A Method of Mapping Resistive or Conductive offshore Targets also an Apparatus for Applying the Method

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is related to a method and apparatus for Controlled Source Electromagnetic Survey. The system invented uses a long solenoid of finite length or a dipole as a transmitter, which has the capability of shallow and deep sounding and is characterized by detecting resistive or conductive targets. Conventional receivers, including potential electrodes, magnetic field sensors and coils are used for measuring electrical field, magnetic field and change of magnetic field respectively. In addition, a toroid coil immersed in the sea water is invented to measure the electrical field in the direction perpendicular to the toroid coil.

2. Background of the Invention

The horizontal wire or vertical loop transmitter are used for conventional onshore for controlled source electromagnetic surveys, while the horizontal wire or vertical wire transmitters are used for marine applications. US Patent US 6,603,313 B1, 2003 and 2003/0050759 A1 both by Srnka, L. J. , et. al. in 2003 disclosed using circular concentrated multiple loop sources and radial concentrated wire sources. US Patent 6,696,839 and 6,717,411 both by Svein Ellingsrud, et al. in 2006 disclosed a system for investigating subterranean strata by using a dipole antenna transmitter and dipole antenna receiver. Barsukov, Pavel, et al. disclosed vertical wire transmitter by PCT International Publication Number WO 2007/053025 A1 in 2007 and WO 2008/066389 A1 in 2008.

None of the above mentioned patents disclosed usage of a solenoid as electromagnetic transmitter. Neither of the above mentioned patents disclosed a method and apparatus using acquired electrical, magnetic or change of electrical and magnetic field generated by solenoid transmitter.

The vertical wire transmitter, which is a TM mode EM exploration is difficult to be applied at the shallow water exploration. Also it is impossible to use the vertical wire transmitter on the earth surface except down to a borehole. The solenoid transmitter will enable a TM mode exploration, which so far have ever been applied to the sounding in marine or onshore explorations.

SUMMARY OF THE INVENTION

There are two modes for the electromagnetic exploration, which are TM and TE modes. One of the invention is to disclose a method and apparatus for creating a TM or TE mode electromagnetic transmitter by using long air or cored solenoid. Multiple transmitters could be linked to give multiple power.

Another aspect of the invention is to disclose a method and apparatus for measuring electrical field perpendicular to the plan of a toroid col.

BRIEF DESCRIPTION OF THE DRAWINGS

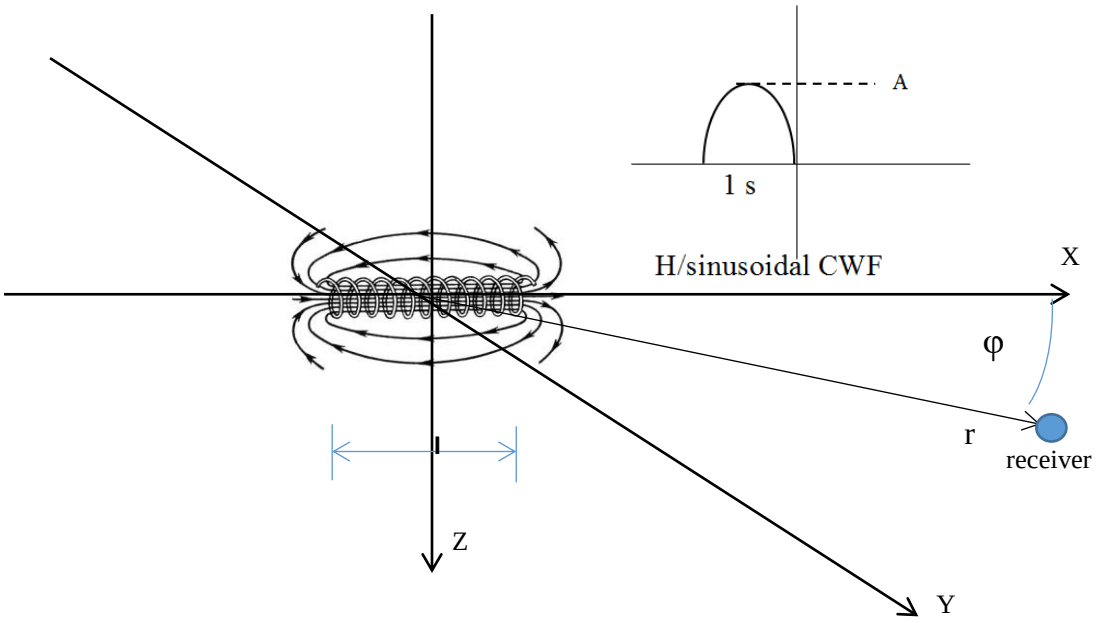

Figure 1. The coordinate system used for the calculated transient field.

