WDA-1/WDA-1A
Super Digital DC Resistivity/IP Meter

User's Manual

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STATEMENT

Thanks for purchasing BTSK WDA-1/WDA-1A Super Digital DC Resistivity/IP Meter!

In order to have the system work at its best efficiency, please read this user's manual carefully before operation and please pay special attention to the items marked "Note", "Warning" or "Precaution".

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The information, figures, tables, specifications and schematics contained herein are subject to change without notice.

PRECAUTIONS

1) Every time before field survey, please ensure that the WDA-1/WDA-1A main frame and the pocket PC (hereafter also referred to as PDA) have enough power. If power is not enough, recharge them in time; and that,
2) Current electrodes A, B, potential electrodes M, N should be correctly and well connected. As to WDA-1, another DC high voltage input port should be correctly connected (red for positive end and black for negative end). Prohibit misconnecting A, B, M, N ports and DC high-voltage input ports.
3) When working in the pole-pole array configuration or Dipole-pole array configuration, connect the infinity Current electrode to the "B(∞)" port on WDA-1/WDA-1A main frame.
4) There are two options of power source for WDA-1A main frame, namely, external DC high voltage and internal high voltage. If both power sources give power supply, WDA-1A will choose the one as it power source whose output voltage range is wider.
5) Since output current of WDA-1A internal high voltage is small, it is recommended to do resistivity survey; however, for induced polarization (chargeability) survey, external DC high voltage power source is recommended.
6) If WDA-1/WDA-1A is used together with WDZJ-3 Multiplex Electrode Converter, DC High Voltage is not allowed to be over 400V; if the main frame WDA-1/WDA-1A is used with intelligent resistivity/IP cable, DC High Voltage is not allowed to over 800V.
7) When taking the intelligent cable to conduct multi-electrode resistivity imaging, the cross-borehole dipole array configuration needs the two cable sockets (Socket 1 and Socket 2), and only one of the other fifteen electrode array configurations could work with it.
8) Before commencing measurement of a new section, first set parameters correctly.
9) If system clews "Over-current protection", please cut off power supply of WDA-1/WDA-1A main frame and check whether AB gets short-circuited.
10) When conducting multi-electrode resistivity imaging, grounding resistances of two electrodes locating in a section should not vary too much. Please decrease the grounding resistance as possible to favor power supply. If the surface soil is too dry, water it to make sure the electrodes are well grounded.
11) Power source of **WDA-1A** main frame may be external DC high voltage or internal high voltage. If both power sources give power supply, WDA-1A will automatically choose the one as it power source whose output voltage range is

wider.

12) WDA-1A is designed with a high voltage battery fuse to protect internal circuit when output high voltage gets short-circuited. If the fuse breaks off because of short-circuit, take off the fuse box cover to replace the 2A fuse with a new one.
13) DO NOT store the instruments in a damp place or a gas-corrosive environment for a long time. Storage temperature should also **NOT** be lower than -20℃.
14) DO NOT conduct field survey in rainy days, especially when there are a lot of water accumulating on the ground surface.
15) The WDA-1A mainframe can work with 8V rechargeable lithium battery and high voltage power supply, rechargeable 48V lithium battery.
16) If the instruments are not to use for a long time, DO recharge it every three month; otherwise, the lithium battery will discharge itself and thus damage the battery. Recharge temperature range of the lithium battery is 0℃~45℃.
17) When conducting imaging with two-pole array configuration or three-pole array configuration, connect the Current electrode to the "B(∞)" (on the front panel of WDA-1/WDA-1A mainframe).
18) Under combined electrical profiling (3P-PREL) or combined electrical sounding (3P-VES) configurations, the "B (∞)" port (on the front panel of the mainframe WDA-1/WDA-1A) connects to the infinity electrode and while the "3-Pole B" port (on the front panel of the mainframe WDA-1/WDA-1A) connects to the Current electrode A or B.
19) Valid distance for the Bluetooth wireless communication is 10 meters. If it is more than 10 meters, communication will fail, and the Bluetooth should be paired once again.
20) In order to have WDA-1/WDA-1A main frame compatible with notebook PC to control the data sampling, we provide each WDA-1/WDA-1A with a Bluetooth USB adapter driver and a Bluetooth USB adapter. First the Bluetooth USB adapter driver is installed in the notebook PC and then the USB adapter inserts to the notebook PC through a USB port. Operation of the system program is the same with that on the PDA. Please refer to Appendix D to install the Bluetooth USB adapter.

OVERVIEW

WDA-1/WDA-1A Super Digital DC Resistivity/IP Meter (hereafter also referred to as WDA-1/WDA-1A system) is developed basing on years' experience of studying and manufacturing advanced electrical resistivity instruments. Its leading technical characteristics and function are much superior to the instruments of its kind worldwide.

It's mainframe, WDA-1/WDA-1A super digital DC resistivity/IP meter, is a newly developed electrical method instrument, adopting many advanced technologies such as pocket PC, Bluetooth, 24bit A/D, and high power control. It features compact size and lightweight. Its main performance and functions are better than its similar products at home and abroad.

WDA-1/WDA-1A system can conduct,

a). General resistivity/IP survey, in association with only **one/two Current electrodes, one/two Potential electrodes, AB connecting wire, MN connecting wire and power source.** For this part, please refer to Section Three and Section Four)

b). Multi-electrode 2D resistivity imaging when works together with **WDZJ-3 Multiple Electrode Converter, power source, electrodes and corresponding cables.** For this section, please refer to Section Six.

c). Multi-electrode 2D resistivity imaging (in Section Seven), **Multi-electrode 3D resistivity imaging** (in Section Ten) and **Multi-electrode 2D induced polarization (IP) imaging** (in Section Nine), in association with **10-take-out intelligent cables, electrodes and power source.**

WDA-1/WDA-1A can be applied in a variety of complex regions, energy resource and city geophysical exploration, railway and bridge prospecting, metal and non-metal mineral resources prospecting, city geophysical exploration, hydrology and engineering geology to inspect base of dam and flood protection levee for incipient faults. Besides, it contributes to geothermal survey.

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SECTION ONE: INTRODUCTION TO WDA-1/WDA-1A

1.2 Main Function and Features

- **Portability and flexibility**: the transmitting unit and the receiving unit are designed in one device, small and lightweight. The 96V internal battery of WDA-1A mainframe can conduct multi-electrode imaging in wide variety of environments.
- **Unique and open measuring process control**. User-defined power-on time and power-off time controls measuring process. The main frame can also monitor variation of electrode potential automatically. If the parameter exceeds the user-defined over-variation limit, it stops measuring, and wait to measure again until it becomes stable. Thanks to this function, WDA-1/WDA-1A system can ensure accurate measured result even in harsh environment.
- WDA-1/WDA-1A is designed with **two cable sockets** which enable cross-hole electrode array configuration works without switching control unit, and thus makes the measuring process much simpler and easier.
- **Multiple functions**: voltage and current range and small signal accuracy are allowed to increase dramatically, which makes it suitable to work with rock sampling tester, high-power IP receiver, general electrical method instrument, IP instrument, water finder, 2D and 3D multi-electrode electrical method instrument, etc.
- **Measuring various parameters, wide application**: it is able to acquire data of voltage (V_P), current (I_P), apparent resistivity (R0), Self-Potential (SP), apparent polarizability (M~M7), metal factor (G1~G7), half decay time (TH), deviation (r), induce polarization ratio (J), etc.
- **High power supply, wide current range, high accuracy**: maximum power reaches 7200W (1200V×6A), voltage input is 64Vp-p, small signal measurement precision is high (voltage is less than 0.1mV and current is less than 0.1mA with ±1% measurement precision), both of which make WDA-1/WDA-1A main frame an ideal device for regions of high resistivity and to achieve better measured results.
- On its panel there is an "B(∞)" port for pole-pole and dipole-pole electrode array. As to dipole-pole array configuration, ResA, ResB, and Res can be measured automatically with high efficiency and fewer errors.
- **Bluetooth technology facilitating wireless remote control**: Bluetooth technology enables the pocket PC to control the WDA-1/WDA-1A main frame in 10 meters. Sampling control, parameters setting, measurement manipulating, data transferring and displaying, graph plotting can also be realized through the pocket PC, and thus field work becomes easier.

- **Pocket PC controlled and powerful function**: English version pocket PC to control sampling and relevant parameters setting, data displaying and storing, graph plotting for 10 kinds of electrode array configurations (such as, 4P-VES Schlumberger, 4P-VES Wenner, Combined electric sounding, four-pole electric profiling, Combined electric profiling, Rectangle/Middle Gradient, dipole-dipole, Five-pole Longitudinal Axis Electrical Sounding, Quadratic time difference array, etc). Moreover, advance hardware enables operator to have agenda and to connect with Internet wirelessly, with software such as WORD, EXCEL, PowerPoint, Media Player and so on.
- **16 kinds of electrode arrays of multi-electrode system:** In addition to the 10 electrode arrays of general electrical resistivity survey system, there are 16 electrode arrays for multi-electrode imaging, 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 Alpha 2 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**, Cross-Hole Dipole/Equatorial Dipole-dipole array (**CR-DIPOLE**).
- **Extendable system**: data sampling and storing are controlled by pocket PC. Data management is easy. Software is flexible to be upgraded and extended (extending data storage capacity and collection software functions, also extend to special multi-electrode electrical instrument).
- **Excellent anti-interface performance**: integrated with multistage filtration and signal enhancement technologies and suppresser against common mode interference and differential mode interference. Measurement precision is high.
- Automatically achieving SP, drift and electrode compensation (maximum compensation reaches ±10V).
- **Receiving unit** supports transient over-voltage protection for input voltage; transmitting unit supports over-voltage protection, over-current protection and AB open-circuit protection as well as DC high voltage reverse connection protection.
- **Earth resistance check**: earth resistance of AB Current electrodes and MN Potential electrode can be inspected at any time.
- Diagnosis program can find the fault or failure quickly and accurately.
- Sealed constitution features waterproof and dust-proof design, long lifetime.
- **Flexible option of control**: control unit may also be notebook PC to remotely manipulate measurement.

1.3 Configuration and Technical Specifications

WDA-1/WDA-1A Main Frame (Standard)

- Maximum transmitting power: 7200W
- Maximum supply voltage: 1200V (with WDZJ-3, no more than 450V)
- Maximum supply current: 6A (with WDZJ-3, no more than 2.5A)
- Transmitting power pulse width: 1~60s, duty cycle is 1:1.
- Voltage: ±32V (24 bit A/D). If Vp≥5mV, accuracy is ±0.2% ±1LSB. If 0.1mV≤Vp＜5mV, accuracy is ±1% ±1LSB.
- Input impedance: >50MΩ
- Apparent polarizability accuracy: ±1％±1LSB
- SP compensation range: ±10V
- Current: 6A (24bit A/D). If Ip≥5mA, accuracy is ±0.2% ±1LSB. If 0.1mA≤Ip<5mA, accuracy is ±1% ±1LSB.
- Suppression: for 50Hz industrial frequency interference (common mode and differential mode interference), suppression is more than 80dB.
- Power supply: internal 7.4V 4Ah rechargeable battery continuously lasts for 20 hours (or 12V external power supply).
- Ports support (transmitting unit): A, B, M and N connecting ports, DC high voltage input ports and external battery terminals, 2 cable ports, RS-232, Bluetooth.
- Working temperature: -10℃~+50℃, 95%RH
- Storage temperature: -20℃~+60℃
- Weight: ≤4kg
- Dimension:270mmx246mmx123mm
- Internal power source (only for WDA-1A): maximum voltage 96V (two notches, 48V and 96V); maximum current is 0.7A.

HP Pocket PC (Standard)

- Microsoft Windows Mobile 6 Classic
- Microsoft Office Mobile (Word, Excel, PowerPoint)
- Marvell PXA310 624MHz processor
- 3.5-inch TFT display, 320*240 resolution
- 256MB flash ROM/64MB SDRAM
- 2 Gigabyte SD card
- Bluetooth, infrared, serial port

WDZJ-3 Multiplex Electrode Converter (Optional, can be cascaded)

- Maximum electrodes: 60/pcs
- Insulation performance: ≥500MΩ
- Maximum output voltage: 450V DC
- Maximum output current: 2.5A DC
- Power supply: 8Size-D batteries (or ni-cd batteries of the same spec)
- Operating temperature range: -10℃~+50℃

Multi-electrode Cable for WDZJ-3 (Optional)

- Multi-electrode cable: 32-core, outer diameter is Φ6mm
- Maximum voltage: 450V
- Maximum current: 3A
- Accessible for two multi-electrode cables (each cable string has 30 take-out)
- Take-out spacing: standard 5m or 10m (also customized according to order)
- Cable insulation: ≥500MΩ/500V between any two cores

Copper Electrode for Multi-electrode Cable (Optional)

- Copper electrode: Φ12mm x 280mm, with plug-pull clamp
- Quantity: up to order

Intelligent Cable for 2D/3D Resistivity or IP Imaging (Optional)

- Cable: polyurethane coated, outer diameter Φ8mm
- Quantity: up to order
- Connector (take-out) number: 10/sting (ten electrode per string)
- Connector (take-out) spacing: 1~10m (or up to order)
- Connector size: Φ30mmx100mm (connector only), Φ39mmx170mm (including rubber head)
- Maximum voltage: 800V
- Maximum current: 3A
- Cable insulation: cable between A, B connecting ports and cable between A, B connecting ports and the low voltage connecting port, insulation is more than 1000MΩ/1000V; cable between low voltage connecting ports, insulation is more than 500MΩ/500V
- Working temperature: -20°C~+70°C

Stainless Steel Electrode for 2D/3D Resistivity Imaging (Optional)

- Stainless steel electrode: Φ10mm x 280mm, with stainless spring
- Quantity: up to order

1.4 Front Panel

Front panel of WDA-1 super digital DC resistivity/IP meter is as shown in Fig. 1-1).

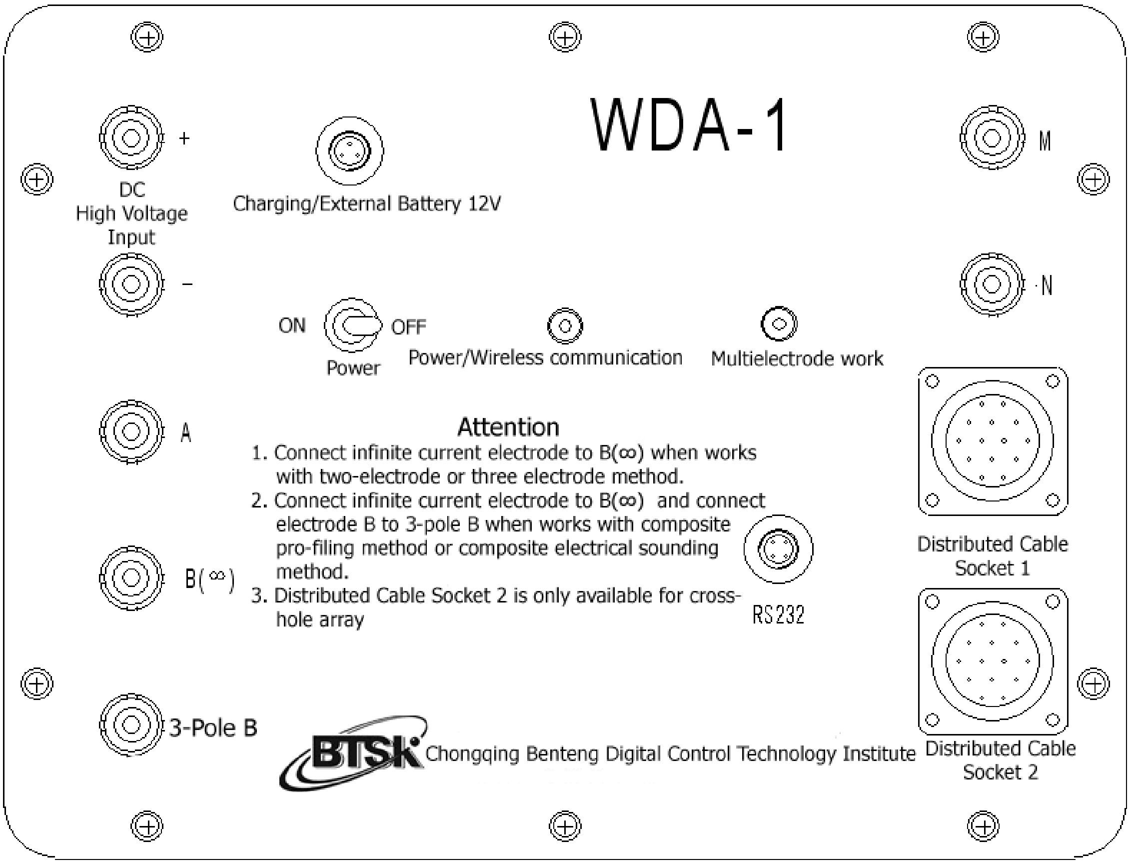

Fig. 1-1 Front panel of WDA-1

① **DC high voltage input**: connecting to the high voltage power supply, "＋" for positive terminal and "－" for negative terminal.

② **A:** port for Current electrode.

③ **B (∞)**: port for Current electrode.

④ **3-Pole B**: when conducting combined electric profiling (3P-PRFL) or combined electric sounding (3P-VES), connecting the infinity Current electrode to the "B (∞)" port and connecting the other Current electrode to"3-Pole B" port.

⑤ **Charging /External battery 12V**: as recharge socket to charge the internal battery; or as power source socket to connect with the 12V external battery.

⑥ **Power**: power switch.

⑦ **Power supply/wireless telecommunication**: turn on the WDA-1 and the indicator light turns on; during measuring process, this indicator light flickers.

⑧ **Multi-electrode work**: this indicator light flickers when conducting multi-electrode imaging mode.

⑨ **RS232**: standard serial communication port.

⑩ **M, N**: ports for signal input. "M" port connects to Potential electrode M electrode and "N" port to Potential N electrode.

⑪ **Cable socket 1, 2**: they are connected with intelligent cables when conducting multi-electrode 2D/3D imaging.

Front panel of WDA-1A super digital DC resistivity/IP meter is as shown in Fig. 1-2).

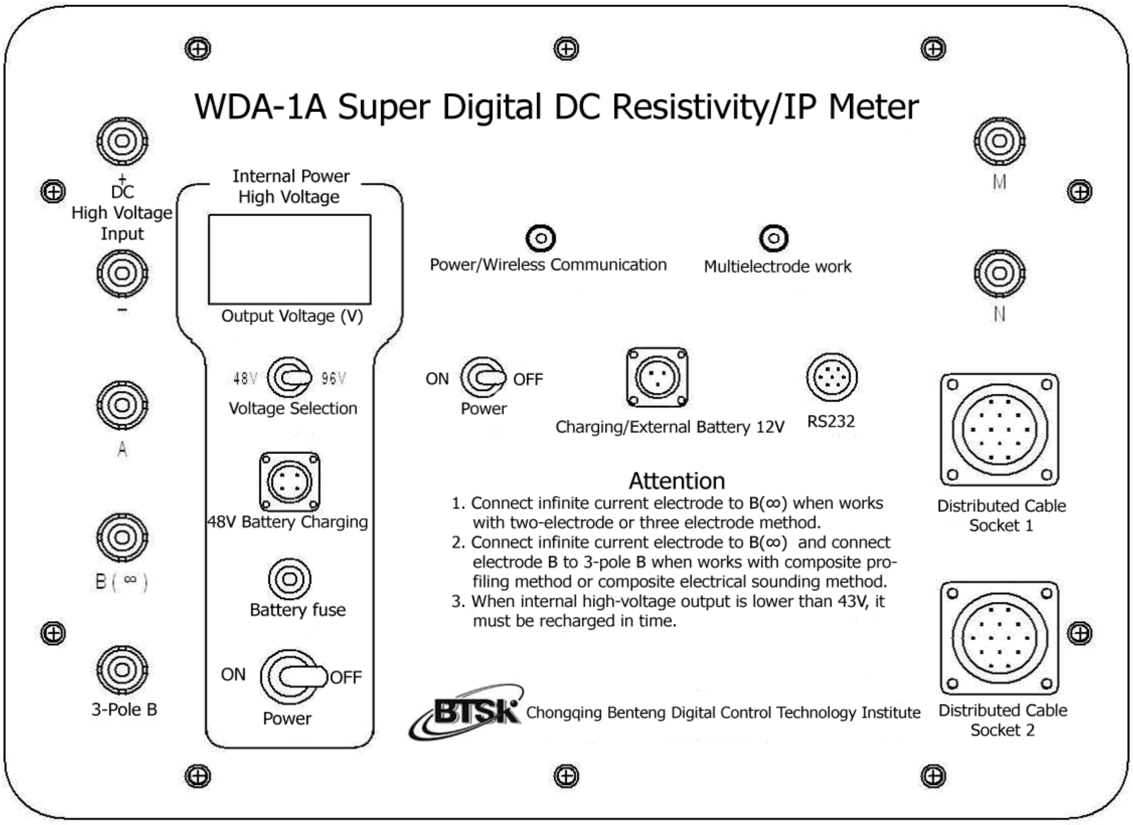

Fig. 1-2 Front panel of WDA-1A

The only difference between WDA-1 main frame and WDA-1A main frame is that **WDA-1A is designed with a 96V internal battery**. Introduction to the section of the internal high voltage battery is as follows:

① **Output voltages (V)**: display output voltage range of the internal high voltage battery.

② **Voltage selection**: 48V or 96V optional.

③ **48V Battery Charging**: recharge socket for the internal high voltage battery.

④ **Battery fuse**: protect the inner circuit when the high output voltage gets short-circuited.

⑤ **Power:** power switch for internal high voltage battery.

1.5 Power Source and Internal Battery

1.5.1 Power Source of WDA-1/WDA-1A

Standard working power source for WDA-1/WDA-1A super digital DC resistivity/IP meter is 8V lithium battery. This kind of lithium battery supports automatic protection function, that is, once voltage battery is lower than 6.6V, power supply is cut off automatically. Therefore, operator needs to pay attention to battery voltage during measuring process to ensure smooth field survey.

Run the data collection program in the PDA, click the battery icon on the menu bar at the screen bottom, or click "Menu"→"Measure"→"Battery volt" to check the battery voltage, and then the battery voltage value is displayed on the screen.

When battery voltage is lower than 6.8V, system clews "Lower battery voltage, please recharge in time". In that case, recharge the battery of WDA-1/WDA-1A main frame in time with the standard charger.

How to recharge

① Switch off WDA-1/WDA-1A main frame, and insert the three-core plug to the "Charging/External battery 12V" socket on the WDA-1/WDA-1A main frame.

② Connect the WDA-1/WDA-1A to 220V DC power supply and indicator light on the charger turns to red, at this time, the internal battery is being recharged.

③ After about 4~6 hours, when the battery is fully charged, the indicator light turns to green.

Note:

Recharging temperature range for the lithium battery is 0℃~45℃. If temperature is too high, the battery will be heated, which will shorten its lifetime or damage the battery.

1.5.2 Internal High Voltage Battery (WDA-1A only)

WDA-1A super digital resistivity/IP meter can not only get power supply from an external high voltage, but also from an internal high voltage battery which directly gives 48V or 96V DC high voltage. Voltage value is displayed on the LCD display on the mainframe.

This high-voltage lithium battery supports automatic protection function, when no output voltage from the internal High Voltage Battery or the voltage is lower than 43V (at 48V notch), system reminds operator to recharge the internal battery. In that case, please DO recharge the internal high-voltage battery with the standard charger packed.

How to Recharge?

① Turn off WDA-1A and insert the four-core plug to the "48V Battery Charging" port on WDA-1A main frame.

② Connect WDA-1A to 220V DC power supply and the indicator light on the charger turns to red. At this time, the internal battery is being recharged.

③ After about 4~6 hours, when the battery is fully charged, the indicator light turns to green.

Note:

Since the output current of this internal high voltage battery is very low, it is recommended to take the internal high voltage battery as power supply for resistivity survey mode; while for induced polarization survey, external DC high voltage battery is recommended.

SECTION TWO: GENERAL OPERATION GUIDE TO POCKET PC (PDA)

2.1 General Operation

Each PDA is equipped with a stylus to select items and input information. For fear of loss of the stylus, please put it in the stylus slot at the right top of the PDA.

The stylus functions as a mouse. General operations are:

1) **Click**: click once the screen by the stylus to open an item or choose an item; during sampling process, click once to choose an item.

2) **Click and hold**: click and hold an item by the stylus to display its available popup menu sub-items; then click a sub-item item to execute the corresponding function.

2.3 Soft Reset

During operation, if the PDA has no response when the screen or buttons are clicked, press the "Reset" button (on the right panel of the PDA) to do soft reset with the stylus.

2.4 Hard Reset

If the PDA system gets into critical fault or failure and refuses to soft reset, execute hard reset function.

What needs to pay attention is that all the data in the flash memory and the programs will lose, and that the PDA will recover to original settings. Please DO backup all the data in the PDA before hard reset.

After hard resets, the PDA system recovers to the original settings. Before field survey, please set parameters by following the steps below:

① Once the PDA hard resets, the Bluetooth also turns off. To continue field survey, turn on Bluetooth by following the steps in Section 2.5.

② Click "Start" → "Settings"→"Personal"→ "Menus" to set the parameters or items according to specific needs.

③ Click "Start"→ "Settings"→ "System"→ "Screen" (Fig.2-1) to choose "Landscape" (right-handed/left-handed, Fig.2-2).

④ Click "Start"→ "Settings"→ "System" →"Power"→ "Advanced" to cancel automatic power-off function.

Fig.2-1

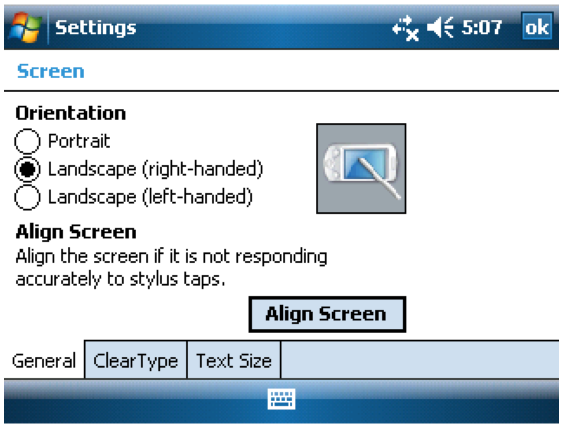

Fig.2-2

2.5 Turn On Bluetooth

Ensure that Bluetooth feature is turned on before field survey (check by the Bluetooth icon (marked in Fig. 2-4). If the Bluetooth icon is bright, Bluetooth feature has been turned on. If the Bluetooth icon is gray (Fig.2-3), click the icon and the Bluetooth icon turns to bright.

Fig. 2-3

Fig.2-4

2.6 Bluetooth Pairing

Based on the Bluetooth wireless communication technology, all operations of the PDA are fulfilled though the Bluetooth terminal. Therefore, before measuring, first pair the Bluetooth to enable WDA-1/WDA-1A to communicate with the PDA smoothly. Specific procedures of pairing Bluetooth are as follows:

1) Firstly turn on the WDA-1/WDA-1A main frame and turn on Bluetooth (please refer to Section 2.5).
2) Enter into the Program Main Interface and click "Menu"→"Bluetooth pairing" to get into the Bluetooth pairing interface (Fig. 2-5).
3) Choose an appropriate Bluetooth port (Bluetooth port varies from various pocket PC. For HP iPAQ pocket PC, choose COM6), then click "Bluetooth pairing" button and click "OK" (at the right top) to execute Bluetooth pairing operation (Fig.2-6).

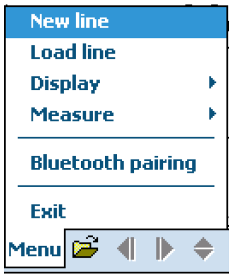

Fig. 2-5

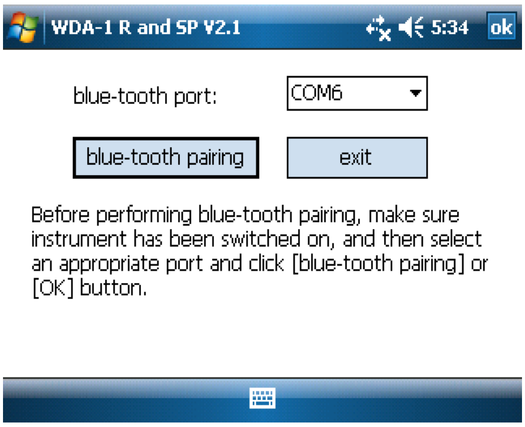

Fig.2-6

4) Click "Exit" to exit from the present program.

Note:

In order to verify the users' validity, sometimes the Bluetooth pairing interface (Fig. 2-6) pops up directly the moment system starts up, prior to the Program Main Interface. In this case, it means that system requires operator to pair the Bluetooth first and then enter into the measure interface.

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5) Once the "Bluetooth pairing" button is clicked, the PDA get into Bluetooth Browser; or then click "Refresh" and all the devices searched are displayed in the Bluetooth console interface (Fig. 2-7).

6) Select a Bluetooth device to pair Bluetooth and input passkey "1234" through the software keyboard that can be called out by clicking the icon . Then click "OK" to finish Bluetooth pairing and the "Bluetooth pairing accomplished" dialog box pops up (Fig.2-8).

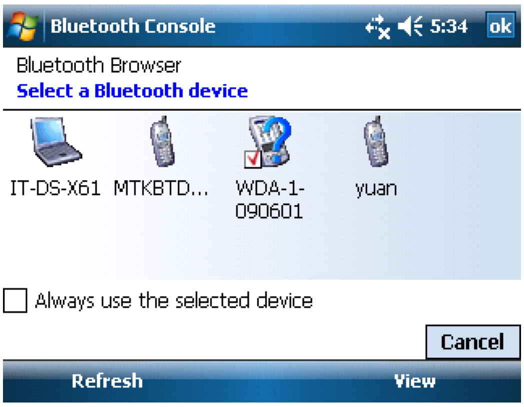


Fig. 2-7

Fig. 2-8

Note:

- **Original passkey is 1234.**
- **Operation of software keyboard: click the “ ” button at the bottom of the screen and software keyboard pops up automatically. Choose an appropriate input mode (at the left button of the keyboard); and then input the value through the stylus. When input finishes, click “ ” button once again to hide the software keyboard.**

2.7 Battery Recharge

Before field survey, ensure that the PDA has enough power; if not, recharge the PDA.

Power of the battery of the PDA can be read from the power supply indicator light. If the indicator light is green and flickering, battery is being recharged. If the indicator light keeps green, the battery is fully recharged.

Specific recharge operation is as follows:

1) Connect the power supply adapter to the PDA with charging wire (attached accessory).

2) Connect the power supply adapter to the 220V power source

Note:

- **Standard configuration of the pocket is a HP iPAQ.**

- **Regarding other operations on the PDA, please read the user guide packed together with the HP iPAQ.**

SECTION THREE: GENERAL RESISTIVITY & SP SURVEY

3.1 Concept and Relevant Parameters

1) **Apparent resistivity ρs/Res**: When the ground surface is flat and medium underground is uniform, infinite and isotropic medium, connect the Current electrode **A** and **B** to the power source and provide a current intensity of **IP** to the earth, then gain the potential differences $\mathbf{V_P}$ between Potential electrode **M** and **N**. Resistivity measured in this way is the homogeneous earth resistivity. But actually, the earth conditions dissatisfy resistivity survey: the measured results are not resistivity of the surrounding rock or the ore body, but apparent resistivity. Apparent resistivity is represented by **ρs** and calculated in **ΩM**. It can be defined as follows:

$$\rho s = K\,(V_P/I_P)$$

Among them, **K** as the array factor (or geometric factor) is calculated by the corresponding electrode array configuration formula, according the specific electrode array configuration and distances among electrode A, B, M, N, etc.

2) $\mathbf{V_P}$: according to resistivity's definition, V_P is the electric potential difference between Potential electrodes M and N.

3) $\mathbf{I_P}$: transmitting current by the Current electrodes A and B.

4) **Array/geometric factor K**: according to the definition formula of the resistivity **ρs** above, we can get the geometric factor by the following formula.

$$K = \frac{2\pi}{AM^{-1} - AN^{-1} - BM^{-1} + BN^{-1}},$$

Among them, AM, AN, BM, BN represents the distances among A, B, M and N. Unit is meter. **K** value depends on relative location of these four electrodes.

5) **Schedule**: there is a table containing relative electrode distance parameter of the four electrodes, which are called **Schedule** in the system program. Different electrode array configurations have different Schedule. For example, electrode distance parameters of 4-pole vertical electric sounding (4P-VES) are AB/2 and MN/2, while those for combined electric sounding (3P-VES) are OB and MN/2. For more details, please refer to the attached *Electrode Array User's Manual*.

6) **Self-potential (SP)**: SP is short name of self-potential; unit is mV.

7) $\mathbf{R_{Earth\ resistance}}$: earth resistance. All the DC electrical methods must be powered supplied by two Current electrodes (for instrument by BTSK, **Current electrodes are defined as A and B**) to form a loop circuit. However,

earthing state directly influences the value of output current. If well grounded, earth resistance is lower; if poorly grounded, earth resistance is higher.

8) **Electrode Array configuration**: referring to electrical method survey, various electrode array configurations are optional, applicable for various geologic structures. An electrode array configuration represents that its electrodes are arranged in certain mode and move at a certain method. Generally, electric profiling and electric sounding are commonly used electrode array configurations.

9) **Electric profiling**: electric profiling is one category of electrical methods, including many electrode array configurations whose electrodes are featured by keeping a certain distance between each electrode, while all the electrodes roll along at the same time along the survey line to measure apparent resistivity. Since that distance between electrodes keeps unchanged during roll-along movement, output current is injected underground to a certain depth, measuring depth of the points on the survey line keeping the same; in other words, the resistivity curve is geologic reflection of a certain layer.

10) **Electric sounding**: similar to electric profiling on variety, electric sounding includes many electrode array configurations. These electrode array configurations feature keeping measuring point position fixed but increasing distances among the electrodes. Since that distance between the current electrodes increases, output current is injected deeper into the ground. Therefore, measured results are geologic reflection of the geological structure of different layers.

3.2 Program Main Interface

Program Main Interface of resistivity method is as the figure below (Fig.3-1).

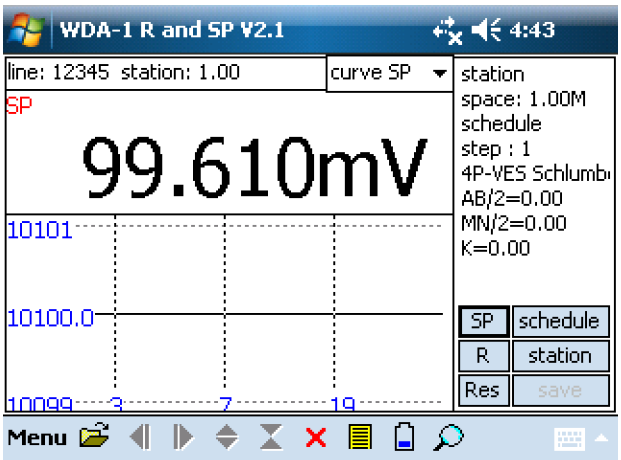


Fig.3-1 Program Main Interface of General Res & SP Survey (Res method)

As shown in Fig. 3-2, in the middle of the screen are data display area and waveform display area. The right section is an area with buttons. Parameters are also displayed at the right side of the screen.

At the top of these shortcut buttons is a button for a pull-down menu which enables operator to choose a parameter to be plotted as curve and displayed, resistivity **ρs** or **SP** are available (Fig. 3-2).

