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(54) **METHODS AND SYSTEMS FOR IMPROVED COMMUNICATION BETWEEN MEDICAL DEVICES**

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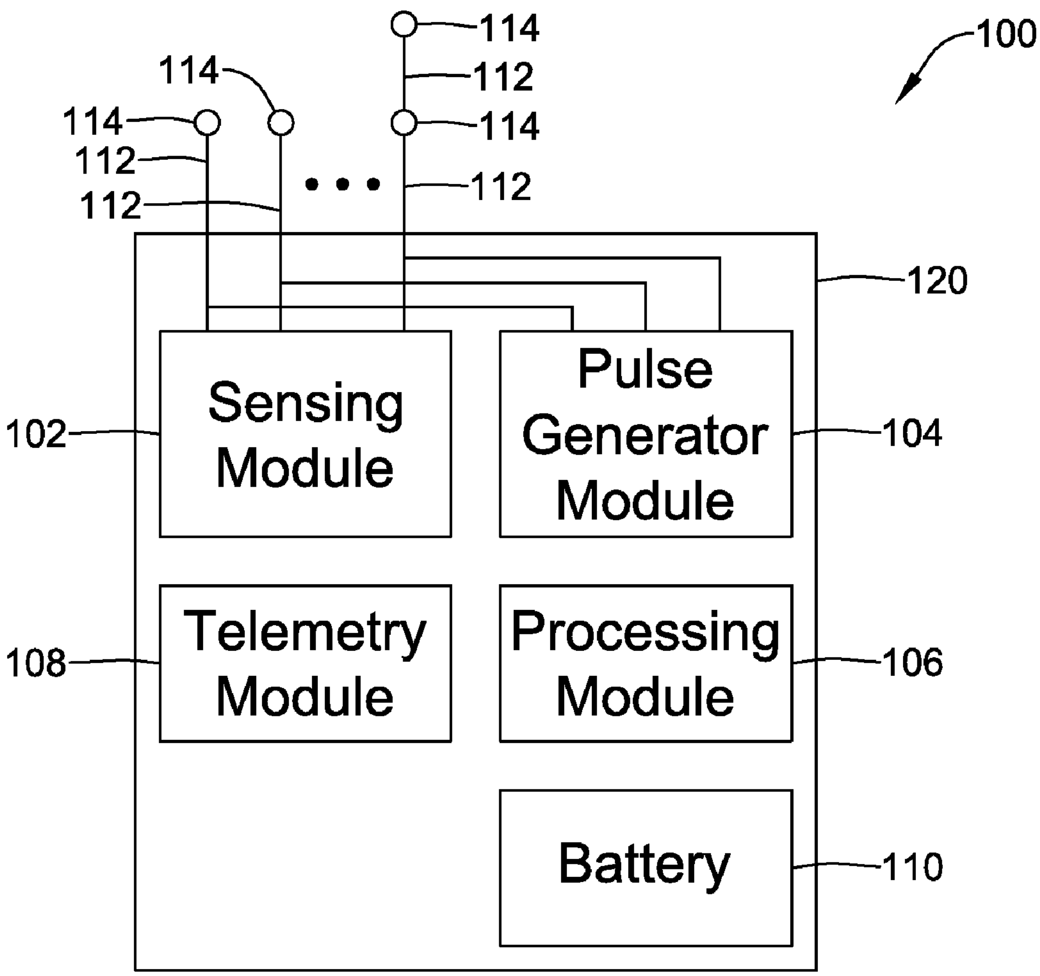
(57) **ABSTRACT**

At least one of a first medical device and a second medical device may be implanted within a patient while the second medical device may optionally be proximate but external to the patient. At least one of the medical devices has an antenna having at least two electrodes and at least one of the medical devices has an antenna having at least three electrodes. The medical devices can communicate via conducted communication through the patient's tissue between a first pair of electrodes and a second pair of electrodes. At least one of the pairs of electrodes can be selected in accordance with the signal strength of the communication vector between the first and second pairs of electrodes.



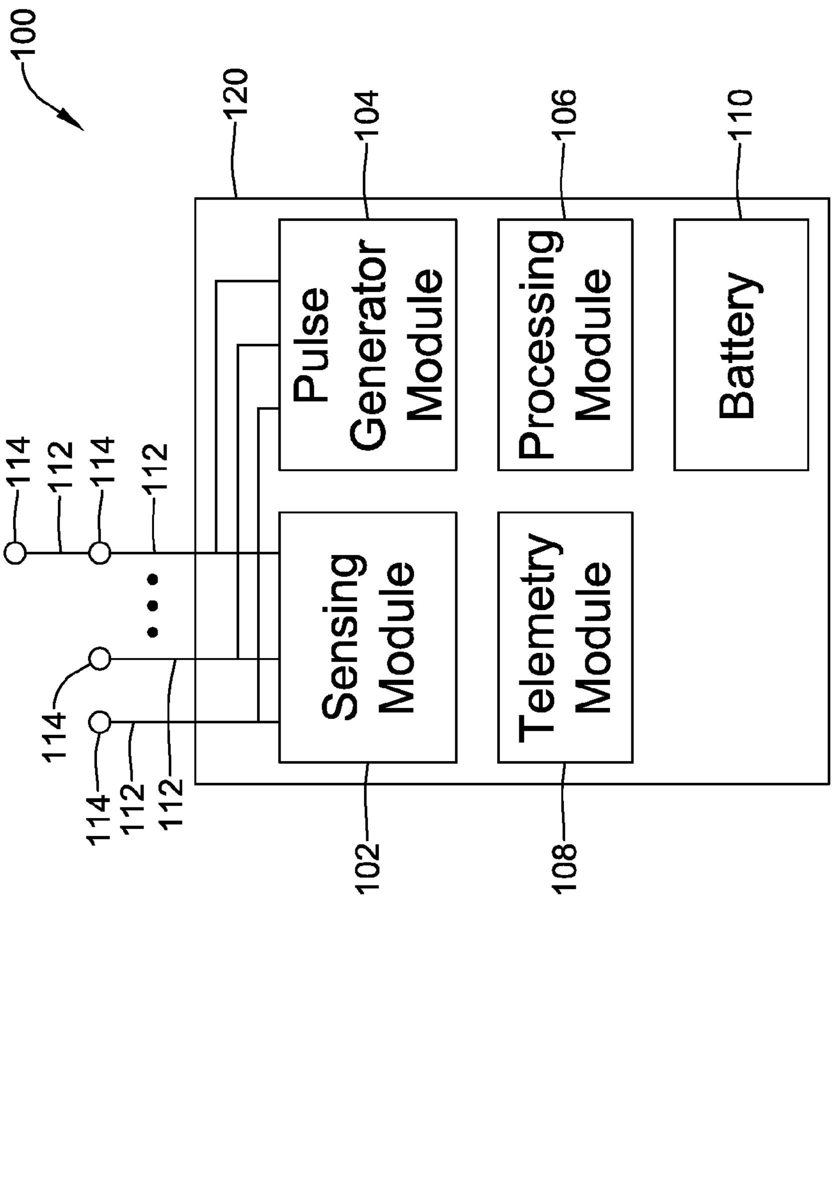

100
120
104
106
110
Pulse Generator Module
Processing Module
Battery
Sensing Module
Telemetry Module
102
108
114
112
114
112
114
114
112
112

FIG. 1

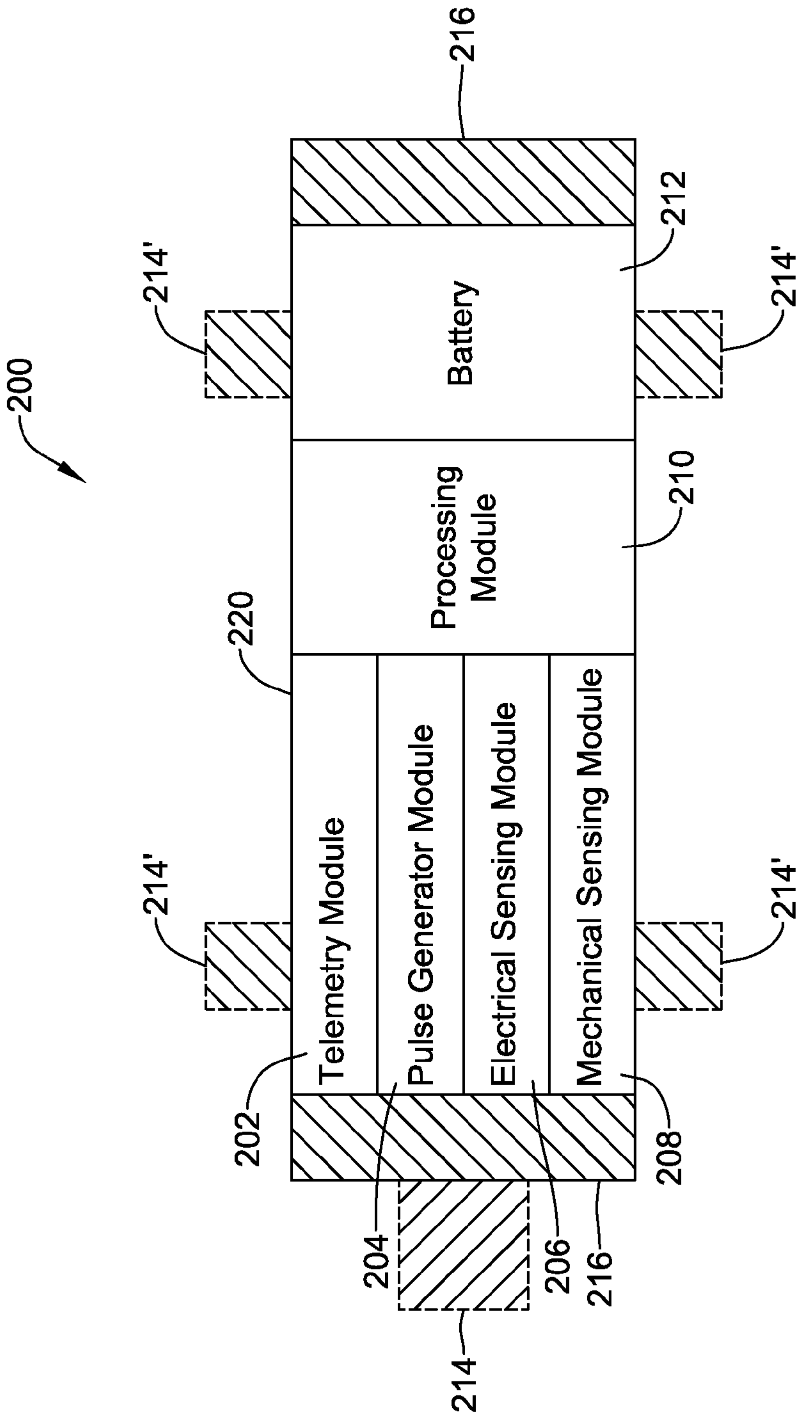

200
216
212
214'
214'
Battery
Processing Module
210
220
Telemetry Module
Pulse Generator Module
Electrical Sensing Module
Mechanical Sensing Module
214'
214'
202
204
206
216
208
214

