ERT concepts and state-of-the-art equipment

Gianfranco Morelli – Stefano Del Ghianda

Geostudi Astier srl

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Italiadomani

Training course about

Syscal TERRA

VES and ERT (Switch version)

Gianfranco Morelli – Stefano Del Ghianda

Geostudi Astier srl - Livorno

Syscal TERRA Switch

REMINDER

- Principle of the electrical resistivity measurement

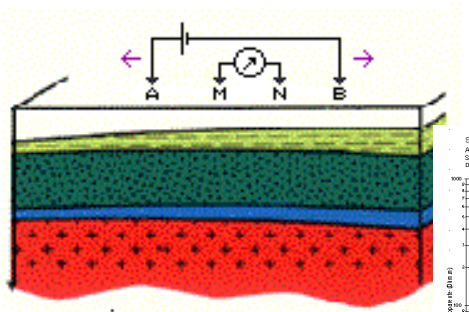
4 electrodes

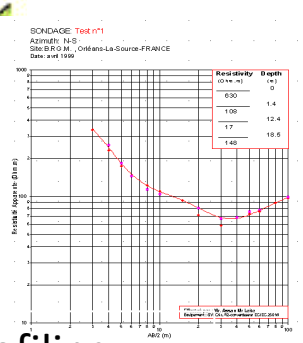
Injection of a current: I_{AB}

Reception of a potential difference: V_{MN}

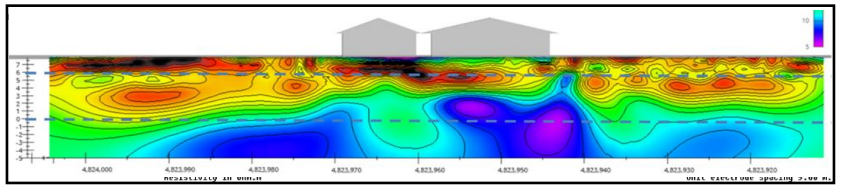
Calculation of the apparent resistivity (Rho) = K * V_{MN} / I_{AB} (K: geometrical factor)

(Ωm) = (m) * (mV) / (mA)

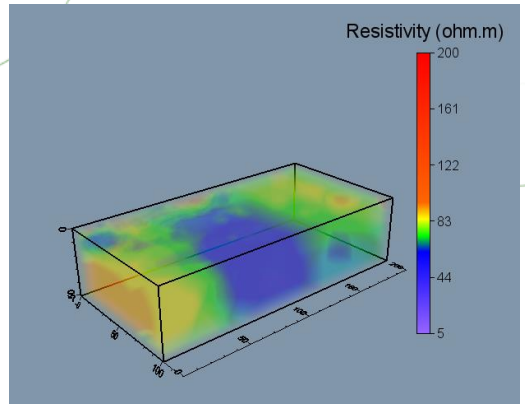




1D Sounding (VES) or profiling



2D Imaging



3D Imaging

Table

1) Presentation of the Syscal TERRA Switch

MAIN CHARACTERISTICS

Compact system in 1 casing: Transmitter / Receiver / Converter / 2 internal Li-Ion 16V batteries / Switching relays boards (for the Switch version)

Possibility to connect any external standard 12V batteries (for Rx and Tx)

Max. output characteristics:

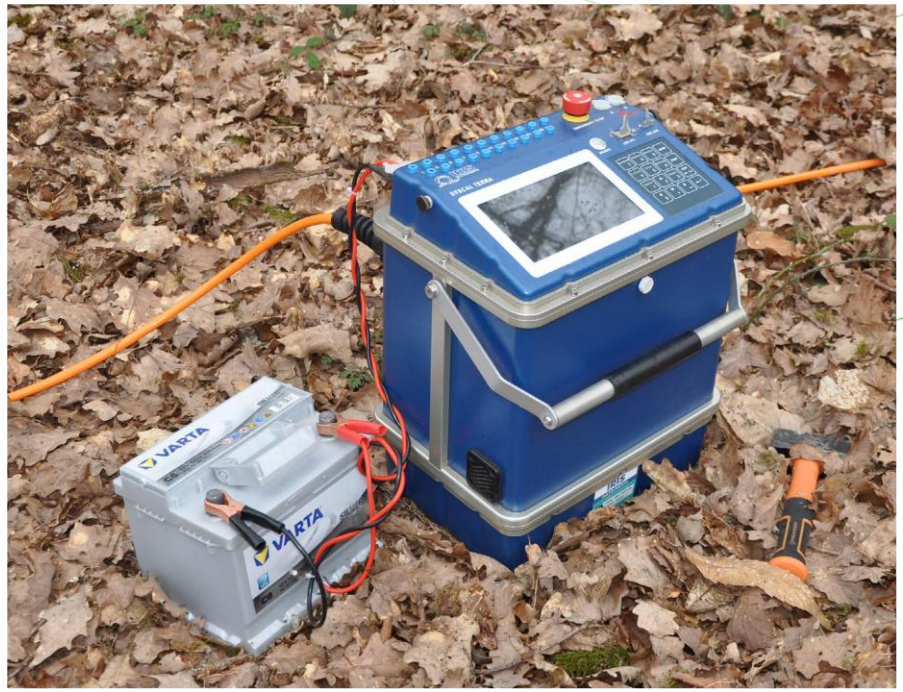
Power: 250 W (1200W external converter with MG)

