

[54] **LOW FREQUENCY DRILL BIT APPARATUS
AND METHOD OF LOCATING THE
POSITION OF THE DRILL HEAD BELOW
THE SURFACE OF THE EARTH**

[76] Inventor: **Albert A. Elwood**, P.O. Box 10592,
Riviera Beach, Fla. 33404

[22] Filed: **May 15, 1972**

[21] Appl. No.: **253,544**

[52] **U.S. Cl.**..... **175/45, 175/61**

[51] **Int. Cl.**..... **E21b 47/024**

[58] **Field of Search**..... **175/1, 61, 73, 40, 45,
175/24; 102/21.6**

[56] **References Cited**

UNITED STATES PATENTS

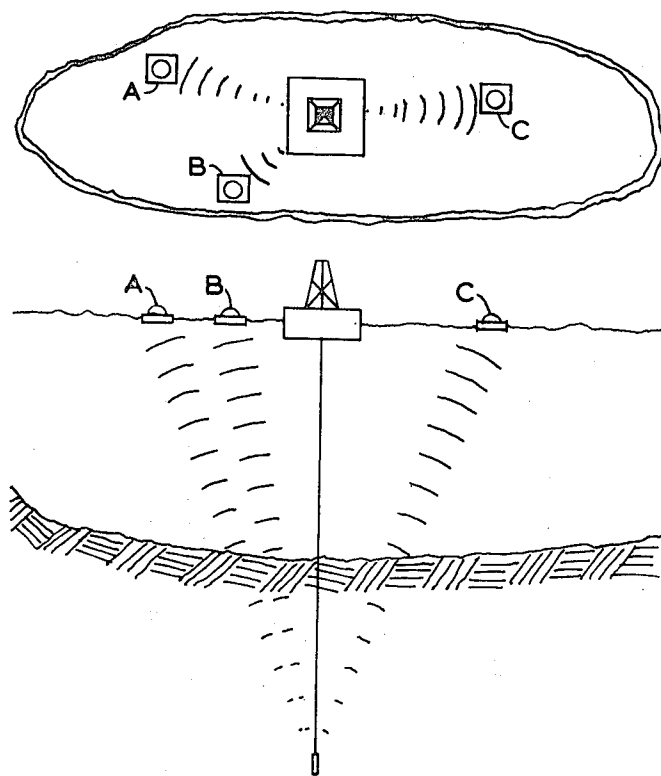
3,100,444	8/1963	Ball et al.	102/21.6
3,406,766	10/1968	Henderson	175/61
3,461,979	8/1969	Newfarmer	175/45
3,465,834	9/1969	Southworth	175/73 X
3,529,682	9/1970	Coyne et al.	175/45
3,693,142	9/1972	Jones	175/45 X
3,712,391	1/1973	Coyne	175/45 X
3,722,605	3/1973	Isham	175/40
3,739,871	6/1973	Bailey	175/1 X

Primary Examiner—David H. Brown
Attorney, Agent, or Firm—Malin & Haley

[57] **ABSTRACT**

An earth drill bit locating apparatus and method of detecting and locating the position of a drill bit below the surface of the earth utilizing very low frequency electromagnetic energy. The apparatus includes a transmitter located adjacent the drill bit for transmitting a very low-frequency electromagnetic wave below 5,000 Hz and a plurality of receivers including antennae placed adjacent to the earth's surface for detecting the low-frequency wave and computing the position of the drill bit by triangulation. Each receiver is a directional indicating receiving means for obtaining raw data in order to display and plot the movement of the drill head as it moves into the earth. The transmitter is powered by an alternator driven by a turbine in the mud supply conduit or collar just above the bit. The drill collar is fitted with electrodes or wire loops which are connected to the transmitter output to cause the drill collar to act as an electric or magnetic radiating dipole.

