US006208266B1

(12) **United States Patent**
Lyons et al.

(10) **Patent No.: US 6,208,266 B1**
(45) **Date of Patent: Mar. 27, 2001**

(54) **REMOTE DATA ACQUISITION AND PROCESSING SYSTEM**

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(73) Assignee: **Scientific Telemetry Corporation**, Middleboro, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **08/847,871**

(22) Filed: **Apr. 28, 1997**

Related U.S. Application Data

(63) Continuation-in-part of application No. 08/518,321, filed on Aug. 23, 1995.

(51) **Int. Cl.**[7] **G08B 23/00**
(52) **U.S. Cl.** **340/870.02**; 340/870.01; 348/160; 382/100
(58) **Field of Search** 340/870.02, 870.03, 340/870.01; 382/100; 348/100

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Intellon; "Marketing Bulletin for RF Spread Spectrum Technology"; Intellon Corporation.

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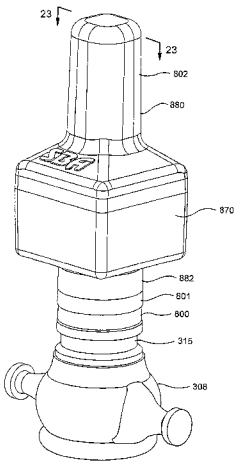
Primary Examiner—Michael Horabik
Assistant Examiner—Albert K. Wong
(74) *Attorney, Agent, or Firm*—Nixon Peabody LLP; Grant E. Pollack

(57) **ABSTRACT**

A remote data acquisition and processing system is provided. One embodiment of the system of the present invention for use in monitoring utility operation includes at least one optical imaging device for generating computer-readable image data of a visual representation, generated by a utility meter, of utility operation-related data. A host processor, which is remotely located from the optical imaging device and the utility meter, is also provided in this embodiment of the present invention for generating the utility operation-related data from the image data and for storing the image data.

15 Claims, 38 Drawing Sheets



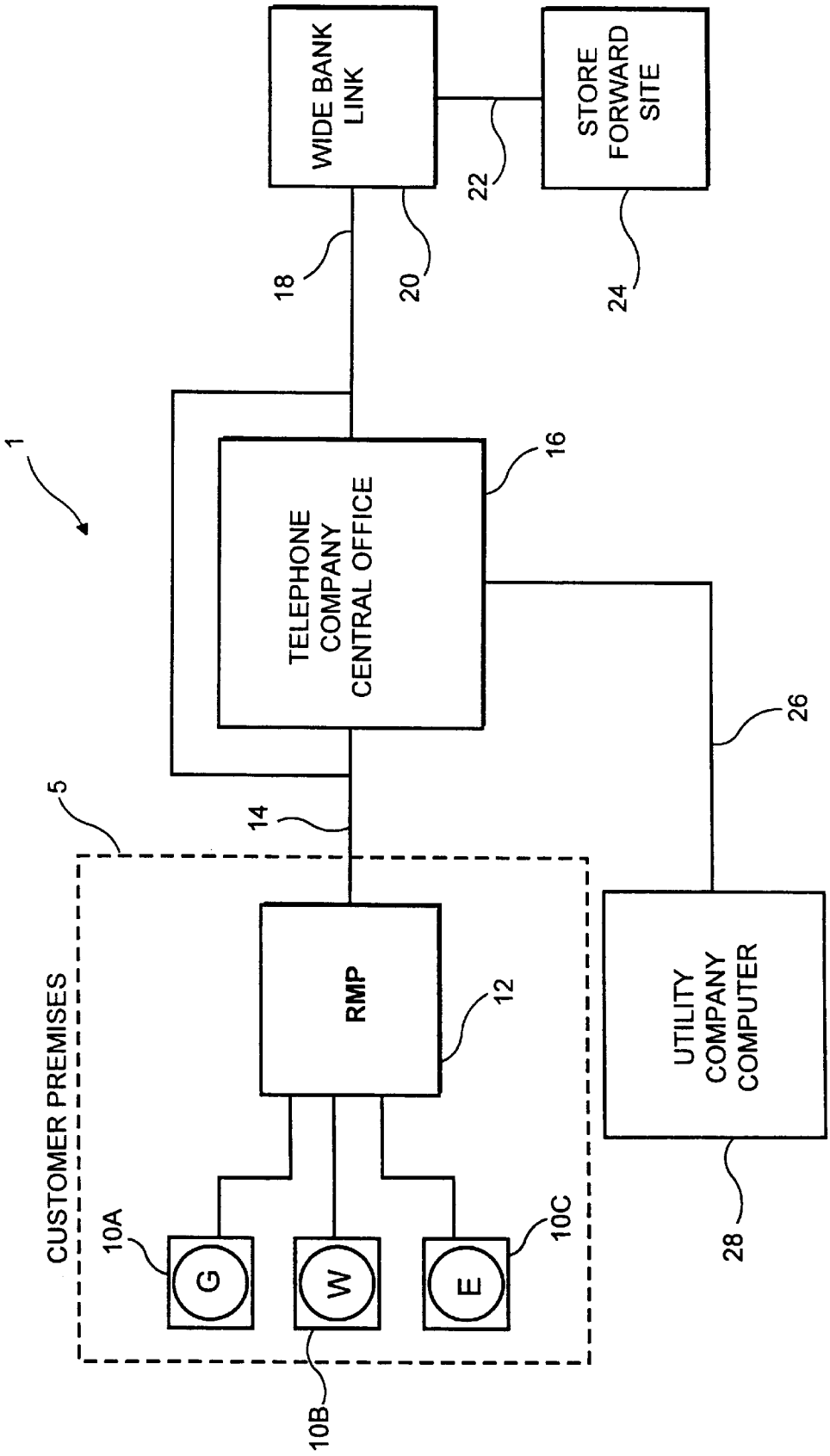

WIDE BANK LINK
STORE FORWARD SITE
22
18
20
24
1
TELEPHONE COMPANY CENTRAL OFFICE
16
26
5
14
RMP
12
UTILITY COMPANY COMPUTER
CUSTOMER PREMISES
10A
G
W
E
10C
28
10B

FIG. 1

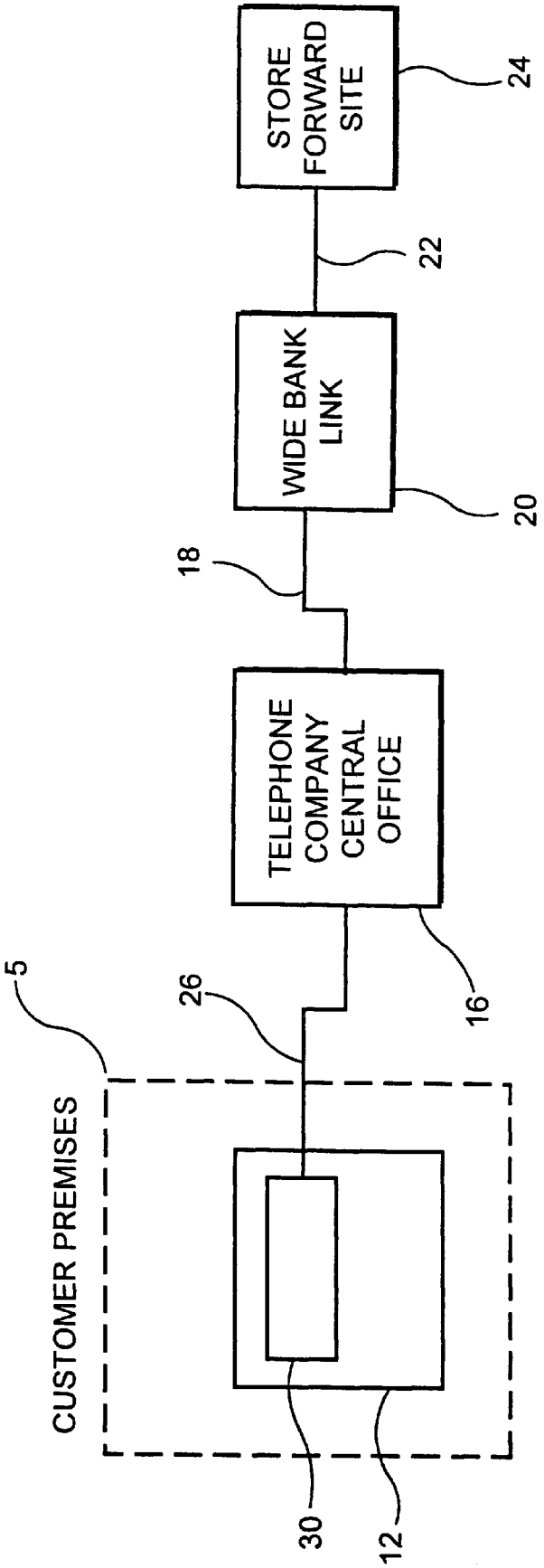

STORE FORWARD SITE
24
22
WIDE BANK LINK
20
18
TELEPHONE COMPANY CENTRAL OFFICE
16
26
5
CUSTOMER PREMISES
30
12

FIG. 2

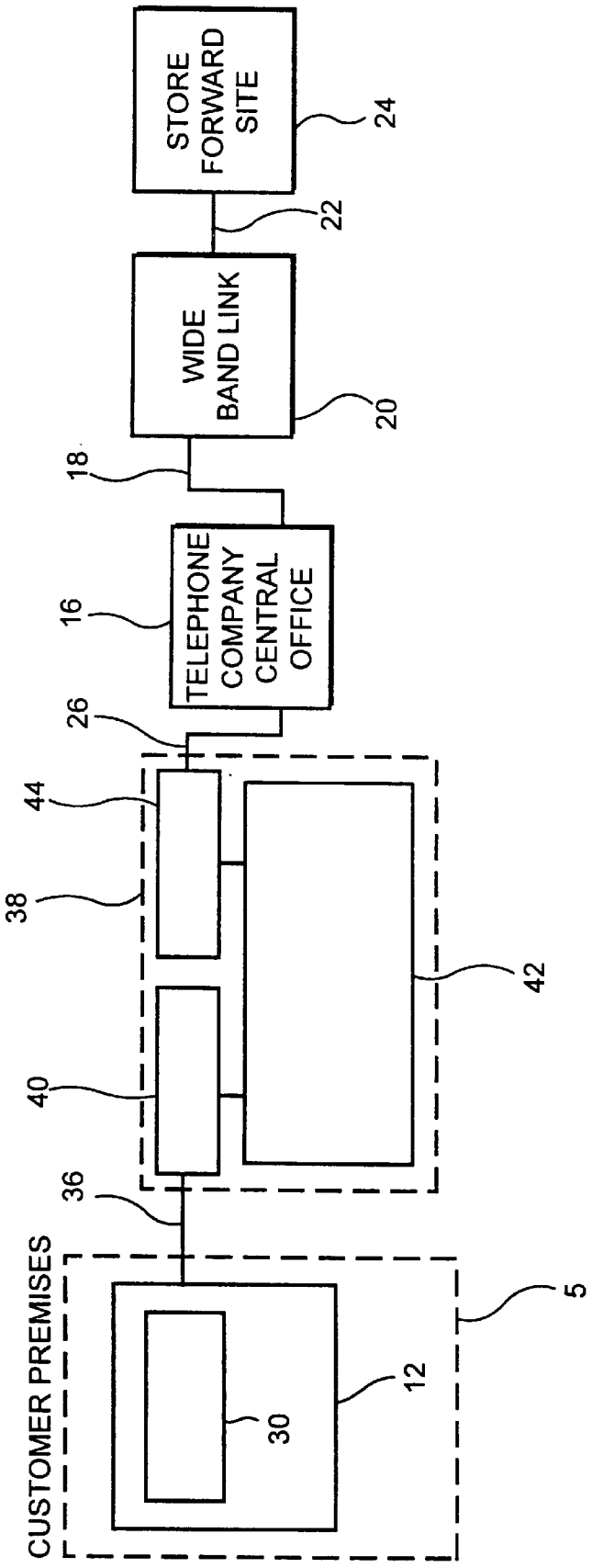

STORE FORWARD SITE
24
22
WIDE BAND LINK
20
18
TELEPHONE COMPANY CENTRAL OFFICE
16
26
44
38
42
40
36
CUSTOMER PREMISES
5
12
30

FIG. 3

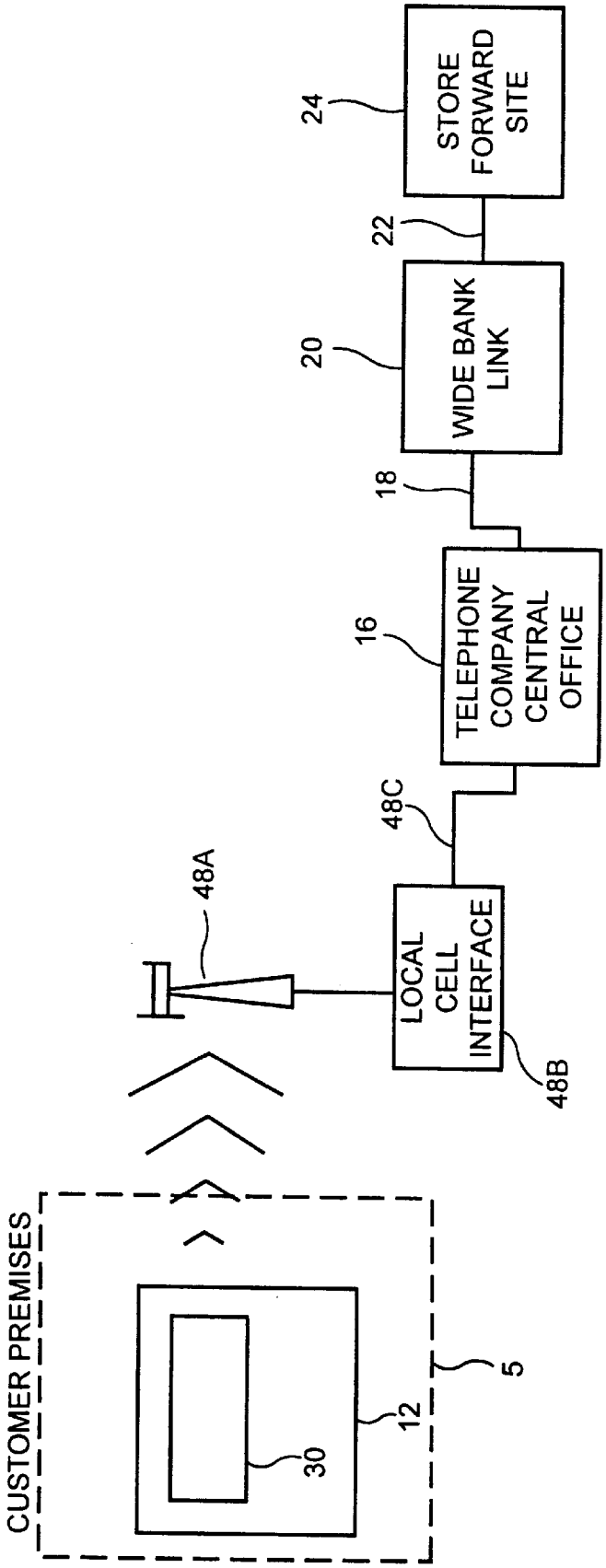

CUSTOMER PREMISES
5
12
30
48A
LOCAL CELL INTERFACE
48B
48C
TELEPHONE COMPANY CENTRAL OFFICE
16
18
WIDE BANK LINK
20
22
STORE FORWARD SITE
24

FIG. 4

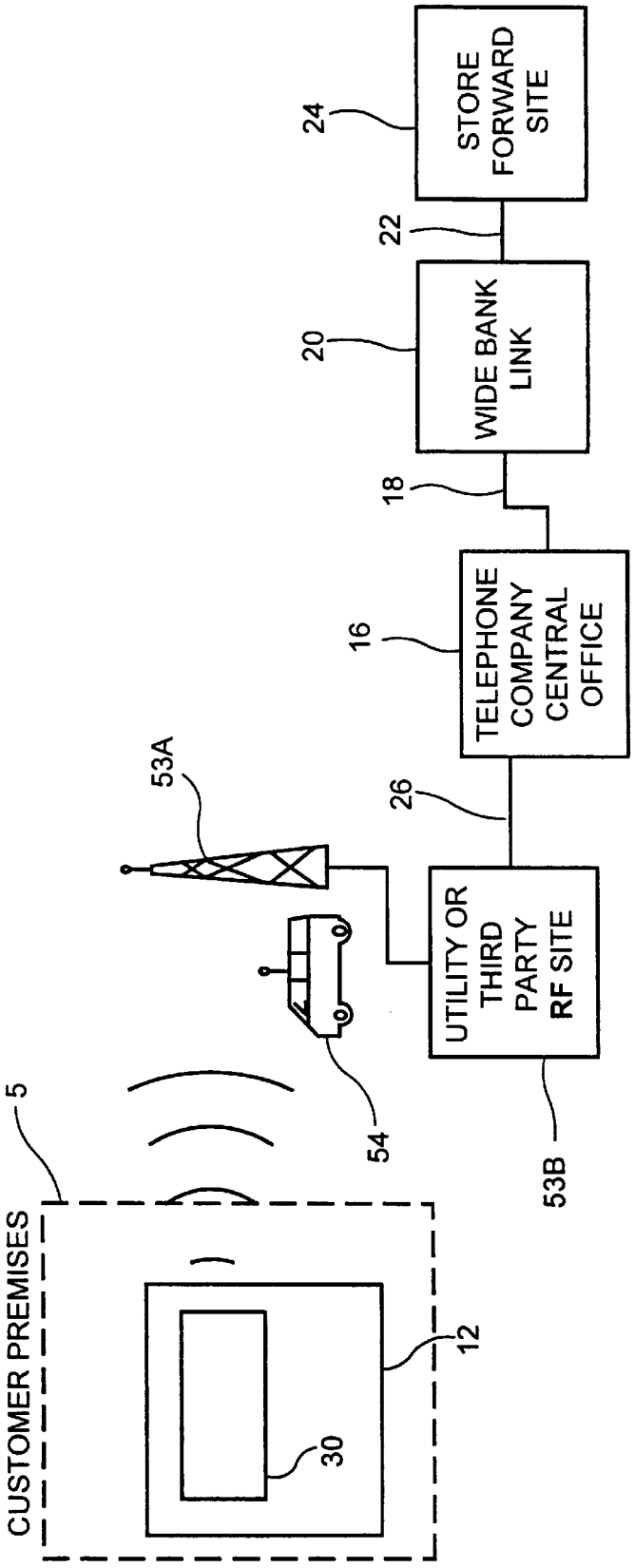

STORE FORWARD SITE
24
22
WIDE BANK LINK
20
18
TELEPHONE COMPANY CENTRAL OFFICE
16
26
53A
UTILITY OR THIRD PARTY RF SITE
53B
54
5
CUSTOMER PREMISES
12
30

FIG. 5

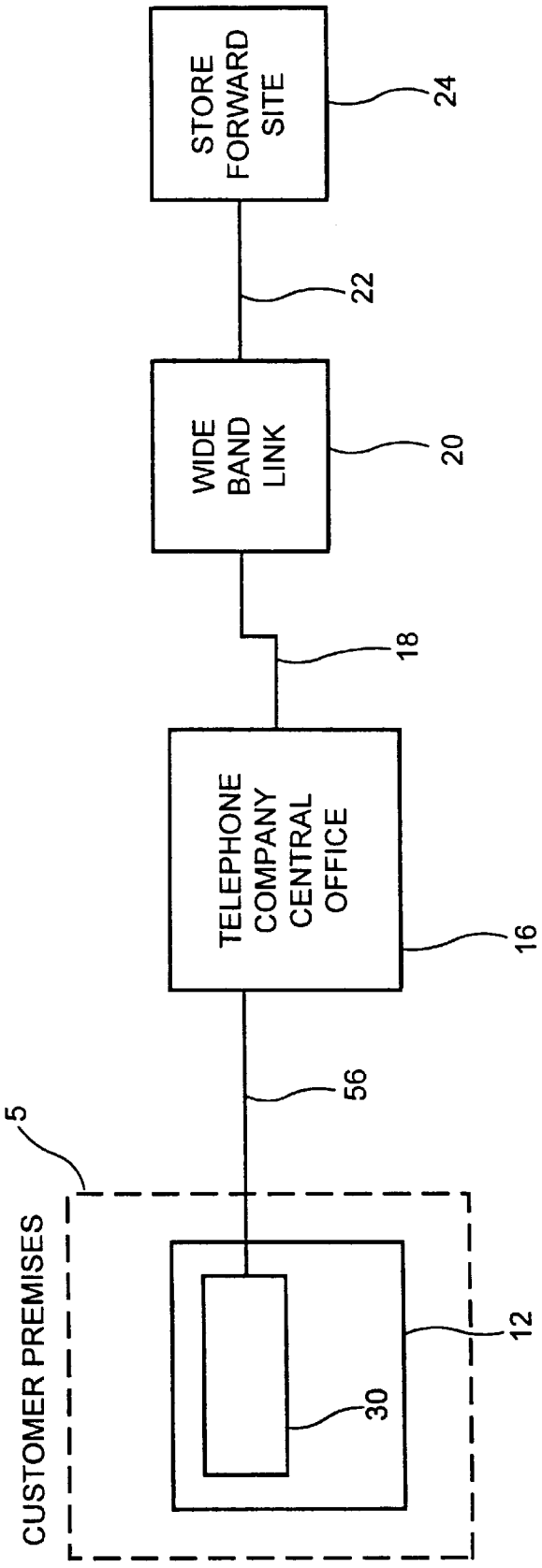

STORE FORWARD SITE
24
22
WIDE BAND LINK
20
18
TELEPHONE COMPANY CENTRAL OFFICE
16
56
5
CUSTOMER PREMISES
12
30

FIG. 6

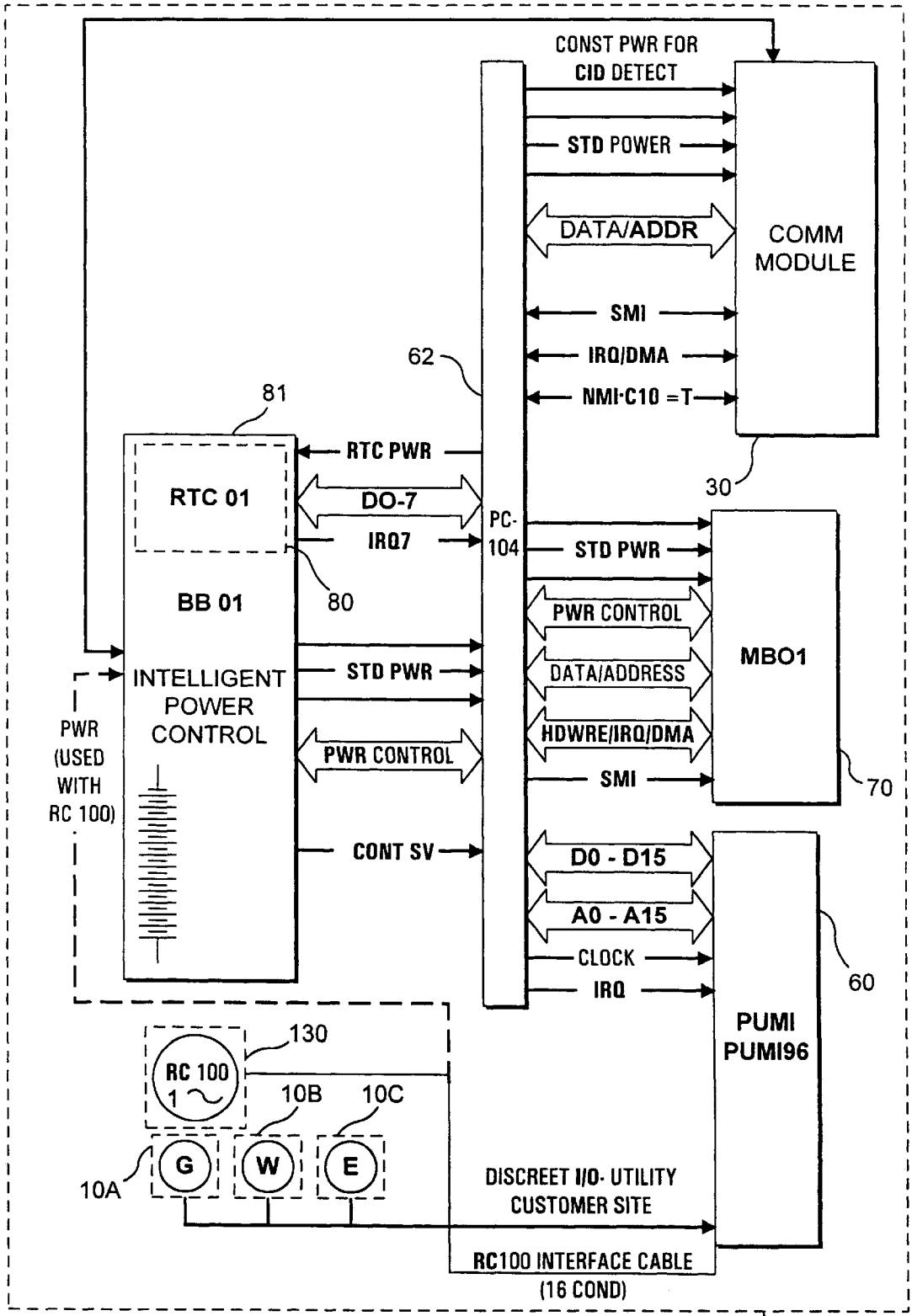

CONST PWR FOR
CID DETECT
STD POWER
DATA/ADDR
COMM
MODULE
SMI
IRQ/DMA
NMI-C10 =T
62
81
30
RTC PWR
RTC 01
DO-7
IRQ7
PC-
104
STD PWR
80
BB 01
PWR CONTROL
MBO1
INTELLIGENT
POWER
CONTROL
STD PWR
DATA/ADDRESS
HDWRE/IRQ/DMA
PWR
(USED
WITH
RC 100)
PWR CONTROL
SMI
70
CONT SV
D0 - D15
A0 - A15
CLOCK
IRQ
60
PUMI
PUMI96
130
RC 100
1
10B
10C
10A
G
W
E
DISCREET I/O- UTILITY
CUSTOMER SITE
RC100 INTERFACE CABLE
(16 COND)
12

FIG. 7

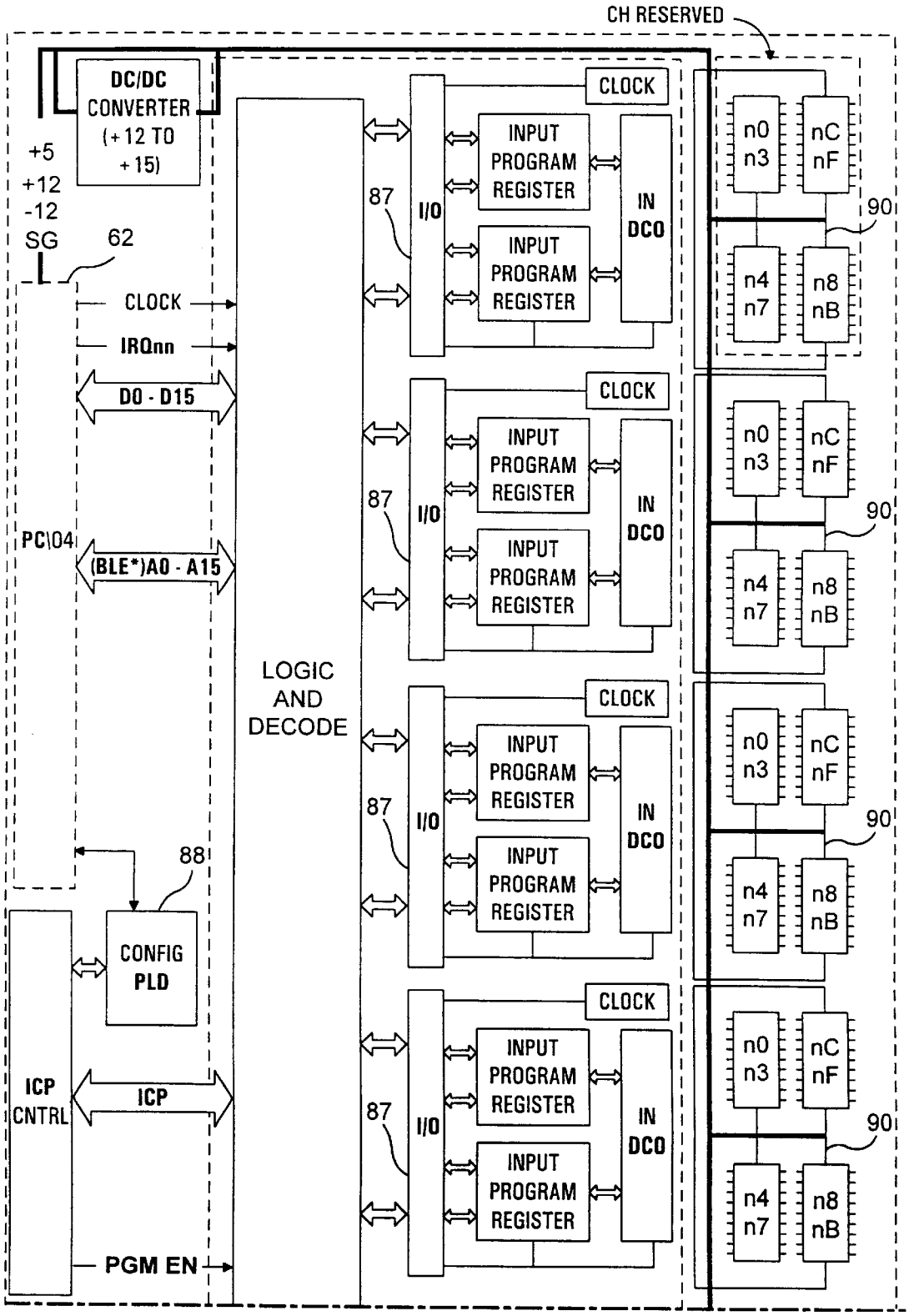

CH RESERVED
DC/DC CONVERTER (+12 TO +15)
+5
+12
-12
SG
62
CLOCK
IRQnn
D0 - D15
PC\04
(BLE*)A0 - A15
LOGIC AND DECODE
88
CONFIG PLD
ICP CNTRL
ICP
PGM EN
87
I/O
INPUT PROGRAM REGISTER
IN DCO
CLOCK
n0 n3
nC nF
n4 n7
n8 nB
90

FIG. 8A

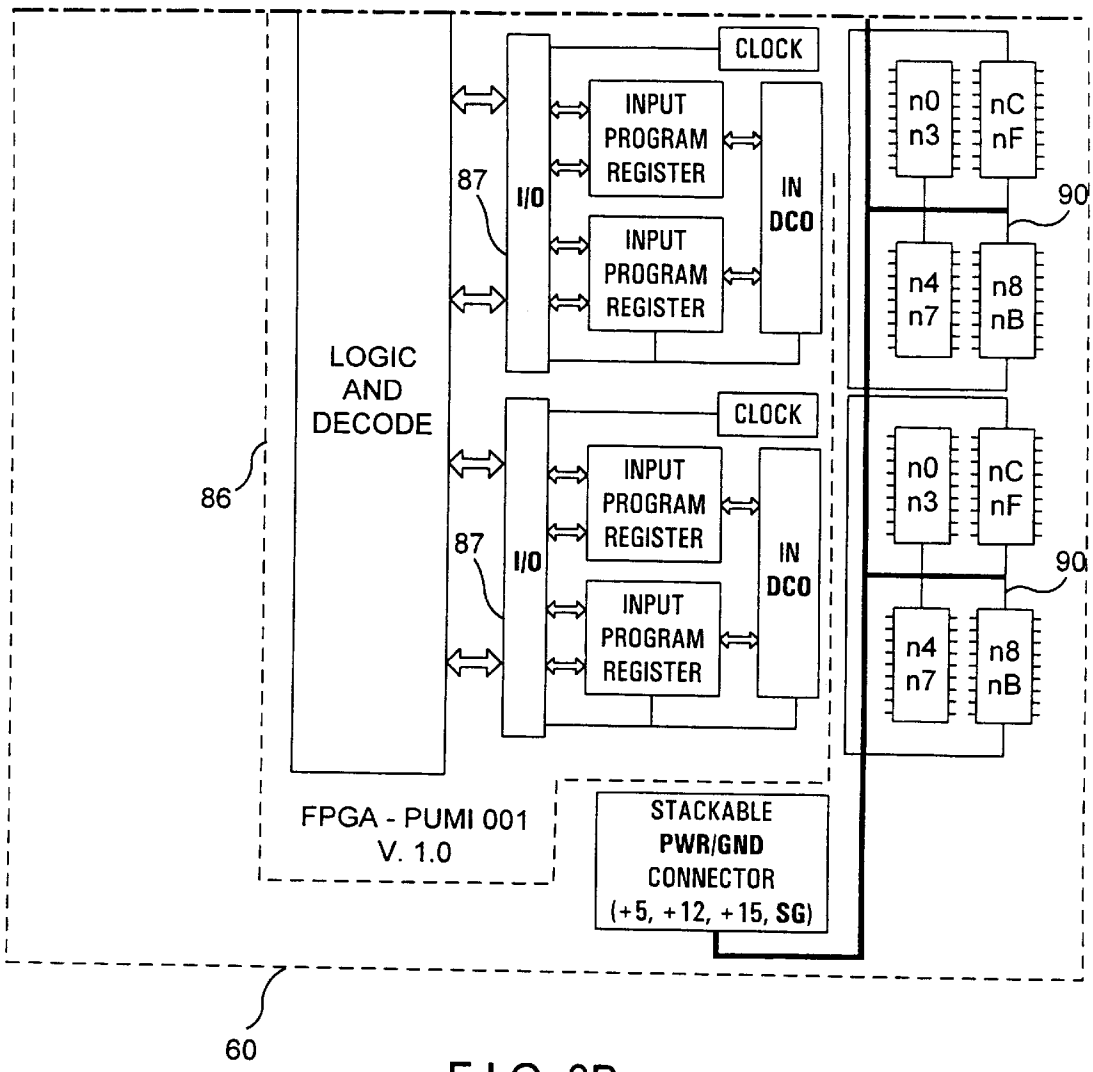

CLOCK
INPUT PROGRAM REGISTER
INPUT PROGRAM REGISTER
IN DCO
I/O
87
LOGIC AND DECODE
86
n0 n3
nC nF
n4 n7
n8 nB
90
FPGA - PUMI 001 V. 1.0
STACKABLE PWR/GND CONNECTOR (+5, +12, +15, SG)
60

