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(54) **DIVERSITY CIRCUIT FOR MAGNETIC COMMUNICATION SYSTEM**

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Appl. No.: **08/696,812**
Filed: **Aug. 13, 1996**

U.S. Applications:
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(63) Continuation-in-part of application No. 08/444,017, filed on May 18, 1995, now abandoned.

(51) **Int. Cl.**
H04B 3/00 (2006.01)

(52) **U.S. Cl.** **375/258**; 375/352; 455/41.1; 455/139; 455/276.1

(58) **Field of Classification Search** 375/257, 375/258, 352, 347; 455/41, 273, 274, 276.1, 455/139, 137, 41.1; 324/318, 319, 322, 320, 324/321
See application file for complete search history.

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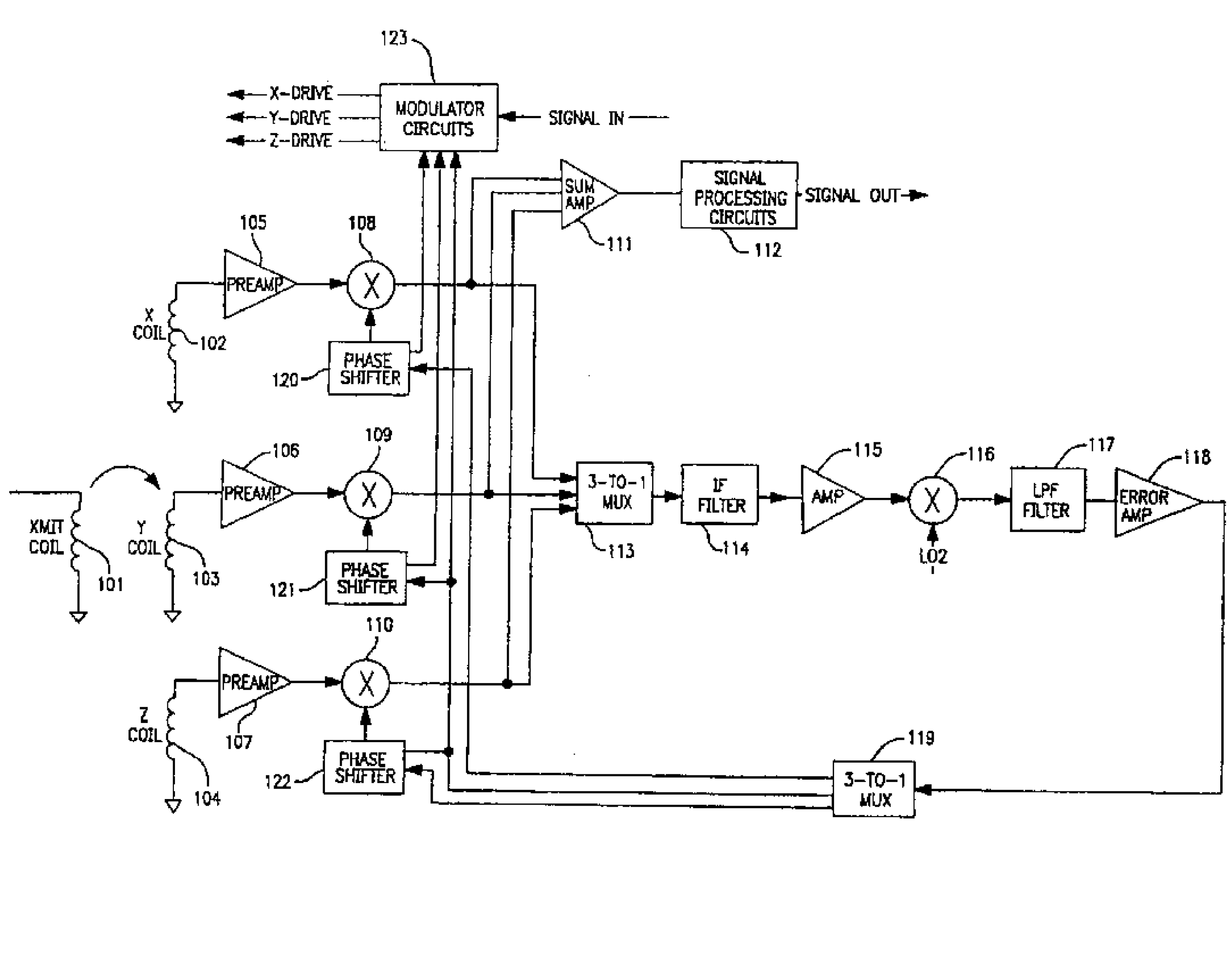

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(57) **ABSTRACT**

A magnetic communication system includes a transmitter have a single coil transducer, and a receiver having a three orthogonally oriented coil transducers. The signal processing circuitry in the receiver adjusts the phases of the signals received by the three transducers to produce signals which are in-phase. The signals are then summed to provide an output signal from the receiver. The processing circuitry adjusts the phases of the incoming signals either serially or in parallel. Transmissions from the receiver to the transmitter are also phase adjusted in accordance with the same adjustments used in reception.

65 Claims, 8 Drawing Sheets

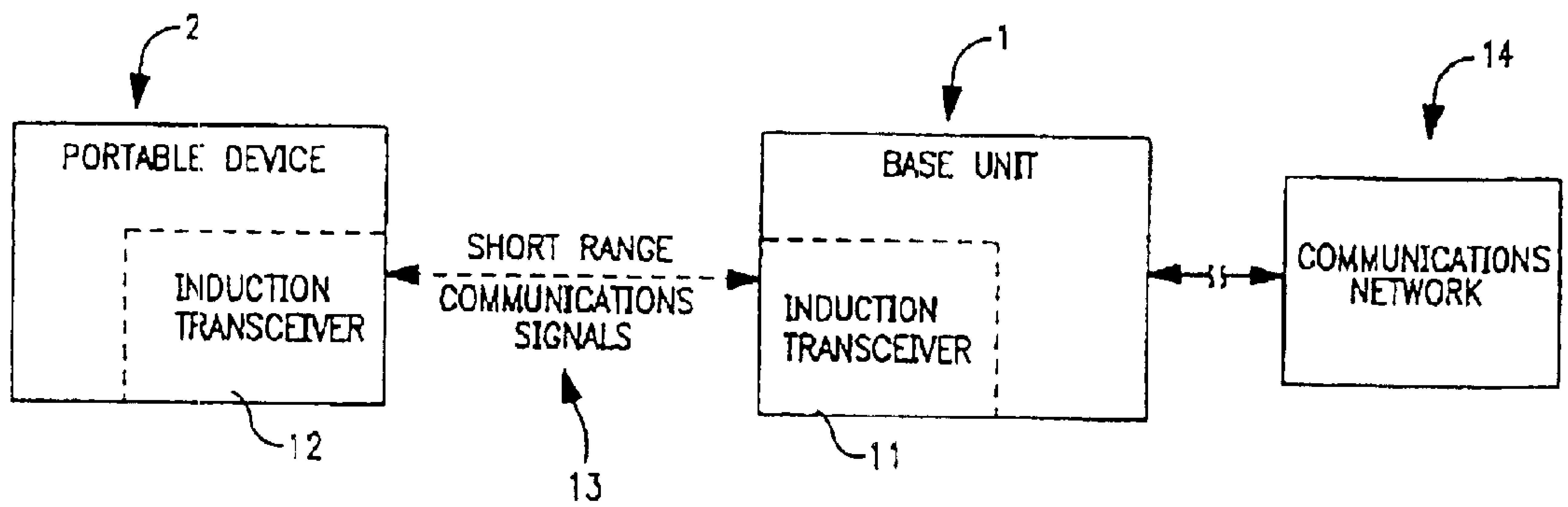

2
PORTABLE DEVICE
INDUCTION TRANSCEIVER
12
SHORT RANGE
COMMUNICATIONS SIGNALS
13
1
BASE UNIT
INDUCTION TRANSCEIVER
11
14
COMMUNICATIONS NETWORK

