(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 902 529 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
13.06.2012 Bulletin 2012/24

(21) Application number: **06774481.3**

(22) Date of filing: **30.06.2006**

(51) Int Cl.:
H04B 5/00 *(2006.01)* ***A61B 5/00*** *(2006.01)*
G01R 33/00 *(2006.01)*

(86) International application number:
PCT/US2006/026015

(87) International publication number:
WO 2007/008493 (18.01.2007 Gazette 2007/03)

(54) **COUPLING LOOP, CABLE ASSEMBLY AND METHOD FOR POSITIONING COUPLING LOOP**

KOPPELSCHLEIFE, KABELBAUGRUPPE UND VERFAHREN ZUR POSITIONIERUNG EINER KOPPELSCHLEIFE

BOUCLE DE COUPLAGE, ENSEMBLE DE CABLE ET PROCEDE DESTINE AU POSITIONNEMENT D'UNE BOUCLE DE COUPLAGE

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

(30) Priority: **08.07.2005 US 697867 P**
08.07.2005 US 697878 P
10.08.2005 US 707094 P

(43) Date of publication of application:
26.03.2008 Bulletin 2008/13

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Description

TECHNICAL FIELD

[0001] The present invention is directed in general to communicating with a wireless sensor, and in particular to a coupling loop and a cable used to communicate with a wireless sensor implanted within the body to measure a physical condition.

BACKGROUND

[0002] Wireless sensors can be implanted within the body and used to monitor physical conditions, such as pressure or temperature. For example, U.S. Patent No. 6,111,520, U.S. Patent No. 6,855,115 and U.S. Publication No. 2003/0136417 all describe wireless sensors that can be implanted within the body. These sensors can be used to monitor physical conditions within the heart or an abdominal aneurysm. An abdominal aortic aneurysm (AAA) is a dilatation and weakening of the abdominal aorta that can lead to aortic rupture and sudden death. In the case of a repaired abdominal aneurysm, a sensor can be used to monitor pressure within the aneurysm sac to determine whether the intervention is leaking. The standard treatment for AAAs employs the use of stent-grafts that are implanted via endovascular techniques. However, a significant problem that has emerged with these stent-grafts for AAAs is acute and late leaks of blood into the aneurysm's sac. Currently, following stent-graft implantation, patients are subjected to periodic evaluation via abdominal CT (Computed Tomography) with IV contrast to identify the potential presence of stent-graft leaks. This is an expensive, risky procedure that lacks appropriate sensitivity to detect small leaks.

[0003] Typically, the sensors utilize an inductive-capacitive ("LC") resonant circuit with a variable capacitor. The capacitance of the circuit varies with the pressure of the environment in which the sensor is located and thus, the resonant frequency of the circuit varies as the pressure varies. Thus, the resonant frequency of the circuit can be used to calculate pressure.

[0004] Ideally, the resonant frequency is determined using a non-invasive procedure. A system and method for determining the resonant frequency of an implanted sensor are discussed in U.S. Application No. 11/276,571 entitled "Communicating with an Implanted Wireless Sensor" filed March 6, 2006 (the '571 application"). The signal from the sensor is weak relative to the signal used to energize the sensor, but is the same frequency and dissipates quickly. In one embodiment, the difference between the signals is on the order of 150 dB and the sensor signal is sampled approximately 35 nanoseconds after the energizing signal is turned off. In order to communicate with the sensor, the system uses a coupling loop and a cable assembly. Due to the unique characteristics of the transmitted and received signals the coupling loop and the cable assembly need to isolate the energizing signal and the sensor signal, support the necessary sampling speed, and support a relatively large bandwidth.

[0005] Some prior art coupling loops use switched capacitor banks to meet the bandwidth requirement, but there are disadvantages to using switched capacitor banks regardless of the type of switching mechanism used. There are reliability issues associated with mechanical relays and loss issues associated with solid-state switches. Thus, there is a need for a coupling loop that provides the required bandwidth, but does not use switched capacitor banks.

[0006] A reflection or resonance from another object in the vicinity of the sensor can cause the system to lock on a frequency that does not correspond to the resonant frequency of the sensor, i.e. generates a false lock. Optimizing the position of the coupling loop relative to the sensor maximizes the coupling between the sensor and the coupling loop and reduces the sensitivity to a false lock. The coupling is maximized when the sensor is centered within the coupling loop and the inductor coil within the sensor is approximately parallel to the coupling loop. For many sensors this is achieved when the flat side of the sensor is approximately parallel to a plane defined by the coupling loop.

[0007] Thus, there is a need for indicating to a physician or other user the relative positions of the coupling loop and the sensor so that the sensor and the coupling loop are placed in magnetic proximity. In order to properly position the coupling loop, the coupling loop and the cable assembly should be easy to manipulate, which requires a lightweight coupling loop of a reasonable size and a flexible, lightweight cable with a relatively small diameter.

SUMMARY OF THE INVENTION

[0008] The primary goal of aneurysm treatment is to depressurize the sac and to prevent rupture. Endoleaks, whether occurring intraoperatively or postoperatively, can allow the aneurysmal sac to remain pressurized and therefore, increase the chance of aneurysm rupture. The current imaging modalities angiography and CT scan are not always sensitive enough to detect endoleaks or stent graft failure. Intrasac pressure measurements provide a direct assessment of sac exclusion from circulation and may therefore offer intraoperative and post operative surveillance advantages that indirect imaging studies do not.

[0009] In one application of the present invention, an AAA pressure sensor is placed into the aneurysm sac at the time of stent-graft insertion. The pressure readings are read out by the physician by holding an electronic instrument, which allows an immediate assessment of the success of the stent-graft at time of the procedure and outpatient follow-up visits, by reading the resonant frequency of the wireless sensor and correlating the frequency reading to pressure.

[0010] The present invention provides a coupling loop assembly and a method of wireless communication as set out in the claims.

[0011] Aspects, features and advantages of the present invention may be more clearly understood and appreciated from a review of the following detailed description of the disclosed embodiments and by reference to the appended drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Figure 1 is a block diagram of an exemplary system for communicating with a wireless sensor in accordance with an embodiment of the invention.

Figure 2 is a block diagram of an exemplary coupling loop assembly for communicating with a wireless sensor in accordance with an embodiment of the invention.

Figure 3(a) is a graph illustrating an exemplary energizing signal in accordance with an embodiment of the invention.

Figures 3(b), 3(c) and 3(d) are graphs illustrating exemplary coupled signals in accordance with an embodiment of the invention.

Figure 4 is a block diagram of an exemplary base unit in accordance with an embodiment of the invention.

Figure 5A illustrates an un-tuned coupling loop and Figure 5B illustrates its equivalent circuit.

Figure 6A illustrates a tuned coupling loop and Figure 6B illustrates its equivalent circuit.

Figure 7A illustrates an un-tuned coupling loop terminated into a high impedance input and Figure 7B illustrates its equivalent circuit in accordance with an embodiment of the invention.

Figure 8 is a graph illustrating the frequency response for various loops within the frequency band of interest.

Figure 9 illustrates exemplary energizing loops in accordance with an embodiment of the invention.

Figure 10 illustrates exemplary energizing and sensor coupling loops in accordance with an embodiment of the invention.

Figure 11 illustrates an exemplary coupling loop housing in accordance with an embodiment of the invention.

Figure 12 illustrates an exemplary sensor in accordance with an embodiment of the invention.

Figure 13 illustrates an exemplary orientation feature in accordance with an embodiment of the invention.

Figures 14a and 14b illustrate another exemplary orientation feature in accordance with an embodiment of the invention.

Figure 15 illustrates an exemplary cable assembly in accordance with an embodiment of the invention.

Figure 16 illustrates an exemplary cross section of the cable assembly in accordance with an embodiment of the invention.

Figure 17 illustrates another exemplary cross section of the cable assembly in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

[0013] The present invention is directed towards a coupling loop and cable assembly that supports precise sampling of a low power, quickly dissipating signal (the sensor signal) and that isolates the energizing signal used to excite the sensor from the sensor signal. Orientation features may be provided for positioning the coupling loop relative to the sensor to maximize the coupling of the sensor signal. Briefly described, the coupling loop includes multiple loops. Preferably two stagger-tuned loops are used for transmitting the energizing signal to the sensor and an un-tuned loop is used for receiving the sensor signal from the sensor. The un-tuned loop is connected to a very high input impedance to minimize the impact of the inductance of the loop. A cable attached to the coupling loop provides maximum isolation between the energizing signal and the sensor signal by maximizing the distance between the coaxial cables that carry the signals and maintaining the relative positions of the coaxial cables throughout the cable assembly. A method for positioning the coupling loop relative to the sensor is provided that maximizes the coupling between the sensor signal and the coupling loop.

Exemplary Operating Environment

[0014] Figure 1 illustrates an exemplary system for communicating with a wireless sensor implanted within a body. The system includes a coupling loop 100, a base unit 102, a display device 104 and an input device 106, such as a keyboard. The base unit includes an RF amplifier, a receiver, and signal processing circuitry. Additional details of the circuitry are described below in connection with Figure 3.

[0015] The display 104 and the input device 106 are used in connection with the user interface for the system. In the embodiment illustrated in Figure 1 the display device and the input device are connected to the base unit. In this embodiment, the base unit also provides conventional computing functions. In other embodiments, the base unit can be connected to a conventional computer, such as a laptop, via a communications link, such as an RS-232 link. If a separate computer is used, then the display device and the input devices associated with the computer can be used to provide the user interface. In one embodiment, LABVIEW software is used to provide the user interface, as well as to provide graphics, store and organize data and perform calculations for calibration and normalization. The user interface records and displays patient data and guides the user through surgical and follow-up procedures. An optional printer 108 is connected to the base unit and can be used to print out patient data or other types of information. As will be apparent to those skilled in the art other configurations of the system, as well as additional or fewer components can be utilized with the invention.

[0016] The coupling loop 100 charges the sensor 120 and then couples signals from the sensor into the receiver. The coupling loop can include switching and filtering circuitry enclosed within a shielded box 101. In the embodiment illustrated by Figure 2, PIN diode switching inside the loop assembly is used to provide isolation between the energizing phase and the receive phase by opening the RX path pin diodes during the period when the energizing signal is transmitted to the sensor, and opening the energizing path pin diodes during the period when the sensor signal is received from the sensor. Additional details of the coupling loop and the cable that connects the coupling loop to the base unit are described below.

[0017] Figure 1 illustrates the system communicating with a sensor 120 implanted in a patient. Each sensor is associated with a number of calibration parameters, such as frequency, offset, and slope. The system is used in two environments: 1) the operating room during implant and 2) the physician's office during follow-up examinations. During implant the system is used to record at least two measurements. The first measurement is taken during introduction of the sensor for calibration and the second measurement is taken after placement for functional verification of the stent graft. The measurements can be taken by placing the coupling loop either on or adjacent to the patient's back or the patient's stomach for a sensor that measures properties associated with an abdominal aneurysm. For other types of measurements, the coupling loop may be placed in other locations. For example, to measure properties associated with the heart, the coupling loop can be placed on the patient's back or the patient's chest.

[0018] The system communicates with the implanted sensor to determine the resonant frequency of the sensor. As described in more detail in the patent documents referenced in the Background section, a sensor typically includes an inductive-capacitive ("LC") resonant circuit having a variable capacitor. The distance between the plates of the variable capacitor varies as the surrounding pressure varies. Thus, the resonant frequency of the circuit can be used to determine the pressure.

[0019] The system energizes the sensor with an RF burst. The energizing signal is a low duty cycle, gated burst of RF energy of a predetermined frequency or set of frequencies and a predetermined amplitude. Typically, the duty cycle of the energizing signal ranges from 0.1% to 50%. In one embodiment, the system energizes the sensor with a 30-37.5 MHz fundamental signal at a pulse repetition rate of 100 kHz with a duty cycle of 20%. The energizing signal is coupled to the sensor via the coupling loop. This signal induces a current in the sensor which has maximum amplitude at the resonant frequency of the sensor. During this time, the sensor charges exponentially to a steady-state amplitude that is proportional to the coupling efficiency, distance between the sensor and loop, and the RF power. Figure 3(a) illustrates a typical energizing signal and Figures 3(b), 3(c) and 3(d) illustrate typical coupled signals for various values of Q (quality factor) for the sensor. When the coupling loop is coupling energy at or near the resonant frequency of the sensor, the amplitude of the sensor return is maximized, and the phase of the sensor return will be close to zero degrees with respect to the energizing phase. The sensor return signal is processed via phase-locked-loops to steer the frequency and phase of the next energizing pulse.

<u>Operation of the Base Unit</u>

[0020] Figure 4 is a block diagram of the signal processing components within an exemplary base unit. The base unit determines the resonant frequency of the sensor by adjusting the energizing signal so that the frequency of the energizing signal matches the resonant frequency of the sensor. In the embodiment illustrated by Figure 4, two separate processors 402, 422 and two separate coupling loops 440, 442 are shown. In one embodiment, processor 402 is associated with the base unit and processor 422 is associated with a computer connected to the base unit. In other embodiments, a single processor is used that provides the same functions as the two separate processors. In other embodiments a single loop is used for both energizing and for coupling the sensor energy back to the receiver. As will be apparent to those skilled in the art, other configurations of the base unit are possible that use different components.

