Using EMI Methods to Map Soil Characteristics

PRESENTED BY ANSLEY J. BROWN

AUGUST 6TH, 2018

Overview

What is Electromagnetic Induction?

Principles of EMI Instruments

Properties Measured by all EMI Devices

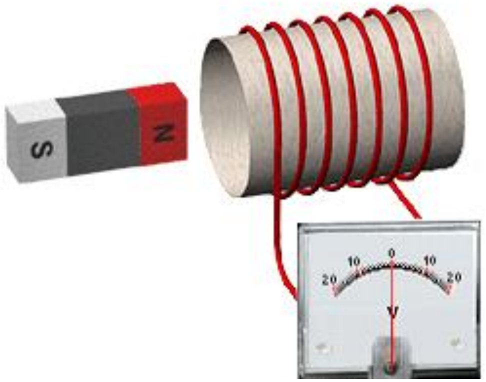
Factors that Affect Apparent Soil Electrical Conductivity

Introduction to the EM38-MK2

Calibration

Survey Setup

Data Downloading



What is Electromagnetic Induction?

EMI is the production of an electric current by changing the magnetic field enclosed by an electrical circuit.

Magnetic fields can create an electromotive force (EMF) which drives an electric current.

EMI is used for the generation of most of the electricity that is produced in the world today, such as in any electric generator.

It is also used in electrical transformers, which increase or decrease the voltage of an alternating current (A/C) power supply.

For us, EMI is used to measure bulk apparent soil conductivity (EC_a) and Magnetic Susceptibility.

Principles of EMI Measurements

EMI instruments operate on the principles of Maxwell’s Equations:

Faraday’s Law – An electric field (voltage) can be generated by a time-varying magnetic field

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

Ampere’s Law – An electric current (amp) or time varying electric field can generate a magnetic field

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

Where:

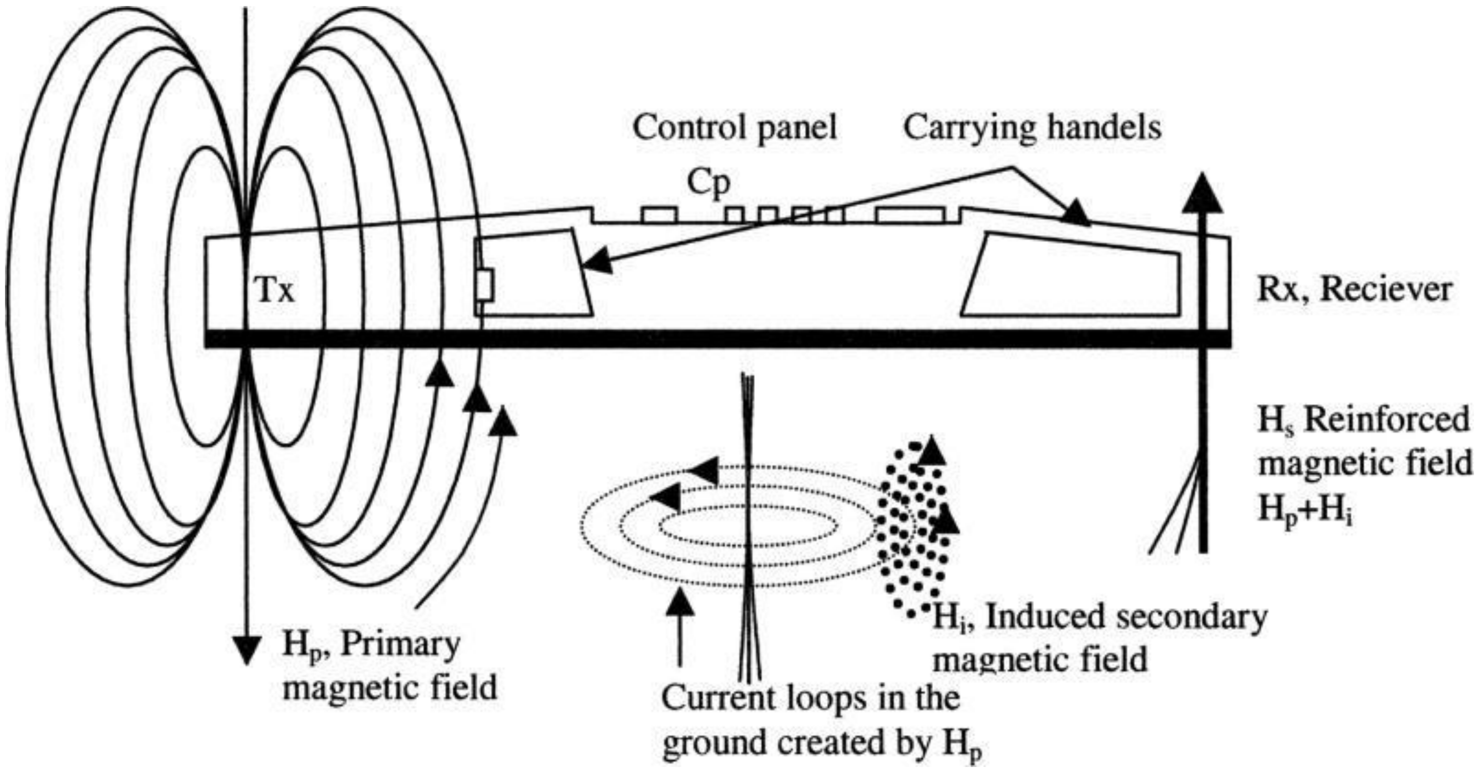
E is the electrical field in V/m

D is the dielectric displacement in Coulomb/m^2

H is the magnetic field intensity in A/m

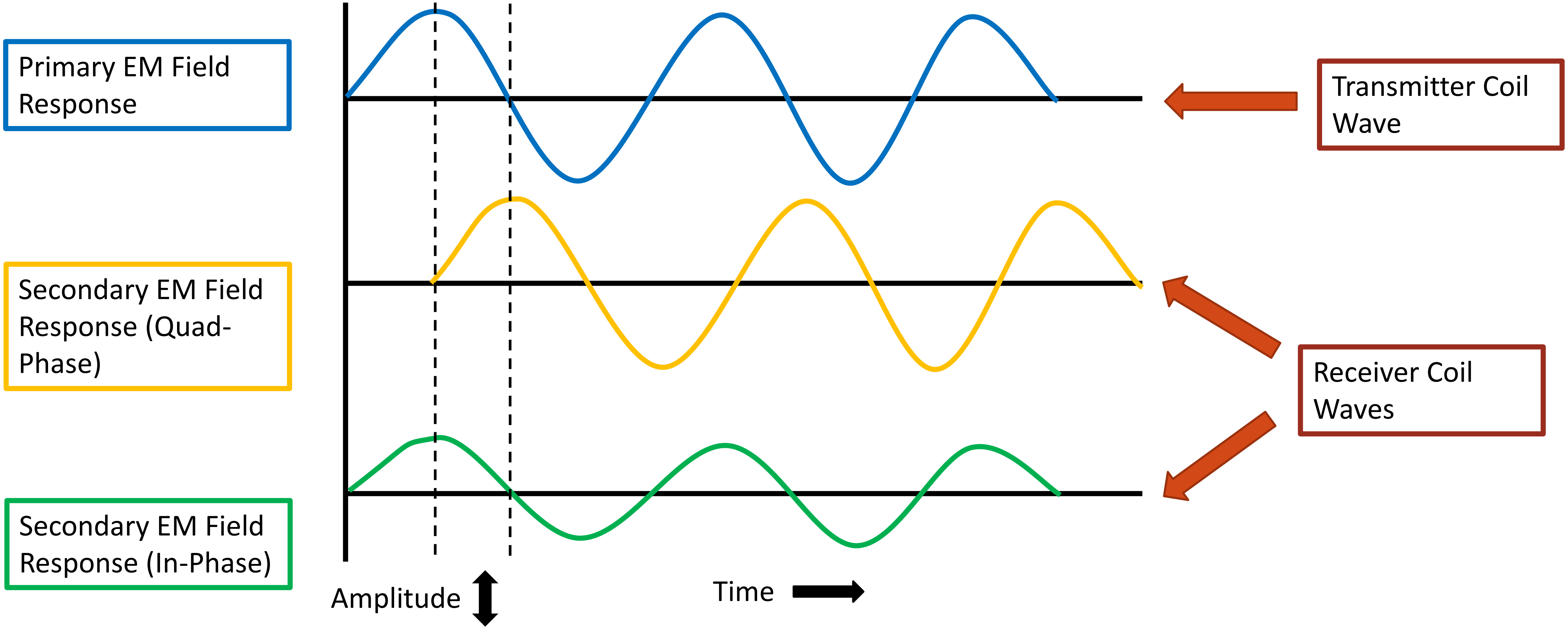
B is the magnetic induction in Tesla

J is the current in A



(Corwin, 2012)

