Measurement of noise characteristics of graphite electrodes in the field and comparison with other types of non-polarizing electrodes

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SUMMARY

Graphite electrodes have been successfully used in MT measurements by a number of Russian companies for decades. This type of electrode has proven itself extremely well in practice. During the continuous use of graphite electrodes, an optimal design was developed, which made it possible to achieve a low level of noise and high reliability in various climatic conditions. However, up to the present time, this type of electrodes has hardly been mentioned even in large western review papers. This work aims to correct this omission. In the course of this work, a technique for measuring electrode noise was developed and an attempt was made to investigate the noise characteristics of graphite electrodes, as well as to compare them with other types of electrodes. It was found that the noise level of graphite electrodes is slightly lower than that of the widely used $Pb\text{-}PbCl_2$ and $Cu\text{-}CuSO_4$ electrodes. Also, this work demonstrates the importance of proper electrode maintenance for the best performance.

Keywords: magnetotelluric, non-polarizing electrode, parallel test

INTRODUCTION

Electrodes are the most critical component in the measurement of the telluric response, and indeed are often the weakest component of any MT system. If reasonable care is taken with all other aspects of the electric measurements, then it is the electrode noise that limits the quality of the electric field measurements (Petiau & Dupis 1980).

Most land MT surveys in the world are carried out with porous-pot $Pb\text{-}PbCl_2$ or $Cu\text{-}CuSO_4$ electrodes. In addition to these two types of non-polarizing electrodes, in the post-Soviet space, a number of geophysical companies actively employ graphite electrodes. Our numerous comparative tests and many years of practical experience show that graphite electrodes have an extremely low noise level and give good results over a wide frequency range under a wide range of temperature and humidity conditions.

This type of electrodes is not widely used outside Russia. Moreover, in a number of publications it is noted that graphite electrodes have a high noise level comparable to the level of the telluric field and, as a result, their use is not recommended for MT surveys (e.g., Petiau 2000; Ferguson at al. 2012). This contradicts our experience in the practical application of electrodes of various types.

The production technology of graphite electrodes was developed by Soviet geophysicists at the dawn of the MT method, and since then this type of electrode has not lost its relevance.

In a simplified form, graphite electrode is basically just a graphite rod placed in Zn-graphite powder (Figure 1). But, obviously, to make a high-quality electrode, it is important to comply with a number of conditions. Among other things, it is important to monitor the quality of all contacts. For example, the contact between the rod and cable must be well isolated from the environment; the shell of the electrode must be well permeable to moisture, etc.

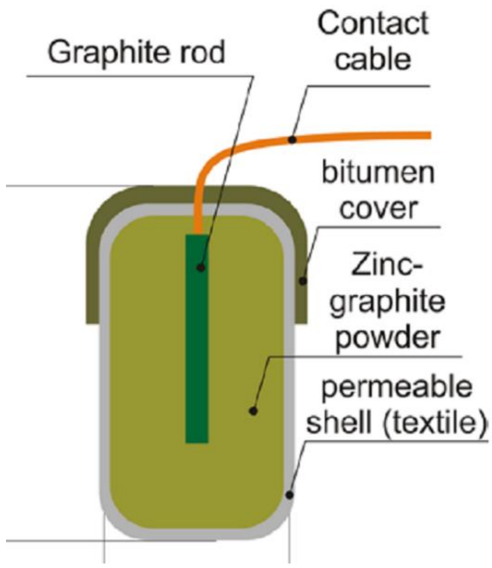

Figure 1. Graphite electrode.

If all conditions are met, then you can get a sensor with decent characteristics.

The main goal of this work is to study the noise characteristics of graphite electrodes and compare them with other types of non-polarizable electrodes. Another important point is to develop a suitable technique of measuring electrode noise in the field.

MEASUREMENTS AND PROCESSING

Comparative tests involved three types of widely used electrodes: graphite (manufactured by the Nord-West company), Cu-$CuSO_4$ and Pb-$PbCl_2$ (both manufactured by internationally recognized geophysical companies). We choose 8 electrodes of each type. All electrodes were brand-new and properly serviced before use.

To estimate the noise, a parallel test technique was applied. Electrodes of each type were grouped into pairs. Each pair formed an electrical line 1 meter long. All electric lines were located in parallel at a small distance from each other. Figure 2 shows two setups for measuring electrode noise (2 pairs of graphite electrodes installed on the left, and 2 pairs of Pb-$PbCl_2$ electrodes installed on the right).

