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(54) **Underground Magnetic-induction Wireless Communication Device and Method.**

(57) The present invention relates to an underground magnetic-induction wireless communication device and a method. The device transmits information through a quasi-static magnetic field, namely a "magnetic channel", between transceiving antennae in an underground environment by magnetic-induction wireless communication technology instead of the traditional electromagnetic wave wireless communication technology, thereby improving the information transmission reliability due to stable communication channel and no multipath loss. Each of the transceiving antennae is of spherical structure and consists of three identical conductor coils that are independent of each other and perpendicular to each other. When transmitting a signal, the three coils together generate an alternating three- dimensional magnetic field, and when receiving a signal, the three coils induce magnetic field information from different directions. Therefore, the transceiving antennae can transmit information at any angle without influence from coupling angles, and the communication distance can be increased by receiving through the three coils.

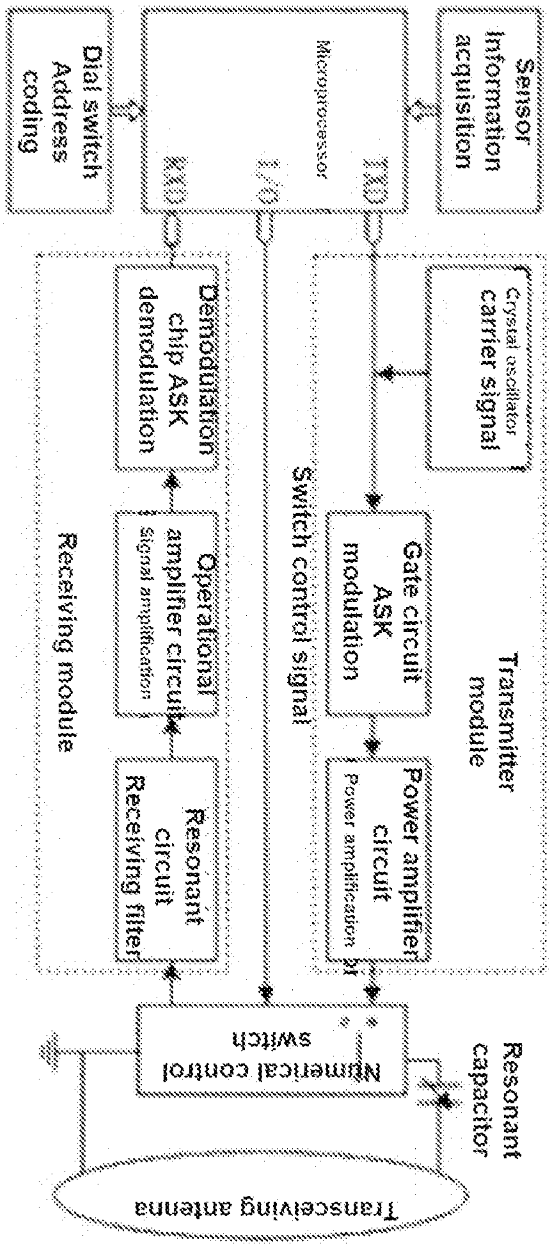

Fig. 1

DESCRIPTION

Underground Magnetic-induction Wireless Communication Device and Method

TECHNICAL FIELD

The present invention belongs to the technical field of underground wireless communication, and relates to an underground magnetic-induction wireless communication device and a method.

BACKGROUND

Wireless underground sensor network is an important emerging technology field developed on the basis of traditional wireless sensor network, which is widely used in many fields such as intelligent agriculture, mine rescue, geological disaster prediction and underground pipe network monitoring. Underground wireless communication technology is the key technology in the development of wireless underground sensor networks.

The communication mode commonly used in traditional wireless sensor networks is electromagnetic wave wireless communication technology. The information transmission medium in wireless underground sensor networks has changed from air to a composite medium such as soil, sand and water. Electromagnetic wave wireless communication is facing severe challenges, mainly including high path loss, unstable channel and large antenna size. Therefore, electromagnetic wave wireless communication technology is not suitable for underground environment, and development of a new underground wireless communication technology is an urgent need for the development of underground wireless sensor networks.

In order to solve the problems arising from electromagnetic wave communication for data transmission in composite media in complex environment such as underground and mines, researchers have proposed a Magnetic-Induction (MI) wireless communication method. MI wireless communication based on the basic principle of Faraday’s law of electromagnetic induction realizes wireless information transmission through the coupling of a quasi-static magnetic field between transceiving antennae. Since the permeability of transmission media such as soil, sand and water is basically the same, the magnetic channel is stable without multipath loss and oversized antenna. Therefore, MI wireless communication is more suitable for wireless underground sensor networks than electromagnetic wave wireless communication. The theory of MI wireless communication has been well established and verified in laboratory. In practice, the MI coupled wireless communication system based on transceiving coils is the simplest way, but single coils will be influenced by the coupling angle between coils while transceiving signals, which limits the application range of MI wireless communication.