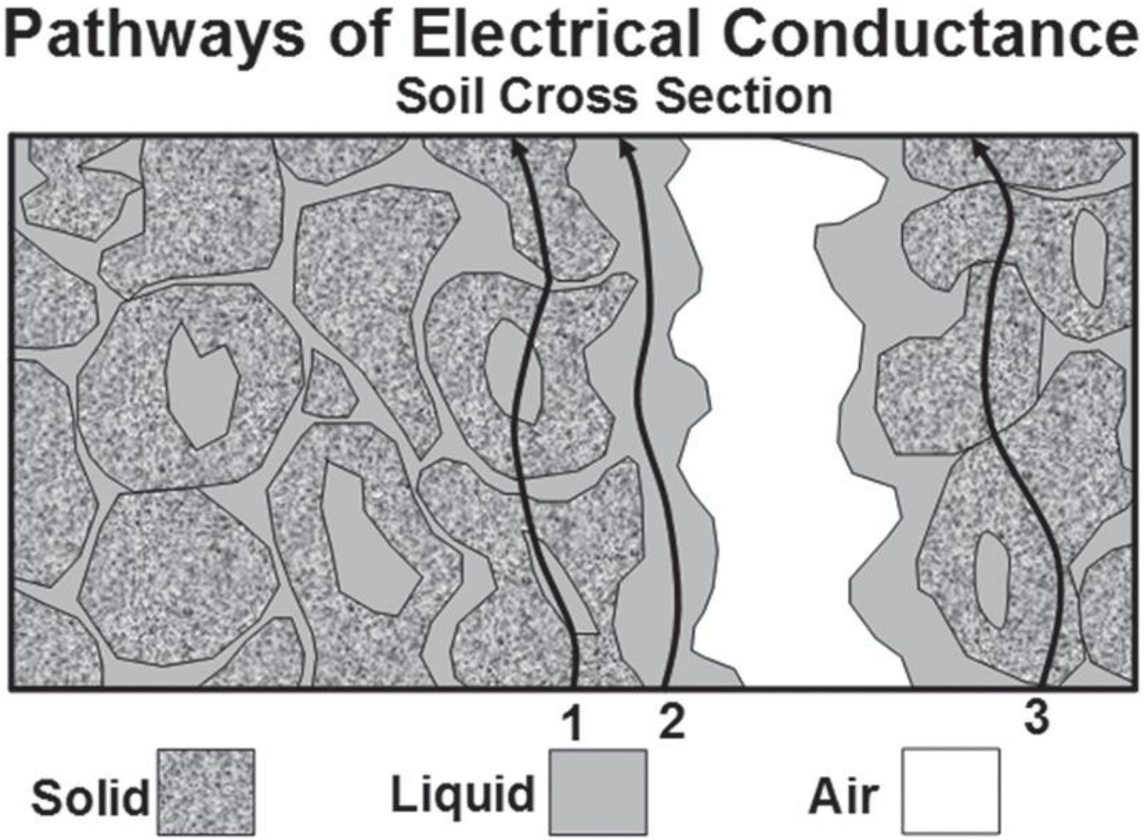
The primary waves induce secondary magnetic fields which are then measured by the receiver coils



Differences between the transmitted and received waves reveal the presence of the conductor and provide information on its geometery and electrical properties:

<u>Quad-phase (Q/P)</u>: Quadrature Component = <u>Conducitivity (mS/m)</u>

<u>In-phase (I/P)</u>: In-phase Component = <u>Magnetic Susceptibility (ppt)</u>



Schematic illustrating the three conductance pathways for the apparent soil electrical conductivity (ECa) measurement:
solid–liquid (Pathway 1), liquid (Pathway 2), and solid (Pathway 3)
(Corwin et. al. 2017)

Factors that Affect Soil Conductivity

Conductivity (EC_a) ≠ Salinity (EC_e)

Conductivity is affected by:
- Water Content
- Soil Texture
- Soil Salinity
- Soil Organic Matter
- Depth to Claypans
- Cation Exchange Capacity (CEC)
- Conductive Ions

3 pathways:
- Solid-liquid
- Liquid
- Solid

Dual Pathway Parallel Conductance (DPPC)

$$\boxed{EC_a = \frac{(\theta_{ss} + \theta_{ws})^2 EC_{ws} EC_{ss}}{\theta_{ss} EC_{ws} + \theta_{ws} EC_{ss}} + (\theta_w - \theta_{ws}) EC_{wc}}$$

Developed by (Rhoades et. al., 1989) to relate ECa to soil properties.

