US006124806A

United States Patent [19]

Cunningham et al.

[11] **Patent Number: 6,124,806**

[45] **Date of Patent: Sep. 26, 2000**

[54] **WIDE AREA REMOTE TELEMETRY**

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[73] Assignee: **Williams Wireless, Inc.**, Tulsa, Okla.

[21] Appl. No.: **09/152,010**

[22] Filed: **Sep. 11, 1998**

Related U.S. Application Data

[60] Provisional application No. 60/058,978, Sep. 12, 1997, and provisional application No. 60/094,057, Jul. 24, 1998.

[51] **Int. Cl.**[7] **G08B 23/00**

[52] **U.S. Cl.** **340/870.02**; 340/870.19

[58] **Field of Search** 340/870.02, 870.07, 340/870.11, 870.03, 870.19, 825.06

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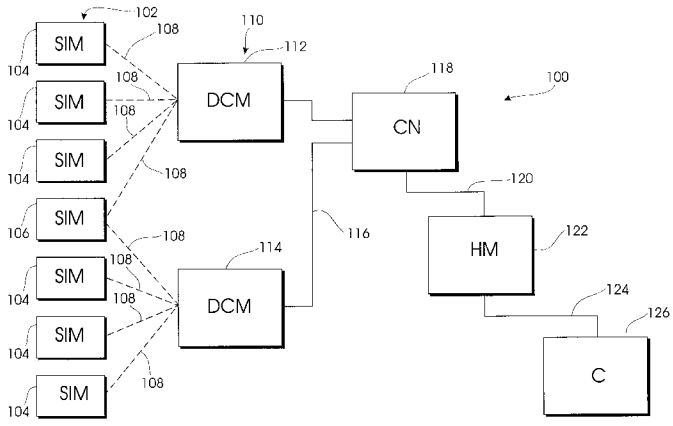
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Primary Examiner—Brian Zimmerman
Assistant Examiner—Timothy Edwards, Jr.
Attorney, Agent, or Firm—Head, Johnson & Kachigian

[57] **ABSTRACT**

A wide-area remote telemetry system which monitors and controls remote devices by means of a information control system. The system uses a plurality of sensor interface modules which constantly monitor devices for triggering events. The sensor interface modules transmit information to at least one data collection module which gathers, process, stores and transmits information to a host system via standard external communication systems. The host module receives, records, processes, and transmits information to the network. The information may then be transmitted to customers or may be accessed by customers as desired.

2 Claims, 42 Drawing Sheets



Emerson Exhibit 1018
Emerson Electric v. Ollnova
IPR2023-00626

FIG. 1

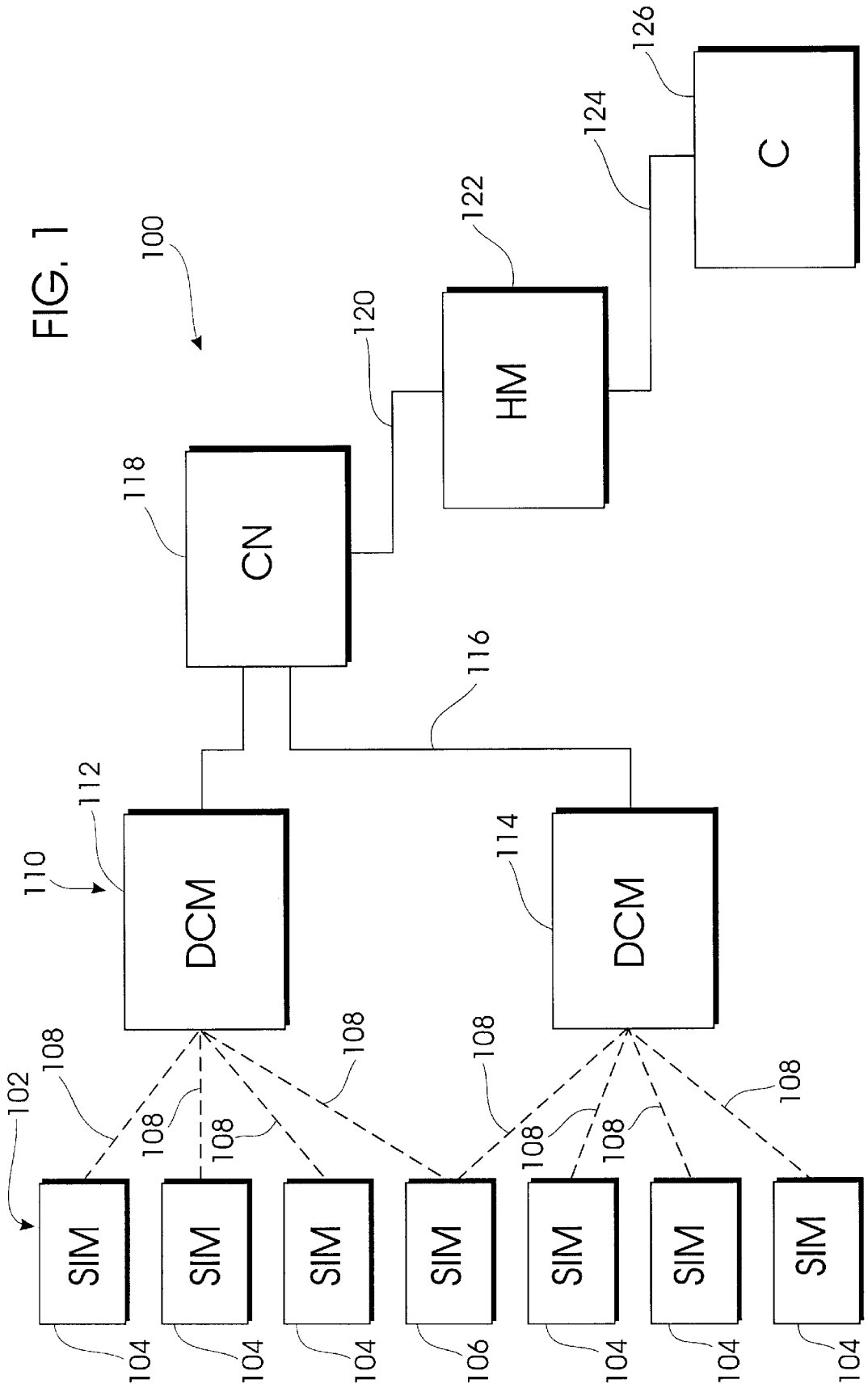

100
102
104
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108
110
112
114
116
118
120
122
124
126
SIM
DCM
CN
HM
C

FIG. 2

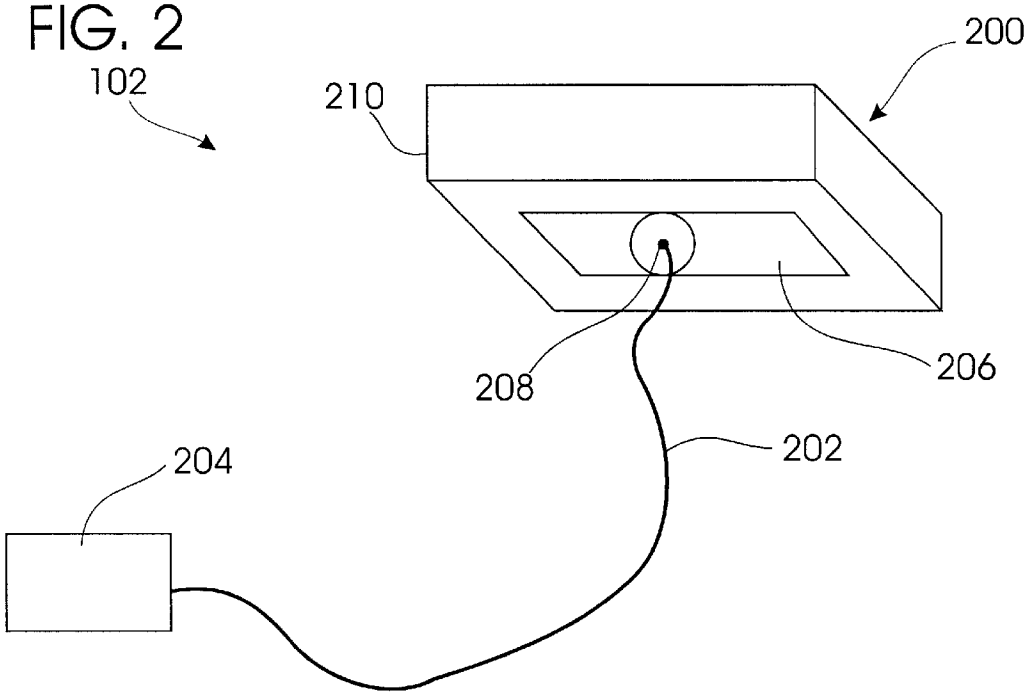
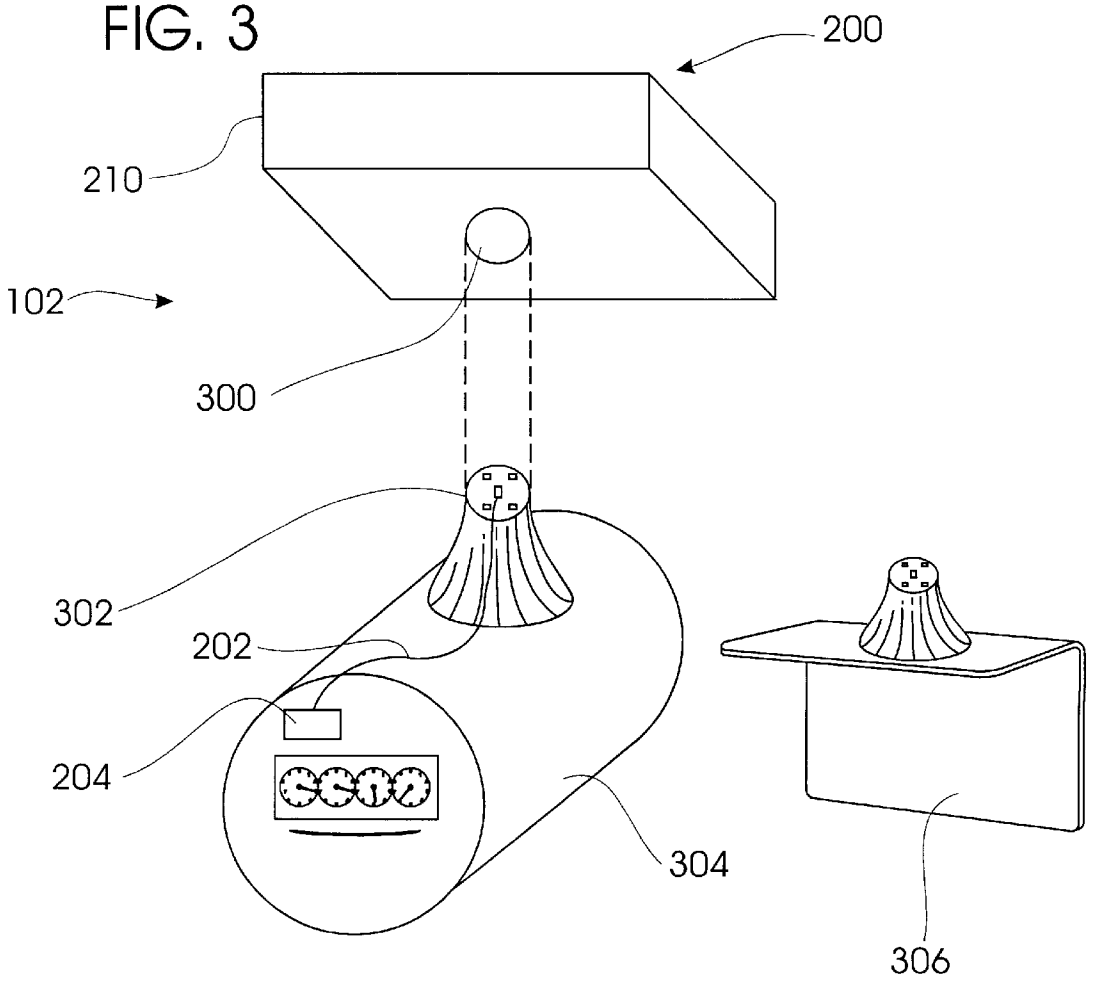


FIG. 3



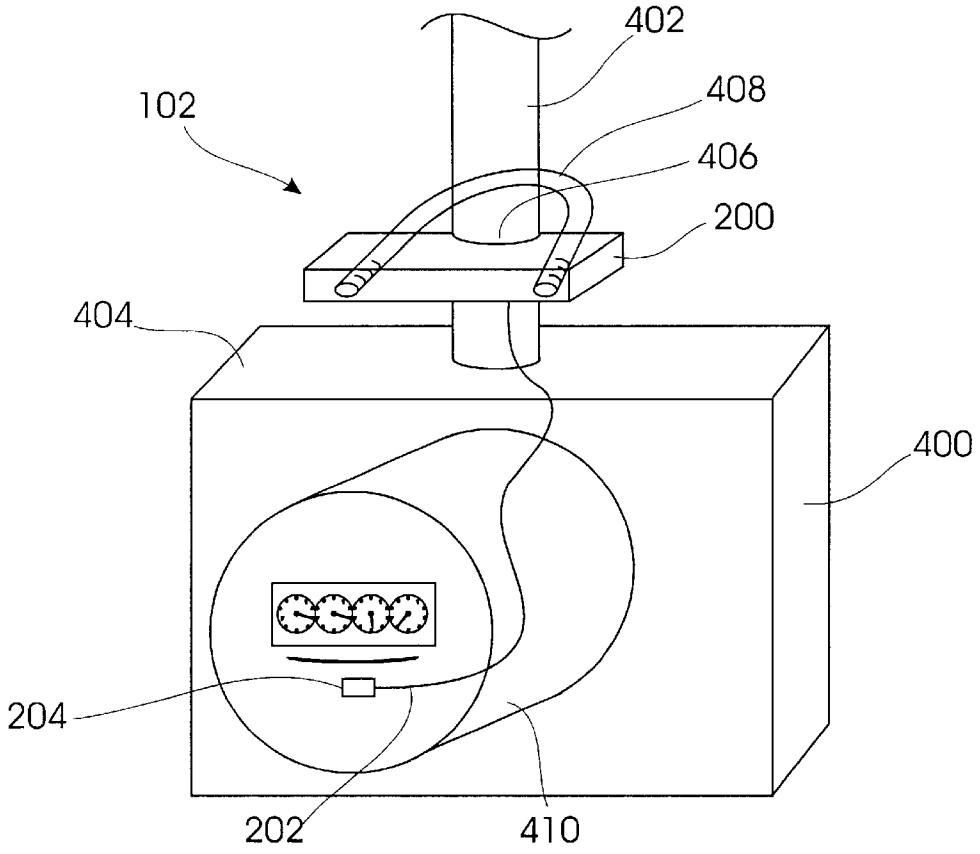

402
408
406
200
102
404
400
204
202
410

FIG. 4

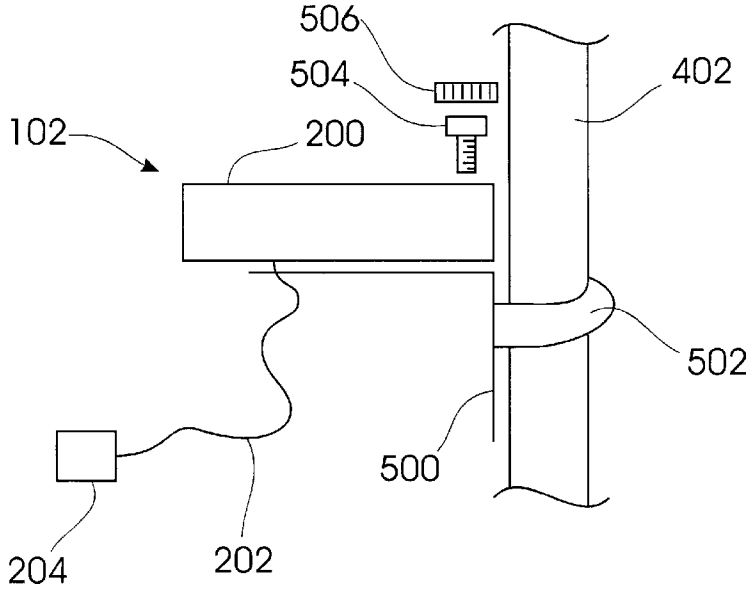

506
504
402
102
200
502
500
204
202

FIG. 5

FIG. 6

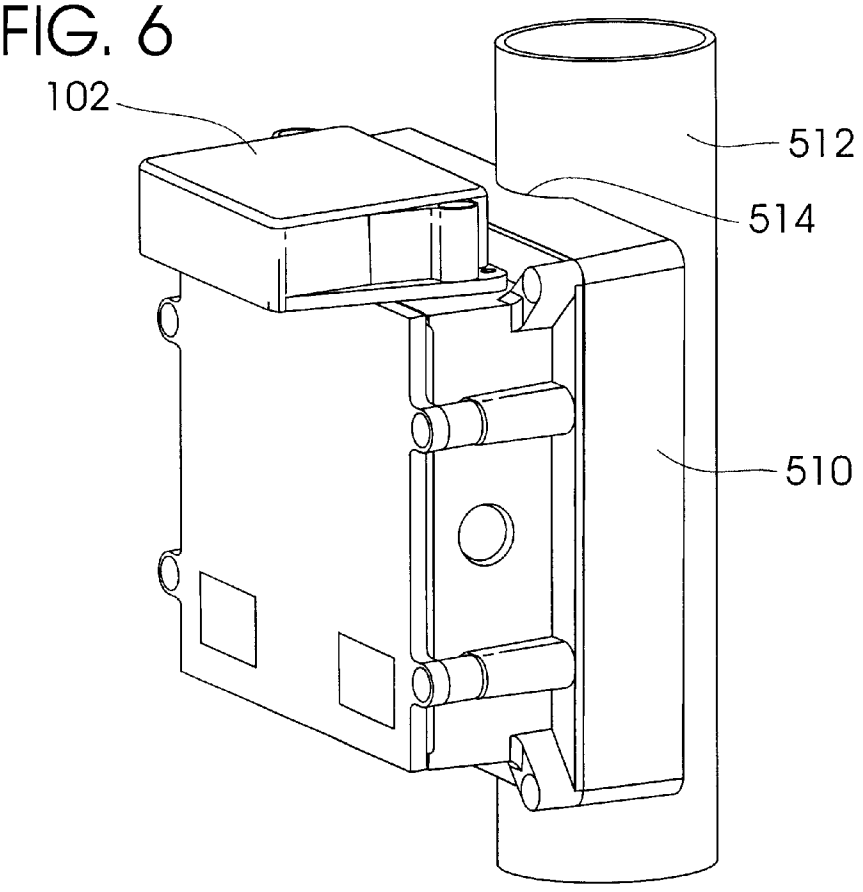
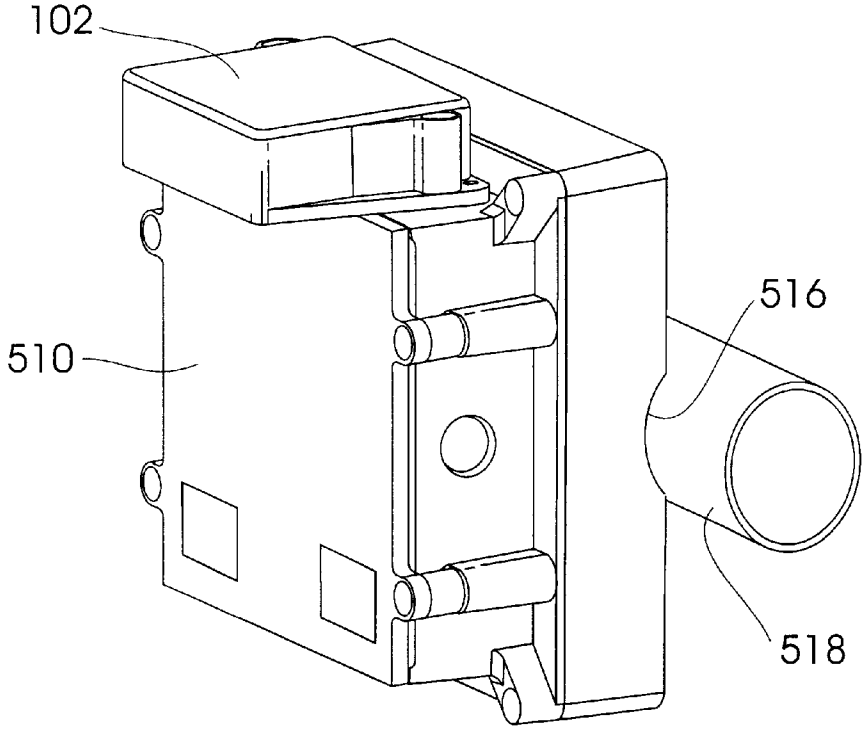


FIG. 7



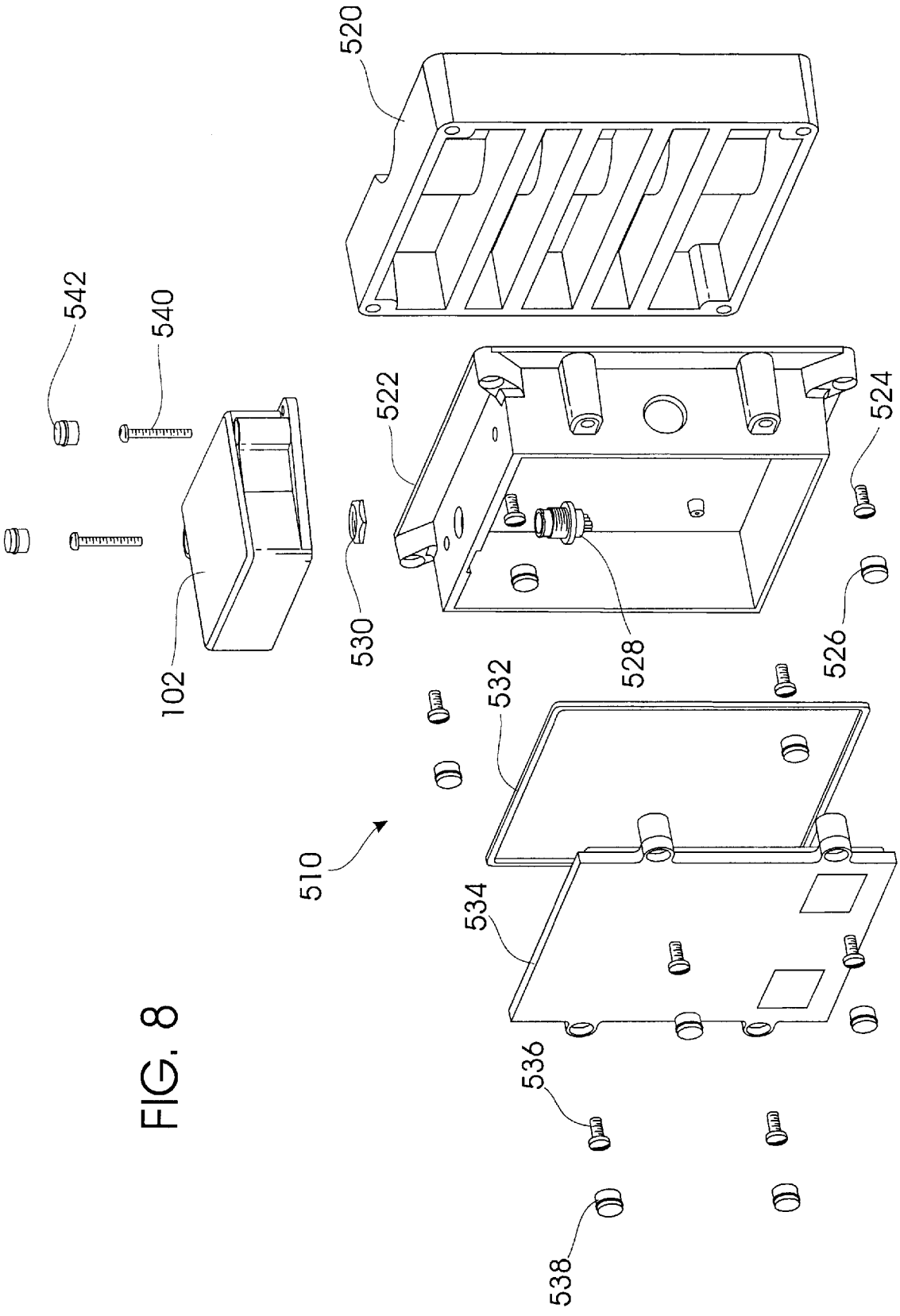
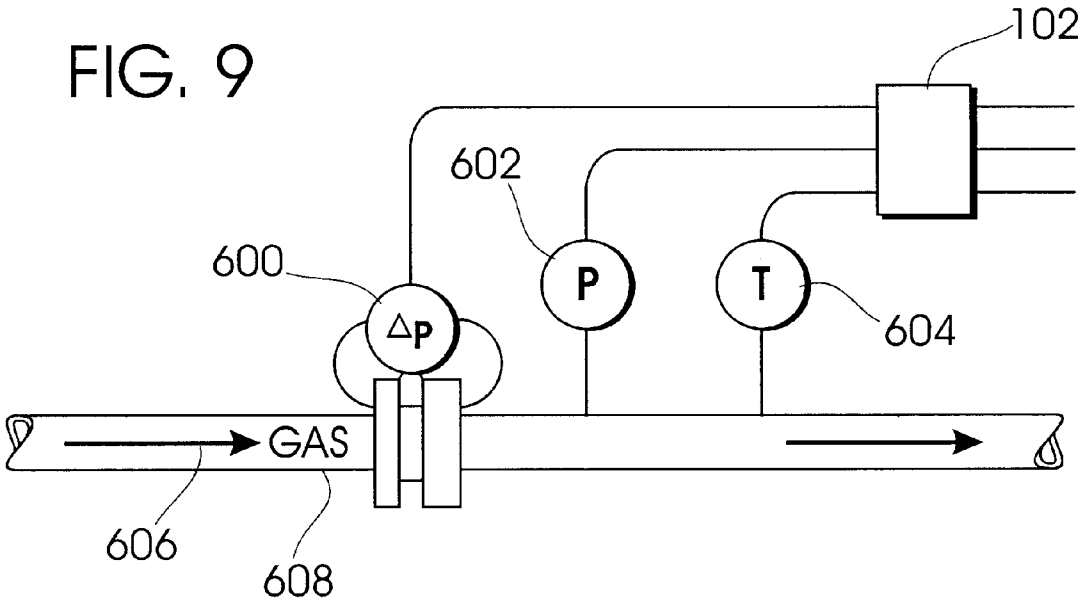
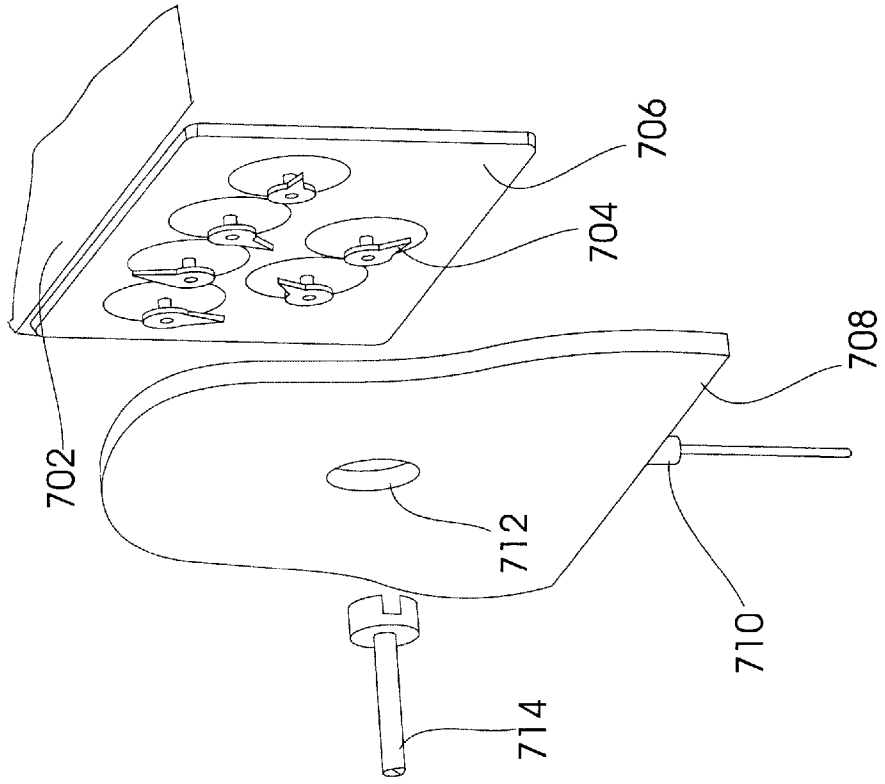


FIG. 8

FIG. 9




702
704
706
708
710
712
714

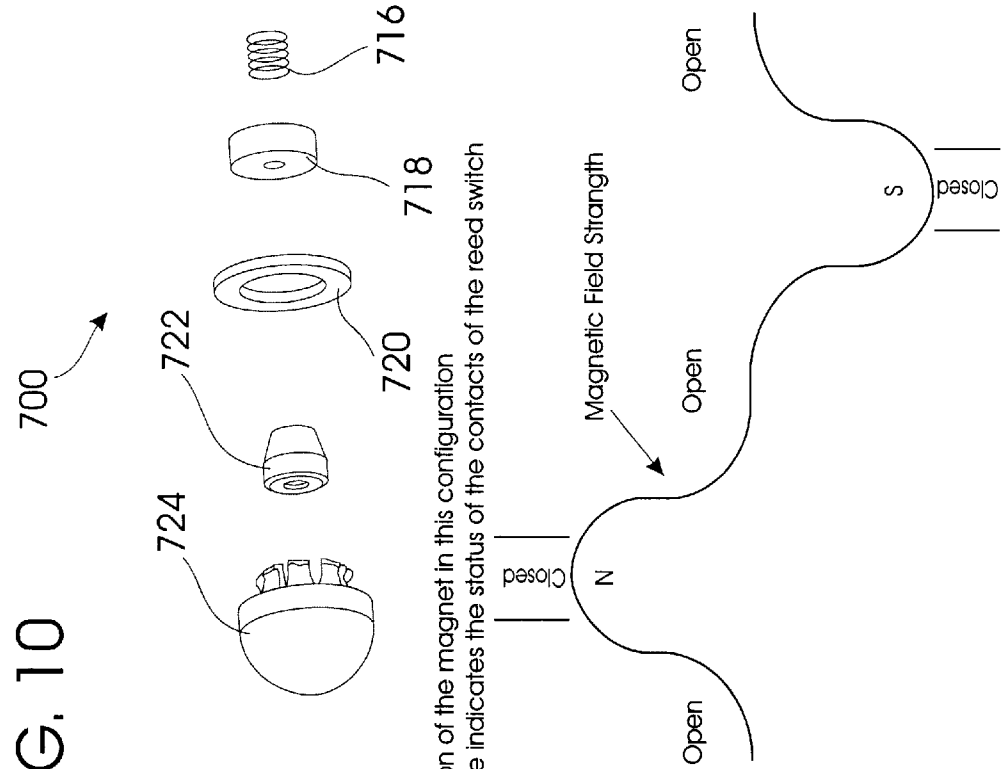

700
716
718
720
722
724
One rotation of the magnet in this configuration
Open/Close indicates the status of the contacts of the reed switch
Magnetic Field Strength
Open
Open
Open
Closed
N
S
Closed

FIG. 10

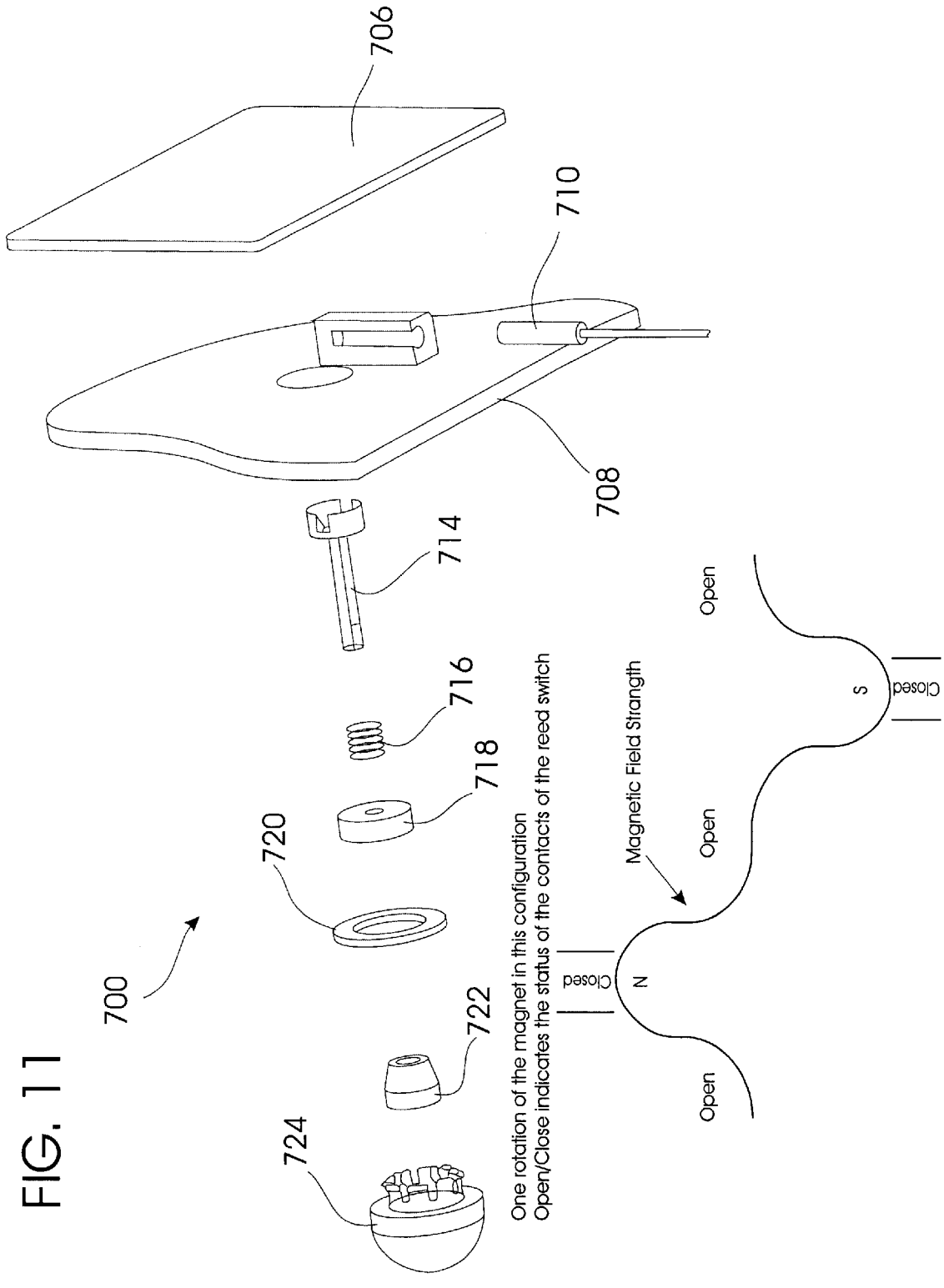

706
710
708
714
716
718
720
722
724
700
One rotation of the magnet in this configuration
Open/Close indicates the status of the contacts of the reed switch
Magnetic Field Strength
Closed
N
Open
Open
Open
S
Closed

