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[54] **APPARATUS FOR TRANSMITTING DATA FROM A HOLE DRILLED IN THE EARTH**

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[51] **Int. Cl.** **G01v 1/40**
[58] **Field of Search** ...... 340/18 NC, 18 FM, 18 LD; 324/1, 5, 10

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[57] **ABSTRACT**

An arrangement for measuring and transmitting geological, physical, geometrical or chemical data of soil strata penetrated by a drilling hole, comprising a signal generator located inside the drilling hole and including a converter which produces signals corresponding to the measured data and a transmitter controlled by the converter and which emits modulated output signals. A receiver is located in the region of the open upper end of the drilling hole for demodulating the received signals and producing a visual display thereof in an indicator. The output of the transmitter of the signal generator and the input of the receiver are connected to conductive dipoles which are in electrically conductive connection with the soil such that the electrical signals are wirelessly transmitted through the soil in accordance with the electrical conductivity of the soil.

8 Claims, 7 Drawing Figures

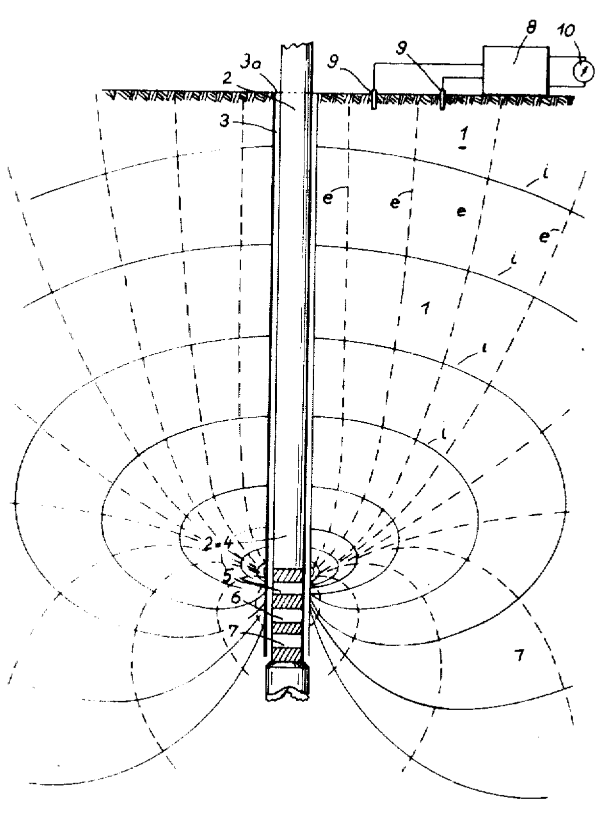


Fig. 1

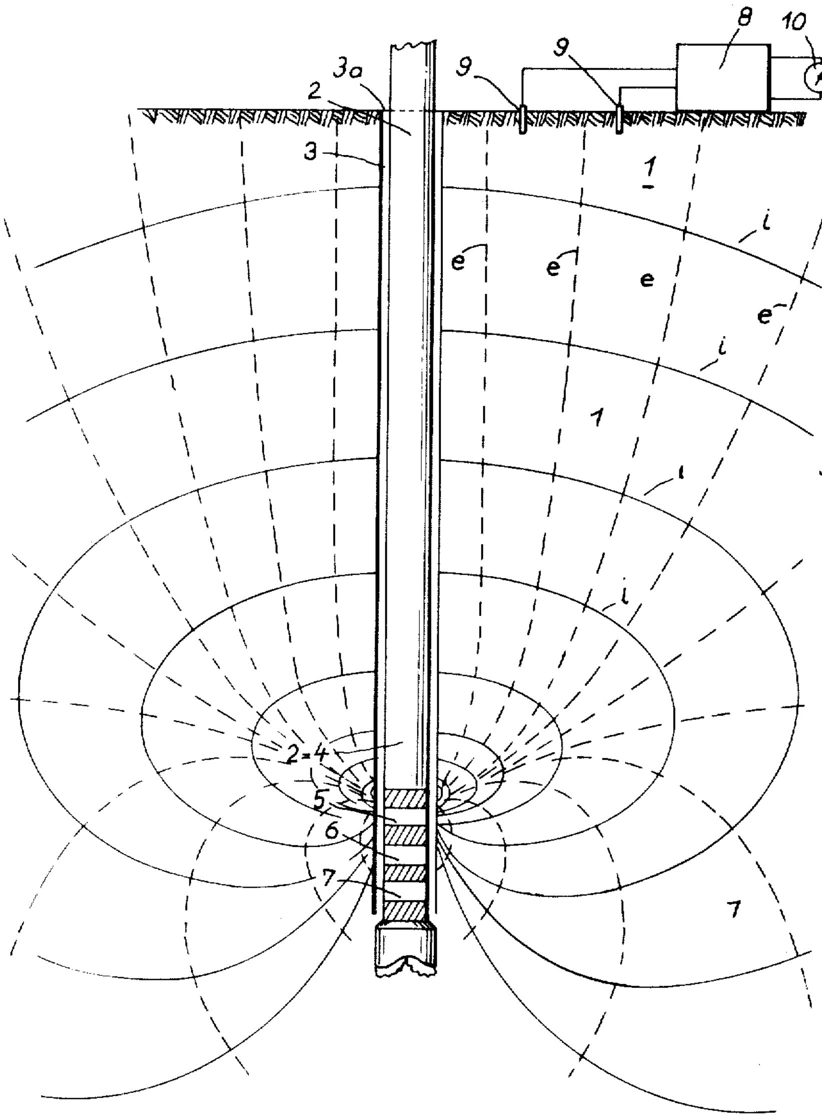
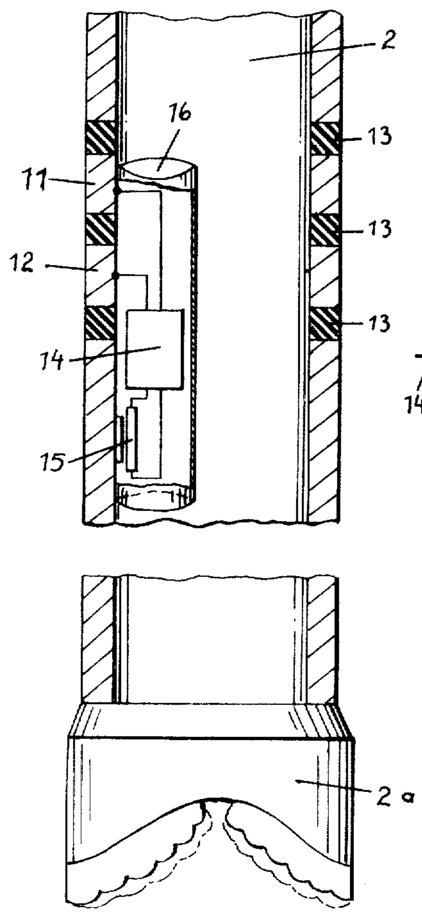