Voltage: 800 V (1000 V in standard mode)

Current: 2.5 A

20 reception channels

100% (ON+ ON-) or 50% Duty cycle (ON+ OFF ON- OFF)



For the Switch version:

Nb of electrodes with internal switch boards: 24-48-72-96-120

Possibility to extend the Nb of electrodes using external

Switch TERRA units

1) Presentation of the Syscal TERRA unit

MAIN CHARACTERISTICS

- Internal memory: 2 Gbytes + USB dongle
- Internal Garmin GPS
- Internal WIFI
- 16 keys keypad, large graphic color touch screen
- 2 sockets for the chargers (Rx and Tx)
- 1 general push ON/OFF button
- Possibility to measure Sounding / Profiling and 2D-3D imaging (ERT)
- Monitoring function
- Fullwave acquisition (10 ms sampling)
- « Receiver mode only » (in case of using an external powerful transmitter (TIP range))
- Master / Slave function (synchronization of several Syscal TERRA units)
- Dynamic acquisition (Marine or Land)
- Measurement of the resistivity, chargeability (rising and decay) and spontaneous polarization
- Display and storage of the whole parameters V_{MN}(mV), I_{AB}(mA), V_{AB}(V), Rho(Ohm.m), Sp(mV) Q(%), M(mV/V)
- Emergency stop button (security)
- Atmospheric pressure regulation (security)

1) Presentation of the Syscal TERRA Switch

MAIN CHARACTERISTICS

- Simultaneous reception channels (ADC converters 24 bits) :
  - **20 channels**
  - 1 injection channel
- Selection of:

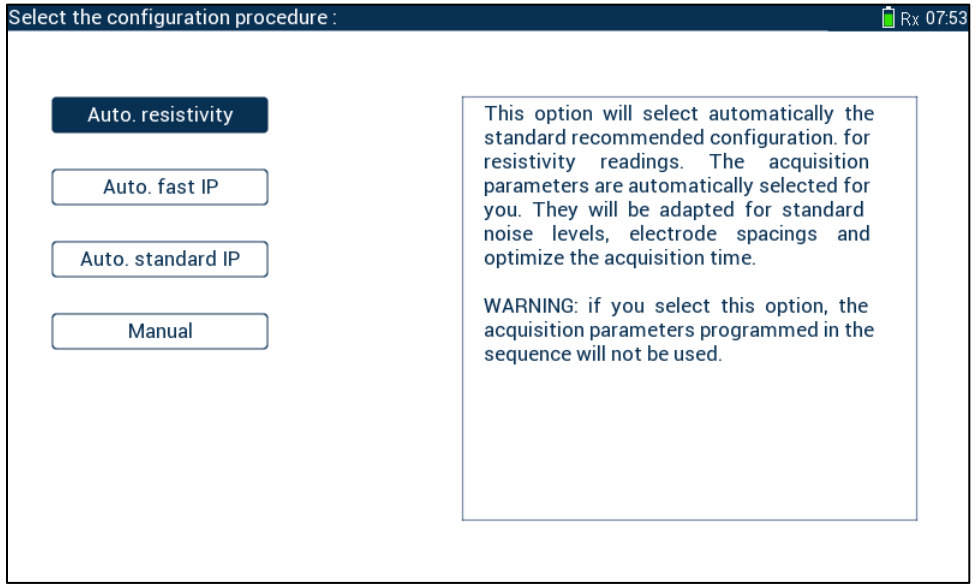
- fixed V_{AB} value
- fixed I_{AB} value
- **V_{AB} regulated value (based on V_{MN} reception signal)**
- **I_{AB} regulated value (based on V_{MN} reception signal)**

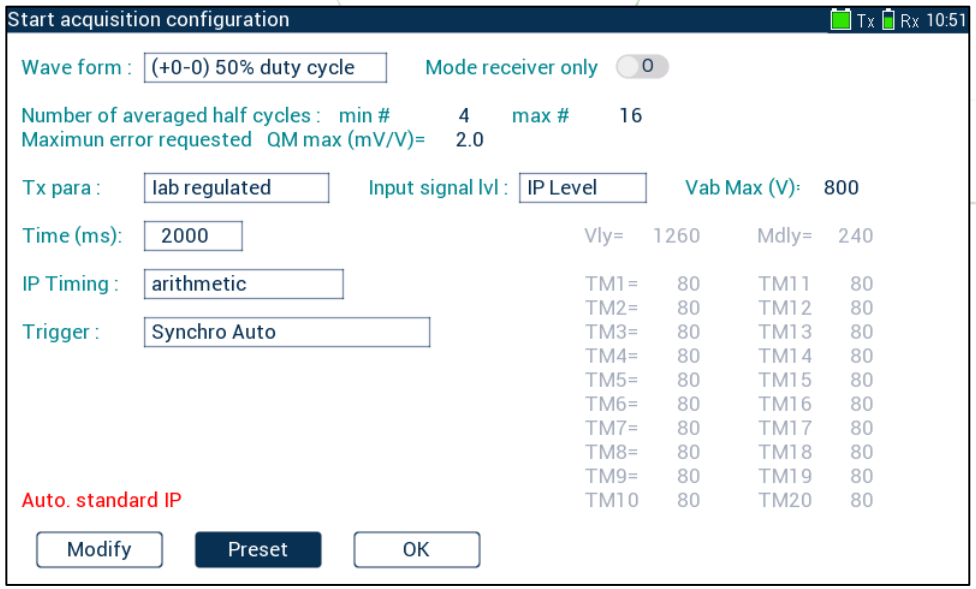
- Sequences generated internally (with some limitations) or uploaded externally (ELECTRE Pro)
- Resistivity / Chargeability measurement
- For the chargeability parameter: 20 partial chargeability windows (pre-defined or programmable)
- Numeric and graphic display
- Preset (Auto Rho / Auto Std IP / Auto fast IP) or Manually defined acquisition parameters

