Lab 7: Electromagnetics

TA: DomFournier
e-mail: fourndo@gmail.com
office: ESB 4021

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Overview

Elementary circuits can be used to simulate the responses for EM surveys. In this lab, you are provided with an Jupyter notebook that allows you to explore the character of the responses under different conditions. The basic principles for EM induction have been provided in the notes and on the GPG . You will use those notes to accompany the abbreviated text provided here.

EM-31

The EM-31 consists of a transmitter (Tx) and a receiver (Rx) which are mounted at the ends of a 3.6m long boom. The Tx carries a sinosoidal (or harmonic) current of frequency f = 9,700 Hz. This generates a time-varying magnetic field everywhere and is called the primary magnetic field H^P. The primary magnetic field induces currents in the target. We can represent a conductive target by a loop of wire that has a resistance (R) and a self-inductance (L). The induced currents in the target then generate the secondary magnetic field H^S. The Rx measures both the primary and secondary magnetic fields. The Rx is sensitive only to magnetic fields that cross its plane, so the co-planar geometry is one of maximum coupling. If the Rx coil was rotated 90 degrees so that it was perpendicular, then no magnetic field lines would cross its plane and no primary field would be measured.

Instructions

- Download and unzip the Zip File
- Use the Jupyter notebook to help you answer the questions in this lab
- Copy images from the Jupyter notebook if they will help your explanation

Resources

- `http://mybinder.org/repo/ubcgif/gpgLabs//notebooks/EM/FEM3Loop/Fem3loop.ipynb`. Thanks to Dikun Yang for the original FEM3loop code.

