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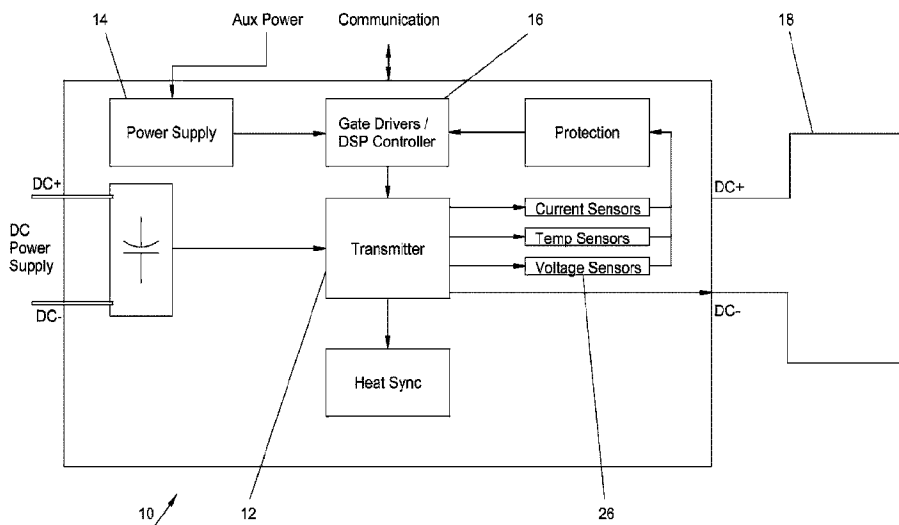
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(54) Titre : AGENCEMENT D'EMETTEUR MODULE HAUTE FREQUENCE

(54) Title: HIGH FREQUENCY MODULATED TRANSMITTER ARRANGEMENT



(57) Abrégé/Abstract:

The invention discloses a high frequency modulated transmitter arrangement for use in geophysical surveying. The transmitter arrangement has a switching transmitter operatively joined to a transmitter loop, wherein the switching transmitter is adapted to control electrical current flow in the transmitter loop. The switching transmitter receives an input voltage and produces an output voltage for causing the current flow in the transmitter loop, wherein the output voltage is regulated by pulse width modulation of the input voltage to produce a desired current waveform in the transmitter loop.

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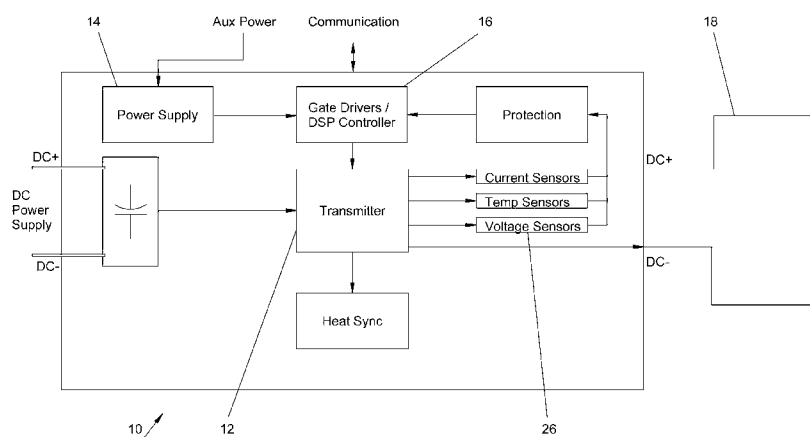


Fig. 1

(57) Abstract: The invention discloses a high frequency modulated transmitter arrangement for use in geophysical surveying. The transmitter arrangement has a switching transmitter operatively joined to a transmitter loop, wherein the switching transmitter is adapted to control electrical current flow in the transmitter loop. The switching transmitter receives an input voltage and produces an output voltage for causing the current flow in the transmitter loop, wherein the output voltage is regulated by pulse width modulation of the input voltage to produce a desired current waveform in the transmitter loop.

TITLE

HIGH FREQUENCY MODULATED TRANSMITTER ARRANGEMENT

FIELD OF INVENTION

[0001] The present invention relates to a high frequency modulated transmitter arrangement.

BACKGROUND TO INVENTION

[0002] Geophysical surveys of the earth's crust are conducted using electro-magnetic scanning techniques. These scanning techniques usually employ a transmitter that drives a low frequency alternating current waveform through variations of a loop of insulated electrical cable arranged on the ground for land based geophysical surveys.

[0003] Similar arrangements can be deployed for use in aerial geophysical surveys where a towed airborne array is deployed. Further, similar arrangements are also deployed in the form of a towed waterborne array in marine geophysical surveys.