FIG. 2

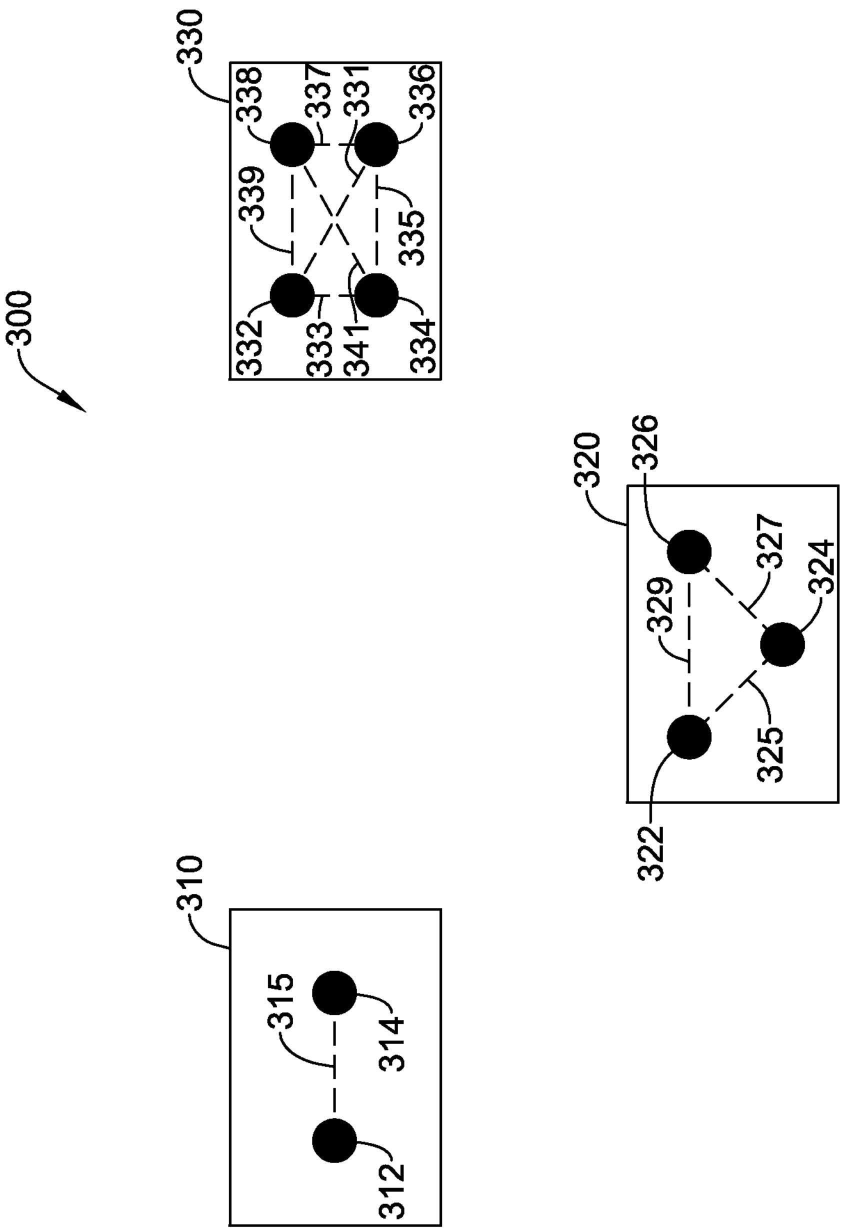

300
310
312
314
315
320
322
324
325
326
327
329
330
331
332
333
334
335
336
337
338
339
341

FIG. 3

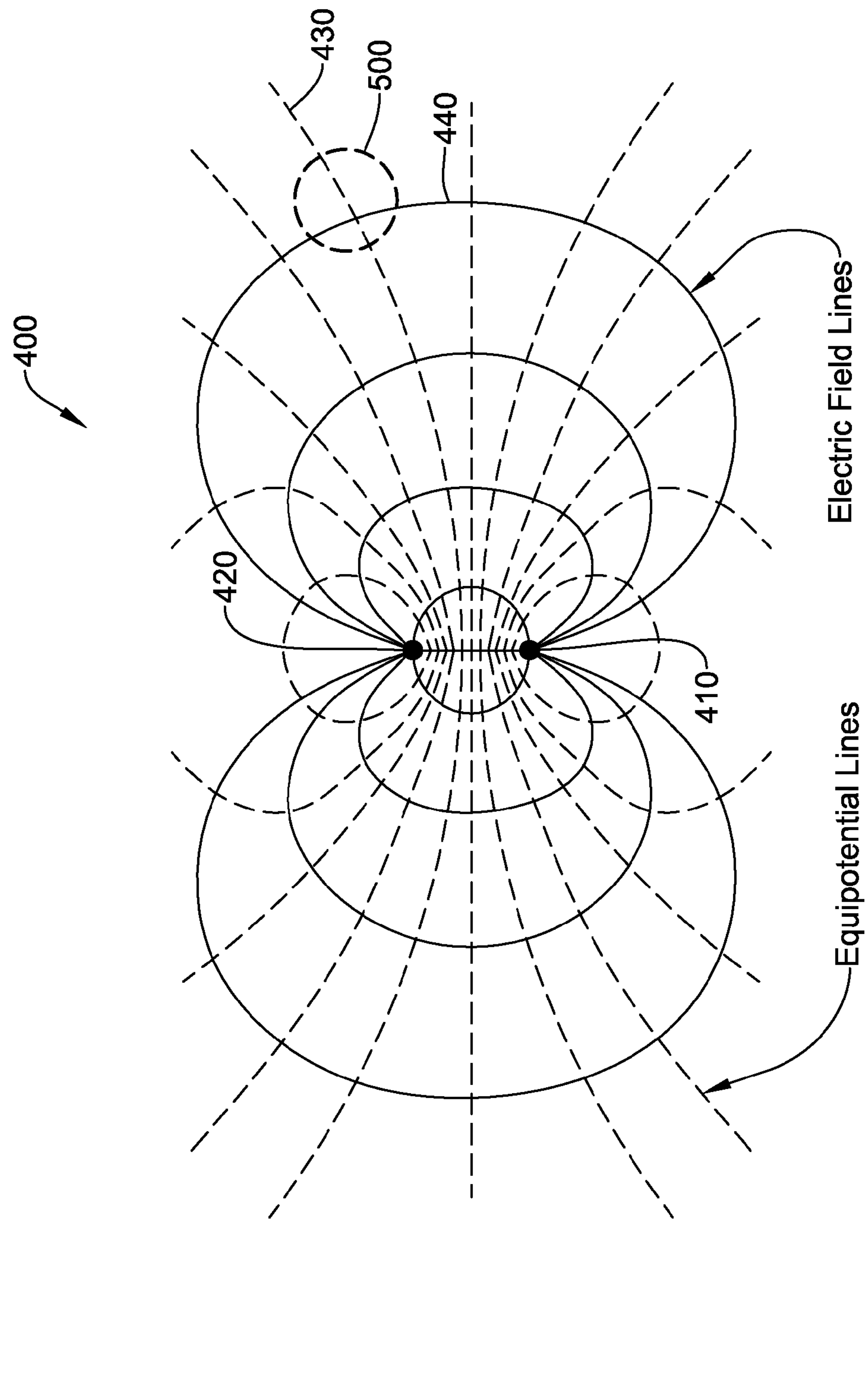

400
430
500
440
Electric Field Lines
420
410
Equipotential Lines

FIG. 4

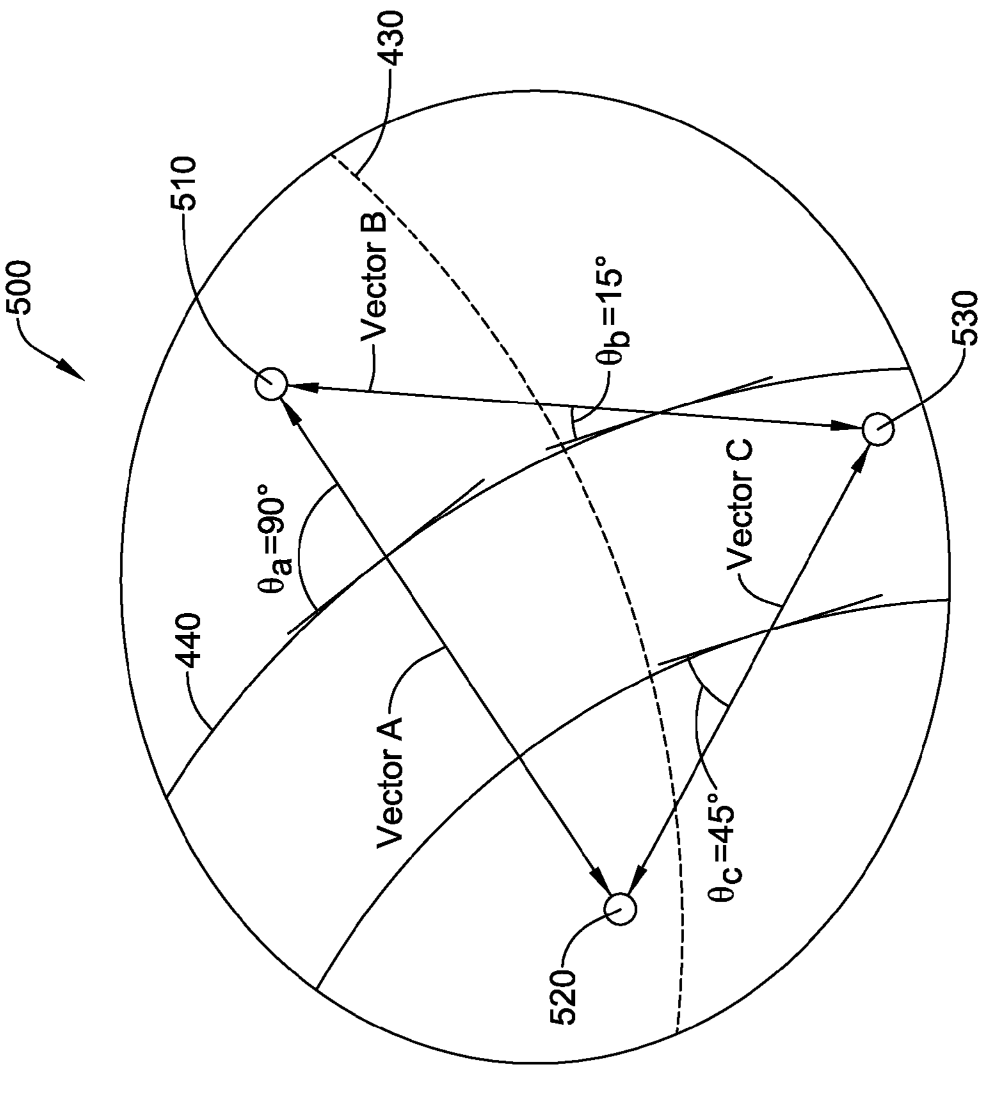

500
510
430
Vector B
θ_b=15°
530
θ_a=90°
Vector C
440
Vector A
θ_c=45°
520

FIG. 5

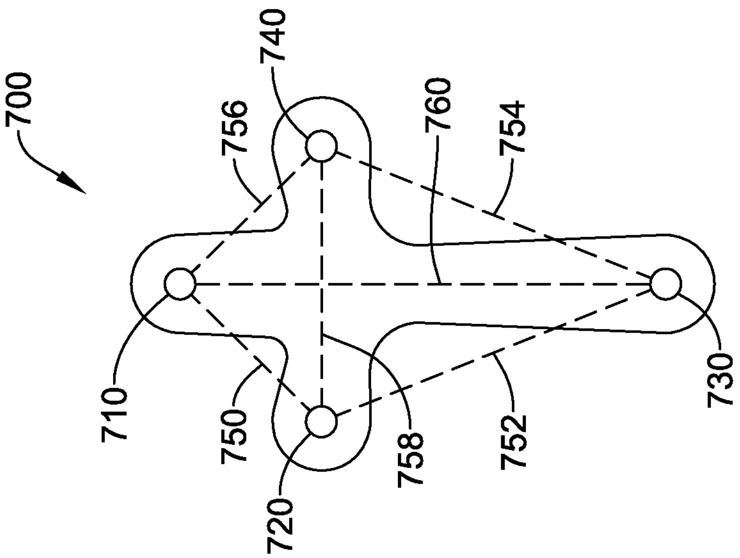

700
740
756
760
754
710
750
720
758
752
730

FIG. 7

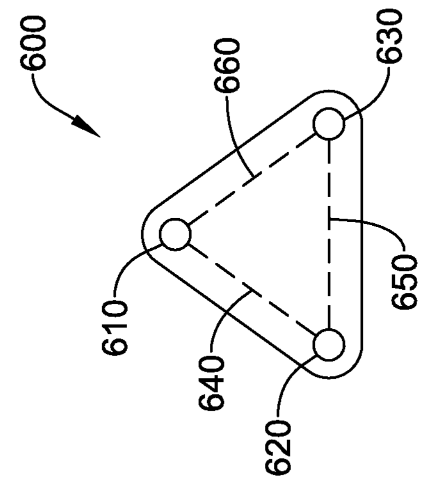
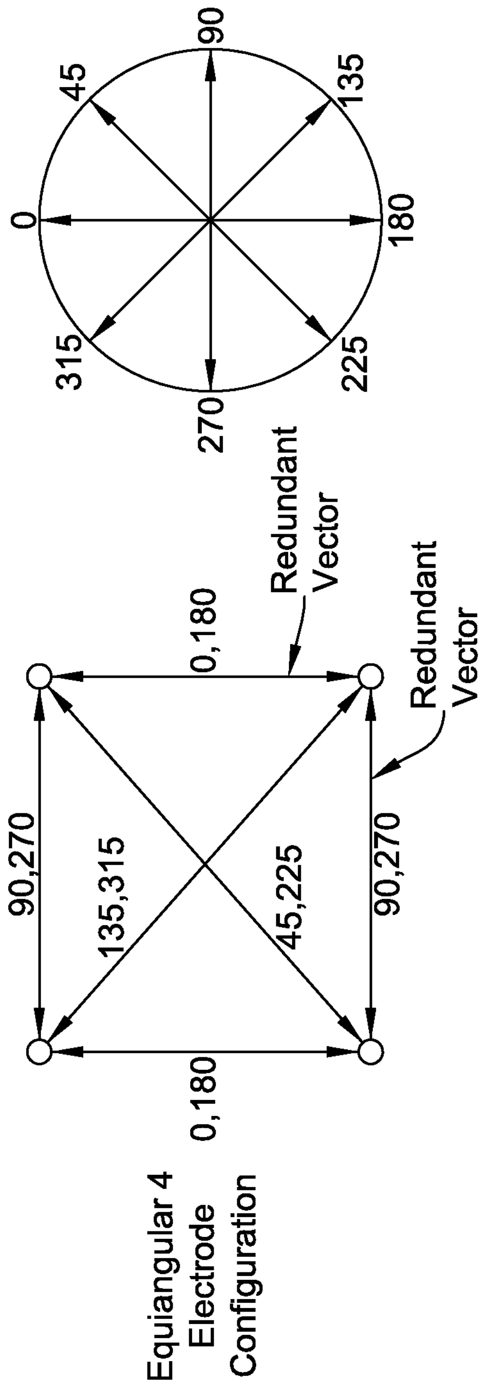