- GPG Geophysical Surveys: Electromagnetics Methods

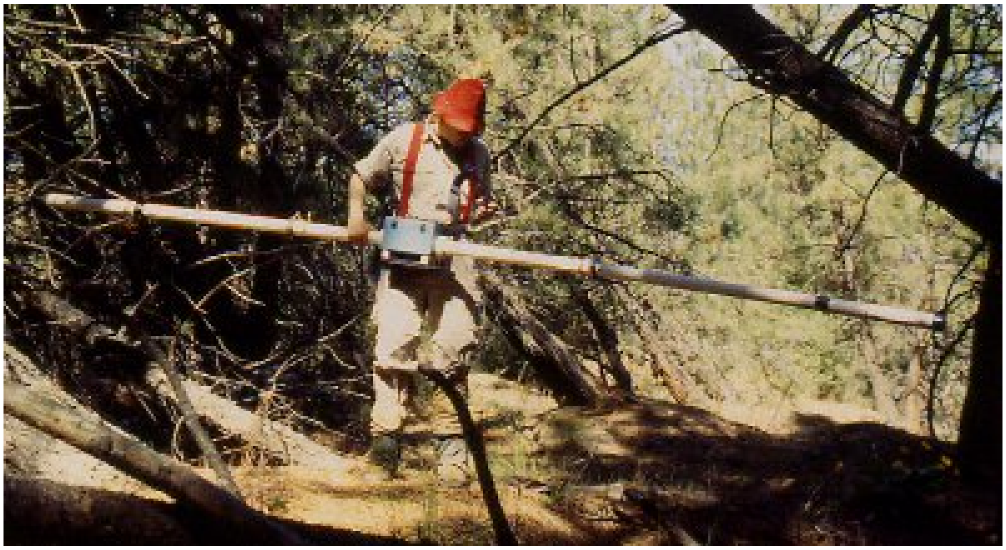


Figure 1: EM-31

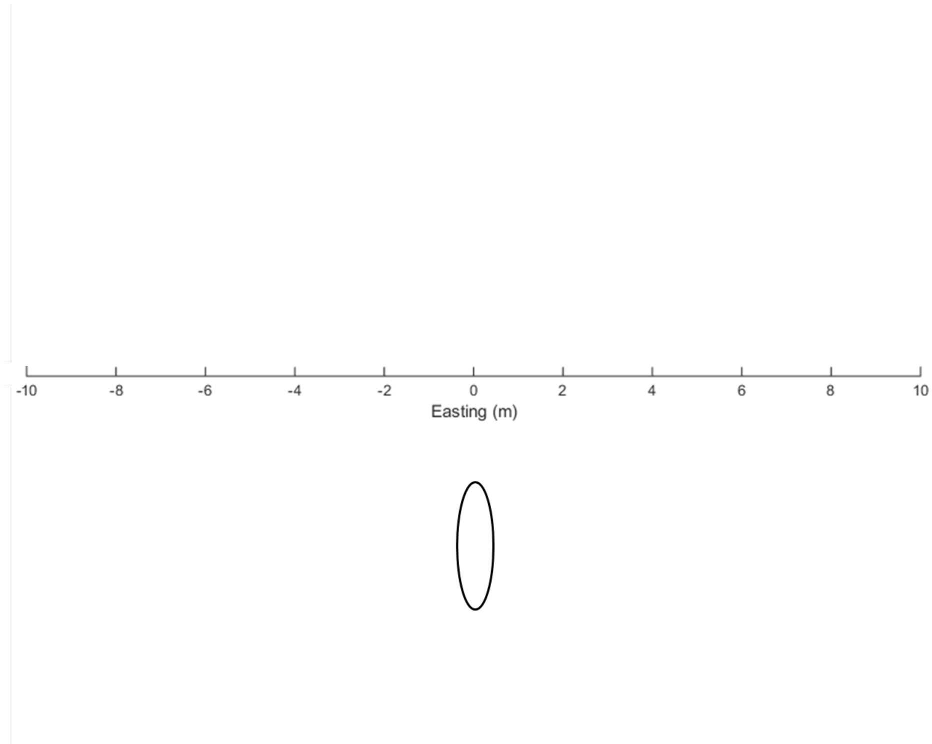
Q1. Assume the Tx-Rx separation is 4 m and that the loops are oriented horizontally. The data point is plotted at the midpoint between the Tx and Rx. For the observation points at Easting = -4, -2, 0, and 4 m, do the following. Diagrams are provided below for you to draw your answers.

a. Sketch and label the Tx with an increasing current going clockwise when looking from above. Sketch and label the primary magnetic field. Sketch and label the Rx.

b. Sketch how the fields interact with the target and the direction of the induced current in the target.

c. Sketch and label the secondary magnetic field.

