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Castle

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(54) **METAL DETECTOR AND METHOD IN WHICH MINERALIZATION EFFECTS ARE ELIMINATED**

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(58) Field of Search 324/225, 233, 324/239, 329; 340/551

(56) **References Cited**

U.S. PATENT DOCUMENTS

- 3,763,424 A * 10/1973 Bennett, Jr. et al. 324/239 X
- 4,110,679 A * 8/1978 Payne 324/329
- 4,128,803 A * 12/1978 Payne 324/329
- 4,325,027 A * 4/1982 Dykstra et al. 324/329
- 4,486,713 A * 12/1984 Gifford 324/329
- 4,600,356 A * 7/1986 Bridges et al. 324/329 X

- 4,700,139 A * 10/1987 Podhrasky 324/329
- 5,414,411 A * 5/1995 Lahr 324/329 X
- 5,506,506 A * 4/1996 Candy 324/329
- 5,576,624 A * 11/1996 Candy 324/329
- 5,729,143 A * 3/1998 Tavernetti et al. 324/329
- 6,172,504 B1 * 1/2001 Earle 324/329
- 6,326,791 B1 * 12/2001 Bosnar 324/329

FOREIGN PATENT DOCUMENTS

- GB 2 041 532 * 9/1980 324/329
- GB 2 071 327 * 9/1981 324/329

* cited by examiner

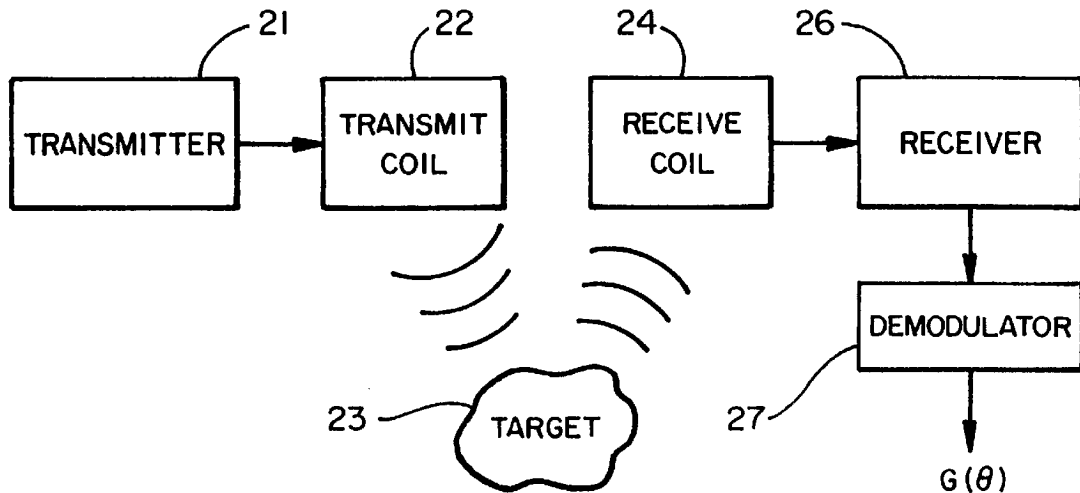
Primary Examiner—Gerard R. Strecker

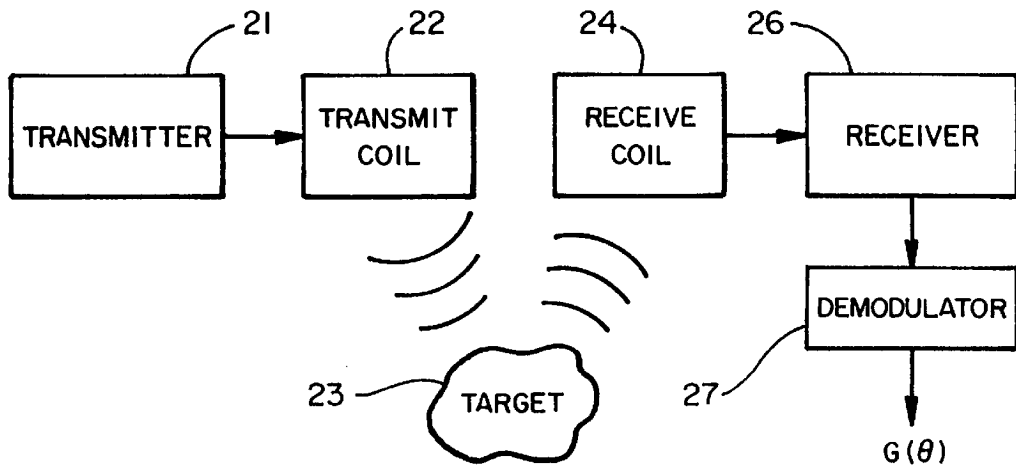
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(57) **ABSTRACT**

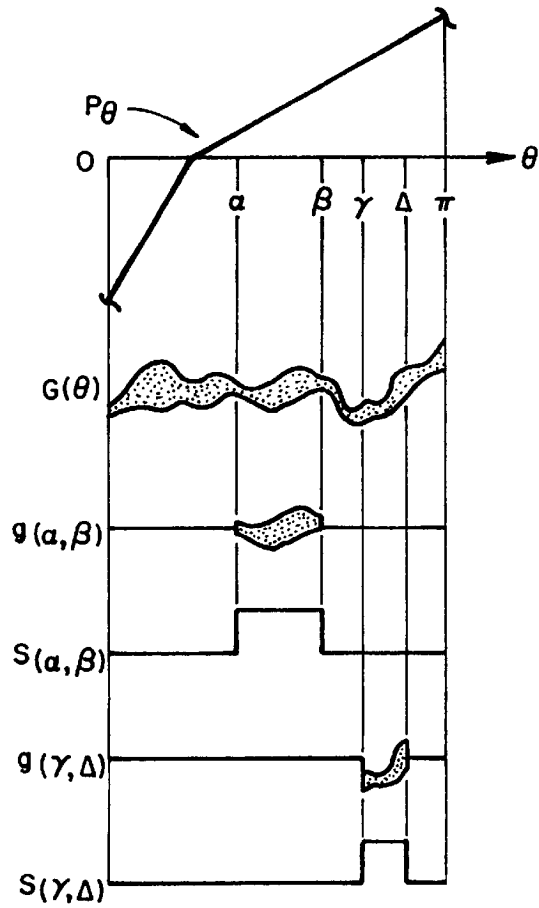
Metal detector and method in which soil mineralization effects and responses to other undesired materials are eliminated. A periodic excitation signal is transmitted into an area where a target is to be detected, and signals returned by the target are processed to provide an output signal corresponding to the target. A plurality of signals are extracted from the output signal during different phase intervals in the period of the excitation signal and processed to provide signals which are free from ferrite response and/or response to other undesired materials. The signals which are free from response to ferrite and/or other undesired materials are then compared to identify the target.

