

【DESCRIPTION】**【Title of Invention】**

MAGNETIC FIELD COMMUNICATION-BASED TAP WATER AND WASTEWATER LEAKAGE DETECTION SYSTEM FOR AUTOMATING MAINTENANCE DETERMINATION FOR WATER LEAKAGE AND AGING OF UNDERGROUND PIPELINE

【Technical Field】

[1] The present disclosure relates to a magnetic field communication-based tap water and wastewater leakage detection system for automating maintenance determination for water leakage and aging of an underground pipeline. In more detail, the present disclosure relates to a real-time monitoring system that has high wireless communication performance in a specific section such as a riverbed and that can find out whether there is water leakage and a water leakage generation location by measuring hydraulic pressure/flow rate at each section of tap water and wastewater pipelines buried in the ground because a transmission circuit and a reception circuit are configured to be able to perform communication even in an underground environment with non-uniform media using a magnetic field that is almost not influenced by variation of media unlike electromagnetic waves in poor underground and riverbed, a weak ground, a mountain slope, and an underwater environment.

【Background Art】

[2] 35,800km of tap water pipelines which are about 20% of all the tap water pipelines in Korea are aged pipelines that are over 20 years old, and 8 hundred million tons of water leaks every year due to investment and management neglect of the operation states of large valves, air valves, new-constructed pipes, etc. Further, about 34% of the wastewater pipelines in Korea have exceeded the persisting period and 41,820km of 123,311km of the wastewater pipelines in Korea have aged over 20 years. Further, it is expected that the generation

frequency and the danger of leakage of tap water and wastewater, rapid variation of the level of underground water, etc. will further increase.

[3] At present, water leaking out of tap water and wastewater pipelines sweeps away earth and sand, and underground water flows into tap water and wastewater pipelines due to aging and poor installation of joints, and in this process, earth and sand enter the pipelines or cause accidents such as ground sinking. Accordingly, facilities are mainly maintained and managed at present by municipalities, but precise management of tap water and wastewater is actually insufficient due to aging of pipe networks and technical limitations.

[4] In order to prevent such accidents, it is actually required to develop a sensing technology that can predict in advance or find out water leakage from tap water and wastewater pipelines and a system that analyzes a water leakage situation by monitoring in real time a water leakage situation on the basis of IoT.

【Disclosure】

【Technical Problem】

[5] The present disclosure has been made in an effort to solve the problems described above and an objective of the present disclosure is to provide a magnetic field communication-based tap water and wastewater leakage detection system for automating maintenance determination for water leakage and aging of an underground pipeline.

[6] The technical subjects to implement in the present disclosure are not limited to the technical problems described above and other technical subjects that are not stated herein will be clearly understood by those skilled in the art from the following specifications.

【Technical Solution】

[7] In order to achieve the objectives, according to an embodiment of the present disclosure, there is provided a tap water and wastewater leakage detection system that includes pipeline monitoring modules installed at a specific pipeline, an upstream pipeline

coupled to an upstream side of the specific pipeline, and a downstream pipeline coupled to a downstream side of the specific pipeline, respectively, and performing near field communication therebetween, in which at least one module of the pipeline monitoring modules transmits information sensed from the specific pipeline, the upstream pipeline, and the downstream pipeline to a management server through magnetic field communication.

[8] The pipeline monitoring modules include a first monitoring module installed at the specific pipeline and second monitoring modules installed at the upstream pipeline and the downstream pipeline, respectively, the first and second monitoring modules each include: a driving unit including a first sound wave generator generating a first sound wave traveling in a direction perpendicular to an extension direction of corresponding pipelines at which the first and second monitoring modules are installed, respectively, and a second sound wave generator generating a second sound wave traveling in a direction parallel with the extension direction of corresponding pipelines; a sensing unit sensing the first sound wave, the second sound wave, and pipeline state information of corresponding pipelines at which the first and second monitoring modules are installed, respectively; a near field communication unit performing near field communication between the first and second monitoring modules; and a control unit controlling operation of the sensing unit and the near field communication unit, and the first monitoring module includes: a power unit supplying power for driving the first monitoring module; a processing unit processing the sensed pipeline state information; and a magnetic field wireless communication unit transmitting the pipeline state information processed by the processing unit to the management server.

[9] The specific pipeline, the upstream pipeline, and the downstream pipeline are each configured to include a pipeline body having a channel formed therein and a joint disposed at each of both ends of the pipeline body and having a ring shape having an outer diameter larger than the pipeline body, and the sensing unit includes a height sensor, an inclination

sensor, a hydraulic pressure sensor, a flow rate sensor, an earth pressure sensor, a first sound wave sensor sensing the 1-1 sound wave of the first sound wave reflected by the inside of the pipeline body, and a second sound wave sensor sensing the 2-1 sound wave of the second sound wave reflected by the joint.