FIG. 11

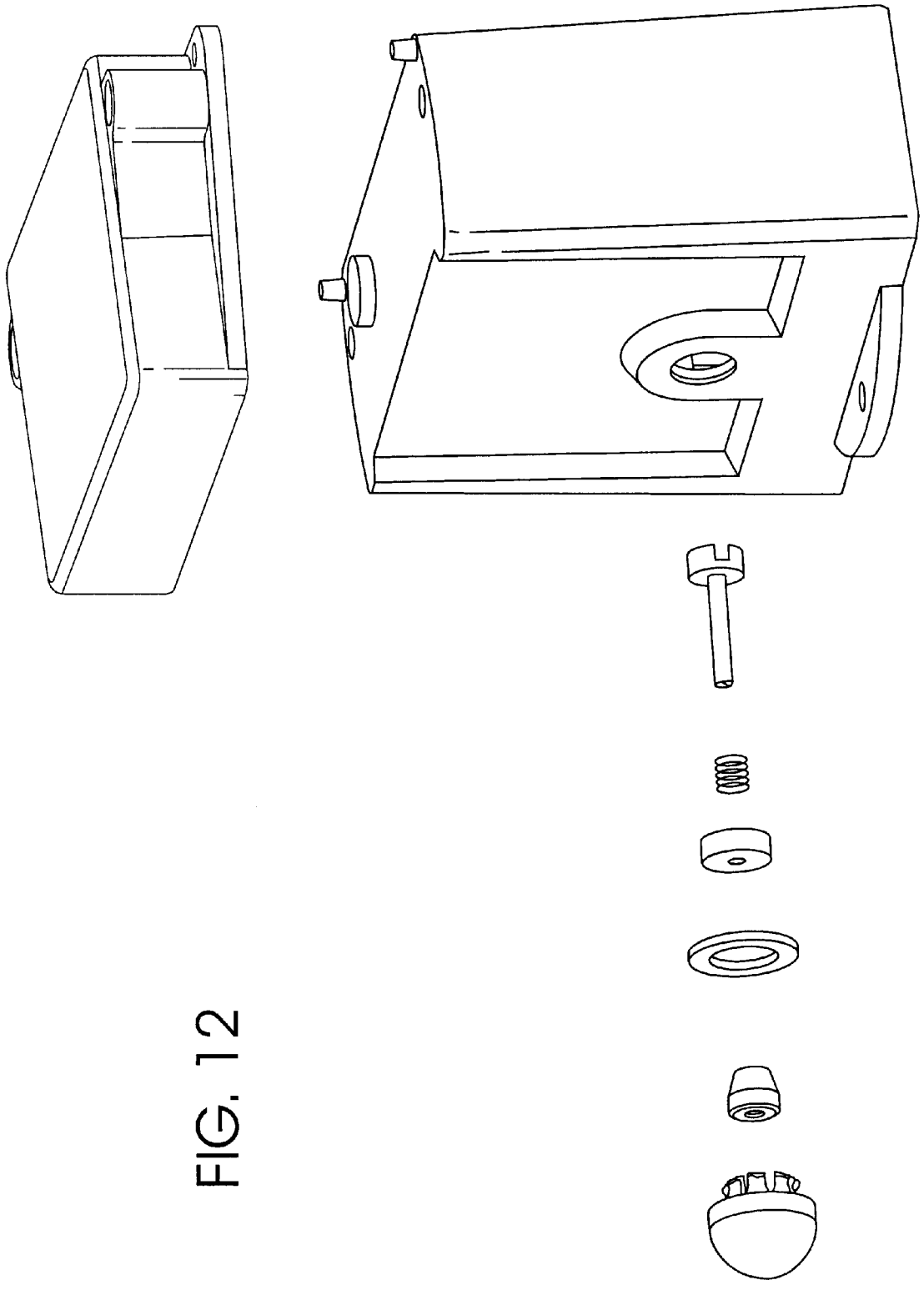
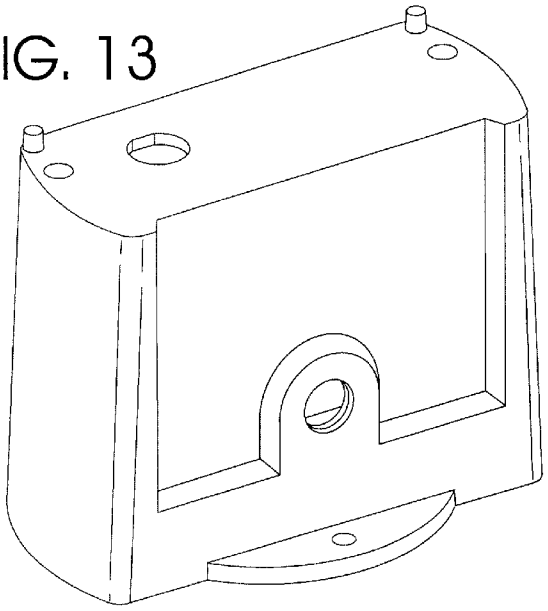


FIG. 12

FIG. 13



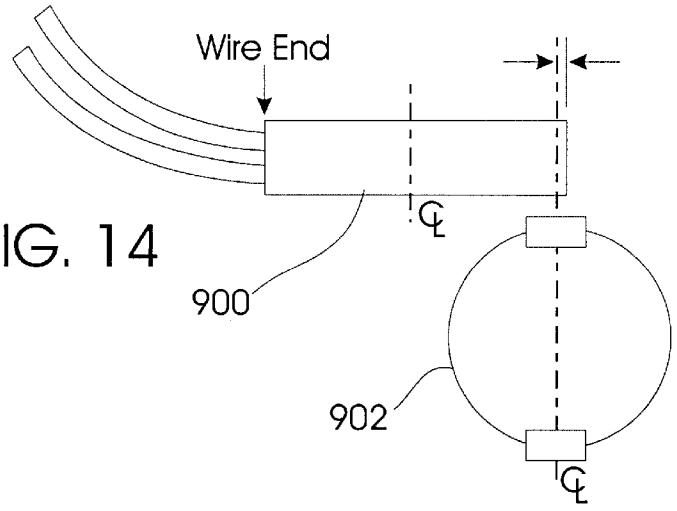


FIG. 14

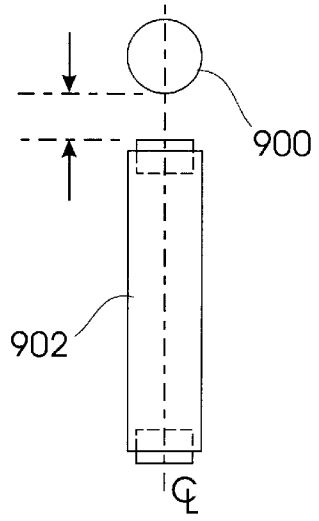
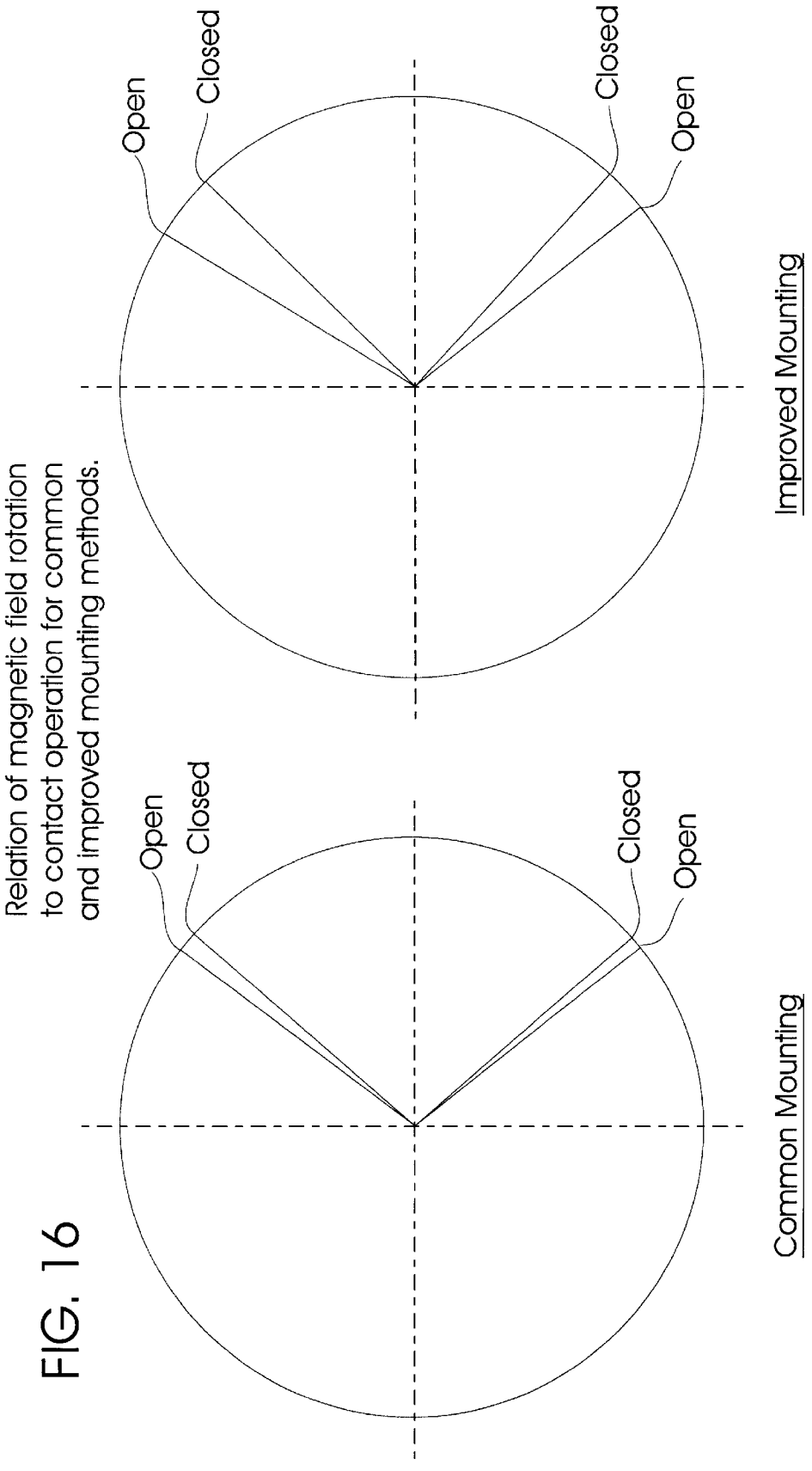


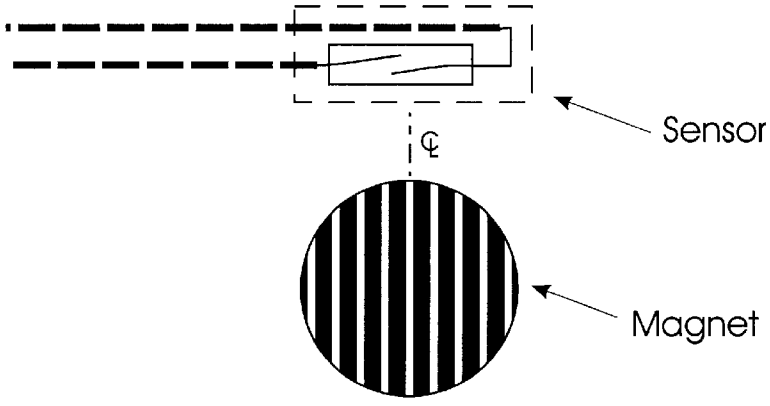
FIG. 15



Relation of magnetic field rotation to contact operation for common and improved mounting methods.

FIG. 16

FIG. 17



One rotation of the magnet in this configuration
Open/Close indicates the status of the contacts of the reed switch

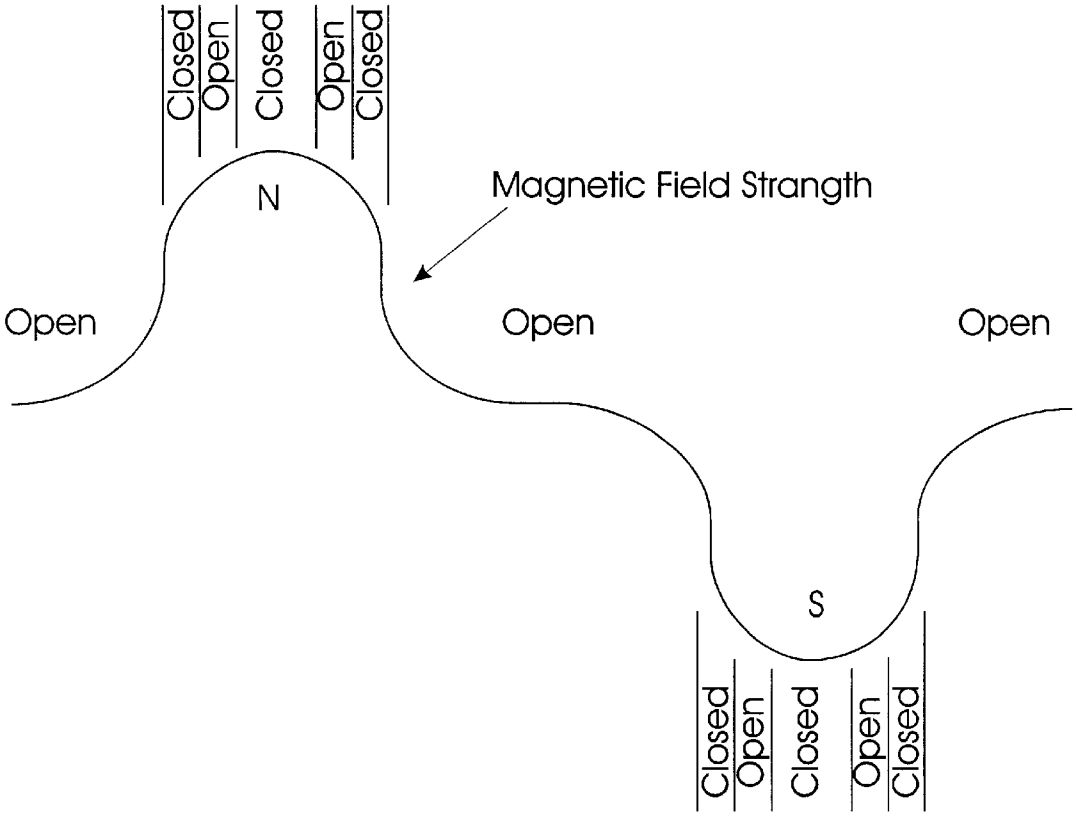
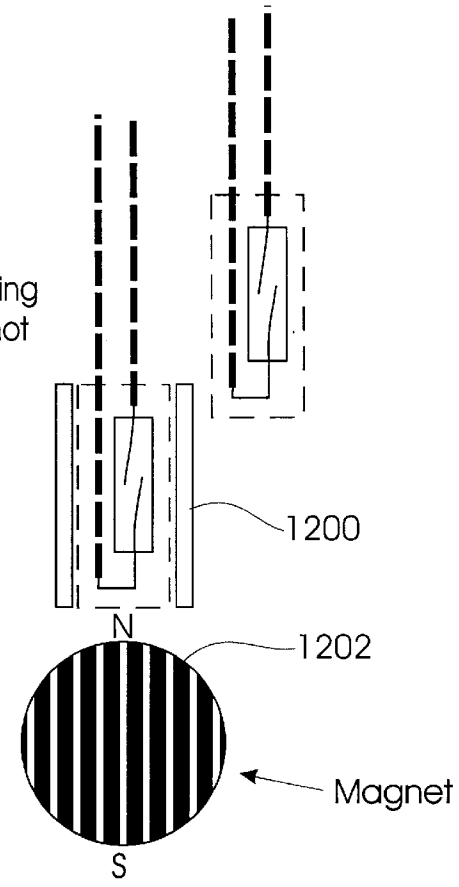


FIG. 18

Use a second sensor to detect tanpering
Be sure that the second sensor does not detect the rotating magnet.



One rotation of the magnet in this configuration
Open/Close indicates the status of the contacts of the reed switch

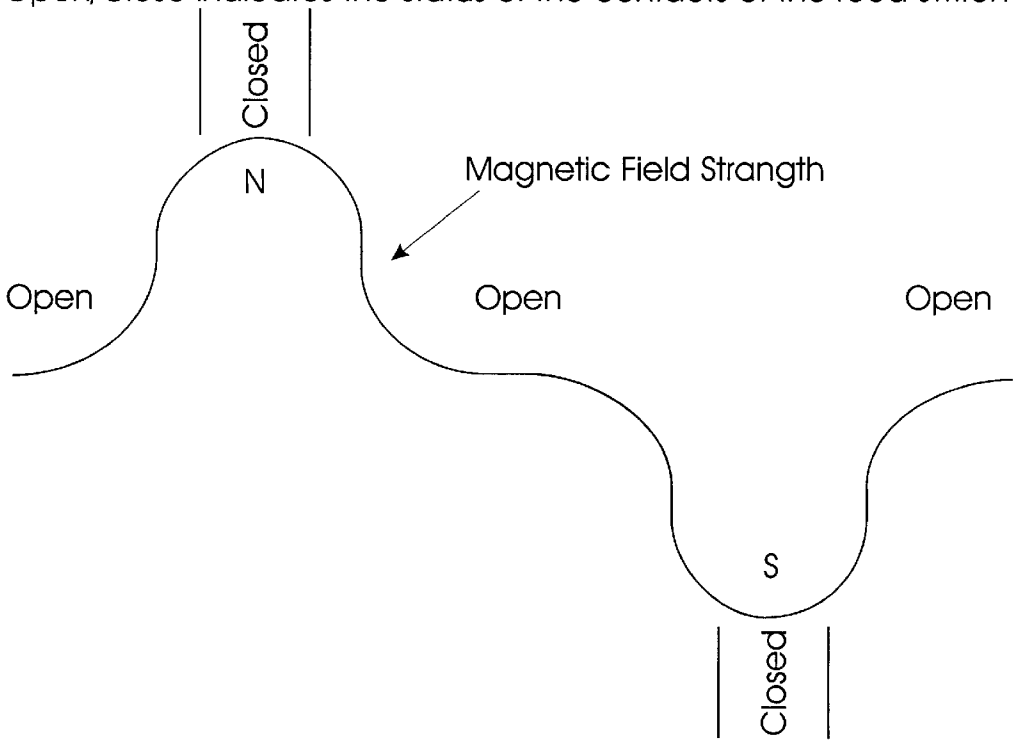
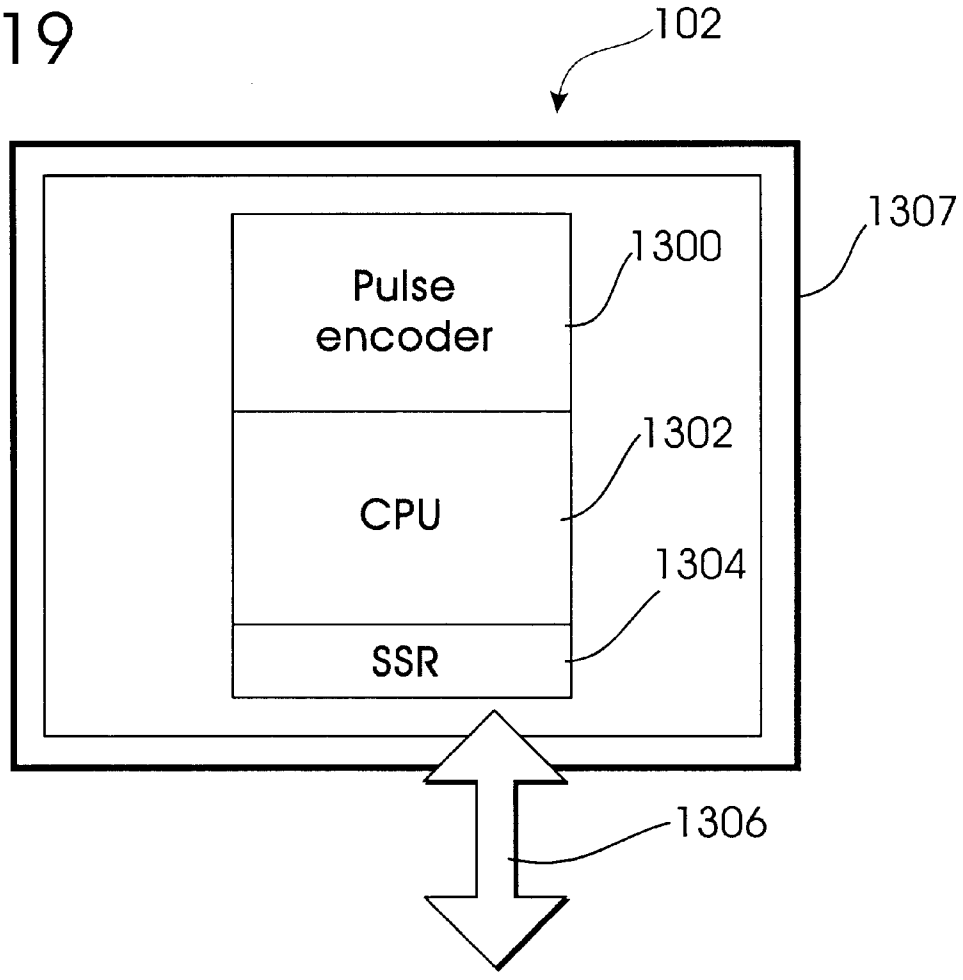


FIG. 19


102
1307
1300
Pulse encoder
1302
CPU
1304
SSR
1306
PAN connection to Telemetry Gateway via short range spread spectrum transceiver (Transmit only option)

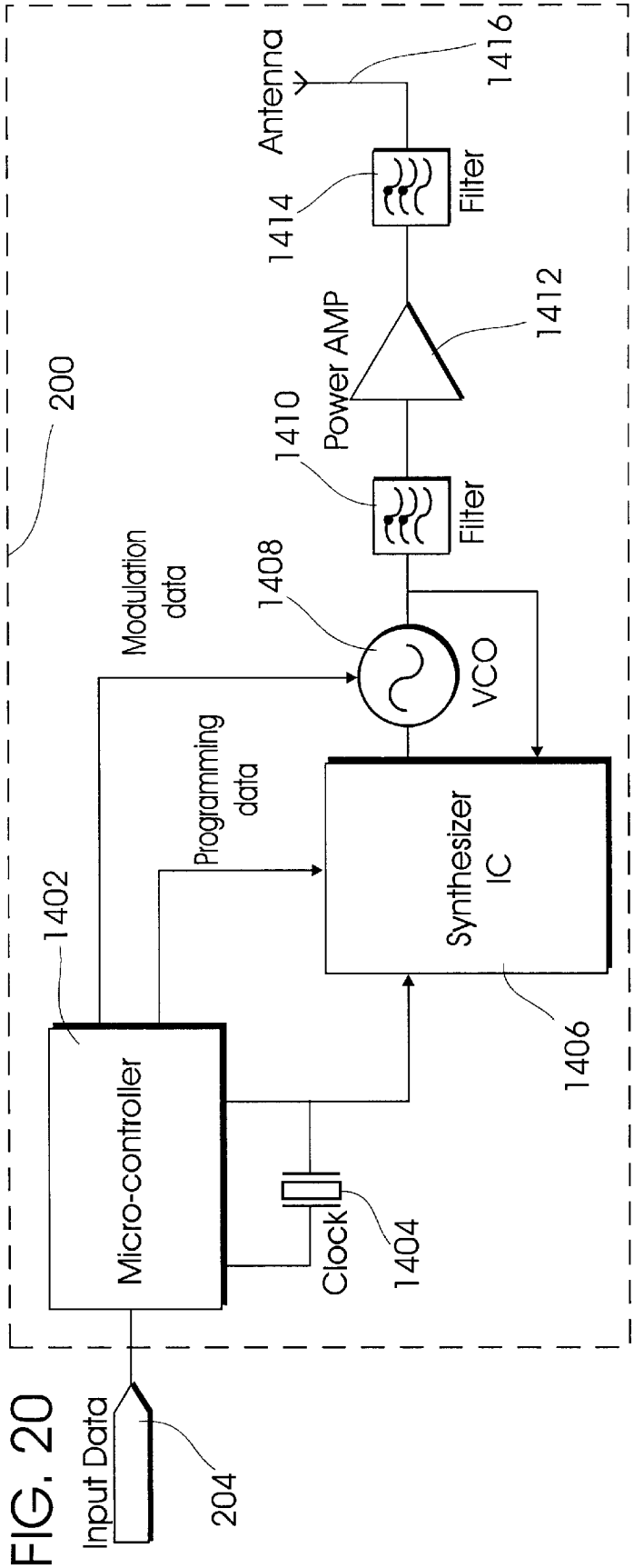

200
Antenna
1416
1414
Filter
1412
Power AMP
1410
Filter
1408
VCO
Modulation data
Programming data
1402
Micro-controller
Synthesizer IC
1406
Clock
1404
Input Data
204

FIG. 20

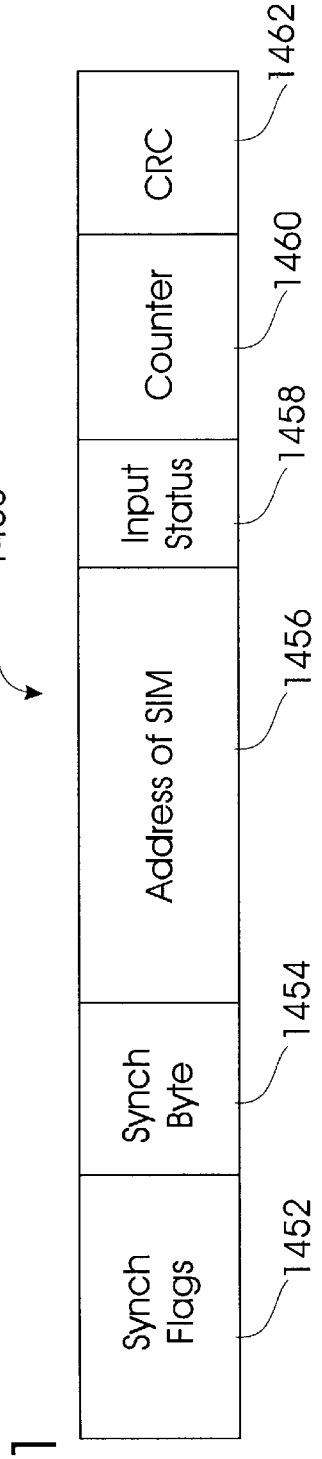

1450
CRC
1462
Counter
1460
Input Status
1458
Address of SIM
1456
Synch Byte
1454
Synch Flags
1452

FIG. 21

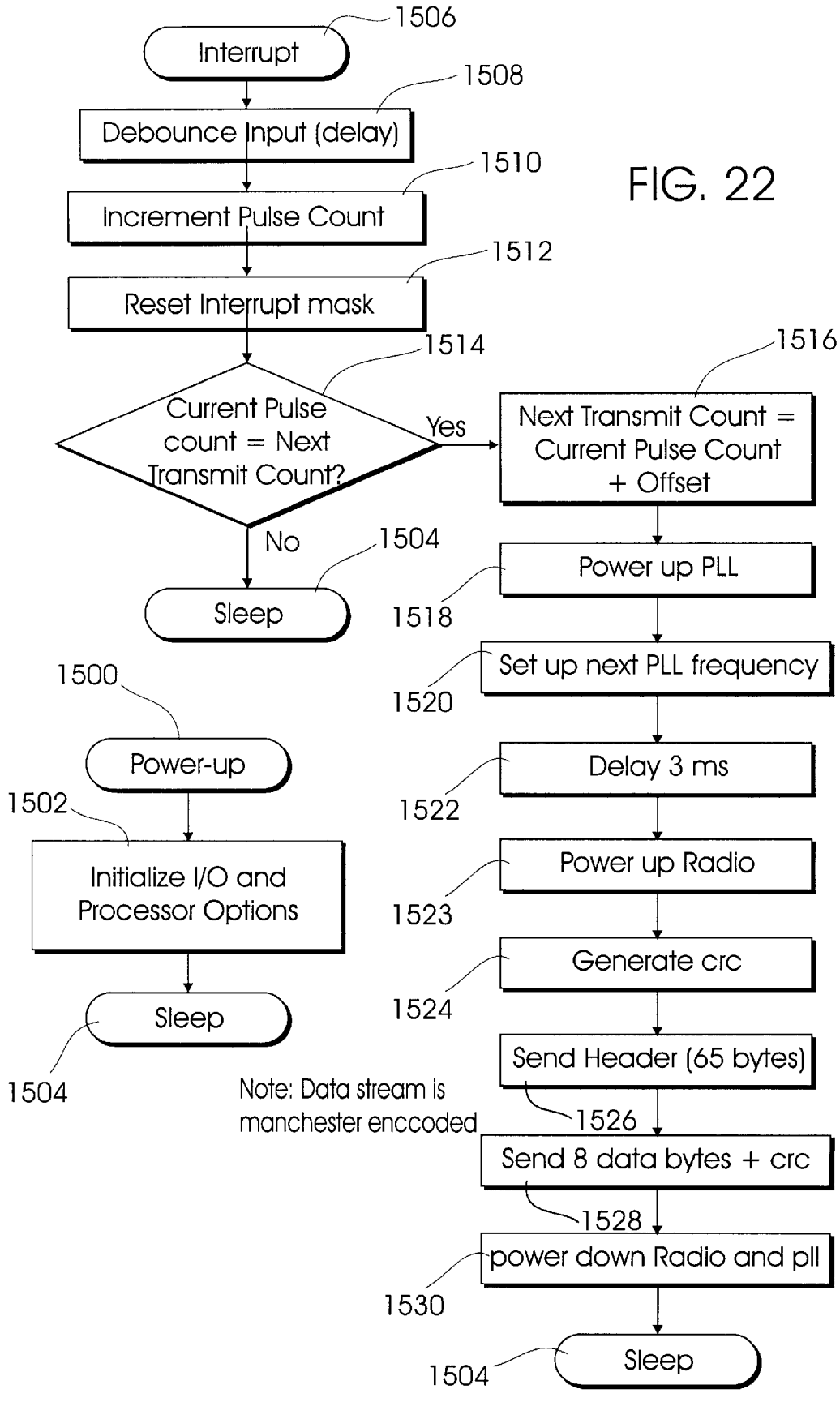
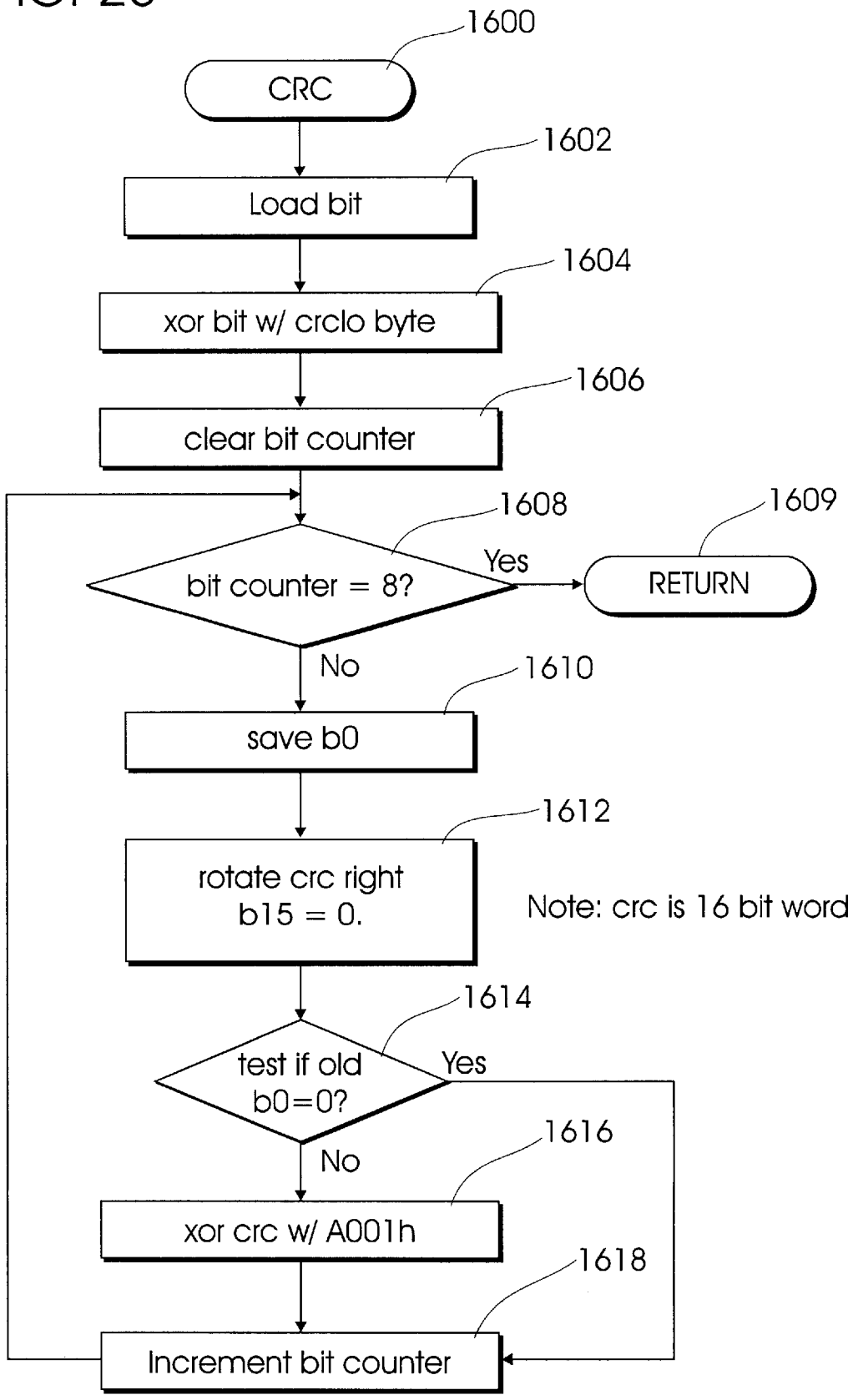

1506
Interrupt
1508
Debounce Input (delay)
1510
Increment Pulse Count
1512
Reset Interrupt mask
1514
Current Pulse count = Next Transmit Count?
Yes
No
1516
Next Transmit Count = Current Pulse Count + Offset
1504
Sleep
1518
Power up PLL
1520
Set up next PLL frequency
1522
Delay 3 ms
1523
Power up Radio
1524
Generate crc
Send Header (65 bytes)
1526
Send 8 data bytes + crc
1528
power down Radio and pll
1530
Sleep
1504
1500
Power-up
1502
Initialize I/O and Processor Options
Sleep
1504
Note: Data stream is manchester enccoded

FIG. 22

FIG. 23


1600
CRC
1602
Load bit
1604
xor bit w/ crclo byte
1606
clear bit counter
1608
bit counter = 8?
Yes
1609
RETURN
No
1610
save b0
1612
rotate crc right
b15 = 0.
Note: crc is 16 bit word
1614
test if old
b0=0?
Yes
No
1616
xor crc w/ A001h
1618
Increment bit counter

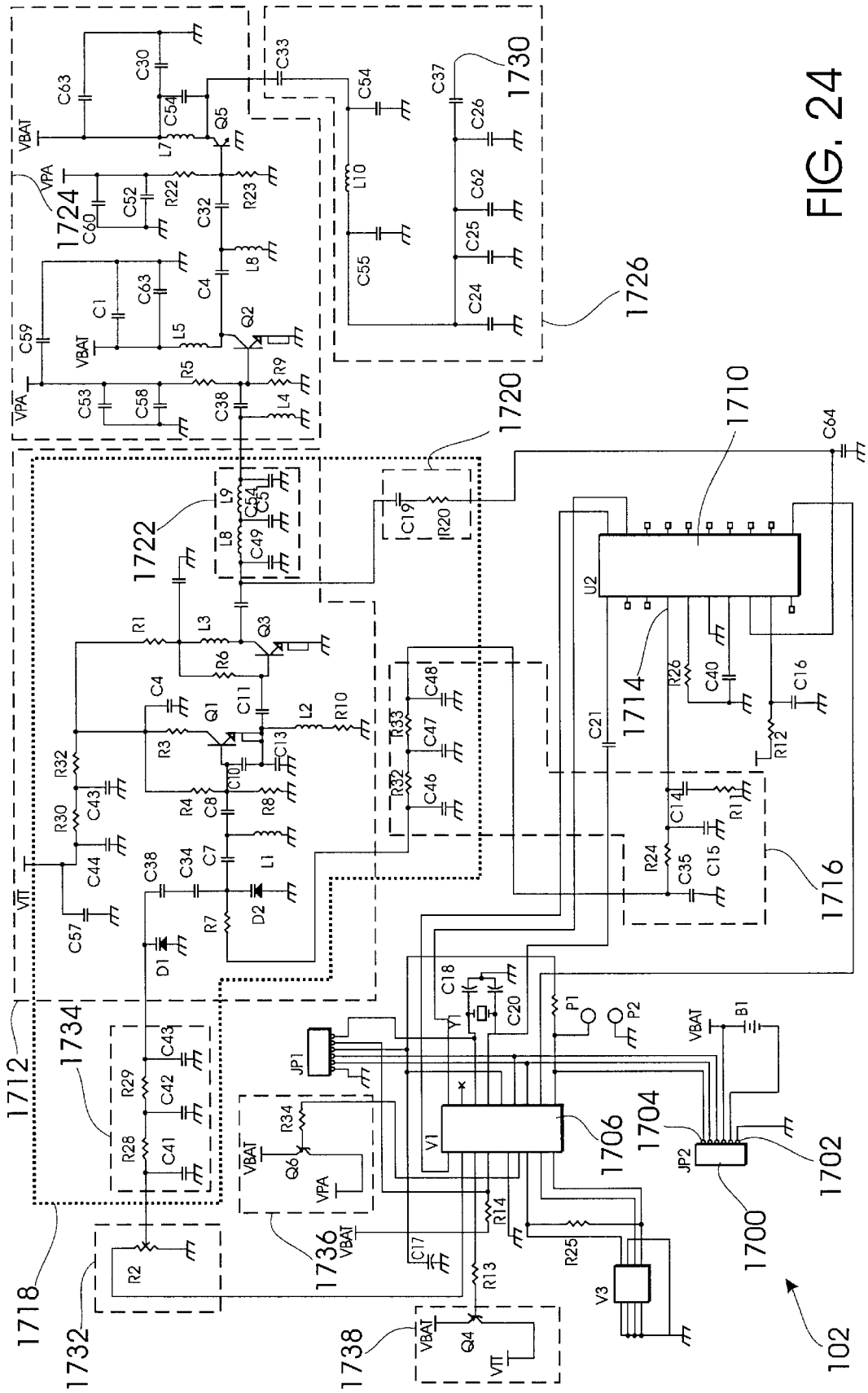

1730
1726
1724
1720
1710
1722
1714
1716
1712
1734
1718
1732
1736
1738
1706
1704
1702
1700
102
VBAT
VPA
VTT
JP1
JP2
V1
V3
Y1
B1
P1
P2
U2
Q1
Q2
Q3
Q4
Q5
Q6
D1
D2
L1
L2
L3
L4
L5
L7
L8
L9
L10
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R12
R13
R14
R20
R22
R23
R24
R25
R26
R28
R29
R30
R32
R33
R34
C1
C2
C4
C7
C8
C10
C11
C12
C13
C14
C15
C16
C17
C18
C19
C20
C21
C24
C25
C26
C30
C32
C33
C34
C35
C37
C38
C40
C41
C42
C43
C44
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C47
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C54
C55
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C58
C59
C60
C62
C63
C64