[0004] Generally, the transmitter is arranged to generate a current waveform within the loop, where the time-on and time-off periods of the transmitter are equal. Further, the transmitter is arranged to generate the current waveform over a broad range of frequencies that typically range from 0.5 Hz and upwards.

[0005] In all of the above geophysical survey approaches, the loop of wire is generally energised using a constant peak current. At a pre-determined time the current is cut-off. It is important to note, that the termination of current flow is not instantaneous, but occurs over a brief period of time, known as the ramp time. Ramp time is normally in the range of a few microseconds, during which the resulting magnetic field is time-variant.

[0006] During ramp time, a current is induced in the subsurface over which the array is positioned. Current is induced in the subsurface through the action of the Faraday-Lenz Law.

[0007] The current induced in the subsurface (eddy currents) dissipate in the subsurface due to ohmic losses, which in turn cause a change in magnetic field of the subsurface thereby inducing further subsequent eddy currents.

[0008] The subsequent diffusion of eddy currents have the net result of causing a downward and outward expansion of current through the subsurface. The manner in which the current diffuses through the subsurface is related to the conductivity distribution of the ground.

[0009] The depth to which current is induced in the subsurface is dependent upon the time interval after shut-off, whereby the larger the time interval the greater the depth to which current will be induced and magnetic field strength changed.

[0010] Arranged to accompany the transmitter is a receiver capable of sensing magnetic field strength. The receiver is arranged to measure and record changes in magnetic field strength over time. The receiver is further arranged to record the magnetic field strength with respect to time as the current is first induced in the subsurface and subsequently as it dissipates through the subsurface. The results of the change in magnetic field strength with respect to time can then be analysed to determine the composition of the subsurface, i.e. if it contains any mineral deposits, and is commonly used as a basis for determining a location for exploratory drilling and other methods of exploration.

[0011] The two types of transmitters normally deployed in geophysical surveys are linear transmitters and unregulated switching transmitters. Linear transmitters regulate their output voltage - they can provide good output voltage and current regulation - however, they tend to be inefficient. At least in part this inefficiency comes from the continual dissipation of power through the pass transistor.

[0012] Linear transmitters tend to be larger and heavier than other transmitter types. At least in part due to the need to dissipate heat generated by current flowing through the pass resistor. Further, because of the inefficiency, the power supply required to drive a linear transmitter needs to be more powerful, this normally means the power supply is also larger and heavier. Due to these limitations, linear transmitters are normally only suitable for low power transmitters, especially in airborne geophysics.

[0013] Unregulated switching transmitters apply the full voltage available from the power supply to the load. However, unregulated switching transmitters are unable to provide profiled current waveforms and are susceptible to irregularities in the power supplied.

[0014] Unregulated switching transmitters are thus efficient and tend to be smaller than other transmitters. The unregulated switching transmitter operates in one of three distinct states, where positive voltage, negative voltage or no voltage is applied to the load respectively. The efficiency and size reductions are possible due to the transistor being used in low power dissipating states.

[0015] Further, unregulated switching transmitters are susceptible to issues on the load side such as changing temperature within the loop, effects that change the load resistance or impedance. These issues tend causing current drifting and changed in the on and off ramp of the transmitter current waveform.

[0016] The present invention attempts to overcome at least in part the aforementioned disadvantages of previous transmitters to produce a transmitter arrangement with a 'clean' current waveform and a stable 'turn off' characteristic.

SUMMARY OF INVENTION

[0017] According to an embodiment of the invention, there is provided a high frequency modulated transmitter arrangement for use in geophysical surveying, the arrangement comprising a switching transmitter being adapted to control electrical current flow in a transmitter loop, wherein the switching transmitter receives an input voltage and produces an output voltage, and wherein the output voltage of the switching transmitter is regulated by pulse width modulation of the input voltage to produce a desired current waveform in the transmitter loop.

[0018] The pulse width modulation may be performed at an operative frequency higher than a fundamental frequency of the desired current waveform.

[0019] The operative frequency may be at least twenty times higher than the fundamental frequency of the desired current waveform.

[0020] The operative frequency may be at least one hundred times higher than the fundamental frequency of the desired current waveform.

[0021] The operative frequency may be at least ten thousand times higher than the fundamental frequency of the desired current waveform.

[0022] The pulse width modulation may be arranged to be apply either a positive or a negative voltage adjustment to the input voltage.

[0023] The pulse width modulation may be arranged to be varied to account for irregularities in the input voltage.

[0024] The pulse width modulation may be arranged to be varied to account for irregularities in electrical resistance of the transmitter loop.

[0025] The pulse width modulation may be arranged to be varied to account for irregularities in electrical impedance of the transmitter loop.

[0026] The controller may be arranged to monitor the transmitter loop to measure electrical and physical characteristics of the transmitter loop.

