New approach to interpret Short-offset transient electromagnetic (SOTEM) data

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Abstract— **Commonly, TEM data is plotted as apparent resistivity versus time. Later on, with improvement in computer technology, inversion programs have got attention of EM geophysical community. Recently, inversion routines are applied to 1-D problems. In this paper we propose a new approach to interpret SOTEM data by carrying out analysis in time, frequency and pseudo-seismic domain. At first, we processed synthetic data for H & K type models using 1-D Occam inversion. Then we transformed time-domain data into quasi-MT domain and conducted 1-D Bostick's algorithm. Finally, EM diffusion field is transformed into wave field reflecting seismic-like response with some reflection and refraction phenomena. Our proposed approach is validated by a case study of a coal field located in Henan province, China.**

Keywords—*interpretation; SOTEM; transient electromagnetic method*

I. INTRODUCTION

The short-offset transient electromagnetic method (SOTEM) is a type of transient electromagnetic sounding method where the offset between transmitter and receiver is approximately set equal to or greater than the target depth. However, to cover a large area, particularly, the offset of SOTEM measurements conducted in rough and complex mountainous regions may be extended to two times that of the sounding depth. Like other TEM methods, the SOTEM has been recognized as promising TEM version applied in in a variety of hydrogeological investigation, mineral and hydrocarbon exploration[1,3,9,14].

The final task of EM response in time/frequency domain is to study electrical structure by transformation of voltage into apparent resistivity which is most common variable in spite of difference in theoretical concepts of both EM methods. However using Fourier technique we can switch the data from TEM to FEM. By comparing resistivity curves of central loop TEM and MT, XUE et al. 2006 proposed a time-frequency (T-F) relationship in range of f = 250 / t ~ f= 119.2 / t (ms) and an optimal relation of f=210 / t which allow us to apply quais-MT inversion method to transformed SOTEM results. In last, we transformed SOTEM data into pseudo-seismic.

II. APPARENT RESISTIVITY

Bisection approach based on simple computational routine to solve nonlinear equations has been extensively applied[6] where EM field response must need to be monotonic with resistivity. Therefore, measured voltage is transformed to magnetic field using (1).

$$H_z(t) = \frac{1}{S\mu_0}\int_t^b V_z(t)dt + H_z(b) = \frac{1}{S\mu_0}\int_t^b V_z(t)dt \quad (1)$$

Where, S is the effective areas of induced coil, μ_0 is the permeability of the air, $H_z(b)$ is the magnetic field of the last time channel.

To fit the observed data, different resistivity values are substituted in (2).

$$H_z(t) = \frac{Idl}{4\pi r^2}\sin\varphi[\frac{3}{\sqrt{\pi}}\frac{e^{-u^2}}{u} + (1-\frac{3}{u^2})\Phi(u)] \quad (2)$$

Where, I is the transmitting current, dl is the length of dipole source, $r=\sqrt{x^2+y^2}$ is the offset, φ is the angle between receivers and transmitter, $u = \frac{2\pi r}{\tau}$, $\tau = 2\pi\sqrt{2\rho t / \mu_0} = \sqrt{2\pi\rho t \times 10^7}$, $\phi(u) = \sqrt{\frac{2}{\pi}}\int_0^{u(t)} e^{-t^2/2}\mathrm{d}t$ is the probability function.

CAGNIARD (1953) gave a (3) used for estimation of apparent resistivity in MT method.

$$\rho^{MT} = \frac{1}{5f}\left|\frac{E_x}{H_y}\right|^2 \quad (3)$$

Where, f is frequency, E_x is the horizontal electric field parallel to source, and H_y is the horizontal magnetic field perpendicular to source.

III. OCCAM INVERSION, T-F TRANSFORMATION & QUASI-MT INVERSION OF SOTEM DATA

Occam's 1D inversion routine[2] were applied to SOTEM data (Fig.1). Different T-F transformation schemes have been introduced by [4,5,10] analyzed the similarity of apparent resistivity curves in two domains at optimal level. So firstly, we converted STEM data using the relation $f = 133.4/t$. Then, we tested simplest Bostick inversion technique[7] to get results in frequency domain (Fig.2).