EC is electrical conductivity

θ is volumetric water content

$(X)_{ss}$ indicates surface conductance

$(X)_{ws}$ indicates soil-water pathway

$(X)_{wc}$ indicates continuous liquid pathway

$\theta_w = \theta_{ws} + \theta_{wc}$

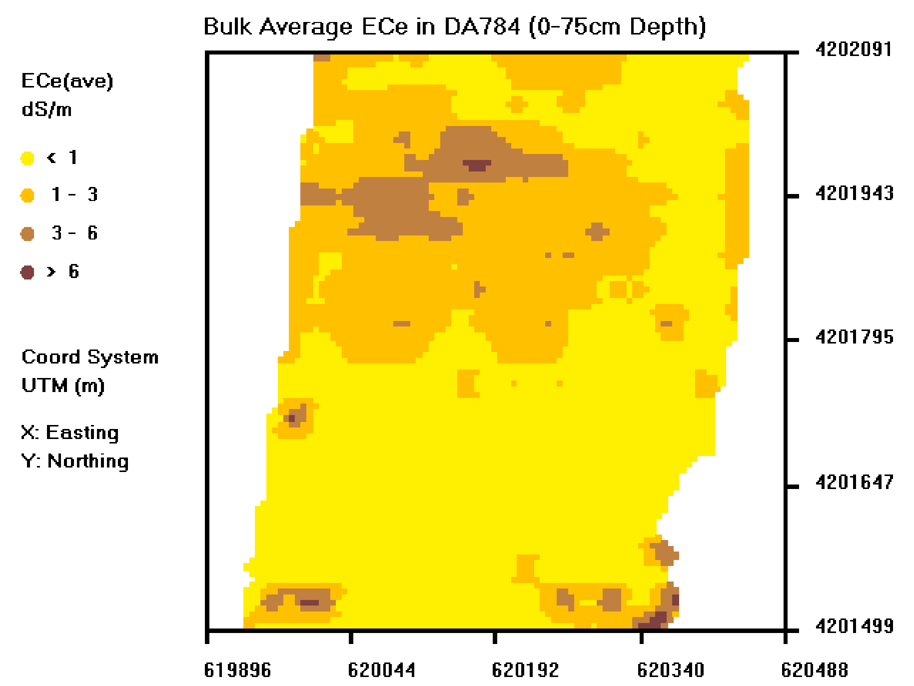
Introduction to the EM38-MK2

Measures Q/P and I/P and 2 different depths simultaneously

Integrates Bluetooth in to survey technology

Has a temperature correction feature

Can be used to generate large scale salinity maps with relative ease



Vertical Dipole Mode

Horizontal Dipole Mode

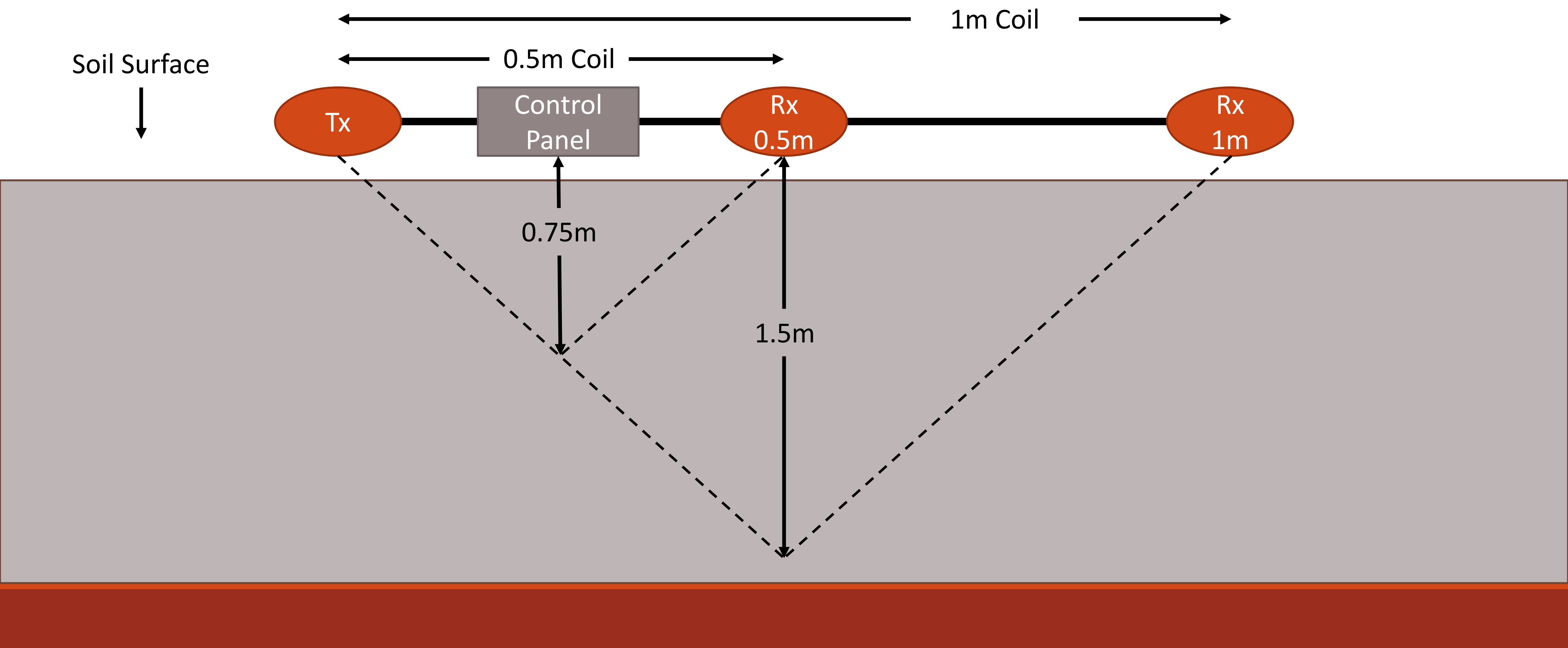
How to Control Depth of EM Measurements

Change coil separation distance

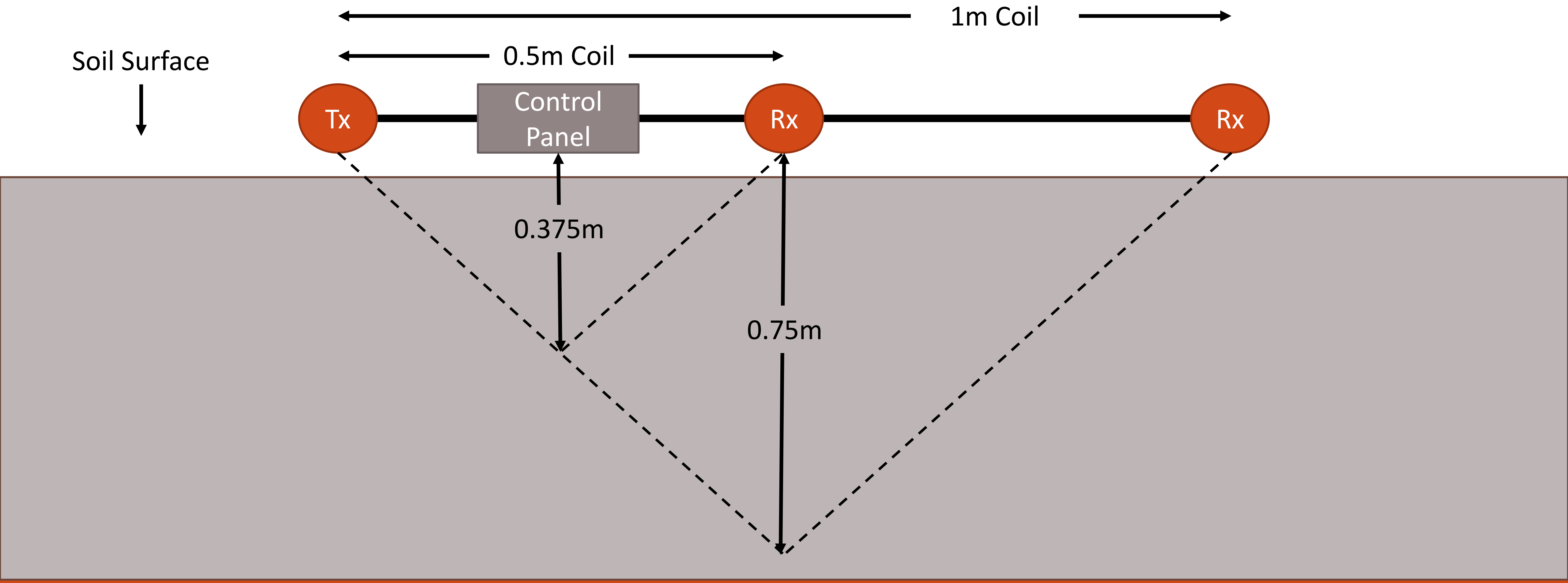
Change the dipole mode or rotate transmitter and receiver coils