[10] The processing unit includes: an individual pipeline state grade calculator calculating a pipeline state grade of each of the specific pipeline, the upstream pipeline, and the downstream pipeline on the basis of sensing values of the height sensor, the inclination sensor, the hydraulic pressure sensor, the flow rate sensor, the earth pressure sensor, the first sound wave sensor, and the second sound wave sensor; and a repair work score calculator calculating a repair work score for determining necessity of maintenance work on the basis of the pipeline state grade of each of the specific pipeline, the upstream pipeline, and the downstream pipeline.

[11] The individual pipeline state grade calculator calculates a pipeline state grade of each of the specific pipeline, the upstream pipeline, and the downstream pipeline from the following Equation 1

[12] [Equation 1]

$$[13] \quad PcS = 3 \times \left| \frac{HPs - HPr}{HPr} \right| + \left| \frac{Vs - Vr}{Vr} \right| + 0.5 \times \left| \frac{SPs - SPr}{SPr} \right| + 0.7 \times \left(\alpha - \left| \frac{SW1_{rms} - SW2_{rms}}{SW2_{rms}} \right| \right) + \frac{5}{\pi} \times (U_{dg} + D_{dg} - S_{dg}) + 3 \times \frac{UD_h + DD_h}{B_{tn}}$$

[14] (where PcS is the pipeline state grade, HPs is a sensing hydraulic pressure value, HPr is a reference hydraulic pressure value, Vs is a sensing flow rate value, Vr is a reference flow rate value, SPs is a sensing earth pressure value, SPr is a reference earth pressure value, SW1_{RMS} is an RMS value of the 1-1 sound wave, SW2_{RMS} is an RMS value of the 2-1 sound wave, U_{dg} is an inclination value of the upstream pipeline, D_{dg} is an inclination value of the downstream pipeline, S_{dg} is an inclination value of the specific pipeline, UD_h is a step height

value of the specific pipeline and the upstream pipeline, DD_h is a step height value of the specific pipeline and the downstream pipeline, and B_{in} is a ring thickness value of the joint).

【Advantageous Effects】

[15] According to embodiments of the present disclosure, it is possible to efficiently determine water leakage and aging of underground pipelines without digging the area in which the underground pipelines are buried, and simultaneously, it is possible to increase ease of maintenance of monitoring modules of the tap water and wastewater leakage detection system.

[16] The effects according to the spirit of the present disclosure are not limited to those described above and other effects may be made apparent to those skilled in the art from the claims.

【Description of Drawings】

[17] The accompanying drawings, which are included to provide a further understanding of the present disclosure and are incorporated in and constitute a part of this specification illustrate embodiments of the present disclosure, together with the description serve to explain the principles of the present disclosure.

[18] FIG. 1 is a diagram conceptually showing a tap water and wastewater leakage detection system according to some embodiments of the present disclosure.

[19] FIG. 2 is a diagram for describing pipeline monitoring modules of the tap water and wastewater leakage detection system according to some embodiments of the present disclosure.

[20] FIG. 3 is a diagram for describing the internal configuration of a pipeline monitoring module of the tap water and wastewater leakage detection system according to some embodiments of the present disclosure.

[21] FIG. 4 is a configuration diagram schematically showing the internal configuration of a magnetic field wireless communication unit provided in a first pipeline monitoring module according to some embodiments of the present disclosure.

[22] FIG. 5 is a diagram showing a simulation result when the turn ratio of a transformer, which is used for an antenna matching unit according to some embodiments of the present disclosure, is 10:1.

[23] FIG. 6 is a diagram showing an output result of a low noise amplifier (LNA) when simulation was performed between 1 Hz ~ 1GHz in a reception circuit according to some embodiments of the present disclosure.

[24] FIG. 7 is a diagram showing an output signal obtained by inputting a sine wave into the LNA for a transient time in the reception circuit according to some embodiments of the present disclosure.

[25] FIG. 8 is a diagram showing a simulation result when a buffer was input with coupling capacitors removed with only the coupling capacitor of an output terminal remaining for the LNA in the reception circuit according to some embodiments of the present disclosure.

[26] FIG. 9 is a diagram showing a simulation result when the LNA was isolated from the reception circuit according to some embodiments of the present disclosure using a UGB and a frequency was continuously changed between 1 Hz ~ 1GHz (AC Sweep).

[27] FIG. 10 is a diagram showing output signals in a section with a bandwidth of 2.7 kHz and the following section at 3 dB when a frequency was changed between 1 Hz ~ 1GHz for the LNA of the reception circuit according to some embodiments of the present disclosure.

【Mode for Disclosure】

[58] Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings. The advantages and features of the present disclosure, and methods of achieving them will be clear by referring to the exemplary

embodiments that will be described hereafter in detail with reference to the accompanying drawings. However, the present disclosure is not limited to the exemplary embodiments described hereafter and may be implemented in various ways, and the exemplary embodiments are provided to complete the description of the present disclosure and let those skilled in the art completely know the scope of the present disclosure, and the present disclosure is defined by claims. Like reference numerals indicate like components throughout the specification.

