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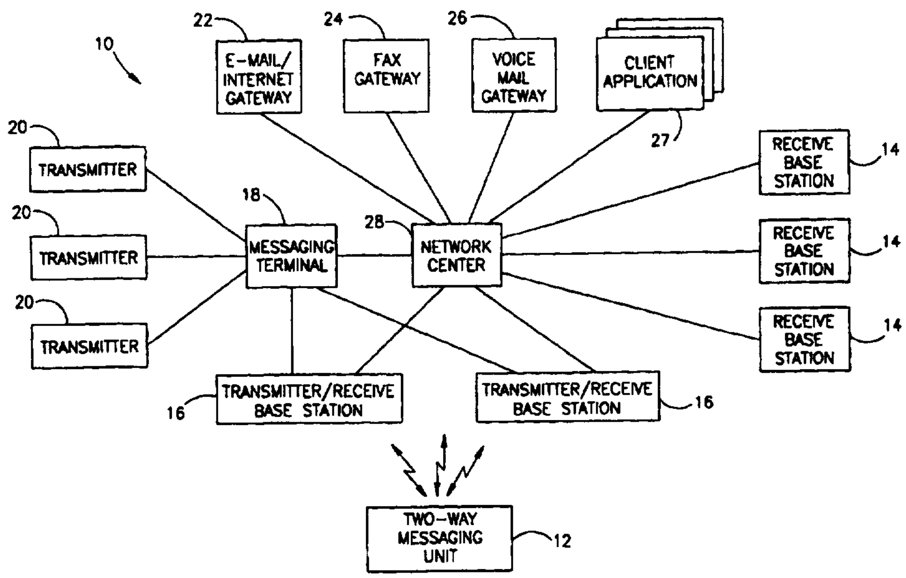

(57) Abstract

A wireless messaging system is disclosed including a two-way messaging system. The two-way messaging system utilizes conventional protocols for the downlink and a direct sequence spread spectrum transmission scheme for the uplink. Included are transmitters (16) for transmitting the downlink signal using a conventional protocol, two-way messaging units (12) for receiving signal and for transmitting a signal on the uplink using direct sequence spread spectrum techniques and receive base stations (16) for receiving the uplink signals from the two-way messaging units. The receive base stations (14) send received messages to a network center (28) for processing and forwarding to an e-mail gateway (22), fax gateway (24), voice mail gateway (26) or client applications (27). For paging applications, a messaging terminal sends messages to be transmitted to the transmitters.

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WIRELESS MESSAGING SYSTEM

FIELD OF THE INVENTION

The present invention relates to a wireless messaging system and more specifically, to a one way spread spectrum messaging system and a two-way messaging system that includes a communication downlink and a spread spectrum based communication uplink.

BACKGROUND OF THE INVENTION

Wireless communication is fast becoming one of the most rapidly growing businesses in the world today. The worldwide market for related products and services is undergoing an explosion. Within the wireless communication field, two of the fastest growing markets are those of two-way paging and telemetry, which are part of the more general market known as two-way messaging. Both the two-way paging and telemetry markets are projected to grow enormously by the year 2000. Currently, the market for two-way pagers is relatively undeveloped because the technology is relatively new. The Personal Communications Industry Association (PCIA) estimates that, in the United States, there will be 48 million one-way paging customers and 8 million two-way customers by the year 2000. Worldwide, it is estimated that the number of two-way pagers in use in the year 2000 is likely to exceed 24 million units. These estimates, however, are for narrowband systems only, they do not factor the use of broadband systems.

Traditional one-way paging systems may be characterized by the delivery of a message from a central point to a remote pager. Paging was originally developed for numeric applications only (i.e. telephone numbers of parties wishing to contact the person holding the pager). Alphanumeric one-way paging has been developed only recently, but is however, for one-way paging only. The alphanumeric one-way pagers require approximately 10 times the amount of air time as compared to numeric one-way pagers. Alphanumeric messages are generally much longer than numeric only messages and alphanumeric messaging requires a system capable of sending all the letters of the alphabet and various grammatical symbols which are not required by numeric only paging. The increase in the number of possibilities per bit of information requires coding with more bits for each symbol than would be required by a strictly numeric only system. In addition, the enhanced complexity of the alphanumeric system requires a greater allocation of system capacity for system management functions than is required for numeric only paging.

In two-way paging, the remote pager receives a message, with the human operator then possibly sending a message back to the central control point. The two-way feature makes this system unique, since in traditional paging there is no data transmission to the pager and no data acquisition by the central point. Two-way paging is typically alphanumeric, so that each message in a two-way system will consume an amount of airtime roughly equivalent to the amount of airtime consumed by any alphanumeric message. However, two-way alphanumeric paging as a system will consume more airtime than one-way alphanumeric paging, because in two-way paging, messages travel in both directions while in one-way alphanumeric paging messages travel only from the controller to the paging unit. Thus, there is a much higher volume of message traffic in a two-way system.

The market for telemetry systems is expected to grow at substantial rates over the next five years. There are approximately 2 million radio telemetry units installed in the United States. This number is expected to rise to 15 million units in the year 2000. Similar growth is expected to occur in other parts of the world. Telemetry applications include transmitting monitored information from the site of a machine or other device to some remote location. It also includes the acquisition of data from remote locations to a central point.

Telemetry by itself may not provide sufficient benefits but when coupled to a supervisory control and data acquisition (SCADA) link, it becomes very beneficial. SCADA systems include both a downlink and an uplink. The downlink conveys command and control data and the uplink conveys acquired data back to the central control. The SCADA uplink can be compared to a telemetry link since most telemetry links are one way. SCADA is important because it means that both data acquisition and supervisory control can occur in the same system. Supervisory control includes control of a device from a central location.

SCADA and telemetry systems usually operate from a fixed central point to fixed remote sites. However, in some systems the remote sites are mobile, such as when located in trucks or railroad engines.

Other applications for telemetry and SCADA are healthcare (i.e. monitoring patients' medical condition), manufacturing environments (i.e. monitoring machines, processes, inventories and tracking shipments), retail and financial markets (i.e. monitoring and controlling point-of-sale (POS) terminals, electronic cash registers, automated teller machines (ATMs), vending machines, lottery machines, computer and video game machines), traffic control (i.e. remote monitoring and control of traffic lights), utility meter reading (i.e. electric, gas, water), security systems, etc.

Recently, the Federal Communications Commission (FCC) in the Unites States allocated a portion of spectrum in the 902 to 928 MHz band to unlicensed uses, such as telemetry and two-way paging. Conventional one-way paging systems exist today that utilize narrowband channels. Currently, traditional one-way paging systems, such as POCSAG, are experiencing much congestion. This congestion is inhibiting the development of one-way alphanumeric paging as well as new two-way services such as acknowledgment paging, compressed voice, two-way paging and telemetry. In order to alleviate this congestion, the FCC recently auctioned off narrowband Personal Communications Services (PCS) radio channels in the 901-902, 930-931 and 940-941 MHz radio bands. The radio channels within these bands include channels having bandwidths of 12.5, 25 and 50 KHz.

Although current one-way paging systems operate almost exclusively on narrowband radio channels, narrowband systems provide imperfect solutions to the problem of channel congestion. Narrowband systems also do not provide a solution for the development of new two-way messaging services. The disadvantage of narrowband systems is that the data rate of the uplink or outbound link is relatively slow. The typical data rate for the downlink or inbound link on a conventional narrowband system will operate at 6.4 Kbps, while the uplink will operate at data rates between 800 bps and 9.6 Kbps depending on the channel bandwidth and infrastructure density.

Infrastructure density is related to the amount of infrastructure per unit area of territory, such as square kilometers or square miles. Infrastructure includes the three basic elements that make up a radio system, the customer end units (i.e. pagers), the base stations and the controllers. The capacity of a system is a function of the ability of the infrastructure to transmit, receive and process volumes of information traffic flow. System capacity and coverage may be enhanced by increasing the infrastructure density within the target area. Uplink speeds above

800 bps in narrowband systems will require increasingly high infrastructure densities. The maximum uplink data rate of 9.6 Kbps may require a density as high as one base station for every square mile of coverage area. Thus, rapid uplink data rates can be attained on narrowband channels but only with very heavy infrastructure costs. In addition, operators of narrowband systems face the dilemma of accepting very slow uplink speeds or increasing the uplink speed but at the cost of very high infrastructure investments coupled with high annual operating costs.

One attempt to overcome the disadvantages of the prior art utilizes the technique of spread spectrum communication techniques. Spread spectrum communications is a type of broadband radio frequency (RF) communication technique that takes a relatively narrowband message and spreads it out over a relatively much broader bandwidth. The spread spectrum approach has advantages over the narrowband approach in terms of reducing power requirements for the infrastructure and for the remote units (i.e. pagers or telemetry units), increasing cell reuse, resistance to interference and resistance to eavesdropping. These advantages translate into much lower infrastructure costs, less expensive remote units and a generally more secure system than can be offered by conventional narrowband systems.

Spread spectrum techniques include two different methods: direct sequence and frequency hopping. Direct sequence spread spectrum combines the data stream with a pseudo random spreading code running at a much higher bit rate. Each bit in the original message is represented by the much longer pseudo random code. The effect is to smear the bandwidth of the original data stream into a much longer bandwidth, providing much improved resistance to interference and noise. Frequency hopping also achieves an improvement under noisy conditions by hopping from frequency to frequency using a pseudo random pattern known to both transmitter and receiver.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a wireless messaging system that has rapid data transmission speeds and requires low infrastructure and operating costs.

It is a further object of the present invention to provide a two-way wireless messaging system that includes a communication downlink and a communication uplink.

It is also an object of the present invention to provide a one-way wireless messaging system that includes a high speed transmission rate.

Another object of the present invention is that the communication uplink, in the two-way messaging system and also in the transmission scheme in the one-way messaging system, be highly resistant to interference caused by noise, multipath and other nearby transmitters.

The present invention achieves these objects by utilizing direct sequence spread spectrum techniques in the communication uplink of the two-way messaging system and in the transmitter of the one-way messaging system.

Some of the advantages of using direct sequence spread spectrum in the transmitter of both messaging systems are outlined below. Direct sequence spread spectrum permits a much higher loading of messaging units on radio channels when compared to conventional broadcast schemes or even when compared to conventional cellular technology. This lowers the infrastructure cost per messaging unit. Using direct sequence spread spectrum for the uplink requires fewer infrastructure sites compared with the sites required by other technologies at similar data rates. This lowers the annual operating cost for system operators. The faster bit rates of the present invention permits system operators to maximize the volume of data traffic on a particular radio channel. This eliminates queue times and enables high speed applications to be deployed. Direct sequence spread spectrum also permits the messaging units to operate at lower power levels than similar units using conventional narrowband transmission schemes. Thus, the messaging units can get by with relatively inexpensive power amplifiers and less battery energy, reducing the cost of the messaging units. In addition, spread spectrum systems are highly resistant to all forms of environmental interference, including radio noise, environmental degradation, human tampering and eavesdropping.

The present invention is a wireless messaging system which includes both a one-way messaging system and a two-way messaging system. The two-way messaging system utilizes conventional protocols for the communication downlink and a direct sequence spread spectrum transmission scheme for the communication uplink. Included are transmitters for transmitting the downlink signal using a conventional downlink protocol, two-way messaging units for receiving the downlink signal and for transmitting a signal on the uplink using direct sequence spread spectrum techniques and receive base stations for receiving the uplink signal from the two-way messaging units. The one-way messaging system includes one-way messaging units for transmitting a signal using direct sequence spread spectrum techniques and receive base stations for receiving the transmitted signal from one-way messaging units. In both systems, receive base stations send received messages to a network center for processing and forwarding to an e-mail gateway, fax gateway, voice mail gateway or client applications. For paging applications, a messaging terminal sends messages to be transmitted to the transmitters. Also disclosed are the transmitter and spread spectrum receiver in the receive base stations. The power supply and spread spectrum transmitter in both messaging units are disclosed, including the receiver in the two-way messaging unit. A transmit frequency feedback scheme between the receive base station and messaging units provides frequency agility to the system. A scanning algorithm allows the receiver in the receive base stations to compensate for transmit frequency inaccuracies in the messaging units. In addition, mechanisms for reducing the effects of interference and noise in the receive base station are disclosed.

In accordance with a preferred embodiment of the present invention there is provided a two-way wireless messaging system having a communication downlink and a communication uplink, comprising at least one transmitter for generating and transmitting a downlink message on a downlink signal over said communication downlink, at least one two-way messaging unit for receiving the downlink signal on the communication downlink and extracting the downlink message therefrom. The two-way messaging unit generates and transmits an uplink message on an uplink signal over the communication uplink. The two-way messaging unit uses direct sequence spread spectrum to encode and generate the uplink signal. The system also comprising at least one receive base station for receiving and decoding the direct sequence spread spectrum uplink signal on the communication uplink from the two-way messaging unit and for extracting the uplink message therefrom.

The system also provides a network center coupled to at least one receive base station. The network center receives messages received and decoded by at least one receive base station. The system also provides an electronic mail gateway coupled to the network center, the electronic mail gateway for providing the network center access to electronic mail systems. Also provided by the system is a facsimile gateway coupled to the network center, the facsimile gateway for providing the network center with access to facsimile services. The system also provides a voice mail gateway coupled to the network center, the voice mail gateway providing the network center access to voice mail services.

In accordance with a preferred embodiment of the present invention, the system provides a transmitter/receive base station able to generate and transmit the downlink signal to the two-way messaging unit and able to receive and decode the uplink signal transmitted by the two-way messaging unit. In addition, the system includes at least one messaging terminal coupled to the transmitter and the network center. The messaging terminal for constructing downlink messages and transmitting them to the transmitter. The messaging terminal for coordinating messages transmitted with messages received by the network center.

Also provided in accordance with a preferred embodiment of the present invention is a two-way messaging unit which includes a receive antenna for receiving a downlink signal transmitted over a communication downlink, a receiver coupled to the receive antenna, the receiver for receiving the downlink signal from the receive antenna and for decoding and extracting a downlink message from the downlink signal. Also included is a spread spectrum transmitter for encoding an uplink message using spread spectrum encoding techniques and for generating an uplink signal therefrom. In addition, a transmit antenna coupled to the spread spectrum transmitter is included, the transmit antenna for transmitting the uplink signal. Also, a controller is included coupled to the receiver and the spread spectrum transmitter. The controller receives the downlink message from the receiver and generates the uplink message. In addition, a power supply is included for converting energy in an external energy source, coupled to the unit, into supply voltages for the unit.

In accordance with a preferred embodiment of the present invention the system further includes an audio indicator coupled to the controller, the audio indicator for providing an audible alarm means to the user, a vibrator coupled to the controller, the vibrator for providing a vibrating alarm means to the user, a visual indicator coupled to the controller, the visual indicator for providing a visual alarm means to the user.

The system also includes a data link coupled to the controller, the data link for interfacing an external device to the controller, a display coupled to the controller, the display for presenting information to the user, at least one button coupled to the controller, the buttons enabling a user to enter information and/or commands into the unit.

Also in accordance with a preferred embodiment of the present invention, there is provided a receive base station which includes a receive antenna for receiving a spread spectrum uplink signal transmitted over a communication uplink, an RF receiver coupled to the receive antenna, the RF receiver for receiving the spread spectrum uplink signal from the receive antenna and for mixing down the spread spectrum uplink signal to an intermediate frequency. Also included is a spread spectrum decoder coupled to the RF receiver for decoding the spread spectrum uplink signal into a baseband data message, a message processor coupled to the spread spectrum decoder for extracting a received data message, communication circuitry coupled to the message processor, the communication circuitry for transmitting the received data message over a communication link and a controller coupled to the RF receiver, the spread spectrum decoder and the message processor, the controller for controlling and coordinating the operation of the receive base station.

In addition, there is provided in accordance with a preferred embodiment of the present invention a one-way wireless messaging system which includes at least one one-way messaging unit for generating and transmitting a message carried by a transmission signal, the one-way messaging unit using direct sequence spread spectrum to encode the message and generate the transmission signal. Also included is at least one receive base station for receiving and decoding the direct sequence spread spectrum transmission signal from the one-way messaging unit and for extracting the message therefrom.

There is also provided in accordance with a preferred embodiment of the present invention a one-way messaging unit which includes a spread spectrum transmitter for encoding a message using spread spectrum encoding techniques and for generating a transmit signal therefrom, a transmit antenna coupled to the spread spectrum transmitter, the transmit antenna for transmitting the transmit signal, a controller coupled to the spread spectrum transmitter, the controller for generating the message and managing the generation of the transmit signal, and a power supply for converting energy in an external energy source, coupled to the unit, into supply voltages for the unit.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

Fig. 1 is a high level block diagram illustrating a wireless two-way messaging system built in accordance with a preferred embodiment of the present invention;

Fig. 2 is a high level block diagram illustrating the directional antennas used in the base station receiver;

Fig. 3 is a high level functional block diagram illustrating the two-way messaging unit;

Fig. 4 is a high level block diagram of the receiver portion of the two-way messaging unit;

Fig. 5 is a high level schematic diagram illustrating the RF receiver portion of the receiver in the two-way messaging unit;

Fig. 6 is a high level block diagram illustrating the spread spectrum transmitter portion of the two-way messaging unit;

Fig. 7 is a high level functional block diagram illustrating the modulator and RF transmitter portions of the spread spectrum transmitter in the two-way messaging unit;

Fig. 8 is a high level functional block diagram illustrating the power supply portion of the two-way messaging unit;

Fig. 9 is a high level schematic diagram illustrating the step-up converter portion of the power supply in the two-way messaging unit;

Fig. 10 is a high level schematic diagram illustrating the step-down converter portion of the power supply in the two-way messaging unit;

Fig. 11 is a high level block diagram illustrating the receive base station portion of the two-way messaging system;

Fig. 12 is a high level functional block diagram illustrating the RF receiver portion of the receive base station;

Fig. 13 is a high level functional block diagram illustrating the IF circuitry portion of the RF receiver section of the receiver base station;

Fig. 14 is a high level functional block diagram illustrating the spread spectrum decoder portion of the receive base station;

Fig. 15 is a high level schematic diagram illustrating the downconverter portion of the spread spectrum decoder in the receive base station;

Fig. 16 is a high level schematic diagram illustrating the matched filter/correlator portion of the spread spectrum receiver;

Fig. 17 is a high level flow diagram illustrating the process of generating and encoding a data array for transmission by the two-way messaging unit;

Fig. 18 is a high level flow diagram illustrating the process of receiving and decoding the data message in the base station receiver;

Fig. 19 illustrates the bit format for the data message transmitted from the two-way messaging unit to the receive base station;

Fig. 20 illustrates the frequency spectrum of a sample signal received by the receiver portion of the receive base station;

Fig. 21 illustrates the method of tuning the receiver portion of the receive base station to the center frequency of the signal transmitted by the two-way messaging unit;

Fig. 22 illustrates the method of adjusting the center frequency of the signal transmitted by the two-way messaging unit;

Fig. 23 is a high level block diagram illustrating the center frequency fine tuning circuitry portion of the clock circuitry in the two-way messaging unit;

Fig. 24 illustrates the detection window generated by the flywheel mechanism;

Fig. 25 is a high level block diagram illustrating a wireless one-way messaging system built in accordance with a preferred embodiment of the present invention; and

Fig. 26 is a high level functional block diagram illustrating the one-way messaging unit.

DETAILED DESCRIPTION OF THE INVENTION

A high level block diagram of a two-way messaging system, generally referenced **10**, built in accordance with a preferred embodiment of the present invention is illustrated in Figure 1. System **10** comprises both transmitters for the communication downlink and receivers for the communication uplink. A messaging terminal **18** is coupled to one or more transmitters **20**. Messaging terminal **18** can be configured for any type of downlink protocol such as any one of the protocols in use today. Typically the protocol is transmitted over the communication downlink using conventional narrowband radio channel techniques. The protocols used can be related to paging, telemetry or SCADA, security, healthcare, utility metering or any other type of downlink protocol. Messaging terminals **18** are well known in the art for conventional one-way paging systems. These conventional systems may be employed in the present invention for the communication downlink. Transmitters **20** transmit the downlink message to a plurality of two-way messaging units **12**. Two-way messaging units **12** can be configured for two-way paging, SCADA, telemetry or any other type of application utilizing a two-way communication link. Examples of existing paging protocols that can be supported by two-way messaging unit **12** are POCSAG, ERMES, FLEX and APOC. In addition, a non-paging protocol can be implemented in two-way messaging units **12** such as a SCADA protocol for SCADA or telemetry applications.