FIG. 8B

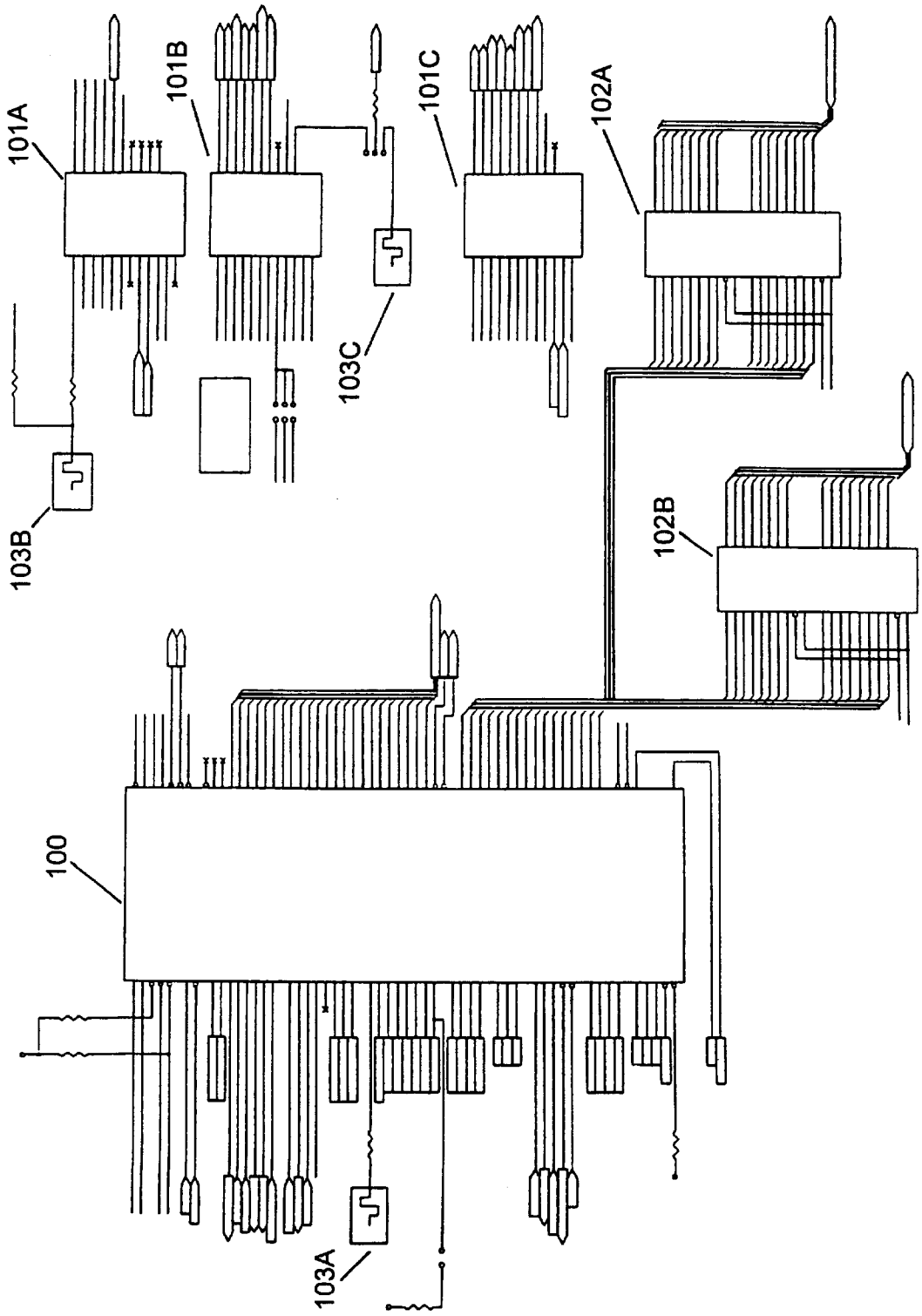


FIG. 9

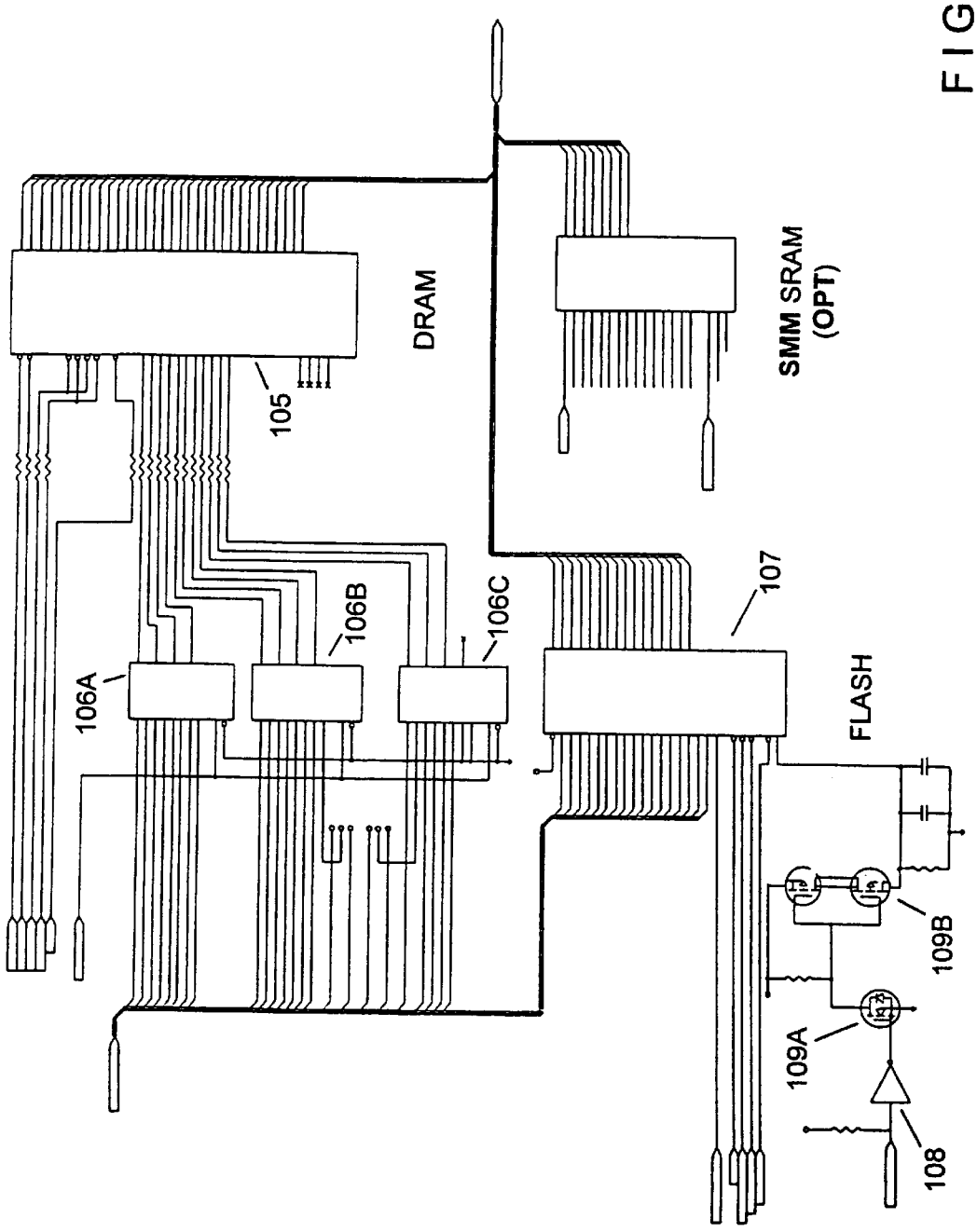


FIG. 10

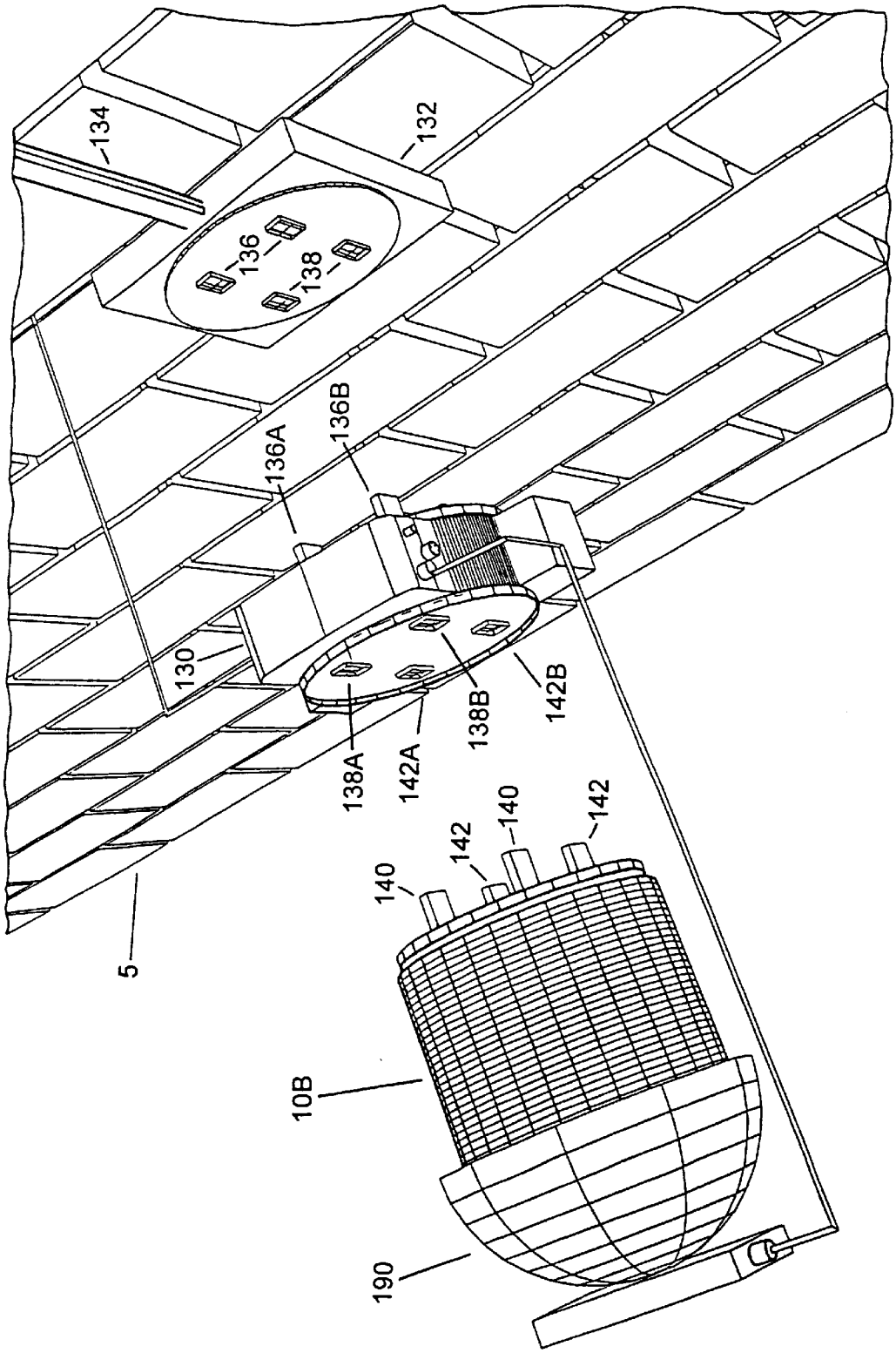

134
132
136
138
136A
136B
130
138A
142A
138B
142B
140
142
140
142
5
10B
190

FIG. 11

FIG. 12

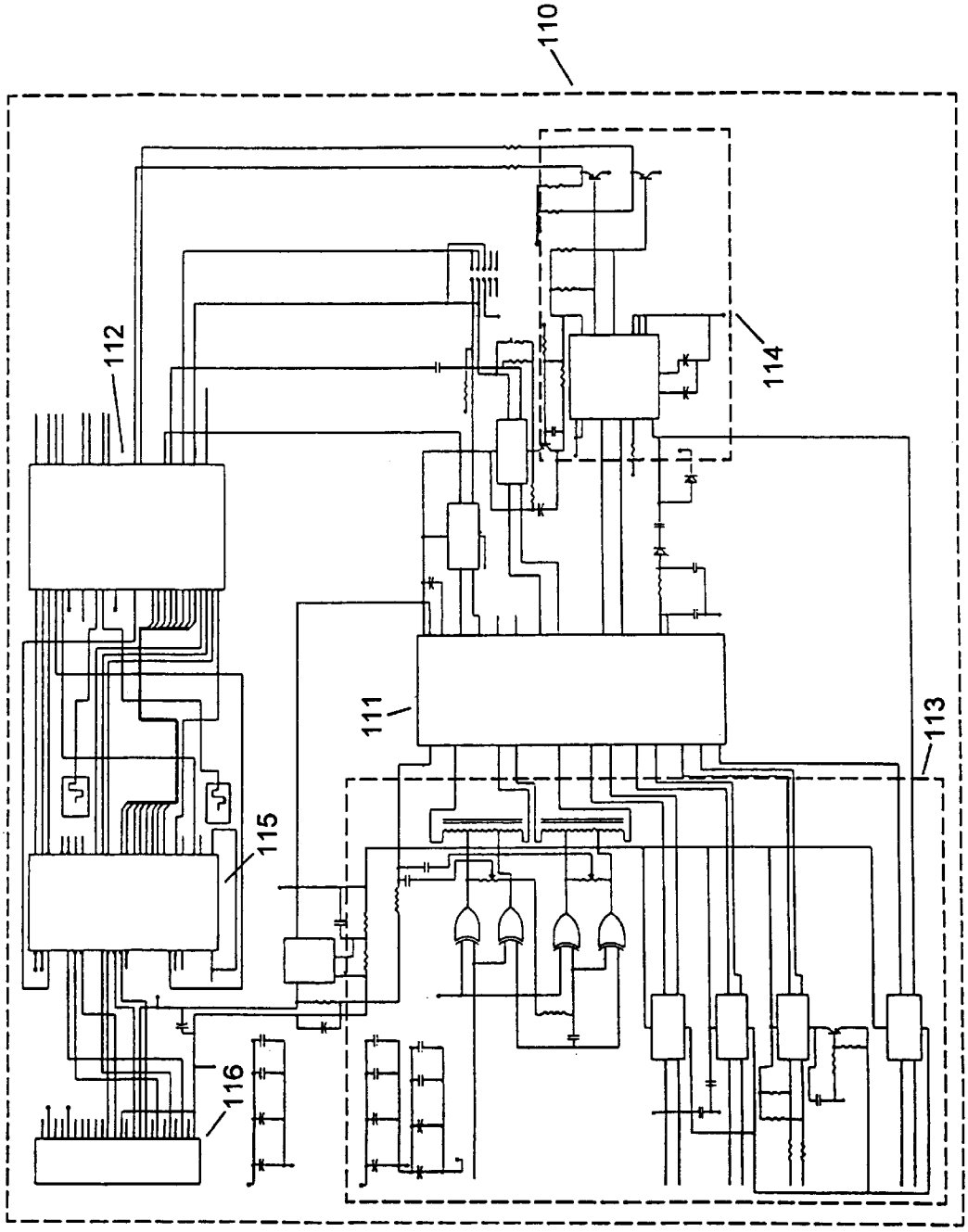
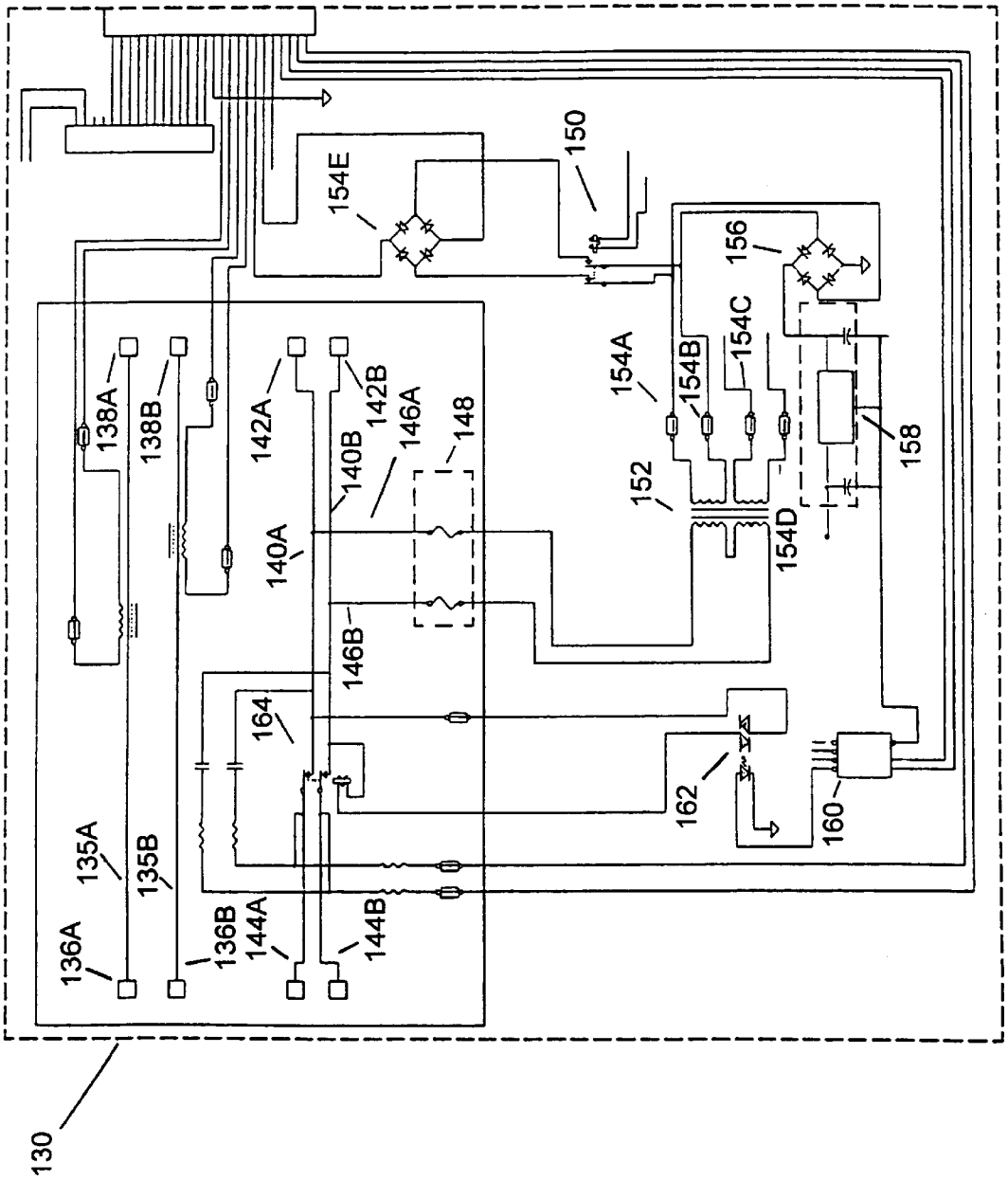


FIG. 13


130
136A
135A
135B
136B
144A
144B
138A
138B
142A
142B
140A
140B
146A
146B
148
164
150
154E
154A
154B
154C
154D
152
156
158
162
160

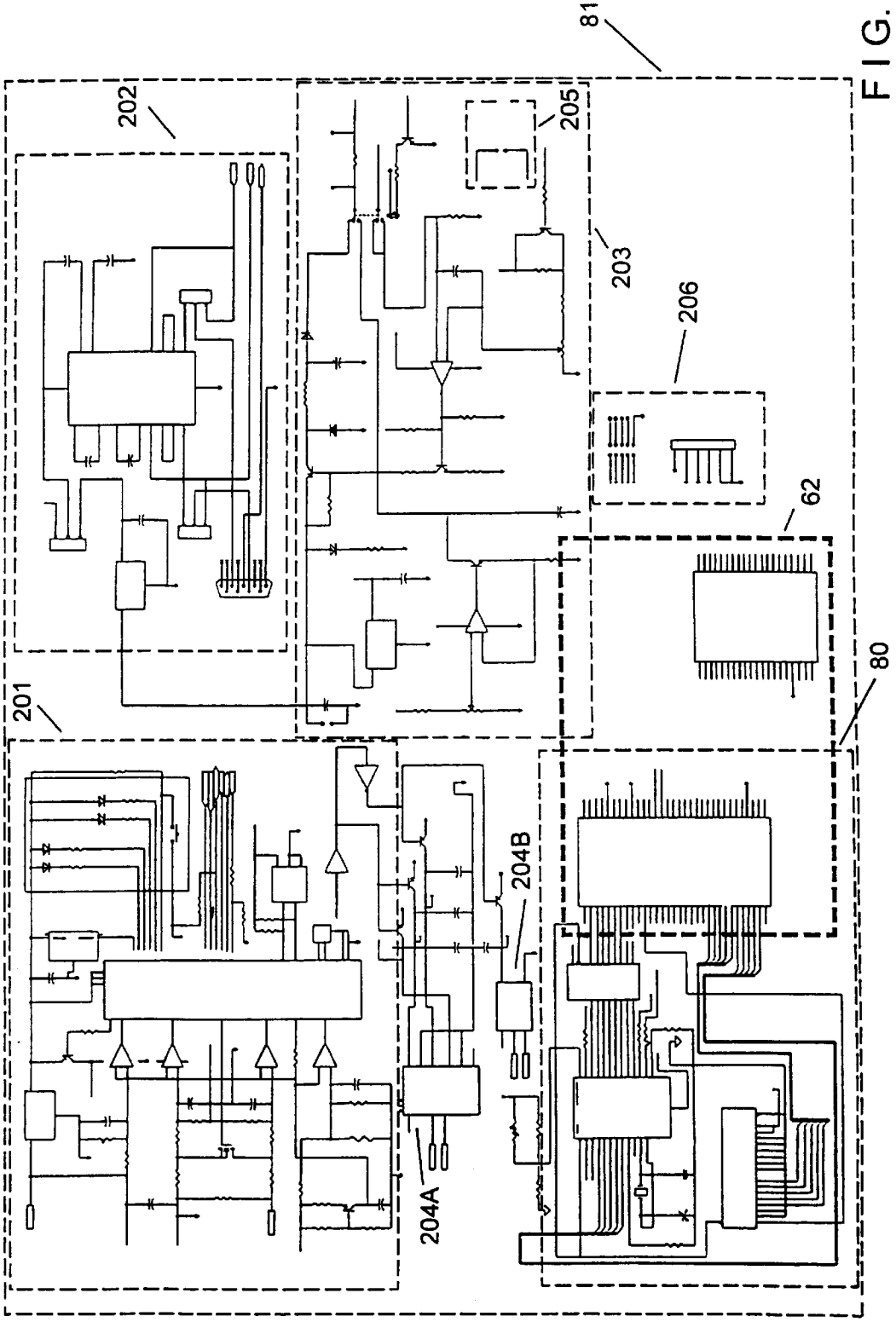


FIG. 14

FIG. 15

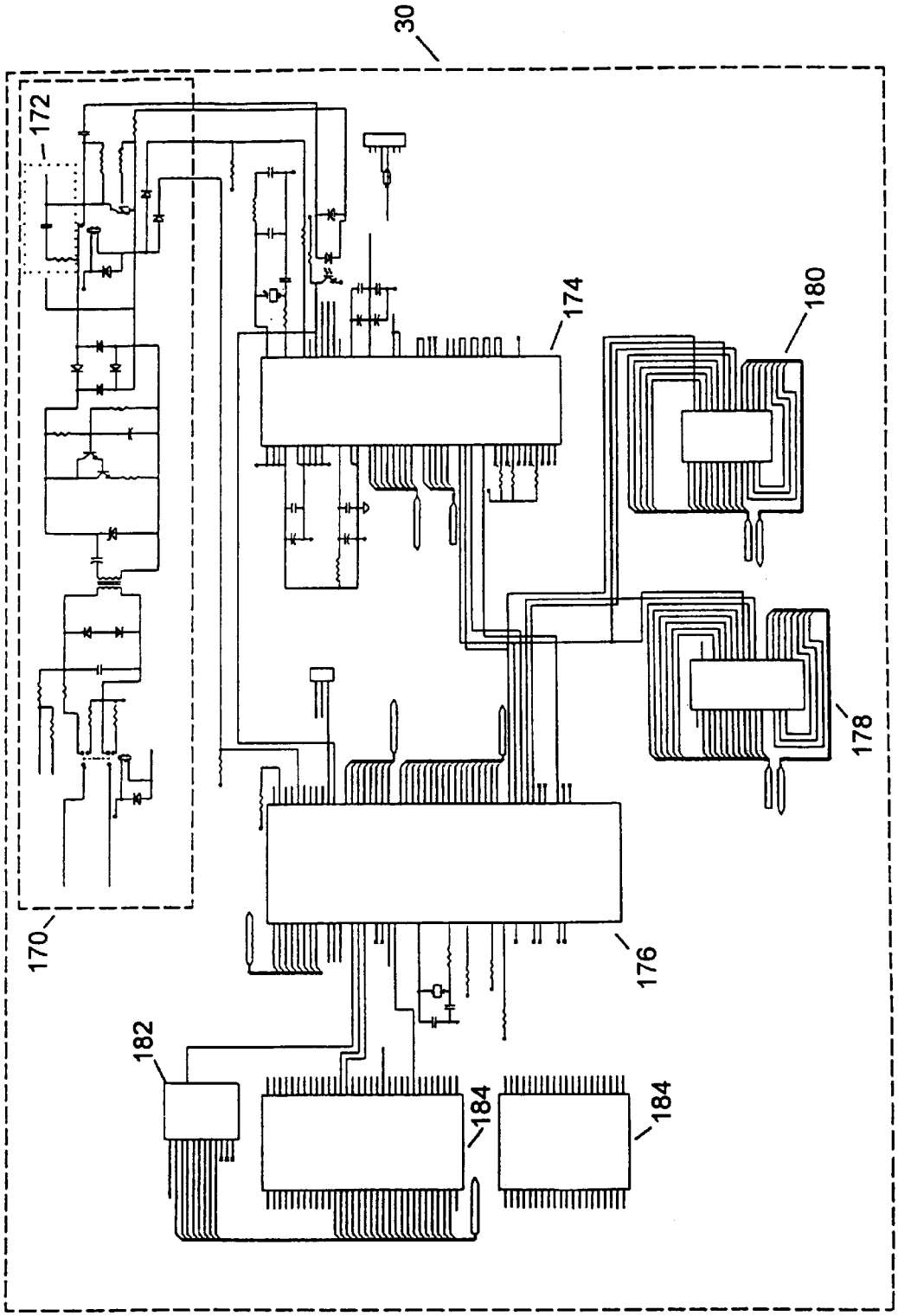


FIG. 16

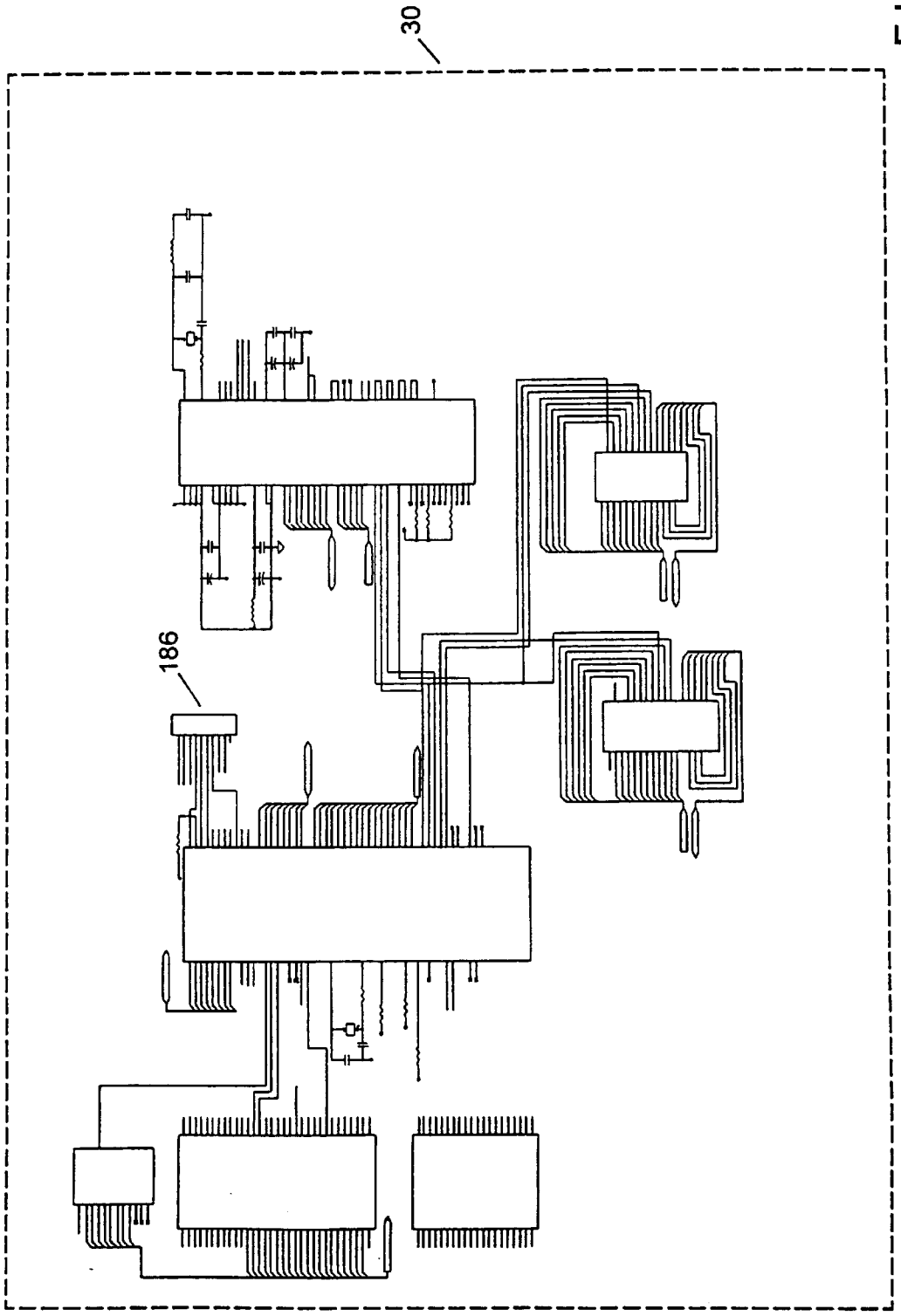
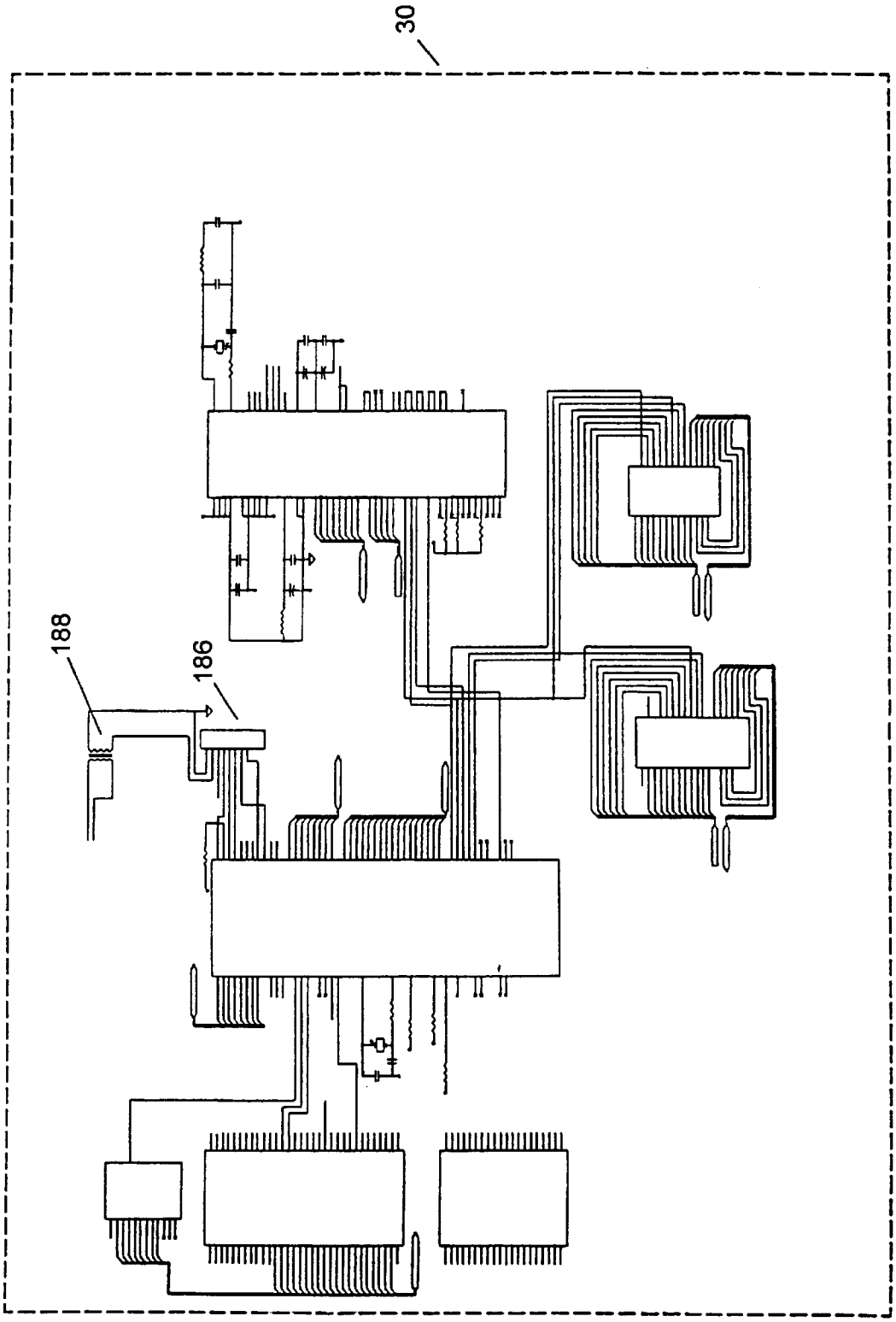


