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Multi-antenna array-based charging system for implantable electronic medical equipment

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ABSTRACT

A multi-antenna array-based charging system for implantable electronic medical equipment comprises a multi-antenna array transmission module and an implantable charging module. The multi-antenna array transmission module comprises a clock distribution system, eight universal software radio peripherals, eight power amplifiers and eight RFID antennas. A radio-frequency daughter board is configured in each universal software radio peripheral, and the transmitting frequencies of the eight radio-frequency daughter boards are set to be different respectively by means of the corresponding universal software radio peripherals. A beam forming algorithm is installed in a UHD driver of each universal software radio peripheral. The clock distribution system synchronously provides eight clock signals. The eight universal software radio peripherals are connected to the eight power amplifiers in a one-to-one correspondence manner. The eight power amplifiers are connected to the eight RFID antennas in a one-to-one correspondence manner. The implantable charging module is realized by a micro RFID tag. The multi-antenna array-based charging system has the advantages of being free of potential safety hazards and high in charging efficiency.

FIG. 2

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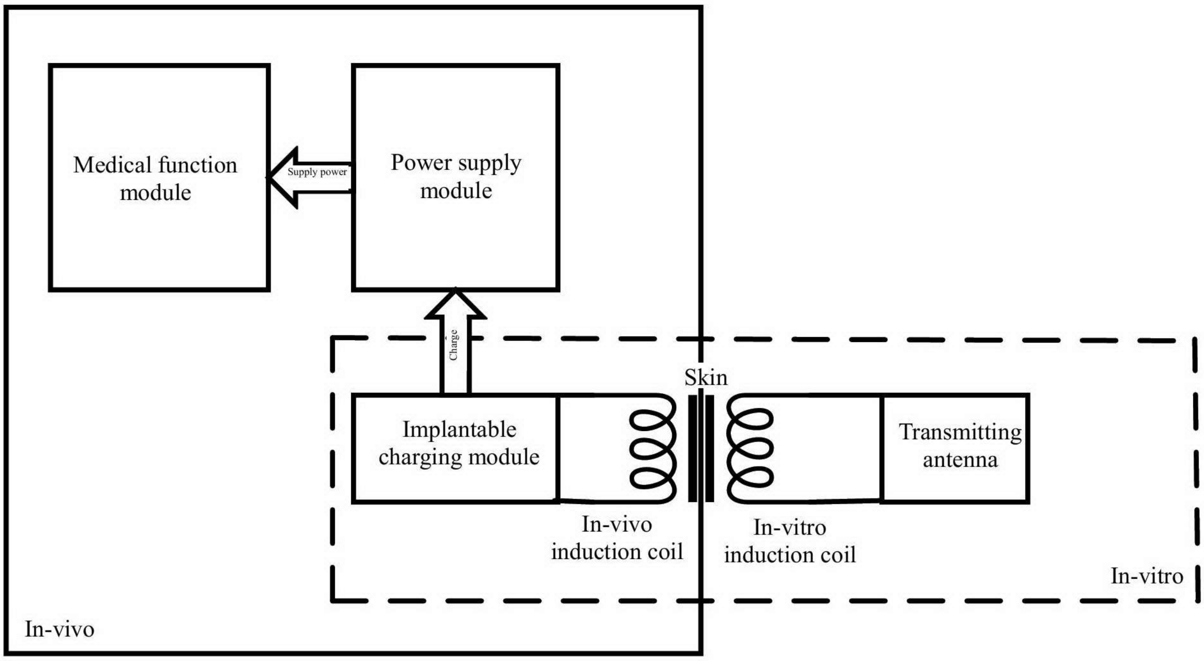

