# A NEW JOINT INVERSION ALGORITHM FOR CROSS-HOLE RESISTIVITY DATA

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**SUMMARY**

We have developed a new inversion algorithm for hole-to-hole and single hole electrode arrays. Inversion result of various electrode arrays are compared according to resolution of the model with the developed algorithms. It is showed that each hole-to-hole arrays has different advantage. To combine these advantage, we have suggested joint inversion of two- and three-electrode hole-to-hole arrays data sets. The suggested algorithm tested for synthetic data.

**Keywords:** Joint inversion, resistivity tomography, 2D, cross-hole, single hole

## INTRODUCTION

Last decades there have been important growth in the resistivity tomography method. Some studies in literature of the resistivity tomography refer to the cross and single hole measurement capabilities(Shima and Satio 1988; Daily ve Owen,1991; Sasaki 1992; Shima 1992; Zhou and Greenhalgh 2000; Torres-Verdin 2000; Goes and Meekes 2004; Danielsen and Dahlin, 2010; Leontarakis and Apostopoulos, 2012). Resistivity tomography method has proven useful for; hydro-geophysics studies (LaBrecque et all,1996), geotechnical and environmental investigations (Goes and Meekes, 2004; Degranche and Kaufmann, 2004) , mining surveys(Spitzer and Chouteau, 2003), agricultural investigations (Hagrey and Petersen, 2011) and archaeological studies (Leontarakis and Apostolpoulos, 2013).

In this study, a new resistivity tomography algorithm is offered. We used finite difference discretization (Dey and Morisson 1979) to solve Poisson equation and a smoothness-constrained least-squares approach is used in inversion part of the algorithm (Tikhonov et.al. 1995; Candansayar, 2008).

The resolution of cross-hole and single hole surveys depends on several factors (Sasaki 1992; Hagrey S. A. A., 2011; Leontarakis and Apostolopoulos, 2012). One of the most important factor of inversion result is electrode array. In this study, we compared resolving capability of inversion results various hole-to-hole and single hole electrode arrays. To combine each hole-to-hole arrays, it is suggested to use joint inversion of three and four electrode hole-to-hole and single hole arrays.

## 2D INVERSION OF HOLE TO HOLE RESISTIVTY DATA

The algorithm was developed in MATLAB programming language. Individual and joint inversion of the cross-hole, surface-to-hole and single hole measurements are possible with this algorithm. In this study, we offer joint inversion of the different cross-hole electrode arrays. Inversion and modeling of all electrode arrays can be done with prepared a protocol file.

If same electrode pairs(current or potential) are in the same hole, geometric factor will be changed large scale and will have very big values. Therefore, the measure of potential differences will be very small. These values may be smaller than the minimum measureable voltage of used resistivity meter.

The distance between holes and hole length ratio is an important factor for resolution of the target area (LaBrecqueetal.,1996; Demirel and Candansayar 2013). To produce adequate image resolution in hole-to-hole survey, the distance between the boreholes should be smaller than half length of the borehole depths.

For a 100 ohm-m homogenous model, 32 (each hole includes 16 electrodes) electrodes were used with the inter-electrode distance of 1m.The synthetic data was calculated for two holes with the inter-hole distance 6 m. For the four electrode borehole arrays, the number of data, maximum and minimum geometric factor values and also minimum potential values ($\Delta V_{MN}$) were showed in Table 1. In Table 2, number of data, maximum geometric factor, minimum geometric factor and minimum potential values($\Delta V_{MN}$) with 1000m geometric factor limit are showed. The data which has greater than 1000 m geometric factor value were removed in AB-MN array. In this case, number of data was decreased from 568 to 25. It means that if distance between holes increased, data signal will be decreased for AB-MN array. The same situation is also possible for A-MN / AM-N and AB-M / A-BM arrays.

Each array has its own signal contribution section. Signal contribution sections can be used to estimate distance of investigations affects of different electrode arrays (negative and positive contribution sections) and distance of investigation between holes (Demirel and Candansayar 2013).

In Fig. 1, one meter separated 20 electrodes were used in each boreholes and the distance between the holes is taken as 10 meter. There are two bodies with 500 Ohm-m resistivity and a body with 15 Ohm-m resistivity buried in 75 ohm-m homogenous resistivity medium. The resistive bodies dimensions are 3x3m and 2x3m and conductive body dimension is 4x4m. These three bodies are buried at different depth. The synthetic data were calculated for cross-hole and single hole three- and four-electrode arrays (AM-BN, AB-MN, BAMN, A-MN and ABM-N) and the %2 Gaussian noise is added to the data before inversion.

The inversion result of AMN, ABM and A-BMN arrays are shown Fig. 2. a, b and c, respectively. The joint inversion result is also represented in Fig. 2 (d).

The resolution of the area between holes will be decreased if distance between the holes is increased. In this situation, AM-BN array which produce strength and positive direction signal can be added to joint inversion process for better solutions.

Table 3. including RMS(%),number of data and iteration value for AMN, ABM, A-BMN and joint inversion.