Fig. 2



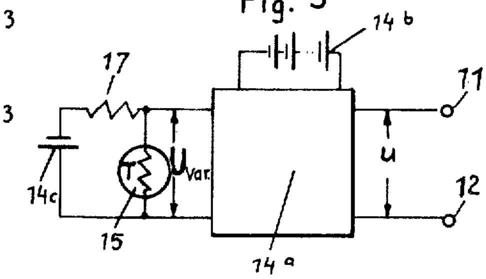


Fig. 3

Fig 4

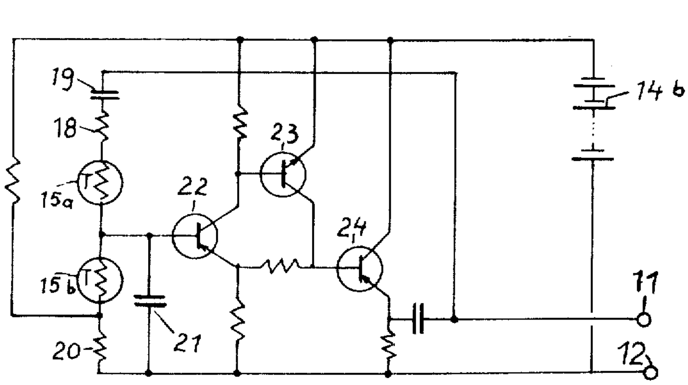


Fig. 5

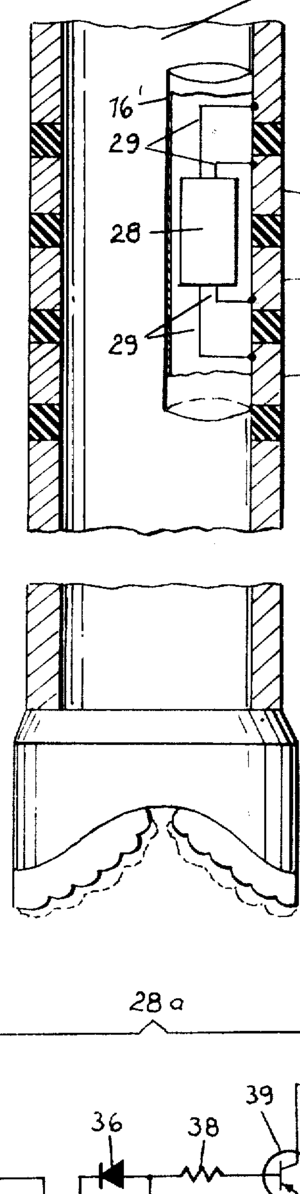


Fig. 6

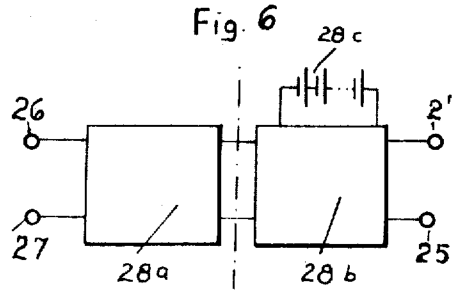
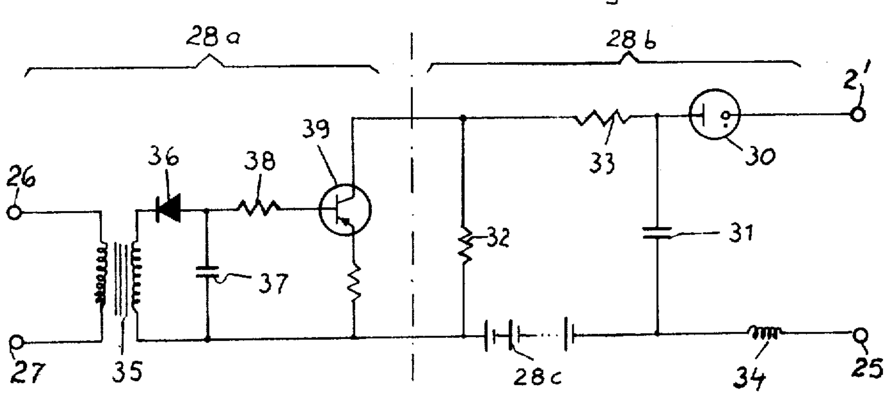


Fig. 7



APPARATUS FOR TRANSMITTING DATA FROM A HOLE DRILLED IN THE EARTH

BACKGROUND

A. Field of the Invention

The invention relates to apparatus for measuring and transmitting data from soil strata penetrated by a drilling hole. Such data may include information of a geological, physical, geometrical or chemical nature.

B. Prior Art

According to known geophysical drilling hole measuring techniques, measuring probes are sunk into the drilling hole, in order to measure geological, physical, geometrical or chemical data of soil strata penetrated by a drilling hole. The probes can be inserted only after the mechanical drilling operations have been completed. The transmission of the data, which is detected by means of probes or transducers and converted into electric signals, to the surface of the earth is usually accomplished by means of cables. Inasmuch as the probes or transducers need electric energy, this must be supplied to them from the surface of the earth by the cable.

It is disadvantageous in the measuring methods that they cannot be applied simultaneously with the drilling operation. On the contrary, it is necessary that the drilling tube be pulled out of the hole for measuring purposes. Without regard of the fact that this additional working operation is very time consuming, there exists a danger that the walls of the drilling hole may collapse during this procedure. Moreover, such processes do not permit simultaneous monitoring, i.e., a continuous and simultaneous observation during the drilling operation, so that technical drilling decisions cannot be made before the drilling tube is pulled out of the drilling hole.

Since the conventional measuring probes must be connected with a receiver located on the surface of the earth in the proximity of the drilling hole by means of insulated electric lines, it is difficult for technical reasons to attach the measuring probes or transducers directly to the drilling tube in order to enable measurements to be taken in the course of the drilling operation.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an arrangement, by means of which the data measured in the drilling hole can be transmitted to the receiver during the measuring operation without using the cable connection.