FIG. 17



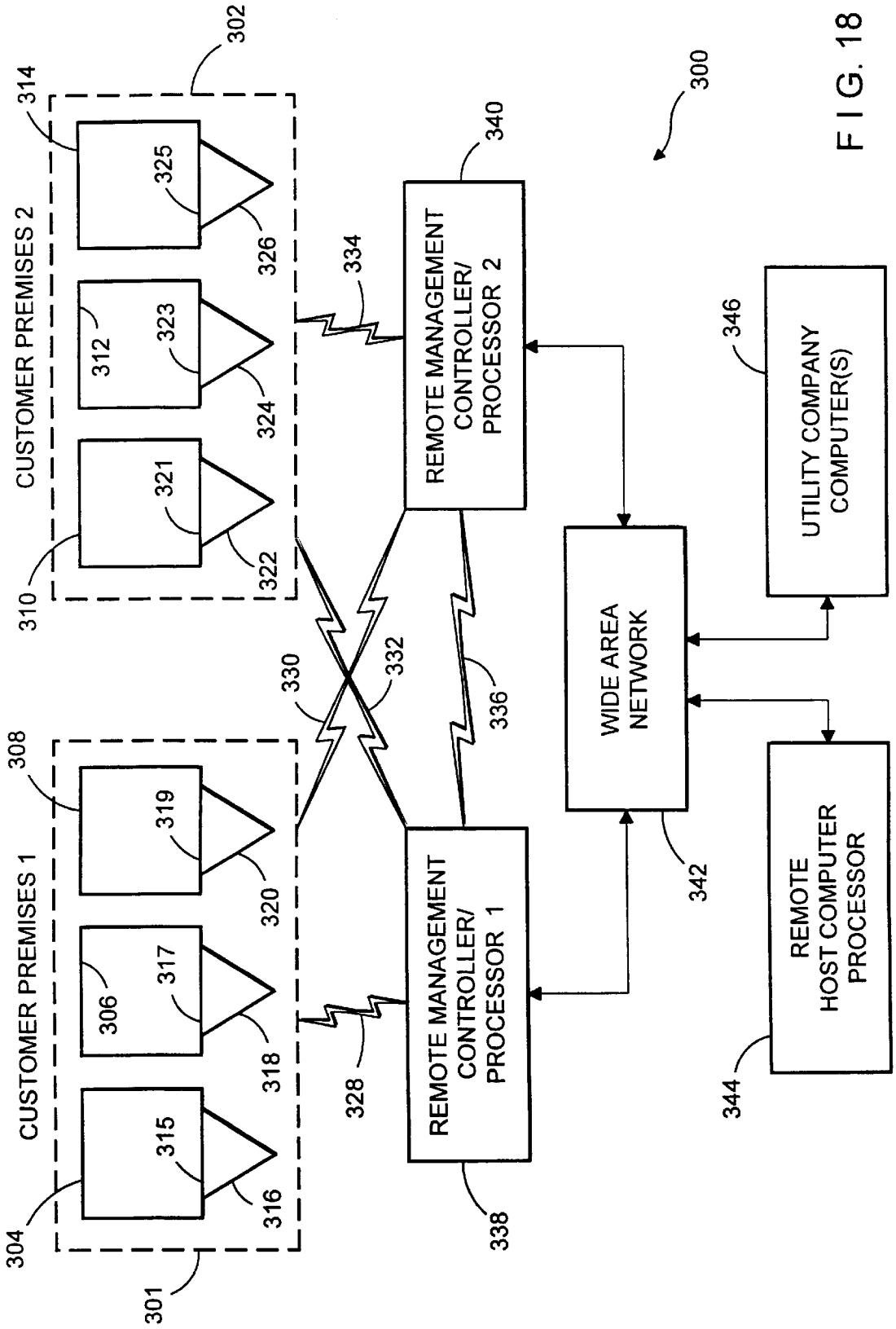

300
CUSTOMER PREMISES 1
CUSTOMER PREMISES 2
REMOTE MANAGEMENT CONTROLLER/ PROCESSOR 1
REMOTE MANAGEMENT CONTROLLER/ PROCESSOR 2
WIDE AREA NETWORK
UTILITY COMPANY COMPUTER(S)
REMOTE HOST COMPUTER PROCESSOR
301
302
304
306
308
310
312
314
315
316
317
318
319
320
321
322
323
324
325
326
328
330
332
334
336
338
340
342
344
346

FIG. 18

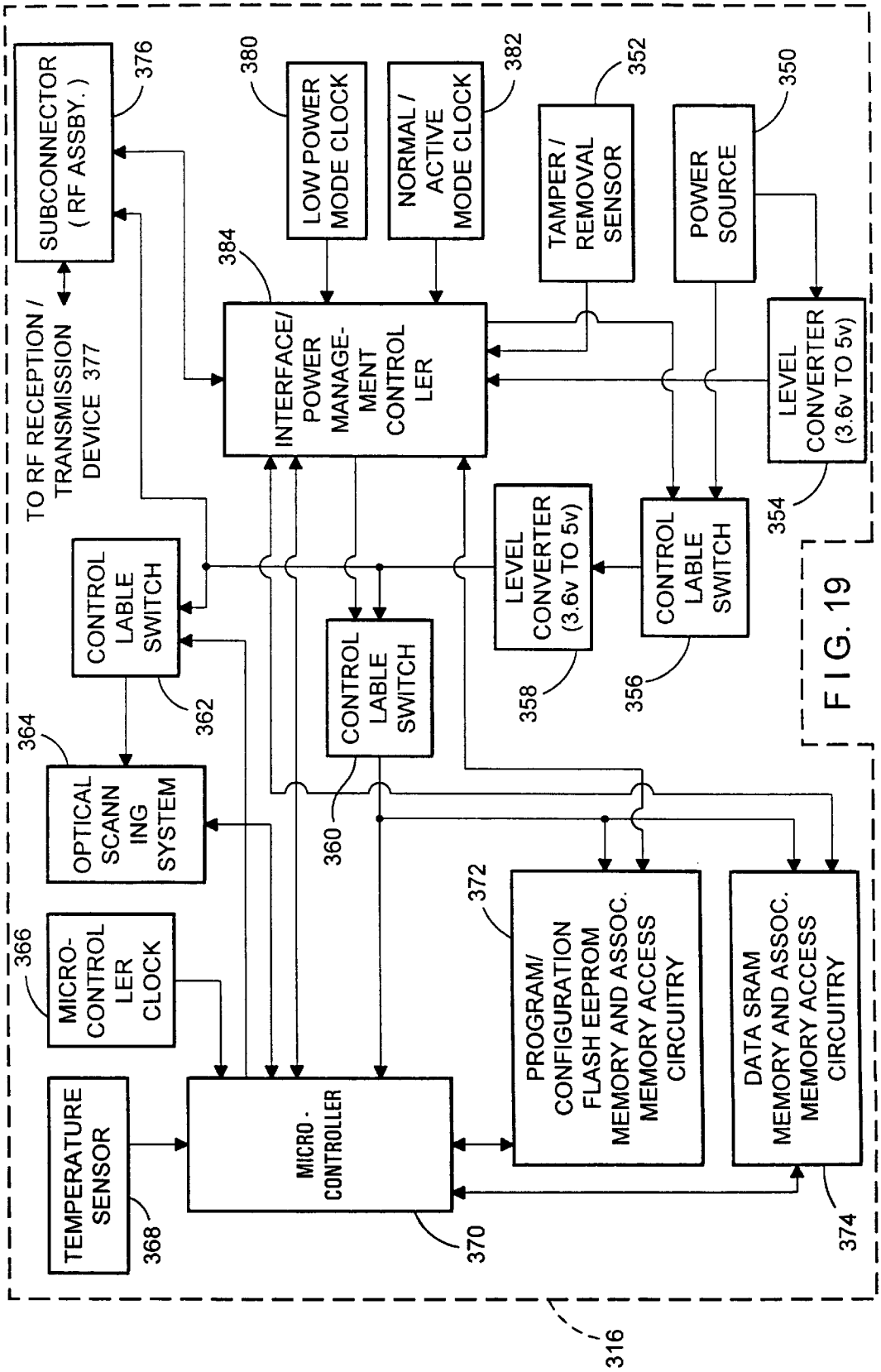

SUBCONNECTOR (RF ASSBY.)
376
TO RF RECEPTION / TRANSMISSION DEVICE 377
380
LOW POWER MODE CLOCK
382
NORMAL / ACTIVE MODE CLOCK
352
TAMPER / REMOVAL SENSOR
350
POWER SOURCE
384
INTERFACE/ POWER MANAGE- MENT CONTROL LER
LEVEL CONVERTER (3.6v TO 5v)
354
CONTROL LABLE SWITCH
362
CONTROL LABLE SWITCH
360
LEVEL CONVERTER (3.6v TO 5v)
358
CONTROL LABLE SWITCH
356
364
OPTICAL SCANN ING SYSTEM
366
MICRO- CONTROL LER CLOCK
372
PROGRAM/ CONFIGURATION FLASH EEPROM MEMORY AND ASSOC. MEMORY ACCESS CIRCUITRY
DATA SRAM MEMORY AND ASSOC. MEMORY ACCESS CIRCUITRY
374
TEMPERATURE SENSOR
368
MICRO- CONTROLLER
370
316

FIG. 19

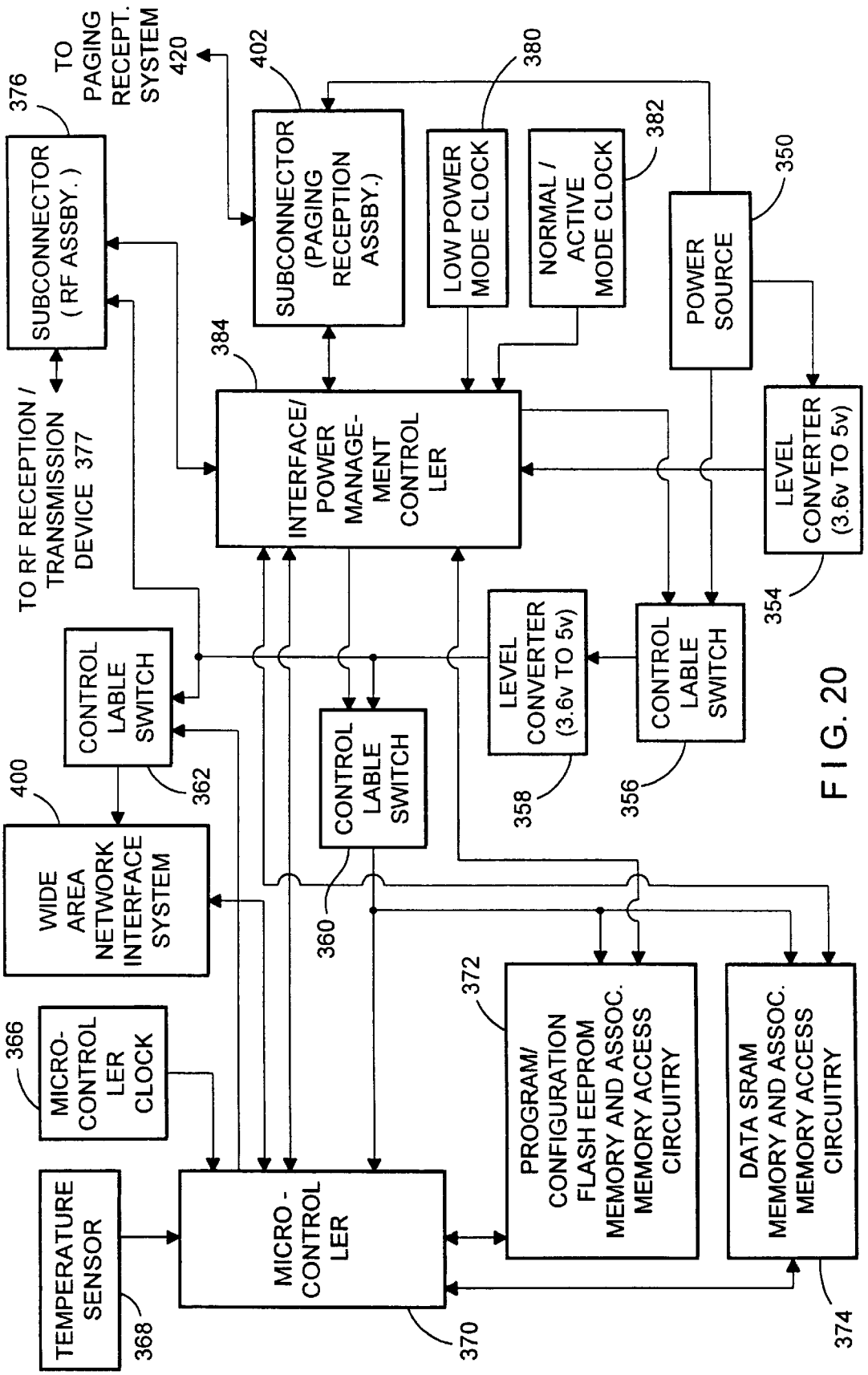

TO PAGING RECEPT. SYSTEM 420
376
SUBCONNECTOR (RF ASSBY.)
402
SUBCONNECTOR (PAGING RECEPTION ASSBY.)
380
LOW POWER MODE CLOCK
382
NORMAL / ACTIVE MODE CLOCK
350
POWER SOURCE
384
INTERFACE/ POWER MANAGE- MENT CONTROL LER
LEVEL CONVERTER (3.6v TO 5v)
354
TO RF RECEPTION / TRANSMISSION DEVICE 377
CONTROL LABLE SWITCH
362
LEVEL CONVERTER (3.6v TO 5v)
358
CONTROL LABLE SWITCH
356
CONTROL LABLE SWITCH
360
400
WIDE AREA NETWORK INTERFACE SYSTEM
366
MICRO- CONTROL LER CLOCK
372
PROGRAM/ CONFIGURATION FLASH EEPROM MEMORY AND ASSOC. MEMORY ACCESS CIRCUITRY
DATA SRAM MEMORY AND ASSOC. MEMORY ACCESS CIRCUITRY
374
TEMPERATURE SENSOR
368
MICRO - CONTROL LER
370

FIG. 20

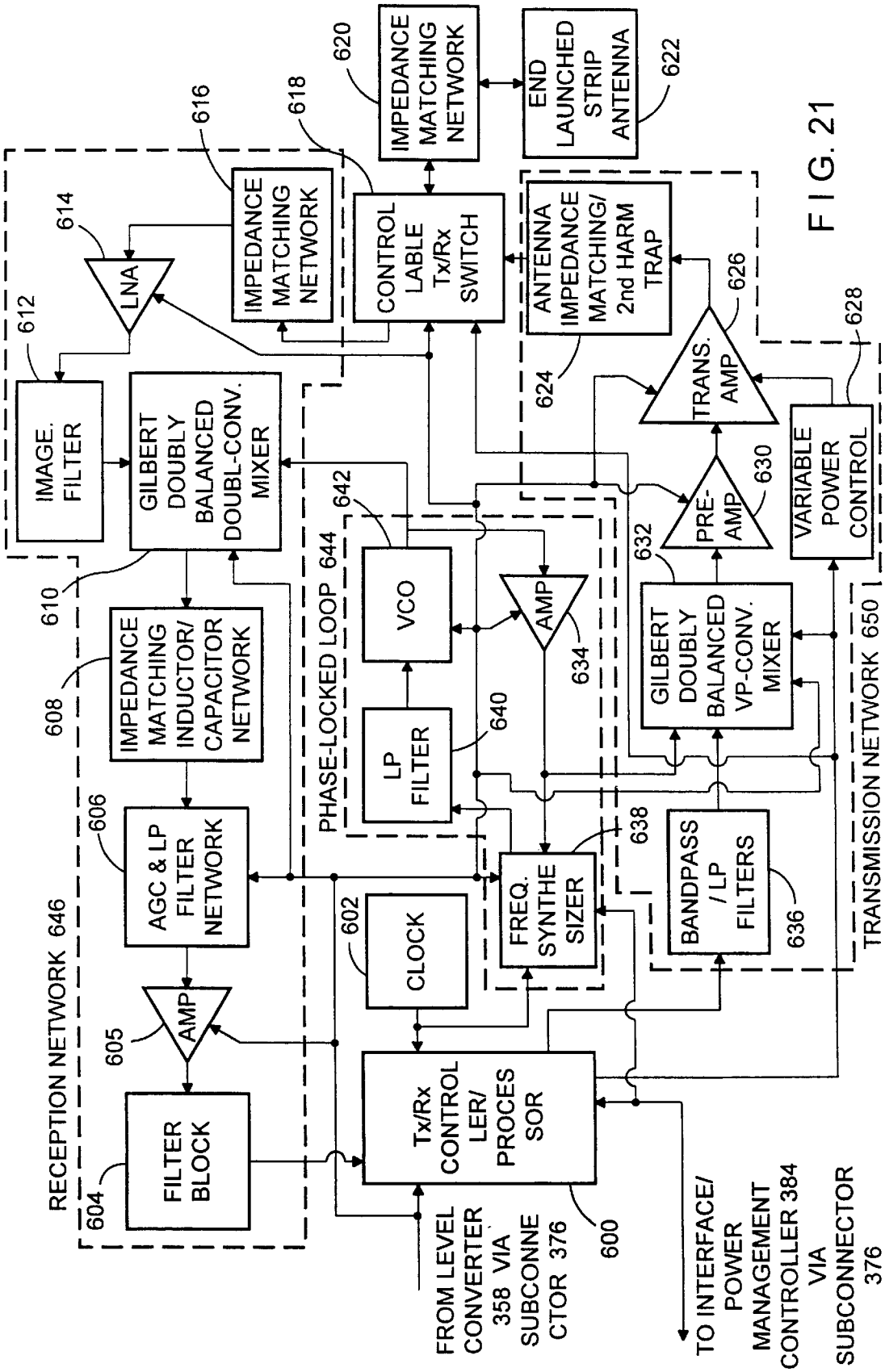

IMPEDANCE MATCHING NETWORK
620
END LAUNCHED STRIP ANTENNA
622
616
618
614
LNA
IMPEDANCE MATCHING NETWORK
CONTROL LABLE Tx/Rx SWITCH
ANTENNA IMPEDANCE MATCHING/ 2nd HARM TRAP
626
628
612
IMAGE. FILTER
GILBERT DOUBLY BALANCED DOUBL-CONV. MIXER
624
TRANS. AMP
VARIABLE POWER CONTROL
630
PRE-AMP
642
PHASE-LOCKED LOOP 644
VCO
AMP
632
610
608
IMPEDANCE MATCHING INDUCTOR/ CAPACITOR NETWORK
634
GILBERT DOUBLY BALANCED VP-CONV. MIXER
TRANSMISSION NETWORK 650
LP FILTER
640
606
AGC & LP FILTER NETWORK
638
BANDPASS / LP FILTERS
636
FREQ. SYNTHE SIZER
602
CLOCK
RECEPTION NETWORK 646
605
AMP
Tx/Rx CONTROL LER/ PROCES SOR
604
FILTER BLOCK
600
FROM LEVEL CONVERTER 358 VIA SUBCONNE CTOR 376
TO INTERFACE/ POWER MANAGEMENT CONTROLLER 384 VIA SUBCONNECTOR 376

FIG. 21

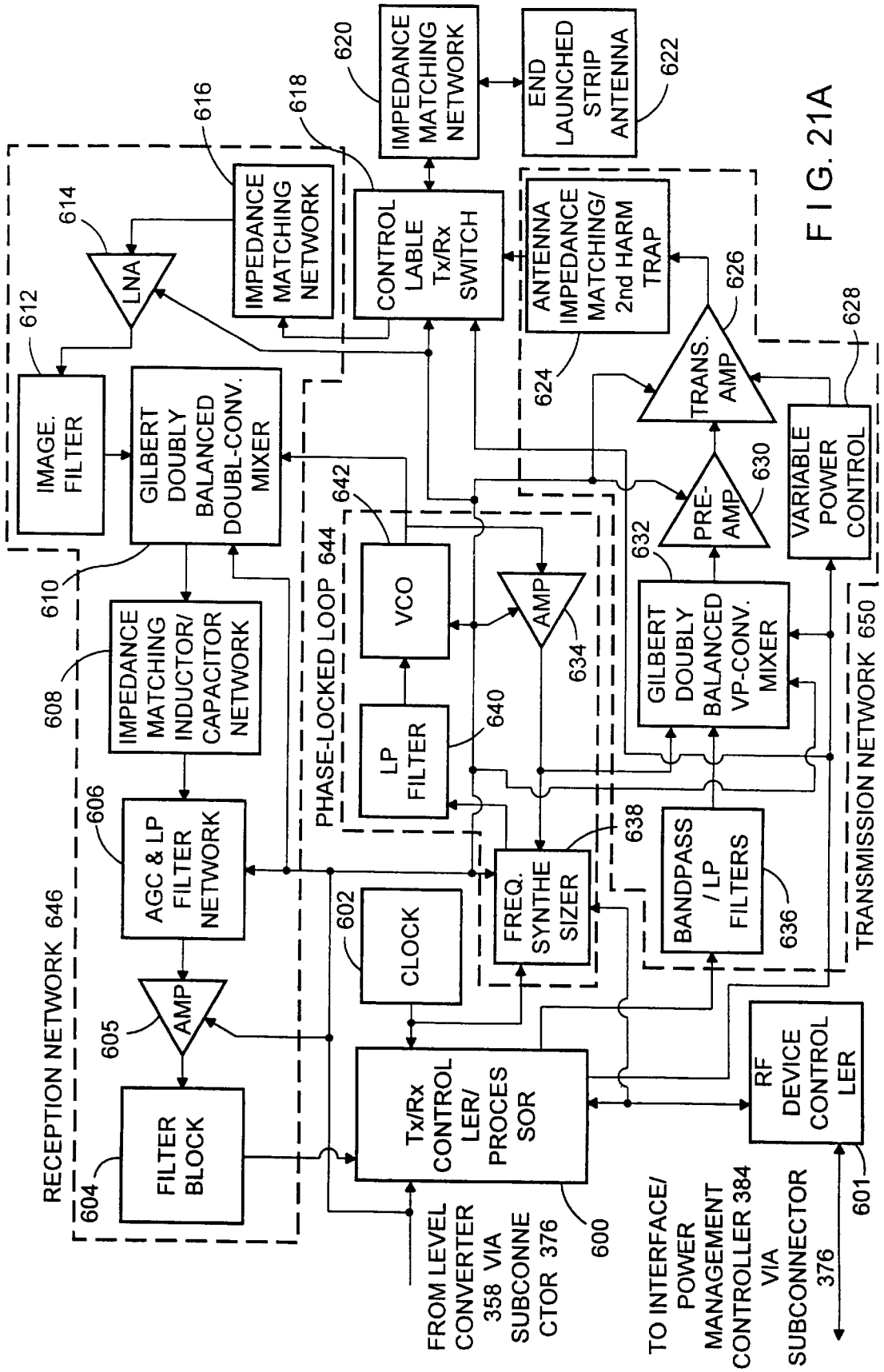

IMPEDANCE MATCHING NETWORK
620
END LAUNCHED STRIP ANTENNA
622
616
618
614
LNA
IMPEDANCE MATCHING NETWORK
CONTROL LABLE Tx/Rx SWITCH
ANTENNA IMPEDANCE MATCHING/ 2nd HARM TRAP
626
624
628
TRANS. AMP
612
IMAGE. FILTER
GILBERT DOUBLY BALANCED DOUBL-CONV. MIXER
642
PHASE-LOCKED LOOP 644
VCO
AMP
634
PRE-AMP
630
VARIABLE POWER CONTROL
632
610
608
IMPEDANCE MATCHING INDUCTOR/ CAPACITOR NETWORK
LP FILTER
640
GILBERT DOUBLY BALANCED VP-CONV. MIXER
606
AGC & LP FILTER NETWORK
638
FREQ. SYNTHE SIZER
BANDPASS / LP FILTERS
636
TRANSMISSION NETWORK 650
RECEPTION NETWORK 646
602
CLOCK
605
AMP
Tx/Rx CONTROL LER/ PROCES SOR
RF DEVICE CONTROL LER
604
FILTER BLOCK
600
601
FROM LEVEL CONVERTER 358 VIA SUBCONNE CTOR 376
TO INTERFACE/ POWER MANAGEMENT CONTROLLER 384 VIA SUBCONNECTOR 376

