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Introduction to the Advanced Multi-electrode Electrical Sounding Method

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Abstract: The Improved Multi-electrode Electrical Sounding method proposed by us in 2010 is a result of the research which is integrated with the reasonable private pre-eminent of the Multi-electrode Electrical Sounding and the Improved Electrical Sounding methods proposed since 2001. However, this method has just stopped in the investigation, analysis of 1D data. The article shall present the results reached after research process, that is introduction of the Advanced Multi-electrode Electrical Sounding method applied for the investigation and analysis of 2D data on the basis of using the SuperSting R8/IP system with 56 take-out and self-built software combined with EarthImager or Res2D software.

Keywords: Multi-electrode Electrical Sounding, electrode array, controlling file.

1. Rationale

We proposed successfully a new method system contributing and supplementing to make more varied for the system of Electrical Sounding methods, those are the Improved Electrical Sounding method - IES): including the Improved Resistivity Sounding methods - IRS and the Improved Induced-Polarization methods - IIP. These methods have released in many previous article [1- 5].

The Multi-electrode Resistivity Sounding method – MRS or called as the Multi-electrode Resistivity Imaging method - MRI [6] with the measurement process in the field, the processing and the analysis which are different from the traditional 1D methods. Simultaneously, they are also different from the proposed IES method.

However, this method has got advantages such as: measure continuously and collect the data on the whole line, the processing result performing even for the resistivity or the induced-polarization section.

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We also propose the Improved Multi-electrode Electrical Sounding method – IMES [7, 8] with the use of the improved electrode array but set up controlling file the measurement process as the Traditional Multi-electrode Electrical Sounding method and apply effectively in a certain way, it has got a lot of significant preeminent features. However, it also just stop in completion of 1D investigation.

In order to take advantage of the reasonable equipments optimally and plan to make the Multi-electrode Electrical Sounding method really more effective in environmental research, we have studied, developed and composed the preeminent features of MRS methods and IES methods for creating the Advanced Multi-electrode Electrical Sounding method - AMES.

2. Set up AMES method

2.1. Set up the Advanced Multi-electrode array

As we know, with the improved electrode arrays (1D), it shall not only keep all advantages, but also recover disadvantages of the previous differential Electrical Sounding methods. The improved electrode arrays shall completely be similar to the traditional ones (only differ in the size and the electrode array coefficient, so we shall measure overlaply at all sizes, except 2 sizes at first and last, especially to an electrode array distance, the position of emitter electrodes shall conincide with the position of precious collecting electrodes), simultaneously they have used the princible of reciprocity in electrical sounding to arrange the inside couple of emitter electrodes to shorten the emitter wire, to simple construction and to reduce cost for mesurement works, at the same time, it shall prevent electrical leakage and secure labor safety. In other words, the improved electrode arrays have got optimums only using a type of electrode array at each investigation point, minimize the measurements while we have still got the information to different types of curve after processing through the simple algebraic transformations, so the information collected will increased many times.

As for the multi-electrode array (2D), the electrodes shall be plugged on the line at the same time, so we shall not need to move many times as the 1D electrode arrays; we could measure simultaneously with many different electrode arrays; the distance of electrode array is equal-spaced, so the collected data shall also be at the more equal-spaced levels of depth increasing the environmental detail more when investigating deeply as compared with traditional electrode array increasing according to log coefficient.

From such comments, our objective is to set up a advanced multi-electrode array (abbreviated as MC multi-electrode array) in order to develop and to compose the optimums of traditional multi-electrode array (2D) and 1D improved electrode arrays.

First of all, we must perform transformation from the 1D improved electrode array with the unequal-spaced distance of electrode array to the electrode array with the equal-space distance of 1D electrode array in order to assemble into the MC multi-electrode array (2D).

We could see that with the improved electrode array, for each time to generation of AB, we shall collect 2 potential difference values M_1N_1 and M_2N_2; with the general rule to different measurements, there are always M_1N_1/AB and M_2N_2/AB that is a constant value (Table 1).

Table1. The improved symmetric electrode array

AB/2	MN/2	MN/AB
0,5	2,8	5,6
0,5	4,0	8
0,7	4,0	5,7
0,7	5,6	8
1,0	5,6	5,6
1,0	8,0	8

From table 1 we can see: $M_1N_1/AB = 5,6$ and $M_2N_2/AB = 8$. Thus, with the improved electrode array increased AB or MN, MN/AB shall always be constant, although the distance of electrode array increases according to the log rate (unequal-spaced). The multi-electrode array is one measuring simultaneously with many different electrode arrays because the file shall control measurement process in which the electrodes could change flexibly and constantly according to the user's objectives; measure constantly the depth point with the distance of electrode array increasing according to the rate which is always the natural number (the distance of electrode array is equal-spaced).

