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(54) **IMPLANTABLE DEVICE TELEMETRY WITH ADAPTIVE FREQUENCY HOPPING**

TELEMETRIE EINER IMPLANTIERBAREN VORRICHTUNG MIT ADAPTIVEM FREQUENZ-HOPPING

TÉLÉMESURE POUR DISPOSITIF IMPLANTABLE AVEC SAUT DE FRÉQUENCE ADAPTATIF

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US-A- 5 752 977 **US-A1- 2006 161 223**
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- **CHEVROLIER N ET AL: "The evolution of wireless LANs and PANs - Bluetooth and wlan coexistence: challenges and solutions" IEEE PERSONAL COMMUNICATIONS SOCIETY, US, vol. 10, no. 6, December 2003 (2003-12), pages 22-29, XP011107077 ISSN: 1070-9916**
- **CHLAMTAC I ET AL: "A survey of quality of service in IEEE 802.11 networks" IEEE WIRELESS COMMUNICATIONS, IEEE SERVICE CENTER, PISCATAWAY, NJ, US, vol. 11, no. 4, August 2004 (2004-08), pages 6-14, XP011117198 ISSN: 1536-1284**

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EP 2 043 741 B1

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Description

TECHNICAL FIELD

[0001] This document relates generally to telemetry for implantable medical systems and particularly to a frequency agile telemetry system with adaptive frequency hopping using channel quality indicators.

BACKGROUND

[0002] Medical devices are implanted in human bodies for monitoring physiological conditions, diagnosing diseases, treating diseases, or restoring functions of organs or tissues. Examples of such implantable medical devices include cardiac rhythm management (CRM) devices, neural stimulators, neuromuscular stimulators, drug delivery devices, and biological therapy devices. When an implantable medical device is intended for long-term use in a patient, its size and power consumption are limited by implantability and longevity requirements. Consequently, many implantable medical devices depend on external systems to perform certain functions. Communication between an implantable method device and an external system is performed via telemetry. Examples of specific telemetry functions include programming the implantable medical device to perform certain monitoring or therapeutic tasks, extracting an operational status of the implantable medical device, transmitting real-time physiological data acquired by the implantable medical device, and extracting physiological data acquired by and stored in the Implantable medical device.

[0003] One type of telemetry between the implantable medical device and the external system is based on inductive coupling between two closely-placed coils using the mutual inductance between these coils. One of the coils is part of the Implantable medical device, and the other coil is part of the external system and is typically attached to the patient during a telemetry session. This type of telemetry is referred to as inductive telemetry or near-field telemetry because the coils must be closely situated for obtaining magnetically coupled communication.

[0004] Far-field radio-frequency (RF) telemetry provides another means for communication between the implantable medical device and the external system. The far-field RF telemetry is performed using an RF transceiver in the implantable medical device and an RF transceiver in the external system. The far-field RF telemetry frees the patient from any body surface attachment that limits mobility.

[0005] The far-field RF telemetry between the implantable medical device and the external system often operates in an environment where various sources of electromagnetic interference exist. For example, a far-filed RF telemetry link operating at a frequency within an unlicensed frequency band may be subjected to environmental interferences from various medical electronic de-

vices, communication devices, and home electronic appliances. Such interferences may interrupt the far-field RF telemetry link or cause errors in the data transmission.

[0006] Therefore, there is a need for ensuring the quality of far-field RF telemetry between an external system and an implanted device when interferences are present.

[0007] US 6,978,181 discloses a telemetry architecture that enables multiple programmers to concurrently interact with associated implantable medical devices within a viable telemetry range. The programmers communicate with implantable medical devices over one or more communication channels and may monitor a communication channel for interfering signals and sound an alarm when interference is detected.

[0008] N. Golmie et al, "Bluetooth and WLAN Coexistence: Challenges and Solution", IEEE Wireless Communications, pages 22-29 (2003) discusses solutions to the interference problem caused by the proximity and simultaneous operation of Bluetooth and WLAN networks and describes classifying frequencies as good or bad depending on whether their package loss rate is less than or greater than a threshold value.

SUMMARY

[0009] A far-field RF telemetry system transmits data between an implantable medical device and an external system using an active channel selected from a plurality of channels each representing a frequency band within a predetermined frequency range. One or more preferred channels are identified from the plurality of channels based on channel quality indicators produced for each of the channels. When channel hopping is needed, a hop channel is selected from the one or more preferred channels and becomes the active channel.

[0010] A cardiac rhythm management system in accordance with the present invention is defined in claims 1-10. A method in accordance with the present invention is defined in claims 11-15.

[0011] In one example, a CRM system includes an implantable medical device and an external system communicating with each other via a telemetry link. At least one of the implantable medical device and the external system includes a telemetry circuit including an antenna, a transceiver, a channel selector, a hop controller, a channel quality analyzer, and a preferred channel identifier. The transceiver transmits and receives data using at least one active channel during a telemetry session. The active channel is selected from a plurality of channels each representing a channel frequency band. The channel selector selects at least one hop channel from one or more preferred channels in response to a channel selection signal. The hop controller makes the hop channel the active channel when the hop channel is selected. The channel quality analyzer produces channel quality indicators each associated with one channel of the plurality of channels and each including at least a received signal strength indicator for that channel. The received signal

strength indicator indicates the strength of signal received through a channel. The preferred channel identifier identifies the one or more preferred channels from the plurality of channels based on the channel quality indicators.

[0012] In one example, a method for transmitting data between an implantable medical device and an external system via RF telemetry is provided. In response to reception of a channel selection signal, a hop channel is selected from one or more preferred channels. The hop channel is made an active channel. Data transmission between the implantable medical device and the external system is performed using the active channel. Channel quality indicators each associated with one channel of a plurality of channels are produced. Each channel of the plurality of channels represents a channel frequency band. The channel quality indicator associated with each channel includes at least a received signal strength indicator indicative of the strength of signal received through that channel. The one or more preferred channels are identified from the plurality of channels based on the channel quality indicators.

[0013] This Summary is an overview of some of the teachings of the present application and not intended to be an exclusive or exhaustive treatment of the present subject matter. Further details about the present subject matter are found in the detailed description and appended claims. Other aspects of the invention will be apparent to persons skilled in the art upon reading and understanding the following detailed description and viewing the drawings that form a part thereof. The scope of the present invention is defined by the appended claims and their legal equivalents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] In the drawings, which are not necessarily drawn to scale, like numerals describe similar components throughout the several views. The drawings illustrate generally, by way of example, various embodiments discussed in the present document.

FIG. 1 is an illustration of an embodiment of a CRM system including an implantable medical device and an external system and portions of an environment in which the CRM system is used.

FIG. 2 is a block diagram illustrating an embodiment of a circuit of the CRM system.

FIG. 3 is an illustration of an embodiment of telemetry channels (frequency bands) for data transmission between the implantable medical device and the external system.

FIG. 4 is a block diagram illustrating an embodiment of a telemetry circuit of the CRM system.

FIG. 5 is a block diagram illustrating a specific embodiment of the telemetry circuit.

FIG. 6 is a block diagram illustrating an embodiment of a transceiver of the telemetry circuit.

FIG. 7 is a block diagram illustrating an embodiment of a channel quality analyzer of the telemetry circuit. FIG. 8 is a flow chart illustrating a method for transmitting data between an implantable medical device and an external system.

DETAILED DESCRIPTION

[0015] In the following detailed description, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that the embodiments may be combined, or that other embodiments may be utilized and that structural, logical and electrical changes may be made without departing from the scope of the present invention. The following detailed description provides examples, and the scope of the present invention is defined by the appended claims and their legal equivalents.

[0016] It should be noted that references to "an", "one", or "various" embodiments in this disclosure are not necessarily to the same embodiment, and such references contemplate more than one embodiment.

[0017] This document discusses a frequency agile, far-field RF telemetry system for bi-directional communication between an implantable medical device and an external system. The RF telemetry system includes a plurality of channels each representing a frequency band within a predetermined frequency range. Data transmission is performed using an active channel selected from the plurality of channels. To ensure data transmission quality, the active channel hops from the current active channel to a new active channel during a telemetry session, such as when the data transmission is interrupted. This channel hopping is repeated, when necessary, until the new active channel provides for reliable and efficient data transmission. For the efficiency of the channel hopping process, the new active channel is selected from one or more preferred channels that are identified from the plurality of channels based on a channel quality analysis. This improves the chance of hopping to a "good" channel, thereby decreasing the potential number of channel hops required. The channel quality analysis results in channel quality indicators for the plurality of the channels. Each quality indicator includes one or more quality parameters for a channel and indicates whether that channel is likely to provide for reliable and efficient data transmission when used as the active channel.

[0018] While CRM systems are specifically discussed as an example, the present subject matter is applicable to any RP telemetry between an implantable medical device and an external system. The implantable medical device can be any implantable medical device capable of communicating with an external system or device via RF telemetry.

[0019] FIG. 1 is an illustration of an embodiment of a

CRM system 100 and portions of an environment in which system 100 is used. System 100 includes an implantable medical device 110 and an external system 112. In the illustrated embodiment, after being implanted into a patient's body 102, implantable medical device 110 is coupled to the patient's heart 101 through a lead system 108. In various embodiments, implantable medical device 110 includes one or more of pacemakers, cardioverter/defibrillators, cardiac resynchronization therapy (CRT) devices, cardiac remodeling control therapy (RCT) devices, neural stimulators, drug delivery systems, biological therapy devices, and patient monitoring devices. External system 112 allows a physician or other caregiver to interact with implantable medical device 110 through a telemetry link 114, which provides for bi-directional data communication between implantable medical device 110 and external system 112.

[0020] Telemetry link 114 provides for data transmission from implantable medical device 110 to external system 112. This includes, for example, transmitting real-time physiological data acquired by implantable medical device 110, extracting physiological data acquired by and stored in implantable medical device 110, extracting therapy history data stored in implantable medical device 110, and extracting data indicating an operational status of implantable medical device 110 (e.g., battery status and lead impedance). Telemetry link 114 also provides for data transmission from external system 112 to implantable medical device 110. This includes, for example, programming implantable medical device 110 to acquire physiological data, programming implantable medical device 110 to perform at least one self-diagnostic test (such as for a device operational status), and programming implantable medical device 110 to deliver at least one therapy.

[0021] Telemetry link 114 is a far-field RF telemetry link. A far-field, also referred to as the Fraunhofer zone, refers to the zone in which a component of an electromagnetic field produced by the transmitting electromagnetic radiation source decays substantially proportionally to $1/r$, where r is the distance between an observation point and the radiation source. Accordingly, far-field refers to the zone outside the boundary of $r = \lambda/2\pi$, where λ is the wavelength of the transmitted electromagnetic energy. In one embodiment, a communication range of telemetry link 114 (a distance over which data is capable of being wirelessly communicated) is at least ten feet but can be as long as allowed by the communication technology utilized. Unlike an inductive telemetry link using a coil placed near implantable medical device 110, attached to the patient, and electrically connected to external system 112 with a cable, using telemetry link 114 frees the patient from any physical restraints caused by the coil and the cable and allows external system 112 to be placed entirely away from the sterile field during an operation such as the implantation of implantable medical device 110.