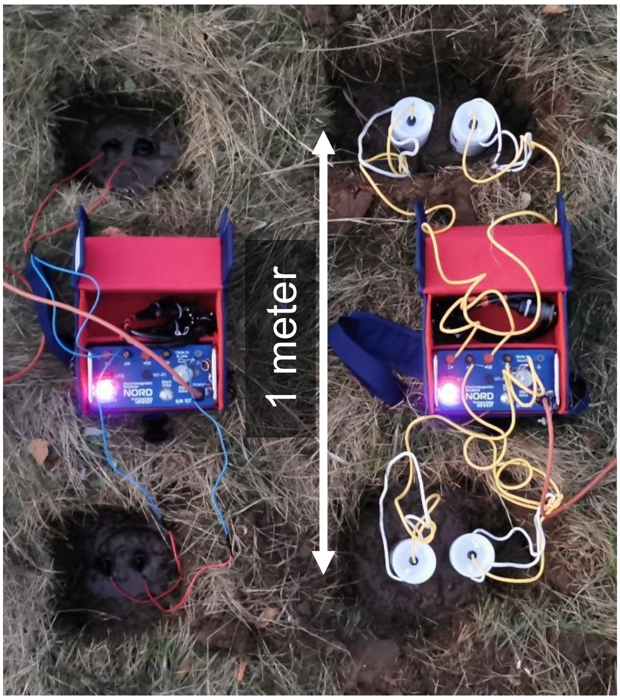

Figure 2. Simultaneous noise measurement for two types of electrodes. Left setup for graphite electrodes (4 electrodes), right setup for Pb-$PbCl_2$ electrodes (4 electrodes)

To study the stability of the characteristics of the electrodes, the signals were recorded periodically for 2 weeks.

Since the electric lines are very short, parallel and have the same length, the measured signals due to electric field in the ground are weak and roughly the same. Noise is the difference between the signals observed for different electrical lines and can be estimated using a simple formula:

$$Noise(t) = \frac{Ch_1(t) - Ch_2(t)}{2} \qquad (1)$$

For the noise function obtained this way, we have calculated the spectral density in a wide range of times (from 0.0001 to 1000 seconds). Examples of spectral density for different types of electrodes are given in Figure 3.

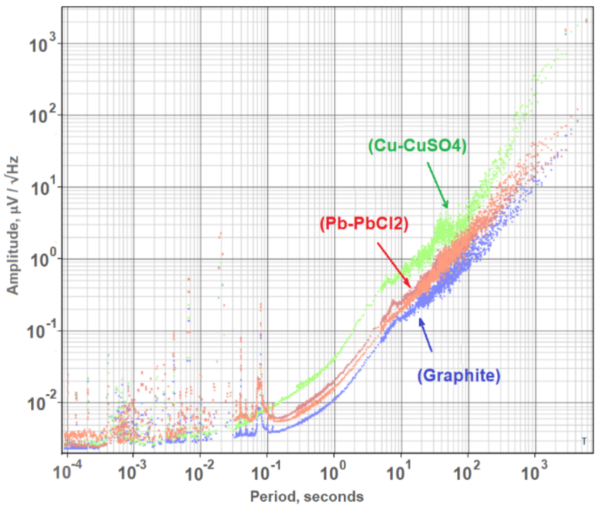

Figure 3. Noise spectral density of different types of electrodes after 24 hours of recording. Raw data (before applying the robust spline approximation).

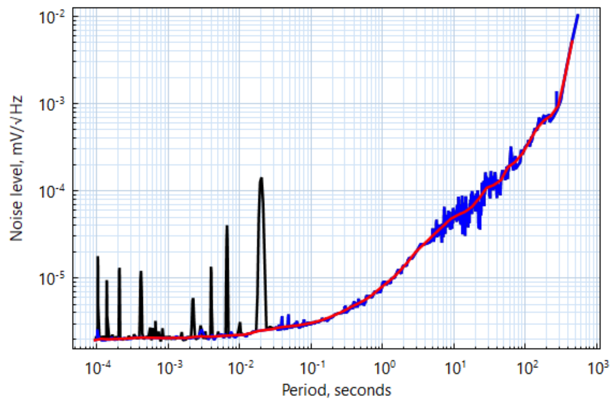

Figure 4. Robust spline approximation. Black line – raw spectra, blue line – spectra after industrial frequencies filtration, red line – smooth spline approximation

The place chosen for observations was located in the area of influence of industrial noise, therefore, distorted values were obtained at certain frequencies (50 Hz and harmonics). These peaks are not related to the self-noise of the electrodes; therefore, to obtain the final result, they were filtered. Then, spline approximation was carried out for the remaining values. This stage is shown in Figure 4.