The invention contemplates an arrangement including a signal generator located inside the drilling hole and a receiver arranged in the neighborhood of the drilling hole collar. The signal generator consists of a converter which generates the electric signal corresponding to the measured values, and a transmitter controlled by the converter for transmitting modulated signals. The receiver demodulates the received signals and provides a visual indication thereof by means of a measuring or plotting instrument.

The arrangement according to the invention is based on the concept of using the electrical conductivity properties of the soil for transmission of the signals. For this purpose, it is proposed in accordance with the invention that the transmitting output of the signal generator and the receiving input of the receiver are each connected to a conductive dipole, which is in electrically conductive connection, in such a manner that the electric signals are wirelessly transmitted by the electrically conductive soil. Advantageously, the transmission current is fed into the soil by means of a dipole which extends parallel to the axis of the drilling hole, and is received by a dipole which extends parallel to the surface of the earth. This method is already known per se in geoelectrics as a dipole method for measuring the electric resistance of soil strata. However, it has not been heretofore used for transmission of electric data. According to this method, electric current is supplied to the soil by means of a transmitting dipole, the current propagating in the form of a current field. This current field causes a current drop at the electrodes of the receiving dipole, from which the transmitted data can be derived after demodulation.

Since no wire connections are needed between the transmitter and the receiver, the transmitter can be accommodated to advantage in a closed container, together with an independent source of energy, for instance a dry battery or an accumulator battery, and located directly at the lower end of the tube line. If higher transmission outputs are required, for instance in the course of measurements at greater depths, the battery or accumulator battery voltage can be transformed upwardly by means of a chopper and subsequent rectifier circuit.

The transmitter dipole can consist of two metallic segments which are arranged above one another at the drilling tube and which are mutually insulated, and which preferably have an annular or tubular shape. It is even more advantageous if one of the segments of the transmitter dipole is formed by the metallic drilling tube itself. If such is the case, then the transmitting dipole approximately consists of a point-like and of a line-shaped current source. Since the line-shaped current source having the form of the drilling tube extends up to the surface of the earth, the magnitude of the current field in the region of the receiving dipole is consequently substantially increased. Herein, a more or less large portion of the entire transmission output is transmitted upwardly also by means of the drilling tube.

The arrangement according to the invention can be used for transmission of all possible geological, physical, geometrical or chemical data, as, for instance, of the electric conductivity, of the temperature, the salt content or similar data.

If temperature measurements are conducted, a thermistor can be used in a conventional manner as a converter, or another similar element depending on the temperature, in which a temperature change induces a change of its characteristic properties, for instance, a change of resistivity.

The four-point method as mentioned above can also be used for determination of the electric resistance of the soil strata penetrated by the drilling hole, according to which method the soil is supplied by an electrical current by means of a pair of metallic segments which serve as emission electrodes, wherein said electric current influences a further pair of metallic segments serving as measuring electrodes, and causes a voltage drop thereon. In order to keep the number of bits of data to be transmitted as low as possible, it is proposed according to a further feature of the invention to either supply the emission electrodes with a current having a constant intensity, or to supply them intermittently with a constant charge. If the intensity of the electric current or the intermittently supplied charge is kept constant, it is sufficient for the determination of the change of resistance to transmit the voltage drop at the measuring electrodes. Thus, the receiver is to be controlled by this voltage.

If modulated oscillations, for example, amplitude modulated, frequency-modulated or phase-modulated oscillations, are used in accordance with a further feature of the invention, the modulation factor or the frequency or phase shift can be a function of the detected data, i.e., the changed electric signals.

In particular, frequency modulation or phase modulation seem to be most advantageous, as the frequency shift or the phase shift are independent of losses.

A signal which is also independent of the losses can be achieved if the amplitude modulation is used in such a manner that only one half-wave of the transmitted oscillation is modulated, while the other half-wave remains intact, wherein the relation of the modulated half-wave to the unmodulated half-wave is a function of the detected data which has been changed in electric signals.

In an embodiment according to the invention, frequency-modulated pulse series are used for transmission of the signals. In addition, amplitude-modulated, wavelength-modulated or phase-modulated pulse series are suitable. Even herein, the modulation factor, respectively the phase of frequency shift or the pulse duty ratio is a function of the detected data, which has been changed in electric signals.

The details of the circuitry of the arrangement of the invention will next be described with reference to an embodiment of the invention with reference to the attached drawings.

