Measuring Soil Conductivity with Geonics Limited Electromagnetic Geophysical Instrumentation

Presented by: Mike Catalano

GEONICS LIMITED

INTRODUCTION

This presentation will briefly discuss the principles of operation and the practical applications of electromagnetic (EM) systems manufactured by Geonics Limited as they relate to agricultural investigations. A review of all soil conductivity models currently available through Geonics will also be made.

The Best Proximal Geophysical Detector Ever !

A Look at some Historical Electromagnetic Induction Systems Manufactured by Geonics Limited

EM15 & EM15-MK2 (Compact Personal Electromagnetic Detector)

- EM15 produced in 1963 & EM15-MK2 in 1965
- Operating Frequency 15 kHz
- Coil separation 83 cm, null coupled by being parallel at 35 degrees from vertical
- Depth penetration 15m for large good conductor
- Used to distinguish between a conductor (sulphide minerals, metals) and magnetically permeable bodies (magnetite, pyrrhotite)
- Meter would display +ve (Red) for conductor and –ve (Blue) magnetic permeable body

Old & New ?

Electromagentic systems

- Frequency Domain
- Time Domain

The transmitter current varies sinusoidally with time at a fixed frequency

The transmitter current, while still periodic, is a modified symmetrical square wave.

Frequency Domain Instrumentation

What do we measure directly?

- An electromagnetic field may be defined in terms of four vector functions E, D, H and B, where:

E is the electrical field in V/m.
D is the dielectric displacement in Coulomb/m².
H is the magnetic field intensity in A/m.
B is the magnetic induction in Tesla.
J is the current in A

The operation of all Geonics instrumentation is controlled by the Following two Laws of Physics which form part of Maxwell's Equations

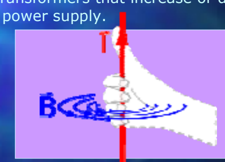
Maxwell's Equations

1. Faraday's Law $E = -dB/dt$ — An Electric Field (Voltage) can be generated by a time varying magnetic field

2. Ampere's Law $H = J + dD/dt$ — An Electric current or a time varying electric field can generate a magnetic field

INTRODUCTION

A magnetic field can be used to induce, or create, an electromotive force (emf). This emf can drive an electric current. Electromagnetic induction is the basis for the generation of most of the electricity that is produced in the world today.
Electromagnetic induction can also be used to change or transform an emf (a voltage). It is used in devices called transformers that increase or decrease the voltage, of an alternating current power supply.



The direction of the force on a **positively-charged** particle is defined by a right hand rule, illustrated in the diagram above. Note that the magnetic field in the illustration is oriented parallel to the screen and the velocity is downward so that we can show the thumb and fingers clearly

An Electric Field (Voltage) can be generated by a time varying magnetic field

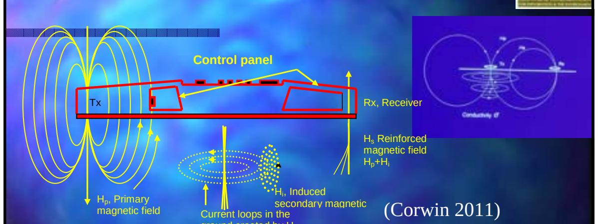
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

Graphical animations of Maxwell's circulation, time-varying, curl equations

$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

An Electric current or a time varying electric field can generate a magnetic field

Principle of Operation



(Corwin 2011)

Where the subsurface is homogeneous there is no difference between the fields propagated above the surface and through the ground (only slight reduction in amplitude). If a conductive anomaly is present, the magnetic component of the incident EM wave induces alternating currents (Eddy currents) within the conductor. The eddy currents generate their own secondary EM field which travels to the receiver.

Principle of Operation
(Understanding Terminology of Data Output for Conductivity Meters)

Receiver detects the primary field which travels through the air.

Receiver responds then to the resultant of the arriving primary and secondary fields.

Consequently, the measured response will differ in both *Phase* and *Amplitude* relative to the unmodulated primary field.