SUMMARY

In order to solve the existing problems of wireless communication technology in complex underground environment, the present invention provides an underground magnetic-induction wireless communication device and a method. A transceiving antenna thereof is of spherical structure and consists of three conductor coils perpendicular to each other. With simple structure, stable channel and no influence of coupling angles on transceiving signals, the device can adapt to complex and changeable underground environment, and has good feasibility and broad application prospects in wireless underground sensor networks.

In order to solve the technical problems, the present invention provides an underground magnetic-induction wireless communication device, comprising a plurality of wireless communication units, wherein wireless signal transmission is realized between adjacent wireless communication units; each of the wireless communication units consists of a microprocessor, a transmitter module, a receiver module and a transceiving antenna, wherein the microprocessor is sequentially connected with the transmitter module, the transceiving antenna, the receiver module and the microprocessor to form a signal transmission loop; the transceiving antenna is provided with a numerical control switch, the transmitter module and the receiver module are both connected with the transceiving antenna through the numerical control switch, and the microprocessor realizes receiving and transmitting conversion for the transceiving antenna through the numerical control switch; the transceiving antenna is of spherical structure, and consists of three vertically intersecting conductor coils with the same diameter and coincident centers; during installation, the wireless communication units are arranged in sequence along a signal transmission direction, and center of the transceiving antenna is kept on the same horizontal line to form a magnetic channel; during communication, the microprocessor loads a signal from the transmitter module onto the transceiving antenna, and the transceiving antenna is in a transmitting state to transmit the signal to the next wireless communication unit, while the transceiving antenna of the next wireless communication unit is in a receiving state to receive the signal, and the received signal is transmitted by the receiver module to the corresponding microprocessor for processing.

The microprocessor uses a low-power ARM chip, and the microprocessor is connected with sensors for acquiring environmental information; in addition, the microprocessor is connected with a dial switch for node address coding, and node address is read in through an I/O port of the microprocessor during power-on.

Each of the wireless communication units is provided with signal modulation and demodulation circuits in a 2ASK modulation and demodulation mode, wherein the modulation circuit is arranged in the transmitter module and the demodulation circuit is arranged in the receiver module; in a signal modulation part, information acquired by the sensors is encoded through a UART serial port built in the microprocessor to generate a baseband signal, a crystal oscillator is used to generate a carrier signal, and the baseband signal and the carrier signal are subjected to 2ASK modulation through a NAND circuit; in a signal demodulation part, center frequency of a frequency selection circuit is set through an external timing resistor and a capacitor of the demodulation chip, and the received signal passes through the frequency selection circuit of the demodulation chip to convert the carrier signal into a 0/1 baseband signal, thus realizing 2ASK demodulation.

The transmitter module comprises a signal modulation circuit and a power amplifier circuit, wherein the power amplifier circuit is a resonant power amplifier circuit composed of a high power triode, and a modulated signal is loaded onto the transceiving antenna through the power amplifier circuit.

The receiver module comprises a signal amplifier circuit, a narrowband filter circuit and a signal demodulation circuit, wherein the signal amplifier circuit is composed of a low-noise triode, the received signal is connected to the demodulation chip after two-stage amplification, and a narrowband phase-locked loop and a transistor switch inside the demodulation chip complete signal demodulation while performing narrowband filtering on the input signal.

The conductor coils are wound by copper wires, with resonant capacitors connected in parallel at both ends to improve the transceiving efficiency, wherein the coils are independent of each other, and the radius and number of turns are determined by the service environment. Resonant capacitors are connected in parallel at both ends to improve the transceiving efficiency. The resonant capacitance C is determined by the measured inductance L of the coils and the signal transmission frequency f based on a calculation formula that the transmitter module and the receiver module are connected with the spherical antenna through the numerical control switch, and the numerical control switch can be controlled by the microprocessor to realize switching between data transmitting and receiving.

A communication method of the underground magnetic-induction wireless communication device, characterized in that signals at both communication terminals are transmitted in the form of magnetic signals, and the magnetic channel formed by the transceiving antennae transmits and receives the magnetic signals, and the specific steps are as follows:

1) an original baseband signal at a transmitting terminal is modulated and amplified to generate an alternating sine wave signal I1=I0e-jwt, and the I1 is loaded onto the three conductor coils of the transmitting antenna at the same time, generating an alternating magnetic field around each conductor coil, and the three mutually orthogonal conductor coils together generate an alternating three-dimensional magnetic field, at which time electrical signals are

converted into magnetic signals, and information is transmitted through the magnetic field; and

2) the receiving antenna at a receiving terminal is in an alternating magnetic field, the magnetic flux in the closed area of each conductor coil changes with the alternating magnetic field, sinusoidal signals I2, I'2, I"2 with the same phase features as the I1 are induced in the three conductor coils, the three mutually orthogonal conductor coils induce magnetic field information from different directions to convert magnetic signals into electrical signals, and the three-way electrical signals are superimposed by an adder and then amplified and demodulated to restore the original information.