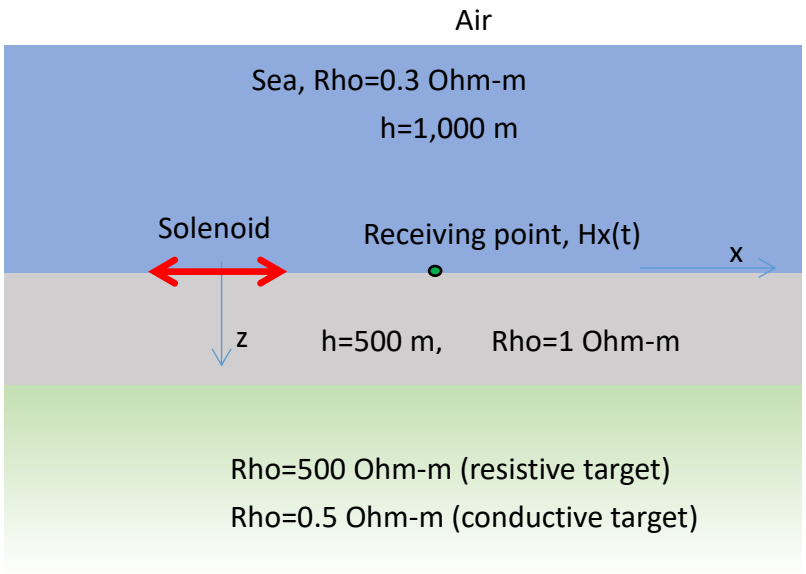

Figure 2. The earth model used for calculating the transient field.

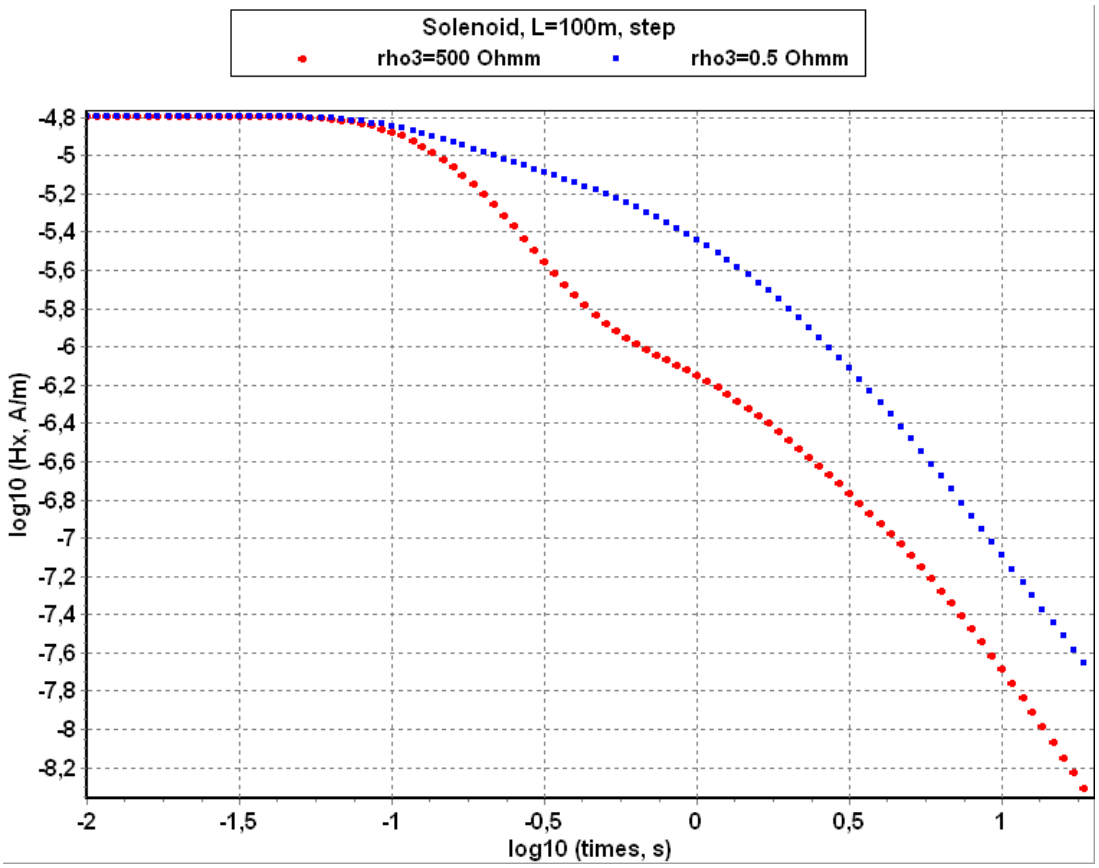

Figure 3. Calculated transient field using a solenoid transmitter and an inline receiver at 1,000 meters away from the center of the solenoid. The length of the solenoid is 100m. The current is a step waveform. The moment of solenoid is 1,000 A*m*m/1m.

