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Resistivity modelling and inversion of square array for archaeological investigations

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INTRODUCTION

Electrical resistivity tomography (ERT) investigations are a growing field due to adequate data acquisition of subsurface resistivity distribution regarding the sufficient contrast between the buried archaeological structures and covering soil (e.g., Papadopoulos *et al.* 2006; Drahor *et al.* 2008). In resistivity surveys, the electrode configuration is a crucial factor in the identification of the apparent resistivities of the subsurface. Apparent resistivities can also be affected by the dimension and depth of the target, moisture content of the soil, bedrock position and climatic conditions (Berge and Drahor 2011). Therefore, various electrode configurations can be used in the field to determine the subsurface archaeological features considering their resolution capability.

Presented in this study is a resistivity modelling and inversion of the square array that was firstly described by Habberjam and Watkins (1967). Application of this array in archaeological prospection is also given by Tsokas *et al.* (1997) and Aspinall and Saunders (2005). However, two- and three-dimensional inversions of the square array data were not sufficiently examined except for Papadopoulos *et al.* (2009). They present the results of 3D inversion for ARP configuration, which is an acquisition system developed from the square array (Dabas 2009). The present study aims to investigate the efficiency of the square array on some synthetic archaeological models by comparing with commonly used arrays (Wenner and dipole–dipole).

METHOD

Modelling studies are an important tool for simulating buried objects. Thus, the case similar to real position of subterranean structures could easily be investigated by modelling studies before the archaeological application. In this study, the simulation of the square array is carried out by using three-dimensional forward modelling and an inversion algorithm.

Forward modelling was achieved by the finite-difference solution of Poisson's equation. Thus, the apparent resistivities for various electrode configurations are calculated by using a mesh system constituted from a number of homogeneous cells. In the inversion, observed apparent resistivities are used to obtain a subsurface model in an iterative manner. A parameter update, which is

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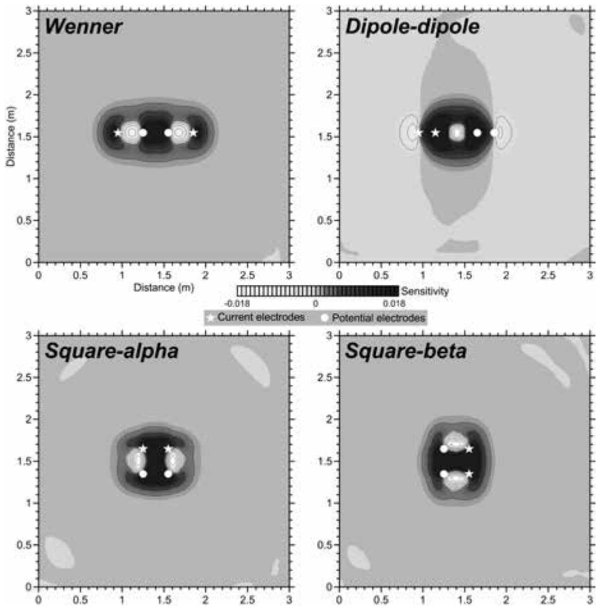

Fig. 1. Sensitivity depth slices of square-alpha, square-beta, Wenner and dipole–dipole arrays for a homogeneous earth model that has a resistivity value of 100 ohm-m. Depth is set to 0.25 m. Stars and circles indicate current and potential electrodes, respectively

necessary to optimize the subsurface model, is solved in iterations by minimizing the difference between observed and calculated data. A Matlab code implemented by Berge (2011) is used for this purpose. Computation time of this three-dimensional smoothness-constrained inversion routine is reduced by using the parallel computation facility of the Matlab software.

RESULTS

In order to define the resolution capability of the square array, the sensitivity of this array is first calculated for a homogeneous medium. In Figure 1, sensitivity depth slices of square-alpha and square-beta arrays are given together with Wenner and dipole–dipole configurations. Depth value is set to 0.25 m in these slices. It is seen that the sensitivity values of the square arrays is enough in comparison with the Wenner and dipole–dipole. The maximum value is on the centre of the configuration and the result is that the target will give a reasonable high anomaly when it is located in the middle of the array. This encouraged us to investigate the efficiency of the square array for inversion results.

For this purpose, a simple idealized model, which simulates a highly resistive (1000 ohm-m) structure, such as a wall in a homogeneous medium (100 ohm-m), is generated to explore the inversion result of the square array (Fig. 2a). The depth of the target is 0.5 m and its dimension is 2 x 2 x 1 m. To optimize the computation time for the inversion process, the modelling area dimensions are fixed to 20 x 10 x 5 m and cell dimensions are 0.5 m in