600
660
630
610
640
620
650

FIG. 6



0
45
90
135
180
225
270
315
Redundant Vector
Redundant Vector
0,180
90,270
135,315
45,225
90,270
0,180
Equiangular 4 Electrode Configuration

FIG. 8

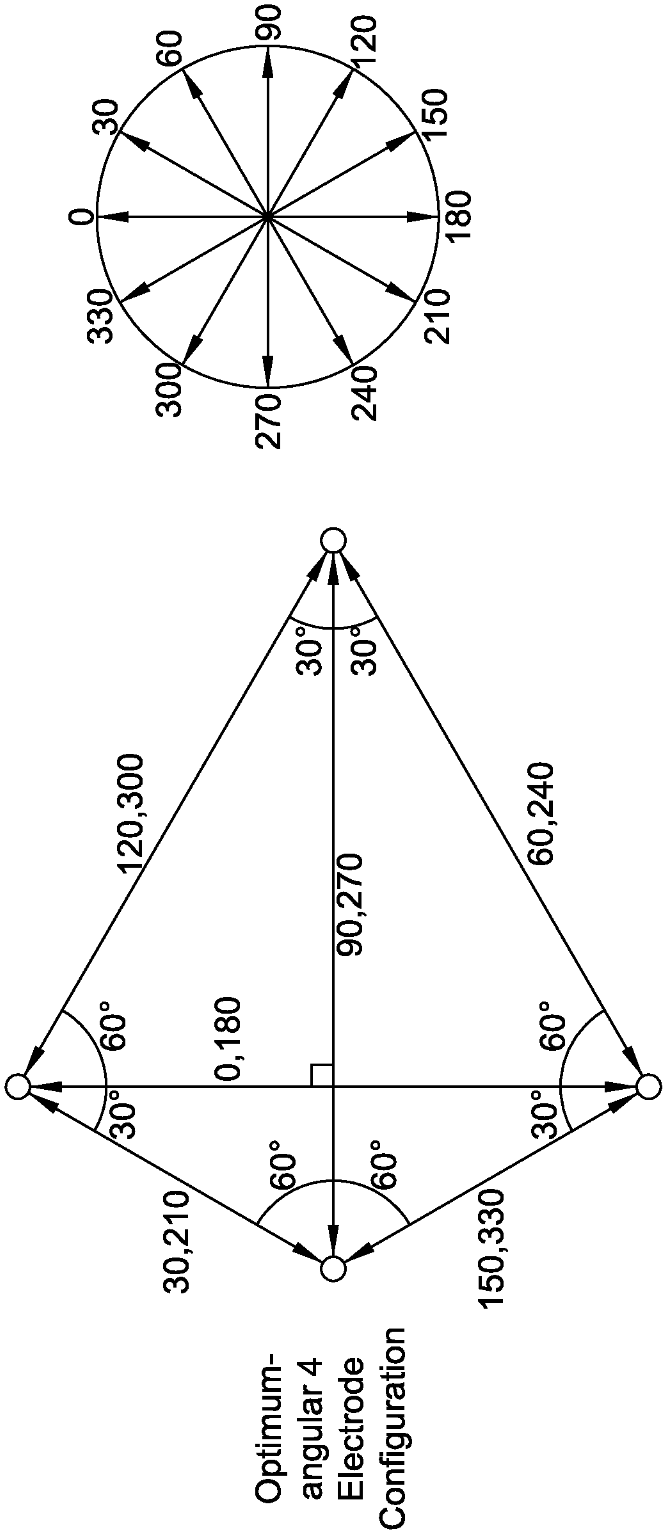

0
30
60
90
120
150
180
210
240
270
300
330
120,300
90,270
60,240
0,180
30,210
150,330
30°
30°
60°
30°
60°
30°
60°
60°
Optimum-
angular 4
Electrode
Configuration

FIG. 9

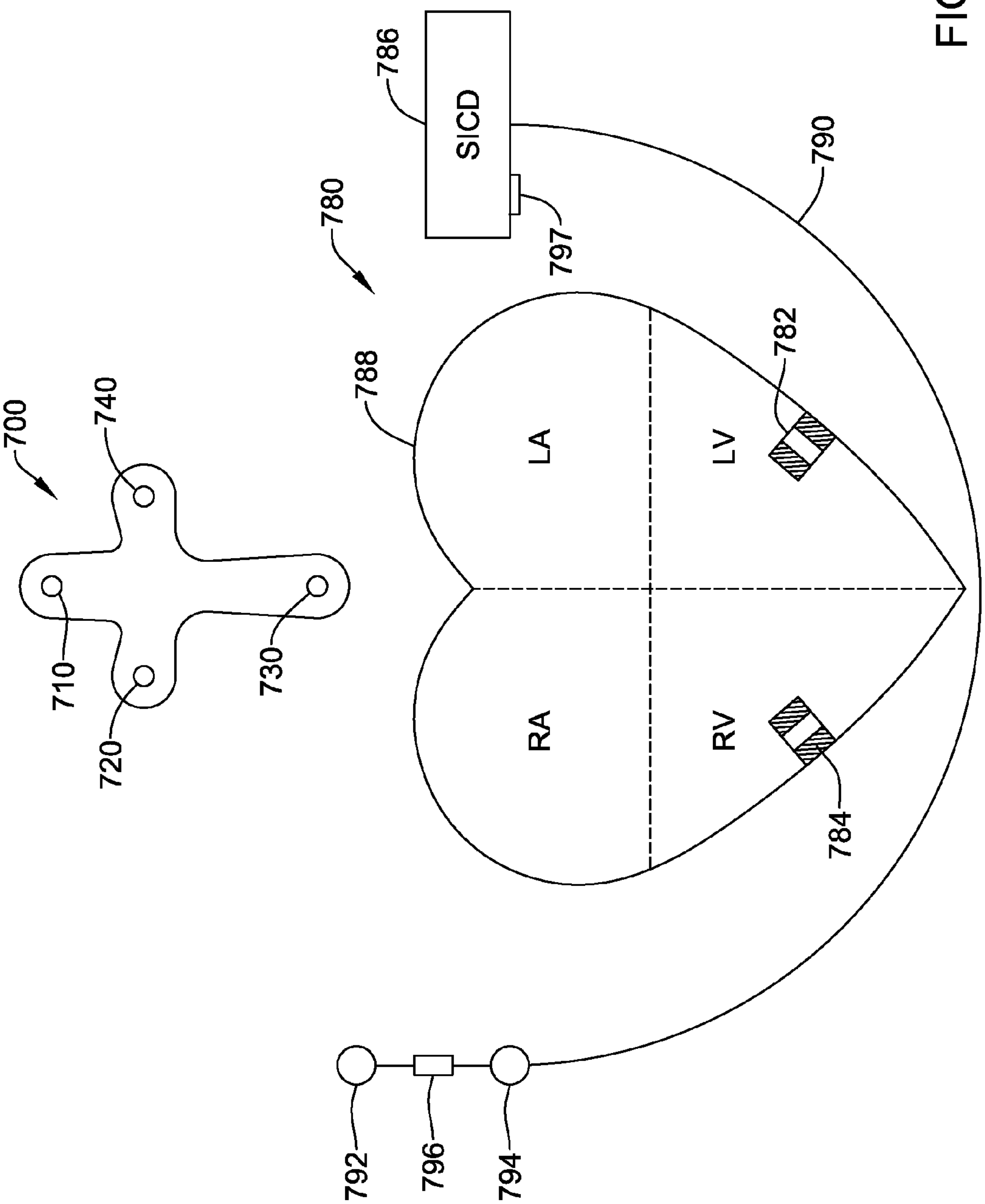

700
710
720
730
740
780
SICD
786
797
790
788
LA
LV
RA
RV
782
784
792
796
794

FIG. 10

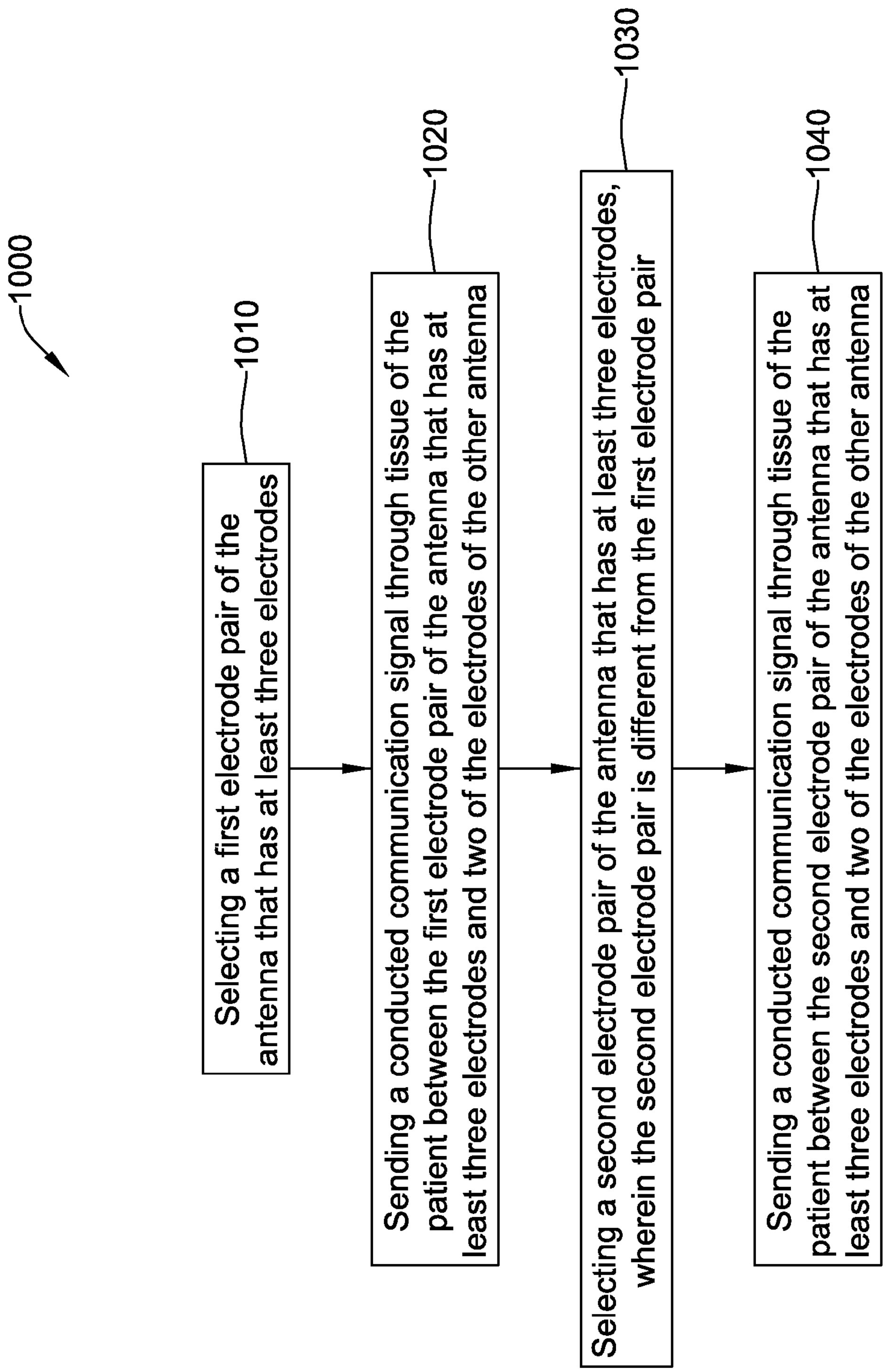

1000
1010
Selecting a first electrode pair of the antenna that has at least three electrodes
1020
Sending a conducted communication signal through tissue of the patient between the first electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna
1030
Selecting a second electrode pair of the antenna that has at least three electrodes, wherein the second electrode pair is different from the first electrode pair
1040
Sending a conducted communication signal through tissue of the patient between the second electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna