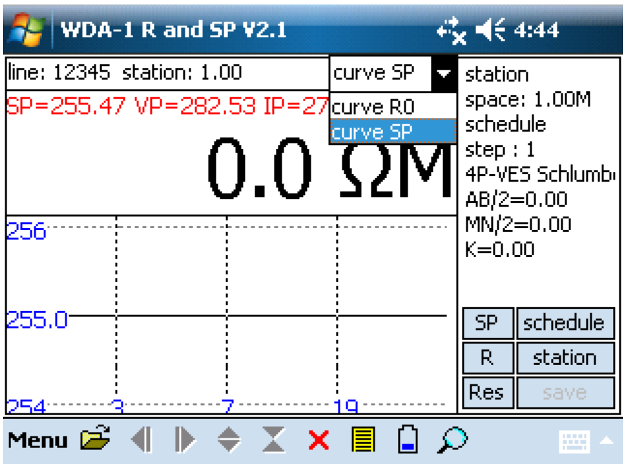


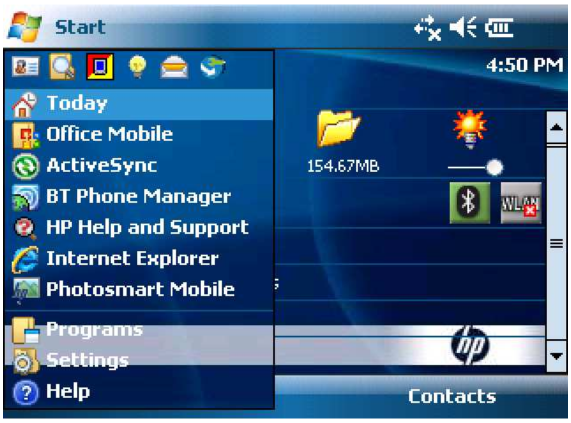
Fig.3-2

3.3 Operation

3.3.1 Turn on WDA-1/WDA-1A and Run System Program

Turn on the WDA-1/WDA-1A main frame and turn on the pocket PC.

Click "Start"→ "Program" (Fig.3-3)→ "File Explorer" (Fig.3-4)→ "Storage Card" file → "WDA-1DR" program to enter into system program of General Electrical Resistivity Survey mode (Fig.3-5).



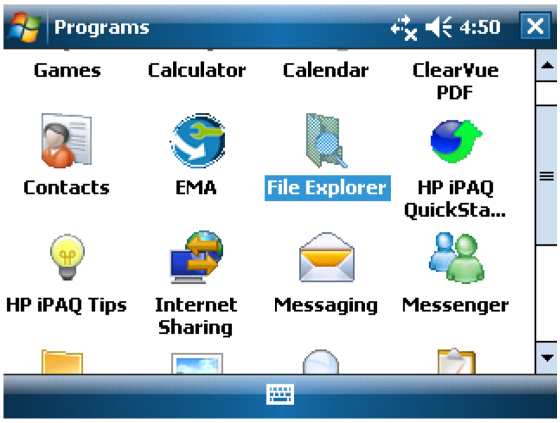


Fig. 3-3 *Fig. 3-4*

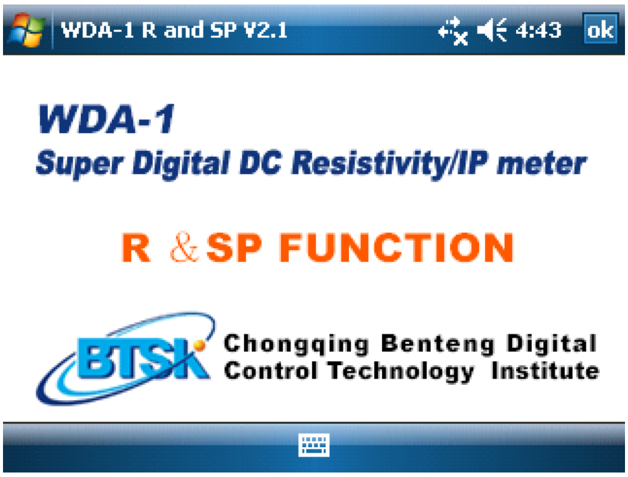


Fig.3-5

Click the screen to get into the Program Main Interface (Fig.3-1).

3.3.2 Bluetooth Pairing

Before any other operation, first pair Bluetooth (for details, please refer to Section 3.6). After that, system enters into "Bluetooth pairing accomplished" interface; click "OK" to back to the Program Main Interface.

3.3.3 Create Survey Line

Under Program Main Interface (Fig. 3-6), click "Menu" → "New line" to set parameters (Fig.3-7).

Input parameters and finally click "Create line" or "OK" (at the right top of the screen).

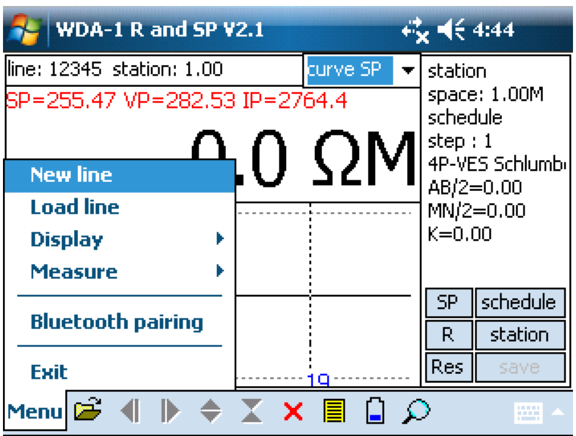


Fig. 3-6

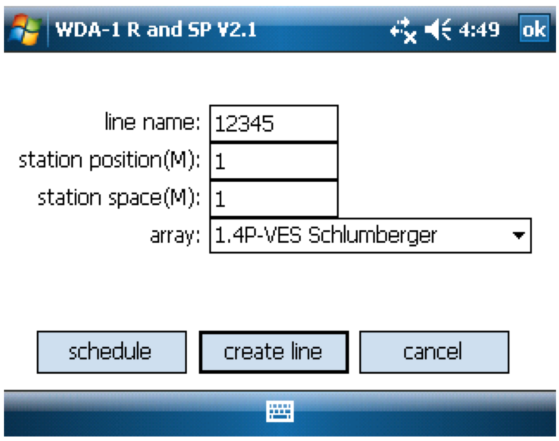


Fig. 3-7

Parameters in the interface are introduced below.

Line name: number of a survey line or name of the corresponding data file stored, which is inputted through the software keyboard.

Station space: distance between two adjacent survey points, that is, spacing/interval of the survey points.

Station position: relative distance between two adjacent survey points. This parameter is also valid in other survey method except for vertical electric sounding. Once data of a survey point are stored, "Station position" automatically adds one Station space. For example, if "Station position" of present survey point is 10 and "Station space" is 2, once data of this point are stored, "Station position" of the next survey point turns to 12 automatically.

Array: 12 electrode array configurations are available for general resistivity/IP survey, namely, 4P-VES Schlumberger, 4P-VES Wenner, Combined electric sounding (**3P-VES**), Four-pole electric profiling (**4P-PRFL**), Combined electric profiling (**3P-PRFL**), Rectangle/Middle Gradient (**RECT**), Dipole-dipole (**DIPOLE**), IP Survey in Well - Well Azimuth Sounding (**IP-BUR**), Five-pole Longitudinal Axis Electrical Sounding (**5P-VES**), Composite Electric Profiling (**C-PRFL**), Four-pole Quadratic time difference array (**QUADR-TD 4P**) and Three-pole Quadratic time difference array (**QUADR TD 3P**). Except for access to these electrode arrays, user can also input geometric factor K value directly through **Item 9 Input K value** for some special electrode array configurations that is not available in this system. For detailed introduction to these electrode array configurations, please refer to the attached *Electrode Array User's Manual*, *Section One, Electrode Array of General Electrical Resistivity/IP Survey*.

Note:

If name of the new survey line already exists, system will fail to create this line. Please input another new name (Fig. 3-8).

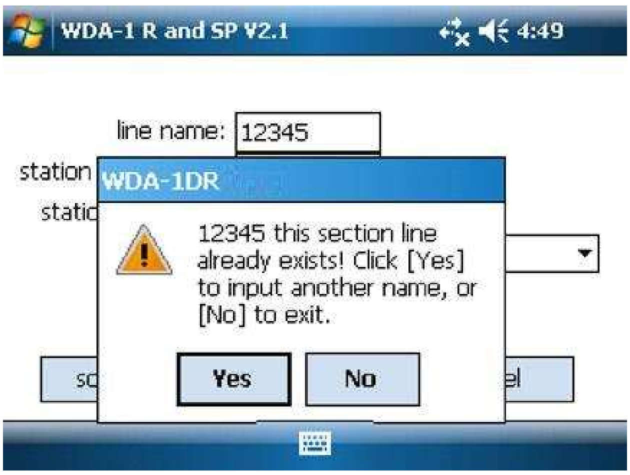


Fig. 3-8

3.3.4 Set Schedule (Electrode Distance)

1) Under Program Main Interface or under Fig. 3-7, click "Schedule" button to enter into Schedule interface (Fig. 3-9) to set interval relations among the electrodes. Electrode intervals of each electrode array configuration are

different. Therefore, operator has to update the Schedule according the specific electrode array configuration. System will automatically calculate geometric factor K automatically according to the electrode distance parameters set.

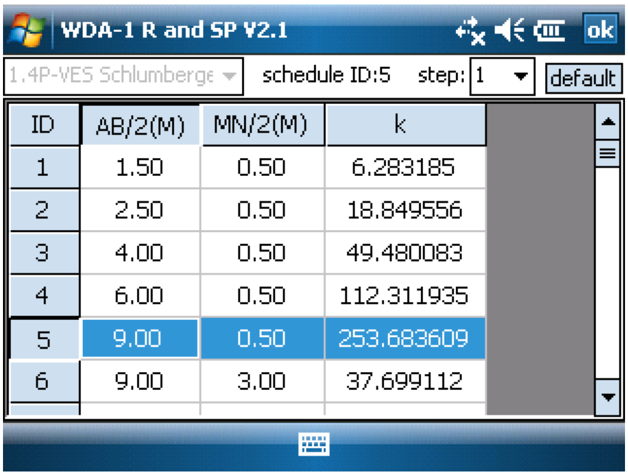


Fig.3-9 Schedule interface

2) After that, click one ID as the present electrode distances (take Fig. 3-9 for example, Schedule ID is 5 and set "Step" (1, -1 and 0 optional). System will move to the next ID according to "Step" parameter. For example, if Schedule ID of present survey point is 2 and Step is 1, once the data of present survey point are stored, Schedule ID turns to 3 automatically.

Note:

① **If Schedule ID is chosen prior to measurement, but later the measured resistivity value proves that the Schedule ID is incorrect, modify this Schedule ID before it is stored. Following the steps in Note ② to change the Schedule ID.**

② **Clicking "Schedule" button to modify the Schedule ID → click "OK" to confirm and exit from the interface. Then, resistivity of this survey point displayed on the screen changes as well.**

3.3.5 Measure

Under the Program Main Interface, click buttons "**SP**", "**R**", "**Res**" to measure self-potential, earth resistance and resistivity respectively, or click "Menu" → "Measure" to conduct the corresponding measurement.

1) Measure Self-Potential (SP)

Click "**SP**" button, and the SP value displays on the screen; unit is mV (Fig.3-10). If absolute value of SP>100,000mV, system clews "Excessive self potential".

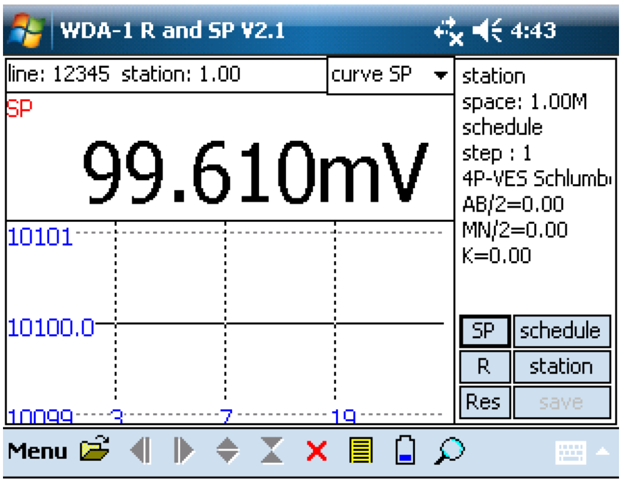


Fig. 3-10

2) Measure Earth Resistance (R)

Click "**R**" button to enter into the measure interface, as shown in Fig. 3-11. Click the "Grounding R" button to start continuous measuring. If the measured resistance is more than 5KΩ, system clews "Too large". To stop measure, press "Terminate" button.

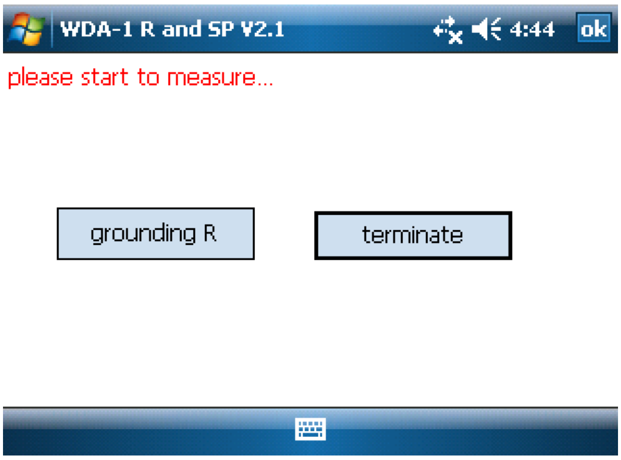


Fig. 3-11

3) Measure Battery Voltage

Click the battery icon on the menu bar to read battery voltage (Fig.3-12).

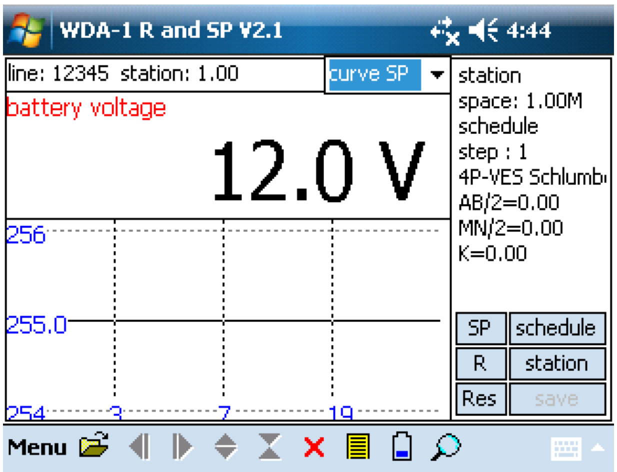


Fig.3-12

4) Measure Resistivity (Res)

Click the "**Res**" button to measure resistivity, and then SP, VP, IP and resistivity values are displayed on the digital display together with curve.

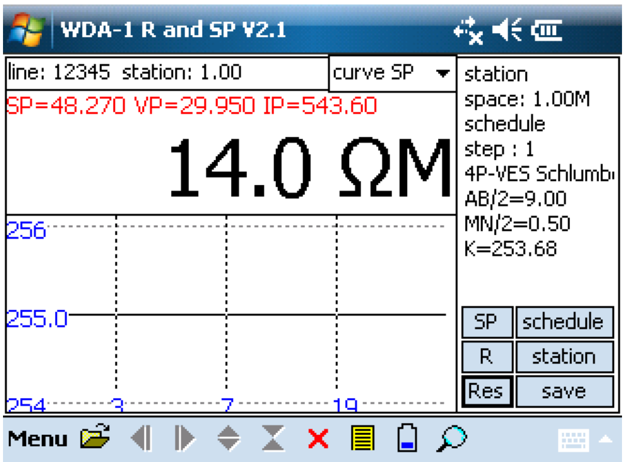


Fig.3-13

Unit of resistivity is **ΩM**. Each time one measuring action finishes, store the data manually and ensure survey point is correct. If data are stored successfully, the "**Res**" button turns to gray.

For non-vertical electric sounding configuration, position and ID of the next survey point changes automatically according to the preset "Station space" and "Step". If operator wants to test a survey point once again, "Station space" and "Step" should be set as 0 (Fig.3-14). Operation is, clicking "Schedule" buttons to modify the parameters and then clicking "Measure".

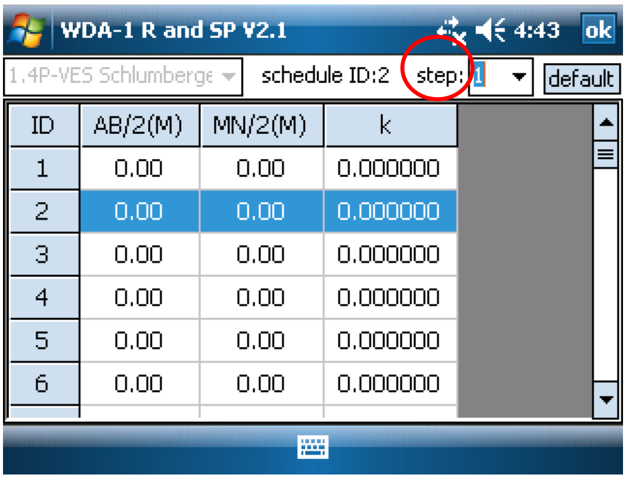


Fig.3-14

For vertical electric sounding configuration, "Station space" is unavailable, for several data points are acquired on a same survey point. The total data points may be unknown. If several data points acquired on a same survey point, the measured results could be stored directly. When electrodes are moved to another survey point, modify "Station position" parameter. Operation order is clicking "**Station**" button inputting a new position, pressing "**OK**" to exit from the interface (Fig.3-15), clicking "**Measure**" to measure again and then system starts a new serial of vertical sounding.

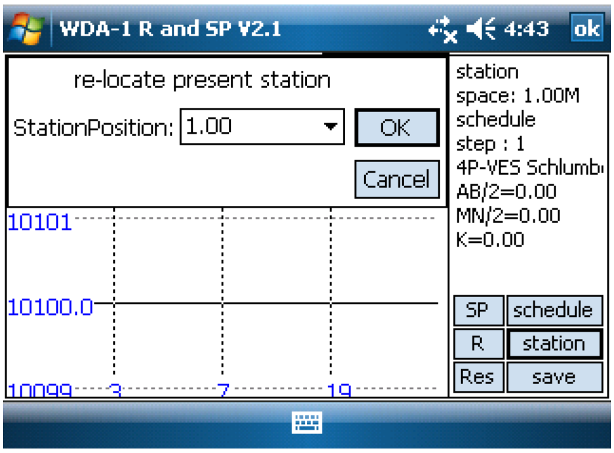


Fig.3-15

3.3.6 Measure in Composite Electric Profiling Array (C-PRFL)

Under the Program Main Interface, click "**Res**" button to enter into the measure interface of the Composite Electric Profiling (Fig. 3-16). Set "Station position", "Station space" and choose parameters to be displayed (R0, SP, VP and IP are available).

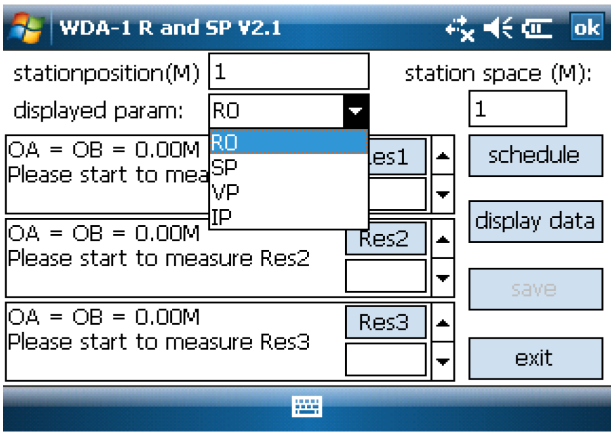


Fig.3-16

Since Composite Electric Profiling is a combination of three combined electrical profiling (**3P-PRFL**), each point should acquire three groups of data, namely, **Res1**, **Res2** and **Res3**, only when all these data are gained could they be stored together. What's more, each group of data includes **Resa** and **Resb** in that current electrode A, B give power supply respectively.

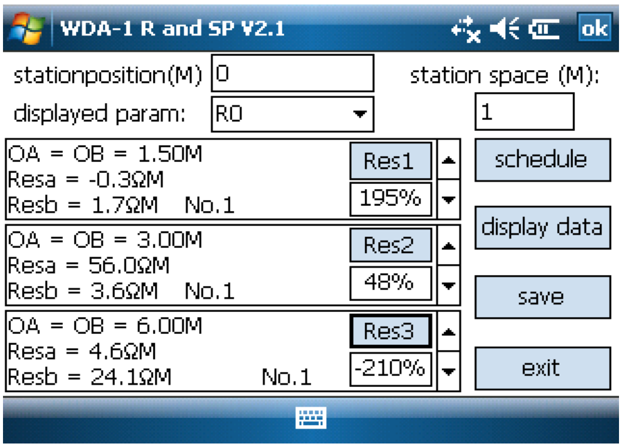


Fig. 3-17

During once period of power supply, system could memorize four groups of measured results for a survey point. Press arrow keys to choose the best group of measured results as the final data gained. When **Res1**, **Res2** and **Res3** are gained, click "Save" to store these data.

For two adjacent measured results of a point, in the right text box is percentage showing approximation of the measured results (Fig.3-17). The higher the percentage, the better the data are.

3.3.7 Display Waveform

For the waveform gained by non-vertical electric sounding, click the arrow buttons, "Zoom in" and "Zoom out" icon, "Delete" icon or click "Menu"→"Display" to adjust the waveform. While for the vertical electric sounding configurations, only "Delete selected data" and "Delete all data" functions are available (at the bottom of the screen, Fig. 3-18).

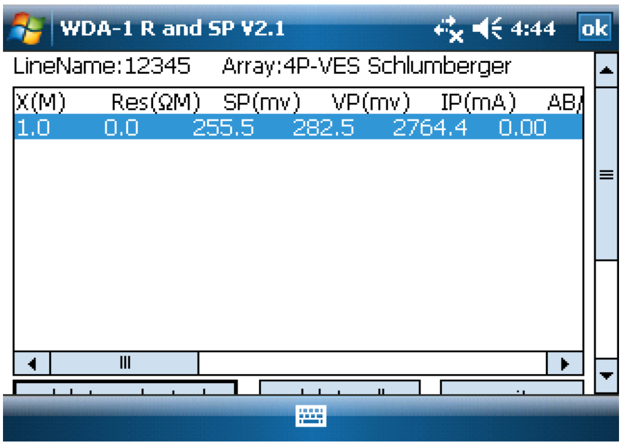


Fig. 3-18

1) Cancel survey point

Click one data point on the waveform by the stylus, and the corresponding information displays at right side of the waveform, including survey point number, corresponding curve, measured data, etc; click "x" icon (at the bottom of the screen) to delete this data point.

2) Display curve data

Click the corresponding icon on the menu bar or click "Menu"→"Display"→ "Review data of curve" to enter into the display interface (Fig. 3-18), the corresponding survey line number, electrode array configuration, data points, measured data, **Res**, SP, etc, are displayed. If measured results of a data point is not ideal, click "Delete selected data" option with the stylus to delete data of this point; to measure this point again, first modify the survey point location and then measure once again and store the measured result.

3.3.8 Open a Survey Line

All the measured data of resistivity are stored in SD card, in "WDA-1D" file. Click the corresponding icon at the left bottom of the screen or click "Menu"→"Load line" to choose as survey line name (Fig. 3-19).

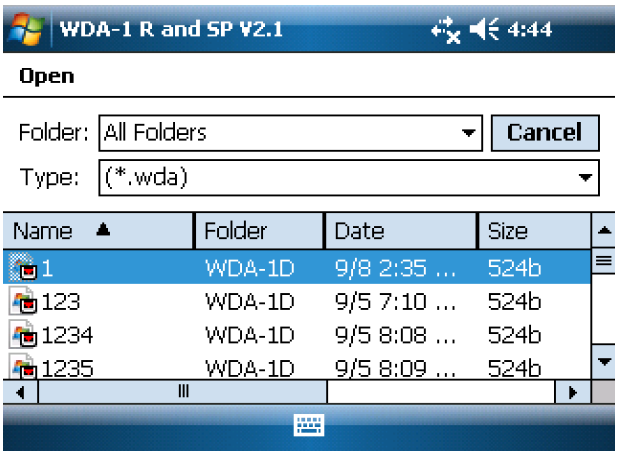


Fig. 3-19

SECTION FOUR: GENERAL IP & SP SURVEY

Even though output current is injected into the earth constantly and stably, it is observed that electric potential between the Current electrodes changes as time and trends to a stable value after a certain time. When output current is cut off, electric potential between the Current electrodes drops instantly first and then slows down and finally decays to zero.

During the process of charging and discharging, an additional electric field forms slowly as time goes by, caused by electrochemistry. This phenomenon is called induced polarization effect (IP or chargeability for short). This kind of electrical method is based on non-homogeneous medium or ore body.

Through observing and studying different chargeability of the surrounding rocks or ore body, we can gain geologic structure and information of a region clearly.

4.1 Concept and Relevant Parameters

1) Apparent Polarizability (M1~M7)

The waveform in Fig. 4-1 is a typical waveform of induced polarization measured data. For sampling time and "Sampling duration" of polarizability M1~M7, please refer to Table 4-1 below.

M1~M7 sampling time and "Sampling duration" of M1~M7 is fixed and has nothing to do with "Transmitting duration. If "Transmitting duration" is shortened, parameters which cannot be measured are 0, for example, when "Transmitting duration" is 2s, only M1~M5 can be measured while M6, M7 are set as 0.

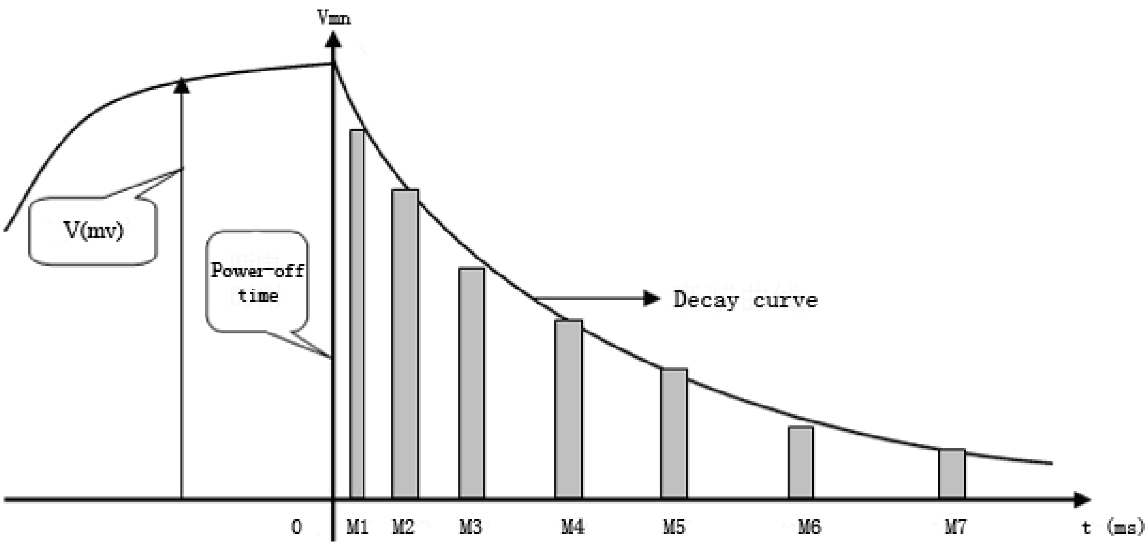


Fig. 4-1 Waveform of induced polarization

	M1	M2	M3	M4	M5	M6	M7
Sampling time (ms)	200	300	500	920	1920	2920	3920
Sampling duration (ms)	40	80	80	80	80	80	80

Table 4-1 M1~M7 sampling time and sampling duration

2) Define Polarizability M

Different from apparent polarizability M1~M7, users can define transmitting duration and M sampling duration of polarizability, that is, in Fig. 4-1, operators can set transmitting duration and sampling duration of M. What should be noted is that transmitting duration (including M sampling duration) is 5000ms; therefore, ensure that time summation of M starting time and M sampling duration is no more than 5000ms.

3) Half Decay Time TH

Provided power-off time prologs to 200ms and secondary field sampling is DVMI, then TH is the time for secondary field decaying to DVMI/2; unit is ms and accuracy is ±10ms.

Note: only when "Transmitting duration" is ≥5s, should this parameter be calculated.

---

4) Decay rate D

$$D = \frac{\frac{1}{5000-200}\sum_{t=200}^{5000} V_{MN}(t)\cdot\Delta t}{DVMI} \bullet 100$$

Where, $\triangle t = 10$ms.

Provided power-off time prologs to 200ms and secondary field sampling is DVMI, that is, D is the ratio of the mean value in 5s of secondary field sample and the first sample.

Note: only when the "Transmitting duration" is ≥5s, should this parameter D be calculated.

---

5) Induced Polarization Ratio J

$$J = \frac{\frac{1}{(5000-200)} \cdot \sum_{t=200}^{5000} V_{MN}(t) \cdot \Delta t}{VP} \cdot 100$$

Among which △t = 10ms.

J is the ratio of the mean value in 5s of secondary field sample and voltage of the primary field.

Note: only when the "Transmitting duration" is ≥5s, should this parameter J be calculated.

---

6) Comprehensive Parameter Z_P

$$Zp = 0.75 \times M1 \times TH / 1000$$

7) Metal Parameter G1～G7

$$Gn = 100 \times Mn / \rho s$$

Among them, n: 1~7

Gn: metal factor

Mn: apparent polarizability of present survey point

ρs: resistivity value of present survey point

8) Decay curve

Actual decay curve of the secondary field

9) Quadratic Time Difference DT2

Quadratic time different is the difference between half decay time measured at high-voltage power supply and half decay time measured at low-voltage power supply. Only when "Transmitting duration" MT⩾6S will this parameter be calculated.

Since that secondary field decay time of aquifer is in direct proportion to the generated current, but it keeps unchanged or decreases in non-aquiferous stratum as the increase of generated current, this parameter Quadratic decay time plays a key role in groundwater exploration.

Quadratic time difference survey method utilizes four/three electrodes.

Working principle of Quadratic Time Difference Survey method:

System transmits two different types of current (high voltage and low voltage) to the earth through the Current electrodes, and system measures twice with the same electrode position and electrode distances. Then system calculates their difference of half decay time of the two secondary fields between these two measurements. If the layer is aquifer, the difference value is a positive value; if the layer is not aquifer, the difference value is zero or negative value.

The measured quadratic time difference values of all the data points will be plotted. Curve sections above the base line indicate aquifer; curve sections below the base line indicate that there is no groundwater. Area formed by the curve of positive values is in direct proportion to the amount of groundwater of a unit.

This parameter is only available in Quadratic time difference electrode array. It is very useful for groundwater exploration.

10) Quality Discriminant Coefficient K

This parameter is to test accuracy of the voltage range of the secondary field. If current intensity is less than 1mA/cm2, voltage range of the secondary field is in direct proportion to the current.

Provided that, $\mathbf{I_D}$ is high transmitting current

$\mathbf{I_X}$ is low transmitting current.

$\mathbf{U_{2D}}$ is voltage of the secondary field that generated by the high transmitting current.

$\mathbf{U_{2X}}$- is voltage of the secondary field that generated by the low transmitting current.

Then,

$$\frac{I_D \cdot U_{2X}}{I_X \cdot U_{2D}} = 1$$

$$K = Ln\frac{I_D \cdot U_{2X}}{I_X \cdot U_{2D}} = 0$$

In actual measurement, it is impossible to have K=0. Statistics prove that the result is reliable when K<0.05. This parameter is only available in "Quadratic time different" survey method.

11) Deviation r

$$r = \frac{1}{\overline{M_i}}\sqrt{\frac{\sum(M_i + k \cdot \log(t_i) - B^2)}{n}} \cdot 100$$

Of which, n stands for sampling point quantity; **n=1～7,** $\overline{M_i} = \frac{1}{n}\sum_{i=1}^{n} M_i$ stands for the mean value of polarizability (M1~M7) of respective sampling points in the observing time period. **K** and **B** are coefficients of equations of the straight Line —— **M(t)=B-k·log(t)**, in the logarithm time axis.

r is used to weigh the difference between practically measured decay curve and "ideal straight line". The larger **r** is, the worse the "linearity" is; the smaller **r** is, the stronger the "linearity" is. So, **r** is called as deviation, i.e. the degree of deviating from "ideal straight line". The research shows that **r** will decrease with the increase of water amount in the rock, i.e. when water amount increases, the "linearity" of decay curve will become stronger.

12) Comprehensive Parameter ZP

$$Zp = 0.75 \times M1 \times TH / 1000$$

13) Metal Parameter G1～G7

$$Gn = 100 \times Mn / \rho s$$

Among them, n: 1~7

Gn: metal factor

Mn: apparent polarizability of present survey point

ρs: resistivity value of present survey point

4.2 Program Main Interface of General IP & SP Survey Function

Turn on the WDA-1/WDA-1A main frame and turn on the pocket PC. Click "Start"→ "Program"→ "File Explorer"→ "Storage Card" file → "WDA-1DRIP" program to enter into the system program of General Induced Polarization Survey mode (Fig.4-2).

Program Main Interface of induced polarization and SP survey is nearly the same with that of the electrical resistivity & SP survey function (Fig.4-3).

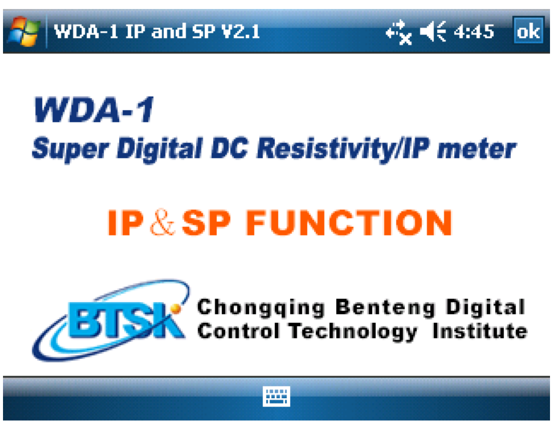


Fig.4-2

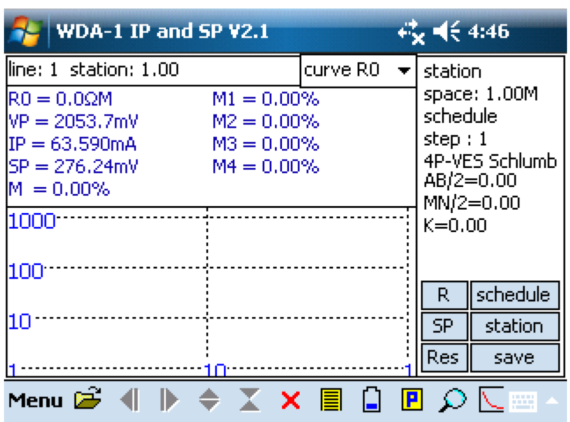


Fig.4-3

4.3 Operation

Operation of IP survey is basically the same with that of resistivity/SP survey mode, but different on the following points.

This section gives introduction only to the parameters that are unique to general induced polarization survey and to the differences between resistivity survey and IP survey. For other introduction and operations, please refer to **Section Four Operation Guide to General Electrical Resistivity & SP survey**.

4.4 Differences Between Resistivity Survey and Induced Polarization (IP) Survey

Compared with the general resistivity survey, IP survey function,

1) Measure other parameters

Some unique parameters of IP survey are apparent polarizability M1~M7, user-defined polarizability M, decay rate D, etc. Each parameter can be plotted in curve (by choosing and clicking the corresponding parameter in the pull-down menu at the right top of the display area on the screen).

2) More parameters are set

Click "P" icon (on the menu bar) or click "Menu" → "Set parameters" (Fig. 4-4) to enter the "Parameter setting" interface (Fig. 4-5). Set parameters of "M Starting time", "M sampling duration", "Transmitting duration" and "Transmitting", as well as parameter to be displayed.

