Introduction

Magnetotelluric method (MT) offers the opportunity to characterize deep reservoirs, in particular deep saline aquifers for CO_2 storage. Since it is a passive electromagnetic (EM) technique, its reliability depends on the signal-to-noise ratio. Noisy data caused by artificial EM sources must be identified and rejected.

Signal from natural sources is expected to be non-polarized, in contrast of the signal originated by artificial ones. Therefore, polarization analysis can be an efficient way to identify EM sources. As MT time-series are non-stationary signals, this study must be done in the time-frequency domain. Wavelet analysis has proved to be a useful tool to describe this behaviour.

An algorithm based on wavelet analysis has been developed in Matlab®. It provides the time-frequency content of MT time-series, as well as their polarization attributes in that domain. This code has been tested with both synthetic signals and field data.

Theory

An elliptically polarized rotating signal S(t), with orthogonal components (S_{NS}, S_{EW}), is described by the following geometric parameters: (Figure 1)

- ρ : ellipticity ratio, $\rho = r / R$, $\rho \in [0,1]$
- θ : tilt angle, $\theta \in [-\pi/2, \pi/2]$
- $\Delta\Phi$: phase difference between its components $\Delta\Phi = \Phi_{EW} - \Phi_{NS}$, $\Delta\Phi \in [-\pi, \pi]$

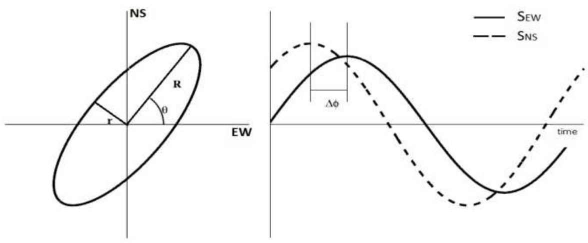

***Figure 1**. Polarization attributes of the signal S(t).*

These polarization attributes have been defined in the time-frequency domain by Diallo et al. (2006), in the context of seismic data analysis. The method is based on constructing a new complex signal: $Z(t) = S_{EW}(t) + i \cdot S_{NS}(t)$, and consider the progressive and regressive components of its continuous wavelet transform.

Methodology

The developed algorithm has been used to analyze synthetic signals whose polarization attributes change over time and frequency. The values obtained computationally agree with the expected ones. In order to check the performance of the algorithm with field data, a real experiment has been carried out in Hontomín site (the Research Laboratory on Geological Storage of CO_2 in Spain). MT time series acquired there have been contaminated at different frequencies, with consecutive emissions of a well-known artificial electromagnetic source. Data were acquired in equidistant sites throughout a NS profile, 3 km long. The artificial source consisted of 2 electric dipoles 1km long, arranged in N-S and E-W directions, located 5.5km south of the center profile. They were powered by a current source, which transmitted a square wave in 18 different consecutive frequencies, in the range between 0.0833Hz and 32Hz.

Results with field data

For the recorded electric signal in each site, they have been computed the scalogram and the polarization attributes in the time-frequency domain. The obtained values are the ones expected in every site, taking into account that the source is a horizontal electric dipole, and its location in relation to the MT profile.

Figure 2 shows the location of the MT profile and the source dipoles. Figure 3 shows the scalograms of the electric field recorded in site 17, during the emission of the N-S dipole source. Frequency and length of the signal emitted by the controlled source are easily identified. The intensity of the artificial signal is different in each component of the recorded electric field, because it depends on the orientation of the dipole source. Figure 4 shows the corresponding polarization attributes. The tilt angle is nearly 90º, the direction of the dipole source. The ellipticity ratio is almost zero, showing that the signal is linearly polarized. The phase difference is nearly constant during all the emission.

Figure 2. *Situation map*

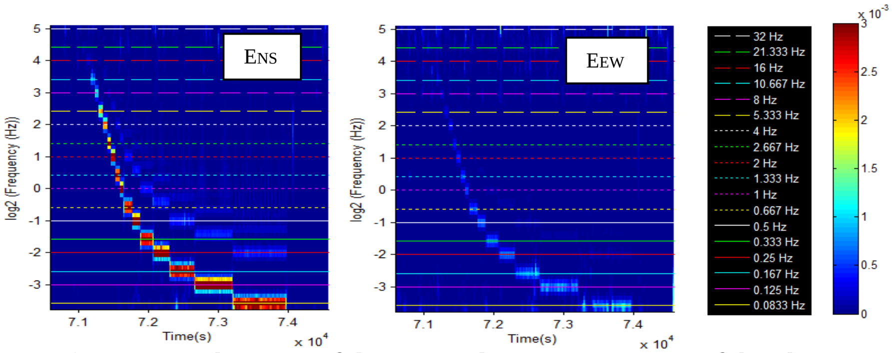

Figure 3*. Scalograms of the N-S and E-W components of the electric field recorded in site 17, during the emission of the N-S dipole source.*

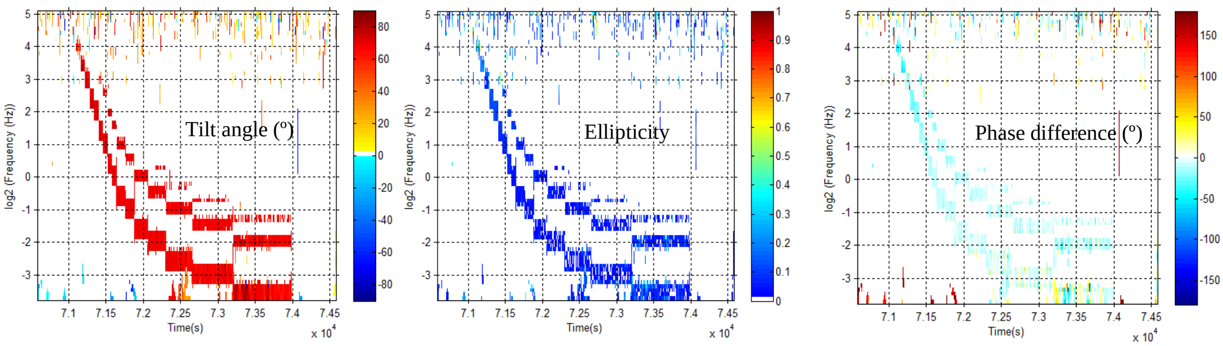

Figure 4*. Polarization attributes of the electric field recorded in site 17, during the emission of the NS dipole source.*

Conclusions

The developed code allows a successful analysis of signals with orthogonal components in the time-frequency domain, and provides a full description of their polarization attributes. The evaluation of these properties enables to identify cultural noise sources in MT time-series, and therefore improve the results obtained with this method.

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References

Diallo, M. S., Kulesh, M., Holschneider, M., Scherbaum, F. and Adler, F., 2006. Characterization of polarization attributes of seismic waves using continuous wavelet transforms, *Geophysics*, 71, 67-77.