FIG. 11

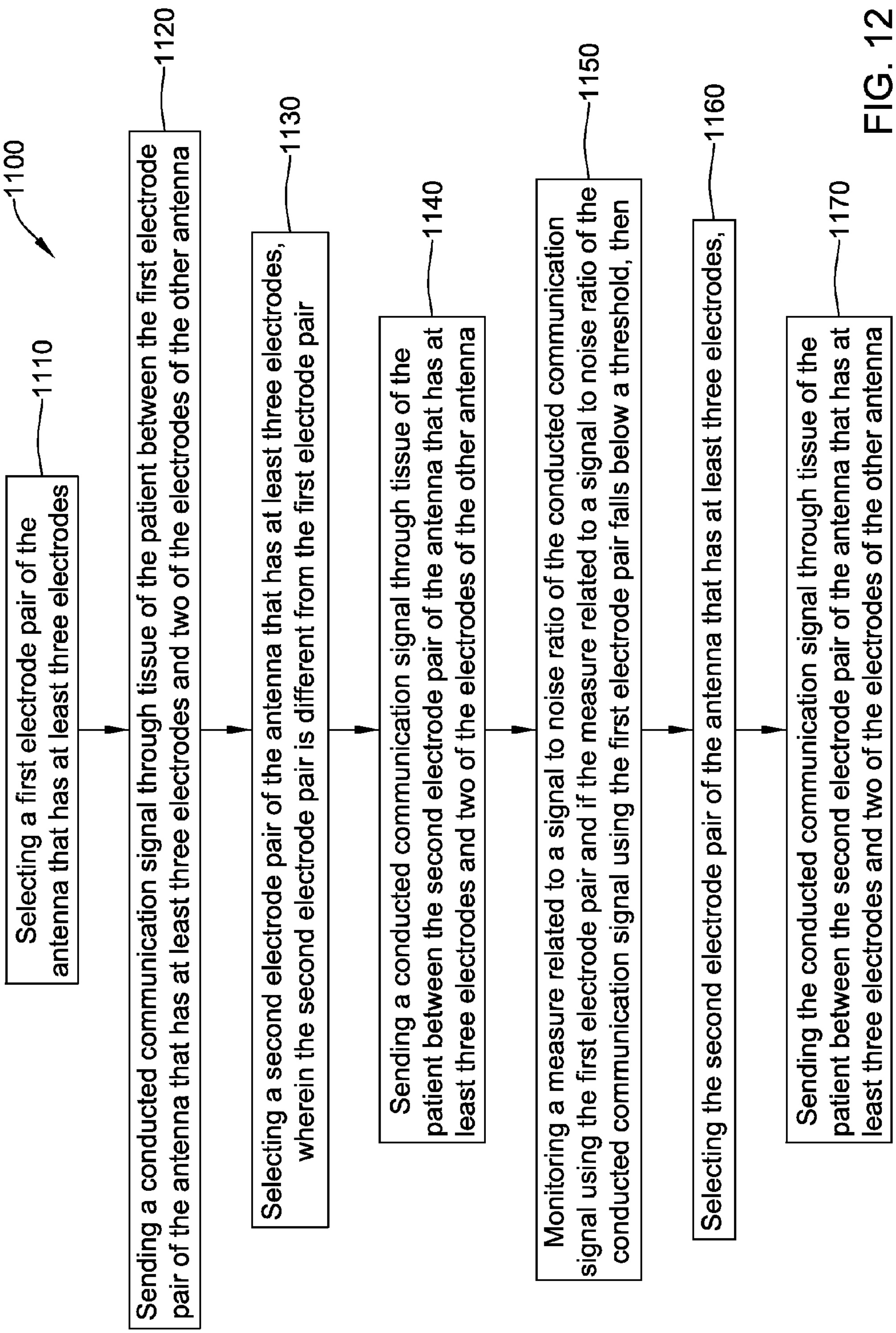

1100
1110
Selecting a first electrode pair of the antenna that has at least three electrodes
1120
Sending a conducted communication signal through tissue of the patient between the first electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna
1130
Selecting a second electrode pair of the antenna that has at least three electrodes, wherein the second electrode pair is different from the first electrode pair
1140
Sending a conducted communication signal through tissue of the patient between the second electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna
1150
Monitoring a measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair and if the measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair falls below a threshold, then
1160
Selecting the second electrode pair of the antenna that has at least three electrodes,
1170
Sending the conducted communication signal through tissue of the patient between the second electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna

FIG. 12

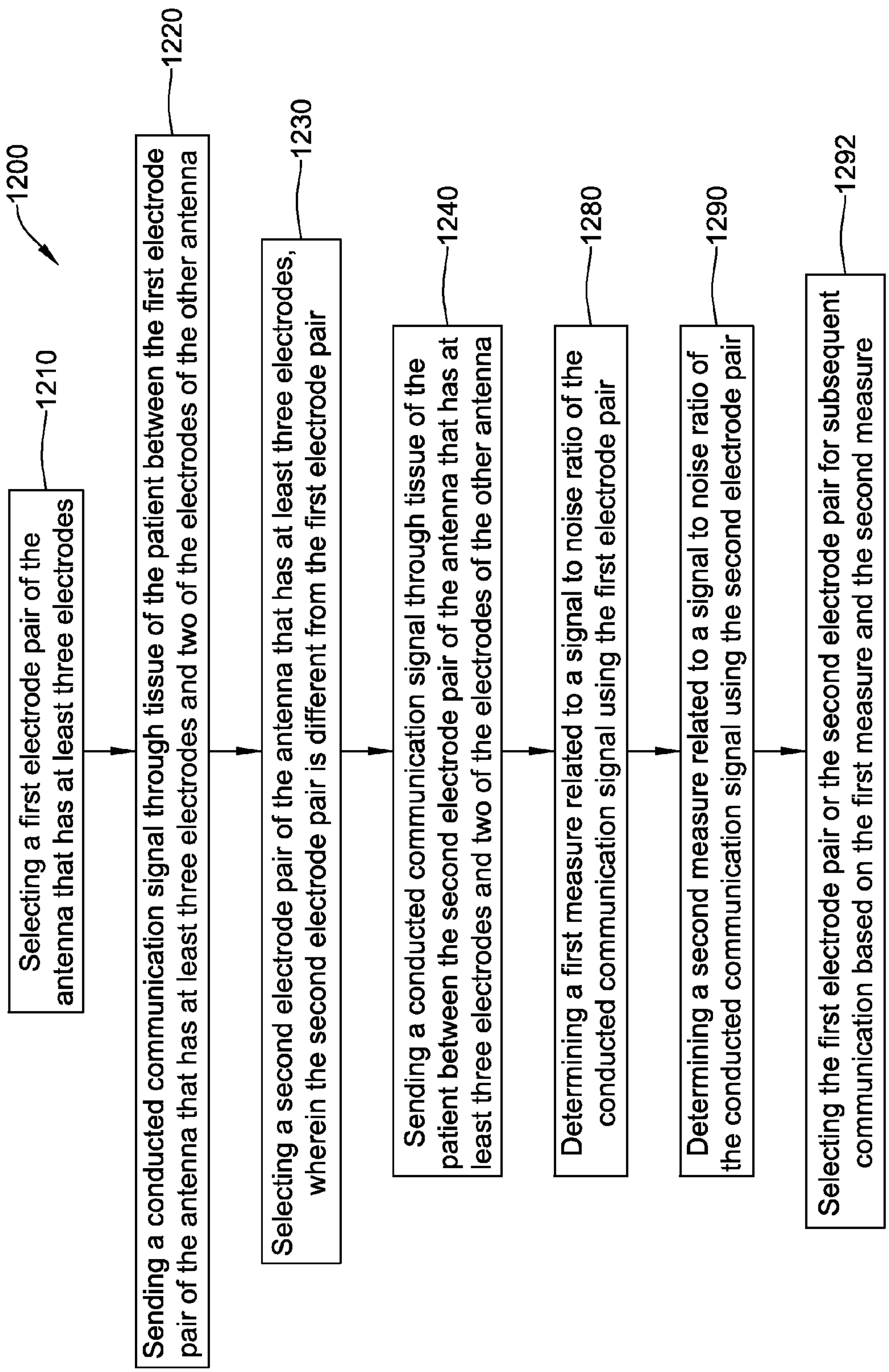

1200
1210
Selecting a first electrode pair of the antenna that has at least three electrodes
1220
Sending a conducted communication signal through tissue of the patient between the first electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna
1230
Selecting a second electrode pair of the antenna that has at least three electrodes, wherein the second electrode pair is different from the first electrode pair
1240
Sending a conducted communication signal through tissue of the patient between the second electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna
1280
Determining a first measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair
1290
Determining a second measure related to a signal to noise ratio of the conducted communication signal using the second electrode pair
1292
Selecting the first electrode pair or the second electrode pair for subsequent communication based on the first measure and the second measure

FIG. 13

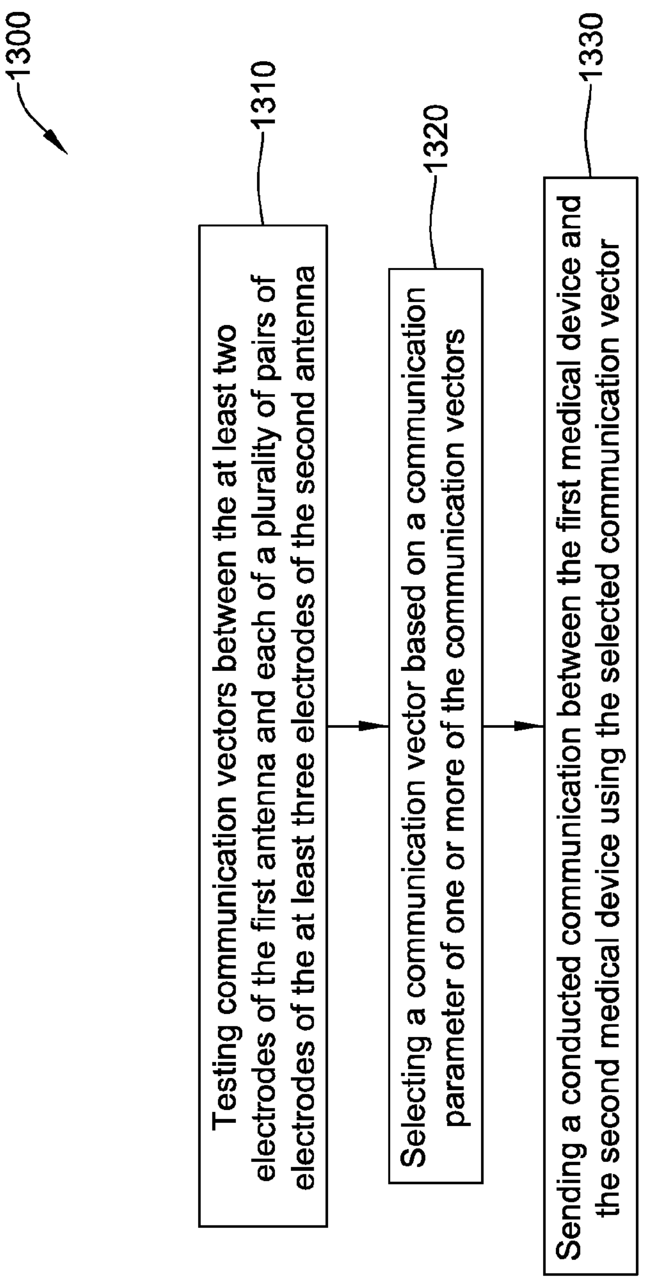

1300
1310
Testing communication vectors between the at least two electrodes of the first antenna and each of a plurality of pairs of electrodes of the at least three electrodes of the second antenna
1320
Selecting a communication vector based on a communication parameter of one or more of the communication vectors
1330
Sending a conducted communication between the first medical device and the second medical device using the selected communication vector

FIG. 14

METHODS AND SYSTEMS FOR IMPROVED COMMUNICATION BETWEEN MEDICAL DEVICES

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 61/926,101 filed Jan. 10, 2014 entitled "METHODS AND SYSTEMS FOR IMPROVED COMMUNICATION BETWEEN MEDICAL DEVICES", which application is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure generally relates to communication between medical devices, and more particularly, to methods and systems for improved communication between medical devices.

BACKGROUND

[0003] Pacing instruments can be used to treat patients suffering from various heart conditions that may result in a reduced ability of the heart to deliver sufficient amounts of blood to a patient's body. These heart conditions may lead to rapid, irregular, and/or inefficient heart contractions. To help alleviate some of these conditions, various devices (e.g., pacemakers, defibrillators, etc.) can be implanted in a patient's body. Such devices may monitor and provide electrical stimulation to the heart to help the heart operate in a more normal, efficient and/or safe manner. In some cases, a patient may have multiple devices that operate together to detect and/or treat various conditions.

