laser wavelengths, electric power supplies and the like to the respective laser irradiators 48 as described previously.

At the time of calibration, laser beams are emitted from all the laser irradiators 48 towards the reflector 50. Laser beams reflected by the reflectors 50 are received by the laser beam receivers 49, and the reception signals are transferred as data to the laser beam reception data sampling unit 53. Here, the laser beam reception data sampling unit 53 performs simple calculations by means of a large amount of data to seek for vibrating direction characteristics and coordinate transformations for the respective wavelengths, that is, for the respective colors, and outputs them to a reflector motion calculator 74 of the CPU 53.

In the reflector motion calculator 74, the position and motion such as speed, acceleration, amplitude, period and the like of the reflector 50 are calculated by making use of these data. Then it outputs the calculated reflector motion to a controller 63 for active vibration suppression of the reflector to cause a wave projector 62 to be controlled by the reflector active vibration-suppressing controller 63 so that a wave opposite to the reflector motion may be formed in a thin gas so as to hold the reflector 50 within a predetermined space. It is to be noted that while a low-frequency loudspeaker is most commonly used as the wave projector 62, besides other means for applying a wave to gas such as a high-frequency sound wave generator can be employed.

Under the condition that the reflector 50 could be stopped in motion or could be suppressed to a vibrating state in a predetermined range, the motion of the reflector under this stationary state is input to a memory 55, and it is later used as a filter.

The above-described is a procedure of calibration, and now description will be made on the operation of the CPU 54 in the case of measuring vibrations as a vibration sensor.

In the case of vibration measurement also, the laser irradiator 48 is held in an ON state continuously from the time of calibration, hence while the laser beam reflected from the reflector 50 is being received by the laser beam receiver 49, the data passed through the laser beam reception data sampling unit 53 are processed in the reflector motion calculator 74 to seek for motion of the reflector 50, furthermore as described previously, the motion under the stationary state read out of the memory 55 is input to the reflector motion calculator 74, and by subtracting the motion from the motion at the present, vibration of the vibration sensor is calculated. The calculated vibration is sent to a data transmission bus 59.

While a system wherein a laser beam is emitted from the laser irradiator 48 then reflected by the reflector 50 and received by the laser beam receiver 49 has been explained in the above-described third preferred embodiment, the present invention is not limited to such system, but any arbitrary energy such as light (visible light and invisible light), electromagnetic waves, sound waves or the like having various frequencies could be employed.

In addition, while a system making use of a reflector 50 has been disclosed in the above-described third preferred embodiment, even if the system employs a transparent refractor as is the case with the second preferred embodiment, similar effects and advantages can be obtained.

As described in detail above, according to the present invention, maintenance of a micro-gravity environment, which is one of the most important problems in a pace system, a space shuttle, an artificial satelite and in micro-gravity environmental system on an aircraft and on the ground, becomes possible.

Also, owing to learning and predicting functions by a software of the system, even with respect to a space environment which cannot be verified at the time of development of this system on the ground, accumulation of data after launching to the space can be utilized for the system as empirical values. Accordingly, a performance of a system is in itself improved in the cosmic space.

In addition, with the vibration sensor according to the present invention, vibrations can be measured accurately under a micro-gravity environment. Moreover, since the reflector mirror has no support, a measurable range of the nature (acceleration, amplitude, frequency, etc.) of the vibrations to be detected is not subjected to any limitation.

Claims

1. A vibration sensor for measuring vibrations under a micro-gravity environment, characterized

by comprising:

a reflector (10) disposed as floating in a micro-gravity space and consisting of a polyhedron having an arbitrary number of surfaces reflecting predetermined energy such as laser beams, electromagnetic waves, sound waves and the like having various frequencies according to known characteristics;

output means (8) fixed to a vibrating body (1) for irradiating said reflector (10) with said predetermined energy; and

receiving means (9) fixed to said vibrating body (1) for receiving reflection energy reflected from said reflector (10) and measuring the natures of vibrations of said vibrating body on the basis of variations of said reflection energy.

2. A vibration sensor for detecting vibrations under a micro-gravity environment, characterized by comprising:

a transparent refractor (30) disposed as floating in a micro-gravity space and having known characteristics;

an irradiator (28) disposed on one side of said transparent refractor (30) and fixed to a structure (1) whose vibrations are to be detected for irradiating with light rays; and

a light receiver (29) disposed on the other side of said transparent refractor (30) as opposed to said irradiator (28) and fixed to said structure (1) for receiving the light rays radiated by the irradiator (28) via the transparent refractor (30).

3. A vibration sensor for detecting vibrations under a micro-gravity environment as claimed in claim 1 or 2, wherein active vibration suppressing means (63) is provided for holding said reflector (10) and refractor (30) stationary in a micro-gravity space.

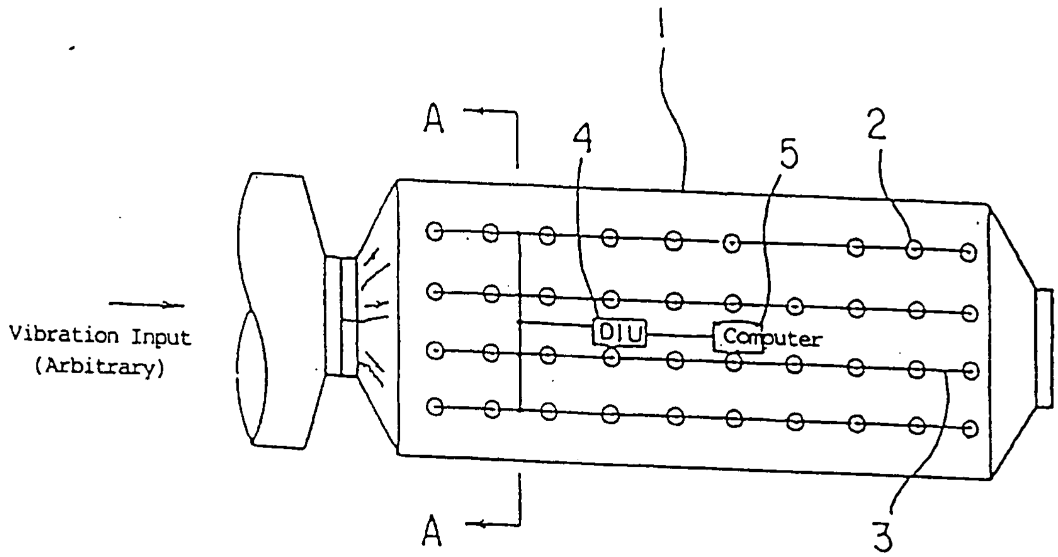


Fig. 1 (a)

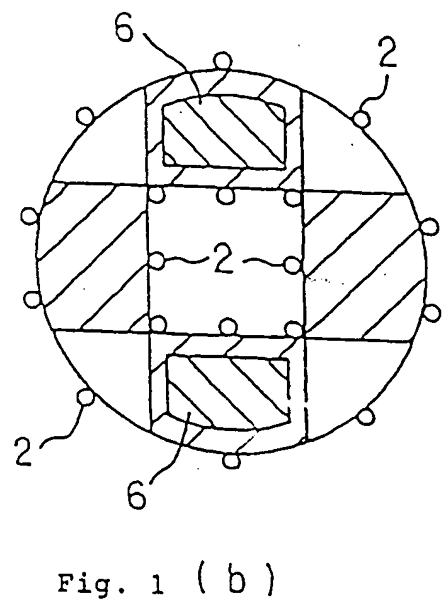


Fig. 1 (b)

Fig. 2

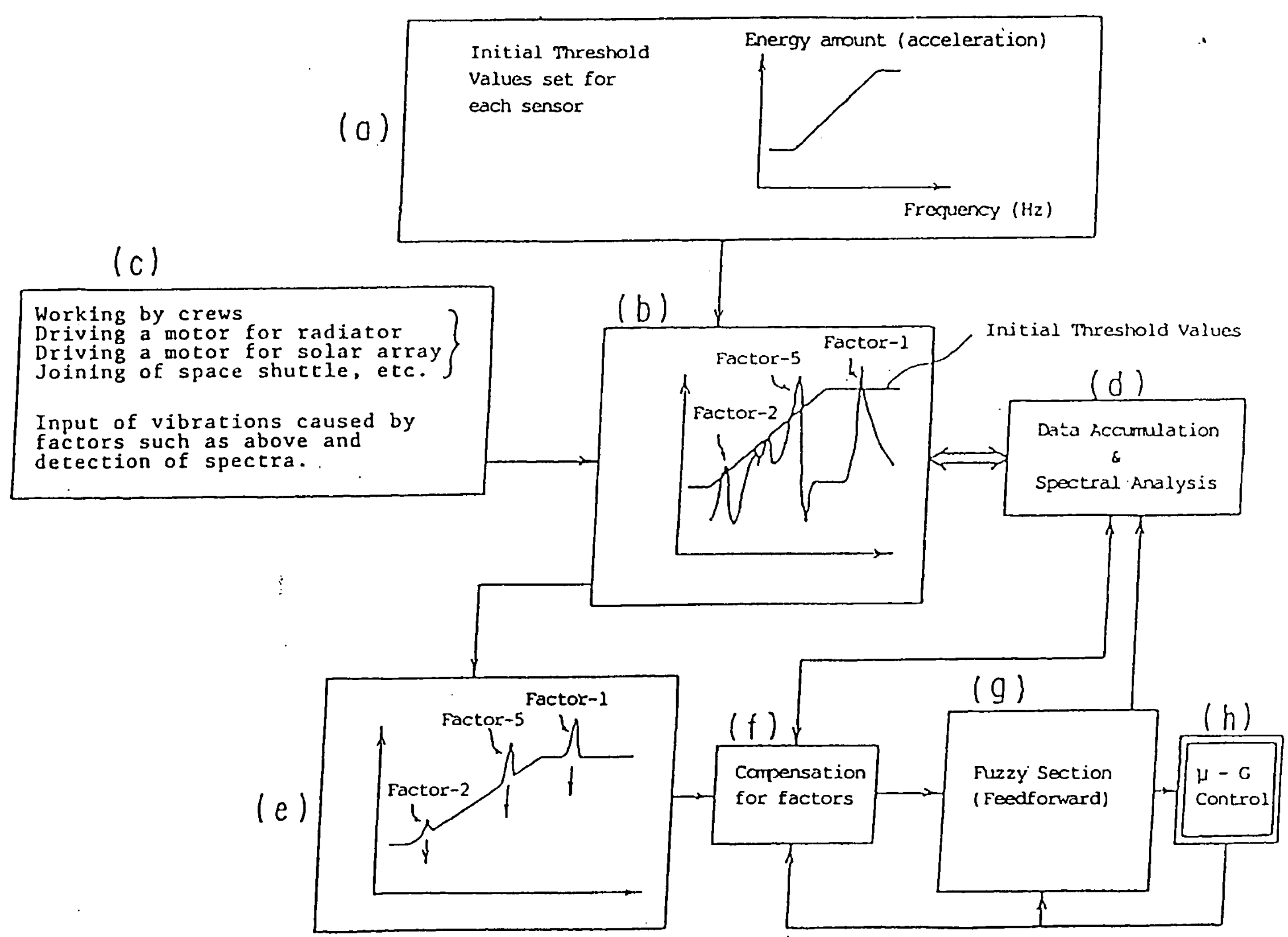
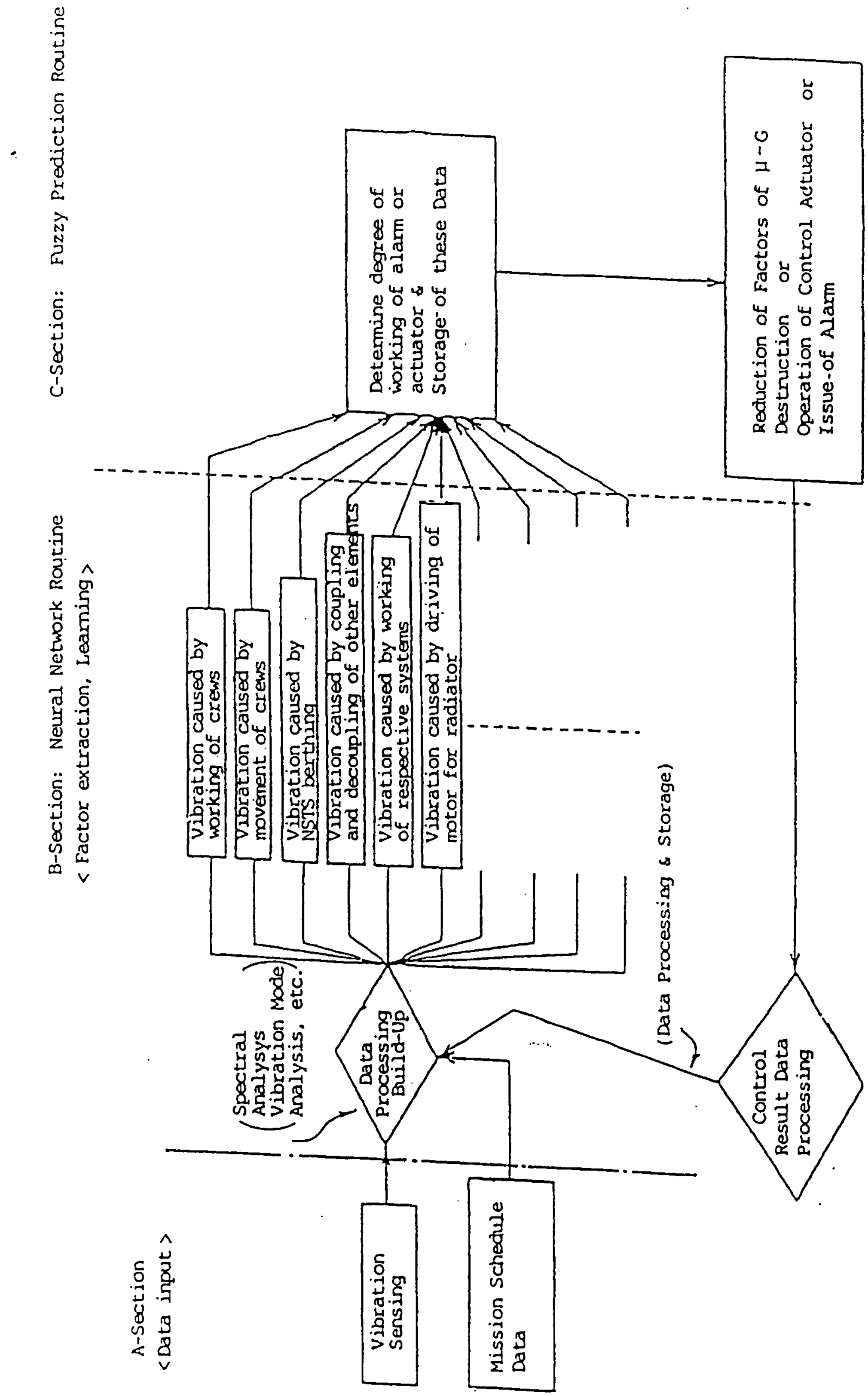

(a)
Initial Threshold
Values set for
each sensor
Energy amount (acceleration)
Frequency (Hz)
(c)
Working by crews
Driving a motor for radiator
Driving a motor for solar array
Joining of space shuttle, etc.
Input of vibrations caused by
factors such as above and
detection of spectra.
(b)
Factor-5
Factor-1
Factor-2
Initial Threshold Values
(d)
Data Accumulation
&
Spectral Analysis
(e)
Factor-1
Factor-5
Factor-2
(f)
Compensation
for factors
(g)
Fuzzy Section
(Feedforward)
(h)
μ - G
Control

Fig. 3



A-Section
<Data input>
Vibration Sensing
Mission Schedule Data
Spectral Analysys Vibration Mode Analysis, etc.
Data Processing Build-Up
Control Result Data Processing
(Data Processing & Storage)
B-Section: Neural Network Routine
< Factor extraction, Learning >
Vibration caused by working of crews
Vibration caused by movement of crews
Vibration caused by NSTS berthing
Vibration caused by coupling and decoupling of other elements
Vibration caused by working of respective systems
Vibration caused by driving of motor for radiator
C-Section: Fuzzy Prediction Routine
Determine degree of working of alarm or actuator & Storage of these Data
Reduction of Factors of μ-G Destruction or Operation of Control Actuator or Issue of Alarm

Fig. 4

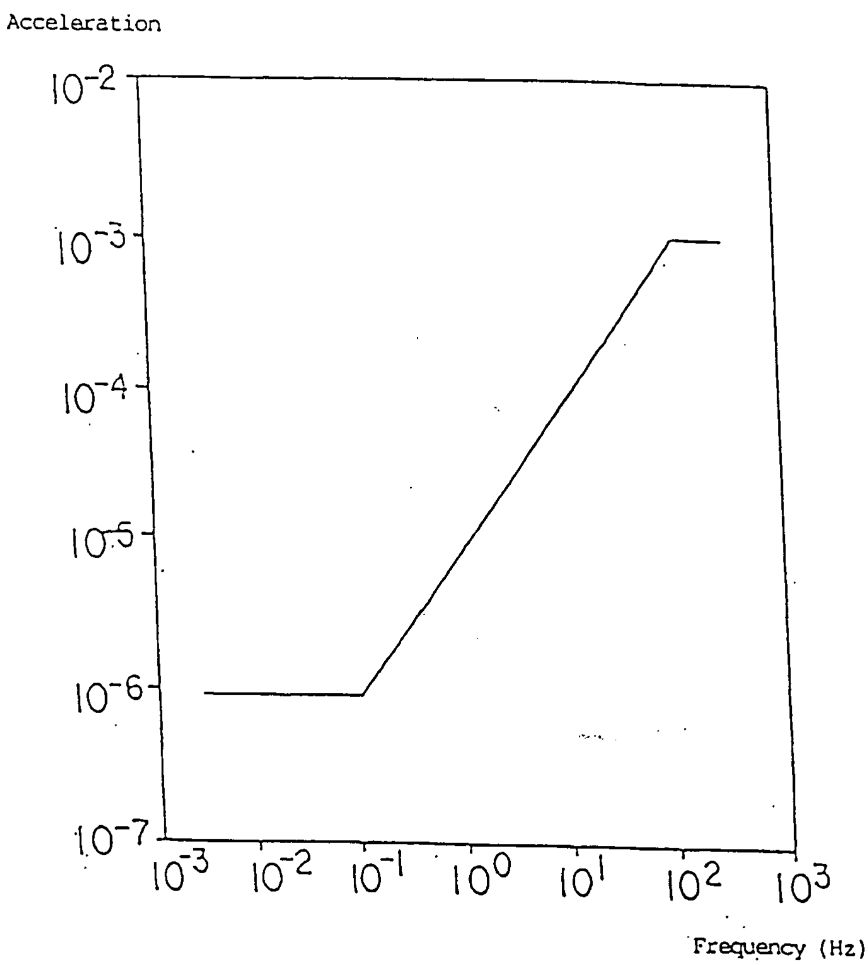

Acceleration
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Frequency (Hz)

Fig. 5

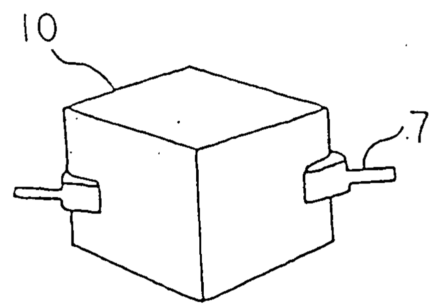


Fig. 6

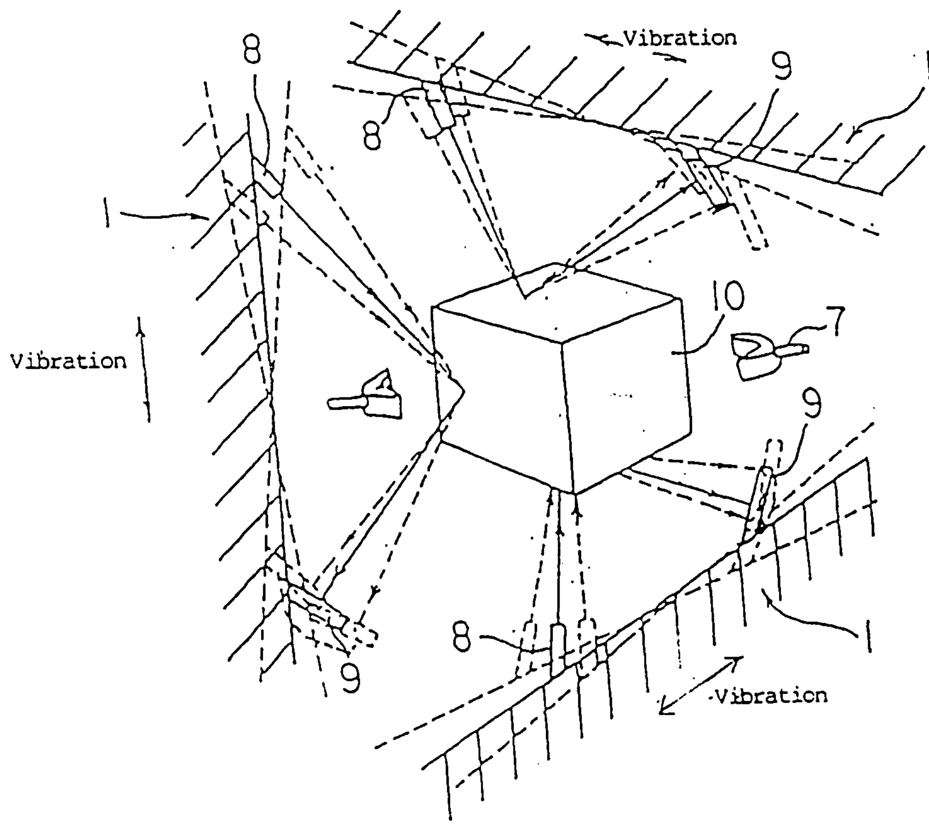
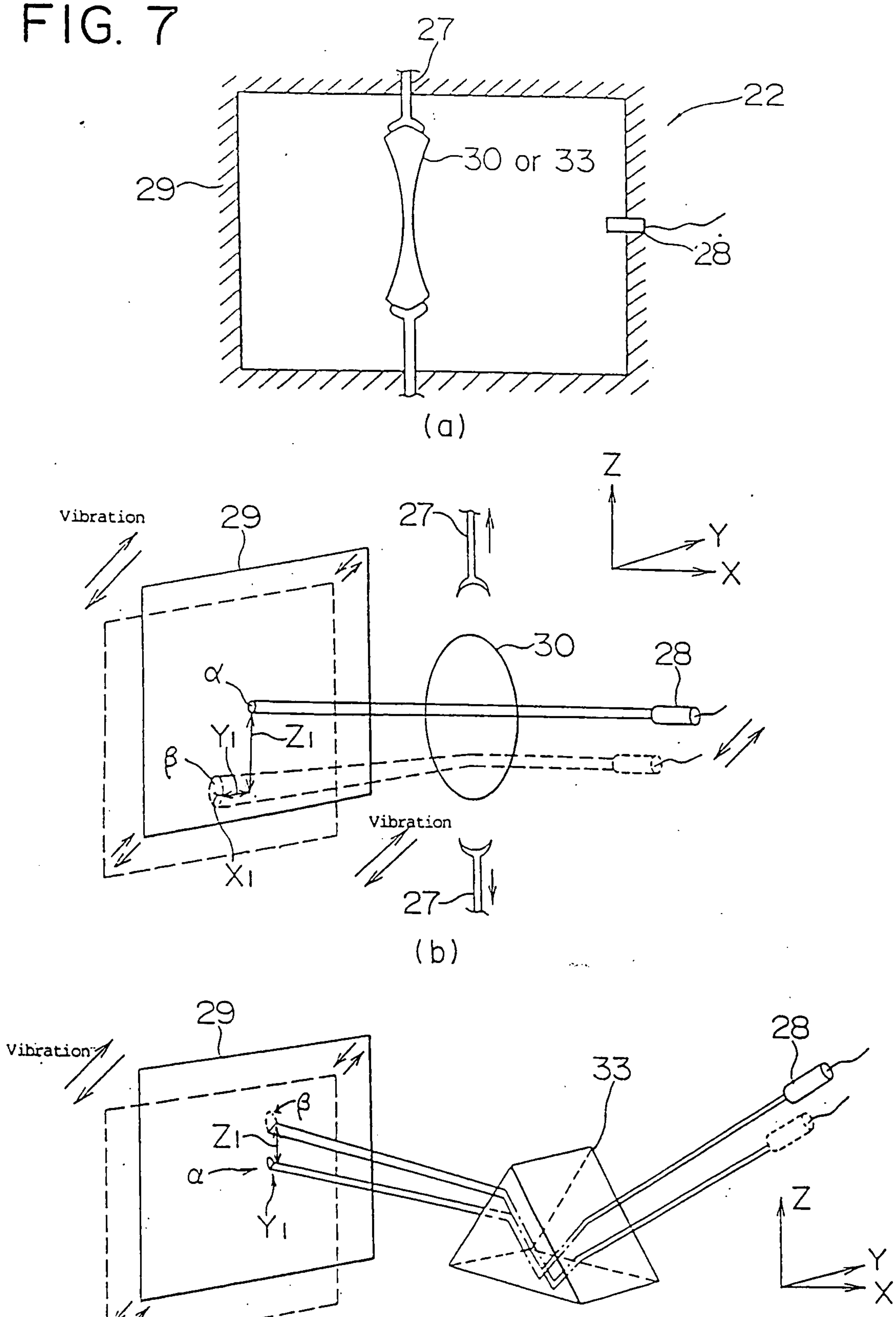
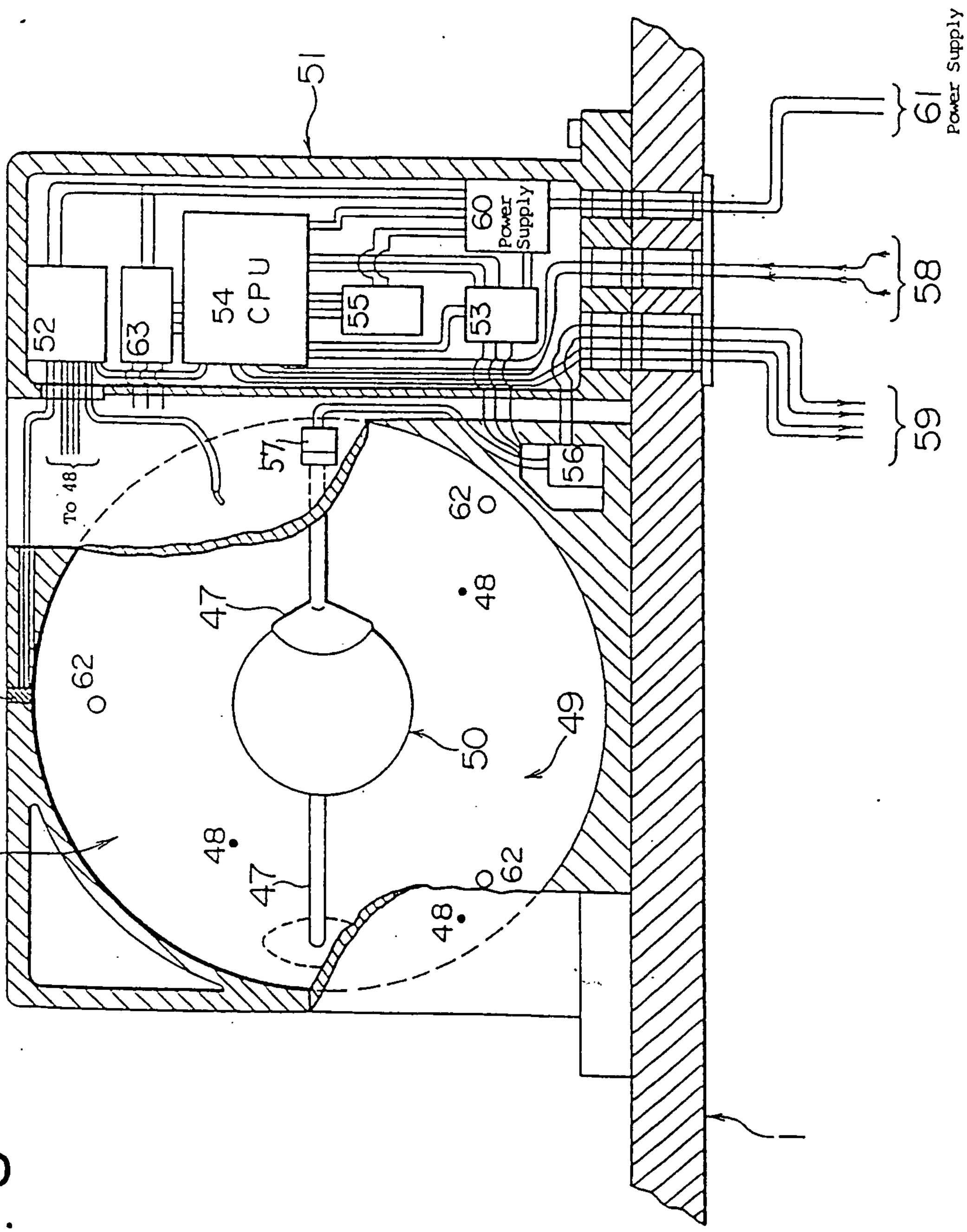


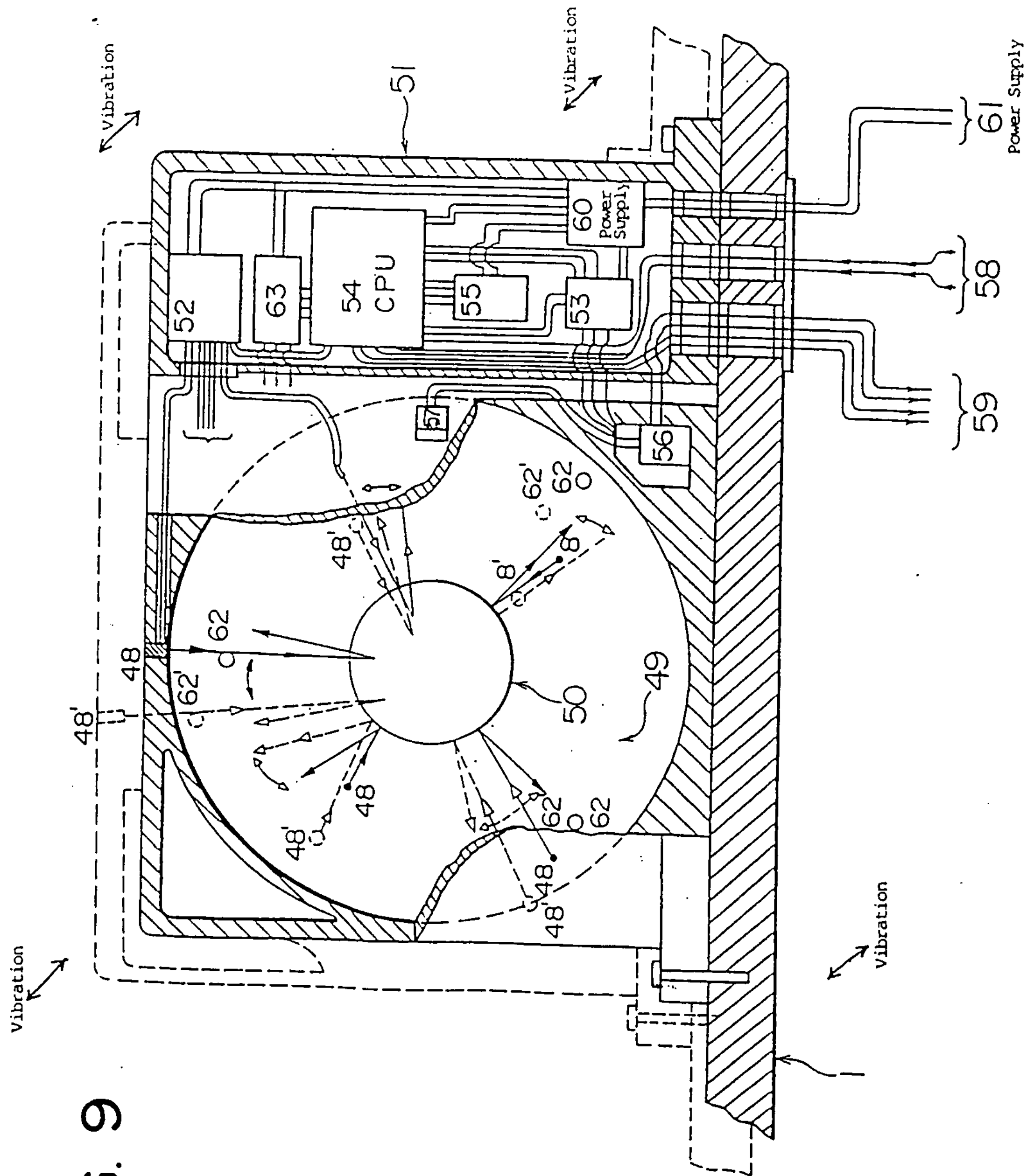
FIG. 7


27
22
30 or 33
29
28
(a)
Vibration
29
27
Z
Y
X
30
28
α
Y1
Z1
β
X1
Vibration
27
(b)
Vibration
29
28
33
β
Z1
α
Y1
Z
Y
X

(c)

FIG. 8

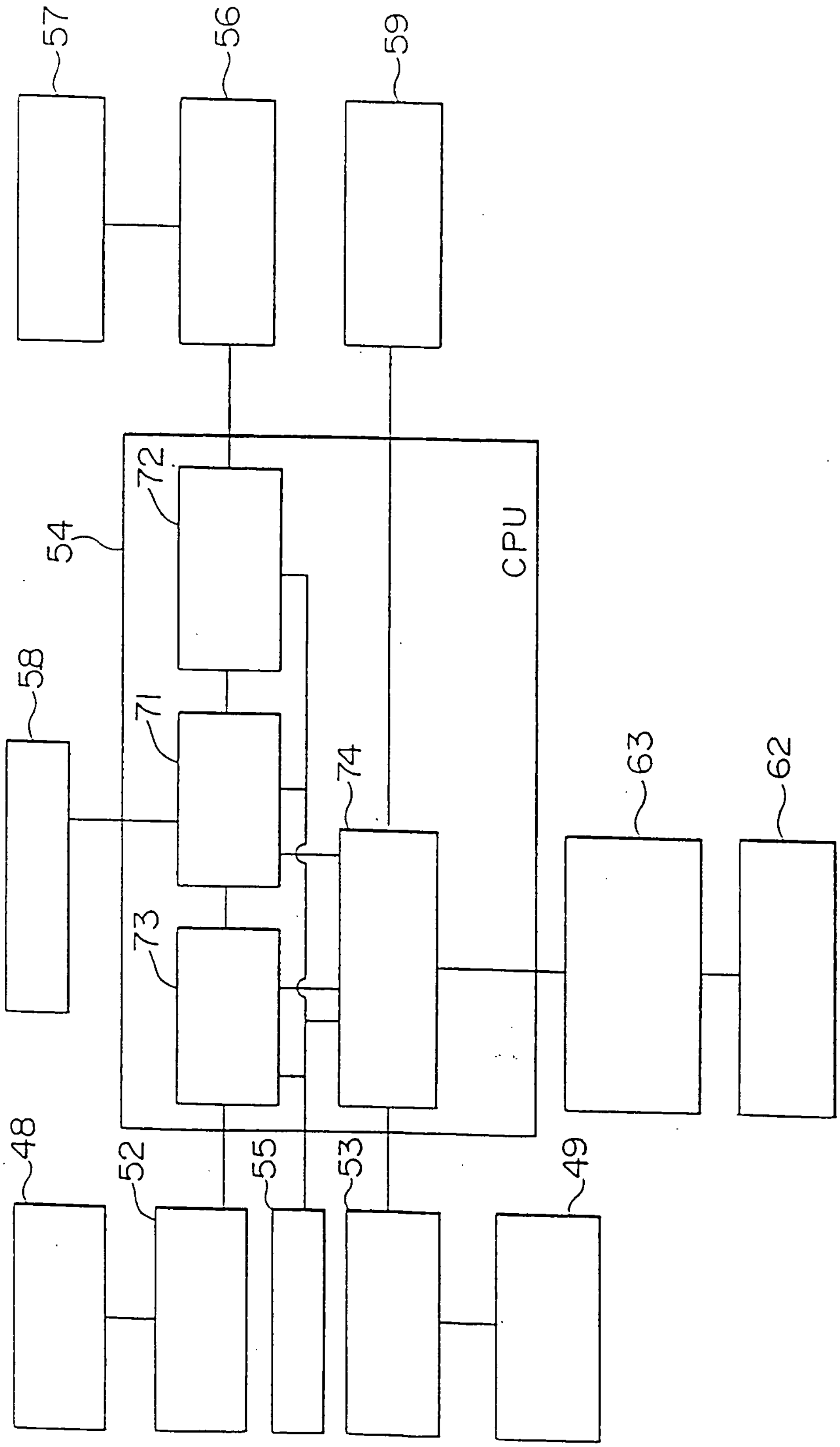

51
52
63
54
CPU
55
53
60
Power Supply
61
Power Supply
58
59
56
57
To 48
48
62
47
50
49
1



Vibration
Vibration
Vibration
Vibration
51
52
63
54
CPU
55
53
60
Power Supply
56
57
58
59
61
Power Supply
48
48'
62
62'
8'
49
50

FIG. 9

FIG. 10



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 11 0844

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	US-A-4 170 904 (FISCHELL ET AL.) * column 1, line 63 - column 2, line 8 * * column 3, line 51 - column 4, line 18 * * column 5, line 49 - column 9, line 65; figures 1-4 * ---	1,2	B64G1/22 G01P15/08 G01H9/00
A	WO-A-90 08962 (KENT SCIENTIFIC AND INDUSTRIAL PROJECTS LIMITED) * page 1, line 1 - line 6 * * page 5, line 19 - page 9, line 2; figures 1,2 * ---	1,2	
A,P	DE-A-41 29 359 (FÜSSL, R.) * column 1, line 30 - column 2, line 16 * * column 2, line 19 - line 65; figure 1 * ---	1,2	
A	EP-A-0 408 825 (THE BOEING COMPANY) * column 3, line 7 - column 5, line 13; figures 1-3 * ---	1,2	
A	US-A-3 232 120 (ENSLEY) * column 2, line 22 - column 4, line 74; figures 1-4 * -----	1,2	**TECHNICAL FIELDS SEARCHED (Int.Cl.5)** B64G G01P G01H G01V

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 August 1995	Rivero, C

CATEGORY OF CITED DOCUMENTS

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : H04L 11/20	A1	(11) International Publication Number: WO 89/09522 (43) International Publication Date: 5 October 1989 (05.10.89)

(21) International Application Number: PCT/US89/01267

(22) International Filing Date: 27 March 1989 (27.03.89)

(31) Priority Application Number: 175,239

(32) Priority Date: 30 March 1988 (30.03.88)

(33) Priority Country: US

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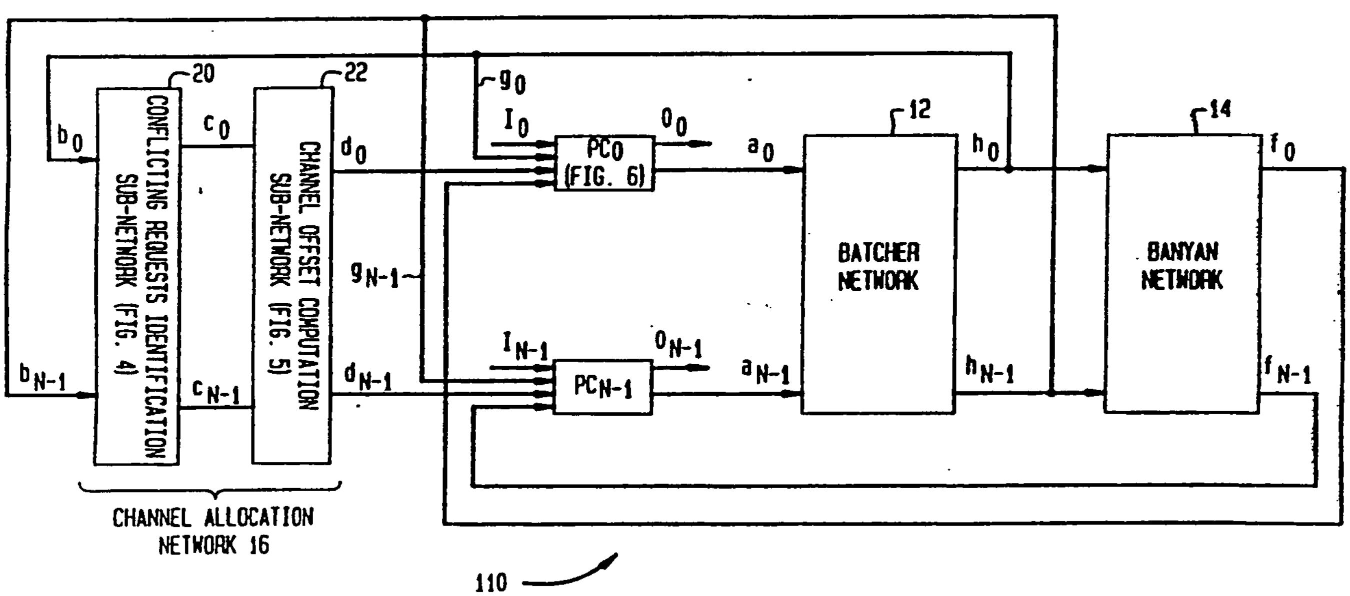
(81) Designated States: AT (European patent), BE-(European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.
With amended claims.

Date of publication of the amended claims: 16 November 1989 (16.11.89)

(54) Title: MULTICHANNEL BANDWITH ALLOCATION



(57) Abstract

A method for allocating bandwith in a broadband packet switching network is disclosed. The inventive method utilizes channel groups which may be defined as a set of parallel packet channels that act as a single data link connection between packet switches. In accordance with the inventive method, bandwidth is allocated in two steps. At virtual circuit setup time, bandwidth is reserved in particular channel groups. At transmission time packets are assigned to individual channels within the groups. The bandwidth allocation technique, known as multichannel bandwidth allocation, leads to increased throughput and reduced packet loss.

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MULTICHANNEL BANDWIDTH ALLOCATION

Field of the Invention

The present invention relates to a broadband packet switching network and, more particularly, to a method for allocating bandwidth in such a network.

Background of the Invention

A packet switching network comprises an array of packet switches interconnected by packet channels. Each packet channel connects two such packet switches. Typically, packets are routed through the network synchronously in time slots.

A packet switch in a broadband packet switching network is expected to have a throughput of several tens of Gigabits per second. An example of such a packet switch is described in "Batcher-Banyan Packet Switch With Output Conflict Resolution Scheme", U.S. Patent Application Serial No. 919,793 filed for E. Arthurs and J. Hui on October 16, 1986 and assigned to the assignee hereof.

To cope with high bit rate data streams, the lower layer communications protocols must be simplified. Simplification is achievable because of the high speed and low error rate qualities of fiber optic links. Dynamic Time Division Multiplexing (see e.g., "Dynamic Time Division Multiplexing", U.S. Patent Application Serial No. 118,977, filed on November 10, 1987 for H.J. Chao, S.H. Lee and L.T. Wu and assigned to the assignee hereof) and Asynchronous Time Division Multiplexing (see e.g., T.A. Coudreuse, J.P. Servel "Asynchronous Time-Division Techniques: An Experimental Packet Network Integrating Video Communication. Proceedings of International Switching Symposium, Florence, Italy, 1984 paper 32.C.2.) provide simple data link layer protocols for broadband packet switching networks.

However, high throughput switches and efficient data link protocols alone do not guarantee an effective transport system. It is important to be able to allocate bandwidth so that resources are efficiently utilized and congestion is kept under control. This is a difficult problem because the traffic characteristics of potential broadband services are uncertain and the capacity of each packet channel has an upper bound related to technology limits (i.e. the maximum bit rate allowed by current technology) and to processing requirements per packet (e.g. the time required for a switch or a multiplexer to process a packet, typically on the order of a few microseconds). Furthermore, the peak rate of traffic sources varies by several orders of magnitude, with peak demands that may approach or exceed the capacity of a single packet channel. Thus additional protocols are needed to support service rates that exceed the capacity of a single packet channel.