7 Claims, 5 Drawing Figures



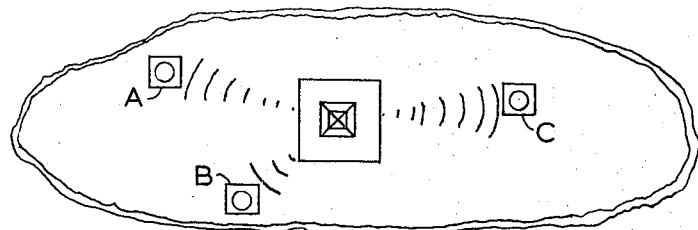


FIG. 1A

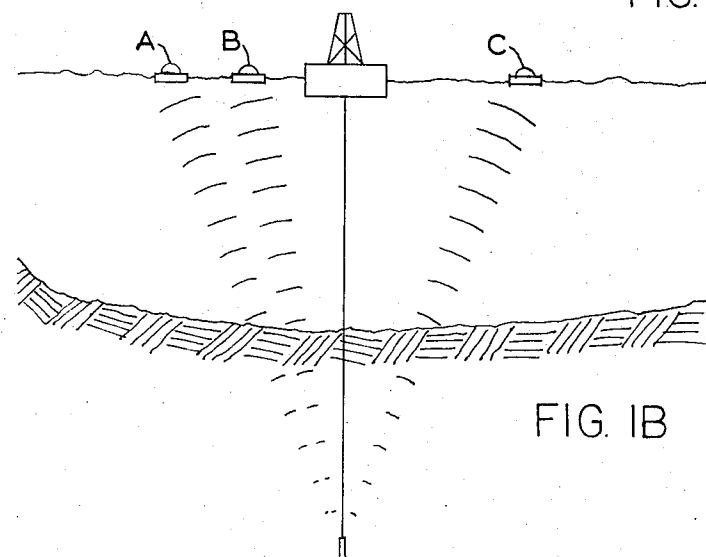


