1: Introduction to resistivity surveys:

The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity of the subsurface can be estimated. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. Electrical resistivity surveys have been used for many decades in hydro geological, mining and geotechnical investigations. More recently, it has been used for environmental surveys.

The resistivity measurements are normally made by injecting current into the ground through two current electrodes (C1 and C2 in Figure 1), and measuring the resulting voltage difference at two potential electrodes (P1 and P2). From the current (I) and voltage (V) values, an apparent resistivity (pa) value is calculated.

$$pa = k\ V / I$$

Where k is the geometric factor which depends on the arrangement of the four electrodes.

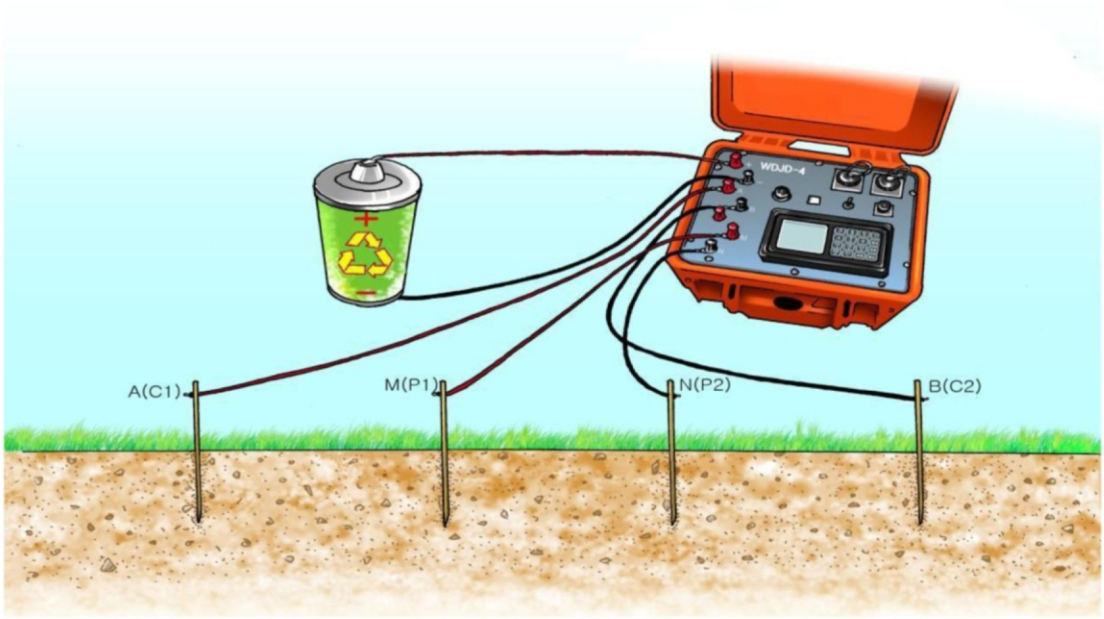


Fig No: 1 Layout of 1D VES Resistivity Sounding

1.1: The relationship between resistivity and geology:

Resistivity surveys give a picture of the subsurface resistivity distribution. To convert the resistivity picture into a geological picture, some knowledge of typical resistivity values for different types of subsurface materials and the geology of the area surveyed, is important. Resistivity values have a much larger range compared to other physical quantities mapped by other geophysical methods. The resistivity of rocks and soils in a survey area can vary by several orders of magnitude. In comparison, density values used by gravity surveys usually change by less than a factor of 2, and seismic velocities usually do not change by more than a factor of 10. This makes the resistivity and other electrical or electromagnetic based methods very versatile geophysical techniques.

2: Concepts of 2D Resistivity imaging

ERI: ERI is abbreviated as Earth Resistivity Imaging. It is Multi-electrode electric Resistivity imaging method, which is the extension of 1D Res VES. Layout dozens or hundreds electrode on one survey line, with automatic conversion of control electrode, the instrument completes automatic composition and fast measurement of many kind of array and program in Res method. It realizes combined measurement of electric profiling and electric sounding and is benefit for shorten time and gaining section information.