FIG. 24

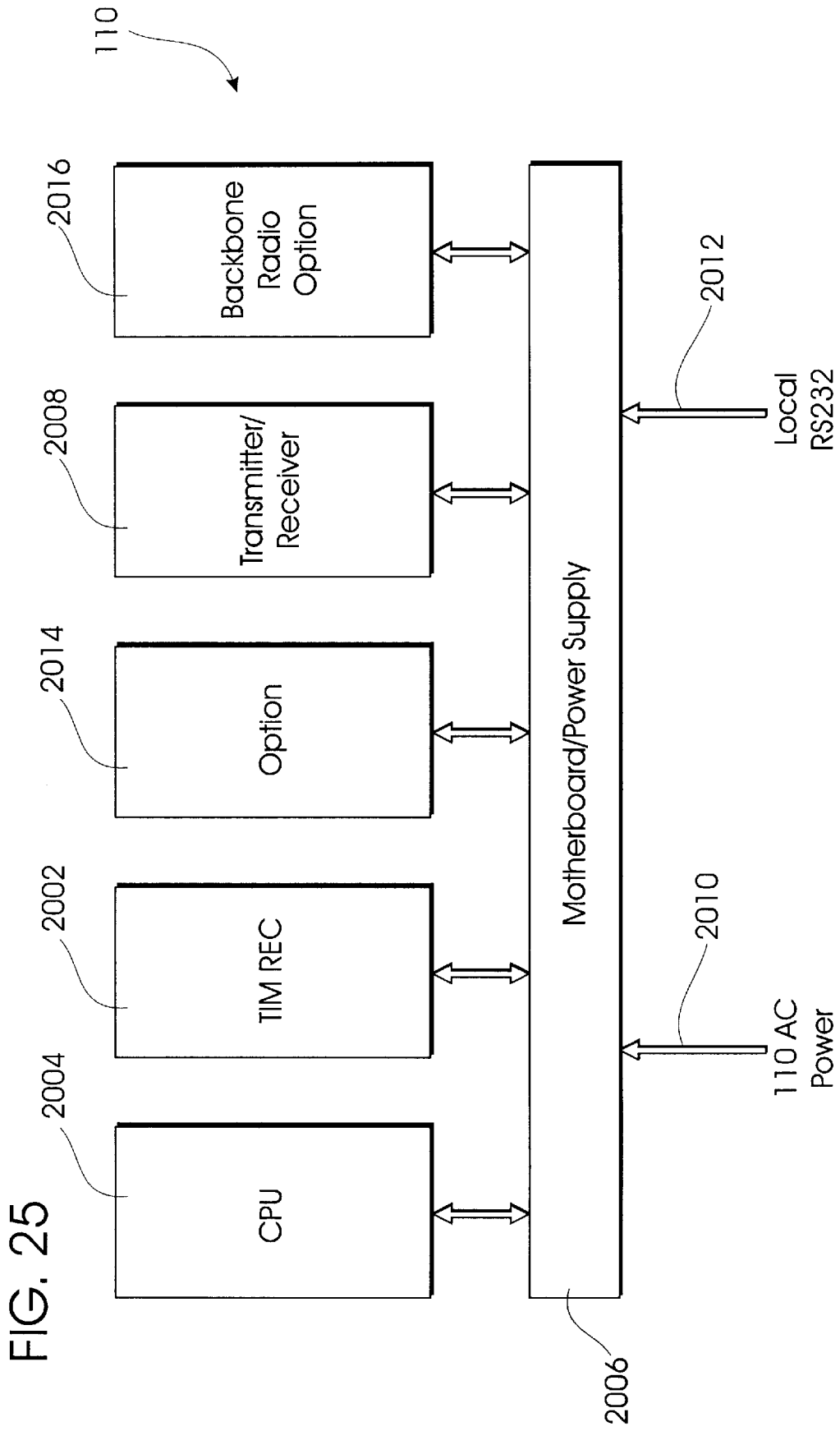

110
2016
Backbone Radio Option
2008
Transmitter/ Receiver
2014
Option
2002
TIM REC
2004
CPU
Motherboard/Power Supply
2012
Local RS232
2010
110 AC Power
2006

FIG. 25

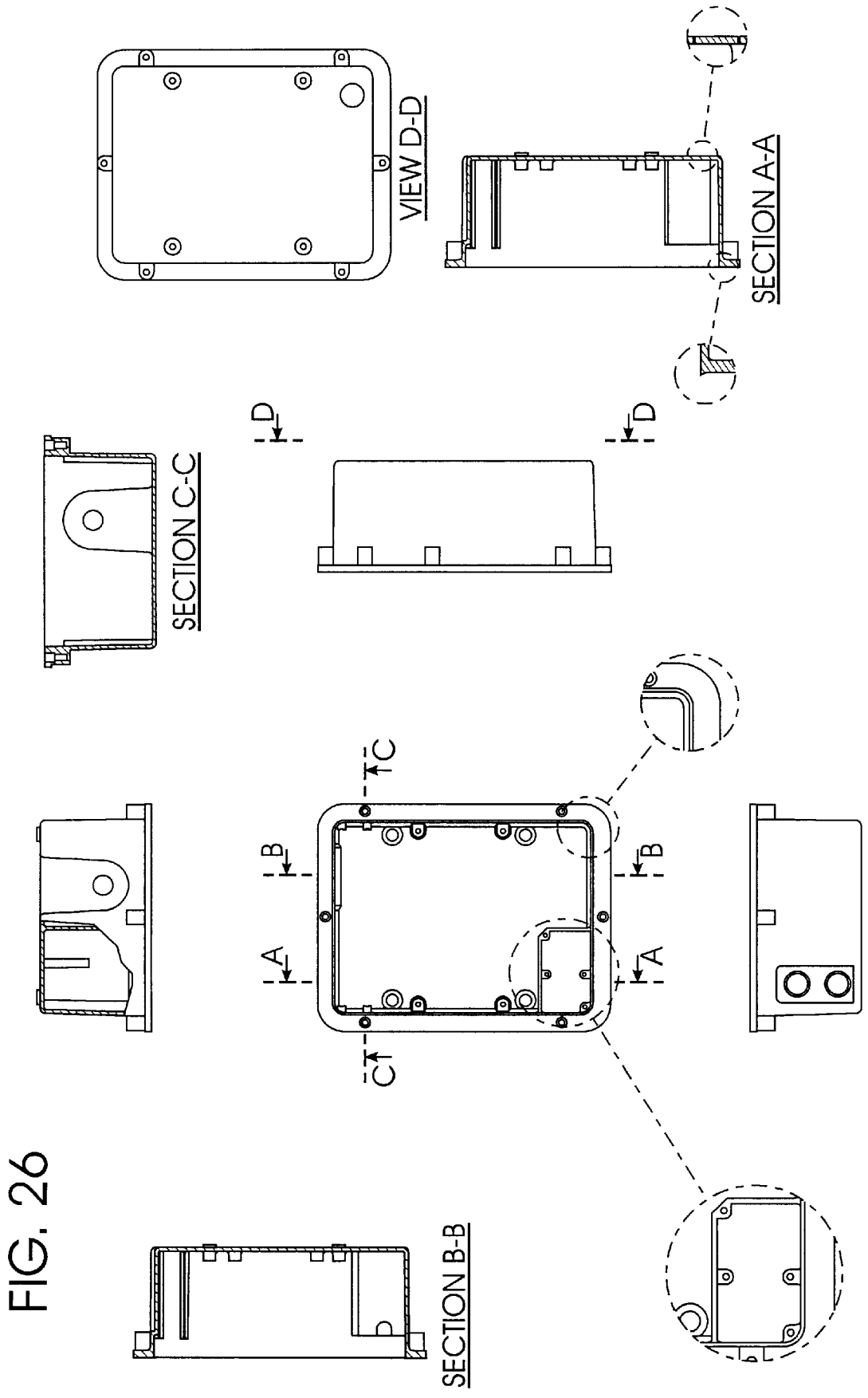


FIG. 26

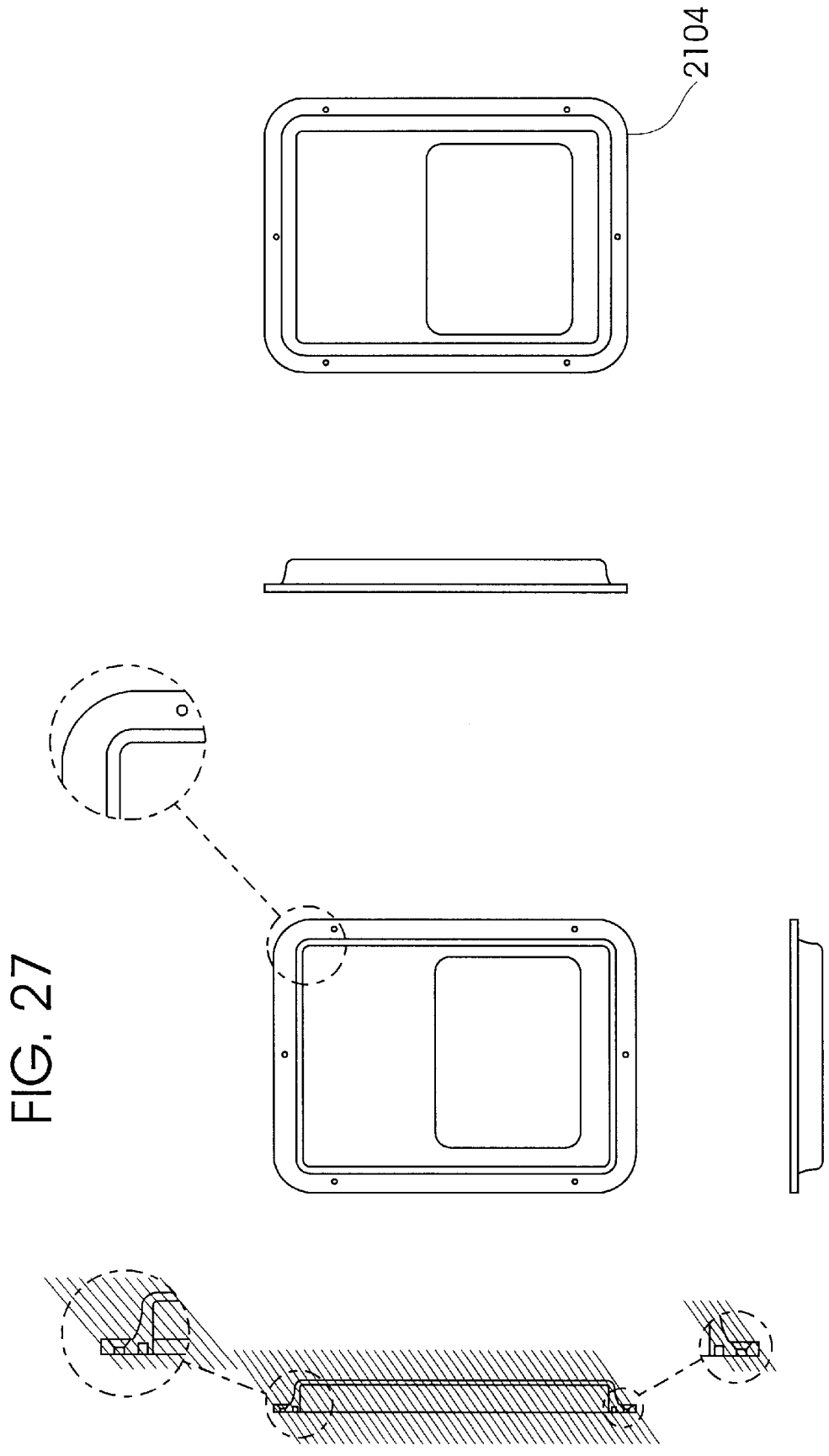


FIG. 27

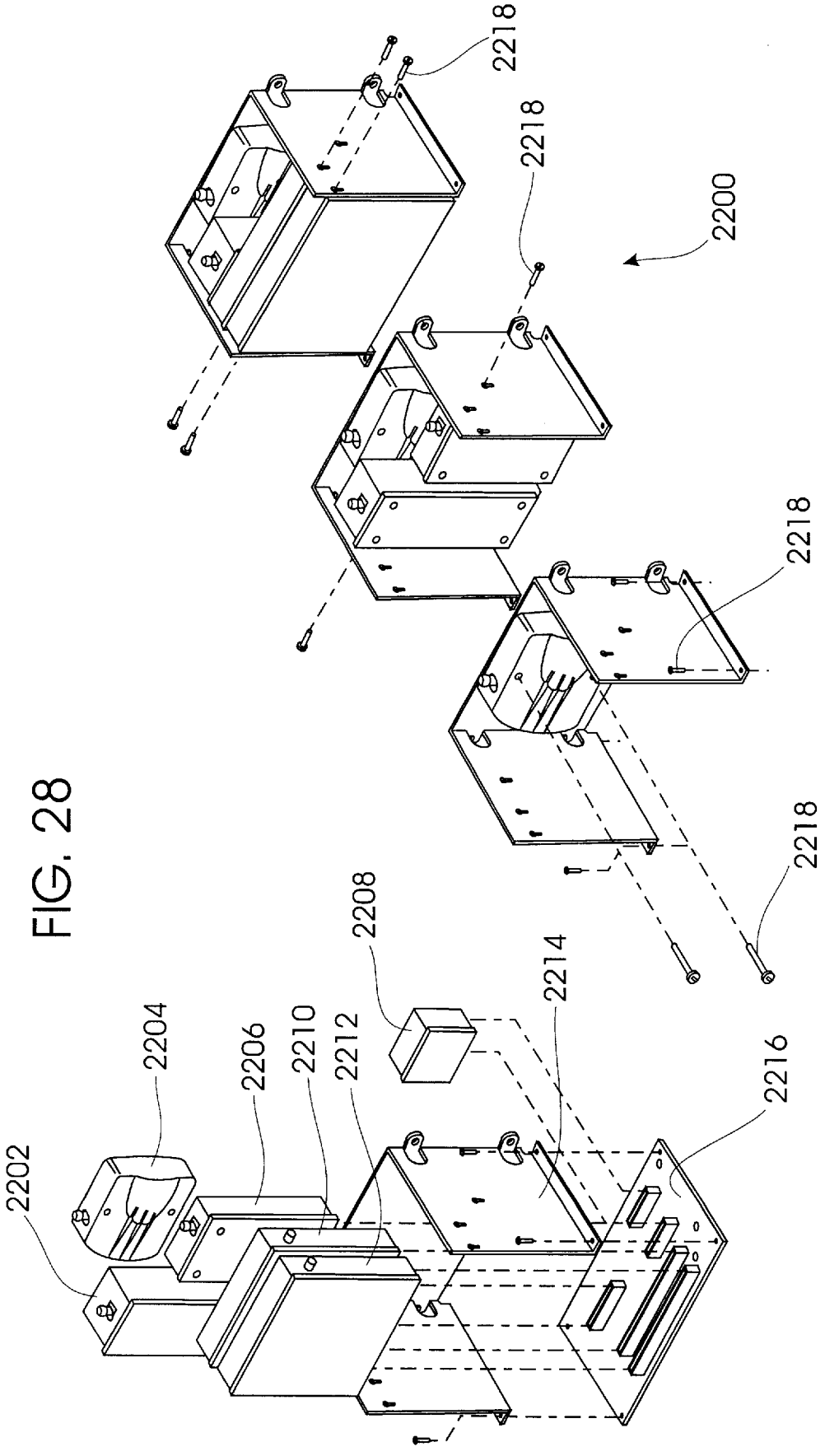

2218
2218
2200
2218
2218
2208
2214
2204
2206
2210
2212
2216
2202

FIG. 28

FIG. 29

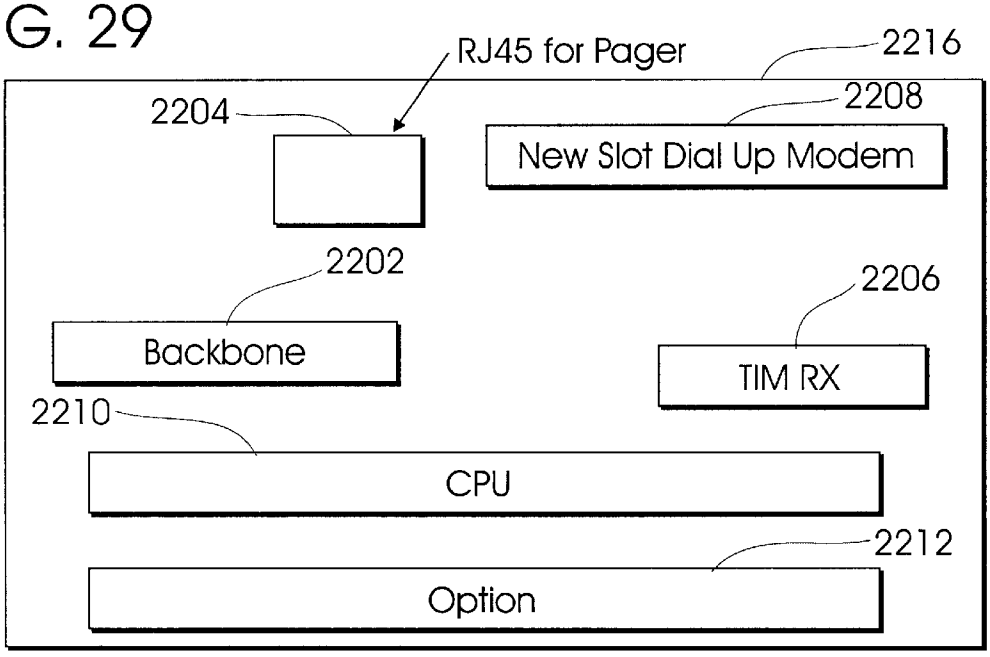
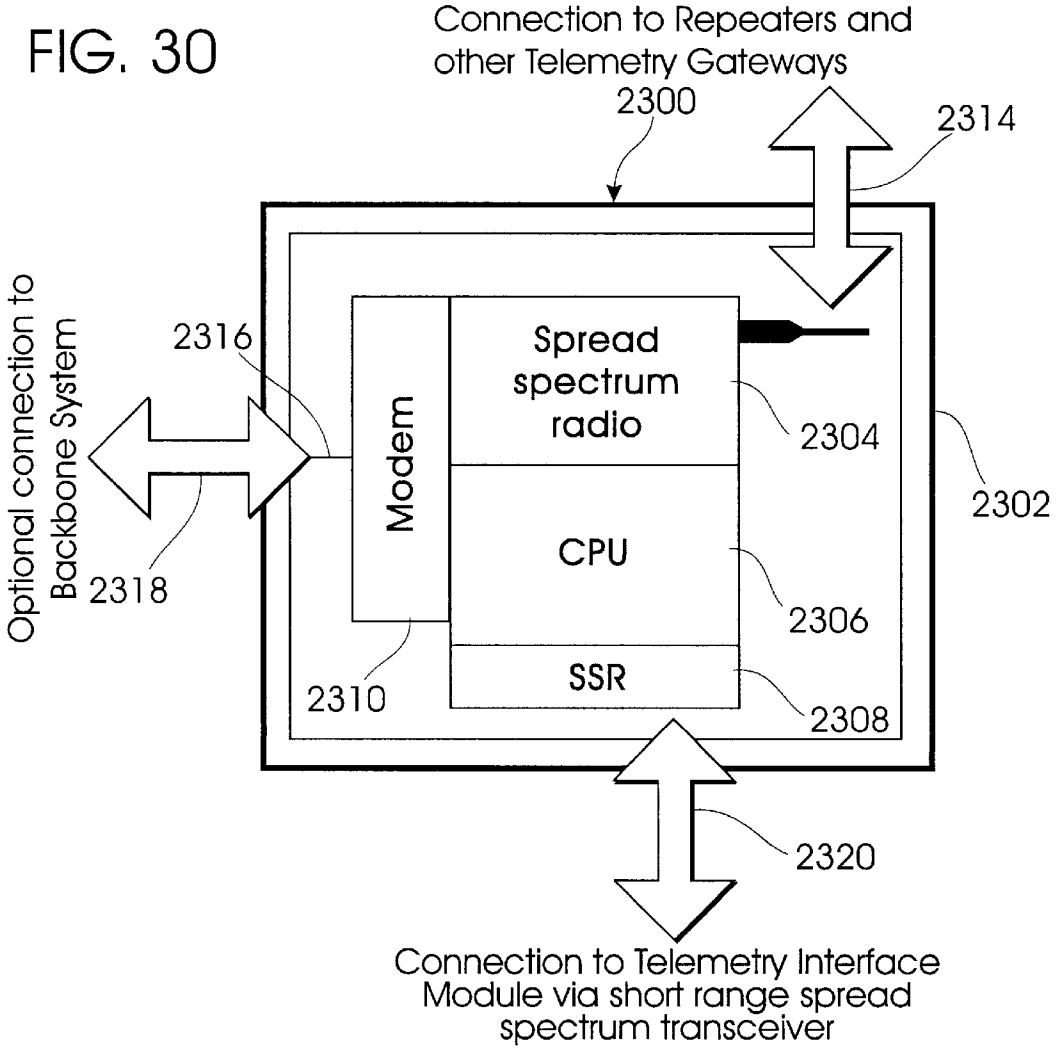

RJ45 for Pager
2216
2204
2208
New Slot Dial Up Modem
2202
2206
Backbone
TIM RX
2210
CPU
2212
Option

FIG. 30


Connection to Repeaters and other Telemetry Gateways
2300
2314
Optional connection to Backbone System
2316
Modem
Spread spectrum radio
2304
2302
CPU
2306
2318
2310
SSR
2308
2320
Connection to Telemetry Interface Module via short range spread spectrum transceiver

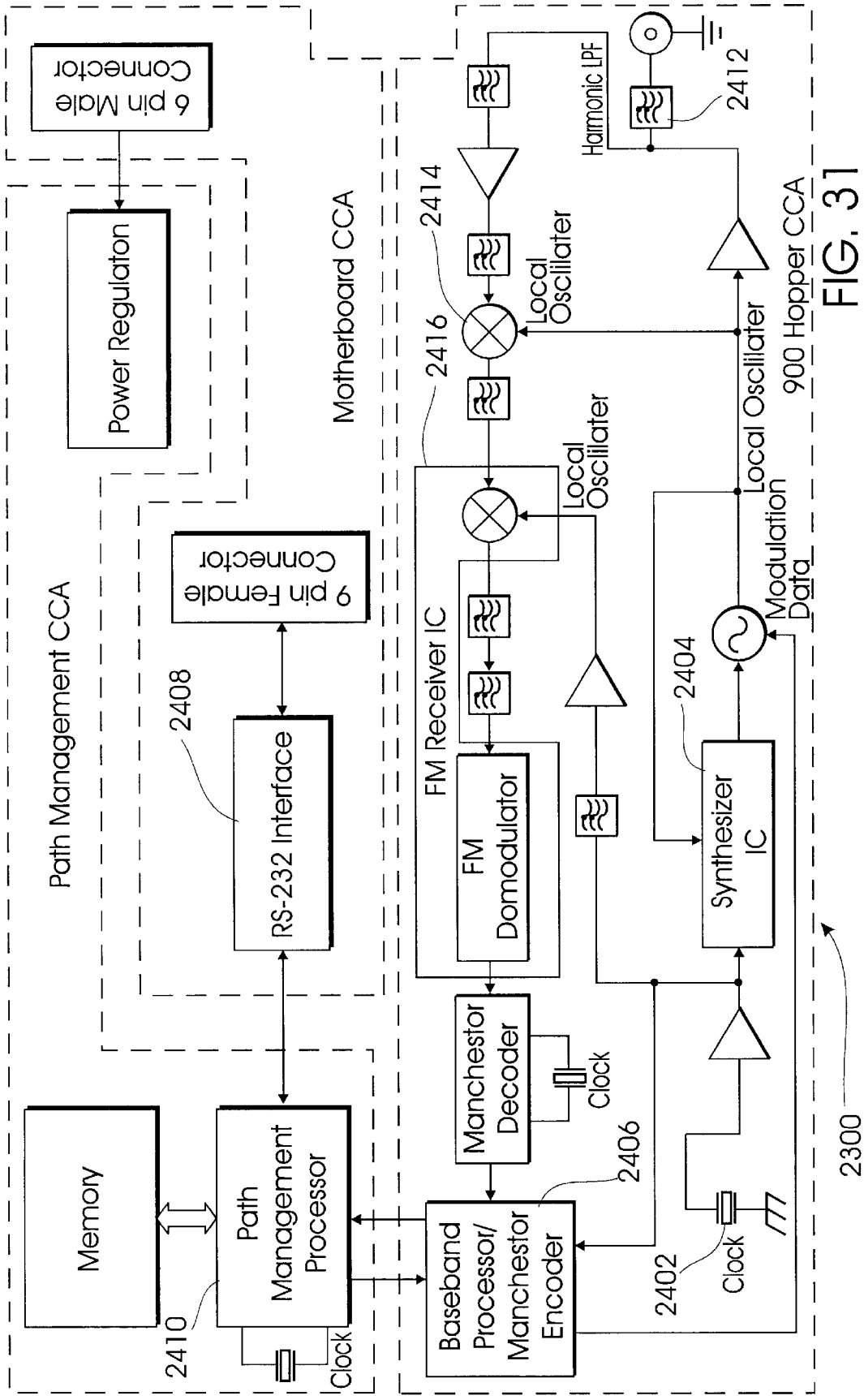
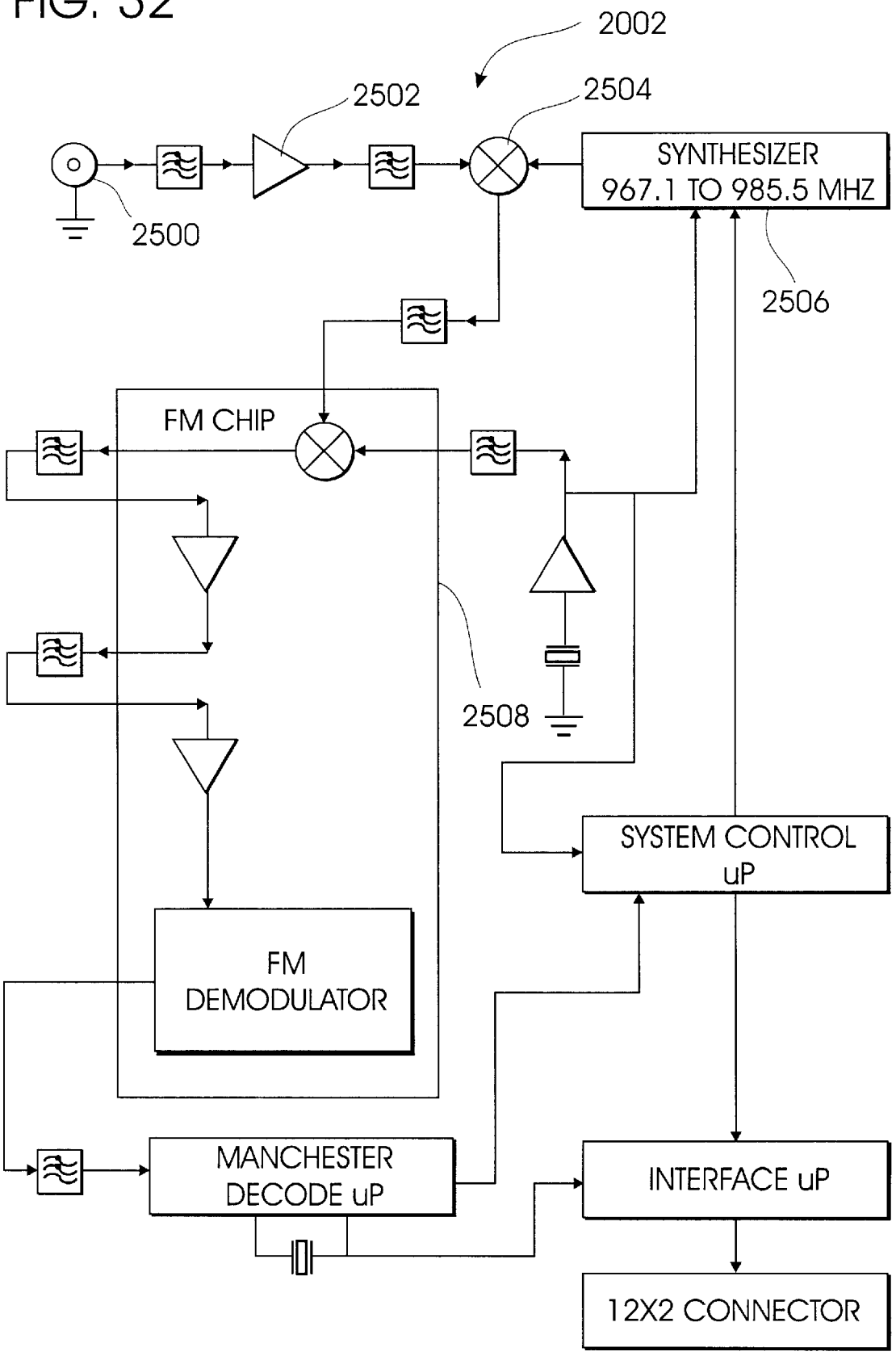

6 pin Male Connector
Power Regulaton
Motherboard CCA
9 pin Female Connector
2408
RS-232 Interface
Path Management CCA
Memory
Path Management Processor
2410
Clock
Baseband Processor/ Manchestor Encoder
2406
Manchestor Decoder
Clock
FM Receiver IC
FM Domodulator
2414
2416
Local Oscillater
Local Oscillater
Harmonic LPF
2412
Local Oscillater
Modulation Data
2404
Synthesizer IC
2402
Clock
900 Hopper CCA
2300

FIG. 31

FIG. 32


2002
2502
2504
SYNTHESIZER
967.1 TO 985.5 MHZ
2500
2506
FM CHIP
2508
SYSTEM CONTROL
uP
FM
DEMODULATOR
MANCHESTER
DECODE uP
INTERFACE uP
12X2 CONNECTOR

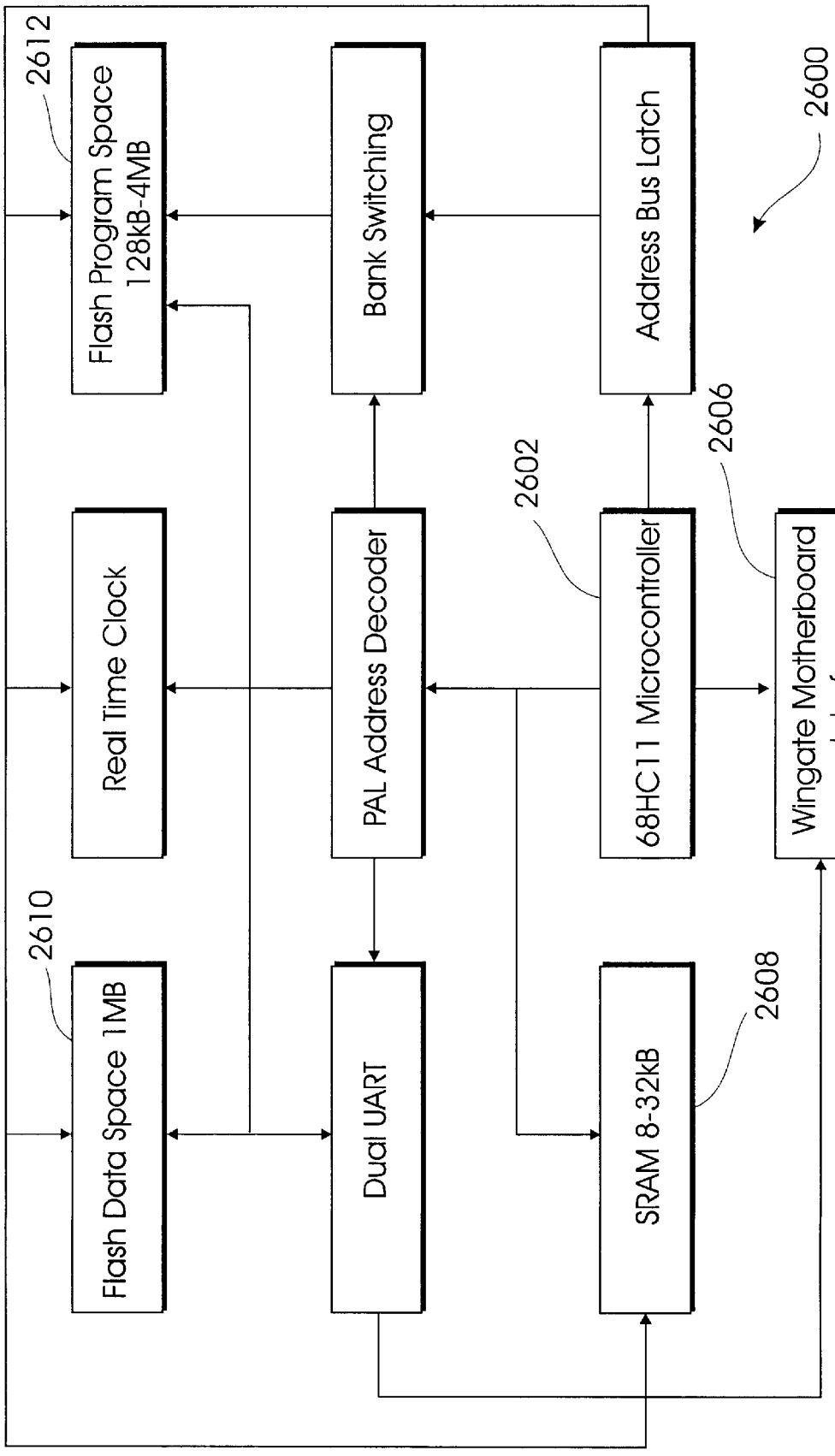


FIG. 33

WinGate CPU Board Functional Block Diagram

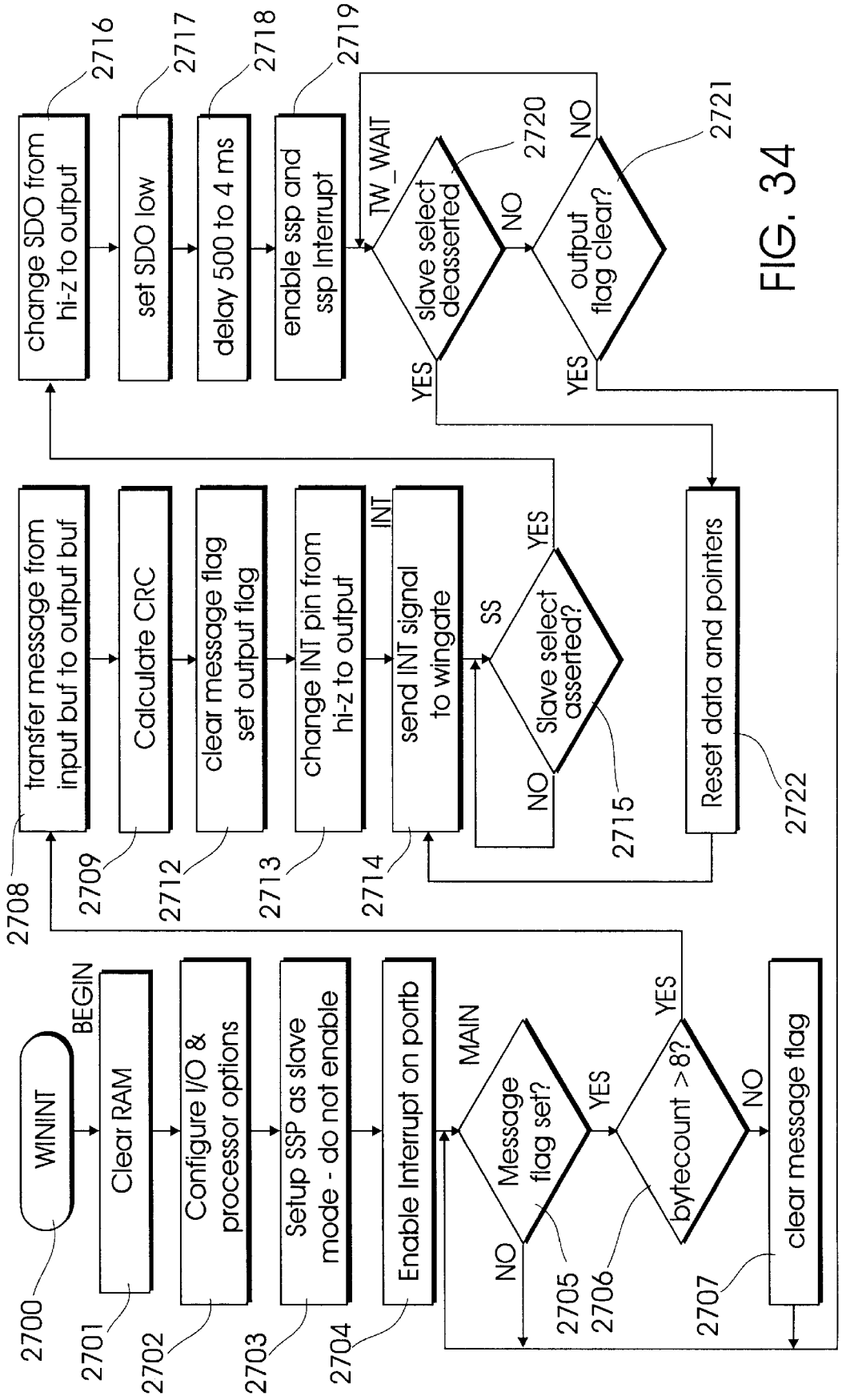

WININT
BEGIN
Clear RAM
Configure I/O & processor options
Setup SSP as slave mode - do not enable
Enable Interrupt on portb
MAIN
Message flag set?
NO
YES
bytecount >8?
YES
NO
clear message flag
transfer message from input buf to output buf
Calculate CRC
clear message flag set output flag
change INT pin from hi-z to output
INT
send INT signal to wingate
SS
Slave select asserted?
YES
NO
Reset data and pointers
change SDO from hi-z to output
set SDO low
delay 500 to 4 ms
enable ssp and ssp Interrupt
TW_WAIT
slave select deasserted
NO
output flag clear?
NO
YES
YES
2700
2701
2702
2703
2704
2705
2706
2707
2708
2709
2712
2713
2714
2715
2716
2717
2718
2719
2720
2721
2722