In a packet network, connections between specific users are achieved by means of virtual circuits. Each virtual circuit typically passes through a plurality of packet switches and packet channels therebetween. A virtual circuit has to be set up before the transfer of user information takes place via the virtual circuit. To set up a virtual circuit, an appropriate amount of bandwidth is reserved for the virtual circuit in the particular packet channels and packet switches comprising the virtual circuit.

More particularly, to set up a virtual circuit in a packet network, a sequence of connections between pairs of packet switches is established. Upon receiving a connection request, a packet switch S_1 acts as follows. According to a routing strategy such as Dynamic Non-Hierarchical Routing, the packet switch S_1 chooses the next adjacent packet switch S_2 in the virtual circuit. Then, out of the set of packet channels connecting the packet switches S_1 and S_2 a particular packet channel is chosen for the virtual circuit depending for example on the bandwidth already reserved on the packet channels between switches S_1 and S_2 and the expected traffic characteristics of the new connection.

A classical problem is the optimal allocation of virtual circuits to specific channels of a transmission facility to improve throughput and reduce delay. This becomes a critical issue when the peak rate of a traffic source is close to the channel capacity. An allocation policy that uniformly books (and loads) the packet channels between two adjacent packet switches minimizes the average delay for each connection but penalizes the establishment of high bandwidth connections because the requested bandwidth is likely to exceed the residual usable capacity of each single channel. Alternatively, a scheme assigning a virtual connection to the fullest channel that can accommodate the new bandwidth request minimizes the blocking probability of high-peak throughput sources, but does not optimize delay.

In view of the foregoing, it is an object of the present invention to provide a more efficient method for allocating bandwidth in a broadband packet switching network.

Summary of the Invention

The present invention is a method for allocating bandwidth in a packet switching network. In accordance with the present invention, a channel group may be defined as a set of parallel packet channels that acts as a single data link connection between two cooperating packet switches. (A similar concept known as a trunk group is described in J. Turner, U.S. Patent 4,374,907, issued on March 29, 1988.)

In accordance with the present invention, bandwidth in a packet network is allocated in two steps, at connection setup time and at transmission time. At connection setup time (i.e. when a virtual circuit is set up) bandwidth is reserved for the virtual circuit on the appropriate channel groups connecting specific pairs of packet switches. At transmission time, packets to be transmitted via particular channel groups are assigned to individual packet channels within the appropriate channel groups. More particularly, at transmission time each packet present at an input port of a packet switch and addressed to a particular outgoing channel group is assigned or allocated to an individual channel within the group. Note that in a particular embodiment, the bandwidth allocation scheme may require coordination between the input ports of a packet switch. Such coordination may be achieved by a central entity associated with the packet switch which collects the channel group requests of the input ports and allocates to the input ports specific channels in the requested channel groups.

Thus, in accordance with the present invention, virtual circuits are set up by reserving bandwidth in particular channel groups (multichannel bandwidth allocation). This is to be compared with the conventional prior art technique whereby virtual circuits are set up by reserving bandwidth in individual channels (unichannel bandwidth allocation). In accordance with the present invention, it is only after a virtual circuit is set up and at transmission time that data packets are assigned to individual packet channels.

The multichannel bandwidth allocation scheme provides several significant advantages. Due to the pooling effect, a channel group can support a greater number of sources than its channels could individually. Because of the statistical smoothing of the large number of sources served by a channel group, the total instantaneous load offered to a channel group is not likely to vary greatly from the average offered load. Thus, the capacity reserved for a virtual circuit using multichannel bandwidth allocation can be kept closer to the average load of the virtual circuit than in the traditional unichannel bandwidth allocation scheme wherein channel assignments must take greater account of the maximum possible load of a virtual circuit. The relatively slight impact on a channel group of a burst from a particular source makes assignment of a source to a particular channel group less a critical problem. In addition, the multichannel bandwidth allocation scheme enables super rate switching. This means that virtual circuits having a bit rate greater than the capacity of a single channel are provided for, since each virtual circuit is assigned to particular channel groups and not individual packet channels.

The multichannel allocation scheme increases the maximum throughout per port of a packet switch. For example, an input port buffered switch whose input ports are uniformly loaded by packet streams characterized by random output port destinations has a maximum throughput per port of about 0.59 when the conventional unichannel bandwidth allocating scheme is used. Throughput is defined as the ratio of the average channel traffic to the maximum channel capacity. In contrast, when channel groups comprising 32 individual channels are utilized in accordance with the present invention the throughput is in excess of 0.9. Finally, in the case of bursty sources the multichannel bandwidth allocation technique leads to a reduction in packet loss probably of several orders of magnitude in comparison with a system utilizing unichannel bandwidth allocation.

Brief Description of the Drawings

FIG. 1 schematically illustrates a packet network in which bandwidth is allocated in accordance with the multichannel bandwidth allocation procedure of the present invention.

FIG. 2 schematically illustrates a packet switch capable of carrying out the multichannel bandwidth allocation procedure in accordance with an illustrative embodiment of the present invention.

FIGS. 3A, 3B, 3C, and 3D schematically illustrate an example of the multichannel bandwidth allocation procedure as carried out by the packet switch of FIG. 2.

FIGS. 4 and 5 illustrate two sub-networks comprising part of the packet switch of FIG. 2.

FIG. 6 schematically illustrates a port controller for use in the packet switch of FIG. 2.

Detailed Description of the Invention

A. OVERVIEW OF MULTICHANNEL BANDWIDTH ALLOCATION

A packet network 100 which allocates bandwidth in accordance with the multichannel bandwidth allocation scheme of the present invention is illustrated in FIG. 1. The network of FIG. 1 comprises an array of packet switches including packet switches 110A, 110B, 110C, 110D. A packet switch 110 is shown in more detail in FIG. 2 and discussed in more detail in section B below. The network interfaces 102A and 102B serve to interface users A and B, respectively, with the network.

The network interfaces and packet switches are interconnected by channel groups 112. A channel group may be defined as a set of parallel packet channels that acts as a single data link between two cooperating routing entities such as packet switches. Thus for example there are three channel groups between switches 110A and 110B and there are two channel groups between network interface 102A and switch 110A.

In FIG. 1, the channel groups 112 are shown as each comprising a group of physically adjacent individual packet channels 114. However, through use of a logical addressing technique discussed below, the channel groups may be formed from individual channels which are not physically adjacent.

In the packet network 100 of FIG. 1, a connection between two users such as A and B is achieved by means of a virtual circuit. One example of a virtual circuit between users A and B comprises network interface 102A, channel group 112A, switch 110A, channel group 112B, switch 110B, channel group 112C and network interface 102B.

In accordance with the present invention, the bandwidth of a channel group is allocated in two steps, at connection setup time and at transmission time. At connection setup time (i.e. when a virtual circuit is set up) an appropriate amount of bandwidth is reserved in the channel groups comprising the virtual circuit. At transmission time, packets to be transmitted via particular channel groups are assigned to specific individual packet channels within the appropriate channel group. More particularly, packets present at the input ports of a particular packet switch and addressed to particular outgoing channel groups are assigned to specific individual channels within the groups.

To set up a virtual circuit in the network 100, a sequence of connections between pairs of packet switches is established. Upon receiving a connection request a packet switch such as a packet switch 110A acts as follows:

(1) According to a particular routing strategy, a switch such as switch 110A selects the next adjacent switch in the virtual circuit, e.g. switch 110B. (An example of a routing strategy at the network layer level is Dynamic Non-Hierarchical Routing).

(2) Within the set of channel groups between switches 110A and 110B, a specific channel group, say 112B, is selected that can accommodate the new connection request; such a choice being based on the current value of the bandwidth already reserved on each channel group between switches 110A and 110B.

(3) A bandwidth W_i is then booked in channel group 112B for the connection being established; if no suitable channel group between 110A and 110B is available the switch 110A searches for an alternate route or rejects the call. W_i is selected as a function of the channel group capacity, the traffic characteristics of the source, and the delay performance expected.

In the foregoing manner a virtual circuit may be set up in the network 100 of FIG. 1 between User A and User B. When virtual circuits are set up in the network 100 in this manner, packets arrive at the packet switches 110 containing a virtual circuit identifier which is mapped into the address of a particular outgoing channel group 112. The packet switches 110 serve to assign each incoming packet to a specific packet channel in the channel group to which the packet is addressed. The packet switches 110 also serve to route the incoming packets to the specific output channels. For example, a data packet to be transmitted via the virtual circuit between A and B arrives at switch 110A via a channel in channel group 112A and is provided with the address of outgoing channel group 112B. The switch 110A assigns this packet to a particular channel in channel group 112B and then routes this packet to the particular assigned channel in channel group 112B. A packet switch capable of accomplishing these tasks is discussed in the immediately following sections.

B. PACKET SWITCH FOR MULTICHANNEL BANDWIDTH LOCATION

A packet switch 110 capable of allocating bandwidth in accordance with the multichannel bandwidth allocation scheme of the present invention is illustrated in FIG. 2.

The packet switch 110 of FIG. 2 comprises a Batcher network 12 followed by a banyan network 14. Packets arriving at the Batcher network 12 via the lines $a_0 \ldots a_{N-1}$ are sorted according to a self-routing address at the head of each packet. An ordered set of packets with non-decreasing or non-increasing self-routing addresses is obtained at contiguous outputs of the Batcher network via the lines $h_0....h_{N-1}$. The banyan network 14 is a self-routing network adapted to route packets present at its inputs to the specific output addresses contained in the packet headers. In the banyan network, only one path exists between any input and output. Different paths corresponding to different input and output pairs may share internal links so that there may be packet collisions within the banyan network. However, packet collisions will not occur if the incoming packets have different self-routing addresses and are offered as an ordered set to a contiguous set of inputs of the banyan network. Hence, a combined Batcher-banyan network provides an internally non- blocking, full access switching network if the packets entering the inputs of the Batcher network are addressed to different outputs of the banyan network.

In addition to the Batcher-banyan network 12, 14, the packet switch 110 of FIG. 2 comprises a plurality of port controllers $PC_0...PC_{N-1}$. The circuitry of a port controller is illustrate in FIG. 6 and is discussed in section G below. The output lines or output packet channels of the switch 110 are designed $O_0....O_{N-1}$. Each of the output channels $O_0...O_{N-1}$ is connected to an associated port controller $PC_0...PC_{N-1}$. The output channels $O_0...O_{N-1}$ are organized into channel groups as shown in FIG. 1. Each of the output channel groups connects the packet switch 110 with another packet switch or with a network interface.

In accordance with the multichannel bandwidth allocation technique of the present invention, at call setup time, a virtual circuit passing through the packet switch 110 of FIG. 2, is assigned some bandwidth in the appropriate input packet channel group (not shown) and output packet channel group.

When virtual circuits are set up in the manner indicated above, each packet arriving at the switch 110 includes a virtual circuit identifier indicating the virtual circuit to which the packet belongs. A packet processor (not shown in FIG. 2) maps the virtual circuit identifier into the address of an outgoing channel group. Thus, each incoming packet present on one of the input lines $I_0...I_{N-1}$ contains the address of an output channel group. Each of the input lines $I_0...I_{N-1}$ is connected to an associated port controller $PC_0...PC_{N-1}$. It is the role of the packet switch 110 to assign to each incoming packet on lines $I_0...I_{N-1}$ an outgoing channel in the appropriate output channel group and to route each packet to the assigned output channel.

The channel assignment function of the packet switch 110 is performed by the channel allocation network 16. The channel allocation network 16 comprises a conflicting requests identification sub-network 20 and a channel offset computation sub-network 22. The conflicting requests identifying sub-network 20 is illustrated in FIG. 4 and discussed in section E below. The channel offset computation sub-network 22 is illustrated in FIG. 5 and discussed in section F below.

The routing function of the packet switch 110 is performed by the Batcher-banyan network 12, 14. The Batcher-banyan network is conventional and is not discussed in detail herein. It should be noted that input packets arrive synchronously in slots at the port controllers

$PC_0 \ldots PC_{N-1}$.

C. OUTPUT CHANNEL ASSIGNMENT ALGORITHM

A three-phase algorithm may be used to carry out the output channel assignment and routing functions of the packet switch 110. In phase I, each port controller with a data packet sends a request to engage a channel of the outgoing channel group indicated in the data packet. These requests are sorted in non-descending order by the Batcher network 12, so that requests for the same channel group are adjacent at the outputs of the Batcher network. This allows the channel allocation network 16, to compute an index for each request that identifies a particular channel in the appropriate output channel group. Those requests that cannot be accommodated in a particular channel group (e.g. because the number of requests for the channel group exceeds the number of channels in the group) are given an index corresponding to a channel that does not belong to the group requested. In phase II, each assigned index is used to form an acknowledgement packet which is transmitted back to the requesting port controller via the Batcher-banyan network. Each requesting port controller determines if it won the contention for the requested output channel group based on the capacity of the channel group requested and the index received. In phase III, the winning port controllers transmit their packets through the Batcher-banyan network to the appropriate output channel destinations. This three-phase algorithm is discussed in detail below.

First, however, it should be noted that in a switch supporting multichannel bandwidth allocation, it is desirable that the addresses of channels of the same group be consecutive. However, such a physical constraint on the output channels could seriously constrain a change of the configuration of the interswitch communication facilities, e.g., following a channel failure or an updating in the expected traffic patterns. For this reason a logical addressing scheme is introduced for the output channels. This logical addressing scheme decouples each output channel address from the physical address of the associated port controller.

Each output channel is assigned a logical address, so that a channel group is composed of channels with consecutive logical addresses. There is a one-to-one correspondence between the output channel logical address and the physical addresses of the associated port controllers. The channel with the lowest logical address in a group is the group leader. The group leader logical address also represents the group address. A specific channel in a group is identified by a channel offset given by the difference between the specific channel logical address and the group leader logical address. Each port controller is provided with two tables K_a and K_c. K_a maps each logical address to the associated physical address (i.e. the associated port controller address) of each output channel. K_c specifies the maximum value, maxoff(j), allowed for the channel offset in channel group j. Examples of the tables K_a and K_c are found in FIGS. 3A and 3B, respectively.

In the discussion which follows, the number of input channels and the number of output channels of the packet switch 110 of FIG. 2 of N. The number of output channel groups is designated by the letter G and D_i is the number of channels in group i which is referred to as the capacity of channel group i. Thus

$$N = \sum_{i=1}^{G} D_i, \text{ and}$$

$$D_i = \text{maxoff}(i) + 1.$$

For simplicity it is assumed that D_{max} is the maximum capacity allowed for a channel group and that N is a power of two. Let n and d denote the number of bits needed to code the logical address of a channel (or the physical address of a port controller) and the channel offset respectively. Thus, $n = \log_2 N$ and, in accordance with the three-phase output channel assignment algorithm to be described in detail below, $d = \lceil 1 + \log_2(D_{max}) \rceil$ where $\lceil x \rceil$ is the least integer greater than or equal to the real x.

In phase I, a port controller PC_i with a data packet to be transmitted to outgoing channel group j sends a request packet REQ (j,i). Each request packet contains, in order of transmission, the identifier j of the destination channel group to which the port controller PC_i wishes to send a data packet and the physical address i of the sending port controller. As indicated above, the identifier j of the destination channel group is the logical address of the channel group leader. The request packets enter the channel allocation network 16 of switch 110 of FIG. 2 via the lines $b_0 \ldots b_{N-1}$ after being sorted by the Batcher network 12 in non-decreasing order according to the destinations j. As indicated above and as shown in FIG. 2, the channel allocation network 16 comprises two sub-networks. The conflicting requests identification sub-network 20 receives a set of request packets REQ(j,i) from the Batcher network 12 sorted according to channel group destination address j on line $b_0 \ldots b_{N-1}$ and identifies requests for the same channel group. As indicated above, there is no guarantee that the number of requests for a group does not exceed the number of channels in the group.

The channel offset computation sub-network 22 assigns an actual offset, actoff(j), to each request for group j, to spread the requests for group j over all the channels of group j. Each offset belonging to the interval $[0, D_{max-1}]$ is assigned to only one request for output channel group j, while other requests for the same group are given an offset actoff(j)$>D_{max}$. Since maxoff(j) $\leq D_{max-1}$, each channel of group j is allocated to only one request for group j. Then, the actoff(j) value present at the channel allocation network 16 output line $d_k(k=0 \ldots N-1)$ is transmitted to the port controller PC_k. The port controller PC_k combines the source field i of the request packet REQ(j,i) present on line b_k with the actoff(j) value present on line D_k to form an acknowledgement packet ACK(i,actoff(j)). Note that the source field of the request packet on line b_k is transmitted to the port controller PC_k via the line g_k.

In phase II of the output channel assignment algorithm, the acknowledgement packet ACK(i,actoff(j)) is reentered into the Batcher network 12 from the port controller PC_k and is routed through the Batcher and banyan networks with the self-routing address i. The packets ACK (...) do not collide with each other in the Batcher-banyan network since there is no more than one acknowledgement packet ACK(i, actoff (j)) addressed to each output of the banyan network. Each acknowledgement packet ACK(i,actoff(j)) emerges from the banyan network on line $f_i(i=0...N-1)$ and is routed via the line f_i to the port controller PC_i. Port controller PC_i, receiving ACK(i,actoff(j)), has thus been given an actoff(j), i.e. an actual offset which may or may not correspond to a member of channel group j depending on the value of maxoff(j) which value indicates the capacity of channel group j. This completes phase II of the output channel assignment algorithm.

In phase III, if actoff(j) ≤ maxoff(j), port controller PC_i sends its data packet DATA(p(j + actoff(j)) to the port controller whose physical address p(x) is mapped by table K_a (see FIG. 3A) to the channel logical address x=j + actoff(j). Packets DATA(p(x)) cross the Batcher-banyan network without collisions, since the winning requests have been assigned different output logical addresses, and, hence, different physical addresses of destination port controllers. If actoff(j) > maxoff(j), the port controller waits for the start of the next transmission cycle to issue a new request for its packet, which remains stored in an input queue.

D. ILLUSTRATIVE EXAMPLE OF THE OUTPUT CHANNEL ASSIGNMENT ALGORITHM

An example of the operation of the switch 110 of FIG. 2 for assigning individual output channels to packets addressed to channel groups is schematically illustrated in FIGS. 3A, 3B, 3C and 3D. FIG. 3A is an example of the above-mentioned table K_a present in each port controller. The table K_a of FIG. 3A provides a logical-to-physical address mapping of the output channels $O_0...O_{N-1}$. Thus, the output channel with logical address "0" has physical address "4". FIG. 3B is an example of the above-mentioned table K_c present in each port controller. The table K_c of FIG. 3B shows the output channel group capacities. FIG. 3C shows the channel allocation network 16 and the port controllers of the switch 110 of FIG. 2. FIG. 3D shows the port controllers and Batcher-banyan portion of the switch 110 of FIG. 2. In FIGS. 3A, 3B, 3C and 3D, N=8 and the maximum capacity of a channel group is three individual channels.

As shown in FIGS. 3A and 3B the N=8 output channels are arranged in five channel groups. The channel in each group with the lowest logical address is the group leader. The group leader logical address also represents the group address. Thus, as shown in FIG. 3B, the five channel groups are each identified by the logical address of the group leader. FIG. 3B also includes the maximum offset (maxoff) of each group. As indicated above, the offset of a particular output channel is the difference between the logical address of the particular output channel and the logical address of the group leader of the group to which the channel belongs. For example, Group #4 has a maximum offset or maxoff of 2. This means that Group #4 comprises three channels i.e. the channels with the logical address 4+0=4, 4+1=5, and 4+2=6. Similarly, group #1 has a maxoff of 1 which means that group 1 comprises 2 channels i.e. the channels with the logical addresses 1+0=1 and 1+1=2.

As previously discussed, in phase I of the output channel assignment algorithm, each port controller PC_i having a data packet to transmit to output channel group j generates a request packet REQ(j,i). These request packets are sorted in non- decreasing order according to destination address j in the Batcher network (12 of FIG. 2). The request packets, sorted by destination address, are then offered to the conflicting requests identification sub-network 20 of the channel allocation network 16. A set of such sorted request packets is shown at the inputs to the channel allocation network 16 of FIG. 3C, i.e. at the left-hand side of FIG. 3C. As can be seen by looking at the request packets there are two requests for group #0, one request for group #1, and five requests for group #4. Note, the number of requests for group #4 exceeds the capacity of group #4.

In the conflicting requests identification sub-network 20 of FIG. 3C, requests for the same channel group are identified. Each destination address is compared with the destination address in the request packet on the line above it. If the destination address in a request packet on line b_{k+1} (k=0...N-2) is equal to the destination in a request packet on line b_k (k=0....N-2) then the output of the conflicting requests identification sub-network on line C_{k+1} (K=0...N-2) is a logic "1". If the addresses are not equal, the output of the conflicting requests identification sub-network on line c_{k+1} (k=0...N-2) is a logic "0". The output on the uppermost line C_0 is always logic "0". The outputs of the conflicting requests identification sub-network as derived from the request packets of the present example are shown adjacent the lines C_0 ... C_7 in FIG. 3C. Thus the conflict identifications for group #0 appear on lines c_0, c_1 and the conflict identifications for group #4 appear on lines c_3, c_4, c_5, c_6 and c_7. There are no conflicts for group #1 as indicated by the zero on line C_2 and by the zero on line C_3.

The channel offset computation sub-network of FIG. 3C, utilizes the values on lines C_0 ... C_7 to compute the actual offsets (actoff(j)). The actual offsets are used to spread the requests for a given channel group over the channels in the group in a manner so that the offsets for each particular group are assigned only once. The channel offset computation sub-network is a running adder network. More particularly, the actual offsets are arrived at by calculating a running sum of the outputs of sub-network 20 for each channel group. The channel offset computation sub-network "knows" the boundaries between the channel groups as each logic "0" on lines $c_0 \ldots c_{N-1}$ indicates the start of the offsets for a new channel group (and hence the start of a new sequence of running sums). These running sums appear on lines d_0 to d_{N-1} (N=8) of FIG. 3C and represent the actual offsets which are added to the group addresses to obtain the individual output channel addresses.

The actual offsets are then transmitted to the port controllers $PC_0 \dots PC_7$ via lines $d_0 \dots d_7$. The port controllers then generate the acknowledgement packets ACK(i,actoff(j)) as follows. PC_i combines the source field of the request packet arriving on line b_i with the offset present on line d_i (i=0...N-1). For example, the request packet present on line b_1 is REQ(0,5) whose source is PC_5 and the offset present on line d_1 is 1. Thus, the acknowledgement packets produced by PC_1 is ACK(5,1). Note that the source fields of the request packets arriving on lines $b_0 \dots b_{N-1}$ are transmitted to the port controllers via lines $g_0 \dots g_{N-1}$ to form the acknowledgement packets. The full set of acknowledgment packets is shown at the right-hand side of FIG. 3C. This completes phase I of the channel assignment algorithm.

In phase II of the channel assignment algorithm, the acknowledgement packets (now located at the right-hand side of FIG. 3C) are routed through the Batcher-banyan network and then returned to the port controllers so that ACK(i,actoff(j)) is at PC_i. The acknowledgment packets, after being routed through the Batcher-banyan network and back to the port controllers, are shown at the left-hand side of FIG. 3D. This completes phase II of the channel assignment algorithm.

In phase III of the channel assignment algorithm, the port controllers PC_i transmit the data packets DATA(p(j+actoff(j)) to the specific output channels p(j+actoff(j)) where p(x) is the physical address corresponding to the logical address x. The port controller PC_i transmits its data packet if actoff(j) ≤ maxoff(j), otherwise the port controller PC_i buffers its packet. In the present example, this condition is not satisfied by port controllers PC_3, PC_5, PC_7. For example, the request packet on line b_7 of FIG. 3C indicates that PC_7 wishes to transmit a data packet to channel group #4. As indicated in FIG. 3B, the maximum offset or maxoff value for channel group #4 is 2, while the actoff in the acknowledgement packet at PC_7 (FIG. 3D) is 4. Thus PC_7 cannot transmit its packet and it must buffer its packet so that it can try again during the next execution of the three phase channel assignment algorithm. On the other hand, PC_0, PC_1, PC_2, PC_4 and PC_6 transmit their data packets for routing through the Batcher-banyan network to the appropriate output channels. For example, as indicated by the request packet on line b_3, PC_0 has a packet addressed to channel group #4. The request packet on line b_3 is assigned an actual offset of zero. Thus, the logical address assigned to the packet to be transmitted by PC_0 is 4. This corresponds to a physical address of 2. Accordingly, the data packet from PC_0 is routed to the output channel having physical address #2. This completes phase III of the output channel assignment algorithm.

E. CONFLICTING REQUESTS IDENTIFICATION NETWORK

FIGS. 4, 5 and 6 schematically illustrate the conflicting requests identification sub-network, the channel offset computation sub-network, and a port controller, respectively. In the discussion that follows, T_x denotes the transmission time of packet x or field x of a packet. For example, T_{ACK} and T_{dest} are the transmission times of packet ACK(...) and the destination field of packet REQ(...), respectively.

A portion of the conflicting requests identification sub-network 20 is shown in detail in FIG. 4. In particular, FIG. 4 schematically illustrates the logic associated with the input lines b_k, b_{k+1} and the output line c_{k+1} (k=0,....N-2) of the conflicting requests identification sub-network 20. The destination channel group identification numbers j of the request packets REQ(j,i) received on input lines b_k, b_{k+1} are compared bit by bit by an EX-OR (exclusive or) gate 30, whose output sets the trigger 32 at the appearance of the first mismatched bits on input lines b_k, b_{k+1}. The trigger 32 keeps its status for a time not less than $2T_{dest}$ (i.e. twice duration of the destination field j) to allow the trunk offset computation sub-network 22 to complete the computation of the channel offset values. The trigger 32 is reset by the rising edge of signal ϕ_{dest} at the start of the address comparison carried out in the sub-network 20. An inverter 33 is connected at the output of trigger 32.

The AND gate 34 in sub-network 20 allows a delay in the start of computation of the trunk offset in sub-network 22 with respect to the end of address comparison in sub-network 20. A signal ϕ_{source} is high for a time T_{source} and its rising edge occurs in $n\text{-}2\lceil\log_2(D_{max})\rceil$ bit times after the end of address comparison in the EX-OR gate 30. As $2\lceil\log_2(D_{max})\rceil$ is the signal latency in sub-network 22, the first bit of actoff(j) is generated by sub-network 22 just after the complete reception of the field source i in packet REQ(j,i) by the port controller PC_k via line g_k (see FIG. 2). This allows the port controller PC_k to generate a packet ACK(i,actoff(j)), with the source field i transmitted first, without buffering either of the two fields composing ACK(...).

The signal on output c_{k+1} of FIG. 4 is logic "1" if the channel group identification number on line b_{k+1} is equal to the channel group identification number of line b_k. If the channel group numbers on lines b_k and b_{k+1} are not equal, the output on line c_{k+1} is logic "0". The signal on output line c_0 is always low, independent of the input signals to the sub-network 20, as is required by sub-network 22, which always gives actoff(j)=0 to the request packet received on line b_0.

F. CHANNEL OFFSET COMPUTATION SUB-NETWORK

The channel offset computation sub-network 22 is shown in FIG. 5 for the case N=16 and $5 \leq D_{max} \leq 8$. The sub-network 22 is a running adder network. The outputs of the conflicting requests identification sub-network 20 are received on the lines c_k (k=0...N-1) and the actual offset values are transmitted via the lines d_k.

More particularly, the sub-network 22 comprises $s = \lceil \log_2(D_{max}) \rceil$ stages of adders. Each AND gate A_2 is enabled by the signal ϕ_1 for one bit time so that the first stage adder connected to line c_k receives the logic "0" or logic "1" value transmitted from the sub-network 20.

Based on the structure of sub-network 22, the output of each adder of stage z ($z=1,2,\ldots,s$) is smaller than or equal to 2^s. This means that the output signal on any line d_k is not greater than 2^s. The AND gates A_1 serve to delimit groups of lines d_k. The groups are delimited so that the offset values start from zero for each channel group j. An example of the channel offset computation is provided in FIG. 5 in which 10 requests for the same channel group j are received on inputs C_{4-13}. As three stages of adders comprise the sub-network 22 of FIG. 5, two of the ten requests will be given the same actoff(j)=8. If $D_j=6$, then four requests for the channel group j, i.e. those received on ports c_{10-13} lose the contention since they receive in actoff(j)>5.

G. PORT CONTROLLER

Operation of a port controller may be understood in connection with FIG. 6 which illustrates the port controller PC_k. Illustratively, the port controller PC_k has a data packet to send to channel group j. This packet arrives on input channel I_k and is stored in the control unit 60. In phase I of the output channel assignment algorithm, the port controller PC_k sends a request packet REQ(j,k) to the Batcher network via the line A_k. The request packet REQ(j,k) is generated in the control unit 60 and is transmitted out of the port controller PC_k via line 62, gate A_6 and gate B_2. The signal ϕ_{REQ} is high for the time T_{REQ}. After all the request packets are sorted by the Batcher network (See FIG. 2), the request packet REQ(l,i) appears on the line b_k (see FIG. 2). The source field of request packet REQ(l,i) is received at port controller PC_k on the line g_k by gate A_4. Similarly, after the channel offsets are calculated by the channel offset network, actoff(l) is received on line d_k by gate A_3 of the port controller PC_k. The signals ϕ_{source} and ϕ_{actoff} are high for times T_{source} and T_{actoff} respectively. The gate B_1 combines the source field, i and the offset actoff(l) to form the acknowledgement packet ACK(i,actoff(l)).

In phase II of the output channel assignment algorithm this acknowledgement packet is transmitted into the Batcher network via line 64, gates A_5 and B_2 and line a_k. The signal ϕ_{ACK1} is high for the time T_{ACK}. Also in phase II of the output channel assignment algorithm, the gate A_1 of the port controller PC_k of FIG. 6 receives the acknowledgement packet ACK(k,actoff(j)) from an output of the Banyan network on line f_k. Signal ϕ_{ACK2}, which is high for time T_{ACK}, enables the port controller PC_k to receive the packet ACK(k,actoff(j)). While actoff(j) is being received, two different tasks are carried out: First, actoff(j) and j are summed to obtain the logical address of the output channel assigned to PC_k; and second actoff(j) and maxoff(j) are compared to verify that the channel assigned to PC_k is a member of output channel group (j). The first task is an addition and may be performed inside the control unit 60. The second task is performed by comparing actoff(j) and maxoff(j) bit by bit in EX- OR gate E_1. At the start of the comparison, the signal ϕ_{actoff} enables the AND gate A_2 for the comparison time T_{actoff} and clears the flip-flop 68 by its rising edge. This flip-flop stores the most significant bit of actoff(j) that is different from the corresponding bit of maxoff(j). When the comparison is over, the output $\overline{Q}$ of the flip-flop 68 is high, if actoff(j) $\leq$ maxoff(j).

In phase III of the output channel assignment algorithm, a high signal on $\overline{Q}$ enables PC_k to transmit its data packet DATA(p(j+actoff(j)) to the appropriate output channel. The data packet is transmitted from the control unit 60 to the physical address p (j+actoff(j)) corresponding to the logical address j+actoff(j) via line 69, gates A_7 and B_2, and the line a_k. The signal ϕ_{DATA1} is high for the time T_{DATA}. At the end of phase III, the data packet DATA(k), if any, is received at PC_k via the line f_k and transmitted to the output channel O_k via gate A_8 which is enabled for the time T_{data} by the signal ϕ_{DATA2}.

H. CONCLUSION

In short, a bandwidth allocation scheme has been described. It is based on the definition of packet channel groups, whose capacity is not bounded by the capacity of a single broadband packet channel. This allows more efficient use of transmission and switching resources and permits super-rate switching. As shown herein, the bandwidth allocation scheme is feasible in a Batcher-banyan switch. The additional hardware utilized in the switch to handle channel groups negligibly increases switch inefficiency. For random traffic, the multichannel bandwidth allocation scheme of the present invention provides for a substantial increase in throughput as compared to the traditional unichannel bandwidth allocation scheme. For bursty traffic, channel groups reduce the packet loss probability by several orders of magnitude.

Finally, the above described embodiments of the invention are intended to be illustrative only. Numerous alternative embodiments may be devised by those skilled in the art without departing from the spirit and scope of the following claims.

What is claimed is:

1. A method for allocating bandwidth in a packet switching network comprising a plurality of packet switches interconnected by packet channels organized into channel groups, said method comprising:

setting up virtual circuits in said network by reserving bandwidth in one or more of said channel groups for each virtual circuit, and

transmitting packets over said virtual circuits by assigning each packet to be transmitted via a particular channel group to an individual packet channel within the particular channel group at the time the packet is to be transmitted via the particular channel group.

2. The method of claim 1 wherein at one of said packet switches said setting up step comprises:

selecting an adjacent packet switch, and

within a set of channel groups connecting said one packet switch and said adjacent packet switch, selecting a channel group in said set that can accommodate the virtual circuit being set up.

3. A method for allocating bandwidth in a packet switch having output channels organized into channel groups, said method comprising the steps of:

at the time a virtual circuit passing through said switch is set up, allocating said virtual circuit to one of said output channel groups, and

at transmission time, receiving packets to be transmitted via particular ones of said channel groups, assigning at least some of said packets to individual output channels in the particular channel groups, and routing at least some of said packets through said switch to the assigned individual output channels.

4. The method of claim 3 wherein said assigning step comprises the step of identifying packets addressed to the same output channel group.

5. The method of claim 4 wherein each of said output channels has an address, the address of each output channel group is the address of a group leader channel, and said assigning step further comprises assigning offsets to packets addressed to the same channel group, each offset corresponding to the difference between a particular group leader address and the address of an individual output channel.

6. The method of claim 5 wherein said routing step further comprises routing at least some of said packets through a self-routing network to said assigned individual output channels.

7. The method of claim 5 wherein said routing step further comprises routing at least some of said packets through a Batcher-banyan network to said individual output channels.

8. The method of claim 3 wherein said assigning step comprises the step of computing an index corresponding to an individual output channel for at least some of said packets.

9. A packet switch comprising:

a plurality of output channels arranged in groups,

means for receiving packets containing information serving to identify particular output channel groups,

output channel assignment means for assigning to said packets individual output channels in said particular output channel groups, and

routing means for routing said packets to said individual output channels.

10. The packet switch of claim 9 wherein said routing means comprises a Batcher network followed by a banyan network.

11. The packet switch of claim 9 wherein each of said output channels has an address and the address of each output channel group is the address of a group leader channel.

12. The packet switch of claim 11 wherein said output channel assignment means comprises a first sub-network for identifying packets containing information serving to identify the same output channel group.

13. The packet switch of claim 12 wherein said first sub-network comprises a plurality of comparators.

14. The packet switch of claim 12 wherein said output channel assignment means further comprises a second sub-network for assigning offsets to packets identifying the same channel group, each offset corresponding to the difference between a particular group leader address and the address of an individual output channel.

15. The packet switch of claim 14 wherein said second sub-network is a running adder sub-network.

16. The packet switch of claim 11 wherein said channel assignment means comprises means for assigning offsets to said packets, each offset identifying the difference between a particular group leader address and the address of an individual output channel.

17. The packet switch of claim 9 wherein said channel assignment means comprises means for computing an index for each packet, at least some of said indices corresponding to individual output channels in said groups.

18. A method for switching data packets in a packet switch having a plurality of output channels arranged in groups, said method comprising:

receiving at said switch a plurality of data packets each containing information corresponding to the address of a desired output channel group,

generating for each packet a request containing the desired output channel group, computing an index for each request which can be used to determine whether or not a particular packet can be accommodated in the desired output channel group, and

routing those packets which can be accommodated in the desired output channel groups through said switch to individual output channels in the desired groups.

19. The method of claim 18 wherein said computing step further comprises the steps of

sorting said requests according to desired output channel group,

identifying requests having the same desired output channel group and generating signals indicative thereof, and

obtaining running sums of said signals to provide said indices.

20. The method of claim 18 wherein said packets are transmitted synchronously through said switch to said individual output channels.

21. The method of claim 18 wherein said indices are utilized to identify said individual output channels.

22. A method for routing data packets through a packet switch having a plurality of output channels organized into groups, each of said data packets containing an address to a desired output channel group, said method comprising

generating a request for each packet containing the address of the desired output channel group,

computing for each request an index for spreading requests for the same channel group over the individual channels comprising the group and for identifying requests that cannot be accommodated in the desired channel group, and

routing those packets which can be accommodated in the desired channel group to the individual channels identified by said indices.

AMENDED CLAIMS

[received by the International Bureau on 16 October 1989 (16.10.89); original claims 1-22 replaced by amended claims 1-22 (5 pages)]

1. A method for allocating bandwidth in a packet switching network comprising a plurality of packet switches interconnected by packet channels organized into channel groups, said method comprising

setting up virtual circuits in said network by reserving bandwidth in one or more of said channel groups for each virtual circuit, and

under the control of centralized coordination means in communication with the input ports of the appropriate one of said packet switches, assigning each packet to be transmitted via a particular channel group to an individual packet channel within the particular channel group and resolving conflicts if the number of packets to be simultaneously transmitted via a particular channel group exceeds the number of individual channels in the particular channel group.

2. The method of claim 1 wherein at one of said packet switches said setting up step comprises:

selecting an adjacent packet switch, and

within a set of channel groups connecting said one packet switch and said adjacent packet switch, selecting a channel group in said set that can accommodate the virtual circuit being set up.

3. A method for allocating bandwidth in a packet switch having output channels organized into channel groups, said method comprising the steps of:

at the time a virtual circuit passing through said switch is set up, allocating said virtual circuit to one of said output channel groups, and

at transmission time, receiving, at a plurality of input ports of said switch, packets to be transmitted via particular ones of said channel groups, assigning through use of centralized coordination means in communication with said plurality of input ports at least some of said packets to individual output channels in the particular channel groups, and routing at least some of said packets through said switch to the assigned individual output channels.

4. The method of claim 3 wherein said assigning step comprises the step of identifying packets addressed to the same output channel group.

5. A method for allocating bandwidth in a packet switch having output channels organized into channel groups, said method comprising the steps of:

at the time a virtual circuit passing through said switch is set up, allocating said virtual circuit to one of said output channel groups, and

at transmission time, receiving, at a plurality of input ports of said switch, packets to be transmitted via particular ones of said channel groups, assigning at least some of said packets to individual output channels in the particular channel groups, and routing at least some of said packets through said switch to the assigned individual output channels, wherein said assigning step comprises the step of identifying packets addressed to the same output channel group, and

wherein each of said output channels has an address, the address of each output channel group is the address of a group leader channel, and said assigning step further comprises assigning offsets to packets addressed to the same channel group, each offset corresponding to the differences between a particular group leader address and the address of an individual output channel.

6. The method of claim 5 wherein said routing step further comprises routing at least some of said packets through a self-routing network to said assigned individual output channels.

7. The method of claim 5 wherein said routing step further comprises routing at least some of said packets through a Batcher-banyan network to said individual output channels.

8. The method of claim 3 wherein said assigning step comprises the step of computing an index corresponding to an individual output channel for at least some of said packets.

9. A packet switch comprising:

a plurality of output channels arranged in groups,

a plurality of input ports for receiving packets containing information serving to identify particular output channel groups,

centralized output channel assignment means in communication with said plurality of input ports for assigning to said packets individual output channels in said particular output channel groups and for resolving conflicts when the number of said packets simultaneously containing information which serves to identify a particular channel group exceeds the number of channels in said group, and

routing means for routing at least some of said packets to said individual output channels.

10. The packet switch of claim 9 wherein said routing means comprises a Batcher network followed by a banyan network.

11. The packet switch of claim 9 wherein each of said output channels has an address and the address of each output channel group is the address of a group leader channel.

12. The packet switch of claim 11 wherein said output channel assignment means comprises a first sub-network for identifying packets containing information serving to identify the same output channel group.

13. A packet switch comprising:

a plurality of output channels arranged in groups,

means for receiving packets containing information serving to identify particular output channel groups, output channel assignment means for assigning to said packets individual output channels in said particular output channel groups, and

routing means for routing said packets to said individual output channels,

wherein each of said output channels has an address and the address of each output channel group is the address of a group leader channel,

wherein said output channel assignment means comprises a first sub-network for identifying packets containing information serving to identify the same output channel group, and

14. A packet switch comprising:

a plurality of output channels arranged in groups,

means for receiving packets containing information serving to identify particular output channel groups,

output channel assignment means for assigning to said packets individual output channels in said particular output channel groups, and

routing means for routing said packets to said individual output channels,

wherein each of said output channels has an address and the address of each output channel group is the address of a group leader channel,

wherein said output channel assignment means comprises a first sub-network for identifying packets containing information serving to identify the same output channel group, and

wherein said output channel assignment means further comprises a second sub-network for assigning offsets to packets containing information identifying the same channel group, each offset corresponding to the difference between a particular group leader address and the address of an individual output channel.

15. The packet switch of claim 14 wherein said second sub-network is a running adder sub-network.

16. A packet switch comprising:

a plurality of output channels arranged in groups,

means for receiving packets containing information serving to identify particular output channel groups,

output channel assignment means for assigning to said packets individual output channels in said particular output channel groups, and

routing means for routing said packets to said individual output channels,

wherein each of said output channels has an address and the address of each output channel group is the address of a group leader channel, and wherein said channel assignment means comprises means for assigning offsets to said packets, each offset identifying the difference between a particular group leader address and the address of an individual output channel.

17. The packet switch of claim 9 wherein said channel assignment means comprises means for computing an index for each packet, at least some of said indices corresponding to individual output channels in said groups.

18. A method for switching data packets in a packet switch having a plurality of output channels arranged in groups, said method comprising:

receiving at said switch a plurality of data packets each containing information corresponding to the address of a desired output channel group,

generating for each data packet a request packet containing the desired output channel group,

computing an index for each request packet which can be used to determine whether or not the corresponding data packet can be accommodated in the desired output channel group, and

routing those data packets which can be accommodated in the desired output channel groups through said switch to individual output channels in the desired groups.

19. A method for switching data packets in a packet switch having a plurality of output channels arranged in groups, said method comprising:

receiving at said switch a plurality of data packets each containing information corresponding to the address of a desired output channel group,

generating for each data packet a request packet containing the desired output channel group,

computing an index for each request packet which can be used to determine whether or not the corresponding data packet can be accommodated in the desired output channel group, and

routing those data packets which can be accommodated in the desired output channel groups through said switch to individual output channels in the desired groups,

wherein said computing step further comprises the steps of

sorting said request packets according to desired output channel group,

identifying request packets having the same desired output channel group and generating signals indicative thereof, and

obtaining running sums of said signals to provide said indices.

20. The method of claim 18 wherein said packets are transmitted synchronously through said switch to said individual output channels.

21. The method of claim 18 wherein said indices are utilized to identify said individual output channels.

22. A method for routing data packets through a packet switch having a plurality of output channels organized into groups, each of said data packets containing an address to a desired output channel group, said method comprising

generating a request packet for each data packet containing the address of the desired output channel group,

computing for each request packet an index for spreading data packets addressed to the same channel group over the individual channels comprising the group and for identifying data packets that cannot be accommodated in the desired channel group, and

routing those data packets which can be accommodated in the desired channel group to the individual channels identified by said indices.