FIG. 1

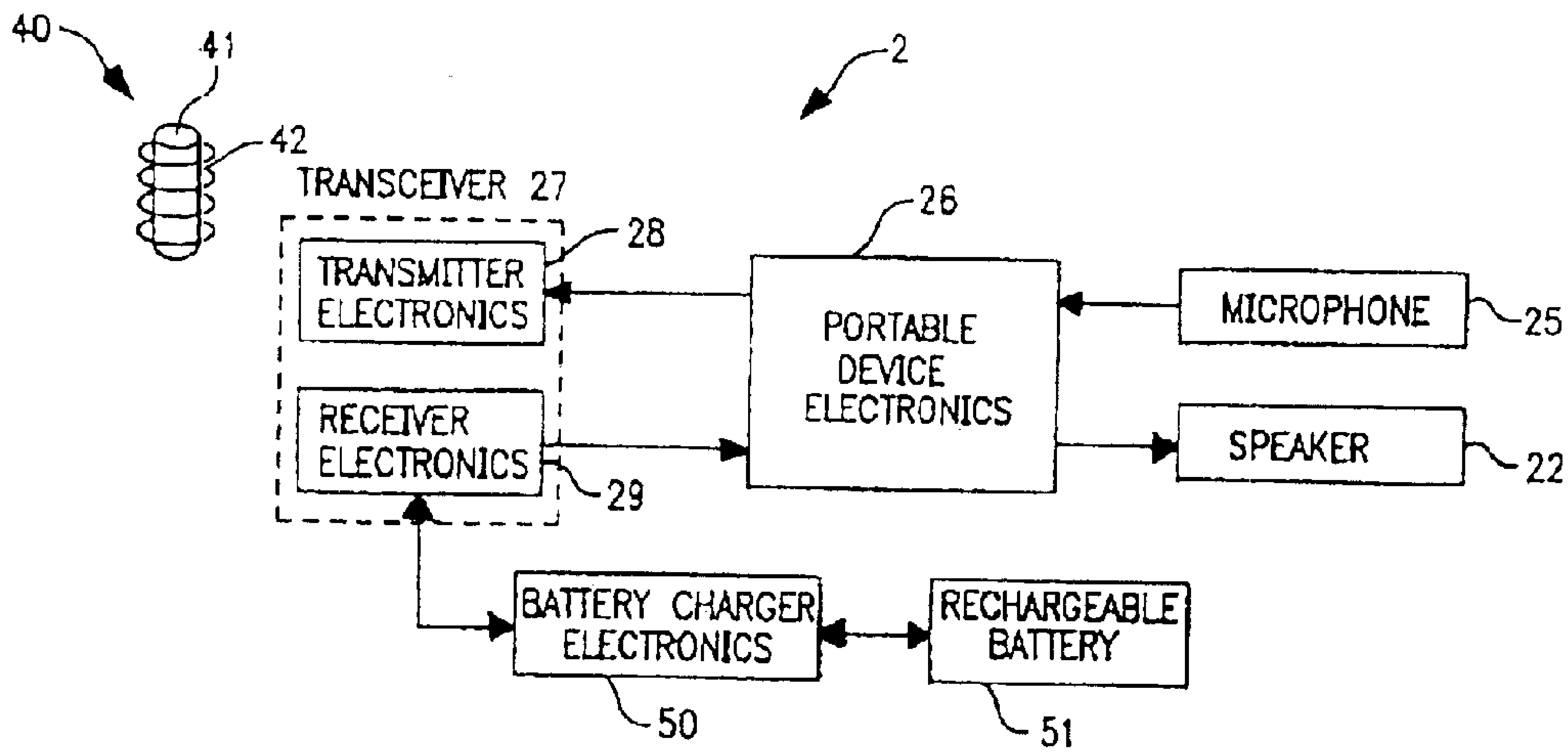

40
41
42
2
TRANSCEIVER 27
28
TRANSMITTER ELECTRONICS
RECEIVER ELECTRONICS
29
26
PORTABLE DEVICE ELECTRONICS
MICROPHONE
25
SPEAKER
22
BATTERY CHARGER ELECTRONICS
50
RECHARGEABLE BATTERY
51

FIG. 4

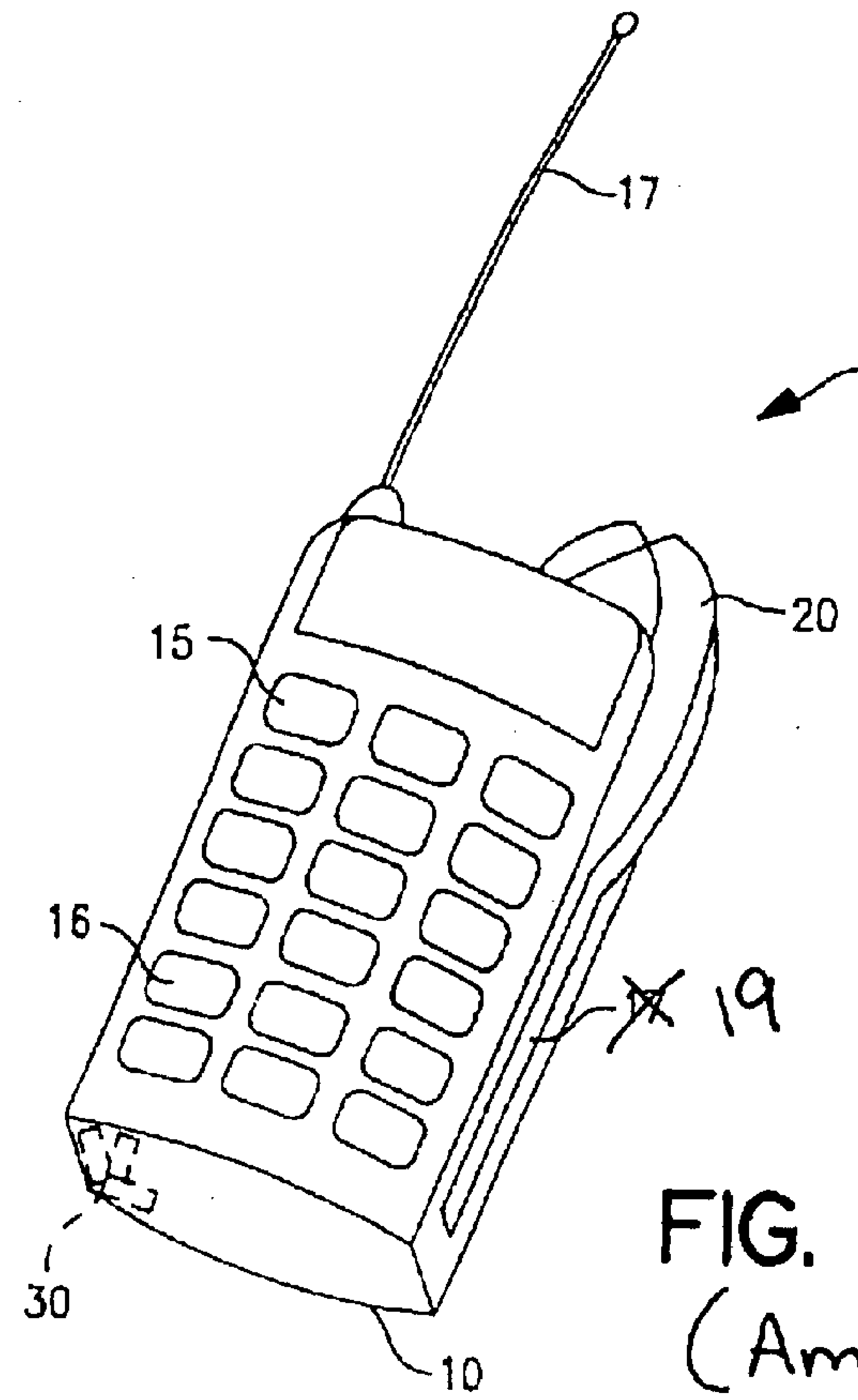


FIG. 2
(Amended)

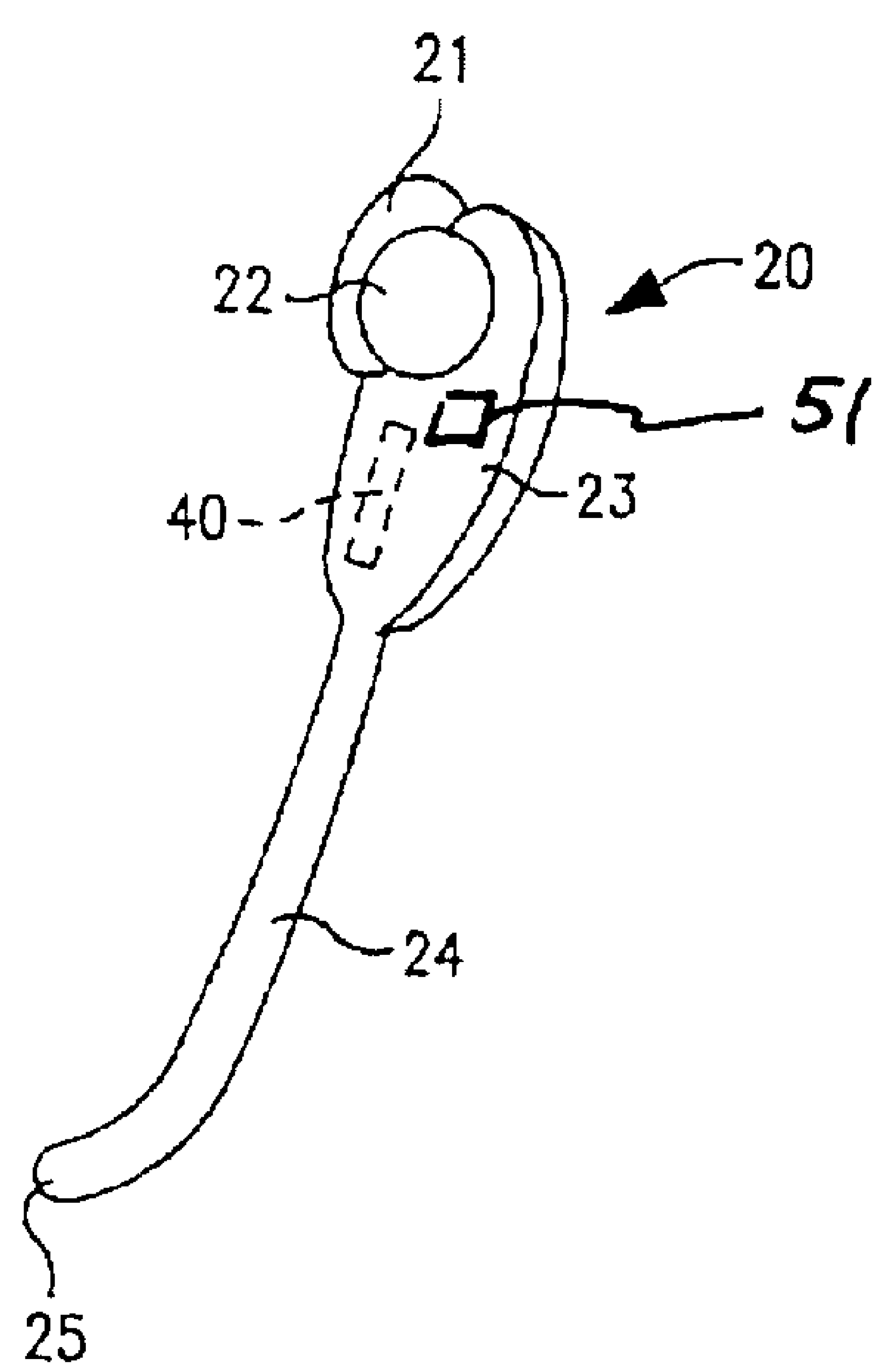


FIG. 3
(Amended)