FIG. 1B

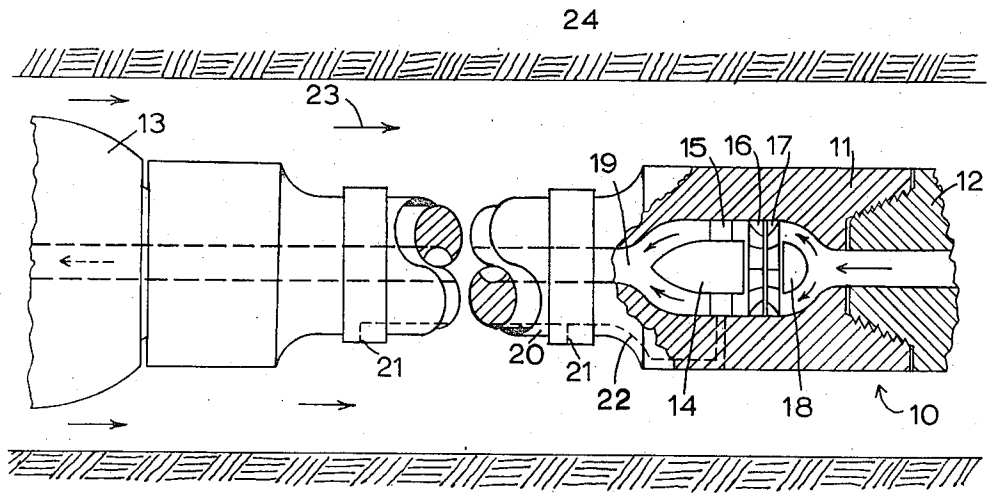
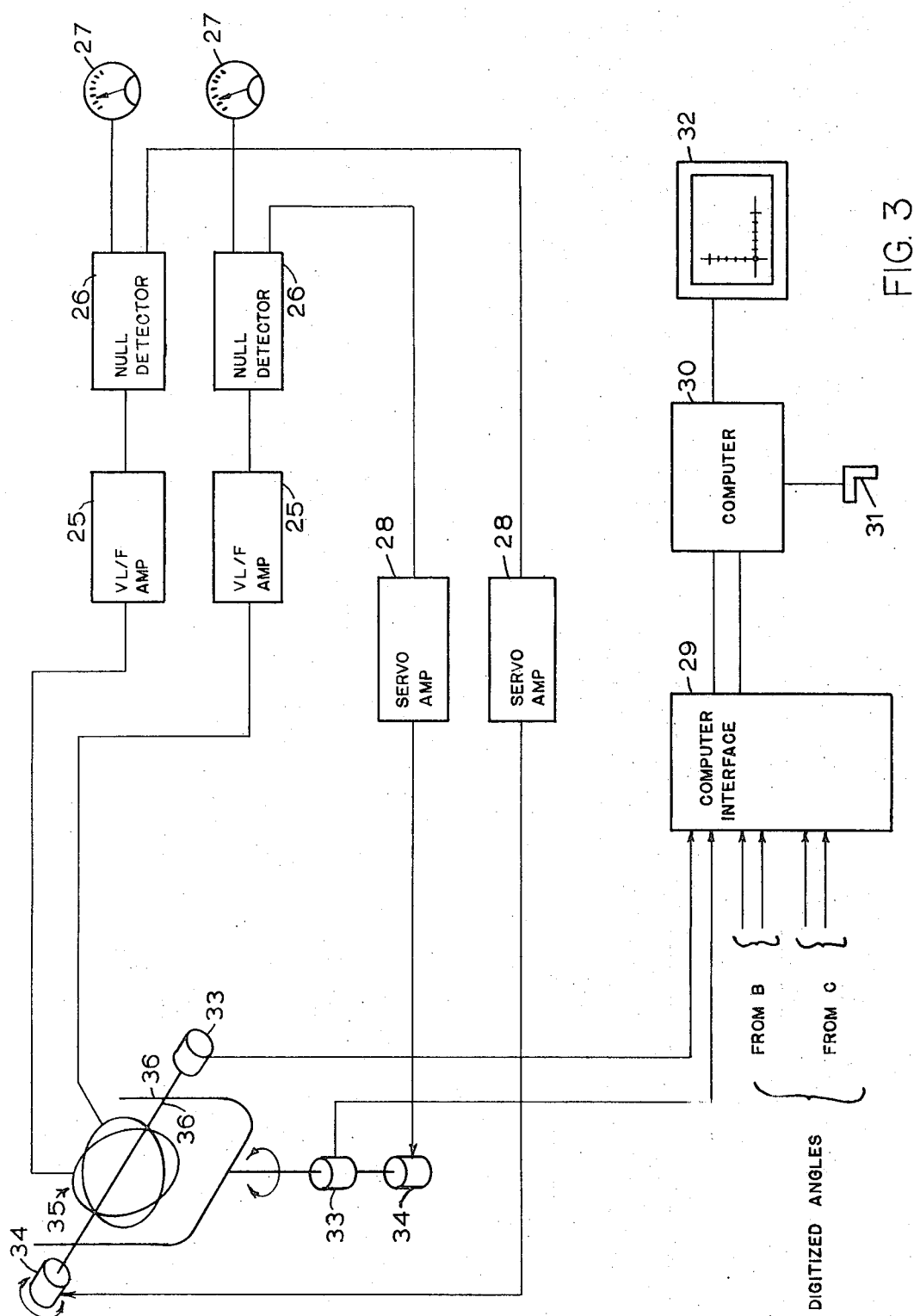