FIG. 1

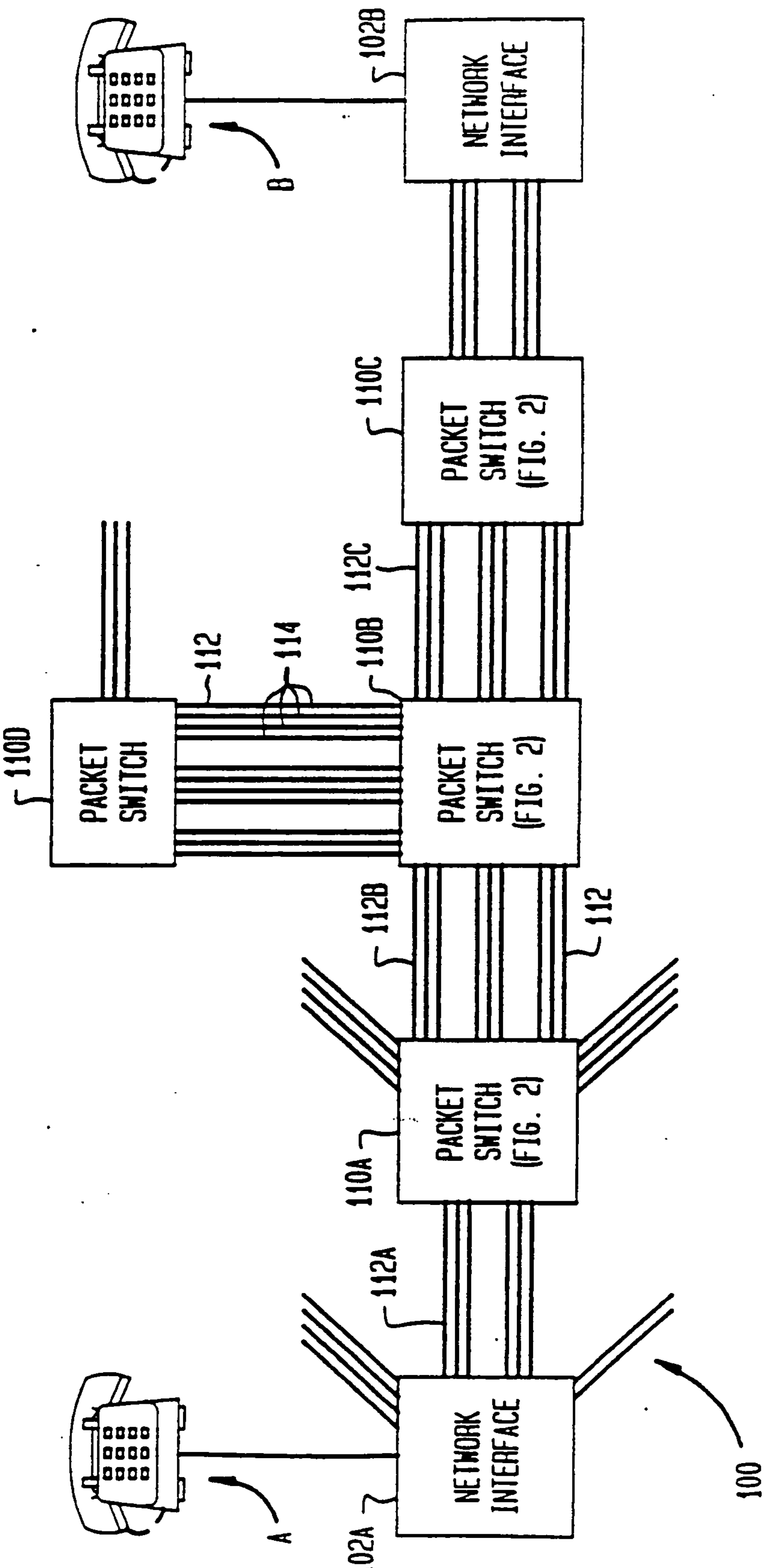

NETWORK INTERFACE
102B
B
PACKET SWITCH (FIG. 2)
110C
112C
110B
114
112
PACKET SWITCH
110D
PACKET SWITCH (FIG. 2)
112B
112
PACKET SWITCH (FIG. 2)
110A
112A
NETWORK INTERFACE
102A
A
100

FIG. 2

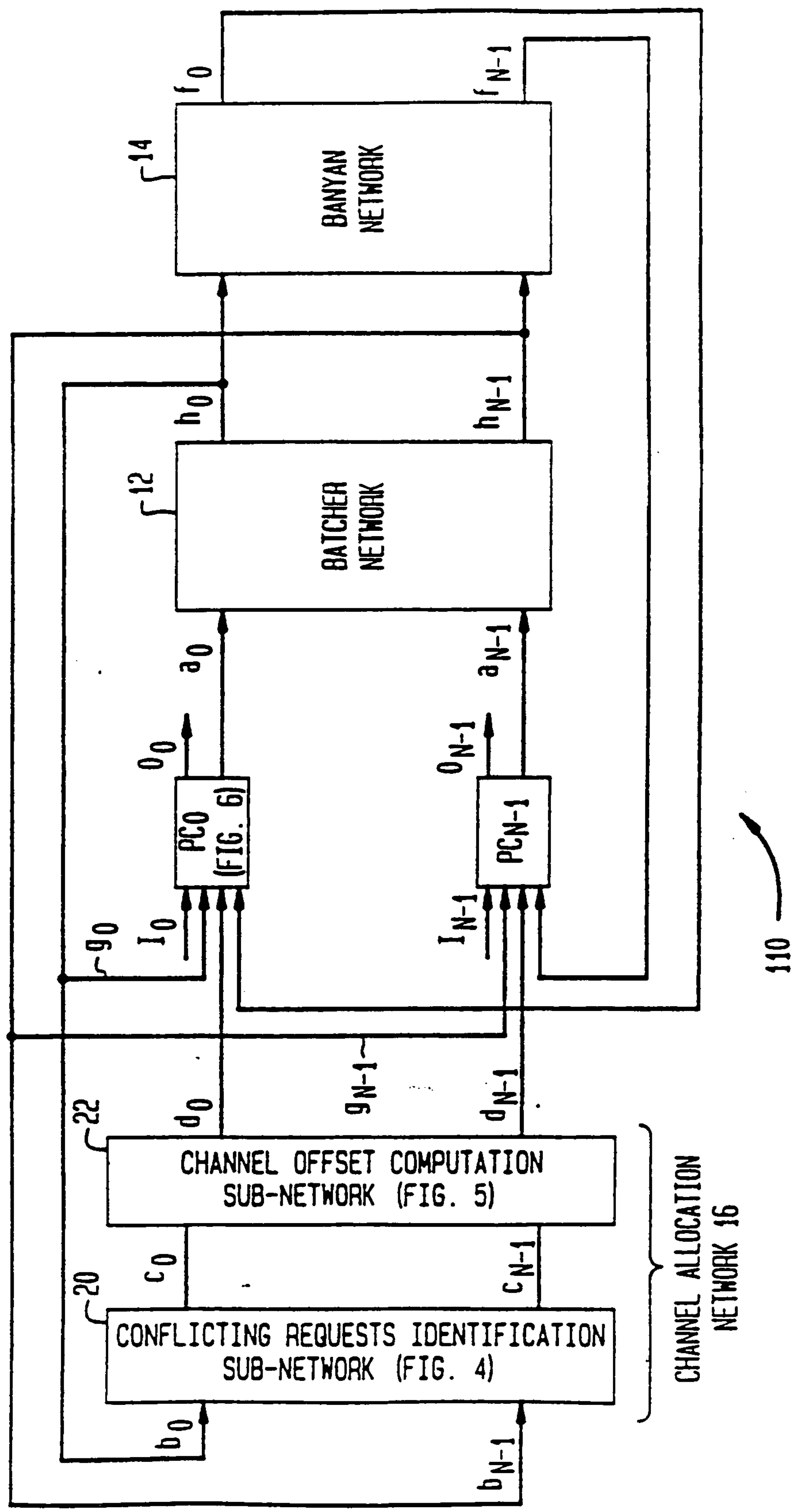

BANYAN NETWORK
14
BATCHER NETWORK
12
f0
fN-1
h0
hN-1
a0
aN-1
o0
oN-1
PC0 (FIG. 6)
PCN-1
I0
IN-1
g0
gN-1
d0
dN-1
22
CHANNEL OFFSET COMPUTATION SUB-NETWORK (FIG. 5)
c0
cN-1
20
CONFLICTING REQUESTS IDENTIFICATION SUB-NETWORK (FIG. 4)
b0
bN-1
CHANNEL ALLOCATION NETWORK 16
110

FIG. 3A

TABLE K_a

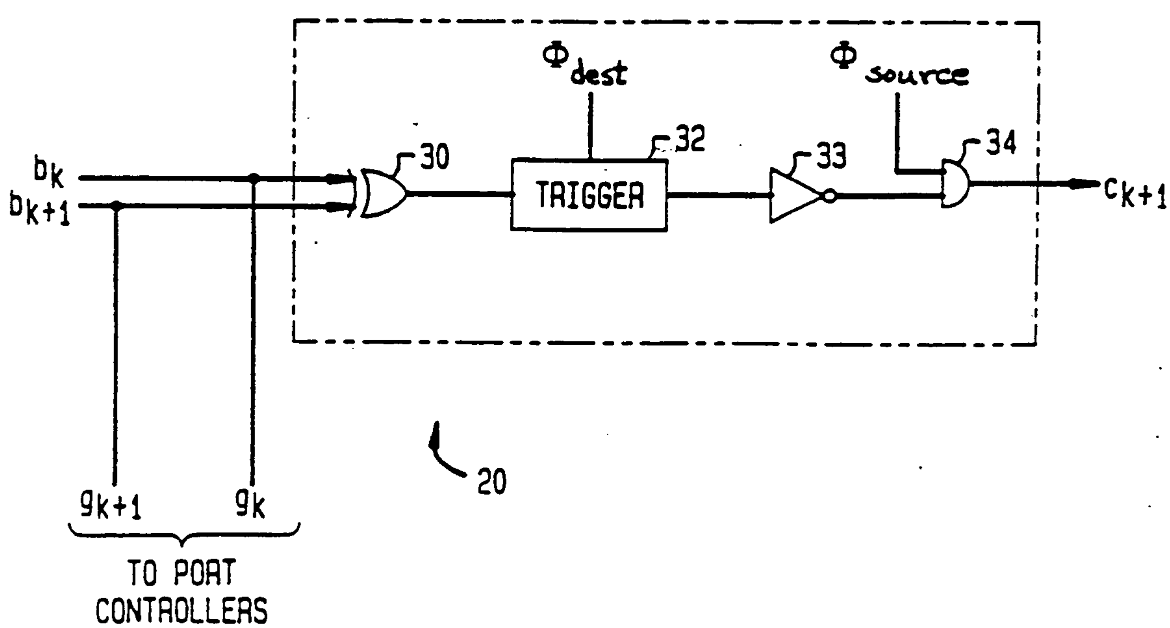
LOGICAL	PHYSICAL
0	4
1	3
2	5
3	6
4	2
5	7
6	0
7	1

FIG. 3B

TABLE K_c

GROUP #	MAXOFF
0	0
1	1
3	0
4	2
7	0

FIG. 4



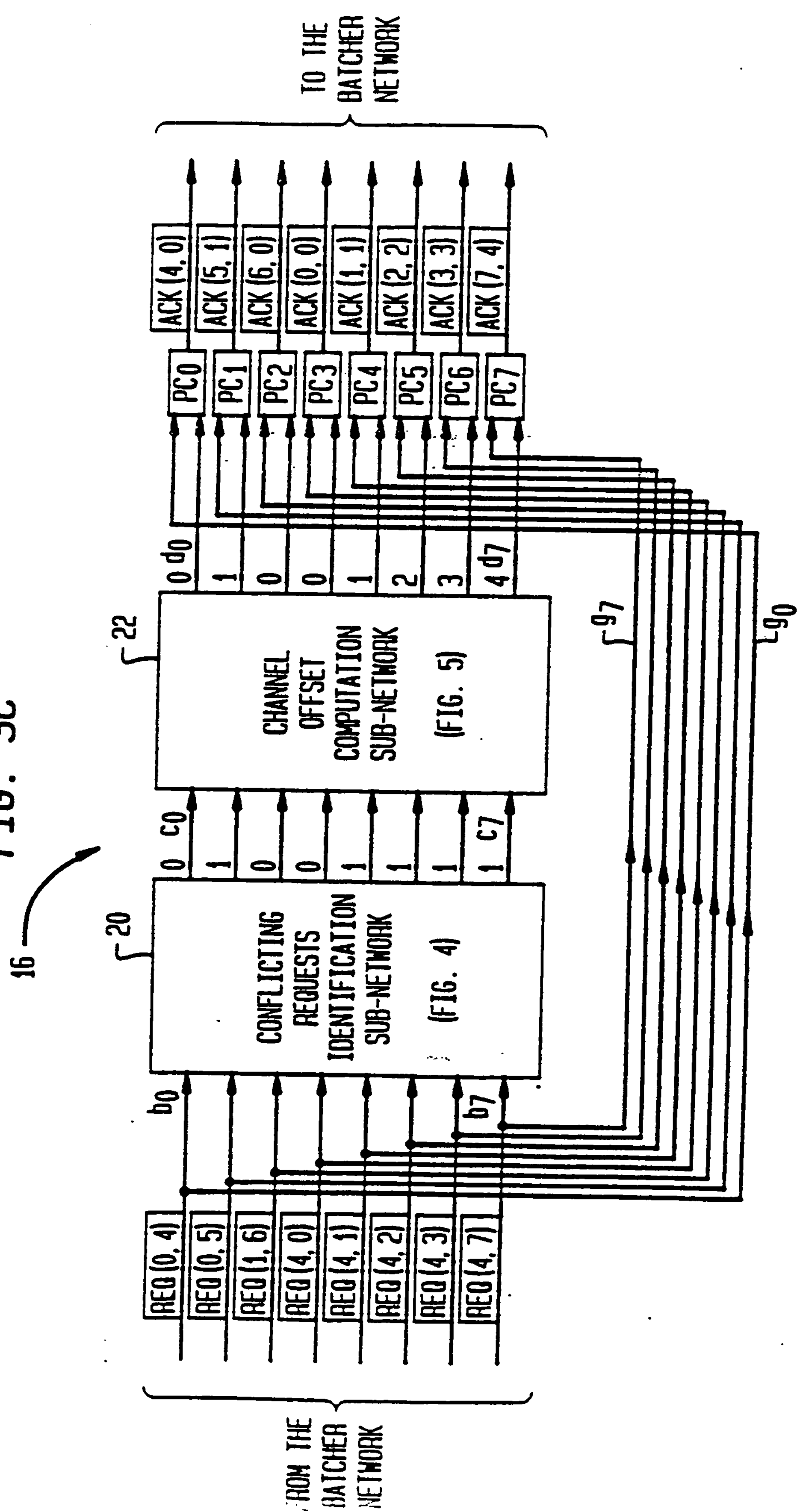

16
TO THE BATCHER NETWORK
ACK (4, 0)
ACK (5, 1)
ACK (6, 0)
ACK (0, 0)
ACK (1, 1)
ACK (2, 2)
ACK (3, 3)
ACK (7, 4)
PC0
PC1
PC2
PC3
PC4
PC5
PC6
PC7
0 d0
1
0
0
1
2
3
4 d7
22
CHANNEL OFFSET COMPUTATION SUB-NETWORK
(FIG. 5)
g7
g0
0 c0
1
0
0
1
1
1
1 c7
20
CONFLICTING REQUESTS IDENTIFICATION SUB-NETWORK
(FIG. 4)
b0
b7
REQ (0, 4)
REQ (0, 5)
REQ (1, 6)
REQ (4, 0)
REQ (4, 1)
REQ (4, 2)
REQ (4, 3)
REQ (4, 7)
ROM THE BATCHER NETWORK

FIG. 3C

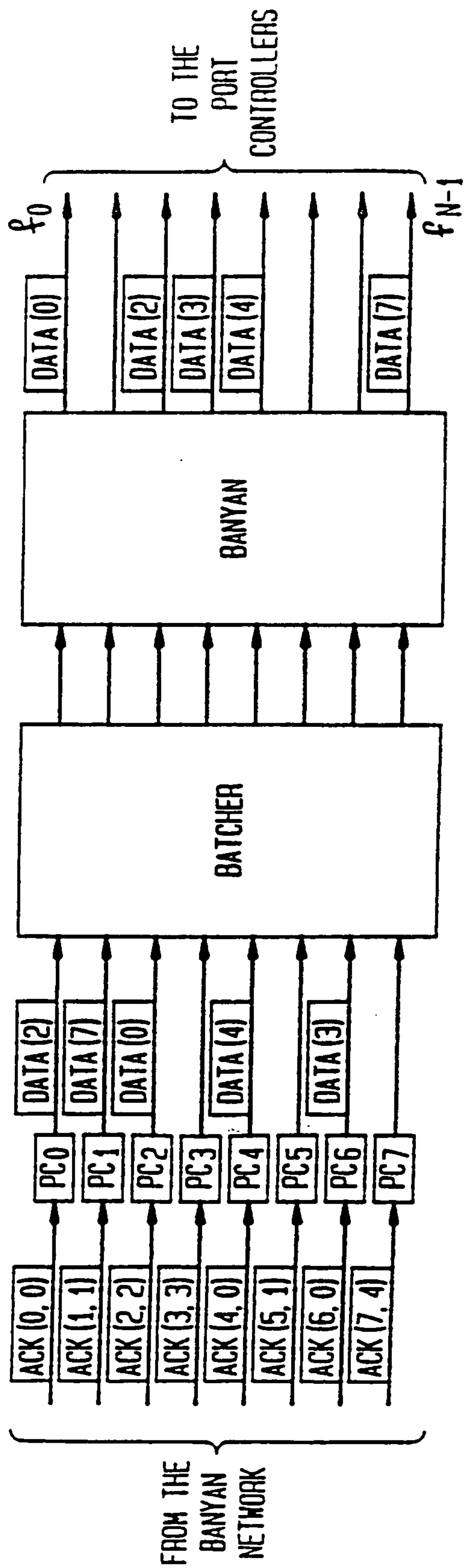

TO THE PORT CONTROLLERS
f_0
f_{N-1}
DATA (0)
DATA (2)
DATA (3)
DATA (4)
DATA (7)
BANYAN
BATCHER
DATA (2)
DATA (7)
DATA (0)
DATA (4)
DATA (3)
PC0
PC1
PC2
PC3
PC4
PC5
PC6
PC7
ACK (0, 0)
ACK (1, 1)
ACK (2, 2)
ACK (3, 3)
ACK (4, 0)
ACK (5, 1)
ACK (6, 0)
ACK (7, 4)
FROM THE BANYAN NETWORK

FIG. 3D

FIG. 5

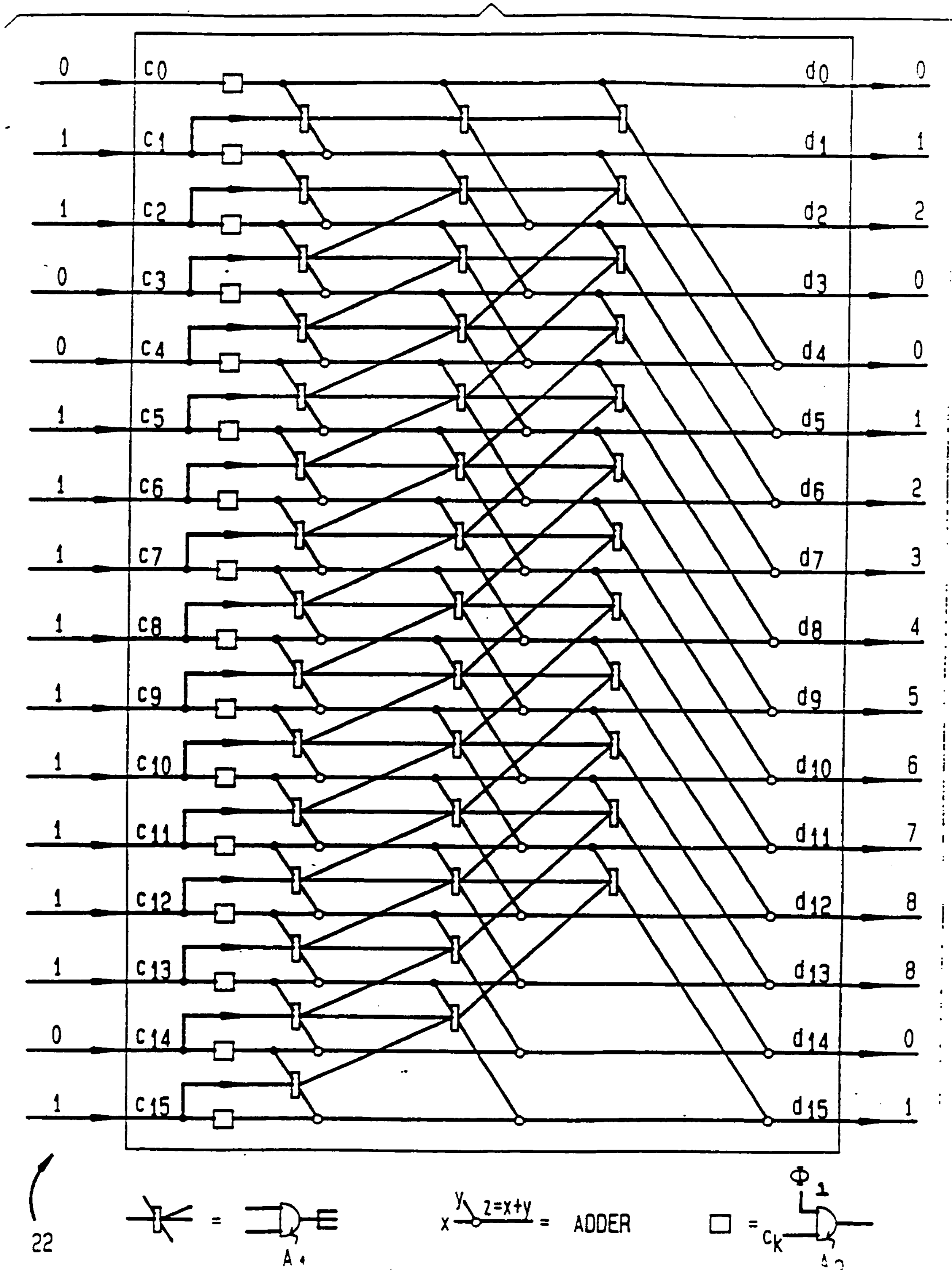
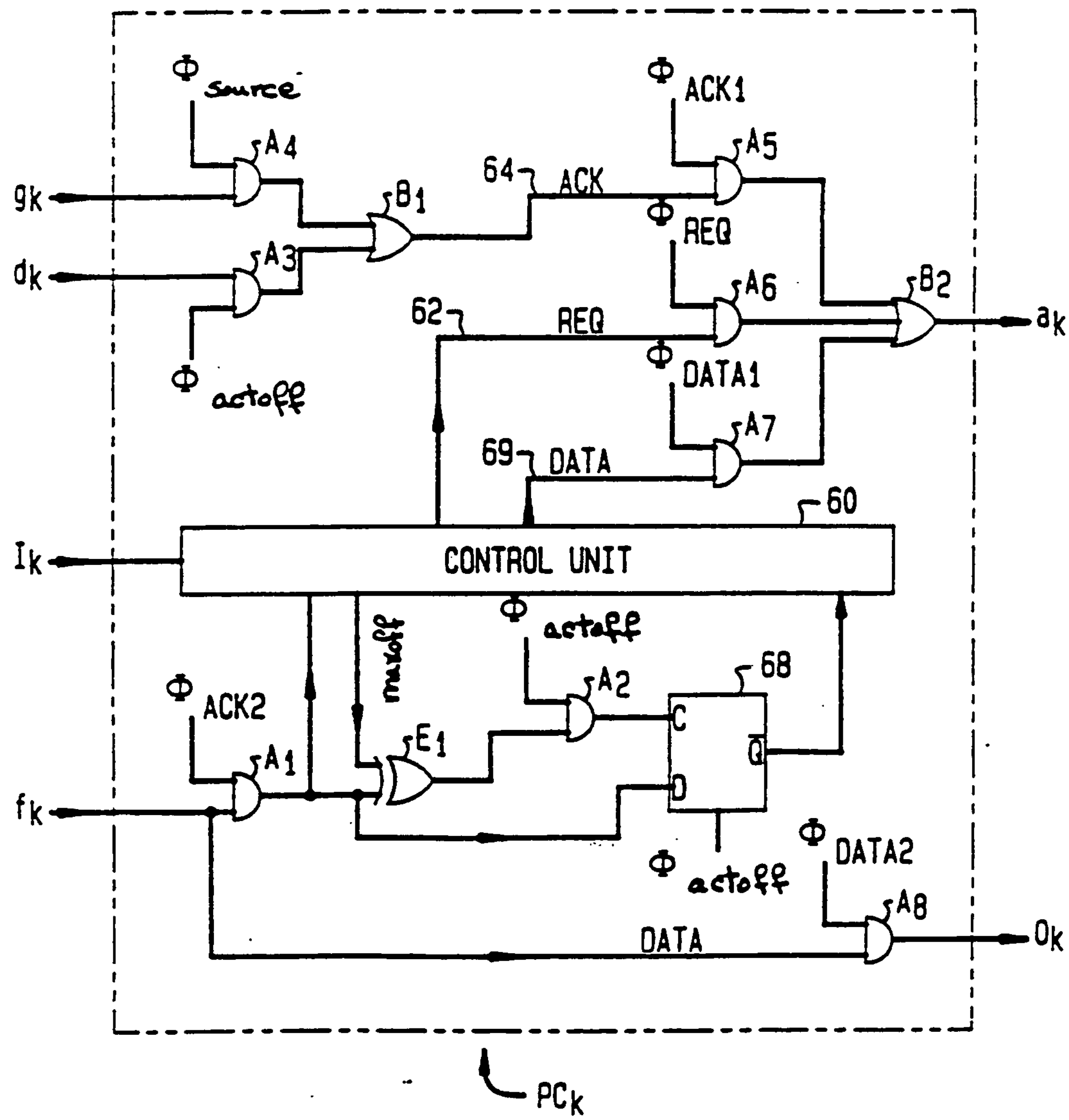

0
1
1
0
0
1
1
1
1
1
1
1
1
1
0
1
c0
c1
c2
c3
c4
c5
c6
c7
c8
c9
c10
c11
c12
c13
c14
c15
d0
d1
d2
d3
d4
d5
d6
d7
d8
d9
d10
d11
d12
d13
d14
d15
0
1
2
0
0
1
2
3
4
5
6
7
8
8
0
1
22
=
A1
x
y
z=x+y
= ADDER
=
Φ1
ck
A2

FIG. 6


Φ source
A4
gk
A3
dk
Φ actoff
B1
64
ACK
Φ ACK1
A5
Φ REQ
A6
62
REQ
Φ DATA1
A7
69
DATA
B2
ak
60
CONTROL UNIT
Ik
Φ actoff
maxoff
68
A2
C
Q
D
Φ ACK2
A1
E1
fk
Φ actoff
Φ DATA2
A8
DATA
Ok
PCk

INTERNATIONAL SEARCH REPORT

International Application No PCT/US 89/01267

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: H 04 L 11/20

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	H 04 L

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
A	EP, A, 0260364 (WASHINGTON UNIVERSITY) 23 March 1988 see column 2, lines 23-28; column 5, line 20 - column 6, line 54; column 9, lines 25-40; column 17, line 49 - column 18, line 27 --	1-4,6,9, 18,22
P,X	IEEE Journal on Selected Areas in Communications, vol. 6, no. 9, December 1988, IEEE, (New York, US), A. Pattavina: "Multichannel band-width allocation in a broadband packet switch", pages 1489-1499 see the whole article ------------	1-22

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
19th July 1989	1 6 AUG 1989
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	M. VAN MOL

Form PCT/ISA/210 (second sheet) (January 1985)

(12) UK Patent Application (19) GB (11) 2 295 070 (13) A

(43) Date of A Publication 15.05.1996

(21) Application No 9521853.3

(22) Date of Filing 25.10.1995

(30) Priority Data
(31) 06275055 (32) 09.11.1994 (33) JP
07001952 10.01.1995

(51) INT CL[6]
B60R 16/02, H04J 3/16

(52) UK CL (Edition O)
H4M MTX1
G4H HNEG HW H1A H13D H14A
H4P PPK
U1S S1820

(56) Documents Cited
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US 5343472 A

(58) Field of Search
UK CL (Edition O) G4H HNEC HNEE HNF HW, H4M MN MTX1, H4P PPK PPNB
INT CL[6] B60R 16/02, H04J 3/16, H04L 12/40 12/42
Online: WPI, INSPEC

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(54) Reducing delays in a multiplex communication system

(57) A multiplex communication system, for example in a vehicle, has a plurality of node devices 1 to 11 connected via a bus line 21 to at least one of a plurality of end node devices to be controlled 12 to 15. As the number of nodes increases, the delays involved in transmitting data along the bus can become unacceptably long. Therefore, the data is divided into a plurality of categories according to the necessity of transmission. For example, engine management data that needs to be transmitted more urgently than door mirror control data has a higher necessity of transmission. The more urgent data is transmitted once every multiplex transmission cycle, while the less urgent data is transmitted once every few transmission cycles, according to the necessity of transmission. This reduces the delays. Alternatively, the transmitting and receiving nodes can be identified without having to append address data to the message data. One of node devices serving as the master node device M sets the transmission cycle of message data transmitted onto the bus line 21 as a cycle of a start pulse that is sent to the bus line 21. This cycle has been set so as not to cause a time lag in data processing executed by the respective node devices. Each time interval between the start pulses is divided into a plurality of time slots. The time slots have been allocated to the individual node devices so that message data can be transmitted from the respective devices in the associated time slots without the need for address data, thereby reducing delays.

FIG. 1

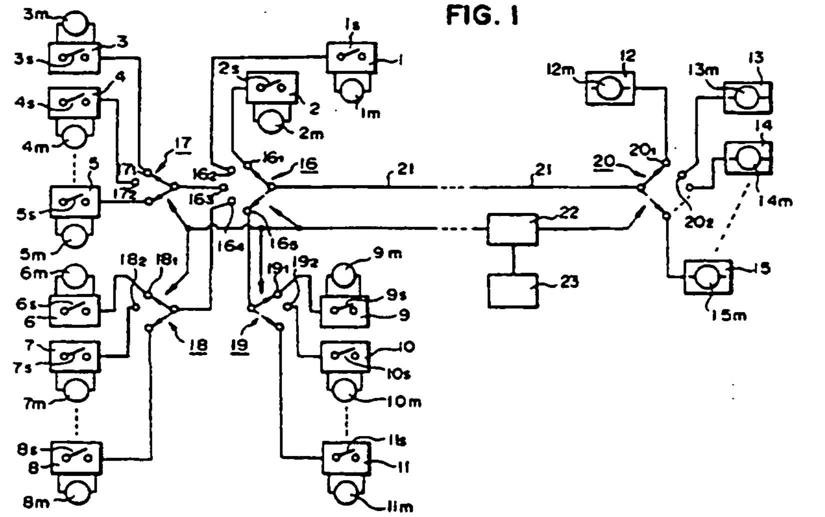

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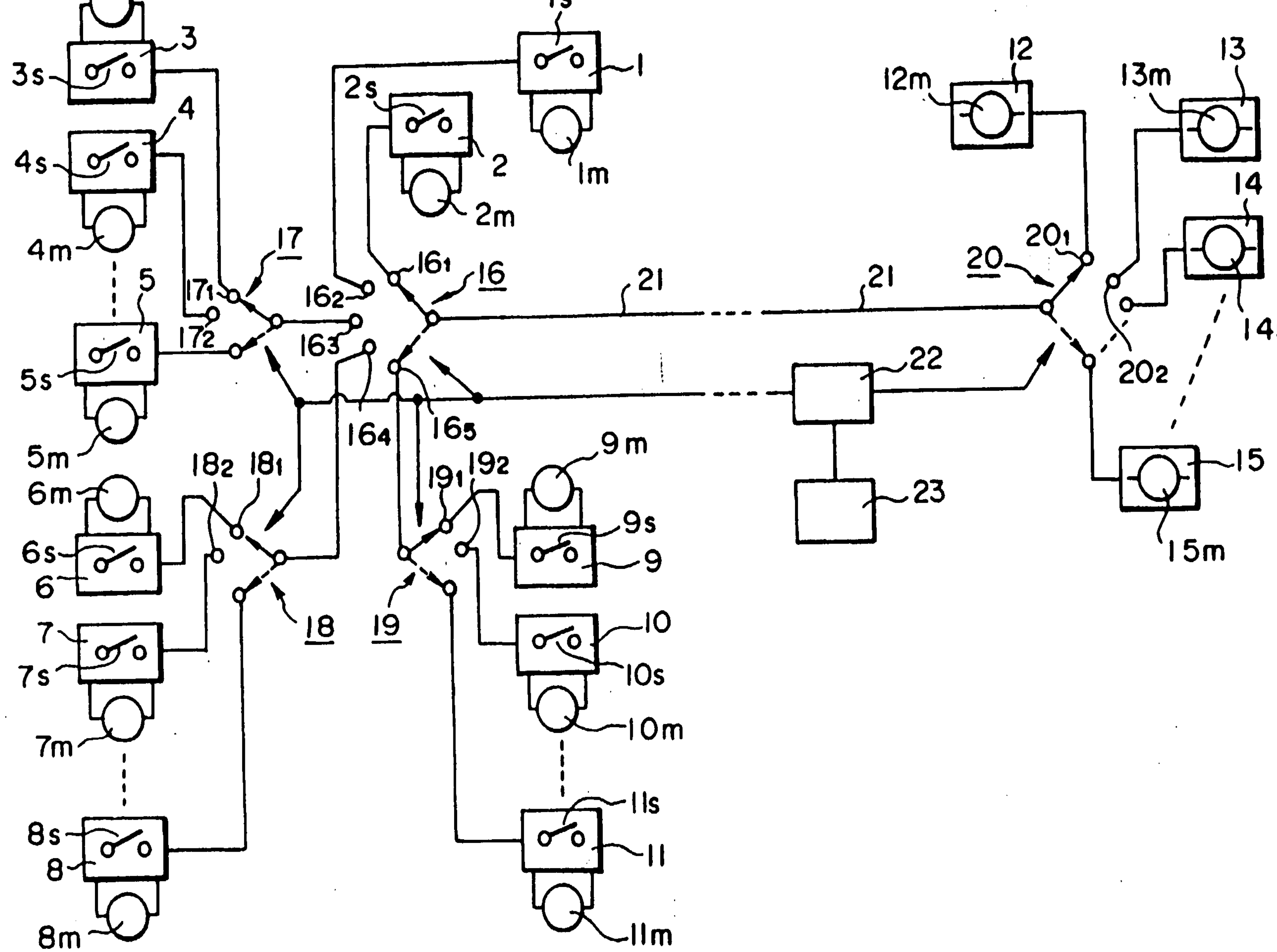
FIG. 1


1
1s
1m
2
2s
2m
3
3s
3m
4
4s
4m
5
5s
5m
6
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6m
7
7s
7m
8
8s
8m
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9s
9m
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10m
11
11s
11m
12
12m
13
13m
14
14m
15
15m
16
16_1
16_2
16_3
16_4
16_5
17
17_1
17_2
18
18_1
18_2
19
19_1
19_2
20
20_1
20_2
21
21
22
23

1/5

2/5

FIG.2

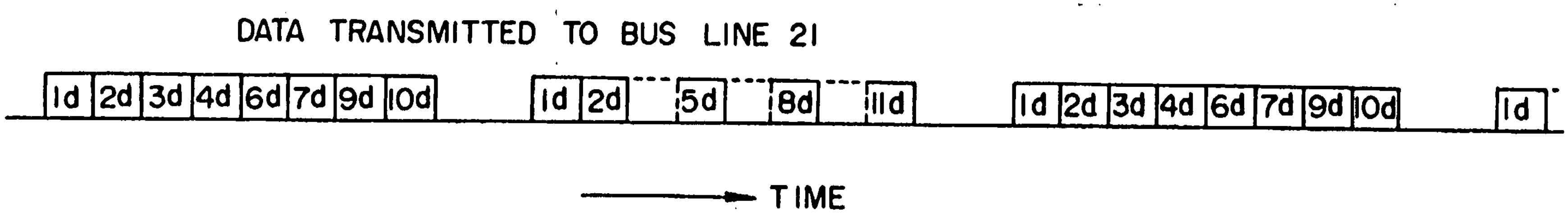
DATA TRANSMITTED TO BUS LINE 21
1d 2d 3d 4d 6d 7d 9d 10d
1d 2d 5d 8d 11d
1d 2d 3d 4d 6d 7d 9d 10d
1d
TIME

FIG. 3

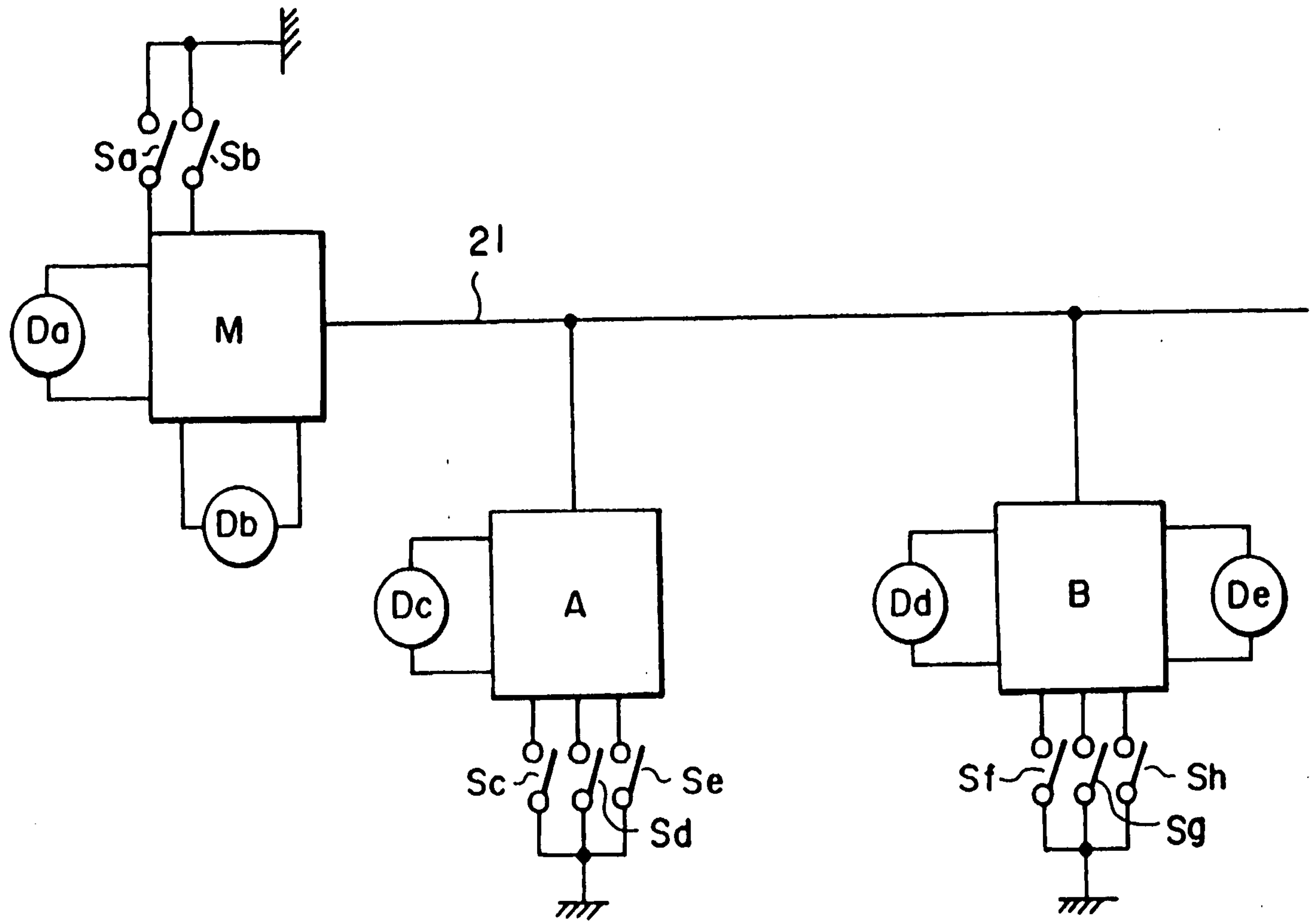

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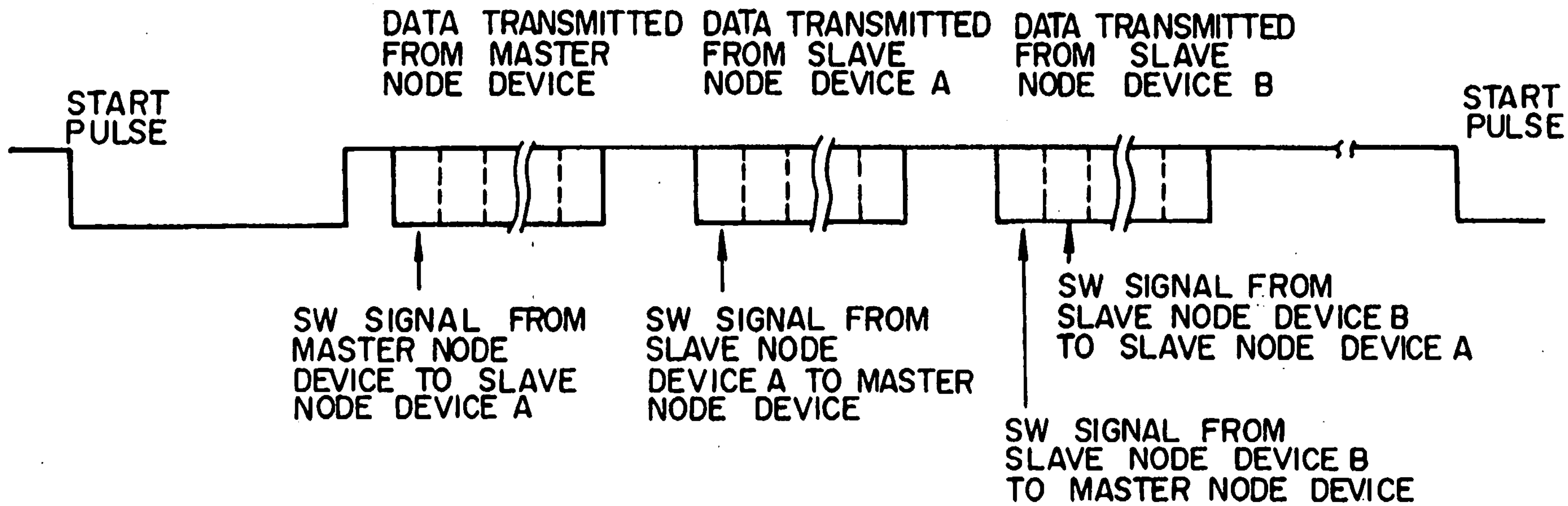
FIG. 4


START PULSE
DATA TRANSMITTED FROM MASTER NODE DEVICE
DATA TRANSMITTED FROM SLAVE NODE DEVICE A
DATA TRANSMITTED FROM SLAVE NODE DEVICE B
START PULSE
SW SIGNAL FROM MASTER NODE DEVICE TO SLAVE NODE DEVICE A
SW SIGNAL FROM SLAVE NODE DEVICE A TO MASTER NODE DEVICE
SW SIGNAL FROM SLAVE NODE DEVICE B TO SLAVE NODE DEVICE A
SW SIGNAL FROM SLAVE NODE DEVICE B TO MASTER NODE DEVICE

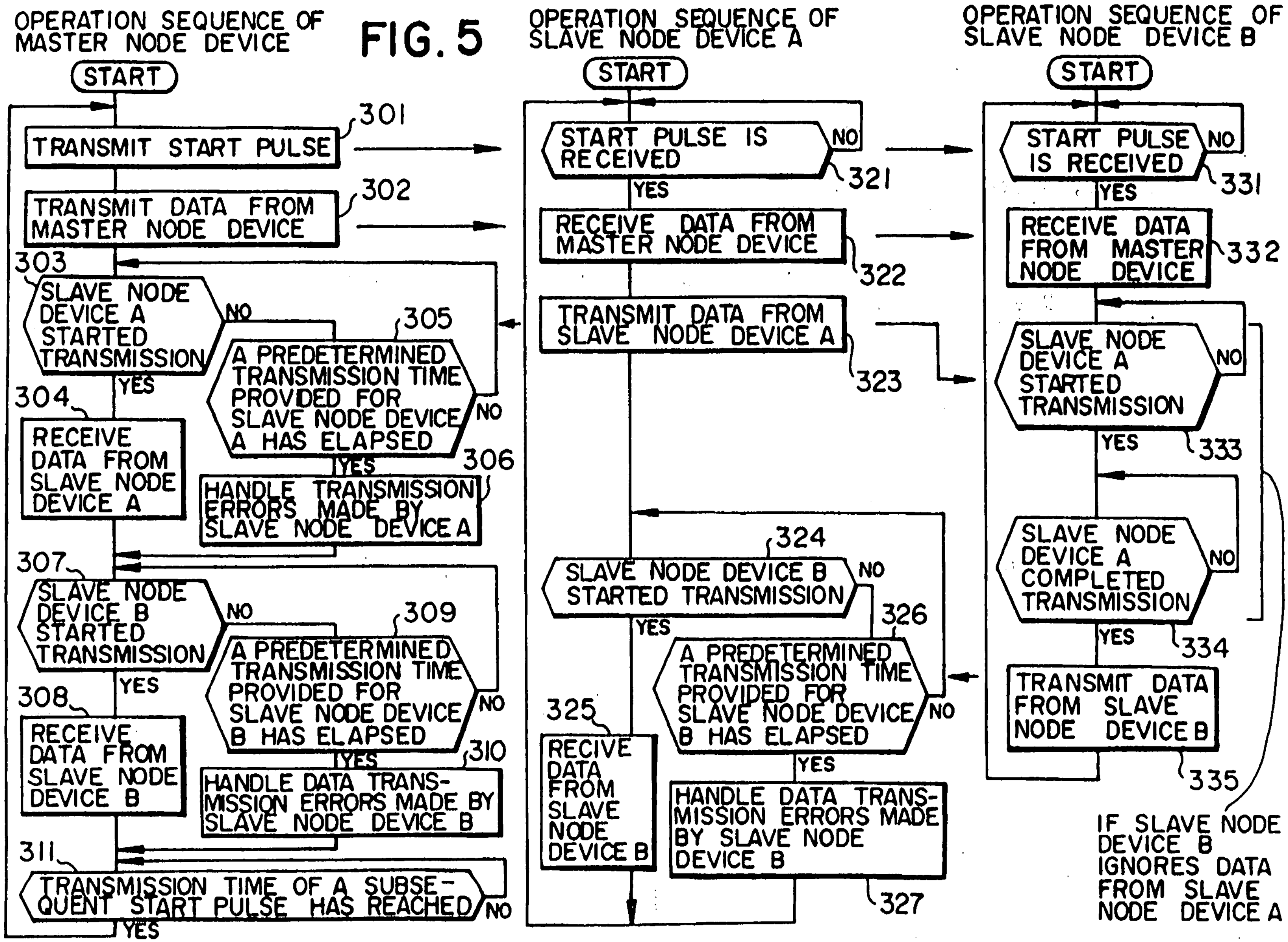

OPERATION SEQUENCE OF MASTER NODE DEVICE
START
TRANSMIT START PULSE
301
TRANSMIT DATA FROM MASTER NODE DEVICE
302
303
SLAVE NODE DEVICE A STARTED TRANSMISSION
NO
YES
A PREDETERMINED TRANSMISSION TIME PROVIDED FOR SLAVE NODE DEVICE A HAS ELAPSED
305
304
RECEIVE DATA FROM SLAVE NODE DEVICE A
HANDLE TRANSMISSION ERRORS MADE BY SLAVE NODE DEVICE A
306
307
SLAVE NODE DEVICE B STARTED TRANSMISSION
A PREDETERMINED TRANSMISSION TIME PROVIDED FOR SLAVE NODE DEVICE B HAS ELAPSED
309
308
RECEIVE DATA FROM SLAVE NODE DEVICE B
HANDLE DATA TRANSMISSION ERRORS MADE BY SLAVE NODE DEVICE B
310
311
TRANSMISSION TIME OF A SUBSEQUENT START PULSE HAS REACHED
OPERATION SEQUENCE OF SLAVE NODE DEVICE A
START
START PULSE IS RECEIVED
321
RECEIVE DATA FROM MASTER NODE DEVICE
322
TRANSMIT DATA FROM SLAVE NODE DEVICE A
323
SLAVE NODE DEVICE B STARTED TRANSMISSION
324
A PREDETERMINED TRANSMISSION TIME PROVIDED FOR SLAVE NODE DEVICE B HAS ELAPSED
326
325
RECIVE DATA FROM SLAVE NODE DEVICE B
HANDLE DATA TRANSMISSION ERRORS MADE BY SLAVE NODE DEVICE B
327
OPERATION SEQUENCE OF SLAVE NODE DEVICE B
START
START PULSE IS RECEIVED
331
RECEIVE DATA FROM MASTER NODE DEVICE
332
SLAVE NODE DEVICE A STARTED TRANSMISSION
333
SLAVE NODE DEVICE A COMPLETED TRANSMISSION
334
TRANSMIT DATA FROM SLAVE NODE DEVICE B
335
IF SLAVE NODE DEVICE B IGNORES DATA FROM SLAVE NODE DEVICE A

FIG. 5

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MULTIPLEX COMMUNICATION SYSTEM

The present invention relates to a multiplex communication system and, more particularly, to a multiplex communication system which is constructed to transmit operational data from a plurality of control units to at least one of a plurality of end devices to be controlled at different transmission frequencies in accordance with the degree of urgency.

