INSTRUMENTATION FOR GROUND WATER EXPLORATION USING ELECTROMAGNETIC TECHNIQUES

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ABSTRACT

Electromagnetic techniques are widely used in different countries for solving diverse geological problems, mainly, soil profiling, geophysical prospecting and determination of water resources,

The paper describes the development of an Inductive Electromagnetic system and methodology used for determination of water table depths in different geological environments in the country. Electromagnetic signals transmitted from the system through the earth are received at a specified distance and are linearly proportional to the conductivity of the media. The variations in conductivity with change in distance between the transmitter and receiver, provides the related information about water table depth in the terrain.

1. INTRODUCTION

It was in the early period of this century that electrical techniques came into use for mapping sub-surface geology by sending electrical currents into the ground and measuring the resulting field distribution. Since that time measurement of terrain resistivity has been used for a variety of geological applications such as mapping of rock lithology and bed rock depth. Ground water table depth and salinity, detecting pollution plumes in ground water, locating geothermal areas, archaeological sites, etc.

In many instances, resistivity mapping provides definite geological information. However there are cases where the results are uninterpretable due to high geological noise. Another limiting factor in resistivity surveying is that the actual value of terrain resistivity itself is seldom diagnostic. As a result of this ambiguity, the variation of resistivity is examined either laterally or with depth, to outline the geological features of interest. Actual conventional surveys are time consuming for mapping larger areas by this technique although resistivity techniques sense to a characteristic depth (determined by inter-electrode spacing) inhomogeneities much smaller than that depth can, if they are located near the potential electrode, yield large errors in measurement and hence a noisy profile is obtained. A major disadvantage of the resistivity technique as that once a high conductivity layer has been detected, existence of another conductive layer below this layer can be detected. This is due to the fact that if the first detected conductive layer extends for a large enough area, all the current introduced into the ground will start flowing through this layer and will not penetrate further into the ground and detection of the second conductive layer is possible only if the first layer extends for a length less than the electrode spacing for that particular layer.

Keeping the above effect in mind, use of various Electromagnetic (EM) techniques has increased considerably in geological surveys such as sub-surface water found in fissured and cavernous rocks, a series of acquifers with different water levels separated from each other by non-porous water tight layers, etc.

The paper describes briefly the development of an Inductive Electromagnetic technique used for the determination of soil salinity and water table depths in different geological environments. As the name implies the method involves the propagation of a time varying low frequency electromagnetic field in and over the earth. There is a close relationship between the transmitted signal, received signal and the conducting media between the transmitter and the receiver in an EM field. In some of the EM systems, the energy may be introduced into the ground by direct contact, although, generally inductive coupling is used and invariably the detector receives its signal by induction.

2. TECHNOLOGY

Whenever alternative current is passed through a loop of wire a time varying magnetic field is generated around it. If another conductor is placed in the field of this current carrying conductor an e.m.f. is induced in this conductor, The coil carrying current is called the primary coil and the coil which is placed in the field associated with the primary coil is called the secondary coil. If a third coil called the receiver coil is also placed on or near the ground surface but at a fixed distance from the transmitter (primary) coil an e.m.f. is induced into it. This e.m.f. has two components. One component is due to the e.m.f. induced into the receiver coil by the magnetic field produced by the current following in the secondary coil (Fig. 1).