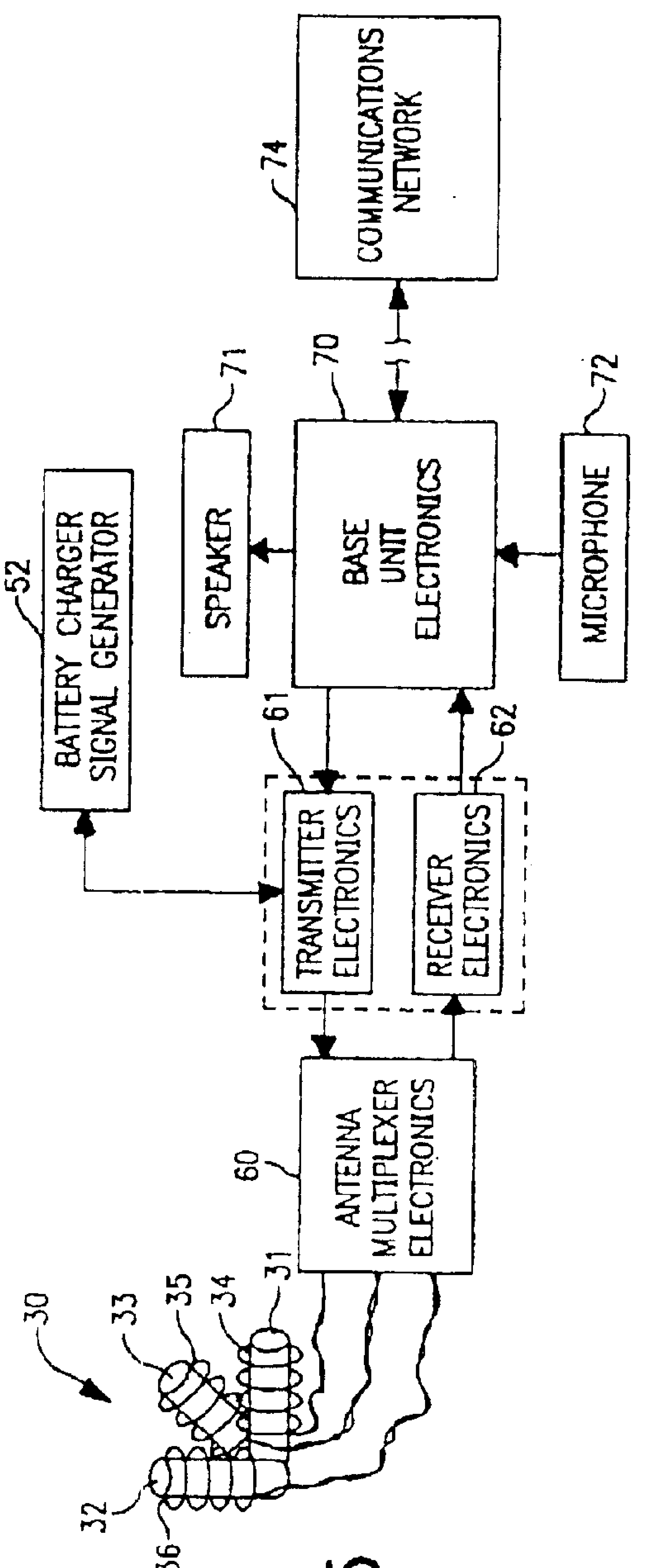

BATTERY CHARGER SIGNAL GENERATOR
52
SPEAKER
71
BASE UNIT ELECTRONICS
70
COMMUNICATIONS NETWORK
74
MICROPHONE
72
TRANSMITTER ELECTRONICS
61
RECEIVER ELECTRONICS
62
ANTENNA MULTIPLEXER ELECTRONICS
60
30
33
35
34
31
32
36

FIG. 5

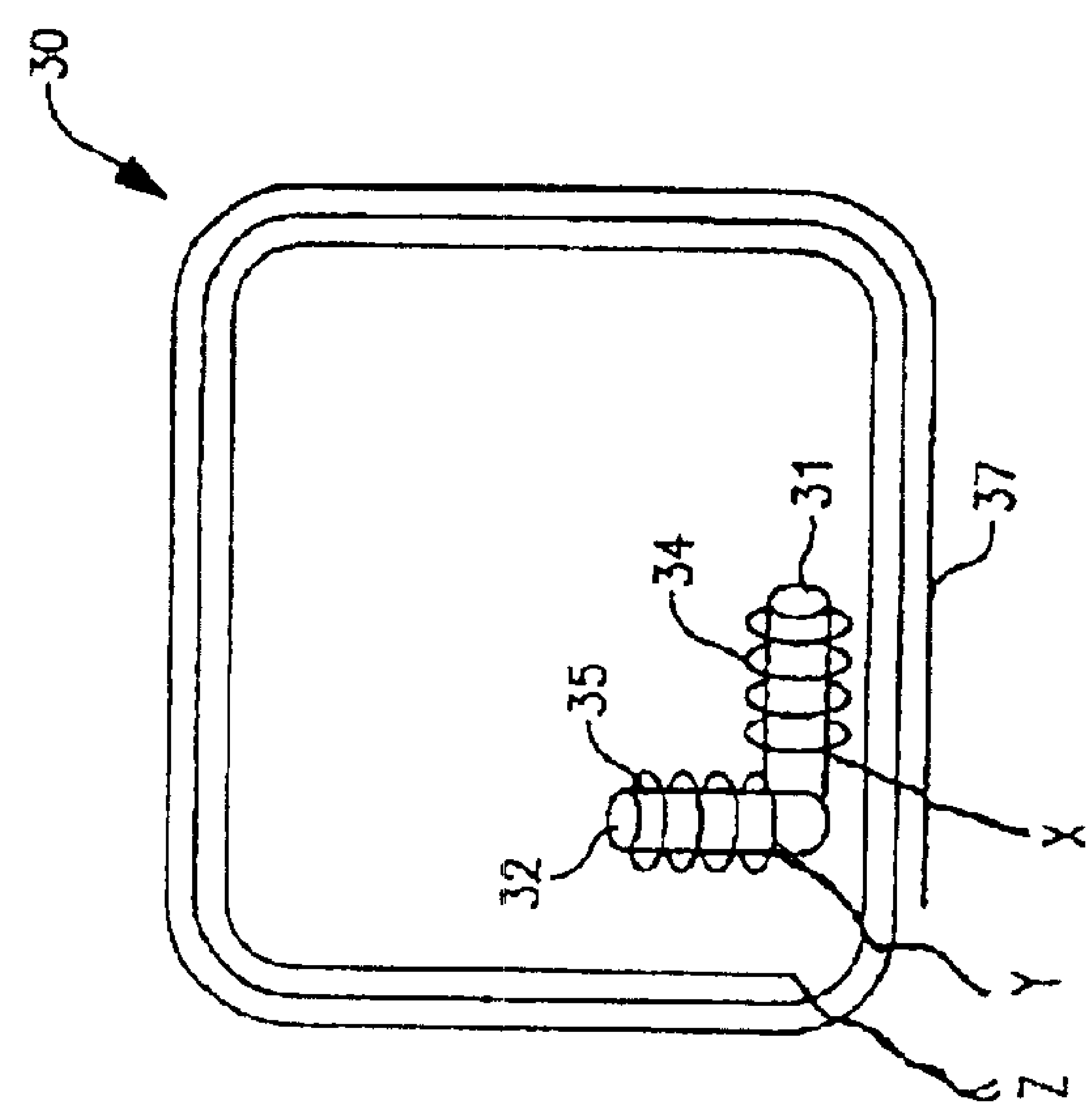
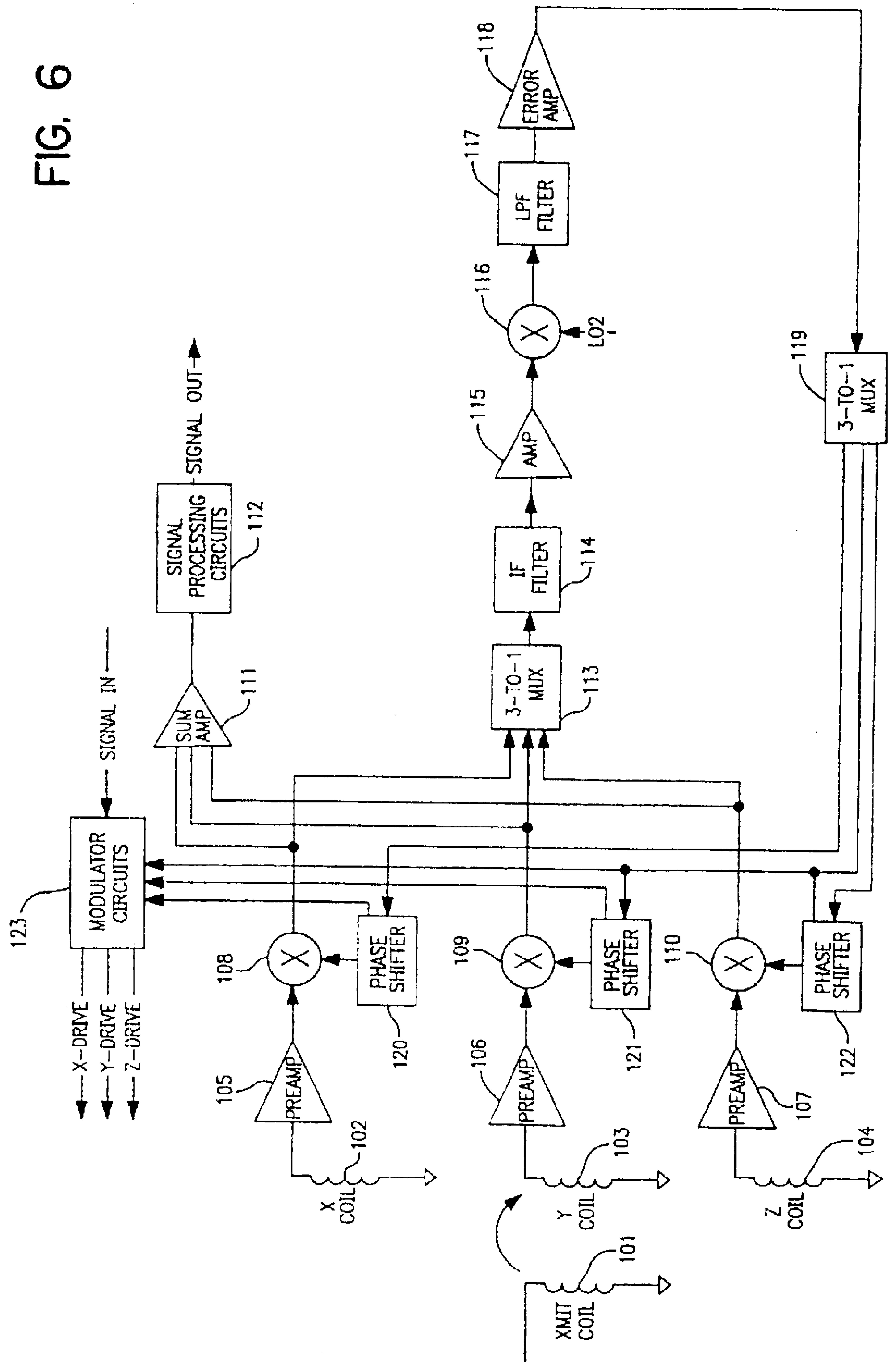