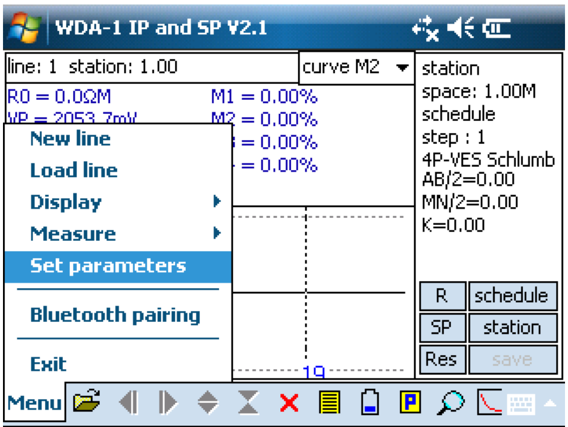


Fig.4-4

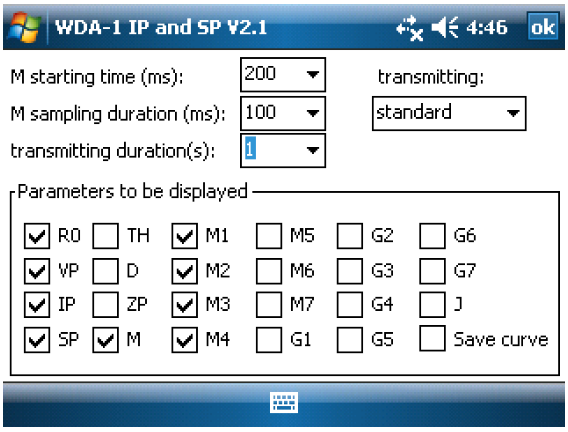


Fig.4-5

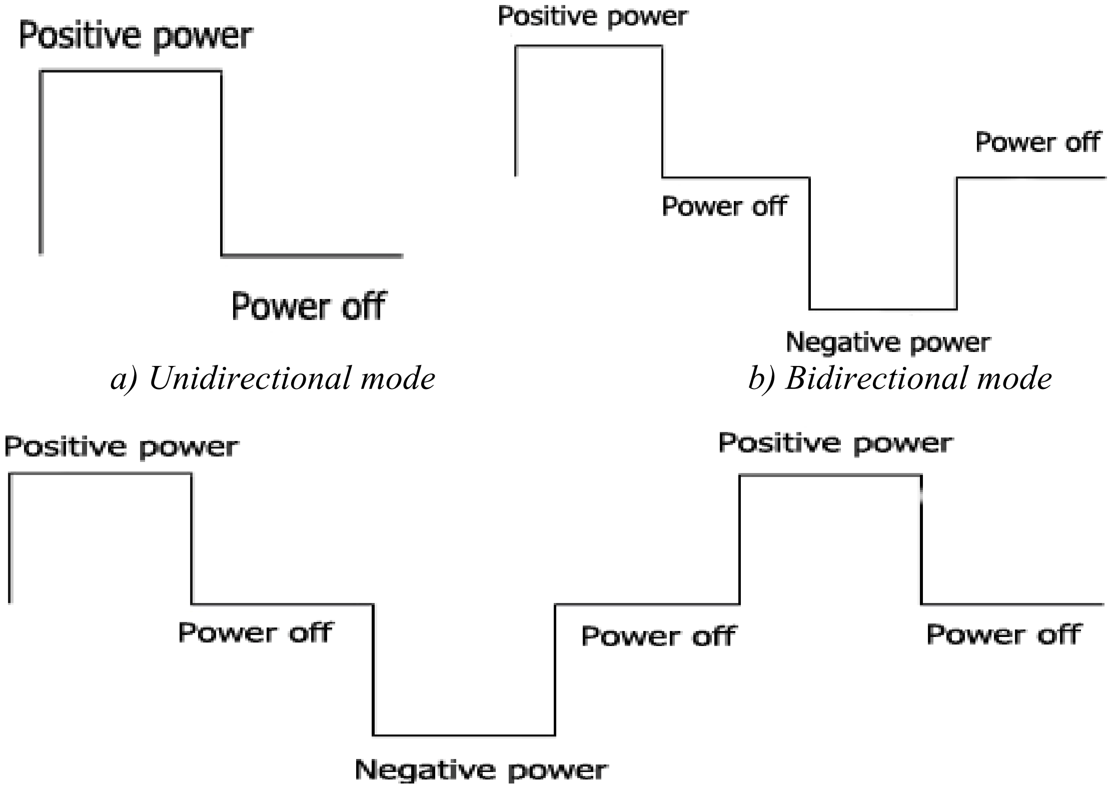
M Starting time: Start sampling time of the polarizability M.

M sampling duration: sample width of polarizability M.

Transmitting duration: power-on time of the current electrodes A, B which inject current to the earth.

Parameters to be displayed: the certain measured data could be chosen to be displayed. They are apparent resistivity (R0), voltage of primary field (VP), current of primary field (IP), self-potential (SP), half decay time (TH), decay rate (D), comprehensive Parameter (ZP), polarizability (M~M7), metal factor (G1~G7), induced polarization ratio (J).

Transmitting: there are three types of power supply modes, namely, standard mode, unidirectional mode and bidirectional mode.



C) Standard mode

Fig. 4-6 Power supply modes

As shown in Fig.4-6, the unidirectional mode has only one power-on period, i.e. "Positive power —Power off" (Fig.4-6a)); bidirectional mode has two power power-on periods, i.e. "Positive power — Power off — Negative power — Power off" (Fig.4-6b)); while the standard mode has three power-on period, i.e. "Positive power — Power off —Negative power — Power off — Positive power — Power off" (Fig.4-6c)). The measuring of parameters is accomplished during power off.

SECTION FIVE: FIELD SURVEY EXAMPLE ——GENERAL IP

1. Measuring Conditions

1) Electrode array configuration is Schlumberger, a kind of 4-pole vertical electrode array (4P-VES).
2) Measure two data points at different depth, along a survey line.
3) AB/2=3.0m, 9.0m, MN/2=0.5m, Transmitting duration=5s.
4) To ensure measuring accuracy, DC high voltage for primary field $V_P \geq 10.0mV$.
5) DC power supply is 30V.
6) Measuring function: electrical resistivity and induced polarization (IP).

2. Operation Procedures

1) Arrange electrodes -- The First Data Point

Arrange the electrodes according to requirements of Schlumberger configuration (Fig.5-1), solid non-polarized electrodes M, N locate at in the center of the two current electrodes A, B symmetrically, MN/2=0.5m, AB/2=3.0m.

Electrodes A, B, M and N respectively connect to the terminals A, B (∞), M and N connecting port on the WDA-1/WDA-1A main frame.

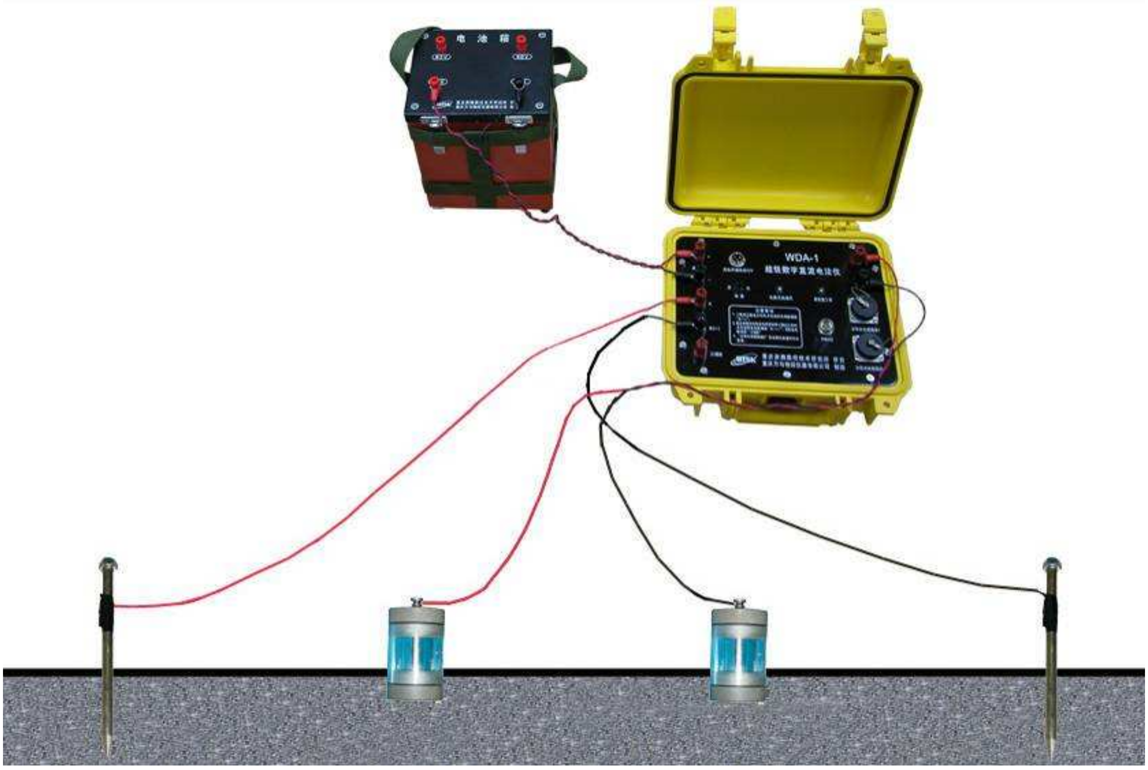


Fig.5-1 Layout of the system in field

2) Ensure connections are correct and then turn on the WDA-1/WDA-1A main

frame and the PDA.

3) Run the resistivity and induced polarization program "WDA-1DRIP".
4) Pair Bluetooth. For detailed operating procedures, please refer to Section 3.6 in this user's manual.
5) Set survey line parameters

Click "Menu"→"New line", the interface pops up as shown in Fig.6-2. Set Line name, Station position, Station space and choose electrode array "4P-VES Schlumberger".

Note:

"Station space" is unavailable for vertical electric sounding configurations. When present survey point has been measured, manually modify survey point location to measure the next point.

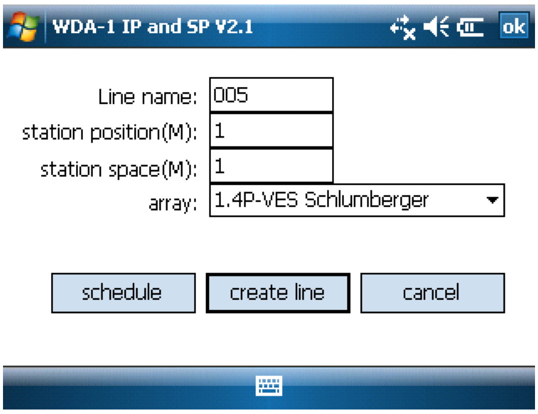


Fig.5-2

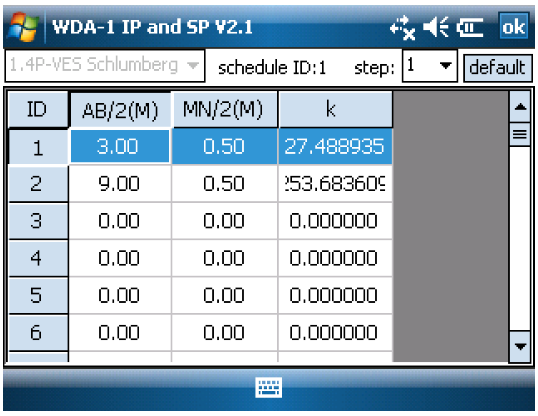


Fig.5-3

Click the button "Schedule" in the screen (Fig.5-2) to enter into Schedule interface (Fig.5-3) and choose "1" as the "Step".

To measure two data points at different depth, modify Schedule AB/2 and MN/2 that are under ID 1, ID 2. For ID 1, AB/2=3, MN/2=0.5; for ID 2, AB/2=9, MN/2=0.5, instantly, system calculates array factor K automatically. Then choose ID 1 and click "OK" to exit from the setting interface.

Finally, click "Create line" button to back to the Program Main Interface and setting of this survey line finishes.

6) Set power supply parameter and sampling parameters

Click "Menu"→"Set parameters". Set "M starting time" of self-defined polarizability M as 200ms, "M sampling duration" as 100ms, "Transmitting duration" as 5s, and power supply mode "Transmitting" as standard, or choose some "Parameters to be displayed" on the Program Main Interface (Fig.5-4).

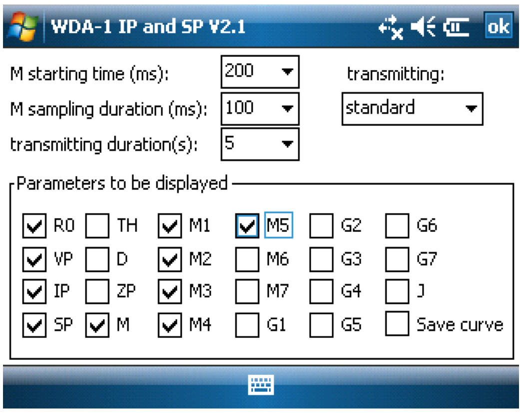


Fig.5-4

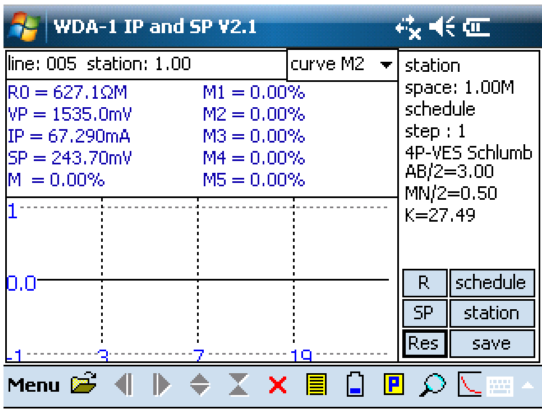


Fig.5-5

7) Measure and save

When all the parameters have been set, start to measure. Click "**Res**" button (at the right bottom of the screen, see Fig. 5-5) or click "Menu" →"Measure" →"Res". Measured result is then displayed in the middle of the screen. At this time, click "Save" button to save the measured data.

8) Rearrange electrodes -- The second Data Point

Enlarge the distance between two Current electrodes A and B: AB/2=9. Distance between electrodes M and N keeps unchanged. In the system, schedule ID turns to 2 automatically since the "Step" is 1 (Fig.5-6).

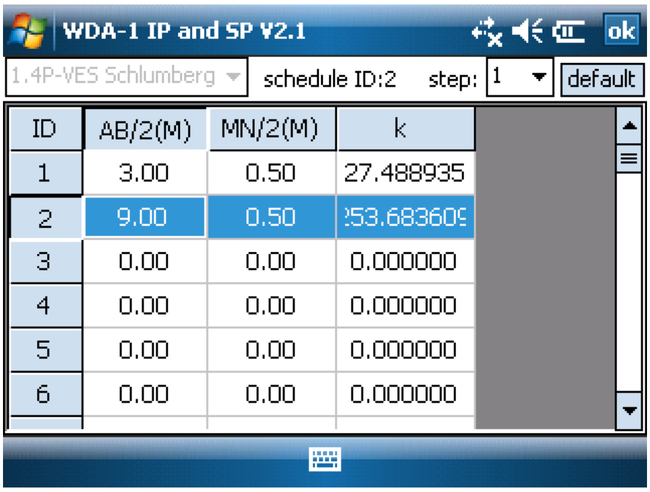


Fig.5-6

9) Measure and save

Click the button "**Res**" to measure the second data point. Measured result is then displayed at the middle of the screen. After saving this group of measured data, curve formed by these two data points is displayed on the screen (Fig.5-7).

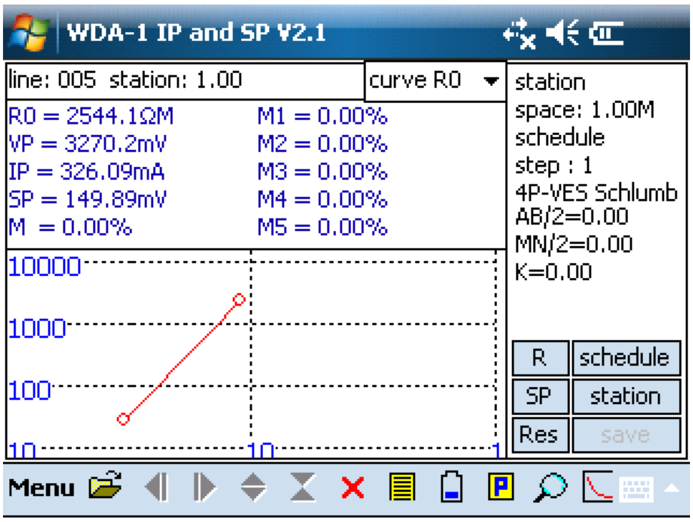


Fig.5-7

10) Till then, measurement of these two data points finishes. Shutdown the system.

Note:

- **If more data points need to be measured, repeat step 8~9.**
- **For input of "Station position" before measure another survey point, click "Station" button (at the right bottom of the screen, and click the software keyboard to input position of the next survey point (Fig.5-8).**

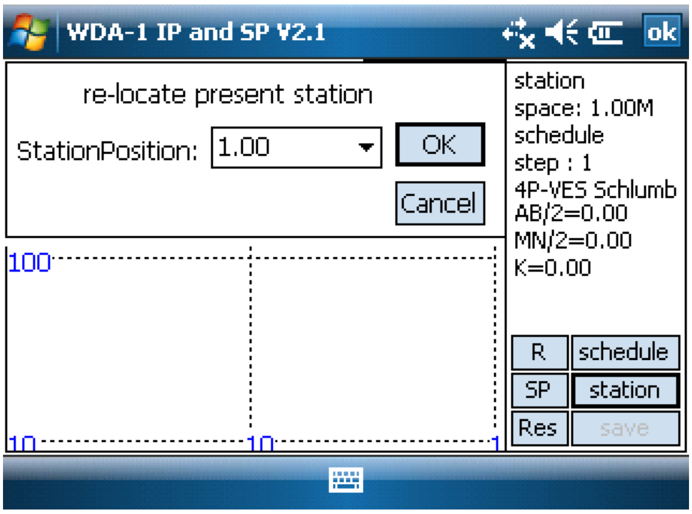


Fig.5-8

SECTION SIX: MULTI-ELECTRODE 2D RESISTIVITY IMAGING (WITH WDZJ-3 /30-TAKE-OUT MULTI-ELECTRODES CABLE)

6.1 Overview

There are two systems that can conduct 2D resistivity imaging, both of which take WDA-1/WDA-1A as the mainframe. One system is composed of one WDA-1/WDA-1A mainframe, one WDZJ-3 multiplex electrode converter (hereafter also referred to as WDZJ-3 converter), multi-electrode cables and electrodes. The other system consists of one WDA-1/WDA-1A mainframe, intelligent cables and electrodes.

Section six only devotes to the introduction and operation guide of the former system, that is, the 2D resistivity imaging system with WDZJ-3 multiplex electrode converter. **WDA-1/WDA-1A super digital DC resistivity/IP meter** as its mainframe to do control and imaging, completes with **WDZJ-3 multiplex electrode converter** and **multi-electrode cables** and **electrode**s, to fulfill **2D resistivity imaging**.

Regarding introduction to the latter system, please refer to Section Seven in this user's manual.

6.2 WDZJ-3 Multiplex Electrode Converter

Front Panel

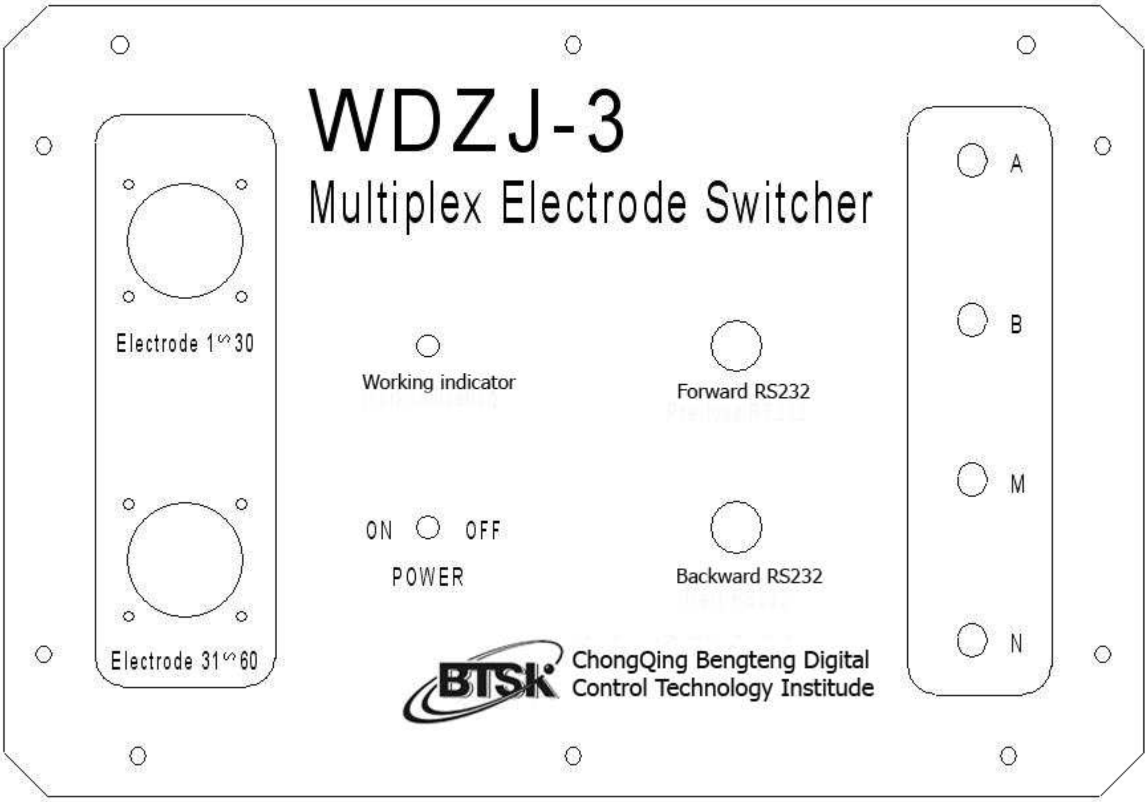


Fig. 6-1 Front panel of WDZJ-3 converter

1) **Electrode 1-30**: the first 30-take-out cable socket, electrode numbered from 1 to 30.
2) **Electrode 31-60**: the other 30-take-out cables socket, electrode numbered from 31 to 60.
3) **A, B**: power supply terminals, connecting to the corresponding ports on WDA-1/WDA-1A mainframe when measuring.
4) **M, N**: signal terminals, connecting to the corresponding terminals of WDA-1/WDA-1A mainframe when measuring.
5) **Forward RS-232**: serial port, connecting to RS-232 port on front panel of the mainframe WDA-1/1A, receiving control commands from the WDA-1/1A.
6) **Backward RS-232**: serial port transmitting commands of WDA-1/1A backward to the next WDZJ-3 converter. If several WDZJ-3 converters is in serial connection with more electrodes, communication cable should connect the previous WDZJ-3 converter to next WDZJ-3 converter through the RS-232 ports, namely, "Forward RS-232" port and "Backward RS-232" port. "Forward RS-232" port connects to the previous WDZJ-3 converter and the "Backward RS-232" port connects to the next WDZJ-3 converter.
7) **Working indicator light**: this indicator light keeps on when it works well. It flickers when system starts up, initializing, receiving or transmitting commands of mainframe.

Working Principle

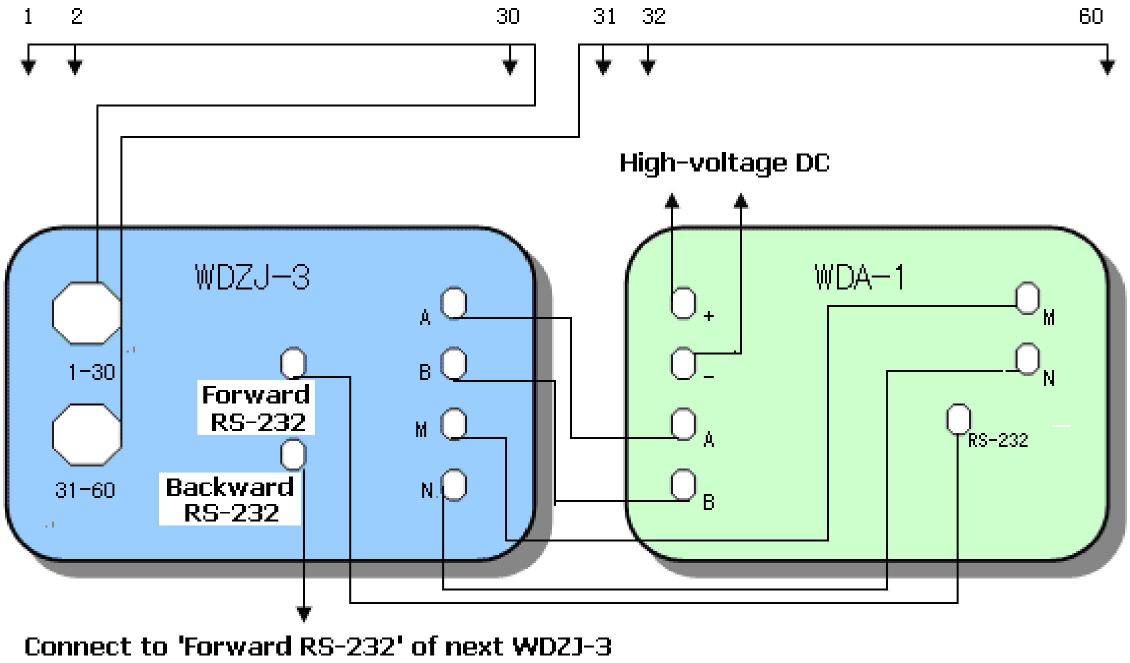


Fig. 6-2 Circuitry

As mainframe, WDA-1/WDA-1A controls the WDZJ-3 multiplex electrode converter through RS-232, select A, B, M, N electrodes by turns among 1~60 electrodes, according to the specific electrode array (for interpretation of different kinds of electrode arrays, please refer to the attached *Electrode Array User's Manual*, *Section Two, Electrode Array of Multi-electrode Electrical Resistivity Survey*).

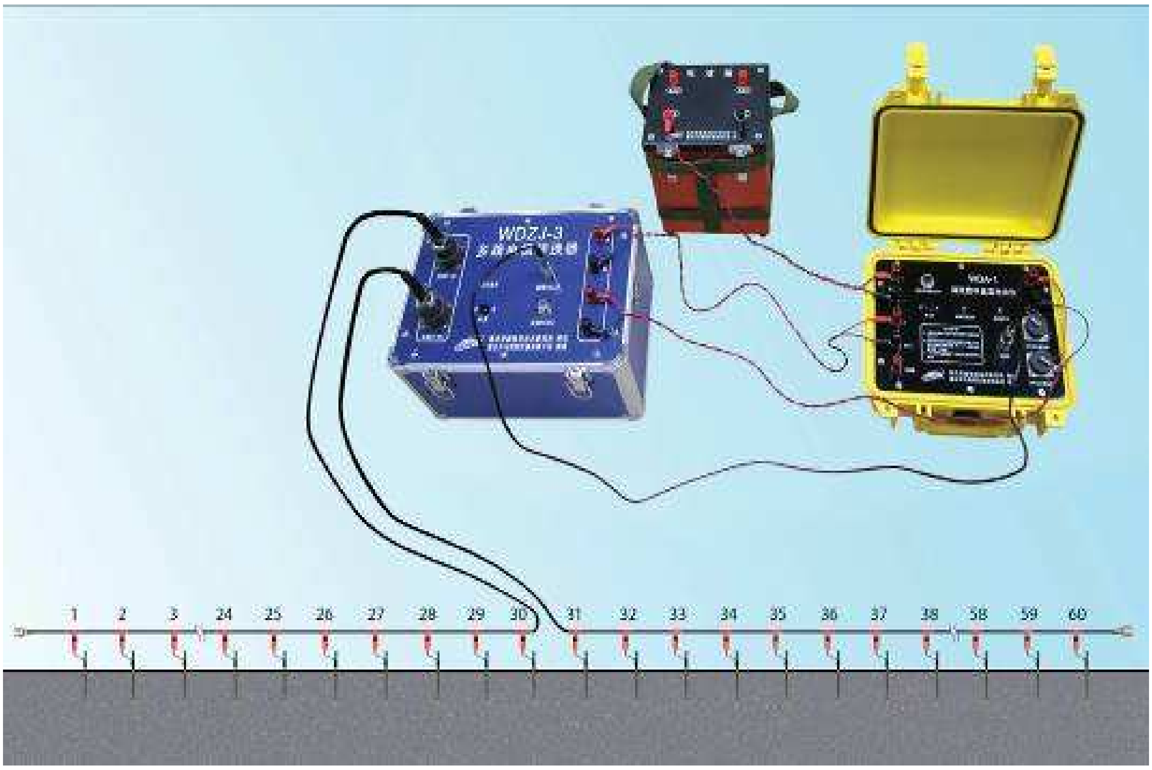


Fig. 6-3 Field survey layout

WDZJ-3 converter in Fig. 6-3 is numbered as 1 automatically. To cascade more WDZJ-3 converter, just connect them together through "Backward RS-232" port and "Forward RS-232" port, and connect A, B, M, N port to each corresponding electrodes. The mainframe will number the next WDZJ-3 converter as 2 and electrodes on the second WDZJ-3 converter will be numbered as 61~120.

Note:

- **Examine regularly whether WDZJ-3 converter works well and make sure switch-on or switch-off functions are normal. For detailed operation, please refer to Appendix B).**
- **Periodically check insulating property of WDZJ-3 converter and make sure that insulation between each pin of "1~30 Socket" and "31~60 Socket" and terminals A, B, M, N on panel are more than 500Ω (by 500VMΩ resistivity meter). If insulation fails to meet the requirements, please contact the supplier.**
- **Generally, each size-D battery of WDZJ-3 converter could last for 10 hours. If the output voltage is about 70~80% of the nominal voltage, please replace the batteries with new ones, otherwise, battery box will be damaged by battery leakage.**

6.3 Operation

6.3.1 Turn on WDA-1/WDA-1A and Run System Program

Switch on WDA-1/WDA-1A, turn on the pocket PC and then click "Start"→ "Program"→ "Explorer"→ "SD card" → "WDA-2DR" to enter into the system program (Fig. 6-4).

Fig. 6-4

6.3.2 Pair Bluetooth

Please refer to Section 2.6.

6.3.3 Set Parameter

1) Create Cross-Section

Click "Menu"→ "New section" (Fig. 6-5) and system enters into the Parameter setting interface (Fig. 6-6).

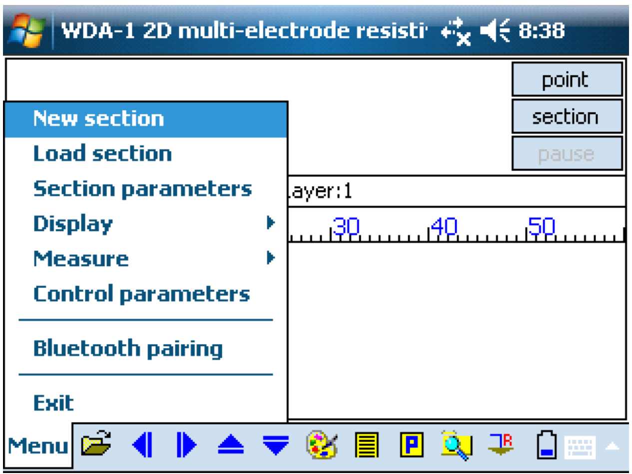


Fig. 6-5

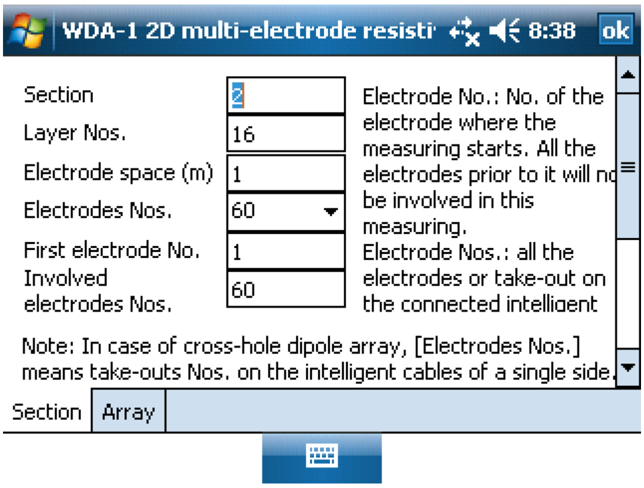


Fig. 6-6

Section: section/cross-section is the collection of all the survey points on the same vertical plane where the survey line locates. Section is the name of one cross-section in field survey and the name of the corresponding file stored in disk.

Layer Nos.: a layer is the collection of all the survey points at the same depth. And "Layer Nos." comes from total layers measured at the different depth.

Electrode space: it is the distance between the two adjacent electrodes; unit is meter. This parameter functions calculating the geometrical factor K of each electrode array configuration and recording points locations.

Electrode Nos.: amount of all the electrode take-out that used at present, connecting to all the multi-electrode cables.

Note: in cross-hole dipole, "Electrode Nos." means the number of take-out on the cable along a single side.

First electrode No.: number of the electrode where the measurement starts, all the electrodes which are prior to this electrode are not involved in this measurement.

Involved electrodes nos.: amount of the electrodes connected along the survey lines and in use.

2) Choose Electrode Array Configuration

Array: there are 15 electrode array configurations available, 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 Alpha 2 array (**SCHLMBG**), Self-Potential M array (**SP-M**), Self-Potential MN array (**SP-MN**), Charging M (**CHG-M**), Charging MN (**CHG-MN**) which are applicable for fixed cross section roll-along scan measurement; and 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 are applicable for extendable cross section continuous roll-along measurement (Fig. 6-7). For detailed introduction, please refer to the attached *Electrode Array User's Manual.*

Note:

Only the 15 electrode array configurations are available when WDA-1/WDA-1A works with WDZJ-3, the last option of cross-hole dipole array is excluded. In other words, if you choose Cross-hole Dipole array (CR-DIPOLE) as the electrode array of an newly created section, then system automatically choose "Intelligent cable" and "Socket 1" and "Socket 2" as the cable and switches (Fig. 6-11).

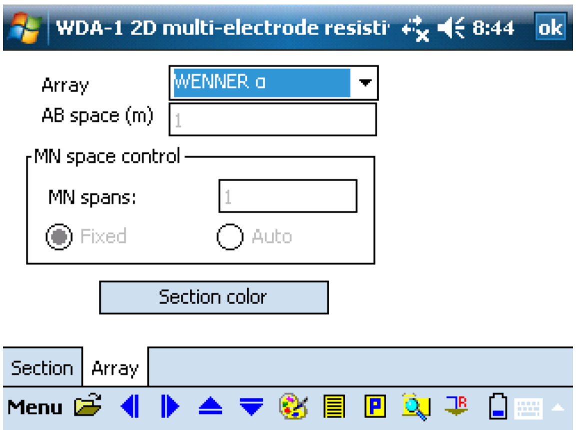


Fig. 6-7

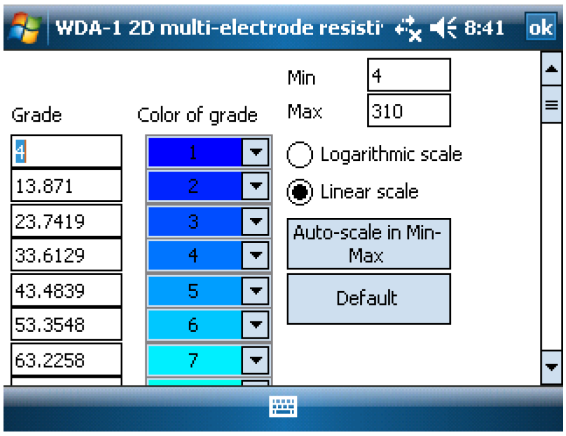


Fig. 6-8

AB space: AB distance, unavailable.

MN spans: distance between potential electrodes M and N. "Fixed" and "Auto" are options. "Fixed" means MN interval is set by the operator; while "Auto" means the center of MN keeps fixed; yet adds two electrode spacings every eight layers on the section. For example, if the original setting of "MN spans" is 1, the ninth layer is 3 and the seventeenth layer is 5. When the electrode array is three-pole roll along array (**3P A-MN** and **3P AB-M)** array, MN-B array or Wenner Alpha 2 array (**SCHLMBG**), this parameter is distance between Potential electrodes M and N.