In accordance with a preferred embodiment of the present invention, one or more receive base stations **14** receive messages from two-way messaging units **12** on the communication uplink. In a preferred embodiment, receive base stations **14** receive direct sequence spread spectrum encoded radio signals from two-way messaging units **12**. In turn, receive base stations **14** relay received messages to a network center **28**. Network center **28** is coupled to receive base stations **14** and to messaging terminal **18** through communication links. The communication links from receive base stations **14** to network center **28** may comprise a modem on each end connected through an ordinary telephone line. Other communication links would work as well such as, RF modem, packet switched X.25, frame relay, asynchronous transfer mode (ATM), etc. Network center **28** is also coupled to an electronic mail (e-mail) gateway **22**, facsimile gateway **24** and a voice mail gateway **26**. Depending on the message and the service subscribed to by the customer, the received messages from receive base stations **14** may be forwarded to one or more of the coupled gateways. For example, if system **10** is implemented as a two-way paging system, two-way messaging unit **12** can respond to a received page transmitted on the communication downlink. In a preferred embodiment, the response would be transmitted, using direct sequence spread spectrum techniques, from the two-way messaging unit to one or more receive base stations **14**. Depending on the proximity of the two-way messaging unit, more than one receive base station **14** will be able to receive the transmitted message.

In addition to sending information through a gateway, receive base stations **14** transmit received messages to one or more client applications **27**. Service subscribers or other end users of the system receive the data messages from the receive base stations and process these messages using one or more custom applications **27**. For example, custom applications **27** may be used in systems such as SCADA, telemetry, vending machines, financial, etc.

Information is exchanged between network center **28** and messaging terminal **18** in order to correlate messages received from two-way messaging units **12** with the original message sent by messaging terminal **18** via transmitters **20**. In an alternative embodiment, the downlink transmitters are combined with the uplink receivers in a transmitter/receiver base station **16**. In this embodiment, transmitter/receive base stations **16** maintain communication links with both messaging terminal **18** and network center **28**. Both embodiments are not limited to one network center and one messaging terminal. A two-messaging system may comprise more than one network center and more than one messaging terminal.

For paging applications, two-way messaging units **12** can support different types of messages on the communication uplink. For example, messages may be programmed beforehand by the user into two-way messaging units **12**. In this case, the service operator at the network center must also have knowledge of the user's messages programmed into the two-way messaging units. Thus, only a short code needs to be transmitted in place of the actual message. This saves airtime and reduces the operating costs of the system. In addition, the two-way messaging unit can be preprogrammed with frequently used responses such as "yes," "no" or "I'll call you later." These messages would also be represented by much shorter codes when actually being transmitted on the uplink. Additionally, a user can form a random alphanumeric message not represented by any preprogrammed codes. These types of messages utilize the most air time and would be the most costly for a two-way paging system operator. An additional type of message supported by two-way messaging units **12** is compressed voice. A user can generate a voice message to be sent on the communication uplink.

Two-way messaging unit **12** records the voice message, formats and compresses it for transmission to the receive base stations where it is processed further.

A high level block diagram of receive base station **14** is illustrated in Figure 2. In a preferred embodiment, a receive base station comprises one or more directional antennas **30** forming an antenna array **32**. Each directional antenna **30** is coupled to a separate receiver **34**. Each receiver **34** is able to receive and decode direct sequence spread spectrum encoded signals. Both directional antennas **30** and receivers **34** can be optimized to receive signals in any radio frequency range between 800 MHz to 1 GHz, including the 902-928 MHz industrial, scientific and medical (ISM) band allocated by the FCC for unlicensed use. Many broadband personal communication services (PCS) applications currently use this unlicensed band. In addition, antennas **30** and RF receivers **34** can be optimized to receive at other frequencies such as 1.9 GHz and 2.4 GHz ISM bands. If used for a paging application, for example, a processor **38** receives the data decoded by receivers **34** and formats a message containing the data for transmission to network center **28**. Processor **38** is coupled to a telephone communication link through a modem **40**. A watchdog **36** provides a margin of safety if one or more receivers **34** or processor **38** lose control or stop operating properly. Watchdog circuits are well known in the art and can be adapted to receive base station **14**.

In two-way messaging system **10**, more than one receive base station **14** may be required in order to cover the geographic area dictated by the particular application. In addition, not every receive base station **14** needs to deploy four directional antennas **30** as illustrated in Figure 2. The actual number of directional antennas **30** will depend on the needs of the particular site. The radio frequency band of the receive base station also will depend on the application. For example, the radio frequency band will likely vary according to the country in the world the system is deployed in and the type of two-way messaging system used (i.e. paging, telemetry, SCADA, security, healthcare systems, vending machines, etc.).

A high level block diagram of two-way messaging unit **12** is illustrated in Figure 3. Two-way messaging unit **12** comprises, at the core, a controller **54** for supervising and coordinating the activities and functions of the unit. For the communication downlink, signals transmitted from transmitters **20** (Figure 1) are received by receive antenna **48**. Receiver antenna **48** is coupled to a receiver **52**, which in turn is coupled to controller **54**. For the communication uplink, controller **54** sends outgoing messages to a spread spectrum transmitter **58** which is coupled to a transmit antenna **60**. A clock circuit **56** provides clock and timing signals to controller **54**, receiver **52**, spread spectrum transmitter **58** and to other parts of two-way messaging unit **12**. Controller **54** is also coupled to a data link circuit **62** which in turn communicates with an external device **44**. Controller **54** also is coupled to various user interface devices such as a button/keypad **50**, display **64**, audio indicator **66**, a vibrator **68** and a visual indicator **70**. A power supply **46** provides the needed voltages to various parts of two-way messaging unit **12** and receives its source of power from an energy source **42**.

Receive antenna **48** is adapted to receive signals in the particular radio frequency band chosen for the application. Receiver **52** is a conventional RF narrowband receiver constructed using techniques well known in the art. For paging applications, antenna **48** and receiver **52** receives, demodulates and decodes conventional one-way downlink paging protocols, such as POCSAG, ERMES, FLEX or APOC. Based on the received message or on command from the user, a message may be transmitted on the communication uplink from two-way messaging unit **12** to receive base stations **14**. As previously described, messages can be preprogrammed or randomly entered. In either case, the message is formatted by controller **54** and passed to spread spectrum transmitter **58**. Spread spectrum transmitter utilizes direct sequence spread spectrum techniques to encode and modulate the message. The message is subsequently modulated up to the carrier frequency of the uplink, typically in the range of **800** MHz to 1 GHz but may also be in the 1.9 GHz or 2.4 GHz ISM bands. The message is then transmitted via transmit antenna **60**. Both receiver **52** and spread spectrum transmitter **58** are described in more detail below.

Two-way messaging unit **12** can be adapted for various applications such as two-way paging, SCADA, telemetry, security, vending machine data acquisition, traffic control, healthcare, etc. In applications where portability and small size are desired, an advantage of two-way messaging unit **12** is that it is able to operate from a relatively small source of energy such as a conventional AA or AAA alkaline battery. Power supply **46** uses the energy from energy source **42** to generate the various voltages needed by different components of two-way messaging unit **12**. Power supply **46** is described in more detail below.

Clock circuitry **56** generates the various clocks used throughout the two-way messaging unit. Included are clocks and other timing signals for receiver **52**, controller **54** and spread spectrum transmitter **58**. Clock circuitry **56** generates a regular operating set of clock signals and in addition, also generates clock signals at a much reduced frequency for low power operation of the two-way messaging unit circuitry. A control signal from controller **54** determines whether clock circuitry **56** generates clock signals at the normal nominal rate or at the lower frequency for power down mode of operation. In addition, clock circuitry **56** has frequency adjusting circuitry, described in more detail below, to allow fine tuning of the center frequency used to modulate the transmit signal in spread spectrum transmitter **58**. In a preferred embodiment of the present invention, clock circuitry **56** generates a 2 MHz clock for regular operation and a **32** KHz clock for reduced power mode (i.e. sleep mode) of operation.

Data link circuitry **62** provides the means for an external device **44** to communicate with the two-way messaging unit. In a preferred embodiment data link circuitry **62** provides a standard RS-232 interface to the outside world. External device **44** can be any device able to communicate via RS-232. Such devices include a personal computer (PC), handheld computers, specialized programming devices, etc. Data link circuitry is provided to enable service operators to program the units, facilitate troubleshooting and maintenance, to allow a user to program messages into the unit, download messages received from the downlink or for other related purposes.

As embodied as a two-way pager, two-way messaging unit also comprises a set of buttons and/or a keypad **50** for a user to enter messages and commands as part of the user interface of the unit. In addition, the user interface includes a display **64** such as a liquid crystal display (LCD) type, well known in the art. Display **64** is used to convey alphanumeric and other data to the user. An audible indicator **66**, such as a buzzer or other type of alarm device, provides an audible alarm to signify certain events such as when messages are received or low battery indication. A vibrator **68** provides indication to a user that messages or pages have been received. Vibrator **68** is useful when it is desirable that the user receive messages or pages without an audible alarm going off that might be disturbing to others. Unit **12** also comprises one or more visual indicators **70** to alert the user to various events such as when messages have been received. Visual indicator **70** serves as another indicating means for use by the user.

Receiver **52** is shown in more detail in Figure 4. Illustrated is receive antenna **48** coupled to receiver **52** which comprises an RF receiver **92** coupled to a decoder **94**. Communication downlink signals transmitted from transmitters **20** (Figure 1) are received by two-way messaging unit **12** via receive antenna **48**. The signal from receive antenna **48** enters RF receiver **92** which mixes down and demodulates the received signal and outputs a digital data stream representing the received message. Decoder **94** receives data bits from RF receiver **92** and decodes them in accordance with the particular protocol in use in that particular system. The output of decoder **94** is the message received such as a numeric or alphanumeric message, in the case of a two-way paging unit. In paging applications, for example, the protocol decoded may be POCSAG, ERMES, FLEX, etc. As mentioned previously, RF receiver **92** and decoder **94** can both be adapted to handle any transmitted signal suitable for a particular application, such as paging, SCADA, telemetry, security, etc. In a preferred embodiment, decoder **94** can readily be adapted to decode the POCSAG protocol using the PCO5003 or the PCF5001T integrated circuits manufactured by Philips Semiconductors, Sunnyvale, California.

The output of decoder **94** is then passed to controller **54** (Figure 3), which then alerts the user via audio indicator **66**, vibrator **68** and/or visual indicator **70**. Controller **54** also displays the message on display **64**. The user then is able to respond to the received message by using buttons/keypad **50** to key in a response.

RF receiver **92**, shown in Figure 5, will now be described in more detail. RF receiver comprises a differential band pass filter **72**, low noise amplifier **74**, phase shifters **76** and **78**, mixers **80** and **82**, local oscillator **90**, low pass filters **84** and **86** and demodulator **88**. Receive antenna **48** can be adapted to receive signals at VHF, UHF and **900** MHz frequencies and is preferably a loop antenna. Band pass filter **72** receives a differential signal from receive antenna **48** and is constructed to pass only frequencies in the band containing the message signal. The output of band pass filter **72** is also a differential signal and is input to low noise amplifier **74** which amplifies the input signal to a higher level. The differential output of low noise amplifier **74** is simultaneously input to **45** degree phase shifters **76**, **78**. Phase shifter **76** shifts its input signal +45 degrees and phase shifter **78** shifts its input signal by -45 degrees. Shifters **76**, **78** are LC networks, well known in the art, constructed to apply quadrature phase shifted RF signals, I and Q, to mixer inputs **80**, **82**. Local oscillator **90** is input to both mixers **80**, **82**. The I and Q output signals of both mixers **80**, **82** feed identical signal channels in phase quadrature. Low pass filters **84**, **86** remove the unwanted upper frequency spectrum. The I and Q outputs of both low pass filters are input to demodulator **88**. Demodulator **88** detects the relative phase of both input channel signals at each zero crossing point in either channel. In a preferred embodiment, demodulator **88** receives a signal originally modulated using frequency shift keying (FSK). If the I channel signal leads the Q channel, the FSK tone frequency lies above the local oscillator frequency (i.e. using the POCSAG protocol, the data is a `0'). If the I channel signal lags the Q channel, the FSK tone lies below the local oscillator frequency (i.e. POCSAG data `1'). The data bits output by demodulator are input to decoder **94** (Figure 4). RF receiver can be constructed using the UAA2080 paging receiver integrated circuit chip manufactured by Philips Semiconductor, Sunnyvale, California. As discussed previously, decoder **94**, receives the data bits output by RF receiver **92** and, in accordance with the particular protocol, decodes them, outputting the numeric or alphanumeric message, in the case of a paging protocol. In an alternative embodiment, RF receiver **92** performs conventional heterodyning, well known in the art, rather than the direct conversion technique illustrated in Figure 5.

Illustrated in Figure 6 is a detailed block diagram of spread spectrum transmitter **58**, used to transmit data destined for the communication uplink. Comprising a spread spectrum encoder **96**, modulator **98** and RF transmitter, spread spectrum transmitter **58** receives a block of data comprising the data message from controller **54**, encodes the data message using direct sequence spread spectrum techniques and subsequently transmits the encoded message via transmit antenna **60**. As discussed previously, controller **54** receives a block of data either from external device **44** through data link circuitry or from the buttons/keypad **50** (Figure 3). In a preferred embodiment, controller **54** adds an error correcting code (ECC), cyclic redundancy check (CRC) checksum and synchronizing (sync) words to the data message. In addition, controller **54** performs bit interleaving on the data block, preferably to a depth of eight, creating a new interleaved bitstream. In the beginning of the message, controller **54** inserts a preamble of all 0's or all 1's as a training sequence, to assist receive base stations **14** in locking onto the received signal. Spread spectrum encoder **96** receives the formatted block of data from controller **54** and performs direct sequence spreading and differential encoding functions to output baseband I and Q symbols, using techniques well known in the art.

Direct sequence spread spectrum communications takes an input data stream having a particular bit rate and spreads the bandwidth of that data stream over a bandwidth many times the original bandwidth. This is achieved by multiplying pseudo random codes or pseudo noise (PN) codes having finite bit lengths with the input bit stream. In a preferred embodiment, a pseudo random code sequence with a length of **255** is used for the spreading function. The pseudo random length code used in a preferred embodiment is a maximal length code (i.e. length of 2^N - 1). Other code lengths could also be used with varying performance results. A 4 Kbps input data bit stream achieves a final output data rate, after spreading, of 1 Mbps, generally referred to as chips per second or cps.

In a preferred embodiment, spread spectrum encoder **96** supports code division multiple access (CDMA) and time division multiple access (TDMA). These schemes allow the spread spectrum based system to support multiple simultaneous users on the same wideband channel (i.e. the **902** to **928** MHz ISM band). In a CDMA system, each CDMA receiver recovers only the end user information it is looking for (i.e. information related to the particular pseudo random code assigned to the receiver). The other direct sequence spread spectrum signals continue to look like white noise. Thus, an advantage to CDMA is that no there is no need to segregate users into distinct channels or time slots.

In a preferred embodiment, the chip rate used by spread spectrum encoder is 1 Mcps. The pseudo random code length used in a preferred embodiment is **255** bits long. A longer code is used to achieve better immunity against interference and multipath for bit rates, shorter length PN codes can be used. Depending on the modulation scheme used by modulator **98**, the input data stream is either kept as a single bit stream (i.e. I channel) or split into two alternating bit streams (i.e. I and Q channels) representing the data message to be transmitted on the uplink. In a preferred embodiment, the data message remains one data stream. In this case, the data bits of the formatted messages are multiplied or XORed by the PN code sequence. From this bit stream, a differential bit stream is created representing the difference from one output bit to the next. In an alternative embodiment of two bit streams, each stream is multiplied or XORed by the PN sequence and the output passed through a differential encoder, forming I and Q baseband channels.

Modulator **98** and RF transmitter **100** are illustrated in more detail in Figure 7. Baseband I and Q channels are input to low pass filters **102**, **104** respectively. Low pass filters **102**, **104** have a cutoff frequency of approximately 1.33 MHz. The filtered output signals are input to phase shift key (PSK) modulator **106**. In a preferred embodiment, only the I channel is used, therefore PSK modulator **106** generates a binary phase shift keyed (BPSK) output signal. In an alternative embodiment, both I and Q channels are used and PSK modulator **106** generates a quadrature phase shift keyed (QPSK) output signal. The local oscillator signal used by PSK modulator **106** is derived from frequency source **108**, synthesizer **110** and voltage controlled oscillator (VCO) **112**. Preferably a temperature compensated (TC) crystal oscillator is used for frequency source **108**. The output of frequency source **108** is coupled to synthesizer **110**, which in a preferred embodiment, is a UMA1018M manufactured by Philips Semiconductor. The output of synthesizer **110** is fed into VCO **112**. The output of VCO **112** provides the local oscillator signal for PSK modulator **106**.

The signal output from PSK modulator **106** is first amplified by RF preamplifier **114** which boosts the output of PSK modulator to approximately 7 dBm (i.e. 7 mW). The signal is then input to RF power amplifier **116**, which preferably is a PM2103A class A/B amplifier manufactured by Pacific Monolithics. RF power amplifier **116** amplifies the output of RF preamplifier **114** to a level of approximately **30** dBm, the equivalent of 1 W of RF power. The signal is then filtered to conform to FCC Part **15** regulations and matched to **50** ohm transmit antenna **60** which transmits the output signal over the air.

Power supply **46** is illustrated in more detail in Figure 8. Two-way messaging unit **12** operates from a portable energy source when embodied as a two-way paging unit or a remote SCADA or telemetry unit without a source of utility power or other constant energy source. Thus, the power requirements on power supply **46** are severe. Receiver **52** (Figure 3) draws relatively little power from energy source **42**. Spread spectrum transmitter **58**, however, draws a significantly larger amount of power. The power consumption of spread spectrum transmitter **58** is of a bursty nature, occurring only during actual transmission. During transmission, RF power amplifier **116** (Figure 7) must be supplied with sufficient power to transmit the signal at 1 W. The transmit message make take up to approximately **100** ms to transmit and RF power amplifier requires approximately **600** ma of current at 5 V. Standard alkaline or NiCad AA or AAA batteries cannot supply sufficient power to fulfill this requirement. To overcome this problem, power supply **46** utilizes a step-up converter **120** coupled to an energy storage device **122**. Energy storage device **122** is coupled to step-down converter **124**. When a message is ready to be transmitted onto the communication uplink, step-up converter **120** boosts the voltage of energy source **42**, which is typically a standard AA or AAA battery cell, from a nominal 1.5 V to approximately **25** V. The energy is stored as electrical charge on energy storage device **122**. Preferably, energy storage device **122** is a capacitor of sufficient capacity to hold the necessary charge to power RF power amplifier **116** (Figure 7). To provide sufficient charge capacity, it is readily shown that a capacitor of at least **1000** uF is required. Soft start circuitry **126**, coupled to step-up converter **120** provides a controlled smooth ramping up of the current applied to energy storage device **122**. Soft start circuitry **126** prevents huge current from flowing through energy storage device **122** initially when step-up converter **120** is first turned on.

At the time of transmission, step-down converter **124** provides sufficient current flow at the proper voltage level to power RF power amplifier **116**. The energy previously stored in energy storage device **122** is released in a controlled fashion by step-down converter **124**. Soft start circuitry **132** controls the rate of discharge of energy storage device **122** so as to prevent potentially damaging large initial currents and/or voltages. Step-down converter **124** and step-up converter are described in more detail below.

Low voltage, low current power is provided by DC/DC converter **128**. Battery voltage is stepped up to a nominal 5 V by DC/DC converter **128**. In addition, upon control of controller **54** (Figure 3), the low voltage output can be switched between 5 V nominal and 3.0 V for low power operation of the circuit. Preferably, DC/DC converter **128** is constructed around a MAX856 adjustable output step-up converter manufactured by Maxim Integrated Products, Sunnyvale, California. In addition to providing a low voltage supply, power supply **46** also supplies an intermediate voltage via intermediate DC/DC converter **130**. The input to intermediate DC/DC converter **130** is the low voltage output of low voltage DC/DC converter **128**. Intermediate voltage DC/DC converter steps the input voltage from a typical 5 V to **10** V. The MAX **680** manufactured by Maxim Integrated Products can be used to construct intermediate voltage DC/DC converter **130**.