[0021] The embodiment illustrated by Figure 4 includes a pair of phase lock loops ("PLL"). One of the PLLs is used to adjust the phase of the energizing signal and is referred to herein as the fast PLL. The other PLL is used to adjust the frequency of the energizing signal and is referred to herein as the slow PLL. The base unit provides two cycles: the calibration cycle and the measurement cycle. In one embodiment, the first cycle is a 10 microsecond energizing period for calibration of the system, which is referred to herein as the calibration cycle, and the second cycle is a 10 microsecond energizing/coupling period for energizing the sensor and coupling a return signal from the sensor, which is referred to herein as the measurement cycle. During the calibration cycle, the system generates a calibration signal for system and environmental phase calibration and during the measurement cycle the system both sends and listens for a return signal, i.e. the sensor ring down. Alternatively, as those skilled in the art will appreciate, the calibration cycle and the measurement cycle can be implemented in the same pulse repetition period. The phase of the energizing signal is adjusted during the calibration cycle by the fast PLL and the frequency of the energizing signal is adjusted during the measurement cycle by the slow PLL.

[0022] In one embodiment, the calibration signal is the portion of the energizing signal that leaks into the receiver (referred to herein as the energizing leakage signal). In this embodiment, the signal is sampled approximately

100 ns after the beginning of the energizing signal pulse. Since the energizing signal is several orders of magnitude greater than the coupled signal, it is assumed that the phase information associated with the leaked signal is due to the energizing signal and the phase delay is due to the circuit elements in the coupling loop, circuit elements in the receiver, and environmental conditions, such as proximity of reflecting objects. During the calibration cycle, the phase difference between the leaked signal and a reference oscillator (local oscillator 2) is determined. The phase of the energizing signal is adjusted until the phase difference is zero or another reference phase.

[0023] During the measurement cycle, the energizing signal may be blocked from the receiver during the on time of the energizing signal. During the off time of the energizing signal, the receiver is unblocked and the coupled signal from the sensor (referred to herein as the coupled signal or the sensor signal) is received. The coupled signal is processed and is used to drive the output of the slow PLL loop filter to a preset value.

[0024] The frequency of the energizing signal is deemed to match the resonant frequency of the sensor when the slow PLL is locked. Once the resonant frequency is determined, the physical parameter, such as pressure, is calculated using the calibration parameters associated with the sensor, which results in a difference frequency that is proportional to the measured pressure. Additional details of the operation of the PLLs are provided in the '571 application.

Coupling Loop Assembly

[0025] In the present invention, the coupling loop or antenna provides isolation between the energizing signal and the sensor signal, supports sampling/reception of the sensor signal very soon after the end of the energizing signal, and minimizes the switching transients that result from switching between the energizing and the coupled mode. The coupling loop also provides a relatively wide bandwidth, for example 30-37.5 MHz.

[0026] In one embodiment, separate loops are used for transmitting the energizing signal to the sensor and coupling the signal from the sensor. Two stagger-tuned loops are used to transmit the energizing signal and an un-tuned loop with a high input impedance at the receiver is used to receive the sensor signal. The term "coupling loop" is used herein to refer to both the loop(s) used to receive the sensor signal from the sensor (the "sensor coupling loop"), as well as the assembly that includes the loop(s) used to transmit the energizing signal to the sensor (the "energizing loop") and the sensor coupling loop (s).

[0027] During the measurement cycle, the sensor coupling loop couples the signal from the sensor, which is weak and dissipates quickly. The voltage provided to the receiver in the base unit depends upon the design of the sensor coupling loop and in particular, the resonant frequency of the loop.

[0028] A coupling loop can be un-tuned or tuned. Figure 5 A illustrates a loop that is un-tuned and Figure 5B illustrates its equivalent circuit. The loop has an inductance, L_1, and is terminated into the receiver using a common input impedance of 50 ohms. The voltage at the receiver, V_1, is less than the open circuit voltage of the loop, i.e. the voltage that would be coupled by the loop if the loop was not terminated, V_s, and can be calculated as shown below.

$$V_1 = V_s \frac{50}{50 + j\omega L_1}$$

Where L 1 is the inductance of the loop and $\omega = 2\pi f$, with f = frequency in hertz.

[0029] To maximize the voltage at the receiver, the loop can be tuned. Figure 6A illustrates a loop that is tuned and Figure 6B illustrates its equivalent circuit. The loop has an inductance, L_1, and a capacitance, C_1. The capacitance, C_1, is selected so that it cancels the inductance, L_1 at the resonant frequency, i.e. the series resonant circuit, C_1-L_1, is 0 ohms at the resonant frequency. At the resonant frequency the voltage at the receiver, V_1, equals the voltage coupled by the loop, V_s. A disadvantage of this type of loop is that it is optimized for only a single frequency. If the loop is used in an environment where the frequency of the coupled signal is changing, then the capacitance is either changed dynamically or set to a compromise value (*e.g.* the loop is tuned to a single frequency within the band of interest).

[0030] To avoid these problems, the present invention uses an un-tuned loop with a high input impedance at the receiver. Figure 7A illustrates a loop terminated into a receiver with a high input impedance and Figure 7B illustrates its equivalent circuit. The input impedance at the receiver is selected so that the energy lost due to the loop impedance, L_1, is relatively insignificant. Using Zin as the input impedance at the receiver, the voltage at the receiver, V_1, is calculated as shown below.

$$V_1 = V_s \frac{Zin}{Zin + j\omega L_1}$$

Since Zin is much larger than $j\omega L_1$, this can be approximated by the following.

$$V_1 = V_s \frac{\infty}{\infty + j\omega L_1}, \text{ or } V_1 = V_s$$

As shown by the foregoing equation, the use of a relatively high input impedance at the input of the receiver negates L_1 for all frequencies. In one embodiment, a high impedance buffer is inserted between the loop and a 50 ohm receiver circuit. In this embodiment, the high impedance buffer is on the order of 1 Mohm while the impedance of the loop is on the order of 200 ohms. In other embodiments, the input impedance is at least two times the loop impedance.

[0031] The frequency response within the band of interest is more monotonic if the sensor coupling loop uses a high input impedance at the receiver, than if a tuned loop is used with a 50 ohm input impedance. Figure 8 compares the frequency response for tuned loops and the frequency response for un-tuned loops with high input impedances at the receiver. The y-axis represents the difference in measured frequency between a calibration system using a network analyzer and the loop. The x-axis represents the frequency of the L-C standard used in the measurements. Linear interpolation was used between measurement points. Band 1 corresponds to a loop resonant at 32 MHz, Band 2 corresponds to a loop resonant at 35 MHz, Band 3 corresponds to a loop resonant at 38 MHz and Band 4 corresponds to a loop resonant at 41 MHz. Bands 1-4 correspond to a prior art design that uses switched capacitors banks to vary the loop resonance to achieve the needed bandwidth. Bands 4 and 5 correspond to un-tuned loops.

[0032] Bands 1-4 illustrate a slope variation within the band of interest, which can affect the accuracy of measurements made using the loop. Bands 4 and 5 illustrate that the variation within the band of interest is less than in the systems using a tuned loop. The more monotonic frequency response of an un-tuned loop with a high input impedance requires a simpler set of calibration coefficients to be used for the frequency conversion calculation.

[0033] An alternative to using an un-tuned loop and a high input impedance is to use stagger-tuned loops. If stagger tuned loops are used to receive the sensor signal, then the loops are tuned in a manner similar to that described in the following paragraphs in connection with the transmission of an energizing signal.

[0034] During the energizing mode, the energizing loop produces a magnetic field. The intensity of the magnetic field produced by the energizing loop depends, in part, on the magnitude of the current within the loop. The current is maximized at the energizing frequency if the impedance of the loop is essentially 0 ohms at the energizing frequency. The resonant frequency of the loop is related to the loop inductance and capacitance, as shown below.

$$f_0 = \frac{1}{2\pi\sqrt{L * C_1}}$$

The impedance of the loop is preferably 0 ohms over the frequency range of interest, which in an exemplary operating environment of the present invention is 30 MHz to 37.5 MHz. To achieve the desired impedance over the desired frequency range, two or more loops are stagger tuned. Figure 9 illustrates two stagger-tuned loops, which are parallel to one another.

[0035] The resonant frequencies for the loops are based on the bandwidth of interest. If there are two loops, then the loops are spaced geometrically. In one embodiment, the resonant frequency of the first loop is 31 MHz and the resonant frequency of the second loop is 36.3 MHz, which corresponds to the pole locations of a second order Butterworth bandpass filter having -3dB points at 30 MHz and 37.5 MHz. Although Figure 9 illustrates two loops, other embodiments can use a different number of loops. The use of additional loops provides coverage for a much wider frequency range. If there are more than two loops, then the loops are spaced logarithmically.

[0036] Figure 10 illustrates the assembly of two stagger-tuned loops 1002, 1004 for transmitting the energizing signal to the sensor and one un-tuned loop 1006 for receiving the sensor signal. The loops arc parallel to one another with the un-tuned loop inside the stagger-tuned loops. Placing the loop used to receive the sensor signal inside of the loops used to transmit the energizing signal helps to shield the sensor signal from environmental interferences. In one embodiment, the loops are positioned within a housing, such as that shown in Figure 11.

<u>Positioning the Coupling Loop</u>

[0037] The signal from an implanted passive sensor is relatively weak and is attenuated by the surrounding tissue and the distance between the sensor and the coupling loop. Optimizing the position and angle of the coupling loop relative to the sensor maximizes the coupling between the sensor and the coupling loop. In particular, the coupling loop is positioned so that a plane defined by the sensor coupling loop is approximately parallel to the inductor within the sensor and the sensor is approximately centered within the sensor coupling loop. For sensors having an inductor parallel to the flat side of the sensor, this corresponds to positioning the coupling loop so that it is approximately parallel to the flat side of the sensor. If the coupling loop is not positioned in this manner relative to the inductor, then the strength of the sensor signal is reduced by the cosine of the angle between the sensor coupling loop and the flat side of the sensor (assuming the inductor within the sensor is parallel to the flat side of the sensor).

[0038] The sensor and/or the housing include orientation features, which are visible using a medical imaging technology, such as fluoroscopy, to facilitate the placement of the sensor during implantation and the coupling loop during follow-up examinations. To position the coupling loop relative to the sensor, the coupling loop is moved or adjusted until a predetermined pattern appears. As previously described, measurements are typically taken by placing the coupling loop either on or adjacent to the patient's back or stomach for an abdominal aneurysm To facilitate these measurements and to minimize the distance between the sensor and the coupling loop, the sensor should be implanted so that the inductor within the sensor is approximately horizontal when the patient is standing.

[0039] The orientation features on the coupling loop can be implemented as a pattern in the ribbing of the housing for the loop. Ribbing is typically used to strengthen and support plastic enclosures or housings. The ribbing may be formed so that it aids in positioning the coupling loop relative to the sensor. Figure 11 is a cross sectional view of an exemplary housing that includes a ring-shaped section 1102 with perpendicular cross supports 1104, 1106 in the interior of the ring-shaped section. At the point where the cross supports intersect, the housing includes an essentially circular section 1108. The diameter of section 1108 is smaller than the diameter of section 1102. When assembled, the sensor coupling and energizing loops are positioned within the ring-shaped section. The orientation features are located in the circular section 1108. Figure 11 illustrates a circular orientation feature 1110 at the center of the circular section 1108. The ribbing for the cross supports 1112, 1114 can also form part of the orientation feature.

[0040] Although Figure 11 illustrates a particular design for the housing, other designs are possible, so long as the housing provides the necessary orientation features. For example, Figure 11 illustrates that there are four open spaces essentially corresponding to four quadrants defined by the cross supports in the interior of the ring-shaped section. These spaces reduce the amount of material needed to form the enclosure and thus minimize the weight of the enclosure, but are not required by the present invention for positioning the loop.

[0041] The orientation features on the sensor can be implemented as radiopaque markings on the essentially flat sides of the sensor. The references herein to the flat side of the sensor assume that the inductor within the sensor is parallel to the flat side of the sensor. As those skilled in the art will understand, the purpose of the orientation features is to position the coupling loop approximately parallel to the inductor within the sensor. If the inductor is not parallel to the flat side of the sensor, then the desired position of the coupling loop relative to the side of the sensor may differ.

[0042] Typically, the sensor is disk-shaped. The flat sides of the disk are essentially parallel and may be of any shape including circular, oval, rectangular, or daisy-shaped. Figure 12 illustrates a sensor with circular sides. The sensor includes an orientation feature 1202 at the center of the sensor that is shaped like a cross where each cross bar is essentially equal in length.

