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Inversion of MT Data of a Prismatic Conductive Body Constrained by Finite Element Cell Dimensions

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ABSTRACT

We have analyzed the inversion of 2D MT synthetic data generated by finite elements applied to a subsurface model formed by a prismatic conductor body surrounded by a homogeneous resistive medium. The parameters estimated in the analysis were the finite element cell dimensions from which the body geometry is derived. The results show that the studied problem can only be solved if *a priori* information is introduced on parameters.

INTRODUCTION

It is well known that inversion of geophysical data is an ill-posed problem. To transform it in well-posed, *a priori* information is always required. Several kind of *a priori* information can be used toward this goal. The most usual however is equality constraint as presented by DeGroot-Hedlin and Constable (1990) and Medeiros and Silva (1996). These authors divide the subsurface model in cells of fixed dimensions and invert for physical properties using equality constraints. In this paper we proceeded in opposite manner, fixing the physical property values and inverting to get cell dimensions. Introduction of wrong physical property values will also be analyzed.

PROBLEM SETTING

In this problem, apparent resistivity and phase of MT data (TE mode) were generated using finite element technique. Figure 1 shows the model (a 10 Ohm.m prismatic body surrounded by a 100 Ohm.m medium) used to generate synthetic data. The width of the conductor body is 500 m, its depth extent (height) is 1000 m, and its top lies at depth of 125 m. The figure also shows the finite element cells used in calculation, to which was attributed individually a constant resistivity value. Synthectic data was generated as vertical soundings at air-earth interface (surface) located at each vertice of finite element cells. The positions of the calculated soundings during inversion procedure was kept at the same locations used for synthetic data.

The finite element grid used was calibrated and fine enought to avoid numerical errs on the computation and to keep cpu time cost effective.

Our inversion problem consists in estimate finite element cell dimensions to get the conductor body dimensions (width and height) and the depth to its top. The resistivity of the body and of the surrounded medium are presumed to be known and will not be searched in the inversion.

We used the same initial guess model for all examples shown.

INVERSION PROCEDURE

The first inversion trial was done using noise free data. In this trial we did not use *a priori* information of any kind on parameters (cell dimensions). Under this condition no convergence was achieved.

In next inversion trial we kept data noise free and added equality constraint to cell dimensions. Inversion was successful as shown in figure 2. An err of 0.098 % for body width, 1.14 % for body height, and -2.17 % for top of body was reached.

Third inversion trial was done with gaussian noise added to data and equality constraint used on parameters. Under these conditions, a physically unacceptable result was reached since one the cells had a negative value as estimate. To get rid of this problem it was necessary to impose an additional constraint to keep the parameters always positive. Such constraint was introduced by transforming each parameter P_j by (Barbosa, 1998)

$$P_j^* = -\ln\left(\frac{P_{\max} - P_j}{P_j - P_{\min}}\right),$$

where P_j^* is the constraint parameter and $P_{\max}$ and $P_{\min}$ are respectively the maximum and the minimum values that each parameter can assume. So, before inversion iterations started, parameters were transformed using the expression above. After last iteration, parameters were recomposed by the following inverse transformation

$$P_j = \frac{P_{\max} - P_{\min}}{1 + e^{-P_j^*}} + P_{\min} .$$

The positive constraint yield a reasonable estimation for body dimensions, but a bad one for its top (Fig. 3). Table I summarizes the results reached for 3 %, 5 %, and 10 % gaussian noise added to MT data.

Table I – Inversion result for 3%, 5%, and 10% noise added to MT data.

	Orig. Dim. (m)	Result (3% noise)		Result (5% noise)		Result (10% noise)	
		Meters	Var.(%)	Meters	Var.(%)	Meters	Var.(%)
Width	500	508,47	1,69	487,66	-2,47	470,73	-5,85
Height	1000	1078,57	7,86	1092,33	9,23	1123,09	12,31
Top	125	60,12	-51,90	60,16	-51,87	60,28	-51,78

In next inversion trial the use of wrong resistivities for both the body and surrounding medium were studied. The MT data used in inversion had 5 % noise added. Figures 4 and 5 summarize the results reached, showing the relation between errs on resistivities and estimated body geometry. The figures show that if wrong resistivities are ascribed to the cells, very bad estimates should result. Acceptable estimates for width and height of the body will result only if the err remains low (less than ± 10 %). The top of the body, on the other hand, will in general be badly estimated for any err.

CONCLUSIONS

The results showed that finite element cell dimensions determination from MT data inversion can provide an acceptable estimation for body width and height (mainly for width) and a poor resolution for the top of the body.
Best results are reached if the resistivities of the body and surrounded medium are well known.
The only way to get acceptable results in inversion is adding constraint to the parameters to be estimated.