FIG. 1

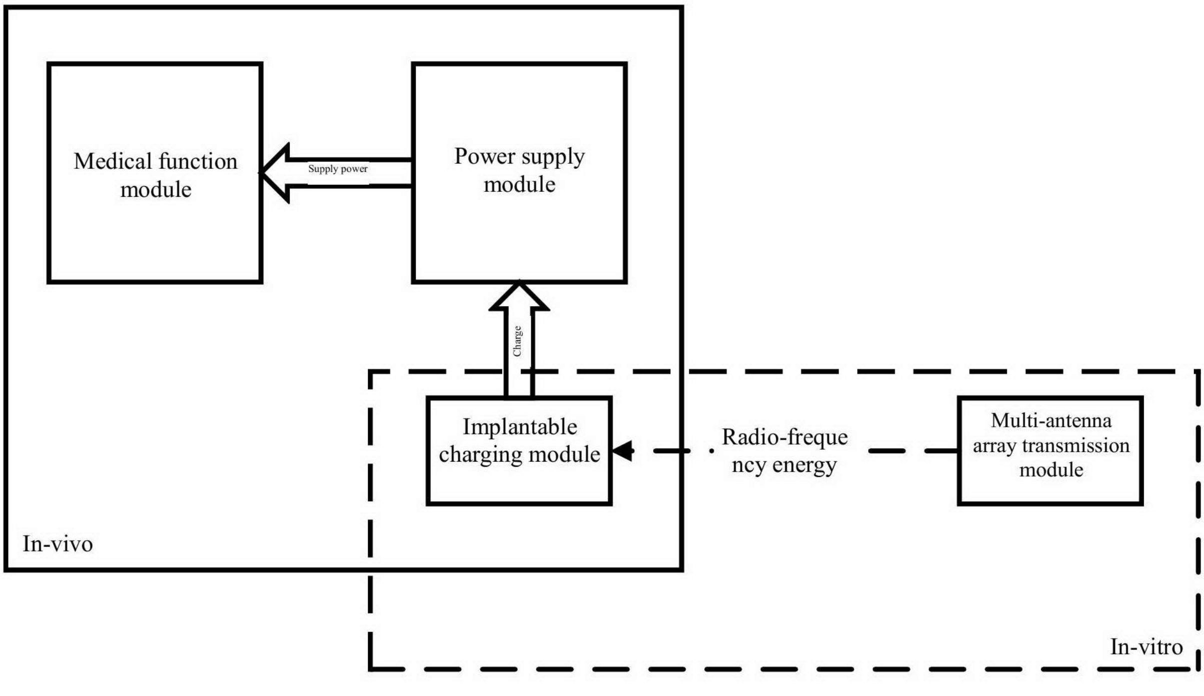

FIG. 2

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MULTI-ANTENNA ARRAY-BASED CHARGING SYSTEM FOR IMPLANTABLE ELECTRONIC MEDICAL EQUIPMENT

TECHNICAL FIELD

[0001] The invention relates to a charging system for implantable electronic medical equipment, in particular to a multi-antenna array-based charging system for implantable electronic medical equipment.

DESCRIPTION OF RELATED ART

[0002] In recent years, implantable electronic medical equipment has gradually replaced traditional portable electronic medical equipment to become medical development and research trending around the world. Compared with the traditional portable electronic medical equipment, the implantable electronic medical equipment is more ingenious in appearance or more convenient to use, can monitor the physical condition of patients in real time, and even can predict diseases. For example, an implantable cardiac pacemaker is an electronic treatment instrument to be implanted in the body of patients and discharges electric pulses through a pulse generator powered by a battery, wherein the electric pulses are transmitted to an electrode through a wire to stimulate cardiac muscles in contact with the electrode to excite or contract the heart to treat some heart dysfunctions caused by arrhythmia and to prevent heart diseases such as paroxysmal atrial tachyarrhythmia and carotid sinus syncope.

[0003] Traditional implantable electronic medical equipment typically includes two parts: a medical function module and a power supply module. Both the medical function module and the power supply module are implanted in the body of a patient, the medical function module fulfills a specific medical function, and the power supply module supplies power to the medical function module. The power supply module of the implantable electronic medical equipment is constituted by a single battery, which has to be replaced when running out of power. However, the battery in the implantable electronic medical equipment cannot be replaced as easily as a battery in consumer electronic equipment, and because the battery is implanted in the body of the patient, the patient has to undergo a surgery to replace the battery. For the patient, this is another painful experience and even may cause the risk of infection. In addition, the battery contains toxic substances, and once these toxic substances leak, the health of the patient will be endangered. The approach of prolonging the battery life by increasing the capacity of the battery will enlarge the size of the battery, which in turn increases the size of the implantable electronic medical equipment and affects the overall design and performance. How to prolong the battery life under the precondition of a small size of the battery to protect the patients against injuries caused by frequency replacement of the battery has become a problem of the implantable electronic medical equipment urgently to be solved at present.