[0043] To receive a signal from the sensor, the physician positions the coupling loop so that the sensor is approximately at the center of the coupling loop and adjusts the angle of the coupling loop until the flat side of the sensor and the coupling loop are approximately parallel, which places the inductor coil within the sensor essentially parallel to the coupling loop. The orientation feature on the housing aids in positioning the coupling loop so that the sensor is at approximately the center of the loop. If the housing illustrated in Figure 11 is used, then the physician moves the coupling loop until the sensor appears within the circular orientation feature 110. The orientation feature on the sensor aids in adjusting the angle of the coupling loop so that the flat side of the sensor and the coupling loop are approximately parallel. If the sensor illustrated in Figure 12 is used, then the angle of the coupling loop is adjusted until the cross appears.

[0044] The cross appears when the coupling loop is essentially parallel to the flat side of the sensor. As shown in Figure 13, if the coupling loop is not essentially parallel to the flat side of the sensor, then the cross is distorted. If the cross is distorted, then the coupling loop is rotated until the cross appears. For example, if the vertical cross bars in Figure 13 are shortened or not visible, then the physician rotates the coupling loop around the x-axis until the vertical cross bars appear with the proper length. Similarly, if the horizontal cross bars in Figure 13 are shortened or not visible, then the physician rotates the coupling loop around the y-axis until the horizontal cross bars appear with the proper length.

[0045] Figures 14a and 14b show the effects of misalignment for another orientation feature. This feature uses a cross hair design. The perpendicular lines 1402, 1404 and the circle 1406 are orientation marks on the housing and the cross hairs 1408a, 1408b, 1410a, 1410b, 1412a, 1412b, 1414a, and 1414b are orientation marks on the sensor. Figure 14a illustrates the desired pattern. If the coupling loop is not essentially parallel to the flat side of the sensor, then the cross hairs are distorted. If the cross hairs are distorted, then the coupling loop is rotated until the cross hairs appear properly. For example, if the vertical cross bars 1410a, 1410b, 1414a, 1414b are shortened or not visible and the horizontal cross bars 1408a, 1408b, 1412a, 1412b are not properly spaced, then the physician rotates the coupling loop around the x-axis until the vertical cross bars appear with the proper length and the horizontal cross bars appear with the proper spacing. Figure 14b illustrates the cross hairs when the coupling loop is rotated 45 degrees along the x-axis. Similarly, if the horizontal cross bars are shortened or not visible and the vertical cross bars are not properly spaced, then the physician rotates the coupling loop around the y-axis until the horizontal cross bars appear with the proper length and the vertical cross bars appear with the proper spacing.

[0046] In one embodiment, the housing includes an orientation feature that matches or complements the orientation feature on the sensor. If the housing includes a matching feature, then the coupling loop is properly positioned when the orientation feature on the housing aligns with, is equal to, or otherwise matches the orientation feature on the sensor. If the housing includes a complementary feature, such as the cross hair design illustrated by Figure 14a, then the coupling loop is properly positioned when a predetermined pattern appears that is a combination of the orientation feature on the sensor and the orientation feature on the housing. As an alternative to matching or aligning the orientation features of the sensor and the housing, the physician can measure a part of or the entire orientation feature. For example, the physician could move the coupling loop until the distance between two bars equals a predetermined distance as measured using a fluoroscope.

[0047] Although the foregoing describes a circular orientation feature, a cross- shaped orientation feature, and a cross hair orientation feature, other patterns, shapes and types of orientation features can be used, including a bull's eye, logo, image or alphanumeric string. The orientation features are not limited to two-dimensional features, but also include three-dimensional features.

Cable

[0048] The isolation of the energizing signal and the sensor signal provided by the base unit and the coupling loop must be maintained in the cable that connects the base unit to the coupling loop. Figure 15 illustrates an exemplary cable 1500 that connects the base unit to the coupling loop and that isolates the energizing signal from the sensor signal. The end of the cable that connects to the base unit includes a multi-pin connector 1502 (e.g. AL06F15-ACS provided by Amphenol) and a right angle housing 1516. The end of the cable that connects to the coupling loop includes three connectors. The first connector 1504 is a multi-pin connector (e.g. AMP 1-87631-0 provided by Amphenol) that connects to the filtering and switching circuitry associated with the loop, the second connector 1506 connects to the energizing loop and the third connector 1508 connects to the loop that couples the signal from the sensor. The right angle housing 1516 and the strain relief 1510 provide strain relief at each end of the cable. When assembled with the housing, the strain relief 1510 is positioned proximate to the housing. Alternatively, other types of strain relief can be implemented, including physical constraints, such as tie wraps, ferrals or epoxy, and/or service loops. The cable also includes ferrite beads, 1512, 1514. The ferrite beads help reduce ground currents within the cable.

[0049] Figure 16 illustrates a cross section of an exemplary cable. The cable includes an inner bundle 1602, two twisted pairs 1604, 1606, and two coaxial cables 1608, 1610. At the end of the cable that connects to the coupling loop, the inner bundle and the twisted pairs are connected to the first connector 1504 of Figure 15, one of the coaxial cables 1608 is connected to the second connector 1506 of Figure 15 and the other coaxial cable 1610 is connected to the third connector 1508 of Figure 15. At the end of the cable that connects to the base unit, the inner bundle, the twisted pairs and the coaxial cables are connected to the multi-pin connector 1502 of Figure 15. An outer sheath 1612 surrounds the inner bundle, twisted pairs, and coaxial cables.

[0050] The position of the coaxial cables within the cable is designed to maximize the isolation between the energizing signal and the sensor signal, while minimizing the diameter of the cable. The cable also is designed to maximize the isolation between the coax cable that transmits the energizing signal and the inner bundle and the twisted pairs and the coax cable that receives the sensor signal and the inner bundle. As shown in Figure 16, the coaxial cables are located on opposite sides of the internal bundle at approximately a 180 degree angle. The isolation is maximized if a 180 degree angle is maintained between the coaxial cables. However, smaller angles may be used so long as the coaxial cables are placed on opposite sides of the internal bundle. The relative position of the coaxial cables is maintained essentially throughout the length of the cable. In some embodiments, additional braided shield surrounds the inner bundle, the twisted pairs and the coaxial cables. The additional braided shield provides additional cross talk isolation and provides a lower impedance common ground since the additional shield surrounding the coaxial cables can contact the additional shield surrounding the inner bundle.

[0051] In one embodiment, the coaxial cables are twisted around the inner bundle essentially throughout the length of the cable. Twisting the coaxial cables around the inner bundle reduces the forces exerted upon the coaxial cables and thus minimizes the potential for cable damage. The approximately 180 degree angle between the two coaxial cables is maintained essentially throughout the length of the cable. The coaxial cables can be held in position by the outer sheath, filler material, or a combination of the two.

[0052] In another embodiment, the coaxial cables are not twisted, but are attached to the internal bundle. For example, the shielding surrounding the coaxial cables is soldered to the shielding surrounding the internal bundle every six inches.

[0053] Figure 17 illustrates a cross section of an alternative embodiment of the cable in which a first shield surrounds the first coaxial cable, a second shield surrounds a second coaxial cable , a third shield surrounds an internal cable, and the first shield and the second shield are soldered to the third shield at a plurality of points along the length of the cable. This embodiment includes shielding 1714 around the inner bundle 1702 and the twisted pairs 1704, 1706. The coaxial cables are located on opposite sides of the internal bundle at approximately a 180 degree angle and the relative position of the coaxial cables is maintained essentially throughout the length of the cable. As described above in connection with Figure 16, additional braided shield can surround the inner bundle, twisted pairs and coaxial cables.

[0054] Shielded coaxial cables 1708, 1710 are soldered to the shielding 1714 approximately every six inches throughout the length of the cable. In other embodiments that use additional shielding around the inner bundle and the twisted pairs, the outer sheath, filler material, or a combination of the two maintains the relative position of the coaxial cables. Although the foregoing describes particular types of internal cables, the invention is applicable to any cable where two conductors are isolated with respect to one another by separating the conductors and positioning the conductors as described herein.

[0055] Additional alternative embodiments will be apparent to those skilled in the art to which the present invention pertains without departing from its scope. For example, the system can operate with different types of sensors, such as non-linear sensors that transmit information at frequencies other than the transmit frequency or sensors that use backscatter modulation. Accordingly, the scope of the present invention is described by the appended claims and is supported by the foregoing description.

Claims

1. A coupling loop assembly used for wireless communication, comprising a sensor coupling loop (1006) having an inductance and connected to an input having an input impedance, **characterised in that**:

- the input impedance is substantially greater than the inductance of the sensor coupling loop (1006); and
- the assembly further comprises a plurality of energizing loops (1002, 1004), for transmitting an energizing signal to a sensor, arranged in parallel, each energizing loop (1002, 1004) having a different resonant frequency.

2. A loop assembly as claimed in Claim 1, wherein the sensor coupling loop (1006) is parallel to the energizing loops (1002, 1004) and the energizing loops (1002, 1004) surround the sensor coupling loop (1006).

3. A loop assembly as claimed in Claim 1 or Claim 2, wherein the input impedance is at least two times greater than the inductance of the sensor coupling loop (1006).

4. A loop assembly as claimed in any one of Claims 1 to 3, wherein the resonant frequency for a first energizing loop (1002) is approximately 31 MHz and the resonant frequency for a second energizing loop (1004) is approximately 36.3 MHz

5. A loop assembly as claimed in any one of Claims 1 to 4, wherein the sensor coupling loop (1006) and the energizing loops (1002, 1004) are connected to a cable (1500) and wherein the cable (1500) comprises:

- a first coaxial cable (1610) connected to the sensor coupling loop (1006);
- a second coaxial cable (1608) connected to the energizing loops (1002, 1004);
- an internal cable (1602); and
- an outer sheath (1612) surrounding the first coaxial cable, the second coaxial cable and the internal cable (1602),

wherein the first coaxial cable (1610) and the second coaxial cable (1608) are positioned on opposite sides of the internal cable (1602) and a position of the first coaxial cable (1610) relative to the second coaxial cable (1608) is maintained along a length of the cable (1500).

6. A loop assembly as claimed in Claim 5, wherein an angle between a center point of the first coaxial cable (1610) and a center point of the second coaxial cable (1608) is approximately 180 degrees relative to a center point of the internal cable (1602).

7. A loop assembly as claimed in Claim 5 or Claim 6, wherein the first coaxial cable (1610) and the second coaxial cable (1608) are twisted around the internal cable (1602) along the length of the cable.

8. A loop assembly as claimed in any one of Claims 5 to 7, wherein a first shield surrounds the first coaxial cable (1710), a second shield surrounds the second coaxial cable (1708), a third shield (1714) surrounds the internal cable (1602), and the first shield and the second shield are soldered to the third shield (1714) at a plurality of points along the length of the cable.

9. A loop assembly as claimed in any one of Claims 1 to 8 comprising orientation features (1112, 1114, 1202, 1402, 1404, 1406) for use in positioning the coupling loop relative to a sensor to maximize the coupling between the sensor and the coupling loop.

10. A loop assembly as claimed in Claim 9, in which:-

- the orientation features (1112, 1114, 1202, 1402, 1404, 1406) comprise an orientation mark (1112, 1114, 1202, 1402, 1404, 1406) that is visible using a medical imaging technology ; or.
- the orientation features (1112, 1114, 1202, 1402, 1404, 1406) on the coupling loop are a pattern in the ribbing (1112, 1114) of a housing

for the loop; or

• a housing surrounds the coupling loop and includes a first area that is coplanar with and approximately at the center of the coupling loop and that includes orientation marks (1112, 1114, 1202, 1402, 1404, 1406) providing the orientation features (1112, 1114, 1202, 1402, 1404, 1406) that is visible using a medical imaging technology.

11. A loop assembly as claimed in Claim 10, in which the orientation features (1112, 1114, 1202, 1402, 1404, 1406) comprise multiple marks that indicate a length or a distance.

12. A method of wireless communication comprising providing an energizing signal to a sensor by means of the plurality of energizing loops (1002, 1004) of a coupling loop assembly as claimed in any preceding claim; and receiving a coupled signal from the sensor coupling loop (1006) of said coupling loop assembly.

13. A method as claimed in Claim 12, wherein receiving a coupled signal comprises using an un-tuned loop (1006) connected to an input impedance that is at least two times greater than an impedance of the untuned loop (1006), wherein the coupled signal is generated in response to coupling the energizing signal to a signal generating circuit, is at least 100 dB less than the energizing signal, and has a frequency similar to a frequency of the energizing signal.

14. A method as claimed in Claim 13, wherein the resonant frequencies of the energizing loops (1002, 1004) are selected based on a mean frequency of a desired bandwidth.

15. A method as claimed in Claim 13 or Claim 14, wherein the coupled signal is sampled less than 50 nanoseconds after the energizing signal is provided.