30
31
34
35
32
37
X
Y
Z

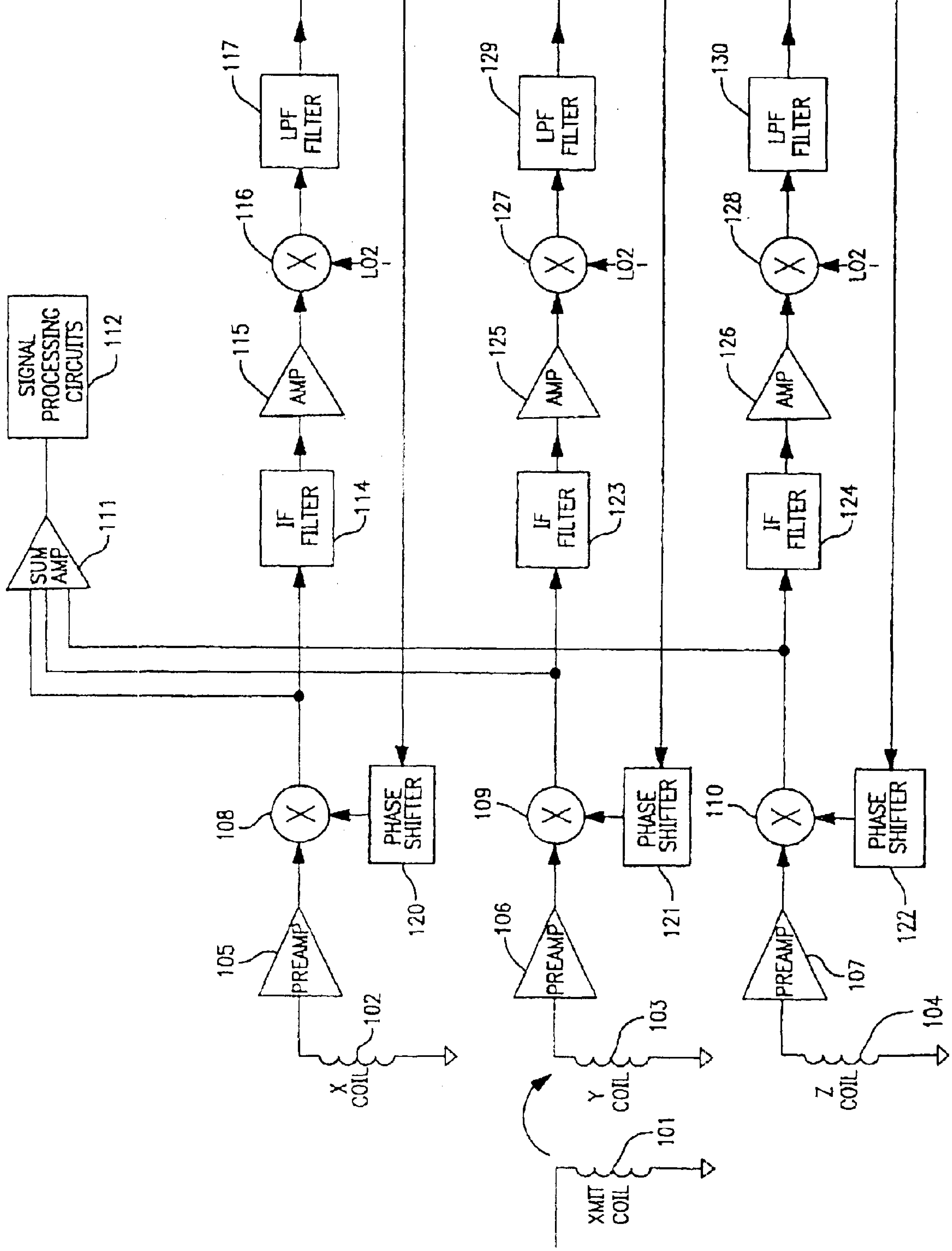
FIG. 11

FIG. 6



SIGNAL IN
SIGNAL OUT
MODULATOR CIRCUITS
123
X-DRIVE
Y-DRIVE
Z-DRIVE
SUM AMP
111
SIGNAL PROCESSING CIRCUITS
112
3-TO-1 MUX
113
IF FILTER
114
AMP
115
116
LO2
LPF FILTER
117
ERROR AMP
118
3-TO-1 MUX
119
PHASE SHIFTER
120
PHASE SHIFTER
121
PHASE SHIFTER
122
108
109
110
PREAMP
105
PREAMP
106
PREAMP
107
X COIL
102
Y COIL
103
Z COIL
104
XMIT COIL
101

FIG. 7


SIGNAL PROCESSING CIRCUITS
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SUM AMP
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ERROR AMP
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132
LPF FILTER
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129
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LO2
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AMP
115
125
126
IF FILTER
114
123
124
108
109
110
PHASE SHIFTER
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121
122
PREAMP
105
106
107
X COIL
102
Y COIL
103
Z COIL
104
XMIT COIL
101

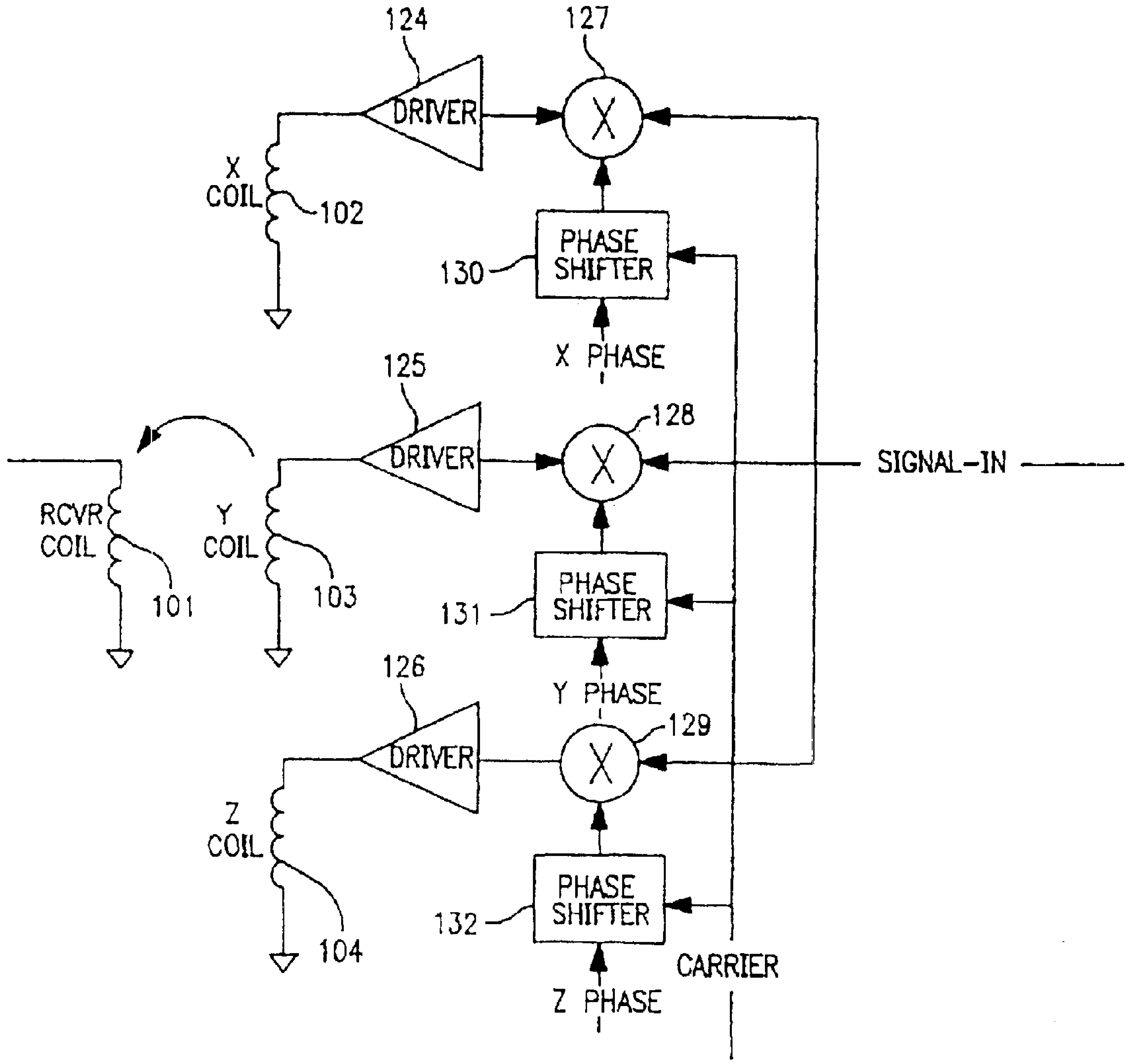
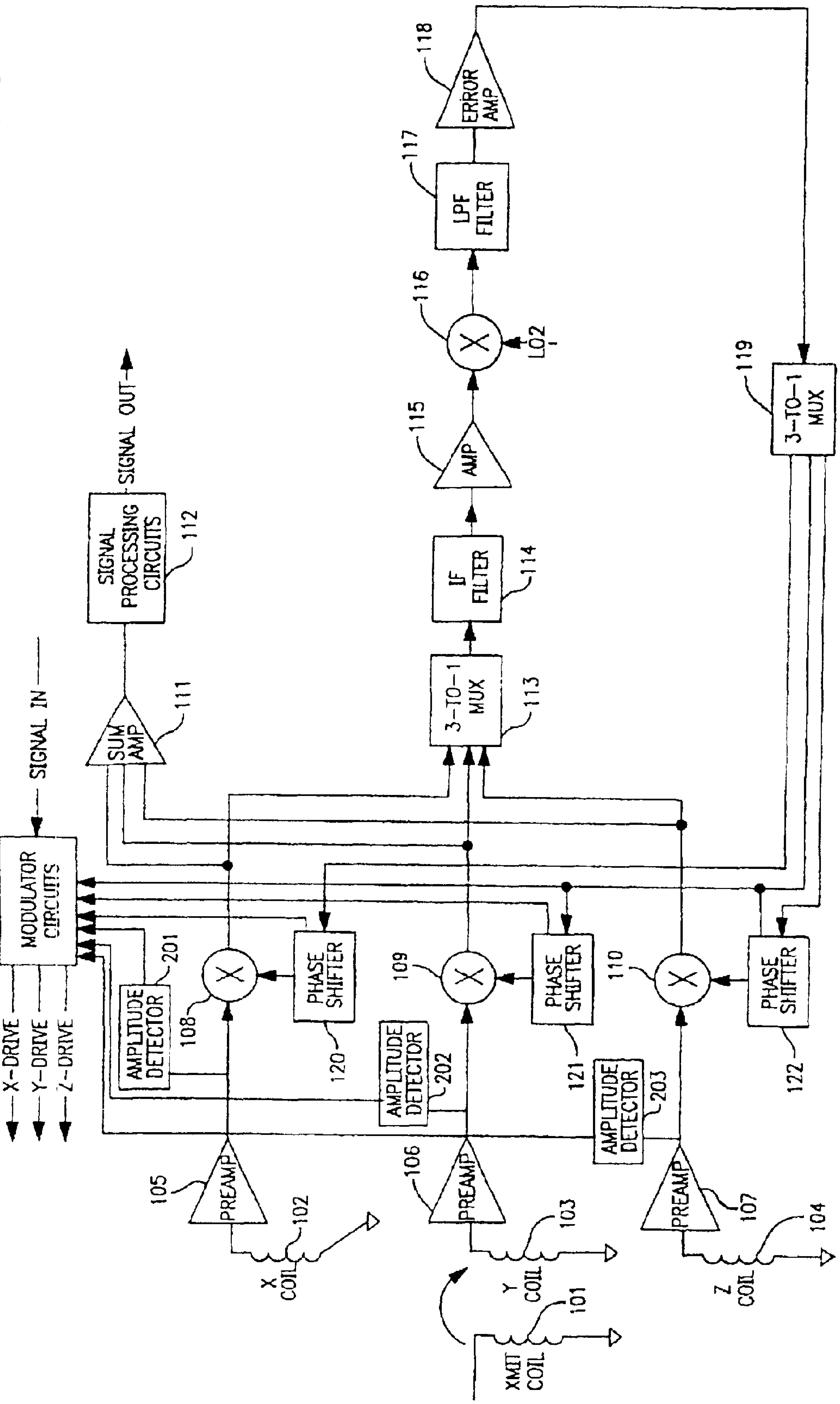