- PRESET parameters (based on a min. reception voltage value):

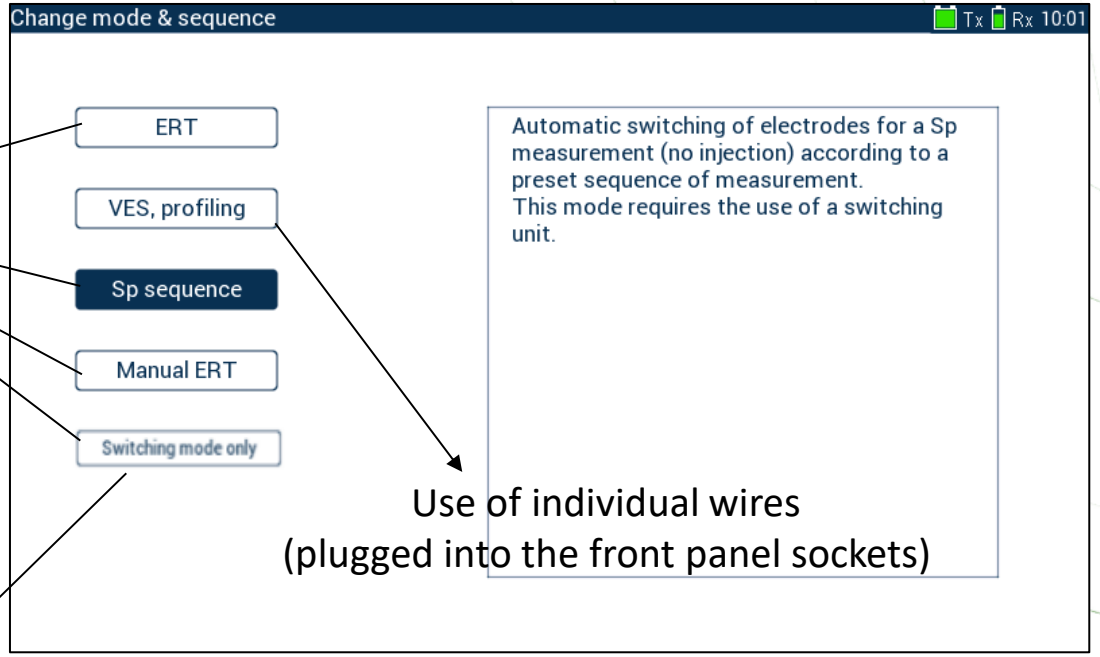
  - Auto Resistivity (100 % Duty Cycle and Vab regulated)
  - Auto fast IP (rising IP) (100 % Duty Cycle and Iab regulated)
  - Auto standard IP (decay IP) (50 % Duty Cycle and Vab regulated)

- Parameters manually defined:





Use of Multicore cables
(plugged into the rear side sockets)



Use of individual wires
(plugged into the front panel sockets)

Only for Master-Slave configuration
(Syscal Terra Switch units synchronized)

2) Operating modes of the Syscal TERRA Switch

SOUNDING / PROFILE

Use of independant wires (plugged into the blue sockets of the front panel): "VES, Profiling" mode:

- Plug the A B M N wires, install stakes, cords, respect alignment and distances
- It's recommended to connect an external battery 12V (60 Ah min) for the Tx: control the batteries: 

- Choose the electrode array and positions: 

- Define the parameters (stack/time/injection type/waveform..) manually or preset: 

- Start the acquisition: 

A control of the RsCheck (grounding resistance measurement) is done just before running the injection process

- Storage offered after measurement (« rpp » file) ; if not, select after: "Store|Measure"
- Visualization of the latest data point: 

2) Operating modes of the Syscal TERRA Switch

TOMOGRAPHY (INJECTION AND RECEPTION DIPOLES HANDLED AUTOMATICALLY)

Use of multicore cables: Multi-electrode acquisition - "ERT" mode:

- Put the Syscal TERRA Switch at the center of the profile
- Install the electrodes and cables (electrodes numbered in relation with the cables) then link each cable takeout to an electrode
- Connect the multicore cables to the rear ride sockets of the Syscal TERRA unit
- Connect an external battery 12V (60 Ah min) for the Tx: (for the Rx part an external 12V battery can also be plugged):
  Control the batteries: 

- Choose the sequence previously uploaded by ELECTRE Pro or created internally ("Sequence | Create sequence"):

Select CONFIG/Change mode & sequence/ERT/Internal+Switch Terra menu

Then, select the sequence in the list

- Run the sequence: 

(RS Check realized first automatically) - Introduce a filename (« rpp ») to be read by Prosys III
- Visualization of the data by pseudo-section: 

- Possibility to use an external transmitter (in case of the AB injection electrodes stay at the same position during the sequence (Gradiant array))