16. A method as claimed in any one of Claims 13 to 15, wherein

• receiving a coupled signal comprises receiving the coupled signal via a first coaxial cable (1610);

• providing an energizing signal comprises providing the energizing signal via a second coaxial cable (1608); and

• the first coaxial cable (1610) and the second coaxial cable (1608) are positioned on opposite sides of an internal cable (1602), an outer sheath surrounds the first coaxial cable (1610), the second coaxial cable (1608) and the internal cable (1602), and an angle between a center point of the first coaxial cable (1610) and a center point of the second coaxial cable (1608) is approximately 180 degrees relative to a center point of the internal cable (1602).

17. A method as claimed in Claim 12 in which a coupling loop assembly (100) comprising orientation features (1112, 1114, 1202, 1402, 1404, 1406) is used, and medical imaging technology is used to position and adjust the angle of the coupling loop assembly (100) relative to a sensor (120) so that a first area of a housing for the coupling loop is in a predetermined position with respect to the sensor (120) and a predefined pattern is formed by markings on the sensor (1408a, 1408b, 1410a, 1410b, 1412a, 1412b, 1414a, and 1414b) and markings on the housing (1112, 1114, 1202, 1402, 1404, 1406).

18. A method as claimed in Claim 17, in which the sensor (120) has a flat side and an inductor parallel to the flat side, and the predefined pattern is formed when a plane formed by the coupling loop assembly (100) is approximately parallel to the flat side of the sensor (120).

Patentansprüche

1. Kopplungsschleifen-Anordnung, die zur drahtlosen Kommunikation verwendet wird und eine Sensorkopplungsschleife (1006) umfasst, die eine Induktivität besitzt und mit einem Eingang verbunden ist, der eine Eingangsimpedanz besitzt, **dadurch gekennzeichnet, dass**:

• die Eingangsimpedanz wesentlich größer ist als die Induktivität der Sensorkopplungsschleife (1006); und

• die Anordnung ferner mehrere Erregungsschleifen (1002, 1004) zum Erregen der Sensorkopplungsschleife umfasst, die parallel angeordnet sind, wobei jede Erregungsschleife (1002, 1004) eine unterschiedliche Resonanzfrequenz hat.

2. Schleifenanordnung nach Anspruch 1, wobei die Sensorkopplungsschleife (1006) zu den Erregungsschleifen (1002, 1004) parallel ist und die Erregungsschleifen (1002, 1004) die Sensorkopplungsschleife (1006) umgeben.

3. Schleifenanordnung nach Anspruch 1 oder Anspruch 2, wobei die Eingangsimpedanz wenigstens zweimal größer als die Induktivität der Sensorkopplungsschleife (1006) ist.

4. Schleifenanordnung nach einem der Ansprüche 1 bis 3, wobei die Resonanzfrequenz für eine erste Erregungsschleife (1002) etwa 31 MHz beträgt und die Resonanzfrequenz für eine zweite Erregungsschleife (1004) etwa 36,3 MHz beträgt.

5. Schleifenanordnung nach einem der Ansprüche 1 bis 4, wobei die Sensorkopplungsschleife (1006) und die Erregungsschleifen (1002, 1004) mit einem Kabel (1500) verbunden sind und wobei das Kabel (1500) Folgendes umfasst:

- ein erstes Koaxialkabel (1610), das mit der Sensorkopplungsschleife (1006) verbunden ist;
- ein zweites Koaxialkabel (1608), das mit den Erregungsschleifen (1002, 1004) verbunden ist;
- ein inneres Kabel (1602); und
- eine Außenhülle (1612), die das erste Koaxialkabel, das zweite Koaxialkabel und das innere Kabel (1602) umgibt,

wobei das erste Koaxialkabel (1610) und das zweite Koaxialkabel (1608) auf gegenüberliegenden Seiten des inneren Kabels (1602) positioniert sind und eine Position des ersten Koaxialkabels (1610) relativ zu dem zweiten Koaxialkabel (1608) auf einer Länge des Kabels (1500) beibehalten wird.

6. Schleifenanordnung nach Anspruch 5, wobei ein Winkel zwischen einem Mittelpunkt des ersten Koaxialkabels (1610) und einem Mittelpunkt des zweiten Koaxialkabels (1608) relativ zu einem Mittelpunkt des inneren Kabels (1602) ungefähr 180 Grad beträgt.

7. Schleifenanordnung nach Anspruch 5 oder Anspruch 6, wobei das erste Koaxialkabel (1610) und das zweite Koaxialkabel (1608) um das innere Kabel (1602) auf der Länge des Kabels verdrillt sind.

8. Schleifenanordnung nach einem der Ansprüche 5 bis 7, wobei eine erste Abschirmung das erste Koaxialkabel (1710) umgibt, eine zweite Abschirmung das zweite Koaxialkabel (1708) umgibt, eine dritte Abschirmung (1714) das innere Kabel (1602) umgibt und die erste Abschirmung und die zweite Abschirmung mit der dritten Abschirmung (1714) an mehreren Punkten auf der Länge des Kabels verlötet sind.

9. Schleifenanordnung nach einem der Ansprüche 1 bis 8, die Orientierungsmerkmale (1112, 1114, 1202, 1402, 1404, 1406) umfasst, um bei der Positionierung der Kopplungsschleife relativ zu einem Sensor verwendet zu werden, um die Kopplung zwischen dem Sensor und der Kopplungsschleife maximal zu machen.

10. Schleifenanordnung nach Anspruch 9, wobei:

- die Orientierungsmerkmale (1112, 1114, 1202, 1402, 1404, 1406) eine Orientierungsmarkierung (1112, 1114, 1202, 1402, 1404, 1406) umfassen, die bei Verwendung einer medizinischen Abbildungstechnik sichtbar sind; oder
- die Orientierungsmerkmale (1112, 1114, 1202, 1402, 1404, 1406) auf der Kopplungsschleife ein Muster in der Riffelung (1112, 1114) eines Gehäuses für die Schleife sind; oder
- ein Gehäuse die Kopplungsschleife umgibt und einen ersten Bereich aufweist, der zu der Kopplungsschleife koplanar ist und sich ungefähr in deren Mitte befindet und Orientierungsmarkierungen (1112, 1114, 1202, 1402, 1404, 1406) enthält, die die Orientierungsmerkmale (1112, 1114, 1202, 1402, 1404, 1406) schaffen, die unter Verwendung einer medizinischen Abbildungstechnik sichtbar sind.

11. Schleifenanordnung nach Anspruch 10, wobei die Orientierungsmerkmale (1112, 1114, 1202, 1402, 1404, 1406) mehrere Markierungen umfassen, die eine Länge oder eine Strecke angeben.

12. Verfahren zur drahtlosen Kommunikation, das das Vorsehen eines Erregungssignals für eine Sensorkopplungsschleife mittels mehrerer Erregungsschleifen (1002, 1004) einer Kopplungsschleifenanordnung nach einem vorhergehenden Anspruch; und das Empfangen eines eingekoppelten Signals von der Sensorkopplungsschleife (1006) der Kopplungsschleifenanordnung umfasst.

13. Verfahren nach Anspruch 12, wobei das Empfangen eines eingekoppelten Signals das Verwenden einer nicht abgestimmten Schleife (1006), die mit einer Eingangsimpedanz verbunden ist, die wenigstens zweimal größer ist als eine Impedanz der nicht abgestimmten Schleife (1006), umfasst, wobei das eingekoppelte Signal in Reaktion auf die Einkopplung des Erregungssignals in eine Signalerzeugungsschaltung erzeugt wird, wenigstens 100 dB geringer ist als das Erregungssignal und eine Frequenz besitzt, die einer Frequenz des Erregungssignals ähnlich ist.

14. Verfahren nach Anspruch 13, wobei die Resonanzfrequenzen der Erregungsschleifen (1002, 1004) anhand einer Mittenfrequenz einer gewünschten Bandbreite gewählt werden.

15. Verfahren nach Anspruch 13 oder Anspruch 14, wobei das eingekoppelte Signal weniger als 50 Nanosekunden nach der Bereitstellung des Erregungssignals abgetastet wird.

16. Verfahren nach einem der Ansprüche 13 bis 15, wobei

- das Empfangen eines eingekoppelten Signals

das Empfangen des eingekoppelten Signals über ein erstes Koaxialkabel (1610) umfasst;
• das Bereitstellen eines Erregungssignals das Bereitstellen des Erregungssignals über ein zweites Koaxialkabel (1608) umfasst; und
• das erste Koaxialkabel (1610) und das zweite Koaxialkabel (1608) auf gegenüberliegenden Seiten eines inneren Kabels (1602) positioniert sind, eine äußere Hülle das erste Koaxialkabel (1610), das zweite Koaxialkabel (1608) und das innere Kabel (1602) umgibt und ein Winkel zwischen einem Mittelpunkt des ersten Koaxialkabels (1610) und einem Mittelpunkt des zweiten Koaxialkabels (1608) ungefähr 180 Grad in Bezug auf einen Mittelpunkt des inneren Kabels (1602) beträgt.

17. Verfahren nach Anspruch 12, wobei eine Kopplungsschleifenanordnung (100), die Orientierungsmerkmale (1112, 1114, 1202, 1402, 1404, 1406) enthält, und eine medizinische Abbildungstechnologie verwendet werden, um den Winkel der Kopplungsschleifenanordnung (100) relativ zu einem Sensor (120) zu positionieren und einzustellen, so dass sich ein erster Bereich eines Gehäuses für die Kopplungsschleife an einer vorgegebenen Position in Bezug auf den Sensor (120) befindet und ein im Voraus definiertes Muster durch Markierungen auf dem Sensor (1408a, 1408b, 1410a, 1410b, 1412a, 1412b, 1414a und 1414b) und durch Markierungen auf dem Gehäuse (1112, 1114, 1202, 1402, 1404, 1406) gebildet ist.

18. Verfahren nach Anspruch 17, wobei der Sensor (120) eine flache Seite und einen Induktor parallel zu der flachen Seite besitzt und das im Voraus definierte Muster gebildet wird, wenn eine durch die Kopplungsschleifenanordnung (100) gebildete Ebene zu der flachen Seite des Sensors (120) ungefähr parallel ist.

Revendications

1. Assemblage de boucle de couplage utilisé pour une communication sans fil, comprenant une boucle de couplage de capteur (1006) ayant une inductance et connectée à une entrée ayant une impédance d'entrée, caractérisé en ce qui :

• l'impédance d'entrée est sensiblement supérieure à l'inductance de la boucle de couplage de capteur (1006) ; et
• l'assemblage comprend en outre une pluralité de boucles d'excitation (1002, 1004), pour transmettre un signal d' excitation à un capteur, montées en parallèle, chaque boucle d'excitation (1002, 1004) ayant une fréquence de résonance différente.

2. Assemblage de boucle selon la revendication 1, dans lequel la boucle de couplage de capteur (1006) est parallèle aux boucles d'excitation (1002, 1004) et les boucles d'excitation (1002, 1004) entourent la boucle de couplage de capteur (1006).

3. Assemblage de boucle selon la revendication 1 ou 2, dans lequel l'impédance d'entrée est au moins deux fois supérieure à l'inductance de la boucle de couplage de capteur (1006).

4. Assemblage de boucle selon l'une quelconque des revendications 1 à 3, dans lequel la fréquence de résonancepourunepremièreboucled'excitation (1002) est d'environ 31 MHz et la fréquence de résonance pour une seconde boucle d'excitation (1004) est d'environ 36,3 MHz.

5. Assemblage de boucle selon l'une quelconque des revendications 1 à 4, dans lequel la boucle de couplage de capteur (1006) et les boucles d'excitation (1002, 1004) sont connectées à un câble (1500) et dans lequel le câble (1500) comprend :

• un premier câble coaxial (1610) connecté à la boucle de couplage de capteur (1006) ;
• un second câble coaxial (1608) connecté aux boucles d'excitation (1002, 1004) ;
• un câble interne (1602) ; et
• une gaine externe (1612) entourant le premier câble coaxial, le second câble coaxial et le câble interne (1602),

dans lequel le premier câble coaxial (1610) et le second câble coaxial (1608) sont positionnés sur les côtés opposés du câble interne (1602) et une position du premier câble coaxial (1610) par rapport au second câble coaxial (1608) est maintenue sur la longueur du câble (1500).

6. Assemblage de boucle selon la revendication 5, dans lequel un angle compris entre un point central du premier câble coaxial (1610) et un centre du second câble coaxial (1608) est d'environ 180 degrés par rapport au point central du câble interne (1602).

7. Assemblage de boucle selon la revendication 5 ou 6, dans lequel le premier câble coaxial (1610) et le second câble coaxial (1608) sont torsadés autour du câble interne (1602) sur la longueur du câble.

8. Assemblage de boucle selon l'une quelconque des revendications 5 à 7, dans lequel un premier blindage entoure le premier câble coaxial (1710), un deuxième blindage entoure le second câble coaxial (1708), un troisième blindage (1714) entoure le câble interne (1602) et le premier blindage et le deuxième blindage sont soudés au troisième blindage (1714) en une pluralité de points sur la longueur du câble.

