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The effects of correlated noise on AMT impedance data

Zhimin-Xu¹²³, Cong-Zhou²³, Huicui-Xin⁴, Yuan-Yuan²³

¹ Institute of Geosciences and Info-Physics, Central South University, Changsha 410083;
² Key Laboratory of Metallogenic Prediction of Nonferrous Metals and Geological Environment Monitoring (Central South University), Ministry of Education, Changsha 410083;
³ Northwest research Institute of Engineering investigations and design, Xi’an 710003;
⁴ Shan Xi energy institute, XianYang, 700012.
E-mail : xuzhimindx@126.com

Abstract. The correlation noise can cause serious distortion of the electromagnetic impedance data of the natural source electromagnetic method, and thus cause the wrong inversion and interpretation results. The influence of correlation noise on impedance data is worth discussing. Firstly, we designed a simplified signal-noise model that contains the plane wave signal and correlation noise. Secondly, by changing the model separation between receiver and transmitter, signal intensity, noise duration and relative observation bearing, the distortion effects to the AMT impedance data is simulated for different noise source distance, azimuth and the related noise of different signal to noise ratio. The simulation results show that the intensity, distance and azimuth of the relative noise sources determine the amplitude, starting frequency and form of the distortion. The addition of multiple noise field sources makes the distortion of the curve more complex.

1. Introduction

To develop AMT detection in ore concentration area, there are many challenges. One of which is the influence of noise on data quality, especially the noise caused by electrified railway system and high tension line, transformer substation, and other related noise source, causing serious distortion of the impedance data, and errors of inversion and interpretation results[1-9]. It is normally considered that relevant noise on the influence of the impedance data conforms to "the law of the near field effect", which is within the distortion spectrum. Impedance apparent resistivity data increased as frequency decreased in the interval of the double logarithmic coordinate system with an angle of 45 °, while phase decreased and approached to zero. However, the issue of whether related noise would definitely cause distortion "near-field effect", other distortions, and the measured data with noise spectrum and other issues are still worth discussing. This paper simulates the influence of noise on AMT impedance data. First, the simplified noise-noise model of non-uniform plane wave signal and related noise is designed with multiple electric and magnetic dipole. Second, by changing the model, it is found that close distance, signal intensity, the noise length and relative parameters such as bearings, simulation of different noise source distance, azimuth and the related noise of different signal to noise ratio of AMT impedance data distortion effect.
2. Simulated data

2.1 Model noise model

Actual natural source form is complicated with various types, such as point source in the form of a transformer, towers, and etc. Line source in the form of dc railway power system, and ac high voltage wire, formed the complicated cultural environment and electromagnetic noise environment in the industrial areas. Nevertheless, these fields can be considered as superposition sufficient point-source effects. The simulation of signal-to-noise model could be established by appropriately fields simplified.

The simplified signal-to-noise model used in the simulation is shown in figure 1. Figure (a) represents the actual signal-to-noise model, the natural field source and the relevant noise field sources are distributed around point M. We observed horizontal electromagnetic field component that perpendicular at point M, based on the observation of electric dipole moment to set up horizontal rectangular coordinate system, and projected the natural source and noise source in the coordinate system. For any single source Si, you can break it down into Six and Siy in the coordinate system, and the response of Si to M can be treated as a superposition of Six with Siy. Therefore, figure (b) shows the simplified signal-to-noise (SNR) model, it is shown in figure (b) signal-to-noise ratio (SNR) of simplified model, the related noise source in different coordinates are distribution on the axis, natural source can be simplified as two sources, with infinite orthogonal coordinates distribution on the axis. Furthermore, to study the effect of single noise field sources, the simplified signal-noise model is shown in figure (c) when the single direction contains only single noise sources. For the convenience of simulation, the point source of the noise-nosing model in this paper is the earth level electric dipole or unearth vertical magnetic dipole.

Figure 1 signal-to-noise ratio (SNR) simulation model, in which the green original point represents the natural electromagnetic field source, red original point represents the relevant noise source of
electromagnetic field, M is the measuring point, the SrX, Sry represents simplified natural electromagnetic field source respectively, Snx, Sny represents simplified related noise source respectively.

2.2 The simulation results

2.2.1 The effect of noise intensity. According to the model shown in figure 1(c), the influence of the relative noise intensity is simulated by the magnetic dipole source. The value of fixed transceiver from the source, was calculated by the appropriate source of magnetic moment of an assignment. We calculated the value of different proportion natural source intensity and different related intensity noise intensity at different frequency, then we calculated the synthetic response and the corresponding Cagniard apparent resistivity, phase data. The conclusion is as following:

(1) when the relative noise magnetic field is much bigger than the natural noise magnetic field (Hcx > Hrx), the apparent resistivity curve rise with an angle of 45° by frequency in evenly spaced double logarithmic coordinate, phase tends to 0; within the 300 ~ 10Hz spectrum, the apparent resistivity and phase curves are distorted and show as the above characteristics.