FIG. 21A

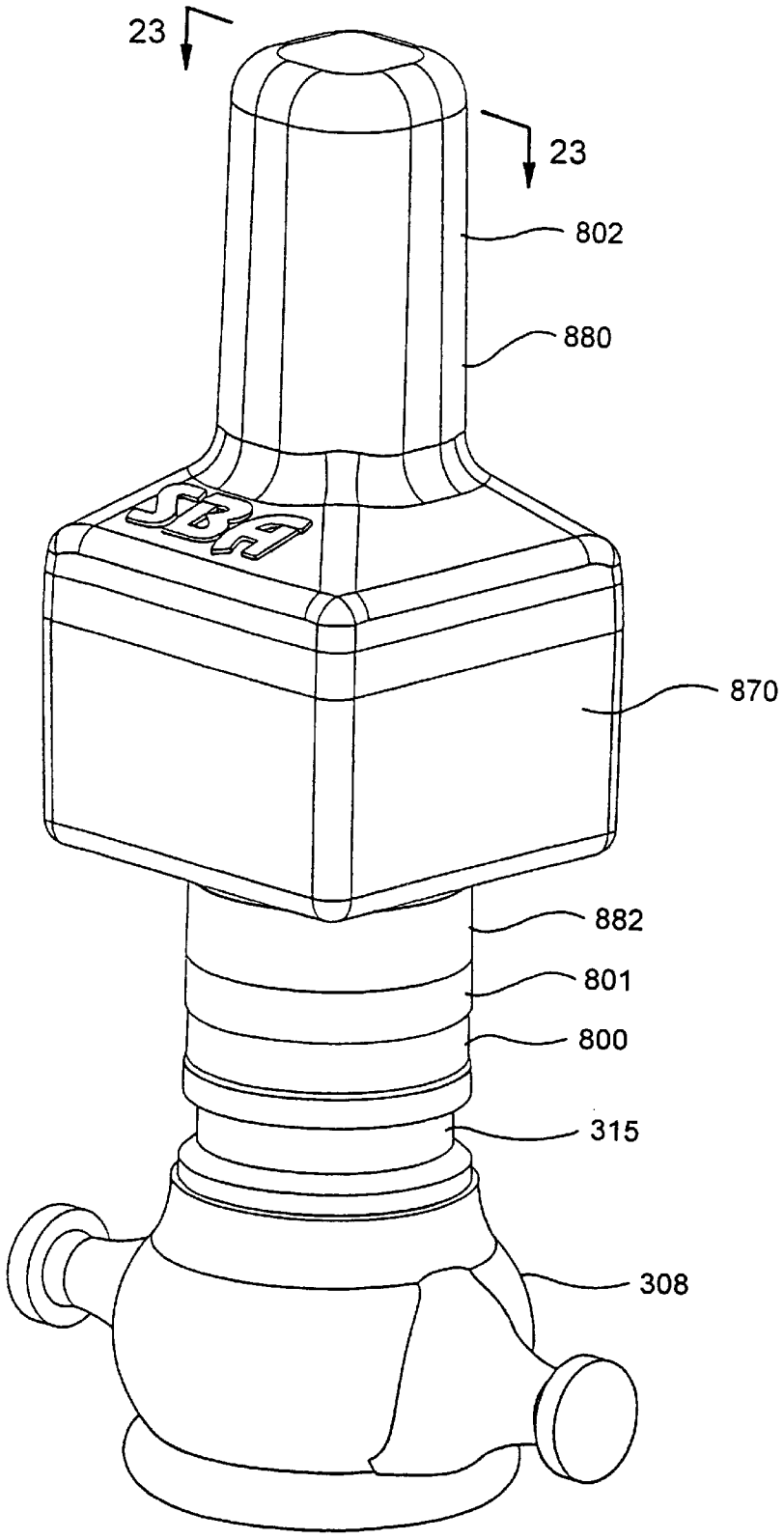


FIG. 22

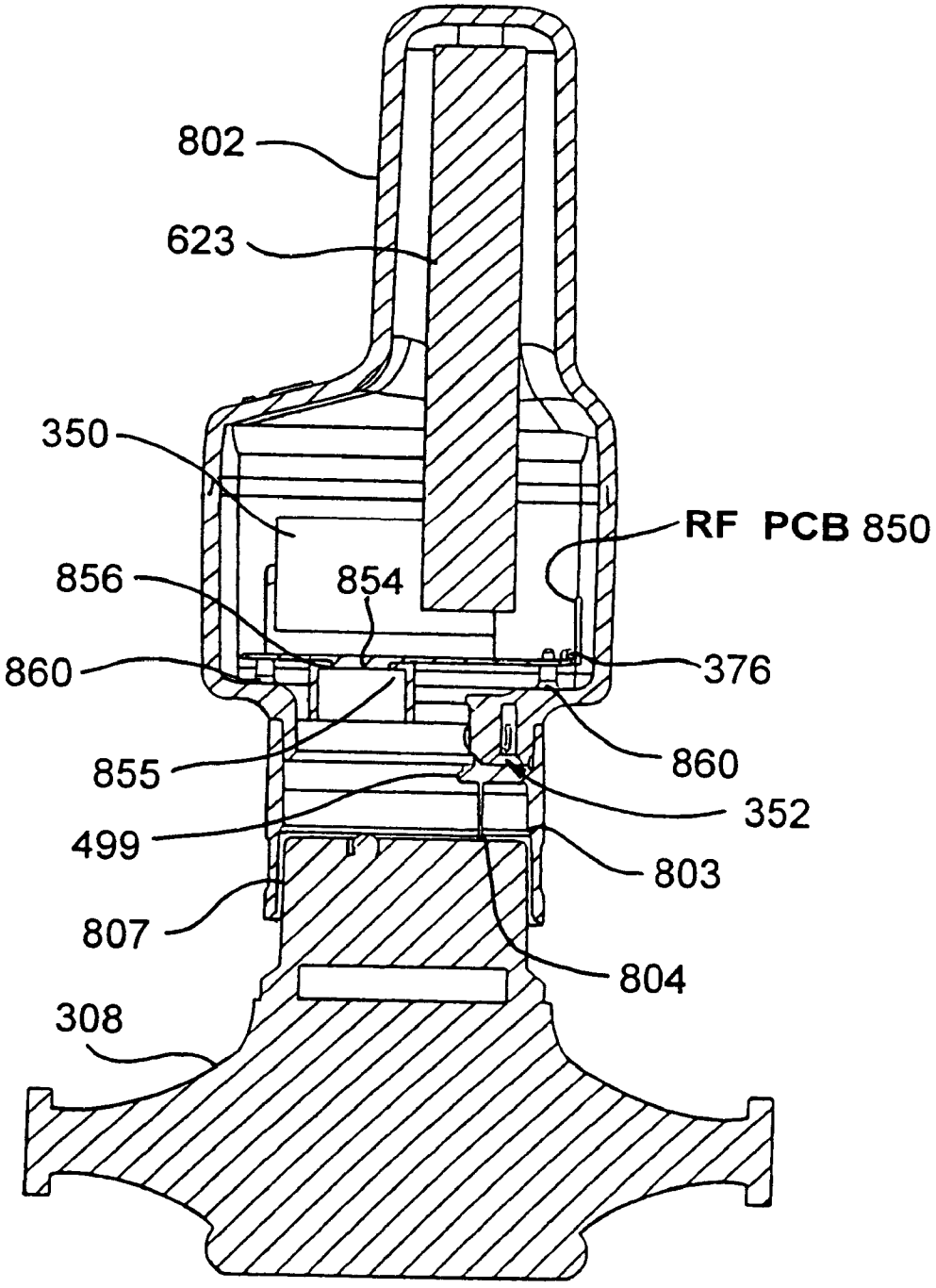

802
623
350
RF PCB 850
856
854
860
376
855
860
352
499
803
807
804
308

FIG. 23

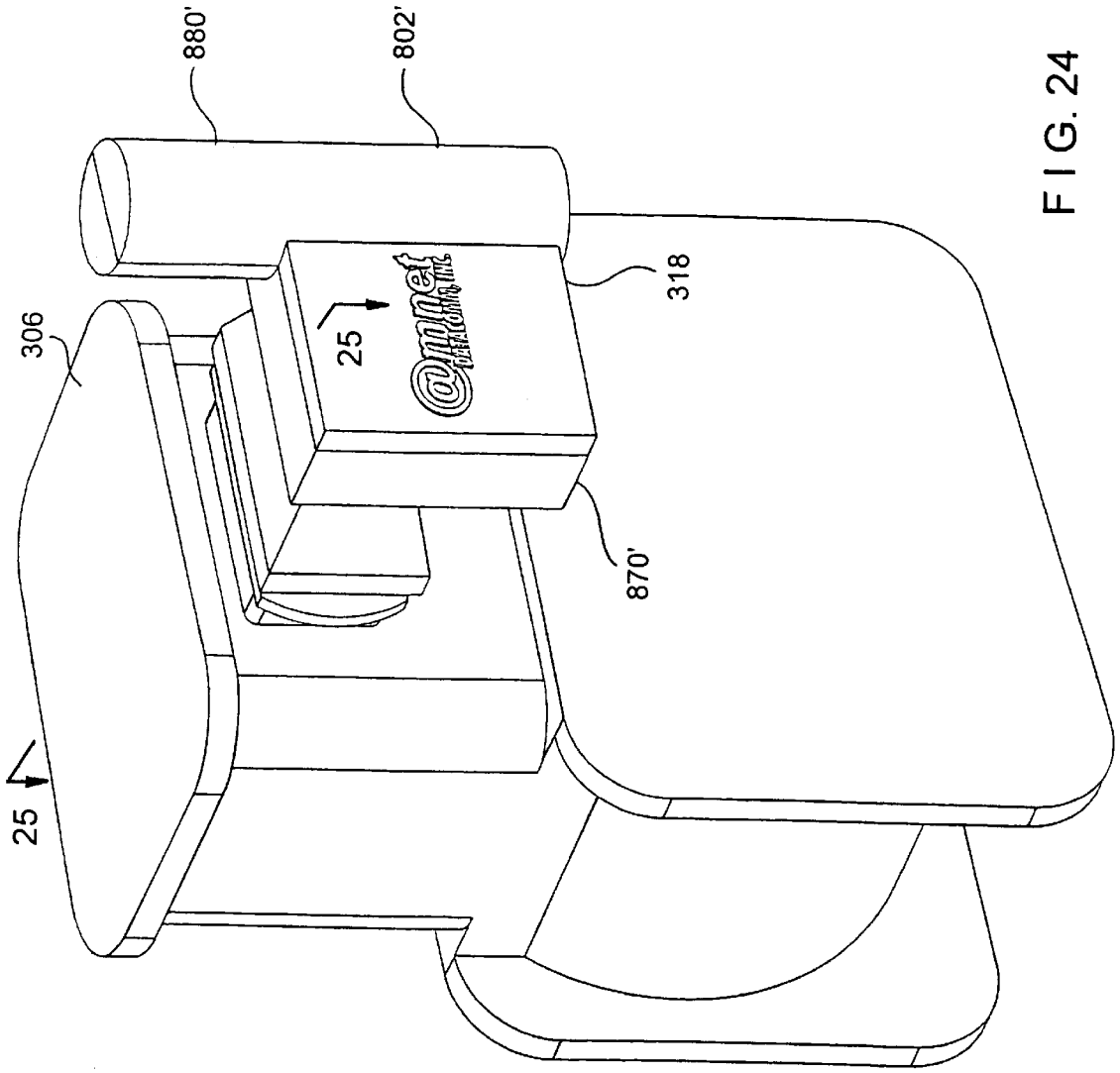
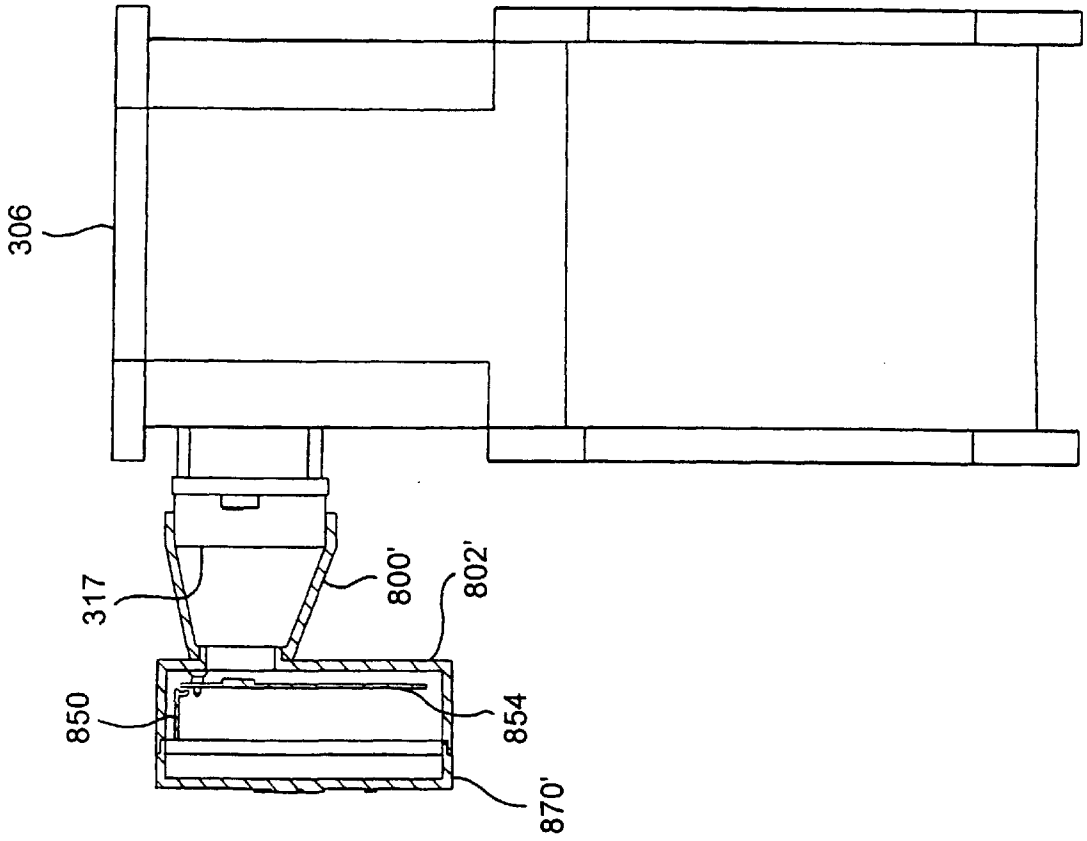


FIG. 24

FIG. 25



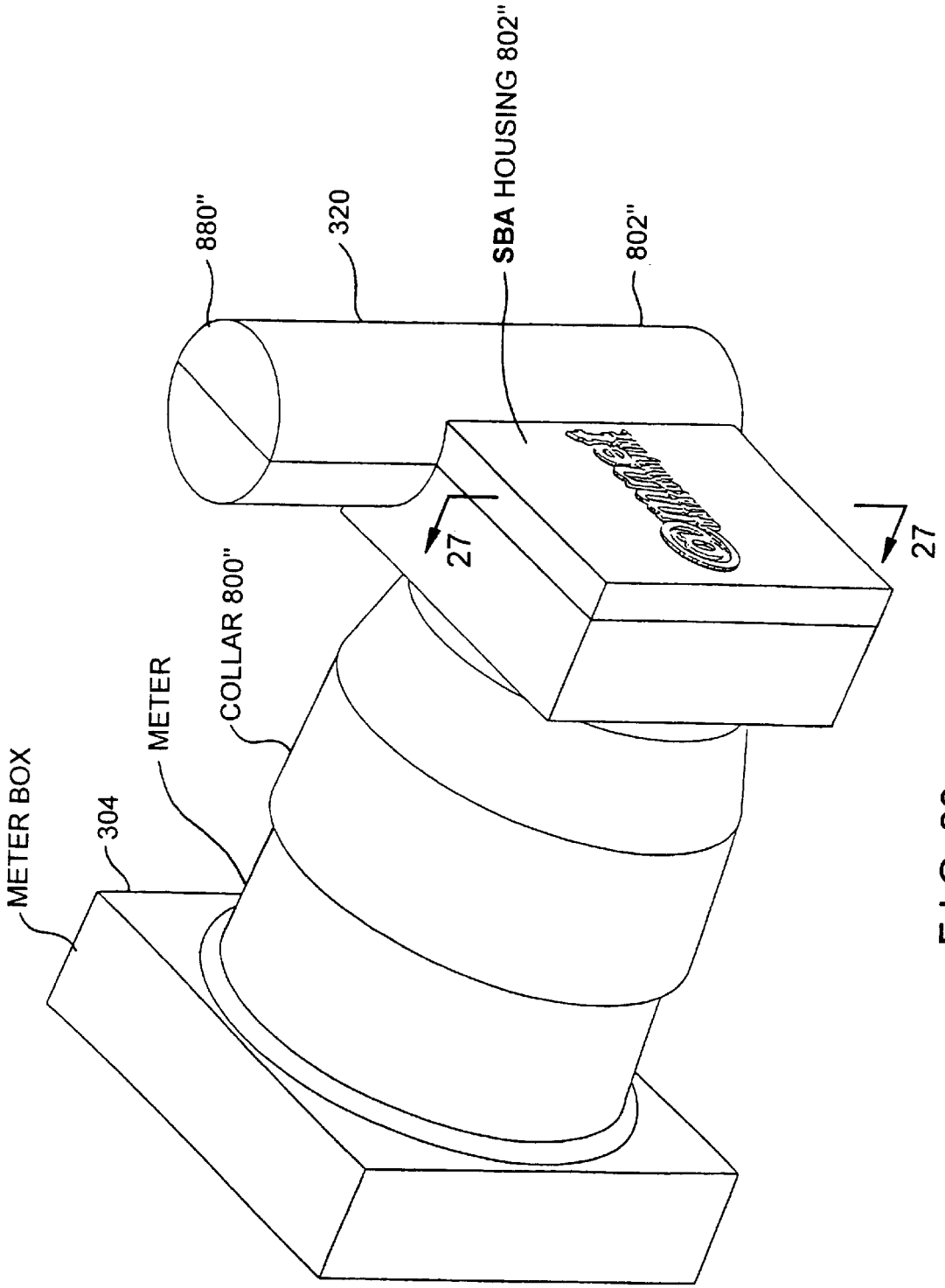

880"
320
SBA HOUSING 802"
802"
27
27
COLLAR 800"
METER
304
METER BOX

FIG. 26

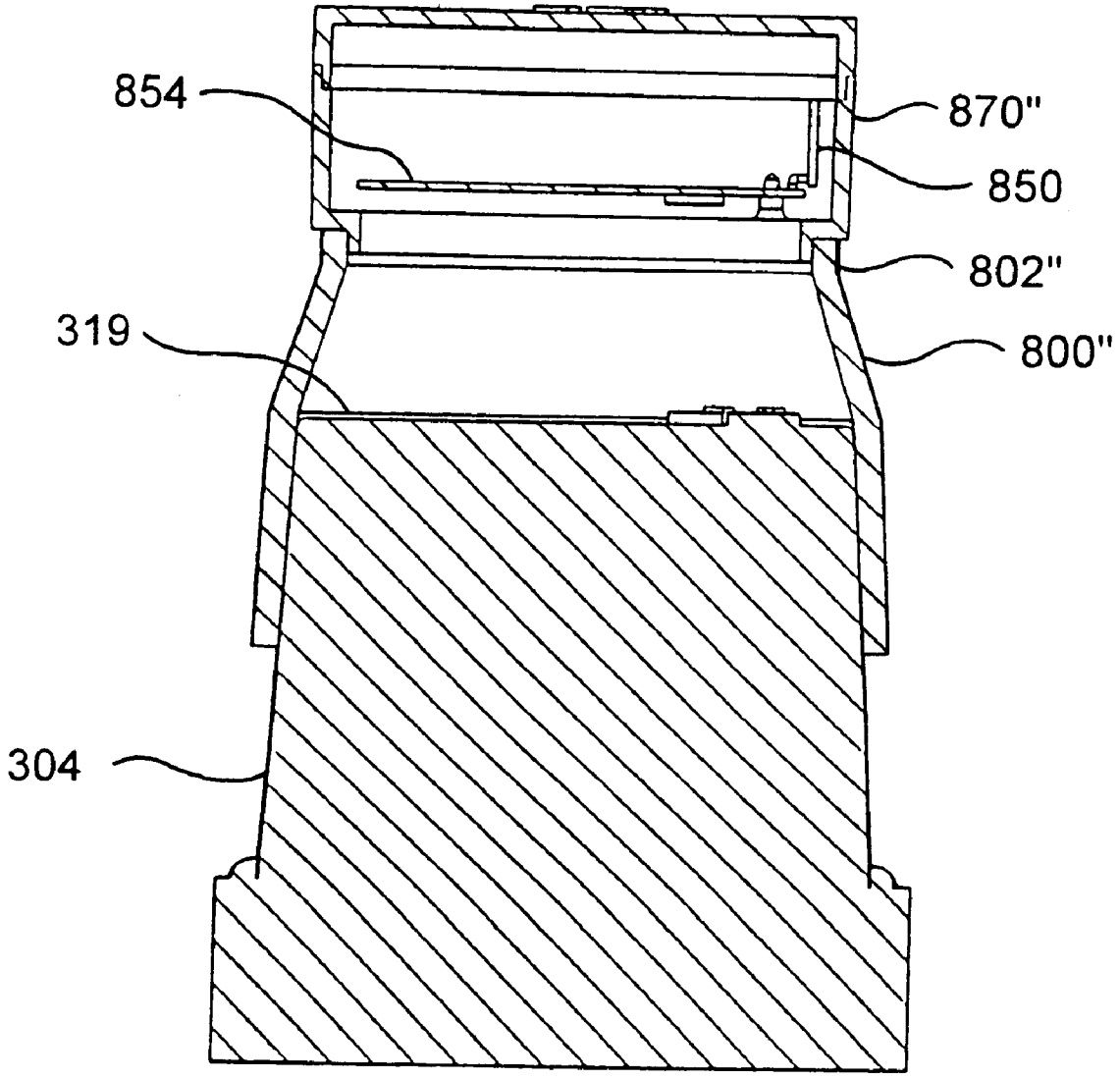


FIG. 27

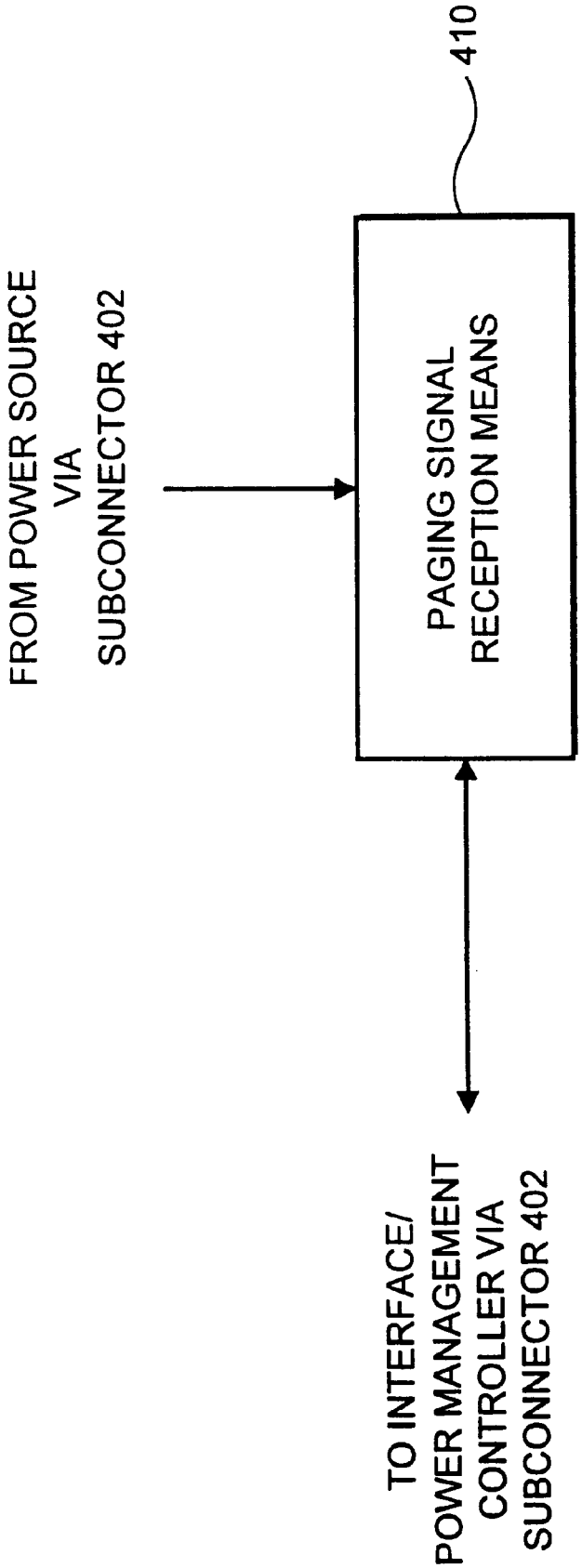

410
FROM POWER SOURCE VIA SUBCONNECTOR 402
PAGING SIGNAL RECEPTION MEANS
TO INTERFACE/ POWER MANAGEMENT CONTROLLER VIA SUBCONNECTOR 402
420

FIG. 28

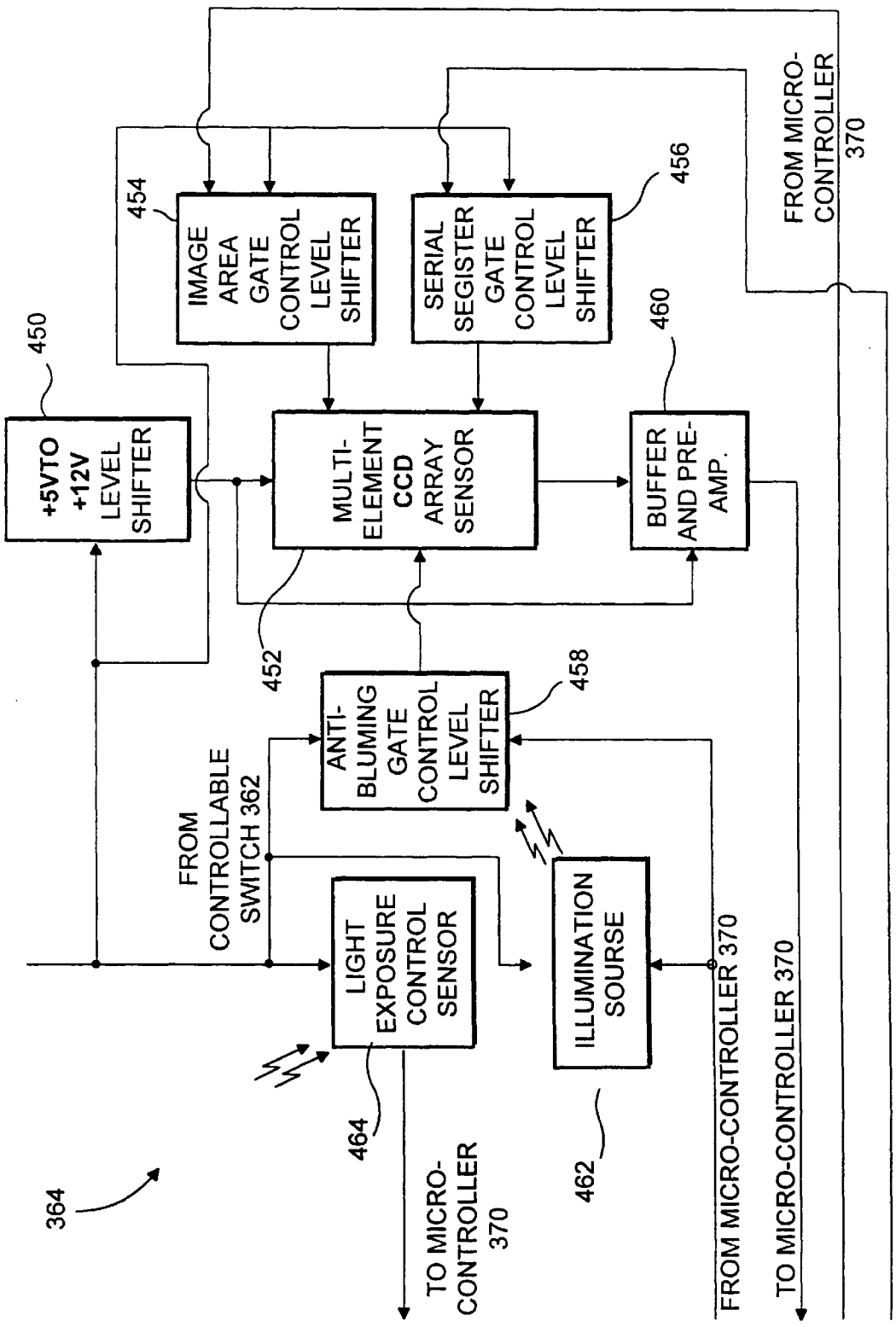

364
450
+5VTO +12V LEVEL SHIFTER
454
IMAGE AREA GATE CONTROL LEVEL SHIFTER
456
SERIAL SEGISTER GATE CONTROL LEVEL SHIFTER
460
MULTI-ELEMENT CCD ARRAY SENSOR
BUFFER AND PRE-AMP.
452
458
ANTI-BLUMING GATE CONTROL LEVEL SHIFTER
FROM CONTROLLABLE SWITCH 362
LIGHT EXPOSURE CONTROL SENSOR
ILLUMINATION SOURSE
464
462
TO MICRO-CONTROLLER 370
FROM MICRO-CONTROLLER 370
TO MICRO-CONTROLLER 370
FROM MICRO-CONTROLLER 370

FIG. 29

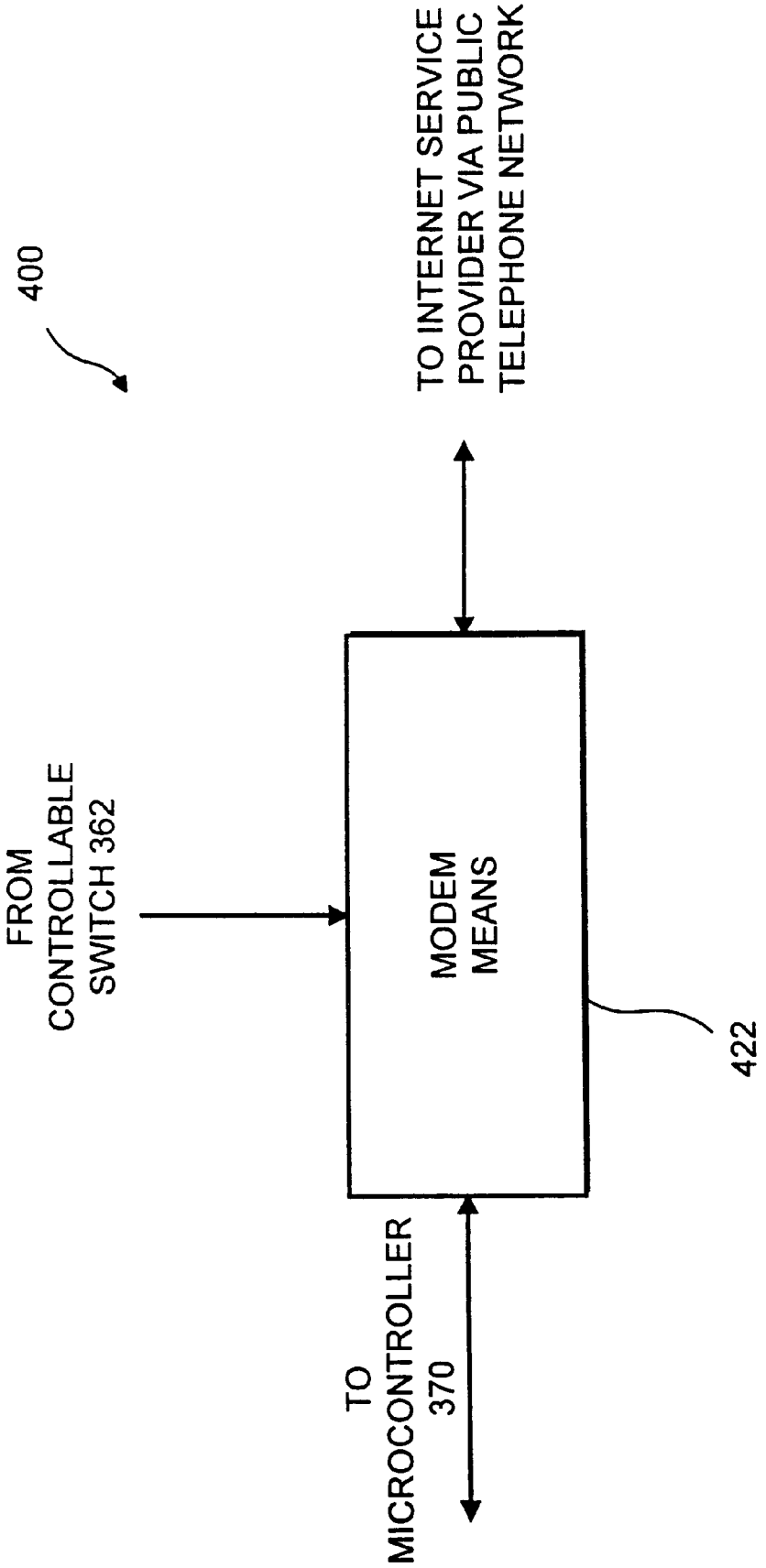

400
TO INTERNET SERVICE PROVIDER VIA PUBLIC TELEPHONE NETWORK
FROM CONTROLLABLE SWITCH 362
MODEM MEANS
422
TO MICROCONTROLLER 370

FIG. 30

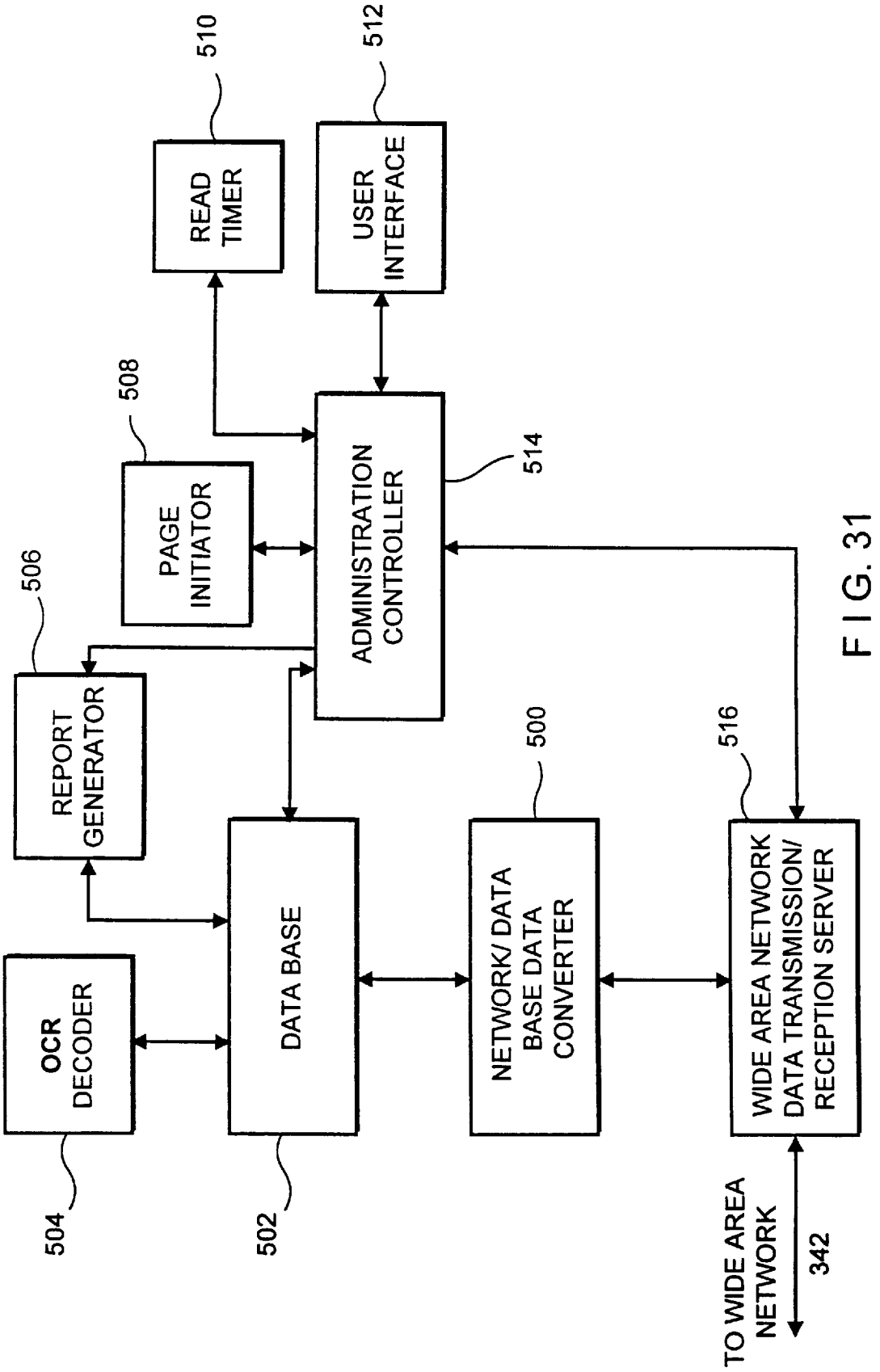

510
READ TIMER
512
USER INTERFACE
508
PAGE INITIATOR
ADMINISTRATION CONTROLLER
514
506
REPORT GENERATOR
500
516
OCR DECODER
DATA BASE
NETWORK/ DATA BASE DATA CONVERTER
WIDE AREA NETWORK DATA TRANSMISSION/ RECEPTION SERVER
504
502
TO WIDE AREA NETWORK
342

