

Lab 6: Modelling of time-domain EM data



General Comments

- Lab write-up is due **by 5 pm on December 4, 2023**
- Late reports require a valid reason to be accepted. Late reports should be handed to the TA directly.
- Include answers to all questions, codes used, required figures, etc.
- All plotting/calculations should be done with MATLAB.
- All work should be your own and original.
- All lab material can be downloaded from the class webpage.

1. Introduction

The **WinPLate** program will be used in this lab. This program calculates the time domain EM response of a **conductive plate** embedded in a highly **resistive halfspace**. It was developed by Peter Annan and others at the University of Toronto and later modified by Pierre Keating at Ecole Polytechnique.

This lab will focus on identifying the behaviour of certain parameters, then using this knowledge to model real data.

To start, copy the **win_platenew.zip** file from the GEOPH424 website to your computer and unzip all files.

Double click on the **win_platenew.exe** file to run the program.

In the “**Time Gate File**” box, click the Browse button and select **MTM_30hz.dat**. This file describes the waveform and window positions for the MEGATEM airborne EM system.

Professor Richard Smith at Laurentian University, an expert in airborne EM, is thanked for his assistance in developing this lab.

- **1.1** Briefly describe how the time domain electromagnetic method (TDEM) works, including the roles of the primary and secondary magnetic fields.
- **1.2** What quantity is measured with the receiver? How and why is this measurement different if flying over a highly conductive target vs. a highly resistive target?

2. Setting up the program

Set the strike length of the plate 600m, and the width-to-strike ratio as 0.5 (default). The strike direction is perpendicular to the flight direction. The width of the plate is the length along the flight direction.

Change the output units to pT/s. **Note that sometimes the plots automatically scale from pT/s to nT/s.**

The dipole moment of the MEGATEM system is 1,625,000 Am². Check that this value is correctly loaded.

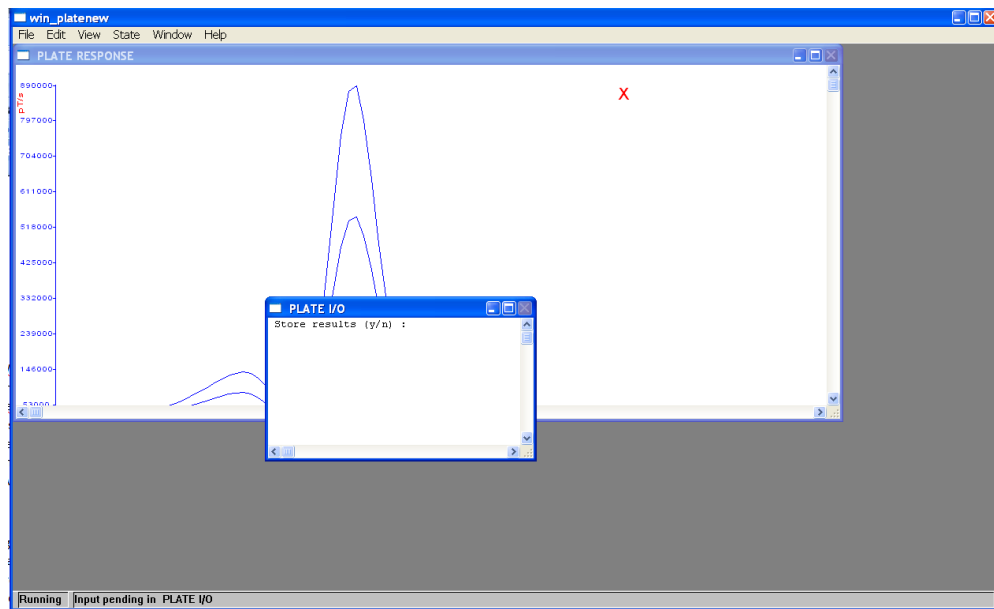
For the profile, note that the top of the plate is always at $x = 0$. X_0 is the start point of the profile (in meters) and Dx and $Npts$ describe the measurement spacing and the number of points on the profile respectively.

Depth is the distance from the top of the plate to the transmitter. The transmitter is flown at an elevation of 120 m. Thus a depth of 120 m means the top of the plate is at ground surface.

Note the receiver is towed 50 m below the transmitter. The horizontal distance between Tx and Rx is 130 m.

Leave all other parameters as their default values.

Click “OK” and you should see the following screen.



Click on the **PLATE RESPONSE** window and resize the window or scroll up and down to see both the x and z component responses. The x-component is horizontal (parallel to flight direction) and the z-component is vertical. Each response contains several curves: note that each curve corresponds to a different time channel. The magnitude of the response decreases as each curve is measured at a later time.