FIG. 2

24



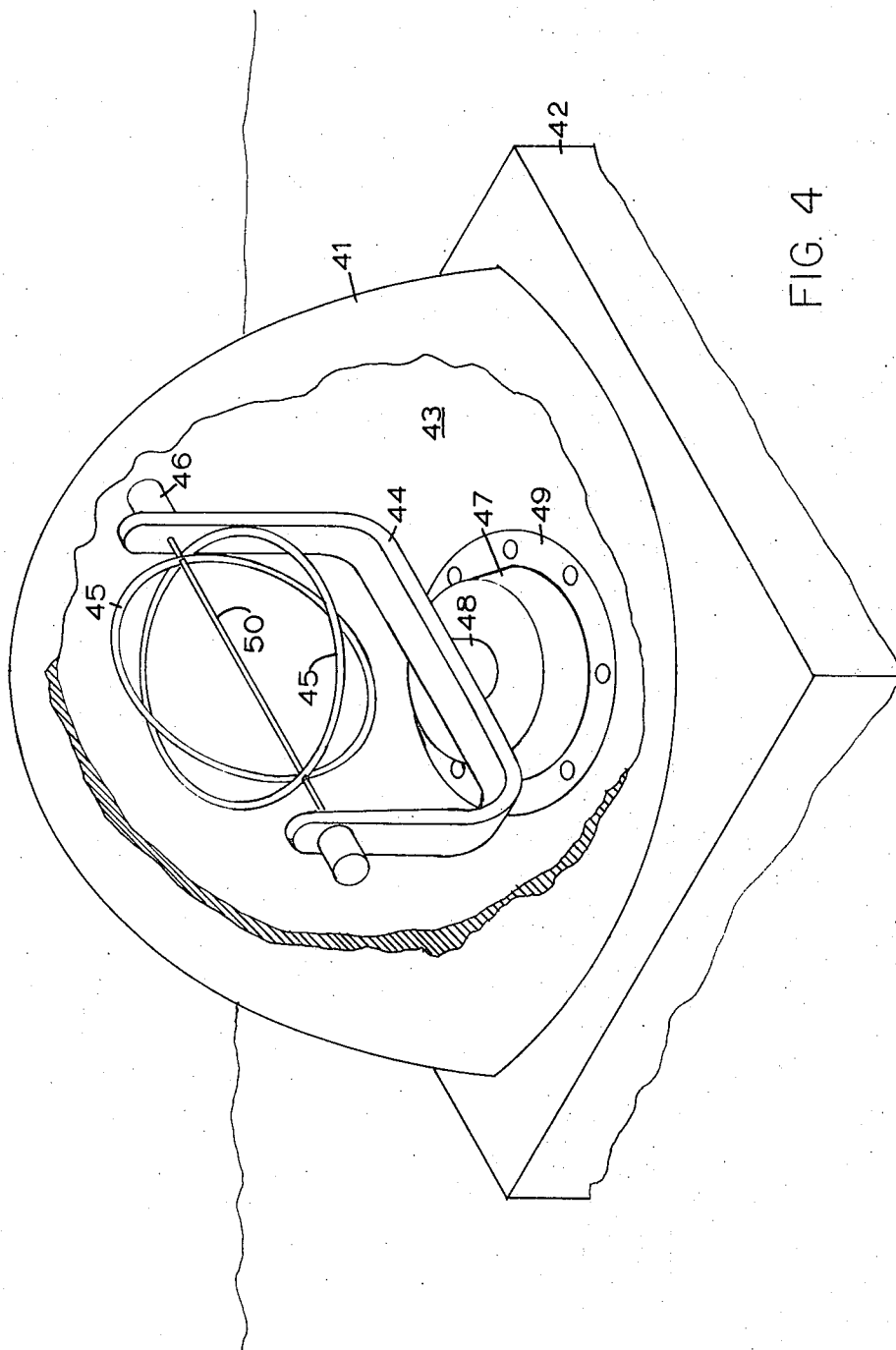


FIG. 4

LOW FREQUENCY DRILL BIT APPARATUS AND METHOD OF LOCATING THE POSITION OF THE DRILL HEAD BELOW THE SURFACE OF THE EARTH

BACKGROUND OF THE INVENTION

This invention relates to apparatus and a method for locating and tracking drill bits as they pass through the earth, and, more particularly, to an apparatus and method utilizing a transmitted energy wave frequency of less than 5,000 Hz.

In the past, gyroscopic survey instruments were built for directionally surveying boreholes. Also single and multiple magnetic methods of orientation have been utilized in conjunction with non-magnetic drill collars. Such devices require the drill string to be pulled out of the drill hole or the drilling operation stopped while survey devices were lowered into the string down to the non-magnetic drill collar. These operations contribute heavily to the expense of drilling a well.