Survey line: a line on the surface of the earth, along the section to be measured, with measured point evenly distributed on it (with interval of one electrode spacing)

Rolling line: a beeline or diagonal line (invisible line), extending in depth direction, with the data points distributed evenly on it.

Profile: the data collection of same depth in one flat.

Section: the collection of all profiles in one flat.

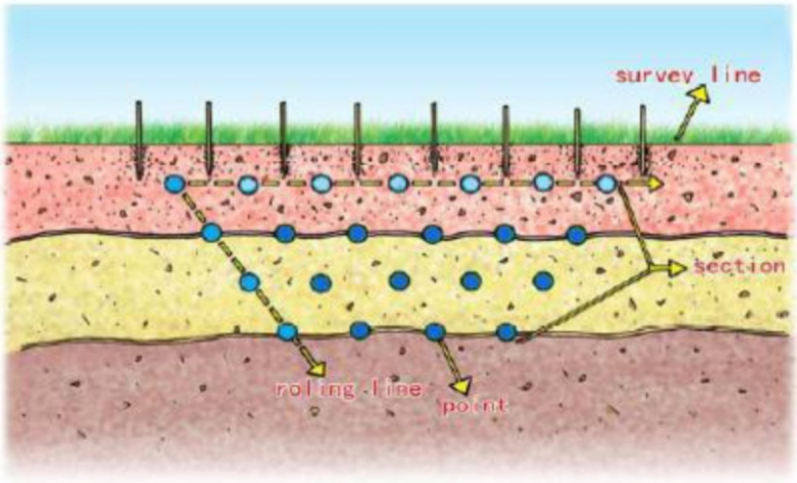
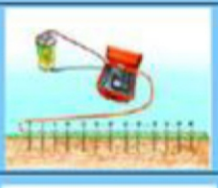
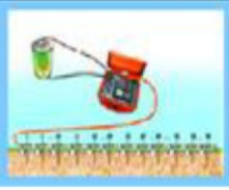


Fig No 2: Sketch Diagram for Multi-Electrode Resistivity Imaging System

2.1 : 2-D resistivity Imaging survey:

We have seen the greatest limitation of the resistivity sounding method is that it does not take into account horizontal changes in the subsurface resistivity. A more accurate model of the subsurface is a two-dimensional (2-D) model where the resistivity changes in the vertical direction, as well as in the horizontal direction along the survey line. In this case, it is assumed that resistivity does not change in the direction that is perpendicular to the survey line. In many situations, particularly for surveys over elongated geological bodies, this is a reasonable assumption. However, at the present time, 2-D surveys are the most practical economic compromise between obtaining very accurate results and keeping the survey costs down. We hereby propose WDJD-4 model for 2D Resistivity imaging survey which is has the mainframe WDJD-4 Multi-function Digital DC Resistivity/IP Meter (also referred to as WDJD-4 or WDJD-4 mainframe) is which install a 12V rechargeable battery. It features multiple functions, high accuracy, fast speed, high reliability and excellent expandability. Measured data of WDJD-4 can be processed by other multi-electrode resistivity software, which makes the interpretation more convenient.WDJD-4 is available in two types of cable system i) Centralized system (performs Imaging Operation using Electrode Switcher Box (WDZJ-4) and ii) Distributed cable system (performs Imaging Operation with Intelligent cable system). Figure No: 3 & 4 shows the configuration of WDJD-4 for Imaging functions using Centralized cable system .Figure 5 & 6 shows the configuration of WDJD-4 using Distributed cable system