Change frequencies of transmitter

Coil Schematic of the EM38-MK2 in Vertical Dipole Mode

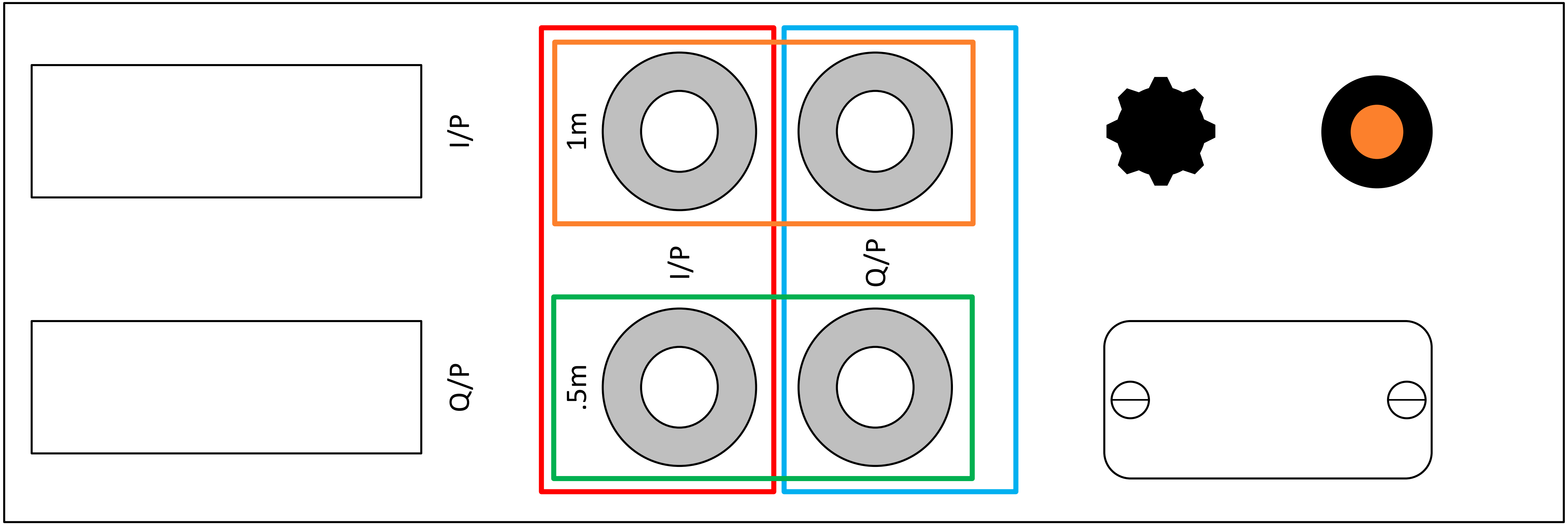


Coil Schematic of the EM38-MK2 in Horizontal Dipole Mode



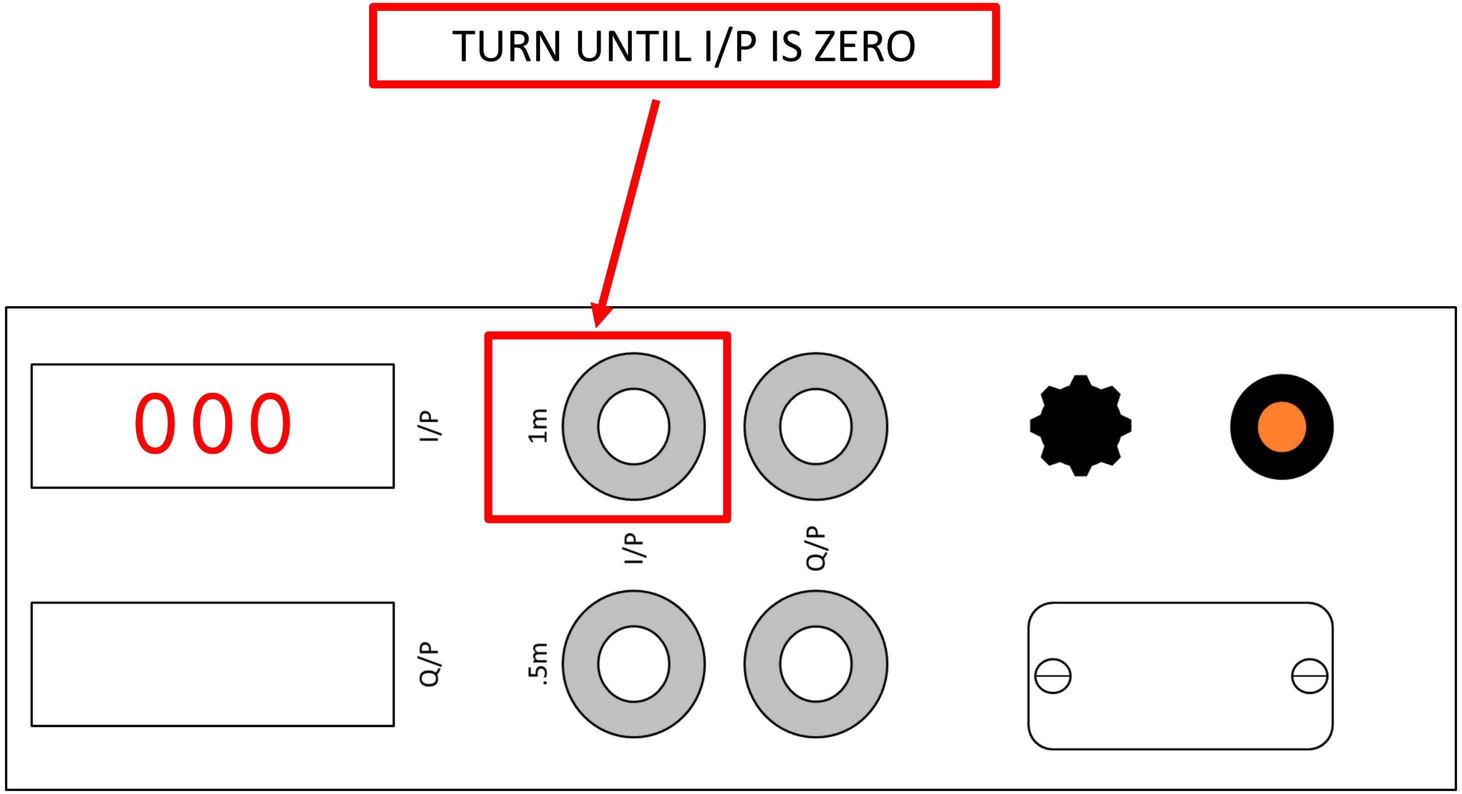
Calibrating the EM38-MK2

1. In-Phase Nulling
2. Instrument Zero or True Calibration
3. Final In-phase Nulling
4. Repeat steps 1-3 for each receiver coil