In order to compose such advantages, we shall propose the MC multi-electrode array with the equal-spaced distance, with the first AB measurement, $M_1N_1/AB = a$, and $M_2N_2/AB = b$ (b>a). In the second measurement time, the AB electrodes shall increase and replace into the M_1N_1 electrodes, and the M_1N_1 shall replace into the previous M_2N_2. With the n measurement time, AB shall be in the position of the $M_{n-1}N_{n-1}$ electrodes, the M_1N_1 shall be in the position of the M_nN_n. Ahead, we shall select 2 electrode arrays that satisfy such conditions as follows:

The electrode array 1:	The electrode array 2:
$M_1N_1/AB = 3$	$M_1N_1/AB = 5$
$M_2N_2/AB = 9$	$M_2N_2/AB = 15$

Therefore, the MC multi-electrode array shall get enough characteristics of the 1D improved electrode array and the traditional multi-electrode array (2D) as mentioned above.

For example, with the electrode array 1, we shall arrange the symmetric electrode array as follows:

MA=AB=BN = na.

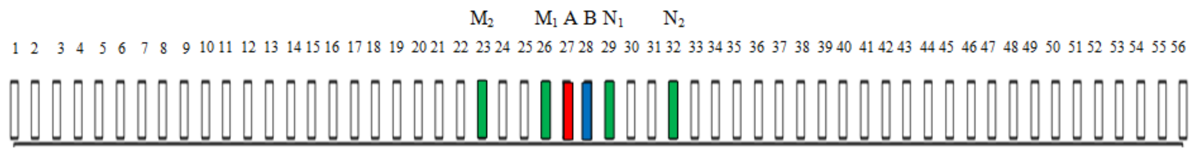
MA=4AB=BN=4na (extend receive)

MA=AB=BN = 3na (extend transmit)

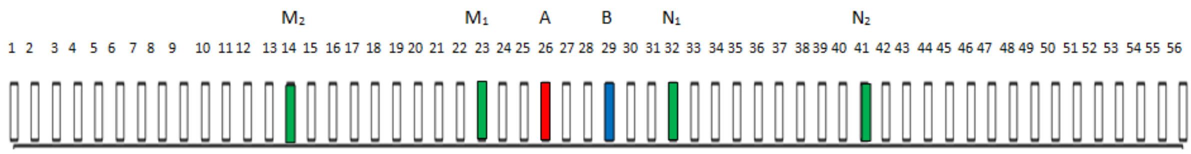
in which: a is the distance between measurement electrodes;

n is the n measurement time.

Thus, the MC symmetric multi-electrode array with the distance of first AB (in the position 27 and 28), we will have 2 measurement times with 2 MN distances (M_1N_1 in the position 26, 29 and M_2N_2 in the position 23, 32) that could be presented as the following diagram:



After that, we shall extend AB (in the position 26 and 29), we will get 2 measurement times with 2 MN distances (M_1N_1 in the position 23, 32 and M_2N_2 in the position 14, 41) that could be presented as the following diagram:



On this basis, we carry out connecting, arranging the electrodes so that we can get the MC multi-electrode array based on the principle of connecting electrode arrays measuring such private depth points from the beginning to the last line. In this article, we shall carry out building the MC multi-electrode array with 56 electrodes which are suitable for the reasonable equipment.

2.2. Introduction of the process of investigation, collection and processing data to the Advanced Multi-electrode Electrical Sounding method.

In reality, the process of investigationg, collection and processing the data to the AMES method similar to the Traditional Multi-electrode Electrical Sounding method [7]. It shall only differ in the arrangement of electrodes in order to create the MC multi-electrode arrays with the new coefficients of such electrode array; differ in the distance of electrode in measurement process; differ in extending the distance of emitter electrode and collecting one, the values collected for each certain AB, differ in processing the data. All of these are the foundation for building and presented in the file controlling the automatic measurement process of method.

The AMES method shall use the SuperSting R8/IP [9] equipment manufactured by Advanced Geosciences Inc. (USA) and correlatively to be the MC multi-electrode array proposed above.

With this process, we shall especially focus on the following issues:

2.2.1. Controlling file

First of all, we must set up the controlling files and install them into the controlling equipment before working in field, not use the controlling file created from the software of supplier.