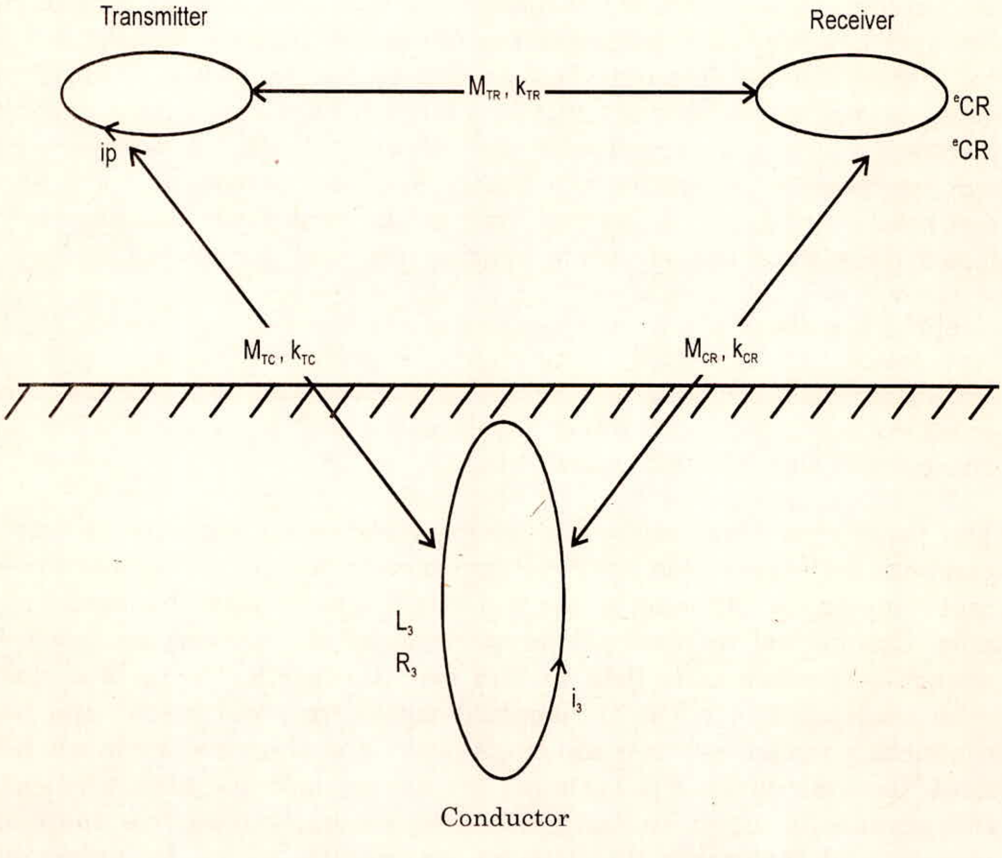

Fig 1 EM Induction Principle (Induced EMF in receiver arising from transmitter and conductor)

3. EM SYSTEMS

We have undertaken development of two types of EM systems for soil profiling. These are:

I) Inductive EM soil salinity testing system for near surface conductivity measurement.

II) Variable depth inductive EM soil salinity and water table depth measuring system.

3. SYSTEM I

Soil Salinity Testing System for Near Surface Conductivity Measurement

This system is designed for agricultural surveys of soil salinity over large areas quickly without ground electrodes. The system consists of an AC source operating at a frequency of 14.5 Khz, transmitter and receiver antennas, receiver amplifier tuned to the transmitter frequency, phase and amplitude compensator for comparison of primary and secondary field signals and a digital read out. Provision is also made for connecting a recorder. The system contains appropriate circuitry to minimise instrument response to the magnetic susceptibility of the soil and to maximise response to EC_a. Bulk soil electrical conductivity, EC_a, of incremental depth intervals within the soil profile can also be obtained from the ground measurements of apparent soil electrical conductivity using multiple regression analysis of EM readings taken at five incremental heights 0,0.3, 0.6, 0.9 and 1.2 meters above the ground level.

3.1 Power Source

The power supply for the EM transmitter is from a small, light battery powered oscillator with a power amplifier having low output impedance. The system has been experimented for use up to a depth of one meter that is the root zone of the plants. Fig. 2 gives the block schematic of the system.

