P145 INTERPRETATION OF TEM SMALL-LOOP DATA

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Summary

The paper presents advances in the interpretation of the Arbitrary Impulse Method (AIM) data. The AIM is the well-known TEM method. The main features of the AIM are small size of sounding loops and the fully controlled current pulse using. Our key achievement is the quantitative interpretation of the AIM data that is in agreement with the results of VES investigation.

Introduction

The AIM was formed as the near-surface modification of TEM. The sphere of its application are: environmental and engineering geophysics, roads, dams and residential area investigations, voids, metallic objects and water content detection. The method was developed by the Laboratory of Electromagnetic Fields in collaboration with the “Luch” company, Novosibirsk.

The main ideas of the method are the full control of sounding impulse, small size of receiver and transmitter loops (2×3 m) and car-mounted equipment. In such conditions it becomes possible to study the upper part of the media as well as to increase the rate of profiling.

In previous paper [1] the results of qualitative AIM data imaging were described. The method was sensitive to voids, metallic objects and water contents. Until recently, it was impossible to advance AIM over the qualitative processing. It was caused by the complex influence of the apparatus to the transient response measured. A lot of problems are now solved.

Problems

The paper defines the electromagnetic field $\varepsilon(t)$ measured by the TEM receiver as a result of interactions of four components.

The first component is the transient response $\varepsilon_0(t)$ of the media to a sounding current pulse. This is our main interest. The mathematical simulation of this process is the standard numerical modeling based on the Maxwell equations.

The second component is the so-called primary field or the induction dependence of the transmitter to the receiver. The self-processes of the transmitter loop are long enough to disturb the $\varepsilon_0(t)$ measurement. Besides, the sounding pulse cannot be immediately switched off.

The third component of $\varepsilon(t)$ is the inertial processes of receiver loop.

The forth component is the electromagnetic noise.

In the ordinary TEM there is a long transient diapason that is free from the last three processes. It is not the same in the AIM case. Small loops are used so that at no times can the pure $\varepsilon_0(t)$ be detected. That is, the AIM is a mixture of the TEM and EM.

Thus, we need to know how either to put the noise and self-processes of loops into account, or to remove them from the measured electromagnetic field $\varepsilon(t)$.

Solutions

To process the very early transient response, the sounding current impulse have to be switched off very quickly and precisely. It is very difficult in the case of the step pulse. Moreover, the spectrum of the step pulse is the lack of high frequencies, and the dynamic range of response is large enough that leads to the complex system of amplifiers being used. There are two reasons why the sinusoidal current pulse was chosen for the first step in the AIM improvement. First, the level of signal measured becomes lower. Second, the numerical processing after 100-300 ns becomes possible.

The next problem to solve is the compensation system that delivers the main part of the noise and primary field.

At last we found how to calculate the self-processes of the receiver system that was represented as the electronic circuit.

The main characteristic of any electronic circuit is the unit-step response $h(t)$. If this function is known the electromagnetic field detected in the receiver can be written as the Duamel integral:

$$\varepsilon(t) = h(0)\varepsilon_0(t) + \int_0^t h'(t-\tau)\times\varepsilon_0(t)d\tau \text{ , (1)}$$

where $\varepsilon_0(t)$ is the media transient response. The shape of $h(t)$ was evaluated by modeling the processes in the circuit with distributed R-L-C parameters, which are close to parameters of the real system.

The results of $h(t)$ are shown in Fig.1. "Curve 1" is the simple modeling of the transient response result. "Curve 2" is the unit-step response $\varepsilon(t)/\varepsilon_0(t)$. "Curve 3" is the result of convolution (1). The form of "Curve 3" is very close to the form of field results.