[0022] Telemetry link 114 is supported by an implant

telemetry module 116 of implantable medical device 110 and an external telemetry module 118 of external system 112. Implant telemetry module 116 and external telemetry module 118 form a frequency agile telemetry system that includes a plurality of channels for data transmission. These channels each represent a frequency band within a predetermined frequency range. The telemetry system uses a channel quality analysis to identify one or more preferred channels from the plurality of channels for channel hopping when needed.

[0023] The bi-directional data communication between implantable medical device 110 and external system 112 includes transmission of data frames each being a logic unit of data including a header, a payload, and a trailer. In one embodiment, the header includes a "comma," which includes a unique set of bits for signaling the beginning of receipt of a frame. A lack of comma, or failure to receive the comma, indicates a failure to receive a frame. The payload includes the data block being transmitted. The trailer includes a cyclic redundancy check (CRC) value having a value generated by a transmitter. A receiver receives that CRC value and also recalculates the CRC value based on the received data block and compares the result to the received CRC value in the trailer. The data is deemed to be correctly transmitted if the recalculated CRC value matches the received CRC value. A CRC error refers to a mismatch between the recalculated CRC value and the received CRC value. Depending on the specific communication formats, the header and the trailer each include additional information for flagging, control of data recovery, and/or synchronization between implant telemetry module 116 and external telemetry module 118. In various embodiments, data frame exchange errors, such as comma errors and CRC errors, indicate a need for channel hopping.

[0024] In one embodiment, external system 112 includes a programmer. In another embodiment, external system 112 includes a patient management system including an external device, a telecommunication network, and one or more remote devices. The external device is placed within the vicinity of implantable medical device 110 and includes external telemetry module 118 to communicate with implantable medical device 110 via telemetry link 114. The one or more remote devices are in one or more remote locations and communicate with the external device through the telecommunication network, thus allowing the physician or other caregiver to monitor and treat the patient from a distant location and/or allowing access to various treatment resources from the one or more remote locations.

[0025] FIG. 2 is a block diagram illustrating an embodiment of a circuit of a CRM system 200, which is a specific embodiment of CRM system 100. System 200 includes an implantable medical device 210, an external system 212, and telemetry link 114 providing for communication between implantable medical device 210 and external system 212.

[0026] Implantable medical device 210 is a specific

embodiment of implantable medical device 110 and includes an implant telemetry module 216 and a CRM module 224. CRM module 224 includes a sensing circuit 226 that senses one or more physiological signals and a therapeutic circuit 228 that delivers one or more cardiac therapies. In various embodiments, the therapy circuit includes one or more of a pacing circuit, a cardioversion/defibrillation circuit, and any other circuit that delivers a cardiac therapy. In various embodiments, CRM module 224 further includes one or more of a drug delivery device and a biologic therapy device.

[0027] External system 212 is a specific embodiment of external system 112 and includes an external telemetry module 218, a programming module 230, and a user interface 232. Programming module 230 allows for processing of data transmitted from implantable medical device 210 via telemetry link 114 and programming of implantable medical device 210 by transmitting instructions via telemetry link 114. User interface 232 allows the physician or other caregiver to observe and analyze physiological signals and device operation data transmitted from implantable medical device 210 and to adjust the operation of implantable medical device 210.

[0028] Implant telemetry module 216 includes a telemetry circuit 220. External telemetry module 218 includes a telemetry circuit 222. Telemetry circuits 220 and 222 are discussed in detail below, with reference to FIGS. 4-7.

[0029] In various embodiments, the system elements, including various modules and circuits, described in this document are implemented by hardware, software, firmware, or any combination thereof. In various embodiments, the circuits or portions thereof described in this document are each an application-specific circuit constructed to perform one or more particular functions, a general-purpose circuit programmed to perform such function(s), or a combination thereof

[0030] FIG. 3 is an illustration of an embodiment of the plurality of channels for data transmission via telemetry link 114. The channels are distributed continuously over the predetermined frequency range. As illustrated in FIG. 3, an example of the predetermined frequency range is approximately 902.25-927.75 MHz. Each channel has a center (carrier) frequency and a bandwidth of approximately 500 kHz. Thus, the plurality of channels includes 51 channels each having a 500-kHz bandwidth within the frequency range of 902.25-927.75 MHz, within the Industrial, Scientific and Medical (ISM) band of the United States. The center frequency for each channel is approximately the mid-point of the frequency band represented by that channel. In the illustrated embodiment, Channel 0 has a frequency band of 902.25-902.75 MHz and a center frequency of 902.50 MHz, Channel 1 has a frequency band of 902.75-903.25 MHz and a center frequency of 903.00 MHz, and so forth. Other examples of the predetermined frequency range include approximately 863.0-870.0 MHz, within the Short Range Device (SRD) band of the European Union, approximately 402.0-405.0 MHz, within the worldwide Medical Implant

Communication Service (MICS) band, and approximately 420.0-430.0 MHz and 440.0-450.0 MHz, within the available bands in Japan.

[0031] FIG. 4 is a block diagram illustrating an embodiment of a telemetry circuit 440. Telemetry circuit 440 represents a specific embodiment of telemetry circuit 220 and/or telemetry circuit 222. In various embodiments, telemetry circuit 220 and telemetry circuit 222 each include a telemetry circuit with all or selected components of telemetry circuit 440, including all the embodiments of these components discussed in this document.

[0032] Telemetry circuit 440 includes an antenna 442, a transceiver 444, a channel selector 446, a hop controller 448, a channel quality analyzer 450, and a preferred channel identifier 452. Transceiver 444 transmits and receives data through antenna 442 using at least one active channel during a telemetry session. The active channel is selected from the plurality of channels. Channel selector 446 selects at least one hop channel from one or more preferred channels in response to a channel selection signal. When the hop channel is selected, hop controller 448 makes that hop channel the active channel. In one embodiment, channel selector 446 selects the hop channel from a sequence of preferred channels prioritized by a degree of preference, and the selection is made according to an order of priority. Channel quality analyzer 450 produces channel quality indicators each associated with one channel of the plurality of channels. The channel quality indicators each include one or more quality parameters each indicative of a channel quality. Preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on the channel quality indicators. In one embodiment, preferred channel identifier 452 identifies the one or more preferred channels by identifying one or more channel quality indicators that meet one or more predetermined requirements. In another embodiment, preferred channel identifier 452 identifies the one or more preferred channels by prioritizing channels according to their associated channel quality indicators. This results in the sequence of preferred channels prioritized by the degree of preference.

[0033] Telemetry circuit 440 allows channel hopping when needed throughout the telemetry session. Channel quality analyzer 450 produces and updates the channel quality indicators continuously, periodically, during time intervals between data frames, or according to any predetermined schedule. Preferred channel identifier 452 updates the list of the one or more preferred channels in response to any change in the channel quality indicators.

[0034] In one embodiment, external telemetry module 218 functions as a master device that controls the channel hopping in both external telemetry module 218 and implant telemetry module 216. External telemetry module 212 transmits the channel selection signal with information specifying the selected hop channel or the one or more preferred channels to implantable telemetry module 216 through telemetry link 114. This allows for

synchronized channel hopping in external telemetry module 218 and implant telemetry module 216. In one embodiment, external telemetry module 218 receives at least one quality parameter of the one or more quality parameters for each channel from implant telemetry module 216. In one embodiment, the channel quality indicator for each channel includes quality parameters produced in both external telemetry module 218 and implant telemetry module 216.

[0035] FIG. 5 is a block diagram illustrating an embodiment of a telemetry circuit 540, which is a specific embodiment of telemetry circuit 440. Telemetry circuit 540 includes antenna 442, transceiver 444, channel selector 446, hop controller 448, channel quality analyzer 450, preferred channel identifier 452, a telemetry quality monitor 554, a hop timer 556, and a telemetry initiation module 558. In various embodiments, telemetry circuit 540 includes one or more of telemetry quality monitor 554, hop timer 556, and telemetry initiation module 558 to initiate each channel hopping by producing the channel selection signal.

[0036] Telemetry quality monitor 554 monitors quality of frame exchange using the active channel and produces the channel selection signal when the quality of frame exchange fails to satisfy one or more criteria. For example, the quality of frame exchange fails when a comma of a data frame is not received, or when a CRC error is detected. The channel selection signal initiates a channel hopping. If the quality of frame exchange using the hop channel (which becomes the new active channel) still fails to satisfy the one or more criteria, telemetry quality monitor 554 produces another channel selection signal to cause another channel hopping. This process is repeated until the one or more criteria are satisfied. The selection of hop channel from the one or more preferred channel potentially minimizes the number of repetitions required to maintain a satisfactory quality of data frame exchange. Hop timer 556 produces the channel selection signal according to a predetermined schedule. Examples of timing channel hopping based on quality of frame exchange or predetermined schedule are discussed in U.S. Patent No. 7,218,969, entitled "DYNAMIC CHANNEL SELECTION FOR RF TELEMETRY WITH IMPLANTABLE DEVICE," issued on May 15, 2007, assigned to Cardiac Pacemakers, Inc., which is hereby incorporated by reference its entirety. Telemetry initiation module 558 produces the channel selection module prior to the beginning of data transmission via telemetry link 114. In one embodiment, telemetry initiation module 558 produces the channel selection signal when a telemetry session begins. In another embodiment, telemetry initiation module 558 produces the channel selection signal when telemetry circuit 540 is activated, for example, upon power-up of external system 212.

[0037] FIG. 6 is a block diagram illustrating an embodiment of a transceiver 644, which is a specific embodiment of transceiver 444. Transceiver 644 includes a band-pass filter 660, a transmit/receive (T/R) switch 662,

a transmitter 664, and a receiver 668. Band-pass filter 660 has a pass band corresponding to the predetermined frequency range within which the channels are distributed. For example, if the predetermined frequency range is the ISM band of 902-928 MHz, the pass band of band-pass filter 660 is approximately 902-928 MHz. T/R switch 662 provides a connection between antenna 442 and one of transmitter 664 and receiver 668 at a time, such that the data transmission via telemetry link 114 is unidirectional at any instant. Transmitter 664 transmits data using an active transmission channel and includes a modulator 670 and a power amplifier 672. Modulator 670 modulates a carrier signal with data to be transmitted. The carrier signal has a frequency being the center frequency of the active transmission channel (F_{CT}). Power amplifier 672 amplifies the modulated carrier for transmission over telemetry link 114. Receiver 668 receives data using an active receiving channel and includes a demodulator 674. Demodulator 674 demodulates the received signal to recover to data received. Receiver 668 receives a signal that is a carrier signal modulated with the data received. The carrier signal has a carrier frequency being the center frequency of the active receiving channel (F_{CR}). In one embodiment, the active transmission channel and the active receiving channel include substantially identical channel frequency bands (i.e., F_{CT} and F_{CR} are approximately equal). In another embodiment, the active transmission channel and the active receiving channel include substantially different channels (i.e., F_{CT} and F_{CR} are substantially different). The active transmission channel and the active receiving channel are selected from the plurality of channels. The discussion in this document regarding the "active channel" applies to each of the active transmission channel and the active receiving channel.