2) Operating modes of the Syscal TERRA Switch

TOMOGRAPHY WITH AN EXTERNAL TRANSMITTER (with different AB positions)

Use of multicore cables: Multi-electrode acquisition - "Manual ERT" mode:

- Put the Syscal TERRA Switch at the center of the profile
- Install the electrodes and cables (electrodes numbered in relation with the cables) then link each cable takeout to an electrode
- Connect the multicore cables to the rear ride sockets of the Syscal TERRA Switch unit
- Control the internal Rx battery: Battery 8 (connect an external 12V / 60 Ah min battery if needed)
- Choose the sequence previously uploaded by ELECTRE Pro (created first manually by *Excel*)

Select CONFIG/Change mode & sequence/Manual ERT/Internal+Switch Terra menu

Then, select the sequence in the list

- By the Param. 4 key, select the "Mode receiver only"
- Run the sequence: START (RS Check realized first automatically) - Introduce a filename (« rpp ») to be read by Prosys III
- Run the transmitter, wait for stability, and introduce into the unit the current value generated (the value will be requested each time AB changes in the sequence)
- Visualization of the data by pseudo-section: Section 3

2) Operating modes of the Syscal TERRA Switch

SP SEQUENCE MODE (NO INJECTION)

Use of multicore cables: Multi-electrode acquisition - "Sp Sequence" mode:

- Put the Syscal TERRA Switch at the center of the profile
- Install the electrodes and cables (electrodes numbered in relation with the cables) then link each cable takeout to an electrode
- Connect the multicore cables to the rear ride sockets of the Syscal TERRA unit
- Control the internal Rx battery: 

(connect an external 12V / 60 Ah min battery if needed)
- Choose the sequence previously uploaded by ELECTRE Pro (created first manually by *Excel*)

Select CONFIG/Change mode & sequence/SP Sequence/Internal+Switch Terra menu

Then, select the sequence in the list

- Run the sequence: 

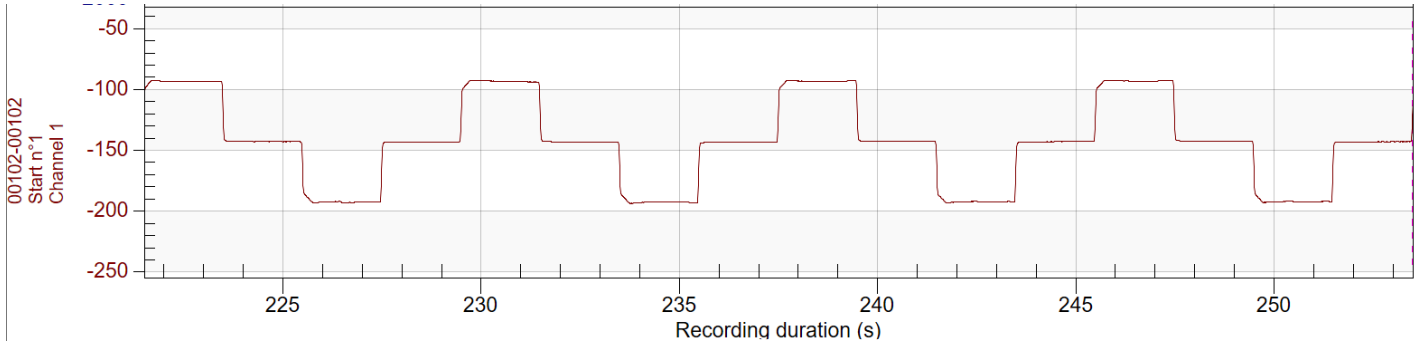
(RS Check realized first automatically) - Introduce a filename (« rpp » extension file) to be read by Prosys III

2) Operating modes of the Syscal TERRA Switch

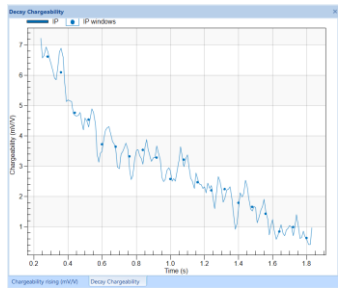
FULLWAVE

Whatever the mode used, fullwave data can be recorded:

- 10 ms sampling
- Current samples can be also recorded
- GPS PPS information supplied by the internal Garmin GPS
- "hrw" file created with the "rpp" file ("hrw" file to be read by FullWave Viewer II)
- Post processing with V and I samples synchronization and recomputation of the Resistivity and chargeability parameters by FullWave Viewer II software



