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A STUDY OF AMBIGUITY ON THE ANISOTROPIC MT TENSOR

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Abstract

We analyze the behavior of magnetotelluric data, in what concerns the process of inversion, in two distinct forms of representation: as apparent resistivity and phase or as the real and imaginary components of the elements of the MT impedance tensor. We notice that the level of ambiguity is different for each representation. We find that, whenever there is a difference, it is better to use the impedance elements as observations in the inversion of MT data. One example is presented where this difference is noticeable, the one-dimensional anisotropic case.

INTRODUCTION

Magnetotelluric observations can be used in two different ways in an inversion process, either as apparent resistivity and phase values or directly as the real and imaginary components of the impedance tensor. One can think of these two forms as analogous, in a sense, to viewing the same data in either polar or Cartesian representation (Abramovici & Shoham, 1977). However, that analogy can be misleading if one is to perform an inversion process on the data and is led to believe in the equivalence of the two forms.

If we use the apparent resistivity and phase representation of the data in the inversion process, the small amount of processing that must be done to determine those values from the impedance tensor alters the data prior to inverting. That change in the data can hide information from the process, making it harder to achieve a stable solution.

An example of one class of model for which there is a real difference between the two forms of representation is the one dimensional anisotropic case (Reddy & Rankin, 1971). We will present here a few results of our study of 1-D anisotropic models. We will see the kind of ambiguity that arises in each form of representing our data.

ONE-DIMENSIONAL ANISOTROPIC MODELS

For this kind of model, the magnetotelluric impedance tensor has all four elements different from zero. The elements in the main diagonal are symmetrical ($Z_{xx} = -Z_{yy}$). So, when we perform the inversion on this kind of data no further information is added by the fourth element, and we use only three tensor elements.

$$\mathbf{Z} = \begin{bmatrix} \mathbf{Z}_{xx} & \mathbf{Z}_{xy} \\ \mathbf{Z}_{yx} & \mathbf{Z}_{yy} \end{bmatrix}$$

We can represent the observations as six elements of the form

$$\mathrm{Re}(Z_{xx}) \quad \mathrm{Im}(Z_{xx}) \quad \mathrm{Re}(Z_{xy}) \quad \mathrm{Im}(Z_{xy}) \quad \mathrm{Re}(Z_{yx}) \quad \mathrm{Im}(Z_{yx})$$

Or as the apparent resistivities and phases:

$$\rho_{xx} = \frac{1}{\omega\mu}\left|Z_{xx}\right|^2, \quad \phi_{xx} = \mathrm{arctg}\left\{\frac{\mathrm{Im}(Z_{xx})}{\mathrm{Re}(Z_{xx})}\right\}; \quad \rho_{xy} = \frac{1}{\omega\mu}\left|Z_{xy}\right|^2, \quad \phi_{xy} = \mathrm{arctg}\left\{\frac{\mathrm{Im}(Z_{xy})}{\mathrm{Re}(Z_{xy})}\right\};$$

$$\rho_{yx} = \frac{1}{\omega\mu}\left|Z_{yx}\right|^2, \quad \phi_{yx} = \mathrm{arctg}\left\{\frac{\mathrm{Im}(Z_{yx})}{\mathrm{Re}(Z_{yx})}\right\}.$$

A SIMPLE MODEL

In order to study the difference between the two forms of representing the data, we will analyze a simple model, formed by two homogeneous layers overlying a resistive basement. The second layer has horizontal anisotropy in the resistivity. The main directions of anisotropy are represented by a system of orthogonal axis (x', y') which is rotated by an angle θ in relation to the directions (x, y) in which the measurements are taken.