24 Claims, 9 Drawing Sheets

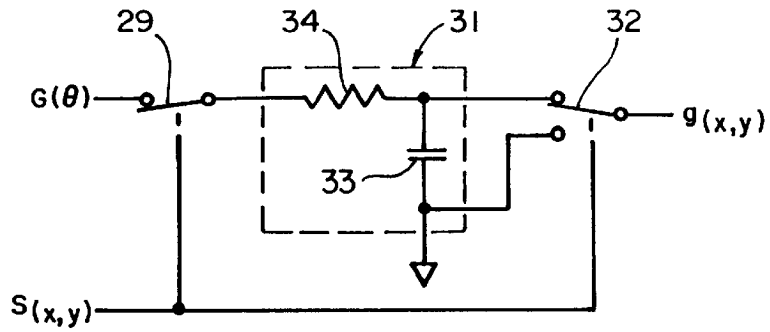




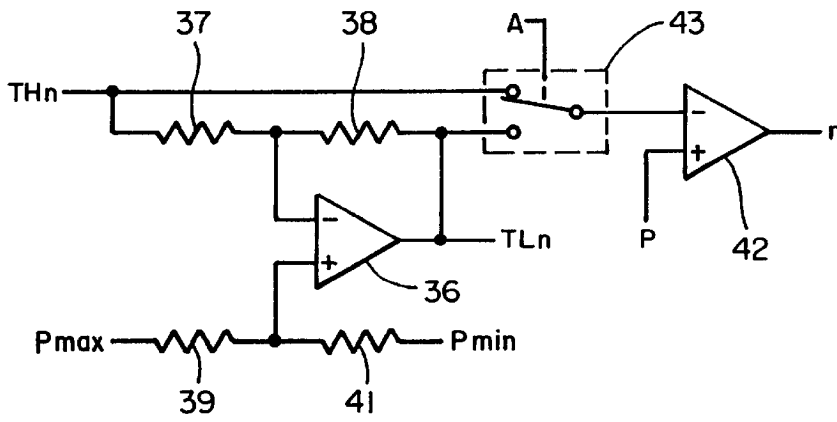
FIG_1



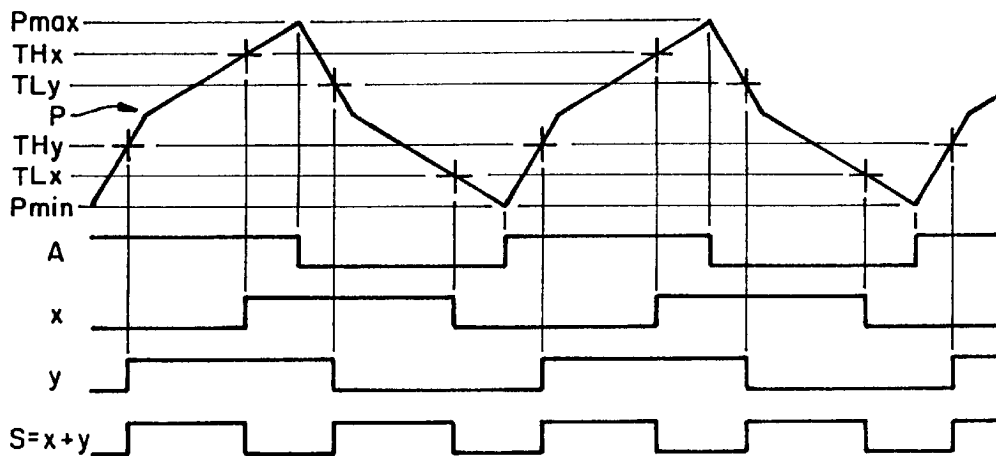
FIG_2



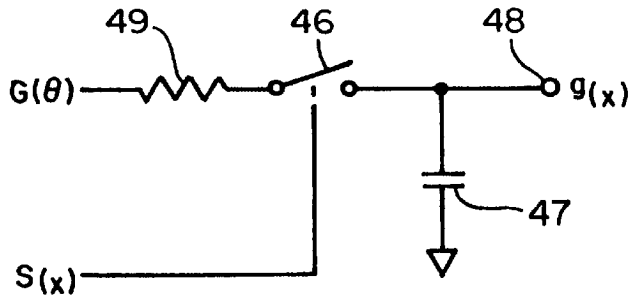
FIG_3



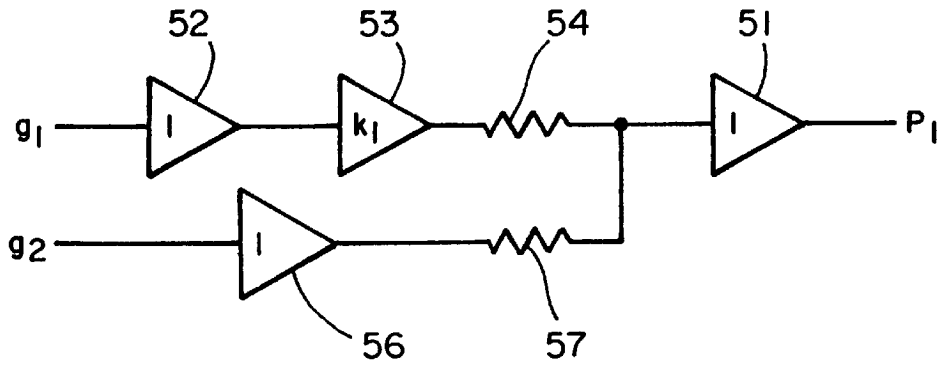
FIG_4