For example: With a depth measurement point, the controlling file has got the structure as follows:

With the single channel measurement machine

;A,B,P1,P2,P3,P4,P5,P6,P7,P8,P9,channels
14,15,9,20,0,0,0,0,0,0,0,1
14,15,8,21,0,0,0,0,0,0,0,1
13,16,8,21,0,0,0,0,0,0,0,1
13,16,7,22,0,0,0,0,0,0,0,1
12,17,7,22,0,0,0,0,0,0,0,1
12,17,6,23,0,0,0,0,0,0,0,1
11,18,6,23,0,0,0,0,0,0,0,1
11,18,5,24,0,0,0,0,0,0,0,1
10,19,5,24,0,0,0,0,0,0,0,1
10,19,4,25,0,0,0,0,0,0,0,1
9,20,4,25,0,0,0,0,0,0,0,1
9,20,3,26,0,0,0,0,0,0,0,1
8,21,3,26,0,0,0,0,0,0,0,1
8,21,2,27,0,0,0,0,0,0,0,1
7,22,2,27,0,0,0,0,0,0,0,1
7,22,1,28,0,0,0,0,0,0,0,1
6,23,1,28,0,0,0,0,0,0,0,1

With the multi-channel measurement machine

;A,B,P1,P2,P3,P4,P5,P6,P7,P8,P9,channels
14,15,9,20,8,21,0,0,0,0,0,13
13,16,8,21,7,22,0,0,0,0,0,13
12,17,7,22,6,23,0,0,0,0,0,13
11,18,6,23,5,24,0,0,0,0,0,13
10,19,5,24,4,25,0,0,0,0,0,13
9,20,4,25,3,26,0,0,0,0,0,13
8,21,3,26,2,27,0,0,0,0,0,13
7,22,1,28,0,0,0,0,0,0,0,1
6,23,1,28,0,0,0,0,0,0,0,1

In which : A,B are the Transmit electrodes
P1, P2, … are the receive electrodes
Channel is the number of collecting channels

As a result, we shall set up the controlling file for the MC multi-electrode array of AMES method as follows:

```
;Automatically created command file
:header
progID=ctR8
type=R
arraytype=6
Binf=0
Ninf=0
MUX=1
:geometry (vị trí các cực với a =1)
1,0.00,0.00
2,1.00,0.00
3,2.00,0.00
4,3.00,0.00
5,4.00,0.00
6,5.00,0.00
7,6.00,0.00
8,7.00,0.00
9,8.00,0.00
10,9.00,0.00
..................
:commands
;A,B,P1,P2,P3,P4,P5,P6,P7,P8,P9,channels
2,3,1,4,0,0,0,0,0,0,0,1
3,4,2,5,1,6,0,0,0,0,0,13
3,5,1,7,0,0,0,0,0,0,0,1
4,5,3,6,2,7,1,8,0,0,0,135
4,6,2,8,0,0,0,0,0,0,0,1
4,7,1,10,0,0,0,0,0,0,0,1
5,6,4,7,3,8,2,9,1,10,0,1357
5,7,3,9,1,11,0,0,0,0,0,13
5,8,2,11,0,0,0,0,0,0,0,1
```

5,9,1,13,0,0,0,0,0,0,0,1
6,7,5,8,4,9,3,10,2,11,0,1357
6,8,4,10,2,12,0,0,0,0,0,13
6,9,3,12,0,0,0,0,0,0,0,1
6,10,2,14,0,0,0,0,0,0,0,1
6,11,1,16,0,0,0,0,0,0,0,1
7,8,6,9,5,10,4,11,3,12,0,1357
7,9,5,11,3,13,1,15,0,0,0,135
7,10,4,13,1,16,0,0,0,0,0,13
7,11,3,15,0,0,0,0,0,0,0,1
7,12,2,17,0,0,0,0,0,0,0,1
7,13,1,19,0,0,0,0,0,0,0,1
8,9,7,10,6,11,5,12,4,13,0,1357
8,10,6,12,4,14,2,16,0,0,0,135
8,11,5,14,2,17,0,0,0,0,0,13
8,12,4,16,0,0,0,0,0,0,0,1
8,13,3,18,0,0,0,0,0,0,0,1
8,14,2,20,0,0,0,0,0,0,0,1
9,10,8,11,7,12,6,13,5,14,0,1357
9,11,7,13,5,15,3,17,1,19,0,1357
9,12,6,15,3,18,0,0,0,0,0,13
9,13,5,17,1,21,0,0,0,0,0,13
9,14,4,19,0,0,0,0,0,0,0,1
9,15,3,21,0,0,0,0,0,0,0,1
....

2.2.2. Ground conditions

In the hard ground conditions, it is necessary to use the better ground methods [10].