KEY =

I/P Control Knobs
Q/P Control Knobs
1m Control Knobs
.5m Control Knobs

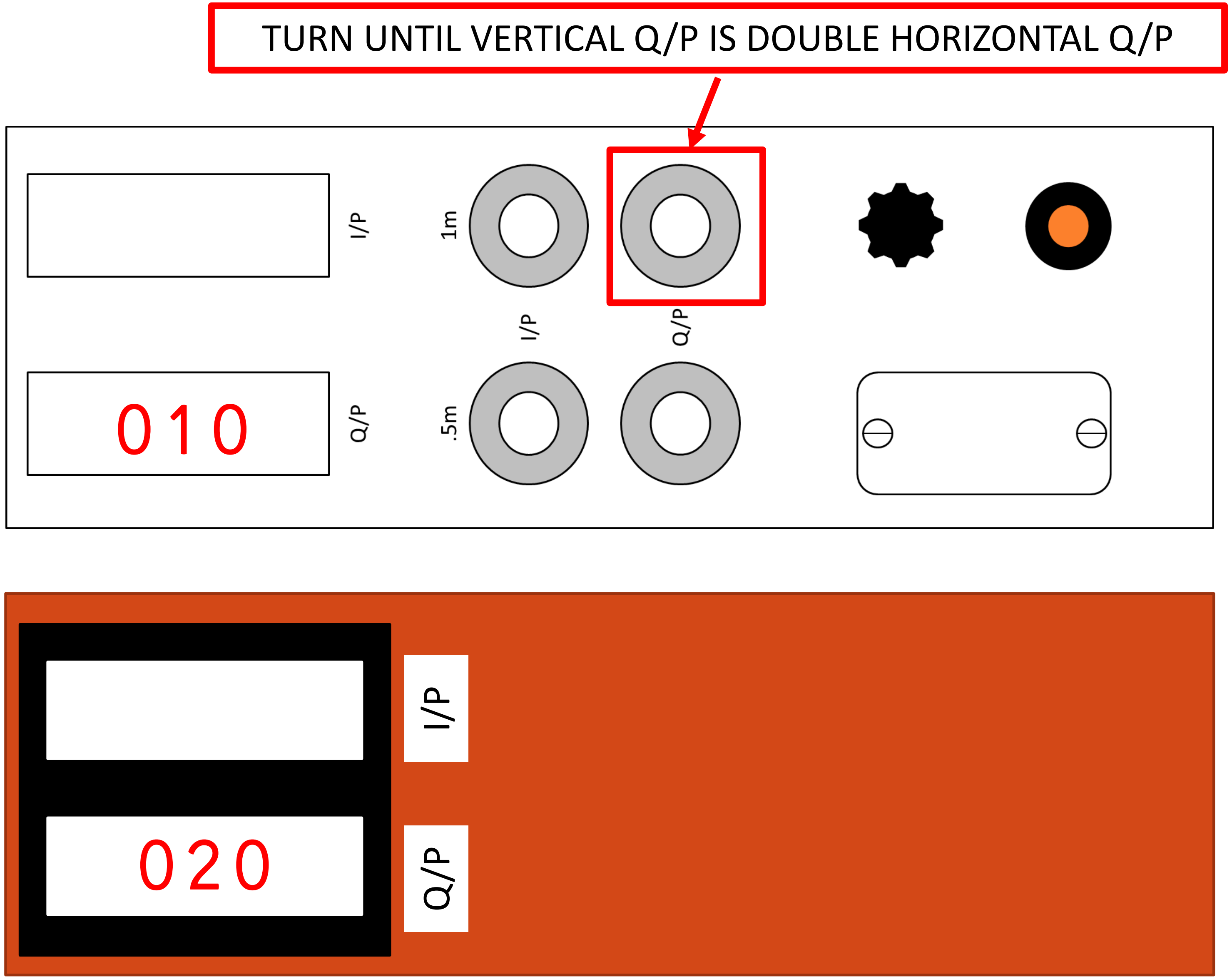


In-Phase Nulling

In order for the receiver coil to measure the signals generated from the eddy currents fount in the soil, the much larger, primary signal must be “nulled” by adjusting the In-Phase knobs on the EM38-mk2.

To null the EM38-MK2:

- Place the instrument on the calibration stand in horizontal dipole mode so that the device is 1.5m above the ground surface
- Turn the indicator knob to the “1m” setting
- Unlock and turn the 1m I/P knob so that the I/P display reading is zero
- Lock the knob again

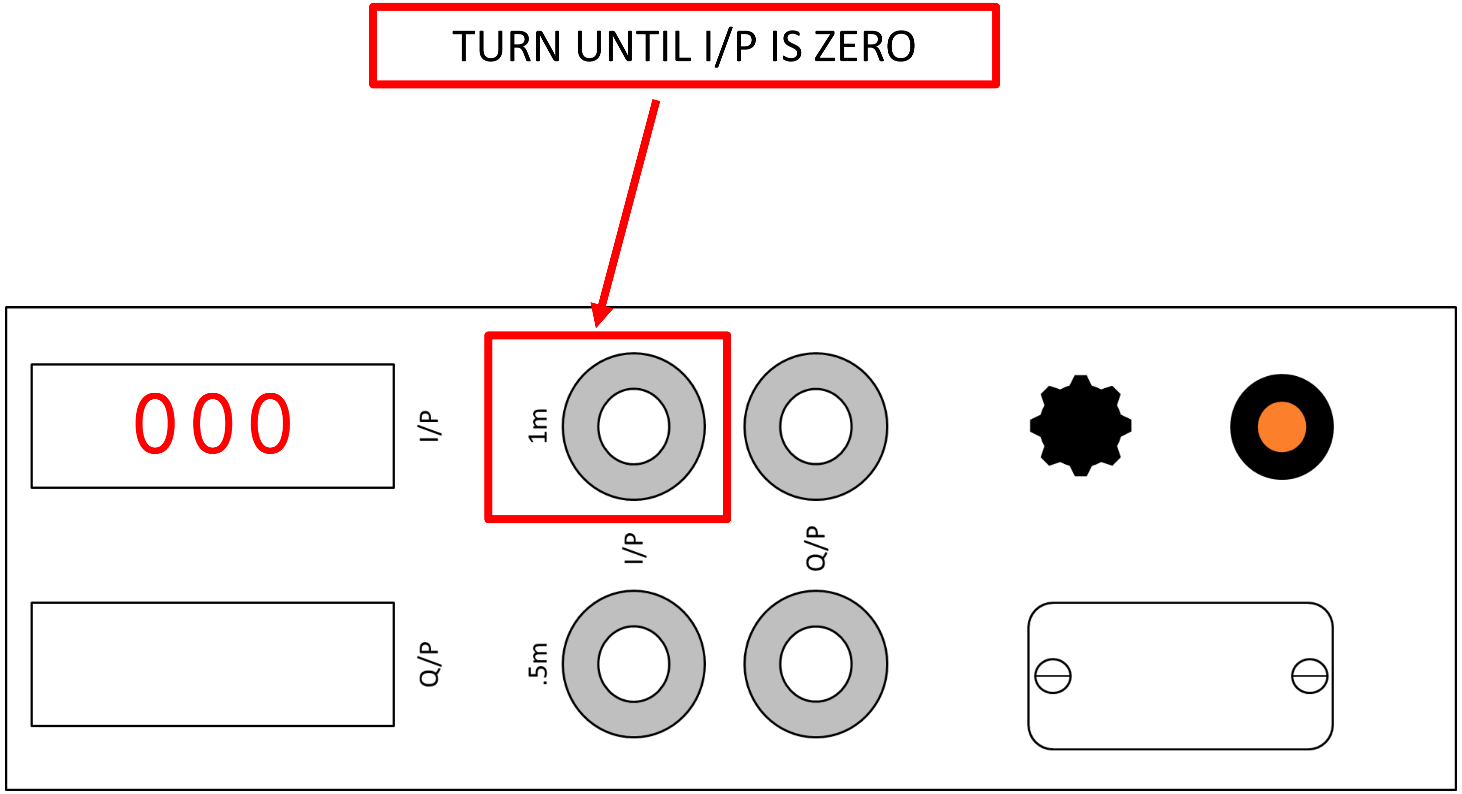


Instrument Zero (Q/P)

In order to accurately measure conductivity of the soil, the EM38-MK2 must be calibrated in a way that is similar to the I/P setting so that the device only reads conductivity generated from the soil profile and not any interfering signals or objects.

To Zero the EM38-MK2:

- Place the instrument on the calibration stand in horizontal dipole mode so that the device is 1.5m above the ground surface
- Turn the indicator knob to the “1m” setting
- Turn the 1m Q/P knob so that the Q/P display is reading an arbitrary, low number (e.g. 10)
- Flip the device to vertical dipole mode and read the Q/P display
- The vertical dipole Q/P reading should be double the value of the horizontal dipole Q/P reading. Adjust the horizontal Q/P reading until this is true.
- Lock the knob once complete



Final In-Phase Nulling

The magnetic susceptibility of soils causes an additional signal to be picked up by the receiver coils when the EM38-MK2 is near to, or lying on the ground surface.

To avoid any bias caused by this:

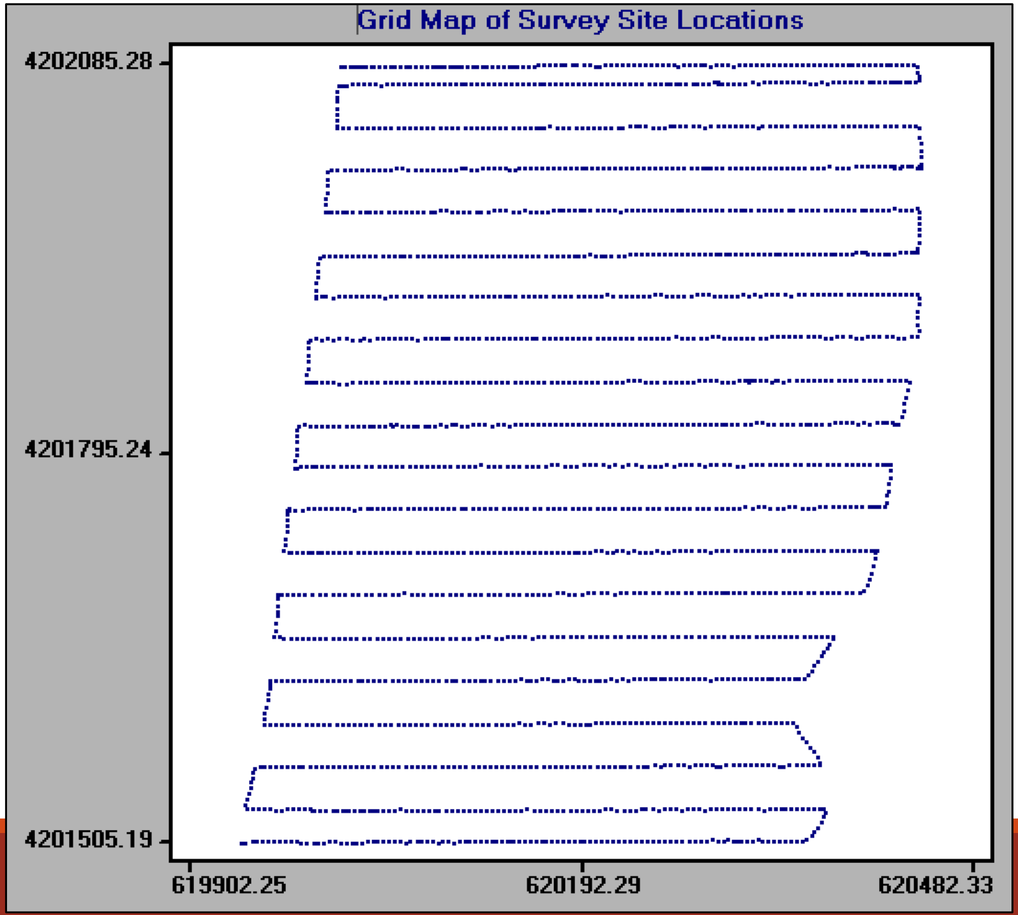
- Place the instrument on the ground in vertical dipole mode
- Turn the indicator knob to the "1m" setting
- Unlock and turn the 1m I/P knob so that the I/P display reading is zero
- Lock the knob again