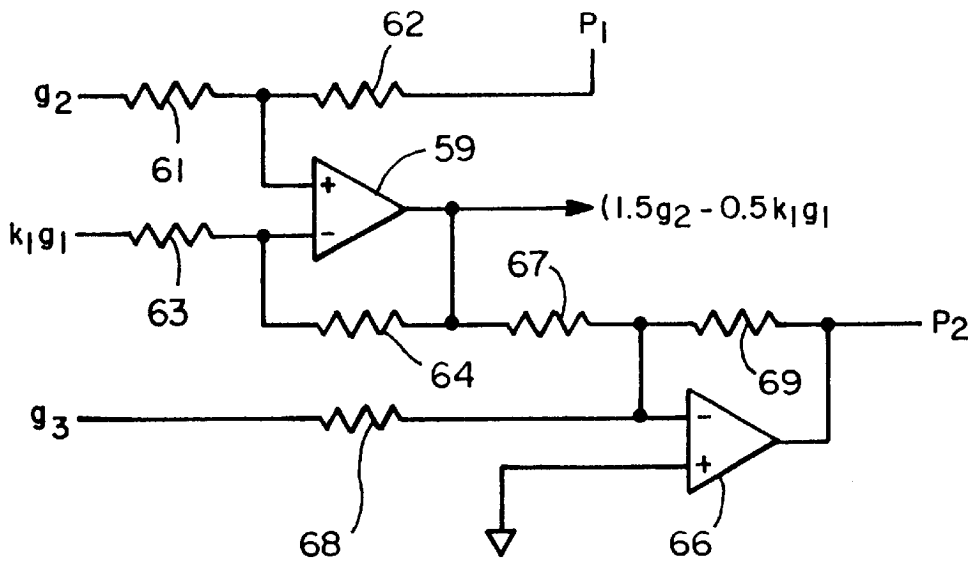
FIG_5



FIG_6



FIG_7



FIG_8

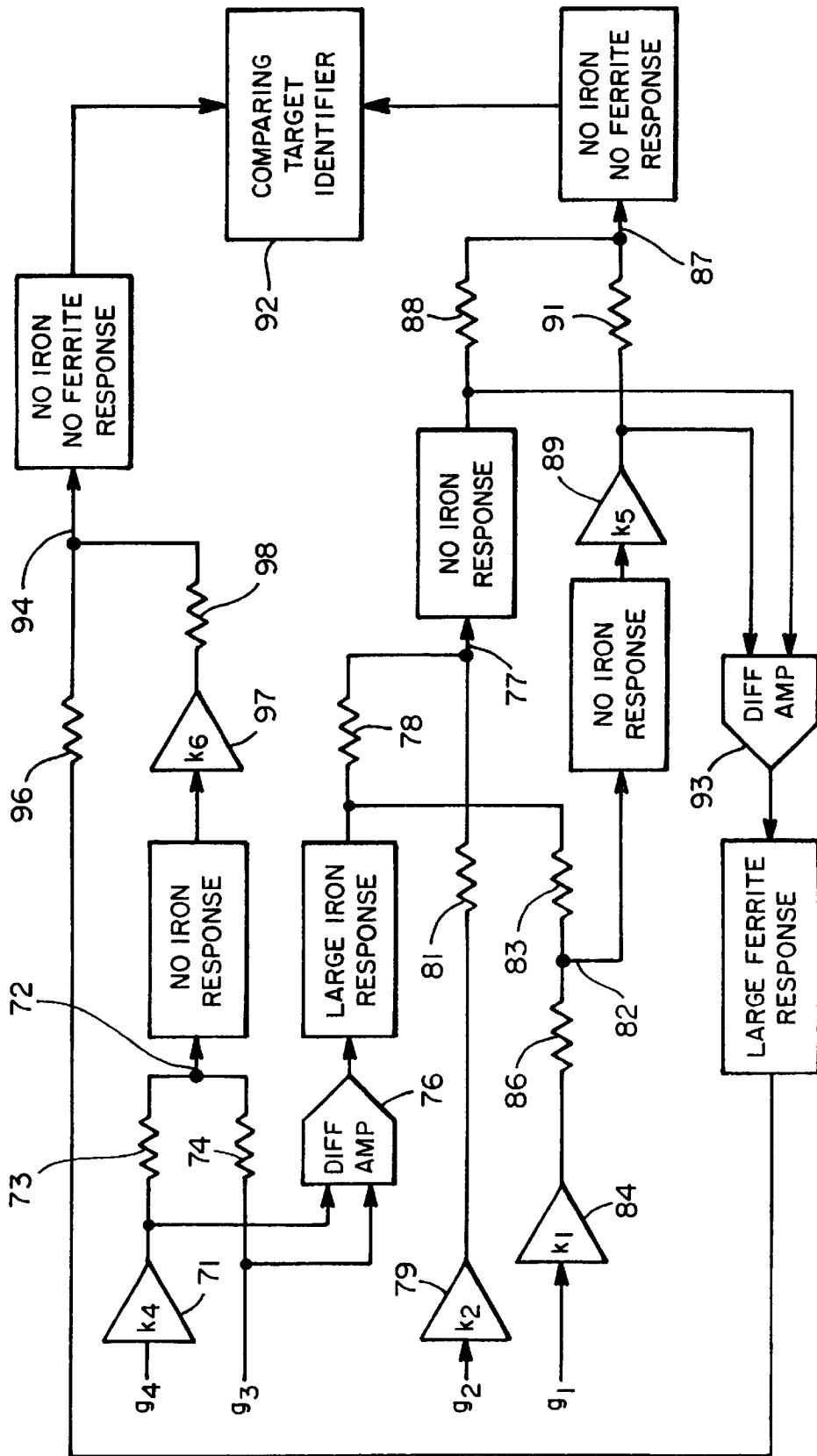


FIG-9

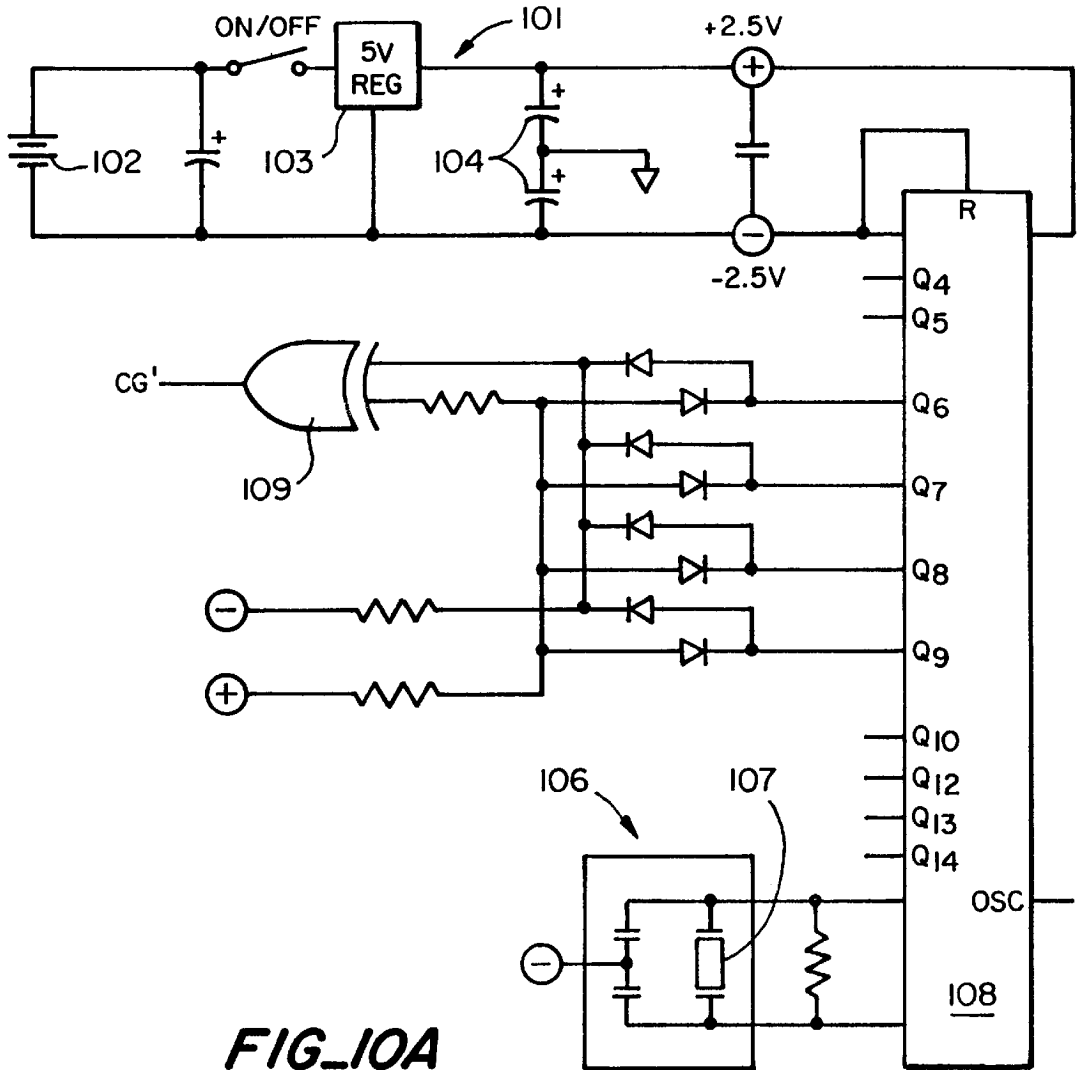


FIG 10A

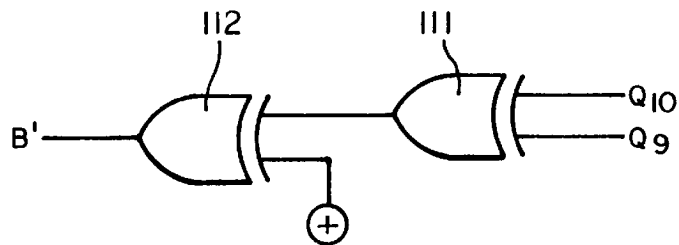
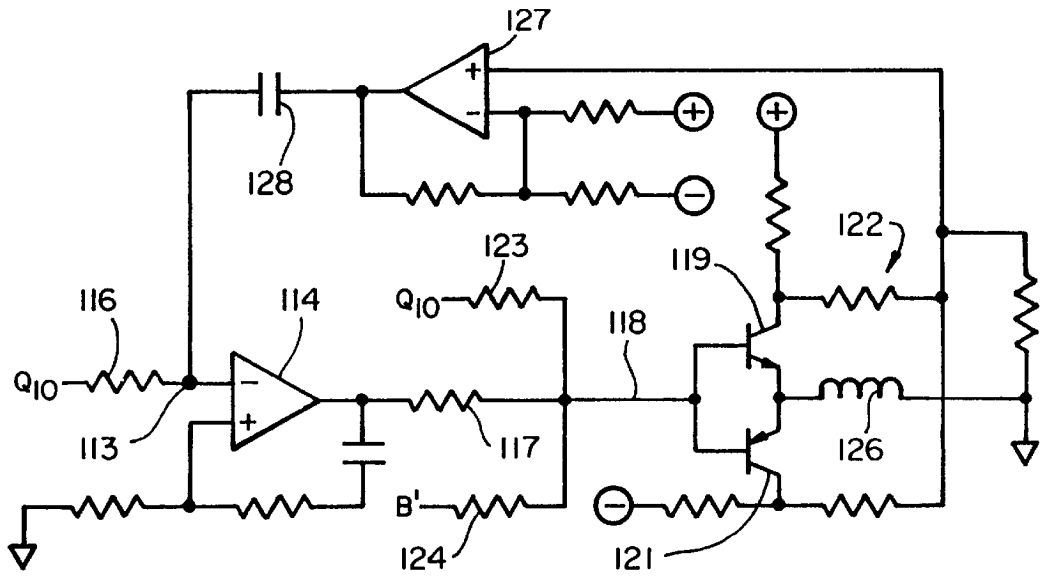
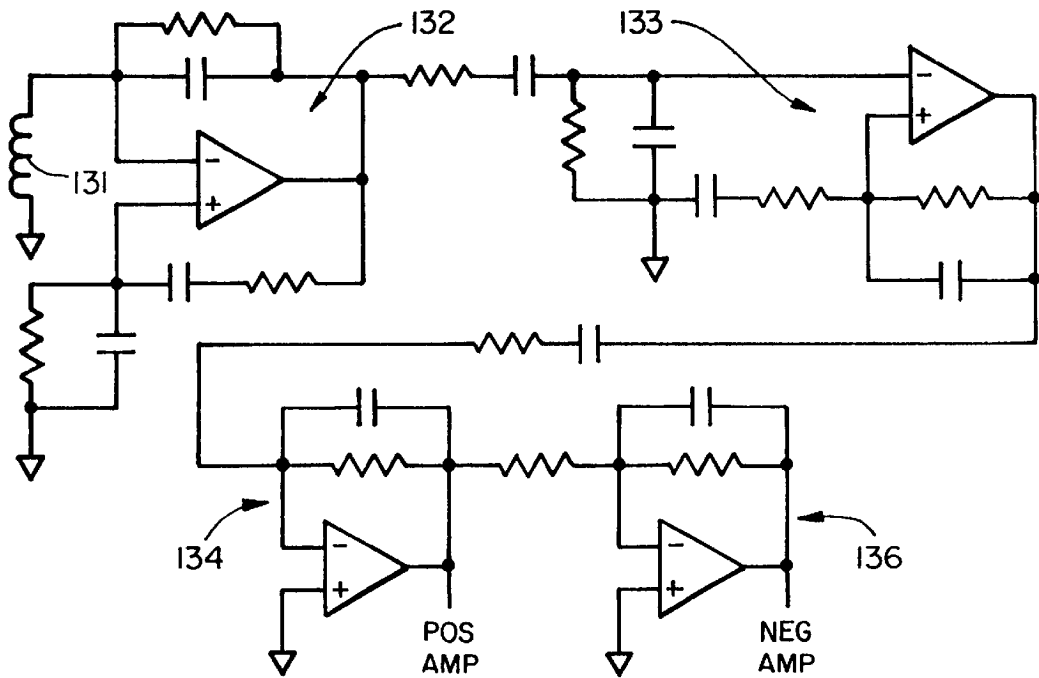