[0027] The transmitter arrangement may comprise a power supply providing the input voltage to the switching transmitter and a controller, wherein the controller performs the pulse width modulation on the input voltage.

[0028] The controller may be adapted to vary the pulse width modulation to account for variations in electrical and physical characteristics of the transmitter loop.

[0029] The controller may operate by modelling the transmitter loop as an electrical circuit comprising a series resistor and inductor.

[0030] The switching transmitter may be connected to the transmitter loop via an inductor or filter.

[0031] Further according the invention, there is provided a land surveying arrangement comprising:

a high frequency modulated transmitter arrangement as described herein, and
a receiver coil

wherein the transmitter arrangement and the receiver coil are arranged for use in land based geophysical surveying.

[0032] Further according to the invention, there is provided an aerial surveying arrangement comprising:

a high frequency modulated transmitter arrangement as described herein, and
a receiver coil

wherein the transmitter arrangement and the receiver coil are arranged for use in aerial geophysical surveying.

[0033] The transmitter loop and the receiver coil may be arranged to be in substantially circular shapes, wherein the transmitter loop has a larger diameter than that of the receiver coil.

[0034] The transmitter loop and receiver coil may be concentrically arranged.

[0035] Further according to the invention, there is provided a marine surveying arrangement comprising:

a high frequency modulated transmitter arrangement as described herein, and
a receiver coil

wherein the transmitter arrangement and the receiver coil are arranged for use in marine geophysical surveying.

[0036] The transmitter loop and receiver coil may be arranged to be located under water and towed by a marine vessel, while the switching transmitter is adapted to be located on the marine vessel.

BRIEF DESCRIPTION OF DRAWINGS

[0037] The present invention will now be described, by way of example, with reference to the accompanying schematic drawings, in which:

Figure 1 is a block diagram of a high frequency modulated transmitter arrangement in accordance with the present invention shown being operatively connected to a loop of insulated electrical cable;

Figure 2 is a schematic block diagram of the high frequency modulated transmitter arrangement being arranged for a land based survey;

Figure 3 is a schematic block diagram of the high frequency modulated transmitter arrangement being arranged for an aerial survey; and

Figure 4 is a schematic block diagram of the high frequency modulated transmitter arrangement being arranged for a marine survey.

DETAILED DESCRIPTION OF THE DRAWINGS

[0038] Referring to the Figures 1 and 2 there is shown a first embodiment of a high frequency modulated transmitter arrangement 10 in accordance with the invention, which is arranged for use in a land based survey, the transmitter arrangement 10 comprising an unregulated switching transmitter 12, an electrical power supply 14 and a controller 16. The transmitter arrangement 10 is operatively connected to and in communication with a loop of electrical cable forming a transmitter loop 18.

[0039] The power supply 14 is in electrical communication with the switching transmitter 12 via the controller 16, wherein the power supply 14 provides an input voltage to the switching transmitter 12 so that the latter can produce an output voltage to be applied to the transmitter loop 18.

[0040] The controller 16 is arranged to effectively transform an alternating current provided by the power supply 14 into a pulse width modulation (PWM) signal. The PWM signal is configured to be able to apply both positive and negative adjustment voltages to the switching transmitter 12 as required.

[0041] The output of the switching transmitter 12 is connected to the transmitter loop 18, such that a current flows within the transmitter loop 18 when the switching transmitter 12 applies a voltage to the transmitter loop 18.

[0042] A separate receiver coil 20 (see Figure 2) is arranged in proximity to the transmitter loop 18, wherein the receiver coil 20 is arranged to measure and record changes in magnetic field intensity with respect to time.

[0043] Sensing means 22 are arranged in communication with the controller 16 and the transmitter loop 18, the sensing means 22 being adapted to determine physical and electrical characteristics of the transmitter loop 18, such as but not limited to, temperature, resistance, impedance, on and off ramps, instantaneous current, instantaneous voltage and current and voltage phase angles.

[0044] The sensing means 22 are arranged to provide a digital input to the controller 16 so that the controller 16 can react and adapt its operation in response to the physical and electrical characteristics of the transmitter loop 18. Preferably, the controller 16 is arranged to respond to any changes in real time.

[0045] Alternatively, in a further exemplary embodiment, the controller 16 can be a digital signal processor (DSP) unit. The controller 16 operates by modelling the transmitter loop 18 as a simple electrical circuit comprising a series resistor and inductor. The controller 16 is arranged to receive a number of signal inputs from sensing means 22 attached to the transmitter loop 18. The sensing means 22 are arranged to determine physical and electrical characteristics of the transmitter loop 18, such as but not limited to, temperature, resistance, impedance, on and off ramps, instantaneous current, instantaneous voltage and current and voltage phase angles. The controller 16 is arranged to adaptively tune its model in accordance with the physical and electrical characteristics of the transmitter loop 18 as provided by the sensing means 22.