**Table 1.** Compared with four electrodes arrays of cross-hole and single hole arrays

| Array | N.of data | Max. K. (m) | Min. K. (m) | $\Delta V_{MN}$ |
|---|---|---|---|---|
| **AM-BN** | 889 | 145 | 5.9 | 0.68 |
| **AB-MN** | 568 | 1341971 | 454 | 1.218e-04 |
| **BAMN** | 460 | 38772 | 11.86 | 0.02 |

**Table 2.** Compared with four electrodes arrays of cross-hole and single hole arrays with geometric factor(1000m) limit

| Array | N.of data | Max. K. (m) | Min.K. (m) | Min. $\Delta V_{MN}$ |
|---|---|---|---|---|
| **AM-BN** | 889 | 145 | 5.9 | 0.68 |
| **AB-MN** | 25 | 978 | 454 | 0.09 |
| **BAMN** | 272 | 989 | 11.86 | 0.01 |

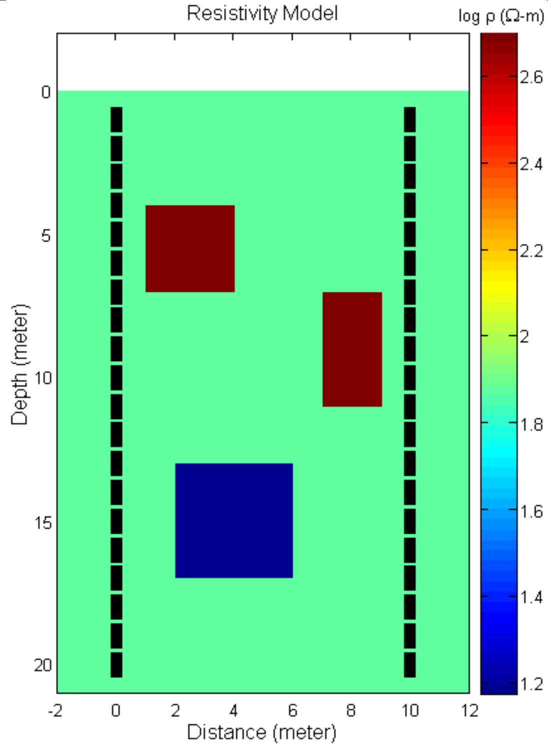


**Figure 1.** 2D resistivity model

**Table 3.** RMS(%), number of data and iteration value of inversion results

| Array | N.of data | RMS(%) | N. of Iteration |
|---|---|---|---|
| **AMN** | 1188 | 1.16 | 5 |
| **ABM** | 888 | 1.25 | 5 |
| **A-BMN** | 1114 | 1.22 | 4 |
| **Joint** | 3190 | 1.14 | 5 |

The boundary and resistivity of the buried structures are resolved better with the joint inversion of three- and four-electorde arrays than the individual inversion of each array if the estimated model compared with the real model.

## CONCLUSION

We suggested joint inversion of different data sets collected by using single hole and cross-hole arrays. Synthetic data inversion showed that, joint inversion of different arrays data set gives better result than the individual inversion of each arrays data set if one compare with the real model.

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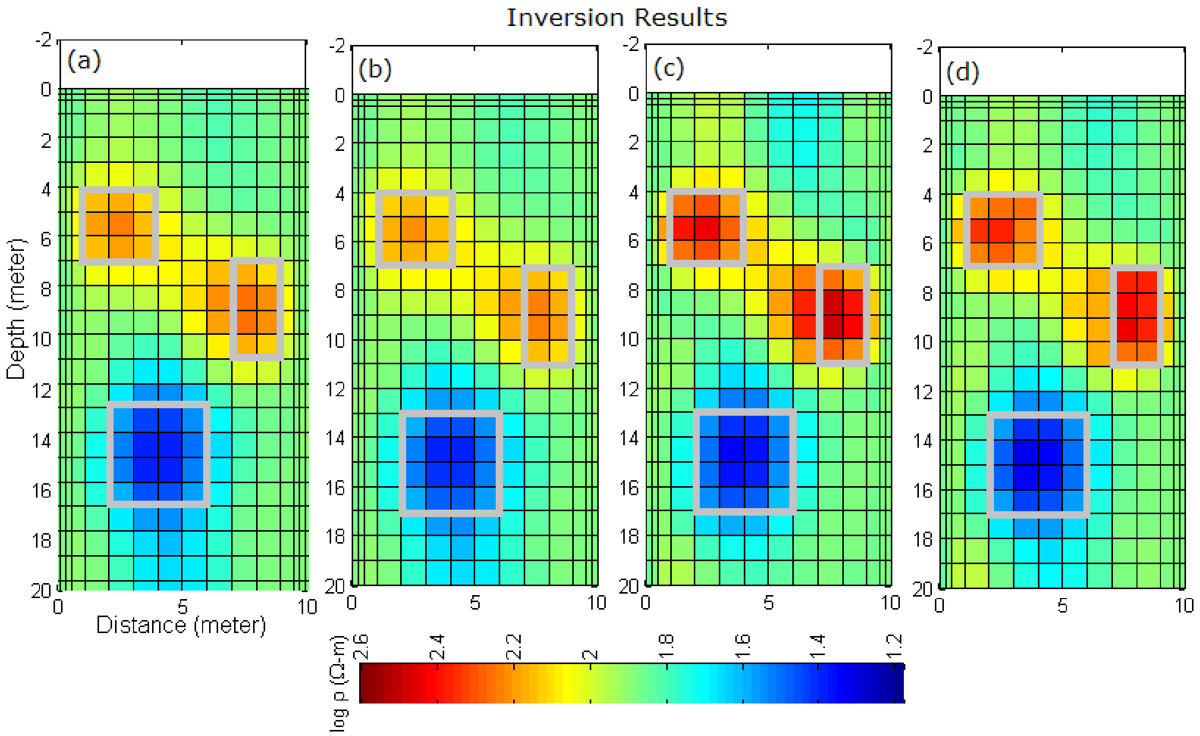


**Figure 2.** Inversion results of (a) AMN array, (b) ABM array, (c) A-BMN array and (d) joint inversion of all arrays data sets