124
127
DRIVER
X
X
COIL
102
PHASE
SHIFTER
130
X PHASE
125
128
DRIVER
X
SIGNAL-IN
RCVR
COIL
101
Y
COIL
103
PHASE
SHIFTER
131
Y PHASE
126
129
DRIVER
X
Z
COIL
104
PHASE
SHIFTER
132
CARRIER
Z PHASE

FIG. 8

FIG. 9



XMIT COIL
101
X COIL
102
Y COIL
103
Z COIL
104
PREAMP
105
106
107
108
109
110
AMPLITUDE DETECTOR
201
202
203
PHASE SHIFTER
120
121
122
MODULATOR CIRCUITS
223
X-DRIVE
Y-DRIVE
Z-DRIVE
SIGNAL IN
SUM AMP
111
SIGNAL PROCESSING CIRCUITS
112
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LO2
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117
ERROR AMP
118
119

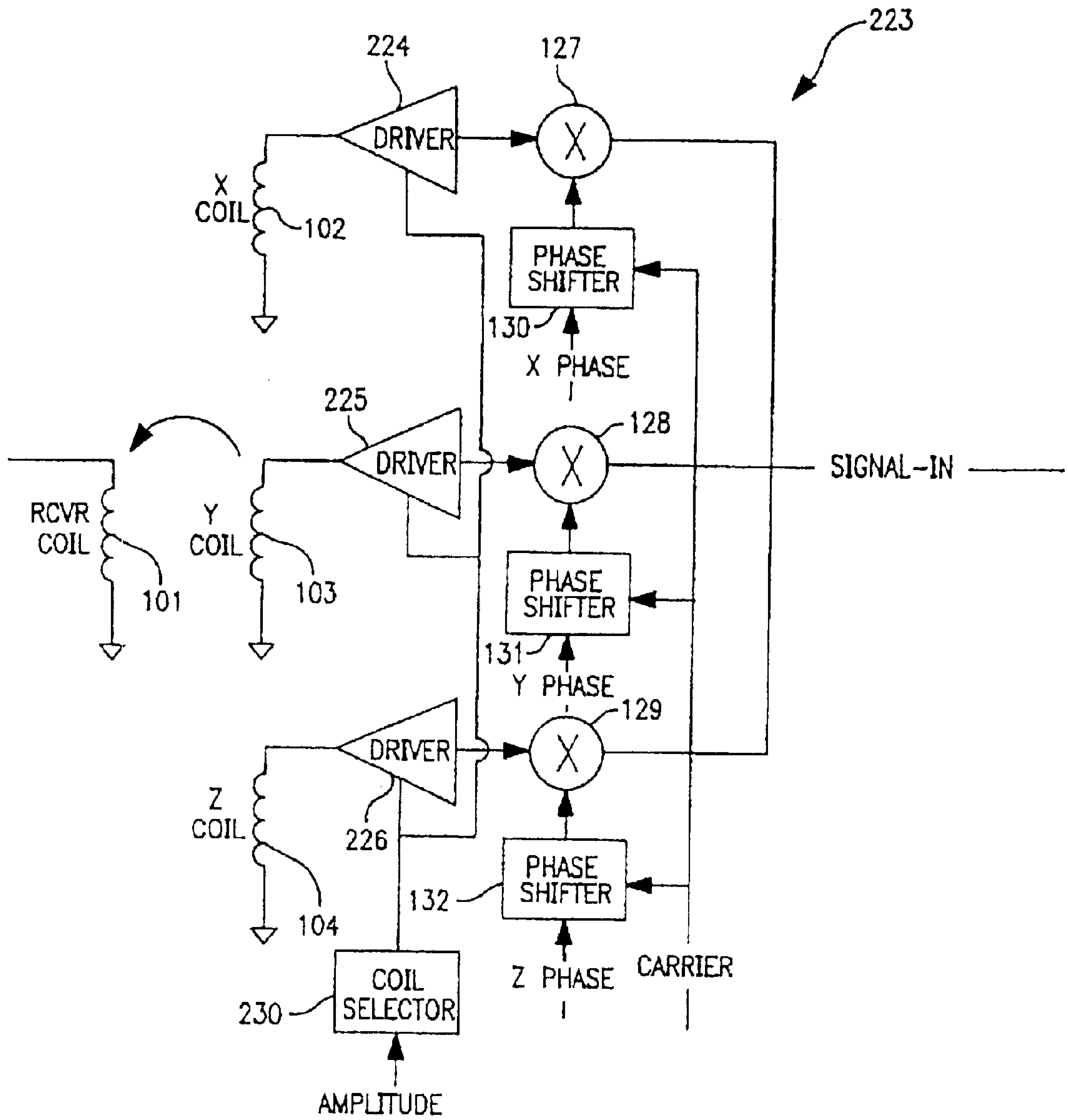
223
224
127
DRIVER
X
X COIL
102
PHASE SHIFTER
130
X PHASE
225
128
DRIVER
X
SIGNAL-IN
RCVR COIL
101
Y COIL
103
PHASE SHIFTER
131
Y PHASE
129
DRIVER
X
Z COIL
104
226
PHASE SHIFTER
132
COIL SELECTOR
230
Z PHASE
CARRIER
AMPLITUDE

FIG. 10

DIVERSITY CIRCUIT FOR MAGNETIC COMMUNICATION SYSTEM

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

CROSS-REFERENCE TO RELATED APPLICATION

This is a continuation-in-part of U.S. patent application Ser. No. 08/444,017, filed May 18, 1995.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to magnetic communication systems. More particularly, it relates to a magnetic communication system which eliminates nulls in a mutual inductance field through a combination of signals from multiple transducers.

2. Discussion of the Related Art

When using a telephone, continually holding the handset to one's ear can be awkward. Also, holding the telephone interferes with the use of both hands for other work while trying to talk. In particular, the use of cellular telephones, which has increased dramatically, can interfere with the user's proper operation of an automobile. Various techniques have been used to overcome these difficulties.

Speaker phones allow one to talk while roaming around a room and using one's hands. However, speaker volume can disturb others around the user. They also cannot be used in close proximity to other speaker phones due to interference. They have limited privacy since the speaker broadcasts the conversation to all within earshot. Typically, the user must speak more loudly than normal to have proper reception at the microphone. Also, they tend to have poor sound quality because the user is not near the microphone and acoustics in the room are poor.

Headsets have been another way to free up the hands of a telephone user. Typically, the headset includes an adjustable strap extending across the user's head to hold the headset in place, at least one headphone located by the user's ear, and a microphone which extends from the headset along and around the user's face to be positioned in front of the users mouth. The headset is attached by a wire to the telephone. Headsets have the disadvantages of being bulky and somewhat awkward to use. Although they permit hands free use of the telephone, the user has limited mobility due to the connecting wire.

Wireless headsets have also been developed which eliminate the connecting wire to the telephone. The wireless headset uses radio frequency (RF) technology or infrared technology for communicating between the headset and a base unit connected to the telephone. The need for communications circuitry and sufficient power to communicate with the base unit increases the bulk and weight of the headset. This increased weight can become tiresome for the user. One alternative has been to attach the headset by a wire to a transmitting unit worn on the belt of the user. As with wired headsets, the wire can become inconvenient and interfere with other actions by the user. Significant interference rejection circuitry is also needed when multiple wireless headsets are used in close proximity.

Magnetic induction fields can be used to provide a communication link between a base unit and a headset. However, magnetic induction fields suffer from signal nulls at certain positions and orientations between the transmitter and receiver. When performing magnetic communications, a specific position and orientation between the transmitter and receiver is typically required. With a single transducer at the transmitter and receiver, certain positions and orientations result in no signal being received due to nulls in the mutual inductance between the transducers. The signal can be recovered by reorienting one of the transducers. It is also possible to use multiple, orthogonally positioned coils at the transmitter or receiver so that at least one coil does not have a null. Different mechanisms have been used to select or combine outputs from the transducers in order to provide communications.

In U.S. Pat. No. 4,489,330, a four coil transducer receiver includes a mercury switch array for selecting a coil transducer. As the receiver is moved, the switch array activates to pick up the positive phase components from the coils. However, this system cannot compensate for changes in position and orientation of the transmitter, and, thus, requires a stationary transmitter. Also, the mercury switch array is large, costly, and sometimes unreliable. Furthermore, switching transients occur as different coils are selected, which causes degradation of the signal and possible loss of information.