FIG. 34

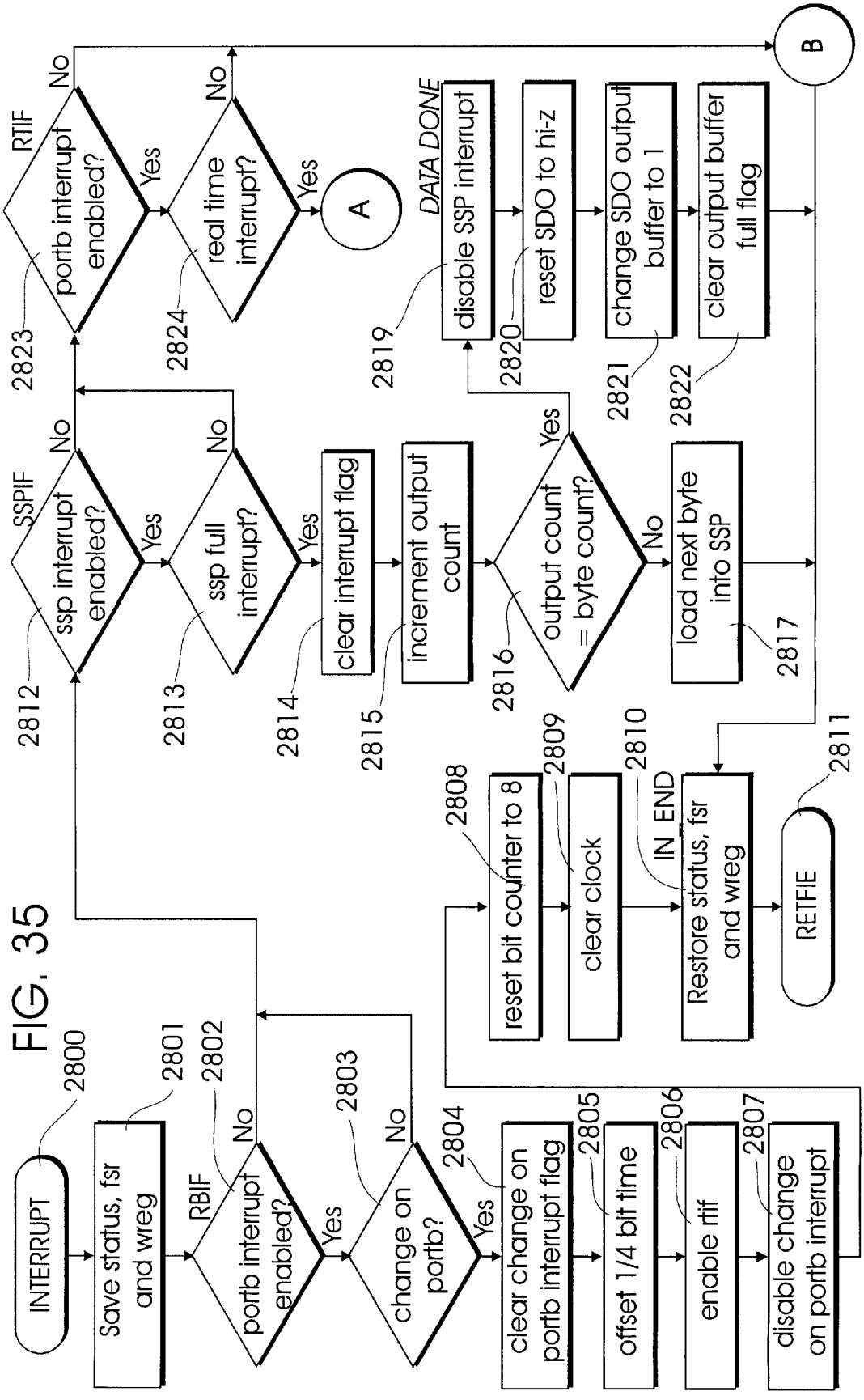

INTERRUPT
2800
Save status, fsr and wreg
2801
RBIF
portb interrupt enabled?
2802
No
Yes
change on portb?
2803
No
Yes
clear change on portb interrupt flag
2804
offset 1/4 bit time
2805
enable rtif
2806
disable change on portb interrupt
2807
reset bit counter to 8
2808
clear clock
2809
IN END
Restore status, fsr and wreg
2810
RETFIE
2811
SSPIF
ssp interrupt enabled?
2812
ssp full interrupt?
2813
clear interrupt flag
2814
increment output count
2815
output count = byte count?
2816
load next byte into SSP
2817
RTIF
portb interrupt enabled?
2823
real time interrupt?
2824
A
B
DATA DONE
disable SSP interrupt
2819
reset SDO to hi-z
2820
change SDO output buffer to 1
2821
clear output buffer full flag
2822

FIG. 35

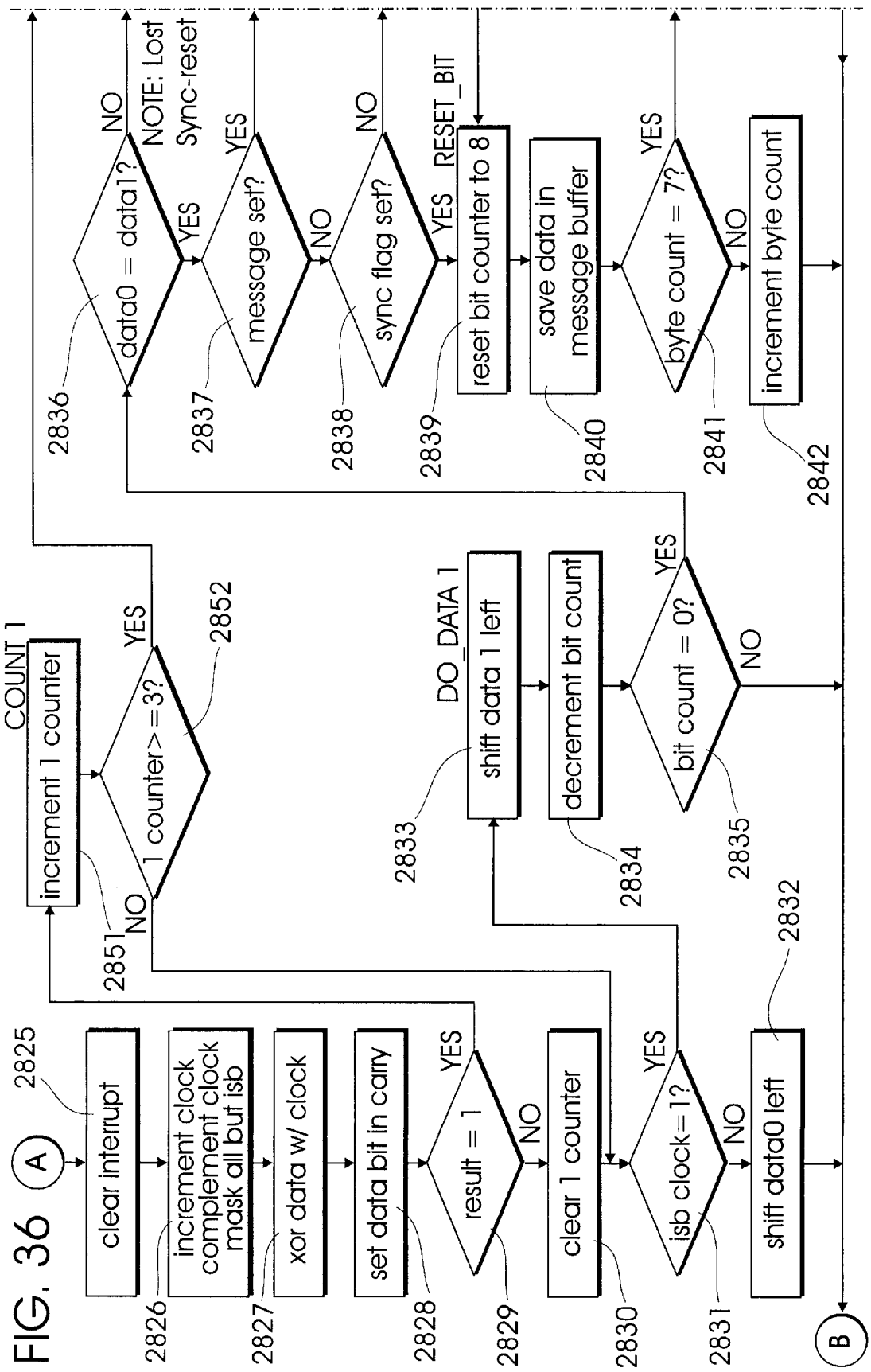

A
clear interrupt
2825
increment clock
complement clock
mask all but isb
2826
xor data w/ clock
2827
set data bit in carry
2828
result = 1
YES
NO
2829
clear 1 counter
2830
isb clock=1?
YES
NO
2831
shift data0 left
2832
B
COUNT 1
increment 1 counter
2851
1 counter>=3?
YES
NO
2852
DO_DATA 1
shift data 1 left
2833
decrement bit count
2834
bit count = 0?
YES
NO
2835
data0 = data1?
NO
NOTE: Lost Sync-reset
YES
2836
message set?
YES
NO
2837
sync flag set?
NO
2838
reset bit counter to 8
YES
RESET_BIT
2839
save data in message buffer
2840
byte count = 7?
YES
NO
2841
increment byte count
2842

FIG. 36

FIG. 36A

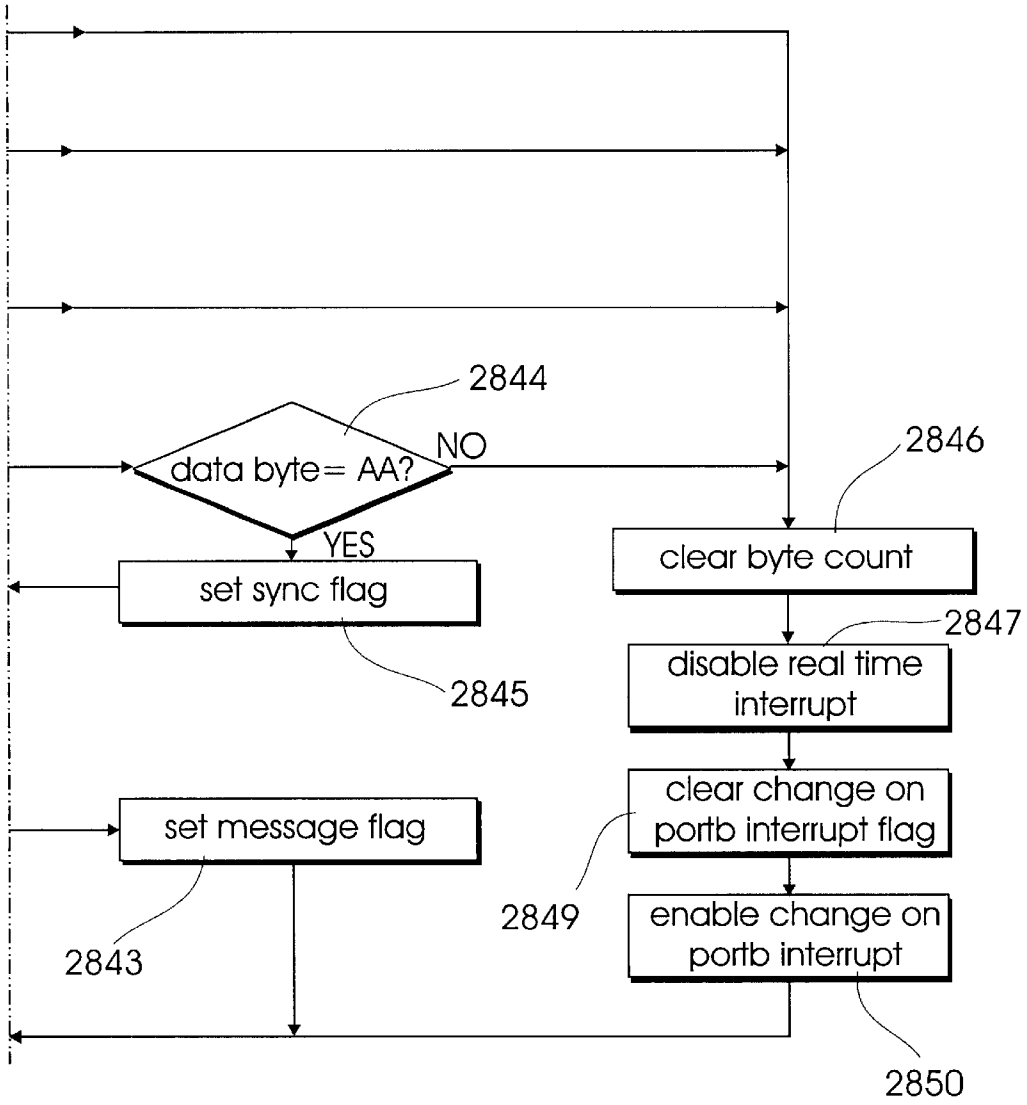
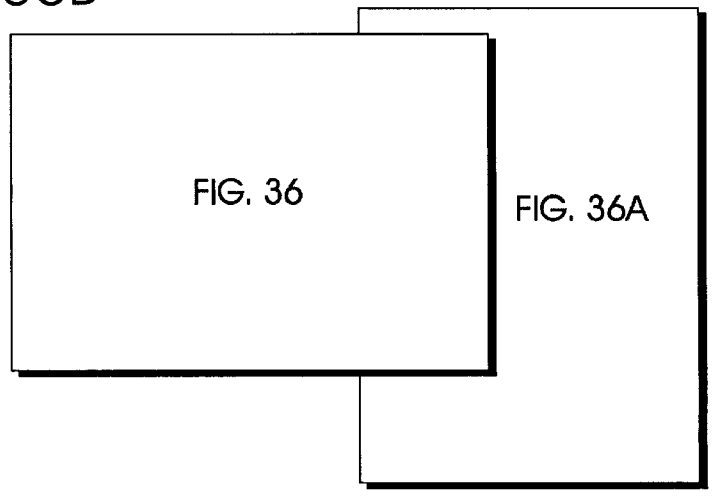


FIG. 36B



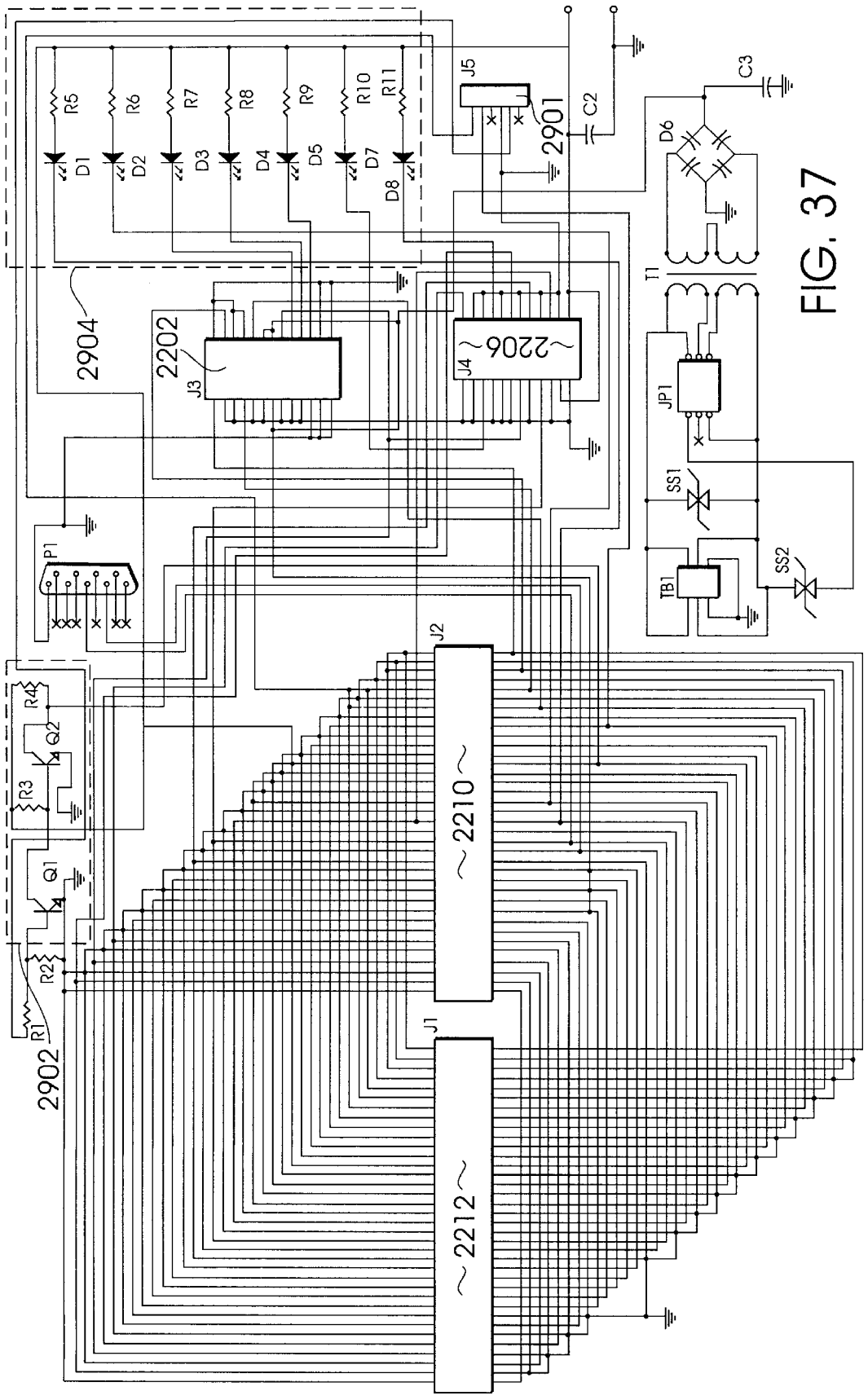

R5
R6
R7
R8
R9
R10
R11
D1
D2
D3
D4
D5
D7
D8
J5
2901
C2
C3
D6
T1
2904
2202
J3
2206
J4
JP1
SS1
SS2
TB1
P1
J2
2210
R4
Q2
R3
Q1
R2
R1
2902
J1
2212

FIG. 37

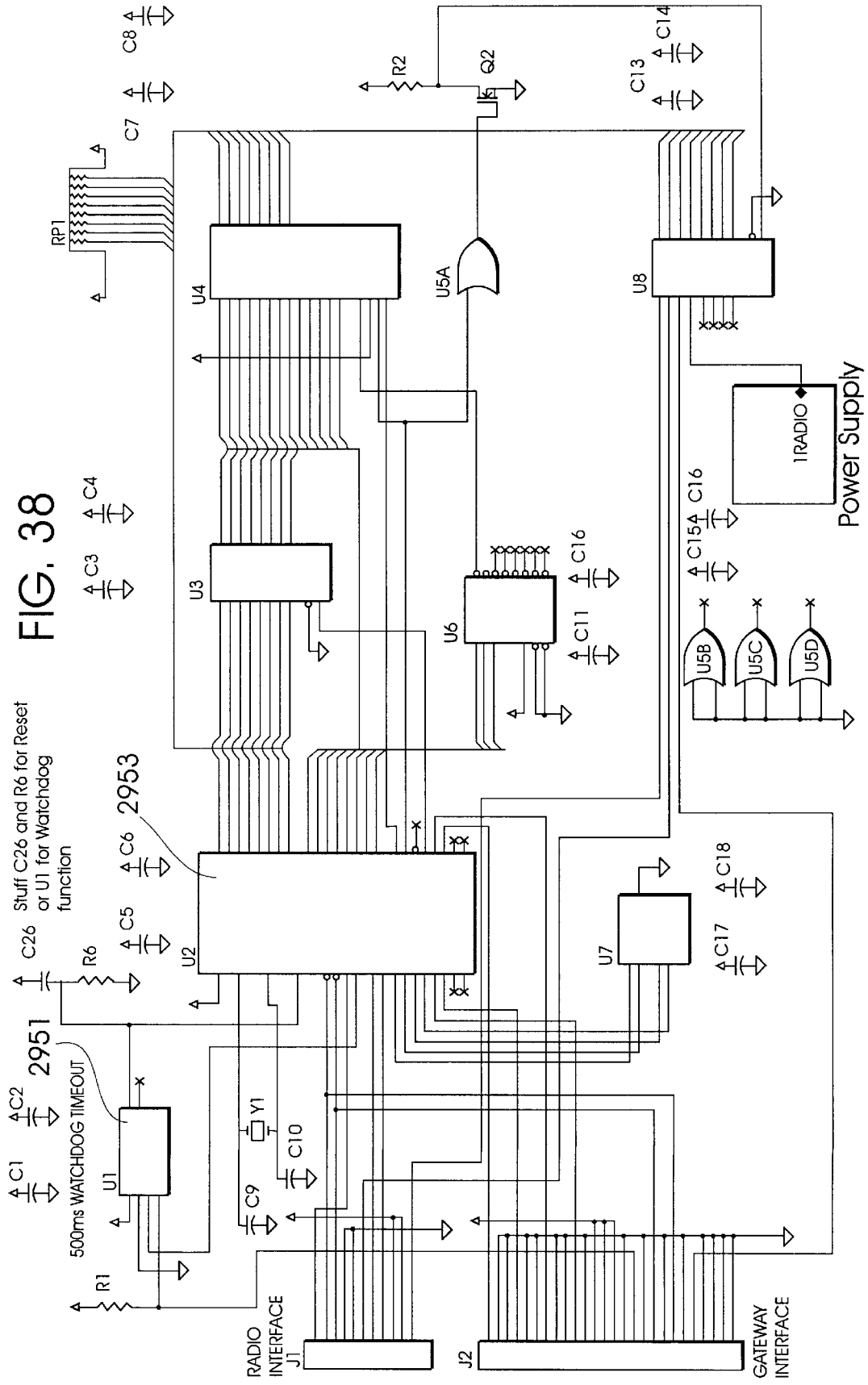

C8
C7
RP1
R2
Q2
C13
C14
U4
U5A
U8
1RADIO
Power Supply
C4
C3
U3
U6
C16
C11
C15
C16
U5B
U5C
U5D
2953
C6
C5
U2
C26
R6
Stuff C26 and R6 for Reset or U1 for Watchdog function
U7
C18
C17
2951
C2
C1
U1
500ms WATCHDOG TIMEOUT
Y1
C10
C9
R1
RADIO INTERFACE J1
J2
GATEWAY INTERFACE

FIG. 38

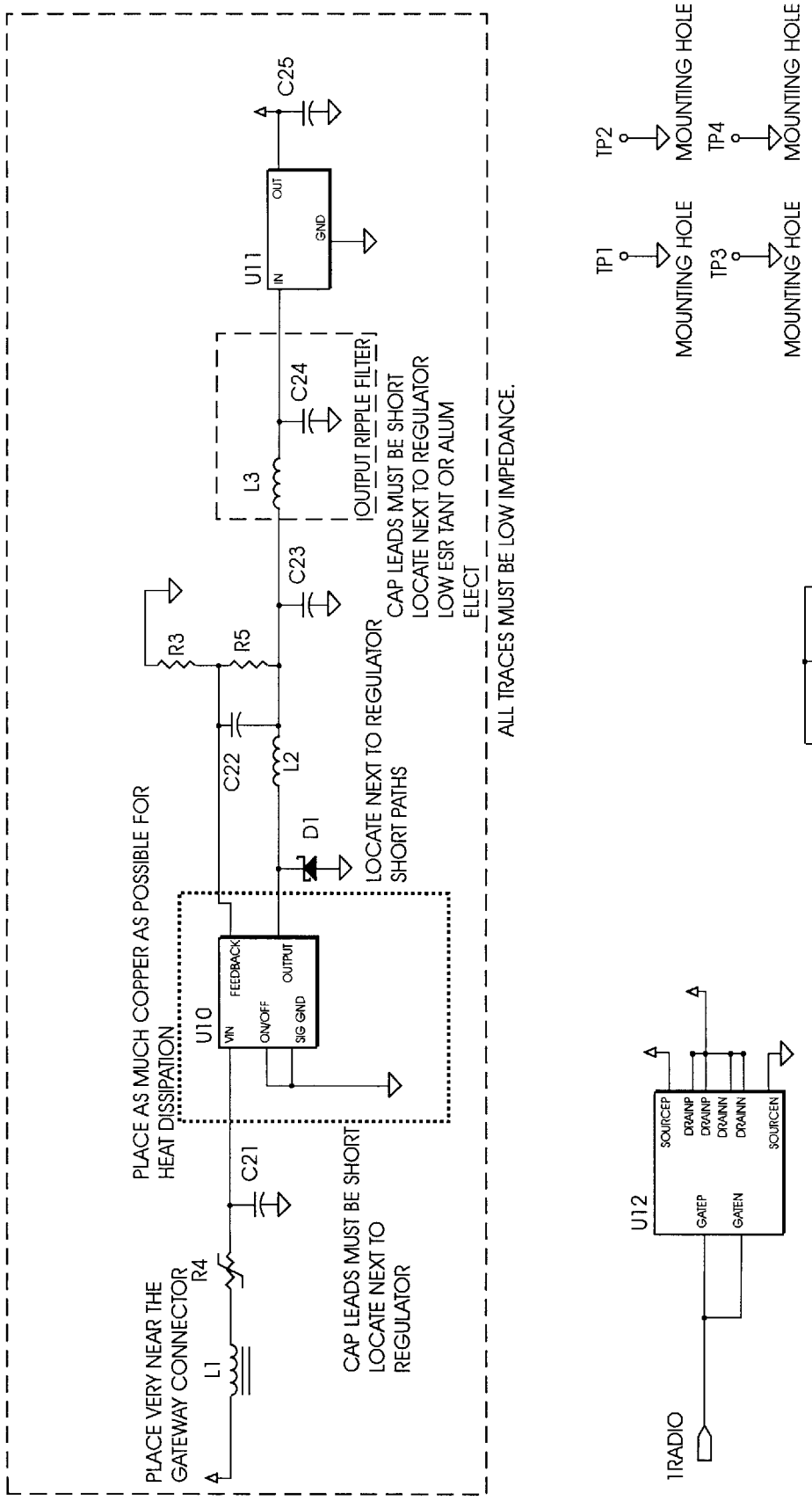

PLACE VERY NEAR THE GATEWAY CONNECTOR
R4
L1
C21
PLACE AS MUCH COPPER AS POSSIBLE FOR HEAT DISSIPATION
U10
VIN
FEEDBACK
ON/OFF
SIG GND
OUTPUT
C22
L2
D1
R3
R5
C23
L3
C24
C25
U11
IN
GND
OUT
CAP LEADS MUST BE SHORT LOCATE NEXT TO REGULATOR
LOCATE NEXT TO REGULATOR SHORT PATHS
OUTPUT RIPPLE FILTER
CAP LEADS MUST BE SHORT LOCATE NEXT TO REGULATOR LOW ESR TANT OR ALUM ELECT
ALL TRACES MUST BE LOW IMPEDANCE.
TP1
MOUNTING HOLE
TP2
MOUNTING HOLE
TP3
MOUNTING HOLE
TP4
MOUNTING HOLE
U12
SOURCEP
DRAINP
DRAINP
DRAINN
DRAINN
SOURCEN
GATEP
GATEN
1RADIO

FIG. 39

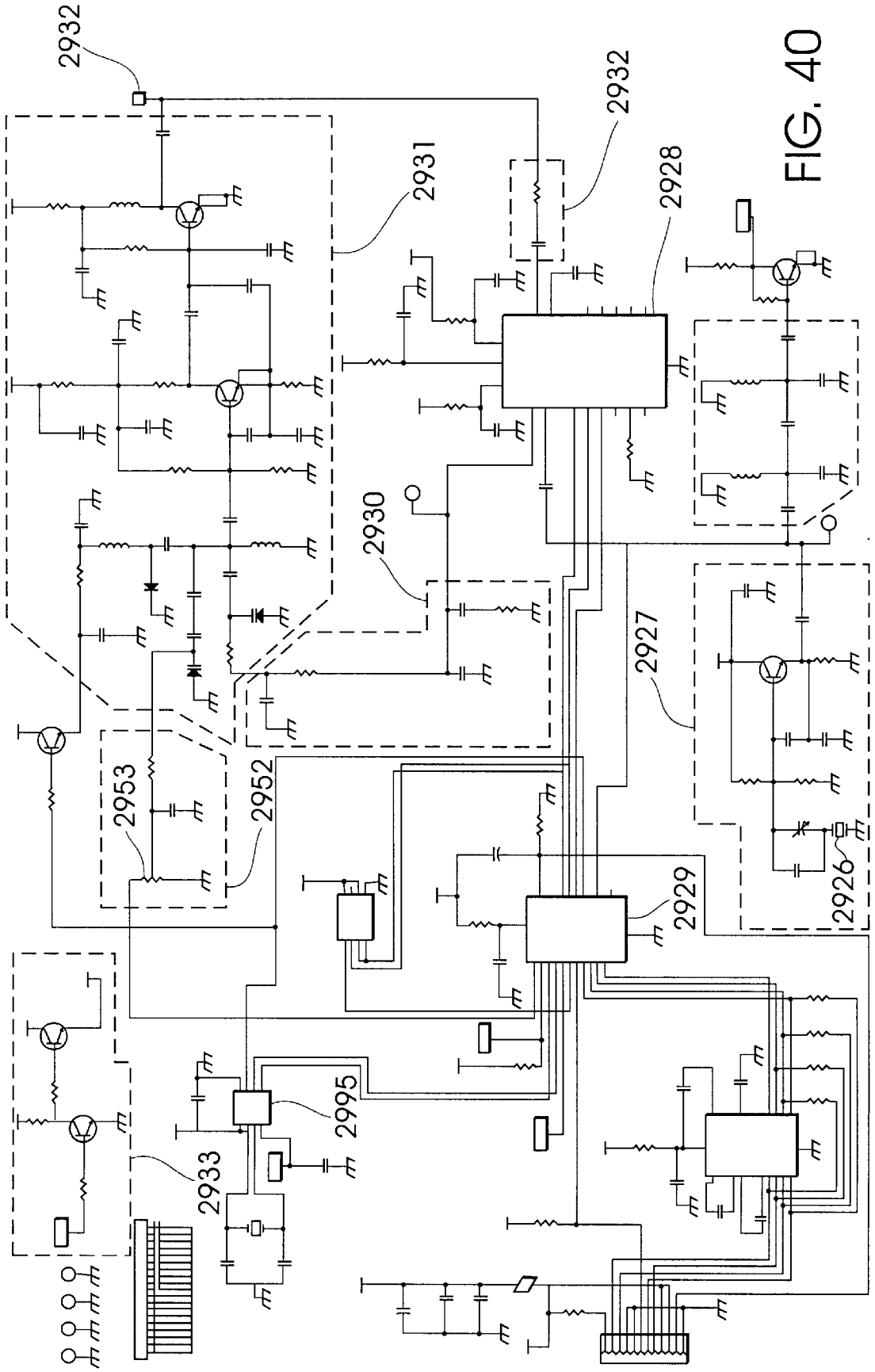


FIG. 40

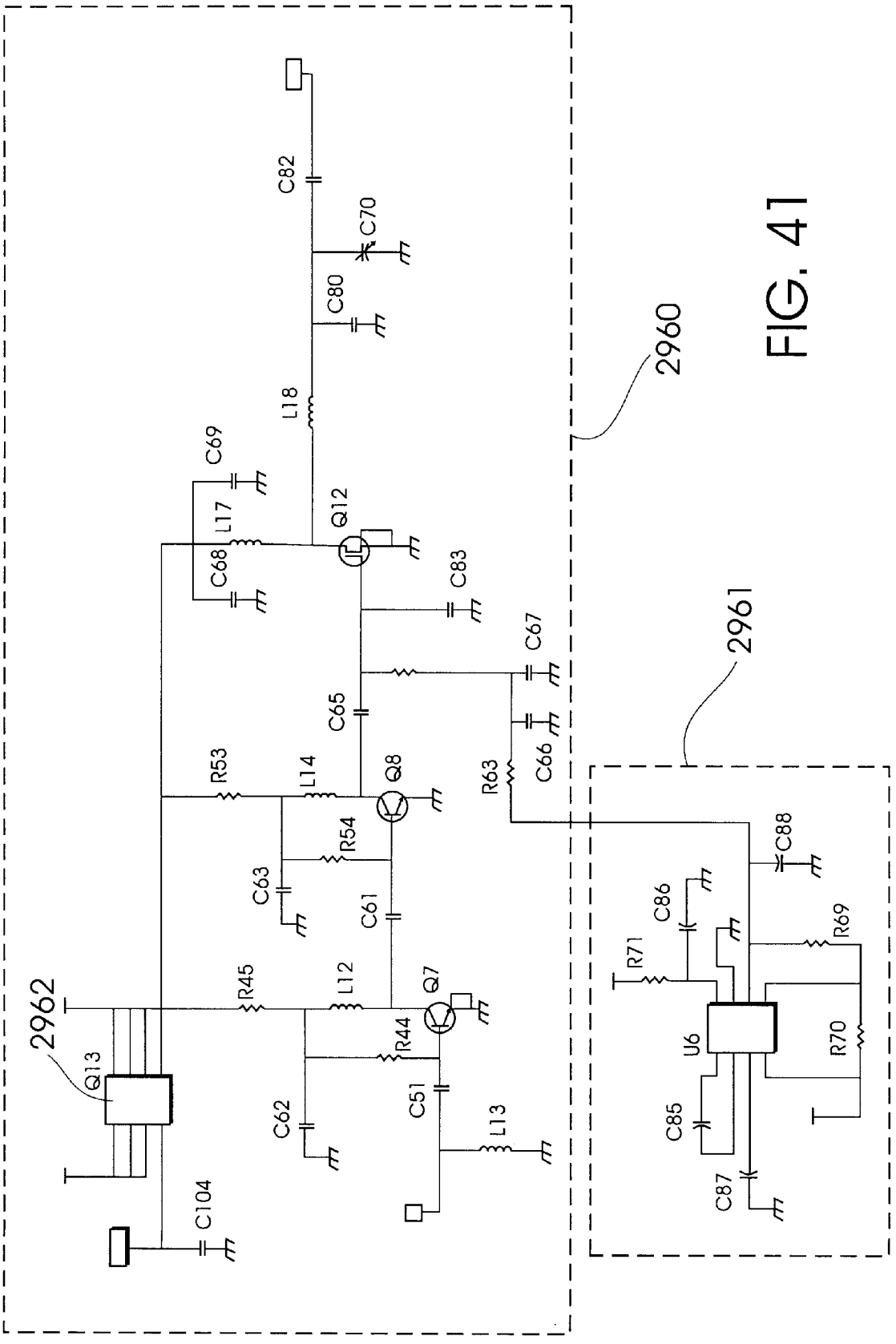
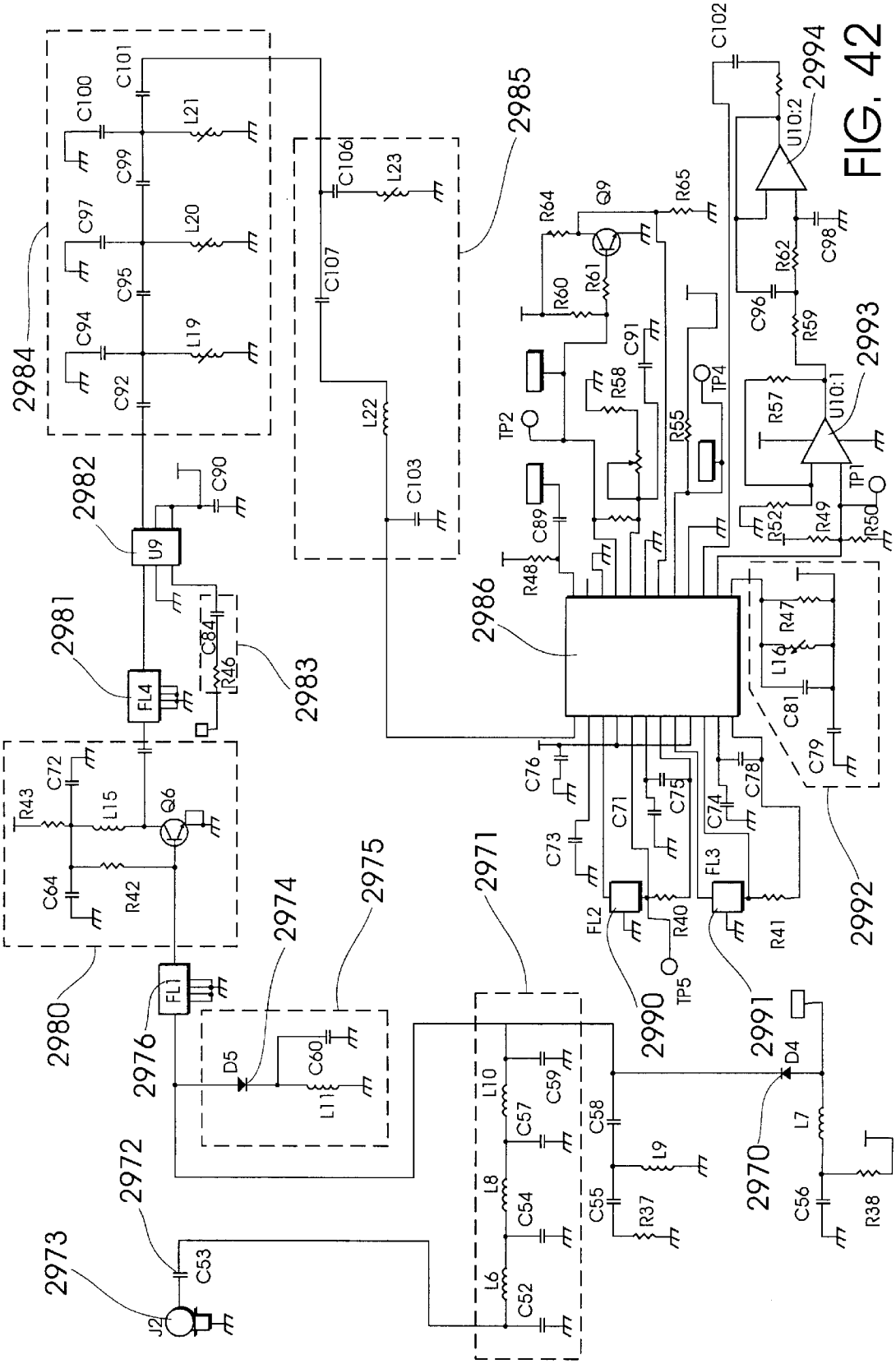