FullWaveViewer II

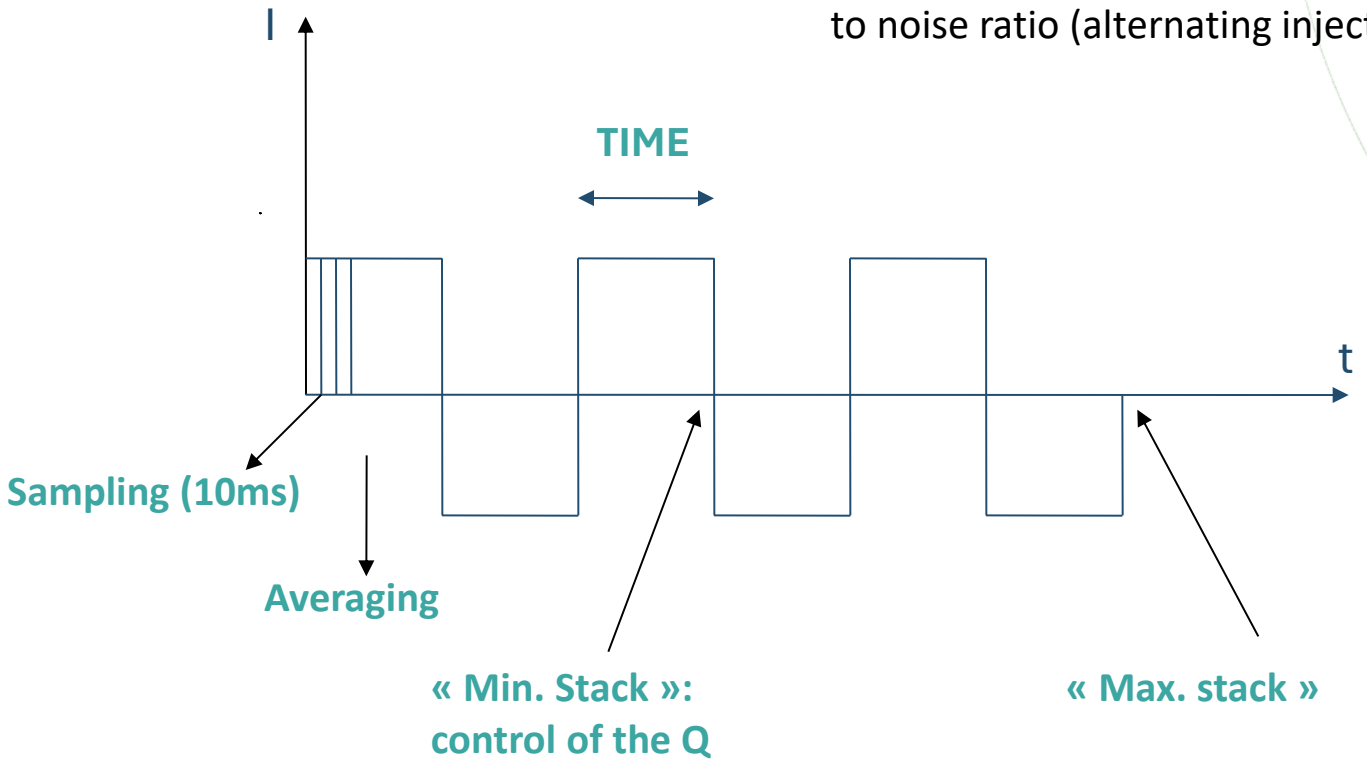


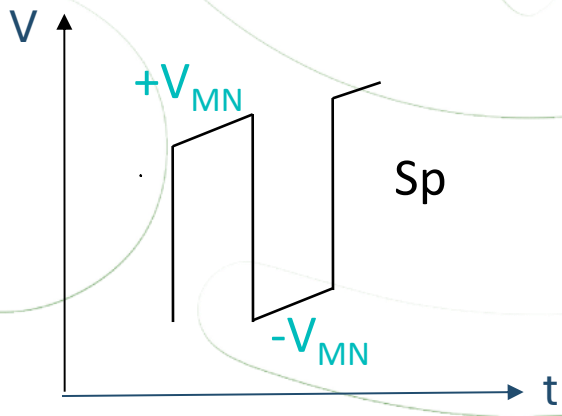
Vmn samples recorded

Chargeability curve

3) Operating of the Syscal TERRA unit

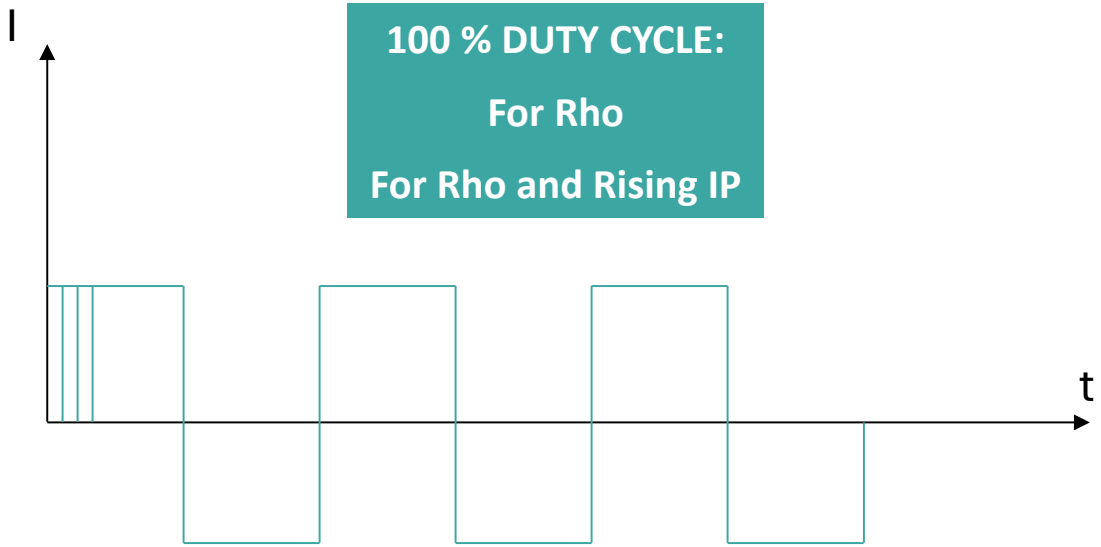
Stacking process for an averaging and an improvement of the signal to noise ratio (alternating injection signal +/- for Sp measurement)