SUMMARY

[0004] The present disclosure generally relates to communication between medical devices, and more particularly, to methods and systems for improved communication between medical devices. For example, a first medical device and a second medical device may be implanted within a patient, or the first medical device may be implanted within the patient and the second medical device may be proximate but external to the patient. At least one of the medical devices may have an antenna with at least two electrodes, and at least one of the medical devices may have an antenna with at least three electrodes. The medical devices may communicate by transmitting signals from two of the electrodes of the transmitting medical device to at least two electrodes of the receiving medical device. It is contemplated that the medical devices may communicate via radiofrequency (RF) communication, inductive coupling, conducted communication, or any other suitable communication technique.

[0005] It will be appreciated that the relative signal strength between any two pairs of electrodes, such as a first pair of electrodes belonging to the transmitting medical device and a second pair of electrodes belonging to the receiving medical device, may depend in part on the orientation of the receiving electrodes relative to the electromagnetic field produced by the transmitting electrodes. The system may be configured to select a particular pair of electrodes for the transmitting medical device and/or the receiving medical device in order help improve the signal strength of communication between the devices. The different combination of electrodes that may be used for communication between medical devices can each be referred to a "communication vector". In some instances, various communication vectors may be tested, and the communication vector that produces the highest relative signal strength and/or signal-to-noise ratio may be selected for subsequent communication. Various communication vectors may be re-tested periodically, upon command, when the relative signal strength and/or signal-to-noise ratio falls below a threshold, when the relative signal strength and/or signal-to-noise ratio changes by a threshold, and/or at any other suitable time as desired.

[0006] An example method of communicating between a first medical device having a first antenna and a second medical device having a second antenna is disclosed. The first medical device is implanted within a patient and the second medical device is proximate to the patient, and the first antenna and/or the second antenna has at least three electrodes and the other antenna has at least two electrodes. The example method comprises:

[0007] selecting a first electrode pair of the antenna that has at least three electrodes;

[0008] at least one of sending and receiving a conducted communication signal through tissue of the patient between the first electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna;

[0009] selecting a second electrode pair of the antenna that has at least three electrodes, wherein the second electrode pair is different from the first electrode pair; and

[0010] sending a conducted communication signal through tissue of the patient between the second electrode pair of the antenna that has at least three electrodes and two electrodes of the other antenna.

[0011] Alternatively or additionally to any of the embodiments above, the method may further include:

[0012] monitoring a measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair;

[0013] if the measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair falls below a threshold, then:

- **[0014]** selecting the second electrode pair of the antenna that has at least three electrodes; and
- **[0015]** sending the conducted communication signal through tissue of the patient between the second electrode pair of the antenna that has at least three electrodes and the two electrodes of the other antenna.

[0016] Alternatively or additionally to any of the embodiments above, the method may further include:

[0017] determining a first measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair;

[0018] determining a second measure related to a signal to noise ratio of the conducted communication signal using the second electrode pair; and

[0019] selecting the first electrode pair or the second electrode pair for subsequent communication based on the first measure and the second measure.

[0020] Alternatively or additionally to any of the embodiments above, the second medical device may be implanted within the patient but spaced from the first medical device.

[0021] Alternatively or additionally to any of the embodiments above, the second medical device may be disposed outside of the patient and the second antenna is positioned on a skin surface of the patient.

[0022] Alternatively or additionally to any of the embodiments above, the antenna that has at least three electrodes may comprise three electrodes that are arranged in a triangular configuration.

[0023] Alternatively or additionally to any of the embodiments above, the antenna that has at least three electrodes may comprise four electrodes that are arranged in a rectangular configuration.

[0024] Alternatively or additionally to any of the embodiments above, the antenna that has at least three electrodes may comprise four electrodes that are arranged in a kite configuration.

[0025] Another example method of communicating between a first medical device having a first antenna with at least two electrodes and a second medical device having a second antenna with at least three electrodes comprises:

[0026] testing communication vectors between the at least two electrodes of the first antenna and each of a plurality of pairs of electrodes of the at least three electrodes of the second antenna;

[0027] selecting a communication vector based on signal strengths of each of the communication vectors; and

[0028] at least one of sending and receiving a conducted communication between the first medical device and the second medical device using the selected communication vector.

[0029] Alternatively or additionally to any of the embodiments above, the first medical device may comprise an implanted medical device and the second medical device may comprise an external device.

[0030] Alternatively or additionally to any of the embodiments above, the first medical device may comprise an external device and the second medical device may comprise an implanted medical device.

[0031] Alternatively or additionally to any of the embodiments above, the first medical device may comprise a first implanted medical device and the second medical device may comprise a second implanted medical device.

[0032] Alternatively or additionally to any of the embodiments above, selecting a communication vector may comprise selecting the communication vector with the strongest signal strength.

[0033] Alternatively or additionally to any of the embodiments above, selecting a communication vector may comprise not selecting the communication vector with the weakest signal strength.

[0034] An example communications system is also disclosed. The example communications system comprises:

[0035] a first medical device in communication with a first antenna having at least two electrodes; and

[0036] a second medical device in communication with a second antenna having at least three electrodes;

[0037] wherein at least one of the first medical device and the second medical device is configured to:

- [0038] test communication vectors between the at least two electrodes of the first antenna and at least two pairs of the at least three electrodes of the second antenna;
- [0039] select a communication vector from the tested communication vectors; and
- [0040] at least one of send and receive a conducted communication along the selected communication vector.

[0041] Alternatively or additionally to any of the embodiments above, the at least three electrodes may comprise three electrodes that are arranged in a triangular configuration.

[0042] Alternatively or additionally to any of the embodiments above, the at least three electrodes may comprise four electrodes that are arranged in a rectangular configuration.

[0043] Alternatively or additionally to any of the embodiments above, the at least three electrodes may comprise four electrodes that are arranged in a kite configuration.

[0044] Alternatively or additionally to any of the embodiments above, at least one of the first medical device and the second medical device may be implanted within a patient.

[0045] Alternatively or additionally to any of the embodiments above, the first medical device is a leadless cardiac pacemaker (LCP).

[0046] The above summary is not intended to describe each embodiment or every implementation of the present disclosure. Advantages and attainments, together with a more complete understanding of the disclosure, will become apparent and appreciated by referring to the following description and claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE FIGURES

[0047] The disclosure may be more completely understood in consideration of the following description of various illustrative embodiments in connection with the accompanying drawings, in which:

[0048] FIG. **1** illustrates a block diagram of an exemplary medical device that may be used in accordance with various examples of the present disclosure;

[0049] FIG. **2** illustrates an exemplary leadless cardiac pacemaker (LCP) having electrodes, according to one example of the present disclosure;

[0050] FIG. **3** shows an illustrative system that includes several medical devices in accordance with the present disclosure;

[0051] FIG. **4** is a diagram of an illustrative electromagnetic field that may be generated by an electrode pair;

[0052] FIG. **5** is a diagram of a portion of the electromagnetic field of FIG. **4**, illustrating different geometric arrangements of electrodes relative to the electromagnetic field;

[0053] FIG. **6** is a schematic diagram of a medical device having an illustrative antenna with three electrodes in accordance with various examples of the present disclosure;

[0054] FIG. **7** is a schematic diagram of a medical device having an illustrative antenna with four electrodes in accordance with various examples of the present disclosure;

[0055] FIG. **8** is a schematic diagram of an illustrative arrangement of four electrodes in accordance with various examples of the present disclosure;

[0056] FIG. **9** is a schematic diagram of another illustrative arrangement of four electrodes in accordance with various examples of the present disclosure;

[0057] FIG. **10** shows an illustrative system in accordance with an example of the present disclosure;

[0058] FIG. **11** is a flow diagram of an illustrative method for communicating between medical devices;

[0059] FIG. **12** is a flow diagram showing another illustrative method for communicating between medical devices;

[0060] FIG. **13** is a flow diagram showing yet another illustrative method for communicating between medical devices; and

[0061] FIG. **14** is a flow diagram showing another illustrative method for communicating between medical devices.

[0062] While the disclosure is amenable to various modifications and alternative forms, specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit aspects of the disclosure to the particular illustrative embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure.

DETAILED DESCRIPTION

[0063] The following description should be read with reference to the drawings in which similar elements in different drawings are numbered the same. The description and the drawings, which are not necessarily to scale, depict illustrative embodiments and are not intended to limit the scope of the disclosure.

[0064] A normal, healthy heart induces contraction by conducting intrinsically generated electrical signals throughout the heart. These intrinsic signals cause the muscle cells or tissue of the heart to contract. This contraction forces blood out of and into the heart, providing circulation of the blood throughout the rest of the body. However, many patients suffer from cardiac conditions that affect the contractility of their hearts. For example, some hearts may develop diseased tissues that no longer generate or conduct intrinsic electrical signals. In some examples, diseased cardiac tissues conduct electrical signals at differing rates, thereby causing an unsynchronized and inefficient contraction of the heart. In other examples, a heart may generate intrinsic signals at such a low rate that the heart rate becomes dangerously low. In still other examples, a heart may generate electrical signals at an unusually high rate. In some cases such an abnormality can develop into a fibrillation state, where the contraction of the patient's heart is almost completely de-synchronized and the heart pumps very little to no blood.

[0065] Many medical device systems have been developed to assist patients who experience such abnormities. For example, systems have been developed to sense intrinsic cardiac electrical signals and, based on the sensed electrical signals, determine whether the patient is suffering from one or more arrhythmias. Such systems may also include the ability to deliver electrical stimulation to the heart of the patient in order to treat the detected arrhythmias. In one example, some medical device systems include the ability to identify when the heart is beating at too low of a rate, termed bradycardia. Such systems may deliver electrical stimulation therapy, or "pacing" pulses, that cause the heart to contract at a higher, safer rate. Some medical device systems are able to determine when a heart is beating at too fast of a rate, termed tachycardia. Such systems may further include one or more anti-tachycardia pacing (ATP) therapies. One such ATP therapy includes delivering electrical stimulation pulses to the heart at a rate faster than the intrinsically generated signals. Although this may temporarily cause the heart to beat faster, such a stimulation protocol may cause the heart to contract in response to the delivered pacing pulses as opposed to the intrinsically generated signals. The ATP therapy may then slow down the rate of the delivered pacing pulses, thereby reducing the heart rate to a lower, safer level.

[0066] Other medical device systems may be able to detect fibrillation states and asynchronous contractions. For example, based on the sensed signals, some systems may be able to determine when the heart is in a fibrillation state. Such systems may further be configured to treat such fibrillation states with electrical stimulation therapy. One such therapy includes deliver of a relatively large amount of electrical energy to the heart (a "defibrillation pulse") with the goal of overpowering any intrinsically generated signals.

[0067] Such a therapy may "reset" the heart, from an electrical standpoint, which may allow for normal electrical processes to take over. Other medical systems may be able to sense that intrinsically generated signals are generated at differing times or that the heart conducts such signals at differing rates. These abnormalities may result in an unsynchronized, inefficient cardiac contraction. The system may further include the ability to administer one or more cardiac resynchronization therapies (CRTs). One such CRT may include delivering electrical stimulation to the heart at differing locations on and/or within the heart. Such methods may help the disparate parts of the heart to contract near simultaneously, or in a synchronized manner if the system delivers the electrical stimulation to the disparate locations at differing times. The present disclosure relates generally to systems and methods for coordinating detection and/or treatment of abnormal heart activity using multiple implanted devices within a patient. In some instances, a medical device system may include a plurality of devices for detecting cardiac arrhythmias and delivering electrical stimulation therapy. For example, illustrative systems may include devices such as subcutaneous cardioverter-defibrillators (S-ICD), external cardioverter-defibrillators, implantable cardiac pacemakers (ICP), leadless cardiac pacemakers (LCPs), and/or diagnostic only devices (devices that may sense cardiac electrical signals and/or determine arrhythmias but do not deliver electrical stimulation therapies).

[0068] FIG. **1** illustrates a block diagram of an exemplary medical device **100** (referred to hereinafter as, MD **100**) that may be used in accordance with various examples of the present disclosure. In some cases, the MD **100** may be used for sensing intrinsic cardiac activity, determining occurrences of arrhythmias, and delivering electrical stimulation in response to determining an occurrence of an arrhythmia. In some instances, MD **100** can be implanted within a patient's body, at a particular location (e.g., in close proximity to the patient's heart), to sense and/or regulate the cardiac activity of the heart. In other examples, MD **100** may be located externally to a patient to sense and/or regulate the cardiac activity of the heart. In one example, cardiac contractions generally result from electrical signals that are intrinsically generated by a heart. These electrical signals conduct through the heart tissue, causing the muscle cells of the heart to contract. MD **100** may include features that allow MD **100** to sense such electrical signals and/or other physical parameters (e.g. mechanical contraction, heart sounds, blood pressure, blood-oxygen levels, etc.) of the heart. Such electrical signals and/or physical properties may be considered "cardiac activity." MD **100** may include the ability to determine occurrences of arrhythmias based on the sensed cardiac activity. In some examples, MD **100** may be able to deliver electrical stimulation to the heart in order to treat any detected arrhythmias. For example, MD **100** may be configured to deliver electrical stimulation, pacing pulses, defibrillation pulses, and/or the like in order to implement one or more therapies, such as bradycardia therapy, ATP therapy, CRT, defibrillation, or other electrical stimulation therapies.