[59] Unless defined otherwise, all terms (including technological and scientific terminologies) used herein may be used as meanings that those skilled in the art can commonly understand. Terms defined in common dictionaries are not construed ideally or excessively unless specifically clearly defined.

[60] Further, in the specification, a singular form may include a plural form unless specifically stated in the sentences. The terms “comprises” and/or “comprising” used herein do not exclude that another component, step, operation, and/or element exists or is added in the stated component, step, operation, and/or element.

[61] FIG. 1 is a diagram conceptually showing a tap water and wastewater leakage detection system according to some embodiments of the present disclosure, FIG. 2 is a diagram for describing pipeline monitoring modules of the tap water and wastewater leakage detection system according to some embodiments of the present disclosure, and FIG. 3 is a diagram for describing the internal configuration of a pipeline monitoring module of the tap water and wastewater leakage detection system according to some embodiments of the present disclosure.

[62] Referring to FIGS. 1 to 3, a tap water and wastewater leakage detection system according to embodiments of the present disclosure may include pipeline monitoring modules 1000 and 2000 and a management server S.

[63] At least one of the pipeline monitoring modules 1000 and 200 can directly or indirectly communicate with the management server S. That is, one of the pipeline monitoring modules can directly perform data transmission and reception with the management server in a magnetic field communication type or can perform data transmission and reception through a relay, etc. disposed in an area adjacent to the ground under which the pipeline monitoring modules are buried.

[64] The pipeline monitoring modules 1000 and 2000 may be installed at each of unit pipelines P constituting tap water and wastewater facilities. The unit pipelines P (that is, P1 to P3) are each configured to include a pipeline body, in which a channel is formed, and a joint Ps disposed at both ends of the pipeline body and having a ring shape larger in outer diameter than the pipeline body.

[65] A first monitoring module 1000 and a second monitoring module 2000 may be alternately disposed at adjacent pipelines. According to a more detailed example, the first monitoring module 1000 may be disposed at a specific pipeline P2 and the second monitoring module 2000 may be disposed at each of an upstream pipeline P1 coupled to the upstream side of the specific pipeline P2 and a downstream pipeline P3 coupled to a downstream side of the specific pipeline P2.

[66] The first monitoring module 1000 and the second monitoring module 2000 installed adjacent to adjacent pipelines (that is, P1 and P2 or P2 and P3) can perform near field communication C1 therebetween, and differences of the first monitoring module 1000 and the second monitoring module 2000 will be described below.

[67] The first and second monitoring modules 1000 and 2000 each may include a near field communication unit 200, a sensing unit 300, a driving unit 400, and a control unit 700. In this configuration, the first monitoring module 1000 may further include a magnetic field wireless communication unit 100, a processing unit 500, and a power unit 600. That is, the

first monitoring module 1000 includes the components shown in FIG. 3 and the second monitoring module 2000 may include components except for the magnetic field wireless communication unit 100, the processing unit 500, and the power unit 600 of the components shown in FIG. 3.

[68] As described above, the first monitoring module 1000 and the second monitoring module 2000 are alternately disposed and only the first monitoring module 1000 includes the magnetic field wireless communication unit 100, the processing unit 500, and the power unit 600, whereby it is possible to maximize the power consumption efficiency of the modules and more simply maintain the modules. That is, when maintenance according to power consumption of the power unit 600 is required, only the first monitoring module 1000 needs to be managed, so ease of maintenance is increased and the cost is decreased.

[69] Meanwhile, the second monitoring module 2000 is driven in a passive type without a separate power unit, and to this end, the first monitoring module 1000 can supply power to the second monitoring module 2000 through near field communication, and the second monitoring module 2000 can perform sensing operation of the sensing unit 300 using the supplied power and can transmit the sensed value to the first monitoring module 1000 through near field communication.

[70] The first monitoring module 1000 can combine first data sensed by the first monitoring module 1000 and second data sensed by the second monitoring module 2000 and transmitted through near field communication and transmit the data to the management server S, or can process/analyze data through the processing unit 500 or transmit the data processing/analyzing result to the management server S.

[71] The near field communication unit 200 may be configured, for example, in a small power-based wireless communication, for example, RFID type.

[72] The sensing unit 300 can sense pipeline state information of the pipelines at which

the monitoring modules are installed, respectively.