BRIEF DESCRIPTION OF THE INVENTION

The present invention relates to a new and improved low frequency drill bit locating and tracking apparatus and method of detecting the location of a drill collar as it moves through the earth by transmitting and receiving a low-frequency electro-magnetic wave below 5,000 Hz. The transmitter is placed adjacent the drill bit in the drill collar. The transmitter includes an alternator driven by a turbine in the mud supply conduit in the drill collar. The alternator functions as the transmitter for continuous operation during the drilling operation. The transmitter may also be a battery powered very low-frequency power oscillator. The drill collar is fitted with two electrodes or a wire loop connected to the transmitter output to cause the drill collar to act as an electrical or magnetic dipole. A plurality of directional indicating receivers with a magnetic or electric dipole antenna systems located in the low-frequency signal and the direction of the signal. A computing means is utilized to manipulate the data in order to plot the movement of the drill collar by triangulation.

The method of operation is to place three receivers at known points with respect to the well head which acts as a reference for the system. The arrangement of the three receivers is basically an equilateral triangle with the well head in the center. All relative angles and distances between stations and the well head are measured and entered into the computer as a basis of computation. The transmitter is connected to the drill collar dipole for continuous operation during the entire drilling operation. The low-frequency electromagnetic signal from the drill collar dipole passes relatively undistorted through the complex inhomogeneous media to each receiver antenna. A vertical magnetic dipole comprising a small wire loop, buried or located at some depth beneath the earth's surface will produce an electromagnetic field on the earth's surface if an alternating current is injected into the loop. The conductivities of the overburden, which may be quite complex, will modify the geometrical character of the vertical and horizontal magnetic field components observed at the surface. However, this effect is quite small provided the burial depths involved are small compared with the free-space wavelength, or electrical skin depth.

The basic reference for the drill bit location system are:

1. The well head
2. The positions of the sensors with respect to the well head
3. The local vertical passing through the positions of the sensors.

Sensors stations are initially set up at convenient locations on the corners of a rough equilateral triangle, spaced approximately equally from the well head at distances depending upon the intended maximum depth of the bit.

The sensors are two-axis, mutually orthogonal receiving loops mounted in highly accurate trunnions on a very stable base or platform. The main trunnion provides means for rotation of the dual axis loop assembly about a vertical axis. The secondary trunnion provides means for rotation of the dual axis loop assembly about a horizontal axis.

The main trunnion is established in the local vertical by use of a helium-neon gas laser interferometer/mercury pool optical level system, to within a few seconds of arc.

In operation, the main trunnion is rotated about the vertical axis to achieve a null in the horizontal sense loop. This establishes the azimuth angle in the horizontal plane between the well head reference and the location of the buried dipole. The secondary trunnion is then rotated about the horizontal axis normal to the bearing line to buried dipole until a null is achieved. This establishes a vertical angle or dip angle between the horizontal plane and a line passing through the location of the buried dipole.

The azimuth and dip angles are measured at all sensor sites, digitized by shaft encoders attached to the trunnions and transmitted to the computer. The computer solves the multiple triangulation problem and establishes position of the buried dipole in the coordinates desired.

It is an object of this invention to detect and plot the movement of a transmitter through an inhomogeneous solid media by transmitting and detecting low-frequency electromagnetic waves below 5,000 Hz.

A further object of this invention is to provide a means to plot the movement of a drill bit as it moves into the ground without removing the drill string.

Another object of this invention is to provide a transmitter powered by the movement of the flow of fluids in the drill string.

An additional object of this invention is to provide two or three receivers or transmitters just below ground level and the opposite component at the head of the drill.

In accordance with these and other objects which will be apparent hereinafter, the instant invention will now be described with particular reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing:

FIG. 1A is a plan view of a geometric illustration of a portion of applicant's invention.

FIG. 1B is an illustration showing geometric arrangement of the three receivers, the drill tower, drill string and drill collar dipole.

FIG. 2 is an elevation in partial cross section of the drill collar showing the turbine driven alternator, transmitter compartment and antenna.

FIG. 3 is a block diagram of the receiver illustrating the receiver antenna, computer and display means.

FIG. 4 is a perspective view in partial cutaway of Applicant's receiver antenna.