[0038] FIG. 7 is a block diagram illustrating an embodiment of a channel quality analyzer 750, which is a specific embodiment of channel quality analyzer 450. In the illustrated embodiment, channel quality analyzer 750 includes a received signal strength detector 778, a noise detector 780, a frame exchange analyzer 782, a performance history tracker 784, and a quality parameter receiver 786. In various embodiments, channel quality analyzer 750 includes one or more of received signal strength detector 778, noise detector 780, frame exchange analyzer 782, performance history tracker 784, and quality parameter receiver 786, depending on various design considerations and/or performance requirements, including whether channel quality analyzer 750 is part of the telemetry circuit of implant telemetry module 216 or part of the telemetry circuit of external telemetry module 218. In other words, channel quality analyzer 750 produces channel quality indicators each including one or more quality parameters produced by one or more of received signal strength detector 778, noise detector 780, frame exchange analyzer 782, performance history tracker 784, and quality parameter receiver 786. In various embodiments, channel quality analyzer 750 includes two or

more of received signal strength detector 778, noise detector 780, frame exchange analyzer 782, performance history tracker 784, and quality parameter receiver 786, and preferred channel identifier 452 identifies the one or more preferred channels using channel quality indicators each weighted by applying a predetermined weighting factor. The channel quality indicators are produced by the two or more of received signal strength detector 778, noise detector 780, frame exchange analyzer 782, performance history tracker 784, and quality parameter receiver 786. The channel quality indicator produced by each of received signal strength detector 778, noise detector 780, frame exchange analyzer 782, performance history tracker 784, and quality parameter receiver 786 are given a predetermined weighting factor.

[0039] Received signal strength detector 778 produces received signal strength indicators each associated with one channel of the plurality of channels and indicative of the strength of signal received through that channel. In one embodiment, the received signal strength indicator associated with a channel is the amplitude of the RF signal received using that channel. In one embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on the received signal strength indicators. In a specific embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels by comparing the received signal strength indicators to a predetermined threshold. In another specific embodiment, preferred channel identifier 452 produces the sequence of preferred channels by prioritizing channels according to their associated received signal strength indicators.

[0040] Noise detector 780 produces noise floor indicators each associated with one channel of the plurality of channels and indicative of a noise floor of that channel. In one embodiment, noise detector 780 produces the noise floor indicators by measuring a noise level associated with each channel of the plurality of channels when external system 212 is not communicatively coupled with implantable medical device 210, such as before the telemetry session begins. In another embodiment, noise detector 780 produces the noise floor indicators by measuring a noise level associated with each channel of the plurality of channels when no data is being transmitted between external system 212 and implantable medical device 210 through that channel. In one embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on the noise floor indicators. In a specific embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels by comparing the noise floor indicators to a predetermined threshold. In another embodiment, preferred channel identifier 452 produces the sequence of preferred channels by prioritizing channels according to their associated noise floor indicators.

[0041] Frame exchange analyzer 782 produces frame

exchange metrics each associated with one channel of the plurality of channels. In one embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on the frame exchange metrics. In a specific embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels by comparing the frame exchange metrics to a predetermined threshold. In another specific embodiment, preferred channel identifier 452 produces the sequence of preferred channels by prioritizing channels according to their associated frame exchange metrics. In one embodiment, the frame exchange metrics each include a success ratio being a ratio of the number of successful frame exchanges to a total number of frame exchanges. Frame exchange analyzer 782 calculates success ratios each associated with one channel of the plurality of channels. Preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels by comparing the success ratios to a predetermined threshold or by prioritizing channels according to their associated success ratios.

[0042] Performance history tracker 784 produces performance history indicators each associated with one channel of the plurality of channels and indicative of a history of at least one of the one or more quality parameters indicative of the channel quality of that channel. Examples of the one or more quality parameters include the received signal strength indicators, the noise floor indicators, and the frame exchange metrics discussed above. In one embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on the performance history indicators. In a specific embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels by comparing the performance history indicators to a predetermined threshold. In another embodiment, preferred channel identifier 452 produces the sequence of preferred channels by prioritizing channels according to their associated performance history indicators.

[0043] Quality parameter receiver 786 receives quality parameters produced and transmitted at the other side of telemetry link 114. The received quality parameters include one or more of the received signal strength indicators, the noise floor indicators, the frame exchange metrics, and the performance history indicators discussed above. In one embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on the received quality parameters. In a specific embodiment, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels by comparing the received quality parameters to a predetermined threshold. In another embodiment, preferred channel identifier 452 produces the sequence of preferred channels by prioritizing channels according to their associated received quality parameters. In one embodiment, quality param-

eter receiver 786 of external system 212 receives one or more quality parameters produced by and transmitted from implantable medical device 210.

[0044] In one embodiment, channel quality analyzer 750 produces other quality parameters such as signal-to-noise ratios (SNRs) each associated with one channel of the plurality of channels. For example, SNRs are calculated as the ratio of the received signal strength indicator to the noise floor indicator for each channel. In general, channel quality indicators produced by channel quality analyzer 750 may include any one or more quality parameters that potentially indicate the efficiency and accuracy of data transmission via telemetry link 114.

[0045] In one embodiment, implant telemetry module 216 and external telemetry module 218 each include a channel quality analyzer that includes some or all of the elements of channel quality analyzer 750 as illustrated in FIG. 7. In one embodiment, the channel quality analyzer of implant telemetry module 216 includes received signal strength detector 778, while the channel quality analyzer of external telemetry module 218 includes all of received signal strength detector 778, noise detector 780, frame exchange analyzer 782, performance history tracker 784, and quality parameter receiver 786. Quality parameter receiver 786 receives the received signal strength indicators produced by and transmitted from implant telemetry module 216. Preferred channel identifier 452 of external telemetry module 218 identifies the one or more preferred channels from the plurality of channels based on one or more of the received signal strength indicators (produced by external telemetry module 218), the noise floor indicators, the frame exchange metrics, the performance history indicators, and the received quality parameters (the received signal strength indicators produced by implant telemetry module 216).

[0046] In one embodiment, channel quality analyzer 750 produces channel quality indicators each include multiple quality parameters that are used to select the one or more preferred channels at different stages of data transmission. In one embodiment, when telemetry circuit 540 is powered up, or prior to the start of a telemetry session, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on the performance history indicators. This is particularly useful if system 200 is used repeatedly in the same environment, such as the same room in a hospital or the same room in the patient's home. In one embodiment, prior to the start of a telemetry session, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on the noise floor indicators produced when no data transmission is performed via telemetry link 114. In various embodiments, preferred channel identifier 452 identifies the one or more preferred channels from the plurality of channels based on either or both of the received signal strength indicators and the frame exchange metrics continuously, periodically, or according to a predetermined schedule during the telemetry session.

[0047] FIG. 8 is a flow chart illustrating a method 800 for transmitting data between an implantable medical device and an external system. In one embodiment, method 800 is performed by system 100, including its specific embodiment system 200 and various embodiments of the elements of system 200 discussed above.

[0048] A telemetry session is started at 802. Bi-directional data transmission is performed via a telemetry link between an implantable medical device and an external system during the telemetry session. The telemetry link includes a plurality of channels each representing a channel frequency band within a predetermined frequency range. At least one active channel is selected from the plurality of channels for the data transmission at any instant during the telemetry session.

[0049] If a channel selection signal is received at 804, a hop channel is selected from one or more preferred channels of the plurality of channels at 806. In various embodiments, the channel selection signal is produced when the telemetry session begins, when the telemetry link is activated, according to a predetermined schedule, or when the quality of data transmission through the telemetry link fails to satisfy one or more criteria. In one embodiment, the one or more preferred channels are prioritized by a degree of preference, and the hop channel is selected based on the priority. The hop channel is made the active channel at 808. Data are transmitted between the implantable medical device and the external system using the active channel at 810.

[0050] If the channel selection signal is not received at 804, no channel hopping is needed. The data are transmitted between the implantable medical device and the external system using a current active channel at 810.

[0051] In one embodiment, two substantially distinctive active channels are used for data transmission in the two directions (one from the implantable medical device to the external system, and the other from the external system to the implantable medical device). In one embodiment, channel hopping with respect to each of the two substantively distinctive active channels is controlled separately using method 800 and performed in parallel during the telemetry session.

[0052] The telemetry session ends at 822 when all the data intended to be transmitted during the telemetry session are transmitted at 812. If more data are to be transmitted at 812, and the active channel is to be switched to another channel at 814, the channel selection signal is produced at 816. The data transmission then continues after channel hopping. If more data are to be transmitted at 812, but the active channel is not to be switched to another channel at 814, the data transmission then continues using the current active channel, i.e., without channel hopping. In various embodiments, the active channel is to be switched to another channel at 814 according to the predetermined schedule, or when the quality of data transmission through the telemetry link fails to satisfy one or more criteria.

[0053] During the telemetry session, channel quality

indicators each associated with one channel of the plurality of channels are produced at 818. The channel quality indicator for a channel includes one or more quality parameters indicative of quality of that channel. The one or more preferred channels are identified from the plurality of channels based on the channel quality indicators at 820. Steps 818 and 820 are performed continuously, periodically, or according a predetermined schedule during the telemetry session to maintain an updated list or sequence of the one or more preferred channels for the hop channel selection at 806. In one embodiment, the one or more preferred channels are identified from the plurality of channels at 820 by identifying one or more of the channel quality indicators that meet one or more predetermined requirements. In another embodiment, the sequence of preferred channels is produced at 820 by prioritizing channels according to their associated channel quality indicators.

[0054] Examples of the one or more quality parameters include received signal strength indicators each indicative of the strength of signal received through a channel, noise floor indicators each indicative of the noise floor of a channel, frame exchange metrics such as the success ratios each being a ratio of the number of successful frame exchanges to a total number of frame exchanges performed using a channel, and performance history indicators each indicative of data transmission performance history of a channel. The data transmission performance history is represented by the history of one or more of the received signal strength indicators, the noise floors, and the frame exchange metrics. In one embodiment, the one or more quality parameters include at least one quality parameter produced at the other side of the telemetry link. For example, the implantable medical device produces the received signal strength indicators each indicative the strength of signal received by the implantable medical device through a channel. The received signal strength indicators are transmitted to the external system. The external system controls the channel hopping in both the implantable medical device and the external system using the one or more preferred channels identified using one or more quality parameters including the received signal strength indicators produced by the implantable medical device.