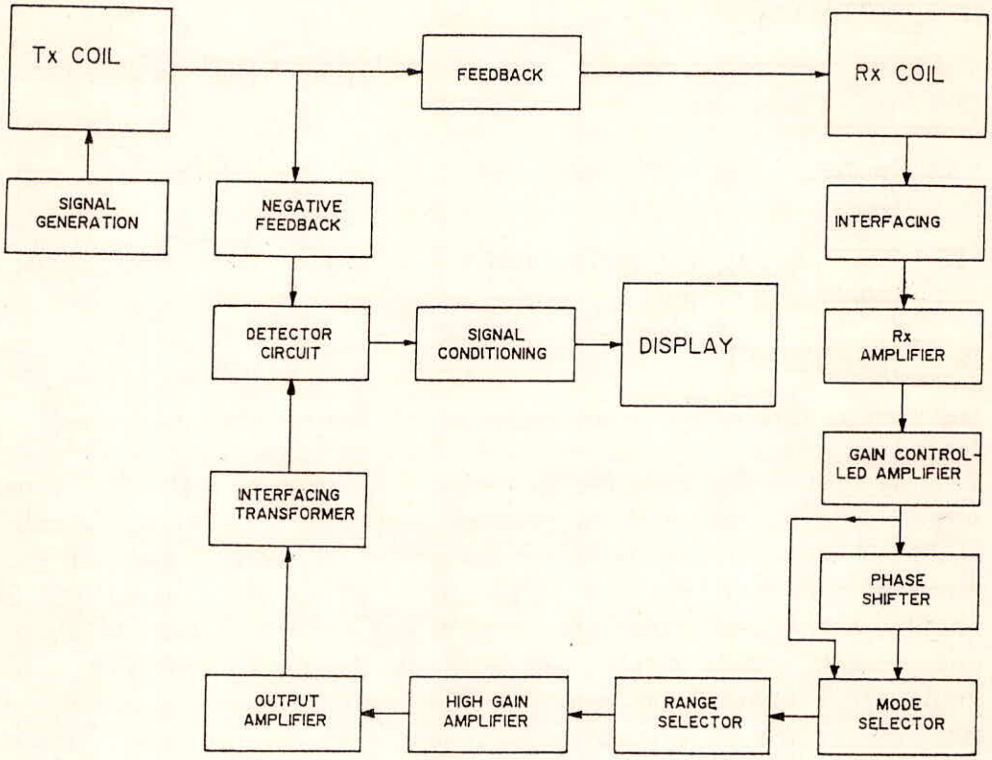

Fig. 2 I-E/M Soil Salinity Tester Block Diagram

3.2 Receiver Sensor

The receiver sensor is a compact and built around a high permeability core. It is tuned by an appropriate capacitative network so as to give parallel resonance at the transmitted frequency. The receiver and transmitter loops are electrostatically shielded to eliminate the capacitance coupling between coil and ground and between the coil and operator.

Shielding is obtained by wrapping strips of conductive foils over the winding. The receiver sensing system is oriented in a certain direction related to the field to be detected. In some ground systems this merely means that the loop is maintained approximately horizontal or vertical.

3.3 Feedback Networks

The receiver loop is oriented in such a manner so as to minimise coupling of the primary wave, the secondary signal is swamped by the primary signal. It is necessary to reduce the primary signal by some means. This is accomplished by introducing at the receiver input an artificial signal of the same frequency and amplitude, but opposite in phase. Compensation of this sort would be sufficient to permit measurement of an amplitude, that is the real component of the secondary field. It is apparent that Hp and Hs generally differ in phase as well as amplitude and that further more, this phase shifts diagnostics of the conductor. The compensator is an R-C network incorporated in the receiver section of the EM set.

3.4 Display Unit

There are two 3-1.2 digits display which are used for displaying the saline contents in milli-mhos/m in horizontal and vertical positions independently. These readings can then be utilised to calculate the salinity of successive layers of soil in the root zone by correlating them with the system response curves.

4. SYSTEM II

Variable Depth Soil Salinity and Water Table Depth Measuring System

This system is a portable EM device which directly measures terrain conductivity. The system operates at low values of induction number, and changing the frequency proportionately changes the quadrature phase response, so to determine variation in conductivity with depth, it is intercoil spacing rather than frequency which is varied. Since maximum intercoil spacing is 40 metres this system has a shallower exploration depth than conventional VLF systems, but nevertheless can be used for all aspects of ground water exploration and ground water contamination mapping as the penetration depth of 60 meters achieved with the system covers the economical drilling range.

4.1 Transmitter

The EM transmitter is a light battery powered crystal oscillator with a power amplifier having low output impedance and high current output.

A frequency selecting network is incorporated to provide optimum frequency selection. Buffering is provided at the output stage of the power amplifier to prevent any overloading of the system. Fig 3 gives the block schematic of the transmitting system.

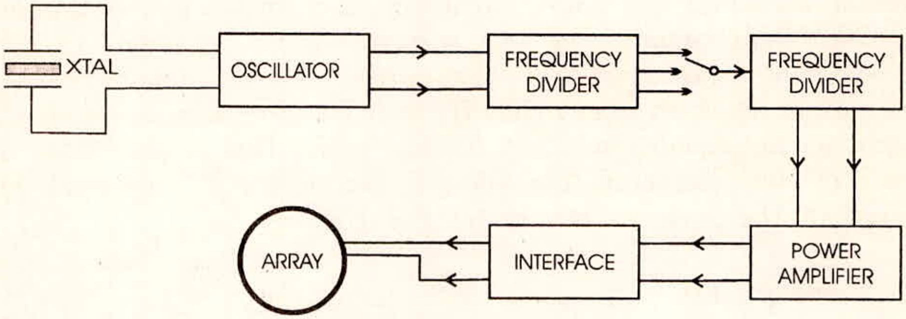

Fig. 3 Block Schematic of Transmitting System

4.2 Receiver

The receiver is an integrated module for detection of both in phase and quadrature phase components and incorporates an inbuilt system for determinig the accuracy of the intercoil spacing. The detection process is similar to that in the Inductive EM soil salinity testing system for near surface conductivity measurements. A special filtering technique using active filters is used to provide a high degree of noise immunity and a high signal to noise ratio. The filtered output is processed in the electronic processing unit for generating direct readings of the conductivity of the underlying strata. The results are suitably displayed on a multi range analog meter. These conductivity readings are used for plotting the soil profile of the terrain which can then be used for determining the location and depth of water bearing strata. Fig 4 shows the block schematic diagram of a receiving system.