[0046] An inductor or filter may be placed between the output of the switching transmitter 12 and the transmitter loop 18 so as to smooth or filter the output of the switching transmitter 12, therein reducing current ripple or any other electromagnetic emissions.

[0047] The sensing means 22 is further arranged to determine other physical and electrical characteristics of all the components of the transmitter arrangement 10. The controller 16 is arranged to monitor a number of these characteristics and, in response to operations outside of expected parameters, to quickly act to shut off either the switching transmitter 12, the controller 16 or the output signal to the transmitter loop 18 so as to prevent operation that may negatively affect results or circuit integrity of components.

[0048] Referring now to Figure 3, there is shown a second embodiment of a high frequency modulated transmitter arrangement in accordance with the invention, being generally indicated by reference numeral 30, which is arranged for use in an aerial survey. The transmitter arrangement 30 is similar to the transmitter arrangement 10 and thus like parts will be indicated by like reference numerals. The arrangement 30 comprises a switching transmitter 12, a controller 16, a transmitter loop 18 and a receiver coil 20.

[0049] The transmitter loop 18 is arranged in a large substantially circular shape such that the receiver coil 20 can be located therein and be substantially concentric therewith, i.e. the receiver coil 20 is centred at or near to the centre of the circle of the transmitter loop 18. The switching transmitter 12 is arranged to be in electrical communication with the controller 16 such that the output of the power supply 14 passes through the controller 16 to the switching transmitter 12.

[0050] The arrangement 30 is adapted to be lifted and towed behind an aircraft, preferably being a rotary wing aircraft such as a helicopter or drone.

[0051] Referring now to Figure 4, there is shown a third embodiment of a high frequency modulated transmitter arrangement in accordance with the invention, being generally indicated by reference numeral 40, which is arranged for use in a marine survey. Again, the transmitter arrangement 40 is similar to the transmitter arrangement 10 and thus like parts will be indicated by like reference numerals. The transmitter arrangement 40 comprises a switching transmitter 12, a controller 16 arranged to be in electrical communication with a power supply 14, a transmitter loop 18 and a receiver coil 20.

[0052] The transmitter loop 18 is arranged to be towed behind a marine vessel along with the receiver coil 20. Preferably, the switching transmitter 12, controller 16 and an electrical power supply 14 are arranged to be located and remain on the marine vessel.

[0053] In use, the transmitter arrangement 10, 30, 40 operates to cause a current to flow through the transmitter loop 18. The switching transmitter 12 draws electrical energy from the power supply 14 and the controller 16 is arranged to provide a PWM regulated voltage for the output of the switching transmitter 12.

[0054] The switching transmitter 12 draws electrical power from the power supply 14. As a result the raw output of the switching transmitter 12 can be effected by all of the disadvantages discussed above in relation to the prior art. Accordingly, the raw output of the switching transmitter 12 is passed as an input to the controller 16. The controller 16 uses the raw output of the switching transmitter 12 as a reference signal for its PWM output signal to regulate the output of the switching transmitter 12 applied to the transmitter loop 18.

[0055] The output of the switching transmitter 12 is passed to the transmitter loop 18, which acts as an inductor in a normal manner to induce a current in ground 50 being surveyed. At a predetermined time the output signal from the controller 16 will be cut off so that the receiver coil 20 can sense and record the magnetic flux in the ground 50 with respect to time and in so doing identify the location of a target 52 buried within the ground 50.

[0056] Advantageously, it has been found that by passing the output of the switching transmitter 12 to the controller 16 it is possible to substantially reduce or entirely remove some of the negative effects encountered in normal use of unregulated switch mode transmitters. Most importantly, by passing the output of the unregulated switching transmitter 12 to the controller 16, a profiled current waveform may be generated. Further, the arrangement allows at least to a degree for the negation of power supply effects on the signal transmitted to the load.

[0057] Further, it has been found that it is possible to switch the current signal off much more quickly than was possible using previous transmitter techniques. The transmitter arrangement 10, 30, 40 is able to turn off the PWM output signal immediately after the

current been cut off. This fast cut off speed is particularly advantageous as it is the most significant sensing time period for the receiver coil 20.

[0058] Preferably the PWM signal output of the controller 16 is arranged to be synchronised with a fundamental current waveform of the switching transmitter 12. The synchronisation of the two waveforms advantageously allows any PWM effects to be accounted for and filtered by the receiver coil 20.

[0059] Further, the PWM signal output of the controller 16 is arranged to have a frequency which is at least twenty, preferably being at least one hundred, times higher than the fundamental frequency of the desired current waveform of the switching transmitter 12. The higher frequency allows PWM effects to be separated from the fundamental waveform.