[0004] At present, some researchers have put forward the solution to guaranteeing the sufficient capacity of the battery by charging so as to avoid frequent replacement of the battery. As shown in FIG. 1, existing implantable electronic medical equipment typically comprises three parts: a medical function module, a power supply module based on a battery, and a charging system for charging the battery. The charging system has two parts, wherein one part is formed by an in-vivo charging module and an in-vivo induction coil, and the other part is formed by an in-vitro radio-frequency antenna and an in-vitro induction coil. The charging module is connected to the power supply module. When the battery is charged, the in-vitro induction coil is attached to the skin surface of a patient, is located over the in-vivo induction coil and is parallel to the in-vivo induction coil, a radio-frequency signal generated by a transmitting antenna enters the in-vitro induction coil to generate an alternating magnetic field, the in-vivo induction coil senses alternating currents generated by the alternating magnetic field, and the implantable charging module converts the alternating currents into direct currents to charge the power supply module. The in-vitro induction coil needs to be closely attached to the body of the patient when the charging system of the existing implantable electronic medical equipment is used for charging the battery, so that the in-vitro induction coil will inevitably generate heat and will scald human tissue in close contact with the in-vitro induction coil when excessive heat is generated, thus resulting in potential safety hazards. In addition, only when the in-vitro induction coil is kept in parallel with the in-vivo induction coil, the in-vivo induction coil can generated large alternating currents to guarantee the high charging efficiency of the charging system. However, due to the particularity of the body of the patient, it is very difficult to keep the in-vitro induction coil in parallel with the in-vivo induction coil in actual operation, so the charging efficiency is low.

BRIEF SUMMARY OF THE INVENTION

[0005] The technical issue to be settled by the invention is to provide a multi-antenna array-based charging system for implantable electronic medical equipment, which is free of potential safety hazards and is high in charging efficiency.

[0006] The technical solution adopted by the invention to settle the aforesaid technical issue is as follows: a multi-antenna array-based charging system for implantable electronic medical equipment comprises an in-vitro multi-antenna array transmission module and an in-vivo implantable charging module, wherein the multi-antenna array transmission module comprises a clock distribution system, eight universal software radio peripherals, eight power amplifiers and eight RFID antennas; a radio-frequency daughter board is configured in each universal software radio peripheral, the transmitting frequencies of the eight radio-frequency daughter boards are set to 915MHz, 922MHz, 935MHz, 964MHz, 983MHz, 988MHz, 1005MHz and 1028MHz respectively by means of the corresponding universal software radio peripherals, a beam forming algorithm is installed in a UHD driver of each universal software radio peripheral, the eight universal software radio peripherals are separately connected to the clock distribution system, the clock distribution system synchronously provides eight clock signals which are input to the eight universal software radio peripherals in a one-to-one correspondence manner to serve as synchronous reference signals, the eight universal software radio peripherals are connected to the eight power amplifiers in a one-to-one correspondence manner, the eight power amplifiers are connected to the eight RFID antennas in a one-to-one correspondence manner, and the implantable charging module is realized by a micro RFID tag;

