ELEM09: EFFECT OF COUPLING IN ELECTROMAGNETIC DATA

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INTRODUCTION

In most parts of Europe and urban areas around the world, geophysical investigations for evaluation of groundwater resources, environmental problems, or geotechnical studies are carried out under high cultural influence. Coupling responses are coherent with the transmitted signal, and very difficult to separate from the earth. Fitterman et al. (1989), and Nekut and Eaton (1990) examined the effect of pipelines on time-domain EM (TEM) soundings. Using field data and numerical models they proposed guidelines to minimise the effects and described the influence of pipelines on inversion. All agreed that it is best to avoid pipelines, because the response cannot be accurately separated from the host response.

We address the effect of EM coupling from features such as railroads, powerlines, metal fences, pipelines and conducting water lines. Although these effects are apparent in both the frequency and the time domain we restrict our discussion to coupling with the TEM method. Currents induced in metallic structures from the TEM transmitter can couple to the earth through direct contact, completing a galvanic circuit, or through insulated material thereby completing the circuit capacitively. Recognising distortions in field data and the effect on the resulting interpretation are illustrated with TEM data collected with a 40 by 40 m central loop array in the County of Aarhus, Denmark.

CAPACITIVE AND GALVANIC COUPLING

The current in a buried insulated cable will leaking capacitively into the earth through the insulating material surrounding the conductive core thus completing the return path of the current loop. The current loop can be regarded as an L-C-R electrical circuit that has an oscillating response when excited by the transmitter signal. This capacitive coupling phenomenon is related to modern high-power lines, telephone cables and other insulated underground cables. A typical capacitively coupled response is shown near an undistorted response in Figure 1a. In most cases the experienced interpreter will be able to detect the distortion from capacitive coupling, as an oscillation pattern does not appear from any natural earth formations.

Galvanic coupling occurs when current induced in cultural conductors leaks galvanically into the earth forming the return path of the current loop between the transmitter and the cultural conductor. This problem arises when the cultural conductor is a metal pipe, or an older type power cable with a metallic protection shielding. The current loop can be regarded as an L-R electrical circuit that has no oscillating response. The distorted decay curves are similar to an undistorted earth response, and hence can be more difficult to detect than that due to capacitive coupling. Coupled data are presented with undistorted data acquire about 250 m away in Figure 1b.

The magnitude of the coupling response varies with the geometry of the structure. In general, structures can be three-dimensional (3D), two-dimensional (2D), or elongated with ends, which we refer to as 2.5D. The geometry is defined with respect to a characteristic length of the system, r, such as the transmitter loop size or the transmitter-receiver offset. The response of a confined 3D conductor decays as r^{-4}. The response of a 2.5D structure goes as r^{-3} and the pure 2D as r^{-2}. Hence one can record rather close to a confined conductor without contamination, while a long powerline or pipeline, with no terminal ends in the field of influence, can have a large zone of distortion. The coupling effect for any given structure is roughly the same in magnitude regardless of the earth. However the ratio of coupling to the earth response can be dramatically different for a resistive or a conductive earth, and for ground versus airborne measurements.

Capacitively coupled data cannot usually be fitted with a one-dimensional (1D) inversion. Transforming field data to apparent resistivity for contouring will also map the oscillation and should still be obvious in plan view. Inspection of the sounding curves in Figure 1b reveals that the undisturbed curve has a decay characteristic of a layered earth, of $t^{-5/2}$, while the coupled data has an exponential decay. The 1D inverse model of the disturbed response, shown in Figure 1c, erroneously indicates that the ground is quite conductive at depth. Five layers were necessary to reach a fit comparable to that achieved with 2 layers, as measured by residuals of 0.97 and 0.93, respectively. These results are not surprising. The increase in energy at late times due to coupling is interpreted with a 1D model as a conductor at depth; this is the only way the model can accommodate the large signal at late times.

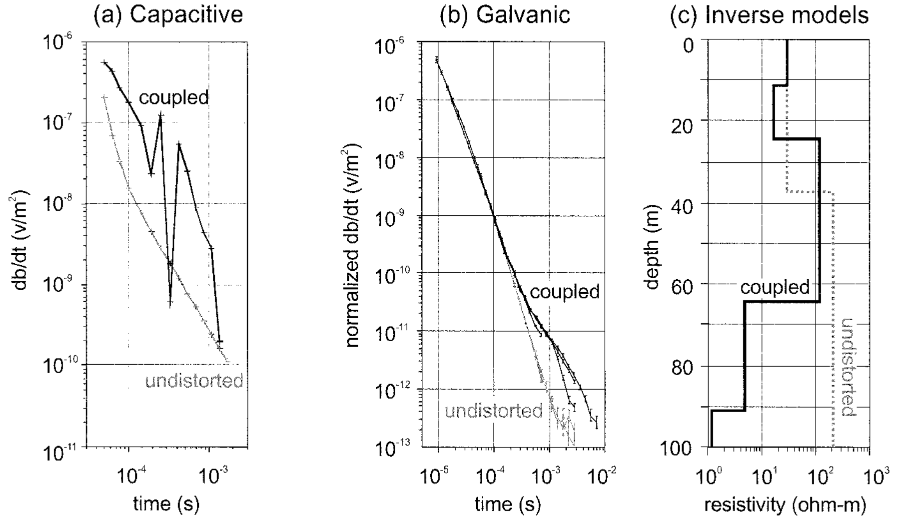

Figure 1. TEM soundings showing (a) capacitive and (b) galvanic coupling along with the undisturbed responses. (c) Inverse models for the soundings of Figure 1b.

We show that TEM systems can couple with electrical structures resulting in inaccurate interpretations. Capacitively coupled data has a characteristic oscillation that can be readily identified in data and removed. Galvanic distortions can be very difficult to distinguish. Interpretation of galvanically coupled data will usually result in anomalously high conductivities at depth. Coupling effects in data cannot be accurately removed to provide a reliable interpretation. Pipelines, cables, power line, roads with underground utilities and auto guards, and metal fences should be avoided. If such structures cannot be avoided the data should be culled from the interpreted dataset. High-density data is necessary to adequate identify and remove distorted data, while still leaving enough data for interpretation.

REFERENCES

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