REPEAT STEPS 1-3 WITH DEVICE IN .5m MODE

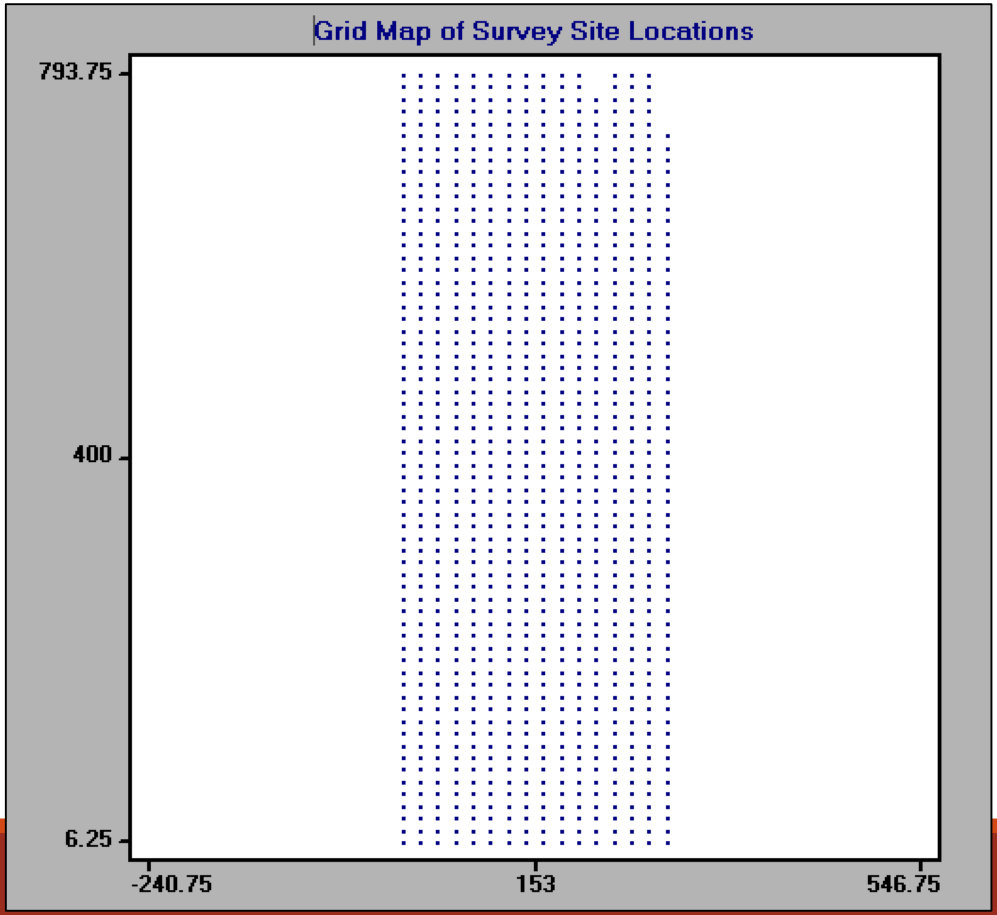
Video of Calibration

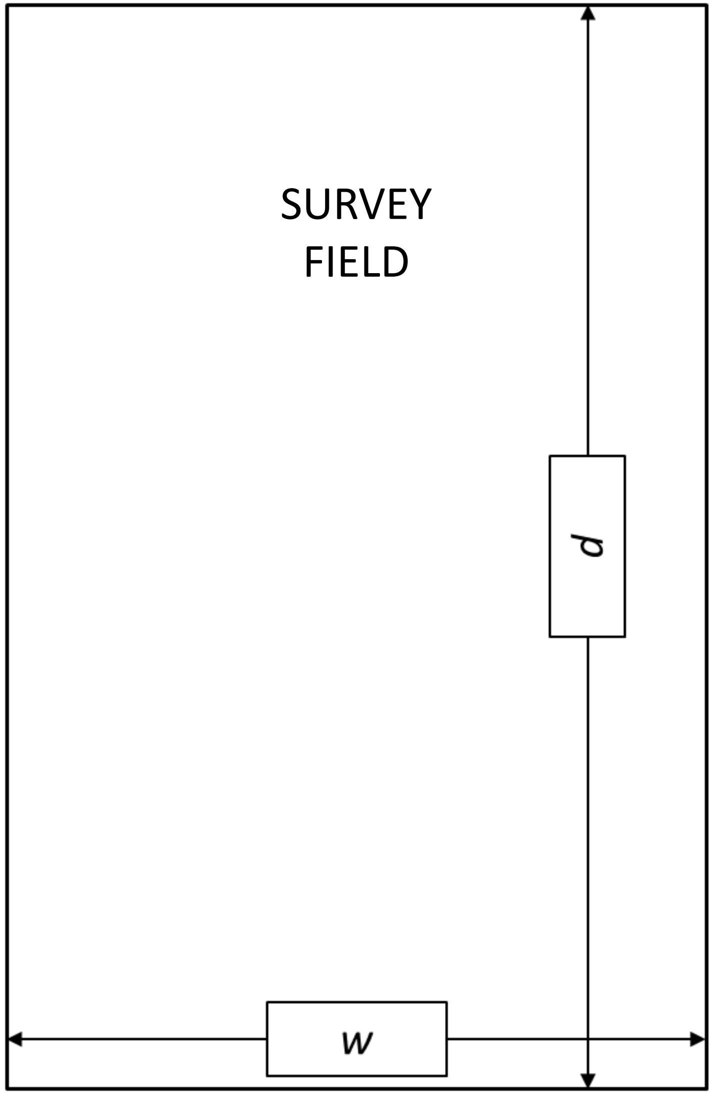
EM38-MK2 Survey Setup

TRANSECT SURVEY



GRID SURVEY



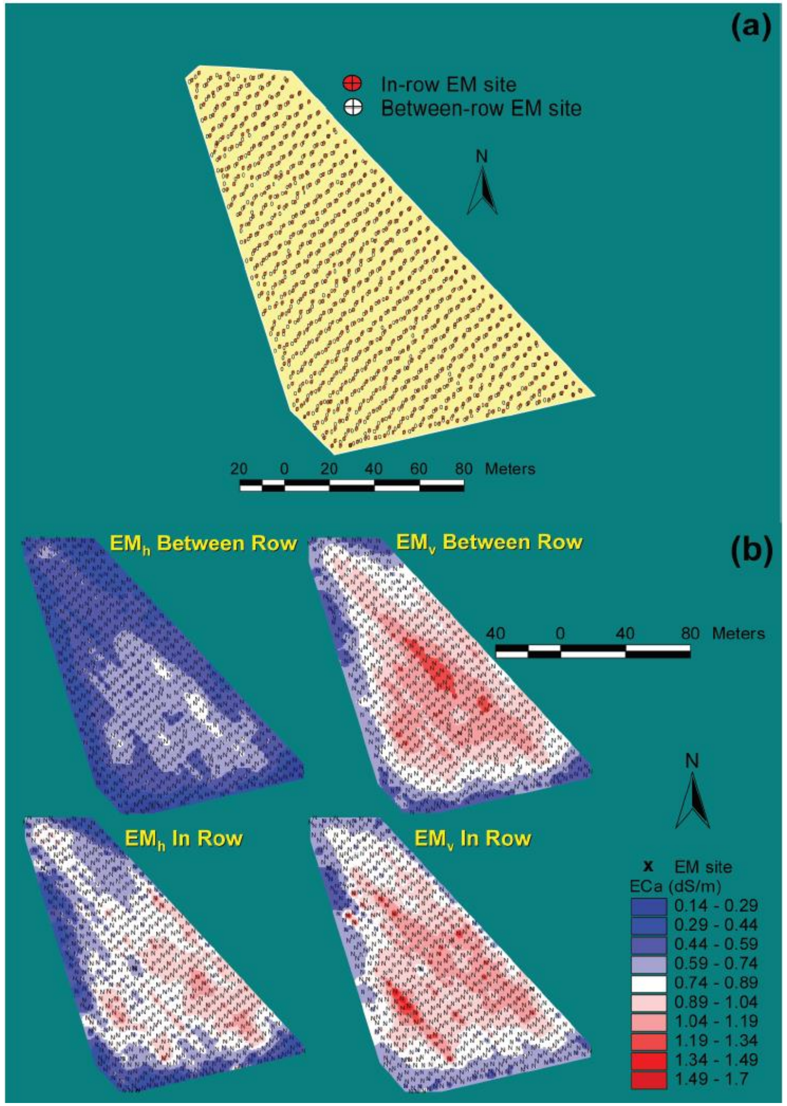


Rule of Thumb

When performing a survey, edge bias is always a concern. To avoid edge bias:

- The number of transects desired in a field is, *n*
- EM38-MK2 should be kept 0.5*(*w/n*) from the width and 0.5*(*d/n*) from the length
- The distance between transects should also be *d/n*
- *d* is always the length parallel to the field furrows (as surveys should always run parallel to furrows to avoid compaction bias)
- Programs like ESAP-RSSD can mask readings with edge bias through edge buffering algorithms

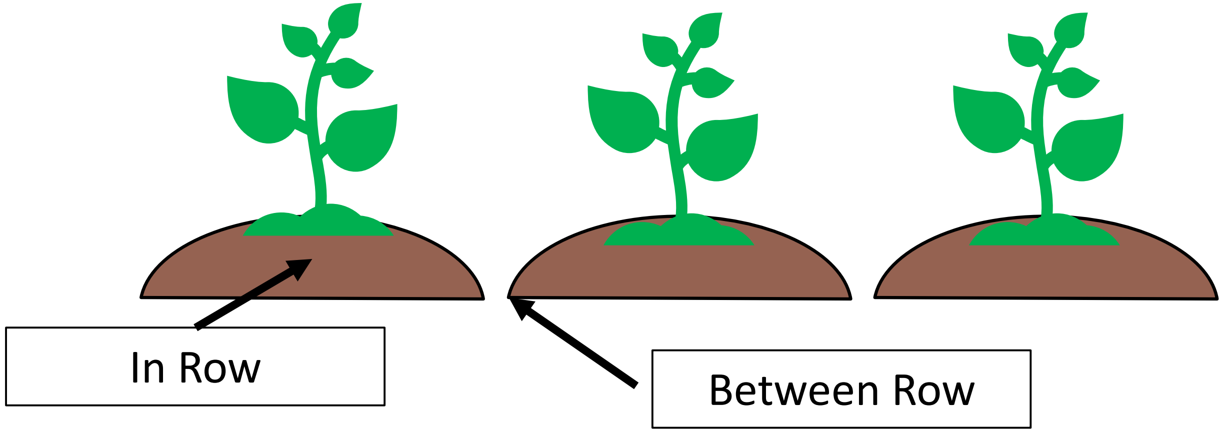
(Corwin, 2016)



On-Row vs. In-Row Measurement

Differences have been seen in measuring ECa in fields where bed furrows are used.

- The important part is to remain consistent within field and between fields of comparison.