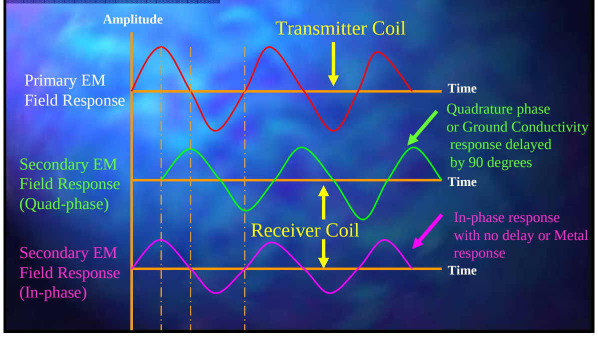
Differences between the transmitted and received electromagnetic fields reveal the presence of the conductor and provide information on its geometry and electrical properties.

Two components measured are :

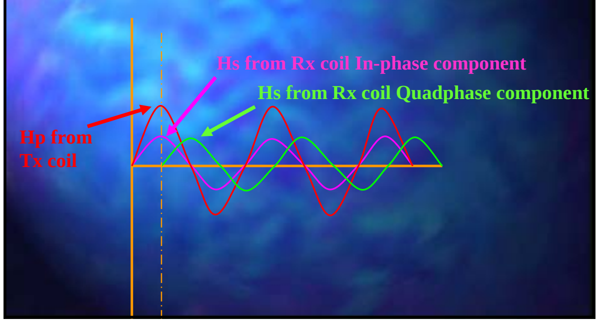
Quad-phase = Quadrature component = ***Conductivity (mS/m)***

In-phase = In-phase component = ***Magnetic Susceptibility (ppt)***

Electrical Principle of Operation



Electrical Principle of Operation



GROUND CONDUCTIVITY METERS

- EM31-MK2
- EM31-SH
- EM38
- EM38-DD
- EM38-MK2
- EM34-3
- EM34-3XL

Factors that affect Soil Conductivity

soil properties include:

- Water Content
- Soil Texture
- Soil Organic Matter
- Depth to Claypans
- Cation Exchange Capacity (CEC)
- Salinity
- Exchangeable Ca and Mg
- Water Holding Capacity of Soil

Two Properties measured by All EM Soil Conductivity Meters

- Apparent Conductivity (mS/m) = Quadrature Component of EM Field
- Magnetic Susceptibility (ppt) = Inphase Component of EM Field

Understanding the Measurement

Conductivity is measured in **milliSiemens/metre (mS/m)** which is equivalent to **millimohs/metre (mmhos/m)**

The displayed reading of the EM38 is in mS/m which can be converted to the following as well:

Symbol most often used for Conductivity is the Greek letter Sigma = σ

Symbol most often used for Resistivity is the Greek letter Rho = ρ

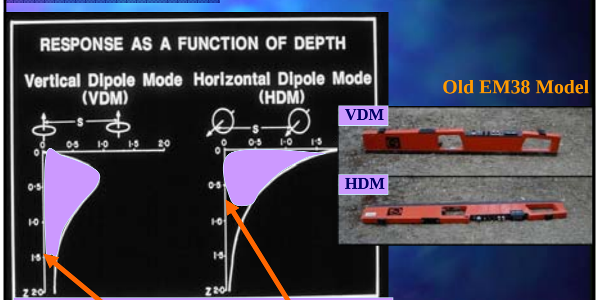
$$\sigma\,(mS/m) = 1000/\rho\,(Ohm*m)$$

1 mS/m = 0.01mS/cm   and 1 dS/m = 0.01 x (mS/m)

Depth Control of EM Soil Conductivity Meters

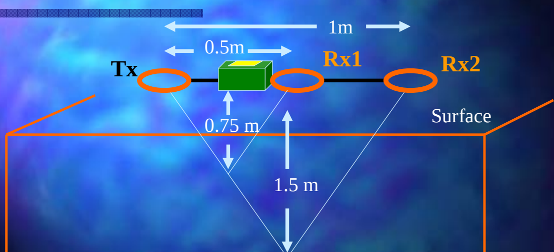
- Changing coil separation distance
- Changing the dipole mode or rotating of coils
- Changing frequencies

Vertical Distribution of EM Response



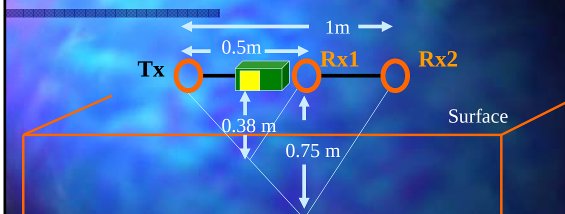
Depth = 1.5 x coil separation   Depth = 0.75 x coil separation