The number of stacks realized during a measurement depends on the Q factor (standard deviation of the V_{MN}/I_{AB} ratio measured during the stacking process)

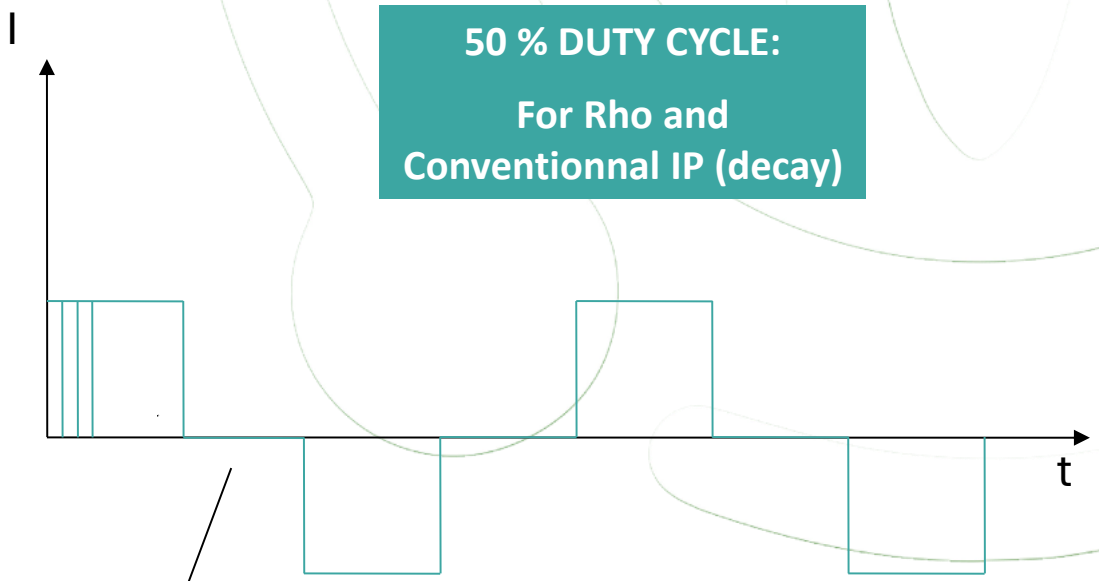
3) Operating of the Syscal TERRA unit



100 % DUTY CYCLE:

For Rho

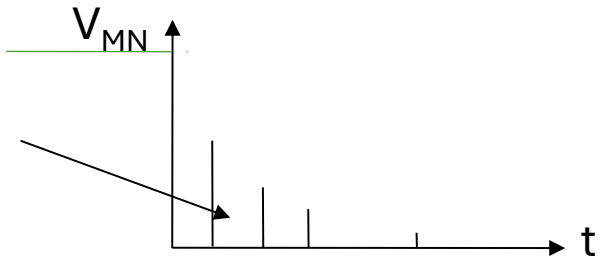
For Rho and Rising IP



50 % DUTY CYCLE:

For Rho and Conventionnal IP (decay)

Up to 20 partial chargeability windows



Analysis of the V_{MN} discharge curve (for the chargeability measurement of the ground by the Induced polarization method (IP))

3) Operating of the Syscal TERRA unit

RISING IP

Conventionnal IP: measurement during OFF time (while the ground discharging)

Rising IP: measurement during the early part of the ON time (while the ground charging)

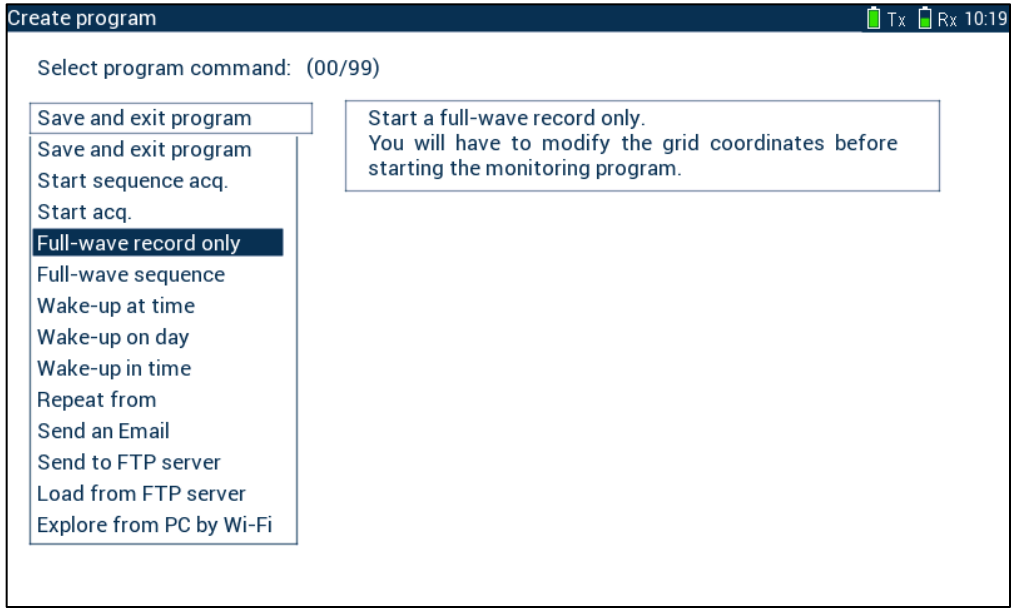
Alternating pulses: + / - :
IP measured twice as fast (no Off time) for a same injection timing
Signal to noise ration increased by a ratio of 2: Ground is charged and discharged in the same time: sum up of the 2 effects