In U.S. Pat. No. 4,967,695, a three axis magnetic induction system used as a proximity detector is described. In this system, the outputs of the three coils are combined to provide a single received signal. While this system eliminates switching transients, it has other deficiencies. Since the output signal reverses polarity when it is rotated 180 degrees, the summed signal can be zero in some situations. Thus, the nulls present in the single transducer system are merely repositioned. Furthermore, the simple summing of signals from all three transducers can increase noise levels. For a proximity detector, noise is not a significant concern because it is merely attempting to determine the existence of a signal. Much better signal to noise ratios are needed in order to receive communication signals.

SUMMARY OF THE INVENTION

The deficiencies of prior art systems are overcome in great part by the present invention which, in one aspect, includes a short-range, wireless communication system including a miniaturized portable transceiver and a base unit transceiver. The miniaturized portable transceiver sends and receives information through magnetic induction to the base unit, which may also be portable. Similarly, the base unit sends and receives information through magnetic induction to the portable transceiver. The information can be voice, data, music, or video. Use of magnetic induction fields reduces the power requirements and thus allows a smaller size and greater convenience.

In another aspect of the present invention, the base unit or portable device may include multiple, orthogonally arranged transducers for generating multiple magnetic fields. The multiple fields substantially eliminates mutual inductance nulls between the base unit and portable unit which result at certain positions in a generated field. In another aspect of the present invention, the multiple transducers may be selectively operated based upon a strongest signal, in order to limit power consumption and improve signal reception. The signals from the transducers are electronically scanned. The signals are then phase adjusted and combined to achieve a maximum signal level. In another aspect of the invention, the same phase information is used for a transmitted signal.

This allows the other device to use a single transducer while maintaining a high signal to noise ratio.

In another aspect of the present invention, the magnitude of the incoming signals is used for selective transmission on one or more of the transmission transducers. The amplitude of the signal from each of the transducers is determined. This amplitude information is used for selecting one or more drivers for the transmission transducers corresponding to the greatest amplitude.

In another aspect of the present invention, a headset contains the miniaturized transceiver which communicates with the base unit through magnetic induction fields. In another aspect of the present invention, the headset may be of the concha type in which the speaker fits into the user's ear without a strap across the head and the transceiving transducer is encapsulated into the microphone boom which is short and straight along the user's cheek. In another aspect of the invention, the base unit may be a portable telephone, which can be attached to the user, to further transmit communications from the wireless communication system to a cellular telephone network or a cordless telephone unit.

In another aspect of the invention, the communication system is half-duplex where the base and headset alternatively transmit and receive digital audio. In another aspect the communication system is a simplex system where the receiver has multiple transducers.

With these and other objects, (a) advantages and features of the invention that may become apparent, the nature of the invention may be more clearly understood by reference to the following detailed description of the invention, the appended claims and the several drawings attached hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates schematically the wireless communication system of the present invention.

FIG. **2** illustrates a telephone handset as the base unit in the communication system of FIG. **1**.

FIG. **3** illustrates a headset that is utilized as the portable device in the communication system of FIG. **1**.

FIG. **4** illustrates schematically the transducer and electronics of the portable device.

FIG. **5** illustrates schematically the transducer and electronics of the base unit.

FIG. **6** illustrates an embodiment of the signal processing circuitry to combine signals from three coil transducers.

FIG. **7** illustrates a second embodiment of the signal processing circuitry to combine signals from three coil transducers.

FIG. **8** illustrates the use of three transducer for transmitting signals to a single reception transducer.

FIG. **9** illustrates a third embodiment of the signal processing circuitry to combine signals from three coil transducers.

FIG. **10** illustrates the use of three transducer for transmitting signals to a single reception transducer in accordance with the signal processing circuitry of FIG. **9**.

FIG. **11** illustrates an alternative transducer configuration for the base unit.

DETAILED DESCRIPTION

FIG. **1** illustrates schematically a short-range magnetic communication system **1** including a portable device **2** and a base unit **1**, which connects to a long-range communication network **14**. Contained within each of the base unit **1** and the portable device **2** is a short-range miniaturized magnetic induction transceiver **11**, **12**, which can simultaneously transmit and receive communications signals **13**. These signals may be voice, audio, data, or video. The communications network **14** may be any network in which it would be desirable for these signals to be communicated over a terminal link without wires, such as a telephone network, personal communications (PCS) network, special mobile radio (SMR) network, computer system or network, and video conferencing systems. The base unit **1** may any part of the communications network **14** from which it would be desirable to communicate to another device without wires; for example, it may be a telephone handset, PCS handset, SMR handset, walkie-talkie, computer or computer peripheral devices, personal digital assistant (PDA), or video game controller. The portable device **2** may be any device from which it would be desirable to communicate without wires to a communications network; for example, it may be a telephone headset or handset, portable computer or computer peripheral device, headphone, or video input device.

As illustrated in FIG. **2**, one example of the base unit **1** is a portable telephone **10** having a plurality of number buttons **15** and a plurality of function buttons **16**. A retractable transducer **17** communicates with a cellular telephone network or a cordless telephone base unit. The portable telephone **10** operates in a manner similar to that of an ordinary cellular or cordless telephone handset. Signals are sent to and received from the telephone network in an ordinary manner. The portable telephone **10** includes a transducer system **30** which communicates by magnetic induction with headset **20**, which operates as the portable device **2**, to provide the outputs and inputs to the portable telephone **10**. The portable telephone **10** may also include a mouthpiece or earpiece (not shown) as in a regular telephone method allowing the user to choose between a conventional method of operation and a hands-free use afforded by the headset **20**.

The portable device **2** as a headset **20** is illustrated more fully in FIG. **3**. It includes a body portion **23** which houses a transducer **40** and processing circuitry. A speaker **22** is connected to the circuitry within the body **23**. An earpiece **21** next to the speaker **22** fits in the user's ear to hold the unit in place and to allow the user to hear sounds from the speaker. A microphone boom **24** extends from the body **23** several inches in order to place a microphone **25**, located at the end of the boom **24**, close to the user's mouth. Alternatively the transducer **40** may be housed in the boom **24**. A rechargable battery **51** is also housed in the body **23** of the headset **20** to provide power to the headset. Other features may be optionally included in the headset **20**, such as switcher or buttons for manually activating different modes. For example, a capacitive switch or push-button could be used to cause the headset **20** to transmit a control signal to the portable phone **10** to activate muting of the microphone. The portable phone **10** may include a receptacle **19** for receiving and holding the headset **20**. Depositing the headset in the receptacle can provide a variety of functions, in addition to maintaining the headset **20** and portable phone **10** together. A switch can be disposed in the receptacle to terminate the telecommunication when the headset **20** is inserted or initiate the telecommunication when it is removed. The receptacle may also include connections to recharge the battery **51** in the headset **20**.

The base unit **1** and portable device **2** communicate through amplitude modulation of inductive fields, although other modulation methods such as frequency, phase, or digital modulation could be employed. During use, the distance between the portable device **2** and the base unit **1** typically is short. Since the distance is short, only an inductive field is necessary, and little or no radiation occurs. This limits the operating power, which allows a smaller size and weight for the rechargable battery **51** and, thus, the portable device **2**. Furthermore, it limits interference between systems operating in close proximity. Therefore, interference rejection circuitry may be limited or not necessary in the portable device **2**.

The transducer system in the portable device **2** is illustrated schematically in FIG. **4**. The transducer **40** preferably includes a ferrite rod transducer having a ferrite rod **41** within a wire coil **42**. The wires from the transducer **40** are connected to a transceiver **27** having transmitter electronics **28** and receiver electronics **29**. The transceiver **27** connects to the portable device electronics **26**, the nature of which is dependent upon the function of the portable device **2**. In the example of the portable device as a headset **20**, the portable device electronics would connect to a speaker **22** and a microphone **25**. Transmission and reception can occur at different frequencies, which permits full duplex operation. Alternatively, separate transmitting and receiving transducers can be used.

The base unit **1** configuration is illustrated schematically in FIG. **5**. The transducer system **30** includes three orthogonally disposed ferrite rod transducers, each including a ferrite rod **31**, **32**, **33** and a respective coil **34**, **35** and **36**. The use of the orthogonally disposed transducers overcomes the occurrence of mutual inductance nulls in the resulting inductive fields. The three transducers are connected to multiplexer electronics **60** for selecting one or more of the transducers for transmission and reception. Circuitry in the multiplexer electronics may be used to select the transducer or transducers having the strongest signal for transmission and reception to reduce the total power consumption of the device. Circuitry can also be used to control the phases of signals from each of the transducers for combining the signals. Thus, the phases should be continuously adjusted to provide a maximum signal level. Alternatively, a non-zero signal can be attained simply be revising the phase of one or more signals so that all signals have the same sign.

The transmitter electronics **61** and receiver electronics **62** provide for processing of the communications signals from the base unit electronics **70** and the portable device **2**. As discussed above, for a portable telephone **10**, the conventional telephone speaker **71** and mouthpiece **72** may be eliminated so that the portable telephone **10** solely uses the headset **20** through the transducer system for communicating to the user. Switching circuitry (not shown) would be included to select between the speaker **71** and microphone **72**, and the headset **20**. The switching circuitry could be included in the receptacle **19** so that the speaker **71** and microphone **72** are disconnected when the headset **20** is removed.

FIG. **6** illustrates an embodiment the multiplexer electronics **60** in the base unit for adjustment of the signal phases in combining signals from the three orthogonal transducers. The coil transducers **102**, **103**, **104**, receive a signal from a transmission coil **101** in the portable device **2**. Preferably, the transmission signal is a modulated carrier, nominally 500 KHz. Preamplifiers **105**, **106**, **107** are respectively connected to the transducer coils **102**, **103**, **104** in the base unit **1** to provide a modest gain to the signals. The phases of the received signals are adjusted by multiplying in mixers **108**, **109**, **110** the received signal by a local oscillator signal from respective phase shifters **120**, **121**, **122**. In addition to adjusting the phases of the signals, the mixers and phase shifters shift the frequency of the signal, including the modulation signal and the carrier signal to an intermediate frequency, such as 455 KHz. The use of an intermediate frequency permits signal processing to occur at a single common frequency, regardless of the frequencies used for transmission and reception. This also allows the signal processing circuitry of the IF section to be optimized independently of the carrier frequencies. A summing amplifier **111** receives and combines the phase adjusted signals from the mixers **108**, **109**, **110**. Since the phases of the signals can be adjusted, the summing of the three signals provides maximum signal strength, which minimizes noise and nulls. The summed signal is then provided to signal processing circuits **112** to provide an output signal for the base unit **1**.