RESULTS

As noted earlier, in order to obtain reliable noise estimates for each electrode type, it is necessary to ensure that each of the electrodes is in good condition and properly maintained. Figure 5 shows how the noise level of new (initially dry) graphite electrodes depends on the time elapsed after their first installation in moist soil. More than 12 hours should pass before the dry electrode starts to give the best results.

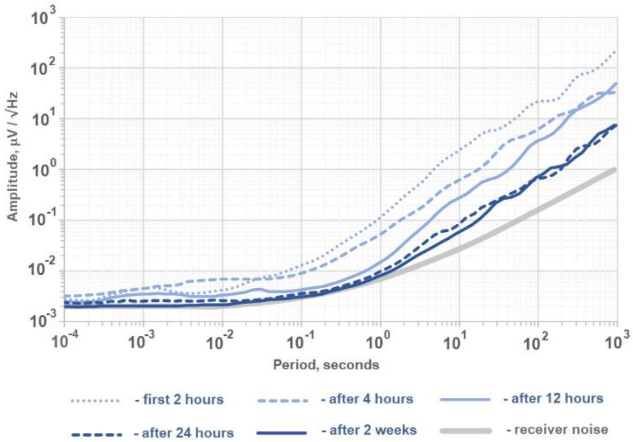

Figure 5. Change in noise level of a dry graphite electrode over time when placed in moist soil. Blue lines demonstrate noise levels for different times since installation. Gray line corresponds to receiver self-noise.

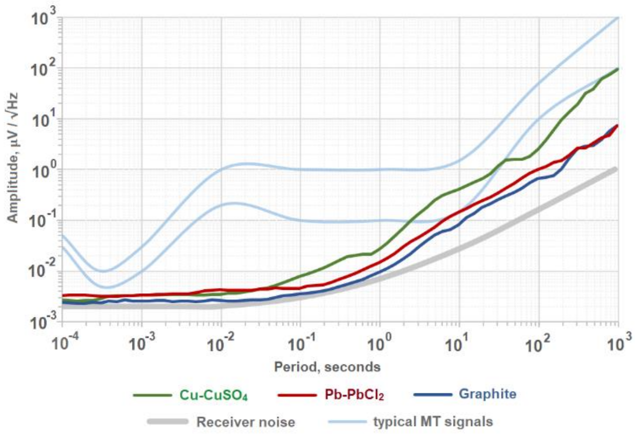

Figure 6. Comparison of the self-noise level of non-polarizable electrodes of various types

Figure 6 shows typical levels of noise of electrodes of different types. The highest noise level was consistently observed for Cu-$CuSO_4$ electrodes. Graphite and Pb-$PbCl_2$ electrodes both show noticeably better results quite similar to each other; but the noise level of graphite electrodes is slightly lower in the entire frequency range.

CONCLUSIONS

We believe that graphite electrodes deserve more attention of the international EM community than they used to have in last decades (e.g., see Lu and Macnae 1998). The presented work is the first step in our planned study of the characteristics of such electrodes. It is necessary to carry out long-term monitoring noise measurements and determine how the noise characteristics of the electrodes will depend on temperature, humidity and other factors.

However, according to the measurements already taken, it can be said with confidence that properly manufactured graphite electrodes demonstrate a noise level low enough to carry out magnetotelluric measurements in a wide frequency range. In all our observations, the noise level of graphite electrodes turned out to be consistently lower than that of the widely used Pb-$PbCl_2$ and Cu-$CuSO_4$ electrodes. Also, the graphite electrodes have a low production cost and are more environmentally friendly than most of metal-electrolyte electrodes, which makes them a very attractive option for MT exploration.

In addition, our measurements have demonstrated that the telluric field registration quality strongly depends on timely electrode maintenance. Before starting work, dry (new) electrodes should be kept in moist soil for about 1 day. This will provide the best measurement quality. This observation applies to any type of electrodes.

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