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Comparison of the results of digital filters in forward modeling of time-domain electromagnetic data

Davood Rajabi[*1]; Saied Mirzaie[2]; Alireza Arab-Amiri [3]

1. Ph.D. Student, ACECR-Research Institute of Applied Sciences, Shahid Beheshti University, Tehran, Iran
2. Professor, ACECR-Research Institute of Applied Sciences, Shahid Beheshti University, Tehran, Iran
3. Associate Professor, School of Mining, Petroleum and Geophysics, Shahrood University of Technology, Shahrood, Iran

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Corresponding author: davoodrajabi@gmail.com

Keywords

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Extended Abstract

Summary

In electromagnetic data forward and inverse modeling, digital filters are used. A fast digital filter with millions of repeatable calculations is required for two- and three-dimensional modeling. Henkel's transformations are frequently used to model frequency-domain electromagnetic data. In time-domain electromagnetic data modeling, the Henkel, sine and cosine integrals complicate digital filter calculations. The purpose of this paper is to investigate different methods of digital filters for solving time-domain or transient electromagnetic (TDEM or TEM) problems. All common methods were fully coded in "MATLAB" software package, and the outcomes were examined. Then, their modeling results were compared with direct analytical solution and layered earth models, and finally, with the results of the "CR1MD" modeling software. This study shows that while the outputs of digital filtering methods usually overlap, increasing the number of coefficients does not necessarily increase calculation accuracy. The 61 coefficients of the "Kong" method produce better results compared to other digital filtering methods investigated in this research work. The results have also shown that the fast sine transformation method is not suitable for forward and inverse modeling due to its poor end-channel results. However, the numerical sine transformation method and "Key" digital filters can be used in TDEM data modeling.

Introduction

To calculate the fields generated by a dipole antenna above or embedded in layered media, Hankel transforms should be evaluated. When using the digital filter technique, the Hankel transforms are first transformed into convolution equations, which are then solved to obtain the filter coefficients. In 1971, Ghosh used digital filters to evaluate Henkel transforms. Due to Fourier transform calculations, TDEM or TEM field data modeling is more complicated and slower than frequency-domain electromagnetic (FDEM) data modeling. The digital filter sine and cosine transformations have long been used in TEM data modeling (Kong, 2007), and researchers are trying to speed up and improve these transformations (Zhao et al., 2018). In this paper, different digital filters have been compared for progressive modeling of TDEM data. A "MATLAB" program was written to test the coefficients used in each digital filtering method for forward modeling of TDEM data. Considering the use of large horizontal loops in TDEM measurements, the comparison of the results with the analytical solution of homogeneous earth in circular loops was made. Then, with different models of layered earth in mind, selected based on the models presented in published relevant references, the results of different algorithms were compared to determine the optimal or suitable algorithm for forward and reverse modeling. Different results of magnetic field and voltage response were compared to the results obtained from homogeneous and layered earths of relevant references. Finally, the results were compared with those obtained from using "CR1MD" software to choose the best option.

Methodology and Approaches

At first, the program related to each of the digital filtering methods was written in MATLAB software package, and then, their modeling results were evaluated according to the following steps:

- The analytical solution of the magnetic field and the voltage response for several homogeneous half space models,
- Layered terrain modeling based on models provided by Spies and Eggers (1986), and
- The forward modeling of layered earth by the "CR1MD" software.

Results and Conclusions

- ✓ The Kong's coefficients provide good results in solving mathematical problems, but they are not suitable for TDEM data modeling.
- ✓ The CR1MD modeling software, based on Ryu et al. (1970) and Anderson (1981), produces the results overlapping the results obtained from other methods used in this research work. Hence, it may be a good choice for modeling TDEM data. However, the number of the coefficients in the method, introduced by Anderson (1981), is almost 4 times of the number of the coefficients in the method introduced by Key (2012).
- ✓ The method, introduced by Key (2012), performs well in all modeling, making it as a good choice for digital filtering to carry out forward and inverse modeling of TDEM data.