Overview of WDJD-4 System

Configuration / Function	Mainframe	Wire/Cable	Electrode	Diagram
1D Res Sounding	 WDJD-4	 Twist pair wire	 Iron electrode	
1D IP Sounding	 WDJD-4	 Twist pair wire	 Iron electrode + solid electrode	
2D Res Imaging	 WDJD-4 + WDZJ-4 (WGMD-4 system)	 Multi-electrode cable	 Electrode with clip	
	 WDJD-4	 Res cable	 Electrode with spring	
2D/3D Res and 2D IP Imaging	 WDJD-4	 IP cable	 Electrode with spring + solid electrode	

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Centralized Cable System

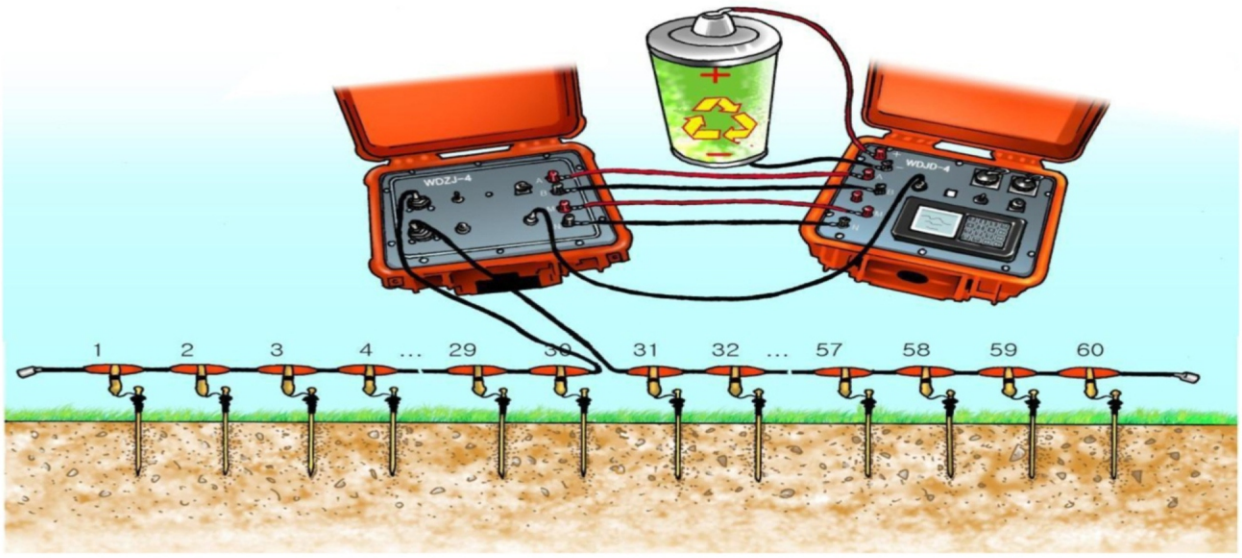

Fig No: 3 Layout for 2-D Resistivity Imaging of WDJD-4 Using 60 take out switcher (Configuration of WGMD-4 with, WDZJ-4(Electrode Switcher),

WDJD-4, Mainframe, Multi-electrode cable with 60 take outs and Power source)