The invention further relates to a multiplex communication system and, more particularly, to a multiplex communication system which is adequate to efficiently transmit and receive data formed of a plurality of bits among a plurality of transmitting and receiving devices, and which is thus suitable for collecting information indicating states of vehicle-loaded equipment and for controlling the driving of the equipment.

Generally, a typical communication system loaded in a vehicle is widely employed to transmit and receive data that is used for collecting information representing states of vehicle-loaded equipment, for controlling the driving of the equipment and for other purposes. The communication system of this type comprises a single bus line, a plurality of control units, i.e., node stations, connected to the bus line, and actuators attached to the respective node stations. Message data transmitted and received among the respective node stations includes data for controlling the actuators and address data indicating the sender and the receiver of the message, and is transmitted cyclically onto the bus line.

Along with the substantial increase in the number of electrical equipment loaded in a vehicle, the amount of signal data passing through a bus line forming a communication system is also increasing. Message data in the system according to the technique discussed above is cyclically transmitted. For example, every time a transmission cycle is started, all the items of operational data, i.e., data 1, data 2, data 3, data 4 and data 5 which are output from first to fifth vehicle-loaded control units, respectively, are sequentially transmitted to the bus line.

The communication system of the above type presents the following problems. A larger number of control units for transmitting the operational data results in an increase in the number of items of operational data to be transmitted during one transmission cycle. Accordingly, the time interval between the transmission of the same item of data (for example, data 1) becomes longer, which delays the timing of transmitting the latest operational data (for example, data 1).

Additionally, each message data contains address data, which disadvantageously increases the amount of data transmitted to the bus line, thereby causing a greater time lag in the data processing of the entire communication system.

Accordingly, various troubles may be caused due to such a delay in data processing in the above-described vehicle-loaded communication system. In particular, a delay in the data processing relative to the actuators, for example, a diagnostic system for the engine, such as a throttle sensor, which is required to be operated very quickly in response to data, is very critical. In other words, among the vehicle-loaded control units, some devices generate operational signals (data) which need to be transmitted urgently, such as a collision detecting section that generates air bag signals, a door lock/unlock detecting section that generates door lock/unlock signals, etc., while other units produce operational signals (data) which do not need to be transmitted urgently, such as a window opening/closing section that generates window opening/closing instruction signals, a mirror actuating section that produces remote control mirror driving signals. A time lag in the transmission timing of the former type of signals (data) that need to be transmitted urgently jeopardizes the safety for the driver and passengers. It is thus very important to solve this problem.

Accordingly, in order to solve the problems inherent in the technique discussed above, a first object of the present invention is to provide a multiplex communication system in which operational data can be transmitted at different frequencies according to the degree of necessity of transmitting the data to a bus line.

A second object of the present invention is to provide a multiplex communication system in which the transmitting and receiving node devices can be identified without having to append address data to the transmitting message data, and a large amount of data can be transmitted without interfering with each other, thereby avoiding a time lag in the processing of controlling vehicle-loaded equipment or the like.

In order to achieve the above first object, according to a first aspect of the present invention, there is provided a multiplex communication system in which a plurality of items of operational data are transmitted in every transmission cycle, in a time division multiplexing manner, via a bus line from a plurality of control devices to at least one of a plurality of end devices to be controlled, the improvement comprising that the items of operational data are divided into a plurality of degrees according to the necessity of transmission, wherein the operational data falling into the greatest degree of transmission necessity is transmitted once in every transmission cycle, while the operational data falling into the smaller degree of transmission necessity is transmitted once in every few transmission cycles according to the degree of the transmission necessity.

In order to achieve the second object of the present invention, according to the second aspect of the present invention, there is provided a multiplex communication system in which a plurality of node devices are connected to a bus line so as to cyclically transmit and receive message data with each other and to execute processing of the received data, wherein the improvement comprises that one of the node devices functions as a master node device so as to determine a transmission cycle of the message data from all the node devices and to take the initiative in determining a transmission timing within the transmission cycle at which each of the node devices, including its own device, transmits the message data onto the bus line, the transmission timing being associated with each of the node devices, so that each of the devices sends the message data to be addressed to another device onto the bus line at the transmission timing determined by the master node device.

A time slot provided at the transmission timing associated with each of the node devices may be divided into a plurality of sub-time slots, and the sub-time slots may be arranged to correspond to the individual node devices to receive the message data transmitted from one of the node devices.

According to the foregoing construction of the first aspect of the present invention, a plurality of items of operational data to be transmitted to the bus line from a plurality of control units, respectively, are divided into a plurality of degrees which have been determined according to the transmission necessity (urgency). The operational data falling into the greatest degree of transmission necessity is positively transmitted once in every transmission cycle. On the other hand, the data falling into the smaller degrees of transmission necessity is transmitted once in every few cycles according to the degree of urgency.

With this arrangement, signals (data) having the greater necessity (urgency) of transmission, such as an air bag signal and door lock/unlock signals that are respectively output from a collision detecting section and a door lock/unlock detecting section among a plurality of vehicle-loaded control units, are positively transmitted once in every cycle. This arrangement inhibits a time lag in transmitting signals having the greater degree of transmission necessity, which further ensures safety for the driver and passengers.

Additionally, signals (data) having the smaller degree of necessity (urgency) of transmission, such as a window opening/closing instruction signal and a remote control mirror driving signal that are respectively output from a window opening/closing section and a mirror actuating section among a plurality of vehicle-loaded control units, are transmitted only once in every few cycles according to the degree of urgency. This arrangement makes it possible to reliably operate each end device to accomplish a required function based on the operational signal (data) without interfering with the transmission timing of signals having the greater degree of urgency.

Further, according to the second aspect of the present invention, the timing at which each node device transmits message data has been determined. Also, the individual sub-time slots obtained by dividing the time slot that is arranged at the above-described predetermined timing are allocated to the individual node devices to receive the message data. With this arrangement, each node device is able to transmit message data to a desired end device without having to append the sender and receiver information to the transmitting data merely by carrying the data onto the sub-time slot provided for the associated end node device within the time slot allocated to its own device.

Through use of this multiplex communication system, it is thus possible to perform faster transmission of message data without a time loss, which further shortens a transmission cycle of message data from the respective node devices. By the application of this system to vehicle-loaded equipment or the like, it is possible to prevent a time lag in the processing of controlling the equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a circuit diagram illustrating the construction of a multiplex communication system according to a first embodiment of the present invention;

Fig. 2 illustrates the operation of the system shown in Fig. 1 in which data is transmitted via a bus line in a time division multiplexing manner;

Fig. 3 is a block diagram illustrating an example of the construction of a multiplex communication system according to a second embodiment of the present invention;

Fig. 4 illustrates the construction of message data transmitted to the bus line in the system shown in Fig. 3; and

Fig. 5 is a flow chart illustrating the operation of the second embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A detailed description will now be given of a first embodiment of a multiplex communication system according to the present invention.

Fig. 1 is a circuit diagram illustrating the construction of a first embodiment of a multiplex communication system according to the present invention. More specifically, Fig. 1 illustrates an example of a multiplex communication system loaded in a vehicle. Fig. 2 illustrates one example of the operation of the multiplex communication system shown in Fig. 1 in which operational data is transmitted in a time division multiplexing manner via a bus line.

Referring to Fig. 1, first to eleventh control units 1 to 11 are loaded in the common vehicle, and first to fourth end devices to be controlled 12 to 15 are also loaded in the same vehicle. The first to eleventh control units 1 to 11 respectively include at least operational switches 1s to 11s, and motors 1m to 11m which are interlocked with the switches 1s to 11s. The first to fourth end devices 12 to 15 respectively include at least motors 12m to 15m. A first changeover switch 16 has a single circuit with a plurality of contacts whose plurality of fixed contacts are respectively connected to the output terminal of the first control unit 1, the output terminal of the second control unit 2, and the respective movable contacts of second and third changeover switches 17 and 18 each having a single circuit with a plurality of contacts. The movable contact of the first changeover switch 16 is connected to a bus line 21. A plurality of fixed contacts of the second changeover switch 17 are respectively connected to the output terminals of the third, fourth and fifth control units 3, 4 and 5. A plurality of fixed contacts of the third changeover switch 18 are respectively connected to the output terminals of the sixth, seventh and eighth control units 6, 7 and 8. A plurality of fixed contacts of a fourth changeover switch 19 are respectively connected to the output terminals of the ninth, tenth and eleventh control units 9, 10 and 11. A fifth changeover switch 20 also has a single circuit with a plurality of contacts whose fixed contacts are respectively connected to the input terminals of the first to fourth end devices 12 to 15. The movable contact of the fifth changeover switch 20 is connected to the bus line 21. An overall control apparatus 22, which is coupled to a storage unit 23, is connected at its output terminal to the first to fifth changeover switches 16 to 20 so that it can exert control over the switching of the contacts of the first to fifth switches 16 to 20.

The operation of the system of this embodiment constructed as described above will now be explained with reference to Fig. 2.

When the key is inserted to the vehicle, the control apparatus 22 starts the control operation. At the start of the operation, the apparatus 22 reads a program which has been stored in the storage unit 23 and permits a built-in buffer memory, or the like, to store information representing the degrees of necessity of transmitting the respective items of operational data, that is, the degrees of urgency of transmitting the data. The information read by the control apparatus 22 determines the switching states of the contacts of the first to fifth switches 16 to 20 and the timing of switching the contacts of the switches 16 to 20. Subsequently, when a first transmission cycle of a plurality of items of operational data is started, the control apparatus 22 causes the contact of the first switch 16 to be sequentially switched from one end to the other end of the fixed contacts at required switching timings. In synchronization with switching the contacts of the first switch 16, the control apparatus 22 also causes the contacts of the second to fourth changeover switches 17 to 19 to be switched according to the content of the above-described information.

An explanation will now be given with reference to Fig. 2 of one example of the switching operation of the respective contacts of the first to fourth switches 16 to

19. The movable contact of the first switch 16 is initially switched and connected to a first fixed contact 16_1 for a given period t so that operational data 1d can be transmitted to the bus line 21 from the first control unit 1. Then, the movable contact of the first switch 16 is switched and connected to the second fixed contact 16_2 for a given period t so that operational data 2d can be transmitted to the bus line 21 from the second control unit 2.

Thereafter, the movable contact of the first switch 16 is switched and connected to the third fixed contact 16_3 for a given period 2t, which is twice as long as the above-described period t. This is because of the following reason. During the switching and connecting operation of the movable contact of the first switch 16 to the fixed contact 16_3, the movable contact of the second switch 17 is sequentially switched and connected to the first and second fixed contacts 17_1 and 17_2, each for the given period t. Simultaneously with this switching and connecting operation, two items of operational data 3d and 4d are sequentially transmitted to the bus line 21 from the third and fourth control units 3 and 4, respectively.

Then, the movable contact of the first switch 16 is switched and connected to the fourth fixed contact 16_4, during which time the movable contact of the third switch 18 is sequentially switched and connected to the first and second fixed contacts 18_1 and 18_2, each for the given period t, in a manner similar to the connection of the movable contact of the first switch 16 to the third fixed contact 16_3. Because of this switching and connecting operation, two items of operational data 6d and 7d are sequentially transmitted to the bus line 21 from the control units 6 and 7, respectively. Finally, the movable contact of the first switch 16 is changed and connected to the fifth fixed contact 16_5, during which time the movable contact of the fourth switch 19 is sequentially changed and connected to the first and second fixed contacts 19_1 and 19_2, each for a given period t. Because of this switching and connecting operation, two items of operational data 9d and 10d are transmitted to the bus line 21 from the control units 9 and 10, respectively.

As a consequence of these switching and connecting operations, the operational data 1d to 4d, 6d and 7d, and 9d and 10d are transmitted in the time division multiplexing manner to the bus line 21 from the first to the fourth, the sixth and seventh, and the ninth and tenth control units, respectively (the combination of these items of operational data shall be referred to as a first combination of operational data).

In this first transmission cycle, if the operation switches 1s to 4s, 6s and 7s, and 9s and 10s of the first to the fourth, the sixth and the seventh, and the ninth and the tenth control units 1 to 4, 6 and 7, and 9 and 10, respectively, are not actuated at all in the transmission timings allocated to the above-described control units, the respective items of operational data 1d to 4d, 6d and 7d, and 9d and 10d transmitted from the control units indicate zero, i.e., the data items do not contain any information. On the other hand, if any of the switches 1s to 4s, 6s and 7s, and 9s and 10s is actuated, the operational data among the data items of 1d to 4d, 6d and 7d, and 9d and 10d transmitted from the associated control unit(s) whose switch(es) are actuated indicates that the data item contains information.

Upon completion of the first transmission cycle, after a lapse of a given transmission interval, a subsequent (second) transmission cycle is started to once again transmit a plurality of items of operational data in a time division multiplexing manner. In the second transmission cycle, the respective items of operational data 1d and 2d are positively transmitted to the bus line 21 from the first and second control units 1 and 2, respectively, by the switching and connecting operation of the contacts of the first to fourth switches 16 to 19 under the control of the control apparatus 22. In contrast, the items of operational data 3d, 4d, 6d, 7d, 9d and 10d from the third, fourth, sixth, seventh, ninth and tenth control units, 3, 4, 6, 7, 9 and 10, respectively, are not transmitted. Instead, the items of operational data 5d, 8d and 11d from the fifth, eighth and eleventh control units 5, 8 and 11, respectively, which have not been transmitted during the first transmission cycle, are transmitted to the bus line 21. As a consequence, during the second transmission cycle, the items of operational data 1d, 2d, 5d, 8d and 11d are transmitted to the bus line 21 from the first, second, fifth, eighth and eleventh control units 1, 2, 5, 8 and 11, respectively, in a time division multiplexing manner (the combination of these items of operational data shall be referred to as a second combination of operational data).

Upon completion of the second transmission cycle, after a lapse of a given transmission interval, a third transmission cycle is initiated. In the third transmission cycle, the first combination of operational data obtained during the first transmission cycle is once again transmitted in a time division multiplexing manner. In a subsequent fourth transmission cycle, the second combination of operational data obtained during the second transmission cycle is once again transmitted in a time division multiplexing manner. The same applies to after the fourth transmission cycle. Every time an updated transmission cycle is started after a lapse of a given transmission interval, the first and second combinations of operational data are alternately transmitted to the bus line 21 in a time division multiplexing manner.

Every time a transmission cycle is started, the control apparatus 22 causes the movable contact of the fifth switch 20 to be switched in a required order. Due to this switching operation, every time operational data is transmitted to the bus line 21, an associated end device to receive the transmitted data is selected by switching the movable contact of the fifth switch 20. For example, if the operational data 1d is addressed to the first end device 12, and the operational data 2d is addressed to the second end device 13, the movable contact of the fifth switch 20 should be switched to the first fixed contact 20_1 connected to the end device 12 and to the second fixed contact 20_2 connected to the second end device 13 in accordance with the transmission timing of the data 1d and 2d to the bus line 21. The same applies to the other items of operational data. Namely, in accordance with the transmission timing of the data to the bus line 21, the movable contact of the fifth switch 20 should be changed so that an associated end device(s) to receive the transmitted data can be selected. The motor provided with the associated end device then suitably acts upon the content of the data so that a required operation can be performed in the end device supplied with the transmitted data.

In this embodiment, the operational data having a greater degree of urgency corresponds to air bag signals that are output from a collision detecting section, door lock/unlock signals that are output from a door lock/unlock detecting section, and so on. On the other hand, the data having a smaller degree of urgency corresponds to window opening/closing instruction signals that are output from a window opening/closing section, remote control mirror driving signals that are output from a mirror actuating section, and so on.

In this embodiment, each of the movable contacts of the second to fourth switches 17 to 19 is sequentially switched and connected to the associated two fixed contacts while the first switch 16 is switched and connected to each of the third to fifth fixed contacts 16_3 to 16_5. However, each of the movable contacts of the second to fourth switches 17 to 19 may be switched and connected to only one of the fixed contacts while the first switch 16 is switched and connected to each of the third to fifth fixed contacts 16_3 to 16_5. Alternatively, each of the movable contacts of these switches may be switched and connected to three fixed contacts or more.

Further, this embodiment has been explained in which the two items of operational data 1d and 2d are positively transmitted from the first and second control units 1 and 2, respectively, in every transmission cycle, while the operational data items 3d, 4d, 6d, 7d, 9d and 10d from the control units 3, 4, 6, 7, 9 and 10, respectively, and the data items 5d, 8d and 11d from the control units 5, 8 and 11, respectively, are alternately transmitted in every other cycle. However, this arrangement is not essential. That is, the data that is positively transmitted in every transmission cycle is not restricted to 1d and 2d, and instead, the data from the other control units may be selected as long as it is required to be transmitted very urgently. Also, the number of items of data to be transmitted is not limited to two, and instead, three or more items of data may be selected.

Moreover, in the above-described embodiment, the respective items of operational data 1d to 11d are divided into two degrees depending on the transmitting urgency, i.e., one degree formed of the data items 1d and 2d that are positively transmitted once in every transmission cycle, and the other degree formed of the other data items 3d to 11d that are alternately transmitted in every other cycle. However, the degrees of necessity (urgency) of transmitting the data are not limited to two, but may be three or more as required. A plurality of degrees of transmitting urgency may be accomplished by the following modification. A plurality of changeover switches each having a single circuit with a plurality of contacts are used and suitably switched to a plurality of control units. At the same time, the switching periods of the change-over switches, each having a single circuit with a plurality of contacts, are selected by the control apparatus 22. With this modification, the following three types of operational data can be generated: the data transmitted in every transmission cycle; the data transmitted in every other cycle; and the data transmitted in every two or three cycles.

As will be clearly understood from the foregoing description, the first embodiment offers the following advantages.

A plurality of items of operational data 1d to 11d transmitted to the bus line 21 from a plurality of control units 1 to 11, respectively, are divided into a plurality of degrees which have been determined according to the necessity of transmission. The operational data falling into the greater degree of transmission necessity is positively transmitted once in every transmission cycle. On the other hand, the data falling into the smaller degree of transmission necessity is transmitted once in every few cycles according to the degree of necessity. As described above, signals having the greater necessity (urgency) of transmission, such as air bag signals and door lock/unlock signals that are respectively output from the collision detecting section and the door lock/unlock detecting section among the vehicle-loaded control units 1 to 11, are positively transmitted once in every cycle. This arrangement inhibits a time lag in transmitting signals having the greater degree of necessity (urgency), which further ensures safety for the driver and passengers.

Additionally, as described above, signals (data) having the smaller degree of transmitting necessity (urgency), such as window opening/closing instruction signals and remote control mirror driving signals that are respectively output from the window opening/closing section and the mirror actuating section among the control units 1 to 11, are transmitted only once in every few cycles according to the degree of urgency. This arrangement makes it possible to reliably operate a desired end device to accomplish a required function based on the operational signal (data) without interfering with the transmission timing of signals having the greater degree of urgency.

The multiplex communication system loaded in a vehicle has been discussed in this embodiment by way of example. However, this system is not only applicable to a vehicle, but also to other uses as long as the system is adequate to generate a plurality of items of data that can be distinctly differentiated into the degrees of transmission urgency and also to transmit them in a time division multiplexing manner.

A second embodiment of a multiplex communication system according to the present invention will now be explained in detail with reference to Figs. 3 to 5.

Fig. 3 is a block diagram illustrating the construction of a multiplex communication system according to the second embodiment. Fig. 4 illustrates the construction of message data transmitted to a bus line. Fig. 5 is a flow chart illustrating the operation of this embodiment. Fig. 3 shows a bus line 21, a master node device M, slave node devices A and B, actuators Da to De, and switches Sa to Sh.

More specifically, the multiplex communication system of the second embodiment comprises the single common bus line 21, the master node device M connected to the bus line 21 so as to determine the transmission timings of all the items of message data in the communication system, and a plurality of slave node devices A and B connected to the bus line 21. It will now be assumed that this system is installed in a vehicle for controlling vehicle-loaded equipment and for other reasons. The master node device M is connected to peripheral equipment, for example, mounted on the driver's seat, such as switches Sa and Sb indicating the states of the door and the window and the state of the window opening/closing switch, etc., and actuators Da and Db, such as a door lock motor, a power window motor, etc. With this construction, the master node device M collects data indicating the state of the switches Sa and Sb and transmits it to the bus line 21 as required so as to exert control over the actuators Da and Db. On the other hand, the slave node devices A and B are connected to peripheral equipment, for example, mounted on the passenger's front seat and on the rear seats so that they can collect and transmit data so as to exert control over the respective actuators, in a manner similar to the master node device M.

Each of the master node device M and the slave node devices A and B is provided with a CPU. The master node device M takes the initiative in determining the transmission timing and cycle of the message data onto the bus line 21. More specifically, the node device M exerts control over the transmission timing and cycle by use of a clock timer of the CPU contained in its own device so that the message data can be transmitted to the bus line 21 from each of the master node device M and the slave node devices A and B at a predetermined timing and cycle. The master node device M transmits and receives message data with the salve node devices A and B in accordance with the above-described predetermined timing and cycle so that it can exert control over required actuators.

The transmission timing and cycle of the message data transmitted to the bus line 21 are determined as indicated in Fig. 4. This will be explained in greater detail below.

As shown in Fig. 4, the transmission cycle of the message data has been set as a start pulse transmitted to the bus line 21 from the master node device M. This cycle has been set so as not to cause a time lag in the data processing executed in the respective node devices. Each of the time intervals between start pulses is divided into a plurality of time slots which have been allocated to the individual node devices, during which slot the node devices transmit and receive message data with each other.

In the example shown in Fig. 4, in a first time slot subsequent to the start pulse, the master node device M transmits message data to the other node devices. In a second time slot, the slave node device A transmits message data to the other node devices. In a third time slot, the slave node device B transmits message data to the other node devices. Similarly, subsequent time slots are arranged for executing data transmission among different node devices. For identifying the respective time slots, time intervals, which are different from the pulse length of the start pulse, each intervene between the time slots.

Each time slot used for transmitting message data from each node device to the other node devices is divided into a plurality of sub-time slots which can carry data formed of one bit or a plurality of bits. Each time slot has been allotted to a predetermined node device for transmitting message data, as described above, and the sub-time slots have also been allocated to the end node devices to receive such data. For example, the leading sub-time slot within the time slot allocated to the data transmission of the slave node device A is used to transmit message data from the slave node device A to the master node device M. A subsequent sub-time slot is used to transmit message data from the slave node device A to the slave node device B.

As has been discussed above, in the second embodiment the timing and cycle for transmitting message data to the bus line 21 have been determined. Additionally, during the individual sub-time slots within each time slot that can carry message data, it has been determined which node device can transmit data to which end device. With this arrangement, each node device connected to the bus line 21 can be notified which message data is to be addressed to its own device merely by monitoring the time slots on the bus line 21 after acknowledging the receipt of a start pulse from the master node device M. Each node device can also be notified which time slot can be used to transmit message data from its own device.

This arrangement enables each of the node devices, including the master node device M, to receive message data from the other node devices as required, and to control the actuator, etc. connected to its own device. Each node device is also able to transmit to a desired node device the state of switches indicating the status of the various types of equipment connected to its own device.

The operation of the second embodiment of the present invention will now be described with reference to the flow chart of Fig. 5. In this embodiment, the multiplex communication system constructed of the master node device M and the slave node devices A and B, all of which are connected to the bus line 21, will be taken as an example.

(1) The master node device M first transmits a start pulse to the bus line 21 (step 301).

(2) Subsequent to the transmission of the start pulse, the time slot allocated to the data transmission of the master node device M is started. The node device M thus transmits message data that is addressed to a desired slave node device by use of the associated sub-time slot (step 302).

(3) Upon completion of the transmission by use of the time slot allocated to the master node device M, a subsequent time slot allocated to the data transmission of the slave node device A is initiated. The master node device M thus monitors the start of transmitting message data from the slave node device A (step 303), and also monitors a lapse of a predetermined time provided for transmission from the node device A (step 305).

(4) If there is any message data addressed to the master node device M from the slave node device A, the node device M receives it by use of the sub-time slot allocated to its own device (step 304).

(5) If the transmission of the message data from the slave node device A is not started after a lapse of the above-described transmission predetermined time (step 305),

the master node device M executes transmission error handling in respect of the slave node device A (step 306).

(6) Upon completion of data transmission by use of the previous time slot, a subsequent time slot allocated to data transmission of the slave node device B is started. The master node device M monitors the start of the transmission of message data from the slave node device B (step 307), and also monitors a lapse of a predetermined transmission time provided for the node device B (step 309).

(7) If there is any message data addressed to the master node device M from the slave node device B, the node device M receives the data by use of the sub-time slot allotted to its own device (step 308).

(8) If the transmission of the message data from the slave node device B is not started after a lapse of the above-described predetermined time, the master node device M executes transmission error handling in respect of the slave node device B (step 310).

(9) The master node device M goes into a standby position until the transmission time of a subsequent start pulse is reached (step 311), and returns to step 301 to transmit the subsequent start pulse (step 311).

The operation of the system has been discussed in terms of the sequence of the master node device M. An explanation will now be given of the operation of the slave node device A in relation to the master node device M.

(10) The slave node device A monitors the bus line 21 in the standby position until a start pulse is transmitted

from the master node device M (step 321).

(11) Upon acknowledgement of the receipt of the start pulse, the time slot allocated to the data transmission of the master node M is started. The slave node device A thus receives the message data from the master node device M in the sub-time slot allocated to its own device (step 322).

(12) Upon completion of the previous slot, a subsequent time slot allocated to the data transmission of the slave node device A is initiated. The node device A thus transmits message data that is to be addressed to the master node device M and the other slave node device by use of the respective associated sub-time slots (step 323).

(13) A subsequent time slot allocated to the data transmission of the slave node device B is started. The node device A thus monitors the start of transmitting message data from the node device B (step 324), and also monitors a lapse of a predetermined transmission time provided for the node device B (step 326).

(14) If there is any message data addressed to the slave node device A from the node device B, the node device A receives the data in the sub-time slot allotted to its own device (step 325).

(15) If the transmission of the message data from the slave node device B is not started after a lapse of the above-described predetermined transmission time, the node device A executes transmission error handling in respect of the node device B (step 327).

(16) Upon completion of the processing of either of

steps 325 or 327, the slave node device A returns to step 321 to continue to receive data in a subsequent cycle.

The slave node device B is operated in a manner similar to the node device A. An explanation will thus be given only of the operation in which the node device B ignores the message data transmitted from the node device A.

(17) The slave node device B monitors the bus line 21 and is stationed at the standby position until it receives a start pulse from the master node device M (step 331).

(18) Upon acknowledgement of the receipt of the start pulse, the time slot allocated to the data transmission of the master node device M is started. The slave node device B thus receives the message data contained in the sub-time slot allotted to its own device (step 332).

(19) Upon completion of the previous slot, a subsequent time slot allocated to the data transmission of the slave node device A is started. During this time slot, the node device B can ignore the unnecessary data from the node device A (step 333), and can be stationed in the standby position until the transmission of the message data from the slave node device A is completed (step 334).

(20) Upon completion of the previous time slot, the time slot allocated to the data transmission of the slave node device B is started. The node device B thus transmits message data that is to be addressed to the master node device M and the other slave node device by use of the respective associated sub-time slots (step 335), and returns to step 331 to continue to receive subsequent data.

This embodiment has been explained in which the multiplex communication system is constructed of the master node device M and the slave node devices A and B, all of which are connected to the common bus line 21. However, this construction is not exclusive. The present invention is also operable when the slave node devices are connected to a plurality of bus lines.

Also, in this embodiment, the master node device M takes the initiative in determining the transmission timing of message data from each of the node devices onto the bus line. However, the master node device M may be constructed as desired. Also, if the master node device M becomes at fault during operation, a desired slave node device may be constructed to act as the master node device. This modification can be achieved by programming into each node device, conditions, such as the states of the other node devices required when its own device functions as the master node device.

As will be clearly understood from the foregoing description, the present invention offers the following advantages.

A plurality of items of operational data to be transmitted to the bus line from a plurality of control units, respectively, are divided into a plurality of degrees which have been determined according to the transmission necessity. The operational data falling into the greatest degree of transmission necessity is positively transmitted once in every transmission cycle. On the other hand, the data falling into the smaller degree of transmission necessity is transmitted once in every few cycles according to the degree of urgency. By the application of this system to a vehicle by way of example, signals having the greater necessity (urgency) of transmission, such as air bag signals and door lock/unlock signals that are respectively output from the collision detecting section and the door lock/unlock detecting section among a plurality of vehicle-loaded control units, are positively transmitted once in every cycle. This arrangement inhibits a time lag in transmitting signals having the greater degree of transmission urgency, which further ensures safety for the driver and passengers.

Additionally, by the application of the multiplex communication system to a vehicle by way of example, signals (data) having the smaller degree of transmitting necessity (urgency), such as window opening/closing instruction signals and remote control mirror driving signals that are respectively output from the window opening/closing section and the mirror actuating section among a plurality of vehicle-loaded control units, are transmitted only once in every few cycles according to the degree of urgency. This arrangement makes it possible to reliably operate each end device to accomplish a required function based on the operational signal (data) without interfering with the transmission timing of signals having the greater degree of urgency.

Further, each node device is able to transmit message data to a desired end device without appending the sender and receiver information to the data merely by carrying the data onto the sub-time slot corresponding to the end node device within the time slot allocated to its own device. This makes it possible to perform faster transmission of message data without a time loss, which further shortens a transmission cycle of message data from the respective node devices, thereby preventing a time lag in the control processing of vehicle-loaded equipment.

CLAIMS

1. A multiplex communication system in which a plurality of items of operational data are transmitted in every transmission cycle, in a time division multiplexing manner, via a bus line from a plurality of control devices to at least one of a plurality of end devices to be controlled, wherein said items of operational data are divided into a plurality of degrees according to the necessity of transmission, wherein the operational data falling into the greatest degree of transmission necessity is transmitted once in every transmission cycle, while the operational data falling into the smaller degrees of transmission necessity is transmitted once in every few transmission cycles according to the degree of the transmission necessity.

2. A multiplex communication system according to Claim 1, wherein said items of operational data are divided according to a program which has been stored in a storage unit, under the control of a control apparatus.

3. A multiplex communication system according to Claim 1 or Claim 2, wherein said control units and said bus line, and said end devices and said bus line are selectively switched and connected by a plurality of change-over switches which are changed under the control of said control apparatus.

4. A multiplex communication system according to any one of Claims 1 to 3, wherein said control units are control unit equipment loaded in a common vehicle, and said end devices are equipment to be controlled which is loaded in the same vehicle and controlled by the operation of said control unit equipment.

5. A multiplex communication system according to any one of Claims 1 to 4, wherein said items of operational data are divided into the degrees of transmission necessity based on the urgency of

transmitting said data.

6. A multiplex communication system in which a plurality of node devices are connected to a bus line so as to cyclically transmit and receive message data with each other and to execute processing of the received data, wherein one of said node devices functions as a master node device so as to determined a transmission cycle of the message data from all the node devices and to take the initiative in determining a transmission timing within said transmission cycle at which each of said node devices, including its own device, transmits the message data onto said bus line, said transmission timing being associated with each of said node devices, so that each of said devices sends the message data to be addressed to another device onto said bus line at said transmission timing determined by said master node device.

7. A multiplex communication system according to Claim 6, wherein a time slot provided at said transmission timing associated with each of said node devices is divided into a plurality of sub-time slots, and said sub-time slots are arranged to correspond to the individual node devices to receive the message data transmitted from one of said node devices.

8. A multiplex communication system according to Claim 6 or Claim 7, wherein one of said node devices acts as said master node device if a failure occurs to said master node device.

9. A multiplex communication system according to any one of Claims 6 to 8, wherein each of said node devices, including said master node device, has a CPU, wherein the CPU of said master node device determines said transmission cycle and said transmission timing associated with each of said node devices arranged within said cycle, while the CPUs of said node devices, including said master node device, controls the transmission timings so that the

message data is transmitted from said devices at the timings determined by the CPU of said master node device.

10. A multiplex communication system substantially as hereinbefore described with reference to, and as illustrated by, the accompanying drawings.

Application No:	GB 9521853.3	**Examiner:**	Simon Rees
Claims searched:	1-5 and 10	**Date of search:**	18 January 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H4M (MN, MTX1), H4P (PPK, PPNB), G4H (W, NEC, NEE, NF)

Int Cl (Ed.6): H04J (3/16), H04L (12/40, 12/42), B60R (16/02)

Other: ONLINE: WPI, INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A,E	GB2290682A	(NIPPONDENSO) Whole document.	1
A	EP0192819A2	(HITACHI) Whole document, especially lines 3-10 on page 4, lines 6-10 of page 6 and lines 6-21 of page 21.	1-5
X	WO89/02141A1	(ERICSSON) Whole document, especially from line 29 of page 2 to line 4 of page 3, and from line 16 of page 4 to line 4 of page 5 .	1-5
X	US5343472A	(MICHIHIRA) Whole document, especially lines 5-67 of column 2 and lines 24-37 of column 3.	1-5

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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Patent and Trademark Office
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Box PCT
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U.S. APPLICATION NO.	FIRST NAMED APPLICANT		ATTY. DOCKET NO.
09/402262	JONES	B	14,442

STOTLAND HAROLD V
EMRICH & DITHMAR
300 SOUTH WACKER DRIVE
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CHICAGO, IL 60606

INTERNATIONAL APPLICATION NO.	
PCT/GB98/00866	
I.A. FILING DATE	PRIORITY DATE
03 APR 98	03 APR 97

DATE MAILED: 17 DEC 1999

NOTIFICATION OF MISSING REQUIREMENTS UNDER 35 U.S.C. 371 IN THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US)

1. The following items have been submitted by the applicant or the IB to the United States Patent and Trademark Office as
   - ☐ a Designated Office (37 CFR 1.494),
   - ☒ an Elected Office (37 CFR 1.495):
   - ☒ U.S. Basic National Fee.
   - ☒ Copy of the international application in:
     - ☐ a non-English language.
     - ☒ English.
   - ☒ Translation of the international application into English.
   - ☐ Oath or Declaration of inventors(s) for DO/EO/US.
   - ☐ Copy of Article 19 amendments.
   - ☐ Translation of Article 19 amendments into English.
   - ☒ The International Preliminary Examination Report in English and its Annexes, if any.
   - ☒ Translation of Annexes to the International Preliminary Examination Report into English.
   - ☐ Preliminary amendment(s) filed ________________ and ________________.
   - ☐ Information Disclosure Statement(s) filed________________ and ________________.
   - ☐ Assignment document.
   - ☐ Power of Attorney and/or Change of Address.
   - ☐ Substitute specification filed ________________.
   - ☐ Verified Statement Claiming Small Entity Status.
   - ☒ Priority Document.
   - ☒ Copy of the International Search Report ☒ and copies of the references cited therein.
   - ☐ Other:
2. The following items **MUST** be furnished within the period set forth below in order to complete the requirements for acceptance under 35 U.S.C. 371:
   - ☐ a. Translation of the application into English. Note a processing fee will be required if submitted later than the appropriate 20 or 30 months from the priority date.
     - ☐ The current translation is defective for the reasons indicated on the attached Notice of Defective Translation.
   - ☐ b. Processing fee for providing the translation of the application and/or the Annexes later than the appropriate 20 or 30 months from the priority date (37 CFR 1.492(f)).
   - ☐ c. Oath or declaration of the inventors, in compliance with 37 CFR 1.497(a) and (b), identifying the application by the International application number and international filing date.
     - ☒ The current oath or declaration does not comply with 37 CFR 1.497(a) and (b) for the reasons indicated on the attached PCT/DO/EO/917.
   - ☒ d. Surcharge for providing the oath or declaration later than the appropriate 20 or 30 months from the priority date (37 CFR 1.492(e)).
3. Additional claim fees of $__________ as a ☐ large entity ☐ small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due. See attached PTO-875.

ALL OF THE ITEMS SET FORTH IN 2(a)-2(d) AND 3 ABOVE MUST BE SUBMITTED WITHIN ONE MONTH FROM THE DATE OF THIS NOTICE OR BY ☐ 21 OR ☒ 31 MONTHS FROM THE PRIORITY DATE FOR THE APPLICATION, WHICHEVER IS LATER. FAILURE TO PROPERLY RESPOND WILL RESULT IN ABANDONMENT.

The time period set above may be extended by filing a petition and fee for extension of time under the provisions of 37 CFR 1.136(a).

4. Translation of the Annexes MUST be submitted no later that the time period set above or the annexes will be cancelled. Note processing fee will be required if submitted later than 30 months from the priority date.
5. ☐ The Article 19 amendments are cancelled since a translation was not provided by the appropriate 20 (37 CFR. 494(d)) or 30 (37 CFR 1.495(d)) months from the priority date.

Applicant is reminded that any communication to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above. (37 CFR 1.5)

A copy of this notice MUST be returned with this response.

Enclosed:
☒ PCT/DO/EO/917 ☐ Notice of Defective Translation
☐ PTO-875

Paulette Kidwell, Paralegal
Telephone: 703-305-3656

FORM PCT/DO/EO/905 (December 1997)

Patent and Trademar... ...e
Address: ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

U.S. APPLICATION NO.		FIRST NAMED APPLICANT		ATTY. DOCKET NO.
09/402262		JONES	B	14,442

STOTLAND HAROLD V
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INTERNATIONAL APPLICATION NO.	
PCT/GB98/00866	
I.A. FILING DATE	PRIORITY DATE
03 APR 98	03 APR 97

DATE MAILED: 17 DEC 1999

NOTIFICATION OF A DEFECTIVE OATH OR DECLARATION

This application fails to contain an oath or declaration acceptable under 35 U.S.C. 371 (c)(4) for entry into the national stage in the United States of America. The period within which to correct these requirements and avoid abandonment is set in the accompanying Office action.

A new oath or declaration, identifying this application by the international application number and international filing date is required. The oath or declaration does not comply with 37 CFR 1.497(a) and (b) in that it:

1. ☒ is not executed in accordance with either 37 CFR 1.66 or 37 CFR 1.68.
2. ☐ does not identify the specification to which it is directed.
3. ☐ does not identify the inventor(s).
4. ☐ does not identify the citizenship of each inventor.
5. ☐ does not state the person making the oath or declaration believes the named inventor or inventors to be the original and first inventor or inventors of the subject matter which is claimed and for which a patent is sought.

FAILURE TO SUBMIT AN OATH OR DECLARATION IN COMPLIANCE WITH 37 CFR 1.497(a) AND (b) WITHIN THE TIME PERIOD SET WILL RESULT IN FAILURE TO ENTER THE NATIONAL STAGE AND THE ABANDONMENT OF THE APPLICATION.

Additionally, the oath or declaration does not comply with 37 CFR 1.63 in that it:

1. ☐ does not identify the city and state or city and foreign country of residence or each inventor.
2. ☐ does not state that the person making the oath or declaration:
   a. ☐ has reviewed and understands the contents of the specification, including the claims, as amended by any amendment specifically referred to in the oath or declaration.
   b. ☐ acknowledges the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.
3. ☐ does not identify the foreign application for patent or inventor's certificate on which priority is claimed pursuant to 37 CFR 1.55, and any foreign application having a filing date before that of the application on which priority is claimed, by specifying the application serial number, country, day, month, and year of its filing.
4. ☐ does not state that the person making the oath or declaration acknowledges the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and filing date of the continuation in part application which discloses and claims subject matter in addition to that disclosed in the prior application (37 CFR 1.63(d)).

Paulette Kidwell, Paralegal
Telephone:703-305-3656

FORM PCT/DO/EO/917 (September 1996)

ISSUE CLASSIFICATION	Class	Subclass

PATENT NUMBER

U.S. UTILITY PATENT APPLICATION

O.I.P.E.	PATENT DATE
② PD SCANNED AA Q.A. KC	

SECTOR	CLASS	SUBCLASS	ART UNIT	EXAMINER
	340	870.1100	2632	Dang

FILED WITH: ☐ DISK (CRF) ☐ FICHE
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PREPARED AND APPROVED FOR ISSUE

ISSUING CLASSIFICATION

ORIGINAL		CROSS REFERENCE(S)						
CLASS	SUBCLASS	CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)					
INTERNATIONAL CLASSIFICATION								

☐ Continued on Issue Slip Inside File Jacket

☐ **TERMINAL DISCLAIMER**

☐ a) The term of this patent subsequent to ________ (date) has been disclaimed.