The phase adjusted signals are also processed to maintain maximum signal strength through the phase adjustment process. Various processes can be used to adjust phases. As noted above, one problem with merely summing signals from different transducers is that the signals can have different polarities which can cancel the signals when summed. One possible phase adjustment is to change polarities of signals. The polarity of each of the signals is determined. Then, the polarity of one or more signals is changed by the phase shifters **120**, **121**, **122** so that the polarities are always the same. Thus, when the signals are combined by the summing amplifier **111**, they never cancel each other and a maximum signal is achieved.

FIG. **6** illustrates another embodiment for adjusting phases of the signals from the transducers. In this embodiment, the phases are continuously adjusted to maintain the signals in phase. The phase adjustment process compares the phases of each of the signals received on the three coils with a reference phase. A local oscillator in the phase shifter is controlled to maintain the phase of the coils coincident with the reference phase. To provide the phase adjustment process, the phase adjusted signals from the multipliers **108**, **109**, **110** are provided to a 3-to-1 multiplexer **113**, which sequentially outputs the signals from each of the three coils as phase adjusted. The phase of the signal selected by the multiplexer is determined by passing the signal through an IF filter **114**, and an amplifier **115**. The filtered signal is then mixed **116** with a local reference oscillator signal. The error between the phase of the adjusted signal and the phase of the local oscillator is determined by passing the mixed signal through a low pass filter **117**. The error is then amplified **118** and returned in a feedback loop through a multiplexer **119** to the appropriate phase shifter, to adjust a respective local oscillator.

According to the embodiment of the invention illustrated in FIG. **6**, the phases of the signals received on the x coil, y coil, and z coil are processed sequentially. Thus, multiplexers **113** and **119** are set to select the x coil until the phase error has been reduced to a minimally acceptable level. The phases of the other two coils, y and z, are maintained while the phase of the first coil, x, is adjusted. After the phase of the x coil has been set, the multiplexers are switched to correct any phase error in the signal received by the y coil and the z coil. The phase adjustment process is fast enough to track relative movements between the transmitting coil **101** and the receiving coils **102**, **103**, **104**. A frequency of 20 Hz has been found to be sufficient for purposes of tracking the coils.

Alternatively, if the coils are likely to be moving more quickly than can be tracked through serial phase adjustment, a phase adjusting circuit can be applied separately to each of the coils. This embodiment is illustrated in FIG. **7**. Each of the mixers **108**, **109**, **110** is connected to a separate IF filter **114**, **123**, **124** and amplifier **115**, **125**, **126** to measure the phase of the signal received at the respective coil. Each phase is then compared with a reference phase by mixing the signal with the output of a local oscillator. Since the same oscillator is used for the signals from each of the coils, the signals will remain in phase with each other. The mixed signal from the mixers **116**, **127**, **128** are passed through respective low pass filters **117**, **129**, **130** and error amplifiers **118**, **131**, **132** to provide error signals representing the difference between the phase of the received signal at each coil and the reference phase. The error signals are applied to the phase shifters **120**, **121**, **122** to adjust the phases of each of the received signals to maintain the phase coincidence for summing. As in the prior embodiment, the phase adjusted signals are combined by the summing amplifier **111** and further processed by the signal processing circuits **112** to provide an output from the base unit **1**.

The phase adjustment information used in receiving signals can also be used in driving transmission signals to provide a maximum signal level at the receiver location. Since the phases of the incoming signals are adjusted to achieve a maximum signal level, the phase adjustments define the position and orientation of the transmitting coil. The same phase adjustments on transmission compensate for this position and orientation. Thus, a single reception coil can be used. According to an embodiment of the invention, the base unit **1** includes three orthogonally positioned coil transducers with phase adjusting circuitry for both reception and transmission. The portable device, therefore, only requires a single coil transducer and can be made smaller in size. As illustrated in FIG. **6**, the phase shifters output a phase adjustment to modulator circuits **123** for driving transmission signals. The modulator circuits **123** are shown more fully in FIG. **8**. A signal to be transmitted is split and inputted into three mixers **227**, **228**, **229**. Three phase shifters **230**, **231**, **232** receive a carrier signal and a respective phase adjustment. The phase adjustments are received from the phase shifters **120**, **121**, **122** in the reception circuitry. The phase shifters provide the phase adjusted carrier signal to the **[**multiplexers**]** *mixers* **227**, **228**, **229**, where they are multiplied by the signal to be transmitted. The resulting multiplied signals are passed to respective drivers **224**, **225**, **226** for the three coil transducers **102**, **103**, **104** for the base unit **1**. When the transmitted signal is phase shifted on each of the three coil transducers, the outputs are summed magnetically in transmission to provide a maximum signal at the receiving coil **101**.

FIGS. **9** and **10** illustrate another embodiment of the present invention for selective transmission on one of the transducers. As illustrated in FIG. **9**, an amplitude detector **201**, **202**, **203** is connected to each of the transducers **102**, **103**, **104**. The outputs of the amplitude detectors are provided to the modulator circuits **223** for transmission. The modulator circuits **223** are illustrated in FIG. **10**. The phase shifters and multipliers operate in the same manner as discussed above. The amplitude information from the amplitude detectors are provided to a coil selection circuit **230**. The coil selection circuit selectively activates one of the drivers **224**, **225**, **226** for the coils. Thus, the coil having the strongest signal can be used for transmission, without having to energize all of the coils. Although FIG. **10** illustrates phase shifting the input signal for all of the coils, when the coils are selectively activated based upon magnitude, the phase shifters can be omitted. Alternatively, if the amplitudes are similar on two or three coils, each of these coils can be activated to increase the transmitted signal. When more than one coil is activated, phase shifting, at least as to polarity, may be needed to avoid cancellation of signals.

FIG. **11** illustrates a second embodiment of the transducer system for the base unit **1**. In the transducer **30** of FIG. **6**, one of the ferrite rod transducers is replaced with a loop coil transducer **37**. A loop coil transducer can replace any or all of the ferrite rod transducers. The loop coil transducer **37** is disposed in the plane of the remaining ferrite rod transducers. This creates a transducer system having a decreased depth. As illustrated in FIG. **2**, the three orthogonal transducers can be placed in a corner along the sides of the portable telephone **10**. Alternatively, the loop coil transducer **37** could be placed along the back of the portable phone **10**, so that it could made thinner.

Additionally, the transmission system can be used for charging the battery **51** of the portable device **2**. The base unit **1** includes a battery charger signal generator **52** connected to the transmitter **61**. This generator **52** produces a recharging signal which is sent through one of the ferrite rod transducers in the base unit **1** to the ferrite rod transducer **40** of the portable device **2**. Since in the telephone embodiment of FIG. **2**, the headset **20** and transducer **40** have a known orientation when in the receptacle **19**, only one transducer in the portable telephone **10** needs to be energized to inductively transmit the recharging signal. As illustrated in FIG. **3**, the wires from the transducer **40** in the portable device **2** are connected to a battery charger **50** which is used to charge the battery **51**.

Although the communication system of the present invention has been illustrated in connection with a concha type headset **20** and a cellular or cordless telephone handset **10** as a base unit **1**, it is readily adaptable for other types of headsets and uses. The headset can be of the over-the-head type, over-the-ear type, or binaural type. The system can be used as a wireless connection to a conventional desktop telephone. Such a system would operate in the manner discussed above with the cordless bandset. Since several such units may be used in close proximity, interference may become more of a problem. Therefore, the system can be designed to operate on various frequencies and can select frequencies for the transmission and reception which are unlikely to have significant interference. Similarly, the system can be used with a computer, either stationary or portable, for voice data entry, sound transmission, and telephone functions. The system can also be used with other types of communication systems, including personal digital assistants (PDAs), cordless phones, PCS and SMR cellular phones, two way (video games), two-way half duplex (walkie-talkies, CBs), or two-way full duplex (phones), one way simplex headphones. When the base unit is stationary and the user is likely to be at certain locations relative to the base unit, fewer transducers may be used in the base unit without encountering mutual inductance nulls. Alternative transducer systems may also be used for generating the inductive fields. Specifically, rather than a single transducer for transmission and reception on different frequencies, separate transducers may be used.

Having thus described one illustrative embodiment of the invention, various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be within the spirit and scope of the invention. Accordingly, the foregoing description is by way of example only and is not intended as limiting. The invention is limited only as defined in the following claims and equivalent thereto.

What is claimed is:

1. A magnetic inductance communications system, comprising:

a first transmission/reception coil producing a magnetic field including a transmitted signal;

a plurality of second transmission/reception coils having different orientations for receiving the transmitted signal and generating a plurality of received signals;

a summing circuit for combining the plurality of received signals to produce a summed signal;

at least one first phase adjusting circuit for adjusting a phase of at least one respective received signal prior to summing to increase the amplitude of the summed signal; and

a modulator circuit for modulating a signal to be transmitted, wherein the modulator circuit includes:

at least one second phase adjusting circuit receiving a carrier signal and a phase adjustment signal from the at least one first phase adjusting circuit;

a plurality of driving circuits, each driving circuit receiving the signal to be transmitted and a respective output signal from one of the second phase adjusting circuits, for generating a respective driving signal on one of the plurality of second transmission/reception coils to generate a second magnetic field; and

signal processing circuitry connected to the first transmission/reception coil to receive the signal in the second magnetic field.

2. The magnetic inductance communication system of claim **1**, wherein said at least one second phase adjusting circuit changes polarity of the carrier signal based upon a polarity of at least one of the received signals.

3. The magnetic inductance communication system of claim **1**, wherein said at least one second phase adjusting circuit adjusts the phase of the carrier signal according to phases of each of the received signals.

4. A magnetic inductance communication system comprising:

a first transmission/reception coil producing a magnetic field including a transmitted signal;

a plurality of second transmission/reception coils having different orientations for receiving the transmitted signal and generating a plurality of received signals;

a plurality of amplitude determining circuits corresponding to the plurality of second transmission/reception coils for determining amplitudes of the plurality of received signals;

a modulator circuit for modulating a signal to be transmitted, wherein the modulator circuit includes:

a plurality of driving circuits each driving circuit receiving a carrier signal to be transmitted for generating a respective driving signal on one of the plurality of transmission/reception coils to generate a second magnetic field; and

a selection circuit for activating at least one of the driving circuits based upon the amplitudes of the received signals; and

signal processing circuitry connected to the first transmission/reception coil to receive the signal in the second magnetic field.