Particular importance is given to an arrangement for measuring and transmitting the specific electric resistance of the soil strata penetrated by the drilling hole, according to the invention. It is characteristic for this arrangement that an alternate current having a low frequency, or a pulse series is supplied to the emission electrodes, said alternate current or pulse series being modulated in dependence of the voltage at the measuring electrode, the emission current modulated in this manner simultaneously serving as a transmission current. In this arrangement, consequently, the emission electrodes simultaneously form the transmission dipole, by which the construction becomes greatly simplified. The electronic device for production of the emission current can also be combined in a very simple manner with the chopping circuit which effects the modulation of the emission current.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic illustration of the arrangement according to the invention showing equipotential and current lines;

FIG. 2 is a diagrammatic view of the lower end of the tube line with a built-in electronic device for temperature measurements;

FIG. 3 is a block diagram of the electronic circuit with a voltage-frequency converter for the arrangement according to FIG. 2;

FIG. 4 is a more detailed circuit diagram of the electronic device for the arrangement according to FIG. 2;

FIG. 5 is a view of the lower end of the tube line with the electronic device according to a second embodiment to the invention for measuring the specific electrical resistance;

FIG. 6 is a block diagram of the electronic circuitry in the arrangement according to FIG. 5; and

FIG. 7 is a circuit diagram of the electronic device of FIG. 6.

DETAILED DESCRIPTION

The mode of operation of the arrangement according to the invention is schematically illustrated in FIG. 1. Therein is seen a drilling tube **2** which is driven into the soil **1** in order to produce a drilling hole **3**. Near the front end of the tube line, there are provided emission electrodes **4** and **5**, as well as measuring electrodes **6** and **7**. The outer surface of the jacket of the tube **2** serves herein as an emission electrode. The current field produced by both the electrodes **4** and **5** is illustrated by current lines *i*. Furthermore, the equipotential lines *e* corresponding to electrodes **4** and **5** are illustrated in dotted lines.

At the surface of the earth, there is provided a receiver **8** in proximity of the drilling hole collar **3***a*, the input of said receiver being connected to probes **9** which are driven into the soil, and which form a conductive receiving dipole. The signals received by this dipole are amplified in the receiver **8** and demodulated or decoded therein, and visually indicated on an indicator or plotting device **10**.

In FIG. 2 of the drawing, there is shown the lower end of the tube line according to the invention, in a partial cross-sectional view. Above the boring bit **2***a*, the drilling tube is formed with annular segments **11** and **12**, which are electrically insulated from each other and the remainder of the drilling tube **2** by means of insulation rings **13**. The illustration of the segments **11** and **12** and rings **13** of the boring tube **2** is purely schematic. It is preferred for reasons of strength to use a continuous, uninterrupted tube, the segments **11** and **12** either being provided on the surface of the tube or embedded in the tube, and simultaneously separated from each other and from the remainder of the tube by insulating elements.

The segments **11** and **12** form a vertical, conductive transmitting dipole, and the segments are connected to the output of a signal generator **14**. A thermistor **15** is connected in the input circuit of the signal generator **14**, the resistance of said thermistor changing in dependence on the temperature. Thus, the thermistor serves as a converter for production of signals corresponding to the temperature of the surroundings, which signals are demodulated or decorded in the receiver **8** and visually displayed by the device **10**.

As shown in FIG. 2, the entire electronic device is accommodated in a closed container **16**, which is fastened in the inside of the tube line **2** in such a manner that the thermistor **15** is in thermal contact with the drilling tube **2** and, consequently, with the earth surrounding the drilling hole.

One embodiment of the circuitry of the signal generator **14** is shown in the block circuit diagram according to FIG. 3. In the input circuit of the transmitter **14***a*, which is not shown in a greater detail and which simultaneously serves as a current-frequency-converter and which is supplied with power from the battery **14***b*, there is provided the thermistor **15**. Current is supplied from the battery 14c through a resistor 17 to the thermistor 15, and the output voltage at the thermistor 15 is designated as U_{VAR}. Since the resistance of the thermistor 15 varies with temperature, the voltage U_{VAR} correspondingly varies. The transmitter 14a is constructed in such a manner that the frequency of the output voltage u varies as a function of the input voltage, so that frequency modulated signals are transmitted by the transmitting dipole whose annular elements 11 and 12 are connected to the output of the transmitter 14a, the frequency of these signals being a function of the temperature of the material surrounding the drilling hole. Since the sources of voltage 14b and 14c form a signal generator together with the transmitter 14a, and are commonly accommodated in the container 16, the arrangement according to the invention does not need any special electrical supply lines.