☐ b) The term of this patent shall not extend beyond the expiration date of U.S Patent. No. ________

☐ c) The terminal ____months of this patent have been disclaimed.

DRAWINGS

Sheets Drwg.	Figs. Drwg.	Print Fig.

________ (Assistant Examiner) ________ (Date)

________ (Primary Examiner) ________ (Date)

________ (Legal Instruments Examiner) ________ (Date)

CLAIMS ALLOWED

Total Claims	Print Claim for O.G.

NOTICE OF ALLOWANCE MAILED

ISSUE FEE

Amount Due	Date Paid

ISSUE BATCH NUMBER

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The information disclosed herein may be restricted. Unauthorized disclosure may be prohibited by the United States Code Title 35, Sections 122, 181 and 368. Possession outside the U.S. Patent & Trademark Office is restricted to authorized employees and contractors only.

Form PTO-436A
(Rev. 6/98)

(LABEL AREA)

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SEARCHED

Class	Sub.	Date	Exmr.
340	870.11	9/6/04	[illegible]
	870.03		
	870.28		
370	538		
	335		
	342		
	441		
375	220		
73	117.3	9/8/04	

INTERFERENCE SEARCHED

Class	Sub.	Date	Exmr.

SEARCH NOTES
(INCLUDING SEARCH STRATEGY)

	Date	Exmr.
-Search EAST	9/6/04	[illegible]
-Consulted with Tim Edward	9/8/04	

(RIGHT OUTSIDE)

ISSUE SLIP STAPLE AREA (for additional cross references)

POSITION	INITIALS	ID NO.	DATE
FEE DETERMINATION			
O.I.P.E. CLASSIFIER		25	10-28-99
FORMALITY REVIEW	[illegible]		10 mar 00

INDEX OF CLAIMS

✓ .... Rejected		N .... Non-elected	
= .... Allowed		I .... Interference	
— (Through numeral)... Canceled		A .... Appeal	
÷ .... Restricted		O .... Objected	

Claim Final	Claim Original	Date 9/7/04	Claim Final	Claim Original	Date	Claim Final	Claim Original	Date
	1	✓		51			101	
	2	✓		52			102	
	3	✓		53			103	
	4	✓		54			104	
	5	O		55			105	
	6	O		56			106	
	7	O		57			107	
	8	O		58			108	
	9	O		59			109	
	10	O		60			110	
	11	O		61			111	
	12	O		62			112	
	13	✓		63			113	
	14	✓		64			114	
	15	✓		65			115	
	16	✓		66			116	
	17	O		67			117	
	18	O		68			118	
	19	O		69			119	
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FORM PTO-1390 (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 14,442

U.S. APPLICATION NO. (If known, see 37 CFR 1.5): 09/402262

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB98/00866	3 April 1998 (04/03/1998)	3 April 1997 (04/03/1997)

TITLE OF INVENTION
WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

APPLICANT(S) FOR DO/EO/US
Jones, Barbara L. and Smith, Paul

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [ ] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [X] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. [X] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). (unsigned)
10. [ ] A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [ ] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information: Form PCT/IB/308 dated 8 October, 1998 (10/08/98)
    International Search Report
    Written Opinion
    Response to Written Opinion
    International Preliminary Examination Report and Annexes

I Hereby Certify That This Correspondence Is Being Deposited With The United States Postal Service As Express Mail No. EL 453 823 906 US Addressed To: Assistant Commissioner for Patents, Washington, D.C 20231 On 10/1/99

Date. 10/1/99

U.S. APPLICATION NO (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
09/402262	PCT/GB98/00866	14,442

17. ☒ The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):

	CALCULATIONS	PTO USE ONLY
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO $970.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO $840.00		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $760.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) $670.00		
International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) $96.00		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$	840
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	25 - 20 =	5	X $18.00	$	90
Independent claims	4 - 3 =	1	X $78.00	$	78
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	$	260
TOTAL OF ABOVE CALCULATIONS =				$	1,268
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also by filed (Note 37 CFR 1.9, 1.27, 1.28).				$	
SUBTOTAL =				$	1,268
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$	1,268
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$	1,268
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of $ 1,268 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ________ in the amount of $________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 05-1060. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Stotland, Harold V.
Emrich & Dithmar
Suite 3000
300 South Wacker Drive
Chicago, Illinois 60606

SIGNATURE:

Harold V. Stotland
NAME

24,492
REGISTRATION NUMBER

FORM PTO-1390 (REV 11-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
14,442

U.S. APPLICATION NO. (If known, see 37 CFR 1.5)
09/402262

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB98/00866	3 April 1998 (04/03/1998)	3 April 1997 (04/03/1997)

TITLE OF INVENTION
WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

APPLICANT(S) FOR DO/EO/US
Jones, Barbara L. and Smith, Paul

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
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    International Search Report
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Date. 10/1/99

US 514 Rec'd PCT/PTO 01 OCT 1999

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b. [ ] Please charge my Deposit Account No. ________ in the amount of $________ to cover the above fees. A duplicate copy of this sheet is enclosed.

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SEND ALL CORRESPONDENCE TO:

Stotland, Harold V.
Emrich & Dithmar
Suite 3000
300 South Wacker Drive
Chicago, Illinois 60606

SIGNATURE:

Harold V. Stotland

NAME

24,492

REGISTRATION NUMBER

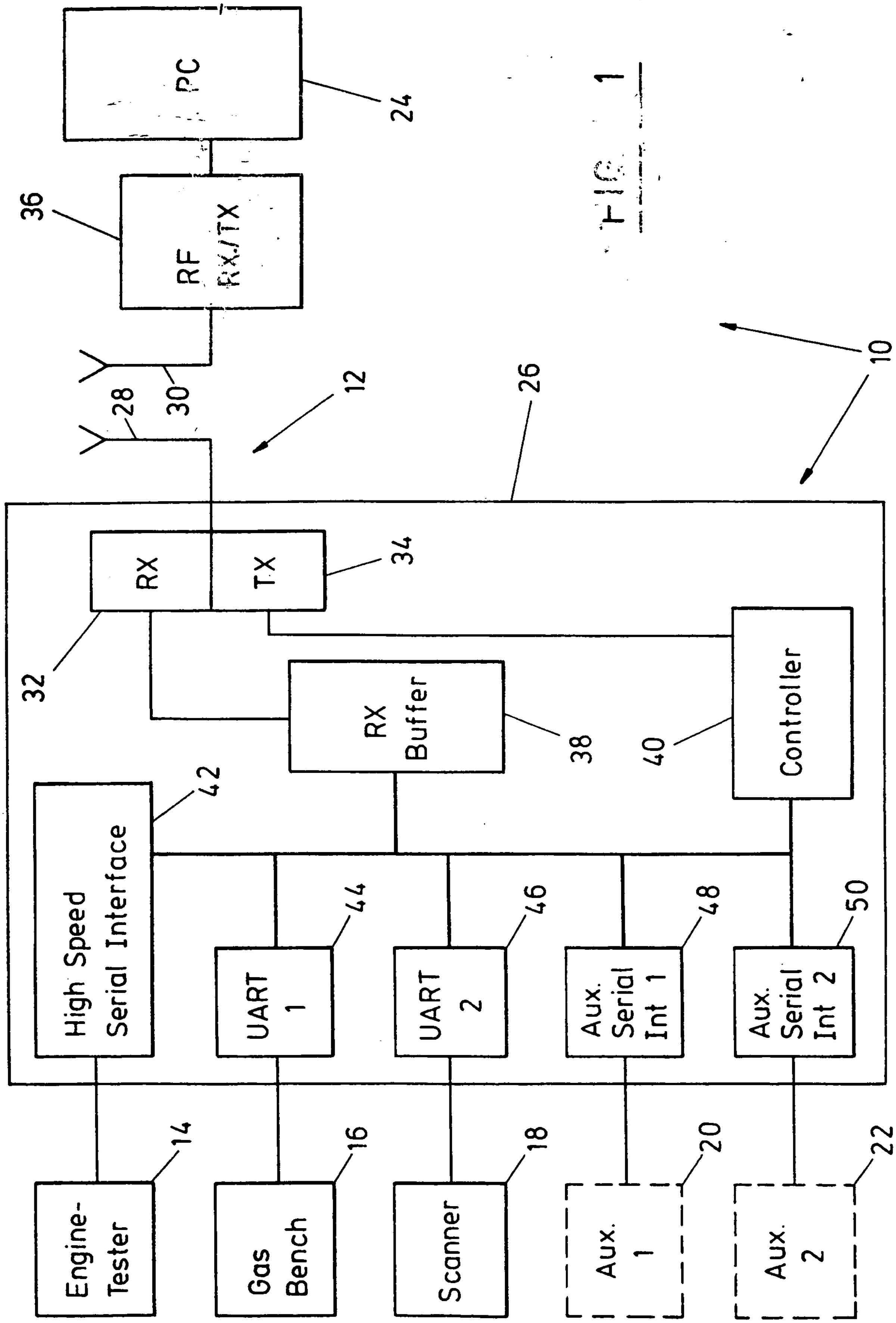

PC
24
36
RF
RX/TX
28
30
12
26
10
RX
TX
34
32
RX
Buffer
38
40
Controller
42
High Speed
Serial Interface
UART
1
44
UART
2
46
Aux.
Serial
Int 1
48
Aux.
Serial
Int 2
50
Engine-
Tester
14
Gas
Bench
16
Scanner
18
Aux.
1
20
Aux.
2
22

FIG. 1

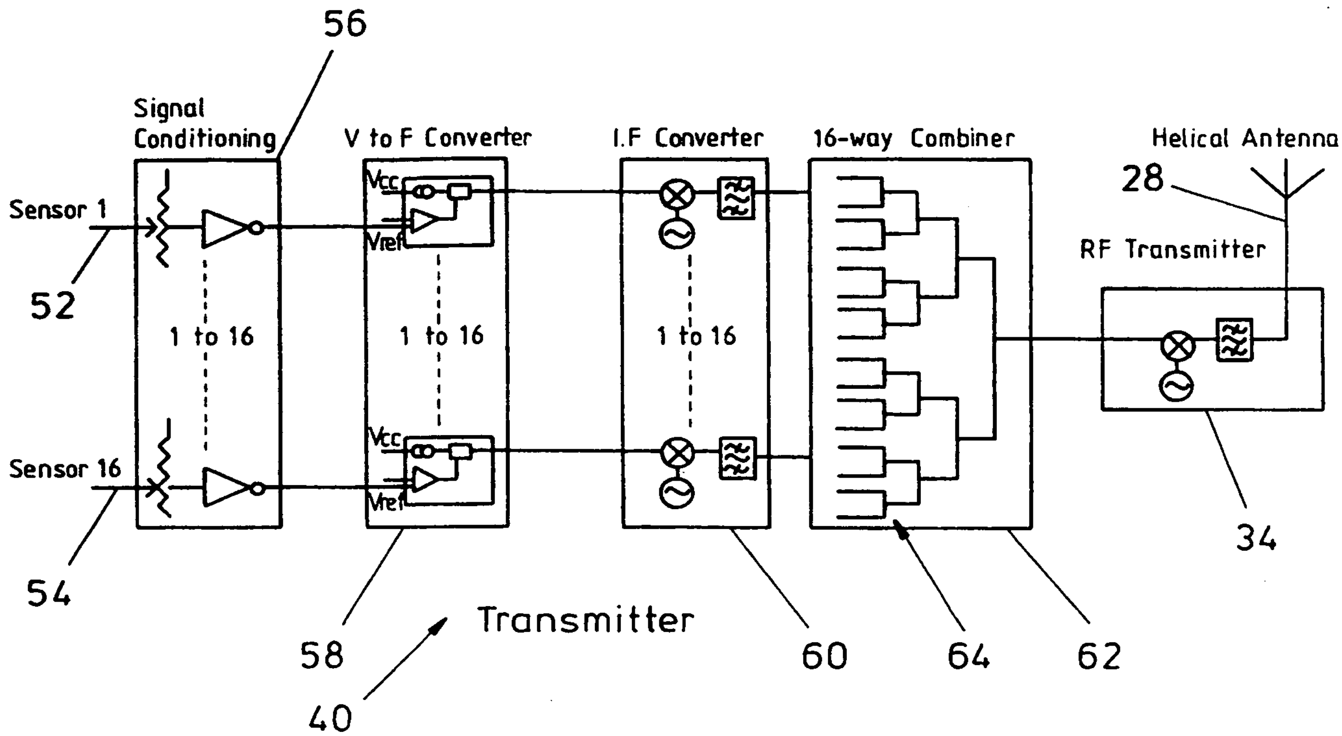

56
Signal Conditioning
V to F Converter
I.F Converter
16-way Combiner
Helical Antenna
28
RF Transmitter
Sensor 1
52
1 to 16
1 to 16
1 to 16
Vcc
Vref
Vcc
Vref
Sensor 16
54
58
Transmitter
40
60
64
62
34

FIG. 2

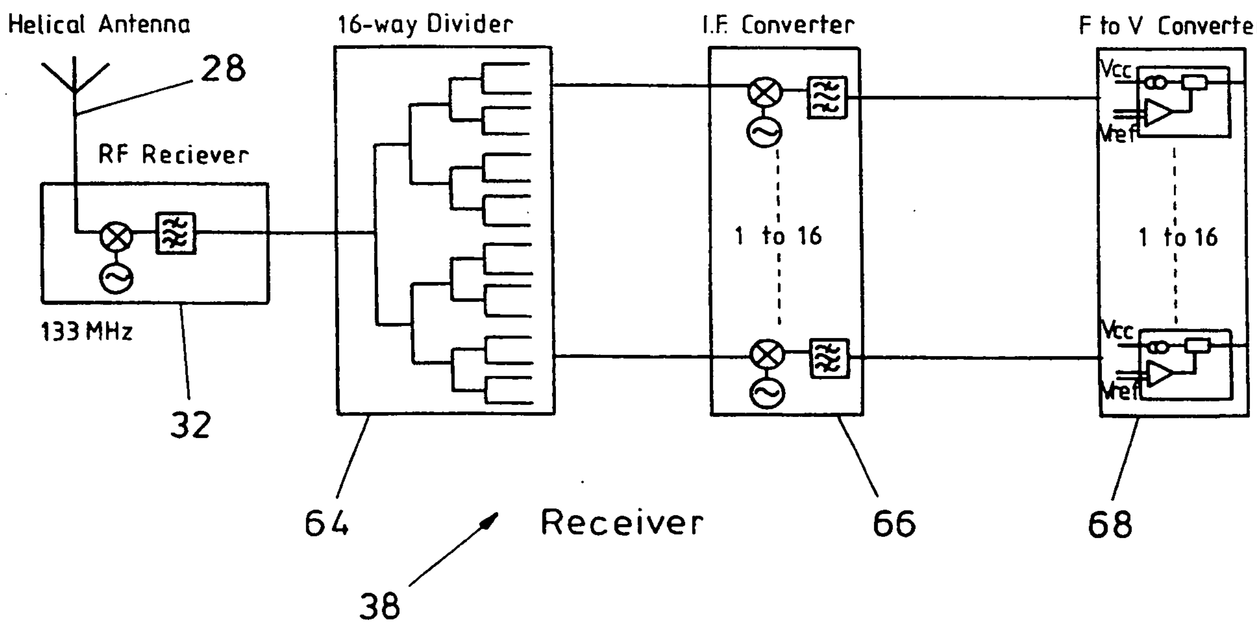
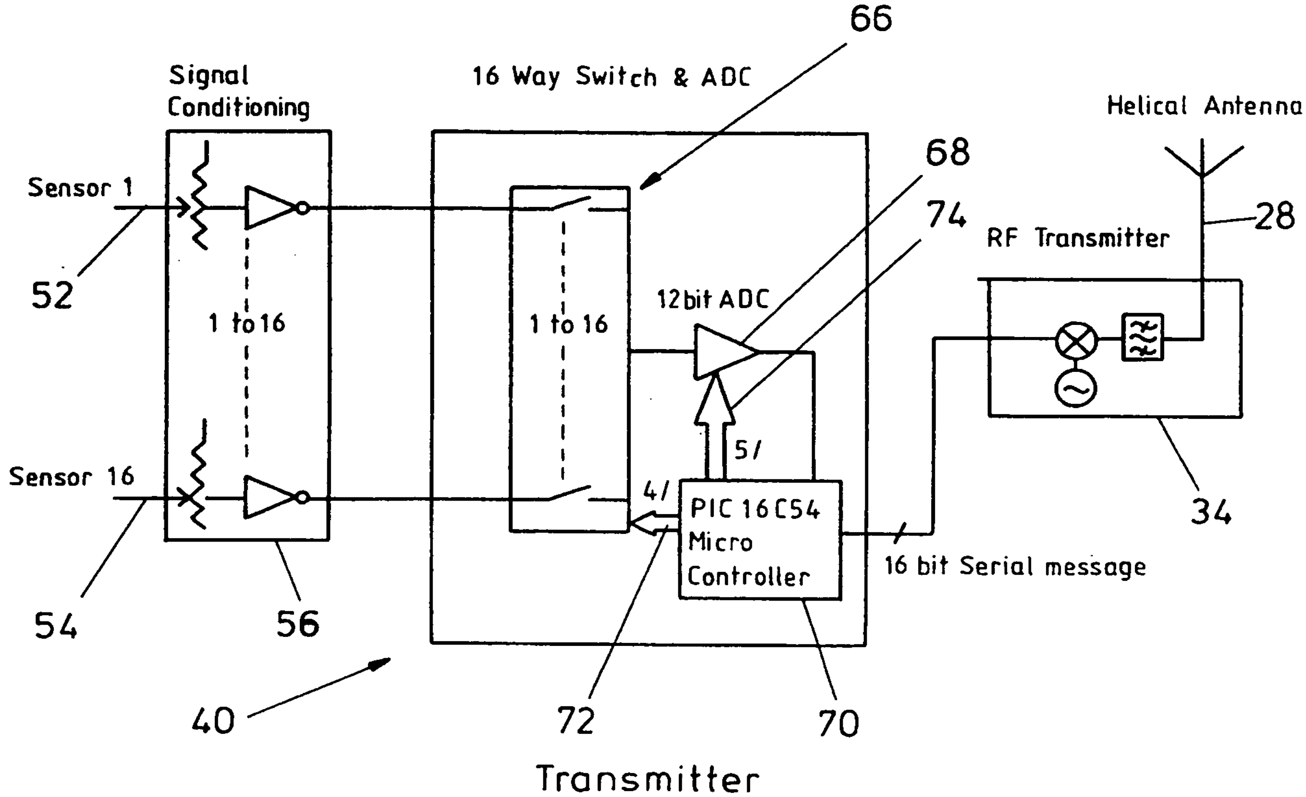
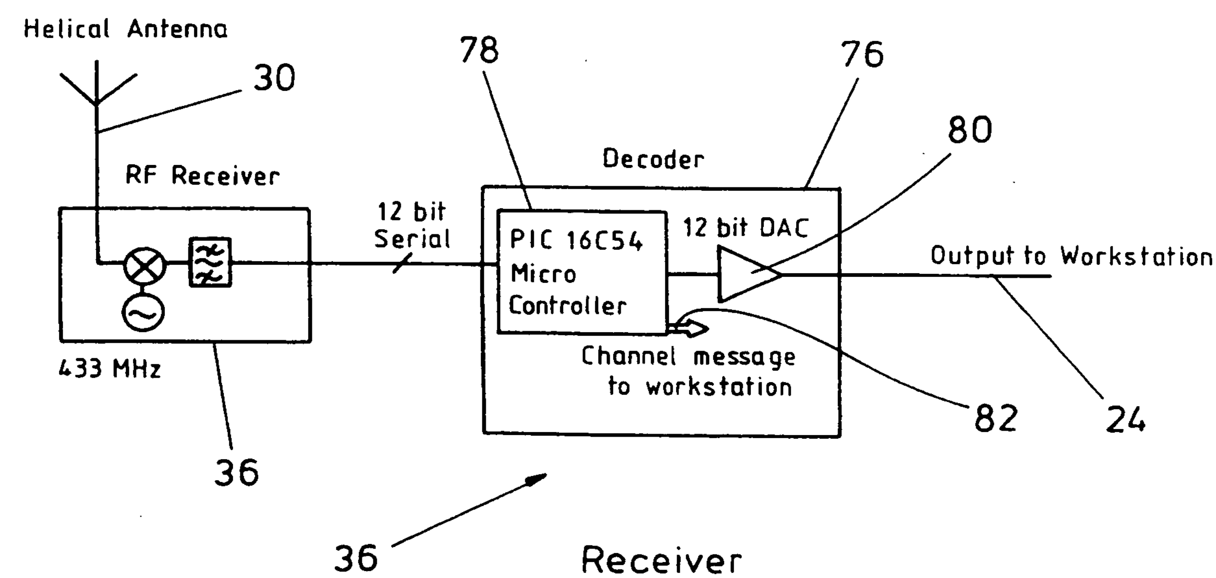

Helical Antenna
28
16-way Divider
I.F. Converter
F to V Converter
RF Reciever
133 MHz
32
1 to 16
1 to 16
Vcc
Vref
Vcc
Vref
64
Receiver
38
66
68

FIG. 3



66
Signal Conditioning
16 Way Switch & ADC
Helical Antenna
68
Sensor 1
74
28
RF Transmitter
52
1 to 16
1 to 16
12bit ADC
5/
Sensor 16
4/
PIC 16C54 Micro Controller
34
16 bit Serial message
54
56
40
72
70
Transmitter

FIG. 4



Helical Antenna
30
78
76
80
RF Receiver
Decoder
12 bit Serial
PIC 16C54 Micro Controller
12 bit DAC
Output to Workstation
Channel message to workstation
433 MHz
82
24
36
36
Receiver

FIG. 5

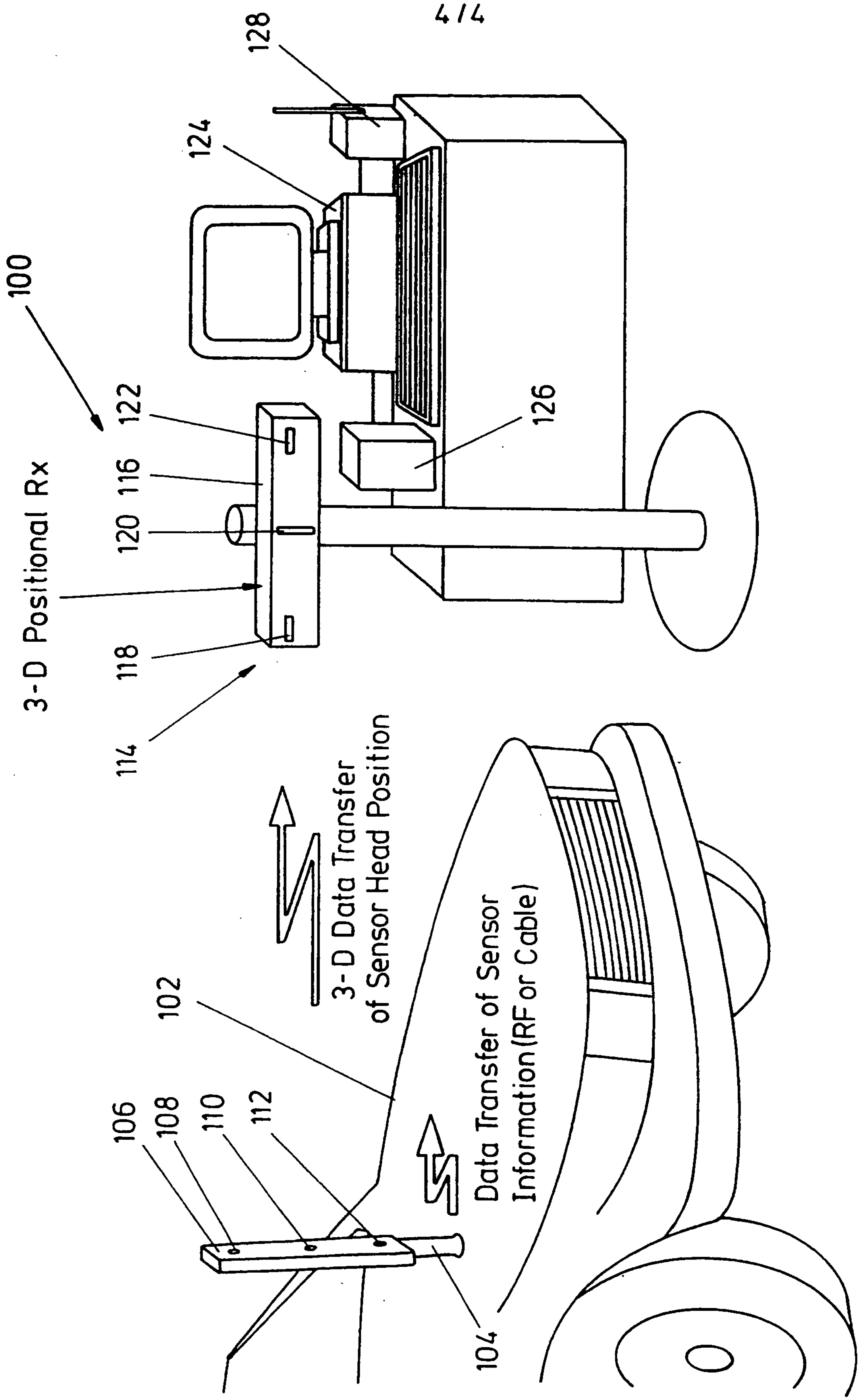

100
3-D Positional Rx
114
118
120
116
122
124
128
126
3-D Data Transfer
of Sensor Head Position
Data Transfer of Sensor
Information (RF or Cable)
102
104
106
108
110
112

FIG. 6

WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

This invention relates to a method and apparatus for wireless transmission of data through a communications channel comprising at least two local data sensors and a data processing function to receive data from the local sensors. A non-limiting example of the application of the method is in the field of automotive diagnostic equipment and related automotive service equipment. A particularly practical application of the invention is to noise vibration harshness (NVH) analysis of automotive and other machines to enable two or three-dimensional location pinpointing of vibration sources, for example in automotive warranty investigations and indeed in many other machine applications. Further examples of the application of the invention arise in relation to business operations for the wireless transmission of data, for example, across a room.

The invention also provides a method and apparatus for vibrational analysis of a machine or other article permitting three-dimensional positional co-ordinate identification of a source of vibration.

In this specification and the claims, references to local data sensors are to be interpreted in accordance with the following, namely that the sensors may transmit raw data for subsequent processing or one or more of these may incorporate some degree of primary data processing whereby the data received at the main processor is partially or totally pre-processed or indeed raw data.

In the field of automotive diagnostics and servicing there has been for a good many years a requirement for a step forward in terms of the transmission of diagnostic and servicing data from data sensors to a data processing function which operates to analyse and/or display the corresponding data for use by a person carrying out servicing and/or diagnostic functions on a motor vehicle. Conventionally, the data is transmitted from the data sensors to the data processing function via conventional conductors or cables which impose obvious inconveniences and limitations on the convenient operation of the equipment. Attempts have been made to reduce these drawbacks in several ways. Firstly, various proposals have been made to simplify the use of cable connectors as such. For example, one proposal in this regard provides for a system in which a boom-mounted data-handling sub-unit is conveniently manoeuvrable to a location close to the automotive sensors and is thus linked to them by relatively short cable connections. This arrangement undoubtedly does reduce somewhat the inconvenience of the cable connection systems but by no means eliminates it.

Various attempts have been made to achieve effective wireless transmission of data between automotive data sensors and a corresponding data-processing and/or display function but these have been relatively unsuccessful. The main shortcoming of such prior proposals has been the sheer volume of data, and the composite nature of the data (such as a mixture of data types eg digital and analogue). A further factor among the shortcomings of these prior proposals is also the composite nature of the data bandwidths to be transmitted. Such data needs to be transmitted and has conventionally been handled by a harness of 12 or more conduction cables. By adopting conventional wireless transmission systems for such data communication there is immediately a problem of excessive bandwidth requirements arising from the fact that some at least of the data sensors for this automotive application produce high data rates necessitating corresponding band widths to accommodate them. This does not apply to all the sensors. Comparable considerations apply to certain business applications where data is transmitted across a room or other relatively short transmission route.

Accordingly, we have identified a requirement for a method and apparatus for the wireless transmission of data through a communications channel from at least two local data sensors with optional primary data processing, to a data processing function, offering improvements in relation to prior proposals in this field, notably in relation to the bandwidth requirement and/or related functions attendant on the simultaneous transmission of data from a multiplicity of such local sensors.

There is disclosed in EP 0 483 549A2 (IBM CORP) a control method and apparatus for a wireless data link, for example, from a handheld workstation which is bidirectionally coupled to a base station through an infrared carrier. A robust control channel is provided separate from a data channel. The modulators employ on/off pulsing, multi-carrier modulation or direct sequence spread spectrum (DSSS) modulation. Each mobile unit is assigned an identifier or address and the system claims to overcome the problem of establishing and maintaining high bandwidth communication by separating the control channel from the data channel whereby the control channel bandwidths can be made significantly smaller.

In WO 89/09522 there is disclosed a method for allocating bandwidths in a broadband packet switching network using a set of parallel packet channels that act as a single data link connection between packet switches. Bandwidth is initially allocated to particular channel groups (at initial circuit set-up

times) and to individual channels within the groups (at transmission times) so as to increase throughput and reduce packet loss. For bursty traffic, the use of channel groups reduces the packet loss by several orders of magnitude.

EP 0 515 728A2 relates to a wireless indoor relay system. AU-A-18143/88 relates to a wireless data transmission link and notably a protocol for establishing a duplex link between first and second data link devices.

Other known references include:

GB 2295070
EP 0483549
EP 0268492
US 5509013
US 5448759
US 5363370

US 4,738,133 discloses a system for wireless transmission of multiplexed data from a plurality of transducers.

US 5,509,013 discloses a multiplexer control system for multiplexing the data from a plurality of input channels having different transmission speeds.

DE 4106572 discloses a system for contact-free measurement of object oscillations by directing laser light onto the object and detecting reflected light at plural spaced sensing heads so as to locate the point on the object from which the reflections are emanating.

According to the invention there is provided a method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors with optional primary data processing and a data processing function, as defined in the accompanying claims.

In a described embodiment, there is provided a method and apparatus in which the step of multiplexing division of the communications channel is effected asymmetrically, whereby the data carrying capacities of the sub-channels are unequal. Likewise in the embodiment, the data rates required for data transmission from the local sensors

AMENDED SHEET

differs substantially between the at least two sensors. Likewise also in the embodiment, the step of allocating data from the local data sensors to the data transmission sub-channels is effected in accordance with the data-carrying capacities of these sub-channels. In this way there is achieved within a

AMENDED SHEET

communications channel, the economical use of the available bandwidth whereby the allocation of bandwidth corresponds with the band width requirements of the individual data sensors. Thus, in the case of a sensor sensing data relating to ignition events which occur at a relatively high speed and thus require a corresponding significant allocation of bandwidth for satisfactory transmission, such is provided, whereas in the case of a sensor sensing alternator voltage (to take a simple example) the required that transmission rate is smaller by many orders of magnitude and likewise the corresponding bandwidth requirements.

Whereas prior proposals in relation to data transmission for automotive and related systems (in which data sensors produce substantially differing data rates) have ignored or overlooked these differing data rate requirements, with the result that the use of equal bandwidth sub-channels has led to a non-utilisation of sub-channel bandwidths for significant numbers of sensors whereby the overall utilisation of data transmission capacity allocated to the communications system has been very far from perfect.

In accordance with the embodiments of the invention, the use of a system in which data is fed via a "multiplexing" control system which allocates data to sub-channels in accordance with the actual data rate requirement of the individual data flow, each such data flow is thereby far more closely matched to the available capacity of its sub-channel and the twin evils of sub-channel under-utilisation and under-capacity (for a given data flow) are thereby avoided.

In one significant embodiment, the multiplex control system divides the communications channel on a frequency basis and allocates the data streams from the sensors to the frequency sub-channels accordingly.

In another important embodiment, the multiplexing control system divides the data communication channel on a time-division basis and likewise divides the data streams accordingly.

The reference above to "multiplexing" has been adopted to draw attention to the fact that references in this specification and in the claims to "multiplexing" are intended not to be limited strictly to non time-overlap or signal-chopping systems (such as would be obtained with a distinct signal-chopping technique). The term "multiplexing" in this description and the claims includes the provision of multiplexing systems which are adapted to effect multiplexing on an interdigitated and non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted. The data allocation systems for data-division between available channels can be readily designed accordingly by the technically skilled person so as to, in this way, more readily meet the technical parameters imposed on the system, as described below.

In a yet further embodiment, the multiplexing system achieves its channel division on a packet-switching basis and the interleaved data packets are distributed on an unsymmetrical basis.

In the embodiment, there is provided a radio frequency data rate of 1 to 4 Mb (megabits) per second. The multi-channel system can accommodate the requirements eg for the transmission of data for operating an oscilloscope system for engine analysis.

While the described embodiments utilise radio frequency transmission, the principles of the invention may well be applicable outside radio frequencies.

An important aspect of the invention relates to

vibrational analysis of machines and other articles and products and systems. In accordance with this aspect of the invention a vibration sensor, for example an NVH (noise vibration harshness) sensor is mechanically coupled to the machine or other article to three-dimensionally locate a source of vibration in a machine or system. Such a sensor may be just one of the local sensors in the wireless transmission system of the other embodiments, or it may be provided with its own cable or other transmission channel for its vibration signals.

In order to three-dimensionally locate a source of vibration, the vibration signals are monitored at three or more positionally-defined locations of the sensor. In the preferred embodiment the sensor is provided with its own three-dimensional location or co-ordinate-defining system (utilising spaced infra-red sensors), so that the sensor's location at any given time is readily defined. Alternatively, the sensor may be caused to sense at three known locations, or three sensors may be provided, one each at three such locations.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Fig 1 shows a functionality block diagram for a high speed RF data link, including both the frequency multiplexing system (of Figs 2 and 3) and the time-division multiplexing system (of Figs 4 and 5 hereof);

Figs 2 and 3 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as it applies to a frequency multiplexing system;

Figs 4 and 5 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as they apply to a time-division multiplexing system; and

AMENDED SHEET

Fig 6 shows a three-dimensional representation of a further embodiment in which a local vibration sensor has its own three-dimensional imaging or location system whereby the single sensor can rapidly positionally locate a source of vibration.

As shown in Fig 1, a system 10 for wireless transmission of data through a communications channel 12 between local data sensors 14, 16, 18, 20 and 22, and a data-processing function or personal computer 24, to receive data therefrom, comprises the following main elements.

Firstly, as regards the local data sensors 14 to 22, as shown these comprise an engine tester 14, a gas bench 16, a scanner 18 and auxiliary sensors indicated as Aux 1 and Aux 2. These sensors are intended to be representative of the entire range of automotive sensors which are currently utilised for diagnostic and servicing processes, including for example vibration sensors (for RPM testing) ignition and alternator ripple sensors (likewise for RPM measurement), emissions analysis sensors, battery analysis sensors and the like.

Indicated at 26 is the remote receive/transmit unit to which the individual sensors 14 to 22 are connected. The duplex (transmit/receive) operating characteristics of this unit arise from the need for the return transmission of data from the data processing function 24 for set-up purposes.

Broadly, the system comprises antennae 28, 30 connected to receive/transmit functions 32 and 34 within remote unit 26. Likewise, a receive/transmit unit or function 36 is provided for PC 24. A receive buffer 38 and a controller 40 serve to interconnect the transmit and receive functions 34, 32 to a series of RS-232 interfaces 42 to 50, each connected to its respective one of the local sensors 14 to 22.

Interfaces 42, 44, 46, 48 and 50 are serial interfaces providing for serial communication between the sensor and the receive/transmit function 32, 34 via buffer 38 and controller 40. Interface 42 is a high speed serial interface. Interfaces 44, 46, 48 and 50 are RS-232 interfaces. Interfaces 44, 46 are designated in Fig 1 as "UART1" and "UART2", referring to their function as universal asynchronous receiver/transmitter devices (or interfaces) for serial transmission of data. Receive buffer 38 and controller 40 provide data processing functions relevant to the inflow and outflow of data for the duplex operating characteristics of system 10 as will be more fully described below in relation to Figs 2, 3, 4 and 5. Accordingly, the details of these aspects of the system 10 will now be described further with reference to Figs 2, 3, 4 and 5.

As shown in Figs 2 and 3, the RX buffer 38 and controller 40 provide data processing/signal conditioning functions to be more fully described below.

As shown in Fig 2, inputs from the individual sensors 14 to 22 are indicated at 52 and 54 which are marked "Sensor 1" and "Sensor 16" to indicate that the system can accommodate 16 individual inputs.

The main function of controller 40 is to provide a multiplexing function whereby communication channel 12 is divided into 16 sub-channels on a frequency basis, these channels being of unequal band width and being allocated according to band width (more band width for greater band width requirement) to the individual data channels 1 to 16.

Interfaces 42 to 50 in Fig 1 provide the signal conditioning function indicated in Fig 2 at 56. The functions of controller 40 are shown as divided into functions 58, 60 and 62, namely voltage frequency conversion, secondary (low frequency) frequency conversion and sub-channel combination respectively. Each function operates in relation to all 16 sub-channels.

The sub-channel combination function at 62 produces a serial data stream which is fed to the RF transmitter function 34 and thus to the helical or other suitable antenna 28.

A further function of controller 40 is to append the relevant sub-channel number to each sub-channel of raw data so that this data stream can be routed to the relevant virtual serial port of PC 24 after radio transmission between antennae 28 and 30.

In this embodiment, the multiplexing sub-division of the data communication channel is provided on a frequency basis, whereas in the embodiment of Fig 4 the multiplexing is effected on a time-division basis.

As shown in Fig 3, RX buffer 38 provides the related inverse functions for signals received via antenna 28 and receiver functions 32. These functions are indicated at 64 and 66 and 68 and correspond, respectively, with the functions 62, 60 and 58 respectively in Fig 2. No further description is therefore deemed necessary.

In operation, data from sensor 14 to 22 (or indeed from the 16 sensors indicated in Fig 2) is processed in accordance with the functions 56, 58, 60 and 62 as shown in Fig 2. The data streams are allocated to the 16 sub-channels indicated diagrammatically at 64 in Fig 2. The allocation is effected in accordance with the known data rate requirements of the individual sensors, according to their known uses. In general terms, the band width of each sub-channel is matched to comfortably accommodate the data rate requirements of its respective data stream, but without the over-provision which tends to occur in certain cases with conventional use of conventional data transmission equipment.

Turning now to the time-division embodiment of Fig 4, parts corresponding to those described above in relation to Figs 2 and 3 are numbered accordingly in Fig 4.

In Fig 4, the signal conditioning function 56 corresponds to that provided by the serial interfaces 42 to 50 in Fig 1. However, in this embodiment the controller function 40 differs from that of Fig 2 in being a time-division based function (utilising a 16-way switch function 66 to provide the time-based multiplexing function corresponding to the frequency-based multiplexing of Figs 2 and 3). A 12 bit analogue-to-digital conversion function 68 processes data from switch function 66 and is linked to a microcontroller 70 (an asynchronous PIC 16C54 communications element) coupled to RF transmitter 34. Microcontroller 70 provides at 72 a control signal to switch 66 in accordance with the time-based multiplexing function which controls the sub-channel data capacities in accordance with the required data rates of the sensor input. A related control function 74 is provided to ADC converter 68.

As shown in Fig 5, the data processing function 24 in Fig 1 receives data via antenna 30 and receiver 36 through a decoding function 76 shown in Fig 5 and comprising a microcontroller 78 corresponding to microcontroller 70 which feeds data via a digital-to-analogue converter 80 to workstation of PC 24. The microcontroller 78 produces a channel message 82 for the workstation enabling same to allocate the decoded data stream to respective virtual serial ports set up in the PC for data analysis and display purposes.

This embodiment allocates data streams to respective data channels on the same principle described above but on a time-division basis instead of a frequency-division basis.

In a further embodiment, not shown, in which a packet-switching data transmission technique is employed, the allocation of data streams to packets is effected asynchronously in accordance with the matching of data rate to sub-channel capacity discussed above, thereby producing the corresponding asymmetrical interleaving of the data packets.

In the frequency-multiplexed embodiment of Figs 2 and 3, a modification may be employed whereby spread spectrum frequency division is utilised thereby reducing or eliminating the requirement to label the sub-channels by means of identifying data.

Amongst other modifications which could be made in the above embodiment are the following. Firstly, it is to be understood that the local sensors may be adapted to produce analogue signals or digital signals. Usually, analogue signals will be produced and conversion to digital will be effected in the data-processing stage. Nevertheless, it may be beneficial for certain applications or in the future to employ sensors producing digital signals, and in some cases both digital and analogue-type sensors could be employed, these transmitting their data through their respective sub-channels. Secondly, it is to be understood that while the invention has been discussed and defined by reference to specific sub-channels and the allocation of data from sensors to respective ones of these, it is to be understood that a sensor producing a high data-rate may for that purpose have allocated to it a number of sub-channels or thus a group of sub-channels accordingly.

Turning now to the embodiment of Fig 6, this shows a system 100 for vibrational analysis of an automotive vehicle 102 to enable three-dimensional location or co-ordinate-identification of a source of vibration. Thus, the apparatus of Fig 6 may be employed for rapidly enabling location of squeaks or rattles or more serious vibrational symptoms.

For this purpose there is provided a local vibration sensor 104 which forms one local sensor of an embodiment of the invention described above and thus is provided with a link (not shown) to the wireless transmission system of the preceding embodiments. Alternatively, the sensor 104 may be provided with its own dedicated vibrational analysis system (not shown) in the case where it is desired to use it as a stand-alone system.

Incorporated as part of the local vibration sensor unit 104 is a three-dimensional location positional transmitter 106 having three spaced-apart infra-red light emitting diodes (LEDs) 108, 110, 112.

Transmitter 106 forms part of a three-dimensional optical localisation system 114. Such systems are available from Image Guided Technologies Inc of Boulder, Colorado, USA. Technology of this kind is described in US 5,622,170 (Schulz/Image Guided Technologies Inc).

System 114 comprises a moveable three-dimensional positional receiver 116 having infra-red LEDs 118, 120, 122 adapted to communicate with the LEDs 108, 110, 112. Receiver 116 communicates with personal computer 124 and with a positional interface 126 and a sensor interface 128, performing decoding functions.

The three-dimensional optical localisation system 114 enables the co-ordinate location of vibration sensor 104 at any given time to be readily identified.

As a result, the single sensor 104 can be monitored at three or more locations while its vibration signals are likewise monitored in accordance with the procedures of the preceding embodiments, enabling the source of a vibration signal within vehicle 102 to be identified in terms of its co-ordinate location.

CLAIMS

1. A method of wireless transmission of data in digital and/or analogue format through a communications channel (72) from at least two local data sensors (14, 16) to a data processing means (24), said method comprising the step of division of said channel into sub-channels and transmitting said data from said data sensors respectively through said sub-channels accordingly;

characterised by

a) said step of division of said communications channel being effected asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) the data rate required for data transmission from said local sensors differing substantially between said at least two sensors; and

c) allocating data from said local data sensors to respective ones or groups of said sub-channels [being effected] in accordance with the data carrying capacities of said sub-channels.

2. A method according to claim 1 characterised by said step of division being effected on a frequency basis.

3. A method according to claim 1 characterised by said step of division being effected on a time-division basis.

4 A method according to any one of claims 1 to 3 characterised by said step of division being adapted to effect said division on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time overlap between channels is permitted.

5 A method according to claim 1 characterised by said step of division being effected by packet-switching of data from said local data sensors, and interleaving said data packet with an unsymmetrical packet distribution.

AMENDED SHEET

6 A method according to any one of claims 1 to 5 characterised by said data processing means comprising a host PC (24) having a series of virtual serial ports, and said method comprising allocating each of said sub-channels to a corresponding one of said virtual serial ports.