2960
2961
2962
C82
C70
C80
L18
C69
L17
C68
Q12
C83
C67
C65
C66
R63
R53
L14
Q8
R54
C63
C61
R45
L12
Q7
R44
C62
C51
L13
Q13
C104
C88
C86
R69
R71
U6
R70
C85
C87

FIG. 41


2984
2982
2981
2983
2985
2986
2980
2976
2974
2975
2971
2972
2973
2970
2990
2991
2992
2993
2994
C101
C100
C99
C97
C95
C94
C92
L21
L20
L19
C90
U9
FL4
C84
R46
C106
L23
C107
L22
C103
C102
U10:2
U10:1
Q9
R64
R61
R60
R65
R62
C98
C96
R59
C91
R58
R55
TP4
TP2
R57
TP1
R52
R49
R50
C89
R48
R47
L16
C81
C79
C76
C73
C71
C75
C74
C78
FL3
FL2
R40
R41
TP5
R43
C72
L15
Q6
C64
R42
FL1
D5
C60
L11
L10
C57
C59
C58
L9
L8
C54
C55
R37
L6
C52
C53
J2
D4
L7
C56
R38
FIG. 42

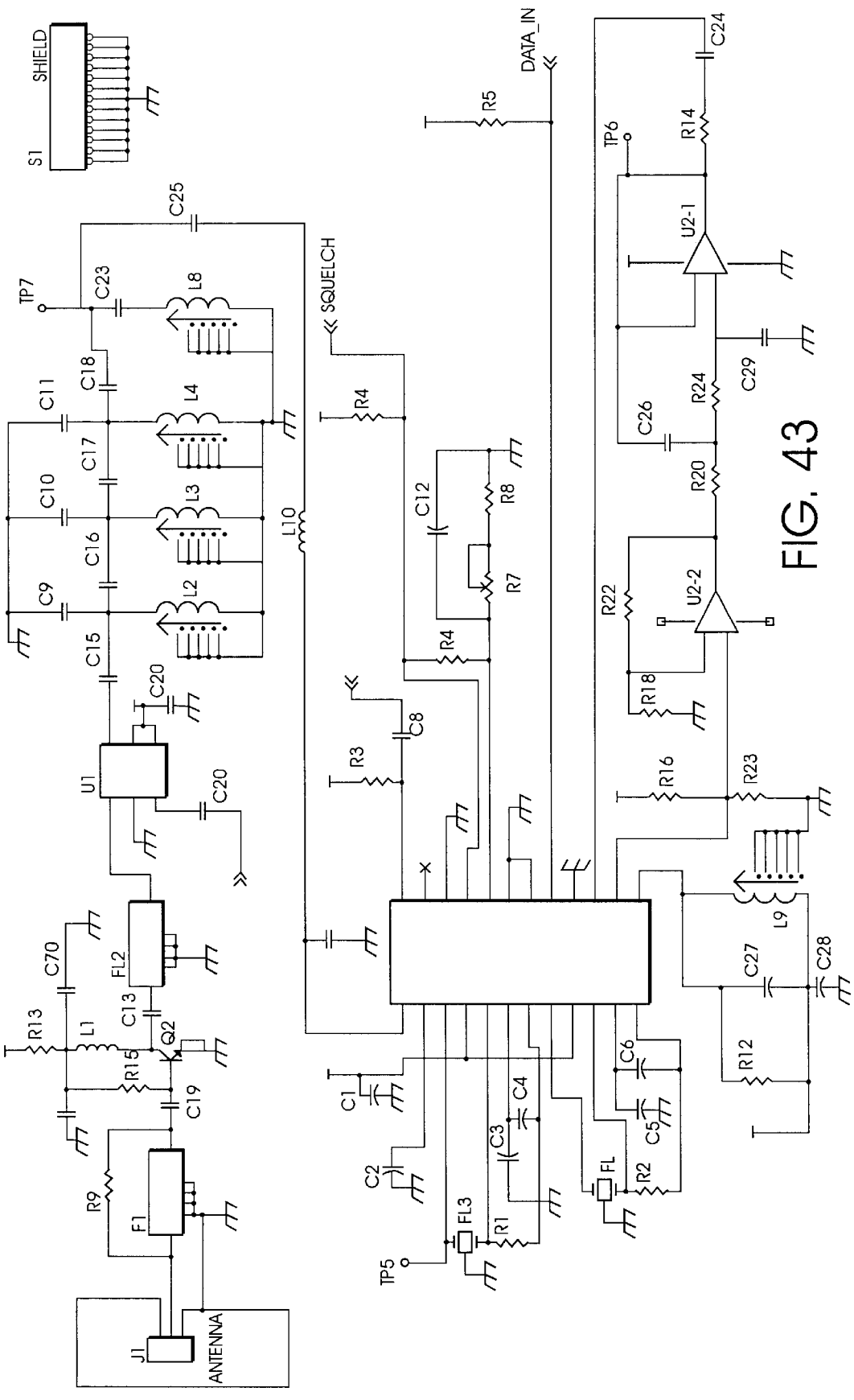
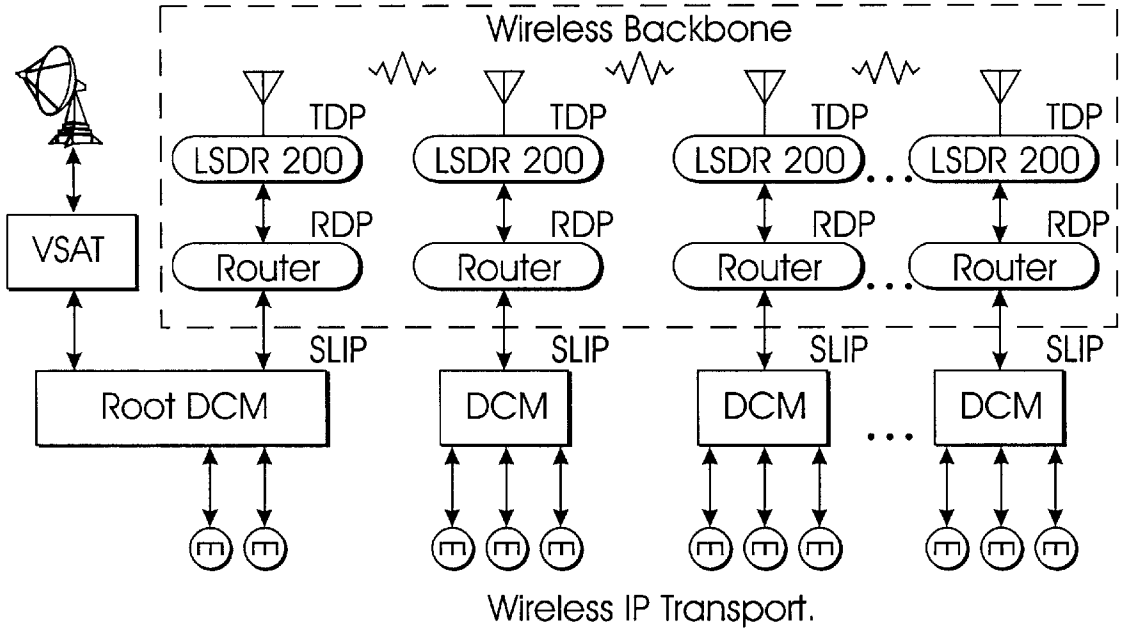

SHIELD
S1
C25
TP7
C23
L8
C18
C11
L4
C17
C10
L3
C16
C9
L2
C15
C20
U1
C20
C70
FL2
C13
R13
L1
Q2
R15
C19
R9
F1
J1
ANTENNA
L10
SQUELCH
R4
C12
R8
R7
R4
R3
C8
DATA_IN
R5
TP6
R14
U2-1
C24
C29
C26
R24
R20
R22
U2-2
R18
R16
R23
L9
C27
C28
R12
C6
C5
C4
C3
C2
C1
FL
R2
FL3
R1
TP5

FIG. 43

FIG. 44


Wireless Backbone
TDP
LSDR 200
RDP
Router
SLIP
VSAT
Root DCM
DCM
Wireless IP Transport.

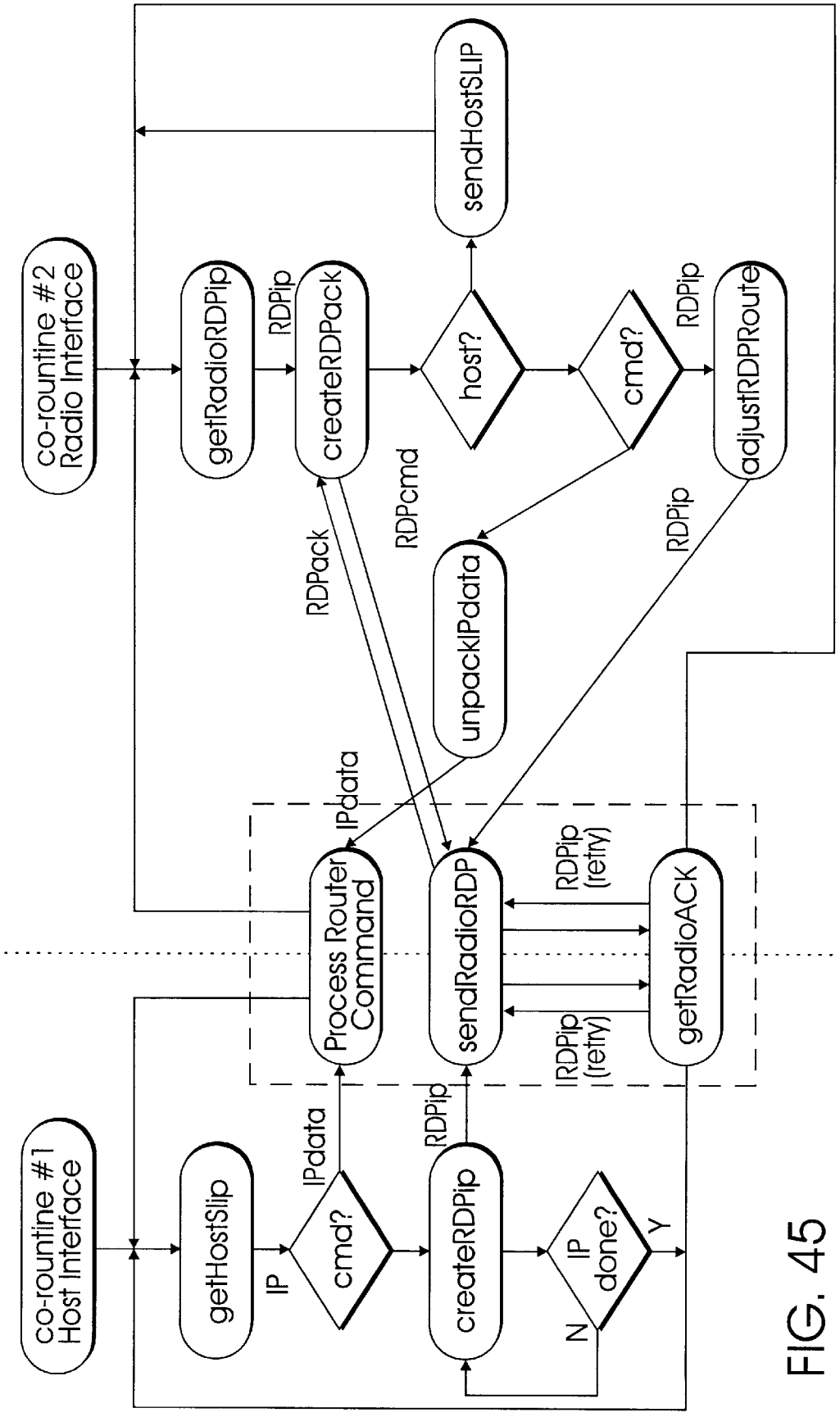

co-rountine #2
Radio Interface
getRadioRDPip
RDPip
createRDPack
host?
sendHostSLIP
cmd?
RDPip
adjustRDPRoute
RDPack
RDPcmd
unpackIPdata
RDPip
IPdata
Process Router
Command
sendRadioRDP
RDPip
(retry)
getRadioACK
IRDPip
(retry)
co-rountine #1
Host Interface
getHostSlip
IP
cmd?
IPdata
RDPip
createRDPip
IP
done?
Y
N

FIG. 45

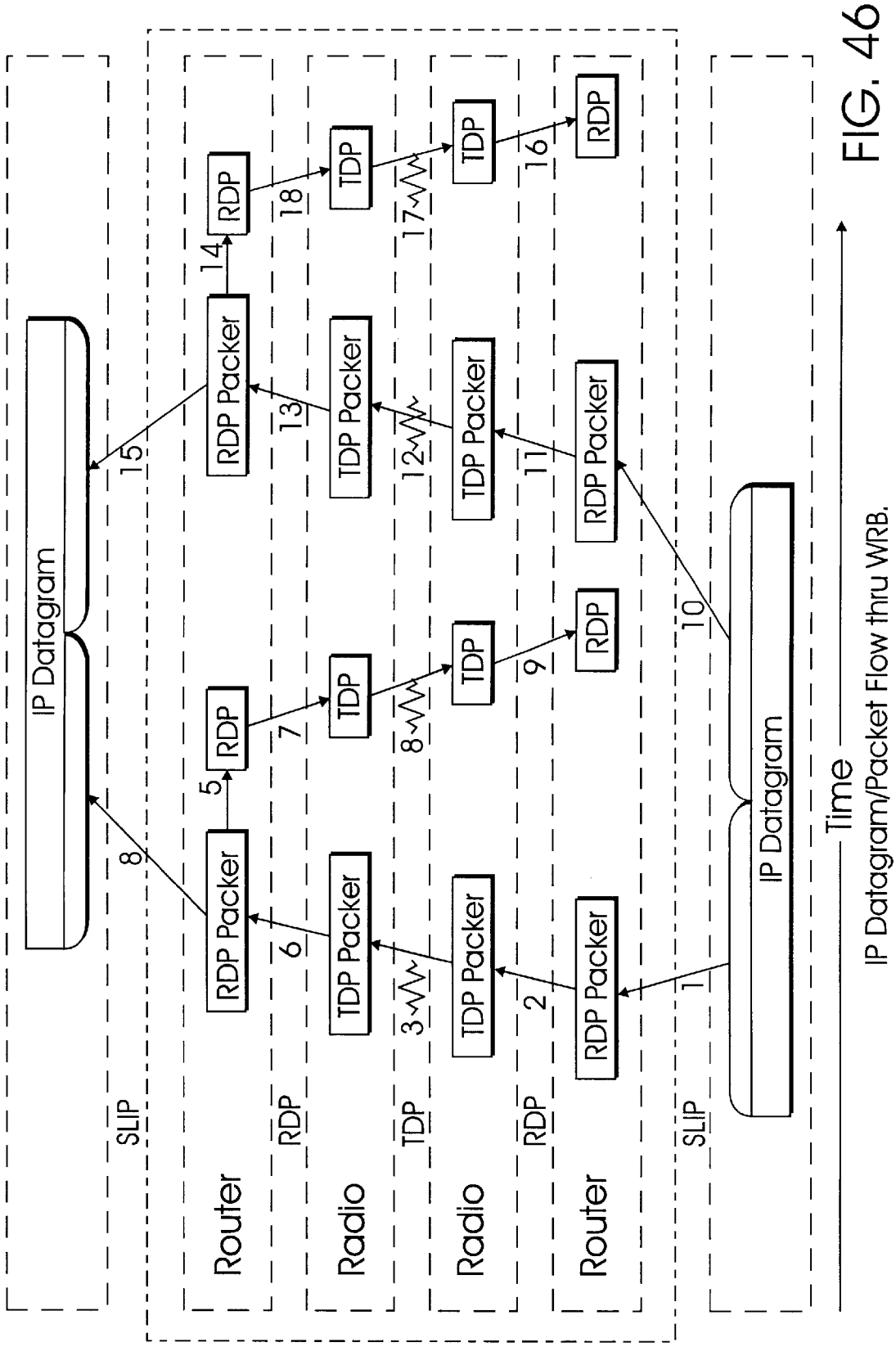

IP Datagram
SLIP
Router
RDP
Radio
TDP
Radio
RDP
Router
SLIP
IP Datagram
RDP Packer
TDP Packer
TDP Packer
RDP Packer
RDP
TDP
TDP
RDP
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Time
IP Datagram/Packet Flow thru WRB.

FIG. 46

FIG. 47

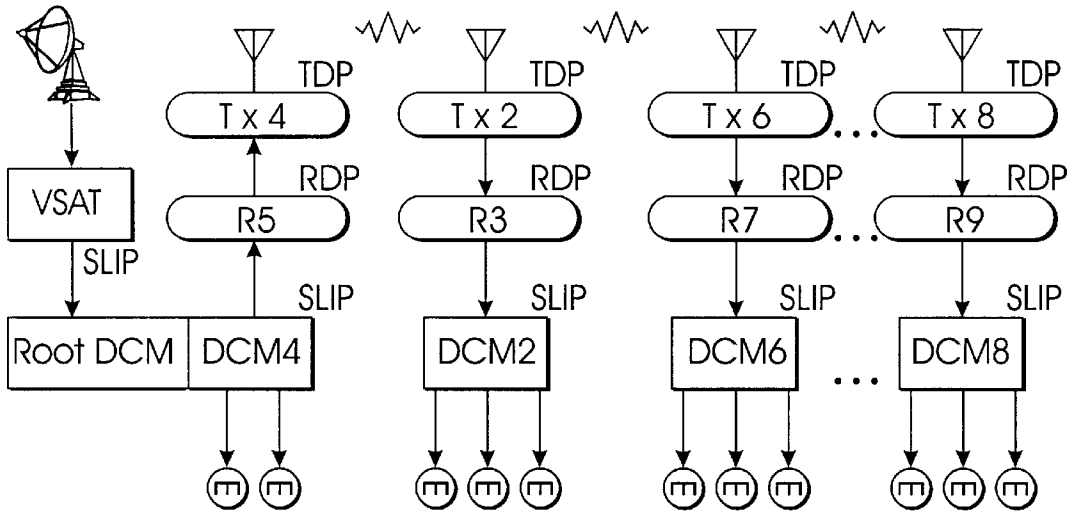
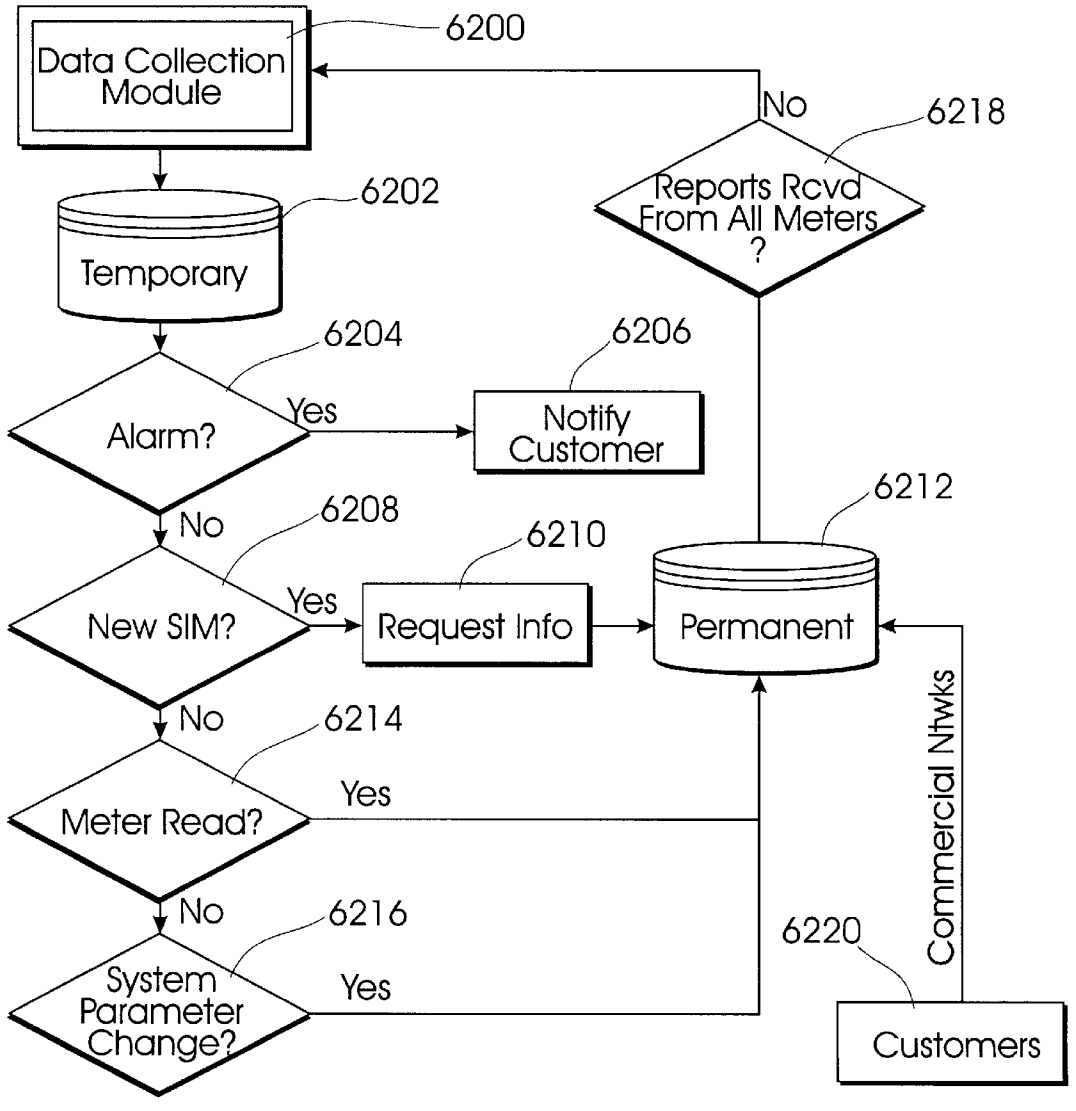

TDP
Tx 4
Tx 2
Tx 6
Tx 8
RDP
R5
R3
R7
R9
VSAT
SLIP
Root DCM
DCM4
DCM2
DCM6
DCM8

FIG. 48


Data Collection Module
6200
Temporary
6202
Alarm?
6204
Yes
Notify Customer
6206
No
New SIM?
6208
Yes
Request Info
6210
Permanent
6212
No
Meter Read?
6214
Yes
No
System Parameter Change?
6216
Yes
Reports Rcvd From All Meters ?
6218
No
Commercial Ntwks
6220
Customers

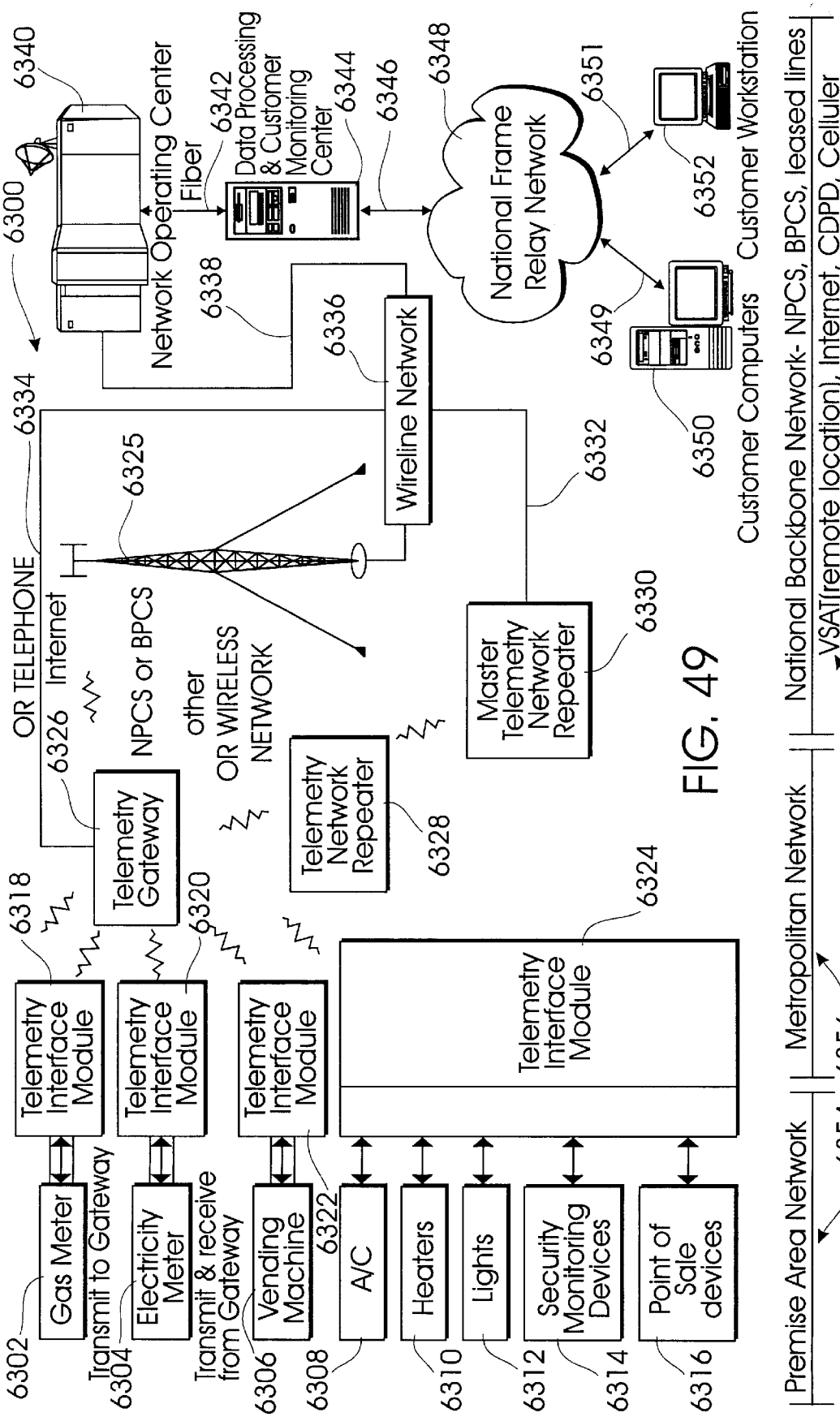

6340
6300
Network Operating Center
Fiber
6342
Data Processing & Customer Monitoring Center
6344
6346
6348
National Frame Relay Network
6351
6352
Customer Workstation
6338
6336
Wireline Network
6349
6350
Customer Computers
6334
OR TELEPHONE
6326 Internet
6325
NPCS or BPCS
other
OR WIRELESS
NETWORK
6332
6330
Master Telemetry Network Repeater
Telemetry Network Repeater
6328
Telemetry Gateway
6318
6320
6324
Telemetry Interface Module
Telemetry Interface Module
Telemetry Interface Module
Telemetry Interface Module
Transmit to Gateway
Transmit & receive from Gateway
6302
Gas Meter
6304
Electricity Meter
6306
Vending Machine
6308
A/C
6310
Heaters
6312
Lights
6314
Security Monitoring Devices
6316
Point of Sale devices
Premise Area Network
6354
Metropolitan Network
6356
National Backbone Network- NPCS, BPCS, leased lines
VSAT(remote location), Internet, CDPD, Celluler
6358

FIG. 49

WIDE AREA REMOTE TELEMETRY

CROSS REFERENCE TO RELATED APPLICATIONS

The present application is related to U.S. Provisional Patent Application Ser. No. 60/058,978, filed Sep. 12, 1997, entitled WIDE AREA REMOTE TELEMETRY and U.S. Provisional Patent Application No. 60/094,057, filed Jul. 24, 1998, entitled WIDE AREA REMOTE TELEMETRY, which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to the fields of automatic meter reading of electric, gas, water meters and other systems, automatic reading of flow data, monitoring of such usage, and distribution of information thereon.

The need for near real-time information is becoming critical to the efficient operation of many types of industries. This invention addresses a need for information from remote monitoring locations. This disclosure will center on preferred embodiments of a monitoring system for the electrical and gas utility industry, although this monitoring system could be used for other areas such as gas pipeline metering, pipeline monitoring, water system monitoring, security systems, vending machines, energy control devices, or other areas where remote monitoring is necessary.

The need for near real-time information from remote locations is becoming more pronounced due to the deregulation of several industries. For the utility industries, deregulation means an increase in competition which demands increased efficiencies in the utility systems. These increased efficiencies require better information about, and better control over, the systems involved. Increased efficiency heightens the need for near real-time information monitoring. Thus, the utilities need the ability to obtain near real-time information on consumer demand, supply, and overall system operations.

As an example, electric utilities need this information to balance the generation of electricity against consumer demand, and to operate the transmission system as efficiently as possible.

In general, electricity is generated at a generating plant, transformed for transmission over distances, and transformed again for the distribution to customers. The deregulation of the electrical utility industry will require innovative solutions to balance the generated electrical supply against the consumer demand for electricity. These solutions will require a reduction in the system costs, by increasing the system efficiencies, to match the competition levels of the deregulated industry. An increase in the electrical transmission system efficiency will require access to remotely-located consumer-usage information to enable the utilities to eliminate the excessive generation of electricity. Thus, increasing the system efficiency will require the utility to reduce excessive generation and balance the amount of generated electricity against the consumer demand.

The onset of deregulation of the electrical utility industry, and other similar industries, will result in unbundling of utility operations and segmenting of the marketplace. Deregulation will widen the gap between the supplier and consumer and increase the competition in the industry. This widened gap and increased competition results in the formation a new type of organization in the electrical utility industry called the independent sales organization (ISO).

The ISO will operate as an intermediary between the electrical generating facilities and the consumers by buying generated electricity, transmitting it from the generating location to the consumer area, and reselling the electricity to the consumers.

Bulk users of electricity will generally have more negotiating power in the purchasing of electricity. To take advantage of bulk rates, local consumers may join together to form a distribution pool which has associated demand levels and other characteristics. These distribution pools of customers will compare prices for electricity and purchase electricity from the lowest cost supplier or ISO. Because of varying electricity prices, the electricity bought and sold by an ISO for use in a particular distribution pool of customers, such as Tulsa, Okla., may actually be generated in remote locations, such as Colorado on one day and in Florida on the next. Thus, potential problems will arise in balancing the generation, transmission, and usage of the nation's electrical transmission system. To avoid these problems, the ISO will need increased access to information in order to predict customer demand, purchase electricity, and resell the electricity to the consumer.

The present invention is additionally capable of providing a number of services to energy users such as energy usage analysis, energy management services, Internet inquiry services, and billing services.

2. Prior Art

Systems and methods for monitoring various types of meters, and collecting information to a centralized location are widely described in the prior art. Examples of these systems can be seen in the following patents:

U.S. Pat. No. 4,940,976, issued to Gastouniotis et al. on Jul. 10, 1990 describing an AUTOMATED REMOTE WATER METER READOUT SYSTEM; U.S. Pat. No. 5,053,766, issued to Ruiz-del-Portal et al. on Oct. 1, 1991 describing a TELEMETERING SYSTEM FOR ELECTRICAL POWER CONSUMED BY VARIOUS USERS; U.S. Pat. No. 5,451,938, issued to Brennan, Jr. on Sep. 19, 1995 describing a RF METER READING SYSTEM; U.S. Pat. No. 5,475,867, issued to Blum on Dec. 12, 1995 describing a DISTRIBUTED SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM; and U.S. Pat. No. 5,673,252, issued to Johnson et al. on Sep. 30, 1997 describing a COMMUNICATIONS PROTOCOL FOR REMOTE DATA GENERATING STATIONS. A brief discussion of these various examples is outlined in the following discussion.

U.S. Pat. No. 4,940,976, issued to Gastouniotis et al. on Jul. 10, 1990 describes an AUTOMATED REMOTE WATER METER READOUT SYSTEM. This system creates a periodic electrical signal whose frequency is proportional to the flow rate. This signal is stored into a solid state counter from which this information is transmitted to a remote receiver by a standard radio frequency telemetry link. The receiver stores the information for multiple meters and periodically sends the data to the data processing office by means of a telephone line, CATV cable, or RF link. The transmitting link between the solid state counter and the remote receiver occurs every time the flow counter is incremented as well as periodically whenever a timer generates a pulse.

The Gastouniotis et al. '976 patent uses sensing and transmitting units which both randomly and periodically sends one burst of consumption data at times throughout the day to the receiving interface unit for the area. This data is then accumulated in memory which is disgorged to the central billing site either periodically or on demand. This

system teaches away from the use of multiple transmission to assure successful information transmittal. This system does not disclose any method for signal verification of the transmission from the sensing and transmitting unit. In addition, this system teaches an inefficient method of double counting the usage information and then dividing it before transmitting.

U.S. Pat. No. 5,053,766, issued to Ruiz-del-Portal et al. on Oct. 1, 1991 describes a TELEMETERING SYSTEM FOR ELECTRICAL POWER CONSUMED BY VARIOUS USERS. This system monitors consumer power usage from meters with disk revolution indicators of power consumption by utilizing a pulse generator, light generating LEDs, light and dark regions on the revolving disk, and sensors which monitor the passage of the light and dark regions of the revolving disk. The system detects and monitors disk revolutions and uses a sending means for transmitting a consumption signal to a meter concentrator, and a means for communicating the information acquired into a central computer.