PREFERRED EMBODIMENT OF THE INVENTION

FIGS. 1A and 1B show a cutaway portion of the earth's surface, with the well head reference and sensors A, B, and C embedded in the earth's surface with associated equipment resting on the earth's surface and a drill string penetrating down into the earth, terminating in the drill collar and drill bit. Attached to the drill collar is an alternating dipole that radiates a 5KHz or below electromagnetic wave which is detectable by sensors A, B and C. A computer (not shown) receives sensed information from which it determines the location of the drill bit relative to the well head reference. It has been determined that employment of a 5KHz or below signal allows for a very accurate triangulation of the received signal because minimum accurate triangulation of the received signal because minimum distortion of the directional propagation of the radiated wave is experienced as the wave proceeds from the dipole through various strata of the earth's surface to the sensors.

The drill and transmitter assembly (FIG. 2) is comprised of a drill collar 10 removeably coupled at one end to the end of drill string 12 and at the other to a drill bit 13. The mud flow supply is provided through internal conduit 19 by struts 15. The alternator 14 is driven by rotating turbine blading 16 coupled to the alternator rotor (not shown). Fixed turbine blading 17 directs the flow of liquid in the internal conduit 19 onto the rotating turbine blading.

The hole cut out by drill bit 13 in the earth 24 provides for a mud flow return (indicated by arrows 23).

The dipole for radiating the 5 KHz wave is provided by a pair of electrodes 21 circumferentially disposed about the drill collar 11 and electrically coupled to the output of alternator 14 by electrical wires (not shown) in electrical conductor conduit 22.

FIG. 3 shows the sensing and computing systems comprising dual axis loop assembly 35 coupled to trunnions 36 moveably positionable by motors 34. The shaft encoders 33 send a signal back to computer interface 29 disclosing the position of the loop assembly.

Energy received in each loop from the dipole is sent to VLF amplifiers 25 which are connected to null detectors 26, one output being to null indicator 27 and the other to servo amplifiers 28 which drive motors 34.

Digital angular information is received from other sensors B and C (not shown) at the computer interface 29 from which the information is sent to computer 30, which solves the geometrical problem and displays the results on display panel 32. Additional manual inputs 31 may be added to the computer.

FIG. 4 shows a receiver antenna comprised of orthogonal loops 45 mounted on support bar 50 coupled to U-shaped moveable mount 44. A servo 46 rotates the loops 45 through support 50. The entire antennae including dome 41 is mounted on base 42. The dome

41 is filled with a liquid 43 having the same conductivity as the surrounding earth, thus permitting movement of the antenna with minimum wave distortion as it proceeds through the earth's surface into the liquid 43. The antenna mount 44 is rotated by shaft 48 coupled through cover plate 47. The entire structure is anchored to base 42 by holding plate 49. In operation the antenna loops are rotated in three planes until a null signal is received. The loop positions are received by the computer, and all antennae positions are correlated to provide an accurate location position of the drill mounted transmitter.

In an alternate embodiment, the transmitter in the drill bit housing may be replaced by a VLF receiver and the three surface receivers by three VLF transmitters positioned in a triangular array. The transmitters are radiated individually during different time periods so that each transmitter antenna is moved until a signal null is indicated by the detector in the drill bit housing. The received signals are transmitted up the drill pipe casing and sent to the computer along with signals from shaft encoders on the antennae for position azimuth and depression angles of the drill bit. The horizontal and vertical position of each transmitter antenna at signal maximum provides sufficient information to determine drill bit location through triangulation. Again in the alternate embodiment the electromagnetic radiation is 5 K Hertz or below.

The antennae for transmitting as shown in the alternate embodiment are radio direction loops that are moveably mounted on a base and include shaft encoders for vertical and horizontal position information and servo drive devices for positioning in different reference planes.

It is essential in either embodiment that both the transmitters or the receivers are properly coupled to the ground surface in order to prevent signal path refraction distortion as would happen at the boundary between the earth and the atmosphere. In order to provide moveable antennae at the coupling point each antenna is submerged in a fluid, the conductivity of which is very close to that of the earth's surface at that location.

With regard to system components, (FIG. 3) the computer interface 29 may be a "316I" model interface produced by Ocean Measurements, Inc. and made for a Honeywell 316 computer. Position recorder 32 may be an XY recorder model 7004B produced by Hewlett-Packard. Shaft encoders 33 that may be utilized are Series II, 2A s/11 from Computer Terminal Systems, Inc. while the amplifiers 25 are Khron-Hite tuneable amplifiers with VLF filters.