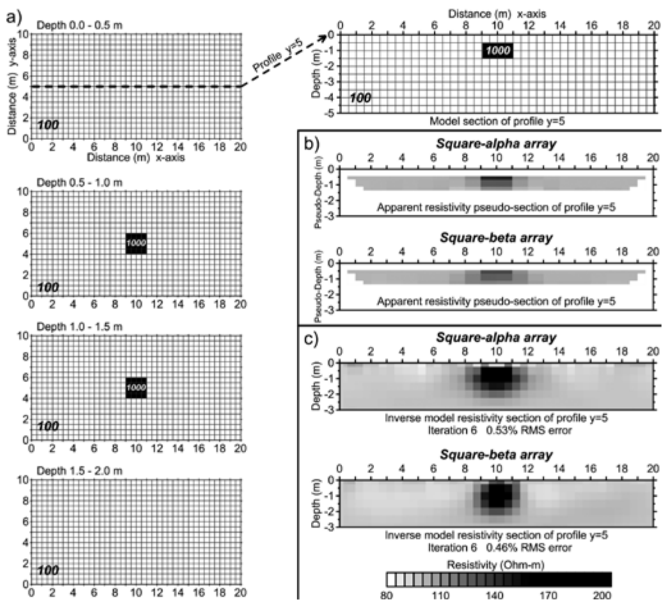

Fig. 2. a) Model section used to simulate the resistive target (1000 ohm-m). Background resistivity is 100 ohm-m. Black dashed line marks the measuring profile traversed through the target (profile y=5). b) Apparent resistivity pseudo-sections and c) inverse model sections of square-alpha and square-beta arrays derived from the profile y=5

each direction. In total, five measuring profiles (y=3, 4, 5, 6 and 7) were designated with an electrode spacing of a=1 m. Used configurations have a maximum of three investigation depths, where the maximum separation is 1a to 3a for square and Wenner arrays and n=1, 2, 3 for the dipole–dipole array, respectively. Synthetic data is corrupted with ±0.02 mV/V random noise. Afterwards, synthetic data of the overall arrays is processed by using the three-dimensional inversion routine. Maximum iteration is fixed to six.

Apparent resistivity pseudo-sections derived from square-alpha and square-beta arrays over the profile (y=5) traversed through the target are given in Fig. 2b. Pseudo-depth is calculated by using median depth of investigation value of the square array. The arrays present high apparent resistivity values (between 131 to 144 ohm-m for square-beta and square-alpha arrays, respectively) around the target as expected.

In Fig. 2c, three-dimensional inversion results of the square arrays are presented as 2D model sections. Considerably high resistivities are produced over the target. But, the different resistivity distributions obtained from the square arrays are remarkable. The target dimensions can be estimated from these inverse model sections.

In order to compare square arrays with Wenner and dipole–dipole configurations, depth slices of the inversion results are plotted up to 1.5–2.0 m depths (Fig. 3). Results show that the target location is defined in overall arrays. However, the bottom of the target is not accurately

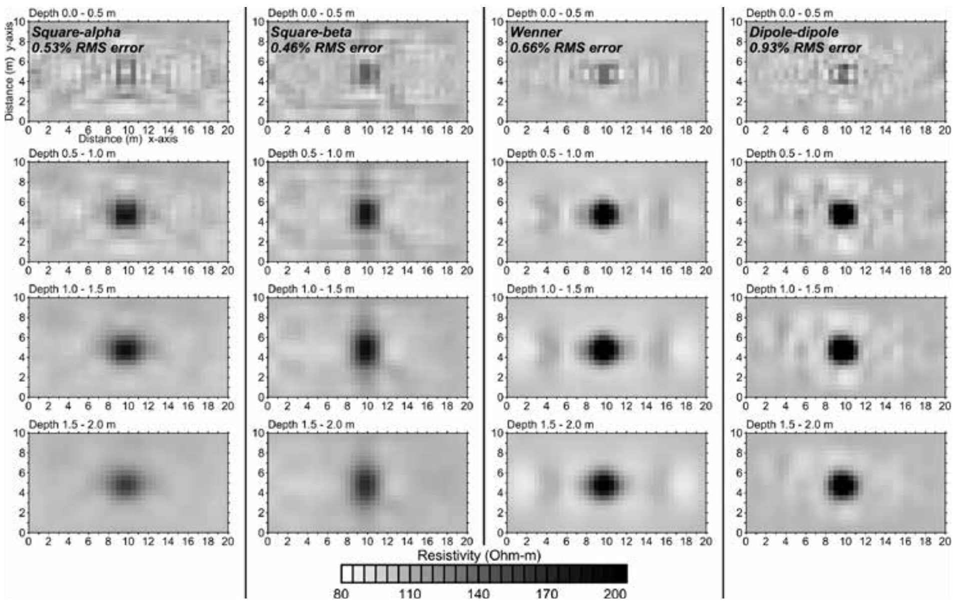

Fig. 3. Inverse model depth slices of square-alpha, square-beta, Wenner and dipole–dipole arrays over a prismatic resistive target (1000 ohm-m). Background resistivity is 100 ohm-m

determined due to the lack of more investigation depths for the used arrays. Inversion of the square arrays generates moderately lesser resistivity values around the target in comparison with Wenner and dipole–dipole configurations. In addition, the square arrays present different resistivity distributions around the target than is expected from their sensitivity maps.

CONCLUSIONS

In this study, the modelling and inversion results of the square-alpha and square-beta arrays are examined for a model based on the archaeological target. In comparison with the presentation of apparent resistivity pseudo-sections, the inversion results are more accurate to resolve the target location as a means of resistivity value and dimensions of the target. However, a comparative study between used electrode arrays indicates that the square array gave partially low resistivity values around the target.

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