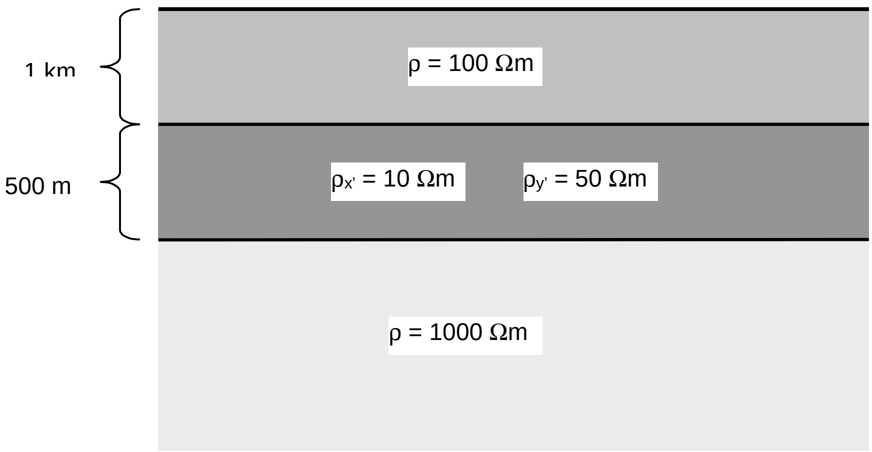

Figure 01: Model used to simulate the measurement of MT data.

A value of zero for the angle θ means that we are taking our measurements in the same directions as the main directions of the anisotropy tensor. We have simulated the measurements of MT data for this model, varying the value of the angle θ, for different frequencies.

When we show the data for a given frequency, in the form of curves plotted against the values of θ, the curves behave as periodic functions. The form of the curves, for each element of the impedance tensor, depends on the characteristics of the model in study. For the very simple model shown in Figure 01 we get the results shown below.

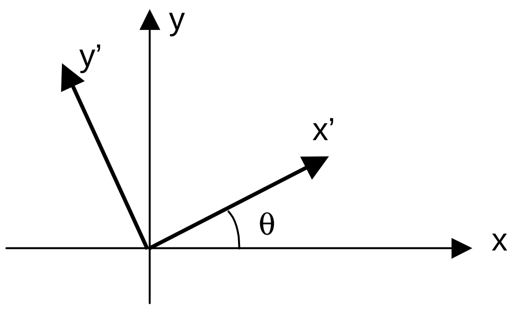

Figure 02: Main directions of the anisotropy tensor (x', y').

RESULTS

In Figures 03 and 04 we have the results of our simulations for the frequency of 0.1 Hz. We plot the data calculated for angles ranging from -90^o to 90^o .

For the elements Z_{xy} and Z_{yx}, the results are shown in Figure 03. We can see that, for these elements, the apparent resistivity and phase curves behave exactly as the curves for the real and imaginary components of the impedances. The two forms of representation carry the same information and the same level of ambiguity. Note that all curves are symmetrical in relation to the zero angle.

In Figure 04 we have the results for the element Z_{xx}. Now, because the apparent resistivity is calculated with the absolute value of the impedance, its curve has a period that is half the one of the impedance curve. The level of ambiguity of the apparent resistivity is higher than that of the impedance components, because the curve for the former is still symmetrical about the zero angle, while the curves for the impedances is not. Note that for each value for the apparent resistivity there are four possible angles that can generate it, while the relation for the components of the impedances is two angles for each value.