FIG. 31

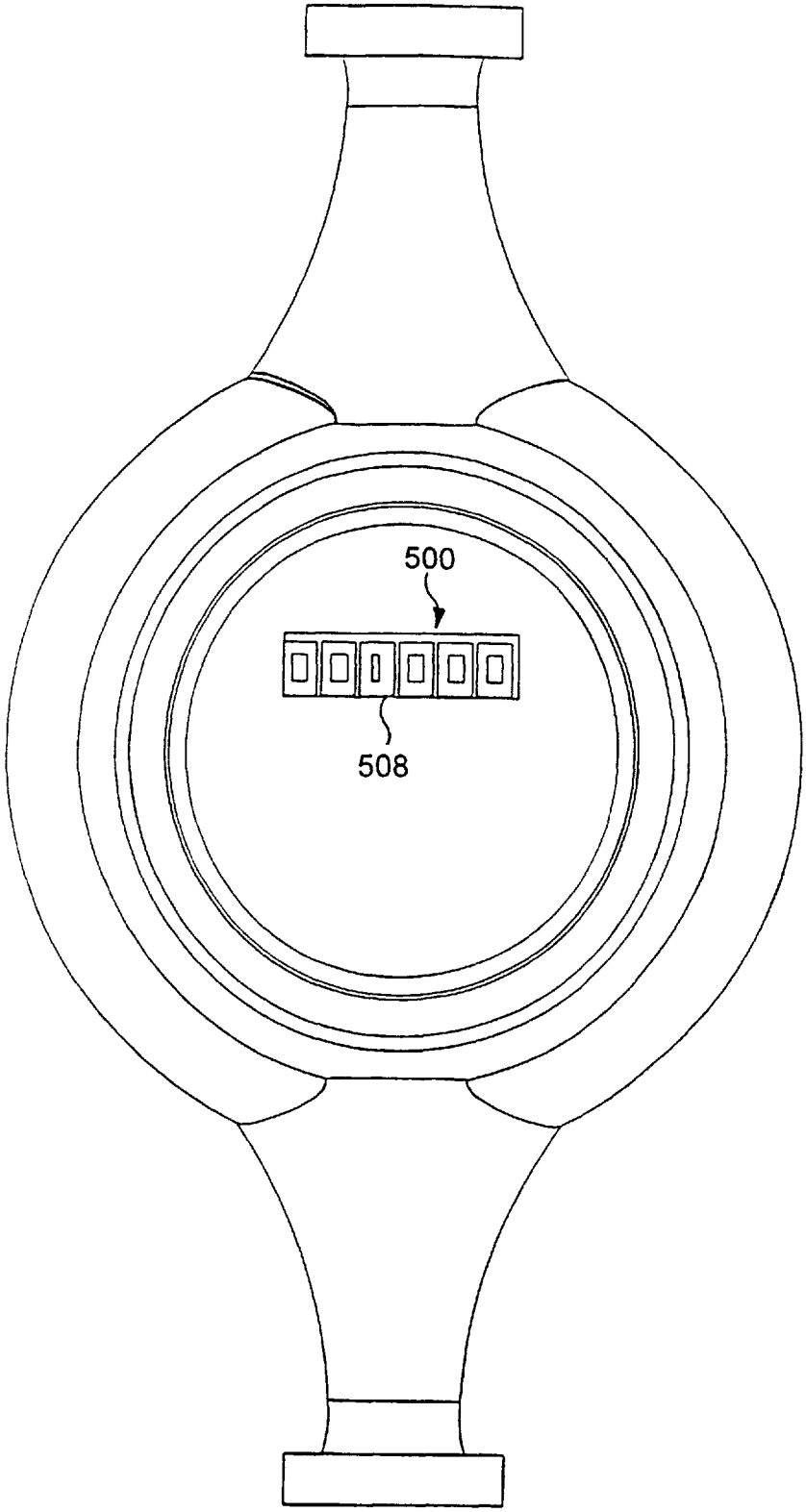


FIG. 32

FIG. 33

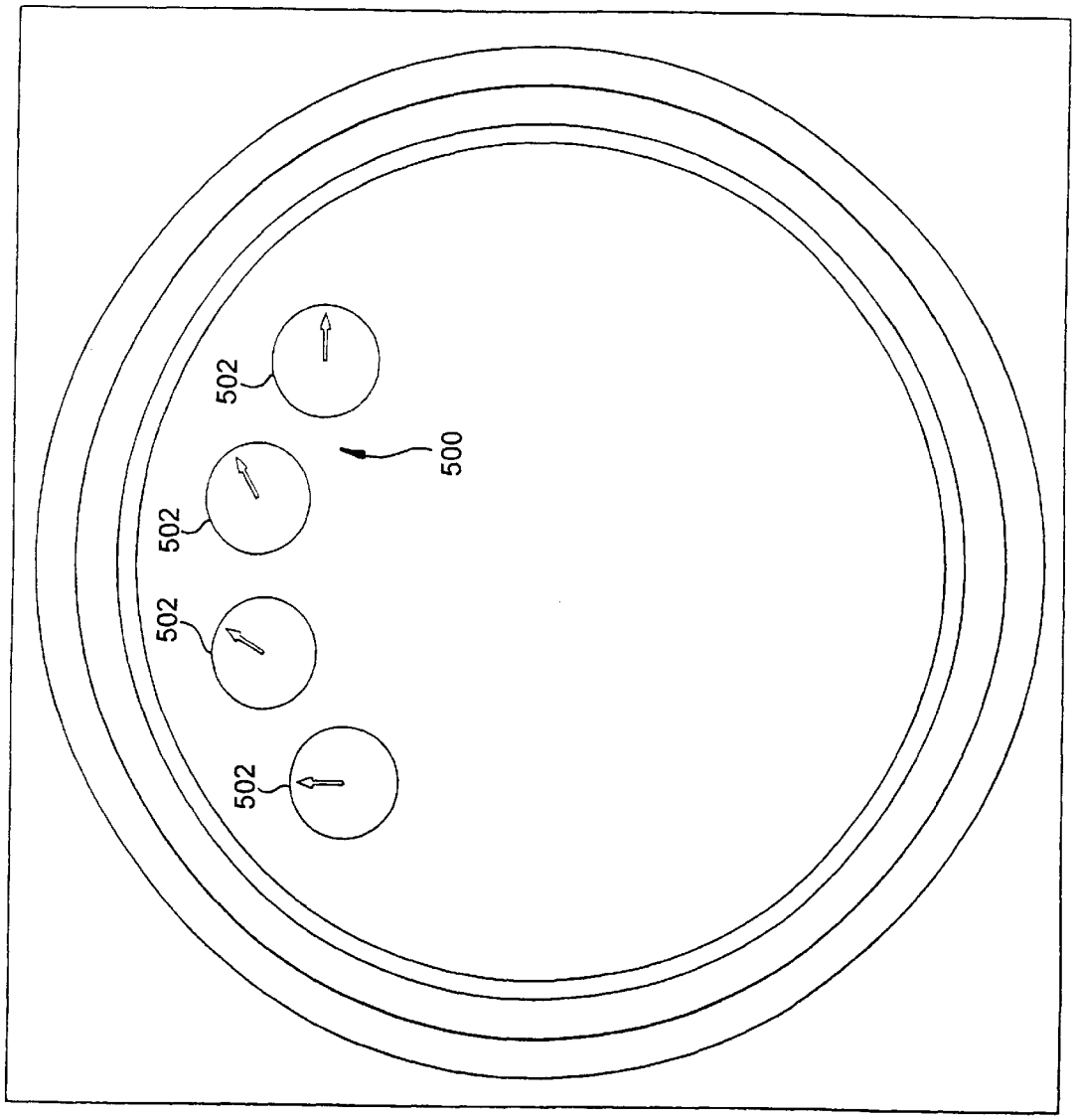
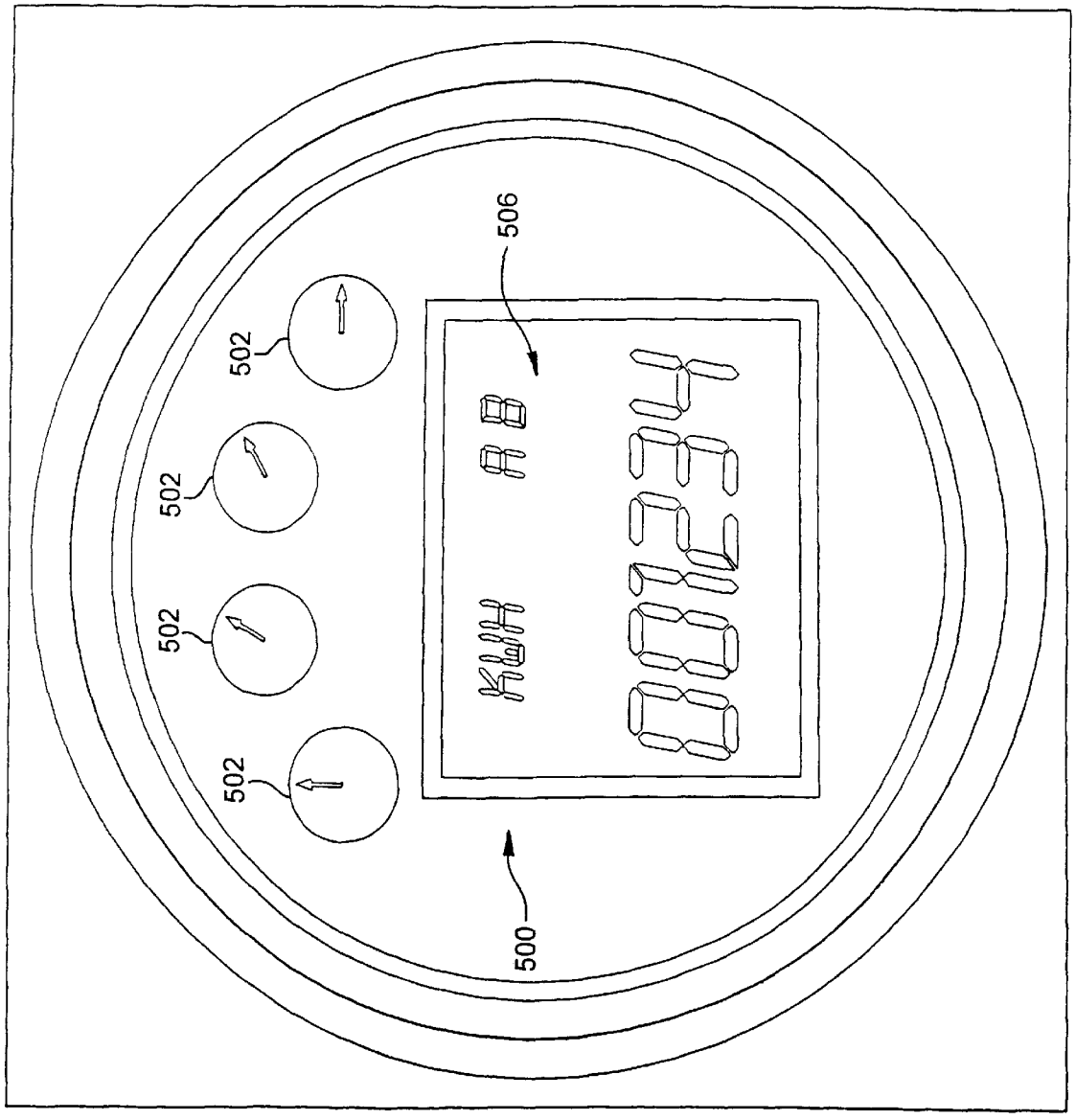


FIG. 34



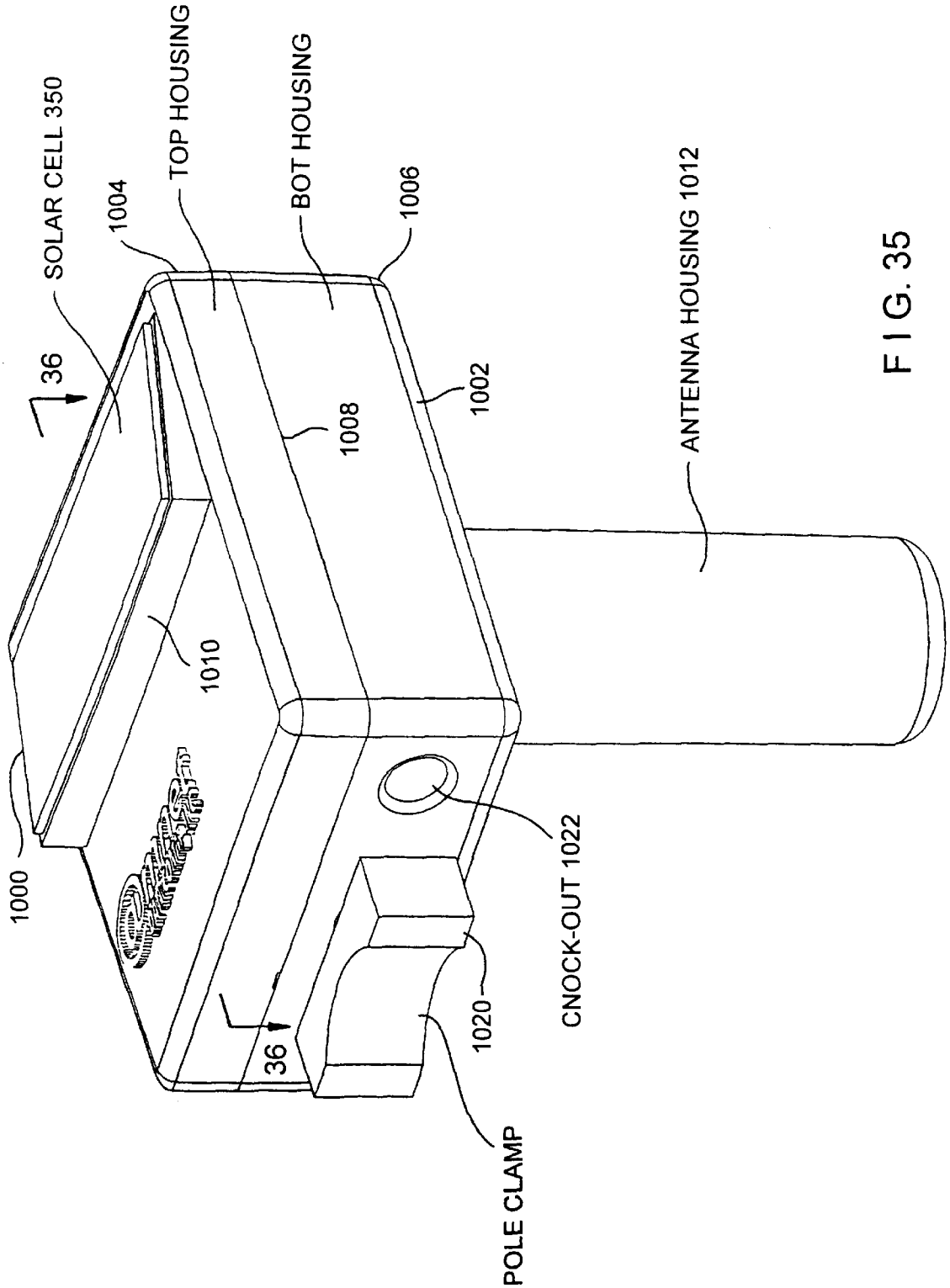

SOLAR CELL 350
TOP HOUSING
BOT HOUSING
1004
1006
1002
1008
1010
1000
36
36
ANTENNA HOUSING 1012
CNOCK-OUT 1022
1020
POLE CLAMP

FIG. 35

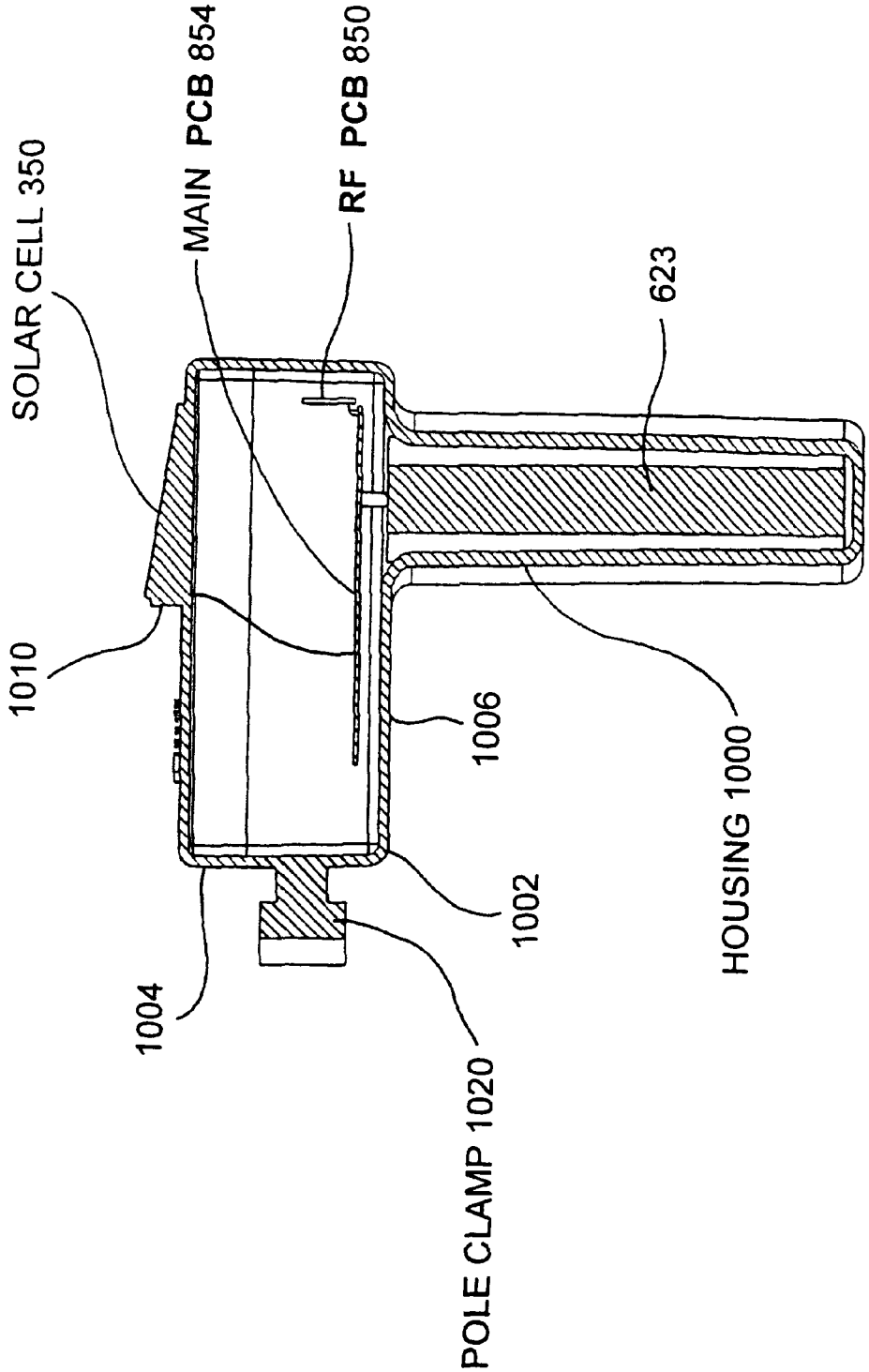

SOLAR CELL 350
MAIN PCB 854
RF PCB 850
623
1010
1006
HOUSING 1000
1002
1004
POLE CLAMP 1020

FIG. 36

REMOTE DATA ACQUISITION AND PROCESSING SYSTEM

This application is a continuation-in-part of copending application Ser. No. 08/518,321, filed Aug. 23, 1995, entitled "Modular System For Automatically And Remotely Monitoring And Managing Utility Consumption."

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to a distributed, information gathering and processing system, and more specifically, to such a system for remotely acquiring and processing data related to a phenomenon or phenomena being monitored by metering devices. Although the present invention has particular usefulness in the area of acquiring and processing utility service consumption and/or distribution information, and will be described in connection with same, other uses are contemplated for the present invention, including remote acquisition and processing of data from distributed pollution monitoring devices for use e.g. in pollution analysis and/or control applications, remote acquisition and processing of information related to vending machine usage and/or operation, and other uses.

2. Brief Description of Related Prior Art

Utility companies, such as those providing electric, gas and water service, measure the consumption of their respective services by customers via meters attached to the customer premises. Such meters continually monitor and record the amount of the service in question consumed by a particular customer and such measurements are used by the utility company for billing and system management purposes. Two types of conventional utility meters exist: machine readable and non-machine-readable type meters.

Machine-readable utility meters typically come in one of two types, pulse/Hall effect and encoder type meters. Pulse and encoder meters are considered machine readable because they produce a signal corresponding to the amount of utility service used by a particular customer, which signal can be read mechanically and/or electronically.

Pulse type meters, e.g., water meters, utilize a pulse generated by an internally mounted magnet coupled to the meter vane; each pulse corresponds to one unit of utility consumption. The pulses are used to increment a mechanical counter or odometer mounted outside of the customer premises.

Encoder type meters have a digital circuit board built into the meter's register head which is used to electronically measure the level of customer utility consumption. The digital circuit board is wired to an externally mounted induction-coupled or standard pin-type receptacle. The meter is read by inserting a data collection device, also known as a gun, into the receptacle. The gun sends a signal into the meter which in turn causes the meter to send a digital representation of the current meter reading into the gun where it is stored. The information can later be downloaded to a utility company computer to process same.

Non-machine-readable meters consist of those meters that can only be read via visual inspection of meter display mechanisms (e.g., analog dials and/or alphanumeric digital displays located on the meter faces).

One typical system utilized by utility companies for accessing utility usage information requires one or more human meter readers to visit every customer premises and physically read each customer's utility meter, whether by visual inspection (e.g., if the meter being read is a non-machine-readable type of meter) or by use of a gun (e.g., if the meter being read is an encoder type of machine-readable meter). In practice, this system of meter reading is extremely costly and time consuming, because the utility company must pay the meter readers for the time spent traveling to and from customer sites and reading the meters. In addition, unrealized revenues due to extending credit to utility consumers for months at a time can disturb the utility company's cashflow and investment. Thus, the utility industry has recognized the need for an automated system for reading and more closely managing utility consumption. In response to this need, various systems have been provided for automatically reading and processing utility meters.

One such conventional system involves use of meters equipped with radio frequency (RF) transmitters which transmit meter reading data to one or more remote locations so as to eliminate the need for human readers to go to each customer premises to read the customers' meters. Essentially, an RF meter of the type used in this conventional system consists of a pulse or encoder type of machine-readable meter having a small RF transmitter built into the meter head. The RF transmitter transmits signals corresponding to the pulses generated by the meter, in the case of a pulse-type meter, or in the case of an encoder-type of meter, the digital representation of the current meter reading, as an indication of the level of utility usage to either a utility company vehicle being driven in the vicinity, known as mobile RF, or to a remote receiver location in the vicinity, known as fixed RF. The information can later be downloaded to the utility company computer. One example of such a system is disclosed in Brunius, et al., U.S. Pat. No. 4,614,945, which utilizes a vehicle to access utility consumption information transmitted by RF transponders attached to the meters at the consumers' premises. A major shortcoming of this type of conventional system is that only machine-readable meters may be automatically read using the system; non-machine-readable meters still must be read via visual inspection by human meter readers.

Other types of conventional automatic meter reading systems utilize remote data units, or RDUs, also known as meter interface units, or MIUs, located at the consumer premises to automatically accumulate utility consumption data from the customer meters and communicate this information back to either a storage site or the utility company over a telephone network. Such conventional systems are of two types: outbound and inbound systems.

In a conventional outbound system, the utility company periodically calls each customer RDU to retrieve customer consumption data stored by the RDU. One example of an outbound system is disclosed in Honick, U.S. Pat. No. 4,852,152. In the Honick system, a utility company central computer communicates with an RDU located at the customer's premises through a special subscriber test trunk telephone line which enables the utility computer to be connected to a particular RDU without ringing the customer's telephone. The system allows the utility computer to call and access any RDU in the system at any time as long as the phone at the customer site is not is use. Such access, known as a demand read, may be necessary when, for example, the utility needs to prepare a final bill because utility service to a customer is to be terminated or discontinued. However, this system has the significant disadvantage of requiring expensive special test trunk access circuitry which must be installed at each telephone exchange to enable the utility computer to communicate with the RDU without ringing the consumer's telephone line. Further disadvantageously, this

system also cannot be used automatically read non-machine-readable meters, but rather, solely can be used to automatically read machine-readable meters.

Another conventional outbound system is disclosed in Sollinger, U.S. Pat. No. 4,811,011. The Sollinger system includes a sensor at each customer's premises for automatically reading the customer's meters, a microcomputer for accepting and storing the data from the sensor, a communications interface connected to the microcomputer, a main computer at a location remote from the customer's premises, and a communications link between the customer's premises and the main computer, wherein the main computer continually polls each customer's meter to initiate transmission of the reading data to the remote location over the communications link. The Sollinger system further comprises means for periodically transmitting the reading data to utility company computers for billing purposes. Unfortunately, in this system, the main computer must continually poll each customer premises rather than having the utility usage data sent automatically from the customer premises to the main computer. Also, disadvantageously, this system is unable to automatically read non-machine-readable meters, and is only able to automatically read machine-readable meters.

Conventional inbound systems are programmed to place a call to a utility billing computer or to a storage facility to download meter readings at specific, pre-defined time intervals. In addition, some conventional inbound systems are bi-directional, meaning that they allow the utility company to make readings on demand much like in a conventional outbound system.

One prior art inbound system is disclosed in Verma, U.S. Pat. No. 4,833,618. The Verma system comprises RDUs located at each customer's premises for accumulating and reporting utility usage data from machine-readable utility meters at the premises, and a utility data processor or UDP located at the utility site for collecting the usage data sent from the RDUs over a conventional telephone network. The system is designed to count each rotation of the least significant dial of the utility meters. Verma also discloses an encoder meter in which the need for a sensor interface is eliminated by providing the meter with built-in circuitry which encodes the utility usage information into an electrical signal which is read directly by the microcomputer.

Also in Verma's disclosed system, at a specified, predetermined times during one day of a billing cycle (which Verma terms a "report time"), the RDUs call the UDP and transmits the utility usage information, which the RDUs have accumulated and stored, to the UDP via the conventional telephone network. The report time is programmed into the RDUs. In addition, an answer window is opened on the system on a predetermined regular basis, e.g., each day, during which the UDP can call the RDUs to obtain utility usage information. This answer window is also programmed into the RDUs. Only during the answer window can the RDUs receive a call from the UDP. Thus, only during the answer window can the utility company recover usage information on demand. The report times may be programmed into the RDUs at the time of installation or by the UDP during a communication therewith.

During the answer window, the RDUs are awakened and await calls from the UDP. All calls that come to the RDUs during the answer window, whether from the UDP or a third party, are detected through ring detection circuitry, which then prevents the telephone from ringing inside the customer premises. Each incoming call then receives a signal from the RDU receiving the call, which signal requests log-in information and a password. If the log-in information and password are not conveyed to the RDU receiving the call (such as is the case when a third party other than the utility company is calling during the answer window), the RDU will terminate the call. If the proper log-in information and password are given to the RDU, the RDU will know that the UDP is calling and will transmit the desired information.

Disadvantageously, Verma's disclosed system interferes with normal utility customer telephone service by preventing third party calls from being received by utility customers during the answer window. Also disadvantageously, Verma's disclosed system requires use of machine-readable utility meters, and cannot automatically acquire and process reading data from non-machine-readable utility meters.

Examples of other conventional meter readings systems are disclosed in Pettis, U.S. Pat. No. 3,922,490; Thomborough et al., U.S. Pat. No. 4,817,131; Thomborough et al., U.S. Pat. No. 4,866,761; Garcia et al., U.S. Pat. No. 5,140,351; White et al., U.S. Pat. No. 5,239,575; and Cerny et al., U.S. Pat. No. 5,298,894. Unfortunately, each of these conventional systems suffers from the aforesaid and/or other disadvantages and drawbacks of the prior art systems discussed above.

SUMMARY OF THE INVENTION

In accordance with the present invention, a remote data acquisition and processing system is provided which is capable of overcoming the aforesaid and other disadvantages of the prior art. In one embodiment of the present invention, a system is provided for remotely monitoring and accumulating utility usage data from utility customer sites and transmitting such data to a remote storage facility where it can be accessed by a utility company. This embodiment of the present invention also includes a system for remotely managing and controlling utility consumption, and comprises a Remote Meter Processor or RMP located at the customer site for automatically monitoring and accumulating utility usage data, a Store Forward Site or SFS at a location remote from the utility customer site and the utility company for accumulating the utility usage data for later access by the utility company and a consumer interconnection medium or CIM connected to a wide band link for automatically transmitting the utility usage data to the SFS.

In this embodiment, the RMP is a self-contained unit which houses data acquisition, processing, control, memory, and data transmission circuitry. Data acquisition is accomplished through a Programmable Utility Meter Interface or PUMI which is capable of being programmed to automatically access utility usage data from any type of commercial meter, including both machine readable and non-machine-readable meters. Data acquisition and processing are controlled by a microprocessor located within the RMP. Customer usage data is acquired from the designated meter by the PUMI and is sent to the microprocessor where it is converted to a common file format for transmission to the SFS. The microprocessor can be programmed to cause the RMP to acquire and transmit data to the SFS at any specified predetermined interval.

In this embodiment, data transmission can be accomplished by any CIM, including, but not limited to, a conventional telephone network, a cellular telephone network, cable TV, RF, ISDN and suitable computer networks (e.g., wide area and Internet networks). The data are transmitted over the CIM to a wide band link for subsequent transmission to the SFS. Data are continually accumulated by the SFS from a number of RMP's corresponding to a number of

customers and is stored by the SFS until accessed and downloaded by the particular utility company for billing purposes.

This embodiment is further provided with an adaptive calling process which is a means of moving the periodic interval at which the RMP automatically accesses information. Such a function may be necessary when the RMP is having difficulty in transmitting information because the customer phone is in use when the CIM utilized is the conventional telephone network. The adaptive calling process analyzes previous connections and attempted connects to determine the optimum low volume time period for initiating automatic assess by the RMP.

Also, this embodiment is a bi-directional type of system, in that it is capable of automatically collecting and sending data to the SFS for access by the utility company, and the utility company can call the RMP on demand at any time to access utility usage. Additionally, the utility can transmit information such as programming updates, service disconnect commands, new autonomous update mode times, and other control and system options or functions to the SFS to be downloaded to the RMP during its next autonomous update mode call. It is further provided that an incoming call from the utility company causes the customer's telephone to go off-hook and the system initiates a bi-directional data connection to the utility company computer. Under most circumstances, innocent third part calls are permitted to pass through unimpeded. If any of the customer's telephones are taken off-hook during either a demand read or during the autonomous update mode, the utility company and the RMP will disconnect, allowing normal operation of the telephone circuit. This insures uninterrupted access to the telephone line by the resident of emergency and other calls. This embodiment also contains a power supply which is adapted to selectively disconnect electrical utility service at the customer site while retaining electrical utility service to the RMP.

Another embodiment of the system of the present invention essentially comprises one or more optical imaging devices for generating computer-readable image data representative of human-readable visual representations of respective portions of utility operation-related data displayed by machine-readable and/or non-machine-readable utility meters. Preferably, the optical imaging devices each include an array of charge coupled optical scanning elements for scanning the metering displays and/or dials of the meters whereby to produce the image data. A host computer processor is provided remotely from the imaging and metering devices for generating from the image data the respective portions of the utility operation-related data. The host computer processor accomplishes this by processing the image data using computer image processing techniques, such as optical character recognition techniques, to extract or generate from the image data the respective portions of the utility operation-related data. The host processor also stores the image data for later recall, and/or for display in the form of computer-generated images or hard copies of the visual representations represented by the image data (e.g., for use in verifying individual customer meter readings so as to ensure accurate billing).

Preferably, the system of this embodiment also includes a plurality of controllers located remotely from the host processor, imaging devices, and metering devices, for generating control signals for independently causing respective ones of the optical imaging devices to generate images and also for causing the controllers to transmit to the controllers the images generated by the imaging devices. The controllers are adapted to temporarily store the images transmitted to them from the imaging devices, and thereafter, to transmit the images to the host processor for processing.

Preferably, the transmission of the image data from the optical imaging devices to the controllers is accomplished via wireless communications links between the controllers and the devices. The wireless communications links may comprises spread-spectrum radio frequency links (e.g., transmitting at between 902 and 928 MHz), although other types of communications links (e.g., cellular telephone, hardwired telephone network, cable television connections, integrated services data network, microwave, and/or satellite communications links) may also be used without departing from this embodiment of the present invention.

Transmission of image data between the controllers and the host processor in this embodiment is accomplished via a public or private communications network connecting the controllers to the host processor. Preferably, this network takes the form of a wide area computer network, such as an Internet computer network, through which the controllers and the host processor exchange data via appropriate hardware and software (e.g., modems, communications software, etc.), and telecommunications facilities (e.g., public and/or private switched data and/or telecommunications networks). The host processor and controllers may also be appropriately provisioned to connect to the wide area network via wireless means, such as Unlicensed National Information Infrastructure (U-NII) communications devices operating within a frequency spectrum located at 5.15 to 5.35 GHz and 5.725 to 5.825 GHz.

Also, in this embodiment of the present invention, the host processor preferably includes a power management and information gathering timing mechanism for causing the controllers and imaging devices to periodically alternate between active periods and inactive ("sleep") periods. Ordinarily, the controllers and imaging devices operate in low power consumption, "sleep" condition wherein only essential components of the controllers and imaging devices are active. However, periodically, the host processor timing mechanism triggers the host processor to generate control signals which are transmitted to the controllers for causing the controllers to enter "active" mode. Once in active mode, the controllers generate control signals for causing the imaging devices to enter active mode, scan the meters to produce the image data, and transmit the image data to the controllers. The controllers then transmit the image data to the host processor. Thereafter, the controllers and imaging devices are either commanded by the host processor to return to sleep mode, or automatically return thereto.

The host processor preferably is also adapted to generate and store data files in which the respective portions of utility operation-related data are associated with respective utility customers. In this embodiment, this is accomplished based upon identification information supplied with the image data to the host processor for permitting association of the respective portion of utility data with the respective imaging device that generated the image data representative of the respective portions of utility data. The data files may then be transmitted to the utility for further processing by the utility (e.g., for facilitating billing of utility customers and/or controlling distribution of utility services based at least in part upon the files).

Advantageously, this embodiment of the present invention is able to automatically generate reading data of both machine readable and non-machine readable types of metering devices, and to process such data for use in e.g.,

customer billing. Further advantageously, this embodiment is able to accomplish these functions without requiring that the non-machine readable metering device being read be internally modified (e.g., to include mechanisms for making such metering devices machine readable).

These and other features and advantages of the present invention will become apparent as the following Detailed Description proceeds and upon reference to the Drawings, wherein like numerals depict like parts, and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of one embodiment of the present invention.

FIG. **2** is a block diagram of one preferred construction of the CIM of the preferred embodiment illustrated in FIG. **1** which utilizes a conventional telephone network.

FIG. **3** is a block diagram of another preferred construction of the CIM of the preferred embodiment illustrated in FIG. **1** which utilizes a cable television network.

FIG. **4** is a block diagram of yet another preferred construction of the CIM of the preferred embodiment illustrated in FIG. **1** which utilizes a cellular telephone network.

FIG. **5** is a block diagram of still another preferred construction of the CIM of the preferred embodiment illustrated in FIG. **1** which utilizes an RF network.

FIG. **6** is a block diagram of another preferred construction of the CIM of the preferred embodiment illustrated in FIG. **1** which utilizes an ISDN network.

FIG. **7** is a block diagram of a preferred construction of the RMP of the preferred embodiment illustrated in FIG. **1**.

FIG. **8** is a block diagram of a preferred construction of the PUMI shown in FIG. **7**.

FIG. **9** and FIG. **10** are schematic circuit diagrams illustrate various aspects of the preferred construction of the main board shown in FIG. **7**.

FIGS. **11** and **12** illustrate various aspects of an optical scanner arrangement for use in the preferred embodiment of FIG. **1**.

FIG. **13** is a schematic circuit diagram of a preferred construction of the power circuitry of the RMP of FIG. **7**.

FIG. **14** is a schematic circuit diagram of a preferred construction of the baseboard of the RMP of FIG. **7**.

FIG. **15** illustrates an embodiment of a modem adapted for use with a conventional telephone network for use with the RMP of FIG. **7**.

FIG. **16** illustrates an embodiment of a modem adapted for use with a cellular telephone network for use with the RMP of FIG. **7**.

FIG. **17** illustrates an embodiment of a modem adapted for use with a cable television network, an RF network, or an ISDN network for use with the RMP of FIG. **7**.

FIG. **18** is a functional block diagram of another preferred embodiment of the present invention.

FIG. **19** is a functional block diagram of the electronic and electro-optical components of an optical imaging device in the preferred embodiment of FIG. **18**.

FIG. **20** is a functional block diagram of the electronic components of one remote management controller/processor of the preferred embodiment of FIG. **18**.

FIG. **21** is a functional block diagram of the spread spectrum radio frequency transmission/reception device of the optical imaging device of FIG. **19**, which transmission/reception device is substantially identical to that of the remote management controller/processor of FIG. **20**.

FIG. **21A** is a functional block diagram of a modification of the device of FIG. **21**.

FIG. **22** is an outer, perspective view of one type of optical imaging device of FIG. **18**, which device is for use, and is shown in conjunction with, a typical non-machine-readable or machine-readable water service type of utility meter.

FIG. **23** is a cross-sectional view taken along lines **23—23** of the imaging device of FIG. **22**.

FIG. **24** is an outer, perspective view of another type of optical imaging device of FIG. **18**, which device is for use, and is shown in conjunction with, a typical non-machine-readable or machine-readable gas service type of utility meter.

FIG. **25** is a cross-sectional view taken along lines **25—25** of the imaging device of FIG. **25**.

FIG. **26** is an outer, perspective view of yet another type of optical imaging device of FIG. **18**, which device is for use, and is shown in conjunction with, a typical non-machine-readable or machine-readable electric service type of utility meter.

FIG. **27** is a cross-sectional view taken along lines **27—27** of the imaging device of FIG. **28**.

FIG. **28** is a functional block diagram of a preferred construction of the paging signal reception and processing system of the remote management controller/processor of FIG. **20**.

FIG. **29** is a functional block diagram of a preferred construction of the optical scanning system of the optical imaging device of FIG. **19**.

FIG. **30** is a functional block diagram of a preferred construction of the wide area network interface system of the remote management controller/processor of FIG. **20**.

FIG. **31** is a functional block diagram of the host processor of the embodiment of FIG. **18**.