Section color: see Fig. 6-8, "Auto-scale in Min-Max" button is to set color automatically according to values chosen in "Max" and "Min" pull-down boxes; "Default" button is to set color automatically according to maximum and minimum resistivity of current profile. User can also choose "Logarithm scale" and "Linearity scale" of the defined color.

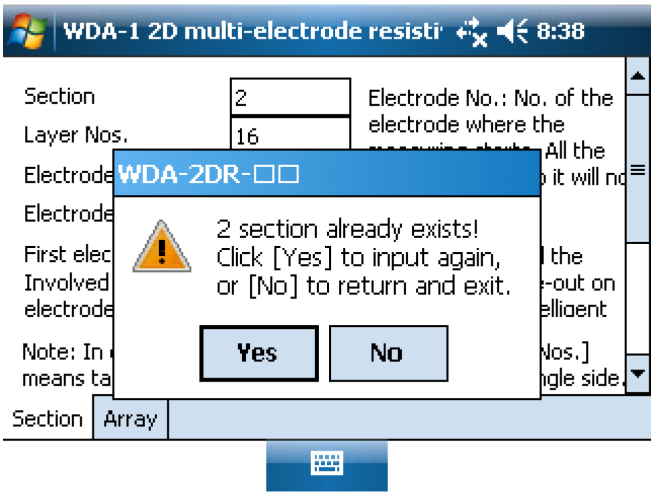


Fig. 6-9

Note:

Section names are not allowed to be the same. Once a new section is created, the parameters can not be modified. If modification is necessary, input a new section name to create another "Section" (Fig. 6-9).

---

3) Set Control Parameter

As shown in Fig 6-10, click the corresponding shortcut icon at the bottom of screen or click "Menu"→"Control Parameter", and the Control parameter setting interface pops up (Fig. 6-11 a). If the currently chosen option is "Intelligent cable", choose WDZJ-3 (Fig. 6-11 b).

Parameters are profile, power supply, self-potential, etc. All these parameters have a default; to recover the default, click the "Restore to Default" button.

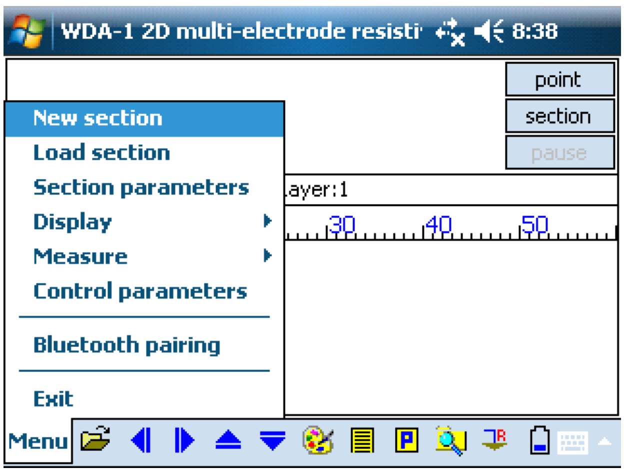
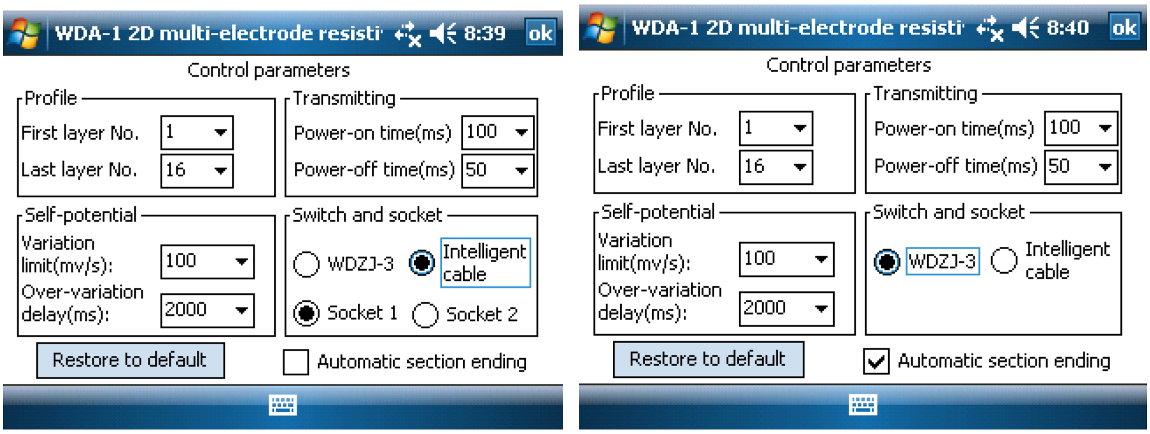


Fig. 6-10



a) *b)*

Fig. 6-11

4) Profile

First layer No.: number of layer from which the system starts measuring. Default is 1.

Last layer No.: Number of profile till which measuring finishes. Default is 16.

Note:

"Last layer No." should not be less than the first layer number (First layer No.).

---

5) Transmitting

Both positive power supply phase and negative power supply phase belong to the Power-on phase (Fig. 6-12). Time of positive power supply phase and negative power supply phase is named as Power-on time; time between them is named as Power-off time.

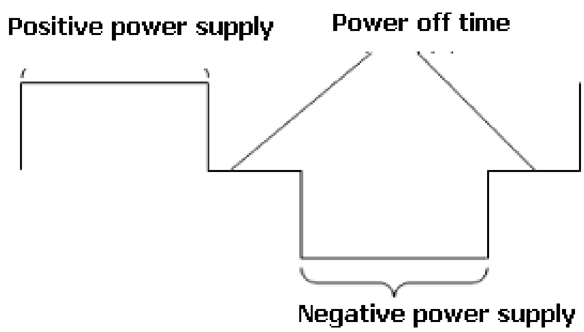


Fig. 6-12

6) Self-Potential

In the multi-electrode resistivity imaging system, there may be a large amount of electrode coulombs left after one measuring action; if go on to the next measuring action immediately, measuring **error** of may be enlarged. In order to improve measuring precision, WDA-1/WDA-1A will wait until the potential recovers, so as to eliminate errors caused by self potential jumping.

However, in some geological conditions whose self-potential is quite active (such as alkaline soil), recovery of self potential may not be satisfying after the above operation; then set appropriate "Variation limit" and "Over-variation delay" to improve measuring precision, which means system compensates self-potential of the next survey point. System first tests and checks whether current self potential jumps and whether it is higher than "Variation limit" defined; if it is higher, set "Over-variation delay" time to wait until self-potential gets stable.

"Variation limit": 10, 20, 50, 100, 200, 500 are available; unit is mV/s. Choose one value according to the actual geological condition (default is 100mv/s). The smaller the value, the higher the measuring precision, and the longer the time needed; the higher the value, the lower the measuring precision and the shorter the time needed.

"Over-variation delay": 500, 1000, 2000, 3000, 5000 are available; unit is ms and default is 2000ms.

Switch and Socket: since the Section you are reading devotes on introduction to multi-electrode 2D Res imaging with WDZJ-3, choose WDZJ-3. Information of the alternative "Intelligent cable", please go to Section Seven.

7) Automatic Section Ending

User decides whether performing the function of ending section automatically or not.

If choose this function, system will end section automatically when the complete section is measured; however, under this mode, system could not conduct extendable cross-section continuous roll-along imaging.

Since cross-section is defined differently by various electrode array configurations, shapes of the ending of the section are different (Fig. 6-13).

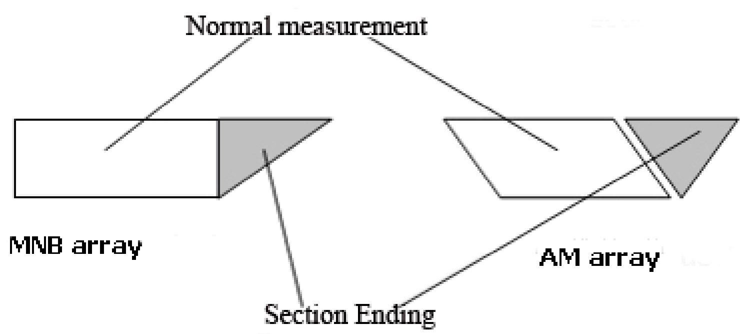


Fig. 6-13

If to continue performing roll-along measurement, deselect this option "Automatic Section Ending" and the system will automatically clew movement of the electrodes (Fig. 6-14). Then follow the prompt message to rearrange the electrode backwards by clicking "Yes" and to do extendable cross-section roll-along imaging, or click "No" to have system end the section.

Since each multi-electrode cable can connect with 30 electrodes, to perform roll-along imaging, all cables should be shifted forwards or backwards.

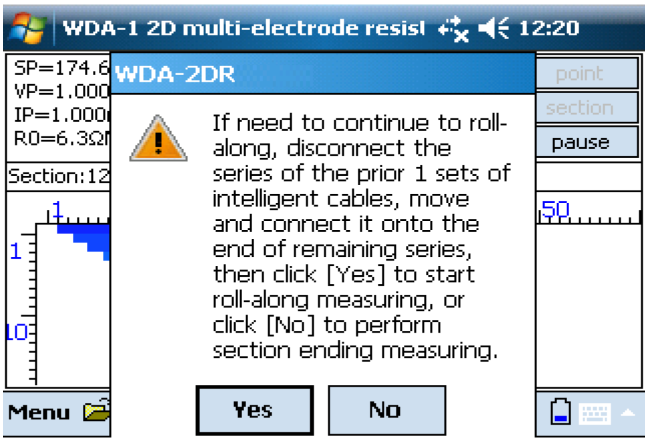


Fig. 6-14

For example, survey conditions are:

a) Electrode: 60 electrodes

b) Electrode array: Wenner Alpha array (WENNER α)

c) Parameters of cross-section: defaults

When conduct multi-electrode 2D Res imaging with WDZJ-3, system prompts as Fig. 6-14 after one cross-section is measured. Move the No.1 electrode to where No.13 electrode is, No.2 electrode to where No.14 electrode is, and the following electrode backwards one by one, until the 60 electrodes are rearranged (Fig. 6-15); then click "Yes" to continual measuring.

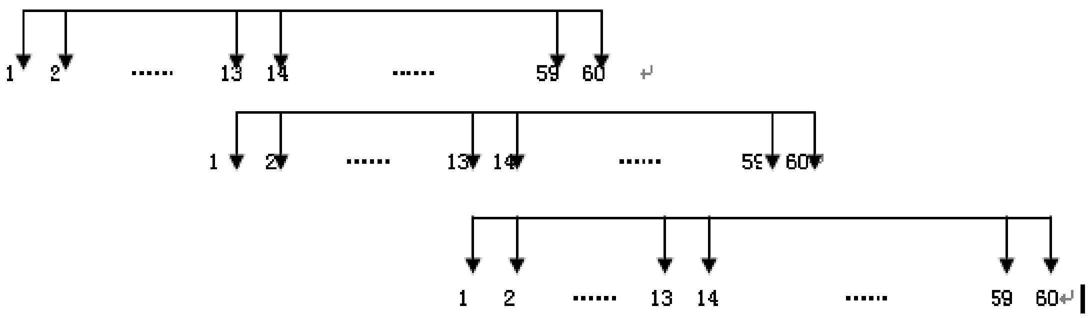


Fig. 6-15

8) Check Parameters

Finishing setting all the parameters of the cross-section, click the corresponding shortcut button at the bottom screen or click "Menu"→"Section parameters" (Fig. 6-16) to display current parameters of a section (Fig. 6-17), so as to check whether any incorrectness exists.

If any parameter is incorrect, go back to the Parameter setting interface to modify it immediately.

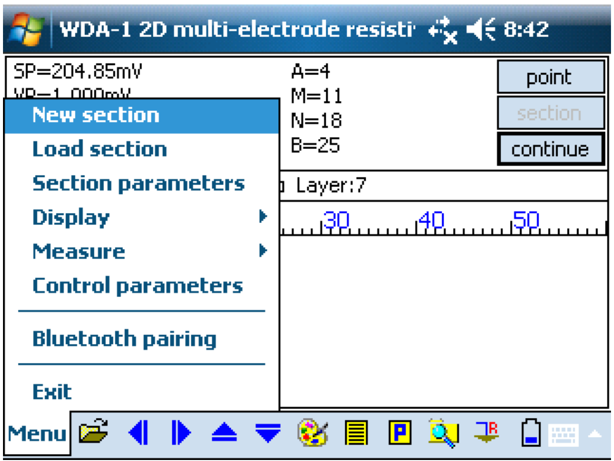


Fig. 6-16

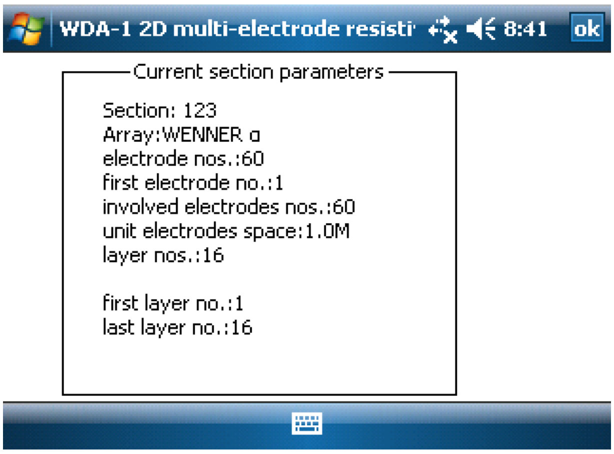


Fig. 6-17

6.3.4 Measure

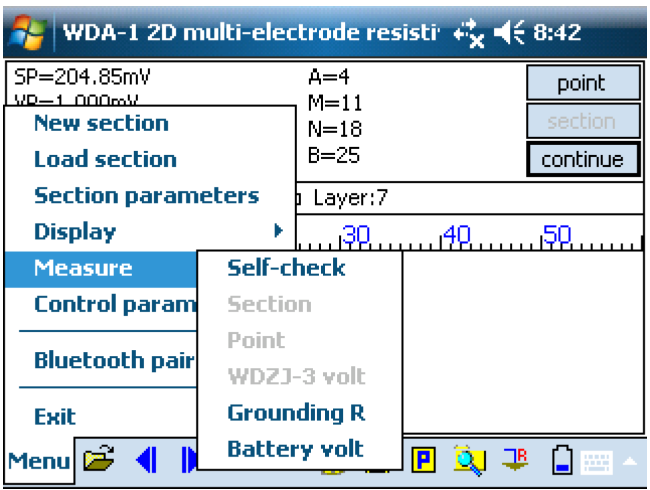


Fig.6-18

Measure interface consists of the following items:

1) Self-check

WDA-1/WDA-1A connects with the multi-electrode cable/electrodes through WDZJ-3 multiplex electrode converter, electrode switches are inside WDZJ-3 converter. Self check is to inspect the switch contacts inside WDZJ-3 converter, which is carried out by WDZJ-3 multiplex electrode converter self-checker (for details, please refer to Appendix B).

2) Section

For a new cross-section, click "Menu"→ "Section" or click the "Section" button to start measuring and save the measured data into "WDA-2DR" file in SD card or CF card of the PDA automatically. During measuring, click "Continue" to continual measuring or click "Pause" button to quit measuring (Fig. 6-19).

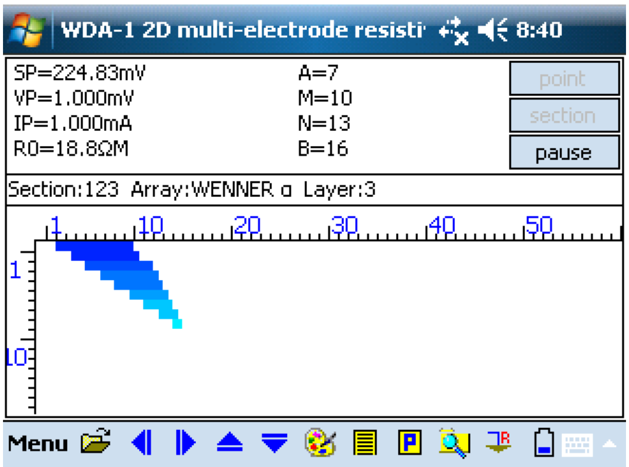


Fig. 6-19

When the complete cross-section is measured, system clews measuring finishes and thereafter, the "Section" button is unavailable, but "Point" button is available. Click a data point in the pseudo-section and click "Point" button, this data point will be measured once again.

Note:

In process of measuring, the multi-electrode working indicator light flickers frequently. If voltage of the WDZJ-3 converter is too low, this indicator light flickers at a lower frequency, in this case, please do replace the batteries for it with new ones.

3) Point

Measure the single point and save measured data automatically. If you are not satisfied with the measured result of one point, measure it once again by this function. Operation is, clicking one data point and then clicking "Point" button.

4) Grounding R

This function is Measure earth resistance of each electrode. click the corresponding shortcut icon (Fig. 6-18) to enter into the measure interface and choose 1-channel or 2-channel. If resistance measured is more than 5 KΩ, system clews resistance is too high.

5) WDZJ-3 Volt

This function is to get battery voltage status of WDZJ-3 converter, "Normal" or "Under-voltage". In case of several WDZJ-3 converters are needed to be paralleled to add in more electrodes, this function will test status of all these WDZJ-3 converters one by one. If voltage of any WDZJ-3 converter is insufficient, it is recommended to replace its batteries, to ensure smooth field survey.

6) Battery Volt

This function is to measure battery voltage of WDA-1/WDA-1A main frame. Click the battery icon at the right bottom of the screen.

6.3.5 View

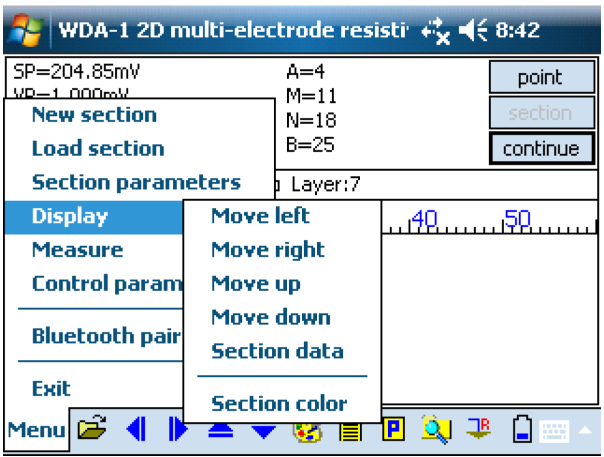


Fig. 6-20

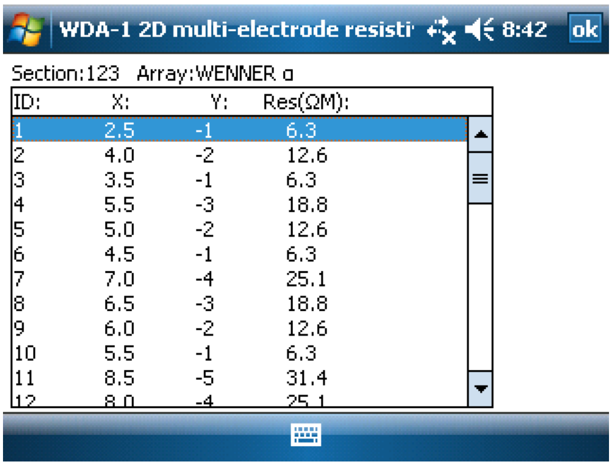


Fig. 6-21

1) **Move left/right/up/down**: cross-section displayed can be moved leftwards/rightwards/up/down by these four functions (Fig. 6-20).
2) **Section data**: this function is to observe resistivity value ρs of all the survey points on a cross-section. What displayed are survey line name, electrode array configuration, X and Y coordinate values and resistivity gained. X direction stands for the actual distance of the measured results in the cross-section and Y direction stands for the layer number (Fig. 6-21).

6.3.6 Load Section

Click the "Open" shortcut icon at the left bottom of main interface or click "Menu"→"Load section" to open the cross-section data stored in "WDA-2D" file.

Note:

All the data by 2D imaging are stored in "WDA-2D" file.

SECTION SEVEN: MULTI-ELECTRODE 2D RESISTIVITY IMAGING (WITH 10-TAKE-OUT INTELLIGENT CABLE)

7.1 Overview

This 2D resistivity imaging system takes **WDA-1/WDA-1A super digital DC resistivity/IP meter** as its mainframe to do control and imaging, completing with **intelligent cables** and **stainless steel electrodes**. This system can conduct multi-electrode 2D/3D resistivity imaging and multi-electrode 2D induced polarization imaging.

In this Section the function of 2D resistivity imaging is elaborated.

7.2 Intelligent Resistivity/IP Cable

The only difference between intelligent resistivity cable (Fig.7-1) and intelligent **IP** cable (Fig.7-2) is that, intelligent **resistivity** cable can **only** perform **2D/3D resistivity** imaging, not 2D IP imaging, while intelligent **IP** cable can both perform **2D/3D resistivity** imaging and **2D IP** imaging.

Fix the Connector at the upper end of the stainless electrode by pulling the string upwards to have electrode top insert into the ringer that is at the end of the spring.

Fig.7-1 Intelligent Resistivity cable

Fig.7-2 Intelligent IP cable

7.3 Field Layout

As shown in Fig.7-3, it is a 2D resistivity imaging system. There are 60 electrodes in all (6 strings of intelligent cables, 10 take-out/string. To add more electrodes in you need to add more strings of intelligent cables).

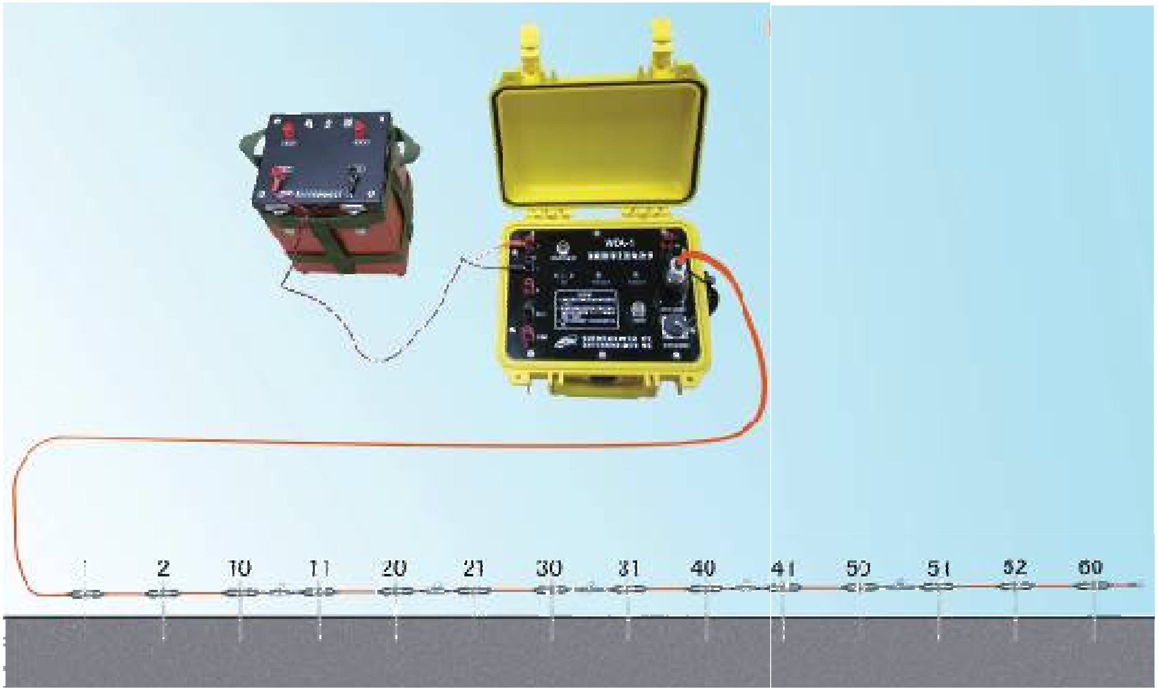


Fig.7-3 Field layout of 2D resistivity imaging system

As mainframe, WDA-1/WDA-1A controls the WDZJ-3 multiplex electrode converter through RS-232 and select A, B, M, N electrodes by turns among 1~60 electrodes (each strings of intelligent cable has 10 take-out for electrodes which are numbered as 1~10 respectively). The intelligent cable head is a 12-core plug, with 12 pin holes at its end; while the tail of the intelligent cable is also 12-core plug, with 12 pins at its ends. Connect the intelligent cables one by one with the take-out. During field survey, the system will automatically number the electrodes on the intelligent cables, No.1~No.60 respectively starting from the one that is nearest to the WDA-1/WDA-1A main frame.

7.4 Program Main Interface

The Program Main Interface of 2D resistivity imaging function is as follows (Fig.7-4).

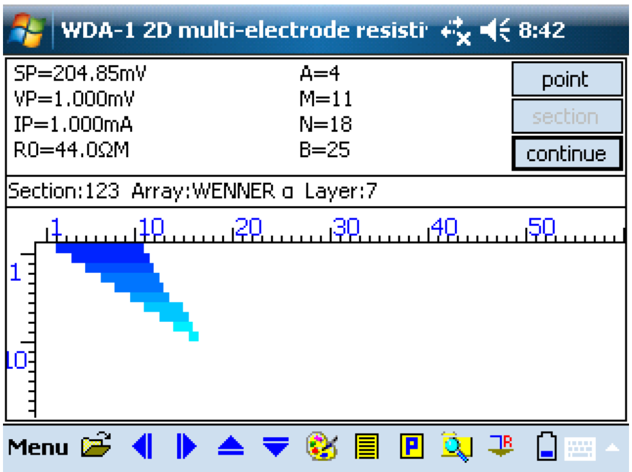


Fig. 7-4 Program Main Interface of 2D resistivity imaging function

In the top of the screen is a display area for measured results (SP, VP, IP, and R0) and electrode array configuration information; at the bottom are a menu bar and shortcut icons; in the middle is a display area for pseudo-section of measured results which varies from electrode array configurations (in Fig. 7-4, it is Wenner Alpha array, the pseudo-section of measured data is a inversed trapezoid. For details of other electrode arrays, please refer to the attached *Electrode Array User's Manual,* Section Two).

To review measured result of a certain point on the cross-section, just click this point on the waveform with the stylus, and then the corresponding values of SP, VP, IP and V0 are displayed at the top section.

7.5 Operation

7.5.1 Turn on WDA-1/WDA-1A and Run System Program

Switch on WDA-1/WDA-1A, turn on the PDA and then click "Start"→ "Program"→ "File Explorer"→"SD card" → "WDA-2DR" to enter into the system program (Fig. 7-5).

Fig. 7-5

7.5.2 Pair Bluetooth

Please refer to Section 2.6 in this user's manual.

7.5.3 Set Parameter

1) Create Profile

Click "Menu"→ "New section" (Fig. 7-6), and system enters into the section parameter setting interface (Fig.7-7).

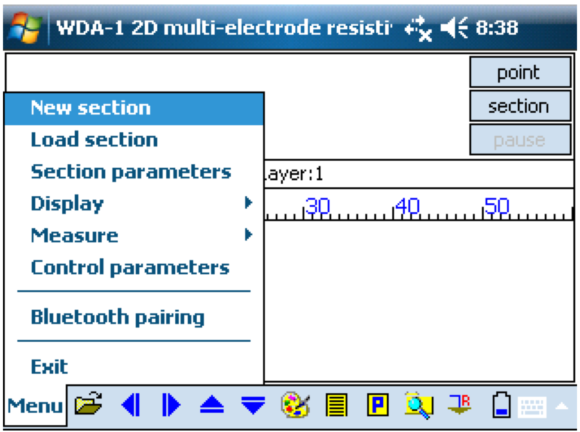


Fig. 7-6

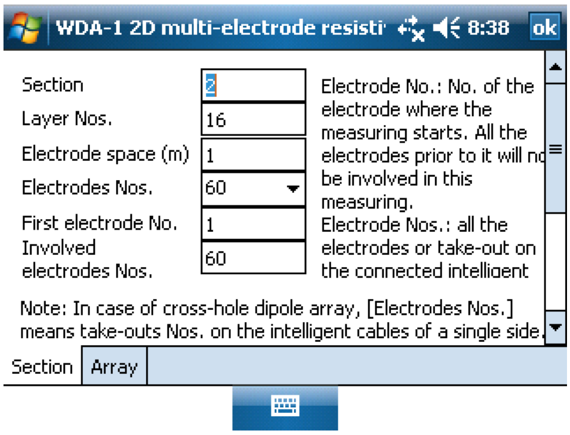


Fig. 7-7

Section: section/cross-section is the collection of all the survey points in the same vertical plane where the survey line locates. Section name is the name of one cross-section in field survey and the name of the corresponding file stored in disk.

Layer Nos.: layer is the collection of all the survey points at the same depth. And "Layer Nos." comes from total layers measured at different depth.

Electrode space: electrode space is the distance between the two adjacent electrodes; unit is meter. This parameter functions calculating array factor of each electrode array configuration and recording points locations.

Electrode Nos.: amount of all the electrode or take-out that used at present, on all of the intelligent cables.

Note:

In cross-hole dipole, "Electrode Nos." stands for the number of electrode or take-out on the intelligent cable along each single side.

First electrode No.: number of the electrode that firstly measured, other electrodes prior to this electrode will not be measured.

Involved electrodes Nos.: amount of the electrodes connected along the survey lines and in use.

Take Fig. 7-8 for example, cascade three strings of intelligent cables one by one. Provided that the "First electrode No." is No.6 and the last five electrodes are not to be counted in for limitation of space. In this case, "Electrode Nos." is 30, "First electrode No." is 6, and "Involved electrode Nos." is 20. "Electrode space" is the distance between two adjacent electrodes in the figure below.

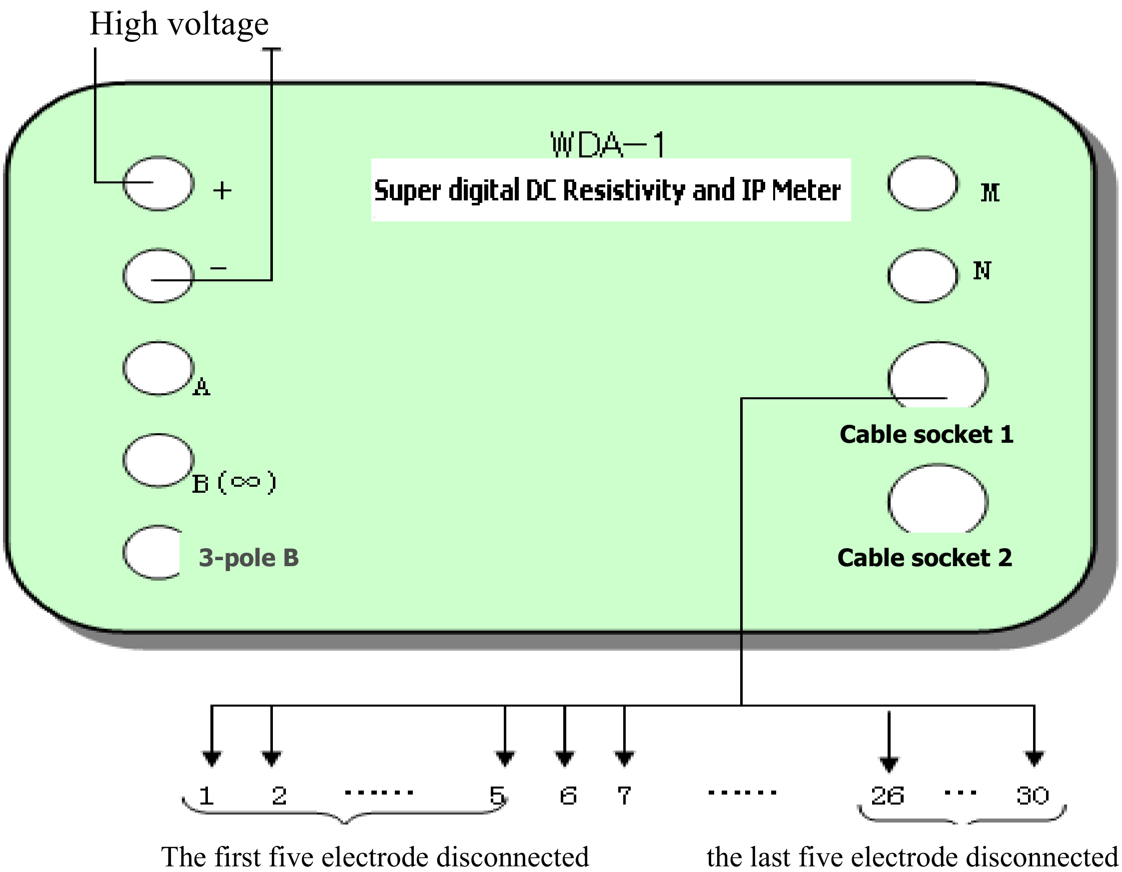


Fig. 7-8

2) Choose Electrode array configuration

Array: there are 15 electrode array configurations available for this system. 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 Alpha 2 array (**SCHLMBG**), Self-Potential M array (**SP-M**), Self-Potential MN array (**SP-MN**), Charging M (**CHG-M**), Charging MN (**CHG-MN**) which are applicable for fixed cross section roll-along scan measurement; and 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**, Cross-Hole Dipole/Equatorial Dipole-dipole array (**CR-DIPOLE**) are applicable for extendable cross section continuous roll-along measurement. For detailed introduction, please refer to the attached *Electrode Array User's Manual*.

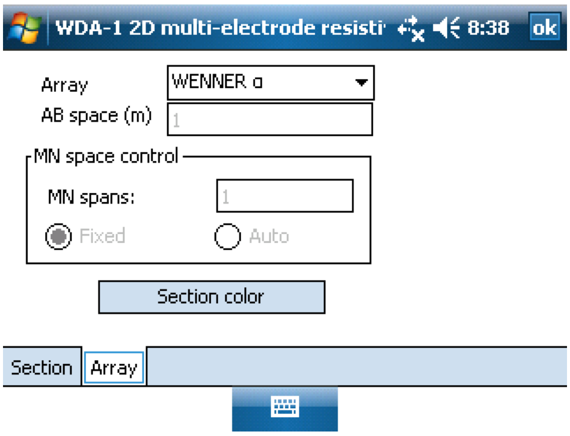


Fig. 7-9

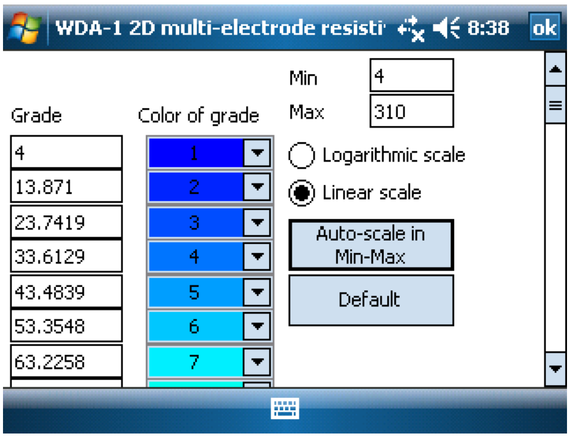


Fig. 7-10

Below are definitions of the related parameters.

AB space: the actual distance between electrodes A, B; unit is meter. It is only available for cross-hole dipole array configuration, not for other electrode arrays.

MN space control: invariable and auto are optional. "Invariable" means MN interval is set by the operator; while "Auto" means the center of MN keeps fixed; yet adds two electrode intervals every eight layers on the profile. For example, if the original setting of MN interval is 1, the ninth layer is 3 and the seventeenth layer is 5.

MN spans: When array is A-MN pole-dipole array, AB-M pole-dipole array, AB-MN dipole electrode array, MN-B array or Schlumberger Array (α2), this parameter is distance between Potential electrodes M and N.