2.2.3. Collecting the field data

After being installed fully such modes, the automatic examination and measurement in the field shall be implemented as for the traditional MRS method. In each the couple of AB emitter electrodes, we collect voltage in the couple of internal collecting electrodes M_1N_1, the couple of external collecting electrodes M_2N_2 (symmetric configuration) and the left couple of collecting electrodes M_1M_2, the right couple of collecting electrodes N_1N_2 (dipolar configuration). After that, we shall extend the couple of emitter electrodes, the process of collecting is the same as that above and to continue until the end. It is noted that with a such arrangement, there are quite a lot of electrodes on the line overlapping, so the measurement time shall be saved.

2.2.4. The process of processing, analyzing data

We shall use the software set up based on improving the processing algorithms, analysis and justifying data of Improved Electrical Sounding method and combine with the Res2D software[11] or EarthImager 2D [12] of Traditional Multi-electrode Electrical Sounding method.

Thus, we have set up the Advanced Multi-electrode Electrical Sounding method based on the composing, development of advantages to the traditional MES method and IES method.

3. The experiment results of AMES method

3.1. The experiment of setting up electrode array

With the such principle of setting up the MC multi-electrode array, we have carried out modeling trials by the EarthImager 2D software. The experimental environment is an identity environment with the resistivity of 100 Ωm. The result of calculating model is the resistivity curves R_s, R_{sr} and R_p [2] presented in the table 2.

Table 2. The experiment results of transformation from the unequal-spaced electrode array (Schlumbeger array) to the electrode array with equal-spaced electrodes.

U/I	K	R	A	B	M	N	Kr	Rs	Rsr	Rp
15,915	6,28	100	0	1	- 1	2				
1,5916	62,83	100	0	1	- 4	5	13,96	100	100	100
5,3052	18,85	100	-1	2	- 4	5				
0,5305	188,50	100	-1	2	-13	14	41,89	100	100	100
1,7684	56,55	100	-4	5	-13	14				
0,1768	565,49	100	-4	5	-40	41	125,66	100	100	100
0,5895	169,65	100	- 13	14	-40	41				
0,0589	1.696,46	100	- 13	14	- 121	122	376,99	100	100	100
0,1965	508,94	100	- 40	41	- 121	122				
0,0196	5.089,38	100	- 40	41	- 364	365	1130,97	100	100	100
0,0655	1.526,81	100	- 121	122	- 364	365				
0,0065	15.268,14	100	- 121	122	- 1.093	1.094	3392,92	100	100	100
0,0218	4.580,44	100	- 364	365	- 1.093	1.094				
0,0022	45.804,42	100	- 364	365	- 3.280	3.281	10178,76	100	100	100

The experiment results show that the results transforming the symmetrical curve to the dipolar curve R_{sr} and the Petrovski curve R_p according to the alternative formulas [2] when modeling shall still match the experiment conditions completely. It proves that the principle of setting up the MC multi-electrode array is accurate, this electrode array shall fully still remain the preeminent features of improved electrode array.

3.2. The experiment of AMES method on the theoretical model

Implementation steps: i) Setting up the theoretical models; ii) Modeling according to the traditional multi-electrode array (Wenner electrode array and Dipole-Dipole electrode array) and according to the MC multi-electrode array; Processing data by the EarthImager 2D software; Analysis and evaluation of results. Next, we shall present some experiment results.

3.2.1 The experiment to horizontal seam model

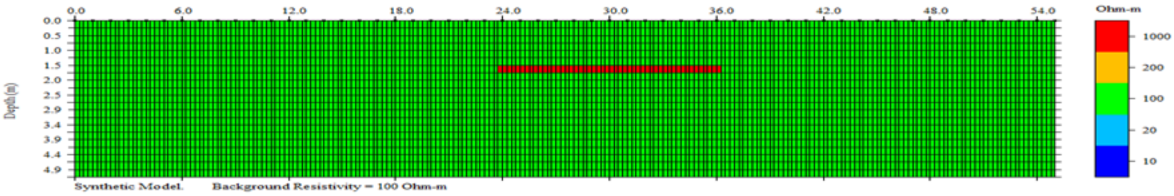


Fig 1a. The experimental model of horizontal seam.