Advantageous effects: The device provided by the present invention transmits information through a quasi-static magnetic field, namely a “magnetic channel”, between transceiving antennae in an underground environment by magnetic-induction wireless communication technology instead of the traditional electromagnetic wave wireless communication technology, thereby improving the information transmission reliability due to stable communication channel and no multipath loss. Each of the transceiving antennae is of spherical structure and consists of three identical conductor coils that are independent of each other and perpendicular to each other. When transmitting a signal, the three coils together generate an alternating three-dimensional magnetic field, and when receiving a signal, the three coils induce magnetic field information from different directions. Therefore, the transceiving antennae can transmit information at any angle without influence from coupling angles, and the communication distance can be increased by receiving through the three coils. Due to simple structure, flexible size and easy installation, the device can be used as both a data transmitting node and a data receiving node in a wireless underground sensor network, so as to facilitate two-way information transmission between nodes.

BRIEF DESCRIPTION OF THE FIGURES

Fig. 1 is a design block diagram of an underground magnetic-induction wireless communication system involved in the present invention.

Fig. 2 is a structural diagram of a magnetic-induction wireless transceiving antenna involved in the present invention.

Fig. 3 is a schematic diagram of 2ASK signal modulation and demodulation involved in the present invention.

Fig. 4 is a work flow chart of underground wireless sensor network nodes based on magnetic-induction wireless communication technology.

DESCRIPTION OF THE INVENTION

The preferred embodiments of the present invention will be further described with reference to the accompanying drawings.

As shown in Fig. 1, a wireless underground magnetic-induction communication device comprises a plurality of wireless communication units, wherein wireless signal transmission is realized between adjacent wireless communication units; each of the wireless communication units consists of a microprocessor, a transmitter module, a receiver module and a transceiving antenna, wherein the microprocessor is sequentially connected with the transmitter module, the transceiving antenna, the receiver module and the microprocessor to form a signal transmission loop; the transceiving antenna is provided with a numerical control switch, the transmitter module and the receiver module are both connected with the transceiving antenna through the numerical control switch, and the microprocessor realizes receiving and transmitting conversion for the transceiving antenna through the numerical control switch. During communication, the microprocessor loads a signal from the transmitter module onto the transceiving antenna, and the transceiving antenna is in a transmitting state to transmit the signal to the next wireless communication unit, while the transceiving antenna of the next wireless communication unit is in a receiving state to receive the signal, and the received signal is transmitted by the receiver module to the corresponding microprocessor for processing. The device can be used as both a data transmitting node and a data receiving node in a wireless sensor network.

The microprocessor uses an STM32 chip based on ARM core manufactured by STMicroelectronics. The chip is provided with rich peripheral resources and is connected with different types of sensors in the sensor network for acquiring environmental information such as temperature and humidity. The microprocessor is connected with a dial switch for node address coding, and node address is read in through an I/O port of the microprocessor during power-on. Transmitting terminal: the information acquired by the sensors is encoded by the microprocessor and then output by the serial port, the output digital signal is connected to the modulation circuit and then connected to the power amplifier circuit after ASK modulation. When a magnetic-induction signal is transmitted, the induced magnetic field intensity is proportional to the current. In order to obtain a higher transmitting current with less power consumption, a high-current triode 8550 is used to form a resonant (Class C) power amplifier circuit to amplify the modulated signal, and the amplified signal is connected to the transceiving antenna through the numerical control switch and transmitted. Receiving terminal: The antenna induces magnetic field information. When the communication distance is far, the received signal from antenna coupling is very weak. In order to extend the communication distance, a low noise triode 9014 is used to form a two-stage amplifier circuit to amplify the received signal at high magnification. The amplified signal is connected to the demodulation chip, and then connected to the microprocessor via a serial port after ASK demodulation, and the original information is decoded and read by the microprocessor.

$$f = 1/2\pi\sqrt{LC},$$

As shown in Fig. 2, the transceiving antenna is of spherical structure, and consists of three vertically intersecting conductor coils with the same diameter and coincident centers. During installation, the wireless communication units are arranged in sequence along a signal transmission direction, and center of the transceiving antenna is kept on the same horizontal line to form a magnetic channel. The conductor coils are wound by copper wires, with resonant capacitors connected in parallel at both ends to improve the transceiving efficiency, the radius and number of turns are determined by the service environment. The resonant capacitance C is determined by the measured inductance L of the coils and the signal transmission frequency f based on a calculation formula that the resonant capacitor is an adjustable capacitor to match transceiving antennae of different sizes. The device transmits information through a quasi-static magnetic field, namely a “magnetic channel”, between transceiving antennae. The original baseband signal at the transmitting terminal is modulated and amplified to generate an alternating sine wave signal I1 = I0e-jwt, and the I1 is loaded onto three conductor coils of the transmitting antenna at the same time. An alternating magnetic field will be generated around each conductor coil, and the three mutually orthogonal conductor coils will together generate an alternating three-dimensional magnetic field, an electrical signal is converted into a magnetic signal, and the information is transmitted through the magnetic field. The receiving antenna at a receiving terminal is in an alternating magnetic field, the magnetic flux in the closed area of each conductor coil changes with the alternating magnetic field, sinusoidal signals I2, I'2, I''2 with the same phase features as the I1 are induced in the three conductor coils, the three mutually orthogonal conductor coils induce magnetic field information from different directions to convert magnetic signals into electrical signals, and the three-way electrical signals are superimposed by an adder and then amplified and demodulated to restore the original information.

