Study of Multiple Small-aperture TEM based on models Test

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SUMMARY

The optimal surveying configuration reformation of the Transient Electromagnetic Method (TEM) is more important for the purpose of improving detecting precision of the TEM soundings. Several popular TEM transmitter-receiver configurations, including long off-set TEM , coincident loop, large loop, and surface-borehole, have been successfully applied in the areas of engineering exploration, mineral investigation and theoretical study. Multi-transmitter electromagnetic surveys are widely used in remote-sensing and geophysical exploration. Multi-transmitter-multi-receiver surveys have been investigated in the situation of marine exploration. However, there are few reports on the study of multi-aperture TEM configurations. In some cases, where the scale length of survey field is small, such as in tunnel survey and in old tomb investigation, we can not lay large enough loop so that a relatively high power TEM transmitter configuration is used to detect longer distance. In this short note, we introduce a TEM array with multi-aperture survey configuration in which a large aperture single transmitter loop was substituted by several relative small aperture TEM arrays. Then we study the primary and secondary TEM fields to find a coherent of multi-source TEM field. Furthermore a coherent stack of multiple transmitter sources can improve the intensities of the primary and secondary field.

Keyword: transient electromagnetic；multi-loop source；model test

Configuration and Laboratory Tests

A conductive copper plate (32 cm×24 cm×2 mm) using a single and a multi aperture transmitter configuration was excited, and the primary and secondary field responses were measured in term of magnitude and alignment.

The single large-loop transmitter source consists of a square loop (20 cm x 20 cm with 10 turns); while the multi-aperture array consists of four smaller square loops (10 cm x 10 cm with 10 turns each) (see Figure 1). In each small aperture transmitter source, the current (with magnitude of 10 A) direction was arranged in clockwise. The transmitting power was 12V and 50 soundings were stacked with a 25Hz transmitting frequency during primary and secondary field survey. The measurements were made on a square receiver loop (10 cm x 10 cm with 10 turns). During the survey, receiver moved along diagonal in horizontal plane or vertical direction in depth. In Figure1a, the current excited in each small-aperture loop is clockwise, so that the corresponding magnetic field is always in the same direction, which is equal to the single-aperture transmitter

Fig.2 is the secondary field curves of the single (or standard) and the multi-aperture source without conductance model, where the vertical distance is 6 cm

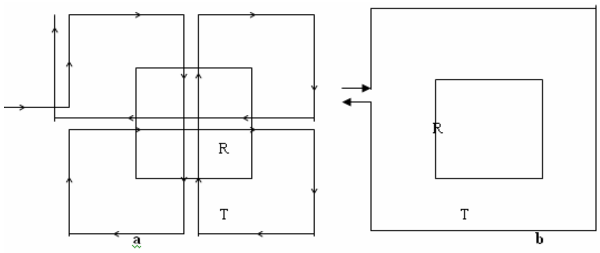

Fig. 1 Multi-aperture transmitter configuration (a: a special transmitter configuration formed by four small loops; b: is a larger square loop configuration).

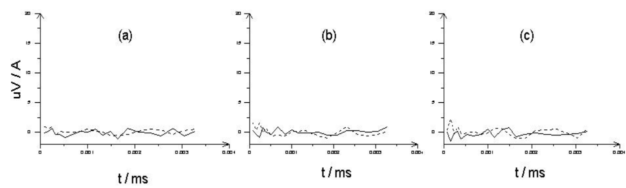

Fig. 2 Secondary field curves of standard and multi-aperture source without conductance plate (in figure lines: results with standard source; dash lines: results with multi-aperture).

(diagram a), 8 cm (diagram b) and 10 cm (diagram c). From Figure 2 it is clear that the two curves almost agree with a small discrepancy when the conductance plate non-existing. So we can ignore the difference of self-transient of two configurations.

The purpose of measuring the primary field is to identify and characterize coherent properties of the multi-aperture field. We generated the primary fields through both the single large-aperture loop and the multiple small-aperture transmitter loops, and measured its strength as a function of horizontal position. The field is measured along diagonal direction in horizontal plane using a roaming receive loop at different vertical displacements relative to the transmitter.

