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Disturbances on Magnetotelluric Data Due to Electrified Railway

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Abstract

Magnetotelluric (MT) soundings were made on two transverse profiles to the Campos do Jordão Railway (CJR) in the period range of 4 to 3000s. The profiles are located in two adjacent regions of the São Paulo State with contrasting conductivity: the conductive sedimentary region of Taubaté Basin and the resistive crystalline region of Serra da Mantiqueira. The data were collected during diurnal and nocturnal periods, when the CJR operates with DC current and when it is turned off, respectively. The objective of this study is to attempt to eliminate the electromagnetic noise produced by the CJR in the diurnal data. To achieve this goal we plan to use some techniques based on the MT response function estimation and then to estimate the resistivity profile of the region. This profile will be compared with the results obtained from nocturnal data, not contaminated with the noise of the CJR, to verify the relative efficacy of the methods employed to filter out the electromagnetic noise. The preliminary results indicate that the Serra da Mantiqueira region is 177.8 times more resistive than the Basin and that the skin depth in the Basin is of 2.7 km.

INTRODUCTION

Man-made electromagnetic noise has been rising continually because of the increased dependence of humans on electricity. New techniques are thus required to eliminate this interference in geoelectric and geomagnetic measurements to obtain trustful results that can be used in understanding geophysical processes. The electromagnetic noises due to DC electrified railways (ER) have been studied in respect to the geomagnetic observations, particularly in the interference produced in magnetic observatories (Yanagihara, 1977) and in MT soundings (Fontes, 1988) because of the noise's long range (tens of kilometers) and strong signal screening effects.

The conventional spectral analysis used to eliminate noises, based on least squares analyses (Sims et al., 1971), is not very efficient in this case because the noise is coherent and irregular. Among the previous techniques, one of the most applied method is the remote reference (RR). This technique consists basically in the simultaneous measurement in two or more stations and the use of the signal (normally the magnetic) from one of the stations in order to eliminate the noise in the others sites, by spectral analysis (Gamble et al., 1979). Another correction technique is the robust spectral analysis that is relatively insensible to the moderate presence of noisy data, or data that do not fit the statistic models, and it acts gradually on these perturbations (Egbert & Booker, 1986; Chave et al., 1987; Larsen, 1989). Normally, these two techniques are combined in one algorithm.

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Jones et al. (1989) compared eight techniques of MT response function estimation. They selected two time series for the comparison: one during a quiet period of solar activity and the other at an active period. The methods that showed more efficiency in this study were those that used RR and robust techniques and those that combined both techniques. Another result showed a "droop" in the apparent resistivity at long periods in the technique that combines the RR and robust function estimation. One possible cause to that "droop" suggested by the authors is source-field effects.

Recently, Larsen et al. (1996) proposed a robust least-square two-sources method for the coherent noise problem. The contaminated data by an ER were analyzed and, with a RR station, they separated the natural electromagnetic signal from the artificial and estimated the MT response. They showed that the single station robust methods are dominated by the signal induced by the train whereas the RR methods showed poor results when compared with the ones obtained by the robust two-sources method.

However, since it is not possible to do measurements without the presence of noise, it is almost impossible to demonstrate the efficacy of the methods employed to filter the electromagnetic noise. In the present work, this problem could be partially overcome, since the CJR is operated only during the day. Thus, it is possible to compare the nocturnal and diurnal results to verify the efficacy of the methods employed. Also it will be possible to verify if the source-field effects generated by the CJR could produce the "droop" in the apparent resistivity at long periods, as supposed by Jones et al. (1989). Again, this test is only possible because of the nocturnal and diurnal data.

PRELIMINARY RESULTS

In the course of 1998, MT soundings were carried out along two profiles, one on the Serra da Mantiqueira, with six stations along 76 km, and another on Taubaté Basin, with three stations along 5.7 km. Figure 1 shows the station sites in relation to the CJR. The CJR has two substations near the town of Santo Antônio do Pinhal, each substation providing

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the energy for one half of the CJR. To facilitate the discussions, from now on, we will call one CJR part as the Pinda side, because it finishes in the town of Pindamonhangaba, and the other part as the Campos side, because it finishes in the town of Campos do Jordão.

The preliminary results shows that in the farthest station away from the CJR, in each profile, the CJR004 and CJR009 stations, the CJR noise appears weak, and it is difficult to identify it in time series. This observation is illustrated in figure 2, where we see the electric channel Ey of the CJR004 and CJR009 stations, and of the EFC005 station measured simultaneously with the CJR004 station. The time series of the EFC005 station show the typical noise form that is not so easy discerned in CJR004 or CJR009. Although the EFC009 and EFC004 stations have not been simultaneously measured, we can see similar structures, like the one indicated by the vertical line in figures. Therefore, as a first approximation, the two profiles are equivalent in relation to the signal attenuation. However, conductive terranes, such as the Basin, are much more efficient in the attenuation of the signal. Because the attenuation is inversely proportional to the square root of the resistivity and directly proportional to the distance, we have for the two equivalent attenuation:

$$\frac{\rho_c}{\rho_b} = \left(\frac{r_c}{r_b}\right)^2$$

Where ρ is the resistivity and r is the distance between the station and the source (CJR). The *b* index refers to the Basin and *c* to the crystalline areas.