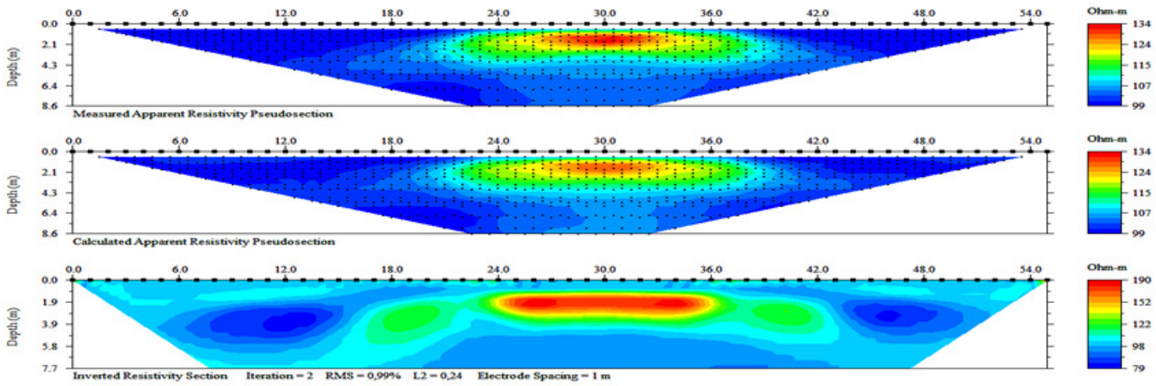


Fig 1b. The experiment result to MC multi-electrode array.

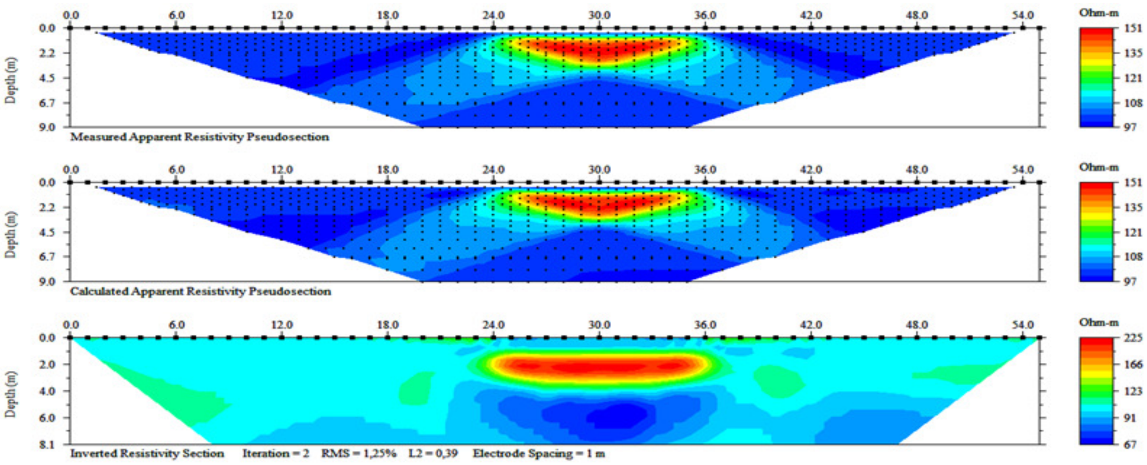


Fig 1c. The experiment result to Dipole-Dipole array.

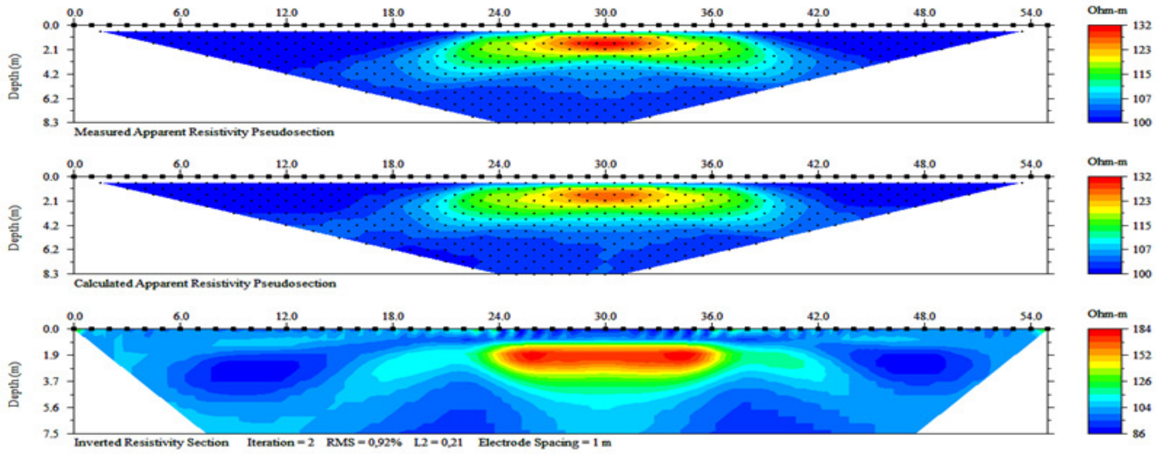


Fig 1d. The experiment result to Wenner array.

Such experiment results and model of horizontal seam show that the experiment results of MC multi-electrode array has got the result similar to the Wenner array, it showed exactly the surface and the horizontal dimension of object.