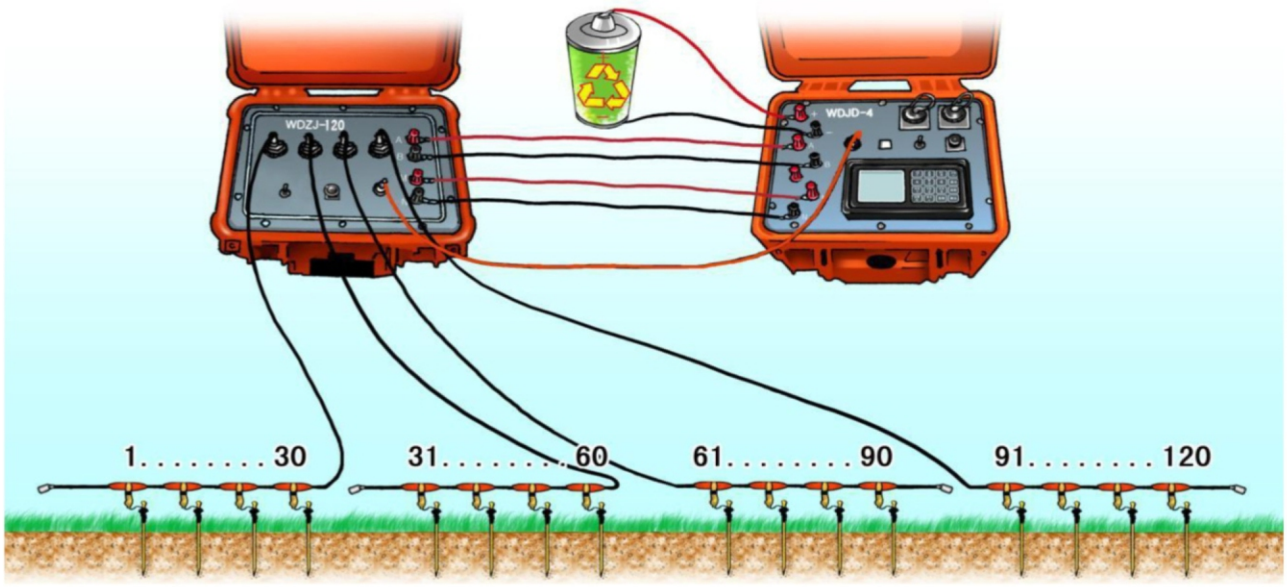

Fig No: 4 Layout for 2-D Resistivity Imaging (Configuration of WGMD-4 with, WDZJ-4(Electrode Switcher),

WDJD-4, Mainframe, Multi-electrode cable with 120 take outs and Power source)

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Distributed Cable System:

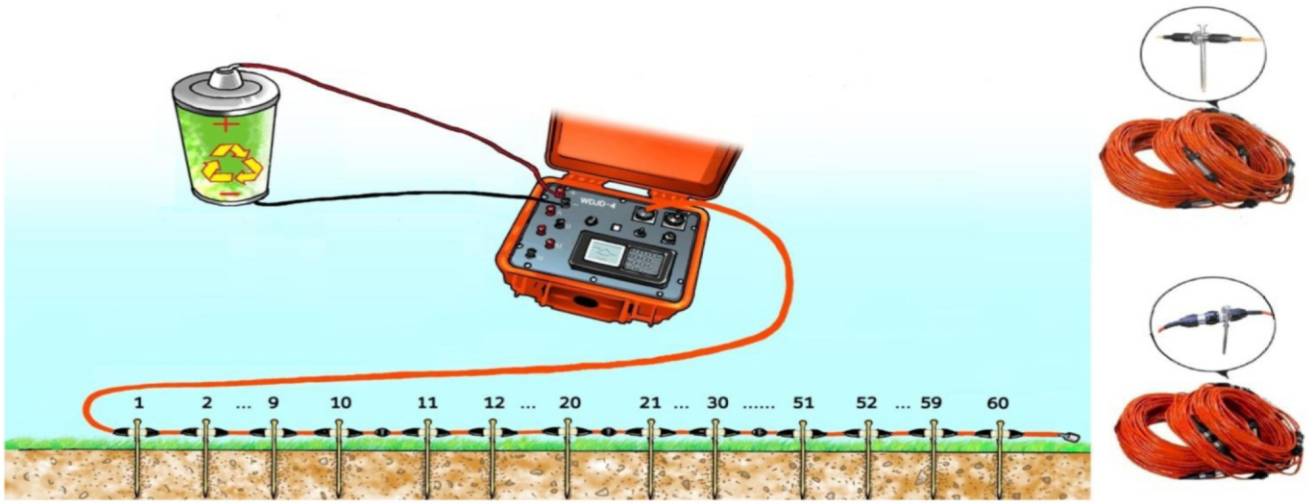

Fig: 5 Layout of 2-D Resistivity Imaging using Intelligent Resistivity Imaging Cable system for continuous profile development (maximum upto 200 electrodes)