9. Assemblage de boucle selon l'une quelconque des revendications 1 à 8, comprenant des caractéristiques d'orientation (1112, 1114, 1202, 1402, 1404, 1406) pour un usage dans le positionnement de la boucle de couplage par rapport à un capteur dans le but de maximiser le couplage entre le capteur et la boucle de couplage.

10. Assemblage de boucle selon la revendication 9, dans lequel :

- lescaractéristiquesd'orientation (1112,1114,1202, 1402, 1404, 1406) comprennent un repère d'orientation (1112, 1114, 1202, 1402, 1404, 1406) qui est visible à l'aide d'une technologie d'imagerie médicale ; ou
- les caractéristiques d'orientation (1112,1114,1202, 1402, 1404, 1406) sur la boucle de couplage constituent un motif dans le nervurage (1112, 1114) d'un boîtier pour la boucle ; ou
- un boîtier entoure la boucle de couplage et comprend une première zone qui est coplanaire avec ou approximativement au centre de la boucle de couplage et qui comprend des repères d'orientation (1112, 1114, 1202, 1402, 1404, 1406) fournissant les caractéristiques d'orientation (1112, 1114, 1202, 1402, 1404, 1406) qui sont visibles à l'aide d'une technologie d'imagerie médicale.

11. Assemblage de boucle selon la revendication 10, dans lequel les caractéristiques d'orientation (1112, 1114, 1202, 1402, 1404, 1406) comprennent des repères multiples qui indiquent une longueur ou une distance.

12. Procédé de communication sans fil, comprenant la délivrance d'un signal d'excitation à un capteur au moyen de la pluralité de boucles d'excitation (1002, 1004) d'un assemblage de boucle de couplage selon l'une quelconque des revendications précédentes et la réception d'un signal couplé issu de la boucle de couplage de capteur (1006) dudit assemblage de boucle de couplage.

13. Procédé selon la revendication 12, dans lequel la réception d'un signal couplé comprend l'utilisation d'une boucle non accordée (1006) connectée à une impédance d'entrée qui est aumoins deux fois supérieure à une impédance de la boucle non accordée (1006), dans lequel le signal couplé est généré en réponse à un couplage du signal d'excitation avec un circuit générant un signal, est d'au moins 100 dB inférieur au signal d'excitation et a une fréquence similaire à une fréquence du signal d'excitation.

14. Procédé selon la revendication 13, dans lequel les fréquences de résonance des boucles d'alimentation (1002, 1004) sont choisies sur la base d'une fréquence moyenne d'une largeur de bande souhaitée.

15. Procédé selon la revendication 13 ou 14, dans lequel le signal couplé est échantillonné à une valeur inférieure à 50 nanosecondes après avoir délivré le signal d'excitation.

16. Procédé selon l'une quelconque des revendications 13 à 15, dans lequel :

- la réception d'un signal couplé comprend la réception du signal couplé via un premier câble coaxial (1610) ;
- la délivrance d'un signal d'excitation comprend la délivrance du signal d'excitation via un second câble coaxial (1608) ; et
- le premier câble coaxial (1610) et le second câble coaxial (1608) sont positionnés sur les côtés opposés d'un câble interne (1602), une gaine externe entoure le premier câble coaxial (1610), le second câble coaxial (1608) et le câble interne (1602), et un angle compris entre un point central du premier câble coaxial (1610) et un point central du second câble coaxial (1608) est d'environ 180 degrés par rapport à un point central du câble interne (1602).

17. Procédé selon la revendication 12 dans lequel on utilise un assemblage de boucle de couplage (100) comprenant des caractéristiques d'orientation (1112, 1114, 1202, 1402, 1404,1406) et on utilise une technologie d'imagerie médicale pour positionner et ajuster l'angle de l'assemblage de boucle de couplage (100) par rapport à un capteur (120) de sorte qu'une première zone d'un boîtier pour la boucle de couplage se trouve dans une position prédéterminée par rapport au capteur (120) et qu'un motif prédéfini soit formé par des repères sur le capteur (1408a, 1408b, 1410a, 1410b, 1412a, 1412b, 1414a, et 1414b) et des repères sur le boîtier (1112, 1114, 1202 1402, 1404, 1406).

18. Procédé selon la revendication 17, dans lequel le capteur (120) a un côté plat et un inducteur parallèle au côté plat et le motif prédéfini est formé lorsqu'un plan formé par l'assemblage de boucle de couplage (100) est approximativement parallèle au côté plat du capteur (120).

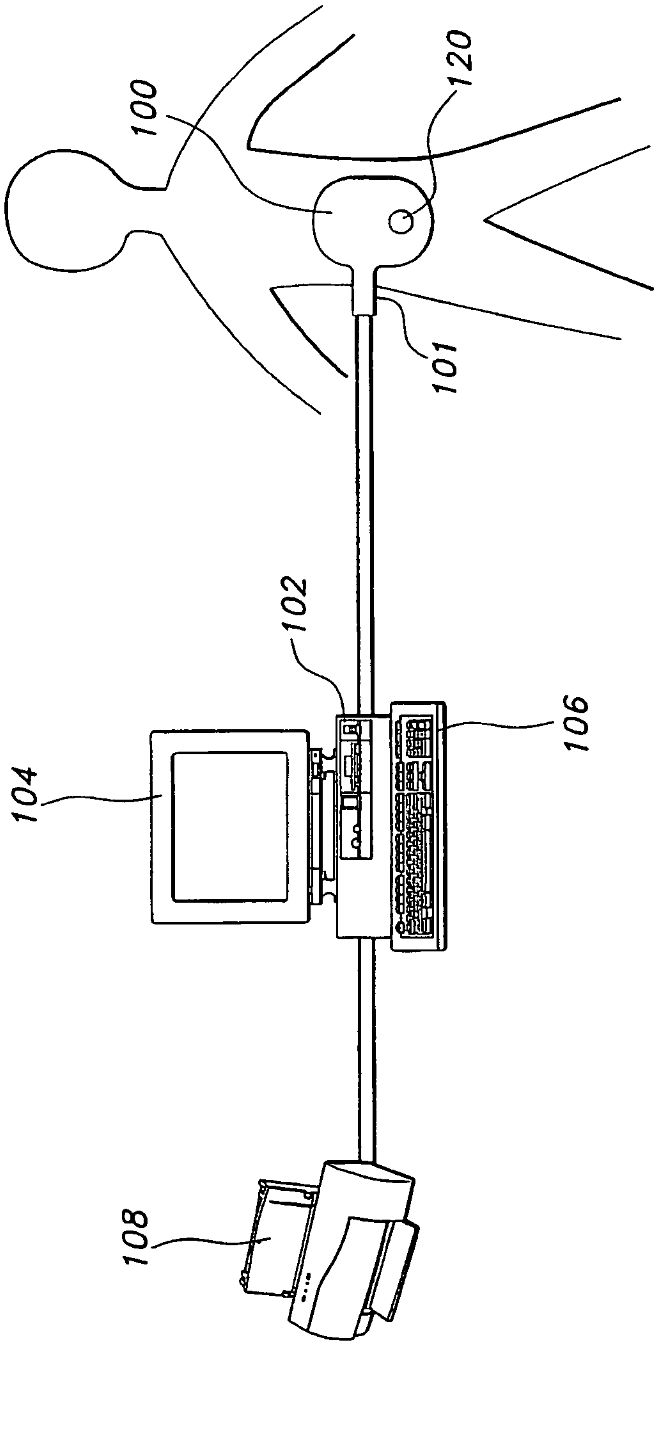

FIG. 1

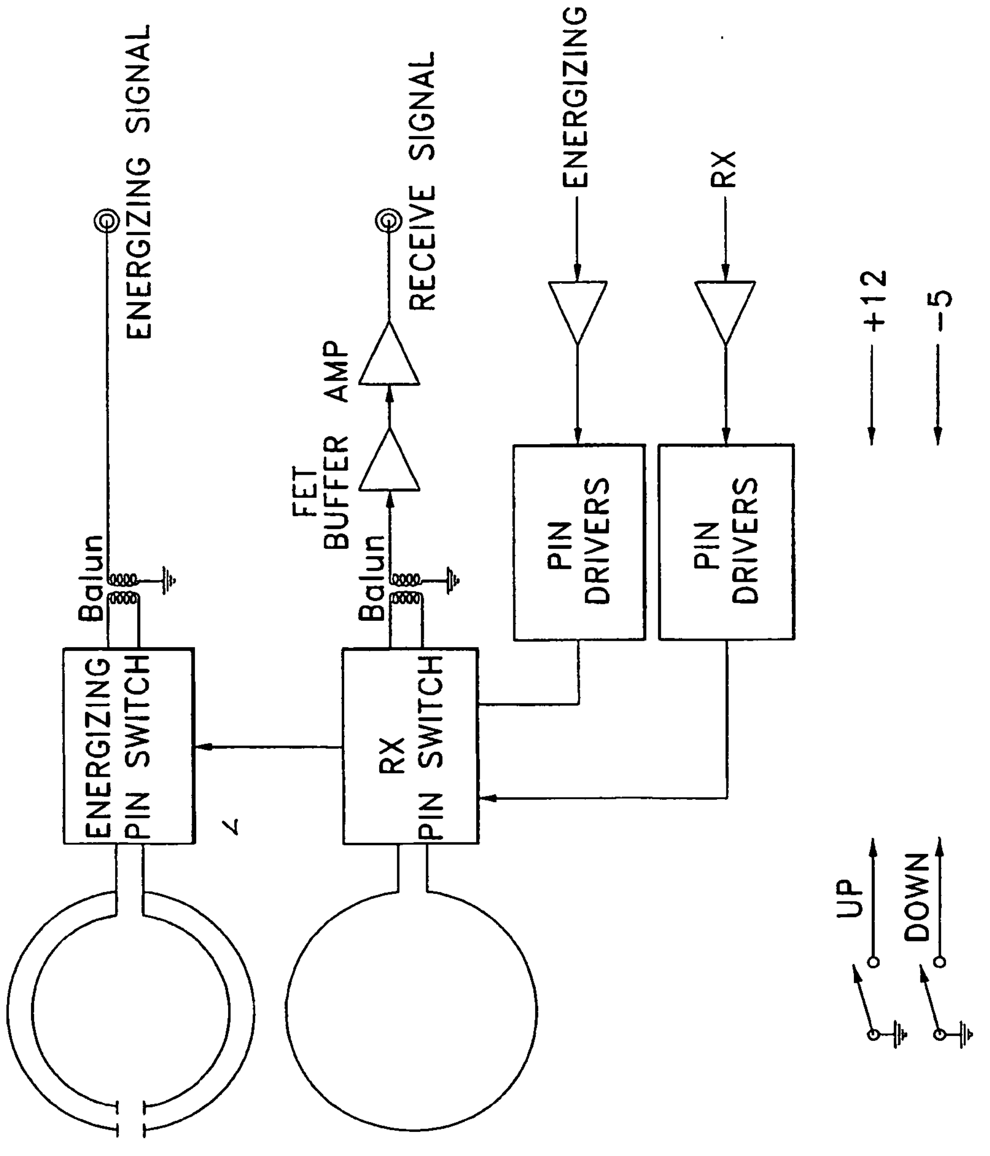
ENERGIZING SIGNAL
Balun
ENERGIZING PIN SWITCH
RECEIVE SIGNAL
FET BUFFER AMP
Balun
RX PIN SWITCH
ENERGIZING
RX
PIN DRIVERS
PIN DRIVERS
+12
-5
UP
DOWN