EM38-MK2 Coil Schematic and Depth of Exploration in V-mode



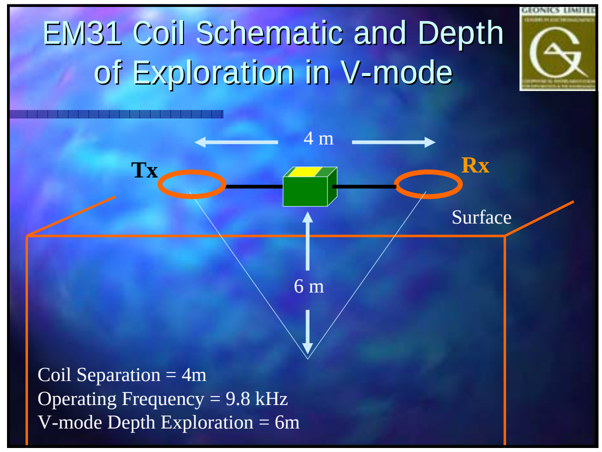
Coil Separation = 1m and 0.5m
Operating Frequency = 14.5 kHz
V-mode Depth Exploration = 1.5m and 0.75m

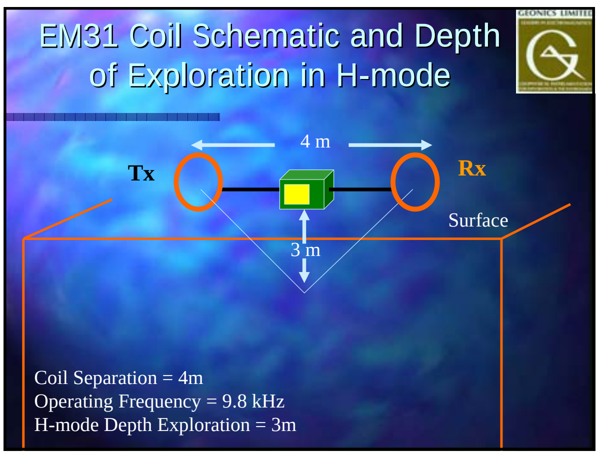
EM38-MK2 Coil Schematic and Depth of Exploration in H-mode



Coil Separation = 1m and 0.5m
Operating Frequency = 14.5 kHz
H-mode Depth Exploration = 0.75m and 0.38m

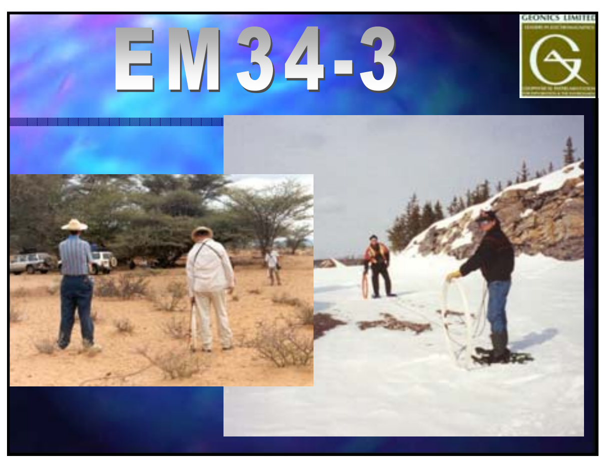

EM31-MK2

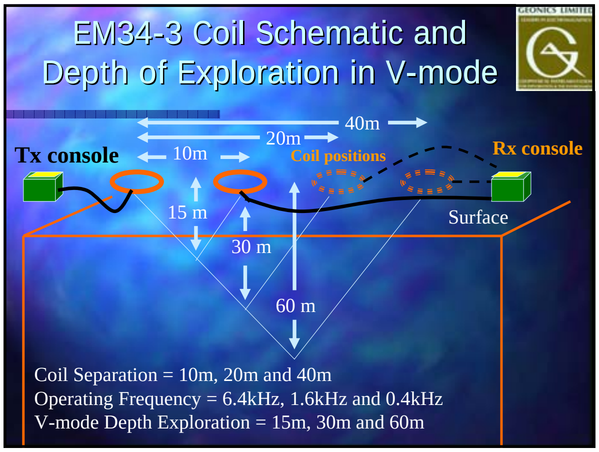

EM31 Coil Schematic and Depth of Exploration in V-mode
4 m
Tx
Rx
Surface
6 m
Coil Separation = 4m
Operating Frequency = 9.8 kHz
V-mode Depth Exploration = 6m