Step-up converter circuit **120** is illustrated in more detail in Figure 9. Energy source **42**, typically a AA or AAA battery **146** is coupled to switch **134**. Switch **134** provides on/off control for two-way messaging unit **12**. Switch **134** turns power on and off to not only step-up converter **120** but also to low voltage DC/DC converter **128** (Figure 8). Step-up converter **120** comprises inductor **136**, semiconductor switch **140**, switch control circuitry **138** and diode **142**. Controller **54** (Figure 3) individually controls the on/off operation of converters **120**, **124**, **128** and **130**. Thus, each element is turned on only when required in order to reduce unnecessary power consumption.

Assuming switch **134** is closed, and controller **54** has enabled step-up converter **120**, battery voltage is applied to inductor **136**. Switch control circuitry **138** operates to open and close semiconductor switch **140**, which may be any suitable semiconductor switch, preferably an n-channel enhancement mode metal oxide semiconductor field effect transistor (MOSFET). Other types of semiconductor switches known in the art would work as well. Switch control circuitry **138** operates, preferably, at approximately **100** KHz opening and closing switch **140**. When switch **140** is closed, current flows from the battery through inductor **136** and forward biased diode **142** to charge energy storage device **122**, a large capacitor **144**. When switch **140** is opened, the back EMF generated across inductor **136** causes a voltage larger then the battery voltage to appear across capacitor **144**. Diode **142** prevents capacitor **144** from discharging through inductor **136** or switch **140**. To achieve the proper voltage/current capabilities for RF power amplifier **116** (Figure 7), capacitor **144** is charged to a voltage of approximately **25** V. As discussed previously, soft start circuitry **126** is coupled to switch control circuitry **138** and functions to prevent large initial currents through capacitor **144**.

Illustrated in Figure 10 is a more detailed schematic diagram of step-down converter **124**. Energy storage device **122**, comprising capacitor **144**, is coupled to step-down converter **124**, which comprises semiconductor switch **150**, capacitor **152**, diode **154**, inductor **158** and capacitor **156**. Step-down converter **124** operates as a conventional step-down converter, well known in the art. Switch **150** is switched on and off at a rate of approximately **100** KHz by switch control circuitry **148**, when enabled by controller **54** (Figure 3) at the moment of transmission. Inductor **158** and capacitor **156** function to reduce the nominal **25** V on capacitor **144** to approximately 5 V supplied to RF power amplifier **116**. Diode **154** prevents the back EMF of inductor **158** from discharging capacitor **156** during the time switch **150** is closed. Soft start circuitry **132** provides a smooth ramping-up of the output voltage and prevents large initial currents through the components.

Capacitor **152** functions to provide a ground reference to enable switch **150**, preferably a MOSFET device, to turn on. Initially, the source terminal of MOSFET **150** has no reference to ground. Thus, V_{GS} is zero and cannot be increased to turn the switch on. In order to create a positive V_{GS} and turn switch **150** on, capacitor **152** is used to generate a lower voltage at the source terminal. It does this by causing inductor **158** to generate a back EMF voltage lowering the source terminal voltage relative to the gate, thus turning switch **150** on.

Thus, power supply **46** provides sufficient power to RF power amplifier **116** by slowly charging an energy storage device to a higher voltage and later stepping this higher voltage down to the appropriate lower voltage and discharging the energy storage device over a relatively short time interval.

A detailed high level block diagram of receiver base station **14** is illustrated in Figure 11. Receive base station **14** comprises antenna **160**, RF receiver **162**, spread spectrum decoder **164**, message processor **166**, communication circuitry **168**, controller **172** and watchdog **170**. In operation, one or more receive base stations **14** would be deployed to cover a geographic area. The number of receive base stations **14** needed depends on the size and type of the terrain within the geographic area, among other things, for example. In operation, uplink signals transmitted from two-way messaging unit **12** are received by receiver antenna **160**. The received signal is input to an RF receiver **162** which mixes the signal down to an intermediate frequency. The signal is then decoded by spread spectrum decoder **164** which passes the spread spectrum signal through a matched filter and a correlator which function to extract the raw data bits of the transmitted message. A message processor **166** receives these raw data bits and de-interleaves the data stream, performs ECC and CRC computations. The original transmitted data message is output by message processor **166** to communication circuitry **168** which, in a preferred embodiment transmits the message over a communication link to network center **28** (Figure 1). A controller **172** directs the various components of receive base station **14** and a watchdog timer **170** assures that controller **172** continues to operate properly.

A detailed high level block diagram of RF receiver **162** is illustrated in Figure 12. The signal is received by antenna **160** and input to a band pass filter **174** having a bandwidth large enough to pass the frequency band of interest. Band pass filter **174** can be any suitably constructed passive filter but preferably is a cavity filter having a suitably large pass band. The output of band pass filter **174** is input to a low noise amplifier **176**. Amplifier **176** should preferably be located as close as possible to antenna **160** so as to minimize relatively large losses in the cable runs. The gain of amplifier **176** is set by an automatic gain control (AGC) control circuitry **196** which is configured so that the IF output of RF receiver **162** is negatively fedback to AGC control circuitry **196**. The output of low noise amplifier **176** is input to a band pass filter **178** having a suitably set pass band. The output of band pass filter **178** is input to mixer **180** which mixes the input signal with a local oscillator signal derived from a synthesizer **182**. In a preferred embodiment, the output frequency output of synthesizer is configured so that the mixer output is centered around **70** MHz. For receiving signals in the **902** to **928** MHz ISM band, the frequency of the output of synthesizer **182** is able to be varied from **972** to **998** MHz. Synthesizer **182** is preferably tunable in **400** KHz steps upon command from controller **172** (Figure 11). In a preferred embodiment, synthesizer **182** can also function to provide a spectrum analysis function. The signal received by RF receiver **162** can be scanned to determine the relative signal strength at each frequency step. This feature can optionally be used to sense the level of interference within the band of interest or to search for the uplink transmitted signal if the system is configured to allow multiple uplink transmit frequencies. Typically, synthesizer **182** is configured to output a particular frequency upon initialization and is not modified thereafter.

An IF low noise amplifier **184** amplifies the output of mixer **180** and outputs the amplified signal to band pass filter **186** which has a center frequency of **70** MHz and a pass band of suitable size. Preferably, band pass filter **186** is a surface acoustic wave (SAW) device such as the BP1042 **70** MHz SAW filter manufactured by RF Monolithics, Inc. The output of band pass filter **186** is amplified by a low noise amplifier **188**. The output of low noise amplifier **188** is input to a mixer **190**. The signal from a local oscillator **191** is mixed with the output of low noise amplifier **188**. The frequency of local oscillator **191** is preferably fixed at **64**.667 MHz and is derived from a stable crystal oscillator as known in the art. Mixer **190** downconverts the **70** MHz signal to approximately 5.33 MHz and outputs the signal to IF circuitry **192**, which is described in more detail below. The output of IF circuitry is input to a low pass filter **194** which has a suitable cutoff frequency.

A detailed high level block diagram of IF circuitry **192** is illustrated in Figure **13**. The function of IF circuitry **192** is to output a relatively constant amplitude signal regardless of the input signal amplitude. IF circuitry **192** applies AGC to the signal so that the output of IF circuitry **192** has a constant amplitude in order that the signal have the maximum dynamic range upon input to the analog to digital (A/D) converters in spread spectrum decoder **164**. AGC is accomplished using three variable gain low noise amplifiers **176** (Figure **12**), **200** and **204**. Each low noise amplifier acts an AGC stage with all three stages applying a unified effect to bring the output signal up to a level of 0 dBm. AGC control circuitry **196** receives a feedback signal from the IF output of IF circuitry **192**. A level detector **198** provides a control signal to AGC control circuitry **196** which generates suitable gain control signals for low noise amplifiers **176** (Figure **12**), **200** and **204**.

The output of mixer **190** is input to low noise amplifier **200**. The gain of low noise amplifier **200** is set by AGC control circuitry **196**. The output of amplifier **200** is input to a band pass filter **202** which, preferably, has a center frequency of 5.33 MHz. The output band pass filter **202** is input to low noise amplifier **204** whose gain control signal is provided by AGC control circuitry **196**. The amplitude of the signal output by amplifier **204** is at a constant level of -30 dBm. This signal is then amplified by fixed gain low noise amplifiers **206** and **208** which have a combined gain of **30** dB to bring the output signal level up to 0 dBm. The output of amplifier **208** is low pass filtered by filter **194** which is set to a suitable cutoff frequency.

The IF output signal is output from low pass filter **194** and input to spread spectrum decoder **164** which is illustrated in more detail in Figure **14**. The bandwidth of the IF input signal is approximately 1.33 MHz, as discussed in the section on spread spectrum transmitter **58** (Figure 6), with a center frequency of 5.33 MHz. The IF input signal is first converted to digital format by A/D converter circuitry **210**. In a preferred embodiment, the A/D converter within A/D converter circuitry **210** is clocked asynchronously at a frequency of **16** MHz. The operation of A/D converter circuitry is not phase locked to the received signal, thus the RF receiver implements incoherent detection. As discussed previously, the modulation scheme used in modulator **98** (Figure 6) may be BPSK or QPSK. Regardless of the modulation scheme, in a preferred embodiment, one A/D converter is required for the I channel. In this embodiment, the digital output of A/D converter **210** is input to a downconverter **212** which mixes the input I channel data with the signal generated by local oscillator **218**. Local oscillator generates both cosine and sine clock signals permitting a complex multiplier within downconverter **212** to generate complex summed products. Local oscillator **218** is preferably a digital numerically controlled oscillator which can be constructed using a sine wave look up table coupled to a digital to analog converter. The look up table can be configured to achieve any desired precision by varying the depth and resolution of the table. The digital downconverter/carrier tracker STEL-2130A from Stanford Telecom, Santa Clara, California can be utilized to perform the downconverter and local oscillator functions.

In an alternative embodiment, two A/D converters are utilized rather than one to digitize the IF in from the RF receiver. Two A/D converters can be used to digitize bit streams at higher rates. If two A/D converters are used, both I and Q channels would be input to downconverter **212** and a complex multiply would be performed on both, as described in more detail below. Alternatively, to digitize bit streams at higher rates, one A/D converter can still be used but it is clocked at a faster clock speed.

A detailed high level block diagram of the complex multiplier portion of downconverter **212** is illustrated in Figure **15**. In the embodiment of one A/D converter, only the I channel is input to multipliers **224** and **226**, the Q channel input is tied to ground, presenting a zero at the Q input and reducing the unit's power consumption. The Q input is coupled to multipliers **228** and **230**. The cosine signal from local oscillator **218** is coupled to multiplier **224** and **230**. The sine signal from local oscillator **218** is coupled to multipliers **226** and **228**. The I channel output signal is generated from the output of multiplier **228** subtracted from the output of multiplier **224**. The Q channel output signal is generated from the output of multiplier **226** added to the output of multiplier **230**.

Referring again to Figure **14**, the I and Q signals output from downconverter **212** are input to a matched filter/correlator **214**. Matched filter/correlator **214** comprises a **256** bit shift register for the I channel bit stream, Q channel bit stream and for the PN code sequence. The PN code sequence must be identical with the PN code sequence used in spread spectrum encoder **96** (Figure 6). Matched filter/correlator **214**, described in more detail below, looks for a correlation between the PN code sequence and the input signal data. When a match is found, the corresponding I and Q bits are output to a demodulator **216**.

A detailed high level block diagram of matched filter/correlator **214** is illustrated in Figure **16**. Matched filter/correlator **214** comprises a **256** bit shift register for the I data channel **236**, Q data channel **240** and the coefficient data **238** (i.e. PN code sequence). Coefficient data register **238** is coupled to multipliers **332** associated with both I and Q registers **236**, **240**, respectively. During each clock cycle, each bit of the PN code sequence is separately multiplied with the corresponding bit from the I and Q channel data via multipliers **332**. The **256** I channel products are summed in summer **242**. The **256** Q channel products are summed in summer **244**. The outputs of summers **242**, **244** are output as I sum and Q sum to demodulator **216** (Figure **14**). A magnitude generator **246** generates the square root of the sum of the squares of the outputs from summers **242**, **244**. The generated magnitude is input to a comparator **248** among with a threshold value stored in a threshold register **250**. Comparator **248** compares the magnitude to the threshold and outputs a detect signal when the magnitude is greater than the threshold. Preferably matched filter/correlator **214** utilizes the STEL-3310 integrated circuit manufactured by Stanford Telecom, Santa Clara, California. In a preferred embodiment, four STEL-3310 devices are cascaded together, each implementing a **64** bit coefficient register, for a total of **256** bits.

Referring again to Figure **14**, the I and Q sum outputs from matched filter/correlator **214** are input to demodulator **216**. Demodulator **216** performs BPSK or QPSK demodulation depending on the modulation scheme used in the transmitter. In a preferred embodiment, demodulator **216** performs differential BPSK demodulation. Differential demodulator **216** can be constructed using the STEL-2120 bit synchronizer/differential PSK demodulator from Stanford Telecom, Santa Clara, California. To help differential demodulator **216** lock onto the received signal, a preamble of either all 1's or all 0's is sent by the transmitter. In addition, due to inaccuracies in the frequency sources used in the transmitter, a controller **220** performs a scanning algorithm, described in more detail below. For proper reception of a 4 Kbps data stream, the output frequency of local oscillator **218** must be within 1 KHz of the center frequency of the received signal. A phase or frequency error signal is generated by demodulator **216** and fed back to controller **220** which then calculates a correction for local oscillator **218**. Controller **220** acts to close a feedback loop between demodulator **216** and downconverter **212**/local oscillator **218** combination. Controller **220** also receives the magnitude generated by magnitude generator **246** (Figure **16**). Once receive lock is achieved, it is possible that a bursty noise source or strong interference can cause matched filter/correlator **214** to lose signal detection. Consequently, the inputs to demodulator **216** are also effected by the interference, corrupting the outputs. To prevent spread spectrum decoder **164** from going out of lock and losing its detect signal, flywheel circuitry **222** functions to insert an artificially created detect signal at the proper time. Flywheel circuitry **222** is explained in greater detail below.

The process of forming a message by controller **54** (Figure 3) in two-way messaging unit **12** and the complementary process of de-formatting the message by message processor **166** will now be described in more detail. The primary function of this process is to combat interference from surrounding noise sources. Illustrated in Figure **17** is the process of formatting a message in two-way messaging unit **12**. Initially, controller **54** (Figure 3) forms the raw data block or array to be sent to receive base station **14** (Figure 1) (step 260). A CRC checksum is generated on the data array using, preferably, the standard CCITT-16 CRC check as is well known in the art (step 262). The checksum is then appended to the data block. An ECC code is then generated on the entire data block, including the CRC checksum (step 264). Preferably, the data is passed through either a Hamming coder or a convolution coder. In a preferred embodiment, a Hamming coder is used. The Hamming code process results in a bit overhead of approximately three code bits for every four data bits. Thus, in a preferred embodiment, for every seven bits, a one bit error can be corrected. The bits are then interleaved to a depth of eight (step 266). The process of interleaving prevents a burst of noise from destroying the ability of the receiver to decode the transmitted message. Using interleaving, noise or interference spanning adjacent bits result in a lost bit only every 8 bits, as opposed to consecutive bits which would destroy reception of the message. One bit error every 7 bits can be corrected by the ECC data transmitted along with the data message. To facilitate finding the beginning and end of a message, three sync words are inserted into the message (step 268). One at the beginning, one in the middle and one at the end of the data message. These sync words are unique bit patterns that allow the receiver to identify the start and end of a message. After the sync words are inserted, the preamble is inserted at the beginning of the data message (step 270). As discussed previously, the preamble may be either all 0's or all 1's. The preamble is used by the receiver to lock onto and begin decoding the received spread spectrum signal. After the preamble is added to the data message, it is passed to spread spectrum transmitter **58** (Figure 3) by controller **54** for transmission (step 272).

The process performed by message processor **166** (Figure 11) is illustrated in more detail in Figure **18**. Message processor **166** receives the I and Q data bit stream from spread spectrum decoder **164**. The I and Q bits output correspond to the original message input to spread spectrum encoder **96** (Figure 6) but interleaved by 2. Message processor **166** de-interleaves the I and Q channel data bit streams forming one bit stream (step 274). The preamble is first searched for (step 276) and then the sync words are located (step 278). Once the sync words are found, it is known that the message lies between the first and the second sync word and the second and the third sync word (step 280). The data message is then de-interleaved (step 282). Following de-interleaving, the data is passed through the ECC coders (step 284). Bit errors having rates of one in seven and lower can be corrected, in a preferred embodiment. After ECC processing, the CRC checksum is computed and compared with the transmitted checksum (step 286). After the CRC check, the complete data message is formed (step 288) and transmitted to network center **28** (Figure 1) through a communication link (step 290). Typically, receive base station **14** would be connected to network center **28** via modems utilizing ordinary telephone lines. The format of the data message as it is transmitted is shown in detail in Figure **19**. Data sections **296** and **300** include the original data array with the ECC, CRC and the interleaving having been already performed. Sync words **294**, **298** and **302** are placed at the beginning, middle and end of the data message. Preamble **292** is added to the beginning of the message.

As discussed previously, the center frequency of the signal transmitted by the transmitter can vary due to inaccuracies in the components used. Sources of inaccuracies are the crystal oscillators, for example, that may have accuracies on the order of 5 to **10** ppm. These inaccuracies may result in the transmitted signal having a center frequency skew of +/- **10** KHz. To improve reception of the transmitted signal, controller **172** (Figure 11) in receive base station **14** performs a scanning procedure which steps through a frequency range hunting for the center frequency of the transmitted signal. A frequency spectrum plot of the received signal is illustrated in Figure **20** to aid in understanding the scanning procedure. A high level flow diagram of the scan procedure is illustrated in Figure **21**. Referring to Figure **20**, the transmitted signal is modeled as a sinx/x frequency pattern. To properly receives the signal, it is desirable that the receiver local oscillator be locked onto the center frequency of the transmitted signal, represented by f_M. In general, for a range of frequencies, controller **172** steps through the range and writes a frequency value into local oscillator **191** in RF receiver **162** (Figure **12**). The magnitude generated by matched filter/correlator **214** (Figure 14) is monitored by controller **220**. The process continues until f_M is located.

Referring to Figures **20** and **21**, the scan procedure begins by initializing local oscillator **218** (step 304). The frequency of local oscillator **191** is set to f_{Low}, the lower limit of the range of frequencies to be scanned (step 306). Next, controller **172** enters into a loop comprising the following steps. First, the lower frequency f_L of the main lobe of the transmitted signal is located (step 308). To scan for f_L, controller **172** increments the local oscillator frequency value until the output of matched filter/correlator **214** crosses a certain threshold T. In a preferred embodiment, T is chosen to be higher then the anticipated level of the first side lobes of the signal but lower than the level of the main lobe. Once the frequency f_L is located, controller **172** continues scanning for f_U (step 310). To find f_U, controller **172** increments the local oscillator frequency value until the output of matched filter/correlator **214** falls below the threshold T. Once the lower and upper frequencies of the main lobe are found, the middle frequency f_M is calculated (step 312). Local oscillator **191** frequency value is set to this value f_M (step 314). If the output of matched filter/correlator **214** is above the threshold and above the values received at frequencies f_L and f_U, then it is likely that the center frequency of the main lobe has been found (step 316). As a check, the frequencies f_{LS} and f_{US} are calculated (step 317). These are the center frequencies of the lower sidelobe and upper sidelobe, respectively. The final frequency chosen is the frequency corresponding to the maximum signal magnitude among frequencies f_M, f_{LS} and f_{US} (step 319). If the frequency determined in step 312 is actually the center frequency of the main lobe than the signal magnitude at f_M will at a maximum. If f_M does have the maximum signal magnitude, the main lobe is actually to either the left or right of this lobe. Next, local oscillator **218** in spread spectrum decoder **164** is fine tuned by controller **220** (Figure 14) (step 318). Based on the error signal from demodulator **216**, controller **220** adjusts the frequency value used by local oscillator **218** to generates the reference signal for downconverter **212**. If during the scan process, f_{HIGH} is reached while searching for f_L or f_U, then an error condition is generated and the signal cannot be received.