[0060] It has been found that the arrangement as described above delivers a number of advantages over previous transmitter arrangements. Particularly, in that it is envisaged that the subsurface material of the ground 50 itself will have a filtering effect and any transmitted PWM effects will be further filtered by the secondary response of the subsurface material.

[0061] Modifications and variations as would be apparent to a skilled addressee are deemed to be within the scope of the present invention.

CLAIMS

1. A high frequency modulated transmitter arrangement for use in geophysical surveying, the arrangement comprising a switching transmitter arranged to control electrical current flow in a transmitter loop, wherein the switching transmitter receives an input voltage and produces an output voltage, and wherein the output voltage of the switching transmitter is regulated by high frequency pulse width modulation of the input voltage to produce a desired current waveform in the transmitter loop, and wherein the desired current waveform in the transmitter loop is arranged to induce magnetic flux in a survey medium, and wherein the switching transmitter is arranged to cut off the output voltage at a predetermined time, and wherein a receiver means is arranged to measure and record changes in magnetic field intensity with respect to time.
2. A transmitter arrangement as claimed in claim 1, in which the pulse width modulation is performed at an operative frequency higher than a fundamental frequency of the desired current waveform.
3. A transmitter arrangement as claimed in claim 2, in which the operative frequency is at least twenty times higher than the fundamental frequency of the desired current waveform.
4. A transmitter arrangement as claimed in claim 3, in which the operative frequency is at least one hundred times higher than the fundamental frequency of the desired current waveform.
5. A transmitter arrangement as claimed in claim 4, in which the operative frequency is at least ten thousand times higher than the fundamental frequency of the desired current waveform.
6. A transmitter arrangement as claimed in claim 1, in which the pulse width modulation is arranged to apply either a positive or a negative voltage adjustment to the input voltage.
7. A transmitter arrangement as claimed in claim 1, in which the pulse width modulation is arranged to be varied to account for irregularities in the input voltage.

8. A transmitter arrangement as claimed in claim 1, in which the pulse width modulation is arranged to be varied to account for irregularities in electrical resistance of the transmitter loop.
9. A transmitter arrangement as claimed in claim 1, in which the pulse width modulation is arranged to be varied to account for irregularities in electrical impedance of the transmitter loop.
10. A transmitter arrangement as claimed in claim 1 further comprising a power supply providing the input voltage to the switching transmitter and a controller, wherein the controller performs the pulse width modulation on the input voltage.
11. A transmitter arrangement as claimed in claim 10, in which the controller is arranged to monitor the transmitter loop to measure electrical and physical characteristics of the transmitter loop.
12. A transmitter arrangement as claimed in claim 11, in which the controller is arranged to vary the pulse width modulation to account for variations in electrical and physical characteristics of the transmitter loop.
13. A transmitter arrangement as claimed in claim 11 or 12, in which the controller operates by modelling the transmitter loop as an electrical circuit comprising a series resistor and inductor.
14. A transmitter arrangement as claimed in claim 1, in which the switching transmitter is connected to the transmitter loop via an inductor or filter.
15. A transmitter arrangement as claimed in any one of claims 1 to 14, wherein the transmitter arrangement is arranged for use in land based geophysical surveying.
16. A transmitter arrangement as claimed in any one of claims 1 to 14, wherein the transmitter arrangement is arranged for use in aerial geophysical surveying.
17. A transmitter arrangement as claimed in claim 16, in which the transmitter loop and a receiver coil are arranged to be in substantially circular shapes, wherein the transmitter loop has a larger diameter than that of the receiver coil.

18. A transmitter arrangement as claimed in claim 17, in which the transmitter loop and receiver coil are concentrically arranged.
19. A transmitter arrangement as claimed in any one of claims 1 to 14, wherein the transmitter arrangement is arranged for use in marine geophysical surveying.
20. A transmitter arrangement as claimed in claim 19, in which the transmitter arrangement is arranged to be located under water and towed by a marine vessel, while the switching transmitter is arranged to be located on the marine vessel.