FIG. 2

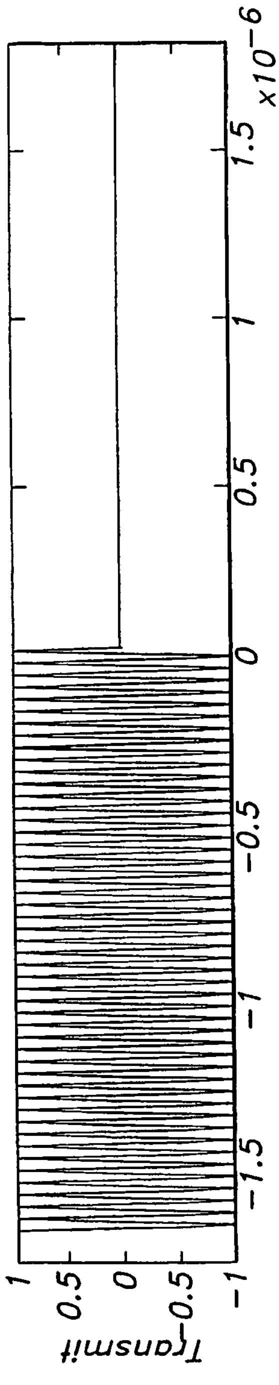

FIG. 3a

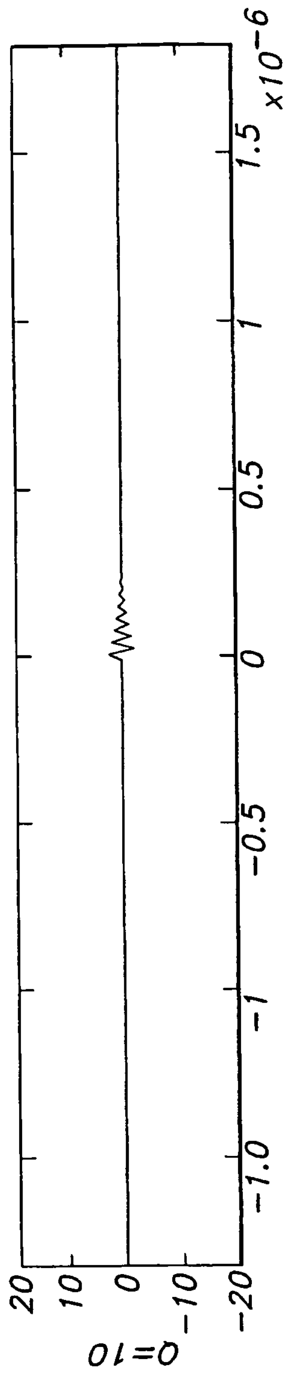

FIG. 3b

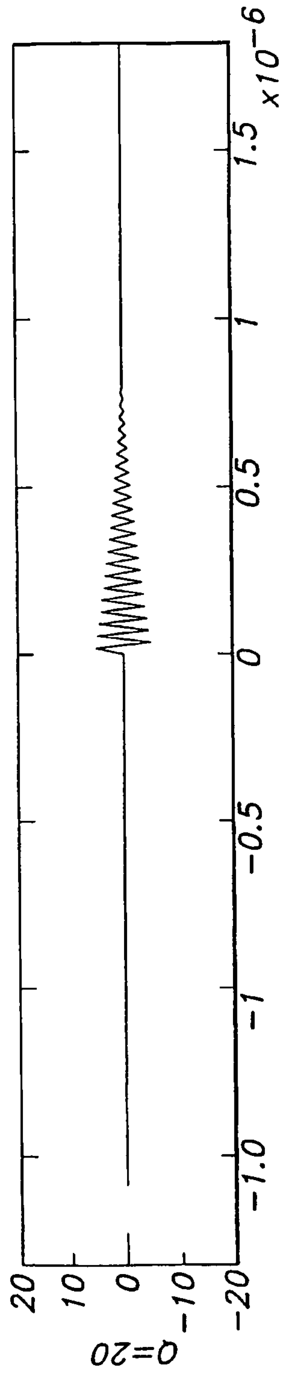

FIG. 3c

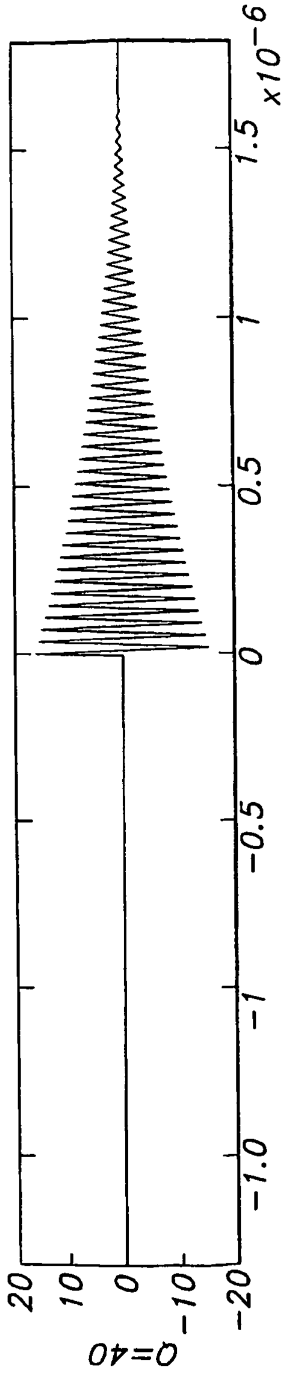

FIG. 3d

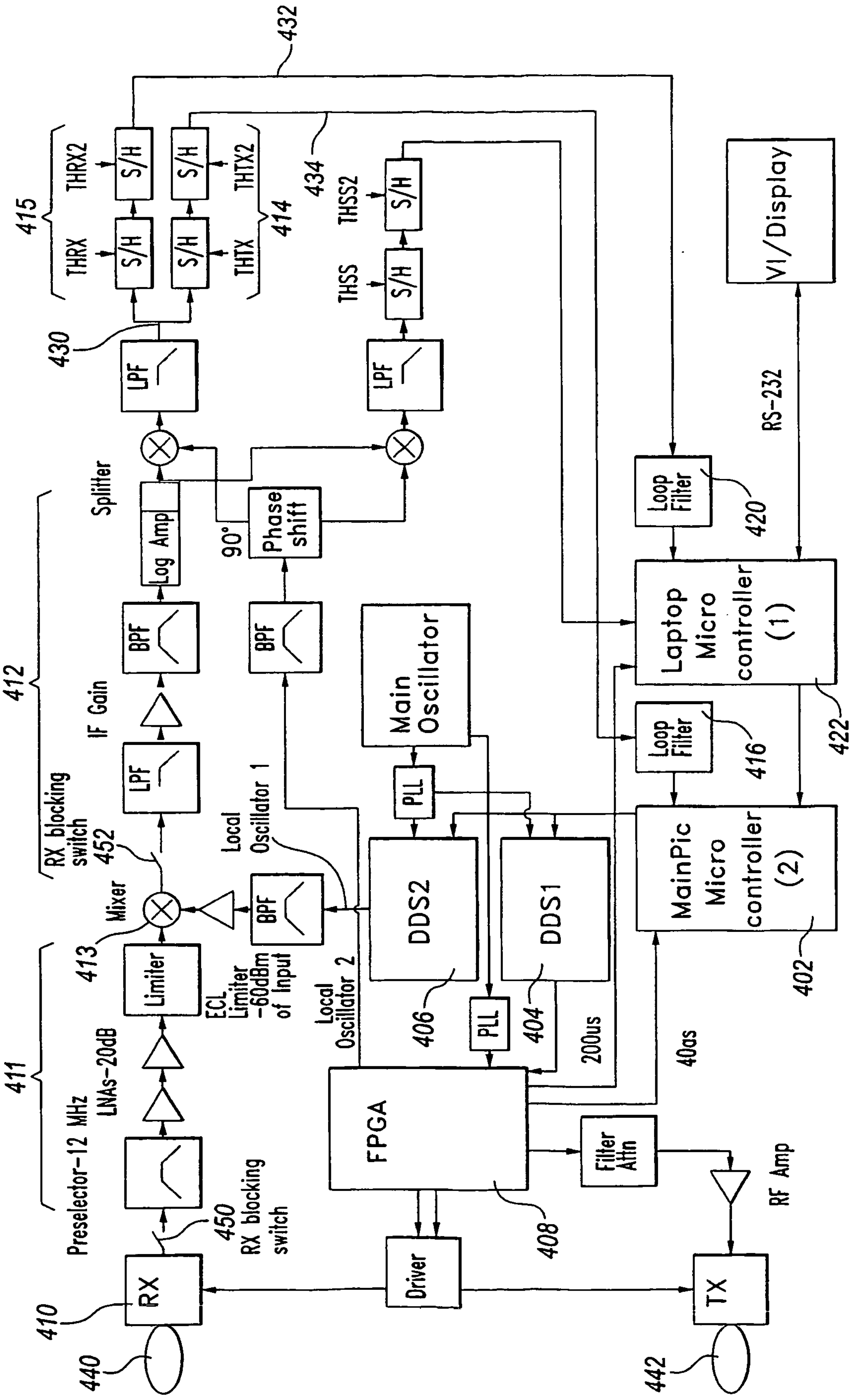
RX
TX
440
442
410
450
RX blocking switch
Preselector-12 MHz
LNAs-20dB
Limiter
ECL Limiter -60dBm of Input
411
413
Mixer
452
RX blocking switch
LPF
IF Gain
BPF
412
Log Amp
Splitter
LPF
430
S/H
THRX
THRX2
415
THTX
THTX2
414
432
434
THSS
THSS2
90°
Phase shift
BPF
Local Oscillator 1
Local Oscillator 2
Main Oscillator
PLL
DDS2
DDS1
406
404
200us
40as
FPGA
408
Driver
Filter Attn
RF Amp
Loop Filter
416
420
Laptop Micro controller (1)
422
MainPic Micro controller (2)
402
RS-232
VI/Display