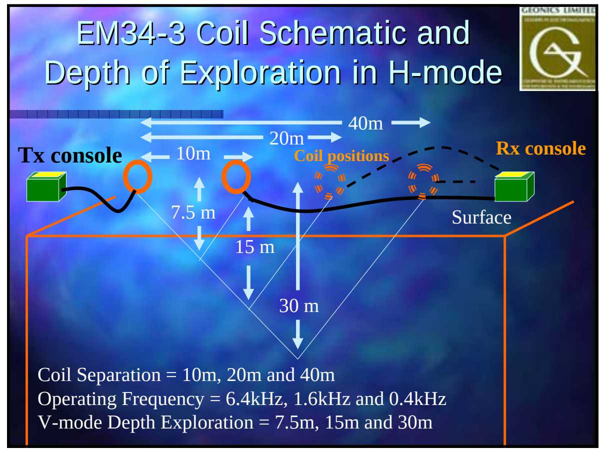

EM31 Coil Schematic and Depth of Exploration in H-mode
4 m
Tx
Rx
Surface
3 m
Coil Separation = 4m
Operating Frequency = 9.8 kHz
H-mode Depth Exploration = 3m


NEW
EM31-SH


NEW
Multi-coil system
EM31-3


EM34-3

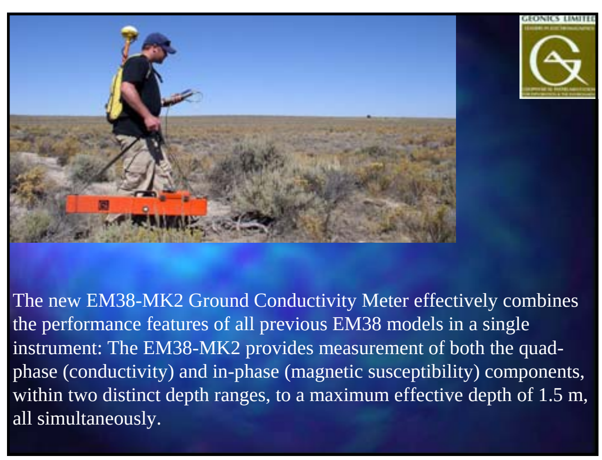

EM34-3 Coil Schematic and Depth of Exploration in V-mode
40m
20m
10m
Tx console
Coil positions
Rx console
15 m
30 m
60 m
Surface
Coil Separation = 10m, 20m and 40m
Operating Frequency = 6.4kHz, 1.6kHz and 0.4kHz
V-mode Depth Exploration = 15m, 30m and 60m


EM34-3 Coil Schematic and Depth of Exploration in H-mode
40m
20m
10m
Tx console
Coil positions
Rx console
7.5 m
15 m
30 m
Surface
Coil Separation = 10m, 20m and 40m
Operating Frequency = 6.4kHz, 1.6kHz and 0.4kHz
V-mode Depth Exploration = 7.5m, 15m and 30m


Back to Shallow EM & our most popular Agricultural Product Line


Old Style EM38 Models
EM38
EM38-DD
EM38-B


GEONICS LIMITED
The NEW model
EM38-MK2


The new EM38-MK2 Ground Conductivity Meter effectively combines the performance features of all previous EM38 models in a single instrument: The EM38-MK2 provides measurement of both the quad-phase (conductivity) and in-phase (magnetic susceptibility) components, within two distinct depth ranges, to a maximum effective depth of 1.5 m, all simultaneously.

In addition, new standard features and options each provide additional benefits: integrated Bluetooth functionality provides the option of wireless data transmission; a power input connector allows for the use of external power sources; a rechargeable external battery pack extends the duration of instrument operation; and a portable calibration stand provides the convenience of an automated calibration.