[73] In some embodiments, the sensing unit 300 may include a height sensor, an inclination sensor, a hydraulic pressure sensor, a flow rate sensor, an earth pressure sensor, and first and second sound wave sensors that sense sound waves and will be described below. In detail, the height sensor senses height information of a corresponding pipeline at which each monitoring module is installed, respectively, the inclination sensor senses inclination information in an extension direction of a corresponding pipeline, the hydraulic pressure sensor senses hydraulic pressure (i.e., water pressure) information in a corresponding pipeline, the flow rate sensor senses flow rate information in a corresponding pipeline, the earth pressure sensor senses earth pressure information of burying earth and sand adjacent to a corresponding pipeline, the first sound wave sensor senses a 1-1 sound wave of a first sound wave reflected and returned from the inside of the pipeline body of a pipeline, and the second sound wave sensor senses a 2-1 sound wave of a second sound wave reflected and returned from a joint. The first and second sound waves may be generated by the driving unit 400. To this end, the driving unit 400 includes a first sound wave generator that generates a first sound wave traveling in a direction (the Y-axial direction in FIG. 2) perpendicular to the extension direction of a corresponding pipeline and a second sound wave generator that generates a second sound wave traveling in a direction (the X-axial direction in FIG. 2) parallel with the extension direction of a corresponding pipeline.

[74] The processing unit 500 serves to process the sensed pipeline state information. In detail, the processing unit 500 included in the first monitoring module 1000 of a specific pipeline P2 can serve to process or combine and process data sensed by the sensing unit 300 of the first monitoring module 1000, data sensed by the sensing unit 300 of the second monitoring module 2000 of an upstream pipeline P1, and data sensed by the sensing unit 300 of the second monitoring module 2000 of a downstream pipeline P3.

[75] In detail, the processing unit 500 may include an individual pipeline state grade calculator that calculates a pipeline state grade of each of a specific pipeline, an upstream pipeline, and a downstream pipeline on the basis of sensing values of the height sensor, the inclination sensor, the hydraulic pressure sensor, the flow rate sensor, the earth pressure sensor, the first sound wave sensor, and the second sound wave sensor of each module, and a repair work score calculator that calculates a repair work score for determining necessity of maintenance work on the basis of the pipeline state grade of each of the specific pipeline, the upstream pipeline, and the downstream pipeline.

[76] Meanwhile, the individual pipeline state grade calculator can calculate a pipeline state grade of each of a specific pipeline, an upstream pipeline, and a downstream pipeline from the following Equation 1.

[77] [Equation 1]

$$[78] \quad PcS = 3 \times \left| \frac{HPs - HPr}{HPr} \right| + \left| \frac{Vs - Vr}{Vr} \right| + 0.5 \times \left| \frac{SPs - SPr}{SPr} \right| \\ + 0.7 \times \left(a - \left| \frac{SW1_{rms} - SW2_{rms}}{SW2_{rms}} \right| \right) + \frac{5}{\pi} \times (U_{dg} + D_{dg} - S_{dg}) + 3 \times \frac{UD_h + DD_h}{B_{tn}}$$

[79] When PcS is a state grade of a specific pipeline, HPs is a sensing hydraulic pressure value of the specific pipeline, HPr is a reference hydraulic pressure value, Vs is a sensing flow rate value of the specific pipeline, Vr is a reference flow rate value, SPs is a sensing earth pressure value of the specific pipeline, SPr is a reference earth pressure value, SW1_{RMS} is an RMS value of a 1-1 sound wave of the specific pipeline, SW2_{RMS} is an RMS value of a 2-1 sound wave of the specific pipeline, U_{dg} is an inclination value of an upstream pipeline, D_{dg} is an inclination value of a downstream pipeline, S_{dg} is an inclination value of the specific pipeline, UD_h is a step height value of the specific pipeline and the upstream pipeline, DD_h is a step height value of the specific pipeline and the downstream pipeline, and B_{tn} is a ring thickness value of a joint of the specific pipeline. In this case, the reference values may be

preset values.

[80] Meanwhile, the repair work score calculator can calculate a repair work score as an average of the state grade of a specific pipeline, the state grade of an upstream pipeline, and the state grade of a downstream pipeline, but is not limited thereto.

[81] Further, the processing unit 500 can determine that a corresponding pipeline has a joint step when an inclination value or a height value comes out of an error range. In detail, the processing unit 500 can determine misalignment between adjacent pipelines when an inclination value is within an error range but a height value is out of an error range, and can determine that there is a gap between adjacent pipelines when a height value is within an error range but an inclination value is out of an error range. Further, the processing unit 500 can determine that a joint of a corresponding pipeline has been corroded when an inclination value and a height value are within error ranges, but a 2-1 sound wave is out of an error range. Further, the processing unit 500 can determine that water leaks out of the pipeline body of a corresponding pipeline or earth and sand enter the corresponding pipeline when an inclination value and a height value are within error ranges and a 2-1 sound wave is also within an error range, but hydraulic pressure or a flow rate is out of an error range.

[82] Meanwhile, the magnetic field wireless communication unit 100 can serve to transmit data sensed from each of the pipelines P1 to P3 and/or state information (ex, the pipeline state grad) of each of pipelines processed by the processing unit to the management server S through magnetic field communication. Hereafter, the operation and configuration of the magnetic field wireless communication unit 100 are exemplarily described with reference to FIGS. 4 to 10.