FIGS. **32–34** are plan views of respective face portions of conventional utility meters for facilitating discussion of operation of the embodiment of the present invention shown in FIG. **18**.

FIG. **35** is an outer, perspective view of the remote controller/processor of FIG. **20**.

FIG. **36** is a cross-sectional view taken along lines **36—36** of FIG. **35**.

Although the following Detailed Description will proceed with reference being made to specific embodiments of the present invention, it should be understood that the present invention is not intended to be limited to these embodiments. Rather, many alternatives, modifications, and variations thereof will be apparent to those skilled in the art. Accordingly, the present invention should be viewed broadly, as being limited only as set forth in the hereinafter appended Claims.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. **1**, a block diagram of one preferred embodiment **1** of the data acquisition and processing system of the present invention is shown. Located at the customer premises **5** are gas meter **10**A, electric meter **10**B and water meter **10**C. Each one of gas meter **10**A, electric meter **10**B and water meter **10**C can be of the pulse type, encoder type or non-machine readable type. Also provided at the customer premises **5** is an RMP **12**. RMP **12** is capable of automatically accessing utility usage data from gas meter **10**A, electric meter **10**B and water meter **10**C and transmit-

ting such data through CIM **14** to a wide band link **20**. A wide band link is any data transmission network capable of bi-directional high speed data transmission. Any wide band link having the ability to form a virtual connection to the SFS **24**, such as the current Packet Switched Data Network or equivalent, can be used. From the wide band link **20**, the data is sent through the wide band link interconnect **22** to SFS **24** where it is stored until accessed by the utility company.

The system **1** is set up such that RMP **12** will transmit data from each customer premises **5** periodically, usually once during the particular utility company's billing cycle, to SFS **24**. The operation of the system **1** in this manner is identified as the autonomous update mode. The particular utility company will stagger such transmissions by its total population of customers over the billing cycle, the end result being that SFS **24** will receive data each day corresponding to a portion of the utility company's customers. Each day, the utility company can then access and download the data which was transmitted and stored in SFS **24** during the previous day's transmissions and use such data for billing purposes. In operation, the utility company computer **28** places a call over telephone line **26** to the telephone company central office **16** which in turn uses telephone company wide band link access **18** to gain access to wide band link **20**. Access to wide band link **20** at the telephone company central office **16** is through providers such as AT&T, MCI Communications and Sprint Net. From wide band link **20**, the desired data can be accessed and downloaded from SFS **24** through wide band link interconnect **22** using protocols available at SFS **24** such as Kermit, ZMODEM, XMODEM or any batch variation of the same. Each utility company is assigned a particular address at SFS **24** corresponding to the location at which its usage data is being stored. Typically, in MS-DOS or UNIX systems, this is achieved by creating subdirectories for each utility. The data is then downloaded from SFS **24** over wide band link interconnect **22** to wide band link **20**. The data is then sent over telephone company wide band link access **18** to the telephone company central office **16** which in turns send the data over telephone line **26** to the utility company computer **28**.

Information such as service termination or reconnect commands, new or updated programs, and current time and date information can be placed at SFS **24** by the utility company to be automatically downloaded by a particular RMP **12** during its next transmission in the autonomous update mode. This is accomplished by having the standard call initiating sequence of RMP **12** examine an update file during the initial data exchange at the beginning of the autonomous update mode.

In addition, the system **1** is capable of being operated in a demand mode. In the demand mode, the utility company is able to access utility usage data from and control utility connection status at a particular customer premises **5** on demand. In operation, the utility company computer **28** places a call over telephone line **26** to telephone company central office **16**. From the telephone company central office **16**, CIM **14** is used to access a particular RMP **12** at a particular customer premises **5**. Each RMP **12** at each customer premises **5** is given a unique address so that it can be accessed in this way. RMP **12** then accesses the utility usage information from one or more of gas meter **10**A, electric meter **10**B or water meter **10**C, depending upon which particular utility company is seeking data, and sends the data out over CIM **14** to telephone company central office **16** which in turn sends the data to the utility company computer **28** over telephone line **26**. Available modes of sending or transmitting data include V.xxbis, BELL or other international standards through protocols as required by the particular SFS **24**.

Any type of CIM **14** having access to wide band link **20** can be used to transmit the utility usage data from the customer premises **5** to SFS **24**, as previously described. Selected CIMs comprise a conventional telephone network, cable television, a cellular telephone network, RF and the Integrated Services Digital Network, or ISDN.

Referring now to FIG. **2**, a block diagram of CIM **14** is shown utilizing a conventional telephone network. In this embodiment, RMP **12** is equipped with a modem **30** configured for use with a conventional telephone network which is adapted to transmit data to and receive data from the telephone company central office **16** through the utilization of telephone line **26**.

Referring now to FIG. **3**, a block diagram of CIM **14** is shown utilizing cable television or CATV. In this embodiment, RMP **12** is equipped with modem **30** configured for use with a cable television network. This is done by connecting modem **30** to a CATV interface device such as a Motorola MHW10000. Modem **30** then transmits the data to CATV head end **38** through the utilization of CATV cable **36** comprising subcarriers on the public assess or CATV control channels. The data then passes through multiplexer/demultiplexer **40** to CATV head end computer **42**. CATV head end computer **42** then sends the data to telephone company central office **16** through the use of telephone line **26** using modem **44**. A virtual connection is then made through wide bank link **20** to SFS **24**.

Referring now to FIG. **4**, a block diagram of CIM **14** is shown utilizing a cellular telephone network. In this embodiment, RMP **12** is equipped with modem **30**, such as a Rockwell RC144ACL/C40, configured for use with a cellular telephone network. Modem **30** then transmits the data to cellular tower **48**A using a modem-ready cellular transceiver. Next, the data is sent from local call interface **48**B to telephone company central office **16** through intercellular connection **48**C. The data is then sent to SFS **24** through a virtual connection over wide band link **20**.

Referring now to FIG. **5**, a block diagram of CIM **14** is shown utilizing RF. In this embodiment, RMP **12** is equipped with modem **30** configured to control an RF transceiver which transmits the data using radio frequency waves to either RF remote location **53**A, a fixed RF site, or vehicle **54**, a mobile RF site. If RF remote location **53**A is used, the data is then sent through the RF site **53**B and telephone line **26** to the telephone company central office **16** and ultimately to SFS **24** over wide band link **20**. In a mobile configuration, data collection by the mobile van is downloaded to SFS **24** via disk, tape or other means, as determined by the particular RF system employed.

Referring now to FIG. **6**, a block diagram of CIM **14** is shown utilizing ISDN. ISDN is an international telecommunications standard that enables a communications channel to carry digital data simultaneously with voice and video information. In such a configuration, RMP **12** is equipped with modem **30** configured for use with an ISDN network. This is done by connecting modem **30** to an ISDN interface device such as a Motorola MC145490EVK. Modem **30** transmits the data to telephone company central office **16** using ISDN local line **56**. A virtual connection is then made over wide bank link **20** to SFS **24**.

Referring now to FIG. **7**, a block diagram of RMP **12** is shown comprising programmable utility meter interface or PUMI **60**, main board **70**, real time clock **80** located on

baseboard **81**, PC**104** bus **62**, and modem **30**, configured for the type of CIM **14** that is to be used. Interconnection of these modules is accomplished utilizing a peripheral interconnection scheme, and preferably the PC-**104** standard as described by the PC-**104** Consortium.

Referring now to FIG. **8**, a block diagram of PUMI **60** is shown comprising a field programmable gate array or FPGA **86** containing a plurality of registers **87**, programmable logic device or PLD **88**, and six 16-bit I/O connectors **90**. Also shown in FIG. **8** is the PC**104** bus **62**. Interconnection of these modules is accomplished using the PC-**104** standard as described above.

Referring now to FIGS. **9** and **10**, main board **70** is illustrated. FIG. **9** shows microprocessor **100**, such as an Intel 1386EXP, programmable logic arrays **101**A, **101**B and **101**C, which provide I/O and memory management support to microprocessor **100**, data buffer chips **102**A and **102**B, which provide data buffering to microprocessor **100**, and oscillators **103**A, **103**B, and **103**C, which provide clocks for microprocessor **100**, COM control and I/O timing. FIG. **10** shows DRAM **105**, address decoders **106**A, **106**B, and **106**C, which provide management and interface of DRAM **105**, flash RAM **107**, which stores system files, a command interpreter, and the execution code used for operation of the RMP **12**, and quad buffer **108** and FETs **109**A and **109**B, which provide 12 v necessary for programming flash RAM **107**.

Functionally, programmable logic arrays **101**A, **101**B and **101**C are used for bus control and, depending on the address and data that microprocessor **100** is currently executing, provide the proper logic levels and timing that are required to communicate with PC-**104** bus **62**, flash RAM **107** and DRAM **105**. Flash RAM **107** provides a diskless alternative for non-volatile, read/writable storage for the operating system, data and programs.

RMP **12** is capable of reading gas meter **10**A, electric meter **10**B, and water meter **10**C irrespective of the type of metering technology being used. PUMI **60** is the device through which acquisition of utility usage data occurs. Referring to FIG. **8**, FPGA **86** is provided with six 16-bit I/O connectors which are then connected to at least one of gas meter **10**A, electric meter **10**B and water meter **10**C in order to access utility usage data. Each meter which is connected to PUMI **60** through the 16-bit I/O connectors is given a specific address which is programmed into FPGA **86**.

If the meter to be connected is a pulse type meter, two wires will be used to connect the pulse type meter to two of the I/O connections of one of the 16-bit I/O connectors so that usage data corresponding to meter pulses can be fed into PUMI **60**. Meter pulses are accumulated by and stored in a register **87** located on FPGA **86**.

If the meter to be connected is an encoder type meter, PUMI **60** is hardwired to the meter by using I/O connectors to directly access the digital signal representing the current meter reading of the meter. The number of I/O connectors is determined by the type of encoder meter being utilized.

Referring now to FIG. **11**, if the meter to be connected is a non-machine readable type of meter, optical scanner **110** or similar imaging device mounted to the face of the meter can be used for reading the meter. An example of such an imaging device is CID Technology, Inc. DIC2250D. Referring now to FIG. **12**, a schematic of optical scanner **110** is provided. CID chip **111** is connected the main board **70** through serial connection **116** which is driven by UART **115**. A masked programmed FLEX PLD **112** is used to generate clock signals that are conditioned by conditioning circuitry **113** and is also used to receive differential drive from drive circuitry **114**. UART **115** then outputs a scan file which represents the current meter face, a corresponding signal of which is then fed electronically to PUMI **60** through the I/O connectors. The scan file is then sent to microprocessor **100**. For meters which numerically indicate the meter reading, such as a meter using an odometer or digital display, an OCR system, such as Calera Recognition Systems OCR software, is used to convert the scan file into a signal representing usage data. For meters which indicate readings through a pointer and dial, a system which determines the meter reading from the location of the pointers on the dials is used, such as those designed to scan monochrome bitmaps for black and white levels.

Referring now to FIG. **14**, real time clock **80** which is located on baseboard **81** is programmed with the specified time during the billing cycle at which RMP **12** is to read a particular meter for a particular utility and send such reading to SFS **24** during the autonomous update mode. The initial autonomous update mode time is programmed into real time clock **80** at the time of installation of RMP **12** and can later be updated by means of placing such information at SFS **24** for download by RMP **12** during its next autonomous update mode session. Real time clock **80** contains ten on-board alarm registers which are used to store such reporting times. Each alarm register corresponds to a particular meter and a particular reporting time. When real time clock **80** reaches a preselected time stored in one of the alarm registers, it sends an interrupt request signal or IRQ down PC **104** bus **62** to main board **70** and more particularly to microprocessor **100**. Along with the IRQ signal, microprocessor **100** is also sent an address signal which indicates the particular alarm register **82** from which the IRQ signal came. Thus, microprocessor **100** is able to determine which meter address, and thus which particular meter is to be read. Microprocessor **100**, having received the request, causes PUMI **60** to read a particular meter so that RMP **12** can later transmit the acquired data to SFS **24**.

DRAM **105** stores information corresponding to each meter connected to the RMP **12** comprising the type of meter and the proper subroutine to be followed by the microprocessor **100** to read such meter. This information is stored in DRAM **105** at a specified address for each meter connected to RMP **12**. Microprocessor **100** accesses the information in DRAM **105** based upon the address signal sent from the real time clock **80**.

Microprocessor **100** then sends the address of the meter to be read to the FPGA **86**. If the type of meter to be read is a pulse type meter, the FPGA **86** then accesses the current value stored in register **87** in FPGA **86** which corresponds to the meter to be read and then sends it to the microprocessor **100** through PC **104** bus **62**. If the type of meter to be read is an encoder meter or a non-machine readable type meter, FPGA initiates a read of the meter by accessing the current meter value using either the encoder connections or the optical scanner connections, whichever is appropriate, and such value is stored in a register **87** in FPGA **86**. FPGA **86** then sends the data to microprocessor **100** through PC **104** bus **62**. Microprocessor **100** will then convert the data to ASCII and initiate transmission of the data through CIM **14** to SFS **24** through a standard boot-up sequence using hardware initialization and software execution.

Microprocessor **100** is also programmed with an adaptive calling process. In a conventional telephone network embodiment, the adaptive calling process is necessary to address the situation in which RMP **12** is attempting to transmit data in the autonomous update mode and telephone

line **26** is unavailable because of use by the customer. The adaptive calling process alters the time at which autonomous update mode transmissions are initiated by analyzing previous connects and attempted connects to determine the optimum time period for initiating transmission.

When the utility company wishes to make a demand read, as has been previously described, the utility company computer **28** initiates a call which addresses RMP **12** and the particular meter **10**A, **10**B or **10**C to be read. Microprocessor **100** then accesses the utility usage information from the desired meter or meters by the same procedure as previously described.

In a conventional telephone network embodiment, a demand read according to the above described procedure requires an actual telephone call to be made by the utility company computer **28** to the customer premises **5**. The system monitors every incoming call to the customer premises **5** and is able to distinguish between innocent third party telephone calls and a demand read call from the utility company computer by using CND, a standard telephone function in which the source of a telephone call can be identified. The CND function enables RMP **12** to detect when a particular call is the utility company seeking to access information rather than a third party placing a call to the customer. To do so, microprocessor **100** is preprogrammed with the phone number to be used by utility company computer **28** such that when modem **30** detects an incoming call from that number, it signals Microprocessor **100**. Microprocessor **100** in turn prevents the call from going through to the customer premises and instead initiates acquisition and transmission of the desired data to utility company computer **28**. Innocent third party calls are permitted to pass through unimpeded. Such a function is not required when the other types of CIM **14** are utilized because the other types of CIM **14** each have a channel or line dedicated solely to the utility company.

Power for RMP **12** is provided through power circuitry **130** as shown in FIG. **13**. Power circuitry **130** provides the RMP with remote disconnect capability and unlimited access to power even after the disconnection of electricity to the customer premises. Meter socket **132** at customer premises **5** is connected to main electrical line **134** to customer premises **5**, as shown in FIG. **11**. Meter socket **132** has two power output connections **136** and two power input connections **138**. Power input connections **138** lead into customer premises **5** to provide electrical service thereto. Electric meter **10**B similarly has two input connections **140** and two output connections **142** and connects across power output connections **136** and power input connections **138** of meter socket **132**, thereby completing the circuit such that electricity is fed into meter **10**B for monitoring purposes and back out into customer premises **5** for use by the customer. Power circuitry **130** is contained in a collar assembly which is inserted between meter socket **132** and electric meter **10**B as shown in FIG. **11**. The collar assembly permits the meter to function normally.

Shunt lines **135**A and **135**B of power circuitry **130** are connected to main electrical line **134** through power output connections **136** using meter socket connectors **136**A and **136**B. Shunt lines **135**A and **135**B are then connected to the input connections **140** of electric meter **10**B through connectors **138**A and **138**B, such that the 240V AC coming from main electrical line **134** is passed through to electric meter **10**B.

Output connections **142** of the electric meter **10**B are connected to shunt lines **140**A and **140**B through connectors **142**A and **142**B, which in turn are connected to the customer premises **5** through power input connections **138** using connectors **144**A and **144**B. The 240V AC power is then taken from shunt lines **140**A and **140**B using lines **146**A and **146**B. Fuses **148** are inserted in lines **146**A and **146**B for current limitation in the primary circuit of transformer **152**. Also, relay **150** is placed in the secondary circuit that supplies power to RMP **12**. Relay **150** will not close and provide power to RMP **12** until RMP **12** is properly connected. Transformer **152** is used to step the 240V present on lines **146**A and **146**B down to a lower voltage appropriate for use by RMP **12**. Transformer **152** has four outputs, **154**A, **154**B, **154**C and **154**D, two of which provide a power connection to RMP **12** through full-wave rectifier **154**E and through the CHGIN connection of power management system **201** as shown on FIG. **14**, and two of which can be used to provide a power connection to auxiliary devices such as an optical scanning device. Two of the outputs are also used to drive bridge rectifier **156** which in turn drives voltage regulator **158**. Voltage regulator **158** is used to provide local power to decoder chip **160** which provides 2-bit decoding of signal sent from RMP **12**. When RMP **12** sends a service disconnect signal, as may be placed at SFS **24** by the utility company and downloaded by RMP **12**, the decoder chip **160** feeds opto-isolator/TRIAC **162** which in turn operates relays **164** placed in shunt lines **140**A and **140**B, such that when relays **164** are open no power is able to get into customer premises **5**. Thus, power circuitry **130** provides the electric utility with remote disconnect capability while still providing power to RMP **12**.

In addition to using power circuitry **130**, power to RMP **12** can be provided by a solar cell mounted outside customer premises **5**, a wall-mounted adapter plugged into an outlet at the customer premises **5**. As shown in FIG. **14**, baseboard **81** consists of a power management system **201** and DC to DC converters **201**A and **204**B, which are used to supply power to PC-**104** bus **62**. Management of metal halide or nickel cadmium cell **205** is accomplished by controlling circuit **203** with commands from power management system **201**. Interface of power management system **201** is provided through level shifter **202** using a standard asynchronous serial protocol.

Power management system **201** is a standard cell charge maintenance circuit and utilizes a Microchip MTA 11200 with the recommended support circuitry. Power is provided to the other elements of RMP **12** through PC-**104** bus **62** and auxiliary power connection **206**.

FIG. **15** illustrates an embodiment of modem **30** adapted for use with a conventional telephone network. DAA interface circuit **170** provides a direct access arrangement or DAA interface for isolation and signal conditioning. Within circuit **170**, filter circuit **172** is provided which comprises a high pass RC filter. Filter circuit **172** permits the higher frequency, lower voltage portion of the telephone signal, which contains the caller ID information, to pass on to the remainder of modem **30** circuitry while blocking the 85–90V ring portion of the telephone signal. The remainder of modem **30** consists of data pump **174**, such as the Rockwell DMP RC144ACL, microcontroller **176** for controlling data pump **174**, such as the Rockwell microcontroller C**40**, ROM **178** and RAM **180**, such as the Intel 27CO10 and 51256, respectively, for configuring data pump **174** and microcontroller **176**, and programmable logic array **182**, which is configured for address decoding of chip select for microcontroller **176**. Connection of modem **30** to PC-**104** bus **62** is provided by PC-**104** connectors **184**. CND detection is accomplished by selection of the components that

make up filter circuit **172** to allow the CND signal through during on-hook operation of the telephone between the first and second ring signals as specified by BELCORE document TR-RSY-000031, "SPCS/Customer Premises Equipment Data Interface."

FIG. **16** illustrates an embodiment of modem **30** adapted for use with a cellular telephone network. The circuitry is essentially identical as that described in reference to FIG. **15** except for the absence of DAA interface circuit **170** and filter circuit **172**. Data pump **174** and microcontroller **176** are configured to cellular operation through software configuration which allows microcontroller **176** to control the cellular phone firmware options which are cell phone manufacturer dependent. Reception and transmission of signals to and from modem **30** when adapted for use with a cellular telephone network are accomplished through connector **186**, such as a multi-pin DIN or LIMA connector.

FIG. **17** illustrates an embodiment of modem **30** adapted for use with a cable television network, an RF network, or an ISDN network. The circuitry is essentially identical to that described in connection with FIG. **16**. Connection to the cable, television, RF or ISDN service interface is accomplished through connector **186** using standard 4-wire serial protocols. Transformer **188** is used to provide differential drive for transmit in order to increase common mode rejection to the network interface.

Thus, advantageously, this embodiment of the present invention essentially comprises a modular system for automatically monitoring and controlling utility consumption at a customer site and transmitting such data to a remote storage facility where it can be accessed by a utility company for billing purposes and related functions. This embodiment is also capable of detecting leaks and tampering at the customer site, is completely independent of the type of meter technology used at the customer premises, and further does not rely upon a specific communication medium for transmitting the data to the storage facility. As such, this embodiment is completely modular. Also advantageously, as is discussed above, this embodiment includes hardware for automatically reading utility meters located at the customer premises and automatically transmitting data to and receiving data from a remote storage facility. In addition, the utility company can access such usage data from a particular customer premises or send data to the customer premises on demand.

With reference to FIG. **18**, another preferred embodiment **300** of the remote data acquisition and processing system of the present invention will now be described. System **300** comprises at least one **316**, and preferably a plurality of meter imaging devices **316**, **318**, **320**, **322**, **324**, **326**, removably, non-invasively mounted, in a manner that will be described in greater detail below, to the respective meter faces **315**, **317**, **319**, **321**, **323**, **325** of respective conventional machine-readable or non-machine-readable utility meters **308**, **306**, **304**, **310**, **312**, **314** at customer premises **301** and **302**. As is typical of conventional utility meters, each of the conventional meters **304**, **306**, **308** . . . **314** comprises visual display means **500** located in the respective meter face portions **315**, **317**, **319**, **321**, **323**, **325** of the meters **308**, **306**, **304**, **310**, **312**, **314**. The display means **500** of each meter includes one or more analog dials **502**, alphanumeric digital displays **506** (e.g., alphanumeric LED or LCD displays), and/or odometers **508** for visually displaying representations (e.g., readings via the positions of dials **502** and numbers or other symbols displayed by digital displays **506** and odometers **508**) indicative of measurement of the phenomena being monitored by the meter displaying such representations. Such phenomena may include, as is the case in embodiment **300**, usage of utility services by the utility customer at the customer premises at which the meter is located, and/or other utility operation-related phenomena (e.g., in the case of water and gas meters, pressures at which water and gas, respectively, are being supplied to the customer premises from their respective utilities, or in the case of electric meters, voltage and current at which electricity is being supplied to the customer premises from the electric utility).

System **300** also includes at least one **338**, and preferably a plurality **338**, **340** of remote management controllers/processors. Each of the remote controllers **338**, **340** controls separate pluralities of optical imaging devices **316**, **318**, **320** and **322**, **324**, **326**, respectively, at each of the customer premises **301**, **302**, via control signals transmitted to each of the optical imaging devices via separate respective primary wireless communications links **328**, **334** between the controllers **338**, **340** and the scanners. Preferably, controllers **338**, **340** are located in relatively inaccessible places (e.g.,. mounted atop conventional telephone poles). Preferably, as will be described in greater detail below, communications links **328**, **334** each comprise separate spread-spectrum radio frequency communications links between each of the controllers and each of the scanners of each of the respective pluralities of scanners controlled by the controllers, each of which radio frequency links comprises two respective reception/transmission devices **377**, one of said devices being located in a respective optical scanner and the other of which devices being located in the respective remote management controller/processor responsible for controlling that respective optical scanner. In this embodiment, controller **338** is adapted to be able to control each of the scanners **316**, **318**, **320** in the plurality of scanners **316**, **318**, **320** controlled by controller **338** independently of the other scanners in the plurality of scanners **316**, **318**, **320** controlled by controller **338**. Likewise, controller **340** is adapted to be able to control each of the scanners **322**, **324**, **326** of the plurality of scanners **322**, **324**, **326** controlled by controller **340** independently of the other scanners in the plurality of scanners **322**, **324**, **326** controlled by controller **340**.

As will be described in greater detail below, in embodiment **300**, each of the scanners **316**, **318**, . . . **326** is adapted to optically scan the display means of the face portion **315**, **317**, **319**, **321**, **323**, **325** of the respective meter **308**, **306**, **304**, **310**, **312**, **314** to which it is attached, based upon control signals supplied thereto via wireless communications links **328**, **334** from remote management controllers/processors **338**, **340**, in order to produce respective computer-readable (i.e., digital) image data of the display means **500** and the aforesaid visual representations being generated by the display means. Once generated, the image data is transmitted from the scanner or scanners generating same, along with respective scanner identifying information (e.g., scanner serial number information), via the appropriate wireless link **328** or **334** to the respective controller **338** or **340** responsible for controlling the scanner or scanners which generated the image data. The image data is then temporarily stored, in association with the identifying information, in the controller or controllers such that respective portion(s) of image data generated by the respective scanner(s) is associated with the respective identifying information of the scanner(s) that generated same, and thence, the image data and associated identifying information are transmitted to a remote host computer processor **344** via public or private wide area network **342**, which network **342** connects the controllers **338**, **340** and the host processor **344**.

Host processor **344** is geographically remotely located from the customer premises **301**, **302**, meters **308**, **306**, **304**, **310**, **312**, **314**, scanners **316**, **318**, **320**, **322**, **324**, **325**, controllers **338**, **340**, and utility company computer **346**. Network **342** preferably comprises a Internet-type of public, wide area computer network wherein data exchange is accomplished via Transmission Control Protocol/Internet Protocol (TCP/IP), although alternatively, network **342** may comprise other types of public and/or private communications networks, including public or private telecommunications or telephone networks. Host processor **344** is also connected to utility computer(s) **346** via network **342**.

FIGS. **19**, **21**, and **29** illustrate a preferred construction of the optical and electronic components of the optical imaging devices **316**, **318**, **320**, **322**, **324**, **326** shown in FIG. **18**. As shown in FIG. **19**, each of the imaging devices includes an optical scanning system **364** which is controlled by a microcontroller or microprocessor **370** (e.g., comprising conventional 8-bit Motorola 68HC811E2FN microprocessor). Each imaging device also includes an interface/power management controller **384** which controls power usage in the imaging device, and acts as an interface controller between the microprocessor **370**, spread-spectrum radio frequency transmission/reception device **377**, and optical imaging device tamper/removal sensor **352**. Preferably, controller **384** comprises a conventional Microchip 16LC74A-04I/TQFP microcontroller. Microprogram code and imaging device configuration information for use by the microprocessors **370**, **384** are stored in memory means **372**, while data memory for use by the microprocessors **370**, **384** is provided by memory means **374**. Preferably, memory means **372** comprises conventional EEPROM memory and associated memory access circuitry for permitting the microprocessor **370** to read therefrom and write data thereto and for permitting the microprocessor **384** to read data therefrom. Preferably, data memory **374** comprises conventional SRAM memory and associated memory access circuitry for permitting reading of data therefrom and writing of data thereto by both microprocessors **370**, **384**.

Preferably, RF transmission/reception device **377** is comprised by a PC board **850** upon which is mounted the electronic components for implementing the functional blocks illustrated in FIG. **21**, which PC board **850** is mounted on optical device PC mother board **854** by connector assembly **376**. The mother board **854** includes electronics and opto-electronics **856** for implementing the functional blocks illustrated in FIG. **19** and RF PC board connector assembly **376** which comprises a conventional 20-pin connector for permitting interconnection between various of the components shown in FIGS. **19** and **21**.

In one preferred form of the optical devices **316**, **318**, **320**, **322**, **324**, **326**, motherboard **854** and RF PC board **850** are mounted within an elastomeric housing **802**, via conventional means **860** which attach the motherboard **854** to the inner surface of the housing **802** so as to be positioned within a generally cylindrical central portion **870** of the housing **802**. Preferably, housing **802** is made of a weather-resistant elastomeric material (e.g., Santoprene™ material) which is permeable (i.e., substantially transparent) to the RF radiation transmitted and intended to be received by the transmission and reception device **377**, and also includes two other generally cylindrical portions **880**, **882** which extend outwardly from opposite ends of the central portions **870**. Board **623**, which comprises end launched strip antenna **622** used by the transmission/reception device **377**, extends longitudinally in a central portion of one **880** of the two extended portions **880**, **882**. Cylindrical portion **882** comprises collar portion **800** which is removably attached to cylindrical lip portion **801** of the housing **802** by conventional means (not shown). Collar portion **800** is slightly oversized compared to the meter face portion **315** of the meter **308** to which the optical device **316** is intended to be attached, and includes raised portion **803** which engages the outer surface of the face portion **315**. A waterproof sealant material may be disposed in the gap **807** in-between the face portion **315** and the collar portion **800** so as to prevent water and other contaminants from entering the housing **802** when the device **316** is attached to the meter **308**. A focusing optical lens **855** is attached to the underside of the board **854** for permitting better scanning of the meter face portion **315** by the imaging system **364** of the device **316**.

It should be understood that the foregoing discussion of the physical layout and construction of the optical imaging device **316** was made with reference to use with a specific type of metering device (i.e., a conventional water service utility meter), and therefore, the optical device housing **802** may also have other preferred forms depending upon type and dimensioning of metering device to which said housing is attached. For example, if meter **306** is a conventional gas service type of utility meter, imaging device **318** may have the physical layout and construction shown in FIGS. **24–25**.

As shown in FIGS. **24–25**, device **318** comprises housing **802'** which includes cylindrical portion **880'** (wherein board **623** is disposed), rectangular portion **870'** (wherein board **854** is disposed), and generally trapezoidal-shaped collar portion **800'** (which attaches to the meter face portion **317**). It should be understood that although various components of device **316** have not been shown in FIGS. **24–25** for purposes of clarity, the components and operation of device **318** are substantially identical to those of device **316**, except that the components and operation of device **318** are appropriately adapted for use with the gas meter **306**.

Likewise, if meter **304** is a conventional electric service type of utility meter, imaging device **320** may have the physical layout and construction shown in FIGS. **26–27**. As shown in FIGS. **26–27**, device **320** comprises housing **802"** which includes cylindrical portion **880"** (wherein board **623** is disposed), rectangular portion **870"** (wherein board **854** is disposed), and collar portion **800"** (which attaches to the meter face portion **319**). It should be understood that although various components of device **316** have not been shown in FIGS. **24–25** for purposes of clarity, the components and operation of device **320** are substantially identical to those of device **316**, except that the components and operation of device **320** are appropriately adapted for use with the electric meter **304**.

Returning now to the previous discussion concerning the various functional electronic components of the imaging devices, controller **384** is connected to the RF device **377** via the subconnector assembly **376**, and clocked by two different clocks **380**, **382**. As will be described in greater detail below, controller **384** controls power usage of various components in the optical imaging device, and is adapted to enter a low power mode of operation under certain conditions (e.g., lack of reception/transmission activity via the device **377**), in order to permit controller **384** to reduce the amount of power consumed by the optical imaging device when the optical imaging device not actively engaged in generation of image data and/or other important processing functions (e.g., receiving and transmitting data via the RF device **377**). Low power mode clock **380** preferably comprises a 32.768 kHz quartz crystal oscillator which clocks the controller **384** when the controller **384** is in a low power ("sleep") mode. Normal ("active") mode clock **382** preferably comprises a 4

MHz quartz crystal oscillator which clocks the controller **384** when the controller **384** is in active (i.e., non-low power) mode. When in an active state, microcontroller **370** is clocked by an 8 MHz quartz crystal oscillator **366**.

Each of the optical imaging devices **316**, **318**, **320**, **322**, **324**, **326** also comprises a conventional power source **350**, which preferably comprises one or more conventional **3.6** volt, rechargeable lithium thionyl chloride battery cells. Power source **350** continually supplies power to microcontroller **384** via conventional level converter **354**, which converter **354** converts the 3.6 volt output of the power source **350** to the 5 volt level required to power the microcontroller **384**. Preferably, converter **354** comprises a conventional Linear Technologies LT 1302CN8-5-ND voltage pump and associated conventional circuitry.

Each optical device **316**, **318**, **320**, **322**, **324**, **326** also includes a plurality of controllable switches **356**, **360**, **362**. Controllable switches **356**, **360** are controlled by controller **384** when controller **384** is in active mode. Controllable switch **364** is controlled by controller **370** when controller **370** is powered-up. Preferably, each of the controllable switches **356**, **360**, **362** comprises a CPCLARE LCA 710 relay switch.

Switch **356** is connected to power source **350** and level converter **358**, and receives switching control signals from controller **384**, which control signals determine whether the switch **356** permits power supplied to the switch **356** from the source **350** to flow to the level converter **358**, and thence to the controllable switches **360**,**362** and RF device **377** via the subconnector **376**. Level converter **358** comprises a conventional Linear Technologies LT 1302-5 voltage pump and associated circuitry for converting the voltage level of power signals supplied to converter **358** from switch **356** (when switch **356** permits such supply) from a 3.6 volt level to a 5 volt level. The 5 volt level power signals supplied from the converter **358** are transmitted to the switches **360**,**362**, and via the subconnector **376** to RF device **377**.

Controllable switch **360** controls supply of 5 volt level power signals from the level converter **358** to the microcontroller **370**, EEPROM memory **372**, and SRAM memory **374**, based upon control signals supplied to the switch **360** from the controller **384**. Controllable switch **362** controls supply of 5 volt level power signals from the level converter to the optical scanning system **364**, based upon control signals supplied to the switch **362** by the controller **370**.

Thus, when the control signals supplied to the switch **356** by the controller **384** causes the switch **356** not to permit flow of power from the source **350** through the switch **356**, the RF device **377** is powered-down (i.e., deactivated), and the microcontroller **370**, optical scanning system **364**, and memories **372**, **374** are also powered-down, regardless of the states of the switches **360**, **362**. However, when the switch **356** permits flow of power from the source **350** through the switch **356**, and the control signals supplied to the switch **360** by the controller **384** cause the switch **360** not to permit flow of power from the source **350** through the switch **360**, the RF device is activated, but the microcontroller **370**, memories **372**,**374**, and optical scanning system **364** are deactivated. The optical scanning system **364** is deactivated in this situation since controllable switch **362** is adapted not to permit flow of power through switch **362** in the absence of supply of control signals to the switch **362** from the microcontroller **370**, and such control signals cannot be supplied to the switch **362** in such situation, since controller **370** is deactivated.