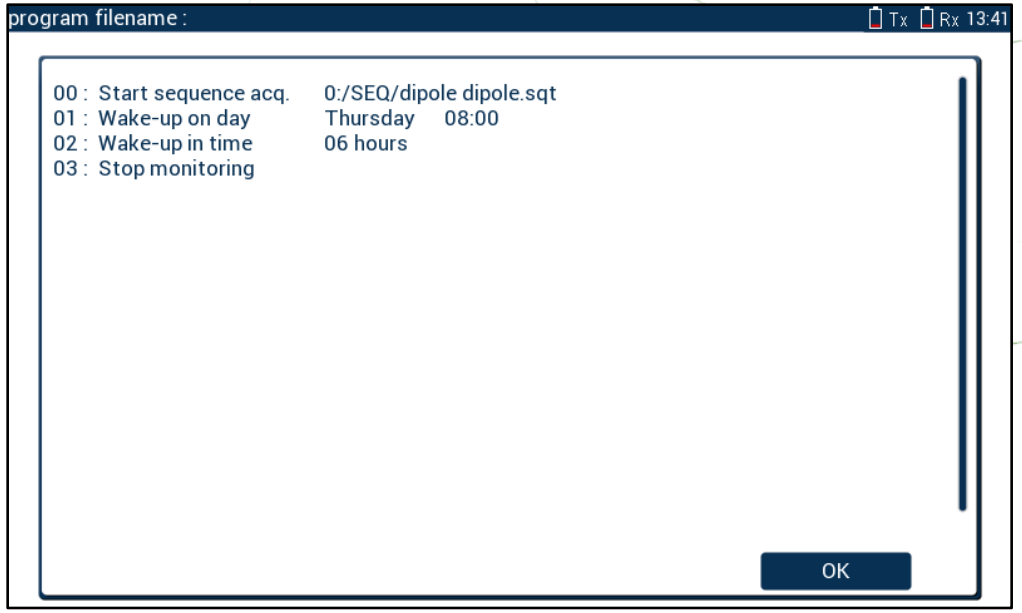
Requires a current injection regulated signal (to ensure a perfect stability of the current signal for data quality): Iab regulated function of the Syscal TERRA or the TIP 6/TIP 12 units in case of using an external transmitter (Rx only mode of the Syscal TERRA)

3) Operating of the Syscal TERRA unit

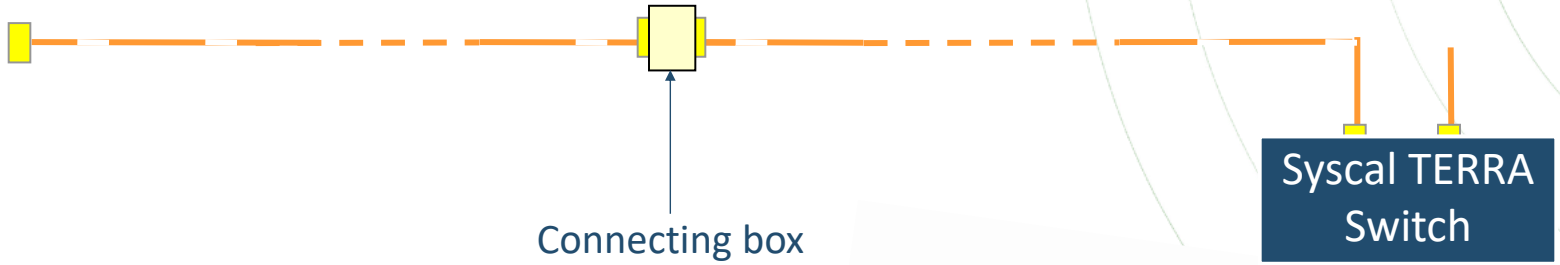
OTHER FUNCTIONS

MONITORING: Creation of a script for some reccuring measurements





4) Multicore cables



X cable segments (depending on the physical spacing between takeout and the total number of electrodes)

- Reverse cables (same connector at each cable end)
- Identical connecting boxes between multicore cables

⇒ Cables and connecting boxes exchangeable

Connection of the cables at the rear side of the SYSCAL TERRA Switch (72) :