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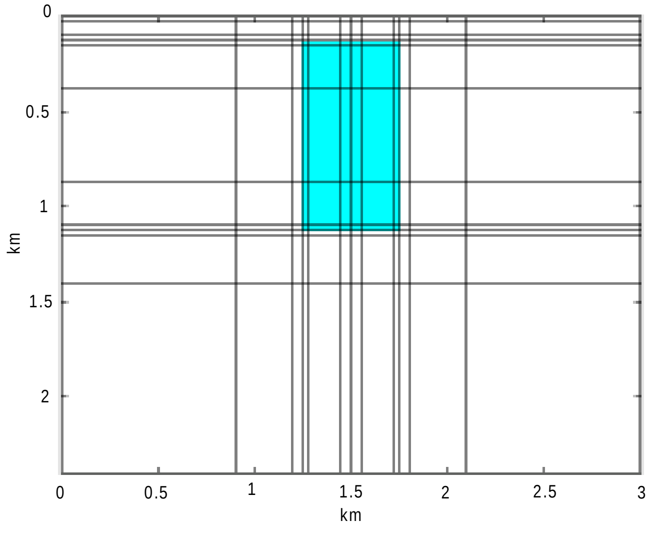

Figure 1 - Finite element cells for subsurface representation.

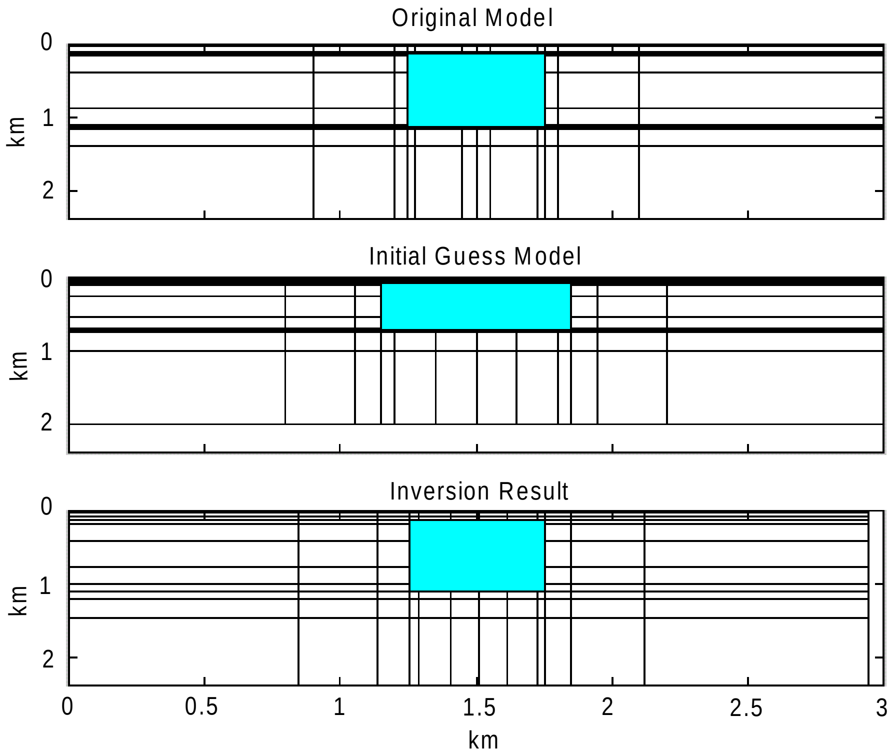

Figure 2 - Inversion of noise free data.

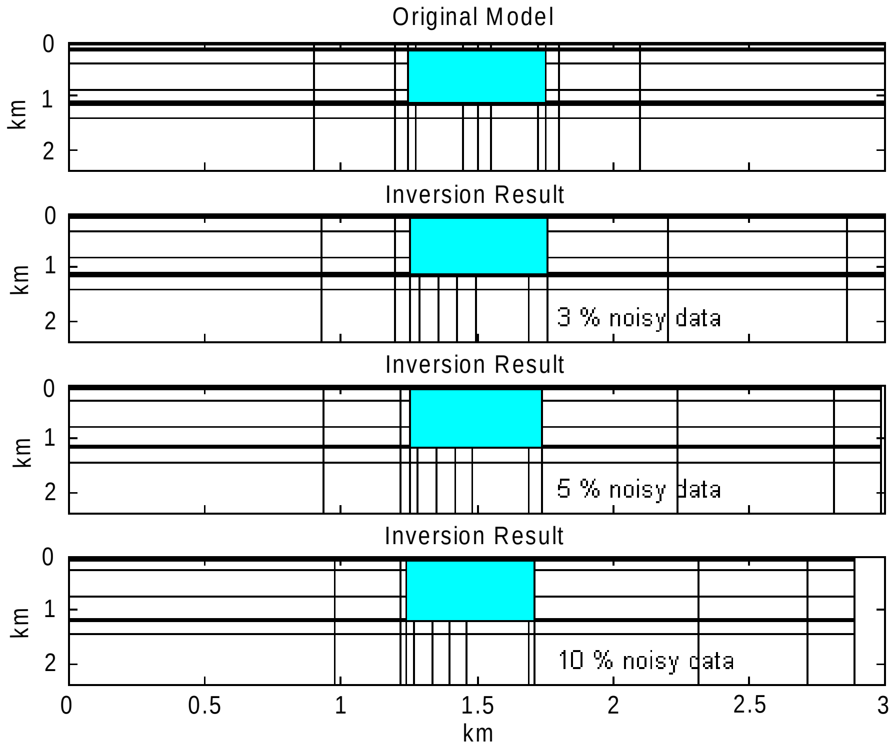

Figure 3 - Inversion of noisy data. The initial guess model is the same shown in Figure 2.