- Sometimes both surveys are desired (i.e. drip irrigation system for vineyard or vegetables)



Other Important Considerations

Metal is a HUGE influencer of EM readings
- Do not wear ANY metal during the survey
- Be aware of any potential metal in the field (i.e. metal fences, vineyard trellises, buried metal objects, and underground metal pipe.)

Surface roughness
- If part of the field is ploughed and the rest is smooth, then differences will be seen in Eca

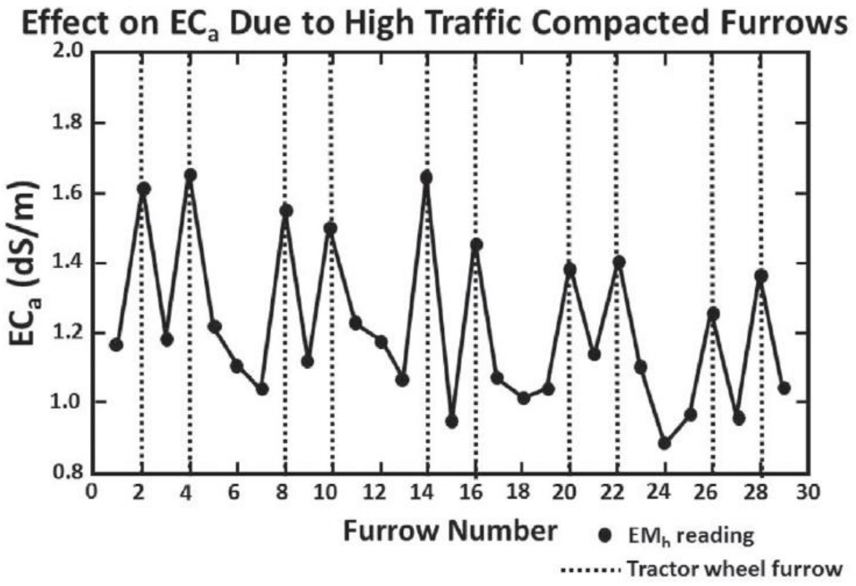
Irrigation Management
- If moisture distribution is uneven (vertically and laterally), expect to see differences in Eca
- Field should be within 70% of field capacity to field capacity to ensure proper EM measurement (too wet, or to dry is bad)

Compaction
- Soil compaction will significantly alter measured ECa.

Elevation
- Non-farm lands tend to be uneven, and elevation surveys should also be performed

Temperature
- The EM38-MK2 has a temperature correction factor, but older models are influenced by temperature