5. The magnetic inductance communication system of claim **4**, wherein the selection circuit activates one of the driving circuits corresponding to a transmission/reception coil having a greatest amplitude of a received signal.

6. The magnetic inductance communication system of claim **4**, wherein the selection circuit activates two of the driving circuits corresponding to a transmission/reception coils having a greatest amplitudes of received signals.

7. The magnetic inductance communication system of claim **6**, wherein the modulator further includes at least one phase adjusting circuit receiving the carrier signal and a phase adjustment signal for adjusting phase of the carrier signal provided to at least one of the two activated driving circuits so that the combined second magnetic field has a maximum value.

8. A method for communicating, the method comprising the steps of:

receiving an inductive input signal on each of multiple uniquely oriented transducers;

generating an electronic signal corresponding to the received inductive input signal for each of the transducers;

compensating for a relative motion of the transducers with respect to the inductive input signal by adjusting a phase of at least one of the electronic signals; and

summing the aligned electronic signals to produce an output signal that corresponds to the inductive input signal.

9. A method as in claim 8 further comprising:

multiplexing each of the electronic signals to an error amplifier circuit and generating corresponding phase adjustment signals to align the electronic signals.

10. A method as in claim 9 further comprising:

maintaining a phase adjustment of at least one electronic signal during which another electronic signal is monitored for generating a corresponding phase adjustment signal.

11. A method as in claim 8, wherein the transducers are inductive transducer devices.

12. A method as in claim 8 further comprising:

adjusting a polarity of one or more of the electronic signals so that the electronic signals have the same sign and sum to produce a larger output signal.

13. A method as in claim 12, wherein a polarity of an electronic signal corresponding to the inductive input signal is changed by phase shifting.

14. A method as in claim 8, wherein the inductive input signal includes information modulated on a carrier frequency signal.

15. A method as in claim 8, wherein the uniquely oriented transducers are orthogonally disposed to each other.

16. A method as in claim 8 further comprising:

comparing a phase of each of the electronic signals with a common reference signal; and

controlling a local oscillator in a corresponding phase shifter to align the phase of each electronic signal with the reference signal.

17. A method as in claim 8 further comprising:

generating an error signal that is used to adjust a phase of at least one electronic signal relative to a reference signal.

18. A method as in claim 8, wherein the phase of the electronic signals are adjusted at a fast enough rate to account for the relative motion of the transducers.

19. A method as in claim 8 wherein adjusting the phase of at least one of the electronic signals substantially aligns the electronic signals with each other.

20. A method for communicating, the method comprising the steps of:

orienting each of multiple transducers along a unique axis to generate a magnetic field;

identifying a target receiver to which the magnetic field is transmitted; and

adjusting a phase output of the multiple transducers to produce the magnetic field for the target receiver.

21. A method as in claim 20, wherein the magnetic field is generated from three orthogonally disposed transducers.

22. A method as in claim 20 further comprising:

receiving the magnetic field on a single reception coil at the target receiver.

23. A method as in claim 22, wherein the single reception coil is disposed in a portable device.

24. A method as in claim 20 further comprising:

generating an electronic signal of information to be transmitted to the target receiver; and

multiplying the electronic signal with corresponding phase adjusted carrier frequencies to produce modulated signals and driving the transducers with the modulated signals to produce the magnetic field.

25. A method as in claim 20 further comprising:

disposing the multiple transducers in a portable device.

26. A method as in claim 25 further comprising:

coupling the portable device to a communications network.

27. A method for communicating, the method comprising the steps of:

receiving an inductive input signal on each of multiple uniquely oriented receiver transducers, the inductive input signal being received from a remote source transducer;

generating an electronic signal from each of the receiver transducers, each electronic signal corresponding to the inductive input signal;

based on a phase difference of the electronic signals, adjusting a phase of at least one of multiple transmitter transducers to produce an inductive output signal that is transmitted to a target receiver transducer near the remote source transducer.

28. A method as in claim 27, wherein the multiple transmitter transducers are aligned along similar axes as the uniquely oriented receiver transducers.

29. A method as in claim 28, wherein the uniquely oriented receiver transducers and the transmitter transducers to transmit and receive corresponding inductive signals are the same transducers.

30. A method as in claim 27, wherein the target receiver transducer near the remote source transducer is oriented along a same axis as the remote source transducer.

31. A method as in claim 27, wherein the target receiver transducer and the remote source transducer are a single transducer that is used to both transmit and receive corresponding inductive signals.

32. A method as in claim 27, wherein the inductive output signal is transmitted to a portable device.

33. A method as in claim 32, wherein the portable device is coupled to a communications network.

34. A method as in claim 27, wherein the receiver transducers are three orthogonally positioned transducers.

35. A method as in claim 27, wherein the inductive input signal is received from a portable headset.

36. A method as in claim 27 further comprising:

multiplexing each of the electronic signals to an error amplifier circuit and generating corresponding phase adjustment signals to align the electronic signals; and

utilizing the phase adjustment signals to produce the inductive output signal.

37. A method as in claim 36 further comprising:

maintaining a phase adjustment of at least one transmitter transducer during which another electronic signal is monitored for generating a corresponding phase adjustment signal for another transmitter transducer.

38. A method as in claim 27, wherein the inductive output signal includes information modulated on a carrier frequency signal.

39. A method as in claim 27, wherein the uniquely oriented receiver transducers are orthogonally disposed to each other.

40. A method as in claim 27 further comprising:

comparing a phase of each of the electronic signals with a common reference signal; and

controlling a local oscillator in a corresponding phase shifter to adjust the phase of each transmitter transducer with respect to the reference signal.

41. A method as in claim 27 wherein:

adjusting a phase of at least one of the multiple transmitter transducers compensates for a relative motion of the receiver transducers with respect to the inductive input signal.

42. A method for communicating, the method comprising the steps of:

receiving an inductive input signal on each of multiple uniquely oriented receiver transducers, the inductive input signal being generated from a remote source transducer;

producing an electronic signal that corresponds to the inductive input signal for each of the receiver transducers, a level of each electronic signal being proportional to a strength of the received inductive input signal at a corresponding receiver transducer;

tracking a phase of each electronic signal during motion of the remote source transducer relative to the multiple uniquely oriented receiver transducers; and

based on the phase of at least one electronic signal, adjusting an inductive output signal from a transmitter transducer for communicating with a target receiver.

43. A method as in claim 42, wherein the transmitter transducer from which the inductive output signal is generated is one of multiple uniquely oriented transmitter transducers.

44. A method as in claim 43, wherein the uniquely oriented transmitter transducers generating an inductive output signal are aligned along similar axes as the uniquely oriented receiver transducers receiving the inductive input signal.

45. A method as in claim 44, wherein the transducers to transmit and receive corresponding inductive signals are the same multiple uniquely oriented transducers.

46. A method as in claim 43 further comprising:

detecting which of the multiple receiver transducers produces a strongest set of electronic signals; and

generating an inductive output signal from transmitter transducers oriented on similar axes as the receiver transducers that generate the strongest set of electronic signals.

47. A method as in claim 46 further comprising:

adjusting at least one phase output of the transmitter transducers generating the inductive output signal for maximal reception at a target receiver transducer located near the remote source transducer.

48. A method as in claim 42 further comprising:

comparing an amplitude of the electronic signals to determine which of the multiple uniquely oriented receiver transducers receives the strongest electronic signal.

49. A method as in claim 42, wherein the inductive output signal is transmitted to the target receiver transducer near the remote source transducer.

50. A method as in claim 49, wherein the target receiver transducer near the remote source transducer is oriented along a similar axis as the remote source transducer.

51. A method as in claim 42, wherein the target receiver transducer and the remote source transducer are a single transducer that is used to both transmit and receive corresponding inductive signals.

52. A method as in claim 42, wherein the inductive output signal is transmitted to a portable device.

53. A method as in claim 52, wherein the portable device is coupled to a communications network.

54. A system for communicating, the system comprising:

multiple uniquely oriented receiver transducers, each of which receives an inductive input signal, the inductive input signal being generated from a remote source transducer;

a circuit coupled to the receiver transducers that produces an electronic signal corresponding to the inductive input signal for each of the receiver transducers, the phase of each electronic signal being a function of the position and orientation of the remote source relative to the multiple uniquely oriented receiver transducers;

a detection circuit that detects the phase of each electronic signal based upon a reception of the inductive input signal; and

a driver circuit that generates an inductive output signal from a based on the phase of at least one of the produced electronic signals.

55. A system as in claim 54, wherein the transmitter transducer from which the inductive output signal is generated is one of multiple uniquely oriented transmitter transducers.

56. A system as in claim 55, wherein the uniquely oriented transmitter transducers are aligned along similar axes as the uniquely oriented receiver transducers receiving the inductive input signals.

57. A system as in claim 56, wherein the transducers to transmit and receive corresponding inductive signals are the same uniquely oriented transducers.

58. A system as in claim 55 further comprising:

a detection circuit that detects which of the multiple receiver transducers produces a strongest set of electronic signals; and

driver circuits to generate an inductive output signal from at least one of the transmitter transducers oriented on similar axes as the receiver transducers that generate the strongest set of electronic signals.

59. A system as in claim 58, wherein at least one phase output of the transmitter transducers is adjusted to generate the inductive output signal for maximal reception at a target receiver transducer located near the remote source transducer.

60. A system as in claim 54, wherein the detection circuit compares an amplitude of each of the produced electronic signals to determine which of multiple uniquely oriented transmitter transducers will generate the inductive output signal.

61. A system as in claim 60, wherein the inductive output signal is transmitted to a target receiver transducer near the remote source transducer.

62. A system as in claim 60, wherein the target receiver transducer near the remote source transducer is oriented along a similar axis as the remote source transducer.

63. A system as in claim 62, wherein the target receiver transducer and the remote source transducer are a single transducer that is used to both transmit and receive corresponding inductive signals.

64. A system as in claim 54, wherein the inductive output signal is transmitted to a portable device.

65. A system as in claim 64, wherein the portable is coupled to a communications network.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : RE 39,982 E
APPLICATION NO. : 09/881645
DATED : January 1, 2008
INVENTOR(S) : Vincent Palermo, Patrick J. Cobler and Neal R. Butler

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

Column 8, line 64, delete “s” in “communications”
Column 9, line 39, delete “the” and insert -- a --
Column 10, line 2, delete “adjusting phase” and insert -- adjusting the phase --

Signed and Sealed this

Twenty-second Day of July, 2008

Jon W. Dudas

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