U.S. Pat. No. 5,451,938, issued to Brennan, Jr. on Sep. 19, 1995 describes a RF METER READING SYSTEM. Brennan '938 collects data from the meter and stores the data for transmission. At preselected pseudorandom timing intervals, the transmitter encodes the data, creates a synch signal, start signal, message signal, and a verification signal. The RF transmitter sends the information signals to the RF receiver which identifies the start signal, receives the transmission, and verifies the accuracy of the transmission.

U.S. Pat. No. 5,475,867, issued to Blum. on Dec. 12, 1995 describes a DISTRIBUTED SUPERVISORY CONTROL AND DATA ACQUISITION SYSTEM. This system is designed to overcome the inherent problems in short range radio broadcast communication by using supplemental controllers to enhance the transmission and control range of master controllers. Supplemental controllers are placed within the range of the master controller, but are capable of broadcasting to supplemental remote terminal units outside of the master controller's range. The supplemental controller transmits messages from the master controller to the supplemental remote terminal units, and relays responses from the supplemental remote terminal units. This allows for the supplemental remote control units to be placed outside the normal broadcast range of the master controller and, thus, extend the operating range of the master controller.

U.S. Pat. No. 5,673,252, issued to Johnson et al. on Sep. 30, 1997 describes a COMMUNICATIONS PROTOCOL FOR REMOTE DATA GENERATING STATIONS. This system is used to gather information and transmit the gathered information to a central location. Specifically, this system uses a Network Service Module (NSM) which communicates with a Remote Cell Node (RCN). The RCN communicates through an optional Intermediate Data Terminal (IDT) to get information to a Central Data Terminal (CDT). As an alternative to the separate IDT, the IDT functions may be implemented by the CDT.

In Johnson '252, the NSM is used to acquire information from utility meters, disconnect service, manage load, or monitor for alarm conditions. The NSM includes a transmitter, processor, memory, antenna, and optionally includes a receiver. The NSM processor monitors, collects, and arranges acquired information into packets of data for a pre-determined monitoring scheme and stores the acquired data in memory. Once the NSM has acquired a period or segment of data for the monitoring scheme, the NSM transmits all of the acquired data as a data packet. This transmission takes place at a predetermined time period over a single frequency to th e RCN. Alarm messages are not stored into memory, but are immediately transmitted to the RCN. The NSM transmits and can receive information through this first frequency and can also receive information through a second carrier frequency. The NSM is designed to utilize a maximum of two frequencies which are controlled by the design of the unit.

Johnson '252 collects information through the RCN which receives, stores, and processes the NSM signals. The RCN includes a transmitter, receiver, processor, memory, and antenna. The RCN receives the NSM data packets and temporarily stores them in memory. The RCN then collates the information, identifies duplicates of NSM data packets already transmitted by other RCN modules and acknowledged by IDT modules, and deletes the duplicate NSM data packets from its memory. The RCN transmits its collated information as a single packet of RCN information when polled by the IDT and deletes the stored information upon acknowledgement of the transmission by the IDT.

Johnson '252 either uses an IDT or a CDT which performs the functions of an IDT. The IDT includes a transmitter, processor, memory, and receiver. The IDT transmits a polling signal to the RCNs, receives the RCN information, transmits an acknowledgment of the receipt of the RCN information, and stores the RCN information in memory. The IDT collates the RCN information and deletes any duplicate NSM data packets to form IDT information which is sent to the CDT.

The Johnson '252 CDT element includes a transmitter, receiver, processor, and memory. The CDT receives IDT information and deletes any duplicate NSM data packets. The CDT then processes and stores the received information.

The prior art as evidenced by the described patents suffers from excessive duplicate information transmission, required polling for second layer information retrieval, being overly complicated, and having excessive parts which are susceptible to failure. Further, the systems disclosed in the patents do not appear to maintain temporary duplicate information at efficient levels for transmission failures and other system problems.

Hence, there remains a need for a simplified remote sensing information collection and information distribution system which addresses these and other problems.

SUMMARY OF THE INVENTION

The need for near real-time processed information on consumer utility usage which is available to the utility or other parties will require innovative solutions to remote-device system monitoring. An effective monitoring system can be developed through the use of a sensor interface module, a data collection module, commercially available information transmission systems, and a host module.

The sensor interface module will constantly monitor individual customer demand and usage to gather information for the monitoring system. The sensor interface module will send this information to the data collection module over unlicensed radio frequency bands. The data collection modules will gather the information from sensor interface modules or other inputs wired directly and transmit the information to the host module over the commercially available information transmission systems. The host module will gather, store, and process the information from the sensor interface modules as needed, and communicate through commercially available information transmission systems to send the processed information to the appropriate consumers as desired.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a block diagram of the general monitoring system and the information flow from sensor interface modules to a customer in a wide area remote telemetry system constructed in accordance with the present invention.

FIGS. **2** and **3** illustrate a sensor interface module with main body and external sensor which are elements of the wide area remote telemetry system shown in FIG. **1**.

FIGS. **4**, **5**, **6**, **7**, **8**, and **9** illustrate various mounting arrangements for the sensor interface module.

FIGS. **10**, **11**, and **12** illustrate exploded views of a hardware sensor for a sensor interface module for a meter for the wide area remote telemetry system shown in FIG. **1**.

FIGS. **12** and **13** illustrate a gas meter cover for mounting a sensor interface module and a pulse encoder hardware sensor.

FIGS. **14**, **15**, **16**, and **18** illustrate improved mounting methods for a magnetically actuated switch.

FIG. **17** illustrates one method for mounting a magnetic switch for actuation by a magnetic field.

FIG. **19** illustrates a simplified block diagram for a sensor interface module.

FIG. **20** illustrates a simplified block diagram of a sensor interface module.

FIG. **21** illustrates the elements of a sensor interface module transmission to a data collection module.

FIGS. **22** and **23** are a flow charts of the transmitter program for the sensor interface module.

FIG. **24** illustrates a schematic diagram of a transmitter design for the sensor interface module.

FIG. **25** is a block diagram of a data collection module which is a part of the wide area remote telemetry system of the present invention.

FIGS. **26**, **27**, and **28** are a schematic view of the mounting enclosure for a data collection module.

FIG. **29** is a schematic diagram for a motherboard mounting arrangement for a data collection module.

FIG. **30** is a block diagram of a data collection module.

FIG. **31** is a block diagram of a receiver of the data collection module.

FIG. **32** is a flow chart of the receiver of the data collection module.

FIG. **33** is a block diagram for the central processing unit of the data collection module shown in FIG. **25**.

FIG. **34** is a process flow diagram for the operation of the sensor interface module is receiver in the data collection module.

FIGS. **35** and **36** are flow charts of the microprocessor program for the data collection module.

FIGS. **37**, **38**, **39**, **40**, **41**, and **42** are schematic diagrams of a data collection module.

FIG. **43** shows a schematic diagram of a sensor interface module receiver.

FIG. **44** shows a schematic diagram of the overall data repeater system, called a Wireless Radio Backbone (WRB).

FIG. **45** shows a schematic view of the PMM software design.

FIG. **46** shows a schematic representation of a IP datagram/Packet flow through the WRB.

FIG. **47** shows a layout of a WRB for a walk-through example.

FIG. **48** is a flow chart of operation of the host module.

FIG. **49** shows an example of an overall network schematic implementing the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings in detail, FIG. **1** is a schematic representation for a wide-area remote telemetry system **100**, constructed in accordance with the present invention. A plurality of sensor interface modules **102**, which are electromechanical interfaces, act as data gathering equipment.

Sensor interface modules **102** communicate with data collection modules **110** through a hardwire or wireless transmission **108**. Standard wire connection may be utilized for the hardwire or wireless transmission **108**, or various types of known, low-power, radio-frequency transmissions may be utilized. The preferred embodiment communicates by using a frequency-hopping spread-spectrum transmission in an unlicensed range, such as 902–928 Mhz.

Sensor interface modules **102** can be a single path sensor interface module **104** or a multiple path sensor interface module **106**. The only difference between the single path sensor interface module **104** and multiple path sensor interface module **106** is the number of data collection modules **110** receiving the hardwire or wireless transmission **108** from the individual sensor interface modules **102**. Single path sensor interface modules **104** communicate through hardwire or wireless transmission **108** to only one of the data collection modules **110**. Multiple path data collection modules **106** transmit a hardwire or wireless transmission **108** to multiple data collection modules **110**.

The method of transmitting information to the data collection modules **110** will be explained by separately describing a first data collection module **112** and a second data collection module **114**. Note, however, that any number of data collection modules **110** may be used in the wide area telemetry system **100**. If the first data collection module **112** is the only reception point for data from a single path sensor interface module **104**, then the first data collection module **112** will have primary responsibility for forwarding the information from the single path sensor interface module **104**. If the second data collection module **114** is the only reception point for data from a single path sensor interface module **104**, then the second data collection module **114** will have primary responsibility for forwarding the information from the single path sensor interface module **104**. If the wireless transmission **108** is received by both the first data collection module **112** and second data collection module **114**, then a priority will be assigned to both the first and second data collection modules **112** and **114**.

As shown in FIG. **1**, the wireless transmission **108** from multiple-path sensor interface module **106** is received by both the first data collection module **112** and second data collection module **110**. Only one of the data collection modules **110** will have primary responsibility for forwarding the information received from a multiple-path sensor interface module **106**. Initially both data collection modules will forward information from a new sensor interface module. Then, either the first data collection module **112** or the second data collection module **114** will be assigned a primary responsibility for forwarding information from the multiple-path sensor interface module **106**. The remaining data collection module **112** or **114** will be assigned secondary responsibility for forwarding the information from the multiple-path sensor interface module **106**. Data collection modules **110** with primary responsibility for a multiple-path sensor interface module **106** will forward information

received from the multiple-path sensor interface module **106** during both the normal transmission of signals and upon a transmit request. Data collection modules **110** with secondary responsibility for a multiple-path sensor interface module **106** will not transmit information from that multiple-path sensor interface module **106** during normal transmissions, and will only transmit the information from that multiple-path sensor interface module **106** upon a transmit request.

In the overall wide area remote telemetry system **100**, only one of the multitude of data collection modules **110** will be assigned primary responsibility for any one of the sensor interface modules **102**, but any number of data collection modules **110** may be assigned secondary responsibility for any one of the sensor interface modules **102**. This method of data transmission allows for an efficient, single-line of communication of messages during normal operation of the system, but allows for multiple paths of data recovery if the system fails during its normal operation.

The data collection modules **110** transmit the information received from the sensor interface modules **102** over a data module connection **116** to a network system **118**. The network system **118** forwards the transmitted information over a network connection **120** to a host module **122** where the information is stored or processed. The stored or processed information may then be transmitted from the host module **122** through a host connection **124** to the customer interface **126**.

Each of the modules, connections, and transmissions will be explained in detail herein.

1. The Sensor Interface Module (TIM)

a. Overview

The sensor interface modules **102** are intelligent communications devices which attach to gas, electric and water meters and other types of monitored equipment. The basic sensor interface modules **102** may be adapted to any number of systems to be monitored, including but not limited to: electrical systems, gas systems, water systems, security systems, temperature control systems, vending machines, and remotely monitored devices of any sort. The sensor interface modules **102** include an appropriate hardware sensor for the device being monitored; a computerized monitoring system with associated firmware; battery power supply and/or a converter for external power; and a transmitter.

b. Physical Characteristics

As shown in FIG. **2**, the sensor interface module **102** can be made with a sensor interface main body **200**, sensor connecting harness **202** and an external hardware sensor **204**. The main body **200** consists of a sensor interface circuit board **206** with sensor connecting terminals **208** for attaching the sensor connecting harness **202** to the external hardware sensor **204**. The main body **200** can be installed internally to the monitored device or can be made to fit in a small enclosure or casing **210** for external mounting on or in close proximity to the monitored device. The external hardware sensor **204** is mounted in a location suitable to the device being monitored and connected to the sensor interface circuit board **206** through the sensor connecting harness **202**. As an example, in one preferred embodiment, the small enclosure or casing **210** can be made from ABS plastic, having approximate dimensions of 5"×3"×1".

As shown in FIG. **3**, an example of the preferred embodiment of one of the sensor interface modules **102** for gas meters has a female sensor harness terminal **300** molded into the casing **210** which allows for matching male sensor harness terminal **302**. The matching male sensor harness terminal **202** is attached to the sensor connecting harness **202**, which is attached to the external hardware sensor **204**. The matching male terminal **302** is installed on, or molded into, a sensor interface meter cover **304** or sensor interface mounting adaptor **306** for the various types of devices to be monitored. In this manner, a common sensor interface main body **200** may be mounted on any type of device by a standard connection method. This greatly simplifies the design of the sensor interface modules **102** by allowing for the use of several different external hardware sensor **204** arrangements and different mounting arrangements for the sensor interface main body **200** while using a standard sensor interface main body **200**.

For gas meters, a sensor interface module **102** will monitor rotation of the dials of the meter display. The small enclosure or casing **210** of the sensor interface module **102** may be mounted on the pipes or conduits surrounding the gas meter, or may be directly mounted on the meter. The sensor interface module **102** and the external hardware sensor may be integrated into the face plate of the meter to effectuate an efficient installation of the monitoring system on pre-existing meter installations.

FIGS. **4** and **5** illustrate further styles of physical mounting arrangements for sensor interface modules **102** that are mounted externally to the device being monitored, such as a conventional electrical watthour meter **400** shown in FIG. **4**. FIG. **4** illustrates how the sensor interface module **102** may be bolted directly to the electrical meter conduit **402** emerging from the electric meter pan **404** of a conventional electrical watthour meter **400**. The sensor interface main body **200** can be molded with an indention or retaining area **406** where main body conduit mounting hardware **408**, such as a threaded u-bolt, washers and nuts, can be used to secure the sensor interface main body **200** to a conduit, pipe, pole, or other convenient location. As shown in this example, the sensor interface main body **200** can be bolted to the electrical meter conduit **402** emerging from the top of the electric meter pan **404**, and wired through the sensor connecting harness **202** to the external hardware sensor **204** which is mounted in the conventional electrical watthour meter **400**. It is preferred to run the wires within the electrical conduit for protection against external forces or weather.

As shown in FIG. **5**, the mounting of the sensor interface main body **200** on the electrical conduit **402** can also be made by a sensor interface mounting flange **500**. This flange **500** is connected to the electrical meter conduit **402** with sensor flange conduit mounting hardware **502**. Sensor flange mounting hardware can be any type of item that may secure the sensor interface mounting flange to the conduit, such as pipe clamps, u-bolts and nuts, Velcro, or any other suitable mounting attachment. The top of the sensor interface mounting flange **500** forms the mounting base for a sensor interface main body **200** which can be attached to the mounting flange **500** by main body flange screws **504**. Furthermore, the unit may be made tamper resistant by covering the heads of the flange screws **504** with tamper resistant screw caps **506**. The main body **200** may then be connected through the sensor connecting harness **202** to the external hardware sensor **204**.

In another preferred embodiment (not shown), the external hardware sensor **204** is mounted in a conventional electrical watthour meter **400** and the meter cover is molded to have a male connector similar to the one previously described for gas meters. This allows for a direct connection of the sensor interface main body to the external hardware sensor through the sensor connecting harness in the meter cover. The sensor connecting harness may be molded into

the meter cover to protect the harness and the molded cover may also provide mounting locations for both the sensor interface main body and the external hardware sensor. In this manner, installation can be quickly accomplished by removing the old meter cover, connecting the sensor to the meter to be monitored, and reinstalling a new meter cover with attached sensor interface module which has already been programmed. This embodiment also protects the wiring connection between the external hardware sensor and the main body by molding the connections into the replacement meter cover. This eliminates long term wire fatigue and other exposure effects on the connections.

As shown in FIGS. **6**, **7** and **8**, the sensor interface module **102** may also be mounted on a termination enclosure **510**. The termination enclosure **510** can be mounted on a vertical conduit **512** through the use of a vertical indention **514**. Alternatively as shown in FIG. **7**, the termination enclosure **510** may be mounted on a horizontal conduit **518** through the use of a horizontal indention **516**. Angled, bent or curved indention mounting applications are also anticipated. Another method of mounting the termination enclosure **510** would be to attach it directly to a wall.

As shown in the exploded view of FIG. **8**, a sensor interface module **102** may be attached to a termination enclosure **510** for mounting purposes. The termination enclosure **510** is made up of a termination enclosure base **520** and a termination enclosure main body **522**. The termination enclosure base **520** is attached to the termination enclosure main body **522** through the use of base attachment bolts **524** which are sealed by tamper resisting caps **526**. The termination enclosure main body **522** also houses the sensor interface connector **528** which is attached by a sensor interface connector nut **530**. The termination enclosure main body **522** is sealably connected to the front cover **534** through the use of gasket seal **532**. Front cover **534** is attached to the termination enclosure main body **522** through the use of cover bolts **536** which are also sealed by tamper resistant screw caps **538**.

The sensor interface module **102** is attached to the termination enclosure main body **522**. The sensor interface module fits over the connector **528** for connection of the external hardware sensor, power, or other such inputs. The sensor interface module **102** is attached to the termination enclosure main body **522** through the use of sensor interface mounting screws **540**. Sensor interface mounting screws **540** are sealed into the sensor interface module **102** through the use of tamper resistant caps **542**.

A further alternative use of the sensor interface modules is illustrated in FIG. **9**. One of the sensor interface modules **102** can be connected to external hardware sensor **204** (not shown) which includes multiple sensing units as a part of the external hardware sensor. An example of these types of sensors are shown as a flow sensor **600**, pressure sensor **602**, and temperature sensor **604** which gather information about the flow of gas or other liquids **606** through a pipeline **608**. Information may be alternatively obtained from a flow computer which is connected to an orifice meter or a turbine meter. Flow computers and meters, such as turbine meters and orifice meters, are well known. Flow computers may be connected to sensor interface modules to allow the data from the flow computer to be delivered to a data collection module. Alternatively, if the flow computer has the appropriate capabilities, the flow computer can be programmed to directly communicate with the data collection module and, thus, bypass the sensor interface module.

Another alternate use for the sensor interface modules (not shown) would be for the monitoring of digital electric meters, external corrosion control monitoring systems, automated tank level control systems, and other types of systems. Additionally, devices which have output capabilities may be capable of being directly connected to the sensor interface modules, where the device itself becomes the external hardware sensor. Another possibility is that the device may have communication capabilities that allow for a direct connection to the data collection module without requiring the use of a sensor interface module.

The sensor interface module may be designed to include meter interface connectors for all of the major residential and commercial gas meters. These connectors may be molded directly into the sensor interface main body casing, or may be accomplished through adapters or various types of sensor interface harnesses. These adaptations allow the sensor interface modules to be installed on new or existing meters and allow monitoring of the entire system or area being monitored regardless of the age of the device being monitored.

c. Hardware Sensor

Each of the sensor interface modules **102** include an external hardware sensor **204** which is capable of monitoring the desired device. Note that the word 'external', as used in describing the external hardware sensor, means external to the standard design of the sensor interface module's data acquisition and transmission capabilities. This is due to the fact that the external hardware sensors will be different for individual applications. Thus, external means external only to the common circuitry for data gathering and transmission, and not necessarily physically external to the enclosure containing the sensor interface module **102**.

FIGS. **10** and **11** illustrate a preferred embodiment of a pulse encoder **700** which is a particular type of an external hardware sensor **204** for the sensor interface module **102**. FIG. **10** illustrates an exploded view of a pulse encoder **700** mounted on a rotational dial meter **702**, such as a natural gas meter, and FIG. **11** illustrates the same pulse encoder **700** viewed from an alternate perspective.

The pulse encoder **700** monitors the flow of gas through a rotational dial meter **702** by monitoring the rotation of the meter dials **704** behind the face plate **708** of the rotational dial meter **702**. The meter dials **704** can be seen on the dial plate **706** behind a partial view of the face plate **708**. Between the dial plate **706** and the face plate **708** is a tubular proximity sensor **710**. This tubular proximity sensor **710** is a magnetic reed switch in the preferred embodiment, although any type of magnetically actuated switch could be used. Extending through an opening **712** in the face plate **708** is an encoder shaft **714**. The encoder shaft fits over one of the meter dials **704** and is rotated by the rotation of the meter dial **704**. The encoder shaft **714** is held in place by a surrounding spring **716** which biases the shaft against the rotating dial **704** and the circular encoder magnet **718**. The encoder magnet **718** fits over the encoder shaft **714** and is secured to the shaft so that the encoder magnet **718** rotates with the rotation of the shaft **714**. The surrounding spring **716** biases the rotating encoder magnet **718** against the insert **722**, and holds the magnet **718** in position near the tubular proximity sensor **710**. Thus, as the circular magnet **718** rotates in corresponding relationship to the meter dial **704**, the magnet creates a rotating magnetic field which opens and closes the proximity sensor **710**. The magnet **718** is biased against the insert **722** which is held in position by the positioning end or protective bubble **724**. The protective bubble **724** is attached to the face plate **708** and the junction between the face plate **708** and the protective bubble **724** is sealed by an encoder faceplate seal **720**. Thus, the pulse

encoder **700** is a sealed external hardware sensor **204** which monitors the rotating meter dials **704** and sends corresponding signals through the opening and closing of the tubular proximity sensor **710**.

As shown in FIGS. **10** and **11**, the mounting location of the tubular proximity sensor **710** for this application is offset from the accepted mounting method for reed switches.

FIGS. **12** and **13** illustrate a gas meter cover for mounting a sensor interface module and a pulse encoder hardware sensor.

FIGS. **14** through **18** illustrate improved changes in the positioning of the magnetic reed switch or proximity sensor **710** and the importance of these improvements in the mounting location.

FIGS. **14** and **15** show an improved dial-type reed switch magnetic interface which aligns the magnetic proximity sensor **900** in an offset tangential relationship to the dial path and the rotation of the magnet **902**. FIG. **14** illustrates an offset-center line mounting location for the reed switch. The reed switch has a center line **910** through the contact closure point of the reed switch. This center-line **910** of the reed switch is offset from the parallel centerline **912** through magnetic axis of the magnet **902**. This prevents a sufficient amount of magnetic field from reaching the wire end of the reed switch and causing a reactivation of the contact closures. This becomes especially important when the meter is in temperature varying mounting locations or when mounted in vibrating conditions. An illustration of the increased distance between magnetic rotation and contact switch opening and closure points may be seen in FIG. **16**. This increased distance means that the units are less susceptible to outside influences such as vibration or temperature changes. This sensor to magnet alignment was engineered in the present configuration due to the very nature of the application. The extremely slow wheel rotation makes the normal contact closure point sensitive to the vibration of the meter or device being monitored. These sensitivities, and the critical nature of consistent contact closure for proper monitoring information, required a deviation from the standard contact alignment methods, which resulted in the improvements disclosed herein. Thus, a common switch or sensor axis to magnet axis alignment would not have been sufficient.

Another improved mounting method is the reed switch alignment of FIG. **18**, which provides the greatest separation between the magnet and the reed switch. This separation provides for the fastest declining magnetic field, which provides for quick release or small hysterysis between the operation and release points. When the appropriate parameters are selected, this mounting method only allows one operation of the switch per magnet passage.

In contrast to the improved mounting of FIG. **18**, the improved reed switch alignment of FIG. **14** is recommended due to the performance requirements of this particular reed switch application. The alignment of FIG. **14** provides a small separation between the sensor and magnet. In addition, the motion of magnet moves along the axis of the switch and, consequently, the magnetic field declines at a slower rate. This provides a larger rotational point separation between the operation and release points.

Note that if the centerline of the switch is moved towards the centerline of the magnet axis so that they will be aligned, such as shown in FIG. **17**, multiple operations of the switch will occur on each rotation of the magnet. When the centerline of the reed switch contacts is perpendicular with a bisecting polar-line the across the axis of the rotation, the reed switch will be open. The reed switch will close as the magnet starts to rotate. The contacts will then open as the polar-line of the magnet approaches the parallel of the contact point centerline, and then re-close as the magnet continues to rotate. This also happens as the magnet rotates past the centerline alignment. Because counting and correcting multiple contact closures is inefficient, it is more efficient to offset the reed switch centerline from the magnet axis rotation centerline and use the mounting arrangement of FIG. **14**.

Note, however, that even using the mounting configuration of FIG. **14**, multiple operations are still possible if the rotational magnet is too large. Thus, the reed switch and magnet alignment need to be selected according to criteria of size, rotational motion, and the longest hysterysis available.

The alignment of FIG. **18** is also an improved mounting method which would be acceptable for this application. The improved alignment of FIG. **18** is most easily contrasted with the alignment of FIG. **17**. As shown in FIG. **17**, the aligned-centerline tangential orientation of the magnetic reed switch or proximity sensor **900** results in several openings and closing of the contacts of the reed switch on each rotation of the magnet **902**. In this configuration, the positioning of the reed switch is critical. The design is very sensitive to the distance from the reed switch to the magnet, the sensitivity of the switch being used, the magnetic strength involved, and the tolerances are very stringent.

As shown in FIG. **18**, an improved method for monitoring dial-type displays can be implemented by realigning the magnetic sensor to be perpendicular to the old style mounting arrangement, but still within the magnetic field of the magnet. This configuration arranges the magnetic fields so that the reeds in the switch will be drawn together and virtually or completely eliminates contact bounce. In this arrangement, the proximity sensor **1200** is located in a perpendicular relationship to the magnet **1202**. In addition to the beneficial effects of reducing or eliminating contact bounce, this arrangement reduces the sensitivity of the reed switch to the aforementioned variables.

Other pulse encoding methods may also be used, including optical sensors designed for implementation with rotational disk electric meters that are well known in the prior art.

d. Sensor Interface Main Body

FIG. **19** shows a simple block diagram layout of a sensor interface module designated by the numeral **102**. The sensor interface module **102** contains a pulse encoder **1300**, central processing unit micro-controller **1302**, and spread spectrum transmitter **1304** which operate together to form transmission signal **1306**. In the preferred embodiment, the hardware device sensor would be external to the housing **1307** with a connection into the pulse encoder **1300**.

The sensor interface module's built-in radio frequency transmitter is designed to communicate with the data collection module to transmit information to be forwarded to the host module. A common RF (radio frequency) module will be incorporated with a microprocessor into a circuit board. The sensor interface module's processor will include different encoding devices or schemes for protecting the information that is being transmitted.

FIG. **20** is a block diagram of a sensor interface module **102** which consists of a sensor interface main body **200** (shown by dashed lines) with an internal circuit board, and a connection **1400** to an external hardware sensor **204** to receive input data, as described above.

The sensor interface module **102** includes a programmable processor micro-controller **1402** with associated code which allows for flexibility in setting user definable param-

eters and to accommodate upgrades to the product. The basic program function of the programmable processor micro-controller **1402** will be explained later. The micro-controller **1402** is connected to a clock **1404**, which may operate in the 4 Mhz range, which provides a reference clock to a synthesizer **1406**. The micro-controller **1402** also has a path to provide programming data to the synthesizer **1406**. The synthesizer **1406** provides voltage to a voltage controller oscillator (VCO) **1408**. The VCO **1408** also receives modulation data from the micro-controller **1402**. In the preferred embodiment, the VCO is designed to operate in the range of 902 to 928 Mhz. Output from the VCO **1408** passes through a VCO filter **1410** and feeds a power amplifier **1412** which is passed through an amplifier filter **1414**. In the preferred embodiment, VCO filter **1410** and amplifier filter **1414** are designed to operate with an Fc of 950 Mhz. The output of amplifier filter **1414** goes to an antenna **1416** which operates in the range of 902 to 928 Mhz in the preferred embodiment.

The unit may be powered by a long life lithium battery (not shown), for a multiple year design life and/or powered from an external source. The battery power supply allows for the connection of sensor interface modules as monitoring devices which will be unaffected by long term power disruptions, power surges, or other system variations. This long life battery also allows the system to monitor areas or items which do not have power systems readily available.

1. Overview of Processing Information from the Monitored Device

The sensor interface module **102** receives information from external hardware sensors attached to the device or devices being monitored. This information is interpreted by the module's processing system which processes the information and then transmits the processed information to a data collection module.

The system detects pulses from the external hardware sensor, refines the sensor external hardware sensor signal to eliminate any erroneous signals, accumulates the signal pulses from the external hardware sensor, interprets the information according to its internal programming, the processed information is stored into memory for future updates, and the information is transmitted to the data collection module.

The external hardware sensor signals are recorded as a cumulative value for metering systems. This cumulative value is transmitted to the data collection modules. A cumulative count ensures that any gaps in information transmission will only have a temporary effect on the overall system's information flow. If a transmission is missed, then the cumulative information from before the missed transmission and a later received transmission will allow the host module to "recover" the missed transmission information by interpolation.

The sensor interface module is programmed to set the unique identifier for the device and the frequency that it transmits to the data collection module.

The sensor interface module **102** may be programmed by a programming computer (not shown) having a program implemented on a hand held processing or personal computer type of device. At the time of programming the sensor interface module, the programming information is either immediately transferred to the host module for permanent storage, or is maintained in the programming device for a future upload to the host module. The sensor interface module has a programmable 32 bit address, with the ability to maintain a maximum pulse count of 65535 from an external input.

In a preferred embodiment, the sensor interface module is designed to transmit via a spread spectrum radio operating on a 30 kHz bandwidth. The radio uses a hopping algorithm and has a maximum transmission time of approximately 50 mS on any one frequency channel. The transmission capabilities are approximately 3 miles in a line of sight transmission. However, the useable transmission distance among buildings, trees, and other disruptions is closer to 2000 ft. In the preferred embodiment, the sensor interface module is located at a maximum distance of 600 ft. to 2000 ft. from a data collection module.

FIG. **21** shows the general layout of the transmitted information signal. The signal consists of a header, information signal, and a CRC. The header information includes a preamble and a sensor interface module identifier.

The preamble is designed to distinguish the transmitted information from spurious radio signals or background noise. The identifier information is designed to identify the specific sensor interface module's transmission that is being received, and to identify any other type of information such as meter-type, count-type or any other information specific the device being monitored. The information signal contains the data collected by the sensor interface module or the emergency code. The CRC provides a basic check-sum type signal verification code which is used to ensure that the signal transmission was correct.

As shown in FIG. **21**, information is transmitted in a 32 bit address and information packet to the data collection module. This 32 bit packet includes the sensor interface module's identification and the transmitted information.

As shown in FIG. **21**, the signal **1450** transmitted from the sensor interface module **102** consists of several sub-components. The sub-components include synchronization flags **1452**, synchronization byte **1454**, address **1456**, input status **1458**, counter **1460**, and CRC bytes **1462**. The synchronization flags **1452** consists of 65 synchronous flags, i.e. data 7EH, which will be sent out to allow the receiver to synchronize on the transmission frequency. The synchronization byte **1454** consists of one synchronization byte, i.e. data AA Hex, which will be transmitted to indicate the start of the packet. The address **1456** is a 32-bit or 4-byte sensor interface module address which is transmitted to the data collection module **110**. The input status **1458** is the status of the external input other than the particular pulse count being transmitted. The status of the input is reflected in the status byte which is sent at the time of transmission. The counter **1460** is a 16-bit or 2-byte up counter which keeps track of the switch closures. In the preferred embodiment, the normal state of the input pin is active high. In this manner, the counter will increment upon a switch closure or the negative edge of the signal. CRC bytes **1462** consists of 2 bytes of CRC data which is transmitted to ensure the accuracy of the entire data transmission.

A full transmission of information consists of a three burst transmission of the packet of information. The information is transmitted initially to the data collection module. This same packet of information is then retransmitted two more times at random spacing intervals to ensure that any data corruption from other simultaneous signals is avoided on at least one of the three transmissions.

FIGS. **22** and **23** illustrate a flow chart of the transmitter program function of the sensor interface module.

In a preferred embodiment, the sensor interface module will transmit to the data collection module at pre-defined intervals based on the number of inputs received from the hardware sensor. This transmission method can extend the

battery life of the unit by transmitting only the amount of information needed. This amount is programmed into the unit.

By following the flow charts in FIGS. **22** and **23**, one can see the flow of the program controlling the sensor interface module. On initial power-up **1500**, the program will run an initialization routine **1502**. The initialization routine will check for programming input, initialize all necessary input and output parameters and set all of the appropriate processor options. After initialization **1502**, the processor will power down to the sleep mode **1504** where the system will wait for the generation of an interrupt.

When the information reaches a specified value or other appropriate parameter, an interrupt **1506** is generated which partially wakes the system to increment the pulse count. Once the interrupt **1506** is detected by the system, the input is debounced **1508** by allowing for a delay in reading the input, and then the pulse count is incremented **1510**. The system then resets the interrupt mask **1512** to watch for another interrupt **1506**, and checks to see if the current pulse count is equal to a next transmit count **1514**. If the incremented pulse count does not meet the transmit count requirements, the system returns to a sleep mode **1504** to await the next interrupt **1506**.

If the incremented pulse count does meet the transmit count requirements, the system creates a new next transmit count **1516** by adding the current pulse count and the offset amount to generate the new next transmit count and stores this information as the next transmit count for use on the next interrupt. The system then powers up the phase locked loop (PLL) **1518** and sets up the next PLL frequency **1520**. The system then waits **1522** for the PLL to stabilize. In the preferred embodiment, the approximate delay for is stabilization is a around 3 mS. The system then powers up the radio **1523** and generates the cyclic redundancy check (CRC) **1524** which can be used as signal verification information after the transmission is received. The CRC will be described further following this discussion. The system then transmits the sensor interface module information in a Manchester encoded signal. The system first sends the header information **1526**, followed by the data bytes and the CRC. In the preferred embodiment, the header information is approximately 65 bytes of information and the data bytes are approximately 8 bytes of information. The CRC can be effectively implemented with a 2 byte information stream. After transmitting the header, data bytes, and CRC information, the system powers down the radio and PLL **1530** and then goes to sleep **1504** to wait for the next interrupt.

As shown in FIG. **23**, the CRC program uses a right rotation exclusive-OR (xor) algorithm to encode the signal for the checksum value. The CRC is a polynomial code obtained from the message bits by passing them through a feedback shift register containing a number of xor gates. This type of code is generally suitable for detecting burst errors occurring in the communication signal transmission.

The CRC subroutine initializes the subroutine **1600**. The CRC program then loads the data for CRC verification **1602**, loads the xor bit with the CRC lo byte **1604**, and clears the bit counter **1606**. At this point the program begins a loop that will run until the CRC sum is fully generated. The program looks to the count to see if it has generated a full signal **1608**. If the program has generated a full signal then the subroutine will end and control will return to the main basic program **1609**. If the subroutine has not finished generating a full signal, then the subroutine will save the least significant bit of the current CRC **1610** and rotate the CRC right with a most significant bit equal to zero to create a new CRC value **1612**. The program then tests the saved least significant bit to see if it is equal to zero **1614**. If the saved least significant bit is equal to zero then the program will increment the bit counter **1618** and return to the start of the loop. If the saved least significant bit is not equal to zero then the program will first perform an xor function on the CRC with another signal **1616**, such as **A001**h, and will then increment the bit counter **1618** and return to the start of the loop.

2. Transmit Information to the Data Collection Module

FIG. **24** is a schematic diagram of the transmitter for the sensor interface module **102**. The system generally performs as follows. While in "sleep" mode, the sensor interface module's micro-controller **1702** will monitor switch closures on pins **1702** and **1704** of connector **1700**. These switch closures will be accumulated in a data packet the size of which can be programmed. Generally, the size of the data packet is programmed at the time the unit is installed in the field.

After a data packet has been collected, the data will be transmitted to a data collection module or other device using Frequency Shift Keying (FSK) modulation. The transmission may be on any one of twenty-five different frequency channels ranging from 902 to 928 Mhz and in the preferred embodiment will transmit for approximately 35 mS. After a packet of data has been transmitted, the sensor interface module will return to "sleep" mode and collect another packet of data. The above process will then be repeated (at a different frequency) once a complete data packet has been collected. The preferred embodiment will efficiently use the channel spectrum by using all of the 25 transmit frequency channels before repeating any transmission frequency. In the preferred embodiment, the sensor interface module will be in the sleep mode for at least one second to conserve battery power. This will also guarantee that any given frequency will not be used again for approximately 25 seconds.

The clock **1708** provides a reference clock for the synthesizer **1710** and the micro-controller **1706**. The preferred embodiment uses a 4 MHz crystal type oscillation clock. The output of the synthesizer **1710** will provide the tune voltage for the voltage controlled oscillator **1712** (shown in dashed lines). The micro-controller **1706** will program the dividers in the synthesizer to values that will select the appropriate frequency. The output **1714** of the synthesizer **1710** will pass through filter **1716** and will provide the tune voltage for the Voltage Controlled Oscillator (VCO) **1718**. The output of the VCO **1718** will provide feedback through a filter **1720** for the synthesizer **1710** and will also feed the power amplifier **1724** through a low pass filter **1722**. The output of the power amplifier **1724** then passes through filter **1726** and feeds the antenna **1730**. In the preferred embodiment, the antenna is etched onto the circuit board.

Serial data from the micro-controller-synthesizer process passes through a variable resistor **1732** and a low pass filter **1734** to the VCO **1712**. This signal then modulates the VCO **1712**. The variable resistor **1732** sets the frequency deviation of the output frequency.