[0069] FIG. **1** is an illustration of an example medical device **100**. The illustrative MD **100** may include a sensing module **102**, a pulse generator module **104**, a processing module **106**, a telemetry module **108**, and a battery **110**, all housed within a housing **120**. MD **100** may further include leads **112**, and electrodes **114** attached to housing **120** and in electrical communication with one or more of the modules **102**, **104**, **106**, and **108** housed within housing **120**. Leads **112** may be connected to and extend away from housing **120** of MD **100**.

[0070] In some examples, leads **112** are implanted on or within the heart of the patient. Leads **112** may contain one or more electrodes **114** positioned at various locations on leads **112** and distances from housing **120**. Some leads **112** may only include a single electrode **114** while other leads **112** may include multiple electrodes **114**. Generally, electrodes **114** are positioned on leads **112** such that when leads **112** are implanted within the patient, one or more electrodes **114** are in contact with the patient's cardiac tissue. Accordingly, electrodes **114** may conduct intrinsically generated electrical signals to leads **112**. Leads **112** may, in turn, conduct the received electrical signals to one or more modules **102**, **104**, **106**, and **108** of MD **100**. In a similar manner, MD **100** may generate electrical stimulation, and leads **112** may conduct the generated electrical stimulation to electrodes **114**. Electrodes **114** may then conduct the electrical signals to the cardiac tissue of the patient. When discussing sensing intrinsic signals and delivering electrical stimulation, this disclosure may consider such conduction implicit in those processes.

[0071] Sensing module **102** may be configured to sense the cardiac electrical activity of the heart. For example, sensing module **102** may be connected to leads **112** and electrodes **114** through leads **112** and sensing module **102** may be configured to receive cardiac electrical signals conducted through electrodes **114** and leads **112**. In some examples, leads **112** may include various sensors, such as accelerometers, blood pressure sensors, heart sound sensors, blood-oxygen sensors, and other sensors which measure physiological parameters of the heart and/or patient. In other examples, such sensors may be connected directly to sensing module **102** rather than to leads **112**. In any case, sensing module **102** may be configured to receive such signals produced by any sensors connected to sensing module **102**, either directly or through leads **112**. Sensing modules **102** may additionally be connected to processing module **106** and may be configured to communicate such received signals to processing module **106**.

[0072] Pulse generator module **104** may be connected to electrodes **114**. In some examples, pulse generator module **104** may be configured to generate an electrical stimulation signals to provide electrical stimulation therapy to the heart. For example, pulse generator module **104** may generate such a signal by using energy stored in battery **110** within MD **100**. Pulse generator module **104** may be configured to generate electrical stimulation signals in order to provide one or multiple of a number of different therapies. For example, pulse generator module **104** may be configured to generate electrical stimulation signals to provide bradycardia therapy, tachycardia therapy, cardiac resynchronization therapy, and fibrillation therapy. Bradycardia therapy may include generating and delivering pacing pulses at a rate faster than the intrinsically generated electrical signals in order to try to increase the heart rate. Tachycardia therapy may include ATP therapy as described herein. Cardiac resynchronization therapy may include CRT therapy also described herein. Fibrillation therapy may include delivering a fibrillation pulse to try to override the heart and stop the fibrillation state. In other examples, pulse generator **104** may be configured to generate electrical stimulation signals to provide electrical stimulation therapies different than those described herein to treat one or more detected arrhythmias.

[0073] Processing module **106** can be configured to control the operation of MD **100**. For example, processing module **106** may be configured to receive electrical signals from sensing module **102**. Based on the received signals, processing module **106** may be able to determine occurrences of arrhythmias. Based on any determined arrhythmias, processing module **106** may be configured to control pulse generator module **104** to generate electrical stimulation in accordance with one or more therapies to treat the determined one or more arrhythmias. Processing module **106** may further receive information from telemetry module **108**. In some examples, processing module **106** may use such received information in determining whether an arrhythmia is occurring or to take particular action in response to the information. Processing module **106** may additionally control telemetry module **108** to send information to other devices.

[0074] In some examples, processing module **106** may include a pre-programmed chip, such as a very-large-scale integration (VLSI) chip or an application specific integrated circuit (ASIC). In such embodiments, the chip may be pre-programmed with control logic in order to control the operation of MD **100**. By using a pre-programmed chip, processing module **106** may use less power than other programmable circuits while able to maintain basic functionality, thereby increasing the battery life of MD **100**. In other examples, processing module **106** may include a programmable microprocessor. Such a programmable microprocessor may allow a user to adjust the control logic of MD **100**, thereby allowing for greater flexibility of MD **100** than when using a pre-programmed chip. In some examples, processing module **106** may further include a memory circuit and processing module **106** may store information on and read information from the memory circuit. In other examples, MD **100** may include a separate memory circuit (not shown) that is in communication with processing module **106**, such that processing module **106** may read and write information to and from the separate memory circuit.

[0075] Telemetry module **108** may be configured to communicate with devices such as sensors, other medical devices, or the like, that are located externally to MD **100**. Such devices may be located either external or internal to the patient's body. Irrespective of the location, external devices (i.e. external to the MD **100** but not necessarily external to the patient's body) can communicate with MD **100** via telemetry module **108** to accomplish one or more desired functions. For example, MD **100** may communicate sensed electrical signals to an external medical device through telemetry module **108**. The external medical device may use the communicated electrical signals in determining occurrences of arrhythmias. MD **100** may additionally receive sensed electrical signals from the external medical device through telemetry module **108**, and MD **100** may use the received sensed electrical signals in determining occurrences of arrhythmias. Telemetry module **108** may be configured to use one or more methods for communicating with external devices. For example, telemetry module **108** may communicate via radiofrequency (RF) signals, inductive coupling, optical signals, acoustic signals, conducted communication signals, or any other signals suitable for communication. Communication techniques between MD **100** and external devices will be discussed in further detail with reference to FIG. **3** below.

[0076] Battery **110** may provide a power source to MD **100** for its operations. In one example, battery **110** may be a non-rechargeable lithium-based battery. In other examples, the non-rechargeable battery may be made from other suitable materials know in the art. Because, in examples where MD **100** is an implantable device, access to MD **100** may be limited, it is necessary to have sufficient capacity of the battery to deliver sufficient therapy over a period of treatment such as days, weeks, months, or years. In other examples, battery **110** may a rechargeable lithium-based battery in order to facilitate increasing the useable lifespan of MD **100**.

[0077] In general, MD **100** may be similar to one of a number of existing medical devices. For example, MD **100** may be similar to various implantable medical devices. In such examples, housing **120** of MD **100** may be implanted in a transthoracic region of the patient. Housing **120** may generally include any of a number of known materials that are safe for implantation in a human body and may, when implanted, hermetically seal the various components of MD **100** from fluids and tissues of the patient's body.

[0078] In some examples, MD **100** may be an implantable cardiac pacemaker (ICP). In such an example, MD **100** may have one or more leads, for example leads **112**, which are implanted on or within the patient's heart. The one or more leads **112** may include one or more electrodes **114** that are in contact with cardiac tissue and/or blood of the patient's heart. MD **100** may also be configured to sense intrinsically generated cardiac electrical signals and determine, for example, one or more cardiac arrhythmias based on analysis of the sensed signals. MD **100** may further be configured to deliver CRT, ATP therapy, bradycardia therapy, defibrillation therapy and/or other therapy types via leads **112** implanted within the heart.

[0079] In some instances, MD **100** may be a subcutaneous cardioverter-defibrillator (S-ICD). In such examples, one of leads **112** may include a subcutaneously implanted lead. In some cases, MD **100** may be configured to sense intrinsically generated cardiac electrical signals and determine one or more cardiac arrhythmias based on analysis of the sensed signals. MD **100** may further be configured to deliver one or more defibrillation pulses in response to determining an arrhythmia.

[0080] In still other examples, MD **100** may be a leadless cardiac pacemaker (LCP—described more specifically with respect to FIG. **2**). In such examples, MD **100** may not include leads **112** that extend away from housing **120**. Rather, MD **100** may include electrodes **114** coupled relative to the housing **120**. In these examples, MD **100** may be implanted on or within the patient's heart at a desired location, and may be configured to deliver CRT, ATP therapy, bradycardia therapy, and/or other therapy types via electrodes **114**.

[0081] In some instances, MD **100** may be a diagnostic-only device. In some cases, MD **100** may be configured to sense, or receive, cardiac electrical signals and/or physical parameters such as mechanical contraction, heart sounds, blood pressure, blood-oxygen levels, etc. MD **100** may further be configured to determine occurrences of arrhythmias based on the sensed or received cardiac electrical signals and/or physical parameters. In one example, MD **100** may do away with pulse generation module **104**, as MD **100** may not be configured to deliver electrical stimulation in response to determining an occurrence of an arrhythmia. Rather, in order to respond to detected cardiac arrhythmias,

[0082] MD **100** may be part of a system of medical devices. In such a system, MD **100** may communicate information to other devices within the system and one or more of the other devices may take action, for example delivering electrical stimulation therapy, in response to the receive information from MD **100**. The term pulse generator may be used to describe any such device that is capable of delivering electrical stimulation therapy to the heart, such as an ICD, ICP, LCP, or the like. In some instances, the MD **100** may be a neural stimulation device, or any other medical device, as desired.

[0083] In some example, MD **100** may not be an implantable medical device. Rather, MD **100** may be a device external to the patient's body, and may include skin-electrodes that are placed on a patient's body. In such examples, MD **100** may be able to sense surface cardiac electrical signals (e.g. electrical signals that are generated by the heart or device implanted within a patient's body and conducted through the body to the skin) In such examples, MD **100** may still be configured to deliver various types of electrical stimulation therapy. In other examples, however, MD **100** may be a diagnostic-only device, a neurostimulator, and/or other implantable medical devices.

[0084] FIG. **2** is an illustration of an exemplary leadless cardiac pacemaker (LCP) **200**. In the example shown, LCP **200** may include all of the modules and components of MD **100**, except that LCP **200** may not include leads **112**. As can be seen in FIG. **2**, LCP **200** may be a compact device with all components housed within LCP **200** or directly on housing **220**. As illustrated in FIG. **2**, LCP **200** may include telemetry module **202**, pulse generator module **204**, processing module **210**, and battery **212**. Such components may have a similar function to the similarly named modules and components as discussed in conjunction with MD **100** of FIG. **1**.

[0085] In some examples, LCP **200** may include electrical sensing module **206** and mechanical sensing module **208**. Electrical sensing module **206** may be similar to sensing module **102** of MD **100**. For example, electrical sensing module **206** may be configured to receive electrical signals generated intrinsically by the heart. Electrical sensing module **206** may be in electrical connection with electrodes **214**, which may conduct the intrinsically generated electrical signals to electrical sensing module **206**. Mechanical sensing module **208** may be configured to receive one or more signals representative of one or more physiological parameters of the heart. For example, mechanical sensing module **208** may include, or be in electrical communication with one or more sensors, such as accelerometers, blood pressure sensors, heart sound sensors, blood-oxygen sensors, and other sensors which measure physiological parameters of the patient. Although described with respect to FIG. **2** as separate sensing modules, in some examples, electrical sensing module **206** and mechanical sensing module **208** may be combined into a single module.

[0086] In at least one example, each of modules **202**, **204**, **206**, **208**, and **210** illustrated in FIG. **2** may be implemented on a single integrated circuit chip. In other examples, the illustrated components may be implemented in multiple integrated circuit chips that are in electrical communication with one another. All of modules **202**, **204**, **206**, **208**, and **210** and battery **212** may be encompassed within housing **220**. Housing **220** may generally include any material that is known as safe for implantation within a human body and may hermetically seal modules **202**, **204**, **206**, **208**, and **210** and battery **212** from fluids and tissues when LCP **200** is implanted within a patient.

[0087] As depicted in FIG. **2**, LCP **200** may include electrodes **214**, which can be secured relative to housing **220** but exposed to the tissue and/or blood surrounding the LCP **200**. As such, electrodes **214** may be generally disposed on either end of LCP **200** and may be in electrical communication with one or more of modules **202**, **204**, **206**, **208**, and **210**. In some examples, electrodes **214** may be connected to housing **220** only through short connecting wires such that electrodes **214** are not directly secured relative to housing **220**. In some examples, LCP **200** may additionally include one or more electrodes **214'**. Electrodes **214'** may be positioned on the sides of LCP **200** and increase the number of electrodes by which LCP **200** may sense cardiac electrical activity and/or deliver electrical stimulation. Electrodes **214** and/or **214'** can be made up of one or more biocompatible conductive materials such as various metals or alloys that are known to be safe for implantation within a human body. In some instances, electrodes **214** and/or **214'** connected to LCP **200** may have an insulative portion that electrically isolates the electrodes **214** from, adjacent electrodes, the housing **220**, and/or other materials.