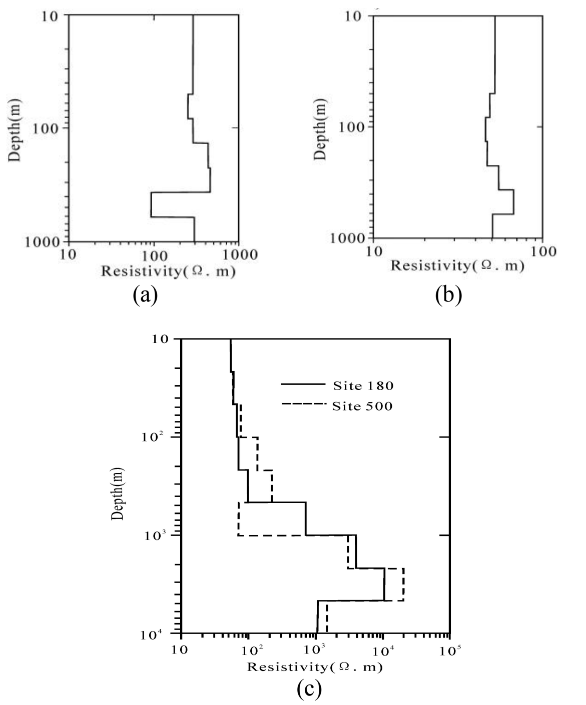
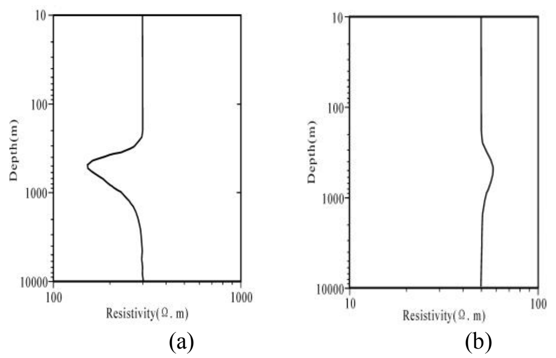


Fig.1. 1-D Occam inversion results (a) H- type (b) K- type (c) real data



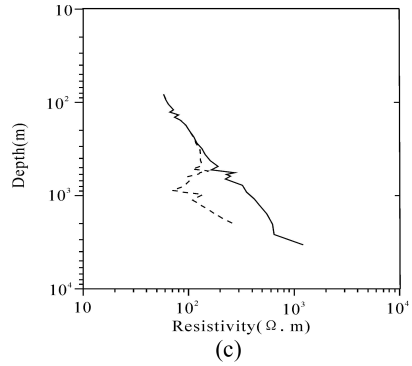


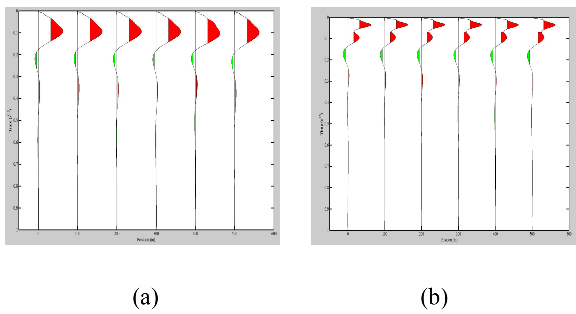
Fig.2. 1D Bostick inversion results of two-layer models H-type (a) , K-type (b) and (c) real data

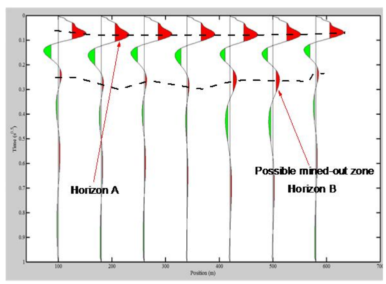
IV. PSEUDO-SEISMIC EQUIVALENT OF SOTEM DATA

SOTEM data is converted to seismic-like (pseudo-seismic) time section (Fig.3), using special (4) [8].

$$H_m(t_i) = \sum_{j=1}^{n} u(\tau_j)\, a(t_i, \tau_j) h_j \qquad (4)$$

Where, $a(t_i, \tau_j) = \frac{1}{2\sqrt{\pi t_i^3}} \tau_j e^{\frac{\tau_j^2}{4t_i}}, h_j$ is the integral coefficient and $H_m(t), U(\tau)$ is diffusion field and the pseudo-wave field, respectively.





(c)

Fig.3. Pseudo-seismic results of two-layer models H-type (a) , K-type (b) and (c) real data

Fig.1 & Fig.2 showed that like synthetic data results, conductive anomaly was resolved clearly in case of both time and frequency domain inversion schemes around 1000m. However, quasi-MT results were not very appreciable in retrieving the anomalous zone (excavated water filled zones) underlain and overlain by sandstone beds in the survey area. Pseudo-seismic section clearly indicated the target zone which can also be correlated to 1-D inversion results within same depth interval ranging from 450-1000m.

V.CONCLUSIONS

First, synthetic and real data were analyzed in time-domain by popular Occam inversion in time-domain which indicated a low conductivity anomaly within 450-100m, which is then verified by subsequent quasi MT inversion, pseudo-seismic and drilling results.

Interpretation of SOTEM field data in different domains provides an alternative way to explore the TEM soundings further in order to improve our understanding by introducing new interpretation methodology.

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