As a first rough estimation, we can say that the resistivity in the Serra is 177.8 times more resistive than the Basin.

Another remark is that the stations on the Serra da Mantiqueira were found to be noisier during the entire day. We attributed this to two reasons: one is that the Campos side, which is located on the Serra, has a more intense train traffic. The other reason is that the traffic of the Pinda side also produces noise in the Serra because both substations are on a crystalline terrain. On the other hand, in the stations on the Taubaté Basin, we clearly noticed the noise produced by the train movement as illustrated in figure 3, in which we see the noise in the electric channel Ex registered in the CJR008 station. In this figure, we see a certain symmetry between the two noisy segments. By the train schedule, we know that there is a train moving from Pindamonhangaba to Piracuama (in the middle of the Basin) at 6:00h, local time (LT), and travel back at 7:00h (LT) to Pindamonhangaba. Then, the noise produced by each train trip can be considered approximately as a standard behavior, for the proposed study.

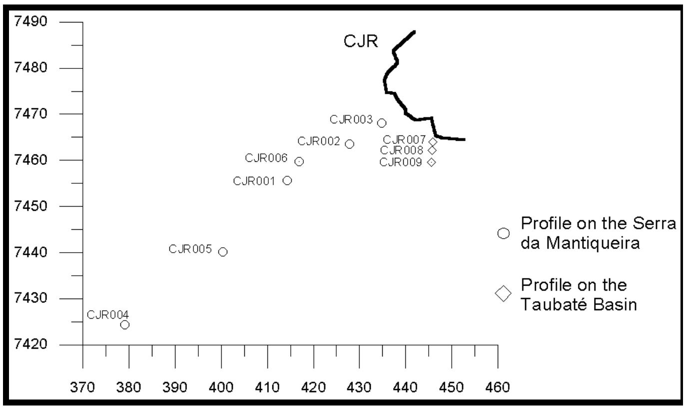

Figure 1: Spatial displacement of the CJR and of the studied profiles (UTM coordinates).

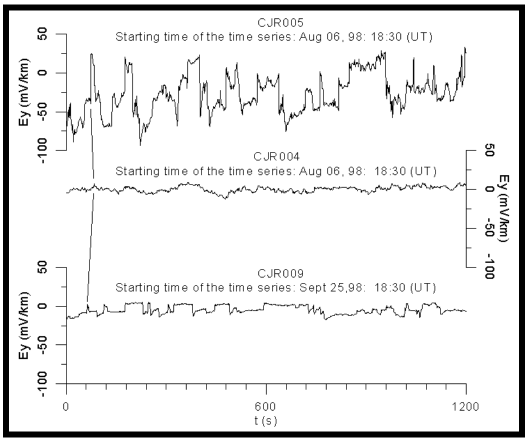

Figure 2: Comparison between the channels Ey of the CJR009 station (the farthest site from the CJR on the Basin) and of the CJR004 (the farthest site from the CJR on the Serra). The signal of the CJR005 (obtained simultaneously with CJR004) is

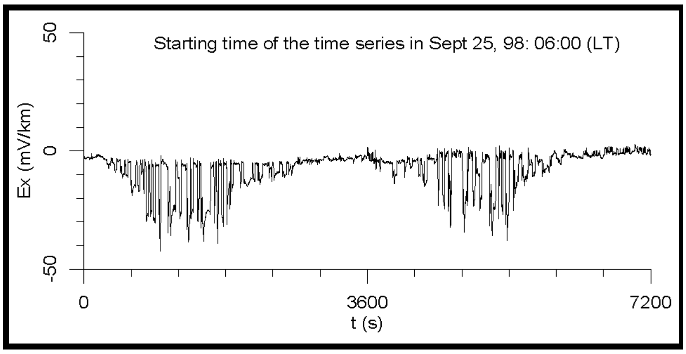

Figure 3: Time series of the Channel Ex of the CJR008 station showing the noise of the CJR when the train goes from Pindamonhangaba to Piracuama, and back.

Because of the simplicity to identify the noise produced by the train trip in the Basin, we can estimate the attenuation of the noise in that region. To obtain that, we have superimposed the time series segments of the electric channel simultaneously recorded at the three stations on the Taubaté Basin. We eliminated eventual data trends and placed them on the same base line, then calculated the ratio between the noise peaks. If we suppose that the signal attenuation is exponential, then the ratio between the noise peaks will be of the form:

$$e^{-\frac{\Delta r}{\delta}}$$

where δ is the skin depth and Δr is the distance between the stations, we can get a skin depth of 2.7 km for the period of 30s and a resistivity of 1Ω.m in the Basin. These values are coherent with the results obtained in this same region by Padilha et al. (1982).

CONCLUSIONS

Although the preliminary measurements have been useful in the understanding of the influence of the CJR noise on the MT soundings, the data is still insufficient to do a satisfactory spectral analysis. Because the recorded time series have had another strong noises, such as electrical storms and electrical signal saturation probably due to an electrode failure. Thus, we do not have records with tolerable noise long enough to obtain good statistical results. In continuation to this work, we are carrying out new MT soundings for a more judicious comparison between the studied methods.

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