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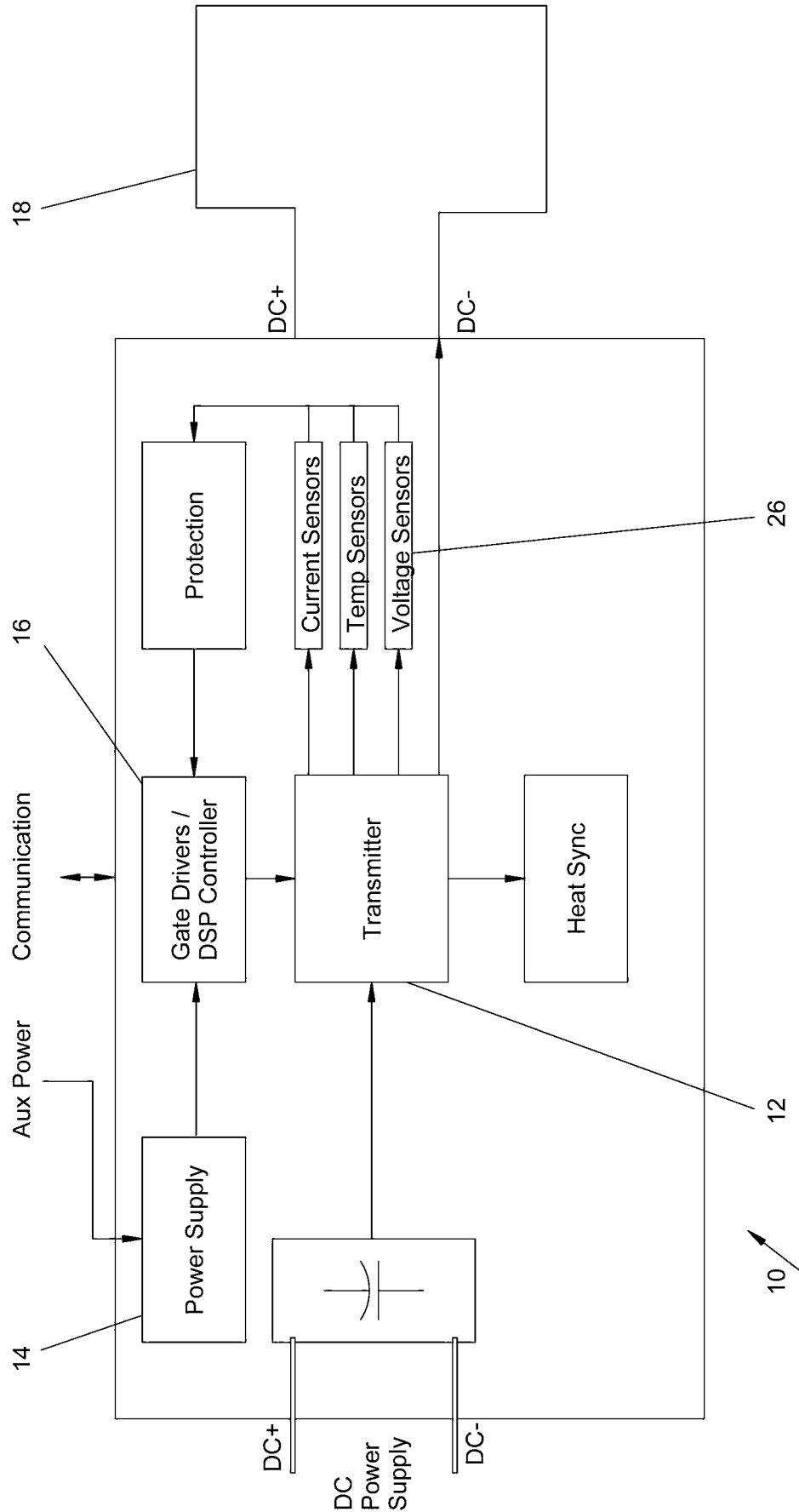