To further overcome improve reception of the uplink signal in receive base station **14**, a preferred embodiment of the present invention includes a mechanism to adjust the center frequency of the transmitted signal in spread spectrum transmitter **58** of two-way messaging unit **12** (Figure 3). Generally, a feedback loop is created between receive base station **14** and two-way messaging unit **12**. The feedback loop is closed by controller **172** (Figure 11) transmitting a frequency correction signal or value back to the two-way messaging unit **12** on the conventional downlink. The error signal is used by controller **54** (Figure 3) in two-way messaging unit **12** to fine tune the reference clock signal input to synthesizer **110** by clock circuitry **56** in modulator **98** (Figure 7). A high level flow diagram illustrating the center frequency fine tuning procedure is shown in Figure **22**. The first step is to determine the center frequency of the actual received signal in the receive base station **14** (step 320). This is done using the scan procedure discussed above. The amount of deviation in center frequency remaining after the scan procedure is performed, is used by controller **172** to calculate a frequency error value (step 322). A control message is generated containing the frequency error value and is transmitted to two-way messaging unit **12** (step 324) using the downlink protocol. Once received by two-way messaging unit **12**, controller **54** fine tunes clock circuitry **56** using the received frequency error value (step 326). Thus, PSK modulator **106** (Figure 7) can generate a signal having much better center frequency accuracy.

The ability to alter the frequency of the transmitter (i.e. change its channel) has other applications as well, not only as a fine tuning mechanism. If, for example, the receiver senses that a particular channel is becoming overloaded or approaching capacity, it can instruct the two-way messaging units to switch their transmitters to another channel. This gives the system frequency agility and enables the system to perform frequency hopping from crowded channels to lightly loaded or other more preferable channels.

A detailed high level schematic diagram of the portion of clock circuitry **56** that enables the center frequency feedback mechanism discussed above, is illustrated in Figure **23**. Generally, a variable capacitance device such as a varactor is used to vary the total capacitance that forms a resonant circuit with a crystal oscillator. In operation, the control message is received over the conventional downlink by receive antenna **48** and receiver **52**. The message is decoded by controller **54** and a suitable frequency error value is written to a frequency error data register **340**. Digital to analog (D/A) converter **342** converts the digital error value into an analog representation and resisters **344**, **346**, **350** and capacitor **348** form a filter network for the analog signal output by D/A converter **342**. The result of the filter network is a voltage generated across a varactor **352**. The capacitance value of varactor **352** is linearly related to the voltage applied across it. Thus, the varactor capacitance combined with capacitor **356** effectively alters the capacitance across crystal **360**. The capacitance coupled across crystal **360** determines the frequency at which it will resonate. Altering the capacitance across crystal **360**, via varactor **352**, allows the frequency of the signal input to a clock generator **364** to be varied, thus altering the frequency of the clock signals sent to spread spectrum transmitter **58**. Using this mechanism, mid message fine tuning of the center frequency of the transmitted message is possible. In addition, frequency source inaccuracies in two-way messaging unit **12** can be compensated for.

Flywheel circuitry **222** in spread spectrum decoder **164** (Figure **14**) will now be described in more detail. Flywheel circuitry **222**, in a preferred embodiment of the present invention, is another mechanism to combat interference, noise and multipath in the received signal. Reference is made to Figure **24** which illustrates the bits of one of the registers **236**, **238** or **240** in matched filter/correlator **214** (Figure **16**). If the noise interference in the received signal is too large and lasts the duration of enough chip times, then reception of that bit is not possible and matched filter/correlator will not detect the bit. Consequently, demodulator **216**

(Figure **14**) will not be able to output the proper message bits. However, the use of ECC codes, CRC codes and interleaving in the transmitter, allow the receiver to recover from multiple bit hits. Once the receiver has locked onto the receive signal, a loss of a finite number of consecutive bits will not prevent correct reception of the message. Thus, flywheel circuitry **222** generates and inserts synthesized detect signals at the proper time to prevent demodulator **216** from losing signal lock. The incorrect bits from demodulator **216** are later corrected by processes within message processor **166** (Figure 11).

Flywheel circuitry **222** operates by first determining the chip position within the PN code sequence time that detect signal **330** would normally be generated for the particular message being received. This chip position is found after two or more consecutive bit detects have occurred. It then creates a gating window **328** around the chip time the detect signal would normally be generated. The width of the gate or window is approximately +/- 2 chip times around the detect signal. Thus, if after initial lock is achieved, a detect signal is not generated by matched filter/correlator **214** within window **328** a detect signal, generated by flywheel circuitry **222**, is substituted into the chip position it would normally have been generated in. Flywheel circuitry **222** reduces multipath interference by gating the false detect signals generated due to noise and multipath. Any false detect signal generated outside window **328** is gated out by flywheel circuitry **222**.

A high level block diagram of a one-way wireless messaging system, generally referred as **10**, built in accordance with a preferred embodiment of the present invention is illustrated in Figure **25**. For a one-way system only receive base stations **14** are needed, as there is no communication downlink. A one-way messaging unit **13** transmits data to one or more receive base stations **14** which are coupled through a communication link to network center **28**. Similarly as with the two-way messaging system, the one-way messaging system of Figure **25** includes gateways **22**, **24**, **26** coupled to network center **28**. In addition, network center **28** is coupled to one or more client applications **27** that receive the messages transmitted by one-way messaging units **13** and further process in accordance with the particular requirements of the user or service subscriber. Applications of one-way messaging system include data acquisition, telemetry, vending machine, or any other one-way data gathering application.

A high level block diagram of one-way messaging unit **13** is illustrated in Figure **26**. One-way messaging unit **13** is similar to messaging unit **12** illustrated in Figure 3. However, one-way messaging unit **13** does not need a receiver because it operates in a one-way only system. One-way messaging unit **13** is thus only required to transmit. Buttons **50**, display **64**, audio indicator **66**, vibrator **68** and visual indicator **70** are optionally included depending on the application. Used in connection with one-way messaging unit **13**, the purpose of these indicators might be different than that in two-way messaging unit **12**.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

CLAIMS

1. A two-way wireless messaging system having a communication downlink and a communication uplink, comprising:
   a. at least one transmitter for generating and transmitting a downlink message on a downlink signal over said communication downlink;
   b. at least one two-way messaging unit for receiving said downlink signal on said communication downlink and extracting said downlink message therefrom, said two-way messaging unit for generating and transmitting an uplink message on an uplink signal over said communication uplink, said two-way messaging unit using direct sequence spread spectrum to encode and generate said uplink signal; and
   c. at least one receive base station for receiving and decoding said direct sequence spread spectrum uplink signal on said communication uplink from said two-way messaging unit and for extracting said uplink message therefrom.
2. The system according to claim 1, further comprising a network center coupled to said at least one receive base station, said network center for receiving messages received and decoded by said at least one receive base station.
3. The system according to claim 2, further comprising an electronic mail gateway coupled to said network center, said electronic mail gateway for providing said network center access to electronic mail systems.
4. The system according to any of claims 2 - 3, further comprising a facsimile gateway coupled to said network center, said facsimile gateway for providing said network center with access to facsimile services.
5. The system according to any of claims 2 - 4, further comprising a voice mail gateway coupled to said network center, said voice mail gateway for providing said network center access to voice mail services.
6. The system according to any of claims 1 - 5, further comprising a transmitter/receive base station able to generate and transmit said downlink signal to said two-way messaging unit and able to receive

and decode said uplink signal transmitted by said two-way messaging unit.

7. The system according to any of claims 2 - 6, further comprising at least one messaging terminal coupled to said at least one transmitter and said network center, said messaging terminal for constructing said downlink messages and transmitting them to said at least one transmitter, said messaging terminal for coordinating messages transmitted with messages received by said network center.

8. A two-way wireless paging system having a communication downlink and a communication uplink, comprising:

   a. at least one transmitter for generating and transmitting a downlink message on a downlink signal over said communication downlink;

   b. at least one two-way paging unit for receiving said downlink signal on said communication downlink and extracting said downlink message therefrom, said two-way paging unit for generating and transmitting an uplink message on an uplink signal over said communication uplink, said two-way paging unit using direct sequence spread spectrum to encode and generate said uplink signal; and

   c. at least one receive base station for receiving and decoding said direct sequence spread spectrum uplink signal on said communication uplink from said two-way paging unit and for extracting said uplink message therefrom.

9. The system according to claim 8, further comprising a network center coupled to said at least one receive base station, said network center for receiving messages received and decoded by said at least one receive base station.

10. The system according to claim 9, further comprising an electronic mail gateway coupled to said network center, said electronic mail gateway for providing said network center access to electronic mail systems.

11. The system according to any of claims 9 - 10, further comprising a facsimile gateway coupled to said network center, said facsimile gateway for providing said network center with access to facsimile services.

12. The system according to any of claims 9 - 11, further comprising a voice mail gateway coupled to said network center, said voice mail

gateway for providing said network center access to voice mail services.

13. The system according to claim 8 - 12, further comprising a transmitter/receive base station able to generate and transmit said downlink signal to said two-way paging unit and able to receive and decode said uplink signal transmitted by said two-way paging unit.

14. The system according to claim 9 - 13, further comprising at least one messaging terminal coupled to said at least one transmitter and said network center, said messaging terminal for constructing said downlink messages and transmitting them to said at least one transmitter, said messaging terminal for coordinating messages transmitted with messages received by said network center.

15. A two-way wireless supervisory control/telemetry system having a communication downlink and a communication uplink, comprising:

a. at least one transmitter for generating and transmitting a downlink message on a downlink signal over said communication downlink;

b. at least one two-way supervisory control/telemetry unit for receiving said downlink signal on said communication downlink and extracting said downlink message therefrom, said two-way supervisory control/telemetry unit for generating and transmitting an uplink message on an uplink signal over said communication uplink, said two-way supervisory control/telemetry unit using direct sequence spread spectrum to encode and generate said uplink signal; and

c. at least one receive base station for receiving and decoding said direct sequence spread spectrum uplink signal on said communication uplink from said two-way supervisory control/telemetry unit and for extracting said uplink message therefrom.

16. The system according to claim 15, further comprising a network center coupled to said at least one receive base station, said network center for receiving messages received and decoded by said at least one receive base station.

17. The system according to claim 16, further comprising an electronic mail gateway coupled to said network center, said electronic mail

gateway for providing said network center access to electronic mail systems.

18. The system according to any of claims 16 - 17, further comprising a facsimile gateway coupled to said network center, said facsimile gateway for providing said network center with access to facsimile services.

19. The system according to any of claims 16 - 18, further comprising a voice mail gateway coupled to said network center, said voice mail gateway for providing said network center access to voice mail services.

20. The system according to any of claims 15 - 19, further comprising a transmitter/receive base station able to generate and transmit said downlink signal to said two-way supervisory control/telemetry unit and able to receive and decode said uplink signal transmitted by said two-way supervisory control/telemetry unit.

21. The system according to any of claims 16 - 20, further comprising at least one supervisory control terminal coupled to said at least one transmitter and said network center, said supervisory control terminal for constructing said downlink messages and transmitting them to said at least one transmitter, said supervisory control terminal for coordinating messages transmitted with messages received by said network center.

22. A two-way messaging unit comprising:

a. a receive antenna for receiving a downlink signal transmitted over a communication downlink;

b. a receiver coupled to said receive antenna, said receiver for receiving said downlink signal from said receive antenna and for decoding and extracting a downlink message from said downlink signal;

c. a spread spectrum transmitter for encoding an uplink message using spread spectrum encoding techniques and for generating an uplink signal therefrom;

d. a transmit antenna coupled to said spread spectrum transmitter, said transmit antenna for transmitting said uplink signal;

e. a controller coupled to said receiver and said spread spectrum transmitter, said controller for receiving said downlink message from said receiver and for generating said uplink message; and

f. a power supply for converting energy in an external energy source, coupled to said unit, into supply voltages for said unit.

23. The unit according to claim 22, further comprising an audio indicator coupled to said controller, said audio indicator for providing an audible alarm means to said user.

24. The unit according to any of claims 22 - 23, further comprising a vibrator coupled to said controller, said vibrator for providing a vibrating alarm means to said user.

25. The unit according to any of claims 22 - 24, further comprising a visual indicator coupled to said controller, said visual indicator for providing a visual alarm means to said user.

26. The unit according to any of claims 22 - 25, further comprising a data link coupled to said controller, said data link for interfacing an external device to said controller.

27. The unit according to claim 26, wherein said data link is an RS-232 data link.

28. The unit according to any of claims 22 - 27, further comprising a display coupled to said controller, said display for presenting information to a user.

29. The unit according to any of claims 22 - 28, further comprising at least one button coupled to said controller, said at least one button enabling a user to enter information and/or commands into said unit.

30. A receive base station comprising:

a. a receive antenna for receiving a spread spectrum uplink signal transmitted over a communication uplink;

b. an RF receiver coupled to said receive antenna, said RF receiver for receiving said spread spectrum uplink signal from said receive antenna and for mixing down said spread spectrum uplink signal to an intermediate frequency;

c. a spread spectrum decoder coupled to said RF receiver for decoding said spread spectrum uplink signal into a baseband data message;

d. a message processor coupled to said spread spectrum decoder for extracting a received data message;

e. communication circuitry coupled to said message processor, said communication circuitry for transmitting said received data message over a communication link; and

f. a controller coupled to said RF receiver, said spread spectrum decoder and said message processor, said controller for controlling and coordinating the operation of said receive base station.

31. The receive base station according to claim 30, wherein spread spectrum decoder decodes a direct sequence spread spectrum uplink signal.

32. A one-way wireless messaging system comprising:

a. at least one one-way messaging unit for generating and transmitting a message carried by a transmission signal, said one-way messaging unit using direct sequence spread spectrum to encode said message and generate said transmission signal; and

b. at least one receive base station for receiving and decoding said direct sequence spread spectrum transmission signal from said one-way messaging unit and for extracting said message therefrom.

33. A one-way messaging unit comprising:

a. a spread spectrum transmitter for encoding a message using spread spectrum encoding techniques and for generating a transmit signal therefrom;

b. a transmit antenna coupled to said spread spectrum transmitter, said transmit antenna for transmitting said transmit signal;

c. a controller coupled to said spread spectrum transmitter, said controller for generating said message and managing the generation of said transmit signal; and

d. a power supply for converting energy in an external energy source, coupled to said unit, into supply voltages for said unit.

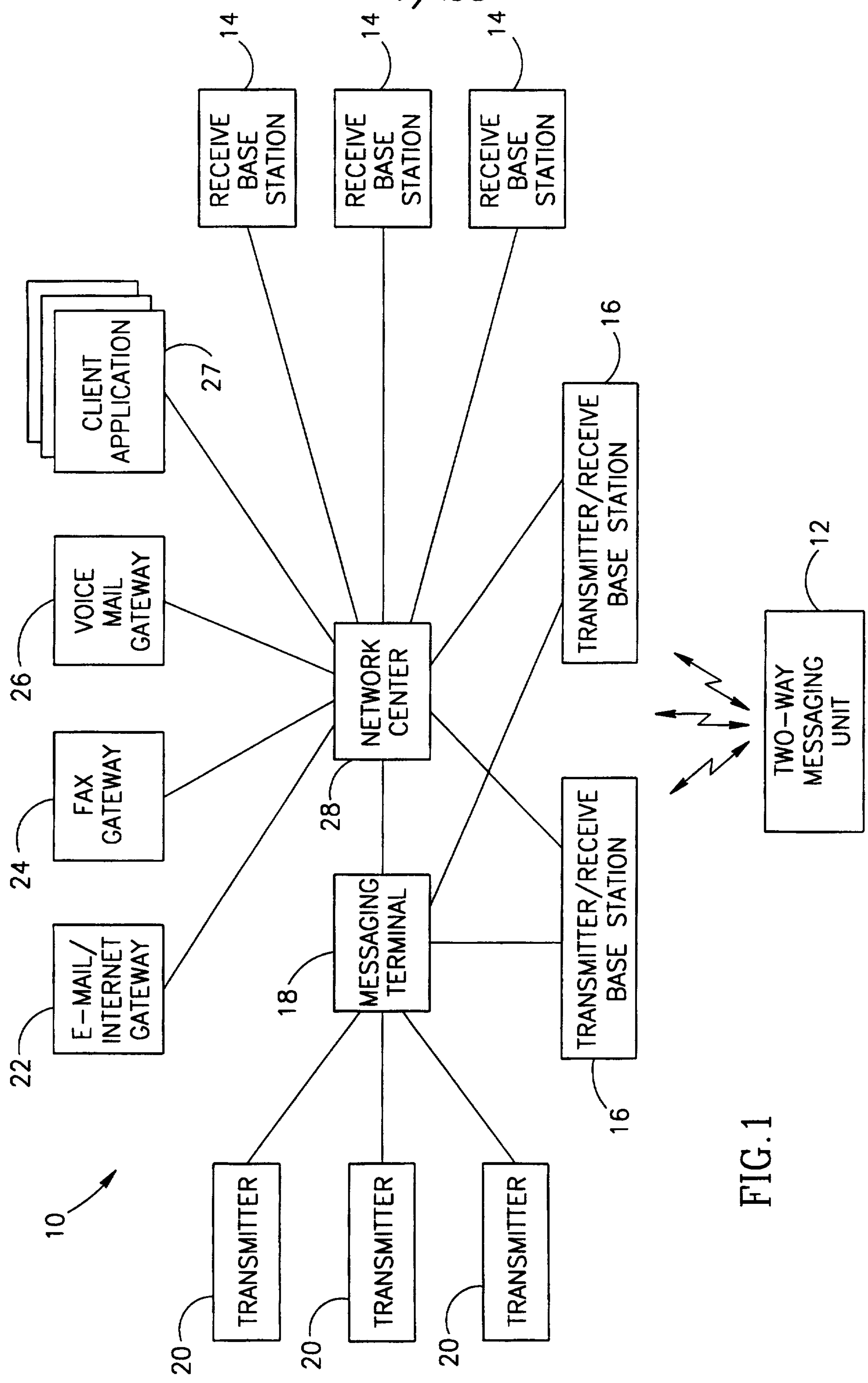
RECEIVE BASE STATION
14
RECEIVE BASE STATION
14
RECEIVE BASE STATION
14
CLIENT APPLICATION
27
VOICE MAIL GATEWAY
26
FAX GATEWAY
24
E-MAIL/ INTERNET GATEWAY
22
NETWORK CENTER
28
MESSAGING TERMINAL
18
TRANSMITTER/RECEIVE BASE STATION
16
TRANSMITTER/RECEIVE BASE STATION
16
TWO-WAY MESSAGING UNIT
12
TRANSMITTER
20
TRANSMITTER
20
TRANSMITTER
20
10