While in "sleep" mode, the micro-controller **1702** powers down the VCO **1712** by stopping power flow through transistor switches **1736** and **1738**.

A connector **1740** is used as interface for "on board" programming of the micro-controller **1706** through serial data transfer. Connector **1740** also allows for the battery to be disconnected until the unit is installed.

The following is a tabular or format listing the minor elements used in the sensor interface module schematic of FIG. **24**.

Item #	Qty.	Ref. Desig.	Description	Package	Value	Rating
1	1	B1	Battery, Lithium	"C" cell		3.6 V
2	11	C1, C3, C4, C19, C30, C39, C40, C41, C46, C52, C53	Capacitor, Ceramic	603	47 PF	16 V
3	1	C6	Capacitor, Ceramic	603	5.6 PF	16 V
4	4	C7, C9, C25, C54	Capacitor, Ceramic	603	3.9 PF	16 V
5	1	C8	Capacitor, Ceramic	603	4.7 PF	16 V
6	1	C10	Capacitor, Ceramic	603	2.2 PF	16 V
7	5	C11, C24, C26, C61, C64	Capacitor, Ceramic	603	2.2 PF	16 V
8	1	C13	Capacitor, Ceramic	603	1.0 PF	16 V
9	3	C14, C16, C17	Capacitor, Ceramic	603	0.1 UF	16 V
10	1	C15	Capacitor, Ceramic	603	0.01 UF	16 V
11	1	C18	Capacitor, Ceramic	603	27 PF	16 V
12	1	C20	Capacitor, Ceramic	603	22 PF	16 V
13	6	C21, C32, C43, C48, C55, C56	Capacitor, Ceramic	603	3.3 PF	16 V
14	1	C33	Capacitor, Ceramic	603	8.2 PF	16 V
15	1	C35	Capacitor, Ceramic	603	1000 PF	16 V
16	4	C36, C38, C58, C62	Capacitor, Ceramic	603	0.5 PF	16 V
17	2	C37, C50	Capacitor, Ceramic	603	2.7 PF	16 V
18	4	C42, C44, C45, C47	Capacitor, Ceramic	603	10 PF	16 V
19	4	C49, C51, C59, C63	Capacitor, Ceramic	603	1.8 PF	16 V
20	2	C57, C60	Capacitor, Ceramic	603	1.5 PF	16 V
21	1	D1	Varactor	SOT-23B		
22	1	D2	Varactor	SOT-23B		
24	1	JP2	Connector, Interface			
25	1	L1	Inductor, SMD	805	2.7 NH	300 mA
26	1	L2	Inductor, SMD	603	68 NH	300 mA
27	1	L3	Inductor, SMD	603	15 NH	300 mA
28						
29	2	L5, L10	Inductor, SMD	603	8.2 NH	300 mA
30	1	L6	Inductor, SMD	603	12 NH	300 mA
31	1	L7	Inductor, SMD	603	4.7 NH	300 mA
32	2	L8, L9	Inductor, SMD	603	6.8 NH	300 mA
34	1	Q1	Transistor, SMD	SOT-143D		
35	1	Q2	Transistor, SMD	SOT-143D		
36	1	Q3	Transistor, SMD	SOT-143D		
37	2	Q4, Q6	Transistor, SMD	SOT-23		
38	1	Q5	Transistor, SMD	SOT-89		
39	5	R1, R3, R12, R30 R31	Resistor, SMD (Chip)	603	10	
40	1	R2	Potentiometer, 1-turn	SMDPOT5	20K	
41	2	R4, R11	Resistor, SMD (Chip)	603	6.8K	
42	1	R5	Resistor, SMD (Chip)	603	3.6K	
43	5	R6, R7, R14, R24, R34	Resistor, SMD (Chip)	603	10K	
44	1	R8	Resistor, SMD (Chip)	603	18K	
45	2	R9, R35	Resistor, SMD (Chip)	603	4.7K	
46	5	R10, R28, R29, R32, R33	Resistor, SMD (Chip)	603	180	
47	2	R13, R23	Resistor, SMD (Chip)	603	1K	
48	1	R15	Resistor, SMD (Chip)	603	2M	
49	1	R20	Resistor, SMD (Chip)	603	JUMP	
50	1	R22	Resistor, SMD (Chip)	603	2.0K	
51	1	R26	Resistor, SMD (Chip)	603	100K	
52	1	U1	IC, SMD	SMD18D		
53	1	U2	IC, SMD	SOJ-20		
54	1	U3	IC, SMD	SO-8		
55	1	Y1	Crystal	HC49	4 MHz	

The following is a tabular format of the specifications for the preferred embodiment sensor interface module.

Pulse Input	Frequency: DC up to 5 KHz, form A contact
Radio frequency range	902 to 928 MHz
Modulation type	Frequency hopping spread spectrum
Data rate	16.1 Kbps
Radio Propagation	3 miles clear line of sight 600 to 2000 feet under expected application conditions
Operating temperature	−40° C. to 85° C.
Power requirements	Voltage 2.7 to 3.6 V @ 140 mA on transmit - provided by onboard Lithium Inorganic battery
Battery life estimates	10 years with transmit intervals greater than 10 minutes.
Transmission power	100 mW
Packaging Options	Rugged, environmentally sealed, tamper proof enclosure with built-in. Cover may be either hermetically sealed or screw closed with tamper proof screws.

-continued

Field Configuration	Initial meter value and data transmission intervals. Hand held device with an RS-232 interface required; Palm Pilot version is available.

2. The Data Collection Module

a. Overview

The data collection module boxes are weatherproof enclosures that house data collection electronics. RF input signals in the range of 902 Mhz to 928 Mhz are received through the horizontally polarized antenna and routed to the receiver module. The receiver module hops the 25 pre-set frequencies looking for a RF signal modulated with a particular format. Once a valid signal is identified, the receiver stops hopping and decodes the entire data packet which is passes along to CPU module for collection and evaluation. The receiver and the CPU modules are connected by a motherboard that also holds power regulation circuitry. At predetermined times, the CPU relays data accumulations out of the box by means of a MOTOROLA™ pager (VAIL50 with external antenna) and the second antenna that protrudes through the top of the box. An RS-232 port is available on the motherboard for field programming. Power for the electronics comes from 110V AC, 60 Hz by way of a power cord. firmware, a motherboard/power supply with battery backup **2006**, and a transmitter/receiver **2008**. The data collection module may also include optional items **2014** such as a modem device and can also include alternate communication systems such as a backbone radio option **2016**. The motherboard **2006** is normally powered by standard 110 Volt 60 Hz alternating current shown at arrow **2010**. An optional solar powered unit that provides 12 VDC output can also be used. An RS-232 serial port shown at arrow **2012** is available on the motherboard **2006** for field programming.

A preferred embodiment of the housing enclosure **2100** for the data collection module **110** is shown in the sectional views of FIGS. **26** and **27** The enclosure **2100** is made up of a data collection base **2102** and a data collection cover **2104**. FIG. **26** shows the data collection base, and FIG. **27** shows the data collection cover **2104**. The enclosure **2100** is weather tight to protect the data collection module **110** from the elements. A chassis **2200** fits within the housing enclosure **2100** and supports the components which are attached by fasteners in the data collection module **110** as shown in FIG. **28**.

The data collection module **110** may also be integrated into other devices, such as meters, or housed in a NEMA 4X enclosure with approximate dimensions of 8"×6"×4". RF input signals are received through an antenna and routed to the receiver module. The data collection module enclosure may be attached to the side of a house, inside a small business, or in other suitable locations. A suitable location is one which allows for receiving sensor interface module information and connection to transmission systems for communication with the host module.

As shown in FIGS. **28** and **29**, the general layout of a data collection motherboard **2216** may be seen. The data collection motherboard **2216** is the base support board for a spread spectrum backbone radio **2202**, pager **2204**, receiver **2206**, central processing unit (CPU) **2210**, modem **2208**, and other optional items **2212**.

The motherboard **2216**, spread spectrum radio **2202**, pager **2204**, receiver **2206**, CPU **2210**, modem **2208**, and option **2212** are all attached together in a secure mounting by a motherboard frame **2214**. Each of these items is attached by appropriate connectors **2218**.

FIG. **30** shows a simplified schematic layout of data repeater module which is generally designated by the numeral **2300**. The data collection module **2300** includes a housing **2302** which minimally contains a central processing unit **2306** and a spread spectrum receiver/radio **2308**. The spread spectrum receiver/radio **2308** is used to receive or transmit signals **2320** to sensor interface modules. The housing **2302** may optionally contain a spread spectrum radio **2304** with connected antenna to transmit and receive signals **2314** to and from repeater modules **2300**, data collection modules **110**, or a host module **122**. Another optional communication method may be implemented by a connected modem **2310** which is hardwired through connection **2316** to transmit and receive signals **2318** from the backbone system communication to a host module.

FIG. **31** is a block diagram of the configuration of the data repeater module **2300**. When in the receive mode, the 900 Mhz transceiver will continuously scan a frequency band of 902 to 928 Mhz searching for a radio frequency signal. If a radio frequency signal is detected, the transceiver will lock on to this signal and demodulate it.

A 24 Mhz crystal will provide a reference clock **2402** for a synthesizer **2404** and baseband processor **2406**.

For transmission, digital data is received via an RS-232 port **2408** located on the motherboard. This data is then sent to a path management processor **2410**. When the management processor **2410** has received enough data and is ready to transmit, it sends the data to the baseband processor **2406** prior to decoding and modulating.

The received radio frequency signal is passed through low pass filter **2412** and then down converted to 61.3 Mhz as shown at **2414**. This signal is then passed to FM receiver **2416** which includes an FM demodulator and then to the baseband processor **2406**.

FIG. **32** is a block diagram of the receiver **2002** for the data from the sensor interface modules located in the data collection module **110**. The receiver **2002** is a frequency-hopping receiver which continuously hops through 25 specific frequencies, stopping just long enough at each frequency to determine whether valid data is being received. If valid data is detected, the receiver stays on frequency long enough to receive the entire packet. An input signal enters the receiver through a connector **2500**, then passes through an amplifier **2502** and to a mixer **2504**. A synthesizer **2506** includes a voltage is controller oscillator. An FM chip **2508** includes an FM demodulator.

FIG. **33** is a block diagram of the central processing unit **2600** of the data collection module **110**. A microcontroller **2602** is connected to the motherboard **2216** (not shown) through an interface **2606**. The CPU **2600** includes random access memory **2608**. Flash data space **2610** and flash program space **2612** are also provided.

FIG. **34** is a process flow diagram for the operation of the sensor interface module receiver **2002** in the data collection module **110**. The program first initializes the hardware **2700** and then clears the random access memory **2701**. The program then configures input

In one preferred embodiment, the communication module uses a MOTOROLA™ 68CH11 central processing unit, 32K of ram, 64K to 1 meg of eprom, and 144K of flash. The flow computer module uses a Rosemont™2055 with HART protocol signal. The differential pressure range is approximately 0–10 to 0–250 in water. The gauge pressure range is

0–80 to 0–2000 psig. The isolator material is 316 sst, the fill fluid is silicon, the flame style/material is co-planar/sst, the drain/vent material is sst, the O-ring is glass-filled tfe, the process temperature is rtd and cable optional, the transmitter housing is polyurethane-covered aluminum, the terminal block is standard block and optional transient protected block, and the software functionality is an averaging method; flow dependent time waited formulaic averaging, compressibility method; AGA report number 8/API NPNS Chapter 14.2, Variable Logging Per API 21.1 In the spread spectrum radio is an LSDR200 with TCIP/IP path management module, packaged with a communications module.

Returning to a consideration of FIG. **1**, the data collection module **110** provides the information transmission connection between the sensor interface module **102** and the network connection **116** to the host module **122**. The data collection module **110** is a local, intelligent, data concentrator residing at or near the location of the sensor interface modules **102**. The data collection module **110** acts as the focal point of all the information which is collected from the sensor interface modules **102** within a monitored area such as a customer's premise and transmits this information to the host module **122** over standard communication systems **118**.

FIG. **25** is a block diagram of a data collection module **110**. The data collection module **110** includes a radio frequency receiver **2002** to receive signals from the sensor interface module **102**, a central processing unit information processor **2004** with associated and output operations and the processor options **2702**. The program also sets up the slave select pointer as being in slave mode, thus the receiver controller is not yet enabled **2703**, and then enables the interrupt controller on portb **2704**. This interrupt flag will be set when a valid message is received from the receiver microprocessor. The program then waits to see if the message flag has been set **2705**. The program will hold in a checking loop at this point to see if the message flag has been set.

Once the message flag interrupt has been set **2705**, the program will check to see if the necessary number of bytes have been sent **2706** with the message. If the necessary number of bytes have not been sent **2706** then the program will clear the message flag **2707** and return to the waiting loop to check to see if the message flag has been set **2705**.

If the correct number of bytes have been received **2706**, then the message is transferred from the input buffer to the output buffer **2708**. Note that at this point only the message is transferred. The CRC and the synchronization byte are stripped from the message packet. The program will then calculate the CRC **2709**, clear the message flag and set the output flag **2712**, change the interrupt pin **2713**, and send the interrupt signal to the data collection controller **2714** to try and assert control over the data collection controller. The program will then hold in a loop until the slave select has been asserted **2715** and the program has control over the data collection controller. Once the slave select has been asserted **2715** the program will change SDO from hi-z to output **2716**. The program then sets the SDO low **2717**, delays an appropriate amount of time **2718**, and then enables both the slave select pointer and slave select pointer interrupt **2719**.

The program checks to see if the data collection controller de-asserts the slave select **2720**. If the data collection controller de-asserts the slave select then the signal was not properly sent out and so the program resets the data and pointers **2722**, and generates another interrupt signal to the data collection controller **2714** to start the transfer process of the signal to the data collection controller all over again.

If, however, the slave select has not been de-asserted **2720**, the program will then check to see if the output flag has been cleared **2721**. If the output flag has not been cleared **2721** then the program will return to waiting to see if the slave select has been de-asserted at **2720**. If the output flag has been cleared then the program will return to waiting for the next message to be sent **2705**.

FIGS. **35** and **36** are flow charts of the microprocessor program for the data collection module **110**. Once an interrupt has been generated for the microprocessor **2800** the program will save its current status, fsr, and wreg **2801**. The program will then check to see if the portb interrupt has been enabled **2802**. If the portb has been enabled, then the program will check to see if there has been a change in the information on portb **2803**. If there has been a change on portb **2803**, then the program will clear the change on the portb interrupt flag **2804**. The program then offsets ¼ bit time **2805** and enables the real time interrupt flag **2806**. The program will then disable any change from portb interrupt **2807** and reset the bit counter to eight **2808**. The program then clears the clock **2809** and restores the status, fsr and wreg **2810**. The program then goes to RETFIE **2811**.

If the portb interrupt has not been enabled **2802** then the program will check to see if the ssp interrupt has been enabled **2812**. Note that if portb interrupt has been enabled **2802**, but there has not been a change on portb **2803**, then the program will also go to check to see if the ssp interrupt has been enabled **2812**.

If the slave select port interrupt has been enabled **2812** the program will then check to see if the slave select port full interrupt has been enabled **2813**. If the slave select port full interrupt **2813** has been enabled then the program will clear the interrupt flag **2814**, increment the output count **2815**, and move on to check to see if the output count equals the byte count **2816**.

If the output count does not equal the byte count **2816** the program will load the next byte into the slave select port **2817** and move on to restore the status, fsr, and wreg **2810** and continue with the program.

If the output count does equal the byte count **2816** then the program will disable the slave select port interrupt **2819**, reset SDO to hi-z **2820**, change SDO output buffer to one **2821**, and clear the output buffer full flag **2822**. The program will then continue on to restore the status, fsr and wreg **2810** and continue with the program.

If the SSP interrupt is not enabled **2812** or the SSP interrupt is enabled **2812** but the SSP full interrupt is not enabled **2813**, then the program will go to check to see if portb interrupt is enabled **2823**.

If the portb interrupt is not enabled then the program will move onto restoring the status, fsr and wreg **2810** and continue with the program.

If the portb interrupt is enabled **2823**, then the program will check to see if real time interrupt is enabled **2824**. If the real time interrupt is not enabled **2824** then the program will continue to restore status, fsr and wreg **2810** and continue with the program.

If the real time interrupt **2824** is enabled then the program will move on to clear the interrupt **2825**. As shown in FIGS. **35** and **36** the program continues from circle "A" on FIG. **35** to circle "A" on FIG. **36** after the real time interrupt **2824** has been checked. The program will then increment clock complement clock mask all but lsb **2826**, and xor data with the clock **2827**. The program will then set data bit in carry **2828**, and check to see if the result equals one **2829**.

If the result does not equal one **2829**, then the program will clear 1-counter **2830** and then check to see if the lab

clock equals 1 **2831**. If the lab clock does not equal one **2831**, then the program will shift the data-**0** left **2832**. The program will then continue on to restore status, fsr, and wreg **2810** and continue with the program.

If the lsb clock does equal one **2831**, then the program will move on to shift data **1** left **2833** and then decrement bit count **2834**. The program will then check to see if the bit count equals zero **2835**.

If the bit count does not equal zero **2835**, then the program will return to restore status, fsr, and wreg **2810** and continue with the program.

If the bit count does equal zero **2835**, then the program will check to see if data-**0** equals data-**1 2836**.

If data-**0** equals data-**1 2836**, then the program will move on to check to see if the message is set **2837**.

If the message is not set **2837**, then the program will move on to see if the synchronization flag is set **2838**.

If the synchronization flag is set **2838** then the program will move on to reset bit counter to eight **2839** and save data in message buffer **2840**. The program will then check to see if the byte count equals seven **2841**.

If the byte count does not equal seven **2841**, then the program will increment the byte count and return to restore status, fsr, and wreg **2810** and continue with the program.

If the byte count does equal seven **2841**, then the program will set the message flag **2843** and return to restore status, fsr, and wreg **2810** and continue with the program.

If the synchronization flag is not set **2838**, then the program will check to see if the data byte equals AA hex **2844**.

If the data byte equals AA hex **2844**, then the program will set the synchronization flag **2845** and move on to reset the byte counter to eight **2839** and continue with the program.

If the data byte does not equal AA hex **2844**, then the program will move to clear the byte count **2846** and disable the real time interrupt **2847**. The program will then clear change on portb interrupt flag **2849** and enable change on portb interrupt **2850**. The program will then restore status, fsr, and wreg **2810** and continue with the program.

If the message is set **2837**, then the program moves on to clear the byte count **2846** and continue with the program.

If data-**0** not equals data-**1 2836**, then the program moves on to clear the byte count **2846** and continued with the program.

If result equals one **2829**, then the program increments 1-counter **2851** and checks to see if 1-counter was >=three **2852**.

If 1-counter is not >=three **2852**, then the program moves on to check to see if the lsb clock equals one **2831** and continues with the program.

If 1-counter is >=three **2852**, then the program moves on to clear the byte count **2846** and continues with the program.

Thus, the microcontroller monitors and controls several flags and the input and output of information within the data collection controller system.

FIG. **37** is a schematic diagram of the motherboard **2216** which includes connectors for configuration options **2212**, for the CPU **2210**, for a router module **2202**, for the receiver module **2206**, an RJ11 jack **2901**, transistors **2902** and light emitting diodes **2904**. In general, the data collection module works by following a simple routine. While in receive mode, the 900 Mhz Transceiver will continuously scan the frequency band of 902 and 928 Mhz searching for a RF signal. If a RF signal is detected, the transceiver will lock on to this signal, demodulate it, Manchester decode the data, and send this data to an RS-232 port. If a RF signal is not detected, this unit will collect data packets via an RS-232 port, Manchester encode the data, and transmit this data on 1 of 50 different frequency channels ranging from 902 to 928 Mhz. This transmission will use FSK (Frequency Shift Keying) modulation and will transmit for approximately 180 msec. After a packet of data has been transmitted, the transmitter will return to receive mode and start scanning again for a RF signal. The unit will also start collecting another transmit data packet. The above process will then be repeated (at a different frequency) once a complete data packet has been collected. All 50 transmit frequency channels will be used before any given frequency is repeated.

FIGS. **38**, **39**, **40**, **41**, and **42** illustrate schematic diagrams of a transceiver design for the data collection module.

FIG. **40** shows how the synthesizer is implemented. The 24 Mhz crystal **2926** will provide a reference clock for the synthesizer IC **2928** and the baseband processor **2929**. The bandpass processor **2929** will program the dividers in the synthesizer IC **2928** to values that will select the appropriate frequency. The output of the synthesizer IC **2928** (pin **6**) will pass through a synthesizer filter **2930** and will provide the tune voltage for the Voltage Controlled Oscillator (VCO) **2931**. The output of the VCO **2931** will provide the feedback through VCO filter **2932** for the synthesizer IC **2928** (pin **11**) and will also provide a Local Oscillator (LO) **2932** for the receiver and the transmitter.

FIGS. **38**, **39**, **40**, **41**, and **42** show how the transmitter is implemented. As shown in FIG. **38**, digital data is received via an RS-232 port connected by the motherboard data controller **2951**. This data is then sent to the path management processor **2953** which controls all receive and transmit functions of the transceiver. When the management processor has received enough data and is ready to transmit, it sends the data to the baseband processor **2929**, as shown in FIG. **40**. The baseband processor **2929** manchester encodes the data and sends this data to the VCO **2931** via deviation adjuster **2952**. This signal then modulates the VCO **2931**. A variable resistor **2953** in the deviation adjuster **2952** sets the frequency deviation of the VCO **2931** output. This output is then fed to the input of the power amplifier **2940** shown in FIG. **41**.

FIG. **41** shows a schematic diagram of the power amplifier and the negative bias voltage supply. The power amplifier **2960** requires a negative bias voltage which is supplied by negative bias voltage supply **2961**.

As shown in FIG. **42**, the output of the Power Amplifier **2960** passes through diode-**4 2970** and signal filter **2971**. The output is then AC coupled by coupler **2972** and is fed to antenna **2973**. A DC bias voltage is applied to diode-**4 2970** and diode-**5 2974** when the transceiver is placed in transmit mode. This allows the transmitted signal to pass through diode-**4 2970** and on to the output circuitry. Signal block **2975** and a quarter-wave length stripline provide a RF short to ground at the input to the receiver front end. This is to protect the receiver front end from the high output power of the transmitter.

When the Transceiver is in the transmit mode, all the receiver circuitry is powered down by receiver switch **2933** shown in FIG. **40** and all the transmitter circuitry is powered **103** up by transmitter switch **2962**, shown in FIG. **41**.

The received RF signal enters antenna **2973**, is AC coupled by coupler **2973** and is low-pass filtered by signal filter **2971**. This signal passes through bandpass filter-**1 2976**, amplifier **2980**, bandpass filter-**2 2981**, and is down-

converted to 61.3 Mhz by down-converter **2982**. The LO for the down-conversion is provided by the synthesizer via LO filter **2983**. This IF signal (61.3 Mhz) then passes through bandpass filter-**3 2984** and then passes through notch filter **2985**. This IF signal is then down-converted to a second IF (10.7 Mhz) by down-converter-**2 2986**.

Returning to FIG. **40**, the 2nd LO for down-converter-**2 2986** is provided from the third harmonic of 24 Mhz crystal (72 Mhz) **2926** that passed through 3rd harmonic filter-**1 2940** and 3rd harmonic amplifier-**1 2941**. This signal is then used in FIG. **42** where this second IF is passes through harmonic bandpass filter-**2 2990**, harmonic amplifier-**2** (internal to A3-U8), harmonic bandpass filter-**3 2991** and then goes to a FM discriminator. The discriminator is adjusted with the tank circuitry **2992**. The output of the discriminator passes though buffer **2993** and buffer lowpass filter **2994**. This filtered baseband signal is then fed into a data slicer and TTL level data is output and the schematic returns to FIG. **40**.

As shown in FIG. **40**, the data passes through manchester decoder **2995** and is sent to baseband processor **2929**, and then to the path management processor **2953**. This processor then transmits digital data over the RS-232 port **2950**.

When the Transceiver is in the receive mode, all the receiver circuitry is powered up by receiver switch **2933**, shown in FIG. **40**, and all the transmitter circuitry is powered down by transmit switch **2962**, shown in FIG. **41**.

FIG. **43** shows a schematic diagram of a sensor interface module receiver. The sensor interface module receiver for the data collection module is a frequency-hopping receiver. It continuously hops through the 25 specific frequencies it has memorized, stopping just long enough at each frequency to determine whether valid data is being received. If valid data is detected, the receiver stays on frequency long enough to accept the entire packet of data, then it continues hopping.

The receiver detects frequency-modulated, manchester-encoded, digital signals using dual down-conversion architecture. On board processors decode and verify that the data is good before passing it to a motherboard through a 24-pin (12×2) connector. Power and control signals are also passed to the receiver through this connector.

An input signal enters the receiver through a female SMA connector. The signal passes through a SAW bandpass filter, an amplifier based on Q2, and another SAW bandpass filter. The signal next passes through a first mixer. The Local Oscillator (1st LO) for this mixer comes from the synthesizer which provides frequencies from 967.1 Mhz to 985.5 Mhz. The Intermediate Frequency (IF) from this mixture is 61.3 Mhz. This IF passes through a four-section bandpass filter before entering the FM Demodulator chip.

The synthesizer consists of a Voltage Controlled Oscillator (VCO) and a Phase Locked Loop (PLL) chip. Oscillations come from a varactor and a single-loop, air-core inductor. The VCO output is buffered before being sent to the mixer or fed back to the PLL chip. A serial control word sent from microcontroller to the PLL chip sets the synthesizer frequency. The reference frequency for the PLL is 24 Mhz.

The 1st IF of 61.3 Mhz enters a second mixer on the FM chip. A 2nd LO of 72 Mhz is derived from the third harmonic of the 24 Mhz crystal oscillator that services the PLL and microcontrollers. The output of the mixer is at 10.7 Mhz. This 2nd IF then passes through a narrowband ceramic filter, an on chip amplifier, another ceramic filter, and back on chip to a limiting amplifier. The final stage is a demodulation using an off chip tuned circuit. The demodulated data signal is then lowpass filtered by an off chip op-amp circuit before passing on to the microcontrollers.

There are three controllers on the receiver. The first one takes the demodulated data stream and decodes the Manchester formatting. The decoded data passes along to a controller which controls the PLL hopping and performs the verification of the bit stream to determine if it is valid data.

The following is a table of values for the schematic diagram shown in FIGS. **38** and **39**.

Item #	Ref. Desig.	Description	Package	Value	Rating	Tot %
1	C1, C3, C5, C7, C11, C13, C15, C17	.1 uF	603	.1 uF		+10%
2	C2, C4, C6, C8, C12, C14, C16, C18	.01 uF	603	.01 uF	+10%	
3	C9, C10	22 pF	603	22 pF		+5%
4	C21	22 OuF 35 V	NACZ	22 OuF 35 V	35 V	20%
5	C22	4.7 nF	1206	4.7 nF	50 V	+10%
6	C23	33 OuF 25 V	NACZ	33 OuF 25 V	25 V	20%
7	C24	100 uF 16 V	TAJD	100 uF 16 V	16 V	
8	C26, C25	10 uF 16 V	TAJD	10 uF 16 V	16 V	10%
9	D1	MBRS360T3	SMC	MBRS360T3	60 V 3 A	
10	J1	CON12	IDC12	CON12		
11	J2	CON26	IDC26R	CON26		
12	L1	NCB1612K480TR	1612	NCB1612K480TR		
13	L2	100 uH .9 A	DS5022	100 uH .9 A	.9 A	
14	L3	22 uH 2 A	IHSM	22 uH 2 A	2 A	
15	Q2	BSS123	SOT-23F	BSS123		
16	RP1	EXB-A10P103J	EXB	EXB-A10P103J		
17	R1, R2, R6	10K	603	10K		10%
18	R3	1K	603	1K		1%
19	R4	SMD200	SMD200	SMD200		
20	R5	3.82K	603	3.82K		1%
21	TP1, TP2, TP3, TP4	Mounting Hole	TPAD	Mounting Hole		
22	U1	DS1232S	SOL-16	DS1232S		

-continued

Item #	Ref. Desig.	Description	Package	Value	Rating	Tot %
23	U2	AT89C52-16JC	PLCC44	AT89C52-16JC		
24	U3	74HC373	SOL-20	74HC373		
25	U4	LH5168N-10L	SMD28B	LH5168N-10L		
26	U5	74HC32	SO-14	74HC32		
27	U6	74HC138	SO-16	74HC138		
28	U7	AT93C66-10SI	SO-8	AT93C66-10SI		
29	U8	74HC374	SOL-20	74HC374		
30	U10	LM2595S-ADJ	TO-263-5	LM2595S-ADJ		
31	U11	MIC2940A-5.OBU	TO-263	MIC2940A-5.OBU		
32	U12	SI4539DY	SO-8	SI4539DY		
33	Y1	14.7456 MHz	XTALS	14.7456 MHz		
34	U2	Socket	PLCC44			

The following is a table of values for the schematic diagram shown in FIGS. **40**, **41**, and **42**.

Item #	Qty.	Ref. Desig.	Description	Package	Value	Rating	Tot %
1	1	L16	Inductor, SMD	5 MM Coll	1 uH		
2	4	L19, L20, L32, L23	Inductor, SMD	5 MM Coll	330 nH		
3	2	FL2, FL3	Filter	10.7 Cerfilt	10.7 MHz		
4	9	C38, C43, C44, C69, C71, C73, C74, C75, C78	Capacitor, Ceramic	603	0.01 uF	16 v	NPO 5%
5	16	C1, C6, C7, C8, C9, C10, C11, C12, C22, C25, C27, C37, C66, C76, C79, C102	Capacitor, Ceramic	603	0.1 uF	16 v	NPO 5%
6	4	C21, C24, C95, C99	Capacitor, Ceramic	603	0.5 pF	16 v	NPO 5%
7	2	C28, C42	Capacitor, Ceramic	603	1 pF	16 v	NPO 5%
8	1	C41	Capacitor, Ceramic	603	1.2 pF	16 v	NPO 5%
9	1	C29	Capacitor, Ceramic	603	1.8 pF	16 v	NPO 5%
10	5	C26, C32, C34, C35, C36	Capacitor, Ceramic	603	2.2 pF	16 v	NPO 5%
11	4	C52, C59, C61, C77	Capacitor, Ceramic	603	2.7 pF	16 v	NPO 5%
12	2	C30, C83	Capacitor, Ceramic	603	3.9 pF	16 v	NPO 5%
13	3	C54, C57, C105	Capacitor, Ceramic	603	4.7 pF	16 v	NPO 5%
14	2	C51, C103	Capacitor, Ceramic	603	5.6 pF	16 v	NPO 5%
15	3	C33, C39, C60	Capacitor, Ceramic	603	6.8 pF	16 v	NPO 5%
16	4	C65, C89, C92, C101	Capacitor, Ceramic	603	8.3 pF	16 v	NPO 5%
17	1	C48	Capacitor, Ceramic	603	10 pF	16 v	NPO 5%
18	2	C94, C100	Capacitor, Ceramic	603	12 pF	16 v	NPO 5%
19	1	C13	Capacitor, Ceramic	603	15 pF	16 v	NPO 5%
20	2	C97, C106	Capacitor, Ceramic	603	18 pF	16 v	NPO 5%
21	1	C93	Capacitor, Ceramic	603	27 pF	16 v	NPO 5%
22	3	C4, C5, C18	Capacitor, Ceramic	603	33 pF	16 v	NPO 5%
23	19	C2, C16, C19	Capacitor, Ceramic	603	47 pF	16 v	NPO 5%
24	1	C98	Capacitor, Ceramic	603	68 pF	16 v	NPO 5%
25	1	C23	Capacitor, Ceramic	603	100 pF	16 v	NPO 5%
26	1	C96	Capacitor, Ceramic	603	150 pF	16 v	NPO 5%
27	1	C107	Capacitor, Ceramic	603	180 pF	16 v	NPO 5%
28	2	C17, C81	Capacitor, Ceramic	603	220 pF	16 v	NPO 5%
29	1	C72	Capacitor, Ceramic	603	560 pF	16 v	NPO 5%
30	3	C20, C90, C91	Capacitor, Ceramic	603	1000 pF	16 v	NPO 5%
31	4	C47, C55, C58, C80	Capacitor, Ceramic	603	NI	16 v	NPO 5%
32	2	L14, L18	Inductor, SMD	603	1.5 nH		5%
33	1	L13	Inductor, SMD	603	5.6 nH		5%
34	1	L12	Inductor, SMD	603	8.2 nH		5%
35	1	L15	Inductor, SMD	603	10 nH		5%
36	4	L1, L5, L7, L11	Inductor, SMD	603	68 nH		5%
37	1	L9	Inductor, SMD	603	NI		5%
38	4	R35, R5, R15, R66	Resistor, SMD (Chip)	603	1K		5%
39	2	R57, R65	Resistor, SMD (Chip)	603	0 Ohm		5%
40	1	R51	Resistor, SMD (Chip)	603	1.8M		5%
41	1	R54	Resistor, SMD (Chip)	603	3K		5%
42	3	R2, R18, R19	Resistor, SMD (Chip)	603	4.7K		5%
43	1	R22	Resistor, SMD (Chip)	603	8.2K		5%
44	7	R3, R10, R27, R30, R31, R67, R71	Resistor, SMD (Chip)	603	10 Ohm		5%

-continued

Item #	Qty.	Ref. Desig.	Description	Package	Value	Rating	Tot %
45	11	R1, R9, R11, R14, R16, R17, R20, R24, R48, R55, R60	Resistor, SMD (Chip)	603	10K		5%
46	1	R44	Resistor, SMD (Chip)	603	11K		5%
47	2	R25, R32	Resistor, SMD (Chip)	603	18K		5%
48	1	R45	Resistor, SMD (Chip)	603	22 Ohm		5%
49	6	R26, R42, R58, R59, R62, R68	Resistor, SMD (Chip)	603	33K		5%
50	1	R13	Resistor, SMD (Chip)	603	39K		5%
51	1	R28	Resistor, SMD (Chip)	603	47 Ohm		5%
52	1	R69	Resistor, SMD (Chip)	603	51K		5%
53	2	R34, R43	Resistor, SMD (Chip)	603	56 Ohm		5%
54	1	R63	Resistor, SMD (Chip)	603	100 Ohm		5%
55	5	R12, R33, R49, R50, R70	Resistor, SMD (Chip)	603	100K		5%
56	2	R29, R36	Resistor, SMD (Chip)	603	180 Ohm		5%
57	2	R21, R56	Resistor, SMD (Chip)	603	390 Ohm		5%
58	3	R40, R41, R46	Resistor, SMD (Chip)	603	430 Ohm		5%
59	2	R23, R38	Resistor, SMD (Chip)	603	470 Ohm		5%
60	9	R4, R6, R7, R8, R37, R47, R52, R61, R64	Resistor, SMD (Chip)	603	NI		5%
61	2	L3, L4	Inductor, SMD	1008	330 nH		10%
62	1	L22	Inductor, SMD	1008	680 nH		10%
63	1	BD1	Ferrite Bead	1206	CL3216U		
64	1	R53	Resistor, SMD (Chip)	1206	5.6 Ohm		5%
65	3	C3, C14, C88	Cap Tant SMT	1510	10 uF	16 V	
66	1	L2	Inductor Aircoll 50 ID		5 nH		
67	1	POT1	Resistor Pot SMT	B Pot	50K		
68	3	C85, C86, C87	Cap Tant SMT	1206	1 uF	16 V	
69	1	C70	Cap Var		JR060		
70	1	C15	Cap Var		JR300		
71	4	L6, L8, L10, L17	Cap Coll		8 nH		5%
72	1	U3	DIP IC	Dip20	AT89C2051		
73	2	FL1, FL4	Filter, Saw	FJ Saw BPF	BPF		
74	1	J1	Connector	IDC12			
75	1	S1	Shield	LT SHIELD			
76	5	Q4, Q5, Q6, Q7, Q11	Transistor, SMD		NE68139		
77	1	J2	Connector	SMA Edge	SMA Female		
78	1	U4	SMT IC	SO-8	NI		
79	1	U6	SMT IC	SO-8	MAX853		
80	1	U10	SMT IC	SO-8	TLC272		
81	1	Q13		SO-8	TPS1101D		
82	1	U2	SMT IC	SO-8W	12C508		
83	1	U1	SMT IC	SO-16	MAX202		
84	1	U5	SMT IC	SOJ-20	MC145191F		
85	1	U8	SMT IC	SOJ-24	MC13156		
86	1	Q9	Transistor, SMD	SOT-23	NI		
87	3	Q1, Q3, Q10	Transistor, SMD	SOT-23	MMBT3904		
88	1	Q2	Transistor, SMD	SOT-23	MMBT3906		
89	3	D3, D4, D5	Diode, SMD	SOT-23	SMP1321-01		
90	1	Q8		SOT-89	NE46134		
91	1	Q12	Var Cap	SOT-223	CLY10		
92	1	U9		TO6/NEC	UPC2758T		
93	2	D1, D2	Varactor		SMV1204-35		
94	1	X1	Crystal, SMD		4 MHz		
95	1	X2	Crystal, SMD		24 MHz		

b. Method of Operation

The data collection module **110** receives information from the sensor interface modules **102** or directly from wired inputs (status, analog) connected to other external devices, and then processes, stores and transmits the information on to the host module or directly to other systems through a serial port. The data collection module **110** may also be configured to display information locally.