In operation, the transmitter on the preferred embodiment may be an alternator producing a power output in the range of five thousand watts and having a frequency between 125 to 5,000 Hz. The alternator is geared to a turbine blade that is placed in the mud supply conduit in the drill head. The mud flowing downward through the conduit will turn the turbine blade to rotate the alternator to produce the output frequency. The head of the drill string will be the transmitting antenna. The receiving system will have three dual axis receivers, each optically surveyed in place with respect to a horizontal azimuth reference. Each dual axis receiver will also have its sensor oriented with respect to a vertical reference. The vertical reference will be established by laser interferometer mercury level. The

antenna for each receiver will be properly coupled to the surface of the earth. Each receiver will determine the angle in the horizontal to the drill bit and the angle in the vertical (dip or depression angle to the drill bit). The intersection of the three lines determines the particular location within the earth of the drill bit.

The computer is utilized to continuously compute and plot the location of the transmitter and drill bit. The low-frequency electromagnetic wave is relatively unaffected as it travels through the various layers of material between the transmitter and the receiver because small variations in media densities are negligible at these electromagnetic frequencies.

The instant invention has been shown and described herein in what is considered to be the most practical and preferred embodiment. It is recognized, however, that departures may be made therefrom within the scope of the invention and that obvious modifications will occur to a person skilled in the art.

What I claim is:

1. An apparatus for locating a drill bit within the earth's crust relative to a predetermined reference position comprising:

a low frequency electro-magnetic wave transmitter within the earth for transmitting an output signal below 10,000 Hertz;
a power supply connected to said transmitter;
at least two directional indicating low frequency receivers in conductive communication with the earth for detecting the transmitted low frequency signals; and

analyzing means coupled to said receivers for analyzing the low frequency received signals providing information giving the reference location of said transmitter relative to said predetermined reference position; and

a drill rig including a drive means, a drill string connected to said drive means, and a drill bit connected at the free end of said drill string, said low frequency electro-magnetic transmitter coupled to said drill string, adjacent said drill bit.

2. A drill location apparatus, as set forth in claim 1, wherein said transmitter includes:

an alternator;
a turbine driveably connected to said alternator;
a mud supply conduit coupled within said drill string, said turbine disposed within said mud supply conduit.

3. A drill location apparatus as set forth in claim 2 including:

indicating means coupled to said analyzing means for providing a visual display of said drill bit location.

4. A drill bit location apparatus as set forth in claim 3, wherein:

said receivers include a housing in contact with said earth surface,

a fluid medium within said housing having a conductivity similar to that of the surrounding earth, said receiver antennas immersed in said medium.

5. A drill location apparatus as set forth in claim 4, wherein:

the lower end of said drill string is connected to the transmitter output to cause the lower end of the drill string to act as an electrical dipole antenna.

6. A method for detecting the location of a drill bit within the surface of the earth by transmitting low frequency electro-magnetic wave energy with reference to a known predetermined reference location comprising the steps of:

transmitting a low frequency electro-magnetic wave below 5,000 Hertz within the earth's surface from a drill bit located within the earth's surface while simultaneously moving the drill bit within the earth's surface to perform drilling;

receiving the transmitted low frequency electro-magnetic energy within the earth's surface; and
comparing the received signals from the receivers with a known reference point location signal thereby determining the location of the transmitting source relative to the known reference point.

7. An apparatus for locating a drill bit within the earth's crust relative to a predetermined reference position comprising:

a low frequency electro-magnetic receiver within the earth for receiving an electro-magnetic signal below 10,000 Hertz;

at least two low frequency electro-magnetic transmitters in conductive communication with the earth's crust for transmitting low frequency signals;

a power supply connected to said transmitters;
an analyzing means coupled to said receiver for analyzing the low frequency received signals for providing information giving the reference location of said transmitters relative to said predetermined reference location; and

a drill rig including a drive means, a drill string connected to said drive means, and a drill bit connected at the end of said drill string, said low frequency electro-magnetic receiver coupled to said drill string.

* * * * *

55

60

65