[83] FIG. 4 is a configuration diagram schematically showing the internal configuration of a magnetic field wireless communicator provided in a first pipeline monitoring module according to some embodiments of the present disclosure, FIG. 5 is a diagram showing a

simulation result when the turn ratio of a transformer, which is used for an antenna matching unit, is 10:1, FIG. 6 is a diagram showing an output result of an LNA when simulation was performed between 1 Hz ~ 1GHz in a reception circuit, FIG. 7 is a diagram showing an output signal obtained by inputting a sine wave into the LNA for a transient time in the reception circuit, FIG. 8 is a diagram showing a simulation result when a buffer was input with coupling capacitors removed with only the coupling capacitor of an output terminal remaining for the LNA in the reception circuit, FIG. 9 is a diagram showing a simulation result when the LNA was isolated from the reception circuit using a UGB and a frequency was continuously changed between 1 Hz ~ 1GHz, and FIG. 10 is a diagram showing output signals in a section with a bandwidth of 2.7 kHz and the following section at 3 dB when a frequency was changed between 1 Hz ~ 1GHz for the LNA of the reception circuit.

[84] Referring to FIGS. 4 to 10, a magnetic field wireless communication unit 100 according to an embodiment of the present disclosure may include an antenna 102, a transmission circuit 110, a reception circuit 120, a transmission/reception switching unit 130, an antenna matching unit 140, a control unit 150, a program memory 162, a data memory 164, an arbiter/decoder 166, a watchdog/timer 168, an interrupt controller 170, an universal asynchronous receiver/transmitter (UART) 172, a field programmable gate array (FPGA) 174, a multi-sensor 176, and a power unit 178.

[85] The antenna 102 transmits a signal to a specific section or receives a signal from the specific section.

[86] The transmission circuit 110 processes data into a signal to be transmitted to a specific section such as a riverbed. To this end, the transmission circuit 110 may include a low pass filter 112 that filters out BPSK I and Q signals input from a digital circuit into low-band signals of which the frequency band is low, and an amplifier 114 that amplifies and transmits the low-band signal filtered out through the LPF 112 to the transmission/reception

switching unit 130.

[87] Further, the transmission circuit 110 can amplify a signal with maximum power through a field effect transistor, which is an analog amplifier, and transmit the signal to the antenna 102 so that a signal is transmitted with maximum power from the antenna 102.

[88] Further, the transmission circuit 110 can filter out BPSK I and Q signals, which are input from a digital circuit, into low-band signals, and amplify and transmit the low-band signals to a specific section through a magnetic field, and the reception circuit 120 can receive a magnetic field by LC resonance in a magnetic field, amplify the magnetic field with low noise, filter out the magnetic field into a low-band signal through a mixer, and then generate and transmit I and Q signals to the digital circuit.

[89] The reception circuit 120 processes the received signal into data. To this end, the reception circuit 120 may include a low noise amplifier 122 that amplifies a received signal by removing noise from the signal, a mixer 124 that generates I and Q signals from the signal amplified with low noise using a mixing unit, a low pass filter 126 that filters out the generated I and Q signals into signals with a low frequency band, and an analog to digital (AD) converter 128 that converts low-passed analog signal into digital data.

[90] Further, the reception circuit 120 may include a multiplexer that generates I and Q signals using two pulse signals of a cosine producer and a sine producer having a phase difference of 90 degrees for a received signal.

[91] Further, the transmission circuit 110 or the reception circuit 120 can change a center frequency of 128 kHz into a frequency with a bandwidth of several MHz and then remove noise components having a frequency lower than the center frequency in order to remove noise from power.

[92] Further, the transmission circuit 110 or the reception circuit 120 can use a high pass filter together with the low pass filter after increasing the frequency of a switching regulator

to a frequency with a bandwidth of several MHz for filtering because a frequency is low to use a lower pass filter. In this case, the frequency may be set as an operable maximum oscillator frequency (f_{osc}), for example, 160 kHz.

[93] The transmission/reception switching unit 130 switches connection of the antenna 102 to the transmission circuit 110 or the reception circuit 120.

[94] The antenna matching unit 140 matches the transmission circuit 110 or the reception circuit 120 switched for connection to a channel of the antenna 110.

[95] Further, the antenna matching unit 140 may include a transformer that increase an applied voltage of DC 12V to a voltage of 120V and a box capacitor that maintains the increased voltage of 120V. In this case, the transformer serves to increase a voltage and consumes a lot of current, so the transformer may be used together with a class E-type power amplifier for efficiency. In this case, when the turn ratio of the transformer is increased, a voltage increases but a current decreases, so it is important to use an appropriate turn ratio for maximum output.

