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A new methodology for the acquisition and processing of audio-magnetotelluric (AMT) data in the AMT dead band

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ABSTRACT

Distant lightning activity, the natural energy source for the audio-magnetotelluric (AMT) method, has a signal minimum between 1 and 5 kHz, the so-called AMT dead band. The energy in this band exhibits both diurnal and annual variation; magnetic-field amplitudes during the daytime are often well below the noise levels of existing sensors (coil magnetometers), thus reducing the effectiveness of the method for quantitative high-resolution studies of near-surface targets. To overcome this deficiency, we propose a hybrid acquisition and processing methodology based on combining the telluric-telluric (T-T) and telluric-magnetotelluric (T-MT) methods in this frequency range. Our method records the telluric channels at several sites and at base and remote reference stations during the day and records the full magnetotelluric (MT) components at the base and remote stations only during the night. Applying a tensor multiplicative relationship between these responses, we obtain the T-MT AMT transfer functions for the sites; these transfer functions can represent a reasonable approximation of the real AMT impedance tensors. To test the approach, a T-MT experiment was carried out in Sudbury, northern Ontario, during summer 2000. We compare the processed daytime data using the conventional MT approach to those obtained from our T-MT approach. The results demonstrate that our method can determine high-quality estimates in the dead band, although the estimates can be severely affected by noise.

INTRODUCTION

Our study of lightning activity (Garcia and Jones, 2002) confirms the diurnal and seasonal variation of the amplitude of electromagnetic (EM) signals at audio-magnetotelluric (AMT) frequencies and demonstrates the problems of acquiring data at AMT dead-band frequencies of 1 to 5 kHz. The daily variation in the amplitude of the EM fields, with a significant decrease during daytime hours, is a result of absorption in the photo-ionized atmosphere. The seasonal variation corresponds to a minimum of source (lightning) activity during winter months for the northern hemisphere. In particular, we show that during the daytime, the AMT dead-band magnetic signals are typically one to two orders of magnitude below sensor noise levels of the best magnetometer coils currently available. This is a severe problem because deep mineralized targets, lying 500 to 1000 m deep within a resistive host such as the Canadian Shield, are first sensed at AMT dead-band frequencies. Thus, for optimum resolution one needs to obtain high-quality AMT responses at those frequencies. As a consequence, we conclude that dead-band AMT data must be acquired during the night. However, this requirement comes at a high logistical cost and, therefore, a high per-site cost, along with concomitant safety concerns about operating during the night.

To address this high cost, we proposed in Garcia and Jones (2002) a novel method of AMT data acquisition with daytime acquisition of telluric channels at local, base, and remote stations along with conventional nighttime acquisition of magnetic and telluric data at base and remote stations. The quasi-magnetotelluric transfer function at each telluric station is then obtained from tensor multiplication of the transfer functions between the daytime telluric channels and the nighttime conventional magnetotelluric (MT) base estimates. This transfer function represents the ratio of the local telluric to base magnetic fields, rather than the conventional local telluric to local magnetic relationship used in MT. The methodology is, in principle, identical to the telluric-magnetotelluric (T-MT) method proposed by Hermance and Thayer (1975), with the exception that the telluric transfer functions are derived at different times from the MT transfer functions. In addition, we require at least two base stations so that we can undertake remote-reference processing of both the telluric-telluric (T-T) and the MT transfer functions. Our hybrid approach has

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