[0055] It is to be understood that the above detailed description is intended to be illustrative, and not restrictive. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

Claims

1. A cardiac rhythm management (CRM) system (100), comprising:

an implantable medical device including an implant telemetry module (116); and
 an external system (112) communicatively coupled to the implantable medical device via a telemetry link (114), the external system including an external telemetry module (118), wherein at least one of the Implant telemetry module and the external telemetry module includes a telemetry circuit (440) including:

an antenna (442);
 a transceiver (444), coupled to the antenna, to transmit and receive data using at least one active channel during a telemetry session, the at least one active channel selected from a plurality of channels each representing a channel frequency band;
 a channel selector (446) coupled to the transceiver, the channel selector adapted to select at least one hop channel from a sequence of preferred channels in response to a channel selection signal, the sequence of preferred channels prioritized by a degree of preference and the selection is made according to an order of priority;
 a hop controller (448) coupled to the channel selector, the hop controller adapted to make the at least one hop channel the active channel when the at least one hop channel is selected;
 a channel quality analyzer (450) coupled to the channel selector, the channel quality analyzer adapted to produce channel quality indicators each associated with one channel of the plurality of channels and each including at least a received signal strength indicator indicative of a strength of signal received through that channel, the channel quality analyzer including a received signal strength detector adapted to produce the received signal strength indicators; and
 a preferred channel identifier (452) coupled to the channel quality analyzer; the preferred channel identifier adapted to identify the sequence of preferred channels from the plurality of channels by prioritizing channels of the plurality of channels using the channel quality indicators.

2. The system according to claim 1, wherein the at least one active channel comprises an active transmission channel selected from the plurality of channels and an active receiving channel selected from the plurality of channels, the active transmission channel and the active receiving channel representing substantially different channel frequency bands, and the transceiver (644) comprises:

- a transmitter (864) to transmit data using the active transmission channel;
 a receiver (668) to receive data using the active receiving channel; and
 a transmit/receive switch (662) to provide a connection between the antenna and one of the transmitter and the receiver.
3. The system according to any of the preceding claims, wherein the telemetry circuit (540) further comprises a telemetry quality monitor (554) adapted to monitor quality of data transmission associated with the active channel and to produce the channel selection signal when the quality of data transmission fails to satisfy one or more criteria.
 4. The system according to any of claims 1 and 2, wherein the telemetry circuit (540) further comprises a hop timer (556) to produce the channel selection signal according to a predetermined schedule.
 5. The system according to any of claims 1 and 2, wherein the telemetry circuit (540) further comprises a telemetry initiation module (558) to produce the channel selection signal when or before the telemetry session begins.
 6. The system according to any of the preceding claims, wherein the channel quality indicators comprise noise floor indicators each associated with one channel of the plurality of channels and indicative of a noise floor of that channel, the channel quality analyzer (750) comprises a noise detector (760) adapted to produce the noise floor indicators by measuring a noise level associated with each channel of the plurality of channels when no data is being transmitted between the external system (112) and the implantable medical device (110) through that channel, and the preferred channel identifier (452) is adapted to identify the sequence of preferred channels from the plurality of channels using at least the received signal strength indicators and the noise floor indicators.
 7. The system according to any of the preceding claims, wherein the channel quality indicators comprise frame exchange metrics each associated with one channel of the plurality of channels, the channel quality analyzer (750) comprises a frame exchange analyzer (782) adapted to produce the frame exchange metrics including success ratios each being a ratio of a number of successful frame exchanges to a total number of frame exchanges, and the preferred channel identifier (452) is adapted to identify the sequence of preferred channels from the plurality of channels using at least the received signal strength indicators and the frame exchange metrics.
 8. the system according to any of the preceding claims,
- wherein the channel quality indicators comprise performance history indicators each associated with one channel of the plurality of channels and indicative of a history of the channel quality indicator of that channel, the channel quality analyzer (750) comprises a performance history tracker (784) adapted to produce the performance history indicators, and the preferred channel identifier (452) is adapted to identify the sequence of preferred channels from the plurality of channels using at least the received signal strength indicators and the performance history indicators.
9. The system according to any of the preceding claims, wherein the external telemetry module (118, 218) comprises the telemetry circuit (222), and wherein the channel selector (446) is adapted to transmit data specifying one or more of the at least one hop channel and the sequence of preferred channels to this implantable medical device (110) through the telemetry link (114).
 10. The system according to any of the preceding claims, wherein the external telemetry module (118, 218) comprises the telemetry circuit (222), and wherein the channel selector (446) is adapted to transmit data specifying one or more of the at least one hop channel and the sequence of preferred channels to this implantable medical device (110) through the telemetry link (114).
 11. A method for transmitting data between an implantable medical device and an external system via radio-frequency telemetry, the method comprising:
 - receiving (804) a channel selection signal;
 - selecting (806) a hop channel from a sequence of preferred channels in response to the channel selection signal, the sequence of preferred channels prioritized by a degree of preference and the selection is made according to an order of priority;
 - making (808) the hop channel an active channel;
 - transmitting (810) data between the implantable medical device and the external system using the active channel;
 - producing (818) channel quality indicators each associated with one channel of a plurality of channels and each including at least a received signal strength indicator indicative of a strength of signal received through the one channel, each channel of the plurality of channels representing a channel frequency band; and
 - identifying (820) the sequence of preferred channels from the plurality of channels by prioritizing channels of the plurality of channels using the channel quality indicators.

12. The method according to claim 11, comprising:

selecting (806) a first hop channel from a first sequence of preferred channels in response to the channel selection signal;
 making (808) the first hop channel a first active channel;
 transmitting (810) the data from the implantable medical device to the external system using the first active channel;
 selecting (806) a second hop channel from a second sequence of preferred channels in response to the channel selection signal;
 making (808) this second hop channel a second active channel; and
 transmitting (810) the data from the external system to the Implantable medical device using the second active channel,
 and wherein the sequence of preferred channels comprises one or more first preferred channels and the one or more second preferred channels.

13. The method according to any of claims 11 and 12, wherein the channel quality indicators comprise noise floor indicators each associated with one channel of the plurality of channels and indicative of a noise floor of that channel, and identifying the sequence of preferred channels comprises:

measuring a noise level associated with each channel of the plurality of channels when no data is transmitted between the external system and the implantable medical device using the each channel; and
 identifying the sequence of preferred channels from the plurality of channels based on the received signal strength indicators and the noise floor indicators.

14. The method according to any of claims 11 and 12, wherein the channel quality indicators comprise frame exchange metrics including success ratios each associated with one channel of the plurality of channels and being a ratio of a number of successful frame exchanges to a total number of frame exchanges, and identifying the sequence of preferred channels comprises identifying the sequence of preferred channels from the plurality of channels based on the received signal strength indicators and the frame exchange metrics.

15. The method according to any of claims 11 to 14, wherein the channel quality indicators comprise performance history indicators each associated with one channel of the plurality of channels and indicative of a history of the channel quality indicator of that channel, and identifying the sequence of preferred channels comprises identifying the one or

more preferred channels from the plurality of channels based on the received signal strength indicators and the performance history indicators.

Patentansprüche

1. Ein Herzrhythmus-Managementsystem (CRM-System) (100), umfassend:

eine implantierbare medizinische Vorrichtung, die ein implantierbares Telemetriemodul (116) umfasst; und
 ein externes System (112) kommunikativ mit der implantierbaren medizinischen Vorrichtung über eine Telemetrie Verbindung (114) gekoppelt, wobei das externe System ein externes Telemetriemodul (118) umfasst,
 wobei mindestens eines von dem implantierbaren Telemetriemodul und dem externen Telemetriemodul einen Telemetrieschaltkreis (440) umfasst, der folgendes umfasst:

eine Antenne (442);

ein Sende-Empfangs-Gerät (444), gekoppelt mit der Antenne zum Übertragen und Empfangen von Daten unter Verwendung von mindestens einem aktiven Kanal während einer Telemetriesitzung, wobei der mindestens eine aktive Kanal ausgewählt wird aus einer Mehrzahl von Kanälen, von denen jeder ein Kanalfrequenzband repräsentiert;

ein Kanalwähler (446) gekoppelt mit dem Sende-Empfangs-Gerät, wobei der Kanalwähler dazu ausgelegt ist, mindestens einen Sprungkanal aus einer Abfolge von bevorzugten Kanälen in Antwort auf ein Kanalauswahlsignal auszuwählen, wobei die Abfolge von bevorzugten Kanälen durch einen Grad an Bevorzugung priorisiert wird und wobei die Auswahl gemäß einer Reihenfolge der Priorität getätigt wird;

einen Sprungcontroller (448) gekoppelt mit dem Kanalwähler, wobei der Sprungcontroller dazu ausgelegt ist, mindestens einen Sprungkanal zum aktiven Kanal zu machen, wenn mindestens ein Sprungkanal ausgewählt wird;

ein Kanalqualität-Analysator (450) gekoppelt mit dem Kanalwähler, wobei der Kanalqualität-Analysator dazu ausgelegt ist, Kanalqualität-Indikatoren zu erzeugen, wovon jeder mit einem Kanal der Mehrzahl von Kanälen assoziiert ist, und wovon jeder mindestens einen Empfangene-Signalstärke-Indikator umfasst, der eine Stärke des Signals angibt, das über diesen Kanal empfan-