7 A method according to any one of claims 1 to 6 characterised by said local sensors comprising automotive diagnostic and/or servicing sensors and said wireless transmission of data being effected at radio frequencies.

8 A method according to any one of claims 1 to 7 characterised by at least one of said local sensors (14) also providing a primary data-processing function.

9 A method according to any one of claims 1 to 8 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration, and said method comprising transmitting said data therefrom.

10 A method according to claim 9 characterised by the step of using as said sensors, sensors (104) adapted to provide vibration data permitting noise vibration harshness (NVH) analysis of the data.

11 A method according to claim 10 characterised by at least three of said sensors being such NVH sensors, and the method comprising employing said sensors at three-dimensionally spaced locations to identify the location or co-ordinates of a source of vibration.

12 A method according to claim 9 or claim 10 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106) and the method comprising the step of using said sensor to sense vibrations at three dimensionally-spaced locations in

sequence, and using said three-dimensional location sensing means to identify the location or co-ordinates of said three spaced locations so as to identify the location or co-ordinates of a source of vibration.

13 Apparatus for wireless transmission of data in digital and/or analogue format through a communications channel (12) from at least two local data sensors (14, 16) to a data processing means (24), the apparatus comprising a multiplexer (62) adapted to effect division of said communications channel into sub-channels, and a transmitter (34) adapted to transmit said data through said sub-channels accordingly;

characterised by

a) said multiplexer being adapted to divide said communications channel asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) control means (40) adapted to allocate data from said local data sensors to respective ones or groups of said communications sub-channels in accordance with substantially different data rate requirements from said local sensors.

14 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a frequency basis.

15 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a time-division basis.

16 Apparatus according to any one of claims 13 to 15 characterised by said multiplexer being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted.

17 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect packet-switching of data from said local sources and to interleave said data packets with an unsymmetrical packet distribution.

18 Apparatus according to any one of claims 13 to 17 characterised by said data processing function comprising a host PC (24) having a series of virtual serial ports, and said control means being adapted to allocate each of said sub-channels to a respective one of said virtual ports.

19 Apparatus according to any one of claims 13 to 18 characterised by at least one of said local sensors (14) being adapted to provide a primary data-processing function.

20 Apparatus according to claim 19 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration whereby said apparatus can transmit said vibration data from said vibration sensing means.

21 Apparatus according to claim 20 characterised by said local data sensors comprising sensors adapted to provide vibration data permitting noise vibration harshness (NVH) data for analysis thereof.

22 Apparatus according to claim 21 characterised by said local data sensors comprising at least three or more such NVH sensors whereby said sensors can be located at three-dimensionally spaced locations to provide data enabling identification of the location or co-ordinates of the source of a vibration in a machine.

23 Apparatus according to claim 20 or claim 21 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106)

whereby said vibration sensor means can sense vibrations at three-dimensionally-spaced locations in sequence and said three-dimensional location sensing means can identify the co-ordinates or locations of said three locations so as to enable identification of the location or co-ordinates of a source of vibration.

24 A method for vibration analysis of a machine or other article comprising:

a) providing a vibration sensor (104);

b) causing said sensor to sense vibrations;

c) analysing signals produced by said sensor;

characterised by

d) providing said sensor with three-dimensional location sensing means (106);

e) causing said vibration sensor to be mechanically coupled to the machine or other article to sense vibrations at three-dimensionally-spaced locations and using said three-dimensional location sensing means to determine the co-ordinates of said three locations; and

f) identifying the location or co-ordinates of a source of vibration accordingly.

25 Apparatus for vibration analysis of a machine or other article comprising:

a) a vibration sensor (104) adapted to sense vibrations at chosen locations; and

b) analysis means (124) adapted to analyse signals produced by said sensor;

characterised by

c) said vibration sensor being adapted to be mechanically coupled to the machine or other article and further comprising three-dimensional location sensing means (106);

d) whereby said single sensor can be caused to sense vibrations at three-dimensionally spaced locations at which said three-dimensional location sensing means can identify

the co-ordinate locations thereof whereby the corresponding co-ordinates of a source of vibration can be determined.

AMENDED SHEET

PTO/SB/01 (12-97)
Approved for use through 9/30/00. OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Please type a plus sign (+) inside this box → [+]

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

[X] Declaration Submitted with Initial Filing OR [ ] Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	14,442
First Named Inventor	Jones, Barbara L.
COMPLETE IF KNOWN	
Application Number	/
Filing Date	
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

(Title of the Invention)

the specification of which

[ ] is attached hereto

OR

[X] was filed on (MM/DD/YYYY) 04/03/1998 as United States Application Number or PCT International

Application Number PCT/GB98/00866 and was amended on (MM/DD/YYYY) 04/17/1999 (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
9706797.9	GB	3 April 1997 (04/03/1997)	[ ]	[ ]	[X]
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]
			[ ]	[ ]	[ ]
			[ ]		

[ ] Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)

[ ] Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

PTO/SB/01 (12-97)
Approved for use through 9/30/00. OMB 0651-0032
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Please type a plus sign (+) inside this box → [+]

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)
PCT/GB98/00866	3 April 1998 (04/03/1998)	

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☐ Customer Number [ ] → Place Customer Number Bar Code Label here
OR
☒ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
Stotland, Harold V.	24,492		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

Direct all correspondence to: ☐ Customer Number or Bar Code Label [ ] OR ☒ Correspondence address below

Name	Harold V. Stotland				
Address	Emrich & Dithmar				
Address	300 South Wacker Drive, Suite 3000				
City	Chicago	State	IL	ZIP	60606
Country	U.S.A.	Telephone	312-663-9800	Fax	312-663-9822

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])		Family Name or Surname			
Barbara L.		Jones			
Inventor's Signature				Date	
Residence: City	Norfolk	State		Country	U.K.
Citizenship	U.K.				
Post Office Address	37 Hall Orchards, Middleton, King's Lynn				
Post Office Address					
City	Norfolk	State		ZIP	PE32 1RY
Country	U.K.				

☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

Please type a plus sign (+) inside this box → +

PTO/SB/02A (3-97)
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Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

DECLARATION	ADDITIONAL INVENTOR(S) Supplemental Sheet Page 1 of 1

Name of Additional Joint Inventor, if any:		☐ A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])				Family Name or Surname			
Paul				Smith			
Inventor's Signature						Date	
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Post Office Address	Sunnyside, Main Road, Brookville,						
Post Office Address	Methwold, Thetford						
City	Norfolk	State		ZIP		Country	U.K.
Name of Additional Joint Inventor, if any:		☐ A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])				Family Name or Surname			
Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
City		State		ZIP		Country	
Name of Additional Joint Inventor, if any:		☐ A petition has been filed for this unsigned inventor					
Given Name (first and middle [if any])				Family Name or Surname			
Inventor's Signature						Date	
Residence: City		State		Country		Citizenship	
Post Office Address							
Post Office Address							
City		State		ZIP		Country	

Burden Hour Statement: This form is estimated to take 0.4 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

DO/EO BIBLIOGRAPHIC DATA ENTRY

SERIAL NUMBER: 09 / 402262
IA NUMBER: PCT/ GB98 / 00866
FAMILY NAME: JONES
GIVEN NAME: BARBARA
PRIORITY CLAIMED (Y/N): Y
NO BASIC FEE (Y/N): N
ATTORNEY DOCKET NUMBER: 14,442
CORRESPONDENCE NAME/ADDRESS: CUSTOMER NUMBER:

RECEIPT DATE: 10 / 01 / 99
IA FILING DATE: 04 / 03 / 98
DELAY WAIVED (Y/N): N
DEMAND RECEIVED (Y/N): Y
PRIORITY DATE: 04 / 03 / 97
US DESIGNATED ONLY (Y/N): N
COUNTRY: GBX
TELEPHONE
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EMAIL:
APPLICATION TITLES:
WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

TAB TO LAST POSITION,PUSH SEND

PATENT APPLICATION SERIAL NO. ____________________

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

10/05/1999 WCLAYBRO 00000098 09402262

01 FC:970	840.00 OP
02 FC:966	90.00 OP
03 FC:964	78.00 OP
04 FC:968	260.00 OP

01/18/2000 UWALKER 00000099 051060 09402262

01 FC:966 72.00 CH

PATENT APPLICATION FEE DETERMINATION RECORD
Effective November 10, 1998

Application or Docket Number: 402262

CLAIMS AS FILED - PART I

FOR	NUMBER FILED (Column 1)		NUMBER EXTRA (Column 2)	SMALL ENTITY TYPE ☐ RATE	FEE	OR	OTHER THAN SMALL ENTITY RATE	FEE
BASIC FEE					380.00	OR		$840
TOTAL CLAIMS	29	minus 20=	* 9	X$ 9=		OR	X$18=	$162
INDEPENDENT CLAIMS	4	minus 3 =	* 1	X39=		OR	X78=	$78
MULTIPLE DEPENDENT CLAIM PRESENT	yes			+130=		OR	+260=	$260
				TOTAL		OR	TOTAL	$1340

* If the difference in column 1 is less than zero, enter "0" in column 2

CLAIMS AS AMENDED - PART II

AMENDMENT A

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	X$ 9=		OR	X$18=	
Independent	*	Minus	***	=	X39=		OR	X78=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+130=		OR	+260=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	X$ 9=		OR	X$18=	
Independent	*	Minus	***	=	X39=		OR	X78=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+130=		OR	+260=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	CLAIMS REMAINING AFTER AMENDMENT (Column 1)		HIGHEST NUMBER PREVIOUSLY PAID FOR (Column 2)	PRESENT EXTRA (Column 3)	SMALL ENTITY RATE	ADDITIONAL FEE	OR	OTHER THAN SMALL ENTITY RATE	ADDITIONAL FEE
Total	*	Minus	**	=	X$ 9=		OR	X$18=	
Independent	*	Minus	***	=	X39=		OR	X78=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+130=		OR	+260=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

PATENT COOPERATION TREATY

REC'D 03 MAY 1999
WIPO PCT

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P53206WO		
International application No. PCT/GB98/00866	International filing date *(day/month/year)* 03/04/1998	Priority date *(day/month/year)* 03/04/1997

International Patent Classification (IPC) or national classification and IPC
G08C15/02

Applicant
SUN ELECTRIC UK LIMITED et al.

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 11 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☒ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
03/11/1998	29.04.99
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. (+49-89) 2399-0 Tx: 523656 epmu d Fax: (+49-89) 2399-4465	Authorized officer Wright, J Telephone No. (+49-89) 2399 2705

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB98/00866

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-3,5,6,8-14	as originally filed			
4,4a,7	as received on	17/04/1999	with letter of	14/04/1999

Claims, No.:

1-25	as received on	17/04/1999	with letter of	14/04/1999

Drawings, sheets:

1/4-4/4	as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
- ☒ paid additional fees.
- ☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-25
	No:	Claims	
Inventive step (IS)	Yes:	Claims	2,4,5,14,16,17
	No:	Claims	1,3,6-13,15,18-25
Industrial applicability (IA)	Yes:	Claims	1-25
	No:	Claims	

2. Citations and explanations

   see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

1. The following document(s) will be referred to in this preliminary examination report;

    D1 US-A-4 738 133 [Breckel et al]
    D2 US-A-5 509 013 [Adachi et al]
    D3 DE-A-4 106 572 [Fraunhofer Gesellschaft München]

    The subject-matter of document D1 is considered to represent the prior art the closest to that of the present application, inventions 1 and 2.

2. In the following discussion, the patentability of the claims will be examined with regard to the requirements of the PCT. In particular, the claims will be examined for novelty, as defined in Art. 33(2) PCT, and for inventive step, as defined in Art. 33(3) PCT. In addition other aspects, such as clarity requirements of Art. 6 PCT, may be discussed as appropriate.

2.1 The application lacks unity within the meaning of Rule 13 PCT, since the claims presently on file claim the following separate inventions or groups of inventions not so linked as to form a single general inventive concept. The application therefore does not comply with the requirements of Art. 3 (4)iii PCT. The application comprises the following separate inventions:

Invention 1. Claims 1-23

Invention 1 relates to **multiplex data transmission** via a wireless with different rates in each channel.

Invention 2. Claims 24-25

Invention 2 relates to a method and apparatus for **vibrational analysis** in a three dimensional space.

Since the applicant has **paid additional fees** under Art. 34 (3) a, **report on the complete application** will be made by the examiner.

For information only, the applicant may chose to prosecute the application on one of the above inventions in the national / regional phase of the application.

2.2 Claim 1

The subject matter of claim 1 of the application is not allowable because it lacks an inventive step, Art. 33(3) PCT, the reasons being as follows:

Document D1 is considered to represent the closest prior art to the subject matter of claim 1 of the application. D1 discloses sensors (1,2,3) which are connected to a central control (5,6).

The examiner is of the opinion that it is a common and obvious problem in such a sensor/control arrangement that some sensors require a higher data carrying capacity than others. The problem is for instance known from the document D2, see for instance col. 1, lines 16-18.

The examiner notes that although D2 specifically relates to channels having varying "transmission speeds" this means different "data carrying capacity", since data carrying capacity only has meaning in terms of a given time period during which data can be sent. Nothing in claim 1 of the application refers to channel band-width or the like.

The person skilled in the art, wishing to solve this problem would use the solution proposed in document D2. D2 discloses the multiplex control system for such a sensor/control arrangement but does not explicitly mention the control/sensors themselves.

D2 discloses that in a plurality of multiplexed channels (these are considered to be sub-channels of a single channel), some channels with higher data rates are assigned correspondingly increased data transmission load, see abstract, col. 6, lines 28-32 (gives a definition of a "cell" and col. 7, lines 14-24 (which defines how data is asymmetrically divided in accordance with the data carrying capacity of the sub-channels) and col. 7, lines 33-37 (dynamic changing of channel data transmission capability). The multiplexing of data is therefore asymmetrically arranged in accordance with the channel data carrying capacity.

The person skilled in the art, incorporating the teaching of D2 into the method/apparatus of D1 would therefore arrive at the subject matter of claim 1 of the application without having made an inventive step.

The above argument hinges on the question of whether the person skilled in the art **would combine** D1 and D2. The examiner notes that D2 does not address the specific environment of data collection from sensors, rather it addresses the more general problem of transmitting by what ever means data from one remote location to another by means of transmission channels of some kind. The examiner furthermore notes that the solution offered to the above problem in D2 which is the same as in the application, has no technical features which relate to the kind of data generated, the means of transmission or to the source of data. The examiner furthermore notes that nearly all data is actually sourced from some kind of sensor, be it a microphone in a telephone, a pressure sensor or a light responsive sensor in a FAX machine.

The examiner concludes that the problem posed in D2 is very general to the field of data transmission and the person skilled in the art would therefore be very aware of this problem when dealing with any data transmission. The features of claim 1 of the application (known in themselves from D1) are merely contextual and do not add technical features which would be considered to involve an inventive step.

Claim 1 is therefore not allowable under Art. 33(3) PCT.

The examiner notes that claim 1 would appear to be clear and therefore to satisfy the requirements of Art. 6 PCT.

2.3 Claims 2 to 5

The examiner notes that claims 2 to 5 relate to the way in which the channels are divided.

From D2, col. 1, lines 54-64 it would appear that the channel division is on a time division basis. The examiner is now of the provisional opinion that claim 3 of the application lacks inventive step, but that the division in accordance with claim 2 could be considered as being both new and involving an inventive step since there is no indication in the prior art to use frequency division.

The examiner is of the provisional opinion that the subject matter of claims 5 could likewise be considered to involve an inventive step, since packet switching is also not known from the available prior art D1 or D2.

The examiner considers that the subject matter of claim 4 **could** contain subject matter which involved an inventive step, but that it is so unclear to the examiner what is being claimed that the present claim does not satisfy the requirements of Art. 6 PCT.

In particular the examiner is not aware of the term "interdigitated non-chopping data-allocation basis" with regard to channel division /multiplexing etc. Furthermore the criteria that a "degree" of data element transmission time overlap is permitted is indefinite and vague.

The applicant is also informed for information only that the examiner is of the provisional opinion that any independent claim (in the regional or national phase of the application) based on the division mechanism, e.g. frequency division, would not be acceptable if based on alternatives, i.e. only one mechanism could be considered as constituting one unifying inventive concept, since the more general concept of the application is already known from D2.

2.4 Claims 6-12

Although the subject matter of the claims 6-12 is not per se known from a combination of D1 and D2, these relate largely to the area of application of the sensor/control arrangement. The technology of the application, for instance vibration sensing, is considered to be independent of the arrangements for data transmission. As such these claims represent various juxtapositions of features which would appear to be known in themselves, as such the examiner considers them not to involve an inventive step, Art. 33(3) PCT.

It is furthermore noted that claim 10 lacks clarity, Art. 6 PCT. The reason being that a reference in parenthesis to "NVH" would appear not to be a reference to the drawings but an attempt to defined a short form for "noise vibration harshness".

The term "NVH" is then used without brackets in claim 22 and with brackets in claim 21. In the opinion of the examiner the brackets with the term "NVH" should not be used in any of the claims.

2.5 Claim 13

Claim 13 relates to an apparatus for wireless transmission of data using divided channels in which an asymmetric data rate in respective (so called sub-) channels is effected in accordance with **the different data rate requirements of local sensors.**

From the document D2, col. 1, lines 10-18 it is known to match data rate requirements with a particular channel transmission speed. The person skilled in the art would apply this principle to the specific example of data passing from a sensor without making an inventive step. The person skilled in the art would therefore incorporate this into the sensor / test arrangement of D1, see D1, fig. 1 and 2. In so doing, the person skilled in the art would assign channels in accordance with the different data rate requirements of respective sensors and so arrive exactly at the subject matter of claim 13 of the application without having made an inventive step.

The subject matter of claim 13 is therefore obvious in the light of the available prior art D1 and D2, and as such not allowable under Art. 33(3) PCT.

2.5 Claims 14-17

Claims 14 to 17 correspond to the method claims 2-5. For the reasons given above the examiner considers that claim 15 lacks an inventive step, time division being known from D2. Claims 14 and 17 could be considered to involve an inventive step and claim 16 could contain patentable subject matter but is so unclear, Art. 6 PCT, that it is not possible to be more specific as to any inventive quality of the claim.

2.6 Claims 18-23

Claims 18-23 comprise subject matter which is of a routine nature. The examiner is therefore of the provisional opinion that the person skilled in the art would arrive at the subject matter of claims 14-23 as a matter of normal design procedure, starting from the obvious combination of D1 and D2. The subject matter of claims 14 to 23 is therefore not allowable under Art. 33(3) PCT.

2.6 Claim 24

Claims 24 and 25 relate to sensing in three dimensions. The closest prior art to claims 24 and 25 would appear to be D3. D3 also relates to vibration sensing in three dimensions.

Claim 24 is a method claim, D3 discloses:

a. a method for vibration analysis of a machine or other article (see abstract) comprising;

a. providing a vibration sensor (1)

b. causing the sensor to sense vibrations (see abstract)

c. analysing signals produced by said sensor (15, see col. 5, lines 60-62)

d. providing the sensor with 3d location sensing means (D3, col. 6, lines 25-50)

e. causing a single vibration sensor to monitor 3 dimensions, (see fig. 2 and col. 4, lines 64-65 of D3) and using the coordinate measuring system to measure the coordinates at these points (D3, col. 6, lines 25-50)

The subject matter of D3 differs from that of the application claim 24 only in that the features:

f. "identifying the location of a source of vibration accordingly" is not explicitly disclosed in D3;

and the feature of mechanical contact is not disclosed in D3, D3 operating with light beams.

However, in col. 1, lines 15-25 of D3, it is disclosed that it is necessary to understand as accurately as possible the vibration characteristics of a machine etc.

In the opinion of the examiner, to identify the source of a vibration is an obvious desire of the person skilled in the art who wishes to understand "as accurately as possible" the vibration characteristics of a machine.

In addition the examiner is of the opinion that the choice of sensor, being light beam sensor or a mechanical sensor is merely one of design choice which the person skilled in the art would make without having made an inventive step.

Since the other features of claim 24 are not different from those of D3, the examiner is of the opinion that claim 24 of the application lacks an inventive step and as such is not allowable under Art. 33(3) PCT.

It is furthermore noted that claim 24 is not allowable under Art. 6 PCT since it lacks clarity. In particular the "said three locations" (line 26) are not actually previously referred to in the claim. It would appear that the author of the claim confuses "three-dimensions" with three locations, in the opinion of the examiner a singe point can be defined in "three-dimensions" and this in no way implies there to be three points.

2.7 Claim 25

Claim 25 is an apparatus claim which claims (in terms of an apparatus) the features a. to d. corresponding to those features a. to d. in claim 24.

As discussed above in part 2.6 of this opinion, these features are all known from the document D3, except for the feature of mechanical sensing. As discussed above the examiner is of the opinion that this combination of features lacks an inventive step as such claim 25 does not fulfil the requirements of Art. 33(3) PCT.

times) and to individual channels within the groups (at transmission times) so as to increase throughput and reduce packet loss. For bursty traffic, the use of channel groups reduces the packet loss by several orders of magnitude.

EP 0 515 728A2 relates to a wireless indoor relay system. AU-A-18143/88 relates to a wireless data transmission link and notably a protocol for establishing a duplex link between first and second data link devices.

Other known references include:

GB 2295070

EP 0483549

EP 0268492

US 5509013

US 5448759

US 5363370

US 4,738,133 discloses a system for wireless transmission of multiplexed data from a plurality of transducers.

US 5,509,013 discloses a multiplexer control system for multiplexing the data from a plurality of input channels having different transmission speeds.

DE 4106572 discloses a system for contact-free measurement of object oscillations by directing laser light onto the object and detecting reflected light at plural spaced sensing heads so as to locate the point on the object from which the reflections are emanating.

According to the invention there is provided a method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors with optional primary data processing and a data processing function, as defined in the accompanying claims.

In a described embodiment, there is provided a method and apparatus in which the step of multiplexing division of the communications channel is effected asymmetrically, whereby the data carrying capacities of the sub-channels are unequal. Likewise in the embodiment, the data rates required for data transmission from the local sensors

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differs substantially between the at least two sensors. Likewise also in the embodiment, the step of allocating data from the local data sensors to the data transmission sub-channels is effected in accordance with the data-carrying capacities of these sub-channels. In this way there is achieved within a

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vibrational analysis of machines and other articles and products and systems. In accordance with this aspect of the invention a vibration sensor, for example an NVH (noise vibration harshness) sensor is mechanically coupled to the machine or other article to three-dimensionally locate a source of vibration in a machine or system. Such a sensor may be just one of the local sensors in the wireless transmission system of the other embodiments, or it may be provided with its own cable or other transmission channel for its vibration signals.

In order to three-dimensionally locate a source of vibration, the vibration signals are monitored at three or more positionally-defined locations of the sensor. In the preferred embodiment the sensor is provided with its own three-dimensional location or co-ordinate-defining system (utilising spaced infra-red sensors), so that the sensor's location at any given time is readily defined. Alternatively, the sensor may be caused to sense at three known locations, or three sensors may be provided, one each at three such locations.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Fig 1 shows a functionality block diagram for a high speed RF data link, including both the frequency multiplexing system (of Figs 2 and 3) and the time-division multiplexing system (of Figs 4 and 5 hereof);

Figs 2 and 3 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as it applies to a frequency multiplexing system;

Figs 4 and 5 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as they apply to a time-division multiplexing system; and

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CLAIMS

1 A method of wireless transmission of data in digital and/or analogue format through a communications channel (72) from at least two local data sensors (14, 16) to a data processing means (24), said method comprising the step of division of said channel into sub-channels and transmitting said data from said data sensors respectively through said sub-channels accordingly;

characterised by

a) said step of division of said communications channel being effected asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) the data rate required for data transmission from said local sensors differing substantially between said at least two sensors; and

c) allocating data from said local data sensors to respective ones or groups of said sub-channels [being effected] in accordance with the data carrying capacities of said sub-channels.

2 A method according to claim 1 characterised by said step of division being effected on a frequency basis.

3 A method according to claim 1 characterised by said step of division being effected on a time-division basis.

4 A method according to any one of claims 1 to 3 characterised by said step of division being adapted to effect said division on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time overlap between channels is permitted.

5 A method according to claim 1 characterised by said step of division being effected by packet-switching of data from said local data sensors, and interleaving said data packet with an unsymmetrical packet distribution.

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6 A method according to any one of claims 1 to 5 characterised by said data processing means comprising a host PC (24) having a series of virtual serial ports, and said method comprising allocating each of said sub-channels to a corresponding one of said virtual serial ports.

7 A method according to any one of claims 1 to 6 characterised by said local sensors comprising automotive diagnostic and/or servicing sensors and said wireless transmission of data being effected at radio frequencies.

8 A method according to any one of claims 1 to 7 characterised by at least one of said local sensors (14) also providing a primary data-processing function.

9 A method according to any one of claims 1 to 8 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration, and said method comprising transmitting said data therefrom.

10 A method according to claim 9 characterised by the step of using as said sensors, sensors (104) adapted to provide vibration data permitting noise vibration harshness (NVH) analysis of the data.

11 A method according to claim 10 characterised by at least three of said sensors being such NVH sensors, and the method comprising employing said sensors at three-dimensionally spaced locations to identify the location or co-ordinates of a source of vibration.

12 A method according to claim 9 or claim 10 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106) and the method comprising the step of using said sensor to sense vibrations at three dimensionally-spaced locations in

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sequence, and using said three-dimensional location sensing means to identify the location or co-ordinates of said three spaced locations so as to identify the location or co-ordinates of a source of vibration.

13 Apparatus for wireless transmission of data in digital and/or analogue format through a communications channel (12) from at least two local data sensors (14, 16) to a data processing means (24), the apparatus comprising a multiplexer (62) adapted to effect division of said communications channel into sub-channels, and a transmitter (34) adapted to transmit said data through said sub-channels accordingly;

characterised by

a) said multiplexer being adapted to divide said communications channel asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) control means (40) adapted to allocate data from said local data sensors to respective ones or groups of said communications sub-channels in accordance with substantially different data rate requirements from said local sensors.

14 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a frequency basis.

15 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a time-division basis.

16 Apparatus according to any one of claims 13 to 15 characterised by said multiplexer being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted.

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17 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect packet-switching of data from said local sources and to interleave said data packets with an unsymmetrical packet distribution.

18 Apparatus according to any one of claims 13 to 17 characterised by said data processing function comprising a host PC (24) having a series of virtual serial ports, and said control means being adapted to allocate each of said sub-channels to a respective one of said virtual ports.

19 Apparatus according to any one of claims 13 to 18 characterised by at least one of said local sensors (14) being adapted to provide a primary data-processing function.

20 Apparatus according to claim 19 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration whereby said apparatus can transmit said vibration data from said vibration sensing means.

21 Apparatus according to claim 20 characterised by said local data sensors comprising sensors adapted to provide vibration data permitting noise vibration harshness (NVH) data for analysis thereof.

22 Apparatus according to claim 21 characterised by said local data sensors comprising at least three or more such NVH sensors whereby said sensors can be located at three-dimensionally spaced locations to provide data enabling identification of the location or co-ordinates of the source of a vibration in a machine.

23 Apparatus according to claim 20 or claim 21 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106)

whereby said vibration sensor means can sense vibrations at three-dimensionally-spaced locations in sequence and said three-dimensional location sensing means can identify the co-ordinates or locations of said three locations so as to enable identification of the location or co-ordinates of a source of vibration.

24 A method for vibration analysis of a machine or other article comprising:

a) providing a vibration sensor (104);

b) causing said sensor to sense vibrations;

c) analysing signals produced by said sensor;

characterised by

d) providing said sensor with three-dimensional location sensing means (106);

e) causing said vibration sensor to be mechanically coupled to the machine or other article to sense vibrations at three-dimensionally-spaced locations and using said three-dimensional location sensing means to determine the co-ordinates of said three locations; and

f) identifying the location or co-ordinates of a source of vibration accordingly.

25 Apparatus for vibration analysis of a machine or other article comprising:

a) a vibration sensor (104) adapted to sense vibrations at chosen locations; and

b) analysis means (124) adapted to analyse signals produced by said sensor;

characterised by

c) said vibration sensor being adapted to be mechanically coupled to the machine or other article and further comprising three-dimensional location sensing means (106);

d) whereby said single sensor can be caused to sense vibrations at three-dimensionally spaced locations at which said three-dimensional location sensing means can identify

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the co-ordinate locations thereof whereby the corresponding co-ordinates of a source of vibration can be determined.

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

ARCHER, Ph.
URQUHART-DYKES & LORD
New Priestgate House
57 Priestgate
PETERBOROUGH, CAMBS PE1 1JX
GRANDE BRETAGNE

01 OCT 1999

PCT

WRITTEN OPINION

(PCT Rule 66)

Date of mailing (day/month/year)	15.02.99
REPLY DUE	within **2 month(s)** from the above date of mailing

Applicant's or agent's file reference P53206WO		
International application no. PCT/GB98/00866	International filing date *(day/month/year)* 03/04/1998	Priority date *(day/month/year)* 03/04/1997
International Patent Classification (IPC) or both national classification and IPC G08C15/02		
Applicant SUN ELECTRIC UK LIMITED et al.		

1. This written opinion is the **first** drawn up by this International Preliminary Examining Authority.

2. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

3. The applicant is hereby **invited to reply** to this opinion.

   When? See the time limit indicated above. The applicant may, before the expiration of that time limit, request this Authority to grant an extension, see Rule 66.2(d).

   How? By submitting a written reply, accompanied, where appropriate, by amendments, according to Rule 66.3. For the form and the language of the amendments, see Rules 66.8 and 66.9.

   Also: For an additional opportunity to submit amendments, see Rule 66.4.
   For the examiner's obligation to consider amendments and / or arguments, see Rule 66.4bis.
   For an informal communication with the examiner, see Rule 66.6.

   If no reply is filed, the international preliminary examination report will be established on the basis of this opinion.

4. The final date by which the international preliminary examination report must be established according to Rule 69.2 is: 03/08/1999

Name and mailing address of the international preliminary examining authority European Patent Office D-80298 Munich Tel. (+49-89) 2399-0, Tx: 523656 epmu d Fax: (+49-89) 2399-4465	Authorized officer / Examiner Wright, J Formalities officer (incl. extensi Röhner, M Telephone No. (+49-89) 2399-:

2 COPIES:- EP.
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WRITTEN OPINION International application No. PCT/GB98/00866

I. Basis of the opinion

1. This opinion has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this opinion as "originally filed".*):

Description, pages:

1-14 as originally filed

Claims, No.:

1-25 as originally filed

Drawings, sheets:

1/4-4/4 as originally filed

2. The amendments have resulted in the cancellation of:

☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. This opinion has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation (Form PCT/IPEA/405) to restrict or pay additional fees, the applicant has:

☐ restricted the claims.

☒ paid additional fees.

☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. This Authority found that the requirement of unity of invention is not complied with for the following reasons and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees:

3. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this opinion:

☒ all parts.

☐ the parts relating to claims Nos. .

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-24 Yes, 25 No
Inventive step (IS)	Claims	1-25 No
Industrial applicability (IA)	Claims	1-25 Yes

2. Citations and explanations

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

1. The following document(s) will be referred to in this written opinion; the numbering will be adhered to in the rest of the procedure:

   D1 US-A-4 738 133 [Breckel et al]
   D2 US-A-5 509 013 [Adachi et al]
   D3 DE-A-4 106 572 [Fraunhofer Gesellschaft München]

   The subject-matter of document D1 is considered to represent the prior art the closest to that of the present application, inventions 1 and 2.

2. In the following discussion, the patentability of the claims will be examined with regard to the requirements of the PCT. In particular, the claims will be examined for novelty, as defined in 33(2) PCT, and for inventive step, as defined in Art. 33(3) PCT. In addition other aspects, such as clarity requirements of Art. 6 PCT, may be discussed as appropriate.

2.1 The application lacks unity within the meaning of Rule 13 PCT, since the claims presently on file claim the following separate inventions or groups of inventions not so linked as to form a single general inventive concept. The application therefore does not comply with the requirements of Art. 3 (4)iii PCT. The application comprises the following separate inventions:

Invention 1. Claims 1-23

Invention 1 relates to **multiplex data transmission** via a wireless with different rates in each channel.

Invention 2. Claims 24-25

Invention 2 relates to a method and apparatus for **vibrational analysis** in a three dimensional space.

Since the applicant has paid additional fees under Art. 34 (3) a, **complete** examination of the application is carried out by the examiner.

For information only, the applicant may chose to prosecute the application on one of the above inventions in the national / regional phase of the application.

2.2 Claim 1

The subject matter of claim 1 of the application is not allowable because lacks an inventive step, Art. 33(3) PCT, the reasons being as follows:

Document D1 is considered to represent the closest prior art to the subject matter of claim 1 of the application. D1 discloses sensors (1,2,3) which are connected to a central control (5,6).

The examiner is of the opinion that it is an obvious problem in such a sensor/control arrangement that some sensors require a higher data rate than others.

The person skilled in the art, wishing to solve this problem would look to document D2. D2 discloses the multiplex control system for such a sensor/control arrangement but does not explicitly mention the control/sensors themselves.

D2 discloses that in a plurality of multiplexed channels (these could also be considered as sub-channels of a single channel), some channels with higher data rates are assigned correspondingly increased data transmission time slots, see abstract. The multiplexing of data is therefore asymmetrically arranged in accordance with the channel data carrying capacity.

The person skilled in the art, incorporating the teaching of D2 into the method/apparatus of D1 would therefore arrive at the subject matter of claim 1 of the application without having made an inventive step. Claim 1 is therefore not allowable under Art. 33(3) PCT.

It is further noted that the following clarity problems exist in claim 1 of the application.

a. The expression "to receive data therefrom", in claim 1, lines 4-5, is unclear since from the sentence construction it is not clear from where the data is received.

b. It is not clear what is meant by (the noun) "data processing function".

c. It is not clear what is meant by "multiplexing division".

The above terms therefore need to be clarified in the claim.

2.3 Claims 2-12

The examiner is of the provisional opinion that the subject matter of claims 2 to 12 is of a routine nature and does therefore not involve an inventive step. The examiner also notes that although the subject matter of the claims is not known from a combination of D1 and D2, these relate largely to the area of application of the sensor/control arrangement. The technology of the application, for instance vibration sensing, is largely independent of the arrangements for data transmission.

2.4 Claim 13

Claim 13 relates to an apparatus for wireless transmission of data using multiplexed channels in which an asymmetric data rate in respective (so called sub-) channels is effected in accordance with **the different data rate requirements of local sensors.**

From the document D2, col. 1, lines 10-18 it is known to match data rate requirements with a particular channel transmission speed. The person skilled in the art would apply this principle to the specific example of data passing from a sensor without making an inventive step. The person skilled in the art would therefore incorporate this into the sensor / test arrangement of D1, see D1, fig. 1 and 2. In so doing, the person skilled in the art would assign channels in accordance with the different data rate requirements of respective sensors and so arrive exactly at the subject matter of claim 13 of the application without having made an inventive step.

The subject matter of claim 13 is therefore obvious in the light of the available prior art D1 and D2, and as such not allowable under Art. 33(3) PCT.

2.5 Claims 14-23

Claims 14 to 23 would appear to relate to subject matter which is very diverse and of a routine nature. The examiner is therefore of the provisional opinion that the person skilled in the art would arrive at the subject matter of claims 14-23 as a matter of normal design procedure, starting from the obvious combination of D1 and D2. The subject matter of claims 14 to 23 is therefore not allowable under Art. 33(3) PCT.

2.6 Claim 24

Claims 24 and 25 relate to sensing in three dimensions. The closest prior art to claims 24 and 25 would appear to be D3. D3 also relates to vibration sensing in three dimensions.

Claim 24 is a method claim, D3 discloses:

a. a method for vibration analysis of a machine or other article (see abstract) comprising;

a. providing a vibration sensor (1)

b. causing the sensor to sense vibrations (see abstract)

c. analysing signals produced by said sensor (15, see col. 5, lines 60-62)

d. providing the sensor with 3d location sensing means (D3, col. 6, lines 25-50)

e. causing a single vibration sensor to monitor 3 dimensions, (see fig. 2 and col. 4, lines 64-65 of D3) and using the coordinate measuring system to measure the coordinates at these points (D3, col. 6, lines 25-50)

The subject matter of D3 differs from that of the application claim 24 only in that the feature:

f. "identifying the location of a source of vibration accordingly" is not explicitly disclosed in D3. However, in col. 1, lines 15-25 of D3, it is disclosed that it is necessary to understand as accurately as possible the vibration characteristics of a machine etc.

In the opinion of the examiner, to identify the source of a vibration is an obvious desire of the person skilled in the art who wishes to understand "as accurately as possible" the vibration characteristics of a machine. Since the other features of claim 24 are not different from those of D3, the examiner is of the opinion that claim 24 of the application lacks an inventive step and as such is not allowable under Art. 33(3) PCT.

It is furthermore noted that claim 24 is not allowable under Art. 6 PCT since it lacks clarity. In particular the "said single vibration sensor" is not referred to previously in the claim, it should have been defined as a "single sensor" in feature a of the claim, if this is indeed the "said single sensor" to which reference is made in feature e.

2.7 Claim 25

Claim 25 is an apparatus claim which claims (in terms of an apparatus) the features a. to d. corresponding to those features a. to d. in claim 24.

As discussed above in part 2.6 of this opinion, these features are all known from the document D3, as such claim 25 is not new, and therefore does not fulfil the requirements of Art. 33(2) PCT.

3. In the following section, certain defects in the International Application will be noted.

3.1 Document D1, D2 and D3 should be mentioned in the description in accordance with Rule 5.1 a ii PCT.

3.2 The description should be brought into accordance with any new claims to be filed in accordance with Rule 5.1 a iii PCT.

3.3 The independent claims should preferably be cast in the two part form of claim in accordance with Rule 6.3 b PCT, relative to the appropriate prior art.

4. The following points of clarity should be taken into account when filing new claims:

4.1 To increase the clarity of the claims, reference signs relating to the drawings should be inserted into the claims between parentheses (). This applies to both the pre and post characterising portions of the claims.

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09/402262

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Our ref: P53206WO/PBA/MB

14 April 1999

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PCT CHAPTER II MU DG2

Dear Sirs

INTERNATIONAL APPLICATION NUMBER : PCT/GB98/00866
SUN ELECTRIC UK LIMITED ET AL
RESPONSE TO FIRST WRITTEN OPINION

We are responding to the first written opinion setting a two month response period from 15 February 1999 and according to Rule 69.2 the final date for the International Preliminary Examination report is :

3 August 1999

leaving just under four months for the remainder of the procedure.

AMENDMENTS

We are filing herewith fair copy amended pages of the description and claims, as detailed below.

We request favourable reconsideration of the application, as amended, accordingly.

In the amended pages of the claims, there is included an "interpretation" edition of the amended claims in which the amendments made are identified by parentheses and underlining in the usual way. These amendments include amendment of the claims responsive to the defects noted in items 3.3 and 4.1 on sheet 6 of the separate sheets of the FWO.

Amended pages of the description include amendments responsive to items 3.1 and 3.2 of the said sheet 6.

UNITY OF INVENTION

The amendments adopted in the claims are not in themselves intended to be responsive to the unity of invention objection and the Applicants intend responding appropriately in this regard to the examination reports issued during the National and Regional phases.

CLAIMS 1 TO 23

We shall respond below to the objection with respect to inventive step raised against these claims, noting that we are in accord with the Examiner that these claims possess novelty with respect to the cited references.

INVENTIVE STEP OF CLAIMS 1 TO 23

Since International Preliminary Examination is being carried out at the EPO, and since published decisions with respect to inventive step available under International Preliminary Examination procedure are relatively not freely available (certainly in a comprehensive collection), we are dealing with the question of inventive step in accordance with the principles applied by the Boards of Appeal of the European Patent Office (third edition 1998). It is understood that these principles will apply, in any case in the European Regional phase in due course.

GENERAL

1. The present invention by its very nature is relatively simple in the sense that item c) of the characterising portion of claim 1 refers to allocating data from local data sensors to the sub-channels in accordance with the data carrying capacities of the sub-channels. It is submitted that care needs to be taken not to allow such simplicity to affect in any way the question of inventive step.

2. Indeed, there is warning in the Guidelines (chapter CIV,9.9) against ex post facto analysis when assessing inventive step, particularly in relation to apparently simple inventions (see T24/81 and T564/89 and T645/92 and T795/93).

   Established case law of the EPO Boards of Appeal has made clear that the relevant question is <u>not</u> whether the skilled person <u>could</u> have carried out the invention, but whether he <u>would</u> have done so in the hope of solving the underlying technical problem, or in the expectation of some improvement or advantage. So in this case, the question is not whether the skilled person could have arrived at the invention by modifying documents D1 in accordance with the disclosure in document D2, but whether he would have done so because of promptings in these prior art documents (see T2/83 and T90/84 and T7/86 and T200/94).

3. So, what in fact is in the present case the underlying technical problem or the expectation of improvement or advantage in question? The answer to this is set out on pages 4 and 5 of the description of the present application which refers to such factors as economical use of available bandwidth and allocation of bandwidth corresponding to bandwidth requirements of the individual data sensors. The text on page 5 goes on to explain that prior proposals have ignored or overlooked these differing data rates or bandwidth requirements and this has led to a non-utilisation of sub-channel bandwidths whereby the overall utilisation of data transmission capacity allocated to a communications system has been very far from perfect. There is a reference to the twin evils of sub-channel under-utilisation and under-capacity (for a given data flow), and the avoidance of these.

4. Therefore, the disclosure in documents D1 and D2 is to be examined having regard to these latter-discussed technical problems and/or the improvements or advantages which might arise from reducing or eliminating them. Specifically, do documents D1 and D2 contain any relevant disclosure with regard to these problems and questions?

5. The disclosure in documents D1 may be summarised as follows:

"There is disclosed in US-A-4,738,133 an automotive testing system applicable to diagnostic analysis, in which prior art use of a plurality of cables or even an umbilical cord single cable (with digital signal conversion) is replaced by a wireless transmitter-receiver link interposed between the sensing transducers in the vehicle under test and the test apparatus. Transmission is by radio in the ultra short wave range, preferably in the gigahertz frequency range.

In accordance with a preferred feature of the disclosed invention the signals from the transducers are transmitted in time-multiplexed mode so that one transmitter can transmit signals from a plurality of transducers, and a plurality of signals from the engine of the vehicle can be transmitted sequentially through a single channel. Frequency multiplexed transmission is also possible whereby each sensor then has its own specific discrete transmission channel. There is no reference anywhere in the text or drawings to the bandwidth or data-carrying capacity of the transmission channels".

6. Turning now to the disclosure in document D2, the disclosure therein may be summarised as follows:

"There is disclosed in US-A-5 509 013 a multiplexer control system to control multiplexing of data of a plurality of channels including channels having different transmission speeds. It is stated that when multiplexing data of channels having different transmission speeds, data of channels having higher transmission speeds are more frequently multiplexed than data of channels having lower transmission speeds and the invention apparently seeks economically to realise a construction capable of multiplexing data on channels having different transmission speeds, and in accordance with the claimed invention this object is achieved by use of a multiplexer control system utilising a bit map memory, a rate setting memory and controlling means determining the multiplexing of the input data to the plurality of channels.

There is apparently no clear reference in the disclosure to the bandwidth or data-carrying capacity of the channels, and this is not surprising since apparently the channels are not wireless channels and therefore this reference apparently contains no disclosure of direct relevance to the question of channel capacity as opposed to channel transmission speed".

7. In view of the above-quoted disclosures in references D1 and D2, it can now be seen that the technical problem with which the present invention is concerned is not addressed in any direct way in either of the two principal cited references D1 and D2. Certainly, in D1 there is complete lack of awareness of the problem with which the present invention addresses. In simple terms, D1 is one of the prior proposals mentioned in paragraph 2 on page 5 of the present application which have ignored or overlooked these differing data rate requirements, with the result that the use of equal bandwidth sub-channels has led to ....(The various short comings there identified and quoted above).

8. As to D2, quite apart from the above-mentioned distinction between transmission speed and bandwidth or channel capacity, there is the basic point that the skilled person would (as opposed to could) not have even considered looking for disclosure relevant to the problem of bandwidth or channel capacity since certainly D1 and very arguably D2 also contain no reference to this.