d. Use the sign convention that the observed data is positive when the secondary field is in the same direction as the primary field at the receiver.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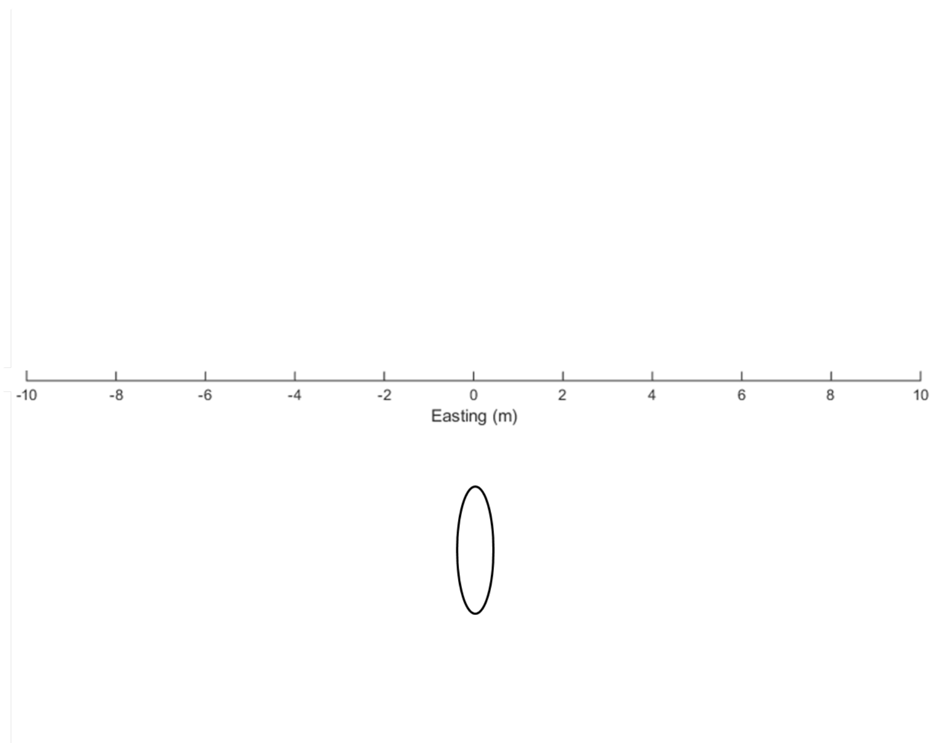
Easting (m)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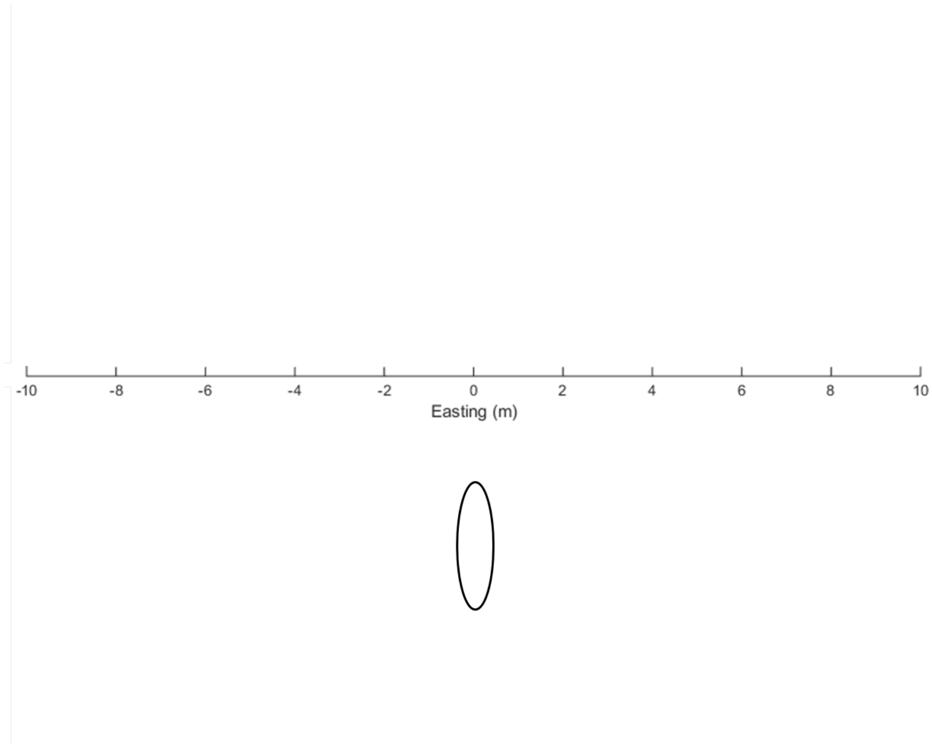
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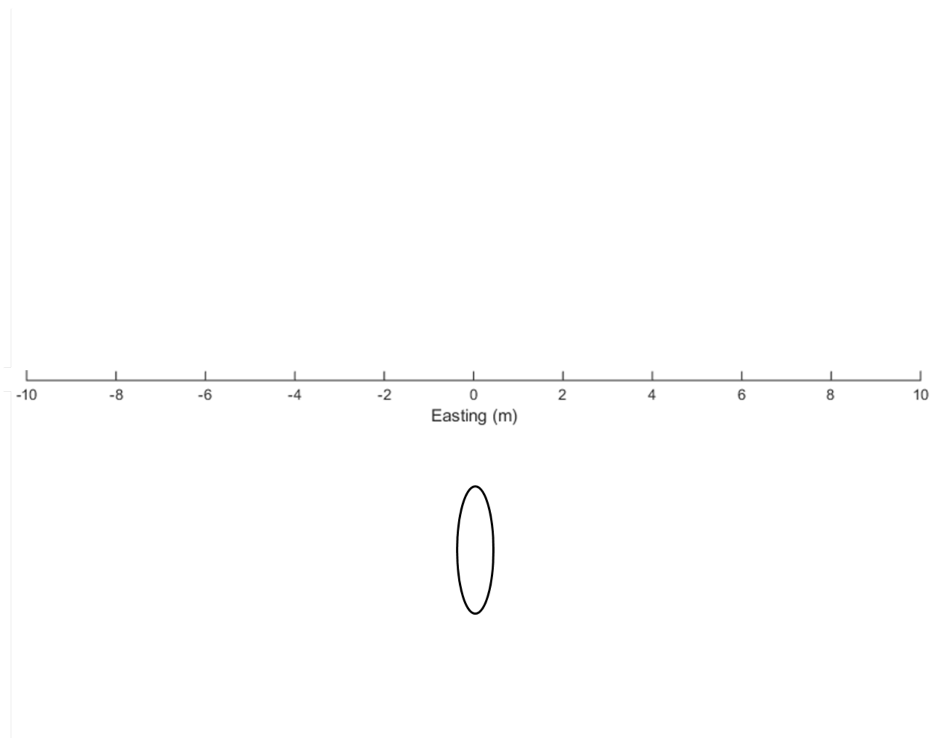
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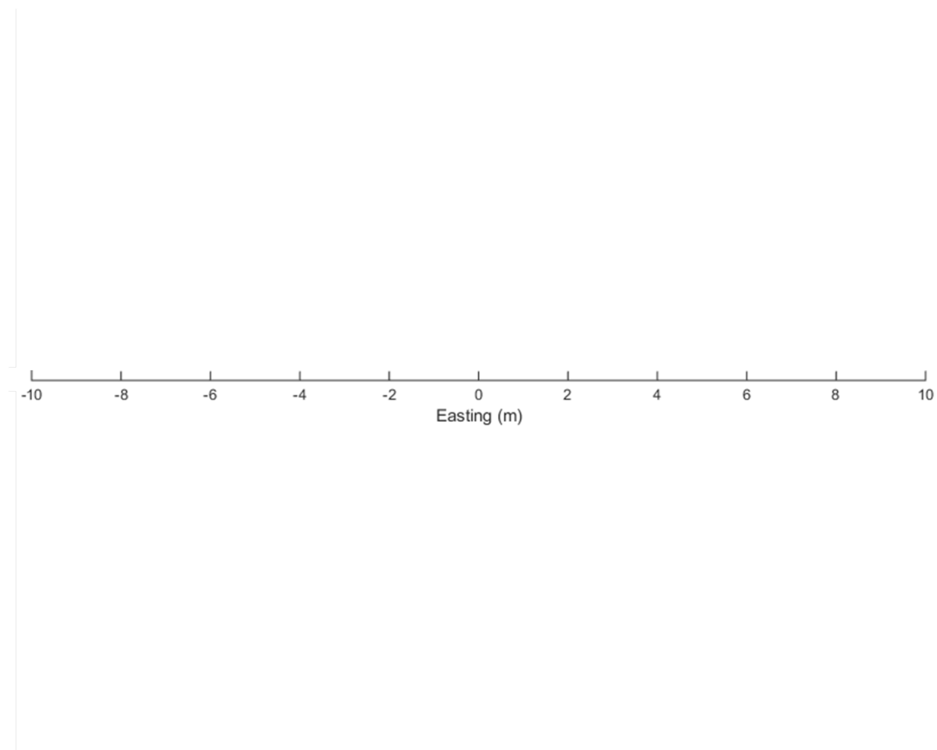
Easting (m)