- gen wurde, wobei der Kanalqualität-Analysator einen Empfangene-Signalstärke-Detektor umfasst, der dazu ausgelegt ist, die empfangenen Signalstärke-Indikator zu erzeugen; und
- ein Bevorzugter-Kanal-Identifikator (452) gekoppelt mit dem Kanalqualität-Analysator, wobei der Bevorzugter-Kanal-Identifikator dazu ausgelegt ist, die Abfolge der bevorzugten Kanäle von der Mehrzahl von Kanälen durch Priorisieren der Kanäle der Mehrzahl von Kanälen unter Verwendung der Kanalqualität-Indikatoren zu identifizieren.
2. Das System nach Anspruch 1, wobei der mindestens eine aktive Kanal einen aktiven Übertragungskanal, ausgewählt aus der Mehrzahl von Kanälen, umfasst und einen aktiven Empfangskanal, ausgewählt aus der Mehrzahl von Kanälen, umfasst, wobei der aktive Übertragungskanal und der aktive Empfangskanal im Wesentlichen unterschiedliche Kanalfrequenzbänder repräsentieren, wobei das Sende-Empfangs-Gerät folgendes umfasst:
- einen Transmitter (664) um Daten unter Verwendung des aktiven Übertragungskanals zu übertragen;
- einen Receiver (668) um Daten unter Verwendung des aktiven Empfangskanals zu übertragen; und
- ein Übertragungs-Empfangs-Schalter (662), um eine Verbindung zwischen der Antenne und einem von dem Transmitter und dem Receiver bereit zu stellen.
3. Das System nach irgendeinem der vorangehenden Ansprüche, wobei der Telemetrieschaltkreis (540) einen Telemetriequalitätsüberwachungsgerät (554) umfasst, das dazu ausgelegt ist, die Qualität der Datenübertragung, die mit dem aktiven Kanal assoziiert ist, zu überwachen und das Kanalauswahlsignal zu erzeugen, wenn die Qualität der Datenübertragung eines oder mehrere Kriterien nicht erfüllt.
4. Das System nach irgendeinem der Ansprüche 1 und 2, wobei der Telemetrieschaltkreis (540) weiter einen Sprungtimer (556) umfasst, um das Kanalauswahlsignal gemäß eines vorbestimmten Plans zu erzeugen.
5. Das System nach irgendeinem der Ansprüche 1 und 2, wobei der Telemetrieschaltkreis (540) weiter ein Telemetrieinitiationsmodul (558) umfasst, um das Kanalauswahlsignal zu erzeugen, wenn oder bevor die Telemetrie Sitzung beginnt.
6. Das System nach irgendeinem der vorangehenden
- Ansprüche, wobei die Kanalqualität-Indikatoren Grundrauschen-Indikatoren umfassen, wovon jeder mit einem Kanal der Mehrzahl von Kanälen assoziiert ist und ein Grundrauschen dieses Kanals angibt, wobei die Kanalqualität-Analysator (750) einen Rauschdetektor (760) umfasst, der dazu ausgelegt ist, die Grundrauschen-Indikatoren zu erzeugen durch Messen eines Rauschpegels, der mit jedem Kanal der Mehrzahl von Kanälen assoziiert ist, wenn keine Daten zwischen dem externen System (112) und der implantierbaren medizinischen Vorrichtung (110) über diesen Kanal übertragen werden, und wobei der Bevorzugter-Kanal-Identifikator (452) dazu ausgelegt ist, die Abfolge der bevorzugten Kanäle von der Mehrzahl von Kanälen unter Verwendung der Empfangene-Kanalqualität-Indikatoren und der Grundrauschen-Indikatoren zu identifizieren.
7. Das System nach irgendeinem der vorangehenden Ansprüche, wobei die Kanalqualität-Indikatoren Rahmenwechsel-Metriken umfassen, wovon jede mit einem Kanal der Mehrzahl von Kanälen assoziiert ist, wobei der Kanalqualität-Analysator (750) einen Rahmenwechsel-Analysator (782) umfasst, der dazu ausgelegt ist, die Rahmenwechsel-Metriken zu erzeugen, die Erfolgsverhältnisse umfassen, wovon jedes Verhältnis eine Anzahl erfolgreicher Rahmenwechsel zu einer gesamten Anzahl von Rahmenwechseln ist, und wobei der Bevorzugter-Kanal-Identifikator (452) dazu ausgelegt ist, die Abfolge der bevorzugten Kanäle von der Mehrzahl von Kanälen unter Verwendung der Empfangene-Kanalqualität-Indikatoren und der Rahmen-Wechsel-Metriken zu identifizieren.
8. Das System nach irgendeinem der vorangehenden Ansprüche, wobei die Kanalqualität-Indikatoren Leistungsverlauf-Indikatoren umfassen, wovon jeder mit einem Kanal der Mehrzahl von Kanälen assoziiert ist und einen Verlauf der Kanalqualität-Indikatoren dieses Kanals angibt, wobei der Kanalqualität-Analysator (750) einen Leistungsverlauf-Verfolger (784) umfasst, der dazu ausgelegt ist, die Leistungsverlauf-Indikatoren zu erzeugen, und wobei der Bevorzugter-Kanal-Identifikator (452) dazu ausgelegt ist, die Abfolge der bevorzugten Kanäle von der Mehrzahl von Kanälen unter Verwendung mindestens der Empfangene-Kanalqualität-Indikatoren und der Leistungsverlauf-Indikatoren zu identifizieren.
9. Das System nach irgendeinem der vorangehenden Ansprüche, wobei das externe Telemetriemodul (118, 218) den Telemetrieschaltkreis (222) umfasst, und wobei der Kanalwähler dazu ausgelegt ist, Daten zu übertragen, die einen oder mehrere des mindestens einen Sprungkanals und der Abfolge der bevorzugten Kanäle zu der implantierbaren medizini-

schen Vorrichtung (110) über die Telemetrie-Verbindung spezifizieren.

10. Das System nach irgendeinem der vorangehenden Ansprüche, wobei der Kanalqualität-Analysator (750) einen Qualitätsparameter-Empfänger (786) umfasst, der dazu ausgelegt ist, mindestens einen Qualitätsparameter von jedem der Kanalqualität-Indikatoren von der implantierbaren medizinischen Vorrichtung zu empfangen. 5 10
11. Ein Verfahren zum Übertragen von Daten zwischen einer implantierbaren medizinischen Vorrichtung und einem externen System mittels Hochfrequenz-telemetrie, das Verfahren umfassend: 15
- Empfangen (804) eines Kanalauswahlsignals; Auswählen (806) eines Sprungkanals aus einer Abfolge von bevorzugten Kanälen in Antwort auf ein Kanalauswahlsignal, wobei die Abfolge von bevorzugten Kanälen durch einen Grad an Bevorzugung priorisiert wird, und wobei die Auswahl gemäß einer Reihenfolge der Priorität getätigt wird; 20
- Machen (808) des Sprungkanals zu einem aktiven Kanal; 25
- Übertragen (810) von Daten zwischen der implantierbaren medizinischen Vorrichtung und dem externen System unter Verwendung des aktiven Kanals; 30
- Erzeugen (818) von Kanalqualität-Indikatoren, wovon jeder mit einem Kanal einer Mehrzahl von Kanälen assoziiert ist, und wovon jeder mindestens einen Empfangene-Signalstärke-Indikator, der eine Stärke des Signals empfangen durch diesen Kanal angibt, umfasst, wobei jeder Kanal der Mehrzahl von Kanälen ein Kanalfrequenzband repräsentiert; und 35
- Identifizieren (820) der Abfolge der bevorzugten Kanäle von der Mehrzahl von Kanälen durch Priorisieren der Kanäle der Mehrzahl von Kanälen unter Verwendung der Kanalqualität-Indikatoren. 40
12. Das Verfahren nach Anspruch 11, umfassend: 45
- Auswählen (806) eines ersten Sprungkanals von einer ersten Abfolge von bevorzugten Kanälen in Antwort auf das Kanalauswahlsignal; 50
- Machen (808) des ersten Sprungkanals zu einem ersten aktiven Kanal;
- Übertragen (810) von Daten zwischen der implantierbaren medizinischen Vorrichtung und dem externen System unter Verwendung des ersten aktiven Kanals; 55
- Auswählen (806) eines zweiten Sprungkanals von einer zweiten Abfolge von bevorzugten Kanälen in Antwort auf das Kanalauswahlsignal;
- Machen (808) des zweiten Sprungkanals zu einem zweiten aktiven Kanal; und Übertragen (810) von Daten zwischen der implantierbaren medizinischen Vorrichtung und dem externen System unter Verwendung des zweiten aktiven Kanals, und wobei die Abfolge der bevorzugten Kanäle einen oder mehrere erste bevorzugte Kanäle und einen oder mehrere zweite bevorzugte Kanäle umfasst.
13. Das Verfahren nach irgendeinem der Ansprüche 11 und 12, wobei die Kanalqualität-Indikatoren Grundrauschen-Indikatoren umfassen, wovon jeder mit einem Kanal der Mehrzahl von Kanälen assoziiert ist und ein Grundrauschen dieses Kanals angibt, und wobei identifizieren der Abfolge von bevorzugten Kanälen umfasst: 15
- Messen eines Rauschpegels, der mit jedem Kanal der Mehrzahl von Kanälen assoziiert ist, wenn keine Daten zwischen dem externen System (112) und der implantierbaren medizinischen Vorrichtung (110) unter Verwendung dieses Kanals übertragen werden; und 20
- Identifizieren der Abfolge der bevorzugten Kanäle von der Mehrzahl von Kanälen unter Verwendung der Empfangene-Kanalqualität-Indikatoren und der Grundrauschen-Indikatoren. 25
14. Das Verfahren nach irgendeinem der Ansprüche 11 und 12, wobei die Kanalqualität-Indikatoren Rahmenwechsel-Metriken umfassen, die Erfolgsverhältnisse umfassen, wovon jedes mit einem Kanal der Mehrzahl von Kanälen assoziiert ist und ein Verhältnis einer Anzahl von erfolgreichen Rahmenwechseln zu einer gesamten Anzahl von Rahmenwechseln ist, und wobei Identifizieren der Abfolge bevorzugter Kanäle von der Mehrzahl von Kanälen Identifizieren der einen oder der mehreren bevorzugten Kanäle von der Mehrzahl von Kanälen basierend auf den Empfangene-Signalstärke-Indikatoren und den Rahmenwechsel-Metriken umfasst. 30
15. Das Verfahren nach irgendeinem der Ansprüche 11 bis 14, wobei die Kanalqualität-Indikatoren Leistungsverlauf-Indikatoren umfassen, wovon jeder mit einem Kanal der Mehrzahl von Kanälen assoziiert ist und einen Verlauf der Kanalqualität-Indikatoren dieses Kanals angibt, und wobei Identifizieren der Abfolge bevorzugter Kanäle von der Mehrzahl von Kanälen Identifizieren der einen oder der mehreren bevorzugten Kanäle von der Mehrzahl von Kanälen basierend auf den Empfangene-Signalstärke-Indikatoren und den Leistungsverlauf-Indikatoren umfasst. 35

Revendications

1. Système de gestion de rythme cardiaque (CRM) (100), comprenant :

un dispositif médical implantable comprenant un module de télémessure d'implant (116) ; et un système externe (112) couplé de manière communicative au dispositif médical implantable via une liaison de télémessure (114), le système externe comprenant un module de télémessure externe (118), où au moins un module parmi le module de télémessure d'implant et le module de télémessure externe comprend un circuit de télémessure (440) comprenant :

une antenne (442) ;
un émetteur-récepteur (444), couplé à l'antenne, pour transmettre et recevoir des données au moyen d'au moins un canal actif au cours d'une session de télémessure, l'au moins un canal actif est sélectionné parmi une pluralité de canaux, chacun représentant une bande de fréquences de canal ;
un sélecteur de canal (446) couplé à l'émetteur-récepteur, le sélecteur de canal est conçu pour sélectionner au moins un canal de saut parmi une séquence de canaux préférés en réponse à un signal de sélection de canal, la séquence de canaux préférés est priorisée selon un degré de préférence et la sélection est faite conformément à un ordre de priorité ;
un contrôleur de saut (448) couplé au sélecteur de canal, le contrôleur de saut est conçu pour faire de l'au moins un canal de saut le canal actif lorsque l'au moins un canal de saut est sélectionné ;
un analyseur de qualité de canal (450) couplé au sélecteur de canal, l'analyseur de qualité de canal est conçu pour produire des indicateurs de qualité de canal, chacun associé à un canal de la pluralité de canaux et chacun comprenant au moins un indicateur d'intensité de signal reçu indicatif d'une intensité de signal reçu à travers ce canal, l'analyseur de qualité de canal comprenant un détecteur d'intensité de signal reçu conçu pour produire les indicateurs d'intensité de signal reçu ; et
un identifiant de canal préféré (452) couplé à l'analyseur de qualité de canal ; l'identifiant de canal préféré est conçu pour identifier la séquence des canaux préférés parmi la pluralité de canaux en priorisant des canaux de la pluralité de canaux au moyen des indicateurs de qualité de canal.