3.2.2. The experiment to model of oblique seam

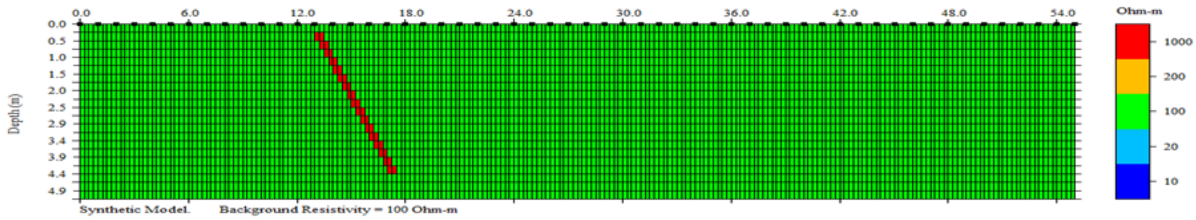


Fig 2a. The experimental model of oblique seam.

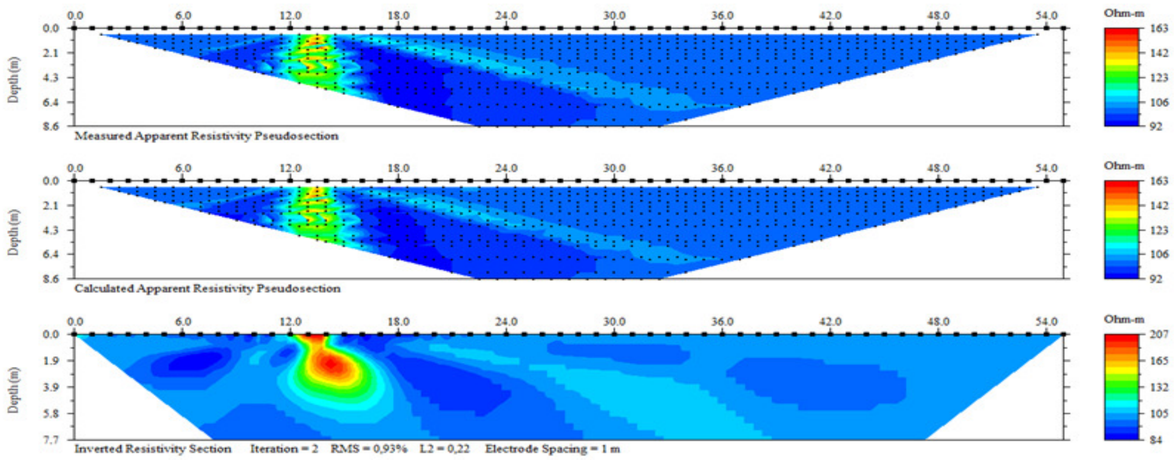


Fig 2b. The experiment result to MC multi-electrode array.

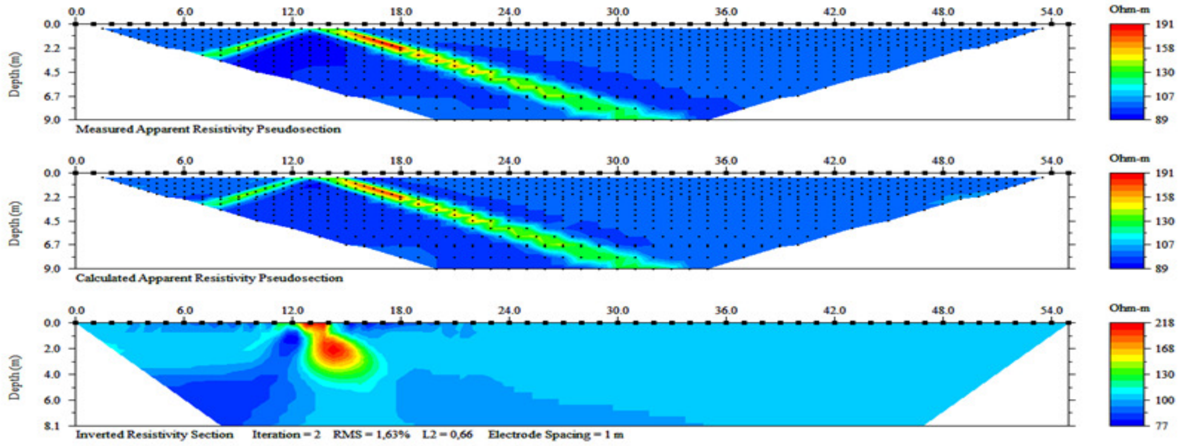


Fig 2c. The experiment result to Dipole-Dipole array.