[0007] When the power supply module is charged, the clock distribution system generates eight clock signals to control the eight universal software radio peripherals and synchronously drive the eight radio-frequency daughter boards configured on the eight universal software radio peripherals, the eight radio-frequency daughter boards each synchronously generate a radio-frequency signal according to the transmitting frequencies, the universal software radio peripherals transmit the radio-frequency signals generated by the corresponding radio-frequency daughter boards to the power amplifiers connected to universal software radio peripherals, the eight power amplifiers amplify the radio-frequency signals transmitted thereto and then transmit the amplified radio-frequency signals to the RFID antennas connected to the power amplifiers, the eight RFID antennas transmit the radio-frequency signals transmitted thereto to an external environment, at this moment, eight radio-frequency transmission signals are generated in the external environment, the universal software radio peripherals and the micro RFID tag capture the eight radio-frequency transmission signals from the external environment, and each universal software radio peripheral selects one corresponding radio-frequency transmission signal from the eight radio-frequency transmission signals and carries out a direction adjustment on the corresponding radio-frequency transmission signal through the beam forming algorithm installed in the universal software radio peripheral until the transmitting direction of the radio-frequency transmission signal aims at the micro RFID tag, so that the directions of the eight radio-frequency transmission signals captured by the micro RFID tag are adjusted to maximize radio-frequency energy acquired by the micro RFID tag, and the micro RFID tag converts the radio-frequency energy into a direct voltage to charge the power supply module.

[0008] The clock distribution system is a CDA-2900 Octoclock high-precision clock source produced by Ettus, the eight universal software radio peripherals are USRPs N210 (Universal Software Radio Peripherals N210) produced by Ettus, the eight power amplifiers are HMC453QS16 power amplifiers produced by ADI Devices, the eight RFID antennas are MT242025 RFID antennas produced by MTI, the radio-frequency daughter boards are SBX-40 radio-frequency daughter boards produced by Ettus, and the micro RFID tag is a Dash-On XS RFID tag produced by Xerafy.

[0009] Compared with the prior art, the invention has the following advantages: an in-vitro multi-antenna array transmission module and an in-vivo implantable charging module are configured, wherein the multi-antenna array transmission module comprises a clock distribution system, eight universal software radio peripherals, eight power amplifiers and eight RFID antennas; a radio-frequency daughter board is configured in each universal software radio peripheral, the transmitting frequencies of the eight radio-frequency daughter boards are set to 915MHz, 922MHz, 935MHz, 964MHz, 983MHz, 988MHz, 1005MHz and 1028MHz respectively by means of the corresponding universal software radio peripherals, a beam forming algorithm is installed in a UHD driver of each universal software radio peripheral, the eight universal software radio peripherals are separately connected to the clock distribution system, the clock distribution system synchronously provides eight clock signals which are input to the eight universal software radio peripherals in a one-to-one correspondence manner to serve as synchronous reference signals, the eight universal software radio peripherals are connected to the eight power amplifiers in a one-to-one correspondence manner, the eight power amplifiers are connected to the eight RFID antennas in a one-to-one correspondence manner, and the implantable charging module is realized by a micro RFID tag; when the power supply module is charged, the clock distribution system generates eight clock signals to control the eight universal software radio peripherals and synchronously drive the eight radio-frequency daughter boards configured on the eight universal software radio peripherals, the eight radio-frequency daughter boards each synchronously generate a radio-frequency signal according to the transmitting frequencies, the universal software radio peripherals transmit the radio-frequency signals generated by the corresponding radio-frequency daughter boards to the power amplifiers connected to universal software radio peripherals, the eight power amplifiers amplify the radio-frequency signals transmitted thereto and then transmit the amplified radio-frequency signals to the RFID antennas connected to the power amplifiers, the eight RFID antennas transmit the radio-frequency signals transmitted thereto to an external