2. Système selon la revendication 1, dans lequel l'au moins canal actif comprend un canal de transmission actif sélectionné parmi la pluralité de canaux et un canal de réception actif sélectionné parmi la pluralité de canaux, le canal de transmission actif et le canal de réception actif représentant essentiellement différentes bandes de fréquences de canaux, et l'émetteur-récepteur (644) comprend :
- un émetteur (664) pour transmettre des données au moyen du canal de transmission actif ;
un récepteur (666) pour recevoir des données au moyen du canal de réception actif ; et
un commutateur d'émission-réception (662) pour fournir une connexion entre l'antenne et un dispositif parmi l'émetteur et le récepteur.
3. Système selon l'une quelconque des revendications précédentes, dans lequel le circuit de télémessure (540) comprend en outre un moniteur de qualité de télémessure (554) conçu pour monitorer une qualité de transmission de données associée au canal actif et pour produire le signal de sélection de canal lorsque la qualité de transmission de données ne satisfait pas un ou plusieurs critères.
4. Système selon l'une quelconque des revendications 1 et 2, dans lequel le circuit de télémessure (540) comprend en outre un timer de saut (556) pour produire le signal de sélection de canal conformément à une planification prédéterminée.
5. Système selon l'une quelconque des revendications 1 et 2, dans lequel le circuit de télémessure (540) comprend en outre un module de déclenchement de télémessure (558) pour produire le signal de sélection de canal au moment où, ou avant que, la session de télémessure commence.
6. Système selon l'une quelconque des revendications précédentes, dans lequel les indicateurs de qualité de canal comprennent des indicateurs de bruit de fond, chacun associé à un canal de la pluralité de canaux et indicatif d'un bruit de fond de ce canal, l'analyseur de qualité de canal (750) comprend un détecteur de bruit (760) conçu pour produire les indicateurs de bruit de fond en mesurant un niveau de bruit associé à chaque canal de la pluralité de canaux lorsqu'aucune donnée n'a été transmise entre le système externe (112) et le dispositif médical implantable (110) à travers ce canal, et l'identifiant de canal préféré (452) est conçu pour identifier la séquence de canaux préférés parmi la pluralité de canaux en utilisant au moins les indicateurs d'intensité de signal reçu et les indicateurs de bruit de fond.
7. Système selon l'une quelconque des revendications précédentes, dans lequel les indicateurs de qualité

- de canal comprennent des mesures d'échange de trame, chacune associée à un canal de la pluralité de canaux, l'analyseur de qualité de canal (750) comprend un analyseur d'échange de trame (782) conçu pour produire les mesures d'échange de trame comprenant des taux de réussite, chacun correspondant à un taux d'un nombre d'échanges de trame réussis sur un nombre total d'échanges de trame, et l'identifiant de canal préféré (452) est conçu pour identifier la séquence de canaux préférés parmi la pluralité de canaux en utilisant au moins les indicateurs d'intensité de signal reçu et les mesures d'échange de trame.
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8. Système selon l'une quelconque des revendications précédentes, dans lequel les indicateurs de qualité de canal comprennent des indicateurs d'historiques de performance, chacun associé à un canal de la pluralité de canaux et indicatif d'un historique de l'indicateur de qualité de canal de ce canal, l'analyseur de qualité de canal (750) comprend un suiveur d'historique de performance (784) conçu pour produire les indicateurs d'historiques de performance, et l'identifiant de canal préféré (452) est conçu pour identifier la séquence de canaux préférés parmi la pluralité de canaux en utilisant au moins les indicateurs d'intensité de signal reçu et les indicateurs d'historiques de performance.
9. Système selon l'une quelconque des revendications précédentes, dans lequel le module de télémétrie externe (118, 218) comprend un circuit de télémétrie (222), et où le sélecteur de canal (446) est conçu pour transmettre des données spécifiant un ou plusieurs des au moins un canal de saut et de la séquence de canaux préférés au dispositif médical implantable (110) par l'intermédiaire de la liaison de télémétrie (114).
10. Système selon l'une quelconque des revendications précédentes, dans lequel l'analyseur de qualité de canal (750) comprend un récepteur de paramètre de qualité (786) conçu pour recevoir au moins un paramètre de qualité de chacun des indicateurs de qualité de canal depuis le dispositif médical implantable.
11. Procédé pour transmettre des données entre un dispositif médical implantable et un système externe via une télémétrie par radiofréquences, le procédé comprenant les étapes suivantes :
- recevoir (804) un signal de sélection de canal ; sélectionner (806) un canal de saut parmi une séquence de canaux préférés en réponse au signal de sélection de canal, la séquence de canaux préférés est priorisée selon un degré de préférence et la sélection est faite conformément à un ordre de priorité ;
- faire (808) du canal de saut un canal actif ; transmettre (810) des données entre le dispositif médical implantable et le système externe au moyen du canal actif ; produire (818) des indicateurs de qualité de canal, chacun associé à un canal d'une pluralité de canaux et chacun comprenant au moins un indicateur d'intensité de signal reçu indicatif d'une intensité de signal reçu à travers ce canal, chaque canal de la pluralité de canaux représentant une bande de fréquences de canal ; et identifier (820) la séquence de canaux préférés parmi la pluralité de canaux en priorisant des canaux de la pluralité de canaux en utilisant les indicateurs de qualité de canal.
12. Procédé selon la revendication 11, comprenant les étapes suivantes ; sélectionner (806) un premier canal de saut parmi une première séquence de canaux préférés en réponse au signal de sélection de canal ; faire (808) du premier canal de saut un premier canal actif ; transmettre (810) les données provenant du dispositif médical implantable au système externe au moyen du premier canal actif ; sélectionner (806) un second canal de saut parmi une seconde séquence de canaux préférés en réponse au signal de sélection de canal ; faire (808) du second canal de saut un second canal actif ; transmettre (810) les données depuis le système externe au dispositif médical implantable au moyen du second canal actif ; et où la séquence de canaux préférés comprend un ou plusieurs premiers canaux préférés et le ou les seconds canaux préférés.
13. Procédé selon l'une quelconque des revendications 11 et 12, dans lequel les indicateurs de qualité de canal comprennent des indicateurs de bruit de fond, chacun associé à un canal de la pluralité de canaux et indicatif d'un bruit de fond de ce canal, et où identifier la séquence de canaux préférés comprend les étapes suivantes :
- mesurer un niveau de bruit associé à chaque canal de la pluralité de canaux lorsqu'aucune donnée n'est transmise entre le système externe et le dispositif médical implantable au moyen de chaque canal ; et identifier la séquence de canaux préférés parmi la pluralité de canaux sur la base des indicateurs d'intensité de signal reçu et des indicateurs de bruit de fond.
14. Procédé selon l'une quelconque des revendications 11 et 12, dans lequel les indicateurs de qualité de

canal comprennent des mesures d'échange de trame comprenant des taux, chacun associé à un canal de la pluralité de canaux et correspondant au taux d'un nombre d'échanges de trame sur un nombre total d'échanges de trame, et où identifier la séquence de canaux préférés comprend d'identifier la séquence de canaux préférés parmi la pluralité de canaux sur la base des indicateurs d'intensité de signal reçu et des mesures d'échange de trame.

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15. Procédé selon l'une quelconque des revendications 11 à 14, dans lequel les indicateurs de qualité de canal comprennent des indicateurs d'historiques de performance, chacun associé à un canal de la pluralité de canaux et indicatif d'un historique de l'indicateur de qualité de canal de ce canal, et où identifier la séquence de canaux préférés comprend d'identifier le ou les canaux préférés parmi la pluralité des canaux sur la base des indicateurs d'intensité de signal reçu et des indicateurs d'historiques de performance.

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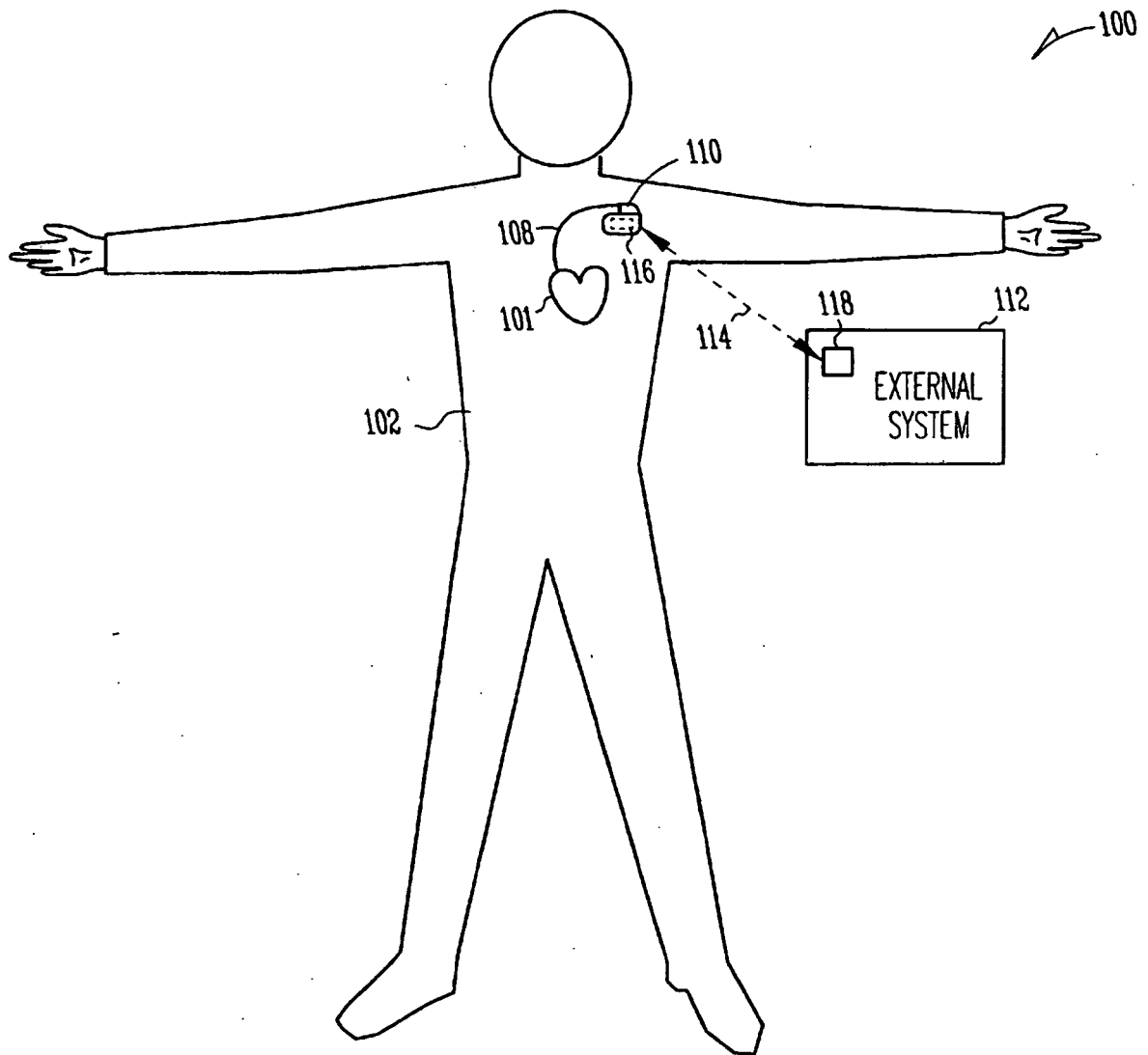