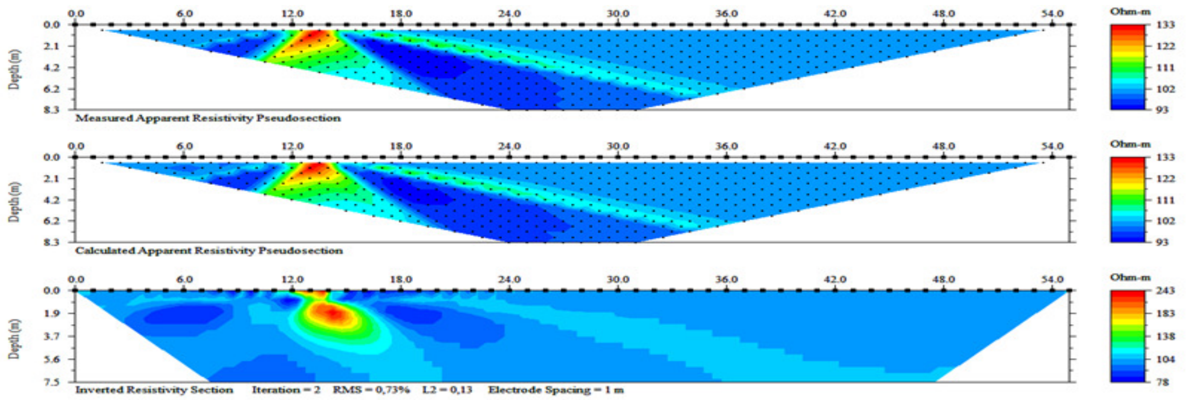


Fig 2d. The experiment result to Wenner array.

Such experiment results to the model of oblique seam show that the experiment results to the MC multi-electrode array show the dimension of anomalie caused by the object being more larger than the result of traditional multi-electrode arrays. However, with the MC multi-electrode array, the random noise filter in model shall be better than that to the traditional electrode arrays.

3.2.3 The experiment to mixed model

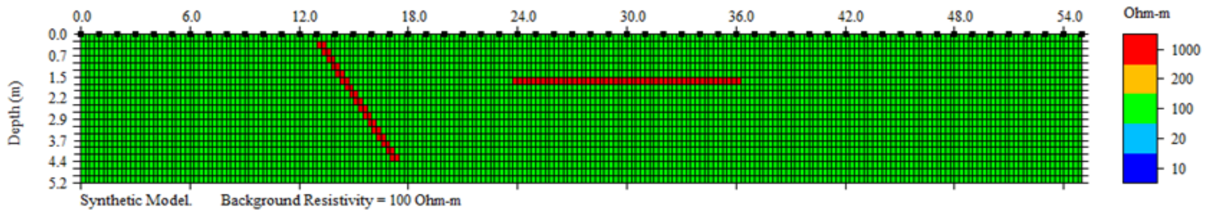


Fig 3a. The experimental mixed model.

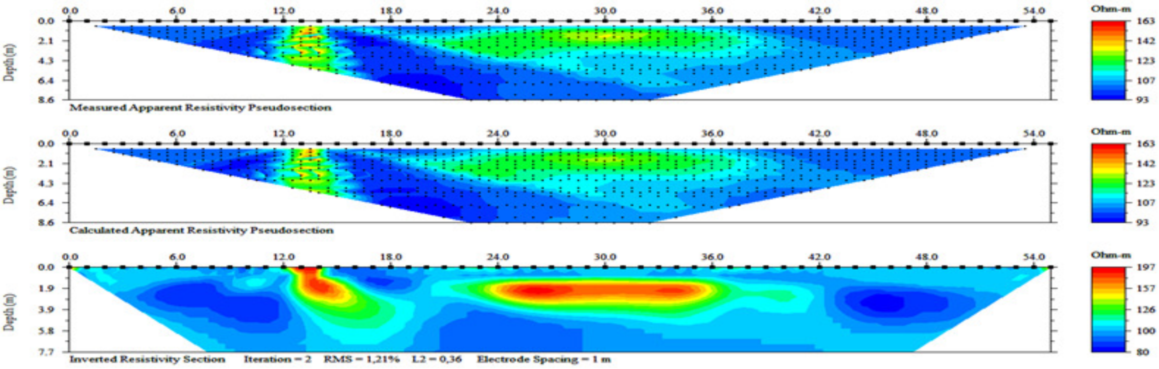


Fig 3b. The experiment result to MC multi-electrode array.