[96] For example, when the turn ratio of the transformer is 10:1, the result shown in FIG. 5 can be obtained. As shown in FIG. 5, when the turn ratio of the transformer is 10:1 and an input amplitude is 2.5V, the output amplitude is 0.25V. Further, an LLC or an LCC may be added between the transformer and the antenna for impedance matching.

[97] Further, the low pass filters 112 and 126 used for the transmission circuit 110 or the reception circuit 120 may include a resistor and capacitor (RC) low pass filter (LPF) and an operational (OP) amplifier (AMP) for a buffer.

[98] The control unit 150, for example, may be implemented as a micro control unit (MCU), an ARM, or the like, and controls a signal to be transmitted to a specific section through the transmission circuit 110 or a signal received from a specific section such as a received signal to be processed as data through the reception circuit 120.

[99] In the reception circuit 120, as the simulation result of continuously changing a frequency between 1 Hz ~ 1GHz for a predetermined time (AC Sweep), as shown in FIG. 6, the LNA 122 can obtain a bandwidth of 157 kHz and a gain of 48 dB. FIG. 6 is a diagram showing an output result of a low noise amplifier (LNA) when simulation was performed between 1 Hz ~ 1GHz in a reception circuit according to an embodiment of the present disclosure.

[100] Further, in the reception circuit 120, as the simulation result of inputting a 1mV sinewave for a transient time of 0 ~ 50 μ sec, as shown in FIG. 7, the LNA 122 can output 300 mV and obtain a gain of 48 dB. FIG. 7 is a diagram showing an output signal obtained by inputting a sine wave into the LNA for a temporal time in the reception circuit according to an embodiment of the present disclosure.

[101] Further, the reception circuit 120 may be configured such that, for the LNA 122, a coupling capacitor is removed, a resistor and capacitor low pass filter (LPF) is configured, and then an operation (OP) amplifier (AMP) for a buffer and a low pass filter (LPF) are repeated.

[102] In the reception circuit 120, as the simulation result of continuously changing a frequency between 1Hz ~ 1GHz for a predetermined time (AC Sweep), as shown in FIG. 8, the LNA 122 with a coupling capacitor removed can obtain a bandwidth of 117.761 kHz at 3 dB and a gain of 55 dB with only the coupling capacitor of the output terminal existing. FIG. 8 is a diagram showing a simulation result when a buffer was input with coupling capacitors removed with only the coupling capacitor of an output end remaining for the LNA in the reception circuit according to an embodiment of the present disclosure. In this case, when a buffer does not exist and a coupling capacitor exists, the transfer function changes, so the LNA 122 can show the characteristics of a bandpass filter.

[103] Accordingly, in order for the transfer function of the LNA 122 terminal to have the

LPF characteristic, it is required to remove the coupling capacitor existing in the middle of the filter and connect a buffer. In this case, the LNA 122 should be isolated using a unity gain buffer (UGB). FIG. 9 is a diagram showing a simulation result when the LNA was isolated from the reception circuit according to an embodiment of the present disclosure using a UGB and a frequency was continuously changed between 1Hz ~ 1GHz (AC Sweep). In the reception circuit 120, as the simulation result of continuously changing a frequency between 1 Hz ~ 1GHz for a predetermined time (AC Sweep), the LNA 122 can obtain the output signal shown in FIG. 16. That is, in the reception circuit 120, as shown in FIG. 16, it can be seen that a voltage is increased from 0V to 10V at a frequency between 1Hz and 1 kHz and is decreased from 10V to 0V at a frequency between 1 kHz and 10 kHz by the LNA 122.

[104] Further, in a simulation in which the LNA 122 continuously changes a frequency between 1 Hz ~ 1GHz for a predetermined time (AC Sweep) in the reception circuit 120, as shown in FIG. 10, it can be seen that a voltage is -0 mV at a bandwidth of 2.7 kHz at 3 dB and starts to decrease from before 10 kHz and keeps decreasing to -400 mV even before 10 GHz. FIG. 10 is a diagram showing output signals in a section with a bandwidth of 2.7 kHz and the following section at 3 dB when a frequency was changed between 1 Hz ~1GHz for the LNA of the reception circuit according to an embodiment of the present disclosure.

[105] Meanwhile, the multiplexer (MUX) can generate an RX+ signal and an RX- signal that have a phase difference of 180 degrees from the signal amplified through the LNA 122 using a transformer U16. When signals having opposite phases are input to A0/B0 and A1/B1 of the multiplexer MUS, an A0/A1 selection signal SYNC1 and an B0/B1 selection signal SYNC2 output signals with a frequency of 128 KHz that have a phase difference of 90 degrees. They can be considered as a cos signal and a sin signal in common communication circuits.

[106] In the magnetic field wireless communication unit 100 according to an embodiment

of the present disclosure, first, the control unit 150 controls switching of the transmission/reception switching unit 130 such that a signal is transmitted to a specific section through the transmission circuit 110 or a signal received from a specific section is processed as data through the reception circuit 120. That is, the control unit 150 controls switching such that the transmission circuit 110 is operated when data need to be transmitted to a specific section and the reception circuit 120 is operated when a signal is received from a specific section.