Fig. 1

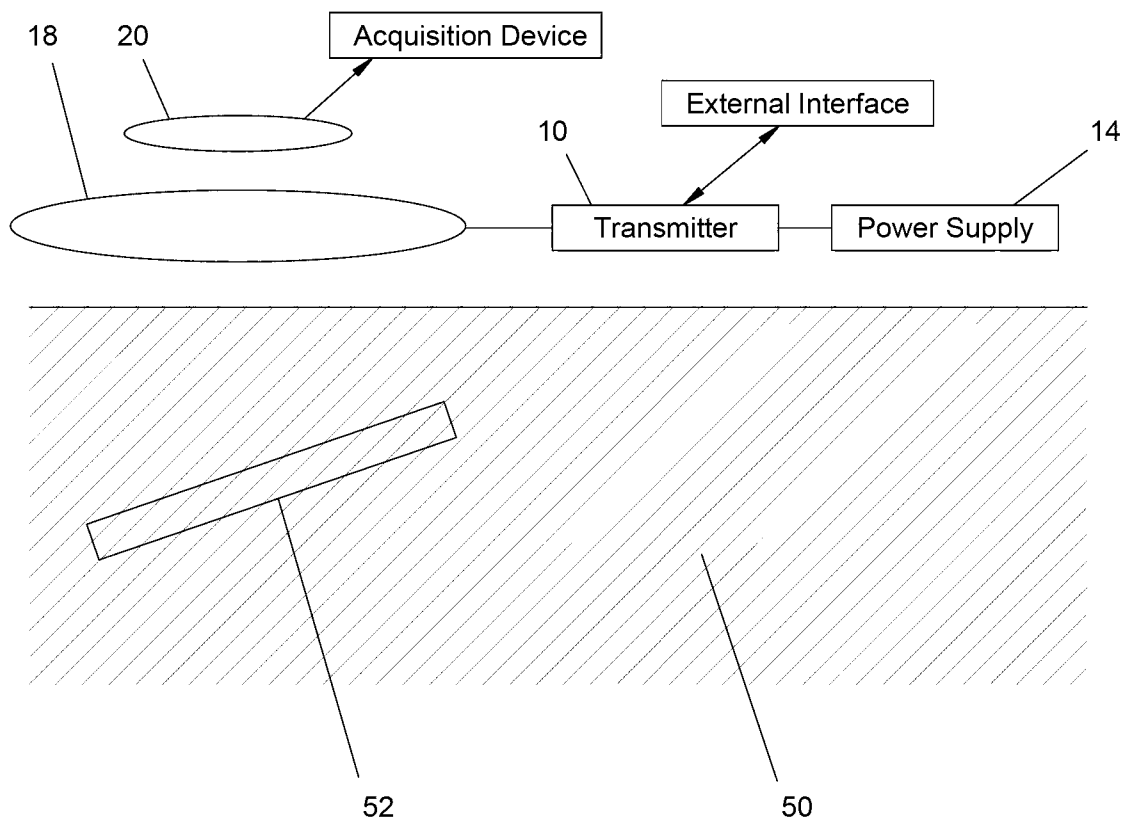
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Fig. 2

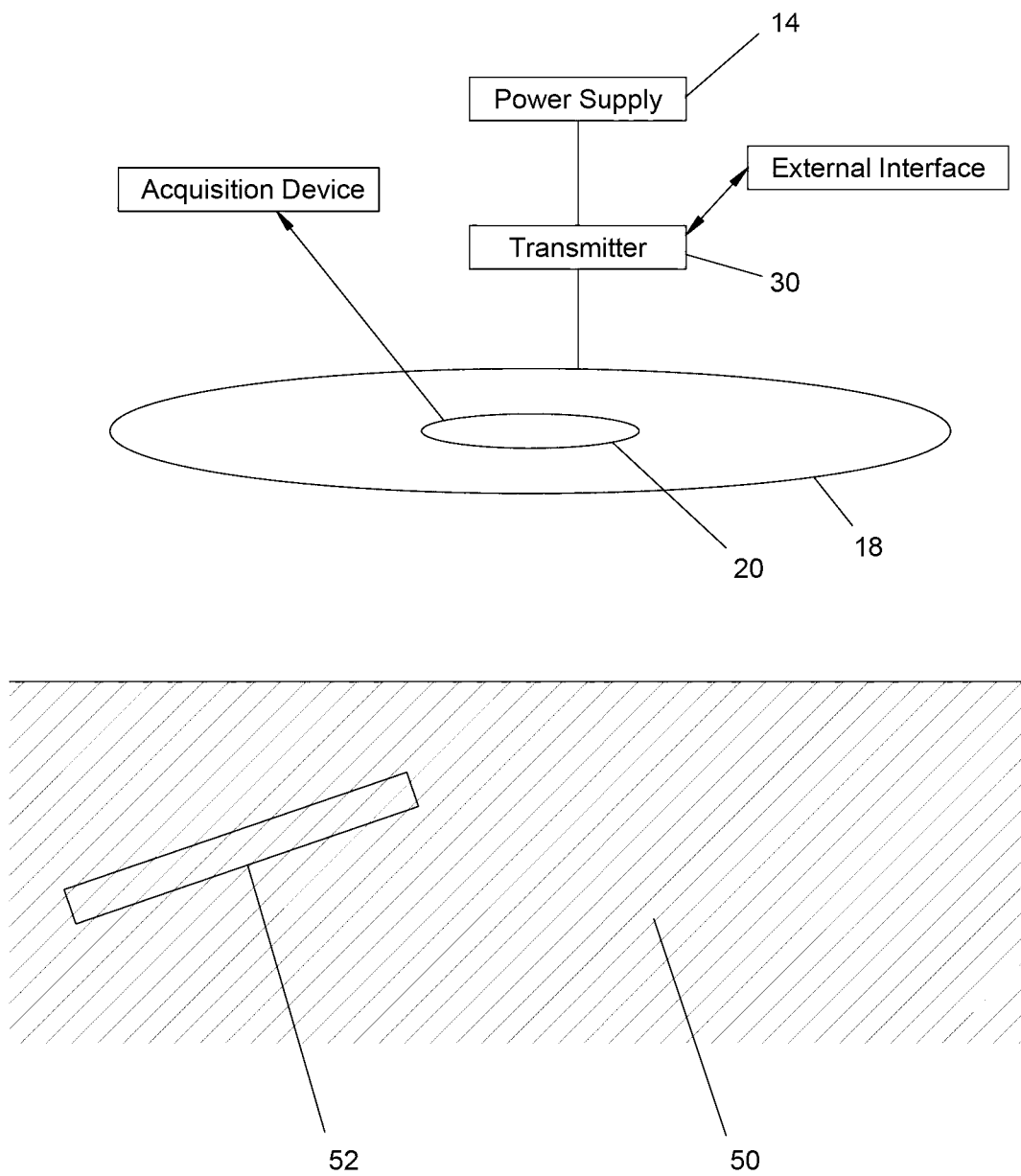
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Fig. 3