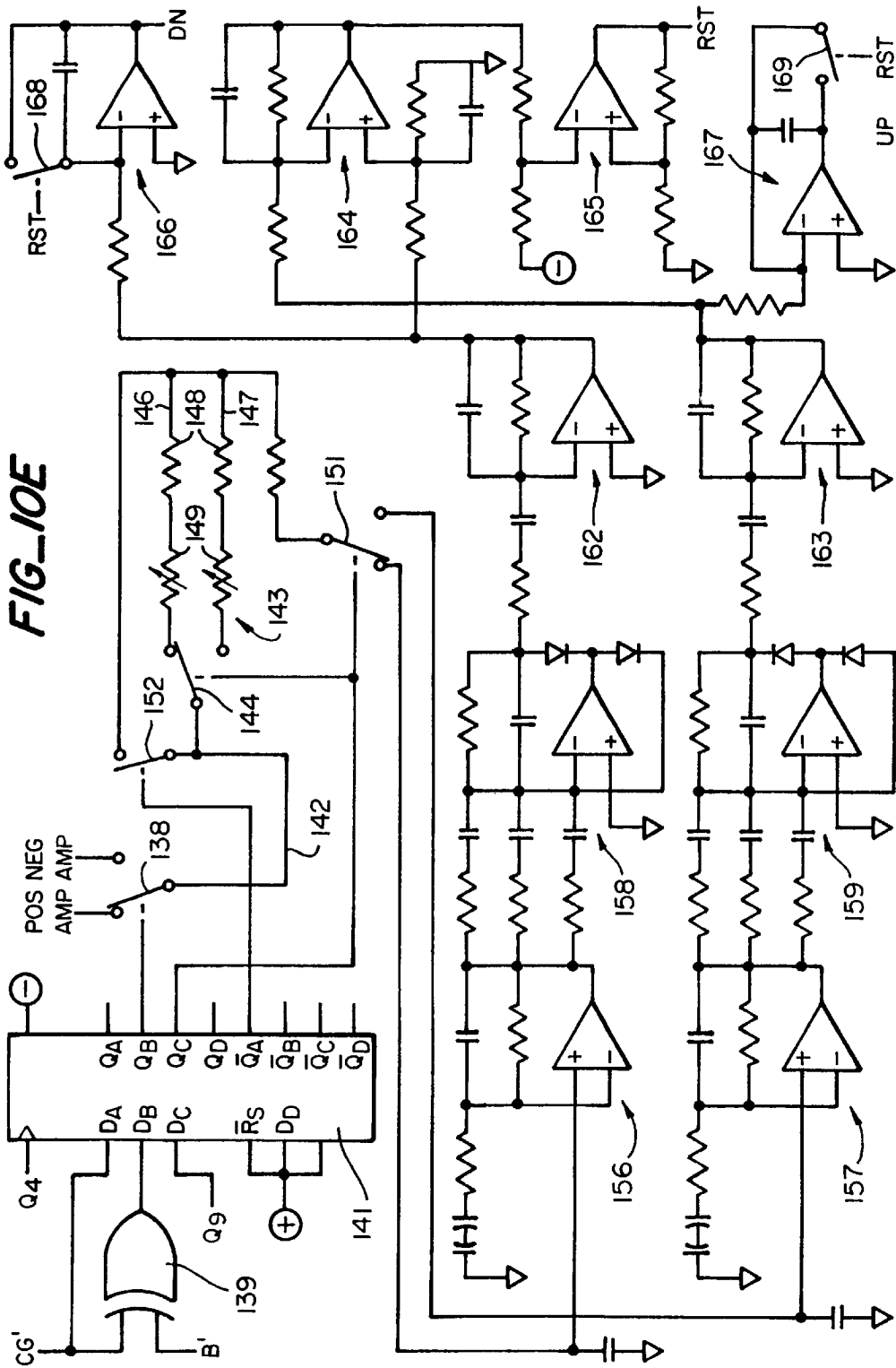
FIG 10B



FIG_10C



FIG_10D



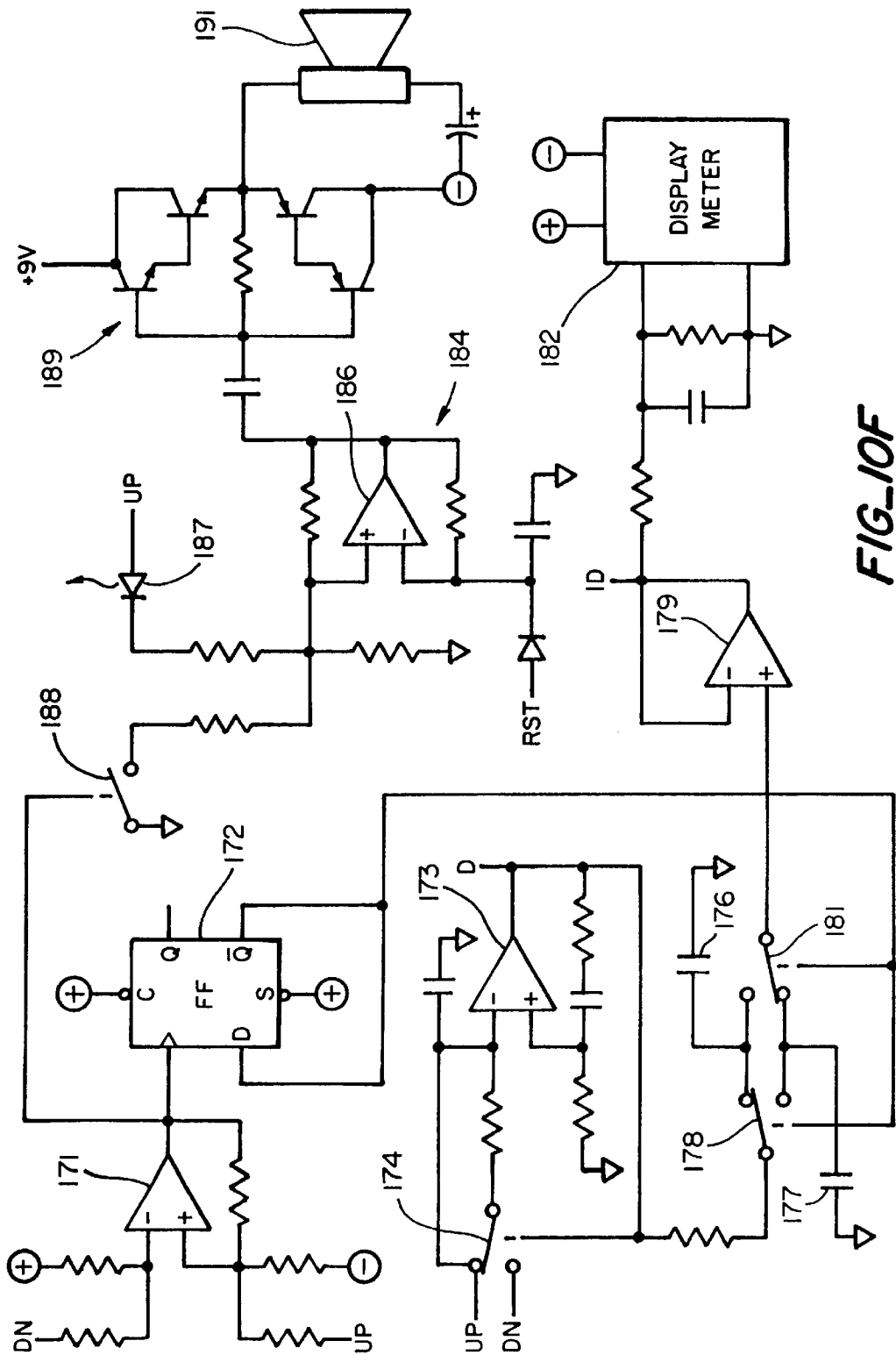
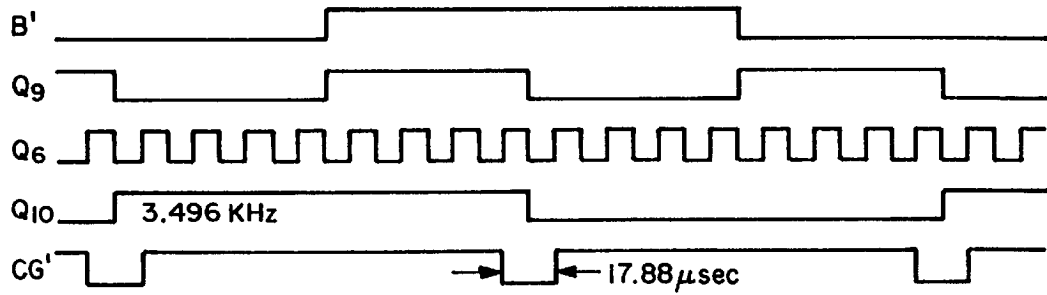
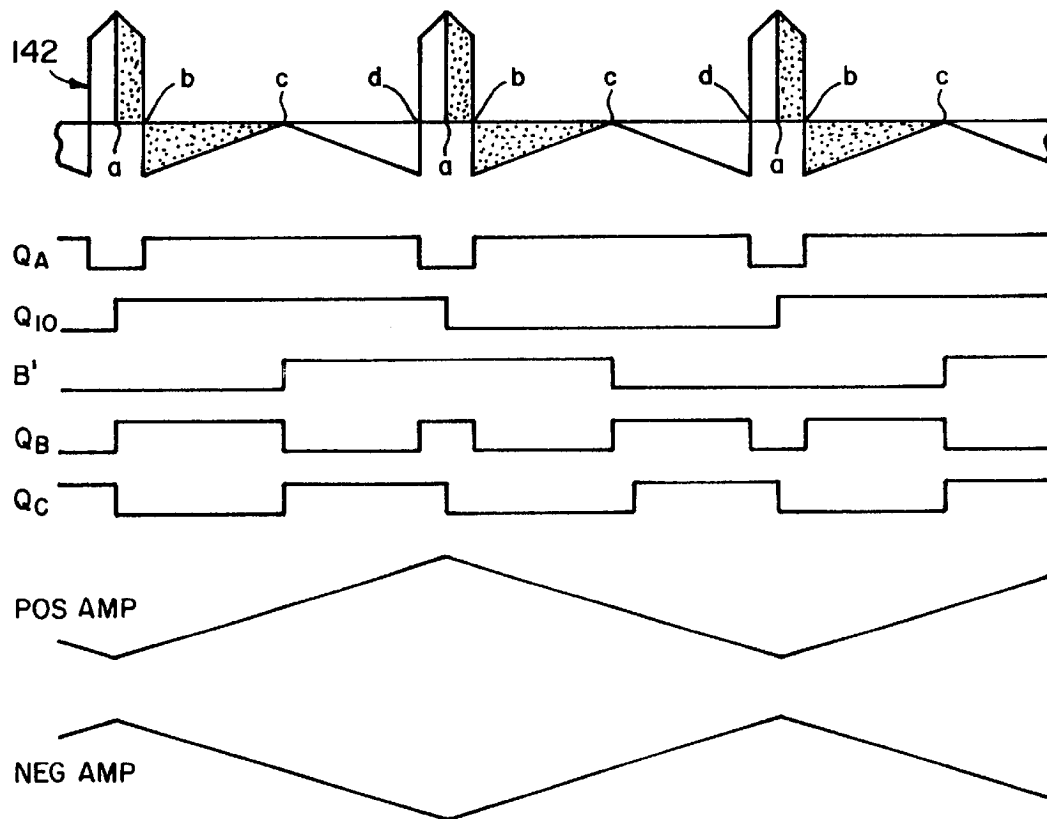


FIG-10F



FIG_11



FIG_12

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METAL DETECTOR AND METHOD IN WHICH MINERALIZATION EFFECTS ARE ELIMINATED

This invention pertains generally to metal detectors and, more particularly, to a metal detector and method in which the effects of mineralization on target identification are eliminated.

A significant problem with metal detectors is that mineralization in the soil surrounding the target can cause the target to appear to be something other than what it is. Numerous attempts have been made to minimize this problem, but the result has remained a function of the background mineralization, with the type of target indicated depending upon the level and distribution of mineralization in the soil. The effect of the mineralization on target identification is sometimes referred to as the "ferrite response".

It is in general an object of the invention to provide a new and improved metal detector and method.

Another object of the invention is to provide a metal detector and method of the above character which eliminate the effects of soil mineralization on target identification.

These and other objects are achieved in accordance with the invention by providing a metal detector and method in which two or more signals containing target information are extracted from the detector response during different phase intervals of the excitation signal and processed to eliminate ferrite response and/or response to other undesired materials. Those signals are then compared to identify targets without interference from ferrous materials or minerals which may be present.

FIG. 1 is a block diagram of a metal detector of the type to which the invention pertains.

FIG. 2 is a waveform diagram illustrating how the response of a metal detector to a given target can be broken up into a number of independent time intervals.

FIG. 3 is a diagram of one embodiment of a circuit for sampling the response of a metal detector individual time intervals.

FIG. 4 is a diagram of a circuit for gating time intervals in an excitation waveform in accordance with a control signal.

FIG. 5 is a set of waveforms illustrating the operation of the circuit of FIG. 4.

FIG. 6 is a diagram of another embodiment of a circuit for sampling the response of a metal detector individual time intervals.

FIGS. 7-8 are diagrams of circuits for sampling the outputs of a metal detector different time intervals to provide output signals which are free of ferrite response.