9. Indeed, the absence of any reference to the channel capacity problem from the disclosure in D1 is of dominant significance because the skilled person is obliged to start from D1 since the disclosure in D2 is effectively merely of a multiplexer and provides few if any other features of

claim 1 of the present application. Therefore, starting from D1, the person skilled in the art is not even aware of the problem which the present invention solves, and does not even consider looking for disclosure solving such a problem.

10. The Examiner states his opinion (see section 2.2 on separate sheet 2 of the FWO) that it is an obvious problem in such sensor/control arrangement that some sensors require a higher data rate than others. However, the Guidelines warn against such an ex post facto approach when assessing inventive step, as mentioned above. In any case, even assuming, arguendo that the transducers disclosed in document D1 eg. trigger tongs for ignition pulses, voltmeters and ammeters, could be shown to have different data generating rates, there is simply no suggestion in D1 of doing anything to accommodate those different rates. Document D2 does deal with the handling of multiple channels having different transmission speeds. In particular, it is directed to a multiplexer control system for controlling the multiplexing of data from pre-existing channels which already have different data transmission rates. Furthermore, the system is dependent on the existence of these pre-existing channels of different data rates, since it must store information relating to the channel identifications and their transmission rates in the rate setting memory 12 which is critical to the operation of the system. It is submitted that there would have been no reason for one of ordinary skill in the art to attempt to use the system of document D2 which is based on pre-existing data channels of different data rates, in a system such as that of D1, which multiplexes data from channels which apparently have the same data rate. It is noted that in the system of D1, the wire conductors coming into the multiplexer and encoder 4a) could all have the same data rate even if the individual transducers 1-3 had different data-generating rates. That being the case, the multiplexer of D2 would not work in the system of D1.

11. Reverting specifically to the question of the disclosure or not in D2 of the concept of differing channel capacity or bandwidth, the following observations are made. As mentioned above, the specific textual disclosure relates solely to channels having "different transmission speeds". In this regard it is commented that channel data transmission speed as such and in the absence of any reference to channel capacity amounts to no more than a reference to the <u>actual</u> data transmission rate at any time rather than an upper limit to the data rate. The disclosure is explicit only as to the words actually used. Nowhere, apparently is there any reference to channel capacity or an upper limit to the data rate. This is significant. Also significant is the actual presence (column 2 at line 48) of a reference to changing the transmission speed of the

channel by employing a re-writeable memory. This endorses the absence of channel capacity disclosure.

12. Summarising, it is submitted that D1 lacks all three features a), b) and c) of the characterising clause of claim 1. D1 also lacks any suggestion of the problem to be solved by the characterising features of claim 1. Therefore the skilled person aware of D1 would not search anywhere for the solution to the problem confronted by the present invention because that problem is unknown to him. Even if that skilled person consulted D2 in combination with D1, he would find that it was of little if any relevance. It discloses a multiplexing system relating to data transmission speeds. Data transmission speeds have no relevance to the disclosure of D1 since it contains no disclosure thereof. It does contain disclosure relating to multiplexing. It refers to time multiplexing and to frequency multiplexing. Neither of these systems relates in any practicable way to the multiplexing system of D2. Time multiplexing is in any case a single channel system. Therefore, the combination of D1 with D2 is not a combination which the skilled person <u>would</u> make. Even if the combination were made, arguably it would not produce the presently claimed invention since D2 arguably contains no disclosure of channels having differing carrying capacities but only disclosure of different actual data transmission rates.

CLAIMS 24 AND 25

1. The FWO indicates that claim 24 possesses novelty but lack inventive step, and claim 25 lacks novelty with respect to document D3.

2. Document D3 discloses a system for contactless detection of oscillations in an object by illuminating the object with a laser beam. By detecting reflected light from a point on the object with three spaced sensing heads, the system of D3 can locate the point by triangulation. By sensing light reflecting from a plurality of points on the object, the overall movement of the object can be determined in D3.

3. In view of the above-described disclosure in D3, claims 24 and 25 have been limited to a system wherein the vibration sensor is mechanically coupled to the machine or other article being sensed. It is submitted that with this amendment, both claims 24 and 25 have clear novelty with respect to D3 and moreover the cumulative effect of the additional features of novelty renders the disclosure of D3 significantly less pertinent whereby the technical advance to be made by the technically competent person as a matter of routine and non-inventive contribution to the state of the art in reaching the invention from D3 becomes

relatively unbridgeable.

Yours faithfully
URQUHART-DYKES & LORD

PHILIP B ARCHER
AUTHORISED REPRESENTATIVE

Encs. 1. Pages 4, 4a and 7 of the description - in triplicate.
2. Amended claims 1 to 25 (fair copy format) - in triplicate.
3. Amended claims 1 to 25 with identification of amendments by underlining and parentheses

times) and to individual channels within the groups (at transmission times) so as to increase throughput and reduce packet loss. For bursty traffic, the use of channel groups reduces the packet loss by several orders of magnitude.

EP 0 515 728A2 relates to a wireless indoor relay system. AU-A-18143/88 relates to a wireless data transmission link and notably a protocol for establishing a duplex link between first and second data link devices.

Other known references include:

GB 2295070

EP 0483549

EP 0268492

US 5509013

US 5448759

US 5363370

US 4,738,133 discloses a system for wireless transmission of multiplexed data from a plurality of transducers.

US 5,509,013 discloses a multiplexer control system for multiplexing the data from a plurality of input channels having different transmission speeds.

DE 4106572 discloses a system for contact-free measurement of object oscillations by directing laser light onto the object and detecting reflected light at plural spaced sensing heads so as to locate the point on the object from which the reflections are emanating.

According to the invention there is provided a method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors with optional primary data processing and a data processing function, as defined in the accompanying claims.

In a described embodiment, there is provided a method and apparatus in which the step of multiplexing division of the communications channel is effected asymmetrically, whereby the data carrying capacities of the sub-channels are unequal. Likewise in the embodiment, the data rates required for data transmission from the local sensors

differs substantially between the at least two sensors. Likewise also in the embodiment, the step of allocating data from the local data sensors to the data transmission sub-channels is effected in accordance with the data-carrying capacities of these sub-channels. In this way there is achieved within a

vibrational analysis of machines and other articles and products and systems. In accordance with this aspect of the invention a vibration sensor, for example an NVH (noise vibration harshness) sensor is mechanically coupled to the machine or other article to three-dimensionally locate a source of vibration in a machine or system. Such a sensor may be just one of the local sensors in the wireless transmission system of the other embodiments, or it may be provided with its own cable or other transmission channel for its vibration signals.

In order to three-dimensionally locate a source of vibration, the vibration signals are monitored at three or more positionally-defined locations of the sensor. In the preferred embodiment the sensor is provided with its own three-dimensional location or co-ordinate-defining system (utilising spaced infra-red sensors), so that the sensor's location at any given time is readily defined. Alternatively, the sensor may be caused to sense at three known locations, or three sensors may be provided, one each at three such locations.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Fig 1 shows a functionality block diagram for a high speed RF data link, including both the frequency multiplexing system (of Figs 2 and 3) and the time-division multiplexing system (of Figs 4 and 5 hereof);

Figs 2 and 3 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as it applies to a frequency multiplexing system;

Figs 4 and 5 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as they apply to a time-division multiplexing system; and

CLAIMS

1 A method of wireless transmission of data in digital and/or analogue format through a communications channel (72) from at least two local data sensors (14, 16) to a data processing means (24), said method comprising the step of division of said channel into sub-channels and transmitting said data from said data sensors respectively through said sub-channels accordingly;

characterised by

a) said step of division of said communications channel being effected asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) the data rate required for data transmission from said local sensors differing substantially between said at least two sensors; and

c) allocating data from said local data sensors to respective ones or groups of said sub-channels [being effected] in accordance with the data carrying capacities of said sub-channels.

2 A method according to claim 1 characterised by said step of division being effected on a frequency basis.

3 A method according to claim 1 characterised by said step of division being effected on a time-division basis.

4 A method according to any one of claims 1 to 3 characterised by said step of division being adapted to effect said division on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time overlap between channels is permitted.

5 A method according to claim 1 characterised by said step of division being effected by packet-switching of data from said local data sensors, and interleaving said data packet with an unsymmetrical packet distribution.

6 A method according to any one of claims 1 to 5 characterised by said data processing means comprising a host PC (24) having a series of virtual serial ports, and said method comprising allocating each of said sub-channels to a corresponding one of said virtual serial ports.

7 A method according to any one of claims 1 to 6 characterised by said local sensors comprising automotive diagnostic and/or servicing sensors and said wireless transmission of data being effected at radio frequencies.

8 A method according to any one of claims 1 to 7 characterised by at least one of said local sensors (14) also providing a primary data-processing function.

9 A method according to any one of claims 1 to 8 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration, and said method comprising transmitting said data therefrom.

10 A method according to claim 9 characterised by the step of using as said sensors, sensors (104) adapted to provide vibration data permitting noise vibration harshness (NVH) analysis of the data.

11 A method according to claim 10 characterised by at least three of said sensors being such NVH sensors, and the method comprising employing said sensors at three-dimensionally spaced locations to identify the location or co-ordinates of a source of vibration.

12 A method according to claim 9 or claim 10 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106) and the method comprising the step of using said sensor to sense vibrations at three dimensionally-spaced locations in

sequence, and using said three-dimensional location sensing means to identify the location or co-ordinates of said three spaced locations so as to identify the location or co-ordinates of a source of vibration.

13 Apparatus for wireless transmission of data in digital and/or analogue format through a communications channel (12) from at least two local data sensors (14, 16) to a data processing means (24), the apparatus comprising a multiplexer (62) adapted to effect division of said communications channel into sub-channels, and a transmitter (34) adapted to transmit said data through said sub-channels accordingly;

characterised by

a) said multiplexer being adapted to divide said communications channel asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) control means (40) adapted to allocate data from said local data sensors to respective ones or groups of said communications sub-channels in accordance with substantially different data rate requirements from said local sensors.

14 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a frequency basis.

15 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a time-division basis.

16 Apparatus according to any one of claims 13 to 15 characterised by said multiplexer being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted.

17 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect packet-switching of data from said local sources and to interleave said data packets with an unsymmetrical packet distribution.

18 Apparatus according to any one of claims 13 to 17 characterised by said data processing function comprising a host PC (24) having a series of virtual serial ports, and said control means being adapted to allocate each of said sub-channels to a respective one of said virtual ports.

19 Apparatus according to any one of claims 13 to 18 characterised by at least one of said local sensors (14) being adapted to provide a primary data-processing function.

20 Apparatus according to claim 19 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration whereby said apparatus can transmit said vibration data from said vibration sensing means.

21 Apparatus according to claim 20 characterised by said local data sensors comprising sensors adapted to provide vibration data permitting noise vibration harshness (NVH) data for analysis thereof.

22 Apparatus according to claim 21 characterised by said local data sensors comprising at least three or more such NVH sensors whereby said sensors can be located at three-dimensionally spaced locations to provide data enabling identification of the location or co-ordinates of the source of a vibration in a machine.

23 Apparatus according to claim 20 or claim 21 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106)

whereby said vibration sensor means can sense vibrations at three-dimensionally-spaced locations in sequence and said three-dimensional location sensing means can identify the co-ordinates or locations of said three locations so as to enable identification of the location or co-ordinates of a source of vibration.

24 A method for vibration analysis of a machine or other article comprising:

a) providing a vibration sensor (104);

b) causing said sensor to sense vibrations;

c) analysing signals produced by said sensor;

characterised by

d) providing said sensor with three-dimensional location sensing means (106);

e) causing said vibration sensor to be mechanically coupled to the machine or other article to sense vibrations at three-dimensionally-spaced locations and using said three-dimensional location sensing means to determine the co-ordinates of said three locations; and

f) identifying the location or co-ordinates of a source of vibration accordingly.

25 Apparatus for vibration analysis of a machine or other article comprising:

a) a vibration sensor (104) adapted to sense vibrations at chosen locations; and

b) analysis means (124) adapted to analyse signals produced by said sensor;

characterised by

c) said vibration sensor being adapted to be mechanically coupled to the machine or other article and further comprising three-dimensional location sensing means (106);

d) whereby said single sensor can be caused to sense vibrations at three-dimensionally spaced locations at which said three-dimensional location sensing means can identify

the co-ordinate locations thereof whereby the corresponding co-ordinates of a source of vibration can be determined.

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1 A method of wireless transmission of data in digital and/or analogue format through a communications channel (72) from at least two local data sensors (14, 16) to a data processing <u>means</u> (24) [function to receive data therefrom], said method comprising the step of [multiplexing] division of said channel into sub-channels and transmitting said data from said data sensors <u>respectively</u> through said sub-channels accordingly;

characterised by

a) said step of [multiplexing] division of said communications channel being effected asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) the data rate required for data transmission from said local sensors differing substantially between said at least two sensors; and

c) [the step of] allocating data from said local data sensors to respective ones or groups of said sub-channels [being effected] in accordance with the data carrying capacities of said sub-channels.

2 A method according to claim 1 characterised by said step of [multiplexing] <u>division</u> being effected on a frequency basis.

3 A method according to claim 1 characterised by said step of [multiplexing] <u>division</u> being effected on a time-division basis.

4 A method according to any one of claims 1 to 3 characterised by said step of [multiplexing] <u>division</u> being adapted to effect said [multiplexing] <u>division</u> on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time overlap between channels is permitted.

5 A method according to claim 1 characterised by said

step of [multiplexing] <u>division</u> being effected by packet-switching of data from said local [sources] <u>data sensors</u>, and [the] interleaving [of] said data packet [being effected] with an unsymmetrical packet distribution.

6 A method according to any one of claims 1 to 5 characterised by said data processing [function] <u>means</u> comprising a host PC (24) having a series of virtual serial ports, and said method comprising allocating each of said sub-channels to a corresponding one of said virtual serial ports.

7 A method according to any one of claims 1 to 6 characterised by said local sensors comprising automotive diagnostic and/or servicing sensors and said wireless transmission of data being effected at radio frequencies.

8 A method according to any one of claims 1 to 7 characterised by at least one of said local sensors (14) also providing a primary data-processing function.

9 A method according to any one of claims 1 to 8 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration, and said method comprising transmitting said data therefrom.

10 A method according to claim 9 characterised by the step of using as said sensors, sensors (104) adapted to provide vibration data permitting noise vibration harshness (NVH) analysis [thereof] <u>of the data</u>.

11 A method according to claim 10 characterised by at least three of said sensors being such NVH sensors, and the method comprising employing said sensors at three-dimensionally spaced locations to identify the location or co-ordinates of a source of vibration.

12 A method according to claim 9 or claim 10 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106) and the method comprising the step of using said [single] sensor to sense vibrations at three dimensionally-spaced locations in sequence, and using said three-dimensional location sensing means to identify the location or co-ordinates of said three spaced locations so as to identify the location or [co-ordinate] <u>co-ordinates</u> of a source of vibration.

13 Apparatus for wireless transmission of data in digital and/or analogue format through a communications channel (12) from at least two local data sensors (14, 16) to a data processing <u>means</u> (24) [function to receive data therefrom], the apparatus comprising a multiplexer (62) adapted to effect division of said communications channel into sub-channels, and a transmitter (34) adapted to transmit said data through said sub-channels accordingly;

characterised by

a) said multiplexer being adapted to divide said communications channel asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) control means (40) adapted to allocate data from said local data sensors to respective ones or groups of said communications sub-channels in accordance with substantially different data rate requirements from said local sensors.

14 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a frequency basis.

15 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a time-division basis.

16 Apparatus according to any one of claims 13 to 15 characterised by said multiplexer being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted.

17 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect packet-switching of data from said local sources and to interleave said data packets with an unsymmetrical packet distribution.

18 Apparatus according to any one of claims 13 to 17 characterised by said data processing function comprising a host PC (24) having a series of virtual serial ports, and said control means being adapted to allocate each of said sub-channels to a respective one of said virtual ports.

19 Apparatus according to any one of claims 13 to 18 characterised by at least one of said local sensors (14) being adapted to provide a primary data-processing function.

20 Apparatus according to claim 19 characterised by said local sensors comprising vibration sensor means (104) adapted to sense machine vibration whereby said apparatus can transmit said vibration data [therefrom] <u>from said vibration sensing means</u>.

21 Apparatus according to claim 20 characterised by said local data sensors comprising sensors adapted to provide vibration data permitting noise vibration harshness (NVH) data for analysis thereof.

22 Apparatus according to claim 21 characterised by said local data sensors comprising at least three or more[,] such NVH sensors whereby said sensors can be located at three-dimensionally spaced locations to provide data

enabling identification of the location or co-ordinates of the source of a vibration in a machine.

23 Apparatus according to claim 20 or claim 21 characterised by said vibration sensor means further comprising three-dimensional location sensing means (106) whereby said [single] vibration sensor <u>means</u> can sense vibrations at three-dimensionally-spaced locations in sequence and said three-dimensional location sensing means can identify the co-ordinates or locations of said three locations so as to enable identification of the location or co-ordinates of a source of vibration.

24 A method for vibration analysis of a machine or other article comprising :

a) providing a vibration sensor (104);

b) causing said sensor to sense vibrations;

c) analysing signals produced by said sensor;

characterised by

d) providing said sensor with three-dimensional location sensing means (106);

e) causing said [single] vibration sensor to <u>be mechanically coupled to the machine or other article to</u> sense vibrations at three-dimensionally-spaced locations and using said three-dimensional location sensing means to determine the co-ordinates of said three locations; and

f) identifying the location or co-ordinates of a source of vibration accordingly.

25 Apparatus for vibration analysis of a machine or other article comprising:

a) a vibration sensor (104) adapted to sense vibrations at chosen locations; and

b) analysis means (124) adapted to analyse signals produced by said sensor;

characterised by

c) said vibration sensor <u>being adapted to be</u>

mechanically coupled to the machine or other article and further comprising three-dimensional location sensing means (106);

d) whereby said single sensor can be caused to sense vibrations at three-dimensionally spaced locations at which said three-dimensional location sensing means can identify the co-ordinate locations thereof whereby the corresponding co-ordinates of a source of vibration can be determined.

times) and to individual channels within the groups (at transmission times) so as to increase throughput and reduce packet loss. For bursty traffic, the use of channel groups reduces the packet loss by several orders of magnitude.

EP 0 515 728A2 relates to a wireless indoor relay system. AU-A-18143/88 relates to a wireless data transmission link and notably a protocol for establishing a duplex link between first and second data link devices.

Other known references include :-

GB 2295070
EP 0483549
EP 0268492
US 5509013
US 5448759
US 5363370

According to the invention there is provided a method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors with optional primary data processing and a data processing function, as defined in the accompanying claims.

In a described embodiment, there is provided a method and apparatus in which the step of multiplexing division of the communications channel is effected asymmetrically, whereby the data carrying capacities of the sub-channels are unequal. Likewise in the embodiment, the data rates required for data transmission from the local sensors differs substantially between the at least two sensors. Likewise also in the embodiment, the step of allocating data from the local data sensors to the data transmission sub-channels is effected in accordance with the data-carrying capacities of these sub-channels. In this way there is achieved within a vibrational analysis of machines and other articles and products and systems. In accordance with this aspect of the invention a vibration sensor, for example an NVH (noise vibration harshness) sensor is utilised to three-dimensionally locate a source of vibration in a machine or system. Such a sensor may be just one of the local sensors in the wireless transmission system of the other embodiments, or it may be provided with its own cable or other transmission channel for its vibration signals.

In order to three-dimensionally locate a source of vibration, the vibration signals are monitored at three or more positionally-defined locations of the sensor. In the preferred embodiment the sensor is provided with its own three-dimensional location or co-ordinate-defining system (utilising spaced infra-red sensors), so that the sensor's location at any given time is readily defined. Alternatively, the sensor may be caused to sense at three known locations, or three sensors may be provided, one each at three such locations.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Fig 1 shows a functionality block diagram for a high speed RF data link, including both the frequency multiplexing system (of Figs 2 and 3) and the time-division multiplexing system (of Figs 4 and 5 hereof);

Figs 2 and 3 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as it applies to a frequency multiplexing system;

Figs 4 and 5 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as they apply to a time-division multiplexing system; and

CLAIMS

1 A method of wireless transmission of data in digital and/or analogue format through a communications channel from at least two local data sensors to a data processing function to receive data therefrom, said method comprising the step of multiplexing division of said channel into sub-channels and transmitting said data from said data sensors through said sub-channels accordingly;

characterised by

a) said step of multiplexing division of said communications channel being effected asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) the data rate required for data transmission from said local sensors differing substantially between said at least two sensors; and

c) the step of allocating data from said local data sensors to respective ones or groups of said sub-channels being effected in accordance with the data carrying capacities of said sub-channels.

2 A method according to claim 1 characterised by said step of multiplexing being effected on a frequency basis.

3 A method according to claim 1 characterised by said step of multiplexing being effected on a time-division basis.

4 A method according to any one of claims 1 to 3 characterised by said step of multiplexing being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time

overlap between channels is permitted.

5 A method according to claim 1 characterised by said step of multiplexing being effected by packet-switching of data from said local sources, and the interleaving of said data packet being effected with an unsymmetrical packet distribution.

6 A method according to any one of claims 1 to 5 characterised by said data processing function comprising a host PC having a series of virtual serial ports, and said method comprising allocating each of said sub-channels to a corresponding one of said virtual serial ports.

7 A method according to any one of claims 1 to 6 characterised by said local sensors comprising automotive diagnostic and/or servicing sensors and said wireless transmission of data being effected at radio frequencies.

8 A method according to any one of claims 1 to 7 characterised by at least one of said local sensors also providing a primary data-processing function.

9 A method according to any one of claims 1 to 8 characterised by said local sensors comprising vibration sensor means adapted to sense machine vibration, and said method comprising transmitting said data therefrom.

10 A method according to claim 9 characterised by the step of using as said sensors, sensors adapted to provide vibration data permitting noise vibration harshness (NVH) analysis thereof.

11 A method according to claim 10 characterised by at least three of said sensors being such NVH sensors, and the method comprising employing said sensors at three-dimensionally spaced locations to identify the location or co-ordinates of a source of vibration.

12 A method according to claim 9 or claim 10 characterised by said vibration sensor means further comprising three-dimensional location sensing means and the method comprising the step of using said single sensor to sense vibrations at three dimensionally-spaced locations in sequence, and using said three-dimensional location sensing means to identify the location or co-ordinates of said three spaced locations so as to identify the location or co-ordinate of a source of vibration.

13 Apparatus for wireless transmission of data in digital and/or analogue format through a communications channel from at least two local data sensors to a data processing function to receive data therefrom, the apparatus comprising a multiplexer adapted to effect division of said communications channel into sub-channels, and a transmitter adapted to transmit said data through said sub-channels accordingly;

characterised by

a) said multiplexer being adapted to divide said communications channel asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) control means adapted to allocate data from said local data sensors to respective ones or groups of said communications sub-channels in accordance with substantially different data rate requirements from said local sensors.

14 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a frequency basis.

15 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect said multiplexing on a time-division basis.

16 Apparatus according to any one of claims 13 to 15 characterised by said multiplexer being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted.

17 Apparatus according to claim 13 characterised by said multiplexer being adapted to effect packet-switching of data from said local sources and to interleave said data packets with an unsymmetrical packet distribution.

18 Apparatus according to any one of claims 13 to 17 characterised by said data processing function comprising a host PC having a series of virtual serial ports, and said control means being adapted to allocate each of said sub-channels to a respective one of said virtual ports.

19 Apparatus according to any one of claims 13 to 18 characterised by at least one of said local sensors being adapted to provide a primary data-processing function.

20 Apparatus according to claim 19 characterised by said local sensors comprising vibration sensor means adapted to sense machine vibration whereby said

apparatus can transmit said vibration data therefrom.

21 Apparatus according to claim 20 characterised by said local data sensors comprising sensors adapted to provide vibration data permitting noise vibration harshness (NVH) data for analysis thereof.

22 Apparatus according to claim 21 characterised by said local data sensors comprising at least three or more, such NVH sensors whereby said sensors can be located at three-dimensionally spaced locations to provide data enabling identification of the location or co-ordinates of the source of a vibration in a machine.

23 Apparatus according to claim 20 or claim 21 characterised by said vibration sensor means further comprising three-dimensional location sensing means whereby said single vibration sensor can sense vibrations at three-dimensionally-spaced locations in sequence and said three-dimensional location sensing means can identify the co-ordinates or locations of said three locations so as to enable identification of the location or co-ordinates of a source of vibration.

24 A method for vibration analysis of a machine or other article comprising :

a) providing a vibration sensor;

b) causing said sensor to sense vibrations;

c) analysing signals produced by said sensor;

characterised by

d) providing said sensor with three-dimensional location sensing means;

e) causing said single vibration sensor to sense vibrations at three-dimensionally-spaced locations and using said three-dimensional location sensing means to determine the co-ordinates of said three locations; and

f) identifying the location or co-ordinates of a source of vibration accordingly.

25 Apparatus for vibration analysis of a machine or other article comprising :

a) a vibration sensor adapted to sense vibrations at chosen locations; and

b) analysis means adapted to analyse signals produced by said sensor;

characterised by

c) said vibration sensor further comprising three-dimensional location sensing means;

d) whereby said single sensor can be caused to sense vibrations at three dimensionally spaced locations at which said three-dimensional location sensing means can identify the co-ordinate locations thereof whereby the corresponding co-ordinates of a source of vibration can be determined.

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G08C 15/02 | A2

(11) International Publication Number: WO 98/44471

(43) International Publication Date: 8 October 1998 (08.10.98)

(21) International Application Number: PCT/GB98/00866

(22) International Filing Date: 3 April 1998 (03.04.98)

(30) Priority Data:
9706797.9 3 April 1997 (03.04.97) GB

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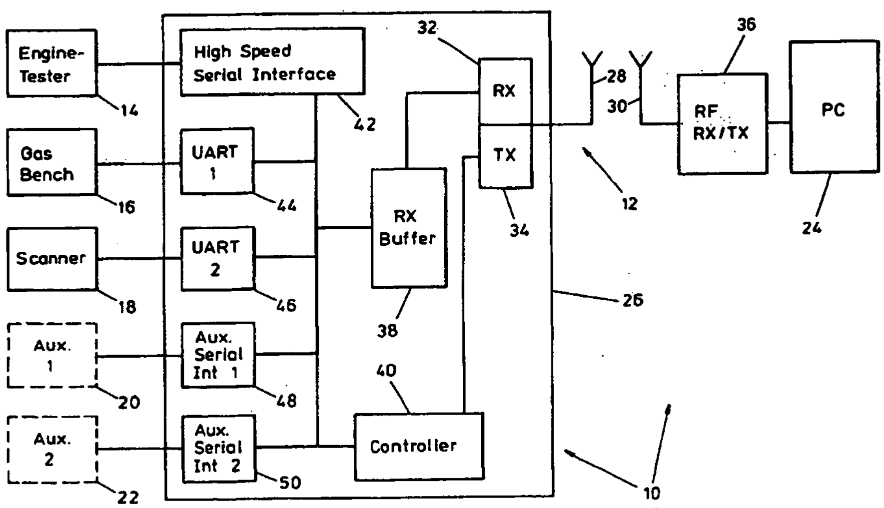
(81) Designated States: AU, CA, CN, JP, KR, MX, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM



(57) Abstract

A method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors (for example automotive diagnostic data sensors or NVH sensors), which may include a primary data–processing function, and data–processing function (for example a PC) to receive data therefrom. The system provides for asymmetrical division of the communications channel on a frequency or time–division or packet–switching basis so that the corresponding asymmetrical data transmission requirement of the local data sensors are matched to the capacity of their respective sub–channels whereby a single channel is capable of transmitting all the required data. A particularly practical application is to noise vibration harshness analysis of wireless–transmitted data from three–dimensionally spaced NVH sensors enabling spacial pinpointing of vibration sources in automotive warranty analysis studies.

A⬤NT COOPERATION TRE T⬤

From the INTERNATIONAL BUREAU

28 Rec'd PCT/PTO 01 OCT 1999

To:

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NOTICE INFORMING THE APPLICANT OF THE COMMUNICATION OF THE INTERNATIONAL APPLICATION TO THE DESIGNATED OFFICES

(PCT Rule 47.1(c), first sentence)

Date of mailing (day/month/year)
08 October 1998 (08.10.98)

Applicant's or agent's file reference
P53206WO

IMPORTANT NOTICE

International application No.	**International filing date** (day/month/year)	**Priority date** (day/month/year)
PCT/GB98/00866	03 April 1998 (03.04.98)	03 April 1997 (03.04.97)

Applicant
SUN ELECTRIC UK LIMITED et al

1. Notice is hereby given that the International Bureau has communicated, as provided in Article 20, the international application to the following designated Offices on the date indicated above as the date of mailing of this Notice:
   AU,CA,CN,EP,JP,KR,US

   In accordance with Rule 47.1(c), third sentence, those Offices will accept the present Notice as conclusive evidence that the communication of the international application has duly taken place on the date of mailing indicated above and no copy of the international application is required to be furnished by the applicant to the designated Office(s).

2. The following designated Offices have waived the requirement for such a communication at this time:
   MX

   The communication will be made to those Offices only upon their request. Furthermore, those Offices do not require the applicant to furnish a copy of the international application (Rule 49.1(a-bis)).

3. Enclosed with this Notice is a copy of the international application as published by the International Bureau on 08 October 1998 (08.10.98) under No. WO 98/44471

REMINDER REGARDING CHAPTER II (Article 31(2)(a) and Rule 54.2)

If the applicant wishes to postpone entry into the national phase until 30 months (or later in some Offices) from the priority date, **a demand for international preliminary examination** must be filed with the competent International Preliminary Examining Authority before the expiration of 19 months from the priority date.

It is the applicant's sole responsibility to monitor the 19-month time limit.

Note that only an applicant who is a national or resident of a PCT Contracting State which is bound by Chapter II has the right to file a demand for international preliminary examination.

REMINDER REGARDING ENTRY INTO THE NATIONAL PHASE (Article 22 or 39(1))

If the applicant wishes to proceed with the international application in the **national phase**, he must, within 20 months or 30 months, or later in some Offices, perform the acts referred to therein before each designated or elected Office.

For further important information on the time limits and acts to be performed for entering the national phase, see the Annex to Form PCT/IB/301 (Notification of Receipt of Record Copy) and Volume II of the PCT Applicant's Guide.

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PATENT COOPERATION TREATY

28 Rec'd PCT/PTO 01 OCT 1999

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P53206WO		
International application No. PCT/GB98/00866	International filing date *(day/month/year)* 03/04/1998	Priority date *(day/month/year)* 03/04/1997
International Patent Classification (IPC) or national classification and IPC G08C15/02		
Applicant SUN ELECTRIC UK LIMITED et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 11 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
03/11/1998	29.04.99
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. (+49-89) 2399-0 Tx: 523656 epmu d Fax: (+49-89) 2399-4465	Authorized officer Wright, J Telephone No. (+49-89) 2399 2705

I. Basis of the report

1. This report has been drawn on the basis of (*substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.*):

Description, pages:

1-3,5,6,8-14	as originally filed			
4,4a,7	as received on	17/04/1999	with letter of	14/04/1999

Claims, No.:

1-25	as received on	17/04/1999	with letter of	14/04/1999

Drawings, sheets:

1/4-4/4	as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

4. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
- ☒ paid additional fees.
- ☐ paid additional fees under protest.

☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

☐ complied with.

☒ not complied with for the following reasons:

see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

☒ all parts.

☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-25
	No:	Claims	
Inventive step (IS)	Yes:	Claims	2,4,5,14,16,17
	No:	Claims	1,3,6-13,15,18-25
Industrial applicability (IA)	Yes:	Claims	1-25
	No:	Claims	

2. Citations and explanations

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

1. The following document(s) will be referred to in this preliminary examination report;

D1 US-A-4 738 133 [Breckel et al]
D2 US-A-5 509 013 [Adachi et al]
D3 DE-A-4 106 572 [Fraunhofer Gesellschaft München]

The subject-matter of document D1 is considered to represent the prior art the closest to that of the present application, inventions 1 and 2.

2. In the following discussion, the patentability of the claims will be examined with regard to the requirements of the PCT. In particular, the claims will be examined for novelty, as defined in Art. 33(2) PCT, and for inventive step, as defined in Art. 33(3) PCT. In addition other aspects, such as clarity requirements of Art. 6 PCT, may be discussed as appropriate.

2.1 The application lacks unity within the meaning of Rule 13 PCT, since the claims presently on file claim the following separate inventions or groups of inventions not so linked as to form a single general inventive concept. The application therefore does not comply with the requirements of Art. 3 (4)iii PCT. The application comprises the following separate inventions:

Invention 1. Claims 1-23

Invention 1 relates to **multiplex data transmission** via a wireless with different rates in each channel.

Invention 2. Claims 24-25

Invention 2 relates to a method and apparatus for **vibrational analysis** in a three dimensional space.

Since the applicant has **paid additional fees** under Art. 34 (3) a, **report on the complete application** will be made by the examiner.

For information only, the applicant may chose to prosecute the application on one of the above inventions in the national / regional phase of the application.

2.2 Claim 1

The subject matter of claim 1 of the application is not allowable because it lacks an inventive step, Art. 33(3) PCT, the reasons being as follows:

Document D1 is considered to represent the closest prior art to the subject matter of claim 1 of the application. D1 discloses sensors (1,2,3) which are connected to a central control (5,6).

The examiner is of the opinion that it is a common and obvious problem in such a sensor/control arrangement that some sensors require a higher data carrying capacity than others. The problem is for instance known from the document D2, see for instance col. 1, lines 16-18.

The examiner notes that although D2 specifically relates to channels having varying "transmission speeds" this means different "data carrying capacity", since data carrying capacity only has meaning in terms of a given time period during which data can be sent. Nothing in claim 1 of the application refers to channel band-width or the like.

The person skilled in the art, wishing to solve this problem would use the solution proposed in document D2. D2 discloses the multiplex control system for such a sensor/control arrangement but does not explicitly mention the control/sensors themselves.

D2 discloses that in a plurality of multiplexed channels (these are considered to be sub-channels of a single channel), some channels with higher data rates are assigned correspondingly increased data transmission load, see abstract, col. 6, lines 28-32 (gives a definition of a "cell" and col. 7, lines 14-24 (which defines how data is asymmetrically divided in accordance with the data carrying capacity of the sub-channels) and col. 7, lines 33-37 (dynamic changing of channel data transmission capability). The multiplexing of data is therefore asymmetrically arranged in accordance with the channel data carrying capacity.

The person skilled in the art, incorporating the teaching of D2 into the method/apparatus of D1 would therefore arrive at the subject matter of claim 1 of the application without having made an inventive step.

The above argument hinges on the question of whether the person skilled in the art **would combine** D1 and D2. The examiner notes that D2 does not address the specific environment of data collection from sensors, rather it addresses the more general problem of transmitting by what ever means data from one remote location to another by means of transmission channels of some kind. The examiner furthermore notes that the solution offered to the above problem in D2 which is the same as in the application, has no technical features which relate to the kind of data generated, the means of transmission or to the source of data. The examiner furthermore notes that nearly all data is actually sourced from some kind of sensor, be it a microphone in a telephone, a pressure sensor or a light responsive sensor in a FAX machine.

The examiner concludes that the problem posed in D2 is very general to the field of data transmission and the person skilled in the art would therefore be very aware of this problem when dealing with any data transmission. The features of claim 1 of the application (known in themselves from D1) are merely contextual and do not add technical features which would be considered to involve an inventive step.

Claim 1 is therefore not allowable under Art. 33(3) PCT.

The examiner notes that claim 1 would appear to be clear and therefore to satisfy the requirements of Art. 6 PCT.

2.3 Claims 2 to 5

The examiner notes that claims 2 to 5 relate to the way in which the channels are divided.

From D2, col. 1, lines 54-64 it would appear that the channel division is on a time division basis. The examiner is now of the provisional opinion that claim 3 of the application lacks inventive step, but that the division in accordance with claim 2 could be considered as being both new and involving an inventive step since there is no indication in the prior art to use frequency division.

The examiner is of the provisional opinion that the subject matter of claims 5 could likewise be considered to involve an inventive step, since packet switching is also not known from the available prior art D1 or D2.

The examiner considers that the subject matter of claim 4 **could** contain subject matter which involved an inventive step, but that it is so unclear to the examiner what is being claimed that the present claim does not satisfy the requirements of Art. 6 PCT.

In particular the examiner is not aware of the term "interdigitated non-chopping data-allocation basis" with regard to channel division /multiplexing etc. Furthermore the criteria that a "degree" of data element transmission time overlap is permitted is indefinite and vague.

The applicant is also informed for information only that the examiner is of the provisional opinion that any independent claim (in the regional or national phase of the application) based on the division mechanism, e.g. frequency division, would not be acceptable if based on alternatives, i.e. only one mechanism could be considered as constituting one unifying inventive concept, since the more general concept of the application is already known from D2.

2.4 Claims 6-12

Although the subject matter of the claims 6-12 is not per se known from a combination of D1 and D2, these relate largely to the area of application of the sensor/control arrangement. The technology of the application, for instance vibration sensing, is considered to be independent of the arrangements for data transmission. As such these claims represent various juxtapositions of features which would appear to be known in themselves, as such the examiner considers them not to involve an inventive step, Art. 33(3) PCT.

It is furthermore noted that claim 10 lacks clarity, Art. 6 PCT. The reason being that a reference in parenthesis to "NVH" would appear not to be a reference to the drawings but an attempt to defined a short form for "noise vibration harshness".

The term "NVH" is then used without brackets in claim 22 and with brackets in claim 21. In the opinion of the examiner the brackets with the term "NVH" should not be used in any of the claims.

2.5 Claim 13

Claim 13 relates to an apparatus for wireless transmission of data using divided channels in which an asymmetric data rate in respective (so called sub-) channels is effected in accordance with **the different data rate requirements of local sensors.**

From the document D2, col. 1, lines 10-18 it is known to match data rate requirements with a particular channel transmission speed. The person skilled in the art would apply this principle to the specific example of data passing from a sensor without making an inventive step. The person skilled in the art would therefore incorporate this into the sensor / test arrangement of D1, see D1, fig. 1 and 2. In so doing, the person skilled in the art would assign channels in accordance with the different data rate requirements of respective sensors and so arrive exactly at the subject matter of claim 13 of the application without having made an inventive step.

The subject matter of claim 13 is therefore obvious in the light of the available prior art D1 and D2, and as such not allowable under Art. 33(3) PCT.

2.5 Claims 14-17

Claims 14 to 17 correspond to the method claims 2-5. For the reasons given above the examiner considers that claim 15 lacks an inventive step, time division being known from D2. Claims 14 and 17 could be considered to involve an inventive step and claim 16 could contain patentable subject matter but is so unclear, Art. 6 PCT, that it is not possible to be more specific as to any inventive quality of the claim.

2.6 Claims 18-23

Claims 18-23 comprise subject matter which is of a routine nature. The examiner is therefore of the provisional opinion that the person skilled in the art would arrive at the subject matter of claims 14-23 as a matter of normal design procedure, starting from the obvious combination of D1 and D2. The subject matter of claims 14 to 23 is therefore not allowable under Art. 33(3) PCT.

2.6 Claim 24

Claims 24 and 25 relate to sensing in three dimensions. The closest prior art to claims 24 and 25 would appear to be D3. D3 also relates to vibration sensing in three dimensions.

Claim 24 is a method claim, D3 discloses:

a. a method for vibration analysis of a machine or other article (see abstract) comprising;

a. providing a vibration sensor (1)

b. causing the sensor to sense vibrations (see abstract)

c. analysing signals produced by said sensor (15, see col. 5, lines 60-62)

d. providing the sensor with 3d location sensing means (D3, col. 6, lines 25-50)

e. causing a single vibration sensor to monitor 3 dimensions, (see fig. 2 and col. 4, lines 64-65 of D3) and using the coordinate measuring system to measure the coordinates at these points (D3, col. 6, lines 25-50)

The subject matter of D3 differs from that of the application claim 24 only in that the features:

f. "identifying the location of a source of vibration accordingly" is not explicitly disclosed in D3;

and the feature of mechanical contact is not disclosed in D3, D3 operating with light beams.

However, in col. 1, lines 15-25 of D3, it is disclosed that it is necessary to understand as accurately as possible the vibration characteristics of a machine etc.

In the opinion of the examiner, to identify the source of a vibration is an obvious desire of the person skilled in the art who wishes to understand "as accurately as possible" the vibration characteristics of a machine.

In addition the examiner is of the opinion that the choice of sensor, being light beam sensor or a mechanical sensor is merely one of design choice which the person skilled in the art would make without having made an inventive step.

Since the other features of claim 24 are not different from those of D3, the examiner is of the opinion that claim 24 of the application lacks an inventive step and as such is not allowable under Art. 33(3) PCT.

It is furthermore noted that claim 24 is not allowable under Art. 6 PCT since it lacks clarity. In particular the "said three locations" (line 26) are not actually previously referred to in the claim. It would appear that the author of the claim confuses "three-dimensions" with three locations, in the opinion of the examiner a singe point can be defined in "three-dimensions" and this in no way implies there to be three points.

2.7 Claim 25

Claim 25 is an apparatus claim which claims (in terms of an apparatus) the features a. to d. corresponding to those features a. to d. in claim 24.

As discussed above in part 2.6 of this opinion, these features are all known from the document D3, except for the feature of mechanical sensing. As discussed above the examiner is of the opinion that this combination of features lacks an inventive step as such claim 25 does not fulfil the requirements of Art. 33(3) PCT.

PAT● COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference P53206WO	**FOR FURTHER ACTION** see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/GB 98/ 00866	International filing date *(day/month/year)* 03/04/1998	(Earliest) Priority Date *(day/month/year)* 03/04/1997
Applicant SUN ELECTRIC UK LIMITED et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 5 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. [ ] **Certain claims were found unsearchable** (see Box I).

2. [X] **Unity of invention is lacking** (see Box II).

