3D 'Tau' imaging of subsurface conductors by contemporary helicopter borne time domain EM systems

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SUMMARY

The 'Tau' parameter, governing the decay behavior of measured transients in the time domain EM methods, represents a combination of the conductivity and size parameters of subsurface conductors. 'Tau' imaging as a function of time describes the depth-wise variations while their values along various profiles provide clues towards the spatial distributions of geological conductors. 3D 'Tau imaging' thus can provide useful information on the subsurface distribution and disposition of various conductors. In this paper we evaluate the efficacy of two generically different helicopter TEM systems, namely, those flying the transmitter loop during the survey and the system employing a grounded transmitter cable ('GREATEM' system), in providing realistic 3D 'Tau' maps describing distribution of subsurface geological conductors. It is found that the mode of primary field excitation in the two systems plays an important role in the resulting 'Tau' images.

Keywords: Helicopter TEM methods, 'GREATEM' system, 'Tau' imaging of HTEM data

INTRODUCTION

The time domain EM methods are based on the diffusion of current pulses in to the earth. These pulses induce eddy currents whose decay behavior depends on the time constant 'Tau' of various geological conductors. The parameter 'Tau' depends on the conductivity and the size of a conductor and is large for excellent conductors and small for poor conductors. 'Tau' maps are frequently used in the modeling of helicopter borne time-domain electromagnetic (HTEM) data. Spatial distribution (map) of 'Tau' for different values of the delay time indicates the subsurface location and disposition of various geological conductors in view of the fact that increasing time implies greater investigation depths. There are a number of ways to compute 'Tau' parameter. For example, for the HTEM systems measuring both *'B'* and *'dB/dt'* fields, the 'Tau' parameter can be computed using the ratio of these measurements while for systems measuring only the *'dB/dt'*, it can be computed utilizing measurements at more than one adjacent time channels.

In this paper we have studied the efficacy of 'Tau' maps in imaging 3D geological conductors by different helicopter borne time domain EM (HTEM) systems. Two different classes of HTEM systems either flying airborne transmitting loops (FlTx) or employing a grounded cable transmitter (GrTx) are considered. While there are a number of FlTx systems, only one GrTx system (Mogi et al., 1998) has been developed so far. It may be mentioned that these two generically divergent systems energize the earth in fundamentally different ways. The FlTx systems generate only the TE mode and record the inductive response caused by horizontal current flows. The GrTx system generates both TE and TM modes and thus records response produced by both the vertical as well as the horizontal current flows in the earth. Another important difference is in the operational strategy. Since the FlTx systems fly with the transmitter loop, the ground below is energized with the same primary field strength for all receiver locations regardless of the continuously moving position of the helicopter. The pulse duration employed by most of the FlTx systems is around 10 msec. The GrTx system employs a long grounded cable as transmitter at fixed location with a roving airborne receiver. Thus the primary field strength varies at different receiver locations. Also the GrTx system employs primary current pulses of very long duration up to 200 or 400 msec with very low repetition frequencies.

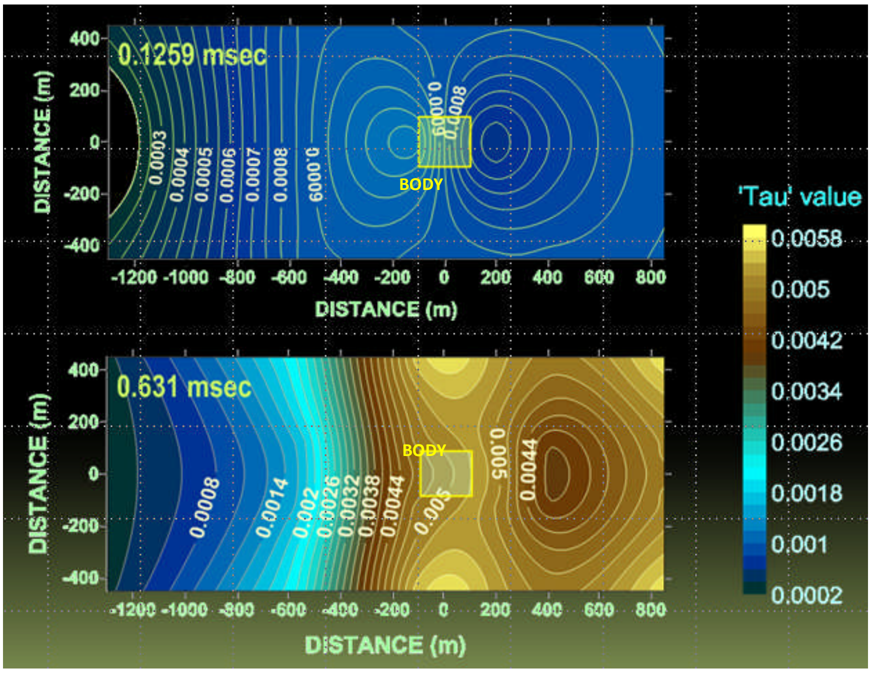

***Figure:** 'Tau images' at delay times 0.1259 and 0.631 msec for the 'GrTx' system for a 3D block of conductivity 1 Sm^{-1} with dimensions 200 m X 200 m X 200 m buried at a depth of 100 m in a half space of resistivity 500 Ohm.m.*

RESULTS

Synthetic profiles for various geological models are computed using the program 'Maxwell' for FlTx systems and a forward algorithm based on 3D finite difference approach for the GrTx system. These are used to create 3D 'Tau' maps that provide information on spatio-temporal disposition of subsurface conductors. The computations are done considering *'dB/dt'* field and following the approach described by Verma (1975). Efficacy of 3D 'Tau' imaging approach in obtaining realistic subsurface conductivity distribution by the two classes of HTEM systems is compared and assessed. It is found that the mode of primary field excitation in the two systems plays an important role in the resulting 'Tau' images. The GrTx system uses galvanic stimulation of the ground at a fixed spatial location in comparison to the FlTx systems that employ a flying transmitter loop in inductive mode with continuously varying location. The FlTx systems induce current systems in TE mode that flow only horizontally while in GrTx system both TE and TM modes of currents are induced that flow both in horizontal and vertical directions. Thus it is sensitive to both resistive and conductive layers. Therefore, the 'Tau' images obtained by the two systems are different. Similar observations are reported by the detailed numerical modelling results of an earlier study by Um and Alumbaugh [2007] wherein they compared the performance of ground-based inductive loop and grounded cable transmitters for terrestrial and marine exploration. More recently Davydycheva and Rykhlinski (2011) report similar differences for focused illumination of targets employing specialized transmitter configurations.

ACKNOWLEDGEMENTS

The first author also acknowledges the award of the Raja Ramanna Fellowship by the DAE, Government of India that enabled him to carry out this work.

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