[107] Next, the transmission/reception switching unit 130 switches connection of the transmission circuit 110 or the reception circuit 120 to the antenna 102 in accordance with control by the control unit 150. That is, the transmission/reception switching unit 130 switches and connects the transmission circuit to the antenna 102 when a transmission circuit switching signal is received from the control unit 150, and switches and connects the reception circuit 120 to the antenna 102 when a reception circuit switching signal is received.

[108] Next, the antenna matching unit 140 matches the switched and connected transmission circuit or reception circuit to the channel of the antenna. In this case, when the antenna matching unit 140 matches the switched and connected transmission circuit 110 or reception circuit 120 to the channel of the antenna 102, the antenna matching unit 140 increases the DC voltage of 12V to a voltage of 120V through the transformer and maintains the increased voltage of 120V through the box capacitor.

[109] Next, the antenna 102 transmits a signal to a specific section or receives a signal from the specific section. In the transmission circuit 110, since electromagnetic waves can reach a desired place only when a signal is transmitted with appropriate maximum power from the antenna 102, the amount of power a signal is finally amplified with is important, so a power amplifier plays this role at an RF and an analog amplifier plays this role at a low frequency. A power circuit for transmission output may use a class C-type differential amplifier as a

power amplifier and may use LR7807Z as a FET. In specific section communication such as a riverbed according to an embodiment of the present disclosure, a field effect transistor may be configured to function as an analog amplifier, and LR7807Z may be used as the FET used in this case.

[110] Accordingly, the frequency characteristic at a bandwidth of 10KHz ~ 10 MHz of the transmission circuit including a differential amplifier and an FET may be maximum at about 125 KHz.

[111] Next, the transmission circuit 100 processes data as a signal to be transmitted to a specific section or the reception circuit 120 processes a signal received through the antenna 102 as data. In this case, the reception signal 110 filters out BPSK I and Q signals input from a digital circuit into low band signals with a low frequency bandwidth through a low pass filter, amplifies the filtered low band signals through the amplifier, and then transmits the signals to the transmission/reception switching unit 130, thereby being able to process data into a signal to be transmitted to a specific section.

[112] Further, the antenna matching unit 140 that matches the transmission circuit 110 to the antenna 102 to transmit a signal increases a DC voltage of 12V to a voltage of 120V through the transformer and maintains the increased voltage of 120V through the box capacitor. In this case, the transmission circuit 110 filters out BPSK I and Q signals, which are input from a digital circuit, into low-band signals, and amplifies and transmits the low-band signals to a specific section through a magnetic field, and the reception circuit 120 receives a magnetic field by LC resonance in a magnetic field, amplifies the magnetic field with low noise, filters out the magnetic field into a low-band signal through a mixer, and then generates and transmits I and Q signals to the digital circuit.

[113] Since a signal received through the antenna from the outside (a specific section) has a very small magnitude and includes very messy noises, the role of the LNA 122 that minimizes

noises and performs amplification is important.

[114] In specific section communication, in the reception circuit 120, an NE5532D element is used for the LNA 122, and then the input and output terminals may be matched using R and C and configured to fit to $f_0 = 128\text{KHz}$.

[115] When a required matter in the LNA 122 is $f_0 = 128\text{KHz}$, $\text{Gain} > 30\text{dB}$, $\text{NF} < 1$ (about $1.5 < \text{NF} < 2$ for 2 stages or more), multiple connections should be minimized, and the relationship of an NF and a gain should be supplemented through trade-off. A class A is usually recommended, but it may be better to use a class AB or B, further considering the aspect of efficiency. As the result of using an NE5532D element, a DC gain of 34.8 dB can be obtained in accordance with the following Equation 2.

[116] [Equation 2]

$$[117] \quad 20 \log \left| \frac{V_{out}}{V_{in}} \right|_{f=f_0} = 20 \log \left| \frac{R_{43}}{R_{46}} \right| \approx 34.8 \text{dB}$$

[118] In this case, it could be seen that a cutoff frequency 3dB was about 134kHz.

[119] Further, in the reception circuit 120, the LNA 122 may be implemented using an NE5532D element, it could be seen that a signal of 128KHz and hundreds of mV was amplified to about 4Vp-p in the corresponding output waveform at R53.

[120] The reception circuit 120, for the received signal, can generate an I signal and a Q signal using two pulse signals having a phase difference of 90 degrees through the multiplexer (MUX). In this case, it is possible to implement the multiplexer (MCU) using an HC4053 element in specific section communication such as a riverbed.

[121] According to the present disclosure described above, it is possible to implement a method and device for transmitting and receiving a signal for specific section communication, the method and device being able to increase wireless communication function in a specific section because a transmission circuit and a reception circuit are configured to be able to

perform communication even in an underground environment with non-uniform media using a magnetic field that is almost not influenced by variation of media unlike electromagnetic waves in a poor specific section environment.