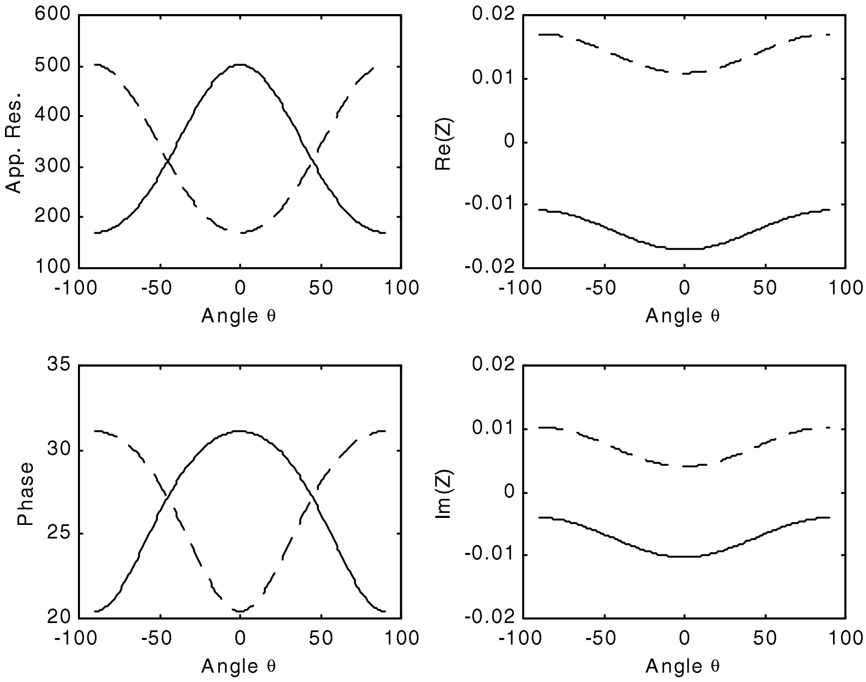

Figure 03: Results for the elements Z_{xy} (dash) and Z_{yx} (solid) of the impedance tensor.

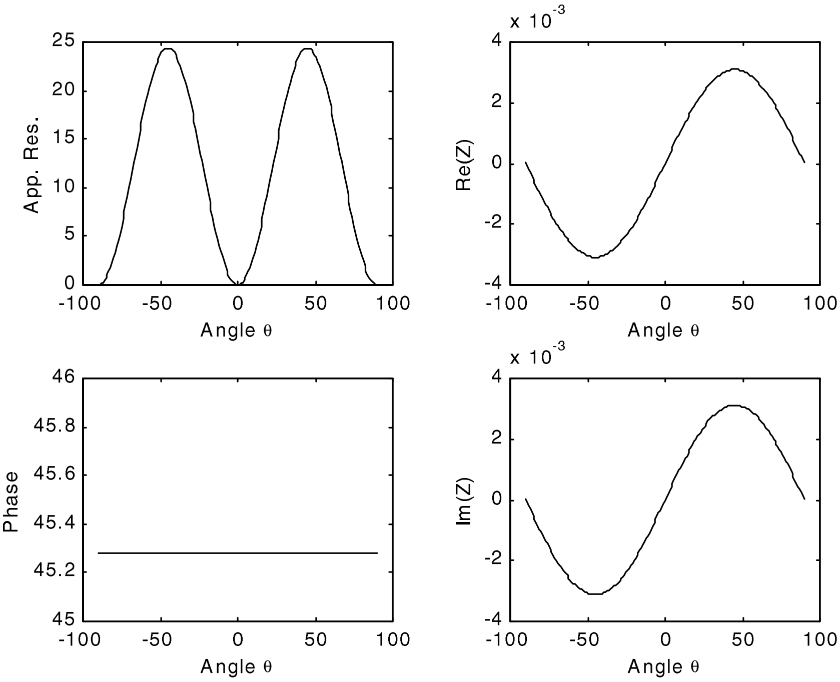

Figure 04: Results for the element Z_{xx}.

MORE COMPLEX MODELS

For more complex models, like the ones formed by a greater number of layers with anisotropy, the results are similar, although the curves may behave differently, because they are formed by superposition of several periodical functions. The fact that there are differences in the ambiguity level of the two representations is true for many different models that we have tested, with several anisotropic layers, and with inclined anisotropy.

CONCLUSIONS

The differences between the two representations have a great influence on the inversion of MT data. We have come to the conclusion that it is always advisable to work with the elements of the impedance tensor, when performing inversion, because the level of ambiguity for this form of representation is often lower then for the apparent resistivity and phase representation.

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