As shown in Fig. 3, the device transmits data at 100% energy by 2ASK modulation and demodulation, also known as On-Off Keying (OOK) modulation, with simple circuit and easy demodulation, thereby improving the system reliability. The microprocessor at the modulation terminal encodes the read node address information and the information acquired by the sensors to generate a baseband signal which is output through a serial port, a 250 KHZ crystal oscillator generates a carrier signal, and the baseband signal and the carrier signal realize 2ASK modulation through a 74HC00 NAND circuit; the demodulation terminal uses an integrated phase-locked loop chip LMC567, and center frequency of a frequency selection circuit is set through an external timing resistor and a capacitor, and the received signal passes through the frequency selection circuit of the demodulation chip to convert the carrier signal into a 0/1 baseband signal, thus realizing 2ASK demodulation.

An embodiment of an underground magnetic-induction wireless communication method of the present invention will be further described with reference to embodiments and the working process of the present invention in Fig. 4. The present invention provides an underground magnetic-induction wireless communication method designed for underground environment, which is mainly used for wireless underground sensor networks. In wireless underground self-organized sensor networks, the device can be used as both a data transmitting node and a data receiving node to realize half-duplex communication between nodes. Taking an intelligent agriculture sensor network as an example, the device is buried in the soil and connected to different types of sensors to acquire soil temperature, humidity and other information. Fig. 4 is a flow chart of monitoring nodes, comprising the following steps:

step 1. powering on a monitoring node system, performing initialization settings, including microprocessor initialization and sensor initialization, reading in node address, turning on a timer, and entering a receiving mode;

step 2. determining whether there is information to be received in the receiving mode, and keeping waiting for receiving if there is no information to be received; if there is information to be received, receiving the information and extracting receiving address information, determining whether the information is data transmitted to the node by the receiving address information, if so, reading, saving and displaying the data, if not, switching to the transmitting mode to forward the information, then switching back to the receiving mode and keeping waiting for receiving; and

step 3: if the timer counts up to 5 s during waiting for receiving (the timing time is set according to the application requirements), waking up the sensor to acquire environmental information such as temperature and humidity, switching to the transmitting mode after the information is acquired, transmitting the acquired information and transceiving address information, then switching back to the receiving mode and entering a waiting for receiving state.

CLAIMS

1. An underground magnetic-induction wireless communication device, characterized by comprising a plurality of wireless communication units, wherein wireless signal transmission is realized between adjacent wireless communication units; each of the wireless communication units consists of a microprocessor, a transmitter module, a receiver module and a transceiving antenna, wherein the microprocessor is sequentially connected with the transmitter module, the transceiving antenna, the receiver module and the microprocessor to form a signal transmission loop; the transceiving antenna is provided with a numerical control switch, the transmitter module and the receiver module are both connected with the transceiving antenna through the numerical control switch, and the microprocessor realizes receiving and transmitting conversion for the transceiving antenna through the numerical control switch; the transceiving antenna is of spherical structure, and consists of three vertically intersecting conductor coils with the same diameter and coincident centers; during installation, the wireless communication units are arranged in sequence along a signal transmission direction, and center of the transceiving antenna is kept on the same horizontal line to form a magnetic channel; during communication, the microprocessor loads a signal from the transmitter module onto the transceiving antenna, and the transceiving antenna is in a transmitting state to transmit the signal to the next wireless communication unit, while the transceiving antenna of the next wireless communication unit is in a receiving state to receive the signal, and the received signal is transmitted by the receiver module to the corresponding microprocessor for processing.

2. The underground magnetic-induction wireless communication device according to claim 1, characterized in that the microprocessor uses a low-power ARM chip, and the microprocessor is connected with sensors for acquiring environmental information; in addition, the microprocessor is connected with a dial switch for node address coding, and node address is read in through an I/O port of the microprocessor during power-on.

3. The underground magnetic-induction wireless communication device according to claim 1, characterized in that each of the wireless communication units is provided with signal modulation and demodulation circuits in a 2ASK modulation and demodulation mode, wherein the modulation circuit is arranged in the transmitter module and the demodulation circuit is arranged in the receiver module; in a signal modulation part, information acquired by the sensors is encoded through a UART serial port built in the microprocessor to generate a baseband signal, a crystal oscillator is used to generate a carrier signal, and the baseband signal and the carrier signal are subjected to 2ASK modulation through a NAND circuit; in a signal demodulation part, center frequency of a frequency selection circuit is set through an external timing resistor and a capacitor of the demodulation chip, and the received signal passes through the frequency selection circuit of the demodulation chip to convert the carrier signal into a 0/1 baseband signal, thus realizing 2ASK demodulation.

4. The underground magnetic-induction wireless communication device according to claim 1 or 3, characterized in that the transmitter module comprises a signal modulation circuit and a power amplifier circuit, wherein the power amplifier circuit is a resonant power amplifier circuit composed of a

high power triode, and a modulated signal is loaded onto the transceiving antenna through the power amplifier circuit.