FIG.1

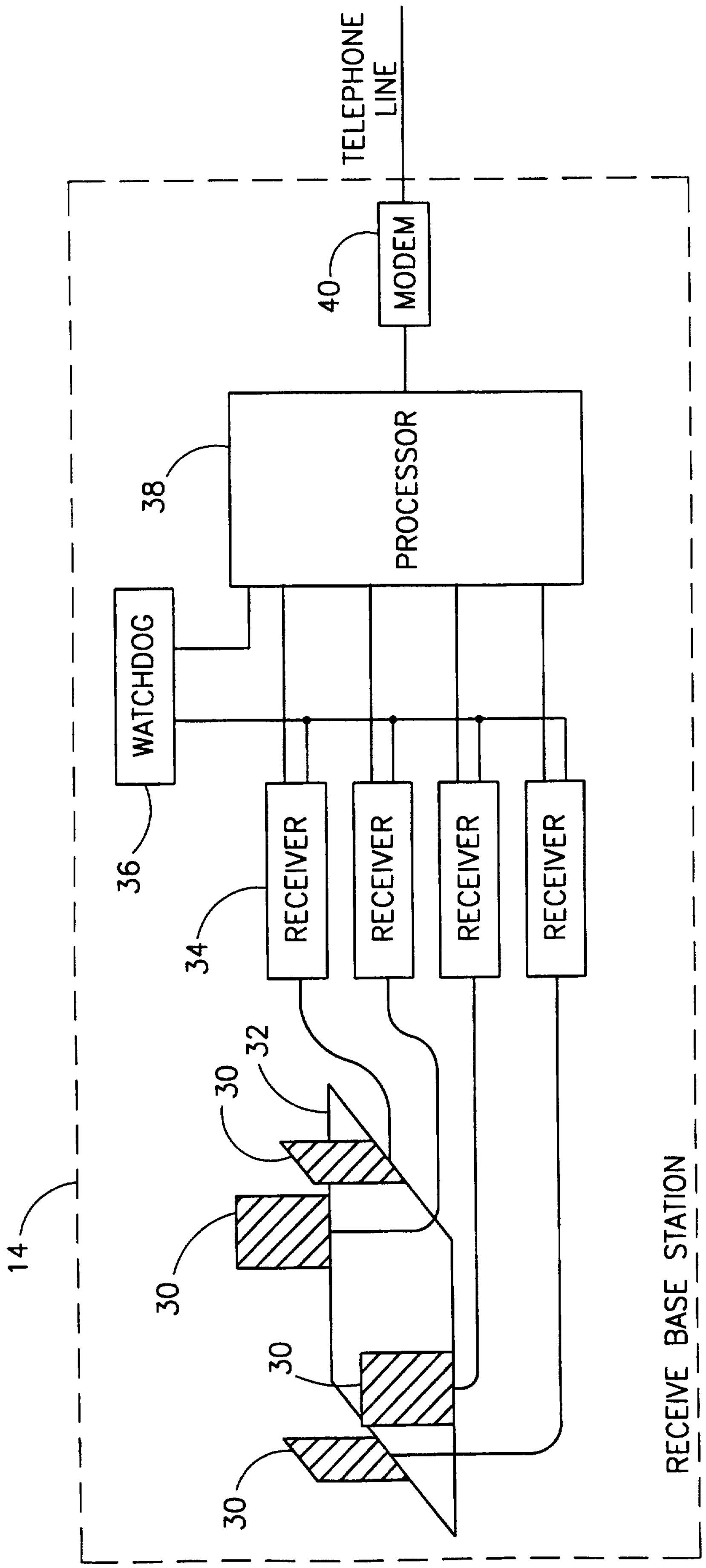
TELEPHONE LINE
MODEM
40
PROCESSOR
38
WATCHDOG
36
RECEIVER
RECEIVER
RECEIVER
RECEIVER
34
32
30
30
30
30
30
14
RECEIVE BASE STATION

FIG.2

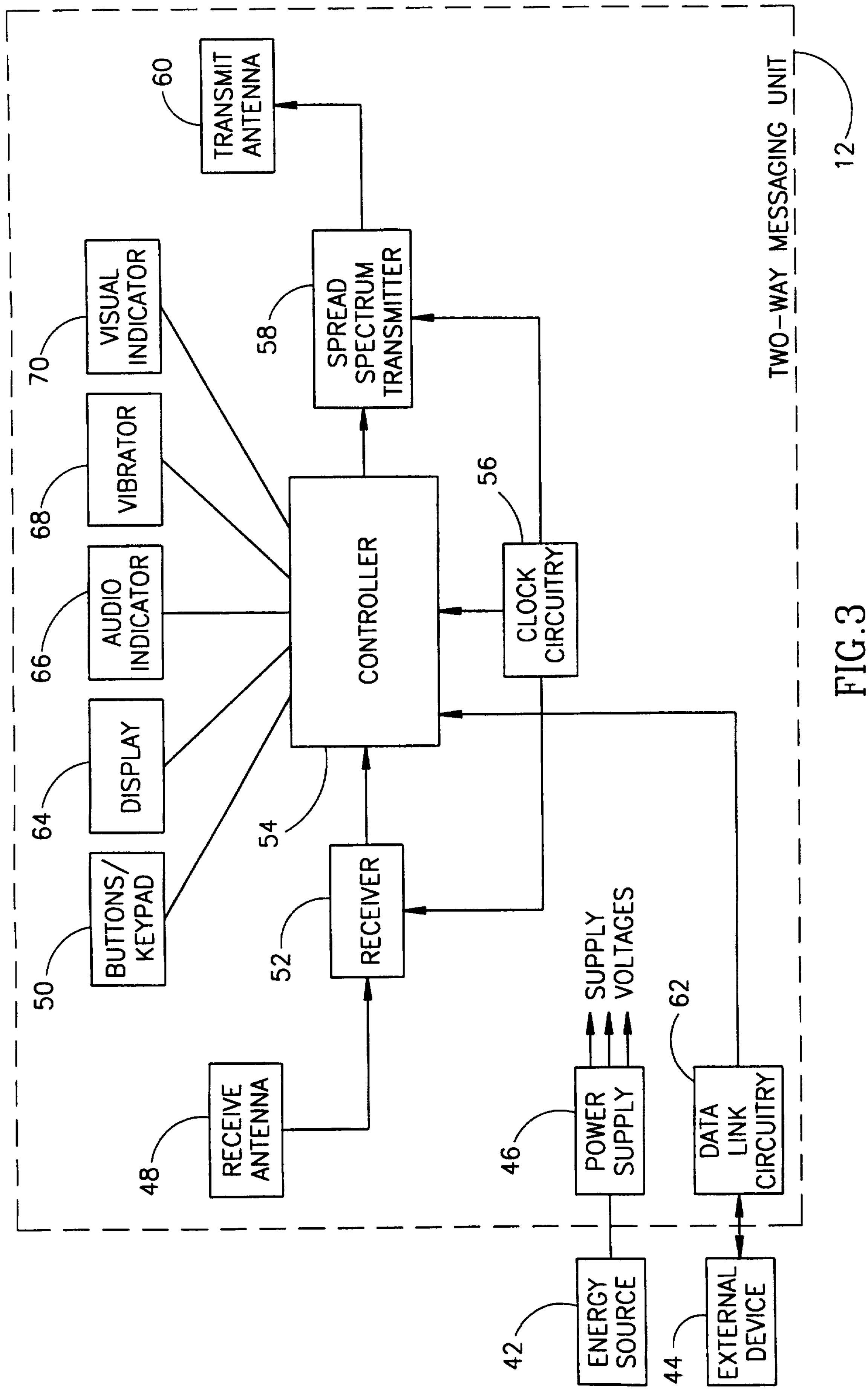
TWO-WAY MESSAGING UNIT
12
TRANSMIT ANTENNA
60
SPREAD SPECTRUM TRANSMITTER
58
VISUAL INDICATOR
70
VIBRATOR
68
AUDIO INDICATOR
66
DISPLAY
64
BUTTONS/ KEYPAD
50
CONTROLLER
54
CLOCK CIRCUITRY
56
RECEIVER
52
RECEIVE ANTENNA
48
POWER SUPPLY
46
SUPPLY VOLTAGES
DATA LINK CIRCUITRY
62
ENERGY SOURCE
42
EXTERNAL DEVICE
44

FIG.3

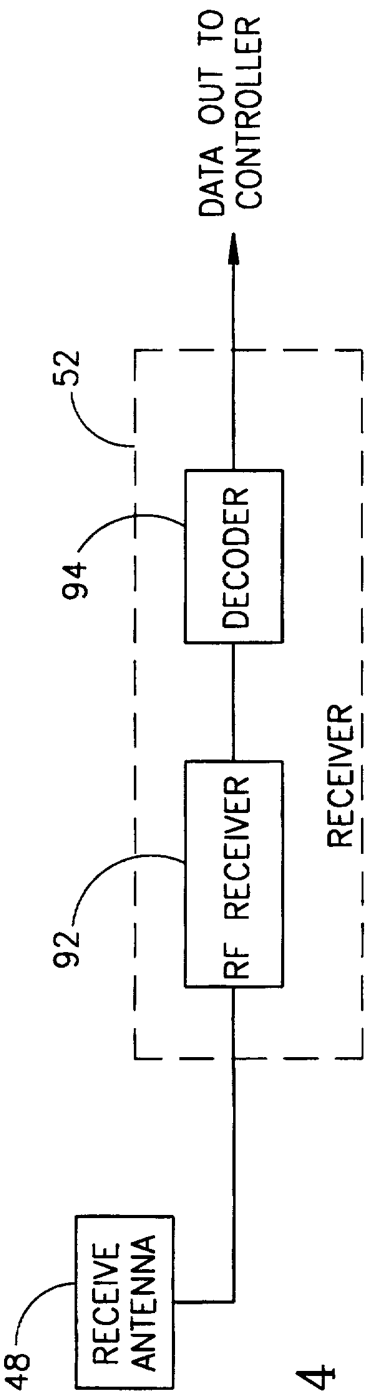
DATA OUT TO CONTROLLER
52
94
DECODER
92
RF RECEIVER
RECEIVER
48
RECEIVE ANTENNA

FIG.4

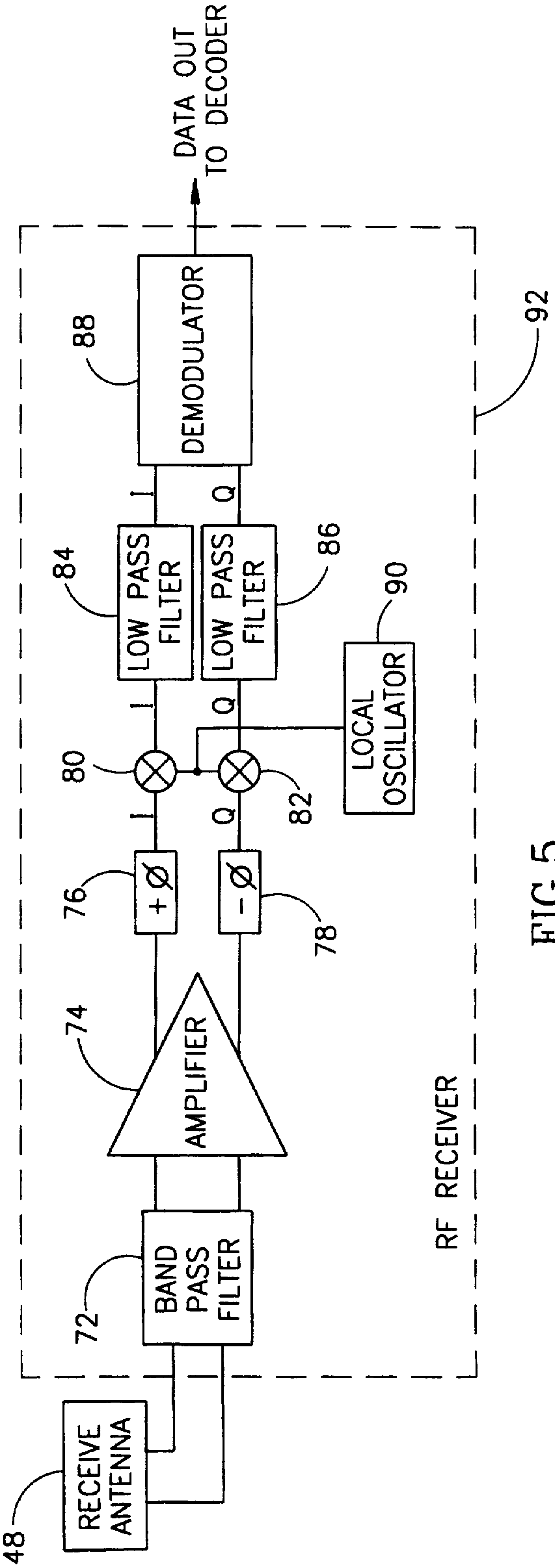
DATA OUT TO DECODER
88
DEMODULATOR
92
I
Q
84
LOW PASS FILTER
86
LOW PASS FILTER
90
LOCAL OSCILLATOR
80
82
76
+Ø
-Ø
78
74
AMPLIFIER
72
BAND PASS FILTER
RF RECEIVER
48
RECEIVE ANTENNA

FIG.5

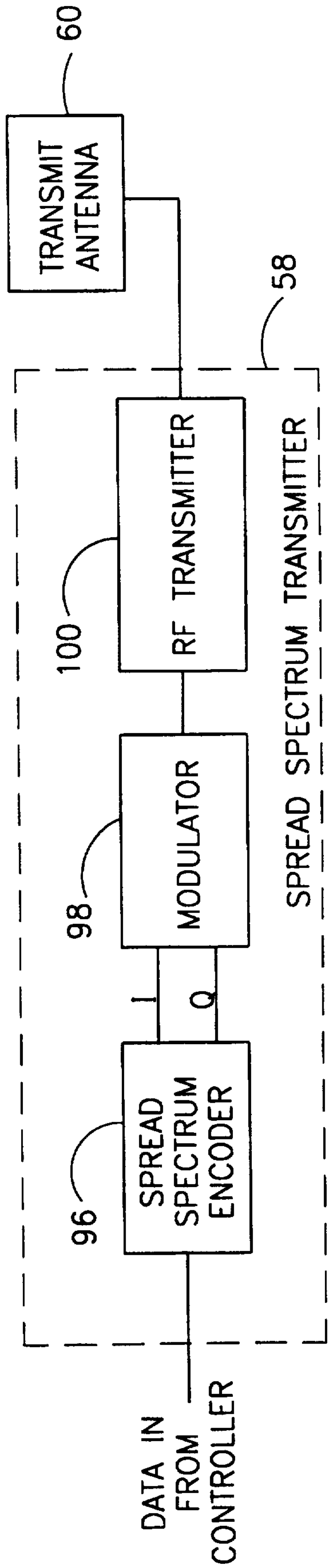
TRANSMIT ANTENNA
60
58
RF TRANSMITTER
100
MODULATOR
98
I
Q
SPREAD SPECTRUM ENCODER
96
SPREAD SPECTRUM TRANSMITTER
DATA IN FROM CONTROLLER

FIG.6

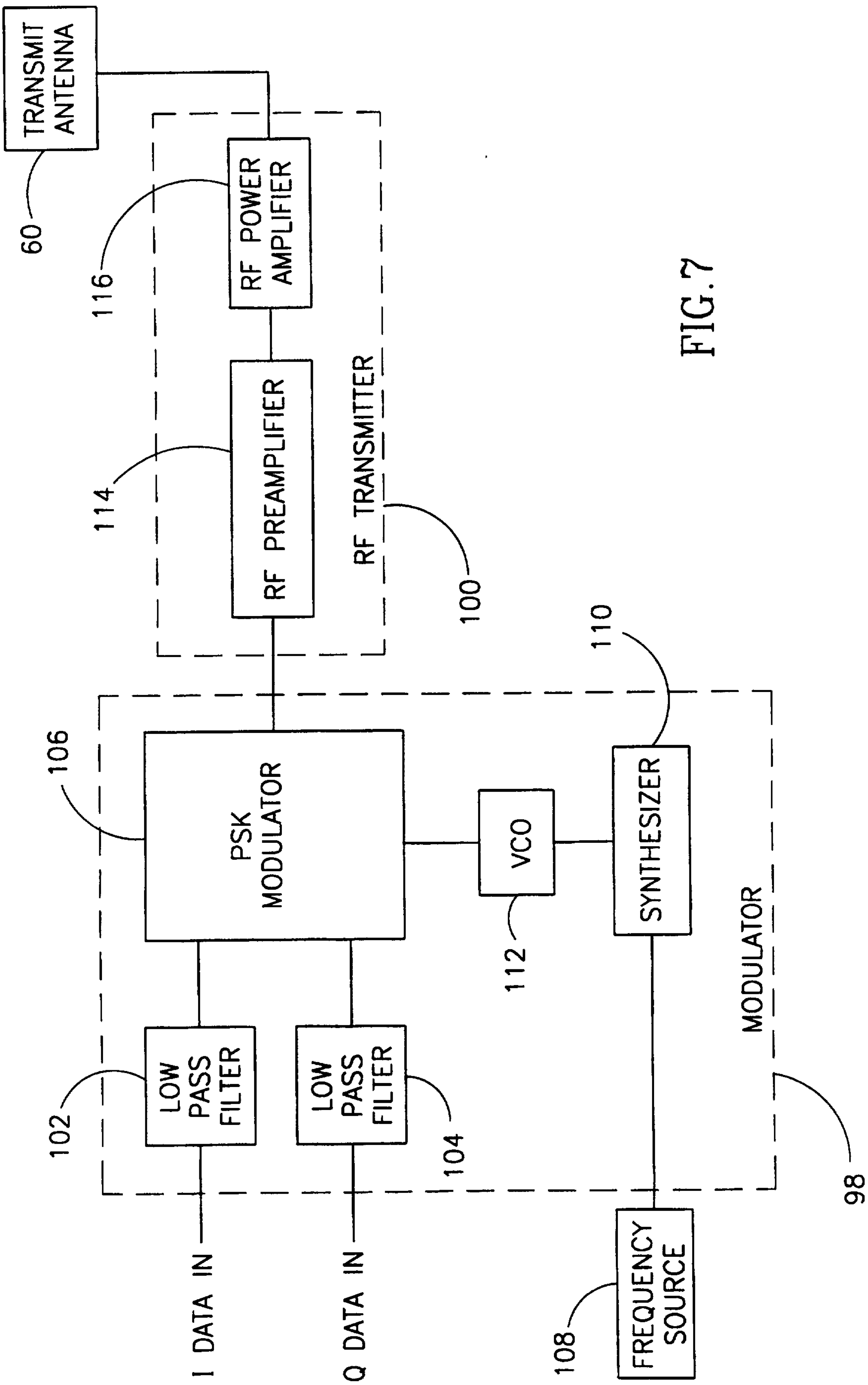
TRANSMIT ANTENNA
60
RF POWER AMPLIFIER
116
RF PREAMPLIFIER
114
RF TRANSMITTER
100
110
106
PSK MODULATOR
VCO
SYNTHESIZER
112
MODULATOR
LOW PASS FILTER
102
LOW PASS FILTER
104
98
I DATA IN
Q DATA IN
FREQUENCY SOURCE
108

FIG.7

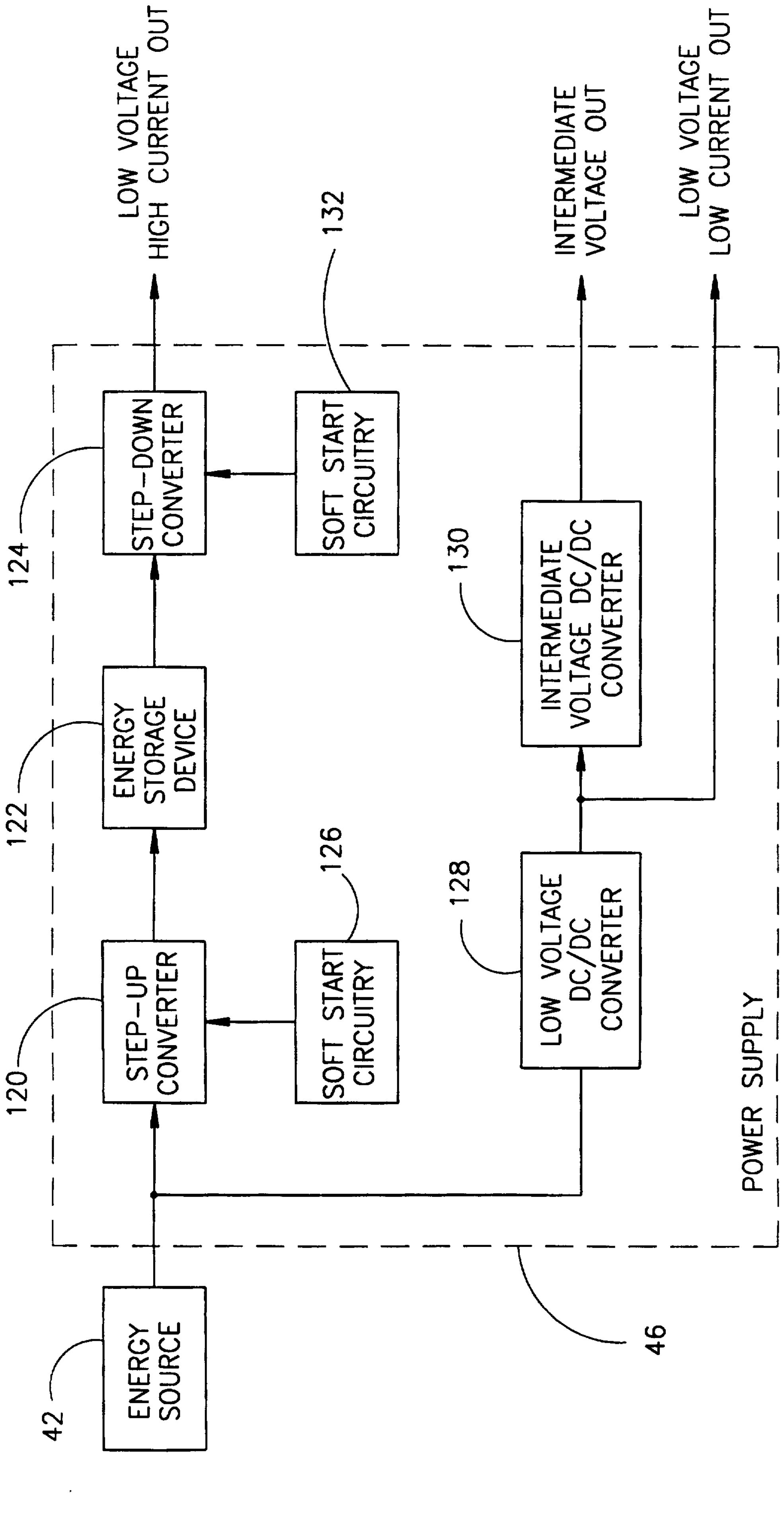
LOW VOLTAGE
HIGH CURRENT OUT
132
INTERMEDIATE
VOLTAGE OUT
LOW VOLTAGE
LOW CURRENT OUT
STEP-DOWN
CONVERTER
SOFT START
CIRCUITRY
124
130
INTERMEDIATE
VOLTAGE DC/DC
CONVERTER
ENERGY
STORAGE
DEVICE
122
126
128
STEP-UP
CONVERTER
SOFT START
CIRCUITRY
LOW VOLTAGE
DC/DC
CONVERTER
120
POWER SUPPLY
ENERGY
SOURCE
42
46