FIG. 4

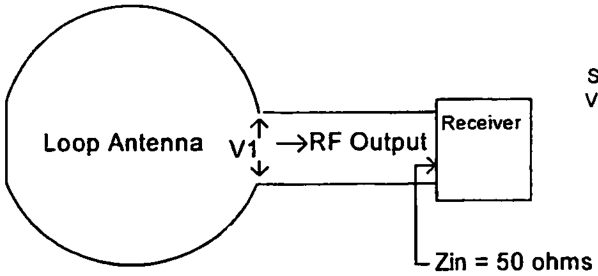

FIG. 5A

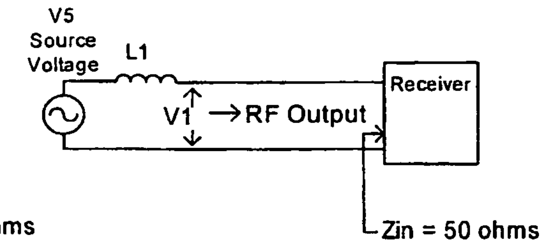

FIG. 5B

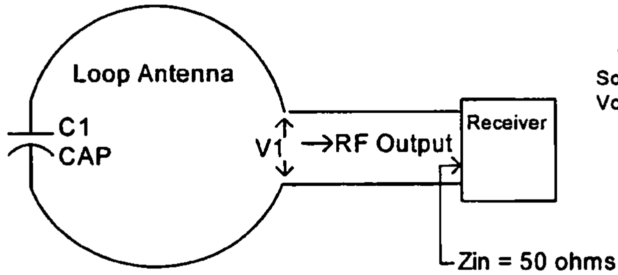

FIG. 6A

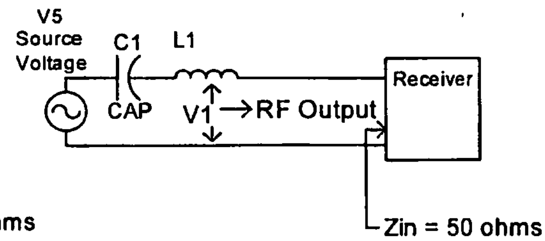

FIG. 6B

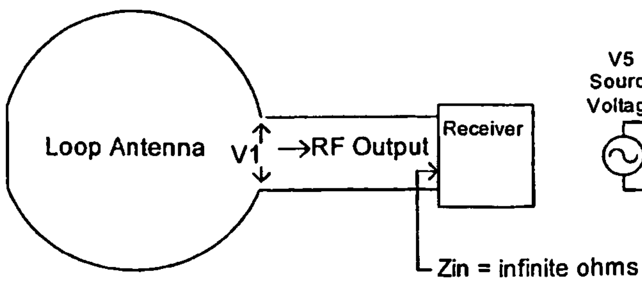

FIG. 7A

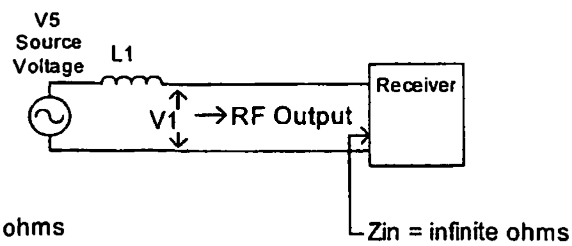

FIG. 7B

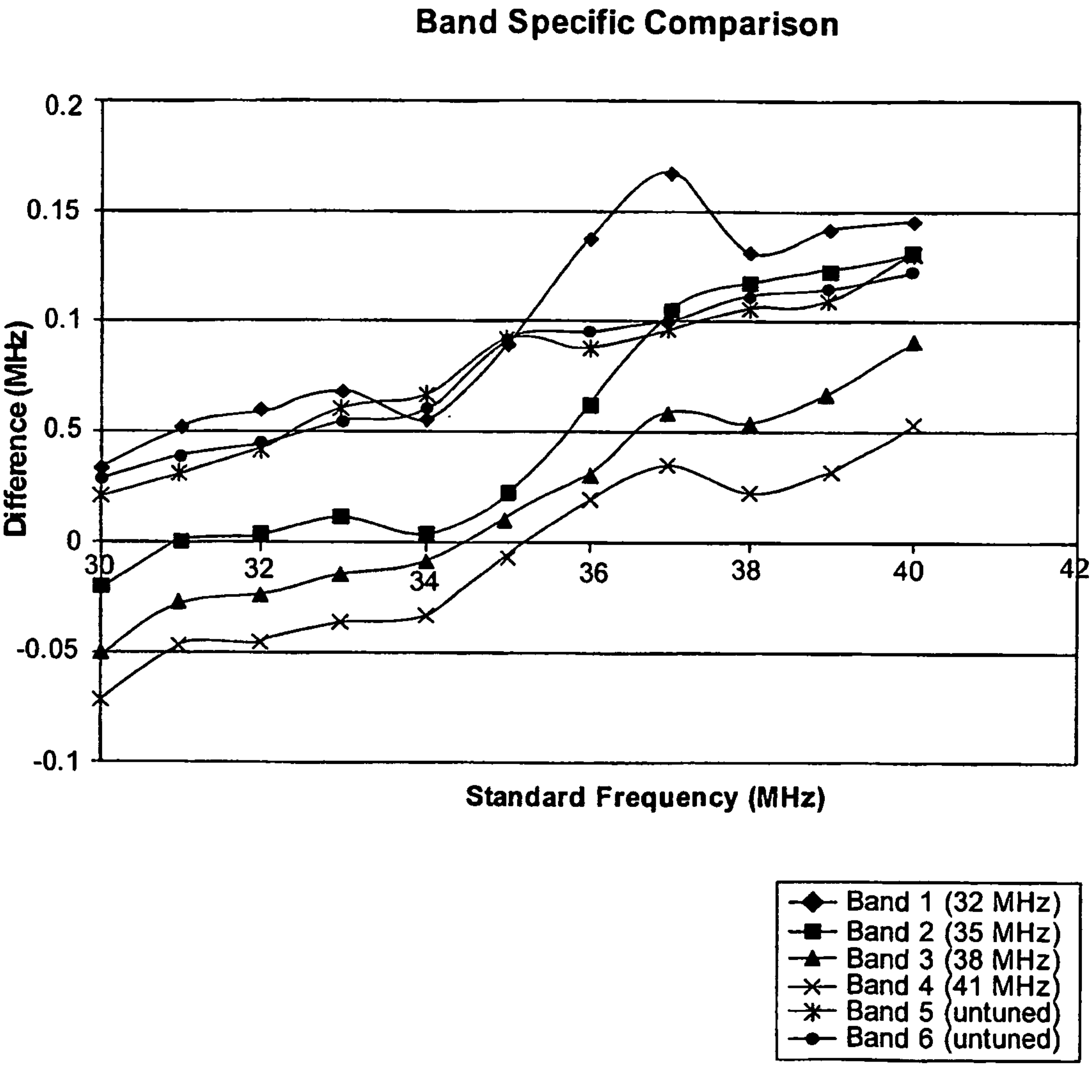
Band Specific Comparison
0.2
0.15
0.1
0.5
0
-0.05
-0.1
Difference (MHz)
30
32
34
36
38
40
42
Standard Frequency (MHz)
Band 1 (32 MHz)
Band 2 (35 MHz)
Band 3 (38 MHz)
Band 4 (41 MHz)
Band 5 (untuned)
Band 6 (untuned)

FIG. 8

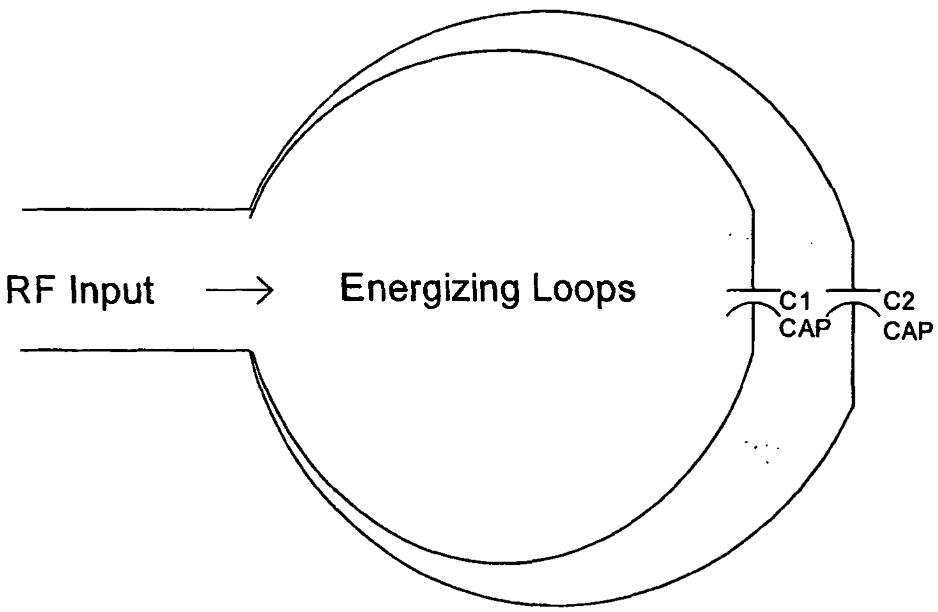

FIG. 9

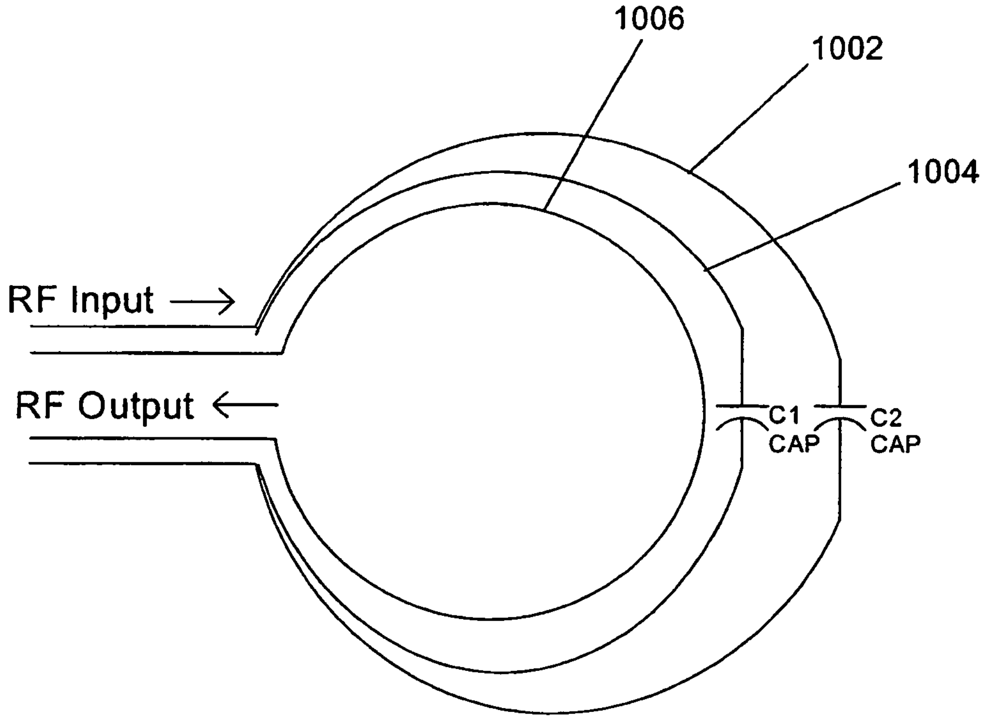

FIG. 10

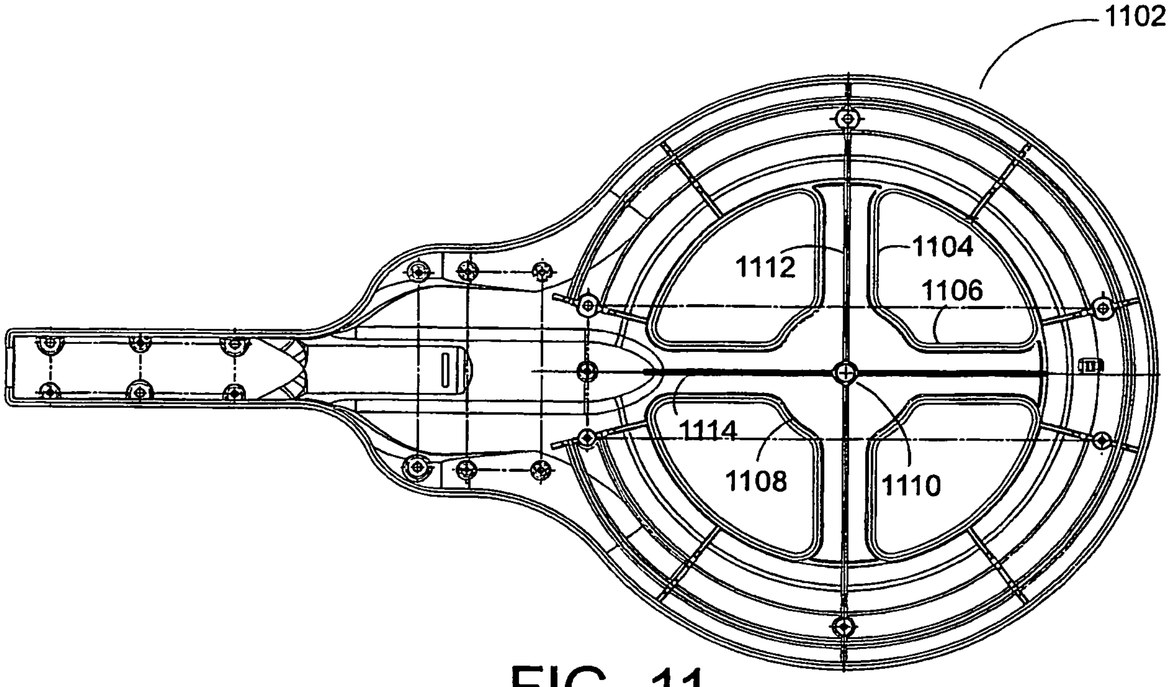

FIG. 11

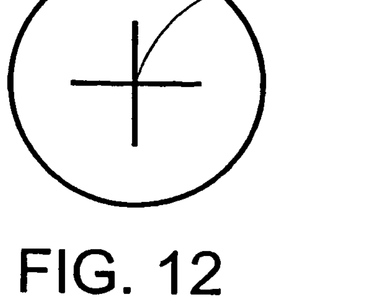

FIG. 12

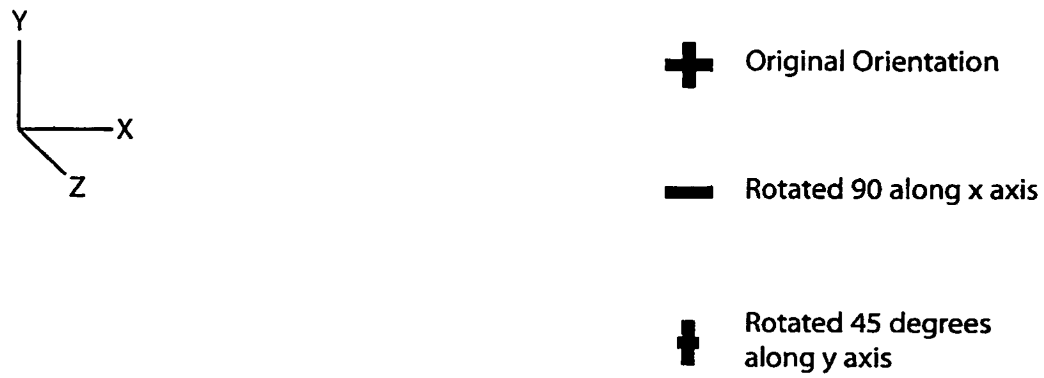
Y
X
Z
Original Orientation
Rotated 90 along x axis
Rotated 45 degrees along y axis