5. The underground magnetic-induction wireless communication device according to claim 1 or 3, characterized in that the receiver module comprises a signal amplifier circuit, a narrowband filter circuit and a signal demodulation circuit, wherein the signal amplifier circuit is composed of a low-noise triode, the received signal is connected to the demodulation chip after two-stage amplification, and a narrowband phase-locked loop and a transistor switch inside the demodulation chip complete signal demodulation while performing narrowband filtering on the input signal.

6. The underground magnetic-induction wireless communication device according to claim 1, characterized in that the conductor coils are wound by copper wires, with resonant capacitors connected in parallel at both ends to improve the transceiving efficiency, wherein the coils are independent of each other, and the radius and number of turns are determined by the service environment.

7. A communication method of the underground magnetic-induction wireless communication device according to any of claims 1-6, characterized in that signals at both communication terminals are transmitted in the form of magnetic signals, and the magnetic channel formed by the transceiving antennae transmits and receives the magnetic signals, and the specific steps are as follows:

1) an original baseband signal at a transmitting terminal is modulated and amplified to generate an alternating sine wave signal I1=I0e-jwt, and the I1 is loaded onto the three conductor coils of the transmitting antenna at the same

time, generating an alternating magnetic field around each conductor coil, and the three mutually orthogonal conductor coils together generate an alternating three-dimensional magnetic field, at which time electrical signals are converted into magnetic signals, and information is transmitted through the magnetic field; and

2) the receiving antenna at a receiving terminal is in an alternating magnetic field, the magnetic flux in the closed area of each conductor coil changes with the alternating magnetic field, sinusoidal signals I2, I'2, I''2 with the same phase features as the I1 are induced in the three conductor coils, the three mutually orthogonal conductor coils induce magnetic field information from different directions to convert magnetic signals into electrical signals, and the three-way electrical signals are superimposed by an adder and then amplified and demodulated to restore the original information.

PATENTANSPRÜCHE

1. Unterirdische drahtlose Kommunikationsvorrichtung mit Magnetinduktion ist dadurch gekennzeichnet, dass die mehrere drahtlosen Kommunikationseinheiten umfasst, wobei eine drahtlose Signalübertragung zwischen benachbarten drahtlosen Kommunikationseinheiten realisiert wird; jede der drahtlosen Kommunikationseinheiten aus einem Mikroprozessor, einem Sendemodul, einem Empfängermodul und einer Sende-/Empfangsantenne besteht, wobei der Mikroprozessor sequentiell mit dem Sendemodul, der Sende-/Empfangsantenne, dem Empfängermodul und dem Mikroprozessor verbunden ist, um eine Signalübertragungsschleife zu bilden; die Sende-/Empfangsantenne mit einem numerischen Steuerschalter versehen ist, das Sendemodul und das Empfängermodul beide über den numerischen Steuerschalter mit der Sende-/Empfangsantenne verbunden sind und der Mikroprozessor über den numerischen Steuerschalter eine Empfangs- und Sendeumsetzung für die Sende-/Empfangsantenne realisiert; die Sende-/Empfangsantenne hat eine kugelförmige Struktur und besteht aus drei sich vertikal kreuzenden Leiterspulen mit gleichem Durchmesser, wobei die Mittelpunkte der drei Leiterspulen zusammenfallen; bei der Installation werden die drahtlosen Kommunikationseinheiten nacheinander entlang einer Signalübertragungsrichtung angeordnet, das Zentrum der Sende-/Empfangsantenne wird auf der gleichen horizontalen Linie gehalten, um einen magnetischen Kanal zu bilden; bei der Kommunikation lädt der Mikroprozessor ein Signal vom Sendemodul auf die Sende-/Empfangsantenne, die Sende-/Empfangsantenne befindet sich in einem Sendezustand, um das Signal an die nächste drahtlose Kommunikationseinheit zu senden, während die Sende-/Empfangsantenne der nächsten drahtlosen Kommunikationseinheit in einem Empfangszustand ist, um das Signal zu empfangen; das empfangene Signal wird durch das Empfangsmodul an den entsprechenden Mikroprozessor zur Verarbeitung übertragen.

2. Die unterirdische drahtlose Kommunikationsvorrichtung mit Magnetinduktion nach Anspruch 1 ist dadurch gekennzeichnet, dass der Mikroprozessor einen stromsparenden ARM-Chip verwendet und mit Sensoren zur Erfassung von Umgebungsinformationen verbunden ist; zusätzlich ist der Mikroprozessor mit einem Wahlschalter für die Kodierung der Knotenadresse verbunden, die Knotenadresse wird beim Einschalten über einen E/A-Anschluss des Mikroprozessors eingelesen.

3. Die unterirdische drahtlose Kommunikationsvorrichtung mit Magnetinduktion nach Anspruch 1 ist dadurch gekennzeichnet, dass die drahtlosen Kommunikationseinheiten mit Signalmodulations- und Demodulationsschaltungen in einem 2ASK-Modulations- und Demodulationsmodus versehen sind, wobei die Modulationsschaltung im Sendemodul und die Demodulationsschaltung im Empfangsmodul angeordnet ist; die von den Sensoren erfassten Informationen werden vom Signalmodulationsteil durch eine im Mikroprozessor eingebaute UART-Seriell-Schnittstelle kodiert, um ein Basisbandsignal zu erzeugen, ein Quarzoszillator wird zur Erzeugung eines Trägersignals verwendet, das Basisbandsignal und das Trägersignal werden über eine NAND-Schaltung einer 2ASK-Modulation unterzogen; in einem Signaldemodulationsteil wird die Mittenfrequenz einer Frequenzauswahlschaltung durch einen Timing-Widerstand und Kondensator an der Außenseite des Demodulationschips eingestellt, das empfangene Signal wandelt das Trägersignal in 0/1-Basisbandsignal durch die Frequenzauswahlschaltung des Demodulationschips um, wodurch die 2ASK-Demodulation realisiert wird.