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environment, at this moment, eight radio-frequency transmission signals are generated in the external environment, the universal software radio peripherals and the micro RFID tag capture the eight radio-frequency transmission signals from the external environment, and each universal software radio peripheral selects one corresponding radio-frequency transmission signal from the eight radio-frequency transmission signals and carries out a direction adjustment on the corresponding radio-frequency transmission signal through the beam forming algorithm installed in the universal software radio peripheral until the transmitting direction of the radio-frequency transmission signal aims at the micro RFID tag, so that the directions of the eight radio-frequency transmission signals captured by the micro RFID tag are adjusted to maximize radio-frequency energy acquired by the micro RFID tag, and the micro RFID tag converts the radio-frequency energy into a direct voltage to charge the power supply module. In this way, a multi-antenna array is constituted by the eight radio-frequency daughter boards, the eight power amplifiers and the eight RFID antennas, radio-frequency signals generated by the multi-antenna array can propagate within a broad range, so that direct contact with body tissue is avoided, and the potential safety hazard of scalding the body tissue is avoided; through the coordination of the eight universal software radio peripherals and the beam forming algorithm in each universal software radio peripheral, radio-frequency transmission signals transmitted by the eight universal software radio peripherals all aim at the micro RFID tag, that is, energy of the eight RFID antennas is focused on the micro RFID tag, so that the radio-frequency energy captured by the micro RFID tag is maximized, and the charging efficiency of the charging system is improved. Thus, the charging system provided by the invention is free of potential safety hazards and is high in charging efficiency.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0010] FIG. 1 is a structural block diagram of implantable electronic medical equipment adopting an existing charging system;

[0011] FIG. 2 is a structural block diagram of implantable electronic medical equipment adopting a charging system of the invention;

[0012] FIG. 3 is a structural diagram of a multi-antenna array-based charging system for implantable electronic medical equipment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0013] The invention will be described in further detail below in conjunction with the accompanying drawings and embodiments.

[0014] Embodiment: As shown in FIG. 2 and FIG. 3, a multi-antenna array-based charging system for implantable electronic medical equipment comprises an in-vitro multi-antenna array transmission module and an in-vivo implantable charging module, wherein the multi-antenna array transmission module comprises a clock distribution system, eight universal software radio peripherals (U1-U8), eight power amplifiers (V1-V8) and eight RFID antennas (N1-N8); a radio-frequency daughter board is configured in each universal software radio peripheral, the transmitting frequencies of the eight radio-frequency daughter boards are set to 915MHz, 922MHz, 935MHz, 964MHz, 983MHz, 988MHz, 1005MHz and 1028MHz respectively by means of the corresponding universal software radio peripherals, a beam forming algorithm is installed in a UHD driver of each universal software radio peripheral, the eight universal software radio peripherals are separately connected to the clock distribution system, the clock distribution system synchronously provides eight clock signals which are input to the eight universal software radio peripherals in a one-to-one correspondence manner to serve as synchronous reference signals, the eight universal software radio peripherals are connected to the eight power amplifiers in a one-to-one correspondence manner, the eight power amplifiers are connected to the eight RFID antennas in a one-to-one correspondence manner, and the implantable charging module is realized by a micro RFID tag; when the power supply module is charged, the clock distribution system generates eight clock signals to control the eight universal software radio peripherals and synchronously drive the eight radio-frequency daughter boards configured on the eight universal software radio peripherals, the eight radio-frequency daughter boards each synchronously generate a radio-frequency signal according to the transmitting frequencies, the universal software radio peripherals transmit the radio-

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frequency signals generated by the corresponding radio-frequency daughter boards to the power amplifiers connected to universal software radio peripherals, the eight power amplifiers amplify the radio-frequency signals transmitted thereto and transmit the amplified radio-frequency signals to the RFID antennas connected to the power amplifiers, the eight RFID antennas transmit the radio-frequency signals transmitted thereto to an external environment, at this moment, eight radio-frequency transmission signals are generated in the external environment, the universal software radio peripherals and the micro RFID tag capture the eight radio-frequency transmission signals from the external environment, each universal software radio peripheral selects one corresponding radio-frequency transmission signal from the eight radio-frequency transmission signals and caries out a direction adjustment on the corresponding radio-frequency transmission signal through the beam forming algorithm installed in the universal software radio peripheral until the transmitting direction of the radio-frequency transmission signal aims at the micro RFID tag, so that the directions of the eight radio-frequency transmission signals captured by the micro RFID tag are adjusted to maximize radio-frequency energy acquired by the micro RFID tag, and the micro RFID tag converts the radio-frequency energy into a direct voltage to charge the power supply module.