3. [ ] The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
   - [ ] filed with the international application.
   - [ ] furnished by the applicant separately from the international application,
     - [ ] but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
   - [ ] Transcribed by this Authority

4. With regard to the **title**,
   - [ ] the text is approved as submitted by the applicant.
   - [X] the text has been established by this Authority to read as follows:

   WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM

5. With regard to the **abstract**,
   - [X] the text is approved as submitted by the applicant.
   - [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this International Search Report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is:

   Figure No. 1
   - [X] as suggested by the applicant.
   - [ ] because the applicant failed to suggest a figure.
   - [ ] because this figure better characterizes the invention.
   - [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/00866

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G08C15/02 G08C17/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G08C G01R H04J G01H A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 738 133 A (BRECKEL ET AL) 19 April 1988	1-3,7, 13-15
A	see abstract	4-6,8, 16-19
	see column 1, line 63 - column 2, line 31; figures 1,2	
Y	GB 2 295 070 A (ALPS ELECTRIC CO. LTD.) 15 May 1996 cited in the application	1-3,7, 13-15
A	see abstract	4-6,8, 16-19
A	US 5 509 013 A (ADACHI ET AL) 16 April 1996 cited in the application see abstract see column 1, line 19 - line 64; figure 1	5,17

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 1998	18. 11. 98

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	O'Reilly, D

2

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	DE 41 31 341 A (MERCEDES-BENZ AKTIENGESELLSCHSAFT) 26 November 1992 see abstract see column 1, line 53 - line 64; figures 1,2 ---	2,14
A	DE 41 06 572 A (FRAUNHOFER-GESELLSCHAFT) 3 September 1992 see abstract see column 2, line 20 - line 29; figure 2 ---	24,25
A	EP 0 685 390 A (MITSUBISHI) 6 December 1995 see abstract see column 2, line 36 - column 3, line 2; figure 6 ---	24,25
A,P	US 5 622 170 A (SCHULTZ) 22 April 1997 cited in the application see abstract see column 4, line 25 - line 49; figure 1A -----	24,25

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 98/00866

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4738133 A	19-04-1988	DE 3538687 A	07-05-1987
		EP 0221383 A	13-05-1987
GB 2295070 A	15-05-1996	JP 8140165 A	31-05-1996
		JP 8191485 A	23-07-1996
		DE 19541637 A	30-05-1996
		US 5737335 A	07-04-1998
US 5509013 A	16-04-1996	JP 7074722 A	17-03-1995
DE 4131341 A	26-11-1992	NONE	
DE 4106572 A	03-09-1992	NONE	
EP 685390 A	06-12-1995	CA 2096069 A	15-11-1993
		CA 2185473 A	15-11-1993
		DE 69315887 D	05-02-1998
		DE 69315887 T	20-05-1998
		EP 0569994 A	18-11-1993
		JP 6135395 A	17-05-1994
		US 5571969 A	05-11-1996
US 5622170 A	22-04-1997	US 5383454 A	24-01-1995
		AU 6666894 A	08-11-1994
		CA 2161126 A	27-10-1994
		EP 0700269 A	13-03-1996
		IL 109385 A	10-03-1998
		JP 8509144 T	01-10-1996
		WO 9423647 A	27-10-1994
		ZA 9402812 A	22-11-1995
		AU 8876391 A	20-05-1992
		CA 2094251 A	20-04-1992
		DE 9117261 U	06-08-1998
		EP 0553246 A	04-08-1993
		SE 9301262 A	18-06-1993
		WO 9206645 A	30-04-1992

INTERNATIONAL SEARCH REPORT

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. [ ] Claims Nos.:
   because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. [X] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. [ ] As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[X] No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-23

   Multiplex data transmission via a wireless with different rates in each channel

2. Claims: 24,25

   Vibration analysis using a sensor

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

ARCHER, Philip, Bruce
Urquhart-Dykes & Lord
New Priestgate House
57 Priestgate
Peterborough
Cambs PE1 1JX
ROYAUME-UNI

Date of mailing (day/month/year) 30 September 1999 (30.09.99)	
Applicant's or agent's file reference P53206WO	**IMPORTANT NOTIFICATION**
International application No. PCT/GB98/00866	**International filing date** (day/month/year) 03 April 1998 (03.04.98)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address	State of Nationality	State of Residence
SUN ELECTRIC UK LIMITED Unit 12 Horsleys Fields King's Lynn Norfolk PE30 5DD United Kingdom	GB	GB
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address	State of Nationality	State of Residence
SNAP-ON EQUIPMENT LIMITED Unit 12 Horsleys Fields King's Lynn Norfolk PE30 5DD United Kingdom	GB	GB
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[ ] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Margret Fourne-Godbersen Telephone No.: (41-22) 338.83.38

P/ :NT COOPERATION TREA'ı

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

United States Patent and Trademark Office
(Box PCT)
Crystal Plaza 2
Washington, DC 20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 26 November 1998 (26.11.98)	
International application No. PCT/GB98/00866	**Applicant's or agent's file reference** P53206WO
International filing date (day/month/year) 03 April 1998 (03.04.98)	**Priority date** (day/month/year) 03 April 1997 (03.04.97)
Applicant JONES, Barbara, Lynn et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

03 November 1998 (03.11.98)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer G. Bähr Telephone No.: (41-22) 338.83.38

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 8901267

SA 28150

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 08/08/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A- 0260364	23-03-88	US-A- 4734907	29-03-88
		CA-A- 1254985	30-05-89
		JP-A- 62155648	10-07-87

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

U.S. Appl. No. 09/4022[illegible]2 International Application No. GB98/00866

Application filed by: ☐ 20 months ☐ 30 months

INTERNATIONAL APPLICATION PAPERS IN THE APPLICATION FILE:

- ☐ International application (RECORD COPY)
- ☐ Article 19 amendments
- ☑ PCT/IB/331
- ☑ PCT/IPEA/409 IPER (PCT/IPEA/416 on front)
- ☑ Annexes to 409
- ☐ Priority document(s) No. ________
- ☐ INTERNATIONAL APPLICATION ON DOUBLE SIDED PAPER (COPIES MADE)
- ☐ Request form PCT/RO/101
- ☑ PCT/IB/302
- ☑ PCT/ISA/210-Search Report
- ☑ Search Report references
- ☐ Other ________

RECEIPTS FROM THE APPLICANT: (other than checked above)

- ☑ Basic National Fee (paid or authorized to charge)
- Translation of international application as filed:
  - ☑ Description
  - ☑ Claims
  - ☐ Words in the drawing figure(s)
  - ☐ Article 19 amendments
  - ☑ Annexes to 409 entered
- ☑ Oath / Declaration
- ☐ DNA diskette
- ☐ Preliminary amendment(s) filed
- ☐ Information Disclosure Statement
- ☐ Assignment document
- ☑ Power of attorney/Change of address
- ☐ Substitute specification
- ☐ Verified small status claim
- ☐ Other ________

Notes:

35 U.S.C. 371 - Receipt of Request (PTO-1390)	01 Oct 99
Date acceptable oath / declaration received	28 Feb 2000
Date complete 35 U.S.C 371 requirements met	
102(e) Date	
Date of completion of DO/EO 906 - Notification of Missing 102(e) Requirements	
Date of completion of DO/EO 907 - Notification of Acceptance for 102(e) date	
Date of completion of DO/EO 911 - Application accepted under 35 U.S.C. 1.11	
Date of completion of DO/EO 905 - Notification of Missing Requirements	12/14/99
Date of completion of DO/EO 916 - Notification of Defective Response	
Date of completion of DO/EO 903 - Notification of Acceptance	10 Mar 00

WIPO Publication

Publication No WO 98/44471

Publication Date 08 Oct 98

Publication Language English

Not Published
- ☐ U.S. only Designated
- ☐ EP request

Screening done by: P. Kidwell

PCT/GB98 / 00866

The Patent Office

The Patent Office 9840 2262
Concept House
Cardiff Road
Newport
South Wales
NP9 1RH

REC'D 22 JUN 1998
WIPO PCT

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed G D Court.

Dated - 2 JUN 1998

PRIORITY DOCUMENT

'ents Form 1/77

Patents Act 1977
(R... 16)

The Patent Office

04APR97 E265116-1 002835
P01/7700 25.00

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

THE PATENT OFFICE
A
-3 APR 1997
RULE 97
RECEIVED BY POST

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1. Your reference	P53206GB	
2. Patent application number *(The Patent Office will fill in this part)*	**9706797.9**	03 APR 1997
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	SUN ELECTRIC UK LTD UNIT 12 HORSLEYS FIELDS KING'S LYNN NORFOLK, PE30 5DD	
Patents ADP number *(if you know it)*	6707442002	
If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM	
4. Title of the invention	WIRELESS DATA TRANSMISSION	
5. Name of your agent *(if you have one)* "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	**Urquhart-Dykes & Lord** New Priestgate House 57 Priestgate Peterborough Cambridgeshire PE1 1JX UNITED KINGDOM	
Patents ADP number *(if you know it)*	1644009	

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

YES

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	11
Claim*(s)*	5
Abstract	1
Drawing*(s)*	3

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	1
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature　　　　Date

URQUHART-DYKES & LORD　　2/4/97

12. Name and daytime telephone number of person to contact in the United Kingdom

PHILIP B ARCHER
01733 340011

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.

b) Write your answers in capital letters using black ink or you may type them.

c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.

d) If you have answered 'Yes' Patents Form 7/77 will need to be filed.

e) Once you have filled in the form you must remember to sign and date it.

f) For details of the fee and ways to pay please contact the Patent Office.

WIRELESS DATA TRANSMISSION

This invention relates to a method and apparatus for wireless transmission of data through a communications channel comprising at least two local data sensors and a data processing function to receive data from the local sensors. A non-limiting example of the application of the method is in the field of automotive diagnostic equipment and related automotive service equipment. A particularly practical application of the invention is to noise vibration harshness (NVH) analysis of automotive and other machines to enable two or three-dimensional location pinpointing of vibration sources, for example in automotive warranty investigations and indeed in many other machine applications.

In this specification and the claims, references to local data sensors are to be interpreted in accordance with the following, namely that the sensors may transmit raw data for subsequent processing or one or more of these may incorporate some degree of primary data processing whereby the data received at the main processor is partially or totally pre-processed or indeed raw data.

In the field of automotive diagnostics and servicing there has been for a good many years a requirement for a step forward in terms of the transmission of diagnostic and servicing data from data sensors to a data processing function which operates to analyse and/or display the corresponding data for use by a person carrying out servicing and/or diagnostic functions on a motor vehicle. Conventionally, the data is transmitted from the data sensors to the data processing function via conventional conductors or cables which impose obvious inconveniences and limitations on the convenient operation of the equipment. Attempts have been made to reduce these drawbacks in several ways. Firstly, various proposals have been made to simplify the use of cable connectors as such. For example, one proposal in this regard provides for a system in which a boom-mounted data-handling sub-unit is conveniently manoeuvrable to a location close to the automotive sensors and is thus linked to them by relatively short cable connections. This arrangement undoubtedly does reduce somewhat the inconvenience of the cable connection systems but by no means eliminates it.

Various attempts have been made to achieve effective wireless transmission of data between automotive data sensors and a corresponding data-processing and/or display function but these have been relatively unsuccessful. The main shortcoming of such prior proposals has been the sheer volume of data, and the composite nature of the data (such as a mixture of data types eg digital and analogue). A further factor among the shortcomings of these prior proposals is also the composite nature of the data bandwidths to be transmitted. Such data needs to be transmitted and has conventionally been handled by a harness of 12 or more conduction cables. By adopting conventional wireless transmission systems for such data communication there is immediately a problem of excessive bandwidth requirements arising from the fact that some at least of the data sensors for this automotive application produce high data rates necessitating corresponding band widths to accommodate them. This does not apply to all the sensors.

Accordingly, we have identified a requirement for a method and apparatus for the wireless transmission of data through a communications channel from at least two local data sensors with optional primary data processing, to a data processing function, offering improvements in relation to prior proposals in this field, notably in relation to the bandwidth requirement and/or related functions attendant on the simultaneous transmission of data from a multiplicity of such local sensors.

There is disclosed in EP 0 483 549A2 (IBM CORP) a control method and apparatus for a wireless data link, for example, from a handheld workstation which is bidirectionally coupled to a base station through an infrared carrier. A robust control channel is provided separate from a data channel. The modulators employ on/off pulsing, multi-carrier modulation or direct sequence spread spectrum (DSSS) modulation. Each mobile unit is assigned an identifier or address and the system claims to overcome the problem of establishing and maintaining high bandwidth communication by separating the control channel from the data channel whereby the control channel bandwidths can be made significantly smaller.

In WO 89/09522 there is disclosed a method for allocating bandwidths in a broadband packet switching network using a set of parallel packet channels that act as a single data link connection between packet switches. Bandwidth is initially allocated to particular channel groups (at initial circuit set-up times) and to individual channels within the groups (at transmission times) so as to increase throughput and reduce packet loss. For bursty traffic, the use of channel groups reduces the packet loss by several orders of magnitude.

EP 0 515 728A2 relates to a wireless indoor relay system. AU-A-18143/88 relates to a wireless data transmission link and notably a protocol for establishing a duplex link between first and second data link devices.

According to the invention there is provided a method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors with optional primary data processing and a data processing function, as defined in the accompanying claims.

In a described embodiment, there is provided a method and apparatus in which the step of multiplexing division of the communications channel is effected asymmetrically, whereby the data carrying capacities of the sub-channels are unequal. Likewise in the embodiment, the data rates required for data transmission from the local sensors differs substantially between the at least two sensors. Likewise also in the embodiment, the step of allocating data from the local data sensors to the data transmission sub-channels is effected in accordance with the data-carrying capacities of these sub-channels. In this way there is achieved within a communications channel, the economical use of the available bandwidth whereby the allocation of bandwidth corresponds with the band width requirements of the individual data sensors. Thus, in the case of a sensor sensing data relating to ignition events which occur at a relatively high speed and thus require a corresponding significant allocation of bandwidth for satisfactory transmission, such is provided, whereas in the case of a sensor sensing alternator voltage (to take a simple example) the required that transmission rate is smaller by many orders of magnitude and likewise the corresponding bandwidth requirements.

Whereas prior proposals in relation to data transmission for automotive and related systems (in which data sensors produce substantially differing data rates) have ignored or overlooked these differing data rate requirements, with the result that the use of equal bandwidth sub-channels has led to a non-utilisation of sub-channel bandwidths for significant numbers of sensors whereby the overall utilisation of data transmission capacity allocated to the communications system has been very far from perfect.

In accordance with the embodiments of the invention, the use of a system in which data is fed via a "multiplexing" control system which allocates data to sub-channels in accordance with the actual data rate requirement of the individual data flow, each such data flow is thereby far more closely matched to the available capacity of its sub-channel and the twin evils of sub-channel under-utilisation and under-capacity (for a given data flow) are thereby avoided.

In one significant embodiment, the multiplex control system divides the communications channel on a frequency basis and allocates the data streams from the sensors to the frequency sub-channels accordingly.

In another important embodiment, the multiplexing control system divides the data communication channel on a time-division basis and likewise divides the data streams accordingly.

The reference above to "multiplexing" has been adopted to draw attention to the fact that references in this specification and in the claims to "multiplexing" are intended not to be limited strictly to non time-overlap or signal-chopping systems (such as would be obtained with a distinct signal-chopping technique). The term "multiplexing" in this description and the claims includes the provision of multiplexing systems which are adapted to effect multiplexing on an interdigitated and non-chopping data-allocation basis in which a degree of data element transmission time-overlap between channels is permitted. The data allocation systems for data-division between available channels can be readily designed accordingly by the technically skilled person so as to, in this way, more readily meet the technical parameters imposed on the system, as described below.

In a yet further embodiment, the multiplexing system achieves its channel division on a packet-switching basis and the interleaved data packets are distributed on an unsymmetrical basis.

In the embodiment, there is provided a radio frequency data rate of 1 to 4 Mb (megabits) per second. The multi-channel system can accommodate the requirements eg for the transmission of data for operating an oscilloscope system for engine analysis.

While the described embodiments utilise radio frequency transmission, the principles of the invention may well be applicable outside radio frequencies.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Fig 1 shows a functionality block diagram for a high speed RF data link, including both the frequency multiplexing system (of Figs 2 and 3) and the time-division multiplexing system (of Figs 4 and 5 hereof);

Figs 2 and 3 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as it applies to a frequency multiplexing system; and

Figs 4 and 5 show block diagrams of the transmitter and receiver functions of the system of Fig 1 as they apply to a time-division multiplexing system.

As shown in Fig 1, a system 10 for wireless transmission of data through a communications channel

12 between local data sensors 14, 16, 18, 20 and 22, and a data-processing function or personal computer 24, to receive data therefrom, comprises the following main elements.

Firstly, as regards the local data sensors 14 to 22, as shown these comprise an engine tester 14, a gas bench 16, a scanner 18 and auxiliary sensors indicated as Aux 1 and Aux 2. These sensors are intended to be representative of the entire range of automotive sensors which are currently utilised for diagnostic and servicing processes, including for example vibration sensors (for RPM testing) ignition and alternator ripple sensors (likewise for RPM measurement), emissions analysis sensors, battery analysis sensors and the like.

Indicated at 26 is the remote receive/transmit unit to which the individual sensors 14 to 22 are connected. The duplex (transmit/receive) operating characteristics of this unit arise from the need for the return transmission of data from the data processing function 24 for set-up purposes.

Broadly, the system comprises antennae 28, 30 connected to receive/transmit functions 32 and 34 within remote unit 26. Likewise, a receive/transmit unit or function 36 is provided for PC 24. A receive buffer 38 and a controller 40 serve to interconnect the transmit and receive functions 34, 32 to a series of RS-232 interfaces 42 to 50, each connected to its respective one of the local sensors 14 to 22.

Interfaces 42, 44, 46, 48 and 50 are serial interfaces providing for serial communication between the sensor and the receive/transmit function 32, 34 via buffer 38 and controller 40. Interface 42 is a high speed serial interface. Interfaces 44, 46, 48 and 50 are RS-232 interfaces. Interfaces 44, 46 are designated in Fig 1 as "UART1" and "UART2", referring to their function as universal asynchronous receiver/transmitter devices (or interfaces) for serial transmission of data. Receive buffer 38 and controller 40 provide data processing functions relevant to the inflow and outflow of data for the duplex operating characteristics of system 10 as will be more fully described below in relation to Figs 2, 3, 4 and 5. Accordingly, the details of these aspects of the system 10 will now be described further with reference to Figs 2, 3, 4 and 5.

As shown in Figs 2 and 3, the RX buffer 38 and controller 40 provide data processing/signal conditioning functions to be more fully described below.

As shown in Fig 2, inputs from the individual sensors 14 to 22 are indicated at 52 and 54 which are marked "Sensor 1" and "Sensor 16" to indicate that the system can accommodate 16 individual inputs.

The main function of controller 40 is to provide a multiplexing function whereby communication channel 12 is divided into 16 sub-channels on a frequency basis, these channels being of unequal band width and being allocated according to band width (more band width for greater band width requirement) to the individual data channels 1 to 16.

Interfaces 42 to 50 in Fig 1 provide the signal conditioning function indicated in Fig 2 at 56. The functions of controller 40 are shown as divided into functions 58, 60 and 62, namely voltage frequency conversion, secondary (low frequency) frequency conversion and sub-channel combination respectively. Each function operates in relation to all 16 sub-channels.

The sub-channel combination function at 62 produces a serial data stream which is fed to the RF transmitter function 34 and thus to the helical or other suitable antenna 28.

A further function of controller 40 is to append the relevant sub-channel number to each sub-channel of raw data so that this data stream can be routed to the relevant virtual serial port of PC 24 after radio transmission between antennae 28 and 30.

In this embodiment, the multiplexing sub-division of the data communication channel is provided on a frequency basis, whereas in the embodiment of Fig 4 the multiplexing is effected on a time-division basis.

As shown in Fig 3, RX buffer 38 provides the related inverse functions for signals received via antenna 28 and receiver functions 32. These functions are indicated at 64 and 66 and 68 and correspond, respectively, with the functions 62, 60 and 58 respectively in Fig 2. No further description is therefore deemed necessary.

In operation, data from sensor 14 to 22 (or indeed from the 16 sensors indicated in Fig 2) is processed in accordance with the functions 56, 58, 60 and 62 as shown in Fig 2. The data streams are allocated to the 16 sub-channels indicated diagrammatically at 64 in Fig 2. The allocation is effected in accordance with the known data rate requirements of the individual sensors, according to their known uses. In general terms, the band width of each sub-channel is matched to comfortably accommodate the data rate requirements of its respective data stream, but without the over-provision which tends to occur in certain cases with conventional use of conventional data transmission equipment.

Turning now to the time-division embodiment of Fig 4, parts corresponding to those described above in relation to Figs 2 and 3 are numbered accordingly in Fig 4.

In Fig 4, the signal conditioning function 56 corresponds to that provided by the serial interfaces 42 to 50 in Fig 1. However, in this embodiment the controller function 40 differs from that of Fig 2 in being a time-division based function (utilising a 16-way switch function 66 to provide the time-based multiplexing function corresponding to the frequency-based multiplexing of Figs 2 and 3). A 12 bit analogue-to-digital conversion function 68 processes data from switch function 66 and is linked to a microcontroller 70 (an asynchronous PIC 16C54 communications element) coupled to RF transmitter 34. Microcontroller 70 provides at 72 a control signal to switch 66 in accordance with the time-based multiplexing function which controls the sub-channel data capacities in accordance with the required data rates of the sensor input. A related control function 74 is provided to ADC converter 68.

As shown in Fig 5, the data processing function 24 in Fig 1 receives data via antenna 30 and receiver 36 through a decoding function 76 shown in Fig 5 and comprising a microcontroller 78 corresponding to microcontroller 70 which feeds data via a digital-to-analogue converter 80 to workstation of PC 24. The microcontroller 78 produces a channel message 82 for the workstation enabling same to allocate the decoded data stream to respective virtual serial ports set up in the PC for data analysis and display purposes.

This embodiment allocates data streams to respective data channels on the same principle described above but on a time-division basis instead of a frequency-division basis.

In a further embodiment, not shown, in which a packet-switching data transmission technique is employed, the allocation of data streams to packets is effected asynchronously in accordance with the matching of data rate to sub-channel capacity discussed above, thereby producing the corresponding asymmetrical interleaving of the data packets.

In the frequency-multiplexed embodiment of Figs 2 and 3, a modification may be employed whereby spread spectrum frequency division is utilised thereby reducing or eliminating the requirement to label the sub-channels by means of identifying data.

CLAIMS

1 A method of wireless transmission of data through a communications channel between at least two local data sensors and a data processing function to receive data therefrom, said method comprising the step of multiplexing division of said channel into sub-channels and transmitting said data from said data sensors through said sub-channels accordingly;

characterised by

a) said step of multiplexing division of said communications channel being effected asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) the data rate required for data transmission from said local sensors differing substantially between said at least two sensors; and

c) the step of allocating data from said local data sensors to said sub-channels being effected in accordance with the data carrying capacities of said sub-channels.

2 A method according to claim 1 characterised by said step of multiplexing being effected on a frequency basis.

3 A method according to claim 1 characterised by said step of multiplexing being effected on a time-division basis.

4 A method according to any one of claims 1 to 3 characterised by said step of multiplexing being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time overlap between channels is permitted.

5 A method according to claim 1 characterised by said step of multiplexing being effected by packet-switching of data from said local sources, and the interleaving of said data packet being effected with an unsymmetrical packet distribution.

6 A method according to any one of claims 1 to 5 characterised by said data processing function comprising a host PC having a series of virtual serial ports, and said method comprising allocating each of said sub-channels to a corresponding one of said virtual serial ports.

7 A method according to any one of claims 1 to 6 characterised by said local sensors comprising automotive diagnostic and/or servicing sensors and said wireless transmission of data being effected at radio frequencies.

8 A method according to any one of claims 1 to 7 characterised by at least one of said local sensors also providing a primary data-processing function.

9 A method according to any one of claims 1 to 8 characterised by said local sensors comprising vibration sensor means adapted to sense machine vibration, and said method comprising transmitting said data therefrom.

10 A method according to claim 9 characterised by the step of using as said sensors, sensors adapted to provide vibration data permitting noise vibration harshness (NVH) analysis thereof.

11 A method according to claim 10 characterised by at least two, and preferably three or more, of said

sensors being such NVH sensors, and the method comprising employing said sensors at three-dimensionally spaced locations to identify the location or co-ordinates of a source of vibration.

12 Apparatus for wireless transmission of data through a communications channel between at least two local data sensors and a data processing function to receive data therefrom, the apparatus comprising a multiplexer adapted to effect division of said communications channel into sub-channels, and a transmitter adapted to transmit said data through said sub-channels accordingly;

characterised by

a) said multiplexer being adapted to divide said communications channel asymmetrically whereby the data carrying capacities of said sub-channels are unequal; and

b) control means adapted to allocate data from said local data sensors to said communications sub-channels in accordance with substantially different data rate requirements from said local sensors.

13 Apparatus according to claim 12 characterised by said multiplexer being adapted to effect said multiplexing on a frequency basis.

14 Apparatus according to claim 12 characterised by said multiplexer being adapted to effect said multiplexing on a time-division basis.

15 Apparatus according to any one of claims 12 to 14 characterised by said multiplexer being adapted to effect said multiplexing on an interdigitated non-chopping data-allocation basis in which a degree of data element transmission time-overlap between

channels is permitted.

16 Apparatus according to claim 11 characterised by said multiplexer being adapted to effect packet-switching of data from said local sources and to interleave said data packets with an unsymmetrical packet distribution.

17 Apparatus according to any one of claims 12 to 16 characterised by said data processing function comprising a host PC having a series of virtual serial ports, and said control means being adapted to allocate each of said sub-channels to a respective one of said virtual ports.

18 Apparatus according to any one of claims 12 to 17 characterised by at least one of said local sensors being adapted to provide a primary data-processing function.

19 Apparatus according to claim 18 characterised by said local sensors comprising vibration sensor means adapted to sense machine vibration whereby said apparatus can transmit said vibration data therefrom.

20 Apparatus according to claim 19 characterised by said local data sensors comprising sensors adapted to provide vibration data permitting noise vibration harshness (NVH) data for analysis thereof.

21 Apparatus according to claim 20 characterised by said local data sensors comprising at least two, and preferably three or more, such NVH sensors whereby said sensors can be located at three-dimensionally spaced locations to provide data enabling identification of the location or co-ordinates of the

source of a vibration in a machine.

22 A method of wireless transmission of data through a communications channel, between at least two local data sensors and a data processing function substantially as described herein with reference to the accompanying drawings.

23 Apparatus for wireless transmission of data through a communications channel between at least two data sensors and a data-processing function to receive data therefrom, substantially as described herein with reference to the accompanying drawings.

ABSTRACT

A method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors (for example automotive diagnostic data sensors or NVH sensors), which may include a primary data-processing function, and data-processing function (for example a PC) to receive data therefrom. The system provides for assymetrical division of the communications channel on a frequency or time-division or packet-switching basis so that the corresponding assymetrical data transmission requirement of the local data sensors are matched to the capacity of their respective sub-channels whereby a single channel is capable of transmitting all the required data. A particularly practical application is to noise vibration harshness analysis of wireless-transmitted data from three-dimensionally spaced NVH sensors enabling spacial pinpointing of vibration sources in automotive warranty analysis studies.

High Speed RF Data Link - Block Diagram

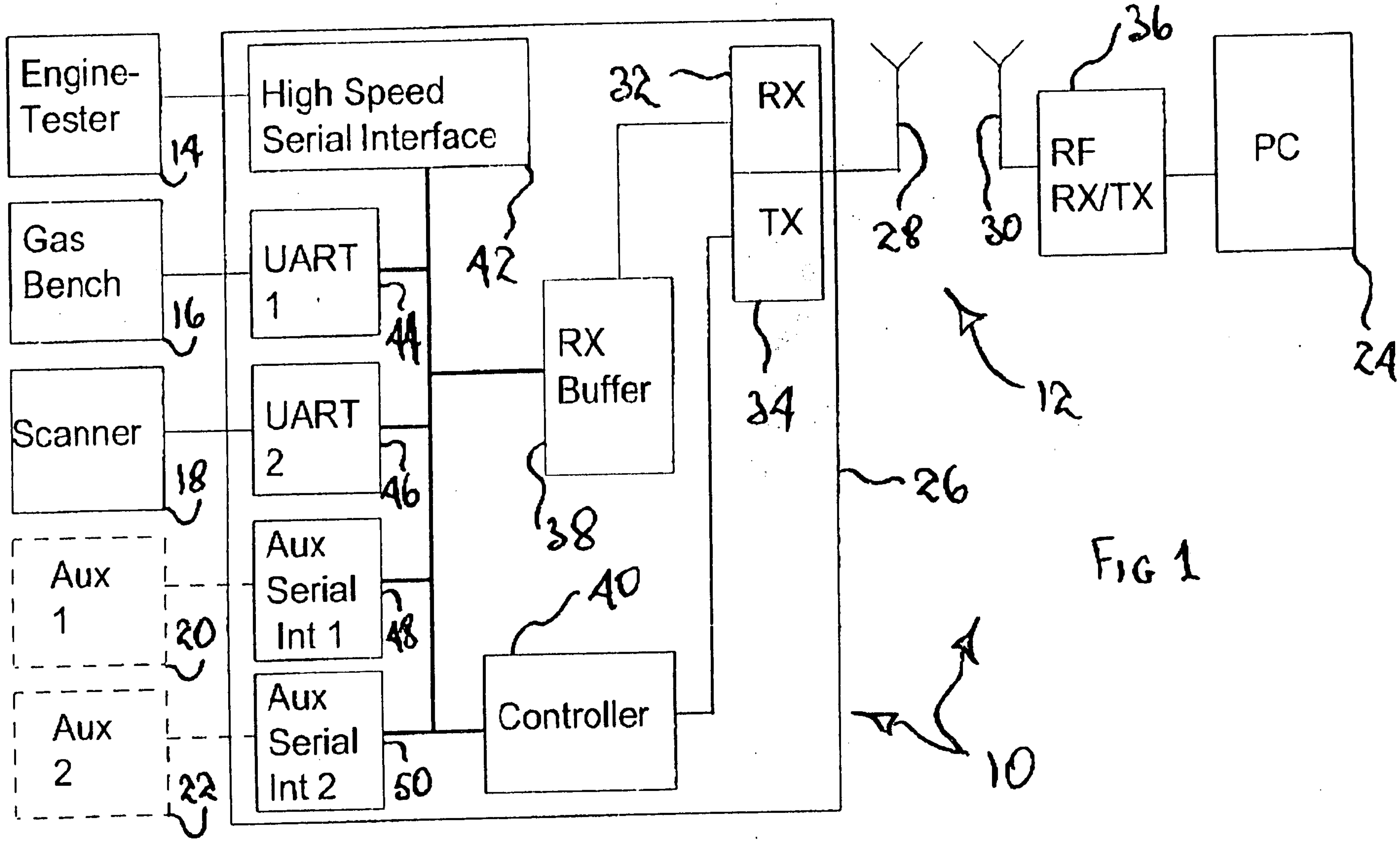

FIG 1

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DIAGNOSTIC RADIO TELEMETRY - FREQUENCY DOMAIN

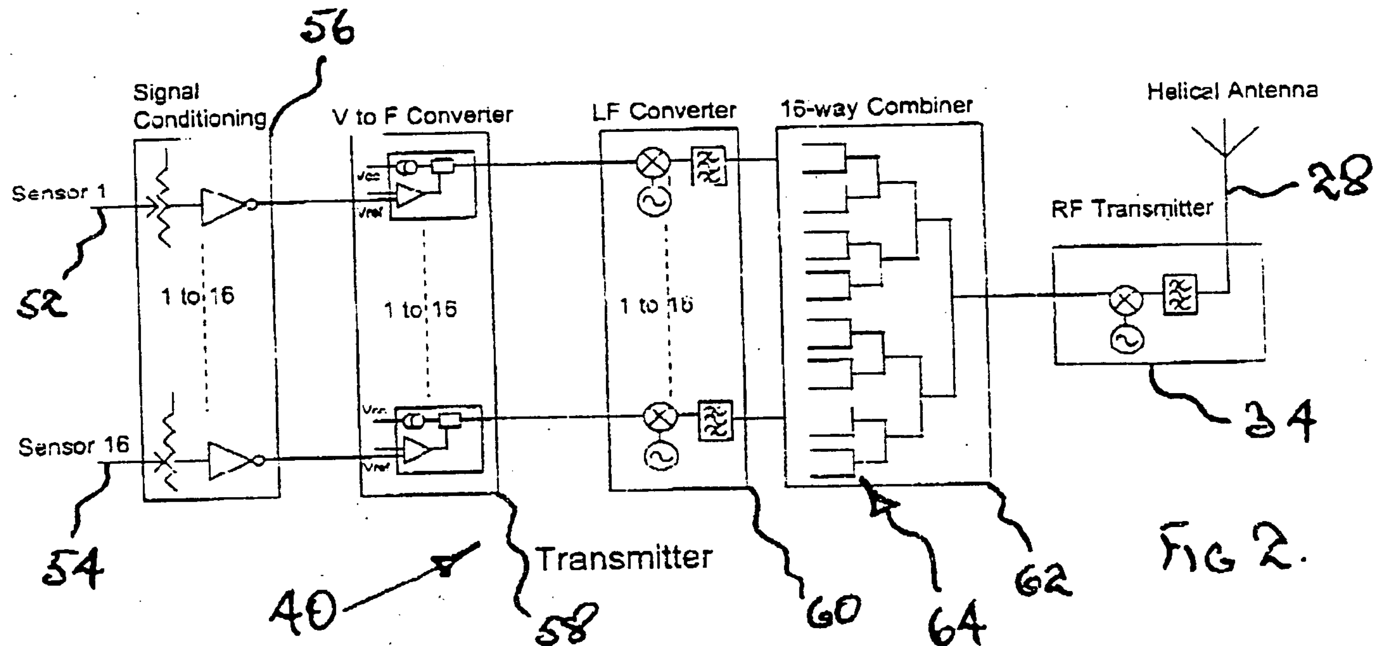

FIG 2.

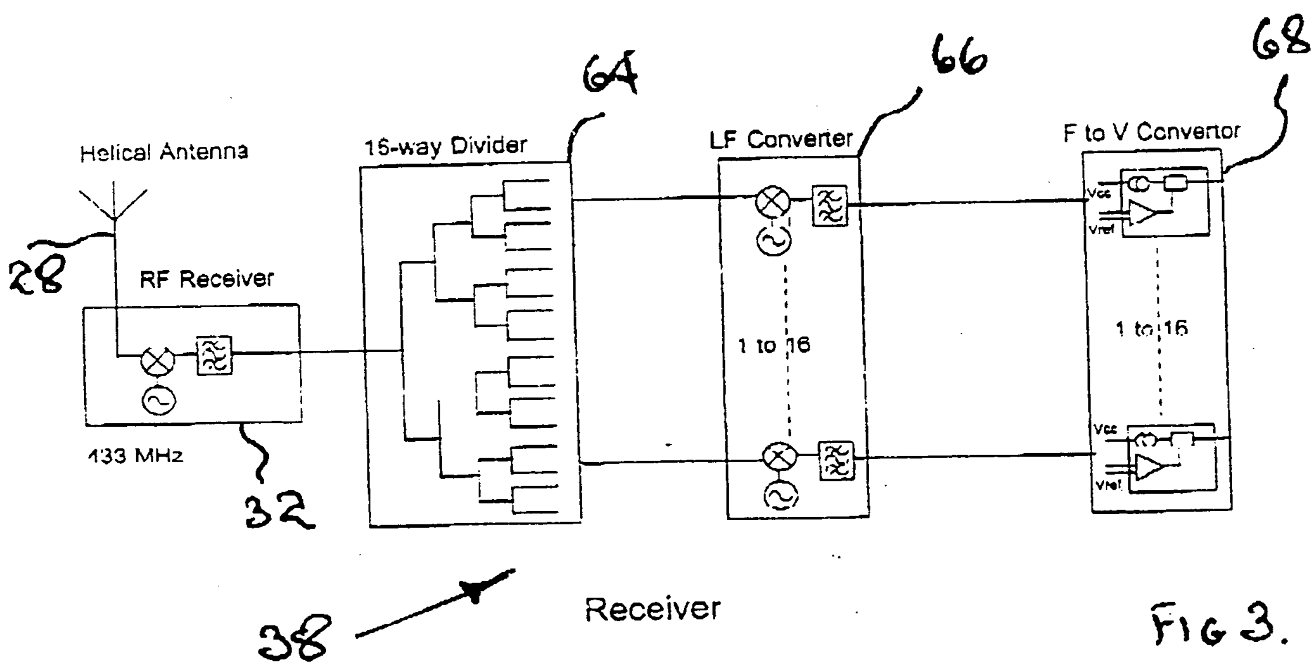

FIG 3.

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DIAGNOSTIC RADIO TELEMETRY - TIME DOMAIN

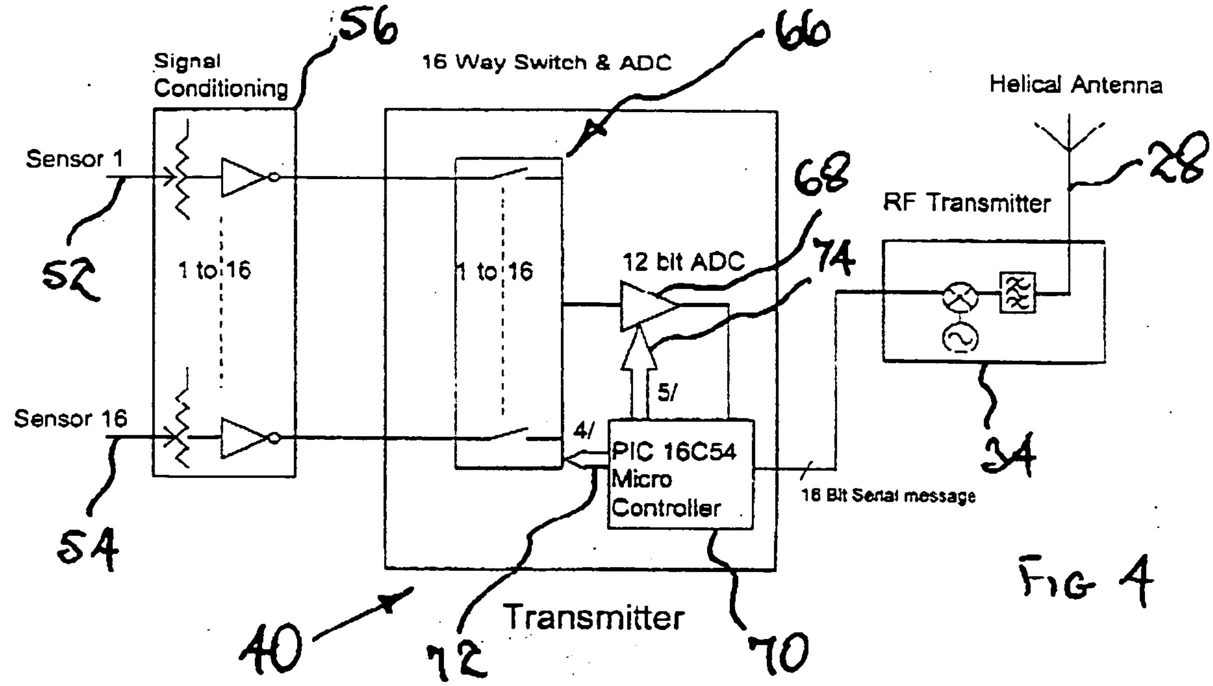

FIG 4

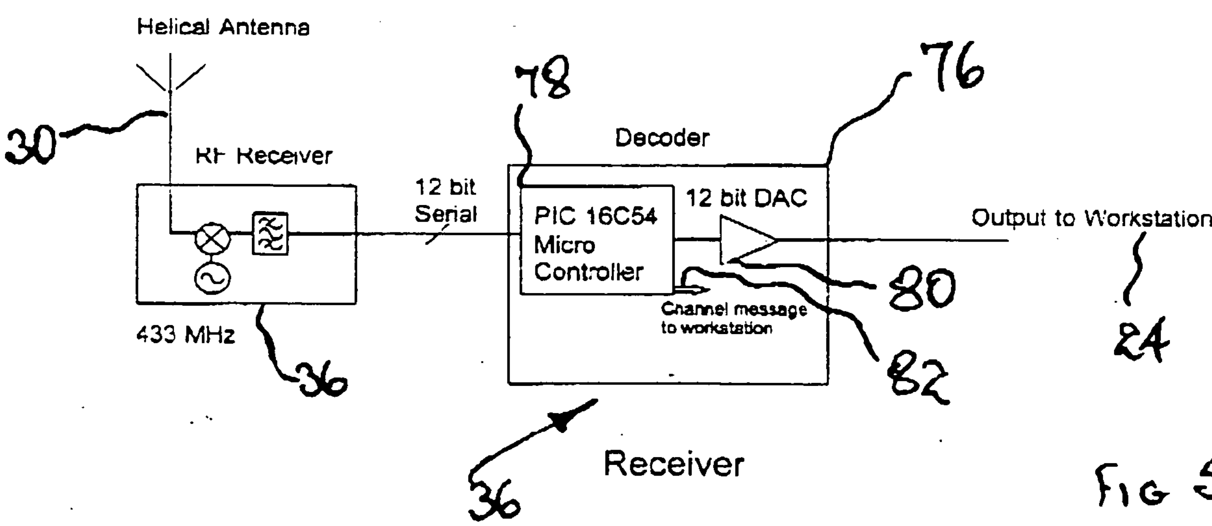

FIG 5.

PCT/GB98/00866

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : G08C 15/02, 17/02

A3

(11) International Publication Number: WO 98/44471

(43) International Publication Date: 8 October 1998 (08.10.98)

(21) International Application Number: PCT/GB98/00866

(22) International Filing Date: 3 April 1998 (03.04.98)

(30) Priority Data:
9706797.9 3 April 1997 (03.04.97) GB

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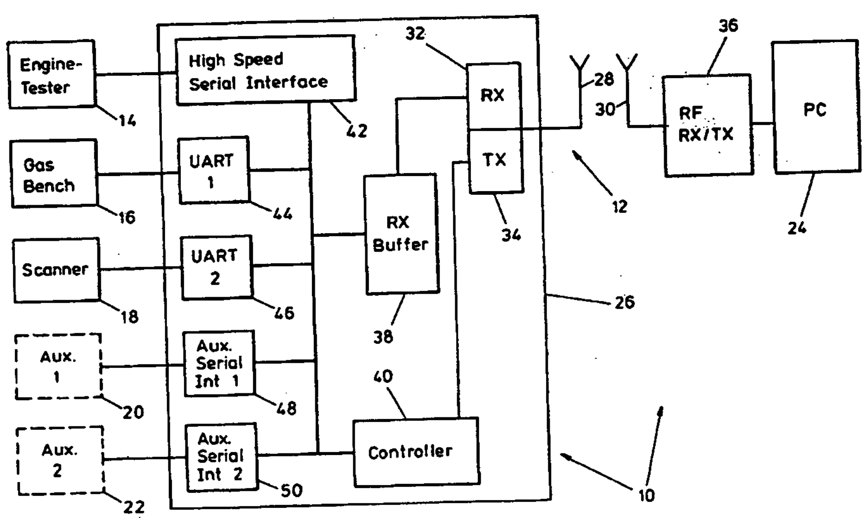
(81) Designated States: AU, CA, CN, JP, KR, MX, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(88) Date of publication of the international search report: 7 January 1999 (07.01.99)

(54) Title: WIRELESS MULTIPLEX DATA TRANSMISSION SYSTEM



(57) Abstract

A method and apparatus for wireless transmission of data through a communications channel between at least two local data sensors (for example automotive diagnostic data sensors or NVH sensors), which may include a primary data–processing function, and data–processing function (for example a PC) to receive data therefrom. The system provides for asymmetrical division of the communications channel on a frequency or time–division or packet–switching basis so that the corresponding asymmetrical data transmission requirement of the local data sensors are matched to the capacity of their respective sub–channels whereby a single channel is capable of transmitting all the required data. A particularly practical application is to noise vibration harshness analysis of wireless–transmitted data from three–dimensionally spaced NVH sensors enabling spacial pinpointing of vibration sources in automotive warranty analysis studies.

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/00866

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G08C15/02 G08C17/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G08C G01R H04J G01H A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 738 133 A (BRECKEL ET AL) 19 April 1988	1-3,7, 13-15
A	see abstract; see column 1, line 63 - column 2, line 31; figures 1,2	4-6,8, 16-19
Y	GB 2 295 070 A (ALPS ELECTRIC CO. LTD.) 15 May 1996 cited in the application	1-3,7, 13-15
A	see abstract	4-6,8, 16-19
A	US 5 509 013 A (ADACHI ET AL) 16 April 1996 cited in the application see abstract see column 1, line 19 - line 64; figure 1	5,17

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

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A	DE 41 31 341 A (MERCEDES-BENZ AKTIENGESELLSCHSAFT) 26 November 1992 see abstract see column 1, line 53 - line 64; figures 1,2 ---	2,14
A	DE 41 06 572 A (FRAUNHOFER-GESELLSCHAFT) 3 September 1992 see abstract see column 2, line 20 - line 29; figure 2 ---	24,25
A	EP 0 685 390 A (MITSUBISHI) 6 December 1995 see abstract see column 2, line 36 - column 3, line 2; figure 6 ---	24,25
A,P	US 5 622 170 A (SCHULTZ) 22 April 1997 cited in the application see abstract see column 4, line 25 - line 49; figure 1A -----	24,25

2

International application No.
PCT/GB 98/00866

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because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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see additional sheet

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1. Claims: 1-23

   Multiplex data transmission via a wireless with different rates in each channel

2. Claims: 24,25

   Vibration analysis using a sensor

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 98/00866

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/00866

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G08C15/02 G08C17/02

28 Rec'd PCT/PTO 01 OCT 1999

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Date of the actual completion of the international search	Date of mailing of the international search report
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Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 98/00866

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A	EP 0 685 390 A (MITSUBISHI) 6 December 1995 see abstract see column 2, line 36 - column 3, line 2; figure 6 ---	24,25
A,P	US 5 622 170 A (SCHULTZ) 22 April 1997 cited in the application see abstract see column 4, line 25 - line 49; figure 1A -----	24,25

International application No.
PCT/GB 98/00866

INTERNATIONAL SEARCH REPORT

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

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because they relate to subject matter not required to be searched by this Authority, namely:

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because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. [X] As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

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4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

[X] No protest accompanied the payment of additional search fees.

International Application No. PCT/GB 98/00866

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

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2. Claims: 24,25

   Vibration analysis using a sensor

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Information on patent family members

Inte ional Application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4738133 A	19-04-1988	DE 3538687 A	07-05-1987
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GB 2295070 A	15-05-1996	JP 8140165 A	31-05-1996
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