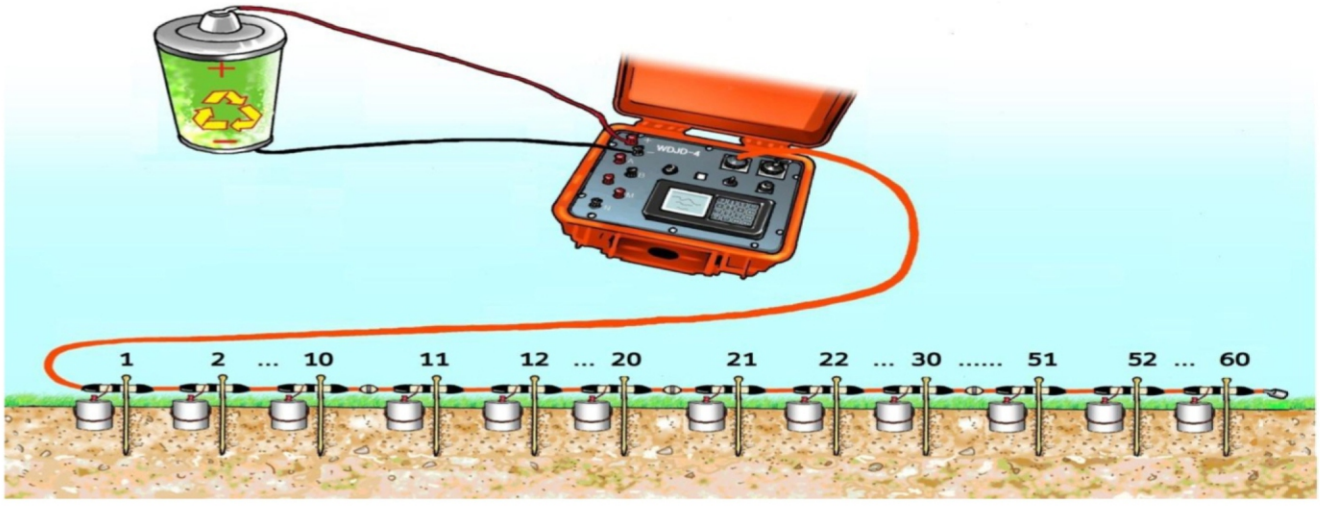

Fig: 6 Layout of 2-D Resistivity& IP (Dual Mode) Imaging, using Intelligent Resistivity Imaging IP Cable system for continuous profile development (maximum upto 200 electrodes)

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2.2: Field Survey method-instrumentation and measurement procedure:

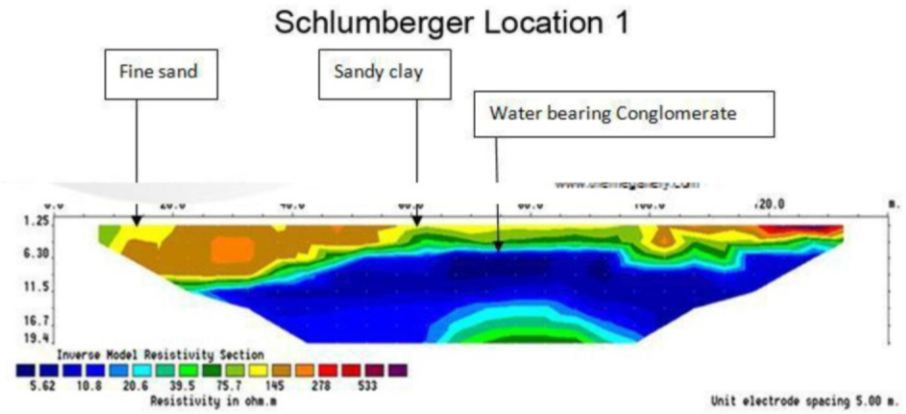
One of the new developments in recent years is the use of 2-D electrical Imaging/tomography surveys to map areas with moderately complex geology (Griffiths and Barker 1993). Such surveys are usually carried out using a large number of electrodes, 25 or more, connected to a multi-core cable. Mainframe, WDJD-4 together with an electronic switching unit,WDZJ-4 is used to automatically select the relevant four electrodes for each measurement. The typical setup for a 2-D survey with a number of electrodes along a straight line attached to a multi-core cable. Normally a constant spacing between adjacent electrodes is used may be 5m or 10 m in standard and also have the provision to scale down from 1m or 2m or 3m or up to 10m according to the purpose of survey. The multi-core cable is attached to mainframe using communication cable. The sequence of measurements to take, the type of array to use and other survey parameters (such the current to use) is normally entered using mainframe settings .the data gathered in field is stored in mainframe which can be later transferred into PC or laptop using USB Cable.