Understanding the Calibration of Geonics Limited Ground Conductivity Meters

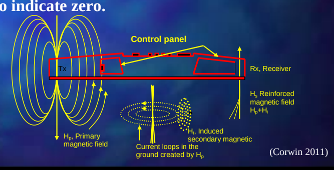
1. Initial Inphase (I/P) Nulling
2. Instrument Zero or True Calibration
3. Final Inphase (I/P) Nulling

Understanding the Calibration of Geonics Limited Ground Conductivity Meters

1. Initial Inphase (I/P) Nulling

It is the task of the receiver electronics to measure the very small signal from the eddy currents in the presence of the much larger signal arising from the primary magnetic field. To facilitate this measurement an internally generated signal is used to cancel or "null" the large primary signal so that it does not overload the electronic circuitry. To null the EM38-MK2, lift the instrument to a height of about 1.5 m above the ground and place in the horizontal dipole mode of operation (Fig. 1). Now null the I/P display to indicate zero.

Fig. 1



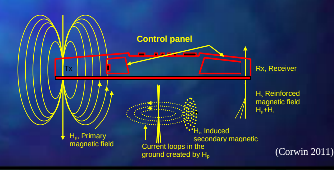
(Corwin 2011)

Understanding the Calibration of Geonics Limited Ground Conductivity Meters

2. Instrument Zero

Calibrating the conductivity meters to a known value (conductivity) is analogous to nulling or zeroing the instrument. The most accurate method of calibrating the instrument would be to raise the instrument to a height where it no longer responds to the ground's conductivity and adjust the instrument response to be zero. This procedure becomes impractical, however, with instruments other than the EM38's or EM38-MK2.

Fig. 1



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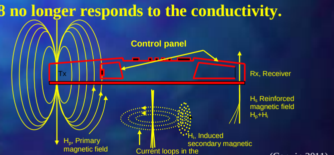
Understanding the Calibration of Geonics Limited Ground Conductivity Meters

2. Instrument Zero (Continued)

The response of the instruments with height results in the following being true: at an instrument height of 1.5 the intercoil spacing (or greater), the vertical dipole response will be equal to twice the horizontal dipole response. In setting the zero, the operator will occasionally find that, on rotating the EM38-MK2 from the horizontal dipole position H to the vertical dipole mode V the meter reading does not change, i.e., V=H. The answer to this puzzle is that the ground is so resistive that at 1.5 meters height the EM38 no longer responds to the conductivity.

Fig. 1

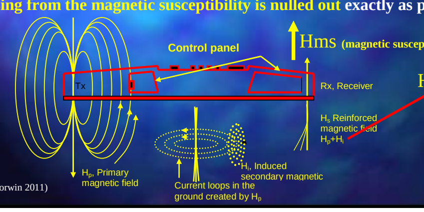


(Corwin 2011)

Understanding the Calibration of Geonics Limited Ground Conductivity Meters

3. Final Inphase Nulling

Unfortunately the magnetic susceptibility of soils causes an additional signal to be picked up by the receiver coil when the EM38-MK2 is located close to or is lying on the surface of the ground. The additional signal is dealt with by simply placing the instrument on the ground in the appropriate position and the residual signal arising from the magnetic susceptibility is nulled out exactly as previous.



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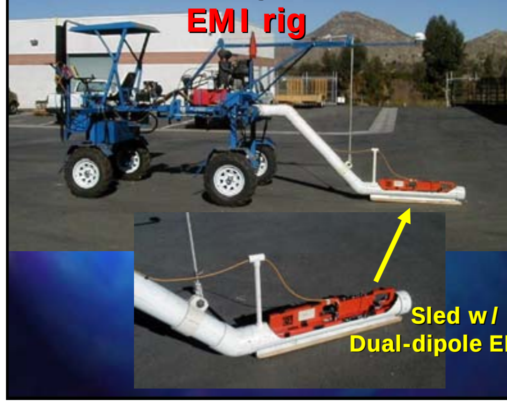
Mobile EM38 Sleds & Trailers

Mobile EM38 Sleds & Trailers

Mobile EM38 Sleds & Trailers

Salinity Lab EMI rig



EM Applications

- Groundwater Exploration & Contamination
- Precision Agriculture/Soil Salinity
- Environmental hazards (ie drums, waste containers, UST's, and UXO's)
- Pipelines, Utilities & Landfill Boundaries
- Buried trenches & pits
- Historical structures and artifacts
- Turfgrass

Moral of the Story


Thank You
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