(2) when the relative noise magnetic field is equal to the magnitude of the natural noise magnetic field, the distortion of the resistivity curve is not fixed angle, and the phase does not approach 0; 10 to 1 Hz frequency, noise related magnetic field is greater than the natural noise magnetic field (Hcx > Hrx), gradually, become less than the natural noise magnetic field (Hcx < Hrx), the apparent resistivity curve with the positive slope distortion to a negative slope distortion as the decrease of frequency, phase distortion value is changed from less than 45° to larger than 45°.

(3) when the relative noise magnetic field is far less than natural noise magnetic field (Hcx < Hrx), The distortion effects of apparent resistivity and phase curves is relatively small, The distortion of sensitive phase curve si more sensitive than apparent resistivity; 0.3 ~ 0.1 Hz, the resistivity data is close to normal and the phase curve is still distorted.

2.2.2 The influence of the relative noise source and the distance between the observation points. According to the model shown in figure 1(c), We employed the magnetic dipole source to simulate the effect of relative noise source and the distance between the observation points. Fix the incentive intensity and change the distance between relative noise source and the the observation point, and calculate and compare the synthetic response and the corresponding Cagniard apparent resistivity and phase data, we can reach the conclusion below:

The distance between the relative noise source and the observation point mainly affect the distorted starting frequency of the AMT impedance data. That is the shorter the distance, the higher the starting frequency of the distorted data; The phase data is more sensitive to the resistivity data, and the distorted starting frequency point is relatively higher. In addition, generally speaking, the closer the distance between noise source and the observation point is, the greater the intensity of the noise is. Thus, it would lead to a more significant distortion of the curve. Therefore, the smaller the distance between the relative noise source and the observation point, the greater the influence it has on the Cagniard apparent resistivity and phase data.

2.2.3 The influence of relative noise sources relative to the location of the observation. Regarding to the grounding electric dipoles related noise source, because the dipole moment has directions, and there are significant differences between the excitation of electromagnetic noise in the dipole moment in the axial and vertical direction, different observation directions and angles different and Cagniard apparent resistivity and distortion effect according to the phase of data, result in different forms of curve distortion. Yx direction distortion form conforms to the so-called "near-field effect" form, that is, as the apparent resistivity curve in the interval such as double logarithmic coordinate on frequency rises in 45° Angle, phase tends to approach 0. However, The aberrations in the xy direction do not conform to this pattern: the resistivity is leaning up and the phase leaning downward.

2.2.4 The effect of multiple related noise sources. When there are multiple correlation noise field sources, the distortion of the Cagniard resistivity and phase curve is more complex, usually the effects are the superposition of different single noise field sources. Distortion curve that contains two related
noise source is within 100 ~ 20 Hz frequency range. Due to the effect of a relative noise source which has relative small distance, apparent resistivity and phase curves show the "near-field effect" features, and frequency distortion starting point is high; for the frequency within 5 ~ 0.1 Hz, the effect of the other relative noise field which has relatively larger distance is more significant., apparent resistivity and phase curves show "near-field effect" characteristic again; Because the model is uniform and half space, it is reasonable to know that the distortion effect of the relative noise field source is lower. Due to electromagnetic fields for plural, The value of Cagniard apparent resistivity and phase data calculated by superposition of the field component may not be the same as many source fields component calculated by the linear superposition of the results respectively.

3. Conclusion

(1) the intensity of the relevant noise determines the distortion of the impedance data, the stronger the correlation noise, the lower the SNR, the worse the distortion. Furthermore, the noise frequencies associated with the noise sources determine the frequency range of the distortion data.

(2) related to noise source and the distance between the observation points determines the distortion of the impedance data starting frequency point, and because of the closer distance, the greater the noise intensity, resulting in the curve of the distortion amplitude is more significant; Overall, the closer the noise source is, the greater the impact.

(3) The direction of the related noise source mainly affects the distortion form of data curve, different observation directions from the same position, the same direction from different observation locations are likely to cause different distortion form; In general, always make the data curve distortion present "the law of the near field effect", namely the distortion curve of apparent resistivity data in interval slope equal to 1 in the double logarithmic coordinate system, phase data tends to 0; or more complex forms of distortion.

(4) contains multiple related noise sources, The distortion of Cagniard apparent resistivity and phase curves are complex, generally shown as the superposition of different single source noises.

(5) All above, phase data is more sensitive to relevant noise than to the resistivity data, in another word, the phase data is more susceptible to noise.

In this paper, the research results show that when the work area is noise, may cause the distortion of the measured curve of AMT, always leads to Cagniard apparent resistivity upward bias, phase downward bias. When relevant noise is occupied by the observed data, the distortion curve always shows the characteristics of significant "near-field effect", the noise can be determined by the characteristics of the curve; However, the noise can also cause the distortion curve presents more complicated forms, this kind of distortion and anomalies caused by underground medium are mutual coupled, the noise situation is difficult to judge from the aspects of curve shape, thus need to analyze time domain data form, spectrum, power spectrum data correlations and polarization direction of parameters.

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