Sensitivity Plots Using COMSOL Multiphysics®: A Tool for Optimizing Geophysical Field Survey

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Abstract

The purpose of electrical surveys in geophysics is to determine the subsurface resistivity distribution by making measurements of potential on the ground surface. From these measurements, the apparent resistivity of the subsurface can be estimated. These apparent resistivities are further inverted to obtain the resistivity of the subsurface. The geophysical inference helps in the geological interpretation. Various types of electrode combinations such as Schlumberger, Wenner, Pole-pole and Dipole-dipole can be used to investigate a particular area. But different array gives different type of response over same sub-surface feature. Response of different array is determined by sensitivity of that array. The sensitivity function of an array describes about the degree to which a small change in the resistivity of a section of the subsurface can influence the potential measured by the particular array. The higher the value of the sensitivity function, the greater is the influence of the subsurface region on the measurement. The sensitivity function has been computed using electric current interface of AC/DC module of COMSOL Multiphysics®. The sensitivity calculation is simulated for a typical situation of surface and borehole measurements using Electrical Resistivity Tomography (ERT) techniques with 25 point electrodes spaced one meter from each other. The model is geometrically parameterized to be easily adaptable to various sizes. As a material, a homogeneous half-space of conductivity, $\sigma = 0.01$ S/m that often serves as a reference model for forward algorithms is used. The model solves for two current dipole situations with a common midpoint. This allow the calculation of the sensitivity of a different electrode configuration according to the equation given below,

S=with(1,ec.Jx)*with(2,ec.Jx)+with(1,ec.Jy)* with(2,ec.Jy) +with(1,ec.Jz)*with(2,ec.Jz))

The sensitivity plot shows that Wenner array (Figure 1) has better sensitivity for vertical changes in the subsurface that is for horizontal structures. In case of Dipole-dipole array sensitivity plot (Figure 2) shows better response for horizontal changes in resistivity The Schlumberger array is sensitive for an area where sub-surface has both kind of horizontal and vertical geological features (Figure 3). But there is limitation of these surface arrays as resolution decreases with increasing depth. The only possible way to improve the resolution is to place the sensors in the borehole. Sensitivity plots (Figure 4) for cross borehole arrays using bipole-bipole array with C1P1-C2P2 arrangement shows large positive sensitivity between two boreholes.

The sensitivity plots generated through COMSOL Multiphysics helps in planning in field survey which is an integral part of geological interpretation

Reference

1.M.H Loke, 2D and 3D electrical imaging surveys.

Figures used in the abstract

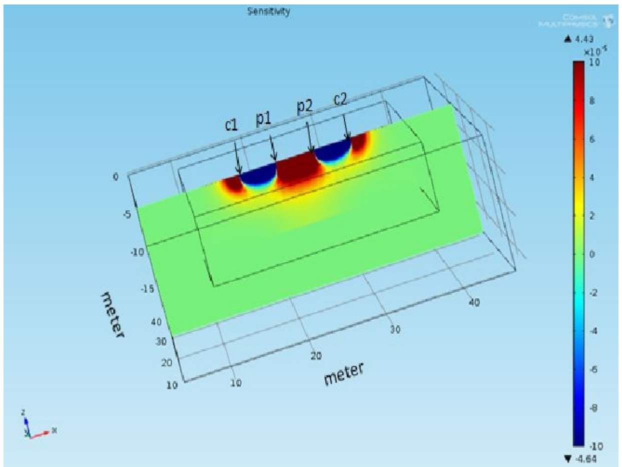

Figure 1: Sensitivity Plot Wenner Array.

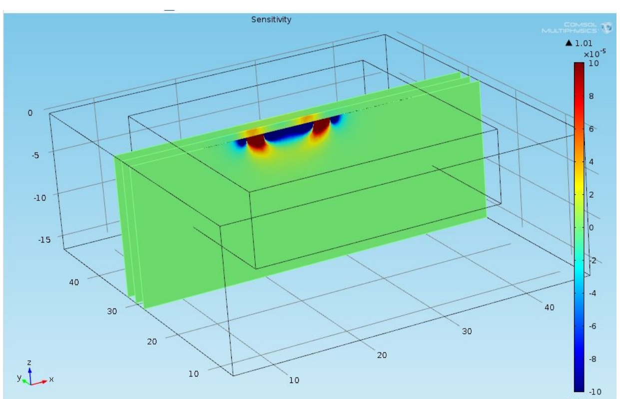

Figure 2: Sensitivity Plot Dipole array n=3.

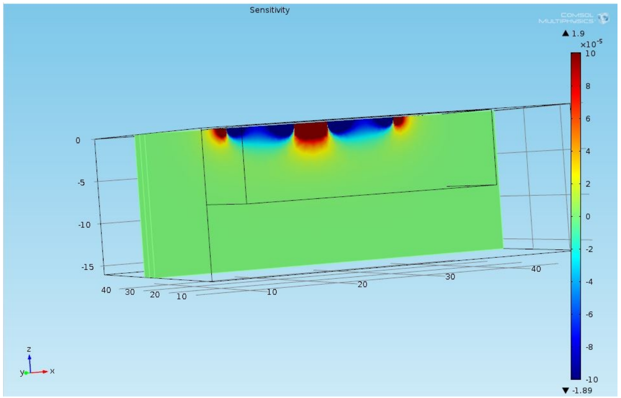

Figure 3: Sensitivity Plot for Schlumberger array.

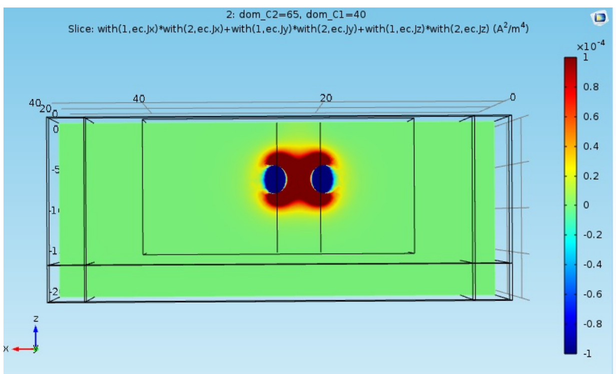

Figure 4: Cross hole array sensitivity plot.