FIG.8

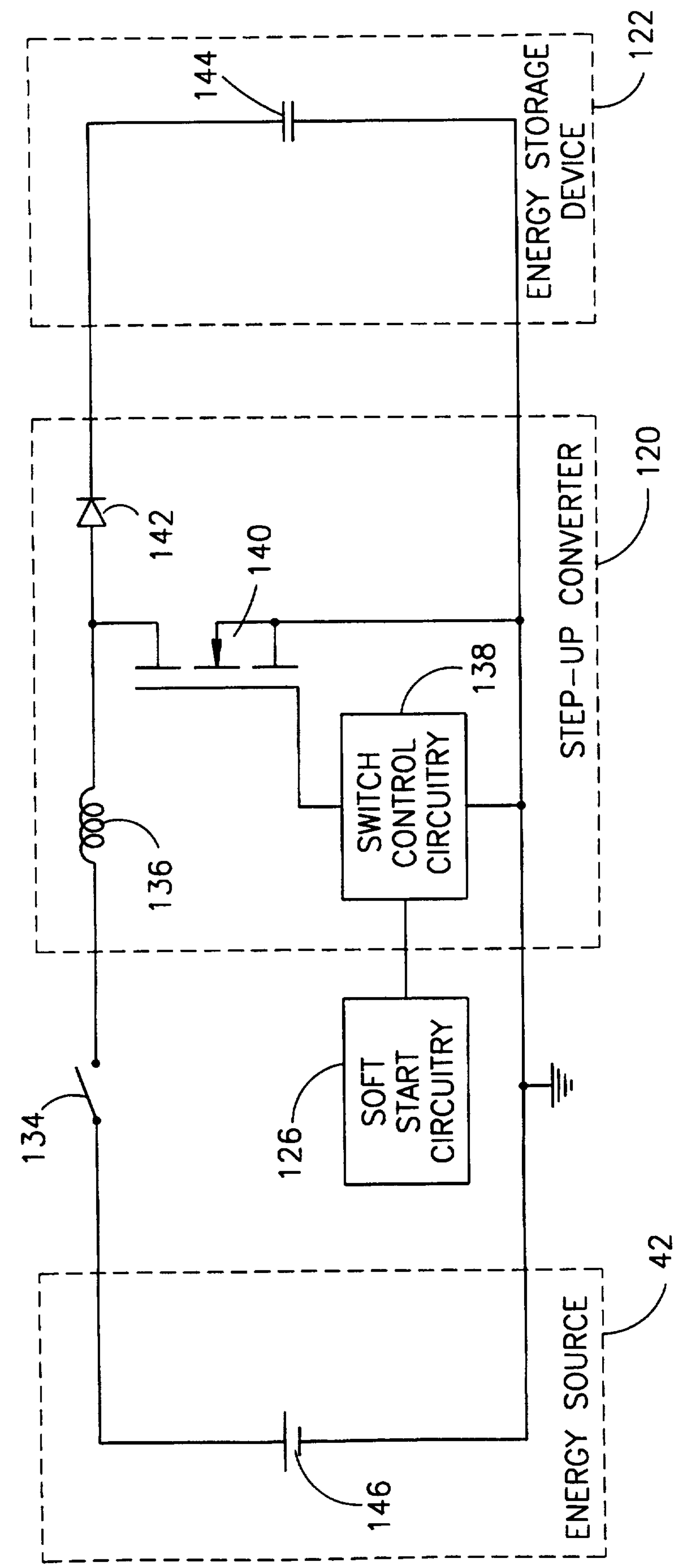
ENERGY STORAGE DEVICE
122
144
STEP-UP CONVERTER
120
142
140
138
SWITCH CONTROL CIRCUITRY
136
SOFT START CIRCUITRY
126
134
ENERGY SOURCE
42
146

FIG.9

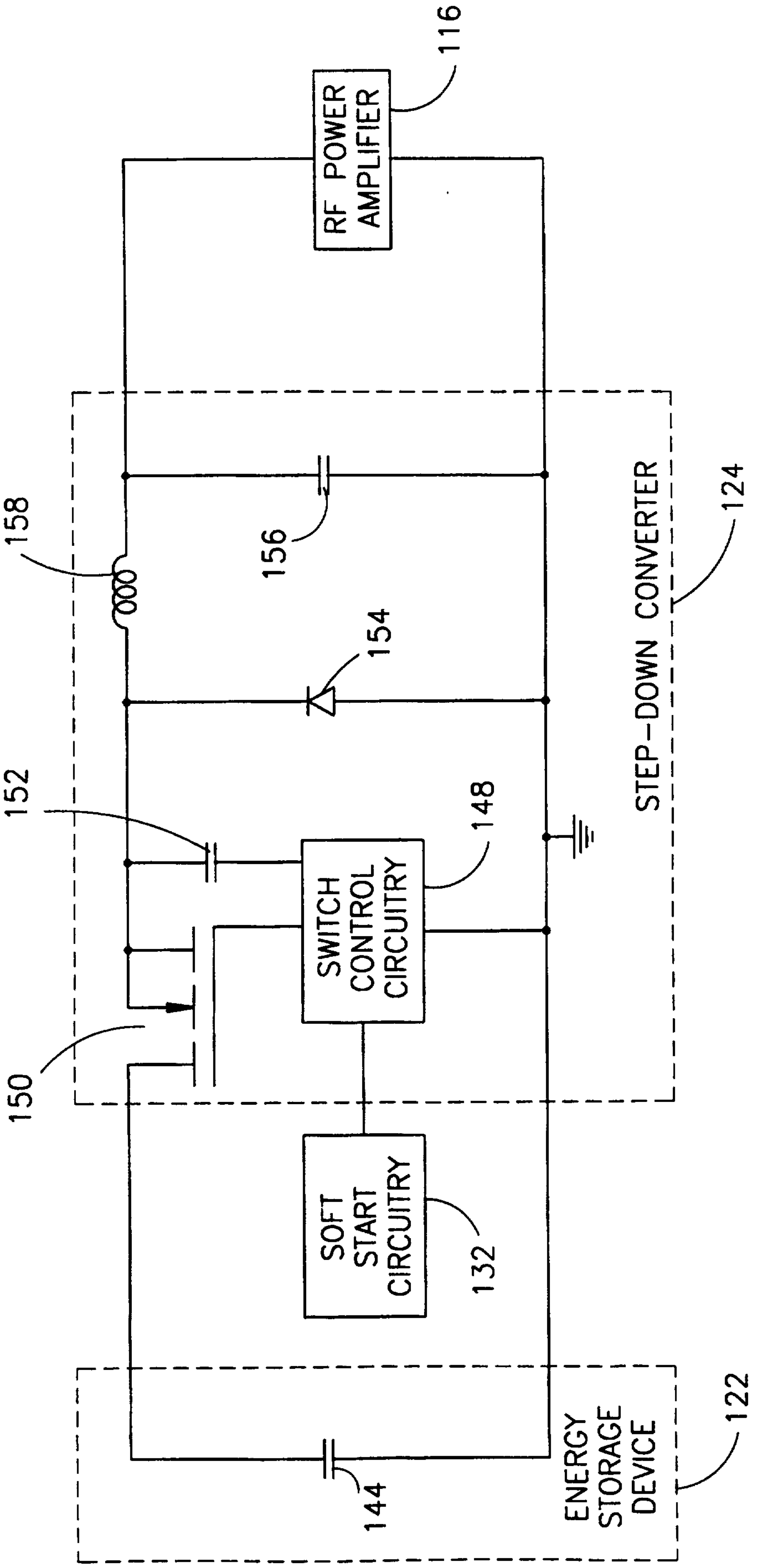
116
RF POWER AMPLIFIER
158
156
154
152
148
SWITCH CONTROL CIRCUITRY
150
SOFT START CIRCUITRY
132
STEP-DOWN CONVERTER
124
ENERGY STORAGE DEVICE
122
144

FIG.10

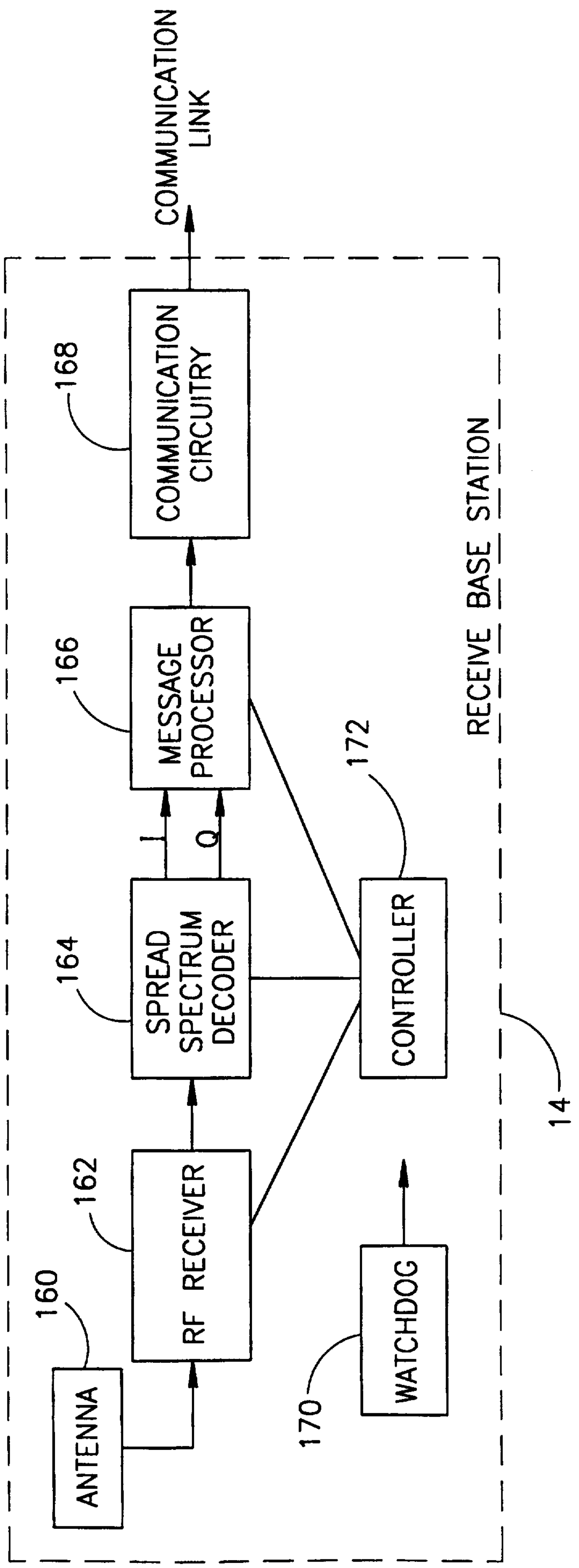
COMMUNICATION LINK
168
COMMUNICATION CIRCUITRY
166
MESSAGE PROCESSOR
RECEIVE BASE STATION
172
I
Q
164
SPREAD SPECTRUM DECODER
CONTROLLER
14
162
RF RECEIVER
160
ANTENNA
WATCHDOG
170

FIG.11

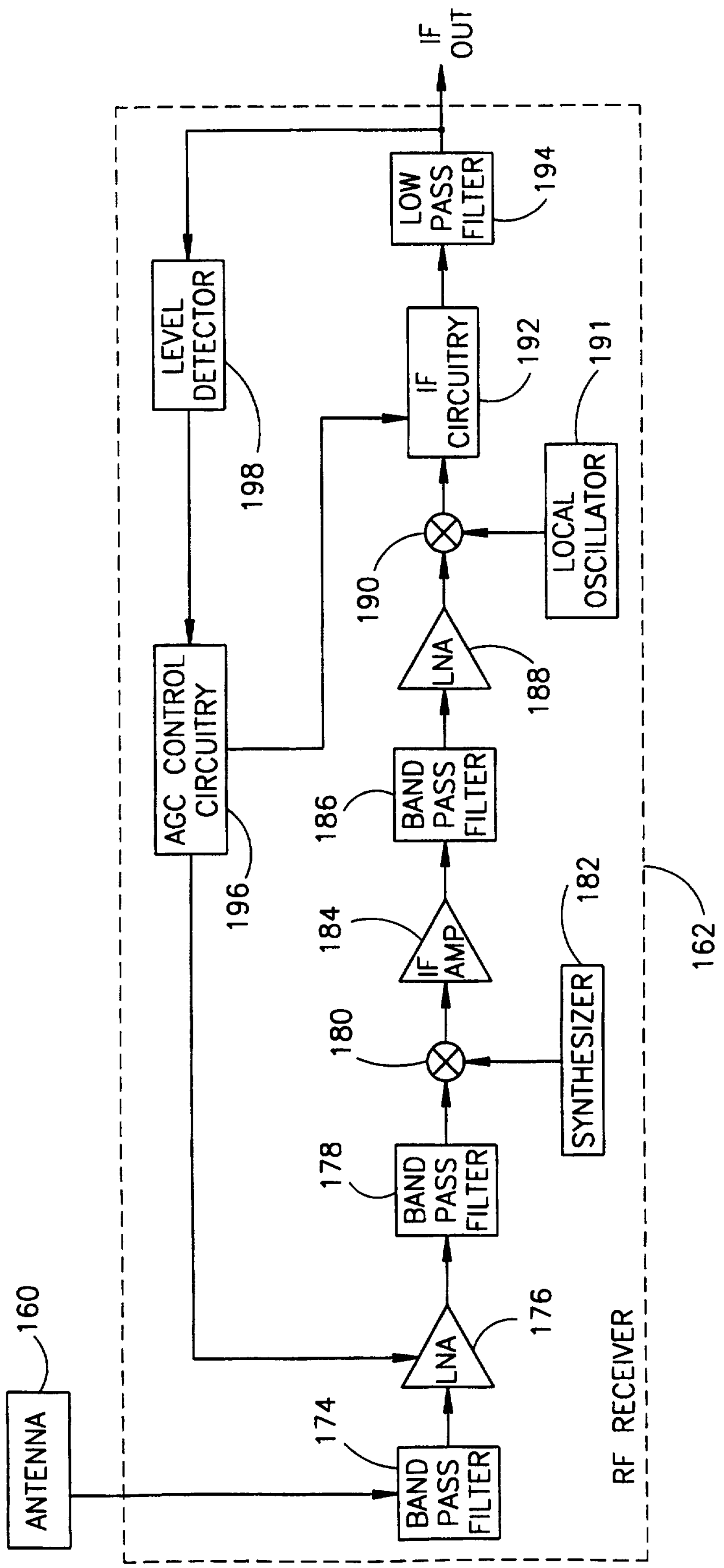
IF OUT
LOW PASS FILTER
194
LEVEL DETECTOR
198
IF CIRCUITRY
192
191
LOCAL OSCILLATOR
190
LNA
188
AGC CONTROL CIRCUITRY
196
BAND PASS FILTER
186
184
IF AMP
182
SYNTHESIZER
180
162
BAND PASS FILTER
178
160
ANTENNA
LNA
176
174
BAND PASS FILTER
RF RECEIVER

FIG.12

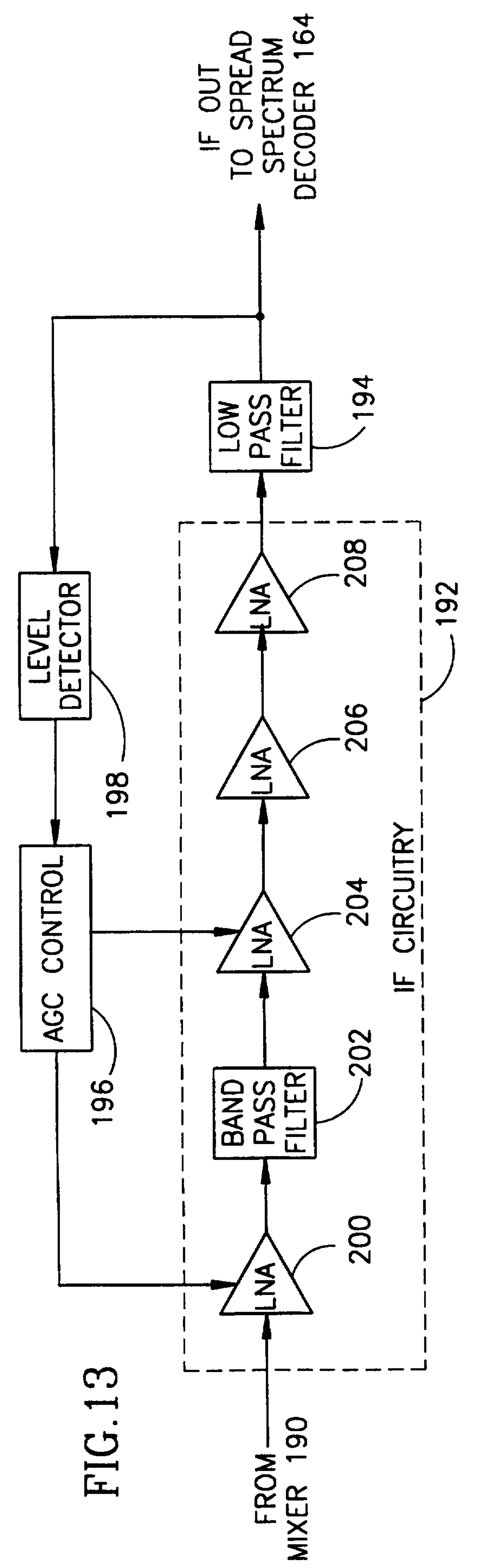
IF OUT
TO SPREAD
SPECTRUM
DECODER 164
LEVEL
DETECTOR
198
AGC CONTROL
196
LOW
PASS
FILTER
194
LNA
208
LNA
206
LNA
204
BAND
PASS
FILTER
202
LNA
200
IF CIRCUITRY
192
FROM
MIXER 190