FIG. 9 is a block diagram of a circuit for combining the outputs of a metal detector at different time intervals to provide output signals which are free of both iron response and soil mineralization response.

FIGS. 10A-10F are circuit diagrams of a preferred embodiment of a metal detector incorporating the invention.

FIG. 11 is a timing diagram illustrating the waveforms at different points in the embodiment of FIGS. 10A-10F.

FIG. 12 is a waveform diagram illustrating the cancellation of ferrite response in the embodiment of FIGS. 10A-10F.

As illustrated in FIG. 1, the metal detector includes a transmitter 21 which is connected to a transmitting coil 22 for transmitting a relatively high frequency signal (e.g. 3.5 KHz) into the area in which a target 23 is located. Signals returned by the target are picked up by a receiving coil 24 and processed by a receiver 26 which includes a demodu-

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lator 27. The signals from the demodulator are compared to identify the target.

In FIG. 2, waveform PΘ represents the excitation current in the transmitting coil and waveform G(Θ) represents the output of the detector in response to a target moving past the receiving coil at a rate much lower than the excitation frequency. For ease of illustration, only the first half of the excitation cycle is shown. The second half is similar to the first. Waveform G(Θ) is sampled during the phase intervals α to β and γ to Δ to provide output signals g_(α,β) and g_(γ,Δ). The sampling is done in accordance with control signals S_(α,β) and S_(γ,Δ) which are high during the sampling windows. For the phase intervals α to β and γ to Δ, the output signals g_(α,β) and g_(γ,Δ) are given by the following relationships:

$$g_{(\alpha,\beta)} = \int_{\alpha}^{\beta} dG(\Theta) - \int_0^{\alpha} dG(\Theta) - \int_{\beta}^{\pi} dG(\Theta), \text{ and}$$

$$g_{(\gamma,\Delta)} = \int_{\gamma}^{\Delta} dG(\Theta) - \int_0^{\gamma} dG(\Theta) - \int_{\Delta}^{\pi} dG(\Theta).$$

FIG. 3 illustrates a simple circuit for producing a waveform g_(x,y). This circuit consists of an input switch 29, an integrator 31 and an output switch 32, with switches 29, 32 being controlled by the sampling signal S_(x,y). Waveform G(Θ) is applied to one terminal of input switch 29, and waveform g_(x,y) appears at the output terminal of switch 32. The integrator consists of a capacitor 33 which is connected to the output terminal of switch 29 by a resistor 34, with the lower side of the capacitor being connected to ground. The input terminals of switch 32 are connected to the top side of the capacitor and to ground.

During the phase interval x to y, when sampling signal S_(x,y) is high, waveform G(Θ) is applied to the integrating capacitor, and the output g_(x,y) is the integral of the waveform G(Θ). At other times, the sampling signal S_(x,y) is low, waveform G(Θ) is disconnected from the integrator, and the output terminal of switch 32 is connected to ground, thereby resetting waveform g_(x,y).

The response of the metal detector to any given target can thus be broken up into any desired number of independent phase intervals, with higher numbers of intervals providing more refined identifications. The control signal S_(x,y) can provide a sampling window of any desired width and can be swept from 0 to π at any desired rate to map the transfer function of the detector's response to any desired targets as a function of phase angle. The implementation can be either analog or digital.

FIGS. 4 and 5 illustrate how a control voltage TH_n can shift an excitation voltage timing waveform A anywhere from 0° to 180° to produce a sampling signal S for any desired sampling windows. In these figures, waveform P is a voltage corresponding to the excitation current in the transmitting coil, which varies about zero between a minimum value P_{MIN} and a maximum value P_{MAX}. Waveform A represents the polarity of voltage P in that it indicates it is positive-going or negative-going. Waveforms x and y are control signals for the phase intervals in which waveform P is between TH_x and TL_x and between TH_y and TL_y, where TL_x = -TH_x and TL_y = -TH_y. Control signal S is the exclusive-OR (XOR) function of waveforms x and y.

In the circuit of FIG. 4, the value TL_n is derived from control voltage TH_n by applying the control voltage to the negative input of a differential amplifier 36 through a resistor 37, with a feedback resistor 38 connected between the output and the negative input of the differential amplifier. A voltage midway between P_{MAX} and P_{MIN} is applied to the positive

input of the differential amplifier by a voltage divider consisting of resistors 39, 41. Resistors 37-41 are all of equal value, and the output of differential amplifier is TL_n which, as noted above, is equal to $-TH_n$.

The circuit of FIG. 4 also includes a comparator 42 and a switch 43 controlled by waveform A for applying either TH_n or TL_n to the negative input of the comparator. The excitation waveform P is applied to the positive input of the comparator, and the output of the comparator is a waveform n which can, for example, be either the waveform x or the waveform y in the example of FIG. 4.

When the waveform A is positive, control voltage TH_n is applied to the input of the comparator. When excitation waveform P rises above control voltage TH_n , the waveform n at the output of the comparator gate goes high. When excitation waveform P falls below control voltage TH_n , the waveform n at the output of the comparator goes low.

When the waveform A is negative, the value TL_n is applied to the input of the comparator. When excitation waveform P falls below TL_n , the waveform n at the output of the comparator goes low. When excitation waveform P rises above TL_n , the waveform n at the output of the comparator goes high.

The outputs of two or more such circuits can be combined in an XOR function to generate a combined control signal such as the waveform S shown in FIG. 5 which can represent the time interval between any two points within the entire cycle of the excitation waveform. This technique is applicable with any symmetrical periodic waveform, e.g. square, sinusoidal, triangular, trapezoidal, etc., as long as the excitation voltage source does not go into current limitation.

FIG. 6 illustrates another embodiment of a circuit for sampling the detector output signal $G(\Theta)$ during a phase interval determined by a control signal $S_{(c)}$ to provide an output signal $g_{(c)}$. This circuit is similar to the circuit of FIG. 3 except that the integrator is not reset when the sampling signal is zero. In this embodiment, there is a single switch 46 which is controlled by signal $S_{(c)}$ with the detector signal $G(\Theta)$ being applied to the integrating capacitor 47 and to the output terminal 48 through resistor 49 when the switch is in its closed position.

FIG. 7 illustrates a circuit for combining the signals g_1 and g_2 from two phase intervals to provide an output signal ρ_1 which has no ferrite response. The signals g_1 and g_2 are chosen to have opposite polarities in their responses to ferrite. The signal g_1 is applied to an output amplifier 51 through a first amplifier 52, a second amplifier 53 and a resistor 54, and signal g_2 is applied to amplifier 51 through an amplifier 56 and a resistor 57. Amplifiers 51, 52 and 56 are unity gain amplifiers, amplifier 53 has a gain of k_1 , and resistors 54 and 57 are equal in value.

$$\rho_1 = (k_1 g_1 + g_2) / 2, \text{ and}$$

k_1 is selected so that ρ_1 has no response to ferrite.

In the circuit of FIG. 8, the signals g_1 , g_2 and g_3 from three time intervals are combined to provide an output signal ρ_2 which has no ferrite response. Signals g_1 and g_2 are applied to the positive input of a differential amplifier 59 through resistors 61, 62 of equal value, and $k_1 g_1$ is applied to the negative input of the amplifier through a resistor 63. A feedback resistor 64 is connected between the output terminal and the negative input terminal of the amplifier. The output of the amplifier is equal to $1.5g_2 + k_1 g_1$.

The output of amplifier 59 is connected to the negative input of a second differential amplifier 66 by a resistor 67, and signal g_3 is to that input through a resistor 68. Output signal ρ_2 appears at the output of amplifier 66, and a

feedback resistor 69 is connected between the output and negative input terminals of that amplifier. Resistors 67 and 68 are selected so that output signal ρ_2 has no ferrite response.

Output signals ρ_1 and ρ_2 are then compared to identify the target. However, since those signals have no ferrite response, ferrous mineralization in the soil surrounding the target has no effect on target identification.