[122] It would be understood by those skilled in the art related to the present embodiment that the present disclosure may be modified without departing from the essential scope of the present disclosure. Therefore, the disclosed methods should be considered in terms of explaining, not limiting. The scope of the present disclosure is not shown in the above description, but claims, and all differences within an equivalent range should be construed as being included in the present disclosure.

【CLAIMS】**【Claim 1】**

A tap water and wastewater leakage detection system comprising
pipeline monitoring modules installed at a specific pipeline, an upstream pipeline coupled to an upstream side of the specific pipeline, and a downstream pipeline coupled to a downstream side of the specific pipeline, respectively, and performing near field communication therebetween,

wherein at least one module of the pipeline monitoring modules transmits information sensed from the specific pipeline, the upstream pipeline, and the downstream pipeline to a management server through magnetic field communication.

【Claim 2】

The tap water and wastewater leakage detection system of claim 1, wherein the pipeline monitoring modules include a first monitoring module installed at the specific pipeline and second monitoring modules installed at the upstream pipeline and the downstream pipeline, respectively,

the first and second monitoring modules each include:

a driving unit including a first sound wave generator generating a first sound wave traveling in a direction perpendicular to an extension direction of corresponding pipelines at which the first and second monitoring modules are installed, respectively, and a second sound wave generator generating a second sound wave traveling in a direction parallel with the extension direction of corresponding pipelines;

a sensing unit sensing the first sound wave, the second sound wave, and pipeline state information of corresponding pipelines at which the first and second monitoring modules are installed, respectively;

a near field communication unit performing near field communication between the

first and second monitoring modules; and

a control unit controlling operation of the sensing unit and the near field communication unit, and

the first monitoring module includes:

a power unit supplying power for driving the first monitoring module;

a processing unit processing the sensed pipeline state information; and

a magnetic field wireless communication unit transmitting the pipeline state information processed by the processing unit to the management server.

【Claim 3】

The tap water and wastewater leakage detection system of claim 2, wherein the specific pipeline, the upstream pipeline, and the downstream pipeline are each configured to include a pipeline body having a channel formed therein and a joint disposed at each of both ends of the pipeline body and having a ring shape having an outer diameter larger than the pipeline body, and

the sensing unit includes a height sensor, an inclination sensor, a hydraulic pressure sensor, a flow rate sensor, an earth pressure sensor, a first sound wave sensor sensing the 1-1 sound wave of the first sound wave reflected by the inside of the pipeline body, and a second sound wave sensor sensing the 2-1 sound wave of the second sound wave reflected by the joint.

【Claim 4】

The tap water and wastewater leakage detection system of claim 3, wherein the processing unit includes:

an individual pipeline state grade calculator calculating a pipeline state grade of each

of the specific pipeline, the upstream pipeline, and the downstream pipeline on the basis of sensing values of the height sensor, the inclination sensor, the hydraulic pressure sensor, the flow rate sensor, the earth pressure sensor, the first sound wave sensor, and the second sound wave sensor; and

a repair work score calculator calculating a repair work score for determining necessity of maintenance work on the basis of the pipeline state grade of each of the specific pipeline, the upstream pipeline, and the downstream pipeline.

【Claim 5】

The tap water and wastewater leakage detection system of claim 4, wherein the individual pipeline state grade calculator calculates a pipeline state grade of each of the specific pipeline, the upstream pipeline, and the downstream pipeline from the following Equation 1

[Equation 1]

$$PcS = 3 \times \left| \frac{HPs - HPr}{HPr} \right| + \left| \frac{Vs - Vr}{Vr} \right| + 0.5 \times \left| \frac{SPs - SPr}{SPr} \right| + 0.7 \times \left(a - \left| \frac{SW1_{rms} - SW2_{rms}}{SW2_{rms}} \right| \right) + \frac{5}{\pi} \times (U_{dg} + D_{dg} - S_{dg}) + 3 \times \frac{UD_h + DD_h}{B_{tn}}$$

where PcS is the pipeline state grade, HPs is a sensing hydraulic pressure value, HPr is a reference hydraulic pressure value, Vs is a sensing flow rate value, Vr is a reference flow rate value, SPs is a sensing earth pressure value, SPr is a reference earth pressure value, SW1_{RMS} is an RMS value of the 1-1 sound wave, SW2_{RMS} is an RMS value of the 2-1 sound wave, U_{dg} is an inclination value of the upstream pipeline, D_{dg} is an inclination value of the downstream pipeline, S_{dg} is an inclination value of the specific pipeline, UD_h is a step height value of the specific pipeline and the upstream pipeline, DD_h is a step height value of the specific pipeline and the downstream pipeline, and B_{tn} is a ring thickness value of the joint).