[0088] To implant LCP **200** inside patient's body, an operator (e.g., a physician, clinician, etc.), may need to affix LCP **200** to the cardiac tissue of the patient's heart. To facilitate fixation, LCP **200** may include one or more anchors **216**. Anchor **216** may be any one of a number of fixation or anchoring mechanisms. For example, anchor **216** may include one or more pins, staples, threads, screws, helix, tines, and/or the like. In some examples, although not shown, anchor **216** may include threads on its external surface that may run along at least a partial length of anchor **216**. The threads may provide friction between the cardiac tissue and the anchor to help fix anchor **216** within the cardiac tissue. In other examples, anchor **216** may include other structures such as barbs, spikes, or the like to facilitate engagement with the surrounding cardiac tissue.

[0089] The design and dimensions of MD **100** and LCP **200**, as shown in FIGS. **1** and **2**, respectively, can be selected based on various factors. For example, if the medical device is for implant on the endocardial tissue, such as is sometimes the case of an LCP, the medical device can be introduced through a femoral vein into the heart. In such instances, the dimensions of the medical device may be such as to be navigated smoothly through the tortuous path of the vein without causing any damage to surrounding tissue of the vein. According to one example, the average diameter of the femoral vein may be between about 4 millimeters (mm) to about 8 mm. For navigation to the heart through the femoral vein, the medical device can have a diameter of less than **8** mm In some examples, the medical device can have a cylindrical shape having a circular cross-section. However, it should be noted that the medical device can be made of any other suitable shape such as rectangular, oval, etc. A flat, rectangular-shaped medical device with a low profile may be desired when the medical device is designed to be implanted subcutaneously.

[0090] While IMD **100** and LCP **200** are described as suitable example medical devices, it is contemplated that the present disclosure is applicable more broadly to communication between any two (or more) medical devices.

[0091] FIG. **3** is a schematic illustration of a medical device system **300**. As illustrated, medical device system **300** includes a first MD **310**, a second MD **320** and a third MD **330**. Each of MD **310**, MD **320** and MD **330** can represent any of a variety of different medical devices that are configured to deliver electrical stimulation, pacing pulses, defibrillation pulses, or the like in order to implement one or more therapies, such as ATP therapy, CRT, or other electrical stimulation therapies, or are diagnostic only or other medical devices, as desired. Each of MD **310**, MD **320** and MD **330** can include leads or be leadless. It will be appreciated that while three medical devices are shown in FIG. **3**, system **300** may include just one or two medical devices, or may include four or more medical devices, depending on the particular application.

[0092] In some embodiments, each of MD **310**, MD **320** and MD **330**, if present, may be implanted and/or positioned proximate the patient. In some embodiments, MD **310** may be implanted, MD **320** may be external to the patient and MD **330** may be optional. MD **320** may include a skin patch including two or more electrodes. In some cases, one or more of MD **310**, MD **320** and MD **330** may be a medical device programmer or communicator that is configured to communicate with and/or program one or more implanted medical device. For example, MD **320** may be a medical device programmer or communicator that is configured to communicate with and/or program one or more implanted medical device - such as MD **310** and MD **330**. In some embodiments, MD **310** may be implanted within the patient and MD **320** and/or MD **330** may also be implanted within the patient but be spaced apart from MD **310** and from each other.

[0093] As illustrated, MD **310** includes a first electrode **312** and a second electrode **314**. MD **320** includes a first electrode **322**, a second electrode **324** and a third electrode **326**. MD **330** includes a first electrode **332**, a second electrode **334**, a third electrode **336** and a fourth electrode **338**. In this example, MD **310** has a single electrode pair **315** that can be used to sense, pace and/or communicate with another medical device. MD **320** has a first electrode pair **325** between first electrode **322** and second electrode **324**, a second electrode pair **327** between second electrode **324** and third electrode **326**, and a third electrode pair **329** between first electrode **322** and third electrode **326** that can each be used, either individually or in combination, to sense, pace and/or communicate with another medical device. MD **330** has a first electrode pair **333** between first electrode **332** and second electrode **334**, a second electrode pair **335** between second electrode **334** and third electrode **336**, a third electrode pair **337** between third electrode **336** and fourth electrode **338**, a fourth electrode pair **339** between first electrode **332** and fourth electrode **338**, a fifth electrode pair **331** between first electrode **332** and third electrode **336** and a sixth electrode pair **341** between second electrode **334** and fourth electrode **338** that can each be used, either individually or in combination, to sense, pace and/or communicate with another medical device.

[0094] It will be appreciated that the relative signal strength received at a particular electrode pair can be a function of, at least in part, the relative orientation of the electrode pair relative to the electromagnetic field that is being generated by a transmitting electrode pair. FIG. **4** is a stylized or idealized electromagnetic field **400** generated by an electrode pair, which includes a cathode electrode **410** and an anode electrode **420**. This is a stylized electromagnetic field **400** as it would appear in a homogenous conducting medium. As the patient's tissue near and around medical devices is not homogenous, the actual electromagnetic field would vary from that shown. The electromagnetic field **400** can be considered as including equipotential lines **430** and electric field lines **440**. FIG. **5** provides an enlarged portion **500** illustrating the effects of electrode orientation relative to the equipotential lines **430** and the electric field lines **440**.

[0095] In the illustration of FIG. **5**, it is assumed that a medical device includes a first electrode **510**, a second electrode **520** and a third electrode **530**. A first electrode pair vector A may be considered as existing between first electrode **510** and second electrode **520**. A second electrode pair vector B may be considered as existing between first electrode **510** and third electrode **530**. A third electrode pair vector C may be considered as existing between second electrode **520** and third electrode **530**. It will be appreciated that the relative signal strength between one of electrode pair vectors A, B and C will be influenced by the angle between the receiving antenna (one of the electrode pair vectors A, B and C) and the local electric field produced by the transmitting antenna (cathode **410** and anode **420** as shown in FIG. **4**). As can be seen, the received signal will be the signal strength times the cosine of the angle **0** between the corresponding electrode pair vector A, B or C and the electric field lines **440**. The electrode pair vectors each represent a pair of electrodes of the medical device. A particular one the electrode pairs A, B, or C selected for communication, in combination with an electrode pair of the transmitting antenna (e.g. cathode **410** and anode **420** as shown in FIG. **4**) can be considered a "communication vector".

[0096] As illustrated, electrode pair vector A forms an angle OA that is **90** degrees. As the cosine of **90** degrees is zero, electrode pair vector A (between first electrode **510** and second electrode **520**) would not receive a signal. Electrode pair vector B forms an angle AB that is 15 degrees. The cosine of 15 degrees is 0.97, and thus electrode pair vector B would receive a signal that is 97% of the strength of the signal at that location. Electrode pair vector C forms an angle Ac that is 45 degrees. The cosine of 45 degrees is 0.71, and thus electrode pair vector C would receive a signal that is 71% of the strength of the signal at that location. It will be appreciated, therefore, that by having several electrode pairs, or electrode pair vectors, to choose from may facilitate the devices MD **310**, MD **320** and MD **330** of system **300** (FIG. **3**) in selecting an electrode pair or electrode pair vector that helps increase the relative signal strength and/or signal-to-noise ratio for communication therebetween. The angles shown in FIG. **5** are illustrative only, as in practice the medical device that includes electrodes **510**, **520** and **530** may have any particular orientation with respect to electromagnetic field **400** (FIG. **4**), and the orientation may change over time as the patient breathes, the heart pumps, or the patient otherwise moves. It is contemplated that a medical device may have two, three, four or more electrodes that can be utilized in pairs to help improve communication between medical devices.

[0097] FIG. **6** illustrates a medical device (MD) **600** that includes a first electrode **610**, a second electrode **620** and a third electrode **630**. A total of three electrode pair vectors **640**, **650** and **660** may be formed using the three electrodes of MD **600**. MD **600** may represent an implanted medical device or an external medical device. MD **600** may, in some cases, represent an external patch that is secured to the skin of a patient, and may communicate with an implanted medical device such as a leadless cardiac pacemaker (LCP). As illustrated, electrodes **610**, **620** and **630** are equally spaced forming an equilateral triangle. In some embodiments, electrodes **610**, **620** and **630** may instead be unequally spaced, thereby forming a non-equilateral triangle.

[0098] FIG. **7** illustrates a medical device (MD) **700** that includes a first electrode **710**, a second electrode **720**, a third electrode **730** and a fourth electrode **740**. In FIG. **7**, a total of **6** electrode pair vectors **750**, **752**, **754**, **756**, **758** and **760** may be formed using the electrodes of MD **700**. MD **700** may represent an implanted medical device or an external medical device. MD **700** may, for example, represent an external patch that is secured to the skin of a patient. As illustrated, electrodes **710**, **720**, **730** and **740** are spaced about MD **700** in a kite pattern. In some embodiments, electrodes **710**, **720**, **730** and **740** may instead be spaced about MD **700** in a variety of different patterns. It will be appreciated that the relative angles between pairs of electrodes **710**, **720**, **730** and **740** may be varied by altering the relative dimensions, i.e., length and/or width of the spacings between the electrodes of MD **700**.

[0099] FIGS. **8** and **9** provide additional examples of possible electrode pair vector angles in medical devices having **4** electrodes arranged in a rectilinear configuration (FIG. **8**) or in a kite like configuration (FIG. **9**). It will be appreciated that these are illustrative only, as the angles in FIG. **8** may be altered by changing the relative length and width of a square or rectangle extending through the four electrodes. Similarly, the angles in FIG. **9** may be altered by changing the relative length and width of a kite-shape extending through the four electrodes.

[0100] It can be seen that having two electrodes can provide a situation in which there can be no or substantially no signal strength at the location of a receiving antennae, depending on orientation of the receiving antennae relative to the emitted electric field. Having three electrodes provides three possible electrode pair vectors that can be selected, whereby selecting the electrode pair vector with the greatest signal strength, may help improve the signal strength received by the receiving antennae. Having four electrodes provides six possible electrode pair vectors that can be selected. In some cases, and to provide even more vectors, two or more of the electrodes may be effectively shorted together so that the shorted electrodes collectively act as an electrode. For example, and specifically with respect to FIG. **7**, electrodes **730** and **740** may be effectively shorted together and may act as a single electrode (e.g. anode), and electrode **710** or electrode **720** may act as the other electrode (e.g. the cathode). This is just one example.

[0101] In some instances, the medical devices described herein, including MD **100**, LCP **200**, MD **310**, MD **320**, MD **330**, MD **600** or MD **700** may be programmed or otherwise configured to test various communication vectors and to select the appropriate communication vector for communication. In some embodiments, the strongest communication vector may be selected. In some embodiments, the weakest communication vector may be excluded from use. In some embodiments, depending on the purpose of the communication, several communication vectors may be used in combination.

[0102] In some instances, one vector may be used during a first part of a single communication and a second vector may be used during a second part of the communication. This may occur when, for example, a device programmer or an S-ICD is communicating with a LCP. The LCP may be moving during each beat of the heart, and the angles between the various electrodes may change over time. In some cases, it may be advantageous to use a first vector to start communication, and then as the LCP moves, switch to a second vector to complete the communication.

[0103] Alternatively, or in addition, communication may be simultaneously performed using two or more vectors. This may provide one or more redundant communication paths, so that if one communication path becomes less effective or drops out, then the redundant communication path(s) can be used. For example, and specifically with respect to FIG. **7**, communication may be simultaneously performed using a first vector **754** extending between electrodes **730** and **740** and a second vector **758** extending between electrodes **720** and **740**. Then, if communication using the first vector **754** becomes less effective or drops out, the system can still communicate using the second vector **758**. In some cases, communication may be performed simultaneously using both vectors, and the system may select the communication path with the highest signal strength, the communication path that provided successful transmission, and/or may use any other criteria for selecting from the two or more communication paths. In some cases, a communication may be performed using multiple vectors, and the results may be compared. If there is no difference in the results, then either result may be used. If there is a difference, other criteria may be used to help identify the correct result. For example, a parity bit and/or checksum may be used to identify which transmissions were successful. If no transmissions were successful, a signal may be sent notifying the sender to repeat the transmission using a different vector or set of vectors.