Section color: see Fig.7-10, "Auto-scale in Min-Max" button is to set color automatically according to values chosen in "Max" and "Min" pull-down boxes; "Default" button is to set color automatically according to maximum and minimum resistivity of the present section. User can also select "Logarithm scale" and "Linearity scale" to set color.

Note:

When system works with the intelligent resistivity/IP cable, the first 15 electrode array configurations need only one socket (on the WDA-1/WDA-1A, Socket 1 or Socket 2), either one works. While Cross-hole DIPOLE (CR-DIPOLE) array needs both sockets simultaneously, "Socket 1" connecting with Current electrodes A, M and "Socket 2" connects with Potential electrodes B, N.

---

3) Set Control Parameter

As shown in Fig.7-11, click the corresponding shortcut icon at bottom of screen or click "Menu"→"Control Parameter", and the control parameter setting interface pops up (Fig.7-12), parameters are profile, power supply, self-potential, etc.

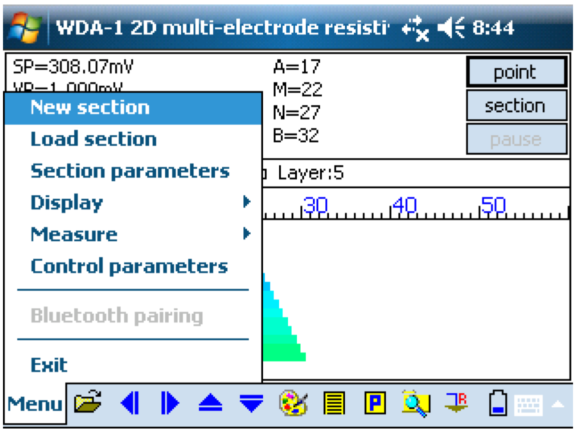


Fig. 7-11

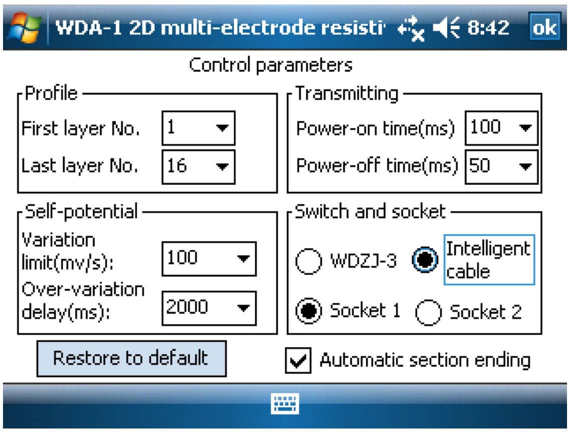


Fig. 7-12

① **Profile**

First layer No.: number of layer where the measuring starts. Default is 1.

Last layer No.: number of layer where the measuring finishes. Default is 16.

Note:

"Last layer No." should not be less than "First layer No.".

---

② **Transmitting**

Both positive power supply period and negative power supply period belong to the power supply phase (Fig. 7-13). The time of positive power supply and negative power supply is also named as "Power-on time". The time between them is power-off time (Power off).

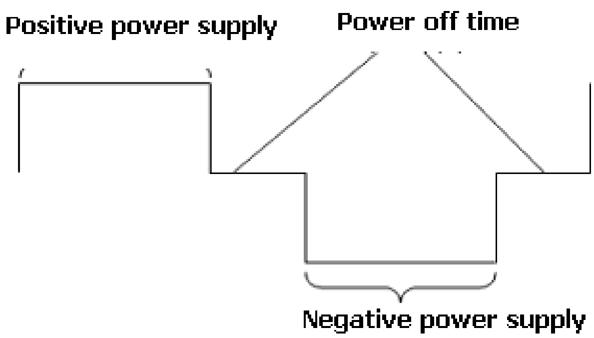


Fig. 7-13

③ **Self-Potential**

Background:

In the multi-electrode resistivity imaging system, there may be a large amount of electrode coulombs left after one measuring action. If go on to the next measuring action immediately, measuring error of may be enlarged. In order to improve measuring precision, WDA-1/WDA-1A will wait until the potential recovers, so as to eliminate errors caused by self potential jumping.

However, in some geological conditions whose self-potential is quite active (such as alkaline soil), recovery of self potential may not be satisfied after the above operation. To meet this need, this system is designed with parameters of "Variation limit" and "Over-variation delay" to improve measuring precision, which enables the system to compensate self-potential of the next survey point. System first tests and checks whether current self-potential jumps and whether it is higher than "Variation limit" defined; if it is higher, set "Over-variation delay" time to wait until self-potential gets stable.

Variation limit: 10, 20, 50, 100, 200, 500 are available; unit is mV/s. Choose one value according to the actual geological condition (default is 100mv/s). The smaller the value, the higher the measuring precision, and the longer the time needed; the higher the value, the lower the measuring precision and the shorter the time needed.

Over-variation delay: 500, 1000, 2000, 3000, 5000 are available; unit is ms and default is 2000ms.

④ **Switch and Socket**

Choose "Intelligent cable" and choose "Socket 1" or "Socket 2" (if the electrode is Cross-hole DIPOLE (CR-DIPOLE) array, select both sockets.

⑤ **Automatic Section Ending**

User decides whether performing the function of "Automatic section ending" or not.

If choose this function, system will end section automatically when the complete cross-section is measured. However, under this function, system could not perform extendable cross-section continuous roll-along measuring.

Since cross-section varies from electrode array configurations, shapes of the ending cross-section are different. As for 2P AM array, 3P AMN array, etc., whose cross-section are parallelograms and MNB array whose cross-section rectangle, shapes of section ending are as shown in Fig.7-14.

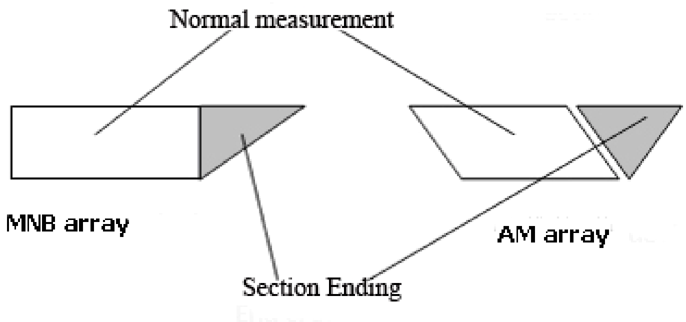


Fig. 7-14

If to perform extendable cross-section continuous roll-along imaging, deselect this option and the system will automatically ask whether to move the electrodes (Fig. 7-15). Follow the prompt message to rearrange the electrode (move forwards) and click "Yes" button, or click "No" button to have the system perform section ending function.

Since each intelligent cable can connect to 10 electrodes, to perform extendable cross-section continuous roll-along imaging, all the intelligent cables shall be shifted forwards or backwards together. **Operator should strictly follow the prompt message to move the electrodes.**

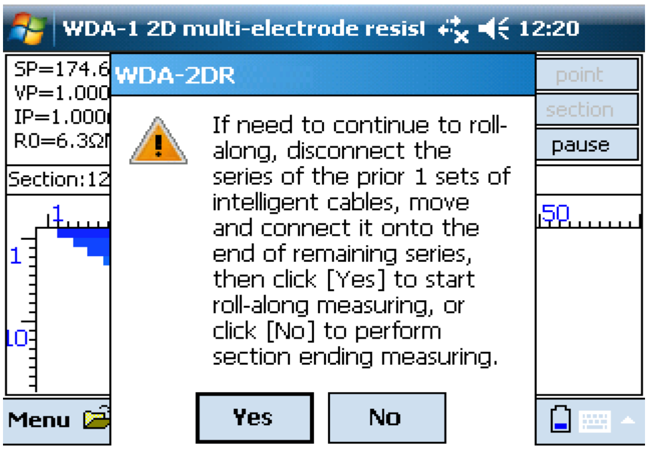


Fig. 7-15

For example, conditions are:

a) Electrode: 60 electrodes

b) Electrode array configuration: Wenner Alpha array (WENNER α)

c) Parameters of cross-section: defaults

While multi-electrode 2D resistivity imaging with the intelligent cable, system prompts as Fig. 7-15 after one cross-section is measured. Follow the message and move the first string of intelligent cable (together with 10 electrodes) to the tail of the last string, and the No.11 survey point turns to No.1 electrode of the present system.

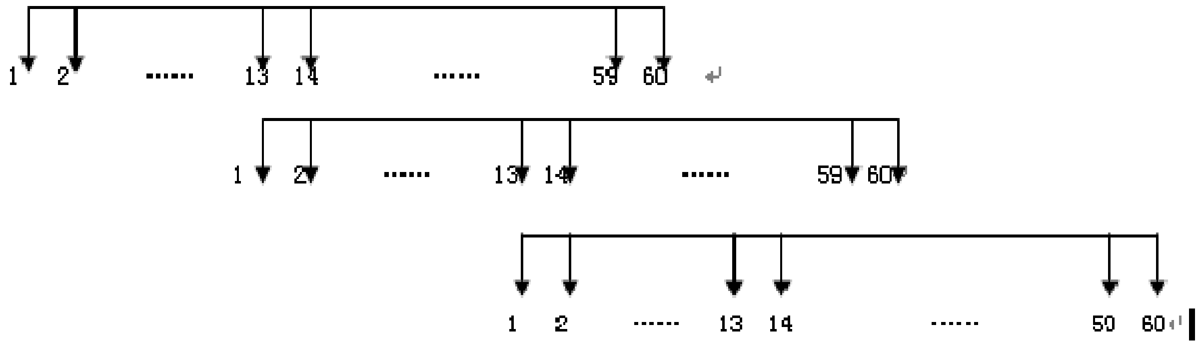


Fig. 7-16

4) Check Parameters

Finishing setting all the parameters of the cross-section, click the corresponding shortcut button at the bottom screen or click "Menu"→"Section Parameters" (Fig. 7-17) to display parameters of the present section (Fig. 7-18), so as to check whether any incorrectness exists. If any parameter is incorrect, go back to the parameter setting interface and modify it immediately.

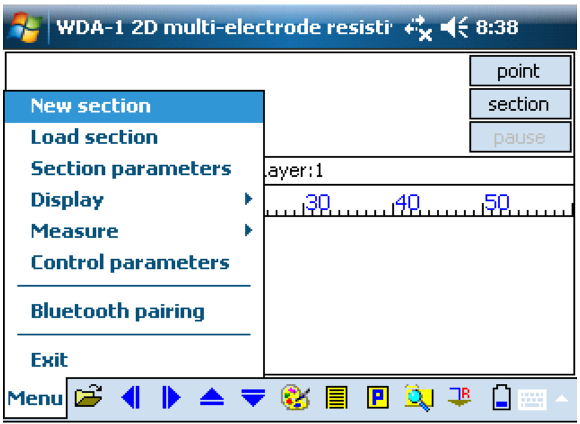


Fig. 7-17

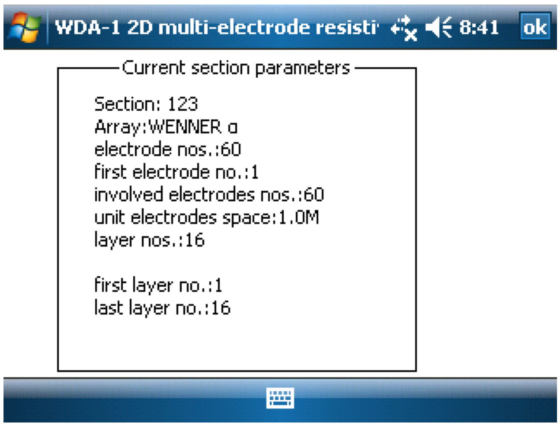


Fig. 7-18

7.5.4 Measure

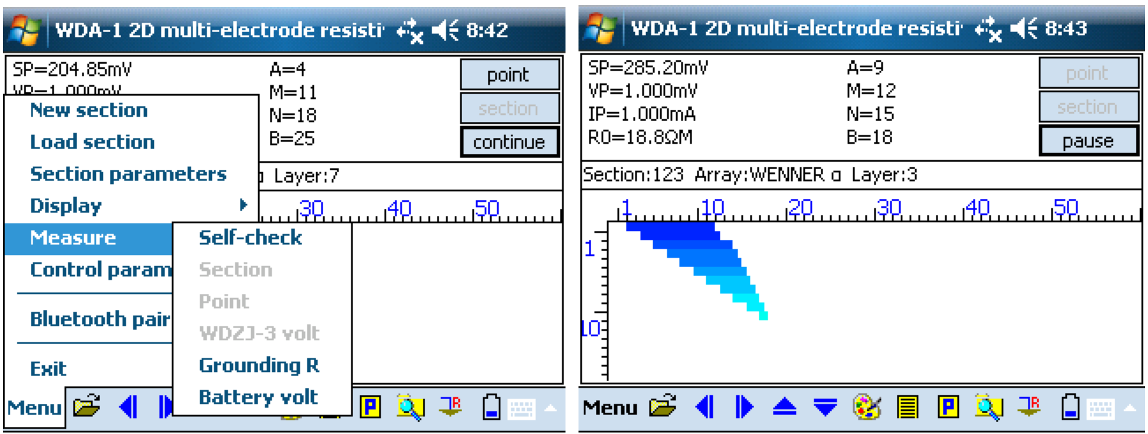


Fig.7-19

Measure interface consists of the following items:

① **Self check**

Imbedded inside each take-out of the intelligent cable is an electrode switch. Function of the electrode switch can also be checked by the PDZ-1 switch adapter self-checker. For detailed operations, please refer to Appendix A in this user's manual.

② **Section**

To measure a new section, click the "Section" button to start measuring and save the measured data into "WDA-2D" folder in SD card or CF card of the PDA automatically; or click "Pause" to quit measuring and click "Continue" to continue measuring (Fig.7-19).

When the complete cross-section is measured, system clews "Section measure is completed successfully" and thereafter, the "Section" button is unavailable, but "Point" button is available. Click a data point that is in the pseudo-section and click "Point" button, this data point will be measured once again.

Note:

In process of measurement, the multi-electrode working indicator light flickers frequently. If the "Involved electrode Nos." is less than the parameter "Electrode Nos.", this indicator light flickers at a lower frequency. That is to say, if parameter "Electrodes Nos." is 60, but the actual amount of electrodes counted in (Involved electrode Nos." is 50, this indicator light flickers at low frequency.

---

③ **Point**

Measure the single point and save measured data automatically. If you are not satisfied with the measured result of one data point, measure it once again through this function. Operation is, clicking one data point that is in the cross-section and then clicking "Point" button or clicking "Menu"→ "Measure"→ "Point".

④ **Grounding R**

This function is to measure earth resistance of each electrode. Click the corresponding shortcut icon (Fig.7-19) to enter into the measure interface and choose 1-channel or 2-channel. The system will clew that earth resistance is too high if it is more than 5 KΩ.

⑤ **Electrode-box Voltage**

For this system with intelligent cable, this function is unavailable.

⑥ **Battery Volt**

This function is to measure battery voltage of WDA-1/WDA-1A main frame; click the battery icon at the right bottom of the screen.

7.5.5 View

Click Menu→ Display to view the measured data of a section (Fig. 7-20).

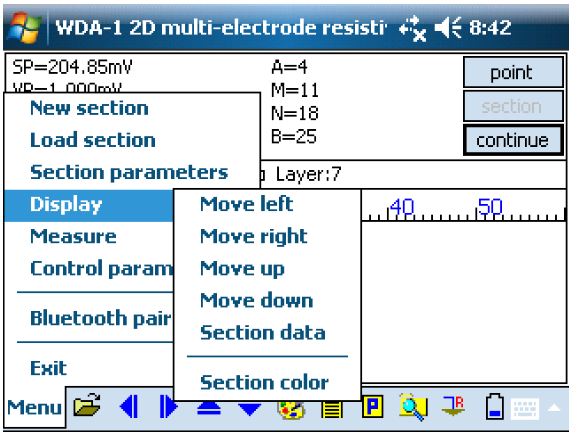


Fig. 7-20

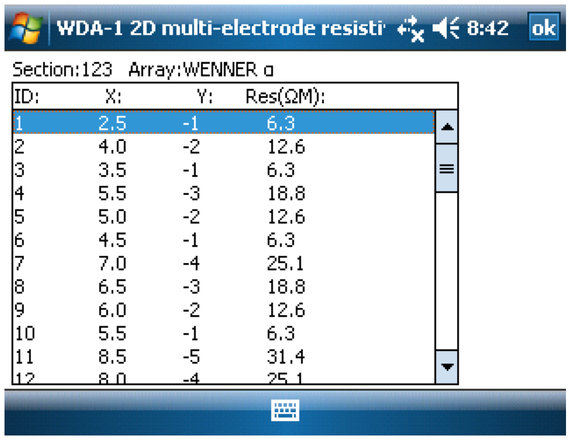


Fig. 7-21

1) **Move left/right/up/down**: cross-section displayed can be moved leftwards/rightwards/up/down by these four function
2) **Section data**: this function is to review resistivity value ρs of all the survey points on a cross-section. What displayed are survey line name, electrode array configuration, X and Y coordinate values and resistivity measured (Fig.7-21). X direction means the actual distance of the measured results in the cross-section and Y direction means the layer number.

7.5.6 Load Section

Click the "Open" icon at the left bottom of the main interface or click "Menu"→"Load section" to open the cross-section data stored in "WDA-2D" file.

Note:

All the data by 2D imaging are stored **in "WDA-2D" file.**

SECTION EIGHT: FIELD SURVEY EXAMPLE — 2D RES (WITH 10-TAKE-OUT INTELLIGENT CABLE)

Measuring Condition:

a) System survey mode: multi-electrode 2D resistivity imaging with intelligent cable

b) Electrode array configuration (**Array**): Winner Alpha array (**Wenner α**)

c) Total numbers of electrode (Electrode Nos.): 60 electrodes

d) Electrode spacing (**Electrode space**): 2m

Operation procedures:

1) Lay Electrode

First of all, clinch the 60 electrodes on the survey line to measured, with electrode spacing of 2 meters, along the cross-section direction.

2) Assemble Cable

The 10 connector (take-out) on each sting of cable are numbered as 1~10 respectively, that is, each string of cable could connect with 10 electrodes, at the head of the cable is a 12-core plug and at the end of the cable is a 12-pin plug (jack plug).

Prior to assemble the cables, get a clear mind of the location of the electrode arrangement where the section locates. Put the cable along the array, keeping its head and end in sequence. Then mount the connector to connect the cables one by one.

Fig.8-1 Layout of intelligent cable and electrode in field

3) Fix Electrode on the Connector of the Intelligent Cable

Fix the connector at the upper end of the stainless electrode by pulling the string upwards to have electrode top insert into the ringer that is at the end of the spring.

Fig. 8-2 shows the connection of **intelligent resistivity cable** and the electrode.

Fig. 8-2

If completing with **intelligent IP cables**, the white plastic ring at the end of ABMN should be rotated to have AB, MN short-circuited, i.e., to have Potential electrodes MN and the Current electrodes AB short-circuited (Fig. 8-3).

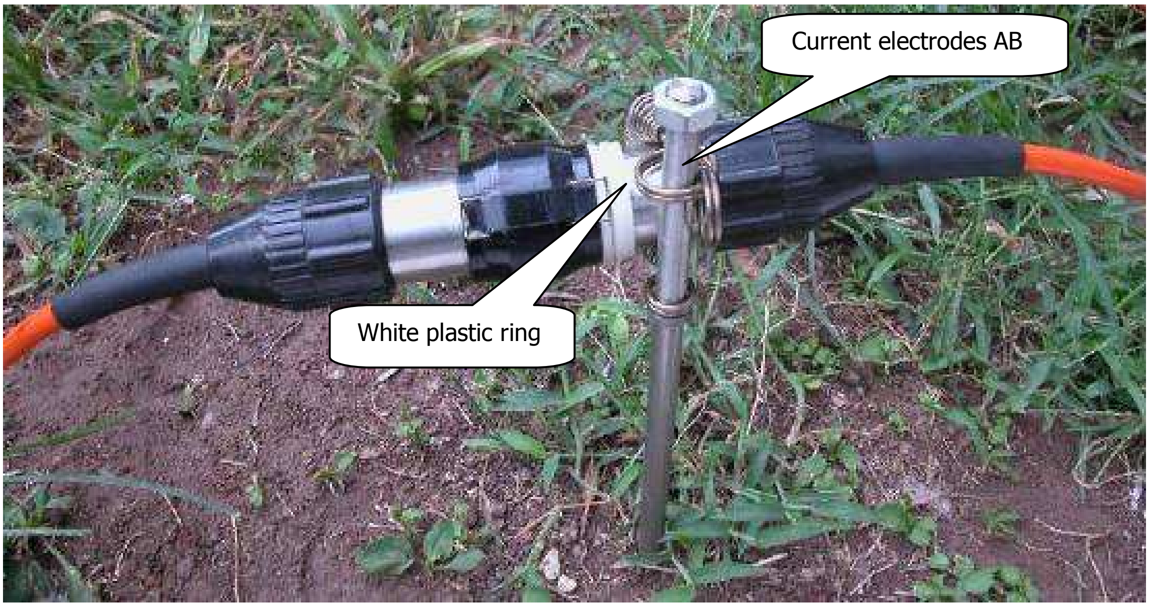


Fig. 8-3

4) Connect to WDA-1/WDA-1A

Insert one end of the intelligent cable into socket 1 or socket 2 on the WDA-1/WDA-1A main frame (Fig. 8-4).

If the mainframe is WDA-1, connect the DC HV positive and negative terminals to those of the DC high-voltage power source respectively.

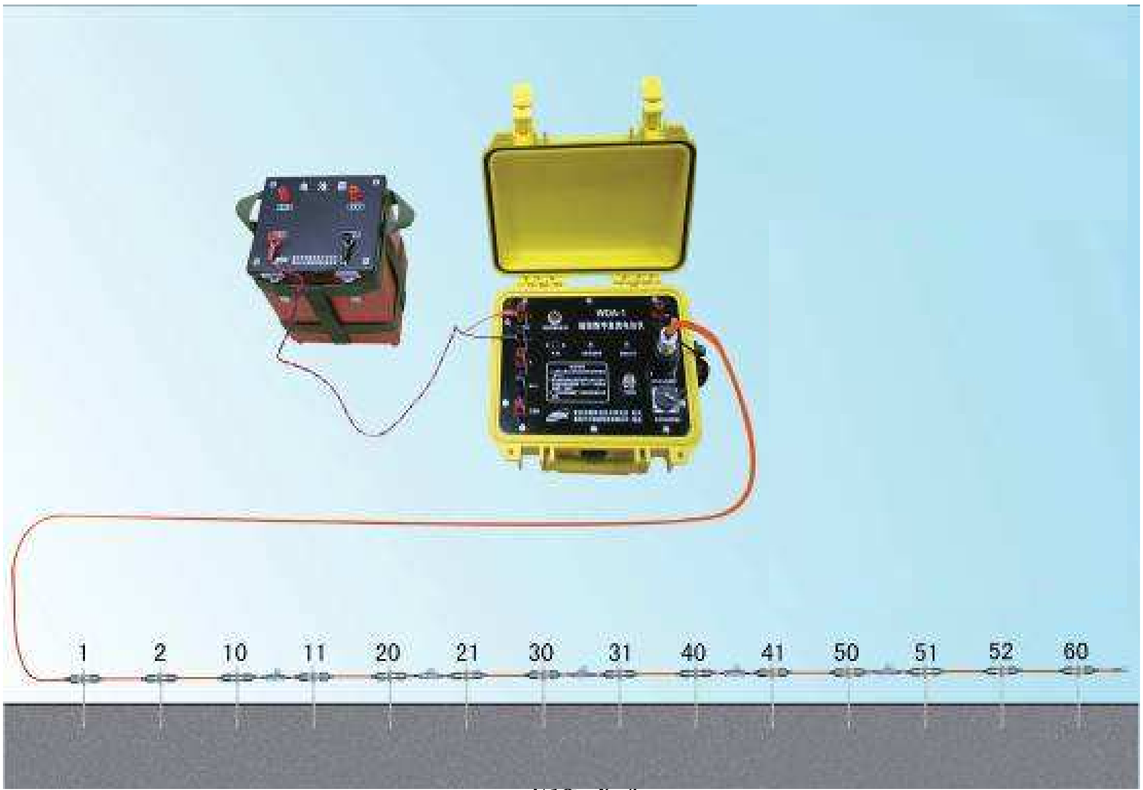


Fig. 8-4

5) Turn on WDA-1/WDA-1A and the Pocket PC

Ensure all the cables are well and correctly connected and then switch on the main frame and PDA.

6) Run System Program

Turn on the pocket PC. Run the multi-electrode 2D resistivity imaging system program "WDA-2DR".

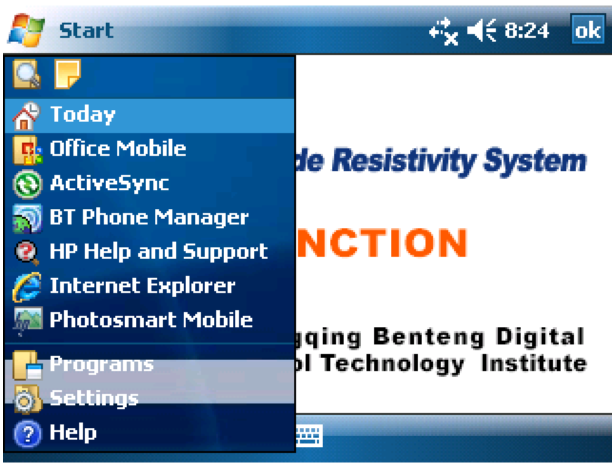


Fig.8-5

Operation is, clicking "Start"→ "Program"→ "File Explorer"→ "SD card"→

"WDA-2DR" program.

7) Pair Bluetooth

Please refer to Section 2.6 in this user's manual.

8) Create New Section and Set Parameters

Click "Menu"→ "New section" to enter into the interface as shown in Fig. 8-7.

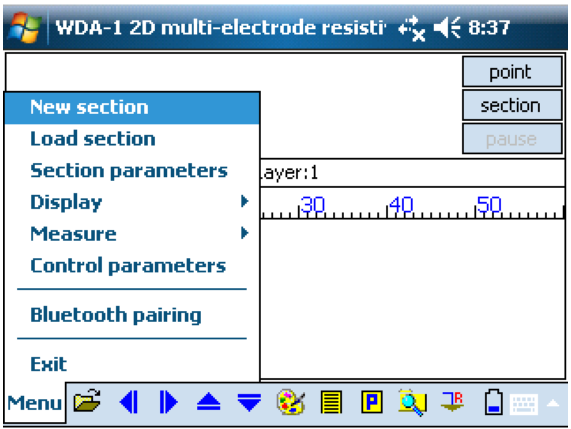


Fig.8-6

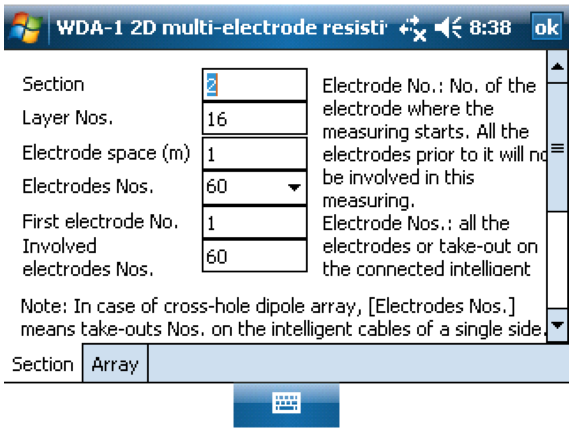


Fig. 8-7

Name the "Section", set "Layer Nos." as 16, "Electrode space" as 2m, "Electrode Nos." as 60, "First electrode No." as 1 and "Involved electrodes Nos." as 60.

Note:

- **If the "Involved electrode Nos." has to be 55 due to limitation of field, "Electrode Nos." equals the total number of take-out 60, "Involved electrodes Nos." then is 55.**
- **Choose Wenner Alpha array (Wenner α) as the electrode array configuration (Array).**

---

9) Set Control Parameters

Click "Menu"→"Control parameters" to get into the interface shown in Fig. 8-8.

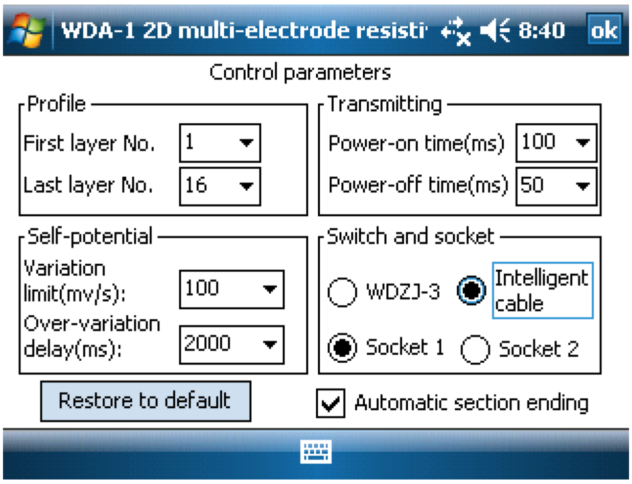


Fig. 8-8

Set "First layer No." as 1, "Last layer No." as 16, "Power-on time" as 100ms, "Power-off time" as 50ms and choose "Socket 1" without the function "Automatic section ending".

10) Start Measure Section

After setting all the parameters, click the icon "Section" or click "Menu"→"Measure"→"Section" (Fig.8-9); measured results are then stored automatically.

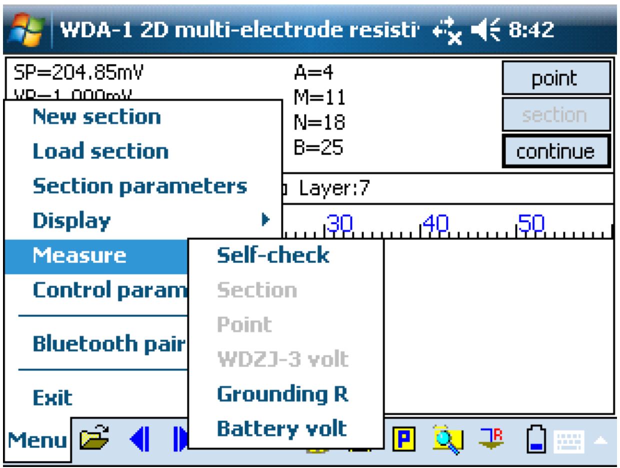


Fig.8-9

Since system measures without the function of "Automatic section ending", when all the connected electrodes are measured, system gives clews as shown in Fig. 8-10, reminding to move the electrodes.

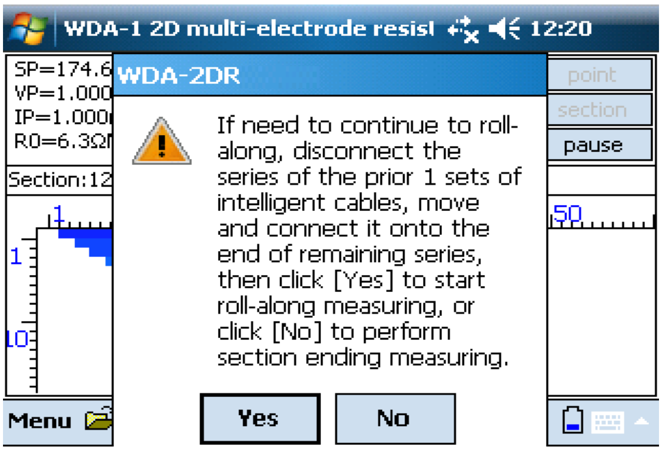


Fig. 8-10

Click "YES" to extend the section and continue measuring, and then move the electrodes according to requirement. Or click "NO" to perform "Automatic section ending" function.

11) Shut Down System

Finishing measuring the wanted section, turn off the pocket PC and the WDA-1/WDA-1A mainframe

SECTION NINE: MULTI-ELECTRODE 2D IP IMAGING (WITH 10-TAKE-OUT INTELLIGENT CABLE)

9.1 Overview

Operation of multi-electrode 2D **induced polarization (IP/chargeability)** imaging is quite similar to that of multi-electrode 2D **resistivity** imaging.

Hereafter are four aspects of differences between them.

9.2 Differences Between 2D Res Imaging and 2D (IP) Imaging

9.2.1 Intelligent IP Cable

As we mentioned in Section Seven, intelligent **resistivity** cable can only perform multi-electrode resistivity imaging (2D/3D). Different from intelligent resistivity cable, intelligent **IP** cable can perform both multi-electrode 2D/3D resistivity and 2D IP imaging. As shown in Fig.8-1, there are two solid non-polarized electrodes function as the Potential electrodes M and N.

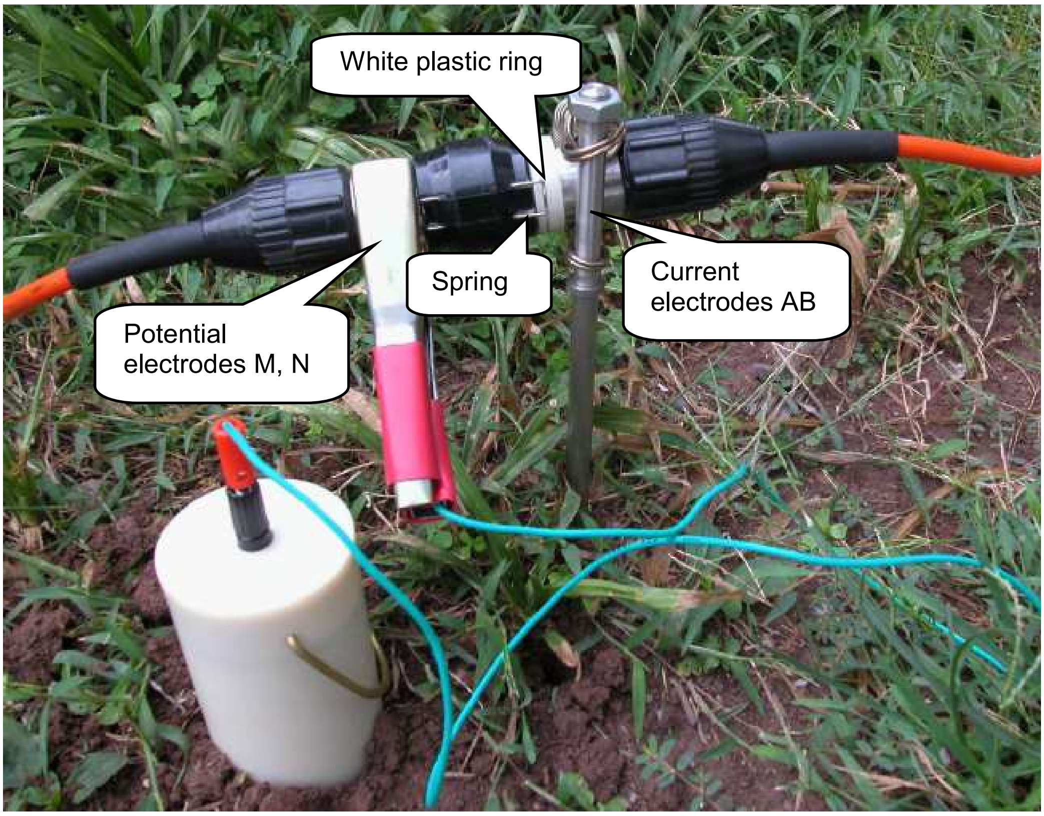


Fig. 9-1

Note:

When performing multi-electrode 2D IP imaging, connections between the

Potential electrodes M, N and the Current electrodes A, B must be cut off; for operation, rotate the white plastic ring to cut off contacts between the spring and the stainless end.

If to conduct 2D **resistivity** imaging with **intelligent IP cables**, the **white plastic ring** at the end of ABMN should be rotated to have ABMN short-circuited, i.e., to have Potential electrodes MN and the Current electrodes AB short-circuited (Fig. 9-2).

Fig. 9-2

9.2.2 Parameter Setting for New Cross Section

If a new cross-section is created, the following parameter should be set.