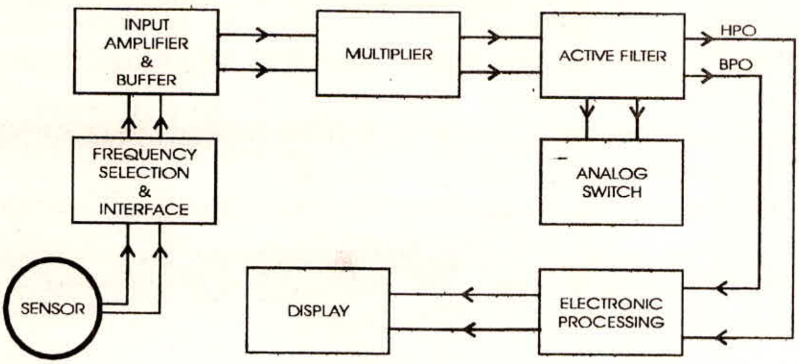

Fig. 4 Block Schematic of Receiving System

4.3 Receiver Sensing Coils

These are made in circular form having a diameter of around three feet and have multiturn fine wires designed and fabricated to minimise the effect of moisture on their operation. The coil is shunted by a capacitor to give parallel resonance at the same frequency as that of the transmitter.

The receiver and transmitter loops are electrostatically shielded to eliminate capacitative coupling between coil and ground and between coil and operator. The shielding is obtained by wrapping a conductive foil over the winding, and the shield is connected to the main circuit ground. The orientation of the receiver and transmitter coils relative to the detected field is made in the horizontal or vertical direction for measuring the desired field.

4.4 Receiver Amplifiers

The input amplifier has high input impedance and very low noise levels. These have high over all gain generally between 10^4 and 10^5, and active band pass filters are incorporated to enhance the signal to noise ratio and can be tuned to different source frequencies. Twin T-Networks of high input impedance are used with these active filters in the receiving system.

4.5 Indicators (Display)

In the system, both transmitter and receiver are moved. A reference signal is obtained from a small pick up coil attached to the transmitter coil; its orientation can be adjusted for coarse amplitude control. This signal is carried by a cable to the compensator where its amplitude and phase are adjusted. The compensator output is connected in series (opposing) with the receiver coil, both being across the input of the tuned amplifier. A null is obtained in an analog meter connected to the amplifier output, when the compensator is adjusted, so that its output cancels the signal in the receiver coil. The fixed relative positions of receiver and transmitter maintains a constant mutual inductance M_{tr}. Thus the direction of traverse is immaterial, that is we can interchange the receiver and transmitter and get the same reading at the same station. Now the receiver coil is moved towards the transmitter coil, the movement is stopped when the separation meter deflects to the full scale mark. The value thus obtained will be in milli siemens/meter or milli-mhos/meter.

5. SPECIFICATIONS

i	Measured Quantity	:	Apparent conductivity of ground, in milli siemens/meter
ii	Range of Conductivity	:	0-300mS/meter
iii	Measured Precision	:	2 percent of full scale deflection
iv	Primary Field Source	:	Self contained dipole transmitter.
v	Sensor	:	Self contained dipole receiver.
vi	Inter Coil Spacing	:	10 meters, 20 meters, 40 meters.
vii	Temperature Range	:	0-50 degrees centigrade.

6. CONCLUSIONS

The measurement of bulk soil electrical conductivity using electromagnetic-induction techniques can be used to great advantage. Soil salinity can be determined directly in the field without requiring laboratory analysis. Detection of water tables and deep soil salinity can be made without boring any holes or digging in of the electrodes as required in conventional techniques for similar measurements. Both the systems described are portable and easy to use. The performance of the systems have been found to be very satisfactory during field trials. The criteria for judging the worth of a particular system includes power source, reliability, speed, and simplicity in field operation, information obtained and ease of interpreting the results.

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