Note that the horizontal axis shows the **receiver location**. This is **behind** the transmitter in GEOTEM. **Flight direction is left-to-right.**

- **2.1** Using the parameters above, what is the width of the plate? (The length along the flight direction.) To understand the survey geometry, draw a sketch and label the plate dimensions, transmitter and receiver dimensions, and an arrow indicating the flight direction.
- **2.2** Using the default parameters above, the z-component response is zero at **two** locations close to the conductive plate. For each location sketch the position of the transmitter and receiver relative to the conductive plate and demonstrate why the z-component is zero. Include in each sketch the primary field generated by the Tx and the secondary magnetic field generated from current flowing within the plate.

3. Anomaly width and plate depth

We will now see how the responses change when the parameters are changed. The x-component half width is the width of the central peak at half the maximum amplitude. The z-component peak-to-peak width is the distance between the two positive peaks. Both of these should be in units of meters.

- **3.1** Estimate the x-component half-width and the z-component peak-to-peak width for when the plate depth below the transmitter is 120, 170, 220, 270, and 320 m. **Include these values in a table in your report.** Include a figure with the responses and showing calculations of the x-component half width and z-component peak width (only show calculations for one depth, you do not need a figure for each depth).

Important: When changing the plate depth, go to the window menu and select the PLATE I/O window. Enter “n” for storing the results and press enter. Then you will see another question about computing a new profile. Enter “y”. **To avoid having to restart the program, re-select the time gate file before hitting OK.** If you make a mistake, you must restart the **win_platenew** program. Be sure to select the correct file and units again.

For example, change the depth to **170 m** and press **OK**. You now have the response for a model with the top of the plate 50 m below surface.

- **3.2** Include a scatter plot of x-component half width vs. plate depth and a plot of z-component peak width vs. plate depth with appropriate axis and units. Use linear regression (*linfit*, or similar) to fit each line (include the best-fit lines with your data). Show the R^2 correlation coefficient, and ensure it is a reasonable value (>0.85).
- **3.3** Give an explanation for the trend observed in this plot. In particular, explain how a deeper plate changes the secondary magnetic field, leading to the x-component half width and z-component peak width variations.
- **3.4** The dip is 90° (vertically symmetric plate) so why is each response vertically **asymmetric**?

4. Rate of transient decay and plate conductance

- **4.1** Now return to the case when the plate is at ground surface (depth=120 m). Looking at the x-component central peak, calculate the ratio of the largest amplitude measured in the first window to the largest amplitude measured in the sixth window. Now calculate the ratio, and repeat for sigma-t (conductance) of 10, 20, 40, 80, 160, 320, and 640 S. **Include these values in a table in your report.** Include a figure with the x-component response and showing calculations of the ratio (only show calculations for one conductance, you do not need a figure for each one).
- **4.2** Plot the ratio as a function of conductance (x-axis). Include this plot with appropriate axis and units. Use a power regression model to fit your data (using *powfit*, or similar) and plot the regression model with your data. The regression model should be plotted as a smooth curve. Show the R^2 correlation coefficient, and ensure it is a reasonable value (>0.85).
- **4.3** Give an explanation for the variation observed in this plot, particularly why changing the conductance changes the decay rate of the secondary magnetic field.

5. Dip angle of plate

- **5.1** Now return to the case with a conductance (σ_t) = 10 S. Calculate the response and read the amplitude of the left z-component positive peak and the right z-component positive peak. Calculate the ratio of the left peak to the right peak. Do this for dip angles of 0° , 30° , 60° , 90° , 120° and 150° . **Include these values in your report.** Include a figure with the z-component response and showing calculations of the ratio (only show calculations for one dip, you do not need a figure for each one). (Note: These dips are measured from the positive x axis, or the right.)
- **5.2** Plot the ratio of the left to right peaks vs. dip angle using an appropriate axis and units. Use an exponential regression model to fit your data (using *expfit*, or similar) and plot the regression model with your data. The regression model should be plotted as a smooth curve. Show the R^2 correlation coefficient, and ensure it is a reasonable value (>0.85).
- **5.3** Give a qualitative explanation for the variation observed in this plot. In your explanation relate the changing plate geometry to the receiver's measurements.

6. Application to field data

- **6.1** The plots on the next page are the responses in the first 10 windows measured over an ore body in Québec, Canada. The survey used the same waveform and time windows as used in this lab. Estimate the depth, conductance ($\sigma-t$), and dip of the ore body by calculating the relevant parameters and using your regression equations from Parts 3/4/5. **Show your work at each step and explain your reasoning.**
- **6.2** Now insert your estimated depth, conductance, and dip values into the WinPlate program to model this deposit, and see how the synthetic response compares to the data. **Make a small adjustment to the depth, conductance, and dip to get a better fit.** In particular try to match the amplitudes, shapes, and decay of the real data curves. Explain the changes you made and why. (If you decide no adjustments are needed for a parameter, explain why. You will lose marks if your final values do not fall within an acceptable range.) Include plots of your x-component and z-component responses using your final parameters.
- **6.3** Name two assumptions or approximations you have made in using this software. Why might these not be valid for the ore body?
- **6.4** Use geological information about the area to explain what type of ore body would give this response.