FIG. 13

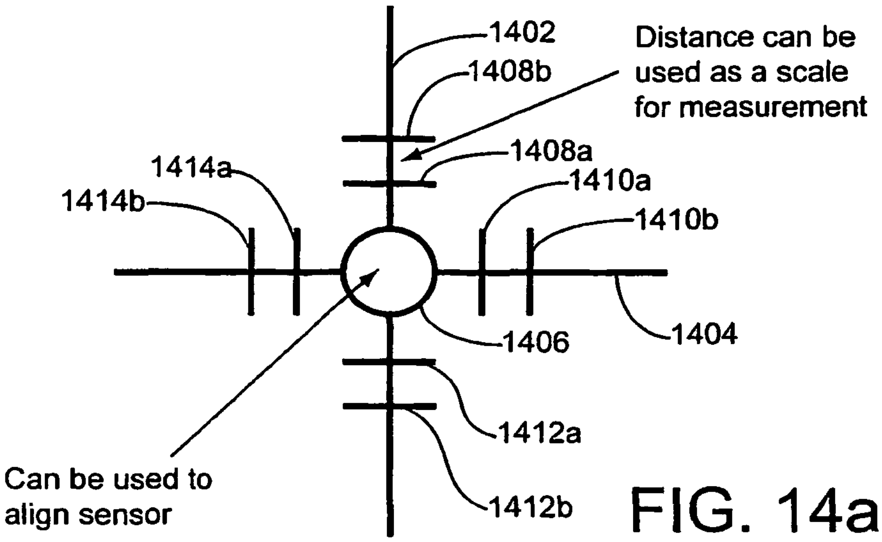

FIG. 14a

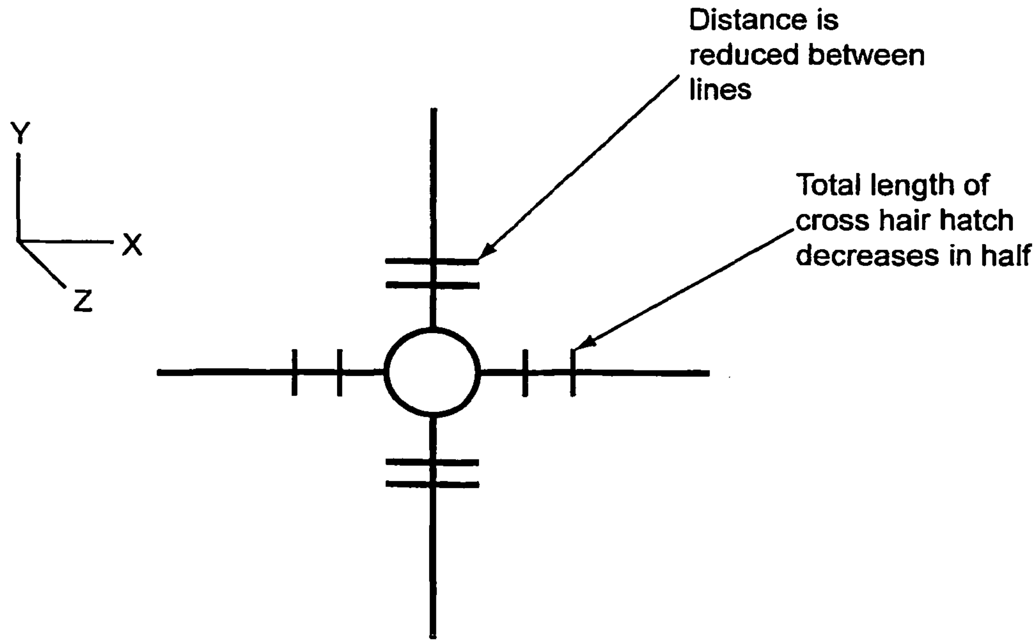

FIG. 14b

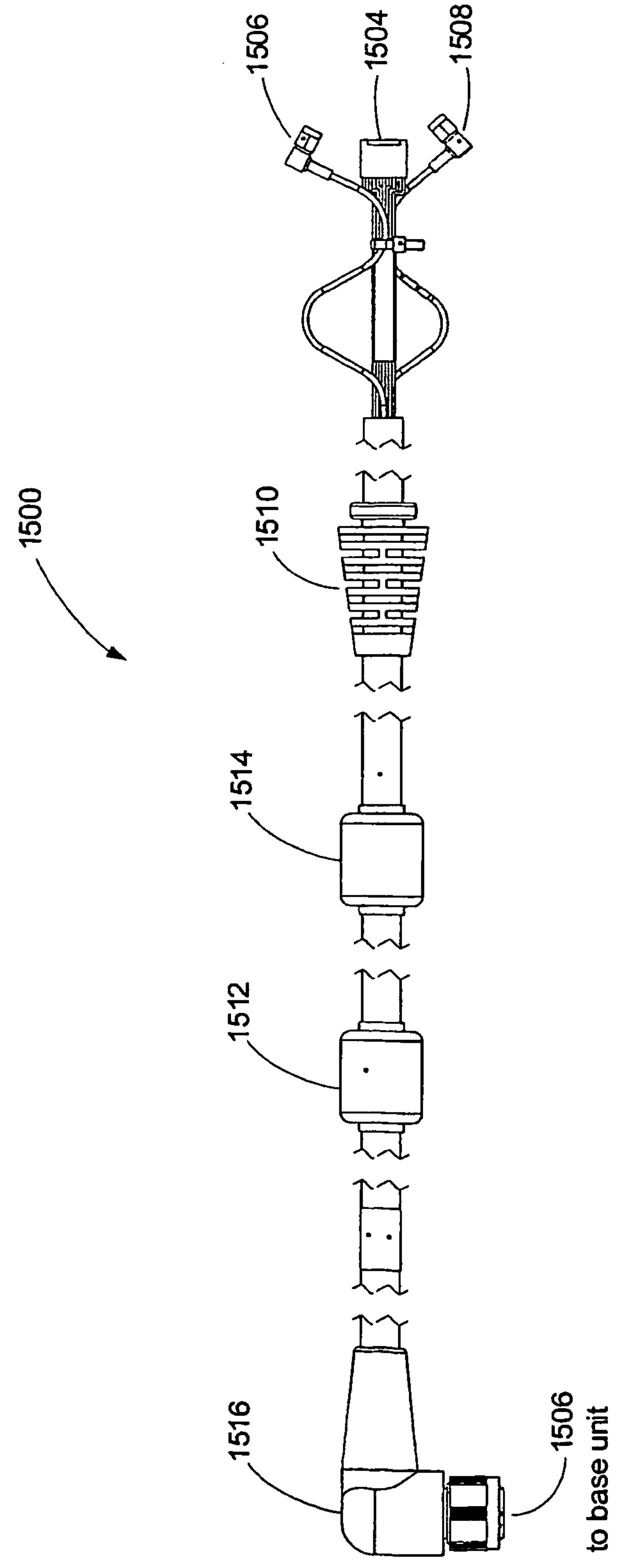

FIG. 15

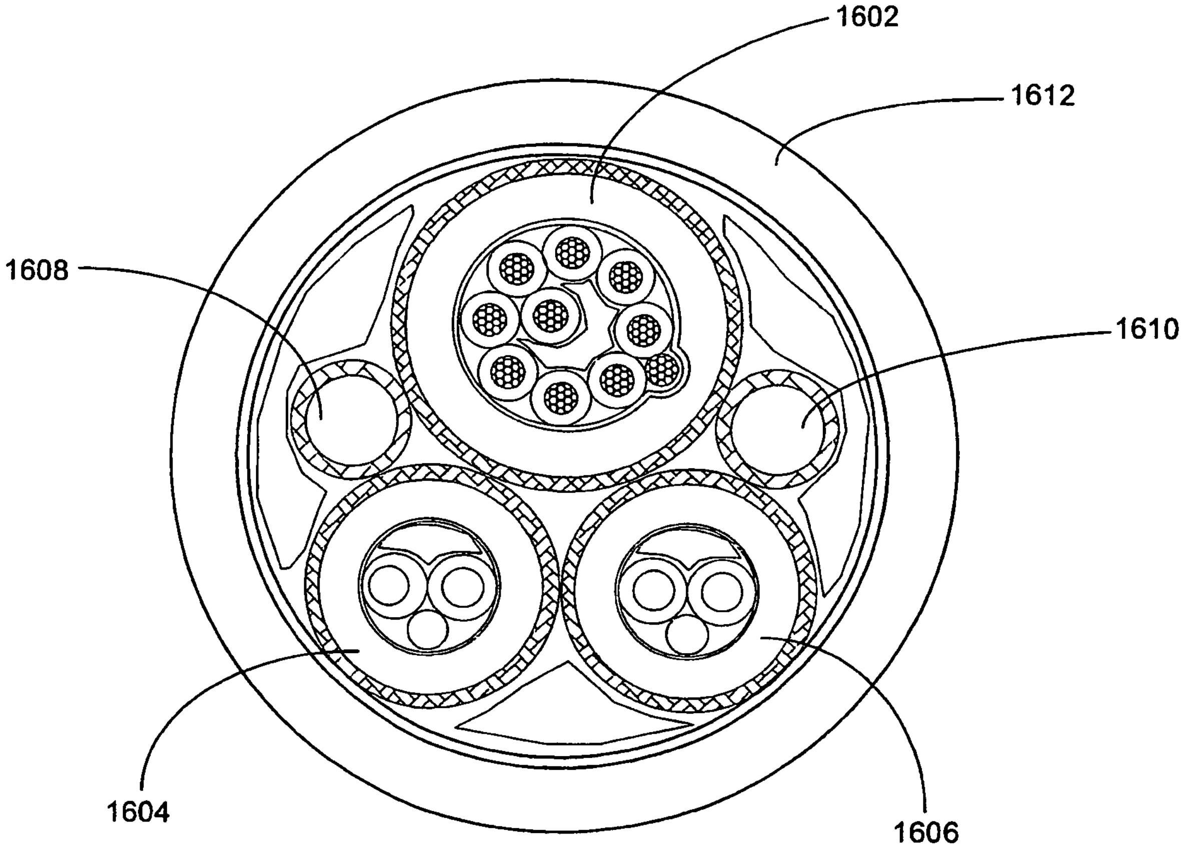

FIG. 16

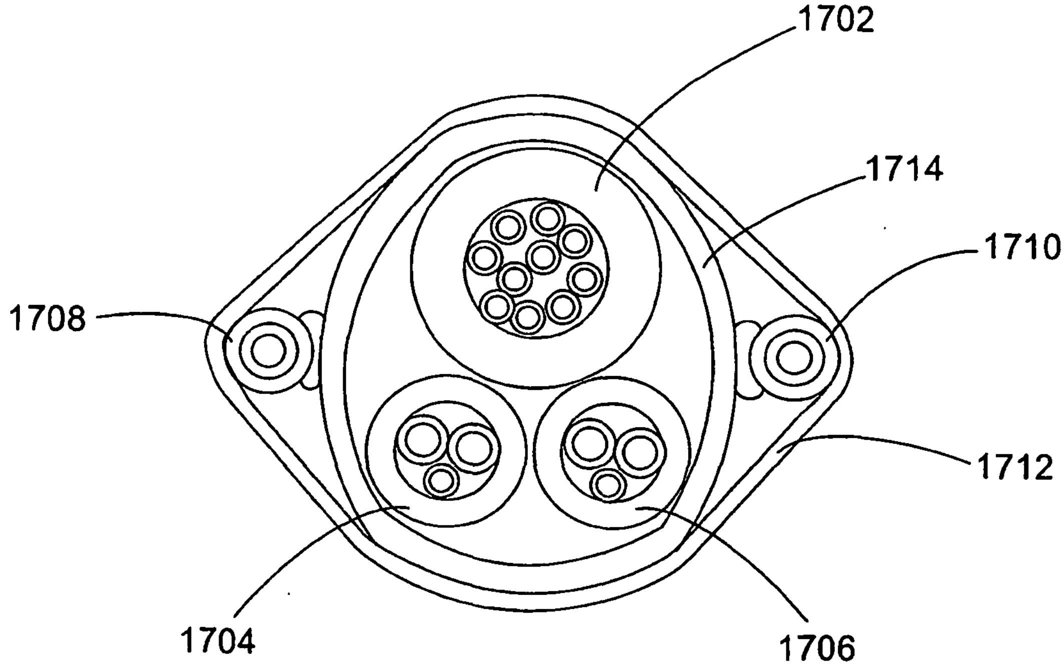

FIG. 17

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6111520 A **[0002]**
- US 6855115 B **[0002]**
- US 20030136417 A **[0002]**
- US 27657106 A **[0004]**

专利名称(译)	耦合回路，电缆组件和用于定位耦合回路的方法		
公开(公告)号	EP1902529B1	公开(公告)日	2012-06-13
申请号	EP2006774481	申请日	2006-06-30
[标]申请(专利权)人(译)	的CardioMEMS		
申请(专利权)人(译)	的CardioMEMS，INC.		
当前申请(专利权)人(译)	的CardioMEMS，INC.		
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IPC分类号	H04B5/00 A61B5/00 G01R33/00		
CPC分类号	A61B5/02014 A61B5/0031 A61B5/064 A61B5/07 A61B2560/0219 H01B11/20 H04B5/0043 Y10S128/903		
代理机构(译)	B关，JAMES CHARLES		
优先权	60/697867 2005-07-08 US 60/697878 2005-07-08 US 60/707094 2005-08-10 US		
其他公开文献	EP1902529A1		
外部链接	Espacenet		

摘要(译)

提供了耦合回路或天线，其可以与通过调节激励信号的相位和频率来确定传感器的谐振频率的系统一起使用，直到激励信号的频率与传感器的谐振频率匹配。耦合环包括多个环。优选地，两个调谐回路用于将激励信号传输到传感器，而未调谐回路用于接收来自传感器的传感器信号。连接到耦合回路的电缆通过最大化承载信号的同轴电缆之间的距离并保持同轴电缆在整个电缆组件中的相对位置，在激励信号和传感器信号之间提供最大隔离。提供用于耦合回路和传感器的壳体上的定向特征，以帮助将耦合回路相对于传感器定位，以最大化传感器信号和耦合回路之间的耦合。

$$V_1 = V_s \frac{50}{50 + j\omega L_1}$$