Fig. 1

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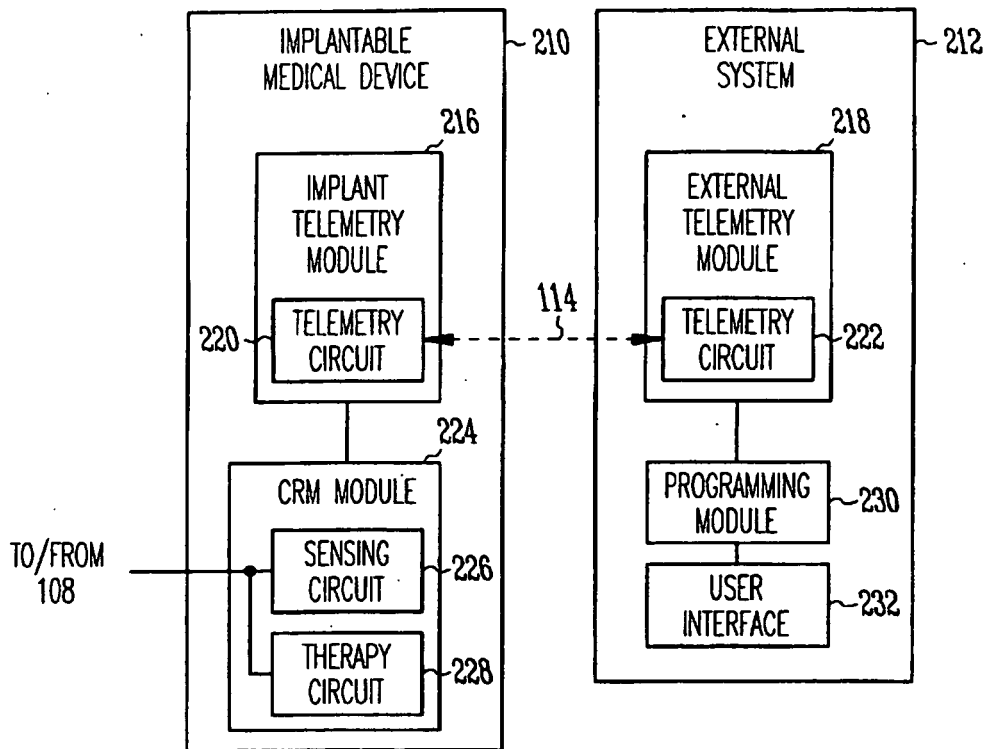