e. In the diagram below, sketch the data profile based on your answers above.

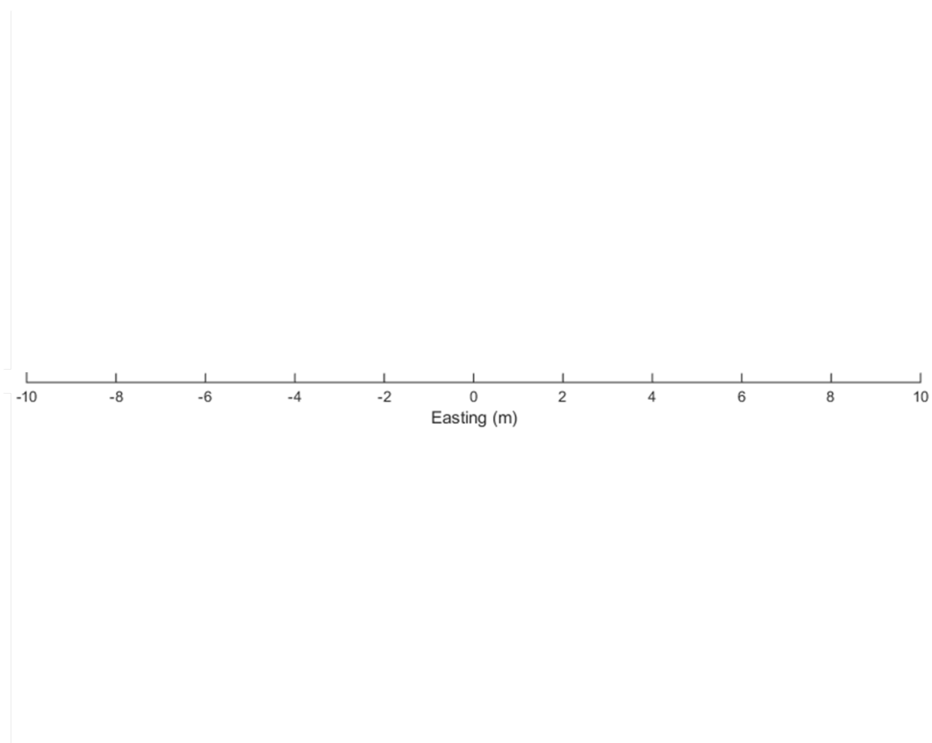


Q2. The above work is geometrical and applies equally well to the Real and Imaginary portions of the recorded data. That is, both Real and Imaginary transect plots will have the same characteristic shapes. Their relative amplitudes however are determined by the properties of the target and the frequency of the instrument. More precisely it is the dimensionless quantity $\alpha = \omega L/R$. Run the app using the defaults provided and look at both Plots 1 and 2.