[0104] FIG. **10** provides an illustrative medical system in which an LCP **782** is shown fixed to the interior of the left ventricle of a heart **788** and an LCP **784** is shown fixed to the interior of the right ventricle of heart **788**. In some embodiments, there may be additional LCPs implanted in heart **788**. In other cases, there may only be one LCP, such as LCP **784**. In some embodiments, one or more LCPs may be fixed to the exterior of the heart **788**. In FIG. **10**, an example SICD **786** is shown. The example SICD **786** includes a lead **790** bearing one or more electrodes **792**, **794** and **796**. In some embodiments, the lead **790** may include more than three electrodes. In some cases, once lead **790** has been implanted, electrodes **792**, **794** and **796** may be considered as being aligned vertically proximate the patient's sternum. Optionally, an additional electrode may be disposed on a horizontal (once implanted) portion of lead **790**. It will be appreciated that as illustrated, SICD **786** may be considered as having a total of four electrodes, as the housing of SICD **786** may also function as an electrode. In some instances, lead **790** may be positioned subcutaneously adjacent heart **788**. In some cases, the illustrative medical system may include an external patch such as MD **700** previously discussed with respect to FIG. **7** for connecting to, for example, an external medical device.

[0105] In some cases, there may be a desire for communication between two or more of LCP **782**, LCP **784**, SICD **786** and/or an MD **700**. It will be appreciated, for example, that for communication between the LCP **782** and MD **700**, there may be a total of four (or more) electrodes on MD **700** and two to four (or more) electrodes on LCP **782**, and thus many different communication vectors may be tested and selected as discussed previously. In some cases, particularly in conducting communication between SICD **786** and any of the other devices shown, it will be appreciated that electrodes **792**, **794** and **796** are arranged in a largely linear fashion near a distal end of lead **790**. Accordingly, in some cases, selecting between these three electrodes for use in a communication vector with an LCP **872** or **784** may not substantially change the geometry of the vector and thus may not substantially improve the communication vector. In some embodiments, communication with SICD **786** may benefit from also considering one or more can electrodes, such as can electrode **797** of the SICD **786**. When so provided, the SICD may have four different electrodes **792**, **794**, **796** and **797**, and each LCP **782** and **784** may have two to four (or more) electrodes. This may provide many vectors to choose from with a variety of different vector geometries. Alternatively, or in addition, the SICD electrodes **792**, **794** and **796** may be arranged in a non-linear manner, such as in a cross-pattern.

[0106] One or all of the electrodes **792**, **794**, **796**, **797** and the SCID **786** housing may be used only for communication; alternatively one or all of the electrodes **792**, **794**, **796**, **797** and the SCID **786** housing may also be used for other purposes such as sensing a physiological parameter (e.g. intrinsic cardiac activity, thoracic impedance) and/or delivering one or more electrical therapies (e.g. cardioversion/defibrillation shocks, cardiac paces, neural stimulation energy).

[0107] In some cases, it will be appreciated that which specific vector or vectors are most useful for communicating between any particular pair of devices may change over time. For example, LCP **782** and/or LCP **784**, if present, may move and change orientation somewhat with each heartbeat. As the patient breathes, and their chest rises and falls, the SICD **786** and an external device such as MD **700** may also move. Accordingly, in some embodiments, it may be advantageous to use a first vector for part of a communication, and then as one or more devices move relative to one another, such as with the heartbeat and/or patient respiration, switch to a second vector to continue the communication. In some cases, signal strength, error rate and/or communication parameter may be monitored over time, and the vector may be automatically switched if desired. While a first and second vector are used here an example, it is contemplated that the system may switch between more than two different vectors if desired. It is contemplated that the vectors may be switched in real or near real time, and/or may be updated from time to time, e.g. every minute, hour, day, month, each doctor visit, and/or any other suitable time.

[0108] FIG. **11** is a flow diagram showing an illustrative method **1000** that may be carried out via any of the medical devices described herein, including MD **100**, LCP **200**,

[0109] MD **310**, MD **320**, MD **330**, MD **600** or MD **700**. At block **1010**, a first electrode pair of an antenna having at least three electrodes is selected. A communication signal, such as a conducted communication signal, may be sent through tissue of the patient between the first electrode pair of the antenna having at least three electrodes and two electrodes of another antenna, as generally seen at block **1020**. At block **1030**, a second electrode pair of the antenna having at least three electrodes is selected. The second electrode pair selected being different from the first selected electrode pair. A communication signal is again sent through tissue of the patient between the first electrode pair of the antenna having at least three electrodes and two electrodes of another antenna, as generally seen at block **1040**.

[0110] FIG. **12** is a flow diagram showing an illustrative method **1100** that may be carried out via any of the medical devices described herein, including MD **100**, LCP **200**, MD **310**, MD **320**, MD **330**, MD **600** or MD **700**. At block **1110**, a first electrode pair of an antenna having at least three electrodes is selected. A communication signal is sent through tissue of the patient between the first electrode pair of the antenna having at least three electrodes and two electrodes of another antenna, as generally seen at block **1120**. At block **1130**, a second electrode pair of the antenna that has at least three electrodes is selected. The second electrode pair is different from the first selected electrode pair. A communication signal may be sent through tissue of the patient between the first electrode pair of the antenna having at least three electrodes and two electrodes of another antenna, as generally seen at block **1140**.

[0111] During operation, and as seen at block **1150**, a measure related to a signal-to-noise ratio of the conducted communication signal using the first electrode pair may be monitored. If the measure related to the signal-to-noise ratio falls below a threshold or changes by more than a threshold, the second electrode pair of the antenna having at least three electrodes is selected, as generally shown at block **1160**. At block **1170**, a communication signal may then be sent through tissue of the patient between the second electrode pair of the antenna having at least three electrodes and the two electrodes of the other antenna.

[0112] FIG. **13** is a flow diagram showing an illustrative method **1200** that may be carried out via any of the medical devices described herein, including MD **100**, LCP **200**,

[0113] MD **310**, MD **320**, MD **330**, MD **600** or MD **700**. At block **1210**, a first electrode pair of an antenna having at least three electrodes is selected. A communication signal is sent through tissue of the patient between the first electrode pair of the antenna having at least three electrodes and two electrodes of another antenna, as generally seen at block **1220**. At block **1230**, a second electrode pair of the antenna that has at least three electrodes is selected. The second electrode pair is different from the first selected electrode pair. A communication signal is sent through tissue of the patient between the first electrode pair of the antenna having at least three electrodes and two electrodes of another antenna, as generally seen at block **1240**.

[0114] During operation, and as block **1280**, a first measure related to a signal-to-noise ratio of the communication signal using the first electrode pair is determined. A second measure related to a signal-to-noise ratio of the communication signal using the second electrode pair is determined, as generally indicated at block **1290**. At block **1292**, the first electrode pair or the second electrode pair is selected for subsequent communication based on the first measure and the second measure.

[0115] FIG. **14** a flow diagram showing an illustrative method **1300** that may be carried out via any of the medical devices described herein, including MD **100**, LCP **200**, MD **310**, MD **320**, MD **330**, MD **600** or MD **700**. At block **1310**, communication vectors are tested between at least two electrodes of a first antenna and each of a plurality of pairs of electrodes of a second antenna that has at least three electrodes. In an embodiment, a communication vector is tested periodically, for example once per second, minute, day or month. In another embodiment, a communication vector is tested only when a communication parameter fails to meet a predetermined criteria. In some embodiments, a communication vector is tested during an office visit. In other embodiments, a communication vector is tested during an interaction between a medical device and an external system that is configured to provide device or patient data to a clinician at a remote location. A communication vector is selected based on a communication parameter of one or more of the communication vectors, as generally indicated at block **1320**. The communication parameter could, for example, be an absolute signal strength, a relative signal strength and/or a signal-to-noise ratio, or any other parameter affecting or potentially affecting communication. At block **1330**, a conducted communication is sent between a first medical device and a second medical device using the selected communication vector.

[0116] As detailed above, the medical devices referenced herein may by any suitable medical device. In some non-limiting example, the methods **1000**, **1100**, **1200**, **1300** may be used in communication between an LCP and a medical device programmer or communicator, an LCP and an Subcoetaneous Implantable Cardioverter Defibrillator (SICD), an LCP and a co-implanted diagnostic device, an LCP and a neurostimulator device, an LCP and another LCP, and/or between any other suitable medical devices, as desired.

[0117] In some embodiments, any of these methods described herein could embody receiving a communication instead or, or in addition to, sending a communication signal. In some embodiments, a selection or determination of a communication vector used for sending a communication signal may be the same as a communication vector used for receiving a communication signal. In some embodiments, a selection or determination of a communication vector used for sending a communication signal may be different than a communication vector used for receiving a communication signal.

[0118] Those skilled in the art will recognize that the present disclosure may be manifested in a variety of forms other than the specific embodiments described and contemplated herein. As one example, as described herein, various examples include one or more modules described as performing various functions. However, other examples may include additional modules that split the described functions up over more modules than that described herein. Additionally, other examples may consolidate the described functions into fewer modules. Accordingly, departure in form and detail may be made without departing from the scope and spirit of the present disclosure as described in the appended claims.

What is claimed is:

1. A method of communicating between a first medical device having a first antenna and a second medical device having a second antenna, wherein the first medical device is implanted within a patient and the second medical device is proximate to the patient, and wherein the first antenna and/or the second antenna has at least three electrodes and the other antenna has at least two electrodes, the method comprising:

selecting a first electrode pair of the antenna that has at least three electrodes;

at least one of sending and receiving a conducted communication signal through tissue of the patient between the first electrode pair of the antenna that has at least three electrodes and two of the electrodes of the other antenna;

selecting a second electrode pair of the antenna that has at least three electrodes, wherein the second electrode pair is different from the first electrode pair; and

sending a conducted communication signal through tissue of the patient between the second electrode pair of the antenna that has at least three electrodes and two electrodes of the other antenna.

2. The method of claim **1**, further comprising:

monitoring a measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair;

if the measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair falls below a threshold, then:
selecting the second electrode pair of the antenna that has at least three electrodes; and
sending the conducted communication signal through tissue of the patient between the second electrode pair of the antenna that has at least three electrodes and the two electrodes of the other antenna.

3. The method of claim **1**, further comprising:
determining a first measure related to a signal to noise ratio of the conducted communication signal using the first electrode pair;
determining a second measure related to a signal to noise ratio of the conducted communication signal using the second electrode pair; and
selecting the first electrode pair or the second electrode pair for subsequent communication based on the first measure and the second measure.

4. The method of claim **1**, wherein the second medical device is implanted within the patient but spaced from the first medical device.

5. The method of claim **1**, wherein the second medical device is disposed outside of the patient and the second antenna is positioned on a skin surface of the patient.

6. The method of claim **1**, wherein the antenna that has at least three electrodes comprises three electrodes that are arranged in a triangular configuration.

7. The method of claim **1**, wherein the antenna that has at least three electrodes comprises four electrodes that are arranged in a rectangular configuration.

8. The method of claim **1**, wherein the antenna that has at least three electrodes comprises four electrodes that are arranged in a kite configuration.

9. A method of communicating between a first medical device having a first antenna with at least two electrodes and a second medical device having a second antenna with at least three electrodes, the method comprising:
testing communication vectors between the at least two electrodes of the first antenna and each of a plurality of pairs of electrodes of the at least three electrodes of the second antenna;
selecting a communication vector based on signal strengths of each of the communication vectors; and
at least one of sending and receiving a conducted communication between the first medical device and the second medical device using the selected communication vector.

10. The method of claim **9**, wherein the first medical device comprises an implanted medical device and the second medical device comprises an external device.

11. The method of claim **9**, wherein the first medical device comprises an external device and the second medical device comprises an implanted medical device.

12. The method of claim **9**, wherein the first medical device comprises a first implanted medical device and the second medical device comprises a second implanted medical device.

13. The method of claim **9**, wherein selecting a communication vector comprises selecting the communication vector with the strongest signal strength.

14. The method of claim **9**, wherein selecting a communication vector comprises not selecting the communication vector with the weakest signal strength.

15. A communication system, comprising:
a first medical device in communication with a first antenna having at least two electrodes; and
a second medical device in communication with a second antenna having at least three electrodes;
wherein at least one of the first medical device and the second medical device is configured to:
test communication vectors between the at least two electrodes of the first antenna and at least two pairs of the at least three electrodes of the second antenna;
select a communication vector from the tested communication vectors; and
at least one of send and receive a conducted communication along the selected communication vector.

16. The communication system of claim **15**, wherein the at least three electrodes comprise three electrodes that are arranged in a triangular configuration.

17. The communication system of claim **15**, wherein the at least three electrodes comprise four electrodes that are arranged in a rectangular configuration.

18. The communication system of claim **15**, wherein the at least three electrodes comprise four electrodes that are arranged in a kite configuration.

19. The communication system of claim **15**, wherein at least one of the first medical device and the second medical device are implanted within a patient.

20. The communication system of claim **15**, wherein the first medical device is a leadless cardiac pacemaker (LCP).

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