FIG. 9 illustrates another embodiment in which the average values of a plurality of detector responses g_n from different time intervals across the excitation waveform are combined to provide composite period averages which are compared with each other to provide target identifications that are free from both iron and soil mineralization responses. In this embodiment, g_n is a signal which is the average of the detector output $G(\Theta)$ over an interval n, with all of the intervals occurring within a single cycle of the excitation waveform, and each of the composite period averages is independently free of response to soil mineralization and iron.

In this embodiment, signal g_4 is applied to an amplifier 71, the output of which is applied to a summing node 72 through a resistor 73. Signal g_3 is applied to node 72 through resistor 74, and the gain k_4 of amplifier 71 is adjusted to provide a signal at the node which has no iron response. The g_3 signal and the signal at the output of amplifier 71 are applied to the inputs of a differential amplifier 76 to provide a signal having a large iron response.

The signal at the output of differential amplifier 76 is applied to a summing node 77 through a resistor 78, and signal g_2 is applied to node 77 through an amplifier 79 and a resistor 81. The gain k_2 of amplifier 79 is adjusted so that the signal at node 77 has no iron response.

The output signal from differential amplifier 76 is also applied to a summing node 82 through a resistor 83, and the signal g_1 is applied to this node through an amplifier 84 and a resistor 86. The gain k_1 of amplifier 84 is adjusted so that the signal at node 82 has no response to iron.

The signal at node 77 is applied to a summing node 87 through a resistor 88, and the signal at node 82 is applied to node 87 through an amplifier 89 and a resistor 91. The gain k_5 of amplifier 89 is adjusted so that the signal at node 87 has no iron response and no ferrite response. That signal is one of the two composite period average signals that are compared in a target identifier 92.

The signals from node 77 and amplifier 89 are also applied to a differential amplifier 93 to provide a signal which has a large ferrite response. That signal is applied to a summing node 94 by a resistor 96, and the signal with no iron response from node 72 is also applied to node 94 through an amplifier 97 and a resistor 98. The gain k_6 of that amplifier is adjusted so that the signal at node 94 has no iron response and no ferrite response. That signal is compared with the signal from node 87 in target identifier 92. Those signals are both composite period average signals that are free from both iron and ferrite response.

One presently preferred embodiment of a metal detector incorporating the invention is illustrated in FIGS. 10A-10F. As illustrated in FIG. 10A, this embodiment includes a battery powered power supply 101 in which a 9 volt battery 102 is connected to a voltage regulator 103 which provides an output voltage of 5 volts. A pair of relatively large (e.g. 1000 μ fd) capacitors 104 are connected in series across the output of the regulator, and the junction of the capacitors is connected to ground. Thus, the supply delivers regulated output voltages of +2.5 volts and -2.5 volts relative to ground.

This embodiment also includes an oscillator **106** which comprises a 3.58 MHz ceramic resonator or crystal **107** connected to the input of a dividing counter **108**. In the embodiment illustrated, the counter is a 74HC4060 binary counter, with the Q_{10} output being utilized as the transmitter excitation signal. That signal has a frequency of 3.58 MHz divided by 2^{10} , or 3.496 KHz.

The Q_6 – Q_9 outputs of the counter are connected to the inputs of an XOR gate **109** to provide a signal CG' which is low just before and just after Q_{10} rises and falls. This waveform is illustrated in FIG. **11**, and it provides a window for sampling around the transitions in Q_{10} .

As illustrated in FIG. **10B**, the Q_9 and Q_{10} signals are combined in a logic circuit consisting of XOR gates **111**, **112** to provide a waveform B'. In this circuit, the Q_9 and Q_{10} signals are applied to the inputs of XOR gate **111**, and the output of that gate is connected to one input of XOR gate **112**. The positive supply voltage is applied to the other input of gate **112**, and the signal B' appears at the output of gate **112**. As illustrated in FIG. **11**, B' goes high in the middle of Q_{10} 's high period and low in the middle of Q_{10} 's low period.

The transmitter section of the metal detector is illustrated in FIG. **10C**. In that section, excitation signal Q_{10} is applied to a summing junction **113** at the negative input of an amplifier **114** through a resistor **116**. The output of that amplifier is applied via a resistor **117** to another summing junction **118** at the bases of a pair of transistors **119**, **121** which are connected together in push-pull fashion in an output stage **122**. The Q_{10} and B' signals are also applied to this junction through resistors **123** and **124**, respectively. A transmitting coil **126** is connected between the emitters of the output transistors and ground, and a signal corresponding to the current in the coil is fed back to summing junction **113** through an amplifier **127** and a capacitor **128**. The excitation current thus applied to the transmitting coil is in the form of a linear triangular waveform.

In the receiver section, which is illustrated in FIG. **10D**, signals from a receiving coil **131** are amplified in an input stage **132** to provide an analog waveform which is proportional to the current in the receiving coil. That waveform is amplified further in stages **133**, **134** and **136**, with amplifiers **134** and **136** providing output signals POS AMP and NEG AMP of similar waveform but opposite polarity.

As illustrated in FIG. **10E**, the signals POS AMP and NEG AMP are applied to the inputs of a polarity selector switch **138**. This switch is controlled by a signal Q_B which is derived from the CG' and B' signals. The CG' and B' signals are applied to the inputs of an XOR gate **139**, and the output of that gate is connected to the D_B input of a register **141**. The register is clocked by the Q_4 signal from divider **108**, and the signal at the D_B input is clocked through to the Q_B output. The CG' and Q_9 signals are applied to the D_A and D_C inputs, and clocked through to the Q_A and Q_C outputs. The Q_B signal thus corresponds to the XOR function of the CG' and B' signals, and the Q_A and Q_C signals are clocked versions of the CG' and Q_9 signals. The Q_A , Q_B and Q_C signals are illustrated in FIG. **12**, together with the demodulated signal **142** at the output of switch **138**.

The signals from polarity selector switch **138** are passed through a scaling network **143** where they are adjusted to eliminate response to ferrite materials. The scaling network includes an input switch **144** which switches the signals between an upper branch **146** and a lower branch **147**. Each of those branches includes a fixed resistor **148** and an adjustable resistor **149**. The signals from the two branches are applied to the input of an UP/DOWN selector switch **151**. Switches **144** and **151** are controlled by the Q_C signal

from register **141** and thus are in each of their positions twice during each cycle of the excitation waveform Q_{10} .

A bypass switch **152** is connected between the input of switch **144** and the output of the scaling network. This switch is controlled by the \overline{Q}_A signal from register **141** and is closed when CG' is high and \overline{Q}_A is low. When switch **152** is open, the response signal POS AMP or NEG AMP is scaled down or attenuated in accordance with the settings of resistors **148**, **149**, and when switch **152** is closed, the response signal passes straight through to the output channels. Compensation occurs while switch **152** is closed during relatively short intervals which are centered about the peaks of the excitation waveform. During those intervals, resistors **148**, **149** are shorted out or bypassed, and the gain of the signal is increased relative to what it is when the resistors are in the circuit.

The waveforms shown in FIG. **12** for signals POS AMP, NEG AMP, and **142** represent responses to a ferrite material. The area beneath the waveform **142** between points a and c represents the average voltage of the rectified received signal during the first half of each phase of the excitation waveform. The first part of the signal (the part between points a and b) is inverted and scaled relative to the second part (the part between points b and c) to make the overall response to ferrite or magnetic soils during the first half of the phase equal to zero. That is done by making the area under the waveform between points a and b equal to the area between points b and c, i.e. by adjusting one of the resistors **149** to make the integral of the demodulated waveform during the first half of the phase equal to zero.

Similarly, the area beneath waveform **142** between points c and a represents the average voltage of the rectified received signal during the second half of each phase of the excitation waveform. The last part of this signal (the part between points d and a) is inverted and scaled relative to the first part (the part between points c and d) to make the overall response to ferrite or magnetic soils during the second half of the phase equal to zero. That is done by making the area under the waveform between points d and a equal to the area between points c and d, i.e. by adjusting one of the resistors **149** to make the integral of the demodulated waveform during the second half of the phase equal to zero.