4. Die unterirdische drahtlose Kommunikationsvorrichtung mit Magnetinduktion nach Anspruch 1 oder 3 ist dadurch gekennzeichnet, dass das Sendemodul eine Signalmodulationsschaltung und eine Leistungsverstärkerschaltung umfasst, wobei die Leistungsverstärkerschaltung eine resonante Leistungsverstärkerschaltung ist, die aus einer Hochleistungstriode besteht; ein moduliertes Signal wird über die Leistungsverstärkerschaltung auf die Sende-Empfangsantenne geladen.

5. Die unterirdische drahtlose Kommunikationsvorrichtung mit Magnetinduktion nach Anspruch 1 oder 3 ist dadurch gekennzeichnet, dass das Empfängermodul Signalverstärkerschaltung, Schmalbandfilterschaltung und Signaldemodulationsschaltung umfasst, wobei die Signalverstärkerschaltung aus einer rauscharmen Triode besteht, das empfangene Signal nach einer zweistufigen Verstärkung mit dem Demodulationschip verbunden wird. Eine Schmalband-Phasenregelschleife und ein Transistorschalter befinden sich innerhalb des Demodulationschips und vervollständigen bei der Durchführung einer Schmalbandfilterung am Eingangssignal die Signaldemodulation.

6. Die unterirdische drahtlose Kommunikationsvorrichtung mit Magnetinduktion nach Anspruch 1 ist dadurch gekennzeichnet, dass die Leiterspulen durch Kupferdrähte gewickelt sind, wobei an beiden Enden Resonanzkondensatoren parallel geschaltet

sind, um die Sende-Empfangs-Effizienz zu verbessern; die Spulen unabhängig voneinander sind; der Radius und die Anzahl der Windungen durch die Betriebsumgebung bestimmt werden.

7. Das Kommunikationsverfahren der unterirdischen drahtlosen Kommunikationseinrichtung mit Magnetinduktion nach einem der Ansprüche 1-6 ist dadurch gekennzeichnet, dass Signale an beiden Kommunikationsanschlüssen in Form von magnetischen Signalen übertragen werden; der durch die Sende-/Empfangsantenne gebildete magnetische Kanal die magnetischen Signale sowohl sendet als auch empfängt, die spezifischen Schritte wie folgt sind:

1) ein ursprüngliches Basisbandsignal an einem Sendeanschluss wird moduliert und verstärkt, um ein alternierendes Sinuswellensignal I1=I0e-jwt zu erzeugen, das I1 wird gleichzeitig auf die drei Leiterspulen der Sendeantenne geladen, wodurch ein alternierendes Magnetfeld um jede Leiterspule erzeugt wird, die drei zueinander orthogonalen Leiterspulen erzeugen zusammen ein alternierendes dreidimensionales Magnetfeld, wobei elektrische Signale in magnetische Signale umgewandelt werden und Informationen durch das Magnetfeld übertragen werden;

2) die Empfangsantenne an einem Empfangsanschluss befindet sich in einem magnetischen Wechselfeld, der magnetische Fluss im geschlossenen Bereich jeder Leiterspule ändert sich mit dem magnetischen Wechselfeld; sinusförmige Signale I2, I´2, I´2´ mit den gleichen Phaseneigenschaften wie I1 werden in den drei Leiterspulen induziert, die drei zueinander orthogonalen Leiterspulen induzieren Magnetfeldinformationen aus verschiedenen Richtungen, um magnetische Signale in elektrische Signale umzuwandeln, die dreifachen elektrischen Signale werden durch einen Addierer überlagert und dann verstärkt und demoduliert, um die ursprünglichen Informationen wiederherzustellen.