Data displayed: Resistivity (R0) and user-defined M or M1 are optional.

M Starting time: starting time for user-defined polarizability M sample.

M Sampling duration: sample width for user-defined polarizability M.

Select Display Parameter: any four of these parameters can be selected to be displayed in the main interface.

9.2.3 Power Supply Mode

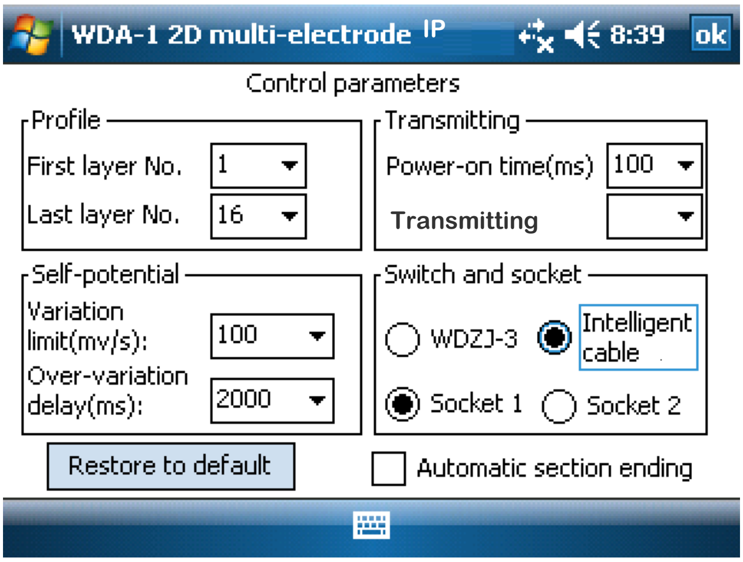


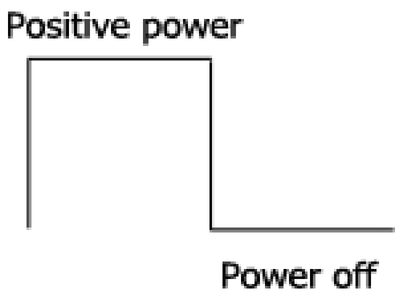
Fig. 9-4

Under the control parameter setting interface, set the power supply mode (Fig.9-4).

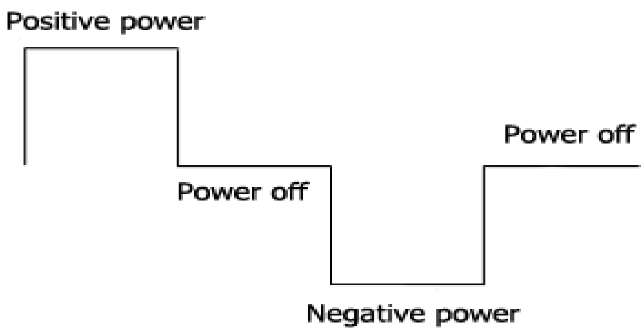
Standard mode: standard mode has three power-on period, i.e. "Positive power — Power off — Negative power — Power off — Positive power — Power off" (Fig. 9-5c)).

Unidirectional mode: unidirectional mode has only one power-on period, i.e. "Positive power —Power off" (Fig. 9-5a)).

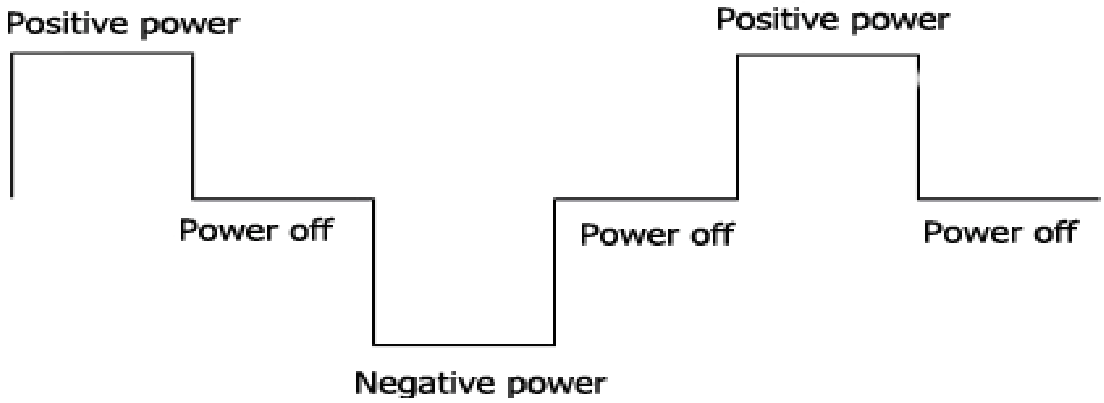
Bidirectional mode: bidirectional mode has two power power-on periods, i.e. "Positive power — Power off — Negative power — Power off" (Fig. 9-5b)).



a) Unidirectional mode



b) Bidirectional mode



C) Standard mode

Fig.9-5 Power Supply Mode Schematic Diagram

9.3 Operations

Except the above mentioned differences on parameters and connection of solid non-polarized electrodes, multi-electrode 2D resistivity imaging system and 2D IP imaging system are the same on instrument operation, please refer to operation guide to the multi-electrode 2D resistivity imaging system in Section Seven.

SECTION TEN: MULTI-ELECTRODE 3D RESISTIVITY IMAGING (WITH 10-TAKE-OUT INTELLIGENT CABLE)

10.1 Working Principle

Along the horizontal plane or the vertical planes of X and Y axis direction, a limited solid space can be divided into numerous short rectangular columns which are combined as the 3D Model of this solid. And in each column, an appropriate point could be regarded as the approximate resistivity of the whole.

3D imaging mode is developed from 2D imaging mode.

What is the difference between them is, 2D imaging mode divides one big cross-section into different smaller ones and measures all the survey points of small sections to complete the measurement approximately, while 3D imaging mode is developed from 2D, finishing the measurement approximately through combining all the points along the planes of different directions (in column mode) on the basis of 2D measurement. However, 3D imaging mode is not only a simple combination of 2D mode but involves data processing by inversion software to make the inversion model more practical.

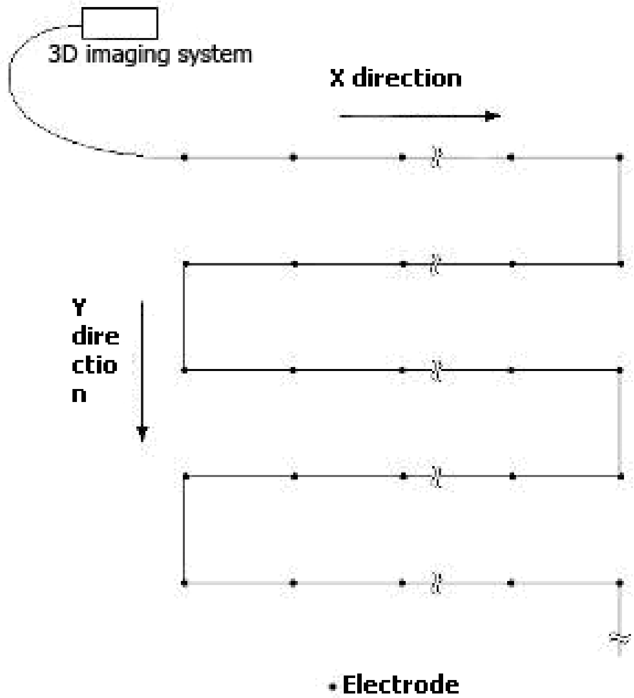


Fig. 10-1

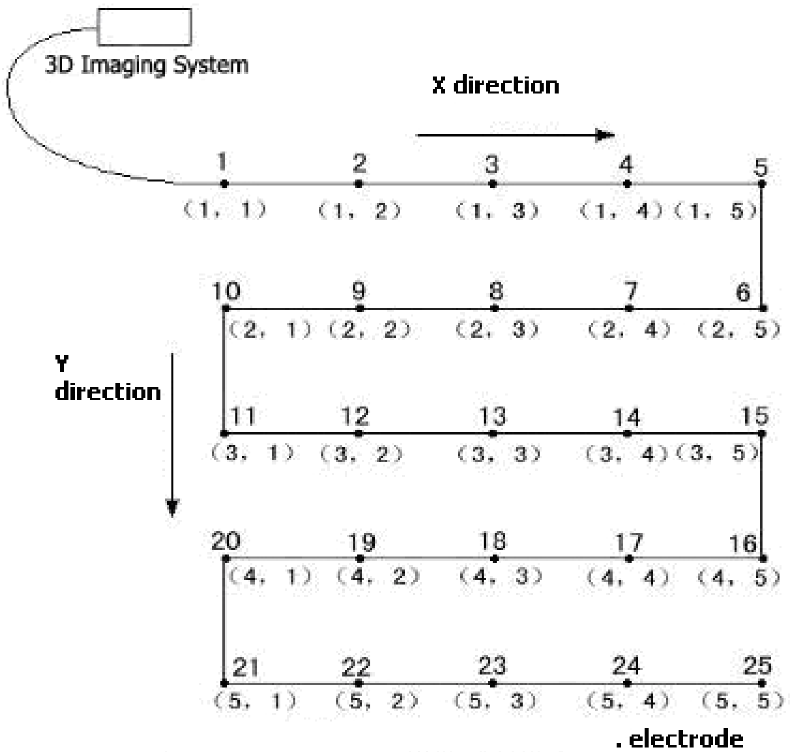
Electrode array of 3D imaging is S-shaped rectangular (Fig. *10*-1), taking four adjacent electrode locations as the corners of small column on the ground, which means the length and width of column is equal to the unit electrode distance. Then resistivity of these columns at different depths could be measured by different electrode combination modes. Finally, measured data is processed by inversion software, reflecting the underground with model.

10.2 Division and Layout

Generally, all the electrodes for 3D imaging are distributed in grid-node-shaped region, of the whole survey district or one portion of the survey district The instrument selects the corresponding electrodes automatically according to the specific array to collect the resistivity data that are with various electrode arrays at all directions. Layout of the cable and electrode is shown as Fig. *10*-1.

Definition of electrode number on the cable and of the electrodes in matrix is shown as Fig. *10*-2.

Electrode array may be pole-pole, pole-dipole and dipole-dipole.



1-25 is the electrode number on cable
The number in () is the electrode coordinate on rectan(

Fig. 10-2

To conduct 3D imaging successfully, data of every electrode, with different electrode distances or in various directions should be gained. Take 5*5 matrix for example, to demonstrate the completely measurement for 3D data in pole-pole array. The 1~25 are serial numbers for the points of the rectangular and they are not consistent with the electrode numbers on the intelligent cable (Fig. *10*-3). According to interchange Law, measure the electrode whose serial number is larger than the one of power supply electrode.

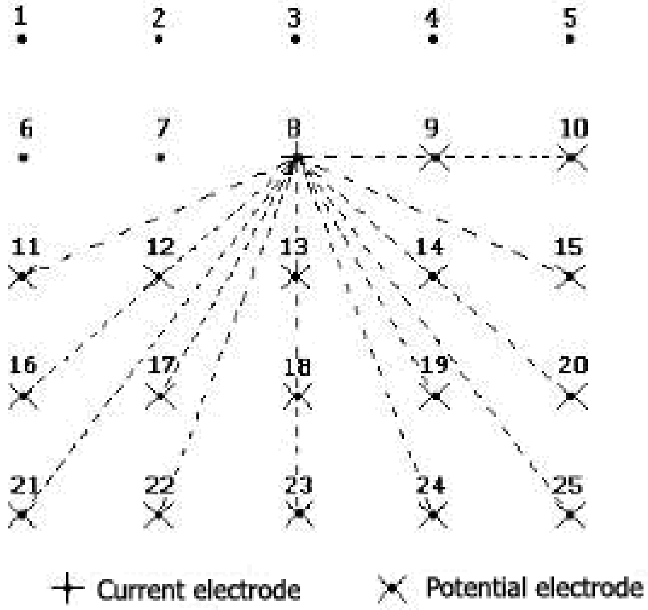


Fig. 10-3

If complete survey district is too large to be covered with the electrodes in one measurement, divide it into several sections. Method is as follows:

① First of all, divide the complete district into several subareas, along Y (or X) direction, to ensure that one section could be covered by all the electrodes. Execute 3D imaging on each subarea in turn.

② If the subareas are still too large, divide than again by following the above procedures.

For example, a 10*10 electrode grids of survey district, only 50 electrodes are available (Fig. *10*-4), steps are: divide it into four sections; divide the district into two 10*5 subareas along Y direction (Fig. *10*-4), set two survey stations and take 3-D measurement one by one; then take the same operation along X direction.

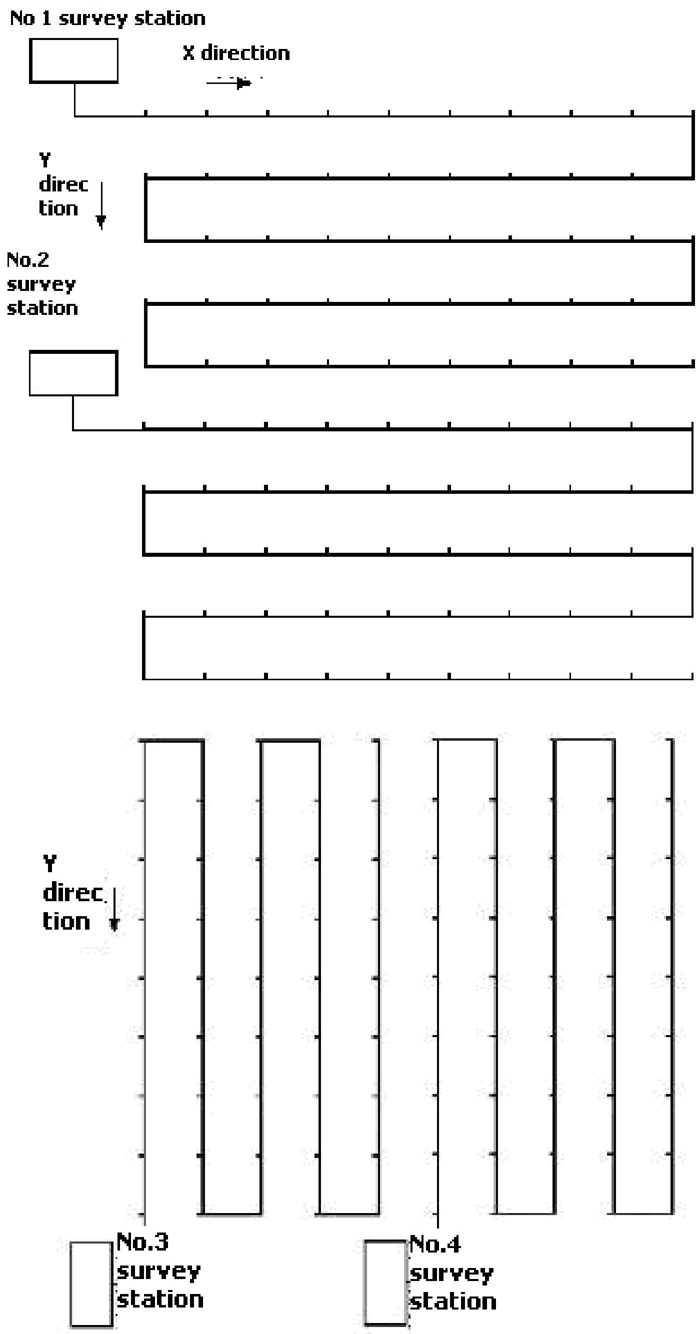


Fig. 10-4

10.3 Concept of Survey Block and Grid

Considering that survey district may be relatively larger but user is in want of electrodes or intelligent cables, we brings about the conception of survey grid and survey block, to enable limited electrodes to measure relatively larger regions (Fig. *10-5)* .

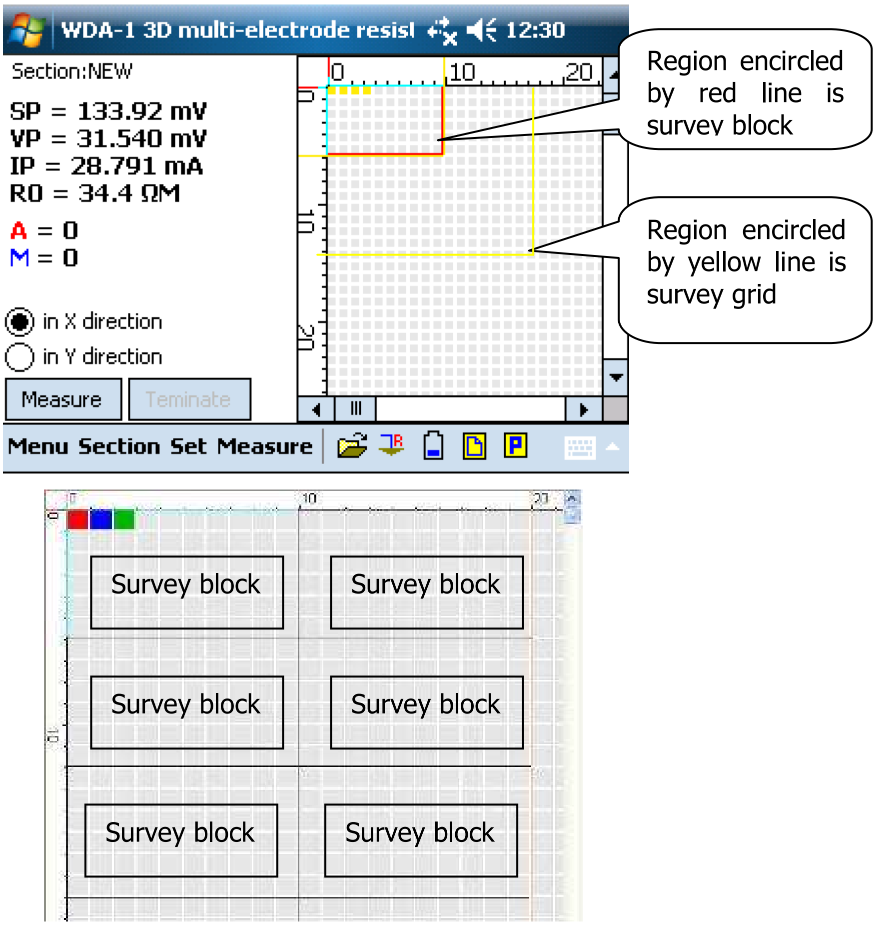


Fig. 10-5

1) Survey Block

Survey block is the maximum section that all the arranged electrodes can fully reach. Size the survey block is defined when it is created and could not be modified.

2) Survey Grid

One survey grid may consist of several survey blocks. Size of the survey is defined when it is created and could not be modified; to gain data of the survey grid, just measure all its blocks one by one.

Note:

When moving among survey blocks, ensure that the actual electrode coordinates are consistent with those on **the graph.**

10.4 Electrode Array of 3D Resistivity Imaging

1) 3D pole-pole (two-electrodes) Array

Pole-pole array is quite simple and usually applied in 3D imaging.

Calculation formula of apparent resistivity in pole-pole array is,

$$\rho=2\pi aV/I,$$

"V": potential observed.

"I": current observed.

"a": distance between the Current electrodes A and Potential electrode M.

To get known electrodes number "n", maximum irrelevant data number in pole-pole array is Nmax=n (n-1)/2

As aforementioned, a lot of electrodes are involved, cross-diagonal observation scheme is recommenced to reduce the work of observation and data processing. What needs to do is to observe the data of every electrode distance arrange of eight azimuths along horizontal, vertical and 45° diagonal directions.

Again, take 5*5 matrix for example and seem 1~25 as the serial numbers of the points in the matrix (Fig. 10-6).

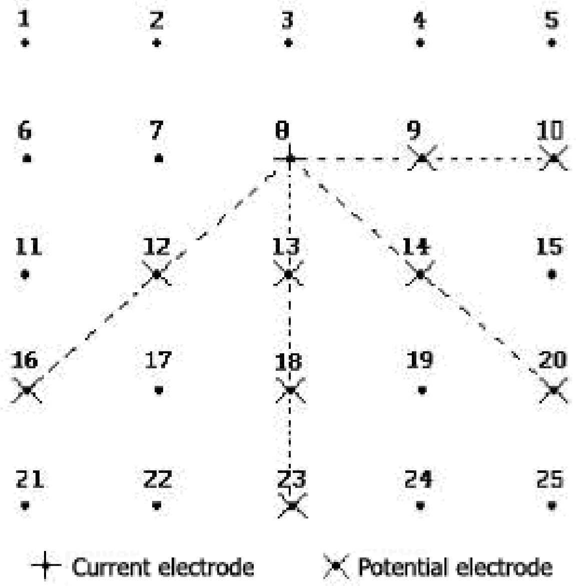


Fig. 10-6 Cross-Diagonal observation

2) 3D Pole-Dipole (Three-Electrode) Array

For 3D survey or imaging of middle-size districts (not less than 12*12 electrodes), pole-dipole array is more fitted, for it interference suppression is better than pole-pole array because the two measuring electrodes locates in the survey district, what's more, the signal observed is greatly improved (Fig. 10-7).

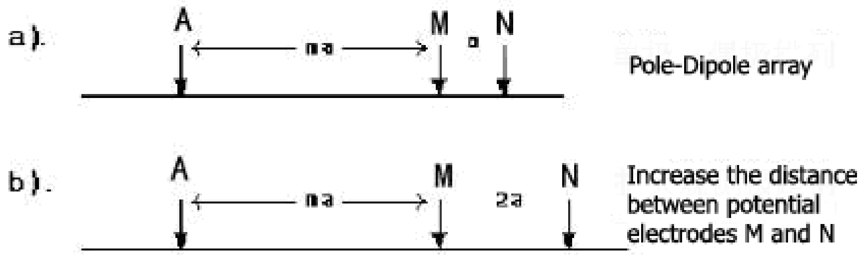


Fig. 10-7 Pole-Dipole Array

Different from other electrode arrays, pole-dipole array is not arranged symmetrically, so is the apparent resistivity gained, which is more complicated for inversion.

Calculation formula of apparent resistivity in pole-dipole array is:

$$\rho=2\prod n\ (n+1)\ aV/I$$

"V": potential observed.

"I": current observed.

"a": distance between the Potential electrodes N and M.

"n": isolation coefficient which equals the ratio of AM electrode distance to MN electrode distance

In that potential difference of the Potential electrodes M, N in opposite proportion of the square of the coefficient "n", "SNR (signal noise ratio)" decreases rapidly when "n" value grows; to increase SNR, enlarging the distance between the measuring electrodes (M, N) as shown in Fig. 10-7(b); if SNR is high and "n" value is low, take the first array (Fig. 10-7(a)). Therefore, data intensity increases and inversion quality improves.

3) 3D Dipole-Dipole (four-electrode) Array

Dipole-dipole array is recommended only when electrode grid-node is larger than 12*12, terrain is rough and the electrodes are hard to be arranged (Fig. 10-8).

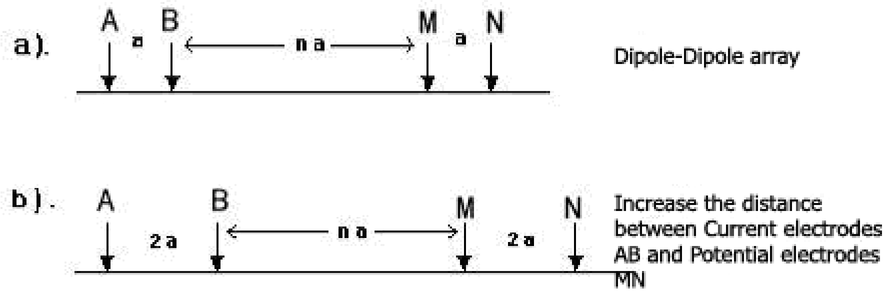


Fig. 10-8 Dipole-Dipole Array

Calculation formula of apparent resistivity in Dipole-Dipole array is:

$$\rho=\prod n\ (n+1)(n+2)aV/I,$$

"a": distance between the measuring electrodes P1, P2.

"V": potential gained

"I": current gained.

"n": isolation coefficient which equals to the ratio of BM electrode distance to MN electrode distance.

The merit of dipole-dipole array is high horizontal resolution. However, signal gained is very poor in that potential difference of the Potential electrodes M, N in opposite proportion of the cube of the coefficient "n", and "SNR (signal noise ratio)" decreases rapidly when "n" value grows. When "n" is higher than 6, data gained are not reliable.

10.5 Field Layout

1) Arrange Electrodes

Firstly, clinch the stainless electrodes in the survey district and electrodes are arrayed in grid-node shape.

2) Assemble Cable

The 10 connectors (take-out) on each sting of intelligent cable are numbered as 1~10 respectively, that is, each string of cable could connect with 10 electrode, at the head of the cable is a 12-core plug and at the end of the cable is a 12-pin plug (jack plug).

Prior to arranging the cables, get a clear mind of the location of the electrode matrix in which the survey station is. Put the cable along the array, keeping its head and end in sequence. Then mount the connector to connect the cables one by one.

3) Lay and Connect Electrodes

Lay the electrode in S-shape (Fig.10-9) as described in Section 10.2.

Fig.10-9

4) Mount Connector (Take-Out) and Lay Electrodes

Fix the connector on the upper end of the stainless electrode by pulling the string upwards to have electrode top insert into the ringer that is at the end of the spring (Fig. 10-10).

Fig.10-10

5) Connect Instrument

After the above steps, insert the 12-core plug of into socket 1 or socket 2 (on the WDA-1A main frame, Fig.10-11).

If the mainframe is WDA-1, connect the DCHV positive and negative connecting ports to those of the DC high-voltage power source respectively.

Fig.10-11

10.6 Instrument Operation

10.6.1Turn on WDA-1/WDA-1A and Run System Program

Switch on WDA-1/WDA-1A, turn on the pocket PC and then click "Start"→ "Program"→ "File Explorer"→ "SD card" → "WDA-3DR" to enter into the system program (Fig. 10-12).

Fig. 10-12

10.6.2Bluetooth Pairing

Before commencement of measuring, first pair the Bluetooth to enable WDA-1/WDA-1A to communicate with the pocket PC smoothly (Fig. 10-13).

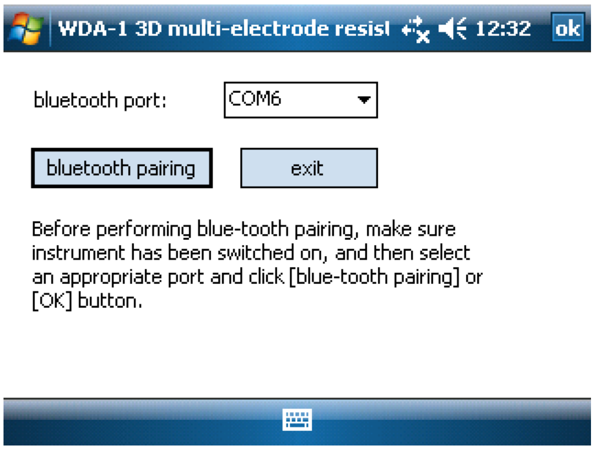


Fig.10-13

10.6.3Create New Section

After Bluetooth pairing, create a new section.

Get into the Main interface as shown in Fig. 10-14 and click "Section"→ "New section" button; and then pops up the next interface (Fig. 10-15).

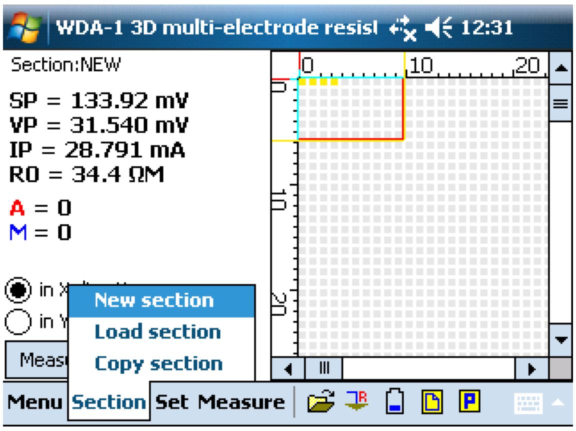


Fig. 10-14

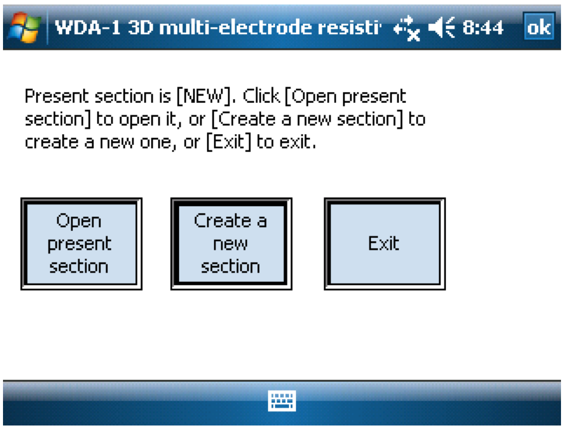


Fig.10-15

Click "Create a new section" button to define this newly created section (Fig.10-16).

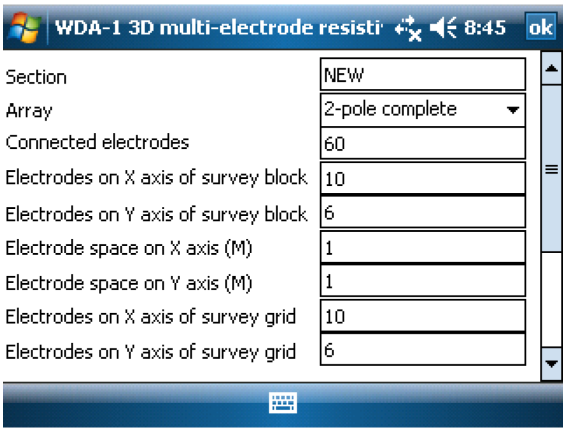


Fig. 10-16

Section: section/cross-section is the collection of all the survey points in the same vertical plane where the survey lines locate. Section name is the name of one cross-section in field survey and the name of the corresponding file stored in disk.

Array: electrode array configuration. There are 4 electrode array configurations are available for multi-electrode 3D resistivity imaging, namely, 2-pole complete, 2-pole diagonal, 3pole-pole diagonal and 4-pole diagonal. For 3-pole and 4-dipole electrode array, only diagonal method is available.

Connected electrodes: it is the total number of electrodes that are connected to the intelligent cables.

Electrodes on X axis of survey block: total electrode numbers on X axis of the survey block. Electrode number along the line direction is in the first row of the S-shape routing. X axis actually means the intelligent cables.

Electrodes on Y axis of survey block: total electrode numbers on Y axis of the survey block, vertical to X axis. The product of the electrodes on X axis and Y axis should be not more than "Connected electrodes". The electrodes on each axis should be more than or equal to electrode numbers of the electrode array configuration.

Electrode space on X axis: distance between the two adjacent electrodes on X axis.

Electrode space on Y axis: distance between the two adjacent electrodes on Y axis.

Electrodes on X axis of survey grid: the total electrode numbers in X axis direction of the whole survey grid.

Electrodes on Y axis of survey grid: the total electrode numbers in Y axis direction of the whole survey grid.

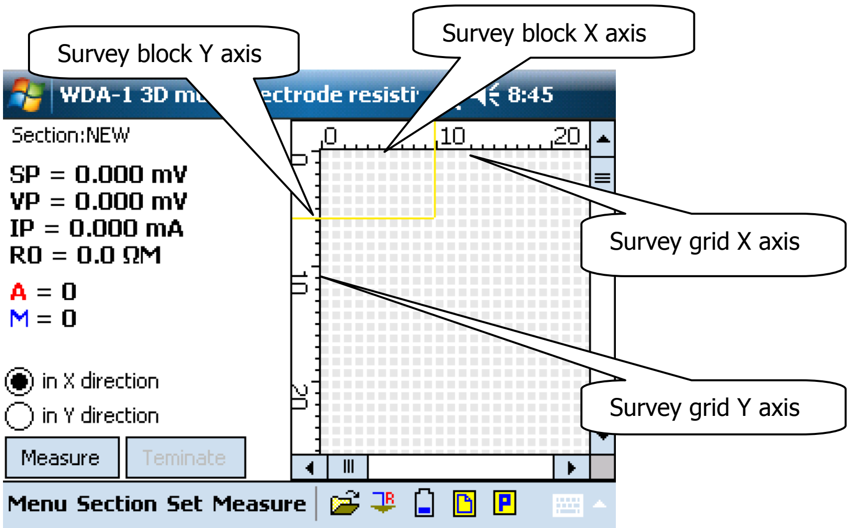


Fig. 10-17

10.6.4Set Measure Parameters

Before commencement of measuring, set measure parameters for this measurement.

Under the Main interface, click "Set" → "Measure Parameter" (Fig.10-18) or click the shortcut icon [P] to enter into the interface as shown Fig. 10-19.

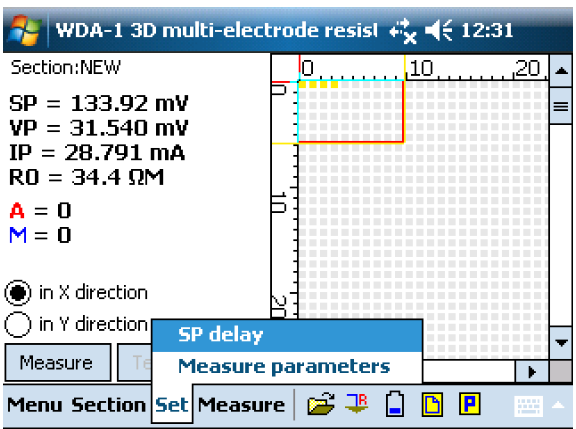


Fig. 10-18

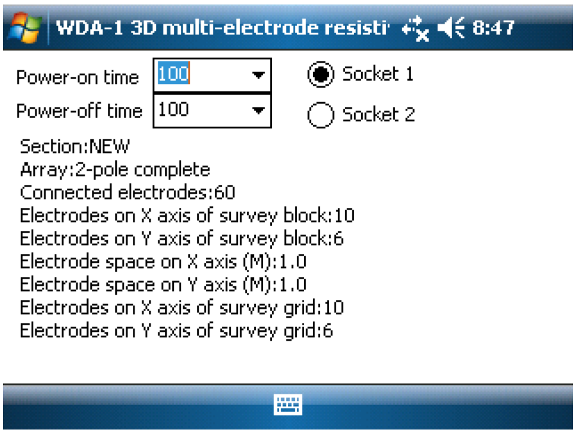


Fig. 10-19

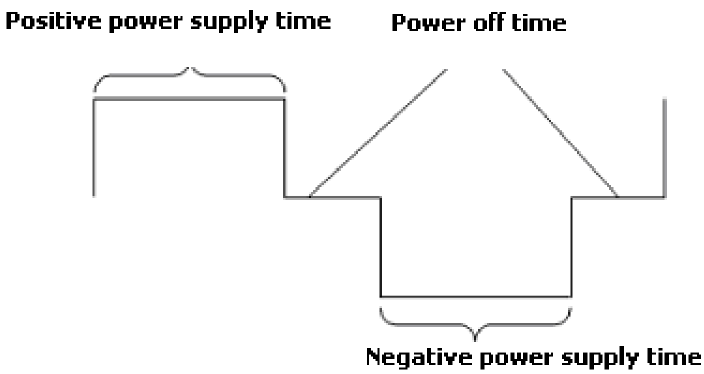


Fig. 10-20

Power-on time: both positive power supply period and negative power supply period belong to the power supply phase. The time of positive power supply period and negative power supply period is Power-on time

Power-off time: the time between positive power supply and negative power supply is Power-off time.

Socket: since multi-electrode 3D resistivity imaging is realized with the intelligent cable. Before commencement of measuring, choose socket 1 or socket 2 according to the actual connection.

10.6.5Self Potential (SP) Parameter

Self-potential parameter is advantageous for WDA-1/WDA-1A system.

Background:

In multi-electrode resistivity imaging system, there may be a large amount of electrode coulombs left after one measuring action. If go on to the next measuring action immediately, measuring error may be enlarged. In order to improve measuring precision, WDA-1/WDA-1A will wait until the potential recovers, so as to eliminate errors caused by self potential jumping.