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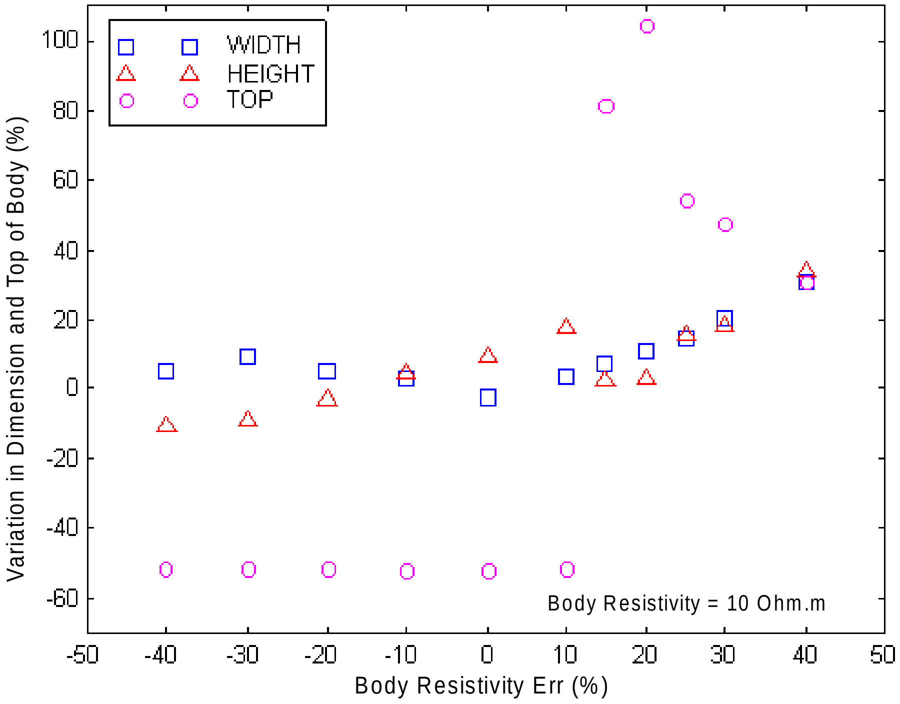

Figure 4 - Results for presuming wrong body resistivities.

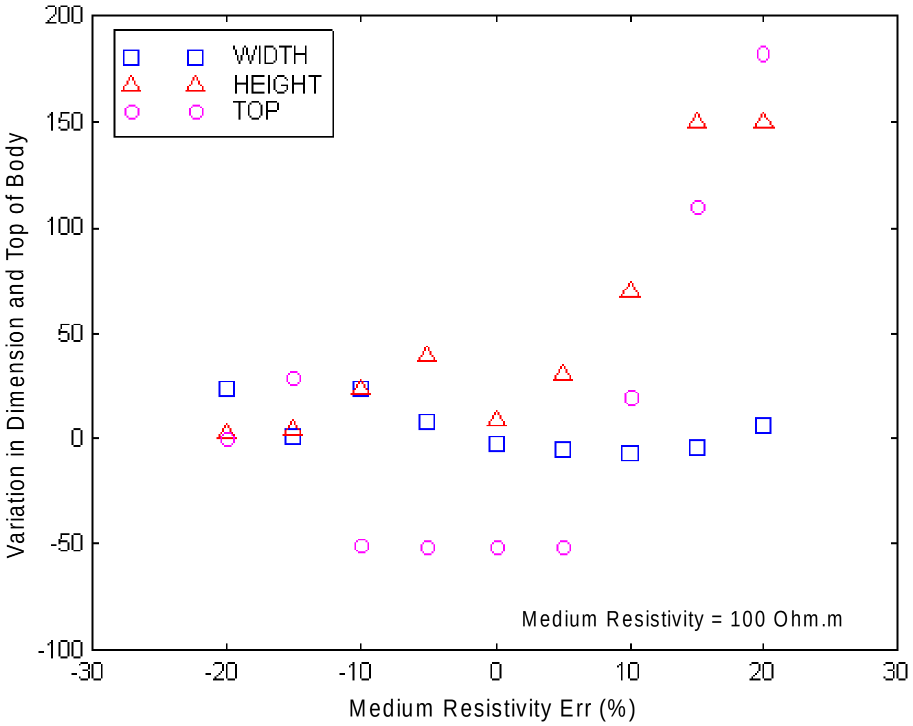

Figure 5 - Results for presuming wrong medium resistivities.