When controller **384** is ready to enter sleep mode, controller **384** informs microcontroller **370** of same. Microcontroller **370** then saves its current program status into memory **374**, and informs controller **384** that controller **384** is permitted to enter sleep mode, whereupon, controller **384** commands switch **356** to no longer permit flow of power through switch **356**. This causes the RF device **376**, microcontroller **370**, memories **372**, **374**, and optical scanning system **364** to be powered-down. Controller **384** then enters its power-conserving sleep mode.

While controller **384** is in sleep mode, controller **384** periodically generates control signals for causing switch **356** to be in a state wherein RF device **377** is activated and initializes the RF device **377** (in a manner that will be described in greater detail below), so as to permit reception of signals being transmitted to the RF device **377** via the appropriate wireless link from the remote management controller/processor responsible for controlling the optical imaging device of which the RF device **377** is a part. Any such received signals are processed by the RF device (in the manner that will be described below in connection with the specific construction and operation of the RF device **377**) to convert same into digital data bit stream useable by the controller **384**, which bit stream is transmitted to the controller **384** via the connector **376**.

Receipt by the controller **384** of the bit stream from the RF device **377** causes the controller **384** to enter active mode. The controller **384** then commands switch **360** to permit flow of power therethrough, thereby powering-up controller **370** and memories **372**, **374**. Microcontroller **370** restores its previously stored status from the memories, and informs controller **384** once controller **370** is in a stable internal state for receipt of data, whereupon, controller **384** transmits the data received from the RF device **377** to the microcontroller **370**.

Microcontroller **370** is programmed (via appropriate program code stored in memory **372**) to decode the data stream whereby to determine which commands are present in the data stream, and whether those commands are intended to be executed by the optical imaging device of which the microcontroller **370** is a part (e.g., whether the remote management controller/processor issuing the commands is the one responsible for controlling the optical imaging device receiving such commands and, if so, whether such commands identify the optical imaging device receiving such commands as being required to execute same).

As noted previously, such commands may include commands to the optical imaging device receiving such commands from the remote management controller/processor responsible for the device to generate and transmit image data representative of the meter face to which the device is attached. If such commands are determined by the microprocessor **370** to be present in the data stream supplied to the microprocessor **370** from the controller **384**, microcontroller **370** generates control signals causing switch **362** to power-up optical scanning system **364**, and also for causing optical scanning system **364** to generate the image data representative of the meter face and to transmit such image data to the microcontroller **370**, in the manner described more fully below. Preferably, switch **362** is only commanded by the microprocessor **370** to permit flow of power to the optical scanning system **364** when it is desired to generate such image data. The microcontroller **370** then transmits the image data (and identifying data discussed more fully below) to the controller **384**, which transmits the image data to the RF device **377** via the subconnector **376**. RF device **377** then converts (in the manner described more fully below) the image data into spread spectrum transmission signals which are transmitted to the remote management

controller/processor responsible for controlling the optical imaging device of which the device **377** is a part. Microprocessor **370** then transmits control signals to the RF device **377** via the controller **384** and connector **376** to cause the RF device **377** to switch to a reception mode from its previous transmission mode.

Once the remote management controller/processor intended to receive the spread spectrum transmission signals representative of the image data actually does receive (and processes, in manner described more fully below) such signals, the remote management controller/processor transmits spread spectrum signals indicative of such receipt together with spread spectrum signals indicative of the optical imaging device from which the spread spectrum signals representative of the image data was received. The RF device **377** of the optical imaging device receives such receipt acknowledgment signals from the remote management controller/processor, processes them (in the manner described more fully below) to produce a data bit stream representative of such signals, and transmits the bit stream to the controller **384** via the connector **376**. The controller **384** transmits the bit stream to the controller **370**, which controller **370** is programmed to decode the bit stream to determine therefrom that remote management controller/processor to which the spread spectrum signals indicative of the image data was transmitted has received same. The microcontroller **370** then completes execution of any other commands received from the remote management controller/processor responsible for controlling the optical imaging device of which the microcontroller **370** is a part, and thereafter, signals the controller **384** that processing of all such commands has been completed.

Upon receipt of such signals from the microcontroller **370**, microcontroller **384** determines whether the aforesaid conditions are present under which microcontroller **384** is programmed to enter low-power mode. If such conditions are present, microcontroller **384** then informs the controller **370** that controller **384** is ready to enter sleep mode, and upon receipt from the controller **370** that controller **370** is ready to be powered down, microcontroller **384** powers down the RF device **376**, microcontroller **370**, memories **372**, **374**, and optical scanning system **364**, and enters power-conserving sleep mode, in accordance with the procedure previously described.

Turning now to FIG. **29** , the preferred construction and operation of the optical scanning system **364** will now be described. System **364** preferably comprises a conventional multi-element monochrome charge-coupled device (CCD) array sensor **452** (e.g., comprising Texas Instruments, Inc. TC211 192×165-pixel CCD image sensor), which array sensor **452** is mounted on the underside of the motherboard of the optical imaging device of which the sensor **452** is a part so as to able to scan the meter face to which the optical imaging device is attached. When switch **362** is commanded by microcontroller **370** to permit flow of power into the optical scanning system **364**, such power is provided to light exposure control sensor **464** and illumination source **462**, and permits these components **464**, **462** to be activated when microcontroller **370** also provides enabling signals to said components. Without such enabling signals from these controller **370**, components **464**, **462** cannot become activated.

Also, when the switch **362** is commanded by the microcontroller **370** to permit flow of power into the optical scanning system, such power is converted to a 12-volt level by level shifter **450** and this 12-volt power level is supplied by the shifter **450** to the sensor **452**, and buffer and preamplifier **460**, to active these components **452**, **460**.

When activated, illumination source (e.g. comprising a conventional light emitting diode) **462** provides sufficient light to the meter face to which the imaging device, comprising the illumination source **462**, is attached to enable the sensor **452** to be able to generate useful image data representative of the meter face when commanded to do so by the controller **370**; light exposure control sensor **464** (e.g., comprising a conventional photodiode or phototransistor) generates signals representative of lighting strength adjacent the meter face, and transmits said signals to the controller **370**.

Controller **370** determines from the signals generated by the sensor **464** if sufficient lighting conditions exists adjacent the meter face to enable generation by the sensor **452** of such useful image data, and if such conditions exist, appropriate control signals are generated by the microprocessor **370** and applied to the anti-bluming, image area, and serial register gates (not shown) of the sensor **452**, via level shifters **458**, **454**, **456**, respectively, for causing the sensor **452** to generate transmit said useful image data to the micro-controller **370** (via buffer and pre-amplifier circuitry **460**). The level shifters **458**, **454**, **456**, respectively, comprise conventional circuitry for converting the respective voltage levels of the control signals generated by the micro-controller **370** for appropriately controlling the anti-bluming, image area, and serial register gates, respectively, of the sensor **452** to those respective voltage levels appropriate for input said gates.

As will be appreciated by those skilled in the art, the control signals applied to the image area gate of the sensor **452** select which of the pixel image lines of the sensor array **452** is imaged to generate image signals (indicative of the strength of light incident to the pixels of the selected image line), which image signals are transferred to the serial register (not shown) of the sensor **452**. The control signals applied to the serial register gate of the sensor **452** cause the image signals currently present in the serial register to be serially transferred (via an output amplifier, which is not shown) to the buffer and pre-amplifier **460** circuitry, which circuitry **460** appropriately conditions for analog to digital conversion by the microprocessor **370**. The control signals applied to the image area and serial register gates of the sensor **452** by the microprocessor **370** are adapted to cause each image line of the sensor **452** to be sequentially imaged, the image signals generated thereby to be transferred to the serial register of the sensor **452**, and to cause the image signals transferred to the serial register to be transmitted to the micro-controller **370** for analog to digital conversion and transmission as image data representative of the meter face to the remote management controller responsible for commanding the optical imaging device to generate such image data.

Preferred construction and operation of the spread spectrum RF reception/transmission device **377** will now be described. It should be noted at the outset that although not shown expressly in FIG. **21** for purposes of clarity, various of the functional components shown in FIG. **21** should be understood as comprising various filtering, decoupling, impedance matching, noise choking, logic level adjusting networks, as needed, to permit the device **377** to operate in the manner described herein. As shown in FIG. **21**, RF device **377** includes a transmission/reception controller/processor **600** connected to transmission network **65**, reception network **646**, and phase-locked loop (PLL) **644**. Processor **600** preferably comprises an Intellon CELinx RF Spread Spectrum Carrier™ RF transceiver chip, which is clocked by a 25.2 MHz crystal oscillator **602**.

As will be explained more fully below, device **377** is a simplex type of transceiver, and is designed such that the antenna **622** (which preferably is designed to be primarily resonant at the central frequency of the spread spectrum signals intended to be transmitted and received by the device **377**, i.e., 915 MHz in this embodiment, and have a 50 ohm characteristic impedance at this primary resonance frequency, although the antenna **622** may be designed to be primarily resonant and have said characteristic impedance at other frequencies, e.g., 926 MHz) may only be in either a transmit mode or a receive mode at any given time. Processor **600** is able to control whether the antenna **622** is in transmit or receive mode by generating signals for controlling the state of transmit/receive mode selector switch **618**. Switch **618** preferably comprises a conventional Motorola MRFIC0903 Broadband GaAs Switch. Depending upon the state of the switch **618**, either the output of the transmission network **650** or the input of the reception network **646** is connected to the antenna **622** via impedance matching network **620** (e.g., comprising a plurality of discrete microstrip paths, and one or more inductors and/or capacitors, and designed to provide impedance matching at the primary resonance frequency of the antenna **622** between the output impedance of the switch **618** and the input impedance of the antenna **622**). It is important to note that in the absence of either control signals from the processor **600** or supply of power from the source **350** (via the switch **356**, converter **358**, and connector **376**), switch **618** will cause the antenna **622** to be in receive mode (i.e., the antenna **622** will be connected to the reception network **646** via the network **620**).

As will be described more fully below, reception network **646** processes spread spectrum signals received via antenna **622** when antenna **622** is in receive mode and device **377** is powered-up, and transmits the processed signals to the processor **600**. After receiving the signals processed by the reception network **646**, the processor **600** spread spectrum baseband decodes the processed signals based upon the reference signals supplied to the processor **600** from the clock **602** and using conventional techniques well known to those skilled in the art, to convert the processed signals into a digital data bit stream representative of the information content of the spread spectrum signals received by the antenna **622** and usable by the controller **370**, optionally performs conventional checksums on the bit stream to ensure that the bit stream consists of valid data, and transmits the bit stream to the controller **384** via the connector **376**. Preferably, the baseband frequency used in such decoding (and for encoding data desired to be transmitted from the device **377**) by the processor **600** is 4.2 to 6.3 MHz. The controller **384** then processes the bit stream in the manner previously described.

After passing through impedance matching network **616** (preferably comprising a plurality of capacitors, one or more inductors, and a plurality of microstrip lines, and designed to provide impedance matching at the central frequency of the spread spectrum signals intended to be received by the device **377** between the output impedance of the switch **618** and the input impedance of the low noise amplifier **614**), the spread spectrum signals received by the antenna **622** when the antenna **622** is in receive mode are amplified by low noise amplifier **614**. Amplifier **614** preferably is comprised within a Motorola MC13142D chip, and outputs amplified spread spectrum signals to image filter **612**. Filter **612** preferably comprises a Ceramic Dielectric Filter chip, and is a bandpass filter which permits frequencies between 902 MHz and 928 MHz to pass through the filter **612** substantially unattenuated, but attenuates signals with frequencies outside this band by about 50 dB. The filtered signals are then transmitted to a Gilbert doubly balanced down-converter mixer **610**.

Mixer **610** preferably is comprised within the same Motorola MC13142D chip comprising the low noise amplifier **614**, and receives as its down converter reference signal the output signal from the voltage controlled oscillator (VCO) **642** comprised within PLL **644**. Preferably, for reasons that will described in detail below, the output signal of the VCO **642** has a frequency of 915 MHz. This output signal is used by the mixer **610** to down convert the frequency of spread spectrum signal entering the mixer **610** such that, if, for example, the spread spectrum signal entering the mixer **610** has a central frequency of 915 MHz, the down converted spread spectrum signal exiting the mixer **610** has a central frequency of 4.2 MHz to 6.3 MHz and also has a further sideband at 14.7 to 16.8 MHz, which further sideband is attenuated.

The down converted spread spectrum signal is then transmitted to impedance matching network **608** (which preferably comprises an inductor/capacitor network, not shown). Network **608** provides impedance matching at the central frequency of the spread spectrum signal exiting the mixer **610** between the output impedance of the mixer **610** and the input impedance of the automatic gain control and low pass filter network **606**.

The spread spectrum signals exiting the impedance matching network **608** enter the network **606**, which includes an automatic gain control portion (not shown) which receives the signals exiting the network **608**, and a low pass filter network (not shown) which receives the signals exiting the automatic gain control portion of the network **606**. The low pass filter portion preferably comprises a plurality of discrete capacitors and inductors and has a 3 dB cutoff point of about 7.5 MHz. The signals filtered by the low pass filter portion of the network **606** are then amplified (preferably by between 0 and 85 dB, and most preferably by 18 dB) by the IF amplifier **605**.

The spread spectrum signals exiting the amplifier **605** are then processed by filter block **604**. Filter block **604** comprises discrete capacitor and inductor networks which together preferably have a 3 dB cutoff point at 7 MHz, and smooth the signals entering block **604** such that the spread spectrum signals exiting same resemble a changing sine wave, so as to accurately reproduce/reconstruct the original transmitting source baseband signals. The signals exiting the filter block **604** are then processed by the processor **600** in the manner discussed above. Preferably, networks **604**, **606** are constructed such that together they attenuate signals more than 3 MHz outside of the band of 4.2 to 6.3 MHz by more than 60 dB.

Transmission network **650** processes digital, spread spectrum baseband encoded signals transmitted from the processor **600** to the network **650**. Network **650** comprises bandpass and low pass filters **636** which initially receives the baseband encoded signals from the processor **600**. Filters **636** comprise a plurality of discrete inductors and capacitors, and together have a 3 dB cut off point at 7 MHz so as to smooth the spread spectrum encoded digital signals transmitted from the processor **600** so as to have a waveform resembling a changing sine wave. Advantageously, this sharp cut off for frequencies outside of this band permits the transmitting gain and frequency out of band rejection characteristics of device **377** to be superior to that possible in the prior art, as result of superior transmit spurious sideband suppression characteristics caused by such attenuation characteristics.

These smoothed signals are transmitted to Gilbert doubly-balanced up converter mixer **632** (e.g., preferably comprising a Motorola MRFIC 2002 Transmit Mixer). Carrier signals are also supplied to the mixer **632** from PLL **644**. When controller **600** supplies enable signals to mixer **632**, mixer **632** up converts the smoothed spread spectrum signals supplied thereto, using the carrier mixing signals, to generate up converted spread spectrum signals with a primary frequency of 915 MHz plus or minus 6.3 MHz. These same enable signals supplied to the mixer **632** also cause the switch **618** to connect the transmission network **650** to the antenna **622**.

The up converted spread spectrum signals are then amplified (preferably by 18 dB) by a conventional pre-amplifier **630**, which amplified signals are then supplied to transmit amplifier **626**. Transmit amplifier **626** (e.g., comprising a Motorola MRFIC0914 LDMOS Integrated Power Amplifier) has a controllable output gain which varies substantially proportionally as a function of the power level of control signals supplied thereto from variable power controller **628**. Variable power controller **628** preferably comprises a user (i.e., human) adjustable network of resistors (not shown) which receive the same enable signals from the processor **600** as those received by the mixer **632**. The attenuation provided to the enable signals received by the controller **628** is user-selectable by adjusting the resistor network (or adjustment pins associated therewith). Thus, by appropriately selecting the attenuation level provided to the enable signals by appropriately adjusting the resistor network, a user may select a desired amount of amplification to be applied to the spread spectrum signals by the transmit amplifier **626**. Preferably, the resistor network is initially set (i.e., at time of manufacturing) to cause the amplifier **626** to amplify the spread spectrum signals supplied to the amplifier **626** by about 22 dB. Depending upon the amount of amplification provided by the amplifier **626**, the output (i.e., transmit power) of the device **377** may vary between 10 mW and 950 mW.

Of course, it will be appreciated by those skilled in the art that the controller **628** need not comprise user-adjustable resistor network as discussed above. Rather, alternatively, if the device **377** is modified in ways apparent to those skilled in the art, the controller **628** may comprise a digitally programmable attenuator device that adjusts the power level of the control signals supplied to the amplifier **626** based upon digital program signals supplied thereto by the microcontroller **384**.

The spread spectrum signals amplified by the amplifier **626** are then supplied to the antenna impedance matching/second harmonic trap network **624** which processes the spread spectrum signals transmitted therethrough by providing both impedance matching at the primary frequency of the spread spectrum signals (i.e., preferably 915 MHz) between the input impedance of the switch **618** and the output impedance of the amplifier **626** and second harmonic trapping of those signals. The signals processed by the network **624** are then transmitted to the antenna **622** via the switch **618** and impedance matching network **620**.

PLL **644** comprises frequency synthesizer **638** (comprising e.g., Motorola MC145191 PLL Frequency Synthesizer) which receives as inputs control signals from controller **384** (via the connector **376**), reference frequency signals generated by the crystal oscillator **602**, and output signals from the VCO **642** (after said output signals are amplified by 18 dB by amplifier **634**). Synthesizer **638** contains at least two programmable counter registers (not shown) of appropriate respective numbers of bits to accomplish the desired functionality therefor, which functionality will be described below. A first counter register is constructed to be incremented each time the clock signal generated by clock **602** cycles one period. Each time the counter overflows, a reference pulse is generated. A second counter register is constructed to be incremented each time the output signal from the VCO **642** cycles one period. Thus, the frequency of the pulses generated by the first counter is equal to the frequency of the clock signals divided by the number of bits of the first counter. The frequency of the pulses generated by the second counter is equal to the frequency of the output signal from the VCO divided by the number of bits of the second counter. The synthesizer **638** includes means (not shown) for comparing the frequency of the pulses generated by the first counter with the frequency of the pulses generated by the second counter, and for generating a feedback error signal whose voltage level varies between 0 and 5 volts, and is proportional to the degree of difference that exists between said frequencies.

The feedback error signal is supplied to low pass filter **640** (which preferably comprises low pass filter network (not shown) consisting of a plurality of discrete capacitors, resistors, and inductors, etc. configured to stabilize the VCO drive voltage.

VCO **642** preferably is comprised in the same Motorola MC13142D chip comprising the mixer **610** and amplifier **614**. As will be readily appreciated by those skilled in the art, VCO **642** is constructed such that the frequency of the signal output by the VCO **642** is controlled by the feedback voltage control signal output by the synthesizer to the low pass filter **640**, and the output signal from the synthesizer **638** causes the frequency of the signal output by the VCO to change until the frequencies of the pulses generated by the first and second counters are the same, at which point steady state ("lock") conditions exist. When such "lock" conditions exist, the synthesizer **638** transmits signals to the controller **384** to inform the controller **384** that such conditions are present.

In response to appropriate control signals from the controller **384**, the first and second counters may be caused to load respective numerical scale factors, which have the effect of varying the respective frequencies of the pulses generated by the counters depending upon the value of the scale factors loaded into the counters. Thus, by appropriately changing the scale factors loaded in the counter registers, the lock frequency of the VCO **642** output signal may be changed to any arbitrary frequency within the VCO's lock range. In accordance with this embodiment of the present invention, the controller **384** is programmed to store in the first and second counter registers of the synthesizer **638**, upon power-up of the device **377**, scale factors sufficient to cause the lock frequency of the output signals of the VCO **642** to be 915 MHz.

Thus, advantageously, since the output signals from the VCO **642** are to up convert the baseband encoded signals generated by the processor **600**, and to down convert the spread spectrum signals received by the antenna **622**, the frequencies at which the device **377** transmits and receives spread spectrum signals may be adjusted (i.e., tuned) over a significant range solely based upon commands issued by the microcontroller **384** to the synthesizer **638**, without the need to replace and/or physically adjust the components of the device **377**. Of course, it will be appreciated that the first and second counter registers may each comprise a plurality of counter registers which together perform the functions described above for each of the first and second counter registers.

As discussed previously, when microprocessor **370** desires to transmit data from device **377** transmits the data to the controller **384** with appropriate control signals for causing the controller **384** to command the device **377** to transmit this data. The data to be transmitted is temporarily stored in the data memory **374**, and controller **384** then commands the processor **600** to cause the switch **618** to connect the reception network **646** to the antenna **622**, and the controller **384** waits a predetermined time period to ascertain detect whether another (i.e., external) device is broadcasting on the same frequency as that to which the device **377** is tuned to transmit. Once the predetermined time period has passed and no such other broadcasts are detected, the controller **384** determines from the synthesizer **638** whether the VCO **642** output signals are in "lock" condition, and if such conditions do not yet exist, the controller **384** waits for same to be signaled by the synthesizer **638**.

Once such "lock" conditions are signaled to the controller **384**, the controller **384** commands the processor **600** to cause the switch **618** to connect the transmit network **650** to the antenna **622**, and to enable the mixer **632** and transmit amplifier **626**. The controller **384** then commands the processor **600** to spread spectrum baseband encode and transmit a data packet indicating that the optical imaging device of which the device **377** is a part is going to begin broadcast. In response, the processor **600** spread spectrum baseband encodes the data packet and transmits the encoded data packet to the antenna **622** via the transmission network **650** and switch **618**.

The controller **384** then commands the processor **600** again to switch the device **377** into reception mode for another predetermined time period, whereby to determine whether an external device is broadcasting on the transmission frequency of the device **377**. After such time period has passed without reception of other such broadcasts, the controller **384** commands the processor **600** to switch the device **377** into transmission mode, retrieves the data to be transmitted from memory **374**, and commands the processor **600** to encode and transmit the data as a bit stream containing preamble information identifying the optical imaging device transmitting the data and a trailer containing a checksum of the data transmitted and an end of data transmission packet symbol. In response, the processor **600** encodes and transmits the bit stream to the antenna **622** via the transmission network **650**, switch **618**, and matching network **620**.

When switch **356** is commanded to permit flow of power therethrough, this results in supply of activating power to the device **377** via the level converter **358** and subconnector **376**, and more specifically, results in supply of power to the processor **600**, networks **606**, Gilbert mixers **610**, **632**, frequency synthesizer **638**, VCO **642**, amplifier **634**, low noise amplifier **614**, controllable switch **618**, pre-amplifier **630**, and transmission amplifier **626**. Supply of this activating power to these components causes the device **377** to be in powered-up state wherein the device **377** is able to transmit or receive spread-spectrum RF signals. Conversely, when controllable switch **356** is commanded not to permit transmission therethrough of power from the source **350**, activating power is not supplied to these components, thereby causing the device **377** to be in a powered-down state wherein the device **377** is unable to transmit or receive such signals. In the absence of instructions from the controller **384** to the processor **600** to transmit signals from the antenna **622**, when the processor **600** is activated, the processor **618** does not supply control signals to the switch **618**, thereby causing the antenna **622** (and thus, also device **377**) to be in receive mode.

The output signal from the converter **354** also used by the controller **384** to permit the controller **384** to determine based upon the strength of such signal whether the power source is in a low power state (i.e., output power from the source **350** has decreased to a level of 2.19 volts. If such a low power state is determined to exist, the controller **384** transmits data via device **377** to the remote controller/processor responsible for controlling the imaging device of which the controller **384** indicating that the controller **384** has sensed a low power condition. Upon receipt of such data, the remote controller/processor reports this information to the host processor **344** so as to permit appropriate human intervention to be initiated to correct the low power condition. Alternatively, controller **384** may be programmed to signal such low power condition when the sensed voltage level falls below 1.6 to 2 volts, and to transmit data indicating such low power condition to the remote controller/processor every time the optical imaging device of which the controller **384** is a part scans the meter to which said device is attached. Further alternatively, if modified in ways apparent to those skilled in the art, the microprocessor **370** (rather than the controller **384**) may be adapted to determine whether a low power condition exists, and to report same in the manner discussed above.

Each optical imaging device also includes both a temperature sensor **368** and a tamper/removal sensor **352**. Temperature sensor **368** preferably comprises a conventional thermistor (e.g., Dale NTHS-1206J0210K10%) for generating an output signal related to the temperature adjacent the electronic components on the mother board and the RF device **377**; the output signal generated by the sensor **368** is transmitted to the microprocessor **370** and is used by the microprocessor **370** to calculate the temperature adjacent these electronic components.

Preferably, in this embodiment of the present invention, the EEPROM memory **372** contains a look-up table relating temperatures adjacent the electronic components on the mother board and RF device **377** to expected drifts in transmission/reception frequency calibration tuning of the RF device resulting therefrom. Microcontroller **370** is programmed via appropriate program code contained in the program memory **372** to determine (based upon the calculated temperature adjacent the electronic components on the mother board and RF device **377**, and the drift in tuning calibration expected to result therefrom stored in the memory look-up table) to command the controller **384** to adjust the spread spectrum transmission and reception frequencies to which the device **377** is tuned, by controlling the synthesizer **638** to generate feedback control signals which cause the frequency of the signals output by the VCO to be appropriately adjusted, in order to ensure that the RF device **377** is in fact tuned to transmit and receive at the nominal spread spectrum central frequency to which it is desired to be set (e.g., between 902 MHz and 928 MHz, and most preferably 915 or 926 MHz).

In a similar fashion, microcontroller **370** may be programmed to ascertain the age of electronic components of RF device **377** critical to proper tuning of the device **377** (e.g., reference clock **602**), and to use this age information to adjust the spread spectrum transmission and reception frequencies to which the device **377** is tuned so as to ensure that the device **377** is in fact tuned to transmit and receive at the nominal spread spectrum central frequency to which it is desired to be set. This may be accomplished by programming controller **384** to maintain a running clock of elapsed time since installation at the customer site of the imaging device of which the controller **384** is a part, and by

storing in memory **372** a look-up table of calibration information relating the age of such components to expected drift in transmission/reception frequency calibration tuning of the RF device **377** resulting therefrom. Microcontroller **370** is programmed via appropriate program code contained in the program memory **372** to determine (based upon the age of the aforesaid electronic components, and the drift in tuning calibration expected to result therefrom stored in the memory look-up table) to command the controller **384** to adjust the spread spectrum transmission and reception frequencies to which the device **377** is tuned by controlling the synthesizer to generate feedback control signals which appropriately adjust the frequency of the signals output by the VCO, in order to ensure that the RF device **377** is in fact tuned to transmit and receive at the aforesaid nominal spread spectrum frequencies to which it is desired to be set.

Removal sensor **352** comprises a conventional means for detecting proximity of and/or engagement of the collar portion **800** of the optical imaging device housing **802** to the meter face portion **315** of the meter **308** to which the optical device **316** is attached. Preferably, proximity detector **352** comprises a conventional 3-way electromechanical switch mechanism (e.g., a Cherry DH2C-C4AA switch) **499** mounted to and within the collar portion **800** of the optical imaging device housing **802**, which switch **499** has an spring-loaded, elongate end portion **804** which is adapted to be set into engagement with the meter face portion **315** of the meter **308** when the collar portion **800** of the housing **802** is brought into engagement with the face portion **315**. When the switch **499** is set in this manner, a spring biasing force is applied to the end portion **804** by the spring-loading mechanism (not shown) of the switch **499**, which biasing force is adapted to cause the end portion **804** to drop down if the collar portion **800** (and thus, also the end portion **804**) is disengaged or otherwise moved from the meter face portion **315**. Switch **499** is adapted to close when this happens and to supply a non-maskable interrupt request signal to the controller **384**.

Upon receipt of this interrupt request signal from the switch **499**, controller **384** is programmed to begin processing of an interrupt handler routine stored in program memory **372**, which routine includes among its processing steps, causing the controller **384** to return to normal (i.e., non-low power consumption) processing mode, if prior to receipt of the interrupt request signal from the switch **499**, controller **384** was in low power mode, and powering up the microcontroller **370**, data memory means **374** and RF reception/transmission device **377** by appropriately controlling the power control switches **356** and **360** to supply power to these components, in the manner described previously. Once these components have been powered up, the controller **384** transmits to the microprocessor **370** appropriate signals for indicating to the microprocessor **370** that the collar portion **800** has been removed from engagement with the face portion **315** of the meter **308**. In response to these signals from the controller **384**, the microcontroller **370** commands the controller **384** to cause the transmission/reception device **377** to transmit to the remote controller/processor **338** that controls the optical imaging device **316**, of which the microcontroller **370** is a part, signals indicative of such removal along with the optical imaging device's identifying information.

Once the controller **338** receives these signals and identifying information, the controller **338** contacts the remote host computer processor **344** via the wide area network **342** and informs the processor **344** of removal of the optical imaging device **316** from the face portion **315** of the meter **308**. The processor **344** preferably is adapted to take appropriate steps to inform human personnel of such removal. For example, processor **344** may be adapted to display and/or sound appropriate warnings of such removal to human operators (not shown) of system **300**, and inform the utility company computer **346** whose services are being monitored by the meter **308** being removed, via appropriate signals transmitted to the computer **346** via the network **342**.

Turning now to FIGS. **20**, **35**, and **36**, a preferred construction and operation of remote controllers **338**, **340** will now be described. It should be appreciated at the outset that unless stated to the contrary, the various functional components of the controllers **338**, **340** are substantially identical to the functional components of like reference numerals in optical imaging devices **316**, **318**, **320**, **322**, **324**, **326**. As shown in FIG. **20**, in each controller **338**, **340**, the optical scanning system **364** of the optical imaging devices is replaced with a wide area network interface system **400**. Preferably, system **400** comprises conventional means **422** (e.g., including Rockwell RC224ATFPPLCC 2400 Baud modem configured in a conventional two-wire telephony direct access arrangement to interface with network **342**) for permitting the microprocessor **370** to communicate and exchange data with the host processor **344** via wide area network **342**. Preferably, microcontroller **370** only permits power to be supplied to the system **400** via switch **362** when microcontroller **370** is actively communicating with host processor **344**.

Each controller **338**, **340** also comprises a paging signal reception system **420** which is connected via a conventional 6-pin connector **402** to the controller's motherboard. The system **420** comprises a conventional paging signal reception means **410** which receives and processes (in a manner described more fully below) RF paging signals caused to be transmitted from a conventional RF paging system (not shown) by host processor **344**. Paging system reception means **410** is continually supplied with power from the power source **350**.

In each controller **338**, **340**, controller **384** preferably is programmed to put the remote management controller of which the controller **384** is a part into reduced power consumption mode when, for example, no information is being transmitted or received from the host processor **344**, another remote management controller, or optical imaging device. When these conditions are determined to exist by the microcontroller **384**, the microcontroller **384** informs the processor **370** that the controller **384** is ready to put the remote management controller of which the controller **384** is a part into such mode. In response, the processor **370** saves its current program status and related data in memory **374**, and informs the microcontroller that same has been carried out.

Once the controller **384** receives this information from the processor **370**, the controller **384** controls switches **356** and **360** to deactivate the RF device **377**, microprocessor **370**, and memories **372**, **374**. This causes system **400** to also be deactivated since microprocessor **370** is deactivated. Once this has been carried out, the controller **384** places itself into sleep mode, wherein it periodically powers-up the RF device **377** to ascertain whether messages are being sent from any of the optical imaging devices over which the remote management controller comprising the controller **384** has control. If such messages are received, the controller **384** powers up the components necessary to process such messages (and inform the host processor **344**, if necessary). Otherwise, the controller **384** maintains these components in a deactivated state.

When paging signals are received by the reception means **410** which the means **410** identifies as being intended for reception by the remote controller of which the means **410** is a part, the means **410** signals receipt of such signals to the controller **384**. This causes controller **384** return to active mode if it was previously in sleep mode, and controller **384** controls the switches **356**, **360** to power-up the RF device **377**, microprocessor **370**, and memories **372**, **374**. After reaching a stable internal state, microcontroller **370** contacts the host processor **344** via system **400** and network **342**, and requests that the host processor **344** provide it with instructions. The host processor **344** then transmits its instructions to the microprocessor **370** via the network **342** and the system **400**. Alternatively, the paging signals provided by the host processor **344** may include one or more command strings for causing the microprocessor **370** to undertake appropriate actions (i.e., initiate meter reading) without having to contact the host processor **344** for instructions.

Upon receipt of these instructions, microprocessor **370** decodes the instructions and then causes them to be carried out. For example, if the host processor's instructions include commanding one or more of the optical imaging devices to scan the respective meter faces to which they are attached, after the microprocessor **370** has decoded these instructions, the microprocessor **370** commands the controller **384** to transmit such commands to the optical imaging devices from which such scans are requested by the host processor **344**.

In response, the controller **384** causes the RF device **377** to transmit such scanning commands to the optical imaging devices from which such scanning is requested, using essentially the same transmission process described above in connection with the optical imaging devices, except that the identifying information provided in the transmission is that of the remote controller transmitting such commands, and information is included in such commands indicating that only those optical imaging devices specifically indicated in the transmission are to generate image data of the respective meter faces to which they are attached. The controller **384** of the remote controller transmitting these commands then causes the RF device **377** of the remote controller to switch into reception mode. When this transmission from the remote controller is received by the imaging devices, it is processed as described above, and the imaging devices transmit to the image data to the remote controller requesting same.

Once the respective image data are received and processed by the RF device **377** of the remote controller requesting same, the image data are transmitted to the controller **384**, which stores them in memory **374** association with the respective identifying information of the respective imaging device that produced the data. Processor **370** then retrieves the data in association with the respective identifying information, and transmits the data in association with the respective identifying information to the host processor **344** via the system **400** and network **342**.