Array : Please refer the „Electrode Array" for Measurement Parameter

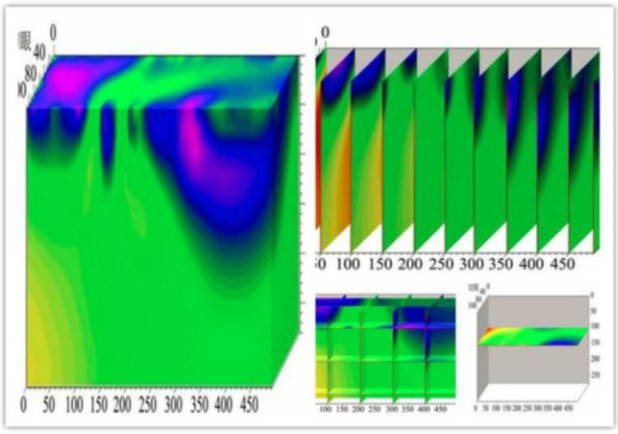
2.3: Data input & processing software:

To interpret the data from a 2-D imaging survey, a 2-D model for the subsurface which consists of a large number of rectangular blocks is usually used. A computer program is then used to determine the resistivity of the blocks so that the calculated apparent resistivity values agree with the measured values from the field survey. The computer program RES2DINV.EXE will automatically subdivide the subsurface into a number of blocks, and it then uses a least-squares inversion scheme to determine the appropriate resistivity value for each block. The location of the electrodes and apparent resistivity values must be entered into a text file which can be read by the RES2DINV program. So ,here, Our instrument WGMD-4 have the provision for data conversion and processing for „RES2DINV „and „Surfer" format respectively. The WDAFC.EXE data format convert software can transform data into „RES2DINV „and „Surfer" format. Besides, for 1D data, surfer format is available; while for 2D data, not only surfer format but also RES2D is available.

Fig :7 2D ERT image retrieved from Arani River near Periapalayam using 'RES2DINV'



Fig;8 2-D & 3-D Resistivity Imaging at Chengdu China



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WDJD-4 Multi-function Digital DC Resistivity/IP Meter (hereafter also referred to as WDJD-4 or WDJD-4 mainframe) which install a 12V rechargeable battery.

3.1 : Function:

- General resistivity /IP Sounding (1-D VES SP IP Sounding)
- 2-D & 3-D Resistivity Imaging (using Multi Electrode)
- 2-D Resistivity & IP Imaging (using Multi Electrode)

3.2 : Application:

- Hydrogeology in Ground water exploration, aquifer mapping
- Engineering geology, inspecting dam base and flood protection level for incipient faults
- Metal and nonmetal mineral resources detection
- City geophysical exploration
- Environmental studies for defining saline groundwater incursions
- Railway and bridge inspection
- Geothermal prospecting
- Profiling landslip geometry