In FIG. 4, there is shown in greater detail a circuit diagram for the electronic device according to FIG. 2 for conducting temperature measurements. Herein, the transmitter consists of a conventional Wien generator, whose input circuit is formed as a Wien bridge. The Wien bridge is composed of an RC-series connection 18, 19 and an RC-parallel connection 20, 21. In series with the resistors 18 or 20 respectively of both RC-connections, there is always provided one thermistor 15a or 15b respectively. When the temperature changes, the ohmic resistance of both RC members vary, which causes variation of the natural frequency of the generator which is constructed in a conventional manner, consisting of transistors 22, 23 and 24. Both thermistors 15a and 15b are in thermal contact with the drilling tube under equal conditions so that they always have the same temperature.

Instead of the annular segment 11 according to FIG. 2, the entire upper part of the drilling tube 2, which is electrically insulated in respect to the segment 12, can serve as an emission electrode of the vertical transmission dipole. If such is the case, a current field will be created corresponding to that shown in FIG. 1 between the annular electrode 12 and the upper portion of the drilling tube 2, wherein the upper end of the drilling tube emits a long line source.

The arrangement illustrated in FIGS. 5 to 7 serves the purpose of measuring the electrical resistance of the soil surrounding the drilling tube in the vicinity of metallic segments 25, 26 and 27, which are the transmitting, or measuring electrodes, respectively. The signal generator feeds a pulse current to the soil by means of the upper line of the drilling tube 2′ serving as a line source and the segment 25 which approximately serves as a point source. The specific electrical resistance ρ of the earth surrounding the drilling hole can be computed from the pulse current detected by the measuring electrodes 26 and 27 in accordance with the conventional dipole-method, using the following equation:

$$\rho = u_M \cdot F / i_E$$

wherein:

u_M = voltage between the measuring probes 26 and 27;

i_E = emission current fed into the soil by means of the drilling tube 2′ and the segment 25; and

F = geometric factor, which depends on the size and the mutual distance of the segments, as well as the arrangement of further metallic masses, for instance, the lower part of the drilling tube, which may be provided and which have short circuit properties.

In order to detect the specific electric resistance by means of measuring devices arranged on the surface of the earth, the current intensity of the emission current as well as the voltage drop between the measuring electrodes 26 and 27 have to be transmitted.

The technical expenditure can be reduced in accordance with a further feature of the invention, if either current having constant intensity or current pulses having constant charge are supplied to the electrodes. In this case, it is sufficient if the voltage drop between the measuring electrodes 26 and 27 is transmitted. It has been proved to be particularly advantageous to feed the emission current to the electrodes in pulses, wherein the pulses have a known and always constant charge, so that the integral with respect to time of the voltage produced between the electrodes 26 and 27 is a measure of the specific electrical resistance of the surrounding soil stratum. By means of a converter 28a which is shown in FIG. 6, a control value is derived from the detected measuring voltage, which modulates the transmitter 28b of the signal generator 28, (preferably by modulating its phase).

A particularly simple circuit results, if the pulse series frequency of the emitted current is varied in dependence of the probe voltage. If such is the case, the emission current can simultaneously serve the function of the transmission current which transmits the signals, as the information is contained in the instantaneous frequency of the emitted pulse series.

As a result of these simple measures, three segments 25, 26 and 27, which are electrically insulated from the drilling tube 2′, are sufficient for detection of the resistance and for transmission of the detected data. Also in this arrangement, the energy source, for instance, a dry battery 28c, is included in the signal generator 28, on the other hand, is accommodated in a protective container 16′ which is attached to the drilling tube 2′. The container 16′ protects the electronic circuitry 28 as well as the supply lines 29 to the electrodes.