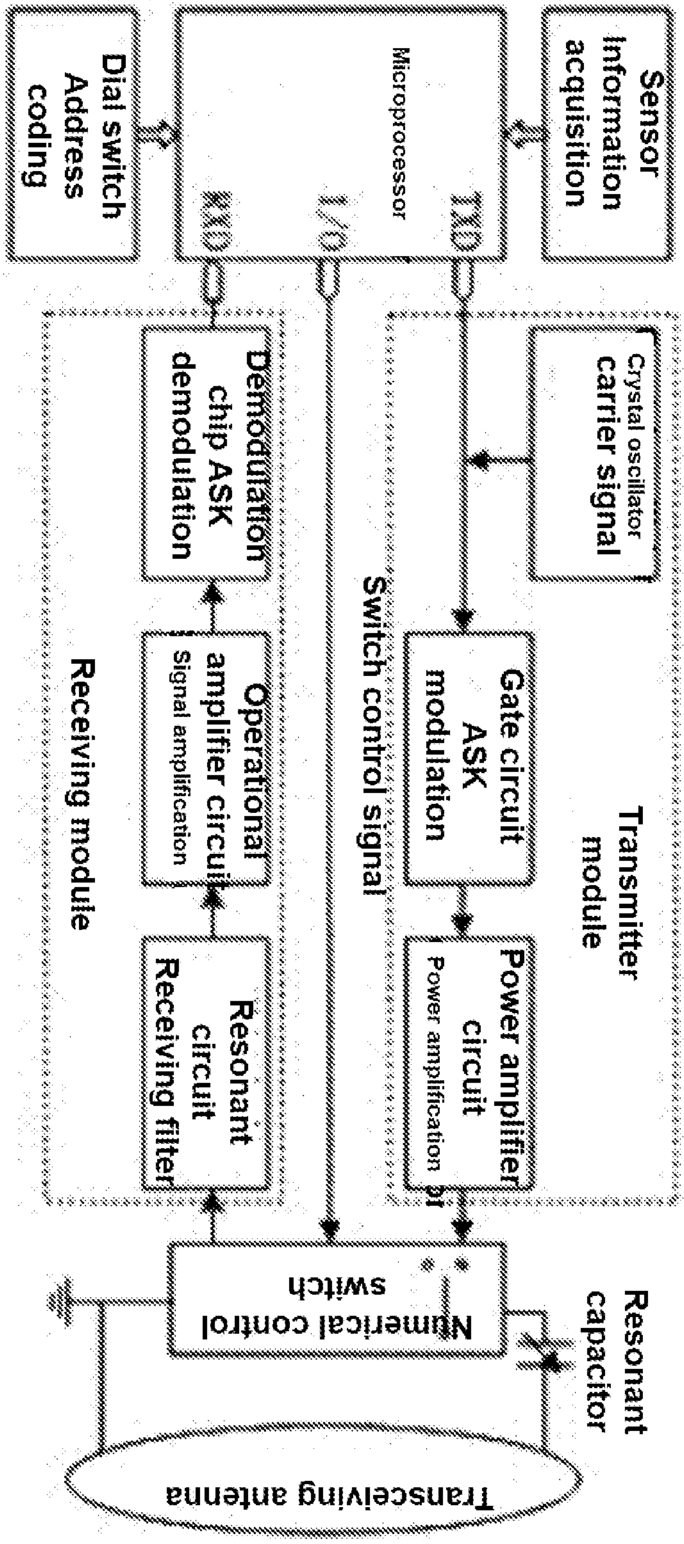
Sensor
Information
acquisition
Microprocessor
TXD
I/O
RXD
Dial switch
Address
coding
Transmitter
module
Crystal oscillator
carrier signal
Gate circuit
ASK
modulation
Power amplifier
circuit
Power amplification
Switch control signal
Receiving module
Demodulation
chip ASK
demodulation
Operational
amplifier circuit
Signal amplification
Resonant
circuit
Receiving filter
Numerical control
switch
Resonant
capacitor
Transceiving antenna