3.3: Main Features:

- Transmitting unit and receiving unit are of all-in-one design, portable and lightweight.
- Super high-power, high anti-interference performance and precision: up to 500w
- Automatically achieve compensation of self-potential, drift and electrode polarization, up to ±10V.
- Receiving unit support transient over-voltage protection, transmitting unit supports over-voltage protection, over-current protection and AB open-circuit protection.
- For general resistivity and IP survey function, 10 types of electrode arrays are available. Electrode distance (namely "Program") can be inputted or called. Geometric factor K can also be generated automatically or calculated manually.
- For multi-electrode 2D resistivity imaging, up to 18 electrode arrays are available.
- Program: the program can memorize 100 groups of electrode distances, avoiding repetitive input. Or you just input a program Id and step to call the corresponding electrode distances.
- Earth resistance inspection: ground condition can be inspected at any time.
- Mass data storage: Up to 1GB capacity (extended) enable store 5,000,000 groups measuring data (including current, voltage, SP, Ro, Ms, metal factor, TH, R, J).
- All parameter and data are under power-failure protection; and thus data will not be lost even thought the system shuts down accidentally.
- USB port enables it to transfer data to computer.

4: Technical Specifications

Table I : Technical Specifications for 'Receiving Unit'

Receiving unit	
Voltage precision	If Vp≥10mV, ± 5‰ ± 1LSB; if Vp < 10mV, ±1% ± 1LSB.
Input impedance	≥50MΩ
Apparent polarizability precision	±1% ± 1LSB
SP compensation range	±10V
Current channel	1.5 A, ±0.4% ± 1LSB, 24 bit A/D
Current precision	If Ip≥ 10mA, ± 5‰ ± 1 LSB; if Ip < 10 mA, ±1% ± 1 LSB.
Suppression	≥80dB for 50Hz industrial frequency (common mode interference or differential mode interference).

Table II: Technical Specifications for 'Transmitting Unit'

Transmitting unit	For general Res/IP sounding, 500W.
Max voltage	For general Res/IP sounding,12V
	For general Res/IP ±2A(Max)/WDJD-4
Pulse width	1~60s, duty ratio 1:1
others	
Display	160 × 160 dot matrix LCD
Storage	≥1GB
Working temperature	-10℃~+50℃, 95 %RH
Storage temperature	-20℃~+60℃
Instrument power	internal 12V 2Ah rechargeable battery , lasts for 30 hours (or 12V external power supply)
Weight	≤ 4.4 Kg

4.1 Electrode array for Multi-electrode configuration (2D Survey):

The 18 electrode arrays are introduced in Multi-Electrode Electrical Resistivity Survey .They are only available for multi-electrode resistivity or IP survey mode. Here, Mainframe WDJD-4 have an option to work together with power source, electrodes and corresponding cables, in order to conduct multi-electrode electrical resistivity/IP survey. System will automatically select Current electrodes and Potential electrodes according to a specific electrode array, and gives measured results of all the data points of a cross-section.

In all, there are 18 electrode arrays of multi-electrode electrical resistivity survey,namely,

- Wenner Alpha array (WENNER α),
- Wenner Beta array (WENNER β),
- Wenner Gamma array (WENNER γ)
- Three-pole direct array (δA ARRAY),
- Three-pole reverse array (δB ARRAY),
- Wenner Alpha2 array (SCHLMBG),
- Self-Potential M array (SP-M),
- Self-Potential MN array (SP-MN),
- Charging M (CHG-M),
- Charging MN (CHG-MN)
- Two-pole Roll along array (2P AM),
- Three-pole Roll along array (3P A-MN and 3P AB-M),
- Dipole-dipole Roll along array (DIPOLE)
- MN-B,
- 4P-VES Roll along array (AMNBVES),
- A-MN Rectangle (A-MN RECT),
- Cross-Hole Dipole/Equatorial Dipole-dipole array (CR-DIPOLE)