Fig. 2

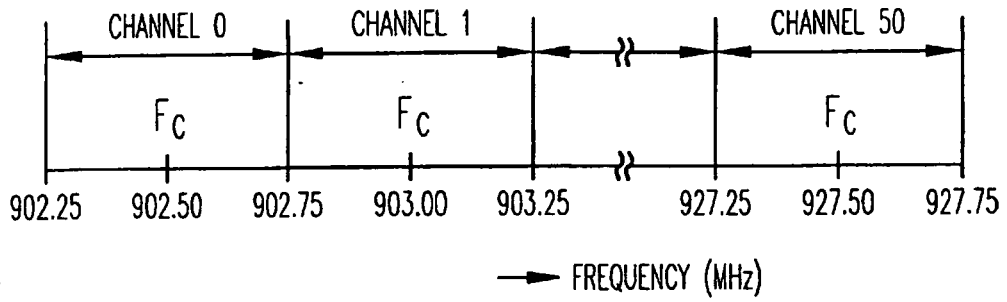


Fig. 3

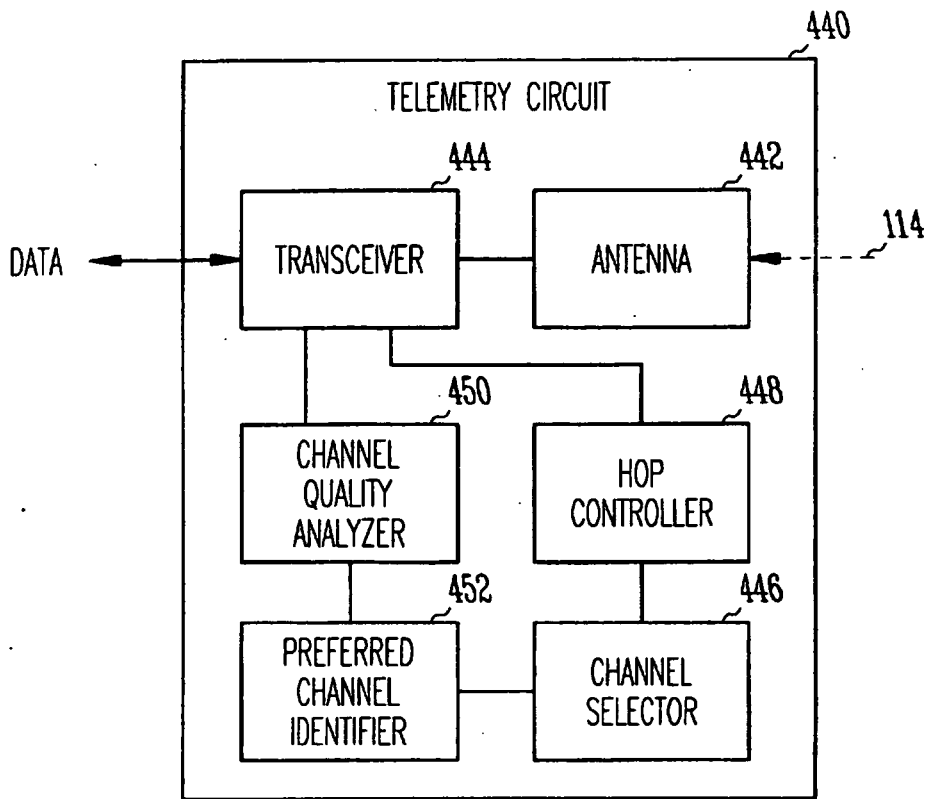


Fig. 4

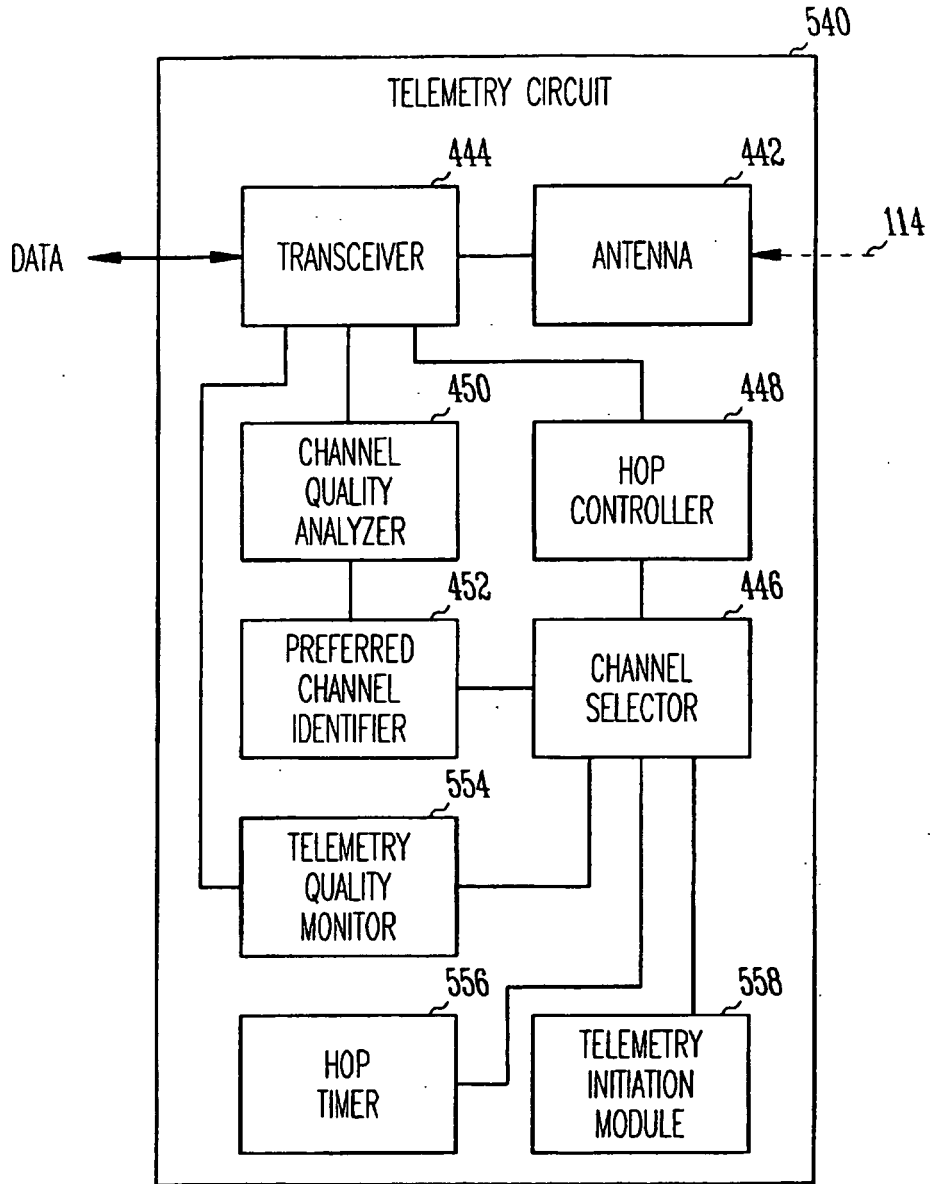


Fig. 5

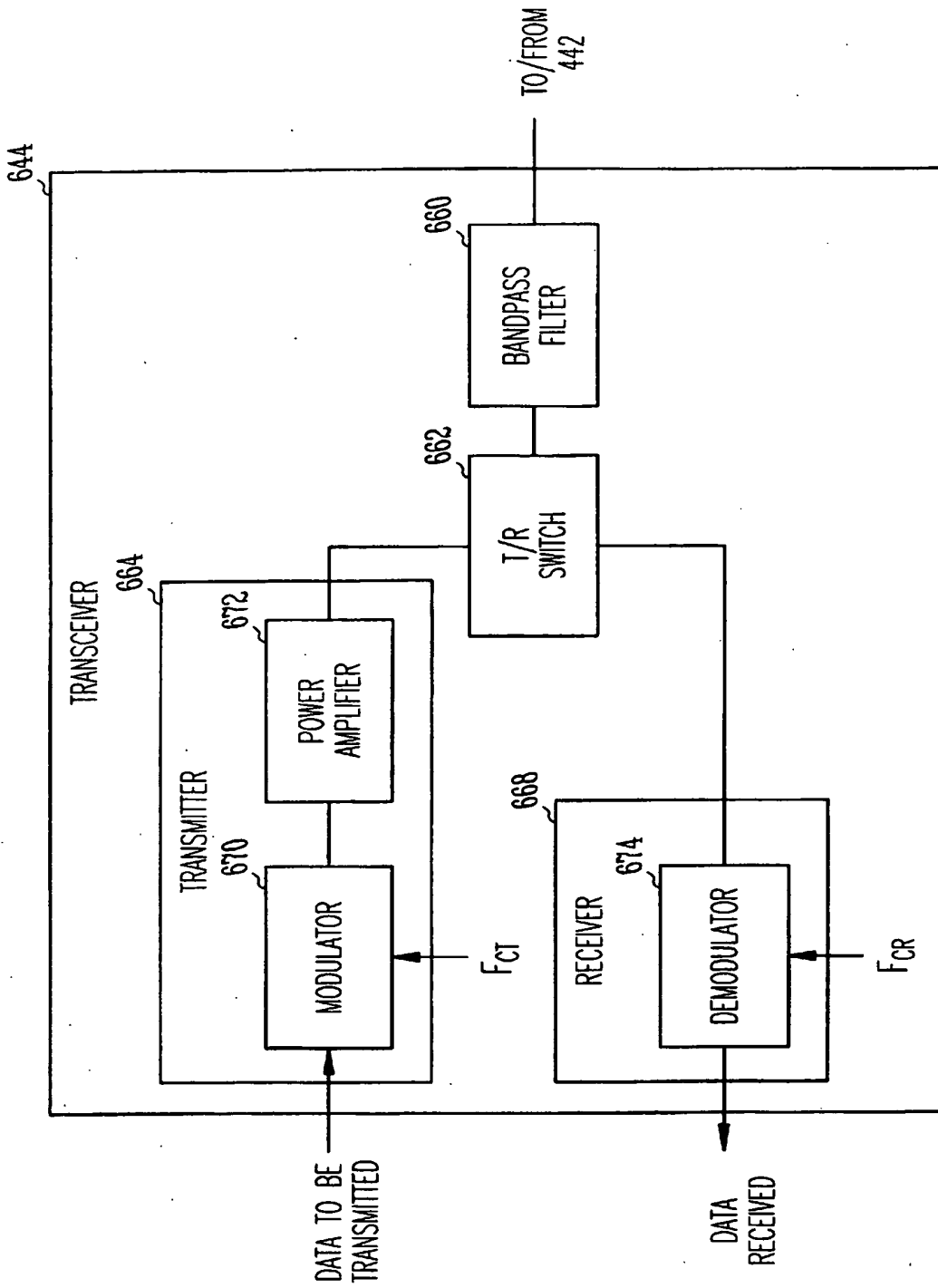


Fig. 6

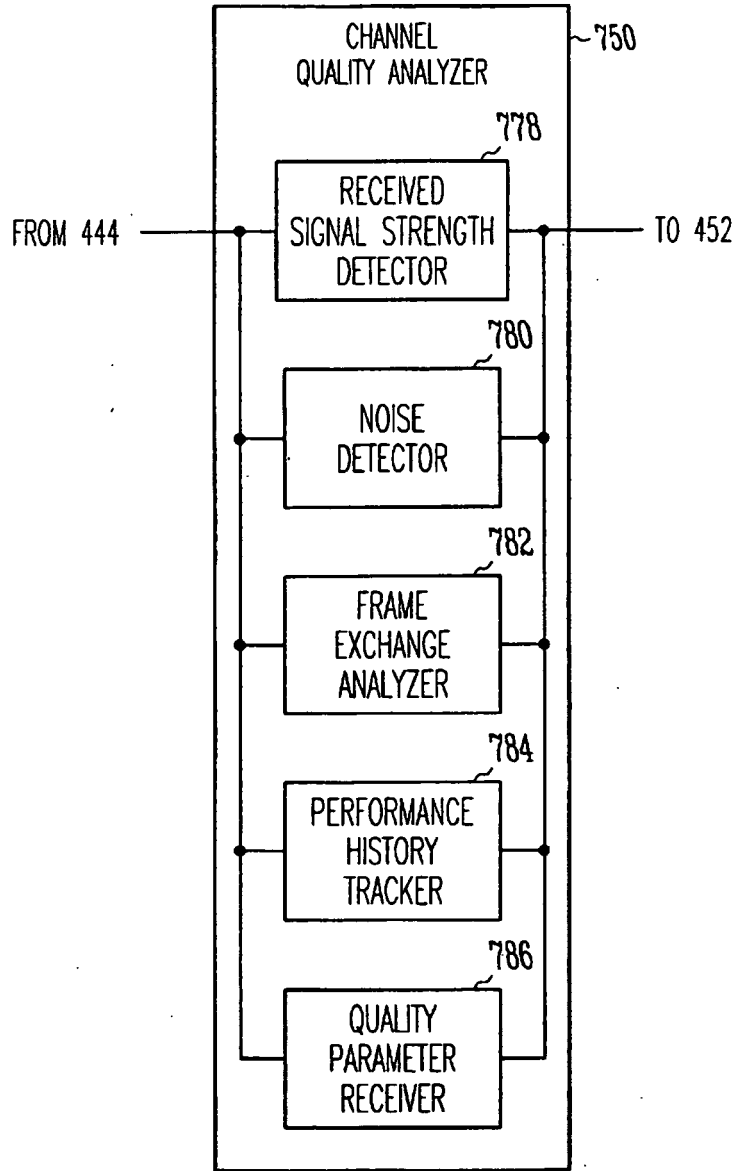


Fig. 7

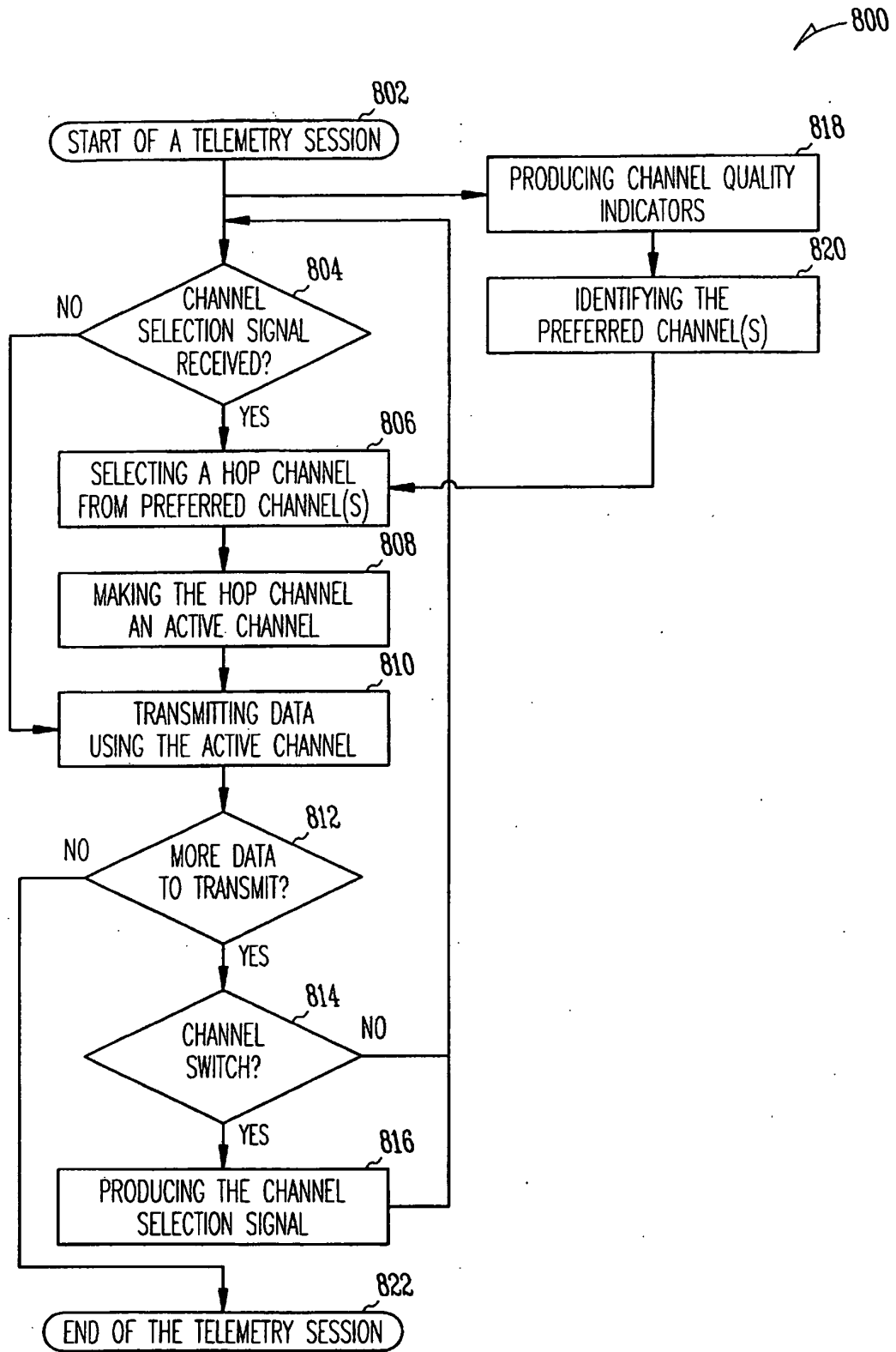


Fig. 8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 6978181 B [0007]
- US 7218969 B [0036]

Non-patent literature cited in the description

- **N. GOLMIE et al.** Bluetooth and WLAN Coexistence: Challenges and Solution. *IEEE Wireless Communications*, 2003, 22-29 [0008]

专利名称(译)	具有自适应跳频的植入式设备遥测		
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申请(专利权)人(译)	心脏起搏器, INC.		
当前申请(专利权)人(译)	心脏起搏器, INC.		
[标]发明人	BANGE JOSEPH E VALLAPUREDDY VINEEL		
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摘要(译)

远场射频 (RF) 遥测系统使用从多个信道中选择的有源信道在可植入医疗设备和外部系统之间传输数据, 每个信道代表预定频率范围内的频带。基于为每个信道产生的信道质量指示符, 从多个信道中识别一个或多个优选信道。当需要信道跳跃时, 从一个或多个优选信道中选择跳信道并成为活动信道。