FIG.13

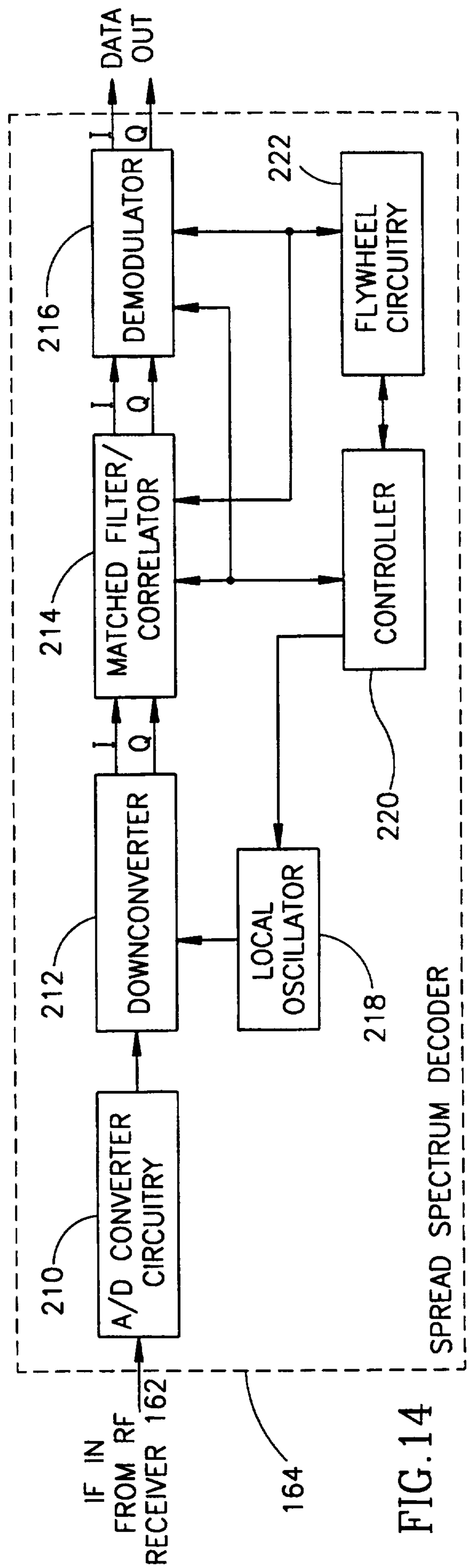
DATA
OUT
I
Q
DEMODULATOR
216
222
FLYWHEEL
CIRCUITRY
MATCHED FILTER/
CORRELATOR
214
CONTROLLER
220
DOWNCONVERTER
212
LOCAL
OSCILLATOR
218
A/D CONVERTER
CIRCUITRY
210
SPREAD SPECTRUM DECODER
IF IN
FROM RF
RECEIVER 162
164

FIG.14

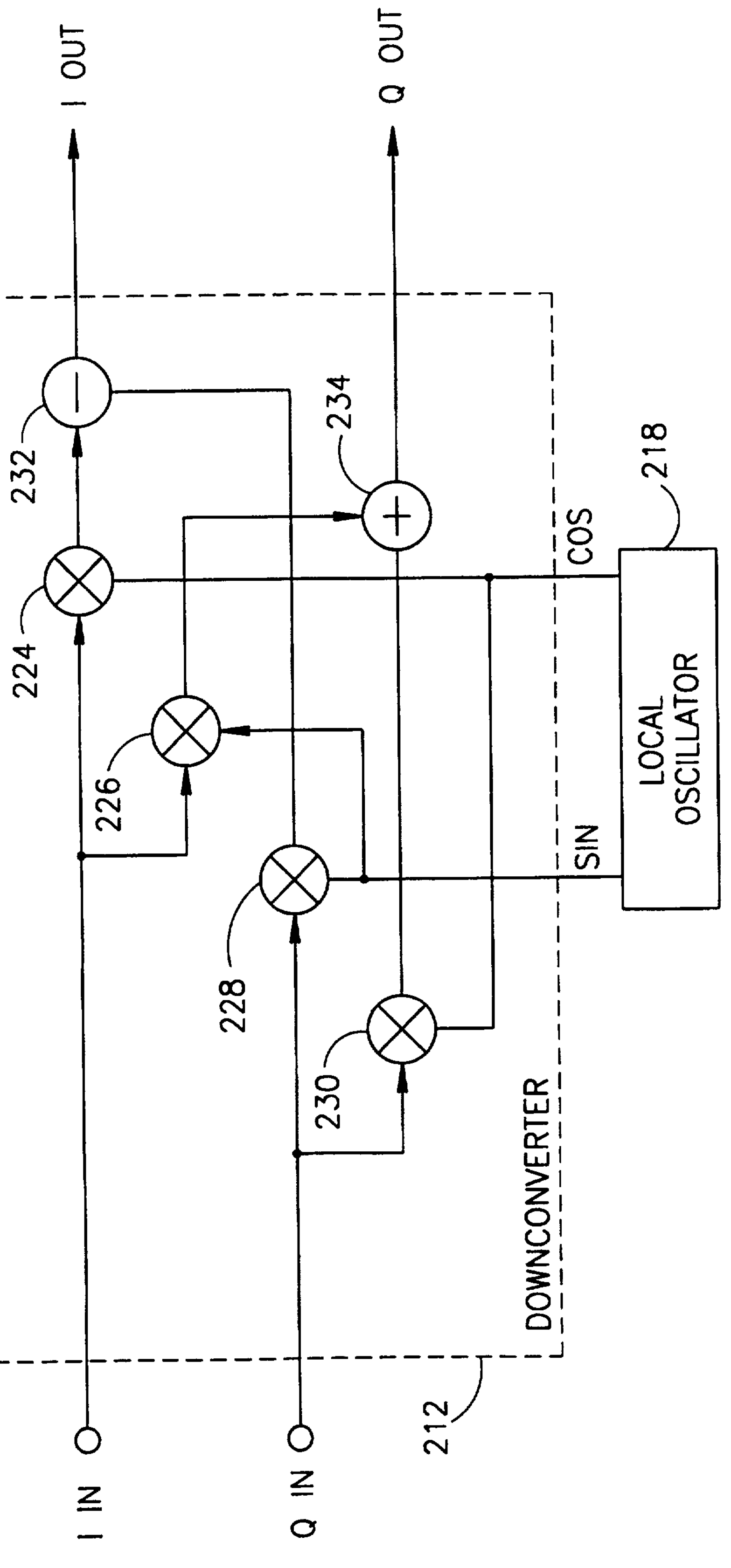
I OUT
Q OUT
232
234
218
COS
224
226
LOCAL
OSCILLATOR
SIN
228
230
DOWNCONVERTER
212
I IN
Q IN

FIG.15

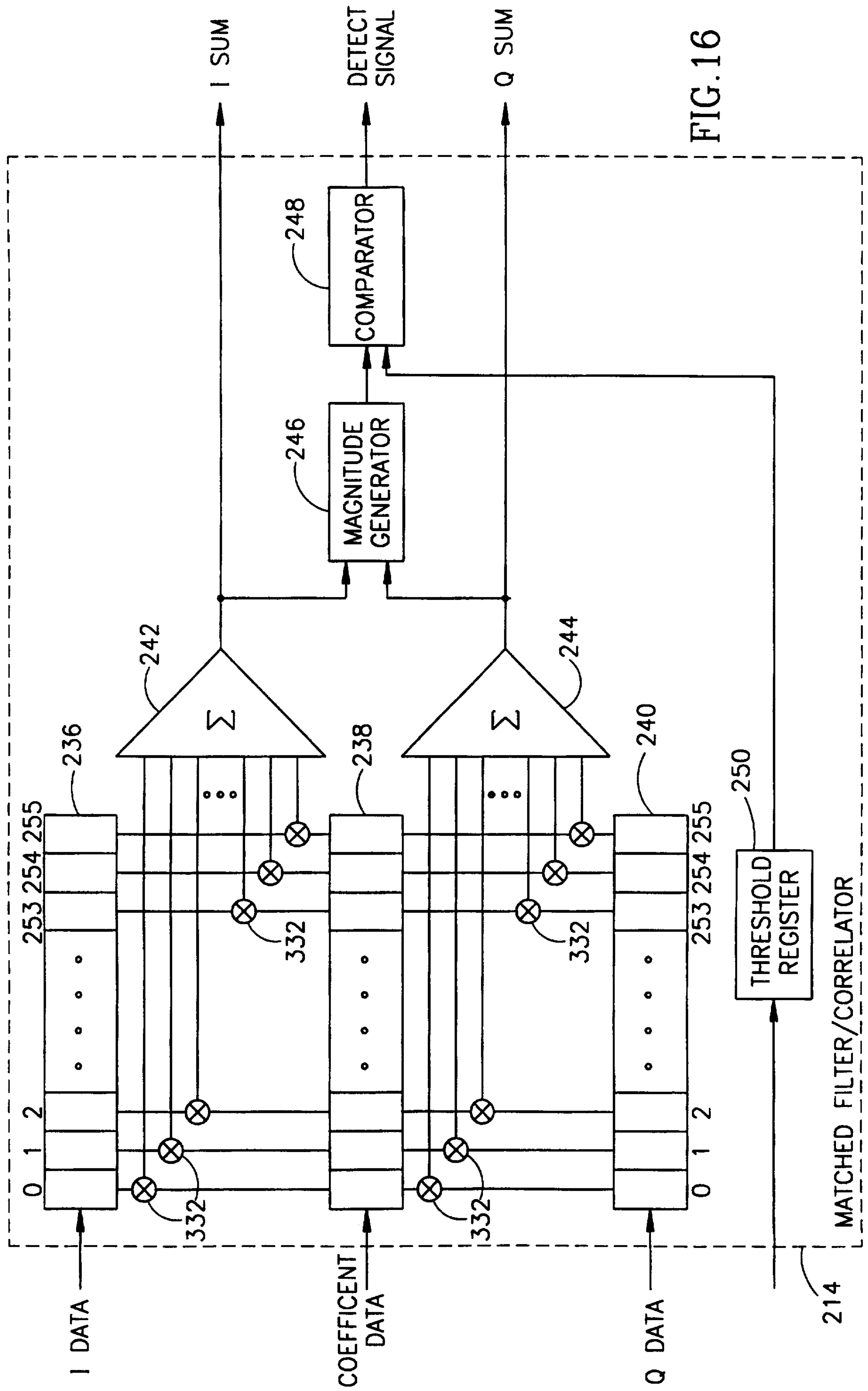
I SUM
DETECT SIGNAL
Q SUM
COMPARATOR
248
MAGNITUDE GENERATOR
246
242
244
Σ
Σ
236
238
240
250
THRESHOLD REGISTER
253 254 255
0 1 2
332
I DATA
COEFFICENT DATA
Q DATA
MATCHED FILTER/CORRELATOR
214

FIG.16

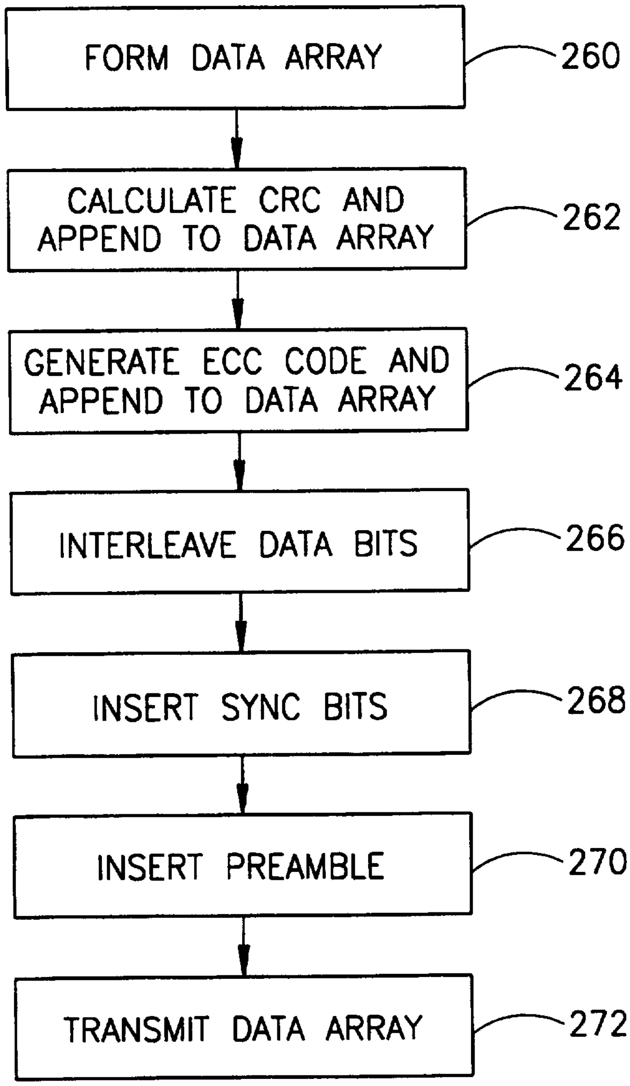
FORM DATA ARRAY
260
CALCULATE CRC AND APPEND TO DATA ARRAY
262
GENERATE ECC CODE AND APPEND TO DATA ARRAY
264
INTERLEAVE DATA BITS
266
INSERT SYNC BITS
268
INSERT PREAMBLE
270
TRANSMIT DATA ARRAY
272

FIG.17

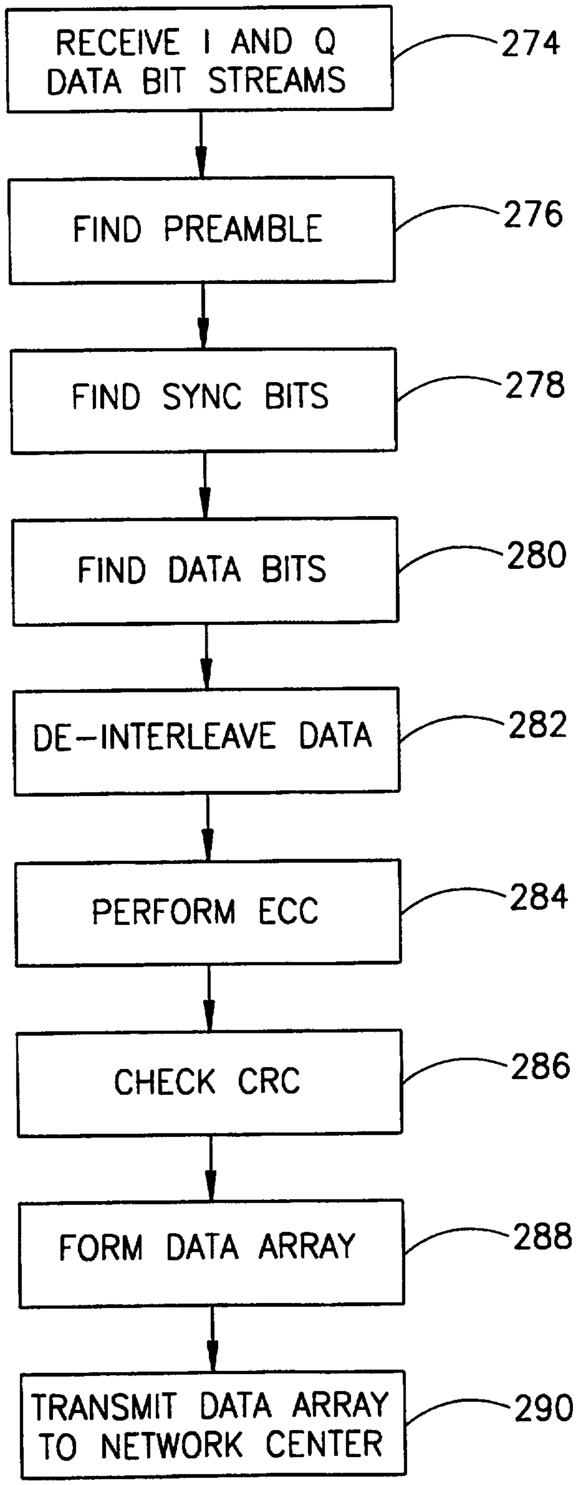
RECEIVE I AND Q DATA BIT STREAMS
274
FIND PREAMBLE
276
FIND SYNC BITS
278
FIND DATA BITS
280
DE-INTERLEAVE DATA
282
PERFORM ECC
284
CHECK CRC
286
FORM DATA ARRAY
288
TRANSMIT DATA ARRAY TO NETWORK CENTER
290

FIG.18

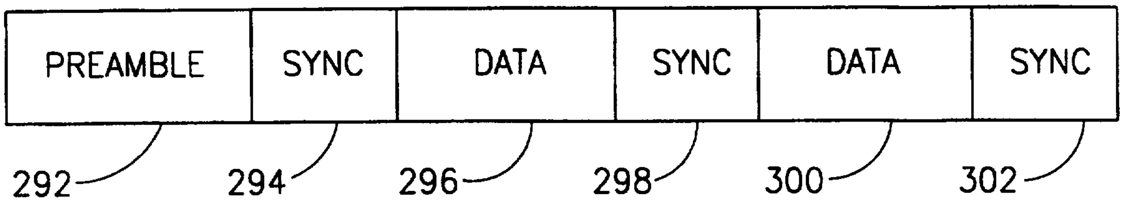
PREAMBLE
SYNC
DATA
SYNC
DATA
SYNC
292
294
296
298
300
302

FIG.19

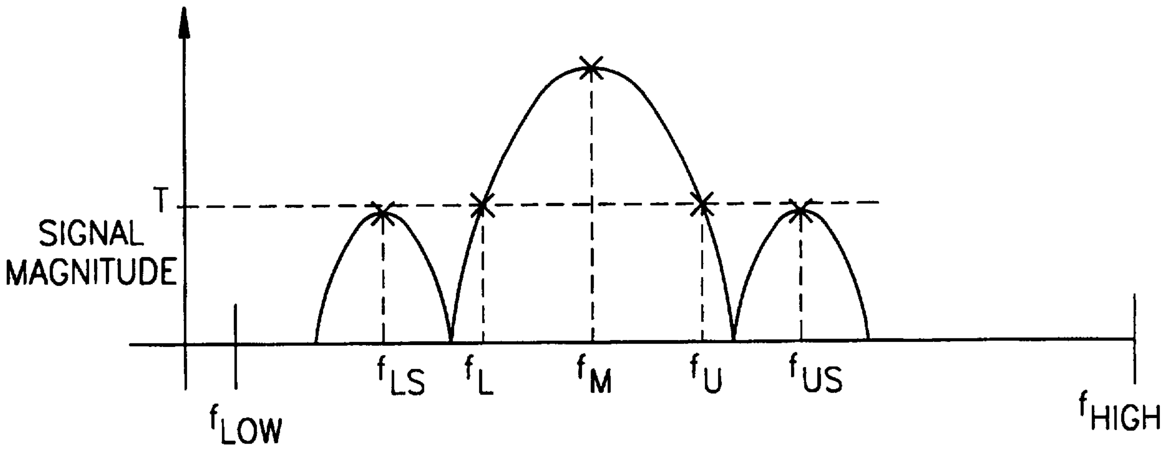
T
SIGNAL MAGNITUDE
f LS
f L
f M
f U
f US
f LOW
f HIGH