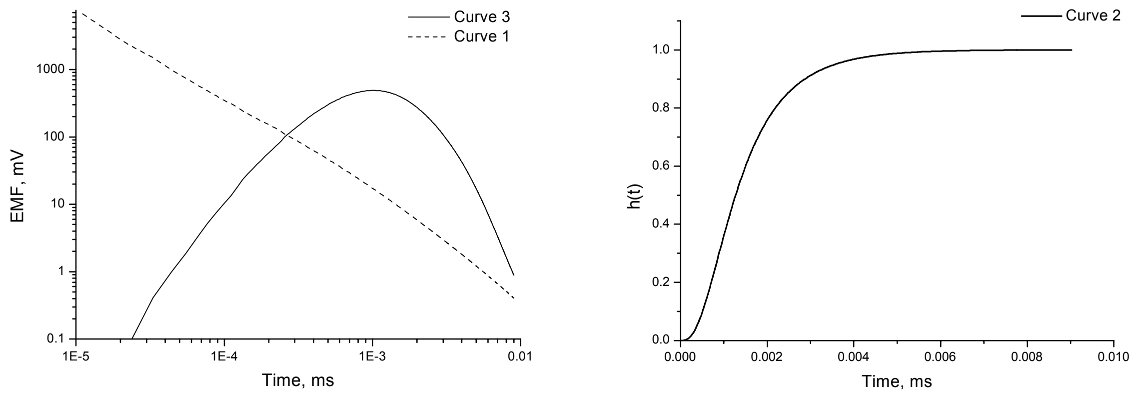

Fig.1

Actual characteristic of the receiver

Practically, the unit-step response of the receiver differs from the theoretically calculated one. This is because of the actual loops, amplifiers and conductors R-L-C value measuring difficulty. Thus, the correction of $h(t)$ by the field sounding is necessary.

For the purpose of this adjustment, a set of two different properties of the media soundings are carried out. The conductivity-dept section for those points obtained from the VES data interpretation. These geo-electrical models are represented in Fig.2. Function $h(t)$ specified for the "Model 1". The comparison of the field data ("Curve 1a") and the numerical simulation ("Curve 1b") is also shown in Fig.2.

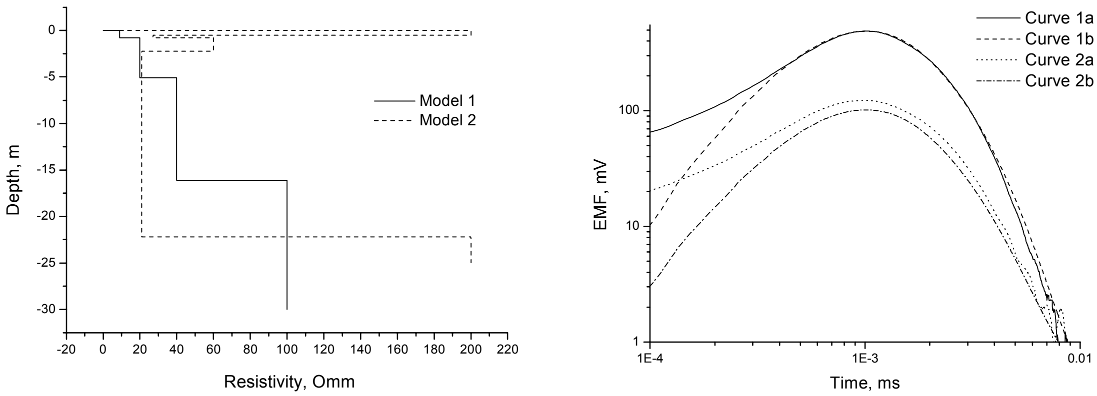

Fig.2

The same unit-step response function was applied for the "Model 2" response calculation. As shown, the computed electromagnetic field ("Curve 2b") does not perfectly agree with the measured one ("Curve 2a"). This may be caused by the uncertainty of the models or the media conductivity dependence of the self-parameters of the transmitter-receiver system. Another reason is not significant in our present case, unlike the first reason, which is associated with difference between the VES and the TEM conductivity definition.