However, in some geological conditions whose self-potential is quite active (such as alkaline soil), recovery of self potential may not be satisfied after the above operation. To meet this need, WDA-1/WDA-1A is design with these two parameters of "Variation limit" and "Over-variation delay" to improve measuring precision, which means that the system will compensate self-potential of the next survey point. System first tests and checks whether current self potential jumps and whether it is higher than "Variation limit" defined; if it is higher, the "Over-variation delay" will controls system to wait until self-potential gets stable.

Access:

Under the Main interface, click "Set" → "SP Delay" (Fig.10-21) to enter into the interface as Fig. 10-22.

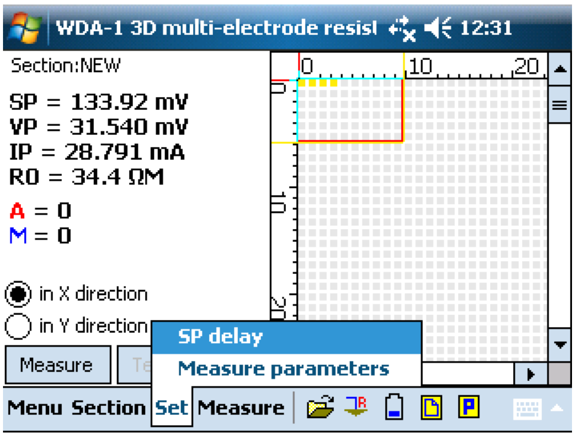


Fig. 10-21

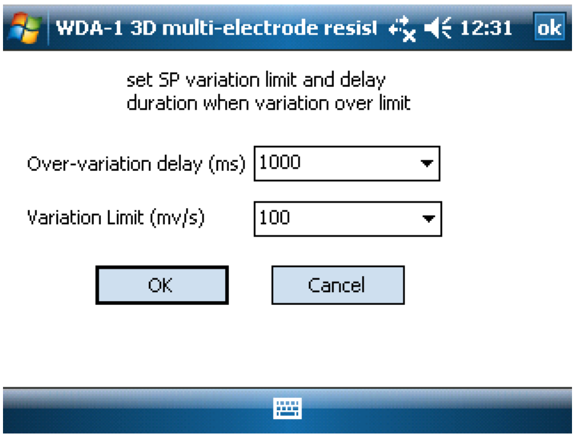


Fig. 10-22

"Variation limit": 10, 20, 50, 100, 200, 500 are available; unit is mV/s. Choose one value according to the actual geological condition (default is 100mv/s). The smaller the value, the higher the measuring precision, and the longer the time needed; the higher the value, the lower the measuring precision and the shorter the time needed.

"Over-variation Delay**":** 500, 1000, 2000, 3000, 5000 are available; unit is ms and default is 2000ms.

10.6.6Measure

After arranging the system in field, setting the parameters above, it is ready to commence measuring. You may execute "Self-check" of the intelligent cable, "Grounding R" of the electrodes or "Battery volt" of the pocket PC.

Get into the Main interface. Click "Measure" → "Self-check/Grounding R/ Battery volt" (Fig.10-23) to perform the corresponding function.

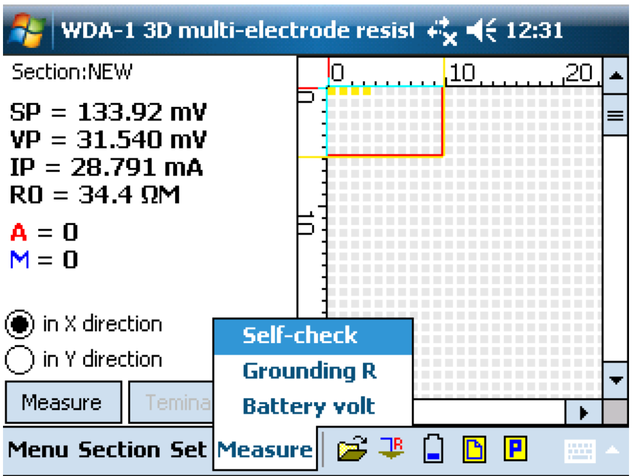


Fig.10-23

1) Self Check

Imbedded in each take-out of the intelligent cable is switch. Function of the switch can also be checked by the PDZ-1 switch adapter self-checker (for detailed operations, please refer to Appendix A in this user's manual).

2) Grounding R

This function is to measure earth resistance of each electrode.

Under the Main interface, click "Measure" → "Grounding R" or click the shortcut icon  to enter into the "Grounding R" measure interface. Choose "Socket 1" or "Socket 2" that is actually connected (Fig. 10-24). Click "Grounding R" button to start measure, then the earth resistance of a certain electrode is displayed (Fig. 10-25).

If earth resistance of that electrode is more than 5 KΩ, the system will beep once.

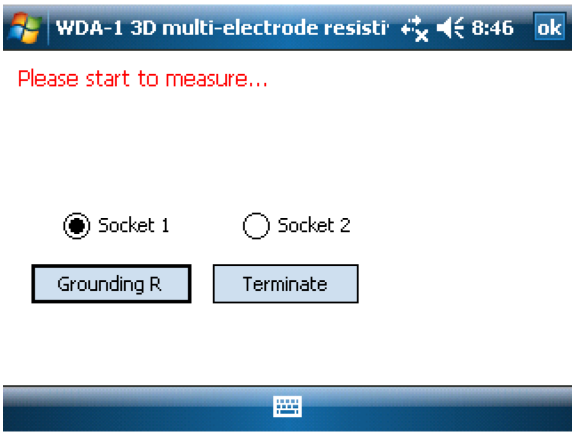


Fig.10-24

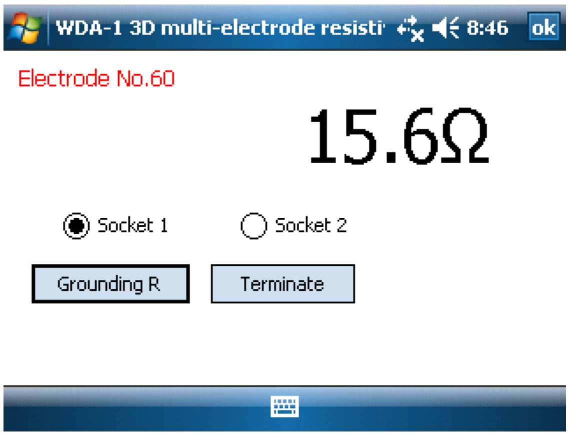


Fig.10-25

3) Battery Volt

This function is to measure battery voltage of WDA-1/WDA-1A main frame.

Click "Measure"→ "Battery volt" or click the battery icon  at the right bottom of the screen and then the battery voltage is displayed (Fig.10-26).

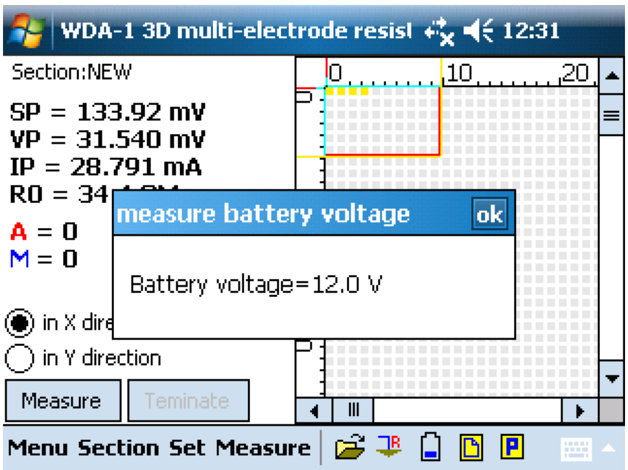


Fig. 10-26

4) Measure Survey Block

After the above operations, system is ready to measure the block.

Click the "Measure" button on the left bottom of the screen to commence measuring of the present survey block, and then system keeps measuring one survey block automatically until all finish (Fig.10-27).

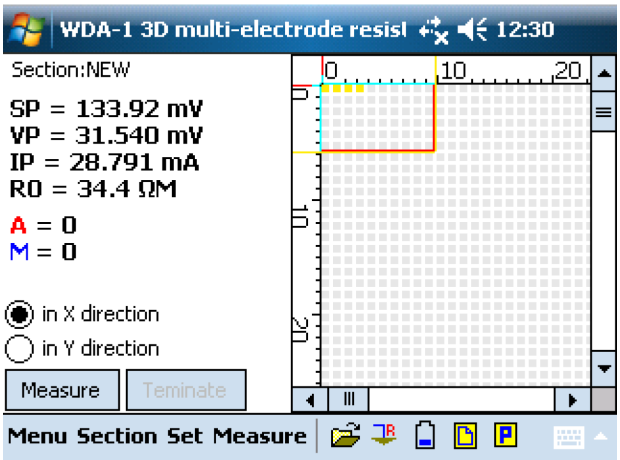


Fig.10-27

During measuring process, click "Terminate" button to quit measuring; to continue the above measuring action, just click "Measure" button once again.

If survey grid is larger than survey block in the settled parameters, move the electrodes to the location of next survey block. Select the actual location of the survey block with the stylus of the pocket PC and then click "Measure" to start to measure the next survey block.

Measure the survey blocks one by one till the complete survey grid is measured.

10.6.7Copy Measured Results

Since parameters of a newly created section are not allowed to be modified, the actual survey region is usually smaller than the one defined in the system.

Through this function, "Copy measured results", user can copy data of the actual survey region and save it for further processing.

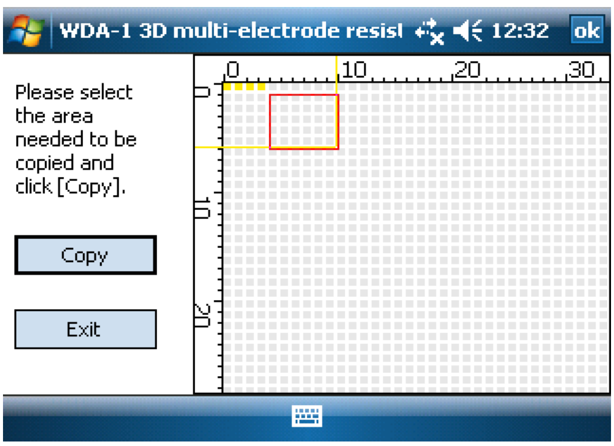


Fig. 10-28

In Fig. 10-28, click the starting point of the survey region (on the screen) and drag till the last survey point. The selected region encircled by a red rectangle is the wanted measured results.

Click "Copy" button and system automatically saves it with the name of [Original name of the section + '-copy/cut'].

Complete Set of System

Standard Configuration:

1. WDA-1/WDA-1A mainframe and accessories:

No.	Description	Quantity
1	WDA-1/WDA-1A mainframe	1set
2	Hp iPAD 112 pocket PC and its standard components. Program software in SD card for General Res/IP survey function	1set
3	An extra original rechargeable battery for the Hp iPAD pocket PC	1pc
4	One CD with Bluetooth USB adapter and installation program, User's manual and Data format convert software	1pc
5	Portable bag for WDA-1/WDA-1A mainframe	1pc
6	One Windows version program software CD	1pc
7	WDA-1/WDA-1A Super Multi-Electrode Resistivity/IP Imaging System User's Manual	1pc
8	Aluminum packaging case for WDA-1/WDA-1A mainframe	1pc

2. Electrodes and other accessories

No.	Description	Quantity
1	Solid non-polarized electrode	2pcs
2	Iron electrode	10pcs
3	Charger for WDA-1/WDA-1A mainframe	1set
4	Charger for internal battery of **only WDA-1A**	1set
5	Power wire for connection to external 12V battery	1pc
6	Aluminum packaging case for electrodes	1pc

Optional Components:

1. Multi-electrode 2D/3D Resistivity/IP Imaging System (with 10-take-out Intelligent Cable)

No.	Description	Quantity
1	Intelligent cable	Quantity and take-out spacing are up to order

2	Multi-electrode stainless steel electrode	Up to order
3	Shoulder bag for multi-electrode stainless steel electrode	1pc/70 electrodes
4	PDZ-1 distributed self-checker, including, 1pc PDZ-1 self-checker main frame 1pc Special cable for election connection 1pc Switching cable for adapter 1pc Shoulder bag	1set
5	Connecting wire for electrodes M and N	Up to order

2. Multi-electrode 2D Resistivity Imaging System (with 30/60-take-out cable):

No.	Description	Quantity
1	WDZJ-3 multiplex electrode converter	1 set
2	RS232 communication cable for connection of WDA-1/WDA-1A mainframe and WDZJ-3 Multiplex Electrode Converter	1pc
3	Cable for connection of A, B, M, N ports between WDA-1/WDA-1A mainframe and WDZJ-3 Multiplex Electrode Converter	4pcs
4	Multi-electrode cable (30pcs electrodes/string, take-out spacing is up to order)	2string
5	Copper electrode (with clamp)	60pcs
6	WDZJ-3 multiplex electrode converter self-checker, including 1pc self-checker 1pc 32-core self-checker cables 1pc Cable for connection of A, B, M, N ports between self-checker and WDZJ-3 multiplex electrode converter	1 set

3. Other Components:

No.	Description	Quantity
1	90V cell box	Up to order
2	Variable speed wire winding frame (for 600m)	Up to order
3	Uniform speed wire winding frame (for 800m)	Up to order
4	Field wire (500m/roll)	Up to order
5	Solid non-polarized electrode	Up to order
6	Iron electrode	Up to order
7	Copper electrode	Up to order

APPENDIX A: PDZ-1 SWITCH SELF-CHECKER

PDZ-1 switch self-checker is an optional component for multi-electrode resistivity imaging system. It mainly functions inspecting connections of the switches in the take-out of the intelligent cable and helping operator to find the fault or failure quickly and correctly.

1) Front Panel

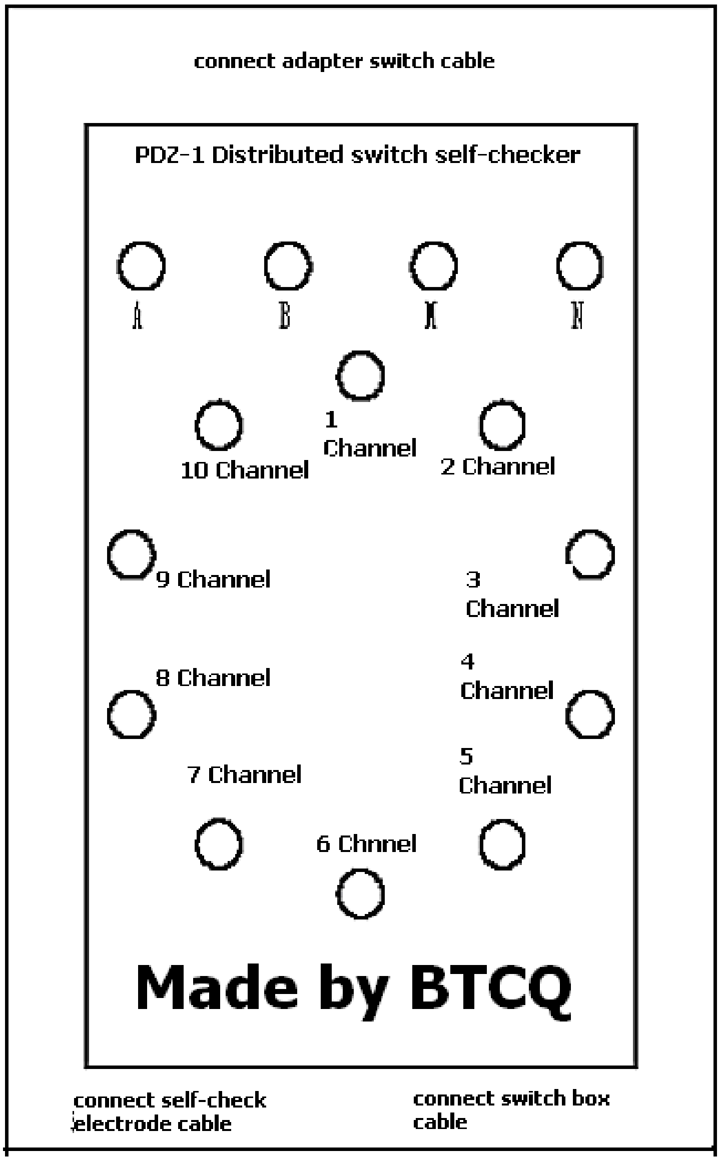


Fig.A-1 Front panel of PDZ-1 switch self-checker

2) Connection

① Plug the self-checker cable into the "Connect self-check electrode cable" socket (on the left bottom of the front panel) of PDZ-1 switch self-checker.

② Plug the intelligent resistivity/IP cable into the "Connect switch box cable" socket (on the right bottom of the front panel) of PDZ -1.

③ Have the 10 clamps (on the self-checker electrode cable) clamp each stainless connector on the intelligent cable take-out. What should be noted is that clamps should not be short-circuited and so are the stainless connectors on each intelligent cable.

④ Connect the "Connect adapter cable" socket (on the front panel of the PDZ-1) and the "Cable socket 1" (on the WDA-1/WDA-1A mainframe) with the special cable.

3) Self-check Procedure

① Turn on the WDA-1/WDA-1A mainframe.

② Turn on the PDA, under "WDA-2DR" program, click "Menu"→ "Measurement"→"Self-check" (Fig.A-2), and system enters into self-check interface (Fig.A-3). Choose "Intelligent" option.

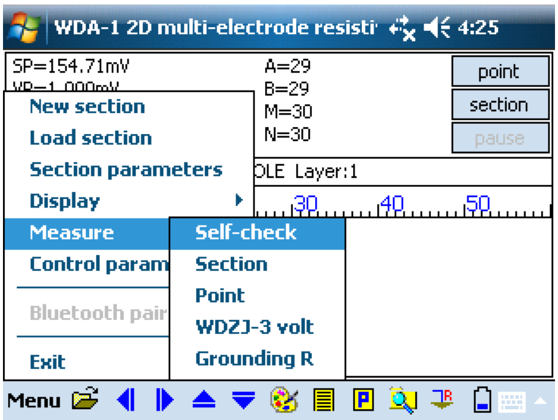


Fig.A-2

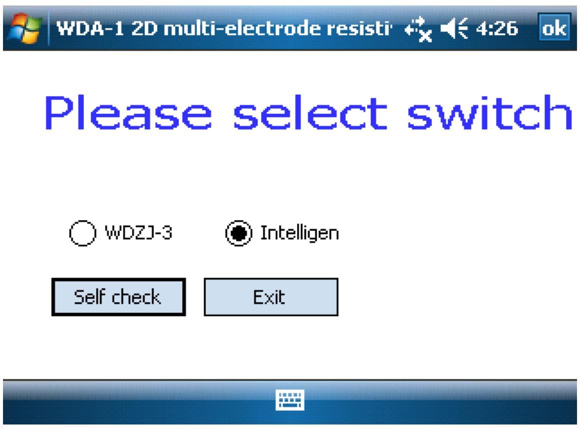


Fig.A-3

③ Click "Self-check" to start self check.

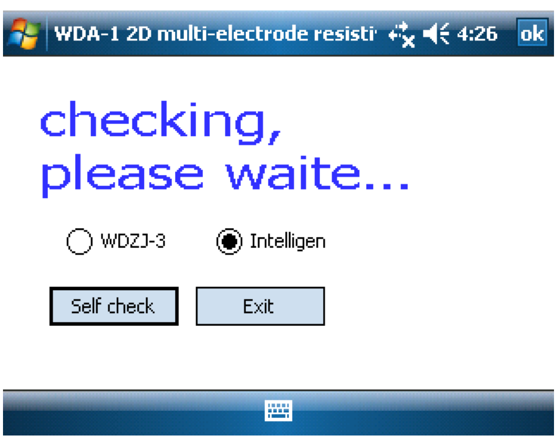


Fig.A-4

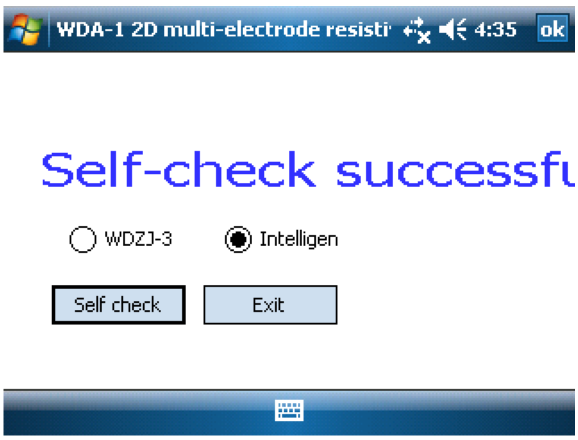


Fig.A-5

④ "A" "B" "M" "N" indicator lights on the self-checker turn on at difference frequencies (A keeps on; B flickers at a high frequency; C flickers at a relative high frequency; N flickers at a low frequency).

⑤ While the 1~10 channels LED first turns on at the frequency of A one by one; then turns on at the frequency of B, M, N respectively, which means self-checker is inspecting ABMN respectively.

⑥ If the 1~10 channel turns on, the switch in the intelligent cable can work well; if any one of the ten channels keeps off, that switch would fail to work.

APPENDIX B: WDZJ-3 MULTIPLEX ELECTRODE CONVERTER SELF-CHECKER

WDZJ-3 Multiplex Electrode Converter self-checker is an optional component for multi-electrode resistivity imaging system. It mainly functions inspecting contacts of electrode switches and helping operator to find the fault or failure quickly and correctly.

1) Front Panel

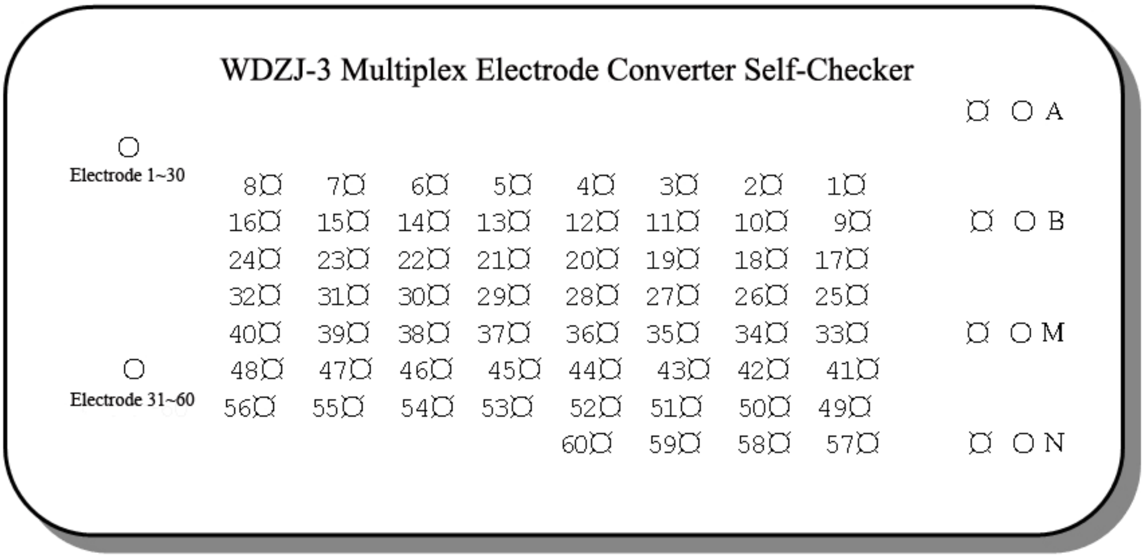


Fig.B-1 Front panel of WDZJ-3 multiplex electrode converter self-checker

2) Connection

① Connect the "Electrode 1~30", "Electrode 31~60" socket (on the WDZJ-3 multiplex electrode converter to the "Electrode 1~30", "Electrode 31~60" socket (on the self-checker) respectively with the special cable.

② Connect the A, B, M, N ports (on the WDZJ-3 converter and the self-checker) with the A, B, M, N connecting ports (on the WDA-1/WDA-1A) correspondingly.

③ Connect the "Forward RS-232" port (on the WDZJ-3 converter) to the "RS-232" port (on the WDA-1/WDA-1A) with special cable.

3) Self-Check Procedure

① Switch on the WDA-1/WDA-1A main frame and the WDZJ-3 multiplex electrode converter.

② Turn on the PDA, under "WDA-2DR" program, click "Menu"→ "Measure"→"Self-check", and system enters into self-check interface. Choose "WDZJ-3".

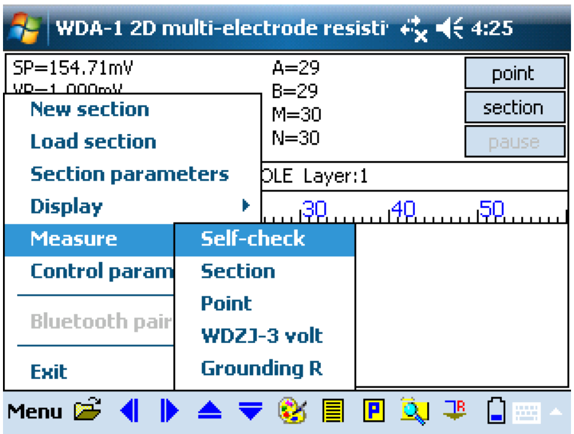


Fig.B-2

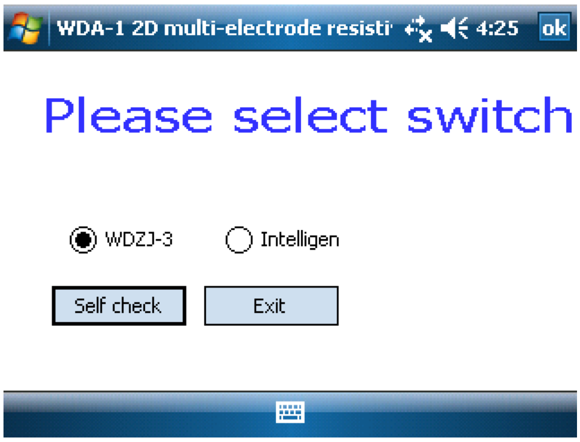


Fig.B-3

③ Click "Self-check" button to start self check.

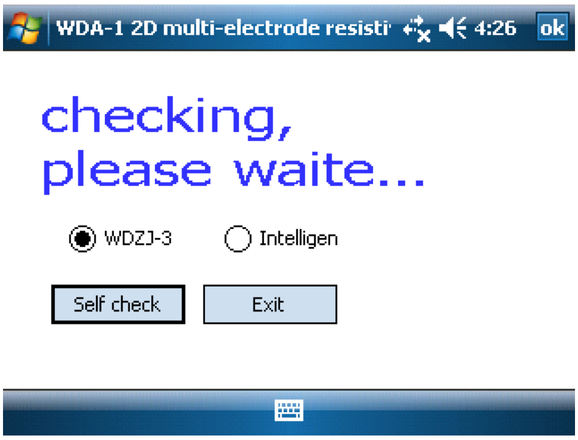


Fig.B-4

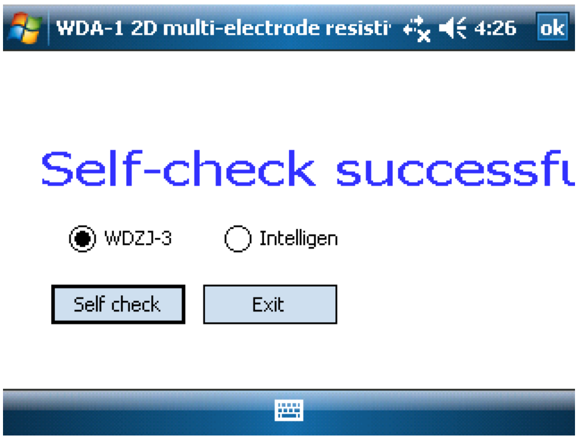


Fig.B-5

④ Observe the LED for each electrode switch; if any indicator light is off, that electrode switch would fail to work.

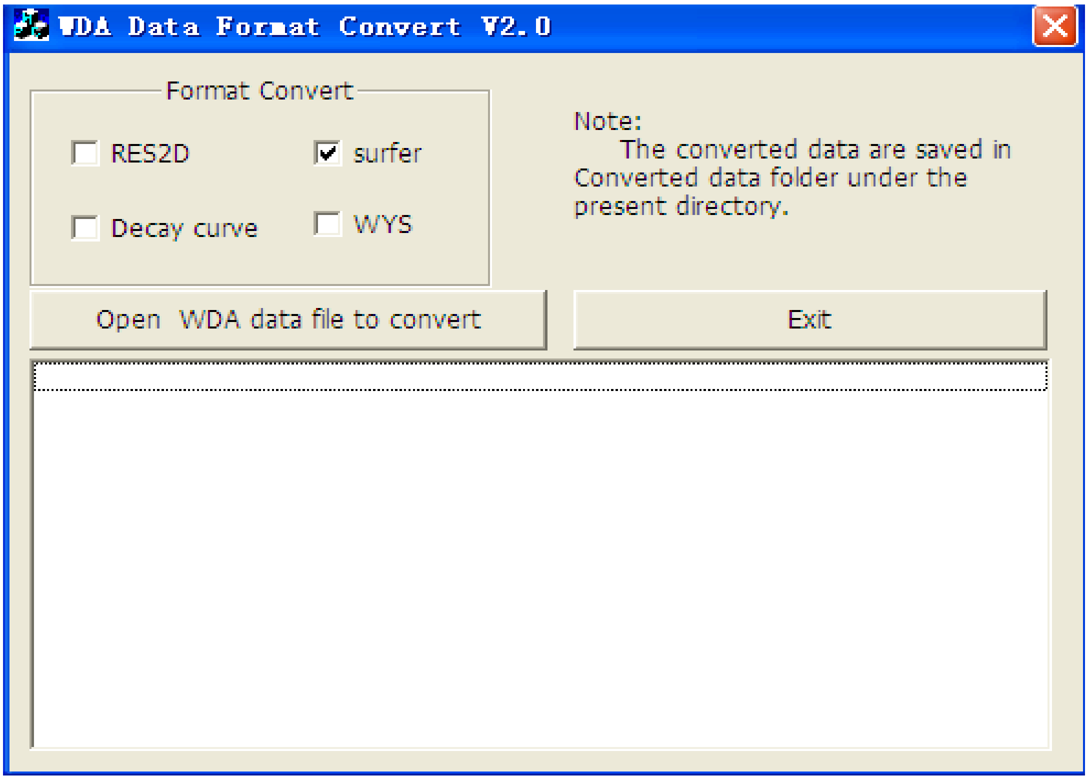
Note:

All the LED should be off when the self-checker and WDZJ-3 converter are well connected and WDZJ-3 converter is switched on. If any light is on, fault may exists (i.e., always switched on and could not be cut off).

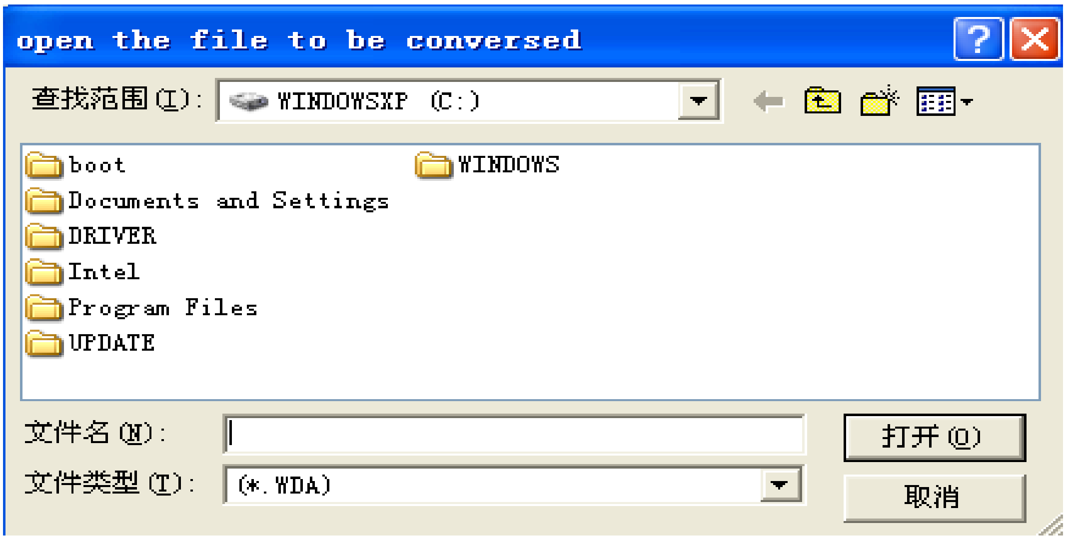
APPENDIX C: FORMAT CONVERSION SOFTWARE

Extension of WDA-1/WDA-1A data file is WDA, in binary format. This WDAFC.EXE data format convert software can transform data file into text file. Besides, data file of general resistivity survey can be transformed to Surfer format. Specific procedures are as follows:

1. Transfer the measured results from the pocket PC to the computer.
2. Run the format conversion software **WDAFC.EXE**.



3. Choose the format corresponding to the data file (RES2D, Decay curve, Surfer, WYS formats are available). For general resistivity method, choose **Surfer** format.
4. Click "Open WDA data file to convert" and choose the file to be transformed (see the following figure).



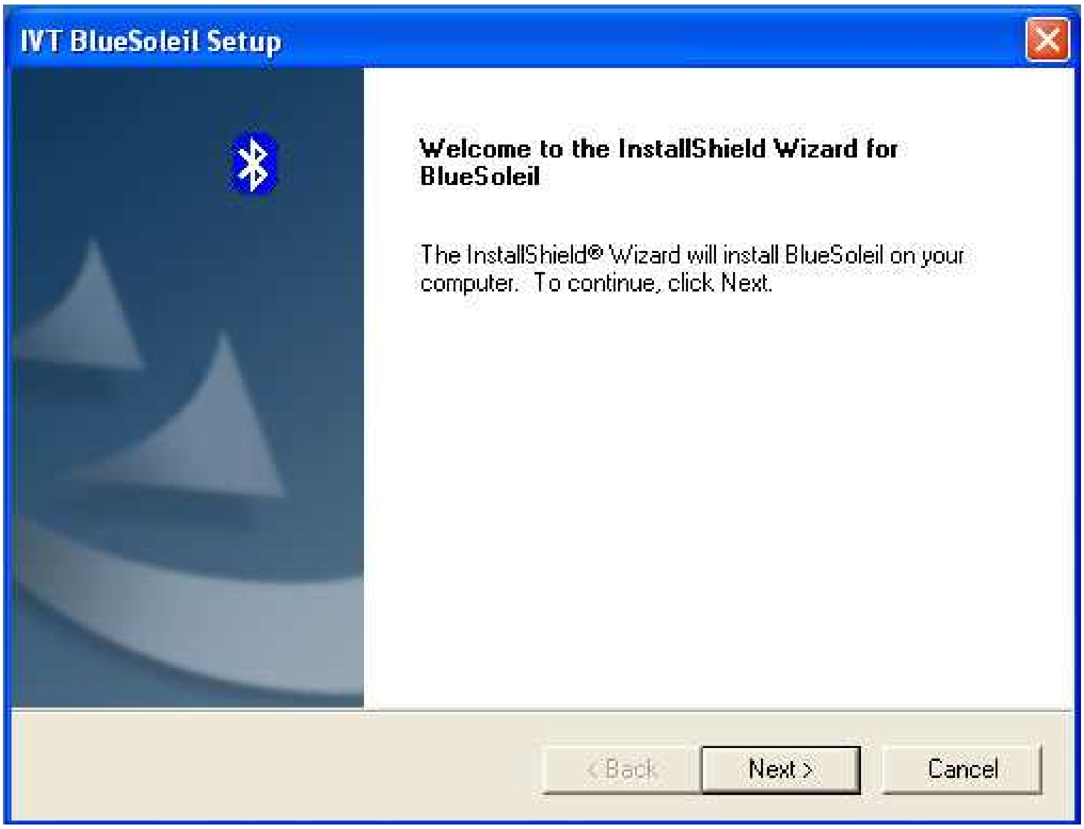
5. Click "Open" and the software transforms the file into the wanted format, to the "Converted data" folder in the present directory.