With the responses to ferrite materials thus eliminated, the responses of the detector to targets other than ferrite are independent of the presence or absence of ferrite. Although the compensation intervals are placed at the endpoints of the excitation waveform in this particular example, they can be placed anywhere in the waveform, if desired. The effects of any number of different materials can be cancelled simultaneously by providing a different pair of compensation intervals for each of the materials.

Referring again to FIG. **10E**, the output signals from switch **151** are passed through bandpass filters **156**, **157** with AC gain so that a quick change produces a large output. From those filters, the signals pass through broadband filters **158**, **159** with diode feedback to prevent long transient recovery periods and attenuate undesirable second derivative responses. The signals are then applied to amplifiers **162**, **163**, and the outputs of these amplifiers are connected to the inputs of a threshold amplifier **164**. The output of the threshold amplifier is connected to the input of a comparator **165** which delivers a reset signal RST.

The outputs of integrators **162**, **163** are also connected to the inputs of a DOWN integrator **166** and an UP integrator **167** which deliver DN and UP output signals. Reset switches **168**, **169** are connected across the integrating capacitors and

controlled by the reset signal RST. When the reset signal is low, the switches are open, and the UP and DN signals build up. When the reset signal is high, the switches are closed, and the integrators are reset.

As illustrated in FIG. 10F, the UP and DN signals are applied to the inputs of a comparator 171, the output of which is connected to the clock input of a flip-flop 172. Comparator 171 and flip-flop 172 serve as a DN/UP duty cycle modulator, with the flip-flop changing state each time the magnitudes of the DN and UP signals are large enough to be a good signal.

The UP and DN signals are also applied to the input of a second comparator 173, the output of which is a duty cycle signal D. The UP signal is connected directly to the comparator input, and the DN signal is connected via a switch 174 which is controlled by the duty cycle signal D. Operation of that switch is thus proportional to the magnitudes of the UP and DN signals.

The duty cycle signal D is also applied to a pair of sample and hold capacitors 176, 177 via a switch 178 which is controlled by the \bar{Q} output of flip-flop 172. The sample and hold capacitors integrate the duty cycle signal to get a DC value. The capacitors are switched only on good values of DN and UP, i.e. when their magnitudes are sufficiently large.

The signals stored on the sample and hold capacitors are applied to the input of an amplifier 179 via a switch 181 which is also controlled by the \bar{Q} output of flip-flop 172. The output of the amplifier is a target identification signal ID which is displayed on a meter 182 to indicate the identification of the target.

Means is also included for providing an audible indication that a good target signal has been found. This means includes an oscillator 184, the frequency of which is modulated in accordance with the magnitude of the UP signal. This oscillator includes a comparator 186, with the UP signal being applied to the positive input of the comparator via a light emitting diode 187. That input can also be connected to ground by a switch 188 which is controlled by the signal from comparator 171. When that signal is large enough for target identification, switch 188 closes, and the frequency of the oscillator varies with the magnitude of the UP signal. The reset signal RST is applied to the negative input of comparator 184 and disables the oscillator when it is high.

The output signal from oscillator 184 is amplified by an amplifier 189 and applied to a speaker 191.

The invention has a number of important features and advantages. Two or more different signals containing different target information, which are independent of ferrous substances, can be extracted from the response to any excitation waveform and utilized to identify non-ferrous targets by the differences in their responses.

It is apparent from the foregoing that a new and improved metal detector and method have been provided. While only certain presently preferred embodiments have been described in detail, as will be apparent to those familiar with the art, certain changes and modifications can be made without departing from the scope of the invention as defined by the following claims.

What is claimed is:

1. In a metal detector: a transmitter for producing a magnetic field having a fixed phase relationship to a periodic excitation signal in an area where a target is to be detected so that the target returns a signal having a phase that is fixed relative to the excitation signal and does not vary with the target, means responsive to the signal returned by the target for providing a waveform having a shape specific to the target and a phase which is fixed relative to the excitation

signal and does not vary with the target, means for extracting samples from the waveform during different intervals in the period of the excitation signal, means for processing the samples to eliminate response to undesired material, and means for identifying the target from the samples.

2. The metal detector of claim 1 wherein the means for processing the samples to eliminate response to undesired material includes means for eliminating ferrite response.

3. The metal detector of claim 1 wherein the means for processing the samples to eliminate response to undesired material includes means for eliminating ferrite response and response to other undesired materials.

4. The metal detector of claim 1 wherein the means for extracting the samples includes means for sampling the waveform during the different intervals.

5. The metal detector of claim 1 wherein the means for processing the samples to eliminate response to undesired material includes means for making the average values of the samples equal to zero for the undesired material.

6. The metal detector of claim 1 wherein the means for processing the samples to eliminate response to undesired material includes means for integrating the samples over the sampling intervals, and means for adjusting the samples to make the integrals equal to zero for the undesired material.

7. In a method of detecting a metal object, the steps of: producing a magnetic field having a fixed phase relationship to a periodic excitation signal in an area where a target is to be detected so that the target, returns a signal having a phase that is fixed relative to the excitation signal and does not vary with the target, receiving signals returned by the target and providing a waveform having a shape specific to the target and a phase which is fixed relative to the excitation signal and does not vary with the target, extracting samples from the waveform during different intervals in the period of the excitation signal, processing the samples to eliminate response to undesired material, and identifying the target from the samples.

8. The method of claim 7 wherein the samples are processed to eliminate ferrite response.

9. The method of claim 7 wherein the samples are processed to eliminate ferrite response and response to other undesired materials.

10. The method of claim 7 wherein the samples are extracted by sampling the output signal during the different intervals.

11. The method of claim 7 wherein the samples are processed to eliminate response to undesired material by making the average values of the samples equal to zero for the undesired material.

12. The method of claim 7 wherein the samples are processed to eliminate response to undesired material by integrating the samples over the sampling intervals, and adjusting the samples to make the integrals equal to zero for the undesired material.

13. In a metal detector: a transmitting coil, means for applying a time varying excitation current to the transmitting coil to produce a magnetic field which has a fixed phase relationship to the excitation current where a target is to be detected, a receiving coil in which a current is induced by a magnetic field from the target, the current in the receiving coil having a phase which is fixed relative to the excitation current and is not affected by the target, means responsive to the current in the receiving coil for providing a waveform having a shape specific to the target, means for extracting samples of the waveform during different intervals of the excitation current, means for eliminating response to undesired material from the samples, and means for identifying

the target from the samples from which response to undesired material has been eliminated.

14. The metal detector of claim 13 wherein the means for eliminating response to undesired material includes means for eliminating ferrite response.

15. The metal detector of claim 13 wherein the means for eliminating response to undesired material includes means for eliminating ferrite response and response to other undesired materials.

16. The metal detector of claim 13 wherein the means for extracting the samples includes means for sampling the waveform during the different intervals.

17. The metal detector of claim 13 wherein the means for eliminating response to undesired material includes means for making the average values of the samples equal to zero for the undesired material.

18. The metal detector of claim 13 wherein the means for eliminating response to undesired material includes means for integrating the samples over the sampling intervals, and means for adjusting the samples to make the integrals equal to zero for the undesired material.

19. In a method of detecting a metal object, the steps of: applying a time varying excitation current to a transmitting coil to produce a magnetic field which has a fixed phase relationship to the excitation current where a target is to be detected, positioning a receiving coil so that a current is induced in the receiving coil by a magnetic field from the

target, the current in the receiving coil having a phase which is fixed relative to the excitation current and is not affected by the target, processing the current in the receiving coil to provide a waveform having a shape specific to the target, extracting samples of the waveform during different intervals of the excitation current, eliminating response to undesired material from the samples, and identifying the target from the samples from which the response to undesired material has been eliminated.

20. The method of claim 19 wherein ferrite response is eliminated from the samples.

21. The method of claim 19 wherein ferrite response and response to other undesired materials are eliminated from the samples.

22. The method of claim 19 wherein the samples are extracted by sampling the output signal during the different intervals.

23. The method of claim 19 wherein response to undesired material is eliminated by making the average values of the samples equal to zero for the undesired material.

24. The method of claim 19 wherein response to undesired material is eliminated by integrating the samples over the sampling intervals, and adjusting the samples to make the integrals equal to zero for the undesired material.

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