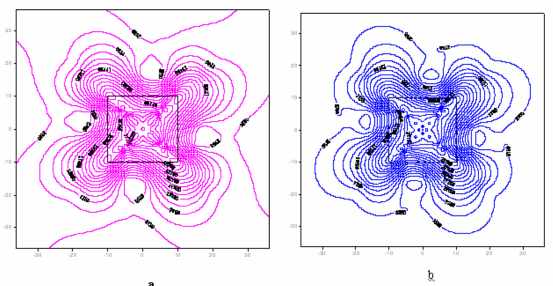

Fig 3 Multi-aperture (a) and single-loop (b) primary field contours at a vertical distance of 6cm from the transmitter. The location of the transmitter loop is illustrated by a square.

Figures 3a and 3b show the primary field contour maps, at 6 cm vertical distance relative to the transmitter, excited by the single large-loop source (diagram a) and by the multiple small-aperture array source (diagram b). In Figure 3b it is obvious that in the situation of the multiple small-aperture array configurations the primary field value at the center is smaller than along the diagonal lines. The maximum value occurs approximately near the center of the individual loops that make up the multi-aperture antenna. While in the situation of the single large-aperture configuration the primary field value (64260uV/a) in the center of loop is smaller than that of the value (72191uV/A) in the center of the loop generated by the multiple small-aperture arrays. The latter is approximately 10.9% larger than that of the former.

Fig.4 shows the curves of the field strengths with varied survey points under two different configurations. These results demonstrate that the multiple small-aperture sources can generate a more powerful primary magnetic field. Furthermore, the multiple small-aperture transmitter configurations can create a coherent single primary field as the single large-aperture transmitter configuration does.

The purpose of measuring the secondary field is to quantify the improved ability of the multiple small-aperture array sources to detect a low resistivity body compared to the single large-aperture source. We employed a copper plate (32 cm×24 cm×2 mm) to simulate a low resistivity body. We used the single large-loop and the multiple small-aperture transmitter sources to initiate electrical currents in the copper-plate at the different buried depths between 0cm and 16 cm with 2 cm interval. The results are shown in Figure 5. The transmitting power was 12V, the transmitting frequency is 25 Hz and the current is 10A. The time delay after switching off the two configurations is 0.087 ms, and the survey time range is from 0.087 ms to 7.19 ms.

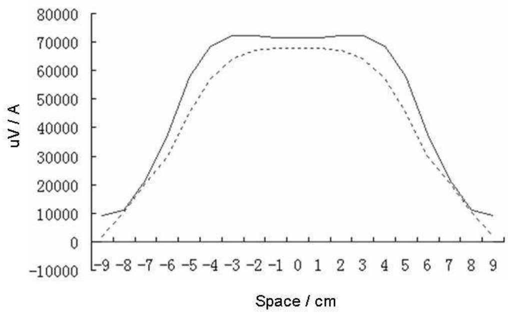

Fig. 4 Multi-aperture and single-aperture primary field curve of different survey point at a vertical distance of 6cm from the transmitter (in figure line: primary field with standard source and dashed line: primary field with multi-aperture).

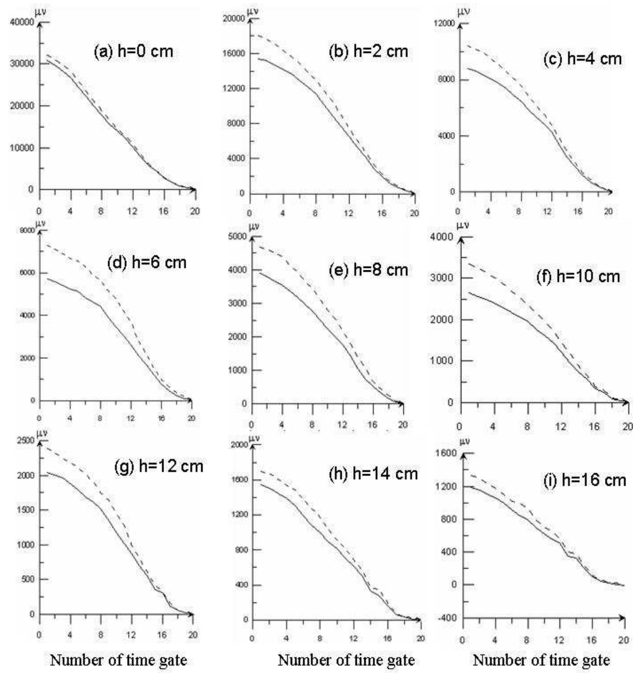

Fig. 5 Secondary field voltage decay curves for conducting copper plate at different buried depths ranging from 0 cm to 16 cm (in figure dashed line: multi-aperture system response and line: single-aperture system response).