APPENDIX D: INSTALLATION OF BLUETOOTH USB ADAPTOR

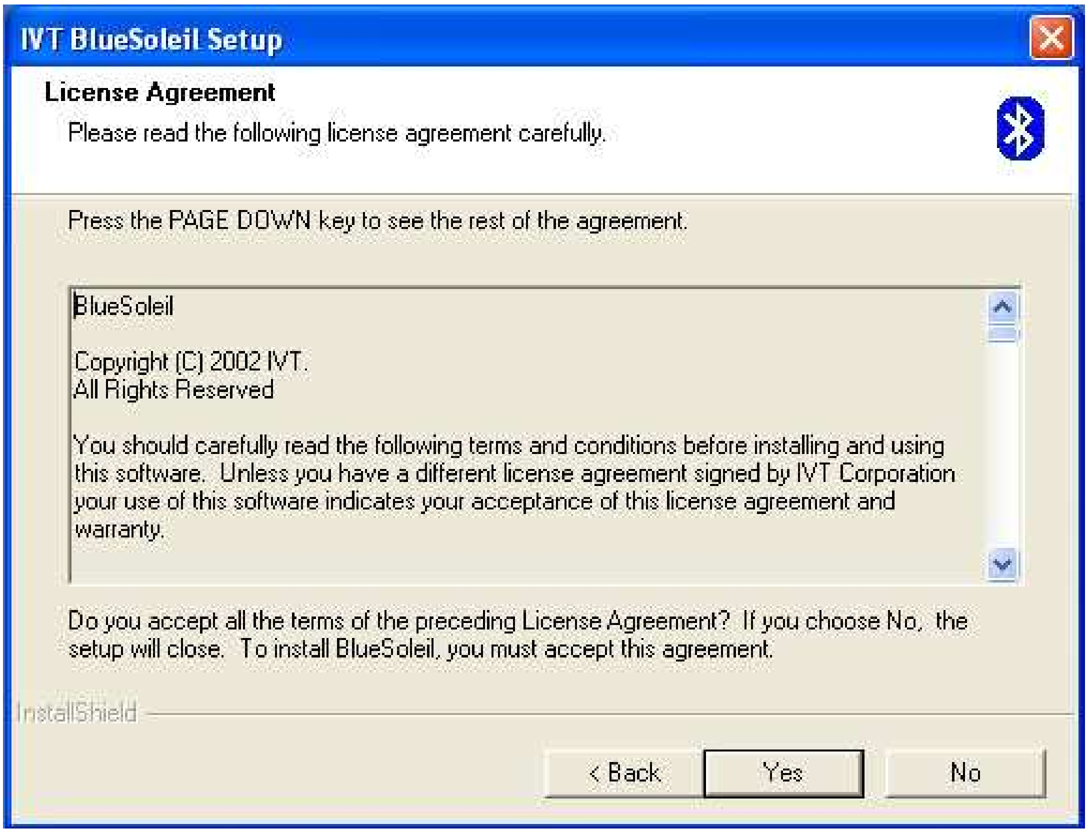
WDA-1/WDA-1A super digital DC Resistivity/IP meter could also use notebook PC or table computer to control sampling. What needs to do is installing Bluetooth USB adaptor drive, and then plugging the Bluetooth USB adaptor into the USB port on the computer.

Procedures of installing Bluetooth USB adaptor is as follows.

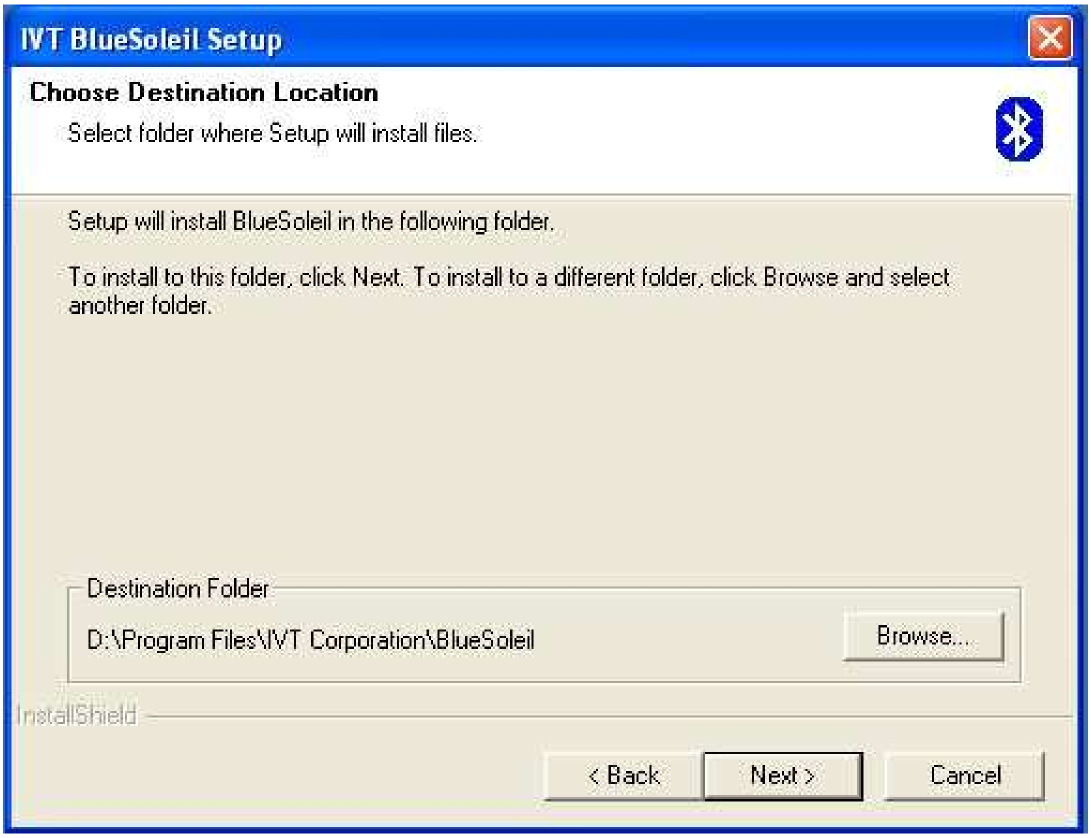
1. Insert the CD into the CD driver and system automatically enters into the installation interface (see the following figure). Note that the Bluetooth adaptor should not be connected with the computer at this time.



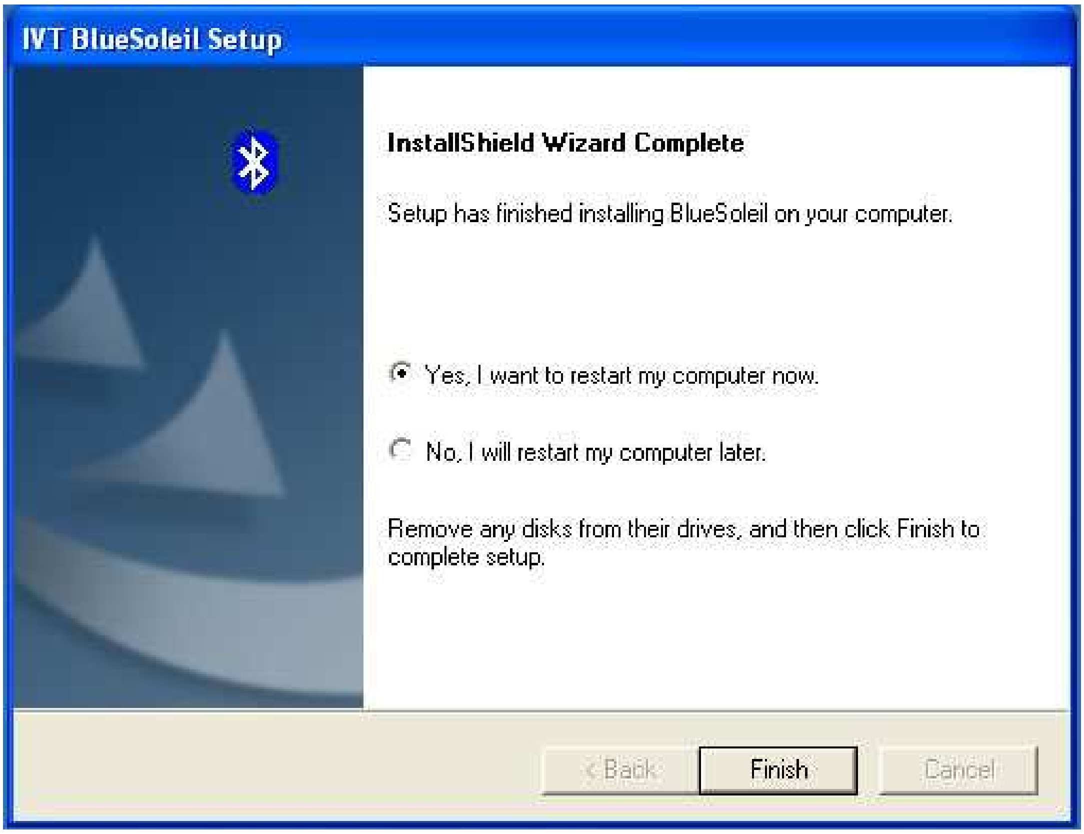
2. Click "Next".



3. Click "Yes".



4. Click "Next" and install it to a directory

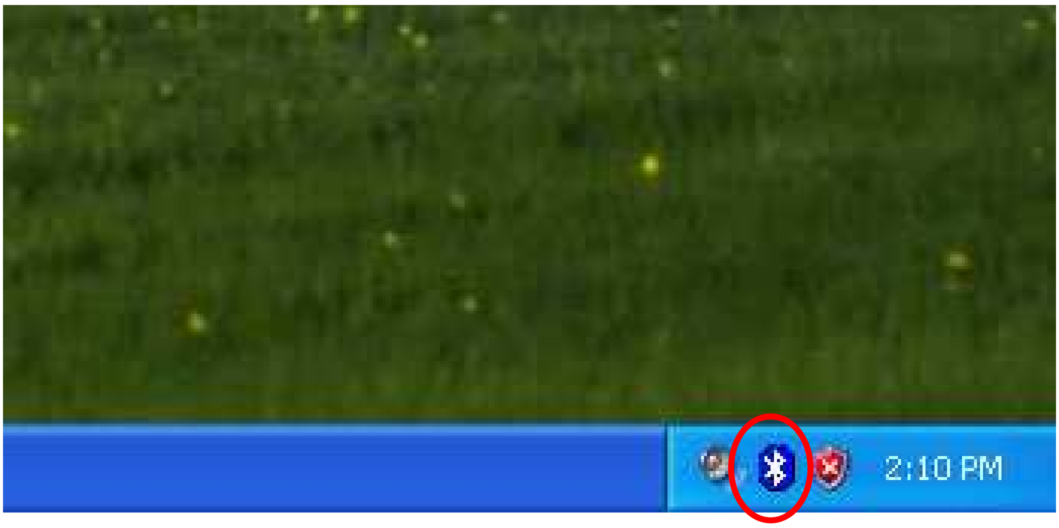


5. Click "Finish" to restart the computer.
6. After restarting, plug the Bluetooth adaptor to the computer and system clews finding a new device. Then system automatically installs driver for this new device.

7. Click "OK". Then, installation finishes.

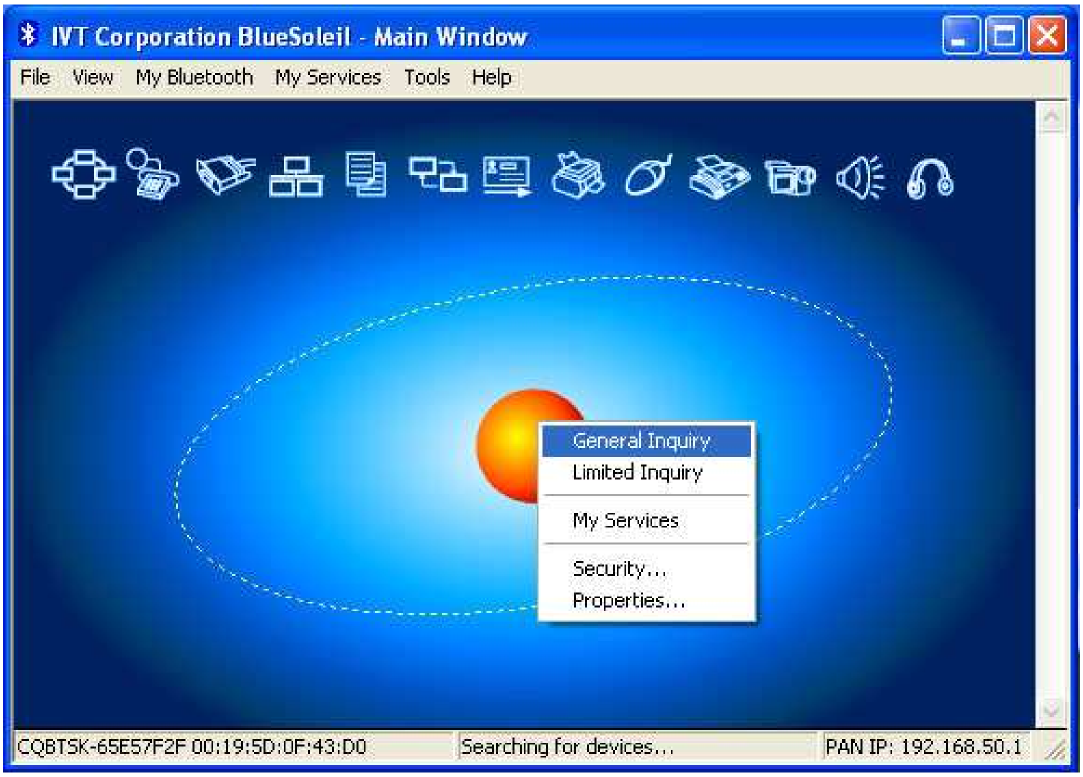
Preparations for Communication

1. After installation, a Bluetooth icon appears at the right button of the screen (see the following figure).

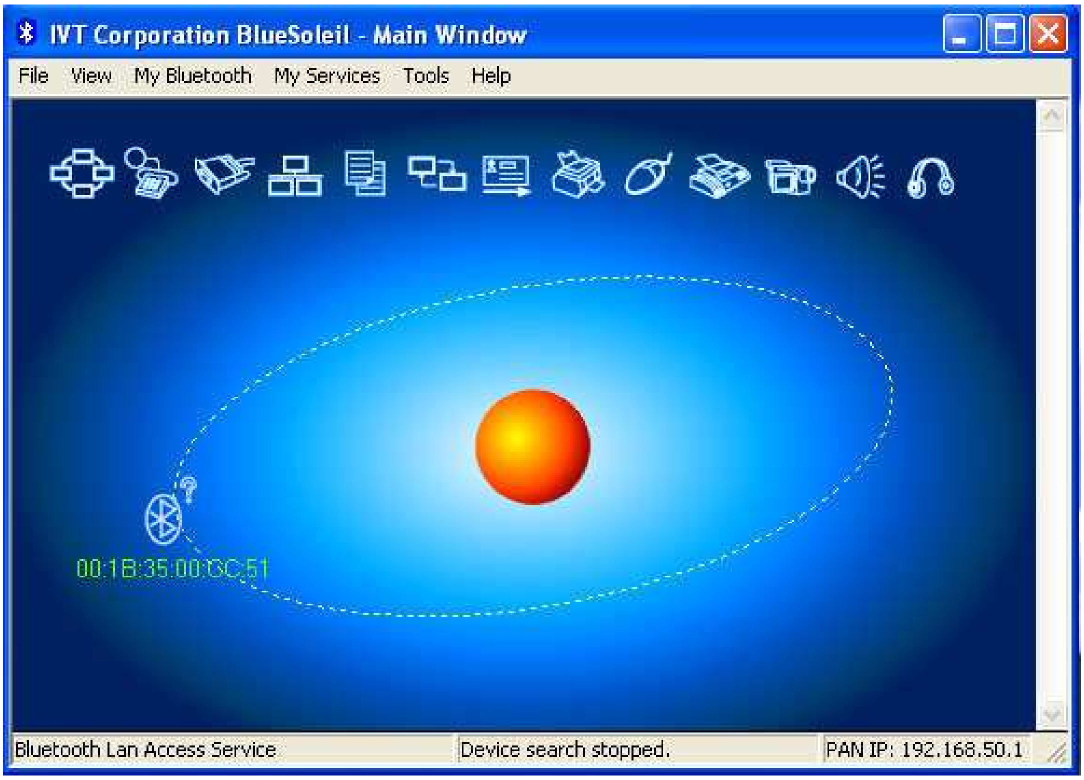


2. Double click the icon to enter into the Bluetooth main interface; then right lick the red ball at the center and pops up a floating menu; click "General

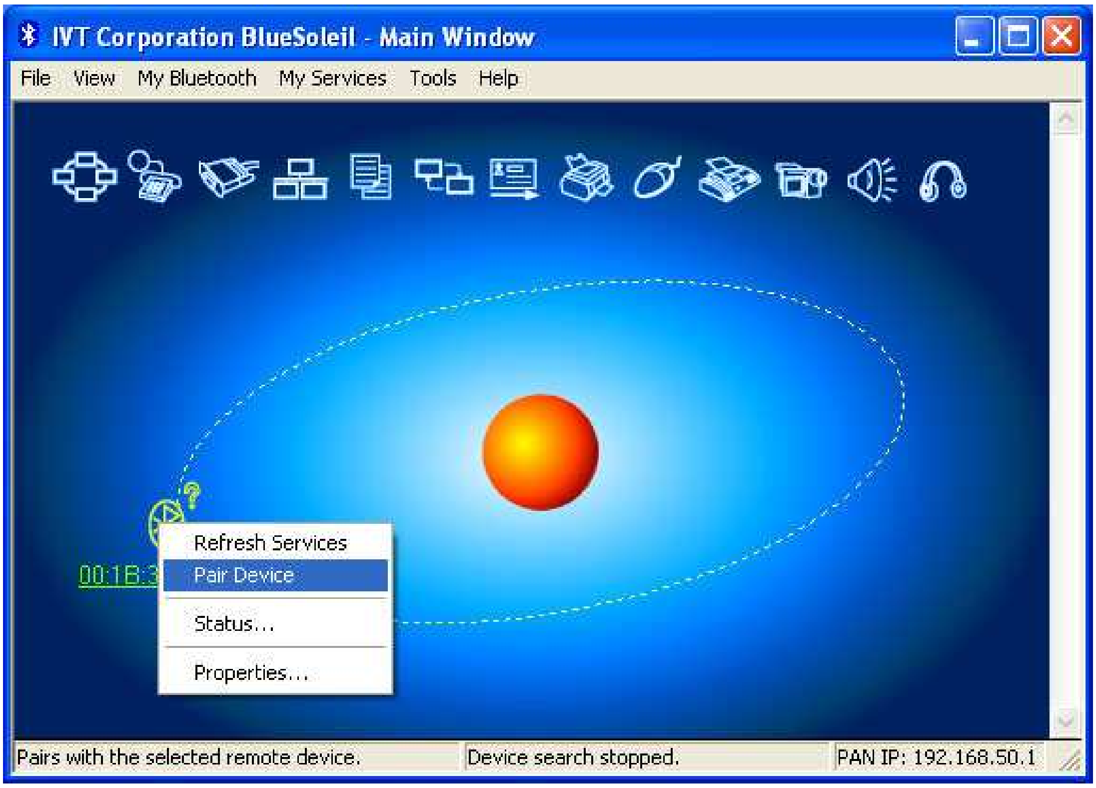
Inquiry" time.



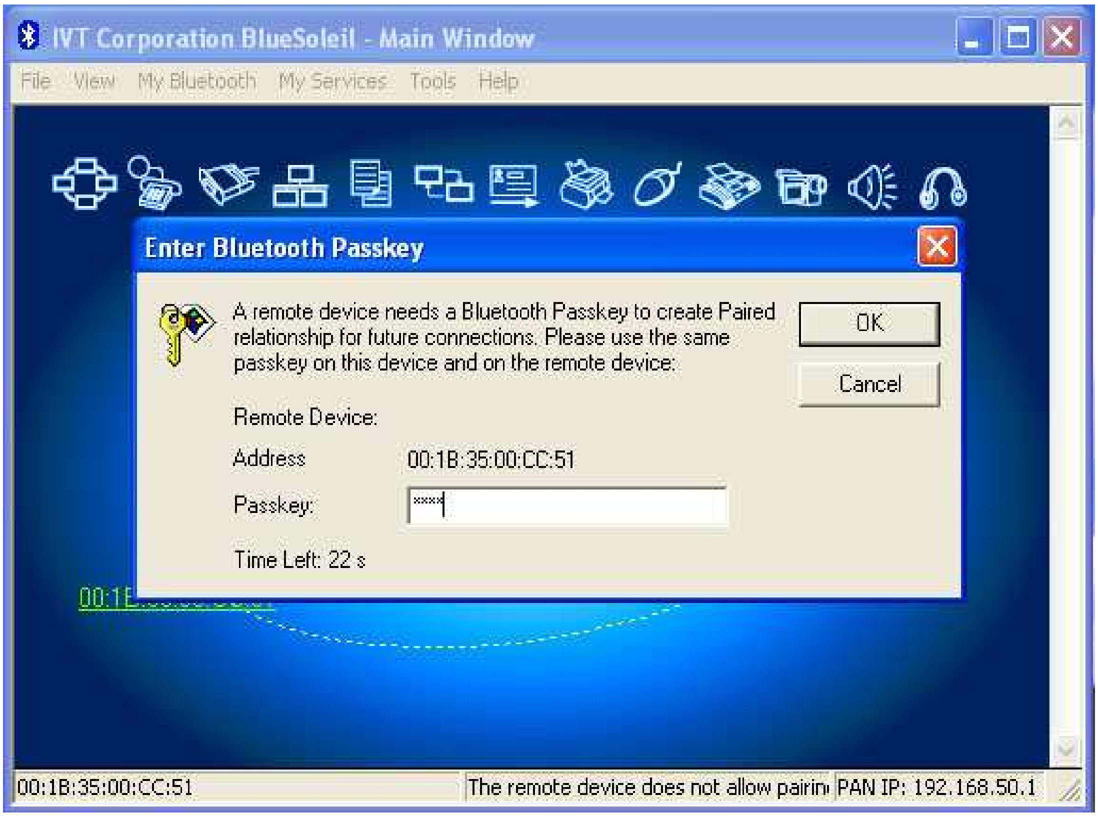
3. Available devices are displayed on the screen then (see the following figure).



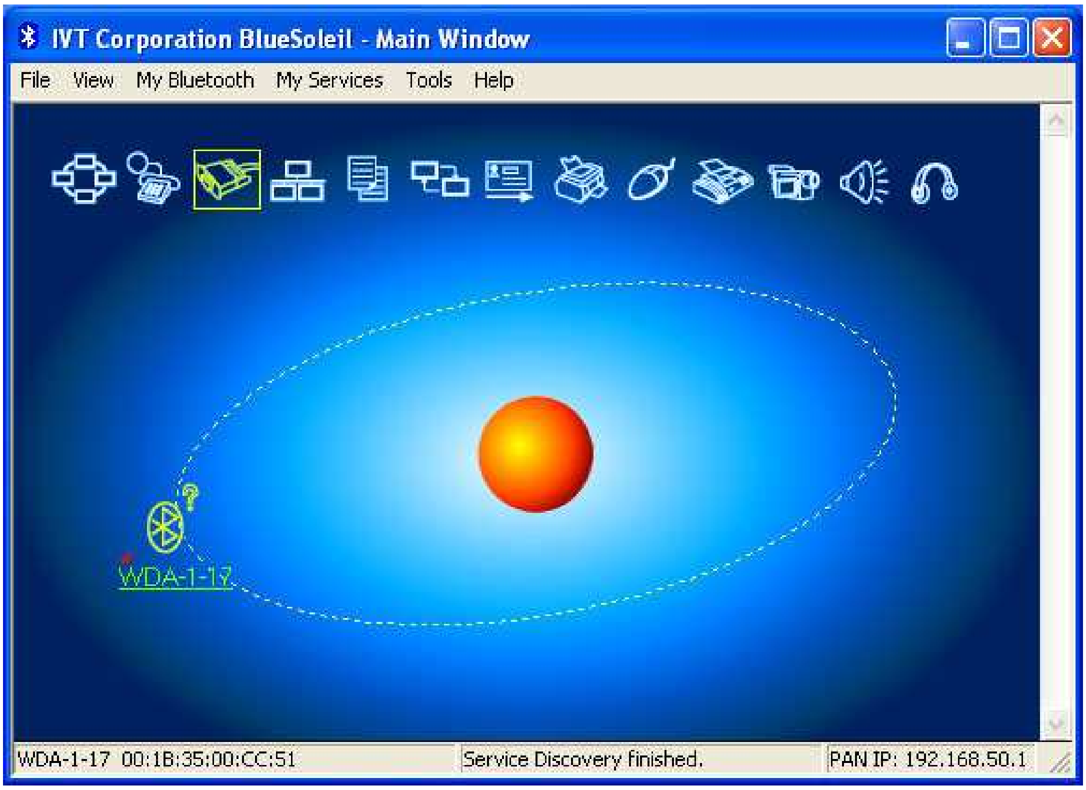
4. Choose on device icon; right click the device and click "Pair Device".



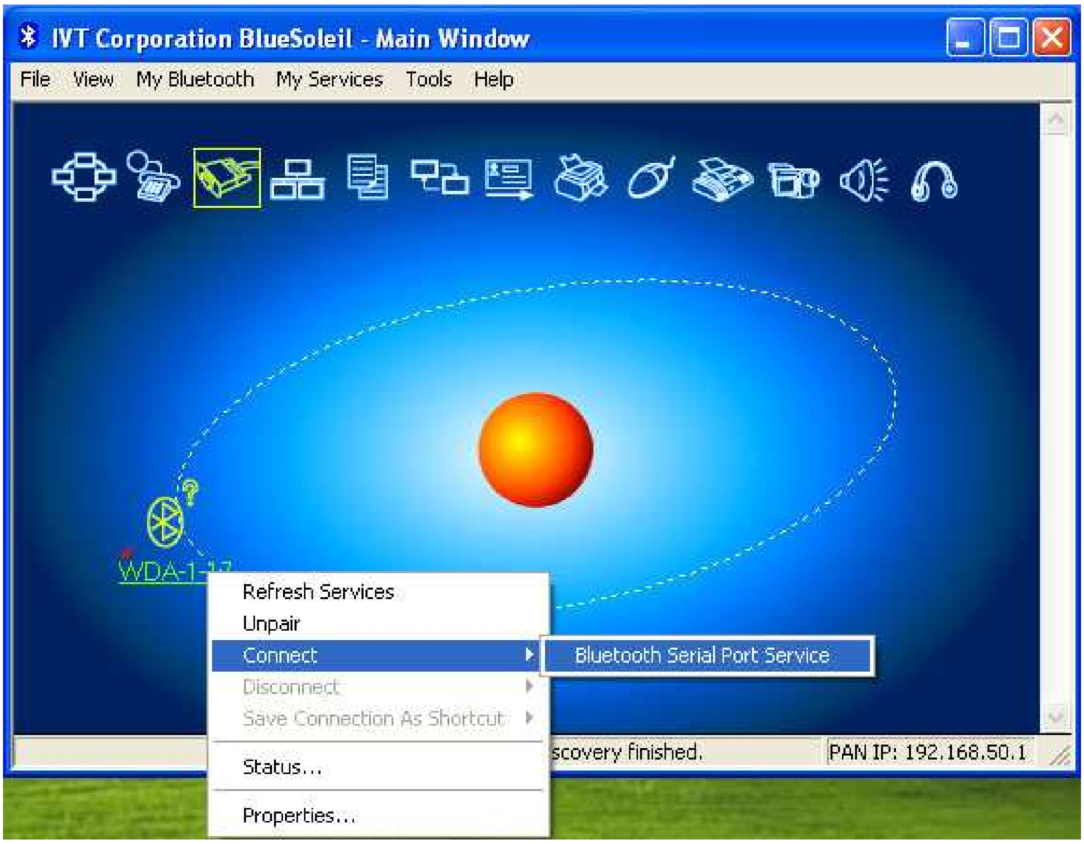
5. System asks for passkey; input "1234" and then press "Enter".



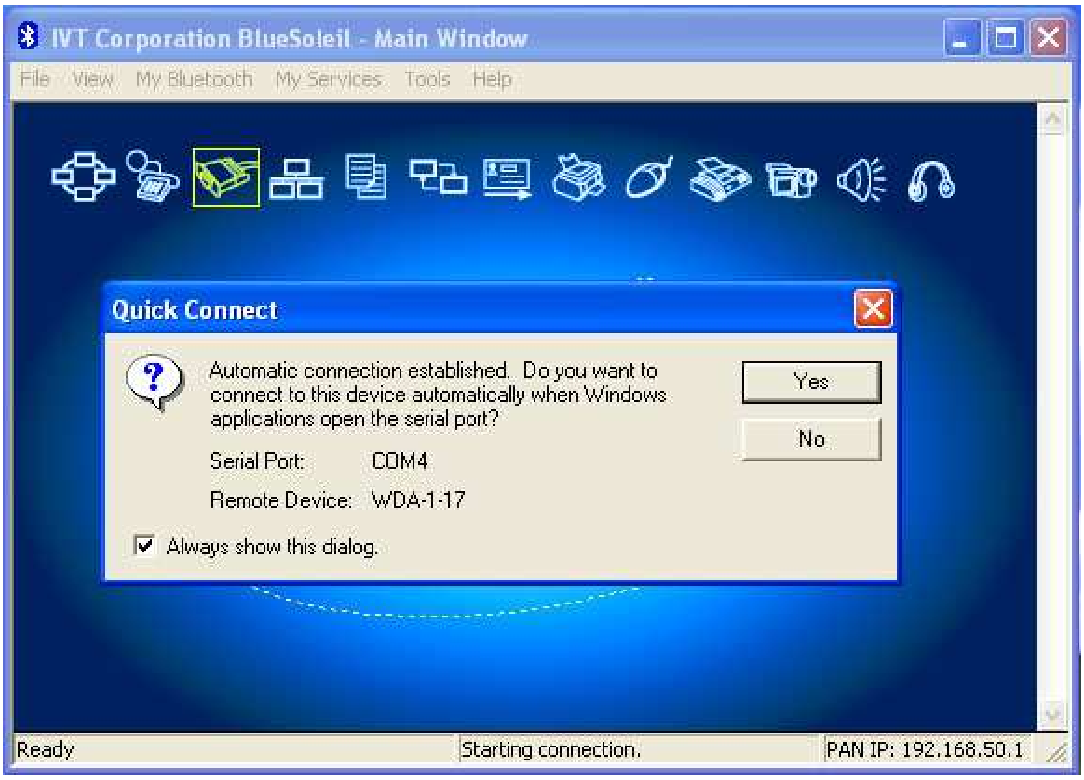
6. If succeeds, this device icon will be marked with a red tick "√".



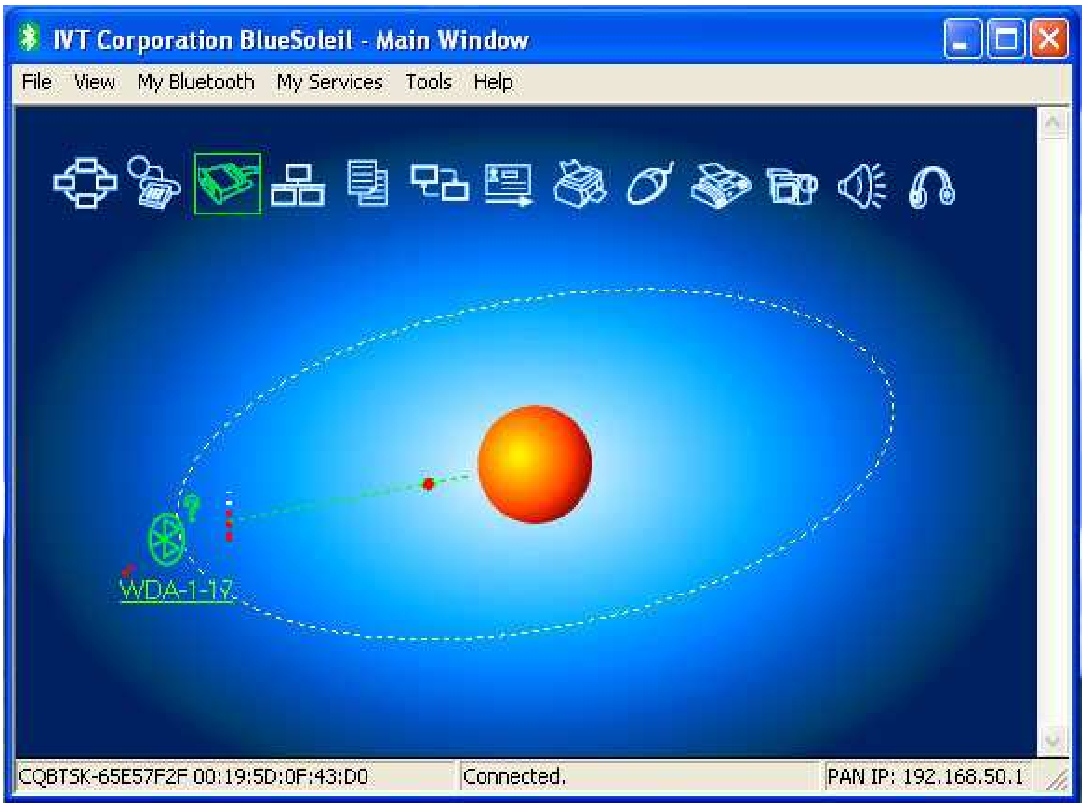
7. Then right click and click "Connect"→"Bluetooth serial port service".



8. After that, system clews successfully building connection between the computer and instrument. Run this program to start sample data.



9. Click "Yes" or "No".



When running this program, choose the corresponding Bluetooth port that is indicated by the system when it clews successfully building connection between the computer and the instrument (that is as displayed in the above figure).

APPENDIX E: USE AND MAINTAINING OF DC-2 SOLID NON-POLARIZED ELECTRODE

1. Features of DC-2 solid non-polarized electrode are: high efficiency and stability, simple use and maintenance.
2. DC-2 solid non-polarized electrodes are prohibited to dip in metal container, or mixed with other chemical materials.
3. DO NOT dip it in light salty solution for long, otherwise the stabilizer inside the solid non-polarized electrode exchanges and thus performance goes down.
4. For transportation and handling, please pack the solid non-polarized electrodes into the original package, plastic bag, special sponge pad and box, to avoid crash.
5. DC-2 solid non-polarized electrode can work directly on humid soil in field, lasting for some time.
6. To measure the potential difference between two DC-2 solid non-polarized electrodes, first get a container filled with 3-5cm high saturated salt solution. Then put the solid non-polarized electrodes into the solution. Measure the potential difference as quickly as possible. After measurement, pack it back into the original package.
7. If the solid non-polarized electrode works in dry field and the surface soil is not humid, every 3~5 days dip the solid non-polarized electrodes into the 3-5cm high salt solution, 3~5 minutes later, pack the electrodes back into the original package.
8. Every time field work finishes, put the solid non-polarized electrode into the plastic bag to keep the water and stabilizer inside the electrode from volatility.
9. If the electrode is not to use for a long time, put the electrode into the original package, and store it in shadowy and cool environment. If it is not to use for about one month, dip it in a container filled with 3-5cm high saturated salt solution, for 5 minutes, and then put it into the original package
10. The solid non-polarized electrode may fail to work because of lead reveal of the electrode which is resulting from long-tern storage or improper use. In that case, those two solid non-polarized electrodes are not allowed to be utilized once again. Please replace them with new ones in time.
11. DO keep it in mind: the pair of DC-2 solid non-polarized electrodes should be abandoned together. Non-polarized electrodes of two different pairs should not work as a new pair.