[0015] In this embodiment, the clock distribution system is a CDA-2900 Octoclock high-precision clock source produced by Ettus, the eight universal software radio peripherals are USRPs N210 (Universal Software Radio Peripherals N210) produced by Ettus, the eight power amplifiers are HMC453QS16 power amplifiers produced by ADI Devices, the eight RFID antennas are MT242025 RFID antennas produced by MTI, the radio-frequency daughter boards are SBX-40 radio-frequency daughter boards produced by Ettus, and the micro RFID tag is a Dash-On XS RFID tag produced by Xerafy.

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CLAIMS

1. A multi-antenna array-based charging system for implantable electronic medical equipment, comprising an in-vitro multi-antenna array transmission module and an in-vivo implantable charging module, wherein the multi-antenna array transmission module comprises a clock distribution system, eight universal software radio peripherals, eight power amplifiers and eight RFID antennas; a radio-frequency daughter board is configured in each said universal software radio peripheral, transmitting frequencies of the eight radio-frequency daughter boards are set to 915MHz, 922MHz, 935MHz, 964MHz, 983MHz, 988MHz, 1005MHz and 1028MHz respectively by means of the corresponding universal software radio peripherals, a beam forming algorithm is installed in a UHD driver of each said universal software radio peripheral, the eight universal software radio peripherals are separately connected to the clock distribution system, the clock distribution system synchronously provides eight clock signals which are input to the eight universal software radio peripherals in a one-to-one correspondence manner to serve as synchronous reference signals, the eight universal software radio peripherals are connected to the eight power amplifiers in a one-to-one correspondence manner, the eight power amplifiers are connected to the eight RFID antennas in a one-to-one correspondence manner, and the implantable charging module is realized by a micro RFID tag;

when the power supply module is charged, the clock distribution system generates eight clock signals to control the eight universal software radio peripherals and synchronously drive the eight radio-frequency daughter boards configured on the eight universal software radio peripherals, the eight radio-frequency daughter boards each synchronously generate a radio-frequency signal according to the transmitting frequencies, the universal software radio peripherals transmit the radio-frequency signals generated by the corresponding radio-frequency daughter boards to the power amplifiers connected to universal software radio peripherals, the eight power amplifiers amplify the radio-frequency signals transmitted thereto and then transmit the amplified radio-frequency signals to the RFID antennas connected to the power amplifiers, the eight RFID antennas transmit the radio-frequency signals transmitted thereto to an external environment, at this moment, eight radio-frequency transmission signals are generated in the external environment, the universal software radio peripherals and the micro RFID tag capture the eight radio-frequency transmission signals from the external environment, and each said universal software radio peripheral selects one corresponding radio-frequency transmission signal from the eight radio-frequency transmission signals and carries out a direction adjustment on the corresponding radio-frequency transmission signal through the beam forming algorithm installed in the universal software radio peripheral until a transmitting direction of the radio-frequency transmission signal aims at the micro RFID tag, so that the directions of the eight radio-frequency transmission signals captured by the micro RFID tag are adjusted to maximize radio-frequency energy acquired by the micro RFID tag, and the micro RFID tag converts the radio-frequency energy into a direct voltage to charge the power supply module.

2. The multi-antenna array-based charging system for implantable electronic medical equipment according to Claim 1, wherein the clock distribution system is a CDA-2900 Octoclock high-precision clock source produced by Ettus, the eight universal software radio peripherals are USRPs N210 (Universal Software Radio Peripherals N210) produced by Ettus, the eight power amplifiers are HMC453QS16 power amplifiers produced by ADI Devices, the eight RFID antennas are MT242025 RFID antennas produced by MTI, the radio-frequency daughter boards are SBX-40 radio-frequency daughter boards produced by Ettus, and the micro RFID tag is a Dash-On XS RFID tag produced by Xerafy.