Fig. 1

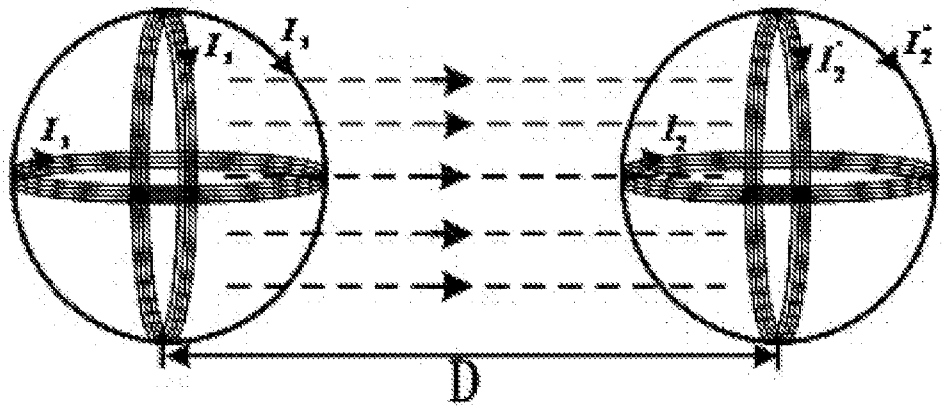

Fig. 2

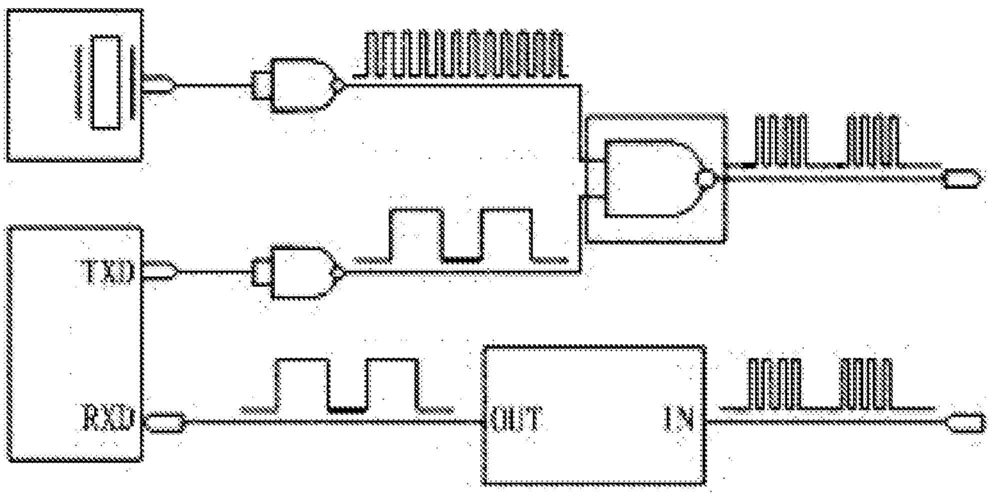

Fig. 3

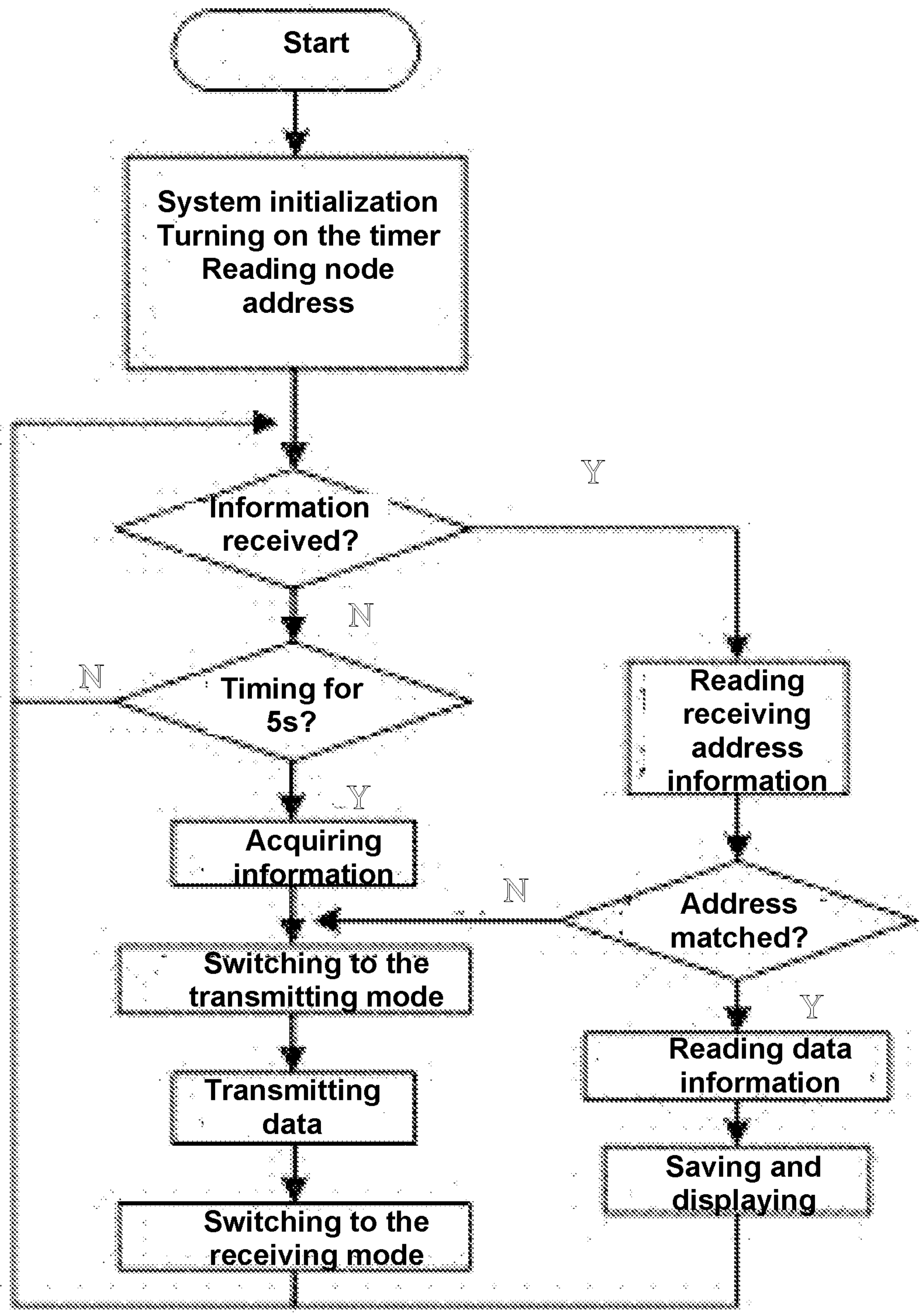
Start
System initialization
Turning on the timer
Reading node address
Information received?
Y
N
Timing for 5s?
N
Y
Acquiring information
Switching to the transmitting mode
Transmitting data
Switching to the receiving mode
Reading receiving address information
Address matched?
N
Y
Reading data information
Saving and displaying

Fig. 4