Physics 699 , Assignment 1

This assignment is a review of material covered in Geophysics 424 and will provide a basis for the more advanced material on magnetotellurics that we will cover in later sections.

Nominal due date : February 11 2011

1. Consider a plane EM wave, travelling vertically downwards (z-direction) and polarized with the electric field in the x-direction. Starting from Maxwell's equations show that:

$$H_y = \frac{-1}{i\omega\mu}\frac{\partial E_x}{\partial z}$$

You can assume a harmonic time dependence with angular frequency, ω.

2. In this question, you will work through the derivation of the MT response for a 2 layer Earth. This was outlined in the notes distributed in class.

   a. Solve the 4 equations derived from boundary conditions at $z=0$ and $z=h$. This will give you expressions for B_1 and B_2 in terms of A_1 , k_0, k_1 and h.

      Thus you will need to eliminate A_2 and C

   b. Show that at $z=0$

      $E_x = B_1 + B_2$

      $H_y = \dfrac{k_1}{i\omega\mu}(B_1 - B_2)$

      $Z_{xy} = \dfrac{i\omega\mu}{k_1}\dfrac{(B_1 + B_2)}{(B_1 - B_2)}$

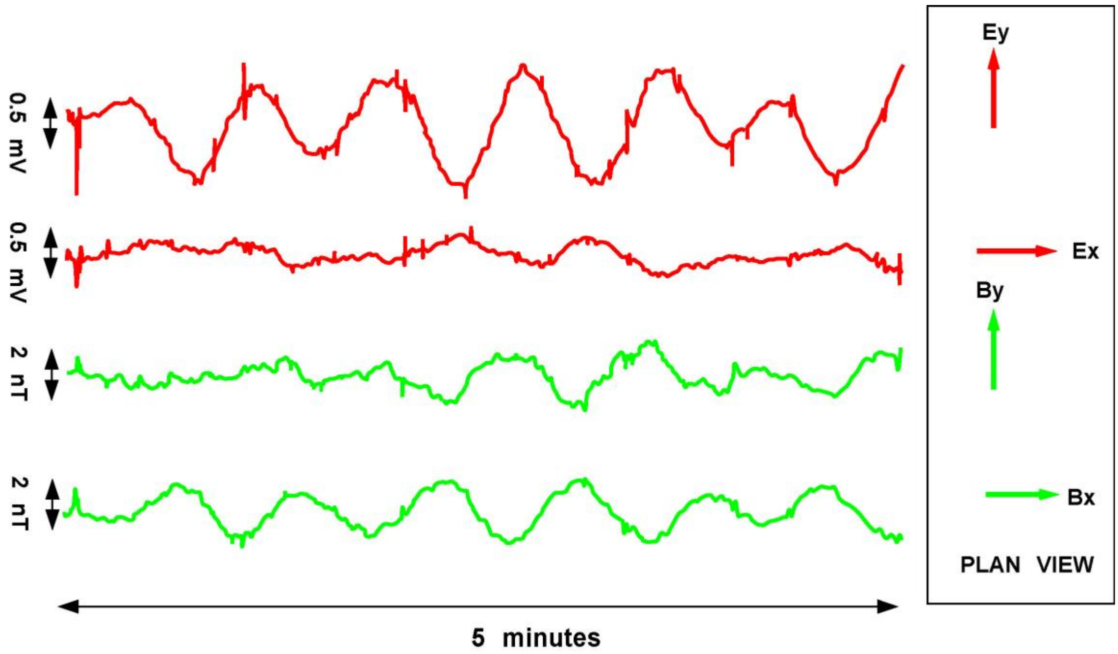
   c. Evaluate this expression by writing a MATLAB script. Compute the apparent resistivity (ρ_a) and phase (Φ) using the following numerical values.

      ρ_1 = 1000 ohm-m; ρ_2 = 100 ohm-m; h = 1000 m

      Frequency range : 1000-0.0001 Hz

      Use **a logarithmic scale** for both apparent resistivity and frequency.

3. To illustrate how apparent resistivity is calculated from an MT time series, look at the time series in the plot below. This shows **MT fields generated by ionospheric resonances.**



(a) "E_y" is actually the voltage in the *y*-direction. Estimate the peak-to-peak value. This voltage is measured over a 100 m dipole. What is the value of E_y?

(b) Convert E_y to so-called **field units**. These are **millivolts per kilometre**.

(c) Measure the peak-to-peak value of the magnetic field, B_x, in nT. The field unit for magnetic field measurements is nT.

(d) Estimate the period, T, of the sinusoidal E_y-B_x variation in seconds.

(e) In class we derived that $\rho_{yx} = \dfrac{1}{\omega\mu}\left|\dfrac{E_y}{H_x}\right|^2$

Convert this equation to field units, noting that $B_x = \mu H_x$. Show that

$$\rho_{yx} = \frac{T}{5}\left|\frac{E_y^{field}}{B_x^{field}}\right|^2$$

(f) Calculate the value of ρ_{yx} for this period.

4. In this question, you will use a MATLAB program to interpret real MT data from station ABA015 in Southern Alberta. A 1-D modelling approach will be used.

The MATLAB script **MT1Dfit_v2011.m** and all data / model files will be distributed by e-mail. Different options are available for handling the defined errors. Please use the "*Constant*" option" in this assignment.

Note that fitting data requires (a) an acceptable r.m.s. value and (b) fitting the data at all periods

Use the following steps:

(1) Rename the data file **MTdata.txt** (or edit the MATLAB script)

(2) Make sure the model file is named **MTmodel.txt**

(3) Start MT1Dfit_v2011.m in MATLAB

(4) Look at the fit between the data and model response

(5) Edit the file **MTmodel.txt** and save the file.

(6) Click "**Change model**" button and the new response will be displayed.

(7) If the fit is not acceptable return to stage 5

(8) If the fit is acceptable, click "**Quit and print**" and a JPEG file of the model and fit will be generated.

(a) For station ABA015 determine the **minimum number of layers** needed to fit the data. Explain your answer.

(b) Generate a 1-D resistivity model with this number of layers, and adjust the resistivity and depth values so that you can fit the MT data. An acceptable r.m.s. misfit should be in the range 1 - 1.5

Include a copy of the JPEG figure showing the fit to the data and resistivity model in your write up.

(c) Can you think of a geological explanation for the resistivity model you obtained?

5. In this question we will use the same 1-D modelling approach to analyse MT data from a station near Rocky Mountain House (FH26). We worked through a **qualitative** analysis of the TE mode data from this station in class last week.

   On the class webpage you will find files **MTdata-FH26TE.txt** and **MTdata-FH26TM.txt.** The TE data has electric field recorded in N45°W and magnetic field in direction N45°E. The TM data has electric field recorded in N45°E and magnetic field in direction N135°E.

   (a) Generate a 2-layer model to fit the TE mode data. An acceptable r.m.s. misfit should be in the range 1 to 1.5. Can the dip in resistivity at periods 1-10 seconds be accounted for by the resonance phenomena?

   (b) Repeat part (a) with a 3-layer resistivity model. Does a 3-layer model give a better fit to the data than the 2-layer model?

   (c) Repeat part (b) for the TM mode data.

   (d) What does the difference between the TE and TM mode data tell you?

   (e) Which parts of the resistivity models for the TE and TM modes are the same, and which are different?

   (f) The data file **MTdata-FH26av.txt** contains the arthimetric average (also called Berdichevsky average) of the TE and TM modes. Again fit this data with a 1-D model.