These plots (Fig. 5) illustrate that for the same buried depth, the response from the multiple small-aperture transmitter system is greater than that of the single large-aperture transmitter system. When the buried depth is increased from 0 cm to 6 cm the response difference with two systems is increased with the buried depth and become the largest at the depth of 6 cm (Figs. 5a-d);

hereafter the response difference is decreased with the buried depth from 6 cm to 16 cm.

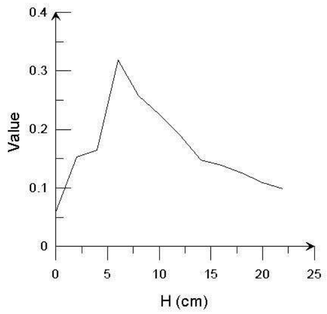

Fig. 6 Curve of relative difference value between multi-aperture loop and single-aperture loop response to a conductive copper plate at various buried depths.

In order to quantify the relationship between the copper plate response of the multiple small-aperture loops and the single large-aperture loop, we calculate the relative difference, defined as , where and are the voltage for the multiple small-aperture loops and for the single large-aperture loop, respectively. The above relative values for two systems with varied buried depths are shown in Figure 6, which coincides with the former conclusion that is the largest value was observed at the buried depth of 6 cm, and from that buried depth the relative values decreased both in positive (from 6 cm to 22 cm) or negative (from 6 cm to 0 cm) directions.

Discussion

We have demonstrated that the magnetic field generalized by the multiple small-aperture array sources is greater than that of the magnetic field excited by the single large-aperture loop so that we can define the relationship as below:

$$H_m = H_s + \Delta H \quad (1)$$

where is the magnetic field difference. We have compared the differences between the multiple small-aperture sources and the single large-aperture source configurations for both the primary and the secondary fields with different offsets from the transmitter in horizontal plane or buried depth in vertical extent, respectively. The results are summarized in Table 1.

We can see from Table 1 that the relative difference value generalized with two different systems mainly distribute around the range of 0.15~0.31. Basing on the statistic data of table 1, we can induce the following equation

$$H_m^2 = H_s^2 + \Delta H_2 = H_s^2 + 31\% H_s^2 \quad (2)$$

The above relation indicates that the secondary field response can be improved by nearly 31% when switching from the single large-aperture loop to the multiple small-aperture array sources.

Table1 relative difference between secondary response of the multi-aperture and single-aperture loop to the copper plate object.

Buried depth (cm)	Relative difference
0	0.058
2	0.1532
4	0.165
6	0.318
8	0.257
10	0.224
12	0.19
14	0.147
16	0.138
18	0.126
20	0.108
22	0.098

Conclusion

This short note puts forward the idea of using the multiple small-aperture electropults to improve intensity of radiation field from an array theory. It compares and analyzes the plenty of experiment data of the primary and the secondary fields generalized directing from different models and demonstrates that the multiple small-aperture TEM radiation field exists interference superpose phenomenon similar to high-frequency electromagnetic wave. It brings forward conception of similar interference superpose. In addition, it obtains experiment formulas of superpose about the multiple small-aperture TEM radiation field by means of counting a lot of experiment data.

We understand from the data and curve that the multiple small-aperture loop can change the direction of magnetic field (no evidence shows that). In the best condition, the multiple small-aperture transmitter systems can gain secondary field response more than 31% in magnitude strengh when compared with a single large-aperture loop system.

The study demonstrate that employing the multiple small-aperture array transmitters can reform the direction of scatter field, concentrate magnetic field of scatter field to the center of transmitter loop, as a result, enlarge the intensity of primary field in the center of loop. It gives us prospective future to apply this theory and technology to improve the field strength of TEM data.

Acknowledgments

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