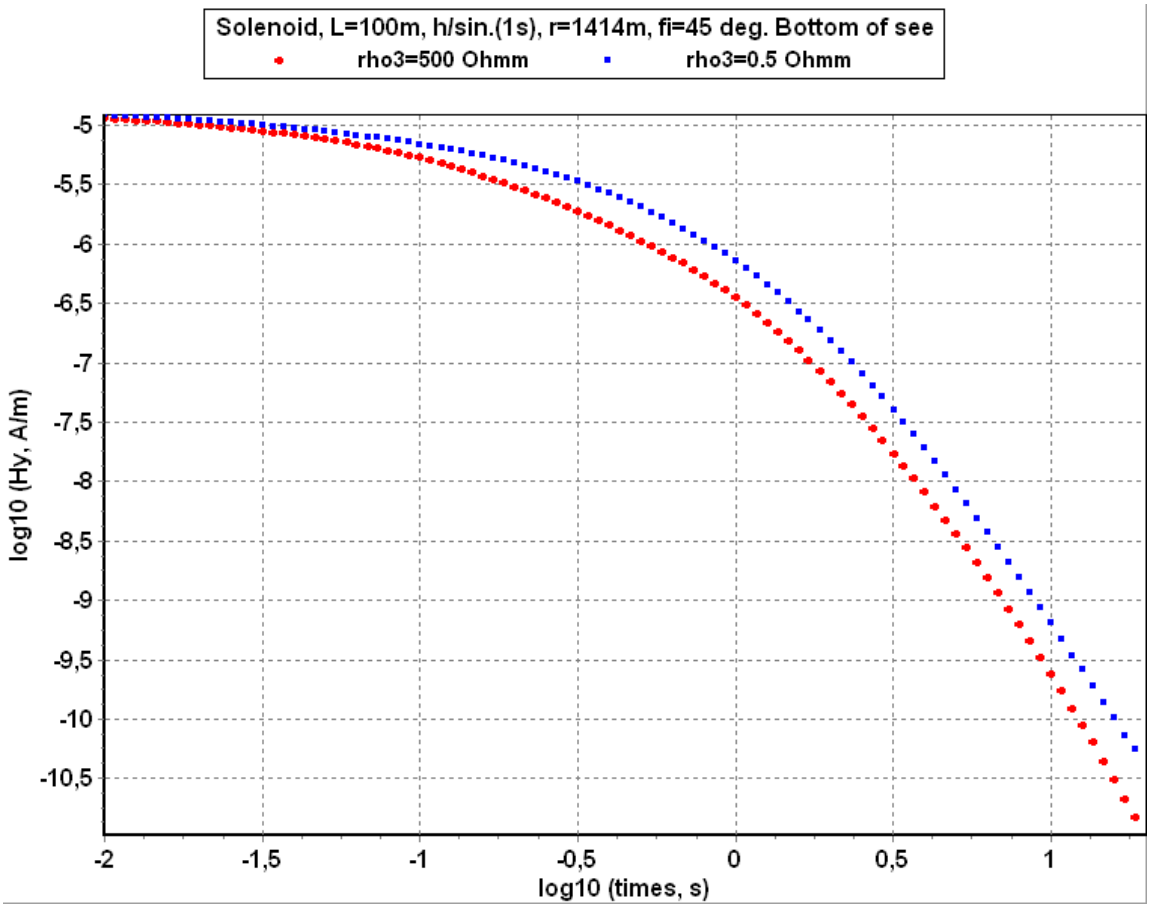

Figure 4. Transient field of a solenoid transmitter and a receiver point located at 1,414 m away from the center of the solenoid and at 45 degree azimuth angle. The length of solenoid is 100m. The current waveform is a half sinusoid of 1 second. The moment of solenoid is 1,000 A*m*m/1m.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention discloses a controlled source electromagnetic survey apparatus and method by using a solenoid transmitter of finite length. Figure 1 describes the coordinate system for the solenoid and the receiver. The axis of the solenoid is along the x axis and the center of the solenoid is at the origin of the coordinate system. Figure 2 shows the earth model used for the numerical calculation. The depth to the sea bed is 1,000 meters. The resistivity of the sea water is 0.3 Ohm-m. The resistivity and thickness of the first layer below the sea bed is 1 Ohm-m and 500 meters respectively. The resistivity of the second layer below the sea bed is

0.5 Ohm-m for conductive target and 500 Ohm-m for resistive target.

Figure 3 describes the transient responses from a conductive and resistive target second layer for an in-line receiver which is 1,000 meter away from the solenoid. Figure 4 describes the transient responses from a conductive and resistive target second layer for an off-line receiver which is 1,414 meter away from the solenoid. The azimuth angle, φ is at 45 degrees.

Figure 5 describes the normalized frequency responses from a conductive and resistive target second layer for an in-line receiver which is 1,000 meter away from the solenoid. Figure 6 describes the normalized frequency responses from a conductive and resistive target second layer for an off-line receiver which is 1,414 meter away from the solenoid. The azimuth angle, φ is at 45 degrees. (TBA)

Claims:

1. An apparatus and method of the marine and onshore controlled source electromagnetic survey using solenoids of finite length as the transmitter.
2. The apparatus and method as claimed in claim 1, wherein the solenoid is cored with high magnetic permeability material to enhance the transmitting power of the solenoid.
3. The apparatus and method of the controlled source electromagnetic survey using toroid coil as the signal receiver.
4. The apparatus and method as claimed in claim 3, wherein the toroid coil is cored with high magnetic permeability material to enhance the signal strength from the toroid coil.