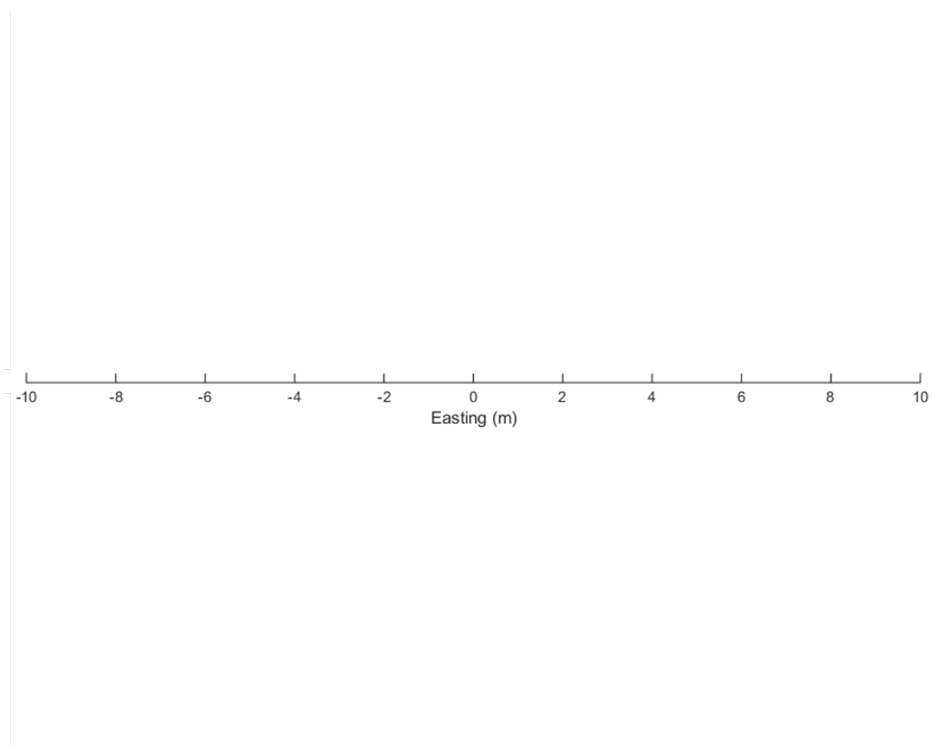
a. Evaluate α for the default settings. Use the diagram in Plot 1 to evaluate the theoretical ratio of Real/Imaginary amplitudes for this example. Now use Plot 2 to see if your recorded data are in accordance with that number.

b. Repeat Part (a) using $R = 20,000\Omega$ (now we have a poor conductor). To do so, adjust the slider for the resistance R.

Q3. Return the sliders to the default parameters (you can rerun the cell to this quickly!). Then change the inclination and the declination of the target to be $I = 0$ and $D = 0$. Sketch the orientation of the Tx, Rx and the target for the datum at x = 0 m and draw the current and fields like you did in Q1. Run Fem3loop for this new setup. Does your sketch match the Fem3loop result? Explain what it is happening in this scenario. Draw the response in the diagram (below the target loop).



Q4. Now change the inclination and declination of the target to be $I = 90$ and $D = 0$. Complete the sketch below for the data point at 0 m, like you've done before. Run Fem3loop for this setup. Describe the difference in the response compared to the other two target loop orientations. Draw the response in the diagram (below the target loop).



Q5. Return the sliders to the default settings ($I = 0$, $D = 90$). Examine how the data changes with the depth of burial of the target. Investigate the depth, $z = 2$ to 10 m in steps of 2 meter increments.

a. How does the amplitude of the anomaly change as a function of depth?

b. What are the most significant changes in the character of the anomaly?

c. How are the zero crossings of the data along the profile affected?

Q6. Again return to the default settings. Now alter the data acquisition strategy. Slowly increase the station and line spacing (dx). Look at both the profile plot and the map views.

a. What is the largest station spacing that can capture the anomaly?

b. What factors do you need to consider when choosing station spacing?

Q7. We can expand the concepts of EM coupling to more complex geometries, such as a pipe. Run the app for modeling the pipe to answer the following questions. The app plots data for two orientations of the EM-31: north-south (NS) and east-west (EW).

a. Using the profile line plot (bottom plot), which of the two boom orientations gives a response most similar to the default set-up for the 3-loop problem (as in Q1)?

b. Using a sketch, explain why you choose that orientation.

c. Adjust the depth of the pipe. What happens to the anomaly?