A very simple embodiment of the invention and of the circuitry according to the invention to be used in the arrangement according to FIGS. 5 and 6, is shown in the circuit diagram according to FIG. 7. The transmitter 28b substantially consists of a self-oscillating time-base circuit with a glow-discharge lamp 30, a chargeable condenser or capacitor 31 and two resistances 32 and 33 which are connected in series. The energy source, preferably dry battery 28c is connected in series with the capacitor 31 and the resistors 32 and 33. The glow-discharge lamp 30 is located in the circuit formed by the chargeable capacitor 31, an inductance 34 and the soil between the electrodes 2′ and 25. This arrangement has the following mode of operation:

The capacitor 31 is charged over the resistors 32 and 33 until it reaches the ignition voltage of the glow-discharge lamp 30. When the ignition voltage is reached, the capacitor 31 discharges itself over the glow-discharge lamp and the soil located between the electrodes 2′ and 25, until the substantially lower extinction voltage of the glow-discharge lamp is obtained. The spent amount of charge is defined by the ignition voltage, extinction voltage and capacity of the capacitor. The inductance has the influence that the steep discharge pulses are changed so as to have approximately sinusoidal character of oscillation.

The charge pulses which are emitted by the electrodes 2' and 25 produce approximately sinusoidal current pulses between the measuring electrodes 26 and 27, which are stepped up by means of a transformer 35, which simultaneously serves the purpose of galvanic decoupling, and the pulses are rectified by means of a rectifier circuit, consisting of a diode 36 and a capacitor 37. The electrode of the diode 36 which is connected to the capacitor 37 is connected by means of a resistor 38 with the base of a transistor 39. The signals produced by the rectifier, which are negative in relation to the emitter of the transistor 39, switch the transistor on for a limited period of time corresponding to a pulse, wherein the duration of the pulse varies in dependence on the magnitude of the transmitted charge and, consequently, also in dependence on the electrical resistance of the surrounding soil strata.

The switched-on transistor 39 bridges with its emitter-collector line, which has a low ohmic resistance during this time period, the resistance 32, so that the condenser or capacitor 31 of the time-base circuit is charged more rapidly. The result of this is that the series frequency of the pulses produced by the time-base circuit increases. In this arrangement, the pulse series frequency increases with increasing electrical resistance of the surrounding soil, since the magnitude of the charge delivered to the capacitor 37 is larger the greater is the specific electrical resistance of the soil.

A characteristic value for any specific resistance can be derived from the current pulses received by the receiving dipole by frequency modulation.

What is claimed is:

1. An arrangement for measuring and transmitting geological, physical, geometrical, or chemical data of soil strata penetrated by a drilling hole, comprising a battery, a signal generator producing an alternating current having a low frequency, said battery and said signal generator being located inside the drilling hole, a pair of mutually insulated transmitter contacts coupled with the signal generator, said pair of transmitter contacts being in electrically conductive connection with the soil surrounding the drilling hole to facilitate electrical signals from said transmitter contacts to be wirelessly transmitted through the soil in accordance with the electrical conductivity thereof, a pair of mutually insulated measuring contacts on a drill stem within the drilling hole for measuring the voltage drop of said electrical signals, said signal generator including a converter coupled with said measuring contacts and modulating said alternating current corresponding to said voltage drop, receiver means located in the region of the open upper end of the drilling hole, a pair of receiver contacts coupling said receiver means with the bottom of said drilling hole for demodulating the receiver signals, and indicator means connected to said receiver means.

2. An arrangement according to claim 1, comprising two pairs of metallic segments being provided on said drill stem and forming, respectively, said transmitting and measuring contacts, said battery supplying a current with constant intensity to the transmitter contacts, the signal generator being controllable by a voltage drop at the measuring contacts.

3. An arrangement according to claim 2, said signal generator producing oscillations which are modulated pursuant to a predetermined modulation factor, said modulation factor being a function of the detected data which is changed into said electrical signals.

4. An arrangement according to claim 3, only one half-wave of the oscillations being modulated, the ratio of the modulated half-wave to the unmodulated one being a function of the detected data.

5. An arrangement according to claim 3, said oscillations comprising a series of pulses.

6. An arrangement according to claim 1, said signal generator having a self-oscillating frequency dependent upon the input voltage, and having an input circuit including at least one thermistor.

7. An arrangement according to claim 5, said signal generator producing a pulse series modulated in accordance with the voltage of the measuring contacts, the thus modulated signals simultaneously serving as a transmission current at the transmitter contacts.

8. An arrangement according to claim 7, said signal generator including a time-base circuit for production of pulses having constant charge, said circuit having an output connected to the transmitter contacts, a control circuit connected to the output of the time-base circuit, the input of the control circuit being a control switch connected with the measuring contacts for controlling the frequency of the time-base circuit in dependence of the voltage at the measuring contacts.

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