FIG.20

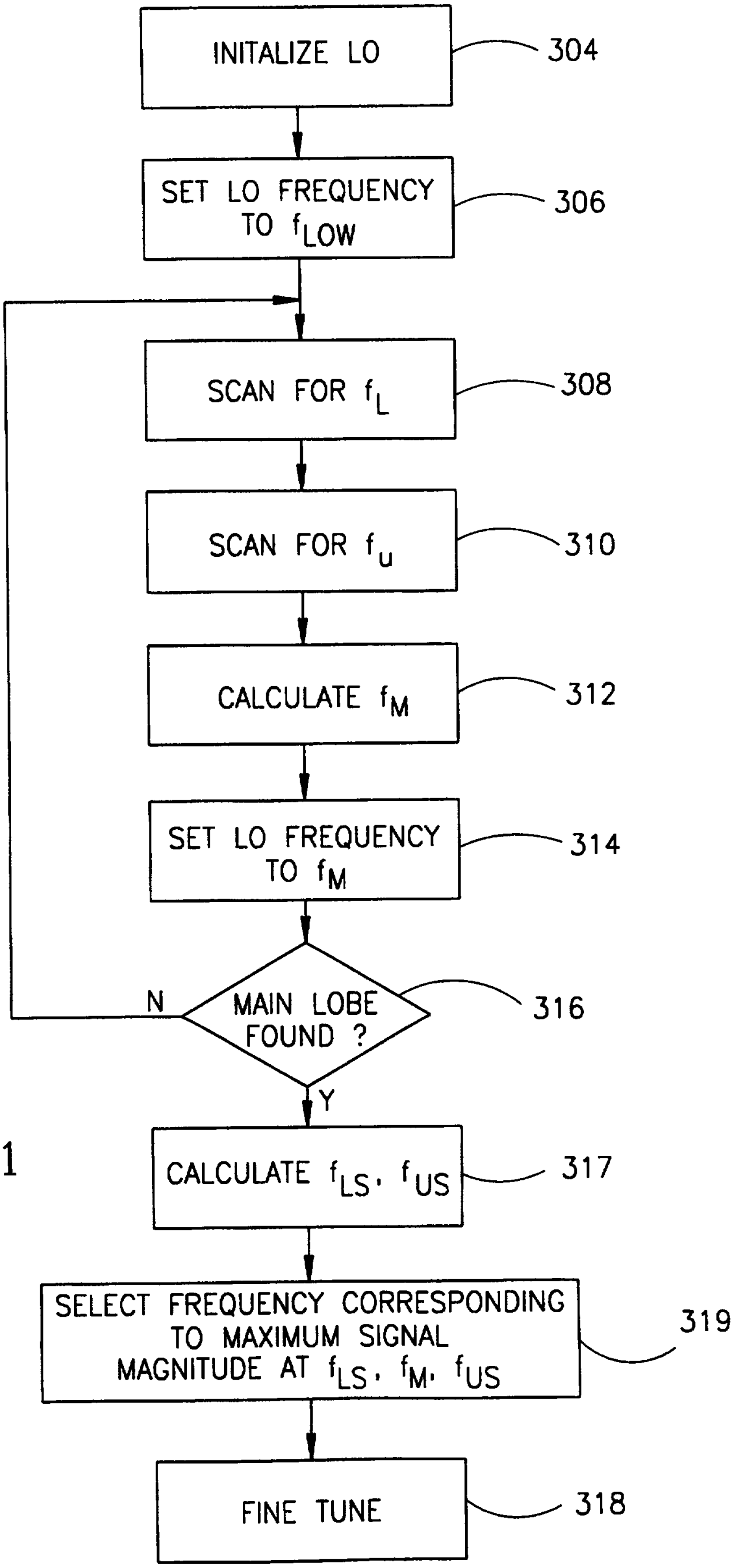
INITALIZE LO
304
SET LO FREQUENCY TO f_{LOW}
306
SCAN FOR f_L
308
SCAN FOR f_u
310
CALCULATE f_M
312
SET LO FREQUENCY TO f_M
314
MAIN LOBE FOUND ?
316
N
Y
CALCULATE f_{LS}, f_{US}
317
SELECT FREQUENCY CORRESPONDING TO MAXIMUM SIGNAL MAGNITUDE AT f_{LS}, f_M, f_{US}
319
FINE TUNE
318

FIG.21

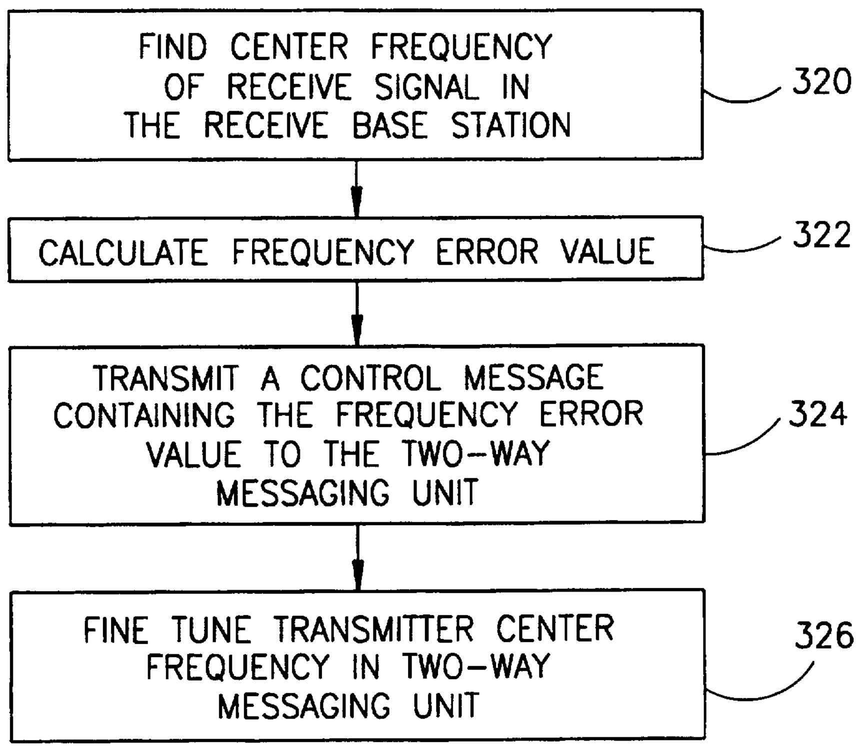
FIND CENTER FREQUENCY OF RECEIVE SIGNAL IN THE RECEIVE BASE STATION
320
CALCULATE FREQUENCY ERROR VALUE
322
TRANSMIT A CONTROL MESSAGE CONTAINING THE FREQUENCY ERROR VALUE TO THE TWO-WAY MESSAGING UNIT
324
FINE TUNE TRANSMITTER CENTER FREQUENCY IN TWO-WAY MESSAGING UNIT
326

FIG.22

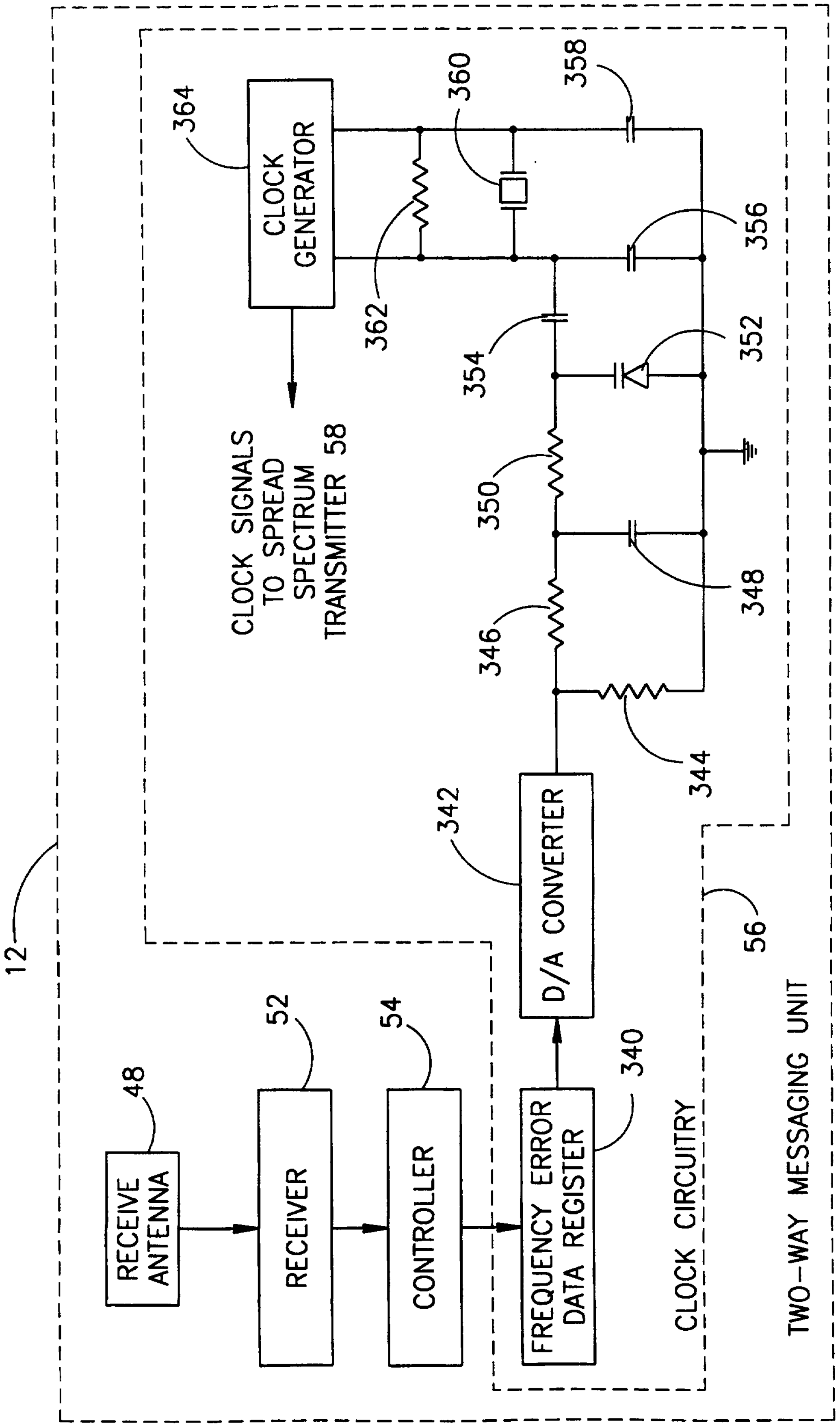
CLOCK GENERATOR
364
360
358
356
362
354
352
350
348
346
344
342
CLOCK SIGNALS TO SPREAD SPECTRUM TRANSMITTER 58
D/A CONVERTER
12
56
RECEIVE ANTENNA
48
RECEIVER
52
CONTROLLER
54
FREQUENCY ERROR DATA REGISTER
340
CLOCK CIRCUITRY
TWO-WAY MESSAGING UNIT

FIG.23

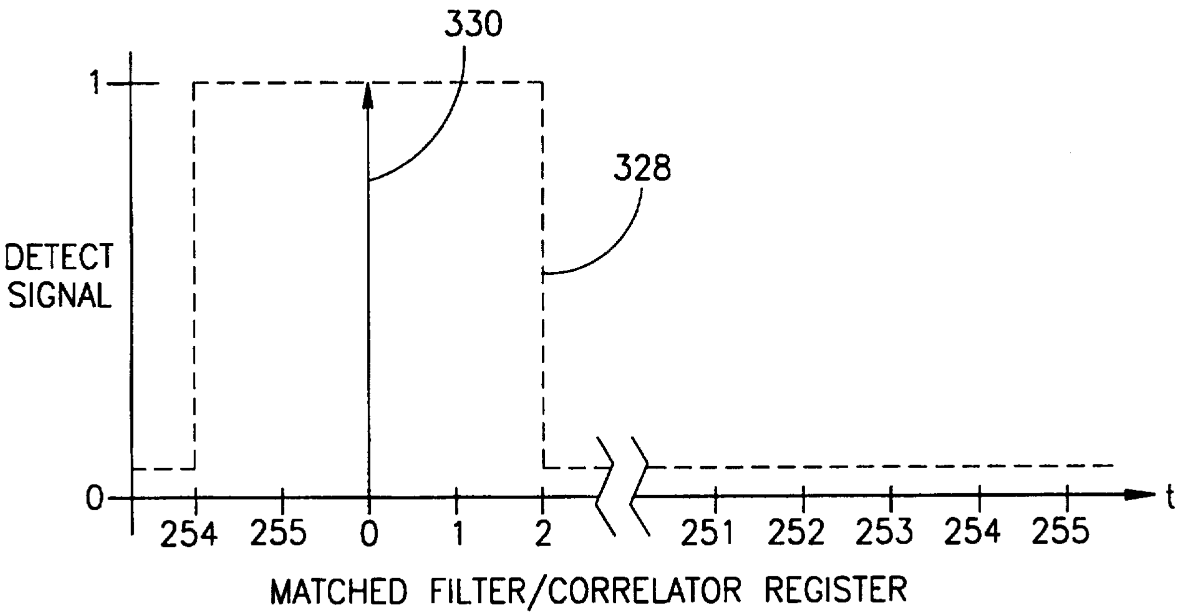
330
1
328
DETECT
SIGNAL
0
254 255 0 1 2 251 252 253 254 255
t
MATCHED FILTER/CORRELATOR REGISTER

FIG.24

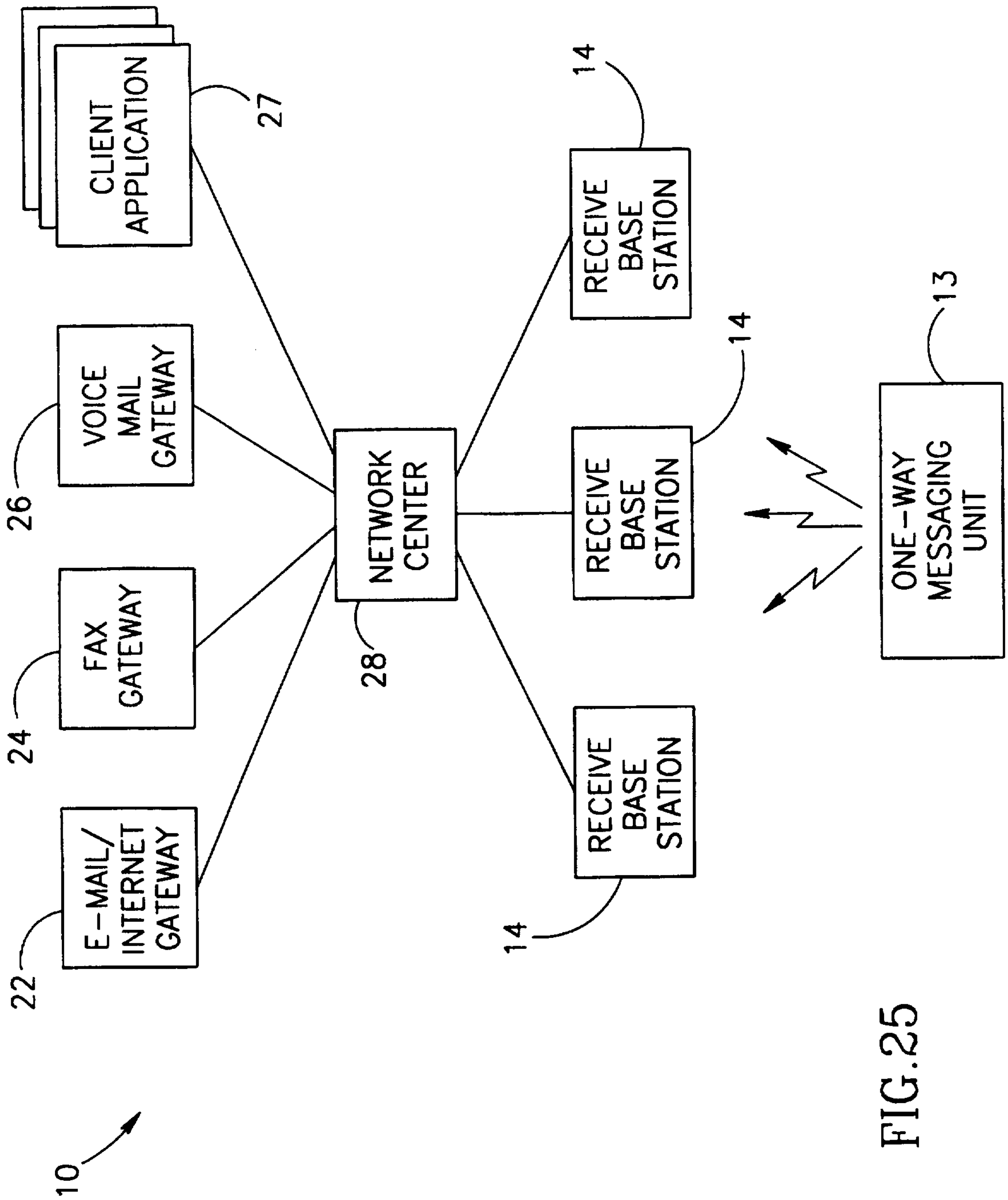
CLIENT APPLICATION
27
VOICE MAIL GATEWAY
26
FAX GATEWAY
24
E-MAIL/ INTERNET GATEWAY
22
NETWORK CENTER
28
RECEIVE BASE STATION
14
RECEIVE BASE STATION
14
RECEIVE BASE STATION
14
ONE-WAY MESSAGING UNIT
13
10

FIG.25

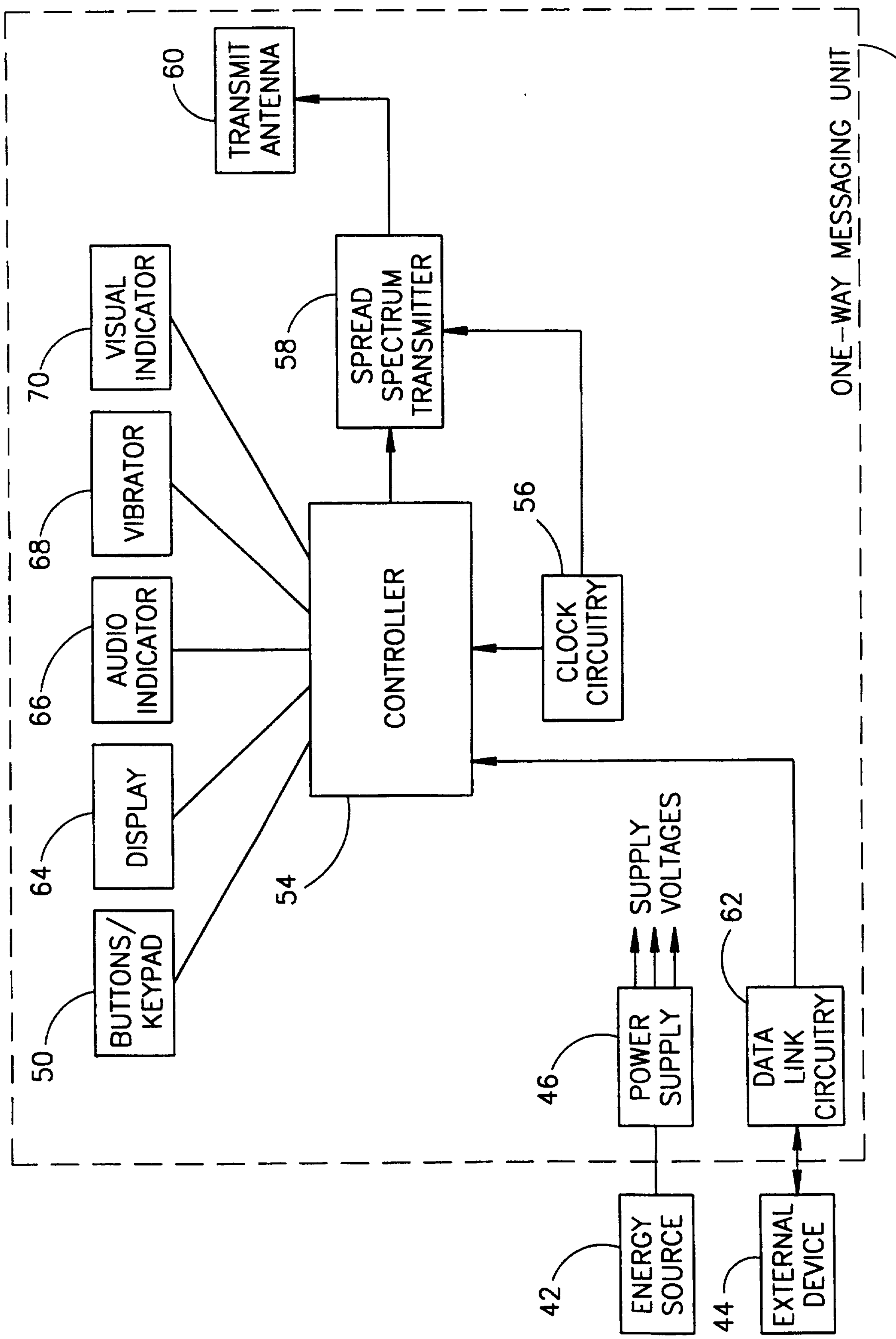
TRANSMIT ANTENNA
60
SPREAD SPECTRUM TRANSMITTER
58
VISUAL INDICATOR
70
VIBRATOR
68
AUDIO INDICATOR
66
DISPLAY
64
BUTTONS/ KEYPAD
50
CONTROLLER
54
CLOCK CIRCUITRY
56
ONE-WAY MESSAGING UNIT
13
SUPPLY VOLTAGES
POWER SUPPLY
46
DATA LINK CIRCUITRY
62
ENERGY SOURCE
42
EXTERNAL DEVICE
44

FIG.26

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL97/00013

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04Q 1/00
US CL : 340/825.44;455/38.1;370/60;375/202
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 340/825.44;455/38.1;370/60;375/202

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 4,882,579 A (SIWIAK) 21 November 1989, col. 1 line 40-col. 2 line 15.	1,2,6-9,13-16,20,21,30,32,33 ---------- 3-5,10-12,17-19,22-31
Y	US 5,436,960 A (CAMPANA JR. et al) 25 July 1995, Abstract.	3-5,10-12,17-19

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 MAY 1997	27 MAY 1997

Name and mailing address of the ISA/US	Authorized officer
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