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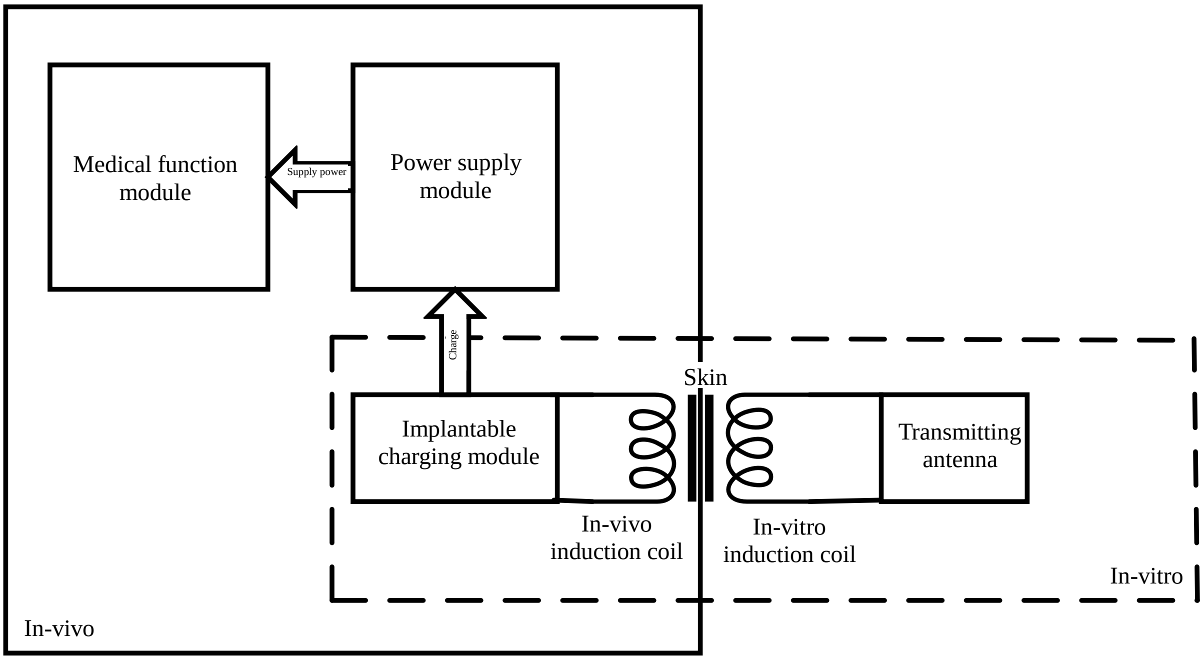

