Study of influential parameters for transient electromagnetic method

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Abstract—Series of models are designed to test the influences of some parameters such as resistivity of overburden layer, basement and transmitter-receiver layouts, to a given 3D conductive anomaly in the layered earth model by transient electromagnetic (TEM) method, which is often used in engineering exploration. The forward modeling procedure used is formulated with volume integral equation based on tensor Green’s function. The response of electromagnetic components are first calculated in frequency domain and then transformed to time domain by digital filtering. Through a series of modeling, it shows that the transient response of both $e_x$ and $V_z$ components are larger if the overburden layer and basement are resistive. The models also illustrate that S-s layouts are not sensitive to the variation of basement resistivity and it is more suitable for surveying shallow target.

Keywords- TEM; sensitivity; 3D forward modeling

I. INTRODUCTION

Controlled source electromagnetic methods (CSEM) are now widely used for engineering exploration including the application in selecting ground sites for ultra voltage power transmission line. The time domain methods are preferred for structure mapping since the vertical resolution is believed higher than frequency domain methods. Different configuration of setup for field survey can be used to probe different type of targets at various depths, and the source current can be delivered by loop or grounded wire. When the steady source current in the circuit is suddenly switched off, a secondary current will be induced in the conductive stratum in accordance with the Maxwell’s EM induction law. The induced secondary field decays with time as the current gradually dissipate on account of the electrical resistance in the conductor. One of the advantages of the TEM method is that it only measures the secondary or scattering field after the primary current is turned off so it is not influenced by the primary field (Strack, 1992). The field responses of different components may have different behavior to different model parameters (Tang et al., 2005). This work is to check the sensitivity of AB-s and S-s setups to the conductive anomalous body, overburden layer and basement resistivity by numerical modeling.

II. MODEL DESIGN

Series of numerical models are designed to test the influential factors to TEM method. Assume a three dimensional anomalous body with conductivity $\sigma=0.1$S/m and the size of $200\times80\times30$ m is sit in a four layer earth model, the parameters of the earth model are listed in Table 1. The purpose is to verify in which case/cases the transient electromagnetic method (TEM) is most sensitive for detecting the target.

Sensitivity checks for different resistivities of overburden layers and basements are firstly carried out. Then layouts of the transmitter and receivers such as AB-s, which uses a dipole as the transmitter and coils as receivers, and S-s, which uses loop or coil as a source and coils as receivers as well, are carried out to test which setting is more suitable to detect shallow target. The model shown in Figure 1 is only the sketch map of the AB-s setup.

TABLE 1. THE PARAMETERS OF THE 4-LAYERED EARTH MODEL

<table>
<thead>
<tr>
<th>Model</th>
<th>Depth (m)</th>
<th>Resistivity (Ω·m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>50/2000(Overburden)</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>500/5000(Overburden)</td>
</tr>
<tr>
<td>3</td>
<td>1000</td>
<td>10(Surrounding)</td>
</tr>
<tr>
<td>4</td>
<td>$\infty$</td>
<td>500/50(Basement)</td>
</tr>
</tbody>
</table>

Figure 1. The schematic plan view shows the transmitter and receivers layouts. The arrow in the left is the dipole source in AB-s array. The circles are receivers. The shaded area is the 3D conductive anomaly.

In the whole process of modeling, the size and resistivity of the 3D body, the transmitter and receivers keep unchanged in order to compare the results quantitatively.

For long offset transient electromagnetic (LOTEM) method, the ground source is usually a grounded horizontal electrical wire of finite length which can be considered as a dipole source if the distance of transmitter and receivers is large enough. This is the so-called AB-s setup. The advantage...
of LOTEM method is that large penetration depth can be reached. In this paper the center of dipole source is located at \( y = -6000 \) m and offsets used in AB-s modeling is 5800 m to 6200 m with the interval of 10 m and the current moment is 200 Am-m.

For central loop (S-s) layout, the transmitter can be a square or a rectangular loop. For modeling convenience, a square loop with dimension of \( 400 \times 400 \) m is used. According to the different layouts, the time derivative of vertical magnetic component \( \frac{\partial h}{\partial t} \) or \( V_z \) and horizontal electric field component \( e_x \) are measured.

The anomalous body is divided into 240 cells in numerical computation and only one quarter is involved in calculation for speeding the computation according to the group theory (Newman et al., 1986).

### III. RESULTS AND ANALYSIS

The results are shown in figure 2 to figure 7. From figure 2 and 3, we can see that the detectability of TEM to the conductive anomaly will change as changing the resistivity of the surface layer. Generally speaking, the higher the resistivity of the surface layer, the easier for TEM method to detect the anomaly, both for \( e_x \) component (figure 2) and \( V_z \) component (figure 3), and vice versa. It is because that conductive surface layer attracts more current due to the current channeling effect, so less current can reach deeper depth.

From figure 4 and 5, we can see that the detectability of TEM to the conductive anomaly will also change when the basement resistivity is different. In generally, the higher the resistivity of the surface layer, the easier for TEM method to detect the anomaly, both for \( e_x \) component (figure 4) and \( V_z \) component (figure 5).

From figure 6 and 7, we can see that AB-s can comparatively more easily detect the conductive target buried both in deep and shallow depth. S-s coupling, on the other hand, is difficult to detect the deep anomaly but it can survey the shallow target more clearly.

![Figure 2](image2.png)

**Figure 2.** The difference of \( e_x \) component between resistive and conductive overburden layers.

![Figure 3](image3.png)

**Figure 3.** The difference of \( V_z \) component between resistive and conductive overburden layers.

![Figure 4](image4.png)

**Figure 4.** The difference of \( e_x \) component between resistive and conductive basement.

![Figure 5](image5.png)

**Figure 5.** The difference of \( V_z \) component between resistive and conductive basement.
IV. CONCLUSION

Transient electromagnetic (TEM) method can be used to explore subsurface anomalies. It is much easier to detect the anomalies for TEM method if the overburden layer and basement is resistive. For AB-s setting, which is often used as LOTEM in field survey, it is easily to detect the conductive anomalies both in deep and shallow depth. For S-s layouts, it is difficult to detect the deep depth, but it is more suitable for shallow targets exploration.

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REFERENCES