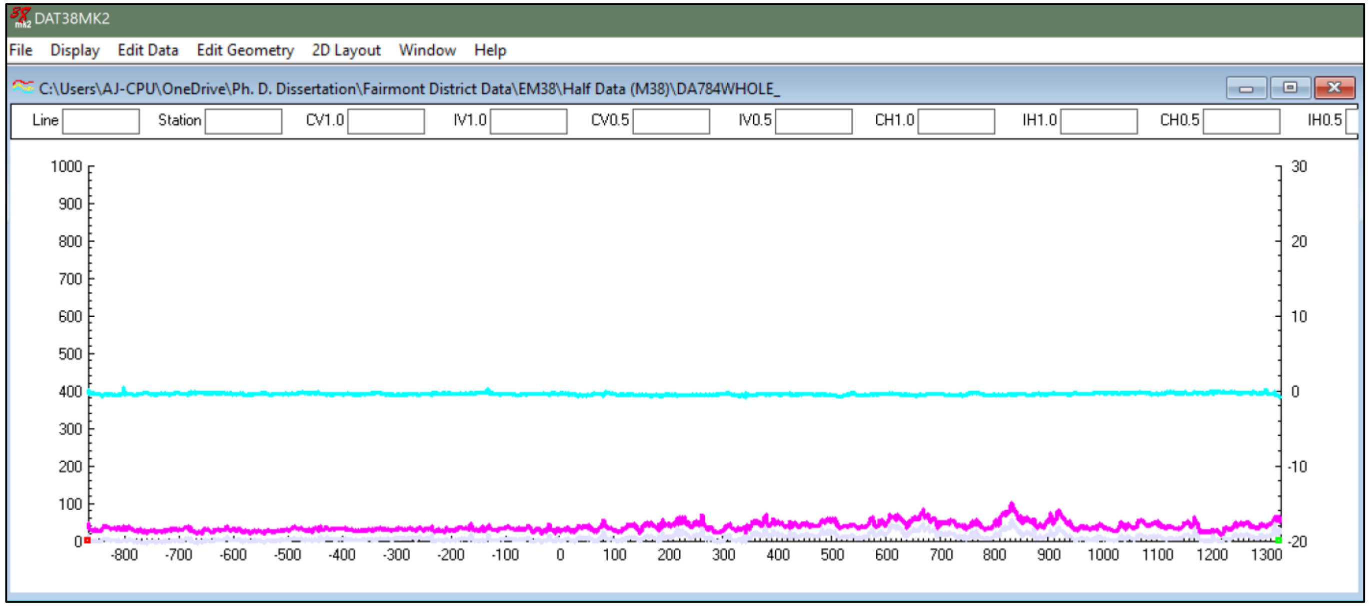
(Corwin and Lesch, 2005)



Downloading EM38-MK2 Data

To download survey data from the EM38-MK2 we must transfer the data from the handheld CPU to a desktop where we can process it in DAT38MK2.

This program takes raw (.N38) files and translates them into Profile(.M38) files, and finally into other usable formats such as .txt and .csv files



Raw File to Profile File

Step 1:

Convert → Convert Raw (N38) Files into Profile (M38) Files

Step 2:

Designate input file location and name output file

Step 3:

Press Convert

Profile File into .CSV File

Step 1:

`File → Open Profile File`

Step 2:

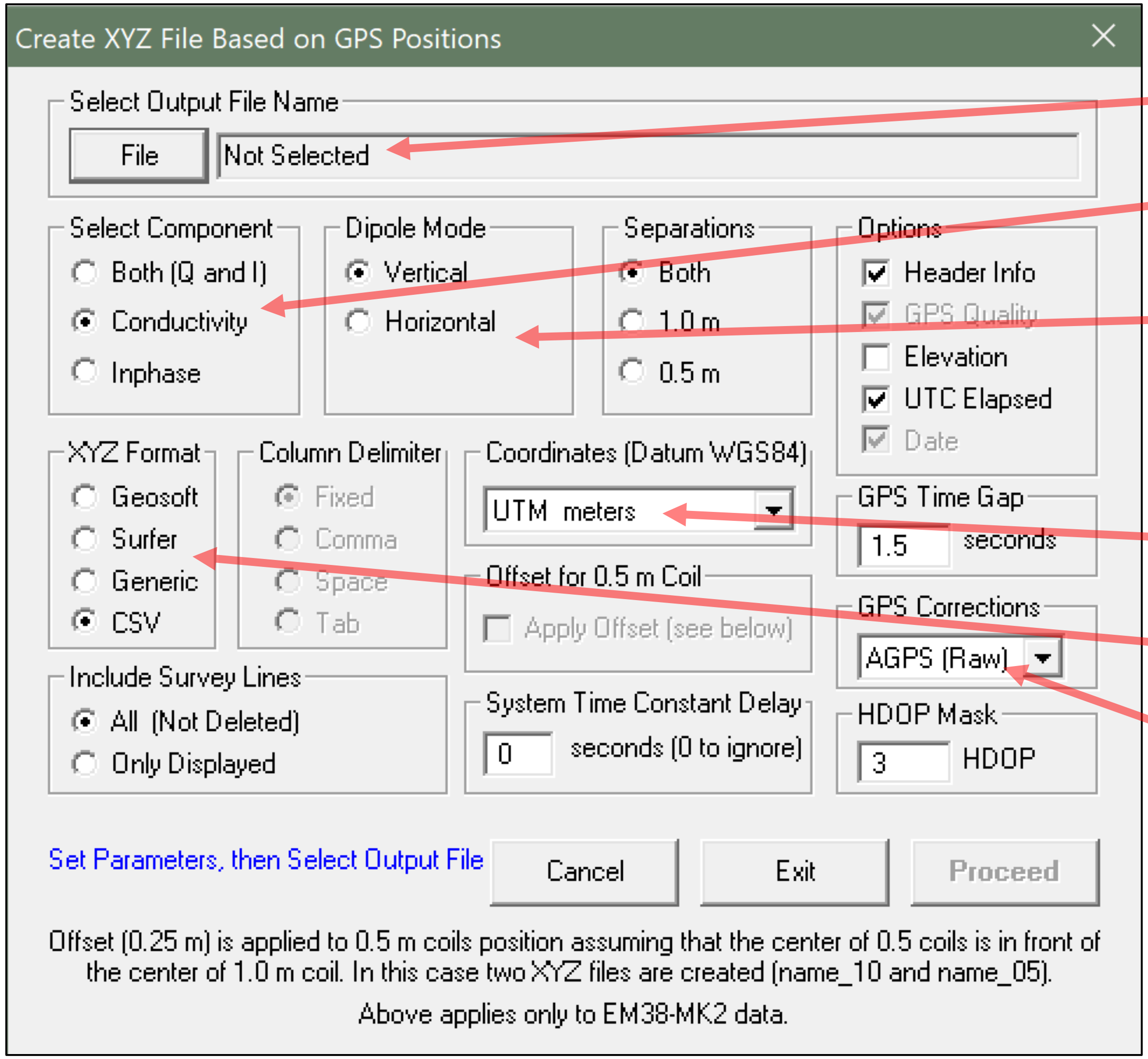
Open .M38 file previously saved

Step 3:

`2D Layout → Create GPS based XYZ File`

Step 4:

Adjust settings accordingly (Shown on next slide) and press `Proceed`



- Designate input file (.M38)
- Select Desired output
- Select dipole mode that survey was carried in
- Specify coordinate system
- Specify output file format
- Specify GPS corrections (for differential or RTK GPS systems)

Data Conversion is Complete!

Output file is now ready for further use

- This file is how the conversion of ECa to ECe is generated in Excel
- This file will also serve as the input data for response surface sampling designs such as in the ESAP-RSSD program

References

Catalano, Michael “Measuring Soil Conductivity with Geonics Limited Electromagnetic Geophysical Instrumentation” Global Workshop on Proximal Sensing. (2011). https://adamchukpa.mcgill.ca/gwpss/Presentations/GWPSS_2011_Catalano.pdf

Corwin, Dennis L., et al. "Laboratory and field measurements." *ASCE Manual and Reports on Engineering Practice* 71 (2012): 295-341.

Corwin, Dennis L., and Elia Scudiero. "Field-scale apparent soil electrical conductivity." *Methods of soil analysis*msaonline2016 (2016).

Corwin, Dennis L., and Kevin Yemoto. "Salinity: Electrical Conductivity and Total Dissolved Solids." *Methods of Soil Analysis* 2.1 (2017).

Rhoades, J. D., et al. "Soil electrical conductivity and soil salinity: New formulations and calibrations." *Soil Science Society of America Journal* 53.2 (1989): 433-439.

Acknowledgements & Sponsors

Timothy Gates, Allan Andales, Jose Chavez, Greg Butters, and Thomas Borch

MEHRAN UNIVERSITY OF ENGINEERING AND TECHNOLOGY JAMSHORO

THE UNIVERSITY OF UTAH

USAID FROM THE AMERICAN PEOPLE

U.S.-Pakistan Centers for Advanced Studies in Water

Questions

THANK YOU