Once the microprocessor **370** is finished carrying out all of the instructions transmitted from the host processor **344**, the microprocessor **370** informs the controller **384** of same. Once the conditions under which the controller **384** is programmed to enter sleep mode are again determined by the controller **384** to be present, the controller **384** then puts the remote controller of which the controller **384** is a part into low power consumption mode in accordance with the aforesaid procedure.

As shown in FIGS. **35** and **36**, preferably each of the remote controllers **338**, **340** comprises an outer housing **1000** made of the same material as that used for the housing of the optical imaging devices. Housing **1000** includes a rectangular portion **1002** (containing main PC board **854** and RF PC board **850**) having two separate portions **1004**, **1006** which are attached together at interface portion **1008**. A conventional solar cell and rechargeable battery power source **350** is mounted in and extends out of a triangularly shaped protrusion **1010** in portion **1004** of the rectangular portion **1002**. Housing **1000** also includes a cylindrical portion **1012** for containing antenna board **623**. Clamp mechanism **1020** extends out of portion **1004** and permits the housing **1000** to be removably attached to e.g., a telephone pole (not shown). Knock out button **1022** provides an user-actuable mechanism by which the mechanism **1020** may be released from the pole (not shown). It should be understood that although, for purposes of clarity, connection is not shown being made through the housing **1000** to the wide area network via which communication is made with the host processor **344**, such connection should be understood to exist nonetheless.

As shown in FIG. **31**, host processor **344** preferably comprises wide area network data transmission/reception interface **516** (which preferably comprises a Microsoft Internet Information Server™-based system), which interfaces the host processor **344** to the network **342** whereby to permit data exchange via the network **342** between the host processor **344** and the controllers **338**, **340**, and between the host processor **344** and the utility company computer(s) **346**. Image data and associated scanner identifying information transmitted from the controllers **338**, **340** to the host processor **344** via the network **342** are first received at the host processor **344** by the interface **516**. Interface **516** then signals receipt of such data to the administration controller **514**, which then issues commands to the interface **516** to transmit the received image data and associated scanner identifying information to network/data base data converter **500**, which converter **500** translates the image data and associated scanner identifying information from the data transmission format (e.g., a TCP/IP compatible format, such as file transfer protocol or hypertext transfer protocol) used in the network **342** to the data storage format (e.g., Microsoft SQL format) used in the database **502**. After being translated into the data format appropriate for storage in the database **502**, the image data and associated scanner identifying information are then transmitted to the database **502** which stores the image data and associated scanner identifying information. Preferably, the database **502** also contains a data file wherein each of the meter scanning devices **316**, **318**, **320**, **322**, **324**, **326** is associated by its identifying information with information related to the respective utility meter (e.g., the respective make, model, type of utility service being measured by the meter, utility customer whose service is being monitored by the respective meter, and utility company to which the meter readings are to be sent) being scanned by each of the scanning devices. Once the image data and associated scanner identifying information are stored in the database, the administration controller **514** commands the database to associate, based upon the aforesaid data file and the scanner identifying information associated with the image data stored in the database, the respective portions of the image data stored in the database with the aforesaid types of respective information related to the particular utility meters from which the respective portions of image data were generated. The database **502** then stores the respective portions of image data in data files wherein the respective portions of image data are associated with the aforesaid types of respective information related to

the particular utility meters from the respective portions of image data were generated.

The respective portions of image data stored in the latter data files are then converted by decoder **504** into the respective data related to the respective phenomena being monitored by the respective meters from which the respective portions of image data were generated. Preferably, decoder **504** accomplishes this by processing the respective portions of image data using computer image processing techniques, including optical character recognition techniques to extract, from the respective portions of image data, data indicative of the respective visual representations of the respective data indicative of measurement of the respective phenomena being monitored by the respective meters, and thereafter, to generate therefrom the respective numeric data indicative of measurement of respective phenomena being monitored by the respective meters.

More specifically, the decoder **504** may be adapted to determine whether the respective image data being processed was generated from an analog dial type of meter (via e.g., appropriate meter type information stored in the host processor's database associating the types of the meters whose faces are being scanned by the system **300** with identifying information of the respective imaging devices scanning those meters), and if the respective image data was generated from a meter type other than an analog dial type of meter, the decoder **504** may utilize Mitec Systems, Inc. Quickstrokes™ software to extract the respective numeric data from the respective image data.

Alternatively, if the decoder **504** determines that the respective image data was generated from an analog dial type of meter, the decoder **504** may be adapted to generate such numeric data by using graphical analysis (e.g., to determine from the image data the directions in which the dial pointers of the analog dial meters are pointing and to thereby derive the numeric data). In this regard, although not shown in the Figures, it should be understood that the meter faces of dial-type meters being scanned by the system **300** are masked with respective overlays for masking out unwanted features (i.e., features not desired to be scanned) of these meters, and the decoder **504** is adapted to contrast enhance the image data generated from these masked meter faces to yield respective, contrast enhanced, two color images. These images are then processed using a data thinning algorithm to reduce the amount of data to be processed by the decoder **504** to produce the numeric data. The center of mass of each of the resulting images is then determined by the decoder **504**; this algorithm essentially generates what can be thought of as a respective point lying on a respective line passing through each respective meter dial indicator, and another algorithm is used by the decoder **504** to determine therefrom slope of each of the meter dial indicators. Finally, potentially ambiguous readings slopes (e.g., 3 or 9, etc.) are identified from this information by the decoder **504**, these readings are resolved by the decoder based upon the slopes generated above by identifying from the foregoing center of mass information the line segment when ends farther from the dial indicator axis line. Image data generated from meters having plural rows of analog dials are processed by the decoder **504** by utilizing the above center of mass algorithm twice, with a biasing factor being utilized in said algorithm so as to appropriately process each of the dial indicator axis lines.

Once extracted from the respective image data, the respective numeric data is then transmitted to the database **502** by the decoder **504**, and is associated in data files with the respective portions of image data from which said respective data was generated.

In this embodiment, administration controller **514** may be programmed (e.g., in accordance with the desires of the utility companies whose operations are being monitored by the system **300**) to periodically command report generator **506** to use the information contained in these latter data files (i.e., the data files containing the respective numeric data indicative of the measurement of the respective phenomena being monitored by the respective meters, and the other information stated above, associated therewith) to generate respective report files for each of the utility companies whose operations are being monitored by the system **300**, and to store such report files in the database **502** for transmission to the utility company computer **346** for use in further processing (e.g., customer billing). In this embodiment, each such respective report file may contain (depending upon the desires of the respective utility company to which such report file is to be made available) readings of all of the respective utility company's meters made to date since the last generation of such readings by the system **300**, in association with the respective utility company customers to whom billings are to be made for services consumed in this time period, and also in association with the respective portions of image data used to generate the respective readings. The report files thus generated are then stored in the database **502**. Of course, it will be appreciated that, in addition to storing the most current of such report files, database **502** may also archive previous report files generated prior to generation of the most current report files (e.g.,. for use in statistical trend analysis to determine future trends in utility operations and service consumption, and for later recall in the event of utility customer billing disputes).

Preferably, in this embodiment, once the current report files are stored in database **502**, database **502** indicates to administration controller **514** that the current reports files have been stored. Controller **514** then causes the database **502** to transmit the current report files to the network/database data converter **500**, which converter **500** converts the report files from the data format that is appropriate for storage in database **502** to that which is suitable for data transmission over network **342**. Converter **500** then transmits the converted current report files to the interface **516**, and once the interface **516** receives the converted current report files from the converter **500**, the interface **516** signals such receipt to the administration controller **514**. Controller **514** then causes the network server **516** to transmit to each utility company **346** via the network **342** the respective current converted report file associated therewith.

Report files stored in the database **502** may also be accessed on demand by the utility companies whose operations are being monitored by system **300**. For example, when a given utility company wishes to access report files associated with its operation stored in the database **502**, the utility company may generate a request for such access in its computer system **346**, which system **346** then transmits the request to the host processor **344** (together with any required security information, such as access passwords, etc.) via the network **342**. Once transmitted to the host processor **344** via the network **342**, the request is first received at the interface server **516**, which transmits the request to the administration controller **514**. The controller **514** then verifies any required security information, and if the requested access is authorized based upon such verification, controller **514** commands database **502** to transmit to the converter **500** the record files requested by the utility **346**. Converter **500** then converts the requested record files to the form appropriate for transmission over the network **342**, and transmits the converted record files to the interface server **516**. Upon

receipt of the converted record files, server **516** signals same to the controller **514**, which controller **514** then commands the server **516** to transmit the converted record files via the network **342** to the utility company computer **346** that issued the request for such files.

Alternatively, a given utility company wishing to access report files associated with its operation stored in the database **502** may contact personnel (not shown) operating the host processor **344** via conventional means (e.g., conventional telephone service, not shown). Such personnel may then use user interface means **512** to command administration controller **514** to command database **502** to transmit the requested report files to the converter **500**. The converter **500** then converts the requested record files to the form appropriate for transmission over the network **342**, and transmits the converted record files to the interface server **516**. Upon receipt of the converted record files, server **516** signals same to the controller **514**, which controller **514** then commands the server **516** to transmit the converted record files via the network **342** to the utility company computer **346** of the utility company that requested such files.

In this embodiment, host processor **344** also controls initiation of scanning of the utility meters by the optical scanning devices. Preferably, this is accomplished by providing host processor **344** with a programmable meter read timing mechanism **510** which generates controls signals for initiating scanning of the meters by the scanners at periodic time intervals, which time intervals may be selected by a user via the user interface **512** or by appropriate control signals supplied to the host processor **344** from the utility company computer(s), as will be described in greater detail below. The control signals generated by the host timing mechanism **510** may be for causing system-wide scanning of the meters (i.e., scanning of all of the meters in the system **300** by the scanners) and/or for causing only a selected portion of the meters designated by the control signals to be scanned by a respective portion of the scanners. Thus, although for purposes of illustrating how the host processor **344** controls scanning of the meters by the scanners in the system **300** the following discussion will proceed on the basis of an example wherein the timing signals generated by the timer **510** are for causing on selected ones **308**, **306** of the meters to be scanned by certain **316**, **318** of the scanners, it should be understood that substantially the same process is undertaken when the signals generated by the timer **510** designate that all (or different ones) of the meters are to be scanned.

Returning now to the present discussion, the control signals generated by the read timer **510** are supplied to the administration means **514** which, in response, commands paging initiator **508** to supply signals to a conventional paging system (not shown) for causing the paging system to send out paging signals to the remote controller **338** that controls the scanners **316**, **318** that are to scan the meters **308**, **306** designated by the control signals generated by the timing mechanism. These paging signals are then received by the remote controller **338**, which processes them in the above-described manner, whereby to cause scanners **316**, **318** to generate image data of meters **308**, **306**, and to cause same to be sent to the host processor **344** for processing.

It should also be understood that alternatively, a user may select one or more optical imaging devices for demand reads via commands issued at user interface **512** or remotely from the utility computer **346** via network **342**, which commands cause administration controller **514** to command page initiation via initiator **508** of those remote controller(s) responsible for the selected imaging device. Preferably, the utility computer **346** includes means (not shown) for permitting the image data to be displayed in the form of one or more computer-generated images of the respective meter face or faces from which the image data was obtained.

Preferably, in this embodiment, each of the functional components of host processor **344** illustrated block form in FIG. **31** are embodied as one or more distributed computer program processes running on one or more conventional general purpose computers networked together via conventional computer networking means. More preferably, each of these functional components is embodied by running distributed computer program processes (based upon the Microsoft Visual Basic™ language) on IBM-type, Intel 80×86 (and most preferably, Pentium™) microprocessor-based personal computers networked together by conventional networking means and including such additional conventional computer, and telephonic and network communications hardware (e.g., modems) and software as is appropriate to enable performance of the stated functionality. For example, decoder **504** may comprise a plurality of computer software modules (e.g., comprising optical character recognition software modules for generating numeric data from image data from the various types of meter display means being read by the system **300**) running on one or more networked computers. Also preferably, these personal computers run the Microsoft Windows™, Windows NT™, Windows **95**™, and/or DOS™ operating systems. However, the various functional components of the host processor **344** may alternatively be constructed out of custom, dedicated electronic hardware and software, without departing from this embodiment of the present invention. Further alternatively, rather than use IBM-type PC's, host processor **344** may instead utilize SUN™ TM and/or conventional RISC-based workstations.

Thus, it is evident that there has been provided a remote data acquisition and monitoring system that fully satisfies both the aims and objectives hereinbefore set forth. Although the present invention has been described in connection with preferred embodiments and methods of use, it will be apparent to those skilled in the art that many variations, modifications, and alternatives thereof are possible without departing from the present invention. For example, although the present invention has been described in connection with preferred embodiments for use in monitoring and controlling utility service usage and/or consumption of utility services by utility customers, it should be understood that the present invention is not intended to be limited to such preferred embodiments and uses. Rather, it should be understood that if appropriately modified in ways apparent to those skilled in the art, the above-described embodiments of the present invention may be used in other remote data acquisition and processing applications, such as remote acquisition and processing of data obtained from distributed pollution metering devices for use e.g. in pollution analysis and/or control applications, remote acquisition and processing of information gathered from metering devices which generate data related to vending machine usage and/or operation, and other uses.

Additionally, as shown in FIG. **18**, a wireless communications link (also of the spread-spectrum radio frequency type, and of the same construction as that of links **328**, **334**) **336** may also be provided between controllers **338**, **340** for permitting each of the controllers **338**, **340** to ascertain whether the other controller is functioning properly. Preferably, each one of the controllers **338**, **340** periodically transmits a predetermined "ping" or inquiry signal via the link **336** to the other controller which, if the other controller

is functioning properly, causes the other controller to transmit a predetermined response signal via the link **336** to the controller that transmitted the inquiry signal. If after a predetermined number of transmissions of the inquiry signal, no response signals or incorrect response' signals are received from the controller to which such inquiry signals were sent by the controller transmitting the inquiry signals, the controller transmitting the inquiry signals assumes that the controller to which the inquiry signals were transmitted has failed, signals this failure condition via the wide area network **342** to the remote host computer processor **344**. Host processor **344** may then transmit to the controller a number of predetermined inquiry signals for generating predetermined responses by the failed controller for verifying (in a manner similar to that used by the controller signaling the failure condition to the host processor) whether the failed controller has in fact failed, or whether other conditions exist which have given rise to signaling of the failure condition to the host processor (e.g., failure of the controller signaling the failure condition to the host processor). If the controller's failure condition is verified by the host processor, the host processor may inform via the user interface **512** personnel (not shown) operating the system **300** of the failure of the failed controller, so as to permit such personnel to undertake steps to correct such failure condition in the failed controller, transmit control signals to the failed controller to deactivate same, and transmit control signals to a normally functioning controller that is closest to the failed controller to cause the normally functioning controller to assume the role of a backup or redundant controller relative to the failed controller (i.e., assume the control and image data processing functions of the failed primary controller). Redundant wireless communications links (also of the spread-spectrum radio frequency type, and of the same construction as that of links **328**, **334**) **330**, **332** may be provided between controller **340** and imaging devices **316**, **318**, **320**, and between controller **338** and imaging devices **322**, **324**, **326**, respectively, to permit controller **338** to assume the role of a backup controller relative to controller **340** in event of failure of controller **340**, and to permit controller **340** to assume the role of a backup controller relative to controller **338** in event of failure of controller **338**.

Likewise, the controllers **338**, **350** may be adapted to "ping" the imaging devices under their respective commands to determine whether their imaging devices are functioning properly, and if not, to determine such failure condition to the host processor **344**.

Other modifications are also possible. For example, the controllers **384** in the remote controllers **338**, **340** may be programmed to initiate timed scanning of the meters and transfer of the image data generated therefrom to the host processor **344**, thereby eliminating the need for read timer **510** in host processor **344**.

Also alternatively, if appropriately modified in ways apparent to those skilled in the art, the modem means of the remote controllers **338**, **340**, and the interface means **516** of the host processor **344**, may be replaced with appropriate U-NII communications devices for permitting wireless exchange of data between the controllers **338**, **340** and host processor **344** at frequencies located between 5.15 and 5.35 GHz or 5.725 and 5.825 GHz.

Additionally, one alternative construction **377'** of device **377** is shown in FIG. **21**A. It should be understood that unless specifically stated to the contrary, device **377'** includes substantially the same components and operates in substantially the same manner as device **377**. Device **377'** includes RF device controller **601** which preferably comprises an ATMEL 90S1200 or MICROCHIP P1C12C508 chip mounted on board **850**. Controller **601** is connected to synthesizer **638** and to controller **384** (via subconnector **376**), and may also be connected to processor **600**. In this alternative construction, controller **601** controls the central transmission/reception frequencies of the device **377** by supplying appropriate controls signals, of the type discussed previously to synthesizer **638**. Controller **601** generates these control signals based upon control signals supplied to the controller **601** from microcontroller **370** via controller **384** and subconnector **376**. In this alternative construction, these control signals from the controller **370** are adapted to cause the controller **601** to select the central transmission/reception frequency of the device **377** from three possible central frequency channels of 911.5 MHz, 915 MHz, and 918.5 MHz; controller **601** may also be programmed to cause the device **377** to enter a test or diagnostic mode of operation for determining whether device **377** is functioning properly, when appropriate control signals for commanding entry into such mode of operation are received by the controller **601** from the controller **370**.

Also alternatively, as shown in FIG. **21**A, controller **601** may also be connected to the processor **600**, and may be programmed to control data encoding and decoding by the processor **600** based upon control signals received by the controller **601** from the microcontroller **370**. Additionally, controller **601** (rather than microprocessor **370**) may be programmed (in the manner described previously in connection with microprocessor **370**) to adjust the nominal transmission/reception frequencies of the device **377** to compensate for tuning drift associated with component age so as to ensure that the device **377** actually transmits and receives at the frequencies to which it is desired to be tuned. Further alternatively, if the embodiment **300** is further modified in ways apparent to those skilled in the art so as to permit the controller **601** to be powered-up continually, controller **601** (rather than microprocessor **384**) may maintain a constant running clock of elapsed time since installation of the device of which the controller **601** is a part, and to use this information in adjusting the nominal transmission/reception tuning frequencies of the device **377** to account for tuning drift due to component aging.

Additional modifications are also possible. For example, rather than comprising an 8-bit Motorola 68HC811E2FN microprocessor, microprocessor **370** may alternatively comprise an appropriately clocked, 16-bit Motorola MC68HC 12A4 microprocessor having built-in memory access circuitry for permitting direct access and control of the memories **372**, **374** by the microprocessor **370** without the need to utilize external direct memory access circuitry, and also having phase lock loop/oscillator circuitry for receiving the clock input signal. This 16-bit microprocessor exhibits faster processing and less power consumption than the aforesaid 8-bit microprocessor. In this alternative construction, it is preferred that the microprocessor **370** directly control the transmission/reception device **377**, rather than control the device **377** via the controller **384**.

Other modifications are also possible. For example, in order to simplify the power management scheme in the controllers **338**, **340**, one or more of the controllable switches **356**, **360**, **362** may be eliminated and/or the configured differently so as to permit different components to power up and power down together (i.e., different components from those specified previously).

Similarly, if the optical imaging devices are appropriately modified in ways apparent to those skilled in the art,

switches **360**, **362** may be made to independently control supply of power from switch **356** to the scanning system **364** and transmission device **377**, respectively, based upon control signals supplied to the switches **360**, **362** by the microprocessor **370**. In this alternative construction, control of supply of power to the microprocessor **370** and memories **372**, **374** may be controlled by the controller **384** via the switch **356**.

Additionally, the optical imaging devices may also be modified to include means (not shown) for permitting the controller **384** to control and/or exchange information with systems (not shown) for managing various customer energy consumption and/or consumption of other utility services at the customer site via conventional CE-bus and LonWorks protocols.

In yet another modification, the imaging system **364** may utilize a VLSI Vision 5430 chip (not shown) or a FUGA 15D chip (marketed by C-Cam, and also not shown) for scanning the meter face. More specifically, when the imaging system **364** comprises a VLSI Vision 5430 chip, timing clock signals and pixel and frame scanning validation control signals are provided to the VLSI Vision 5430 chip by the microprocessor **370**, and control register serial input/output signals are provided bi-directionally between the microprocessor **370** and the VLSI Vision 5430 chip. Serial input/output clock signals and image data are provided from the VLSI 5430 chip to the microprocessor **370**, with the image data being amplified by an amplifier (not shown) prior to entering the VLSI 5430 chip and undergoing analog to digital conversion by an analog to digital converter comprised within the microprocessor **370**.

The FUGA 15D comprises its own analog to digital converter (not shown) for converting the image data from analog to digital form prior to transmitting same to the microprocessor **370**, and when the imaging system **364** comprises the FUGA 15D chip, the microprocessor **370** is adapted to control the FUGA 15D chip via signals provided to the FUGA 15D via the microprocessor's address and data lines (not shown) and via additional scanning control and timing signals provided to the FUGA 15D from the microcontroller **370**, essentially by utilizing a direct memory access scheme in which the FUGA 15D writes its image data directly to the data bus of the microcontroller **370**. Also, it is preferred that when the imaging system **364** comprises the FUGA 15D chip the power management scheme in the optical imaging device is modified such that switch **362** is eliminated and the imaging system **364** is powered up and down automatically with the microprocessor **370** and memories **372**, **374**.

Also, the operational flows of each of the controllers **338**, **340** and each of the optical imaging devices **316**, **318**, **320**, **322**, **324**, **326** may take other forms. For example, each time one **338** of the controllers **338**, **340** is booted up or awakens from sleep mode, the controller **338** may first determine whether it is desired for the controller **338** to undertake initialization of communications with optical imaging devices **316**, **318**, **320** within its desired optical imaging device geographic control region. This determination may be accomplished by checking to see whether certain predetermined flags in the controller's memory have set (e.g, at time of manufacture of the controller, which flags are changed after such initialization), whether the controller has been moved from a previous control region (e.g., by comparing previous readings stored in the controller's memory and generated by a conventional global positioning system (not shown) comprised within the controller with current readings provided by the global positioning system), and/or being commanded to undertake such initialization by control signals supplied thereto by the host processor **344**. If the controller **338** determines that it is desired to undertake such initialization, the controller **338** informs the host processor **344** as to the controller's initialization status and initializes itself to command scheduled readings in accordance with the host processor's schedule for same. Thereafter, the controller utilizes its reception/transmission device **377** to listen for current radio communications traffic from the other controller **340** within the control region of the controller **338**. The controller **338** records data indicative of such traffic activity in memory, and once the other controller **340** has been determined to be finished communicating with the optical imaging devices with the control region of the controller **340**, the controller **338** analyzes the traffic data to determine how to fit (i.e., time) its communication with the optical imaging devices in its control region within communications time table of the other controller **340**, so as to prevent cross-talk of the controllers **338**, **340**. Thereafter, the controller **338** enters sleep mode.

If, however, it is determined that the above initialization has already been accomplished, upon awakening or booting up, the controller **338** may determine whether it is desired to take a prescheduled read of the meters within its control region. If such prescheduled read is not desired, after synchronizing its internal meter read schedule with those of the optical imaging devices under its command (i.e., if those imaging devices are adapted to perform scheduled meter reads without being initiated by the controller **338**), the controller **338** may poll its control region to determine whether the optical imaging devices within its control region have been changed (i.e., whether optical imaging devices have been added or removed). If such change has occurred, the controller **338** may be programmed to modify its internal listing of optical imaging devices within its control region, and negotiate (e.g., exchange appropriate identifying and information, etc.) with any new optical imaging devices within the controller's control region so as to establish the controller's control over such new imaging devices; the updated information concerning the imaging devices under the controller's control is then transmitted to the host processor **344** for recording in and use by same.

However, if no such change has occurred, the controller **338** may be adapted to determine (via e.g., information stored in memory or by polling the imaging devices within its control region) whether any transfers of image data from the imaging devices under its command had been initiated but not completed when the controller **338** was last awake, and to cause any such image data to be transmitted to controller **338** for transmission to the host processor **344**. Of course, if initiation of a prescheduled read is desired, the controller **338** may prompt generation and transmission of appropriate image data from the imaging devices under its command, and transmit such image data to the host processor **344**. Thereafter, the controller **338** may enter sleep mode.

Likewise, each of the optical imaging devices may be adapted to determine upon booting up or awaking whether it is desired for the imaging device to undertake an initialization of its communications with a remote mangagement controller/processor. This determination may be made based upon whether predetermined flags in the imaging device's memory have set (e.g, at time of manufacture, which flags are changed after such initialization), or whether the imaging device has been moved from a previous control region (e.g., by comparing previous readings stored in memory and generated by a conventional global positioning system (not shown) comprised within the imaging device with current

readings provided by the global positioning system). If such initialization is determined to be desired, the optical imaging device may "listen" in its geographic area using its device **377** for polling by one of the controllers **338**, **340** for changes in the imaging devices in its control region, and when the imaging device determines that such polling has occurred, the imaging device may negotiate as described above with that controller and be included in the controller's list of imaging devices being controlled by that controller, whereafter the imaging device enters sleep mode. If, however, such initialization is not desired, the imaging device may "listen" via its device **377** for commands from the remote management controller/processor with which it last negotiated. If such commands are not forthcoming after a predetermined number of "listening" time outs, the imaging device may be adapted to seek out redundant controller by which to be controlled, in the manner described more fully above, whereafter the imaging device may enter sleep mode.

Accordingly, the present invention is intended to embrace all such variations, modifications, and alternatives as may be included within the spirit and scope of the hereinafter appended claims.

What is claimed is:

1. A data acquisition and processing system comprising at least one optical imaging device for generating computer-readable image data of a visual representation generated by a metering device of data related to at least one phenomenon being monitored by said metering device, and a host computer processor remotely located from said optical imaging and metering devices, said host processor being for generating the data related to said phenomenon from said image data and also for storing said image data, the system further comprising,

at least one controller for generating control signals for controlling generation of said image data by said at least one optical imaging device and for gathering said image data generated by said imaging device for transmission to said host processor,

a backup controller for controlling generation of said image data by said optical imaging device and for gathering said image data for transmission to said host processor, upon occurrence of failure condition of said at least one controller, and

at least one communications link between said controllers for permitting exchange of information between said controllers.

2. A data acquisition and processing system comprising at least one optical imaging device for generating computer-readable image data of a visual representation generated by a metering device of data related to at least one phenomenon being monitored by said metering device, and a host computer processor remotely located from said optical imaging and metering devices, said host processor being for generating the data related to said phenomenon from said image data and also for storing said image data, the system further comprising,

at least one controller for generating control signals for controlling generation of said image data by said at least one optical imaging device and for gathering said image data generated by said imaging device for transmission to said host processor,

a wireless communications link between said at least one controller and said imaging device for permitting transmission of said control signals from said at least one controller to said optical imaging device and transmission of said image data to said at least one controller, and wherein said at least one controller is also for transmitting image data received from said optical imaging device to said host processor,

said wireless communications link comprising one radio transmission/reception device included in said at least one controller and another radio transmission/reception device included in said at least one imaging device,

each of said transmission/reception devices comprising a phase-locked loop for generating output signals for being mixed with received radio signals for facilitating generation of incoming data signals and also for being mixed with outgoing data signals for facilitating generation of radio signals to be transmitted, said phase-locked loop having a voltage controlled oscillator for generating said output signals and a phase detector for generating feedback control signals for controlling frequency of the output signals generated by said oscillator, said phase detector including an electronically programmable frequency synthesizer for generating said feedback control signals based upon reference clock signals, said output signals, and digital control signals supplied to said synthesizer.

3. A data acquisition and processing system comprising at least one optical imaging device for generating computer-readable image data of a visual representation generated by a metering device of data related to at least one phenomenon being monitored by said metering device, and a host computer processor remotely located from said optical imaging and metering devices, said host processor being for generating the data related to said phenomenon from said image data and also for storing said image data, the system further comprising,

at least one controller for generating control signals for controlling generation of said image data by said at least one optical imaging device and for gathering said image data generated by said imaging device for transmission to said host processor,

a wireless communications link between said at least one controller and said imaging device for permitting transmission of said control signals from said at least one controller to said optical imaging device and transmission of said image data to said at least one controller, and wherein said at least one controller is also for transmitting image data received from said optical imaging device to said host processor,

said wireless communications link comprising one radio transmission/reception device included in said at least one controller and another radio transmission/reception device included in said at least one imaging device,

each of said transmission/reception devices comprising a phase-locked loop for generating output signals for being mixed with received radio signals for facilitating generation of incoming data signals and also for being mixed with outgoing data signals for facilitating generation of radio signals to be transmitted, said phase-locked loop having a voltage controlled oscillator for generating said output signals and a phase detector for generating feedback control signals for controlling frequency of the output signals generated by said oscillator, said phase detector including an electronically programmable frequency synthesizer for generating said feedback control signals based upon reference clock signals, said output signals, and digital control signals signals supplied to said synthesizer, and

each of said at least one imaging device including a microprocessor for generating said digital control sig-

nals whereby to permit said microprocessor to control generation of said feedback control signals by said synthesizer.

4. A data acquisition and processing system comprising at least one optical imaging device for generating computer-readable image data of a visual representation generated by a metering device of data related to at least one phenomenon being monitored by said metering device, and a host computer processor remotely located from said optical imaging and metering devices, said host processor being for generating the data related to said phenomenon from said image data and also for storing said image data, the system further comprising,

at least one controller for generating control signals for controlling generation of said image data by said at least one optical imaging device and for gathering said image data generated by said imaging device for transmission to said host processor,

a wireless communications link between said at least one controller and said imaging device for permitting transmission of said control signals from said at least one controller to said optical imaging device and transmission of said image data to said at least one controller, and wherein said at least one controller is also for transmitting image data received from said optical imaging device to said host processor,

said wireless communications link comprising one radio transmission/reception device included in said at least one controller and another radio transmission/reception device included in said at least one imaging device,

each of said transmission/reception devices comprising a phase-locked loop for generating output signals for being mixed with received radio signals for facilitating generation of incoming data signals and also for being mixed with outgoing data signals for facilitating generation of radio signals to be transmitted, said phase-locked loop having a voltage controlled oscillator for generating said output signals and a phase detector for generating feedback control signals for controlling frequency of the output signals generated by said oscillator, said phase detector including an electronically programmable frequency synthesizer for generating said feedback control signals based upon reference clock signals, said output signals, and digital control signals supplied to said synthesizer,

each of said at least one imaging device including a microprocessor for generating said digital control signals whereby to permit said microprocessor to control generation of said feedback control signals by said synthesizer, and

each of said at least one imaging device including a temperature sensor, and said microprocessor being adapted to control the generation of said feedback control signals by said synthesizer based at least partially upon temperature sensed by said sensor.

5. A data acquisition and processing system comprising at least one optical imaging device for generating computer-readable image data of a visual representation generated by a metering device of data related to at least one phenomenon being monitored by said metering device, and a host computer processor remotely located from said optical imaging and metering devices, said host processor being for generating the data related to said phenomenon from said image data and also for storing said image data, the system further comprising,

at least one controller for generating control signals for controlling generation of said image data by said at least one optical imaging device and for gathering said image data generated by said imaging device for transmission to said host processor,

a wireless communications link between said at least one controller and said imaging device for permitting transmission of said control signals from said at least one controller to said optical imaging device and transmission of said image data to said at least one controller, and wherein said at least one controller is also for transmitting image data received from said optical imaging device to said host processor,

said wireless communications link comprising one radio transmission/reception device included in said at least one controller and another radio transmission/reception device included in said at least one imaging device,

each of said transmission/reception devices comprising a phase-locked loop for generating output signals for being mixed with received radio signals for facilitating generation of incoming data signals and also for being mixed with outgoing data signals for facilitating generation of radio signals to be transmitted, said phase-locked loop having a voltage controlled oscillator for generating said output signals and a phase detector for generating feedback control signals for controlling frequency of the output signals generated by said oscillator, said phase detector including an electronically programmable frequency synthesizer for generating said feedback control signals based upon reference clock signals, said output signals, and digital control signals supplied to said synthesizer,

each of said at least one imaging device including a microprocessor for generating said digital control signals whereby to permit said microprocessor to control generation of said feedback control signals by said synthesizer,

each of said at least one imaging device including a temperature sensor, and said microprocessor being adapted to control the generation of said feedback control signals by said synthesizer based at least partially upon temperature sensed by said sensor, and

said microprocessor being adapted to determine age of said transmission/reception device whose synthesizer is controlled by said microprocessor and to control the generation of said feedback control signals based at least partially upon said age.

6. A system according to claim **2**, wherein each said transmission/reception device includes a transmission network, a reception network, and a controllable switch, said switch being for controllably connecting and disconnecting each of said networks to an antenna whereby to permit the antenna to operate in only one of a transmission mode and reception mode at any given time.

7. A system according to claim **6**, wherein said antenna is adapted to be primarily resonant at 915 MHz.

8. A system according to claim **6**, wherein said switch is adapted to be controlled based upon a transmission/reception mode select signal, and said transmission network is adapted to be disabled when said select signal is in a condition indicative of reception mode.

9. A system according to claim **8**, wherein said transmission network includes a transmission amplifier network adapted to be disabled when said select signal is in said condition indicative of reception mode and to be enabled when said select signal is in a condition indicative of transmission mode.

10. A system according to claim **9**, wherein said transmission network also includes a frequency up-converter

mixer for mixing said output data signals and said output signals of oscillator, said mixer being adapted to be disabled when said select signal is in said condition indicative of reception mode and to be enabled when said select signal is in a condition indicative of transmission mode.

11. A system according to claim **6**, wherein said reception network includes a frequency down-converter mixer for mixing said output signals and at least a portion of said radio signals so as to generate a pair of differential output signals for facilitating generation of said incoming data signals.

12. A system according to claim **11**, wherein said mixer comprises a double balanced Gilbert mixer.

13. A system according to claim **10**, wherein said mixer comprises a double balanced Gilbert mixer.

14. A system according to claim **9**, wherein said transmission amplifier network is also adapted to have a controllable output gain selectable based upon strength of said select signal when said select signal is in said condition indicative of transmission mode.

15. A system according to claim **14**, further comprising a controllable attenuator for controlling said strength of said select signal.

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