1. Receiving Information from the Sensor Interface Module

The data collection modules **110** collect information from a plurality of different sensor interface modules. One-way transmission from the sensor interface module **102** to the data collection module **110** is preferred because frequent updates to the data collection module provide an adequate time resolution for potential demand reads while allowing the overall system costs to be significantly less than a two-way communication system. In addition, significant power savings can be obtained in the sensor interface modules **102** by utilizing a one-way transmission system between the sensor interface module **102** and data collection module **110**. This one-way transmission is acceptable because the sensor interface module **102** transmits at user configurable thresholds.

Other applications may require two-way transmission, such as monitoring and control of lights, security monitoring

devices, utility disconnect actions, utility outage reporting, or other control functions.

2. Processing Information from Sensor interface module

Information from the sensor interface module **102** is decoded and processed in the data collection module **110** and prepared for transmission to the host module **122**. The processor dynamically builds a table that stores the information received from each of the interface modules. Information is grouped by the unique identifier assigned to each individual sensor interface module. This information is further grouped based on the time interval that defines the resolution of the collected information that will be transmitted to the host module. Time synchronization of the data collection module is provided through the host module or the commercial network.

For example, if fifteen minute usage information is desired, then the data collection module will collect all information received from the sensor interface module during a 15 minute interval, take the most current cumulative reading (discard previous readings), and put that information into a packet to be transmitted to the host module.

Information received from new sensor information modules that have not been configured in the host module, will still be processed by the data collection module and transmitted on to the host module. The host module will identify any new sensor information modules and prompt the system user for the required configuration information.

If reports from different data collection modules include some of the same sensor information modules, then the host module will assign one data collection module as primary and all others bearing the same sensor module as secondary.

If the data collection module is assigned primary status for a particular sensor interface module, then the data collection module will transmit information from the new sensor interface module to the host module. Because a data collection module receives information from multiple sensor interface modules, the data collection module can have primary status for some sensor interface modules and secondary status for others. The data collection module will store all of the information received from any sensor interface module. In this manner, a data collection module which has secondary status for a sensor interface module can report information on that sensor interface module if the primary status data collection module is unable to report the information to the host module.

If the data collection module is assigned secondary status for a specific sensor interface module, then the data collection module will not normally report information from that sensor interface module to the host module. The secondary data collection module will only report information from that sensor interface module if specifically polled for that information by the host module.

The memory system of the data collection module **110** is a maintained information-overwrite system. Information that is placed into memory is maintained until overwritten by new information. The data collection module uses a rolling information storage method to maintain information for extended periods while maximizing the system resources. New information that is received from sensor interface modules is written over the oldest information for that module.

The data collection module maintains a variety of information within its memory for the system use. The data collection module maintains the most current information from the sensor interface modules, as well as the recent history, and stores the information for transmission to the host system. For example, in typical electrical utility monitoring cases, the kWH will be accumulated on an hourly basis and peak demand will be determined in 15 minute interval windows. These values are stored for a subsequent retransmission to the host module. The customer can select the data transfer rate that is appropriate to their billing and monitoring system requirements.

The data collection module can also collect information for alarm conditions. Examples of alarm conditions are low battery status and tamper alarms.

3. Processing Information for Local Display

In one embodiment, the data collection module **110** also has the capability to locally display the information contained in its memory. The data collection module **110** maintains the most current information from the sensor interface modules, as well as the recent is history, and calculates the energy consumption and peak demand on a predetermined time slot for local display. These values are stored for local display and for possible transmission to the host module upon request.

4. Transmitting Information to Host Module

Data is transmitted to the host module through the transmitter/receiver or other modem device of the data collection module **110**. The data collection module **110** concentrates the data collected from the sensor interface modules **102**, and uploads the information to the host module on a periodic time basis, at a preset time, or in response to a demand from the host module. Alarm conditions are immediately transferred to the host module.

The communications between the host module and the data collection module is designed to be two-way and interactive. This allows for the data retrieval to be near real-time. Designed response time is approximately 30 seconds from the host module's poll time to the response from the data collection module.

The transmission from the data collection module **110** to the host module may be by means of any number of various systems including Narrow band PCS, Broadband PCS, WPCS, CDPD, cable modems, a phone line with Internet packet data, or other information transmission systems.

In the embodiment described herein, a transmitter/receiver is employed. Other options include delivery through a two-way serial port (RS 232) to third party host devices. The data collection module is designed to be adaptable to various information transmission networks and to be upgradeable to new information transmission systems which can support the information flow from the sensor interface modules to the host module.

Another embodiment of the present overall system is the use of the sensor interface modules combined with the data collection module to collect information for customer subsystems where the information is not actually transmitted over a commercial network to a host module. An example of this configuration would be for use on a gas meter system. In this instance, the sensory interface modules are mounted on gas meter index covers and acquire pulse data and transmit it to the data collection module. The data collection module may be located inside a third party data concentrator or in its own weatherproof enclosure. The third party device is connected to the data collection module via an RS-232 communications port which is configured to emulate the

data concentrators native communication protocol. The data collection module server thus provides data collection, protocol conversion, and emulation of the third party's data collection scheme such that the data collection module is transparent to the third party data concentrator. In this configuration the third party data concentrator would pull the data collection module using its native protocol. Each data collection module would be able to support up to 32 sensor interface modules. The data collection module can be implemented as a single board solution which is designed to be installed inside the third party communications equipment. And the data collection module can be configured over the serial length from the third party data concentrator.

5. The Data Collection Module as a Data Repeater

If the data collection module is used in remote areas, access to network connections to the host may be few and far between. Thus, it may be necessary for the data collection module to receive information from both sensor interface modules and from other data collection modules and transmit this information towards a data collection module which is connected to the host module through a network system. When the data collection module is used in this manner it is also called a data repeater module.

In one embodiment, the data repeater module is designed to interface with high pressure gas equipment for the monitoring of remote gas line transmission system locations. The data repeater module system uses spread spectrum radio transmission to transmit information in an Internet protocol (IP) stack to get to an Internet or communication line for transmission to the host module. In this manner, each module of the data repeater module system will receive a packet of information and relay the information down the line until it gets to a data collection module with host module transmission capability. The host-module-connected data collection module, or root data collection module, will transmit the information to the host module. The data repeater module can perform both the functions of a standard data collection module in gathering information from sensor interface modules, and perform the repeater functions to get the information to a connected data collection module for transmission over any of a number of the commercial transmission systems for data.

FIG. **44** shows a schematic diagram of the overall data repeater system, called a Wireless Radio Backbone (WRB). The WRB is a wireless radio Serial Line Internet Protocol (SLIP) transport which was designed for bi-directional communication between data collection module processors. Each data collection module has a processor which talks to a router which talks to a radio which transmits and receives signals. Some of the key issues surrounding the WRB will be discussed herein. The following gives general system requirements and specifications for setting up a WRB.

Communications Module	
CPU:	Motorola 68CH11
RAM:	32K
EEPROM:	64K to 1M
FLASH:	144K
Memory mapping:	PAL
I/O control:	PAL
Calendar/clock:	10 year battery-backed RTC
Watchdog:	COP
Headers:	SPI bus (qty. 2) used for expansion boards
	Serial ports (qty. 4 + 1)
Enclosure:	NEMA 4X with padlock (may vary depending on solar power needs)
Power requirements:	1 amp at 9–16 vdc (25 vdc max)
Environmental:	−40 to +85° C. operating at 95% humidity non-condensing

-continued

Flow Computer Module	
Rosemount 2055 with HART protocol signal	
Differential pressure range	0–10 to 0–250 in H_2O
Gauge pressure range	0–80 to 0–2000 psig
Isolator material	316SST
Fill fluid	Silicon
Flange style/material	Coplanar/SST
Drain/vent material	SST
O-Ring	Glass-filled TFE
Process temperature	RTD & cable optional
Transmitter housing	Polyurethane-covered aluminum
Terminal block	Standard block & optional transient protected block
Approvals	Factory Manual explosion proof, Factory Mutual intrinsically safe
Software functionality	Averaging method: Flow dependent time weighted formulaic averaging Compressibility method: AGA Report No. 8/API MPMS Chapter 14.2, variable logging per API 21.1

Spread Spectrum Radio Module	
LSDR 200 with TCIP/IP Path Management Module, packaged with Communications Module	
System Requirements	
LSDR 200	89C2051 processor 2k bytes of ROM 128 bytes of onboard RAM 512 bytes of non-volatile RAM
PMM 200	89C52 processor 8k bytes of ROM 256 bytes of onboard RAM 8k bytes of external RAM 512 bytes of non-volatile RAM
IP datagram	Min size = 576 bytes (512 bytes of data plus 64 bytes overhead) Max size = 4096 bytes

Each node in the Radio Backbone (WRB) consists of a 900 mhz Low Speed Data Radio (LSDR 200) and a 8052 based Path Management Module (PMM 200) or router. The router receives SLIP datagrams via a 9600 baud UART from the host data collection module processor interface, fragments them for switched transport, and sends them to another data collection module processor via other radios and routers.

Serial Line Internet Protocol (SLIP) is an encapsulation protocol for point-to-point, serial transport of IP diagrams. SLIP defines a sequence of characters that frame IP packets on a serial line. An END (0xC0) character starts and ends a SLIP packet. In addition, any internal END character is replaced with the character sequence ESC, ESC_END, (0xDBDC) and any internal ESC (0xDB) character is replaced with the character sequence ESC, ESC_ESC (0xDBDD).

IP transports (and hence the WRB) do not guarantee delivery of datagrams; however, they make the best effort they can to deliver the data. Although there are re-tries and time-outs between radios, problems in transport such as unreachable destination or re-assembly timeouts are not reported in the source IP address. Upper-layer protocols, such as TCP, should be used to build guaranteed delivery services on top of the WRB.

The WRB subnet is assigned a unique 32-bit IP address. The root data collection module processor acts as a firewall

to all other data repeater module processors and data collection module routers on the wireless backbone subnet. Each data repeater module processor and router has a unique internal, Class C subnet IP address. The first three bytes of the subnet IP address are the same for all data collection modules in the subnet. The last byte selects either a data collection module processor (even byte) or a data collection module router (odd byte). All IP addresses for a data collection module in a WRB subnet are even with the next odd address being assigned to the associated router. This means there can be a maximum of 128 data collection module processors and 128 data collection module routers in a WRB subnet. A LSDR 200 radio passes the even and odd address packets to the router. The root data collection module processor is assigned a default IP address such that any unknown addressed packet is automatically sent to the default address.

The IP Destination Address (DA) and the Total Length (TL) are the only parts of an IP datagram that are used by a WRB router. All other fields such as fragment flags (DF and MR), time to live (TTL), header checksum, source IP address, security, record route, and Internet time stamp are the responsibility of the sender and receiver.

IP datagrams are fragmented into smaller units by the root-router for wireless transport by the LDSR 200 radios. These radios are also referred to as "900 mhz radios," "hopping transceivers," "gateway transceivers," "backbone radios," or more commonly, "900 mhz hoppers." The LDSR 200 radios have limited resources and operate under strict FCC regulations which necessitate smaller datagram communication protocols, namely, Radio Data Protocol (RDP) and Transmission Data Protocol (TDP). It is the responsibility of the destination router to re-assemble the fragmented original datagram.

The Total Length field of an IP datagram contains the length, in bytes, of the IP header and data. The maximum size of an IP datagram is 65,535 bytes. However, a sequence byte is used to keep track of fragmented packets on the backbone and thus, the maximum WRB IP datagram length is 4096 bytes (16×256).

The data collection module router is also known as a Path Manager Module (PMM). The PMM or Router operates in three modes. Mode 0 receives/sends SLIP datagrams between host interfaces according to the internal routing table. Mode 1 receives/sends stream data between host interfaces using the last sent IP address router path. Mode 2 receives/sends character lines also using the last sent IP address. The routing table is held in the router non-volatile RAM (NVRAM) and is used to move RDP packets from router A to router B using other router/radios if necessary. Router table entries can come from any of three sources, namely 1) a router IP command packet, 2) an external hookup with a laptop, or 3) remembering the path of a received RDP packet.

IP packets addressed directly to a router or PMM (ie: the last byte of the IP address odd) are commands or interrogation packets for the router. A command mode is available in router stream mode (mode 1) when a designated byte stream/timing is detected by the router.

Router configurations in the NVRAM can be changed directly with a special cable and a laptop computer via a special program. When the router detects a NVRAM change, it automatically reconfigures itself.

If a non-WRB subnet IP addressed packet appears on the backbone, the packet is routed to the root data collection module processor at the default subnet IP address.

Data Repeater Module Processor

Data repeater module processors communicate using SLIP encapsulated Internet Protocol (IP) datagrams. The Radio Backbone (RB) uses the SLIP protocol for input and output data to the RB Path Management Module. An IP datagram from a data collection module processor is sent to its router (via SLIP) for transport to the destination router and its data collection module processor. Only the 16-bit Total Length and 32-bit Destination Address fields of an IP datagram are used by the router. The following shows the general IP protocol for data repeater module communications.

	< ---------- 32 bits ---------- >		
0	Version/1HL	Type of Service	Total Length
4	Identification		0/DF/MF/ Fragment Offset
8	TTL	Protocol	Header Checksum
12	Source Address		
16	Destination Address		
20	Options/Padding		
24	Data		

Field	Description	Length	Index
Version/IHL		1	0
Type of Service		1	1
Total Length	Total Length of the IP datagram	2	2
Identification		2	4
O/DF/MF/Fragment Offset		2	6
TTL		1	8
Protocol		1	9
Header Checksum		2	10
Destination Address	Destination IP Address	4	12
Options/Padding		4	16
Data			20

Path Management Module

A Path Management Module/Router is the gateway to the WRB. A router operates as an SLIP backbone (mode 0) or as a byte stream, point to point link (modes 1 & 2). In mode 0, a SLIP datagram is received by the router from the host interface and broken into sequenced Radio Data Protocol packets (RDP) for transport to another router via the LSDR radios. Such a transfer may involve many router/radio nodes.

IP datagrams are completely encapsulated in the data fields of RDP packets. The sequence byte allows for up to 16 packets or fragments to be transported for a single IP datagram. This translates to a maximum IP datagram length of 4096 bytes (16×256) that can be transported by the RB subnet.

Each router maintains a routing table to get IP datagrams from point A to point B using other LSDR 200 radios if necessary. Each router has a unique Class C subnet IP address which is used to change and interrogate configuration parameters. In addition, an external port is available such that a laptop computer can be connected to the router and with special software, be able to configure the non-volatile configuration RAM (NVRAM). When the router detects a change in the NVRAM, it reconfigures itself automatically.

The router communicates to the host interface through a 9600 baud UART. The router communicates to the LSDR 200 radio interface with RTS and CTS handshaking. In mode 0, the router expects a RDP acknowledgement packet

back from the destination router when a complete RDP packet has been received. If the transfer was successful, the internal packet is thrown away. Otherwise, because of an unsuccessful acknowledgement or a timeout, the RDP packet will be re-sent up to the configurable retry count.

The routing tables are held in the router non-volatile RAM and are used to move RDP packets from router A to router B using other router/radios if necessary. Router table entries can come from any of three sources, namely 1) a router IP command packet, 2) an external hookup with a laptop, or 3) recording the path of a received RDP packet.

The following shows Normal and Acknowledge radio data protocol (RDP) packets.

Sync Word	Destination	Src.	ID	Cmd	Hop	nRts	Routes	Seq	Len	Data	CkSm	
CFA3593E	XX XX XX XX	XX	XX	00	XX	XX	15 bytes	XX	XX	255 bytes	X	16 to
4	4	1	1	1	1	1	0–15	1	1	0–255	1	286 bytes

Sync Word	Destination	Src	ID	Cmd	CkSm	
CFA3593E	XX XX XX XX	XX	XX	FX	XX	
4	4	1	1	1	1	12 bytes

Field	Description	Length
Sync Word	(0-CFA3593E) 4-byte sequence used to detect start of RDP Packet. To sync up, precede this pattern with 290 0x7E's	4
Destination	4 byte IP address. If RB subnet address, then the first 3 bytes are the subnet address while the last byte is a data collection module address (even) or a router address (odd)	4
Src	1 byte source subnet address	1
ID	Packet number (incremented for every different packet)	1
Cmd	0x00 → Mode 0 IP packet. 0x01 → Mode 1 character packet. 0x02 → Mode 2 line packet. Note: add 4 for each retry (ie. 0x04 is 1st retry for IP packet, 0x08 is 2nd, etc.) 0x80 → Set radio IP address (use Destination). 0x81 → Perform radio self check. 0xFD → Timeout. 0xFE → Error in Packet transmission. 0xFF → Packet delivered. (Acknowledge)	1
hop	Current packet hop count (hop=0 means arrived)	
nRts	Number of route bytes to follow	1
Routes	Route path for RDP packets. The last byte is the source address. The RDP destination is in the Destination field. The first byte is the next destination.	0–15
Seq	The first nibble (0–15) plus one is the RDP packet number. The second nibble (0–15 plus one is the total number of RDP packets.	1
Len	The length of the data field in the RDP packet.	1
Data	The data transferred by RDP packets. If the packet destination is even, then the data is an IP fragment. If the destination is odd, the packet is router data.	0–255
CkSm	Checksum byte.	

The following shows a listing of RDP commands.

Cmd	Description	Length	Radio/pmm	Radio/rx
0x00	Mode 0 IP packet	16–286	Send	Check
0x01	Mode 1 character packet	16–286	Send	Check
0x02	Mode 2 line packet	16–286	Send	Check
0x80	Set radio IP address (use Destination)	12	Set IP address	
0x81	Perform radio self test.	12	Perform check	Perform self test
0xFD	Timeout	12	Send	Check

-continued

Cmd	Description	Length	Radio/pmm	Radio/rx
0xFE	Error in Packet transmission	12	Send	Check
0xFF	Packet delivered. (Acknowledgement)	12	Send	Check

PMM Monitor Mode

The PMM on power up, waits 10 seconds for a <CR> to enter a monitor mode. If it receives any other character from the host interface or times out, the NVRAM variables are loaded and it enters normal routing mode.

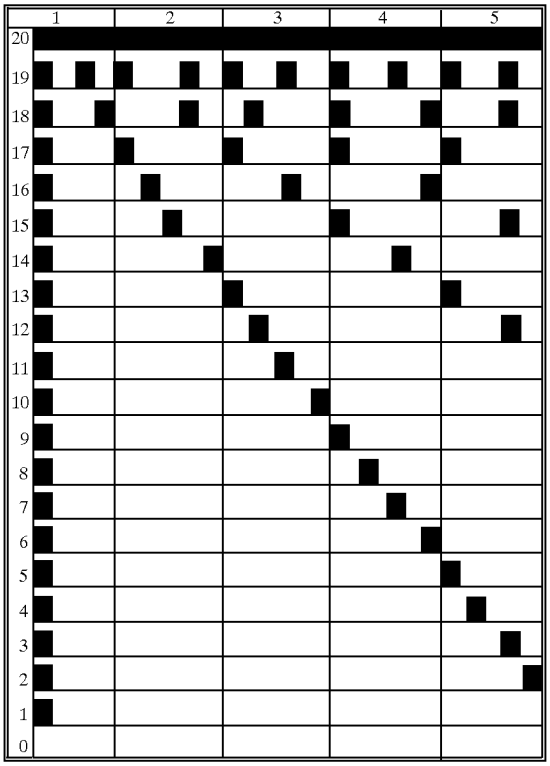
PMM Commands

When a RDP packet is addressed to a PMM module (odd IP address), the data is interpreted as commands.

FIG. **45** shows a schematic view of the PMM software design.

PMM Errors

Error rates in the PMM either due to time-outs or re-tries are tallied and visually displayed on the PMM error LED as a blink rate. The blink rate and corresponding current number of errors per hour are listed below. The blink rate is updated every five minutes.



LSDR 200 Radios

The Low Speed Data Radio (LSDR 200) is a point to point hopping transceiver. The radio receives a Radio Data Protocol (RDP) packet, encapsulates it in a Transmission Data Protocol (TDP) packet, and transmits it to another radio. A TDP packet consists of a preamble, sync word, a RDP packet, next frequency, and CRC. When a TDP packet is received by a radio, the preamble and sync words are checked and then the destination address is examined and compared with the node address (masked with 0xFE). If a match is found or a broadcast command is received (cmd=0×02), the data (a RDP packet) is retrieved and passed to the router through the radio interface. If there is no address match, the TDP packet is discarded and not sent to the router or acknowledged to the source radio.

If an acknowledge RDP packet is received with the maximum transmission window time, it will be immediately broadcast. Otherwise, the radio goes into a search mode for other RDP packets.

LSDR's have two operation modes. Mode 0 receives/sends RDP packets for the router packet interface, while mode 1 let's the LSDR act as a serial interface according to a designated connection. In either mode, radio communication is with TDP packets and only point to point without intervening radios or routers.

The router host interface operates at 9600 baud with TRS and CTS controlling data through-put. Because the goal is to provide as close to 9600 baud radio through-put as possible, only a CRC is used to guarantee valid data delivery and no acknowledgment or retry is implemented. It is the responsibility of a higher level protocol to guarantee data delivery. Data Encapsulation The following illustrates the data encapsulation for a TDP, RDP and an IP.

TDP

Preamble	Sync Word	Destination	Src	Cmd	Data	Next Freq	CRC	
7E 7E 7E 7E	CF A3 59 3E	XX XX XX XX	XX	XX	256 bytes	XX	XX XX	20 to 291 bytes
4	4	4	1	1	0–275	1	2	
	<——————RDP Packet——————>							

RDP

Sync Word	Destination	Src	Cmd	# Routes	Routes	Sequence	Length	Data	
CF A3 59 3E	XX XX XX XX	XX	XX	XX	15 bytes	XX	XX	255 bytes	13 to 283 bytes
4	4	1	1	1	0–15	1	1	0–255	

IP			
	<—————32 bits————>		
0	Version/IHL	Type of Service	Total Length
4	Identification		0/DR/MF/Fragment Offset
8	TTL	Protocol	Header Checksum
12	Source Address		
16	Destination Address		
20	Options/Padding		
24	Data		

Datagram/Packet Flow

FIG. **46** shows a schematic representation of a IP datagram/Packet flow through the WRB. An IP datagram (1) is encapsulated in SLIP and sent through the host interface to the router. The router creates a RDP packet by appending a preamble to the front of a 256 byte fragment of the IP datagram and sends it to the radio (2). The radio receives the RDP packet and creates a TDP packet by appending a preamble, next frequency, and CRC. This packet is broadcast for reception by other radios (3).

When a radio receives a TDP packet (3) that matches its address, the preamble is stripped and the RDP packet (4) is sent to its router. The router sends an acknowledgement RDP packet (5) back to the source and the IP RDP fragment is encapsulated in a SLIP packet and sent on to the data repeater module processor (6).

The radio receives the acknowledgement RDP packet (7), encapsulates it in a TDP packet and sends it back to the source radio (8). The RDP ACK packet is passed to the source router (9) at which time, the router releases its resources and receives the next segment of the SLIP datagram (10).

This process continues until the IP datagram has been transmitted to the destination data controller module processor.

FIG. **47** shows a layout of a WRB for a walk-through example.

The following lists a walk-through example of a WRB communication.

1. Root Data Collection Module (DCM) receives IP datagram from VSAT.	137.75.52.10	137.34.9.55	WinGate 8/IP datagram			
2. DCM extracts RB subnet address from IP data and sends SLIP data to root RB router R5 with WG8 address.	22.22.22.8	137.34.9.55	IP datagram			
3. Router R5 packetizes 256 bytes of IP datagram into a RDP packet and uses router table to create delivery path (8:4→3→7→8). RDP packet is sent to radio Tx4.	22.22.22.3	4	0	7.8	IP datagram	
4. Radio Tx4 adds preamble/sync to RDP packet to router R3 and transmits.	Pre/sync	22.22.22.3	4	0	7.8	IP datagram
5. Radio Tx2 receives TDP packet, verifies correct destination, and sends the RDP packet to router R3.	22.22.22.3	4	0	7.8	IP datagram	
6. Router R3 verifies a valid RDP packet, generates an acknowledge RDP packet to send to source router R5, and sends it to its radio Tx2.	22.22.22.5	3	FF			
7. Radio Tx2 encapsulates the acknowledge RDP packet into a TDP packet and transmits.	Pre/sync	22.22.22.5	3	FF		
8. Upon reception of acknowledge TDP packet, Tx4 verifies correct destination and sends acknowledge RDP packet to router R5 which then releases the packet memory (no re-try necessary).	22.22.22.5	3	FF			
9. Router R3 modifies the RDP packet to address router R7, puts its address as the last route (source), and sends to radio Tx2 for transmission.	22.22.22.7	3	0	8.4	IP datagram	
10. Radio Tx2 adds preamble/sync to RDP packet and transmits.	Pre/sync	22.22.22.7	3	0	8.4	IP datagram
11. Radio Tx6 receives the TDP packet, verifies its destination, and sends the RDP packet to router R7.	22.22.22.7	3	0	8.4	IP datagram	
12. Router R7 verifies a valid RDP packet, generates an acknowledge RDP packet back to the source router R3, and sends it to radio Tx6.	22.22.22.3	7	FF			
13. Radio Tx6 encapsulates the acknowledge RDP into a TDP packet and transmits.	Pre/sync	22.22.22.3	7	FF		
14. Upon reception of acknow-	22.22.22.3	7	FF			

-continued

ledge TDP packet, Tx2 verifies destination and sends acknowledge RDP packet to router R3 which then releases the packet memory (no re-try necessary).					
15. Meanwhile, router R7 modifies the RDP packet to address router R8 DCM8, puts its address as the last route (source), and sends it to radio Tx6 for transmission. It updates its router table.	22.22.22.8	7	0	4.3	IP datagram
16. Radio Tx6 adds preamble/sync to RDP packet and transmit.	Pre/sync	22.22.22.8	7	0	4.3 IP datagram
17. Radio Tx8 receives TDP packet, verifies its destination and sends the RDP packet to router R9.	22.22.22.8	7	0	4.3	IP datagram
18. Router R8 verifies a valid RDP packet, generates an acknowledge RDP packet back to the source router R7, and sends it to radio Tx8.	22.22.22.7	9	FF		
19. Tx8 encapsulates the acknowledge RDP into a TDP packet and transmits.	Pre/sync	22.22.22.7	9	FF	
20. Upon reception of acknowledge TDP packet, Tx6 verifies destination and sends acknowledge RDP packet to router R7 which then releases the packet memory (no re-try necessary).	22.22.22.7	9	FF		
21. Router R9 sees that the RDP packet is for WG8 and sends it through the host interface to WG8 as a fragment of an IP datagram. R9 also updates its router table to the root DCM	22.22.22.8	137349.55	IP datagram		

-continued

(0:8→7→3→4). 22. This process continues until a complete IP datagram has been transmitted from the root data collection module to DCM8.

3. The Host Module

a. Overview

Returning to a consideration of FIG. **1**, host module **122** is in communication with the data collection modules **110** through a network system. The host module **122** is a centrally or regionally located control center or centers which is used to monitor and control all the information exchange required by the monitoring system. The host module monitors the network health, processes customer requests, and notifies the customer authorities of alarm conditions. The host module also performs the functions of a data warehouse which collects all the information from the system and transmits the processed information to the customer's processing and display facilities.

The host module receives the information from the sensor interface module through the data collection modules. The data collection module information is transmitted over commercial carriers, and collected for processing by the host module. The host module then uses application software to compile the information into a user specified readable format. This information may then be made available to the customer. Types of available information include energy usage analysis, energy management operations and energy billing services.

In an alternate arrangement, the host module could be by-passed and a direct link might be provided from the data collection module to a customer's host system. In this application, the data collection module would be programmed to transmit in a manner compatible with the customer's system.

b. Physical Characteristics

The host module is typically a 24 hour per day×7 day per week network control center which consists of hardware devices designed to control and monitor information storage, processing and retrieval. The host module contains a main processing computer, such as a Sun Sparc™ Workstation; access to commercial communication networks, such as Skytel; data storage components, such as a Microsoft Access™ database run on dual Intel™ based NT servers; and communication output connections, such as connections to the Internet.

c. Method of Operation

The host module receives data from a plurality of sensor interface modules through the data collection modules **110** and data repeater modules. The host system validates the data and passes the validated data to an internal data base, such as an Oracle™ data base running on redundant workstations. The database maintains a complete history of information received from the sensor interface modules. The data is stored and available to customers as needed. The host module uses this internal data base to provide information which is processed for communication transmission at the customer's request.

FIG. **48** is a flow chart of operation of the host module **122**. Information is received from the data collection module **6200** and placed into temporary memory storage **6202**. The

information is then processed to determine the type of data signal contained within the information, and the appropriate action is taken for the information received.

First, the information is tested to see if it is alarm condition **6204**. If the information is in alarm condition then the customer is immediately notified **6206**. The program then resumes normal operation. If the information is not in alarm condition, then it is tested to see if it is a new sensor interface module that has been detected **6208**.

If a new sensor interface module has been detected **6208**, then the data collection module will request information **6210** from the host module. The host module will assign a reporting priority to the data collection module receiving the sensor interface module signal. If the data collection module is the first data collection module to report information from the sensor interface module, then it will be assigned primary responsibility for reporting that sensor interface module's information. All other data collection modules reporting information from the same sensor interface module will be assigned a secondary reporting responsibility. The main program will then add the sensor interface module information and the primary or secondary status of the data collection module to the permanent storage record **6212**.

If a new sensor interface module had not been detected **6208**, then the information would be tested to see if it was a proper reading of a meter **6214**. If the information was a proper meter reading **6214**, then this information would be added to permanent data base **6212** to update the system information.

If the information was not a meter reading **6214**, then the information would be checked to see if it was a proper system parameter change **6216**. If the information was a system parameter change **6216** then this information would also be added to the permanent data base **6212**.

If the information fails the system parameter change **6216** then the signal has failed all of the proper signal tests and it is discarded from the main processing of the system.

Once information has been transferred into the permanent or long term storage facilities **6212**, then the information is available to customers through a commercial network **6220**. The information is made available in any manner the customer requires. This manner of transmitting information can be programmed into the host module. Standard commercial networks which can be used are items such as cable TV modems, regular phone line modems, the Internet, or other such communication devices.

Once all the information has been stored in the permanent data base structure **6212**, then the system will return **6218** to receiving reports from the meters at the data collection module **6200**.

1. Receiving Information from the Data Collection Modules

The data collection modules **110** transmit information to the host module. In the preferred embodiment, the data collection modules transmit the information through a commercial network to the host module. Alternatively, the host module can request updates from the data collection module as needed.

In the preferred embodiment, the data collection module will be assigned an Internet address and communicate through a modem as is well known in the prior art. The host module will be assigned an address for transmitting and receiving the data collection module signals. The data collection module will send and receiving information to and from the host module as an Internet protocol (TCP/IP) signal. The information signal will be sent out on the Internet, transferred across the Internet, and received by the other module. This connection allows the use of an extensive network of high grade communication equipment without having to implement an entirely new system for this information collection system.

This Internet transmission system allows for the use of a minimum cost information transmission system, because already existing phone lines may be used, and only local telephone calls are necessary for connection to the Internet. In addition, the Internet service provider may collect the non-alarm condition data collection module signals and create a single data stream signal into the host module at an off-peak usage time for noncritical monitoring applications. A critical monitoring application would require immediate information access and the signals should not be held for later transmission.

2. Processing Information from the Sensor Interface Module

Once the data stream is received by the host module **122**, the data stream is verified for accuracy. The data stream is then divided into the individual sensor interface module information packets. These individual information packets are then used to update the appropriate meter information and storage databases. This updated information is stored into both the most recent information database as well as the long term or permanent database.

3. Storage of Information for Later Retrieval

Information which has been received from the sensor interface modules is stored for later processing by the host module. The information is stored in a short time database. This short time database contains current readings and a definable number of days, 30 days in the preferred embodiment, of the most recent information history.

The validated data from the sensor interface modules is also permanently stored in a long term database. The long term database maintains a complete history of each meter interface device. The data is maintained on behalf of the customer for access by the customer either on demand or on a periodic basis.

4. Transmitting Information to Customers

Information is transmitted to the customer in a customer defined manner. The information is preferably made available over an Internet or other TCP/IP type connection with appropriate protocols and connections. An Internet or other TCP/IP type of connection allows customers to use software applications which allow the user to graphically view the stored information and their energy consumption rates. Other information can be provided through this system as the customer may desire. In the preferred embodiment, the Internet connection allows the customer to see their energy consumption in a graphical format for daily, weekly, monthly, and yearly usage rates by simply accessing a web site on the Internet. In addition, the software allows the customer to run "what-if" software and compare their existing bill against alternative billing options available by their electricity supplier.

5. Device Adjustment Modules

Device adjustment modules are used to monitor and control the operation of various devices and applications according to varying utility prices and the device consumption information. An example of a device control module is

a module to control a Johnson Control™ thermostat by attaching a device control module with a power system, processor with associated firmware, and a radio. The module monitors the energy usage by the air conditioning and heating systems controlled by the thermostat and can adjust the operation usage to stay below increased billing increment costs for energy supply and usage. A two-way sensor interface module would be utilized. The device adjustment module transmits information to the system and receives controlling information from system update transmissions.

4. Complete System Overview

FIG. **49** shows an example of an overall network schematic generally designated by the numeral **6300** implementing the present invention. In this example, a gas meter **6302** is connected to a transmitting and receiving sensor interface module **6318** which transmits and receives information from a data collection module **136**. An electrical meter **6304** is connected to a second transmitting and receiving sensor interface module **6320** which also transmits and receives information to and from data collection module **6326**. A vending machine **6306** is connected to a transmitting and receiving sensor interface module **6322** which transmits and receives information to and receiving sensor interface module **6326**. Air conditioning system **6308**, heaters **6310**, lights **6312**, security monitoring devices **6314**, and point of sale devices **6316** are all connected to transmitting and receiving sensor interface module **6324** which transmits and receives information to and from data collection module **6326**.

Data collection module **6326** is connected to commercial network **6336** by at least one communication system such as those illustrated. The data collection module **6326** is shown with a connection to the commercial wireline network **6336** through a telephone type system **6334**. A second alternative for connection of the data collection module **6326** to the commercial network **6336** is shown by the NPCS or BPCS **6325**. A third alternative for connection of the data collection module **6326** to the commercial network **6336** is shown through the use of a data repeater module **6328** and a connected data collection module **6330** which can communicate directly with communication network **6336** through connection **6332**.

Communication network **6336** is connected through connection **6338** to network operating center **6340**. The network operating center **6340** is connected through connection **6342** to host module **6344** which is also known as a data processing and customer monitoring center. The host module **6344** is connected through connection **6346** to the national frame relay network **6348**. The national frame relay network **6348** is connected through connection **6349** to customer computers **6350**. The national frame relay network **6348** may also be connected through connection **6351** to customer workstation **6352**.

The general layout of the wide area remote telemetry system **6300** is formed from the premise area network **6354**, the metropolitan network **6356** and the national backbone network **6358**. The premise area network **6354** consists of the monitored devices, the sensor interface modules, the data collection modules and the connections to the appropriate elements. The metropolitan network **6356** consists of the data collection modules, and the appropriate connections such as a NPCS or BPCS, or data repeater module and master data collection module. The national backbone network **6358** consists of the elements which transmit, process, store, and forward information to the end customer connections, such as a customer computer or a customer workstation.

Whereas, the present invention has been described in relation to the drawings attached hereto, it should be understood that other and further modifications, apart from those shown or suggested herein, may be made within the spirit and scope of this invention.

What is claimed is:

1. A method for a wide area remote telemetry system, comprising:

receiving information from a sensor;

interpreting information from the sensor;

storing the information into memory for future updates;

generating a first signal of the information to a data collection module at random intervals based on the number of inputs received from the sensor;

transmitting said first signal through a frequency chosen from a collection of frequencies by a hopping algorithm;

scanning the transmission frequencies for the first signal;

detecting the first signal;

receiving the first signal;

storing the first signal information into a data table;

sending a second signal of the information to a host;

receiving the second signal at the host;

verifying the second signal;

compiling the second signal information;

checking the second signal information against an assignment list for primary responsibility assignment;

if no assignment has been made, then relaying primary responsibility information; and

notifying a customer of alarm conditions if necessary.

2. A wide area remote telemetry system, comprising:

at least one sensor interface module;

at least one data collection module with a primary responsibility for acquiring and transmitting information from a sensor interface module;

at least one additional data collection module with a secondary responsibility for acquiring and transmitting information from a sensor interface module wherein each said data collection module stores all information received from each sensor interface module; and

a host module, wherein the information received at the host is verified, compiled, and checked against an assignment list for a primary responsibility assignment, and if no assignment has been made, then primary responsibility information is relayed.

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