Profiling

Finally, we present the interpretation of the AIM profiling. The white-black spectrum of the cross-section in Fig.3 represents the "difference electromagnetic field" values. They are computed as the difference between the profiling and the testing point sounding results. It is an example of the traditional near-surface electromagnetic imaging.

Fig.4 represents the apparent resistivity transformation of the same data.

Obviously, resistivities are much more representative. Moreover, the apparent depth can be calculated. The profiling was realized in the residential area. The metallic objects (the low resistivity areas are more close to white color), building basements (nonconducting areas are black) and heterogeneities of road dam are easy to recognize.

Note that the time of profiling is about 2 minutes.

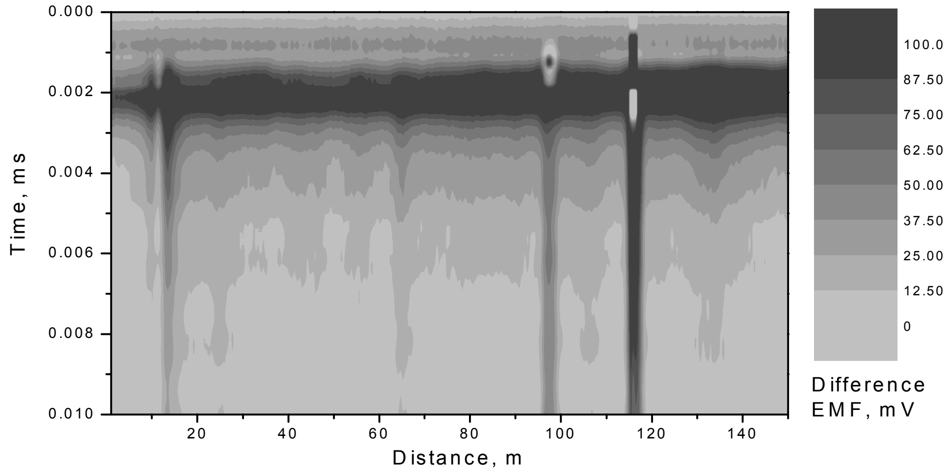

Fig.3

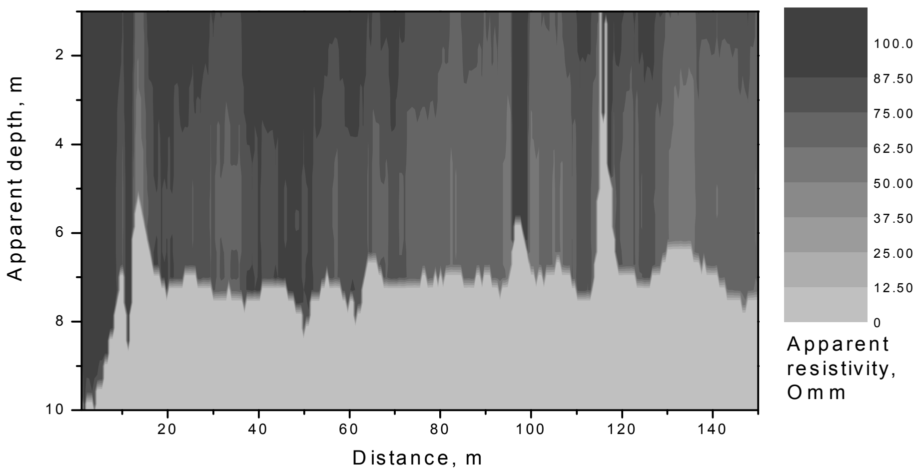

Fig.4

Conclusion

The results demonstrate the abilities of Arbitrary Impulse Method as a near-surface electromagnetic method.

The small-loop TEM data quantitative interpretation is presented.

The geological and engineering interpretation of data is presented as well as the different shape of the sounding current impulse.

References

1. The TEM arbitrary pulse equipment. 5th meeting on the EEGS-ES. September 6-9, 1999. Em6.