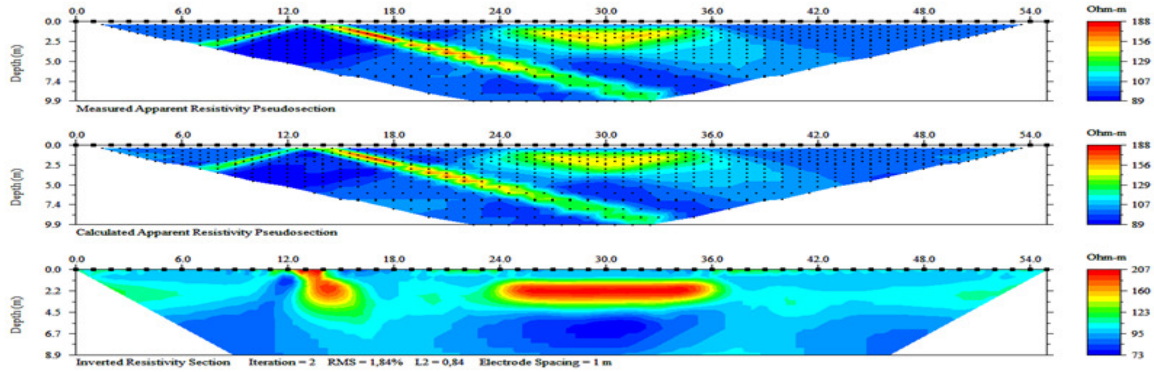


Fig 3c. The experiment result to Dipole-Dipole array.

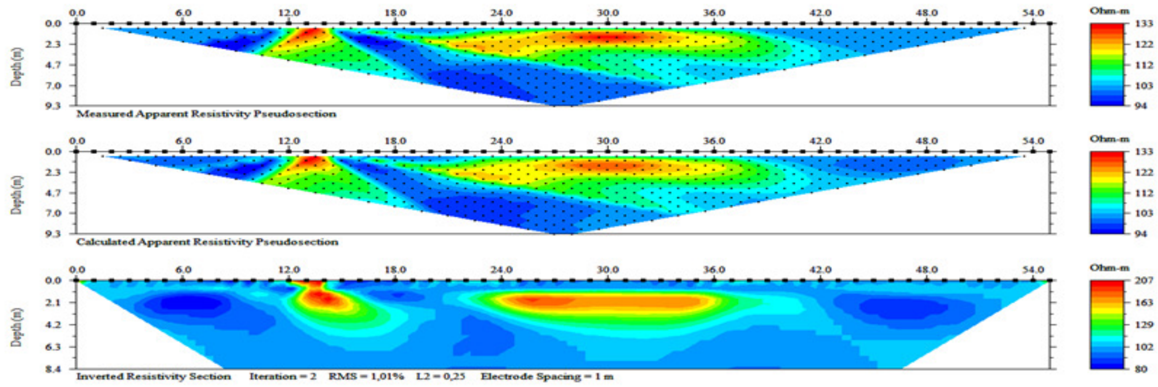


Fig 3d. The experiment result to Wenner array

Such experiment results to the mixed model show that the experiment results to MC multi-electrode array and Dipole-Dipole array give the results of position and dimension of anomalies caused by the objects that are closest to the experimental model. In addition, with the MC multi-electrode array, the random noise filter in model shall be better than that to the traditional electrode arrays.

4. Discuss the results

- Already studied and built the advanced multi-electrode array (MC) which still remains the preeminent features of improved electrode array and composes with the traditional multi-electrode array. This MC electrode array experienced through modeling, its results are good.

- We completed the process of investigation design, collecting and processing data for the Advanced Multi-electrode Electrical Sounding method (AMES), in which it is notable that:

+ Set up the file controlling measurement process for the reasonable SuperSting R8/IP equipment.

+ Use the software built on the basis of improving the processing algorithm, analysis and justifying data of the Improved Electrical Sounding method and combine with the Res2D software or EarthImager 2D of the Traditional Multi-electrode Electrical Sounding method.

- Using the AMES method shall be better than the traditional one because giving us the painting of layers that are more detailed than that to the traditional method. With the traditional measurement, using the Wenner electrode array shall be best. With the advanced measurement, we could combine Wenner electrode array with Schlumberder one because for each AB, the first measurement time has got the collecting electrodes similar to the Wenner electrode array, the second measurement time has got those similar to the Schlumbeger electrode array.

- The AMES method experienced on the theoretical model with the SuperSting R8/IP machine and EarthIamager 2D software shows reliable results.

From such results and comments, we can affirm that the AMES method composes, developes all advantages of IES method and the Traditional MES method, this is a new method with more preeminent features than the old one.

We shall continue to release the practical results of AMES method in studying environment in the next articles.

Acknowledgement

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