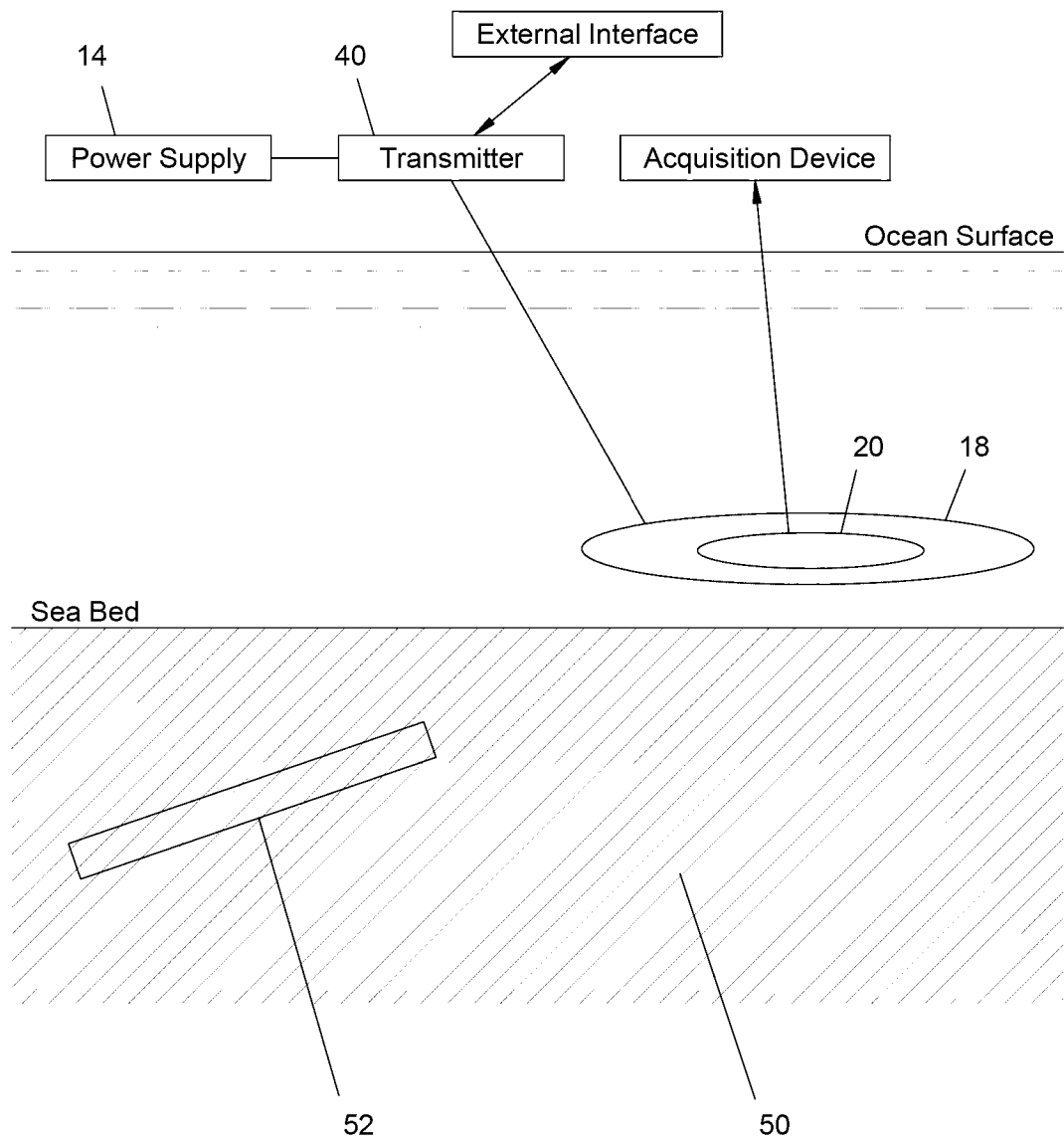
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Fig. 4