FIG. 1

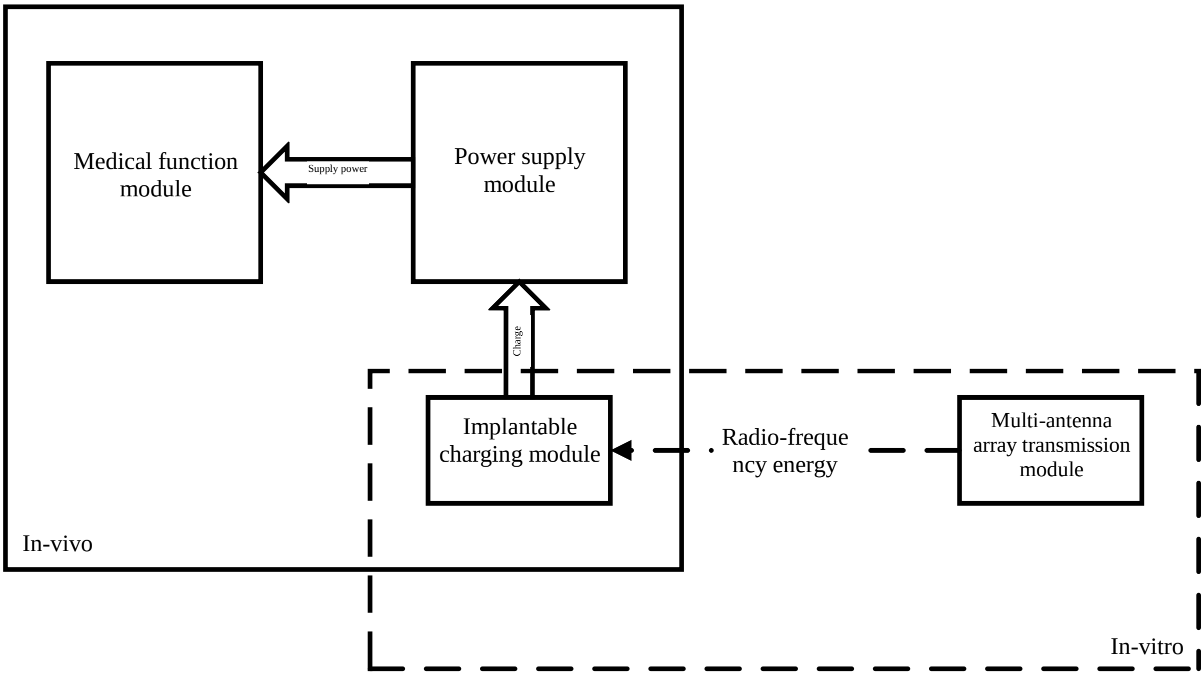

FIG. 2

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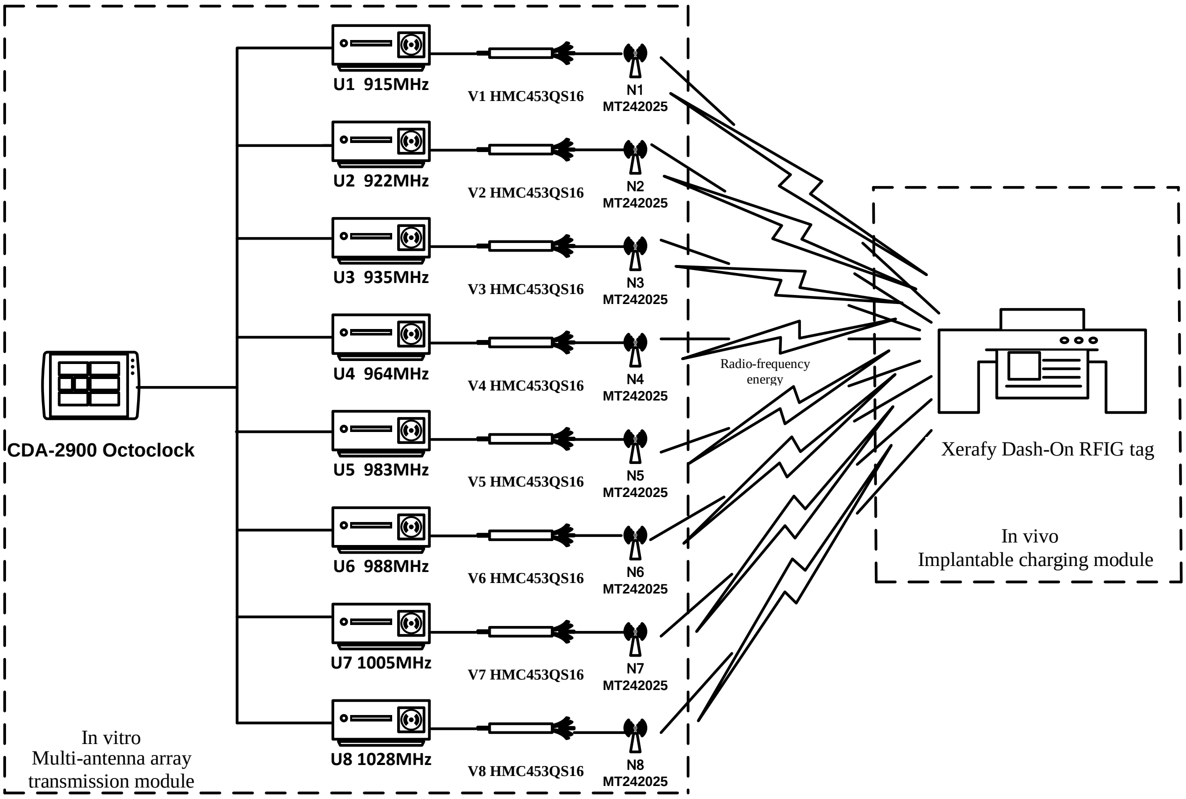

FIG. 3