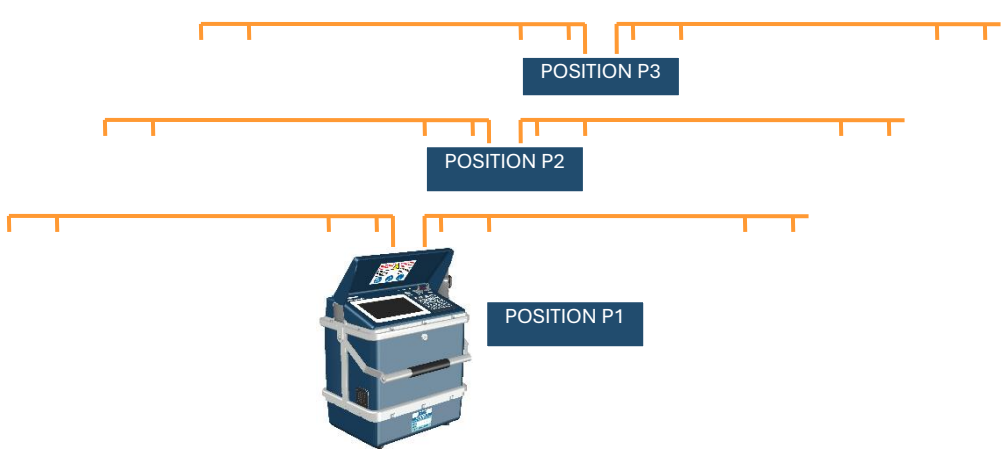
Plug "1-36" for electrodes 1 à 36

Plug "37-72" for electrodes 37 à 72

4) Multicore cables

3D acquisition → 2 solutions for sequence creation

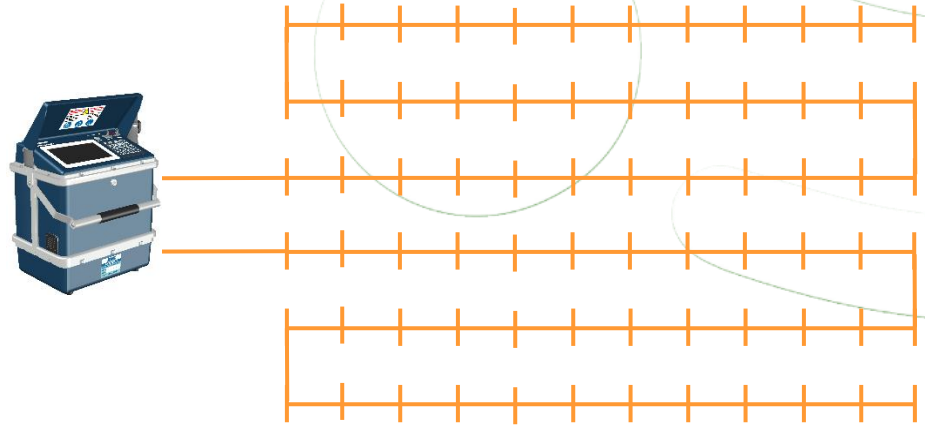
PSEUDO 3D CONFIGURATION MADE OF PARALLEL LINES



X parallel lines measured with the same sequence

Then "File | Add" (after acquisition) in PROSYS III ⇒ Export to 3D inversion software

REAL 3D CONFIGURATION MADE OF X LINES OF Y ELECTRODES

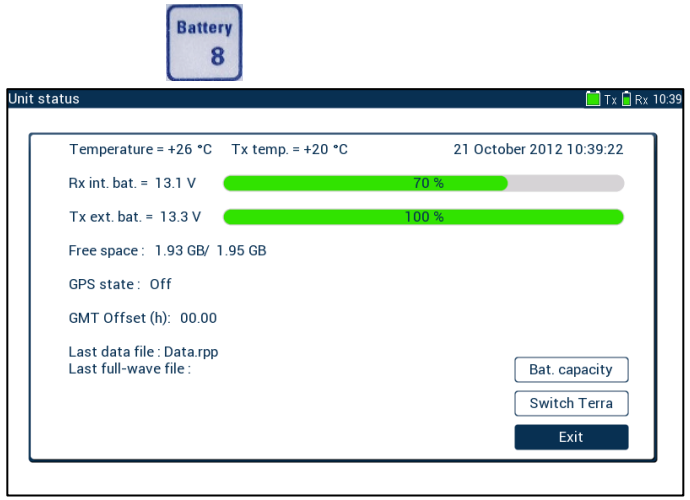


Installation of the electrodes along a snake shape

Acquisition then Export to 3D inversion software

5) Diagnostic

A set of test to control the good operating of the unit:



Display of:

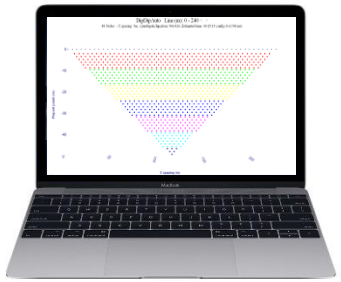
- Internal or external battery voltage level
- Free memory space
- Capacity of the external Tx battery
- Switch Terra information

6) Software Suite (ERT)

1. CREATION OF SEQUENCES
   ELECTRE PRO AND ERTLab Studio

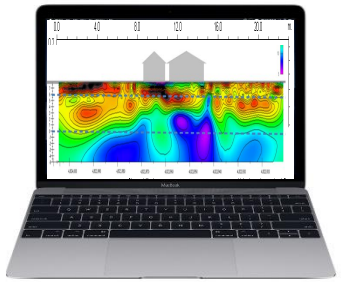
2. DATA TRANSFER / PROCESSING / EXPORT
   PROSYS III

3. DATA INVERSION (1D-2D-3D)
   Tomolab – ERTLab Studio



sequence

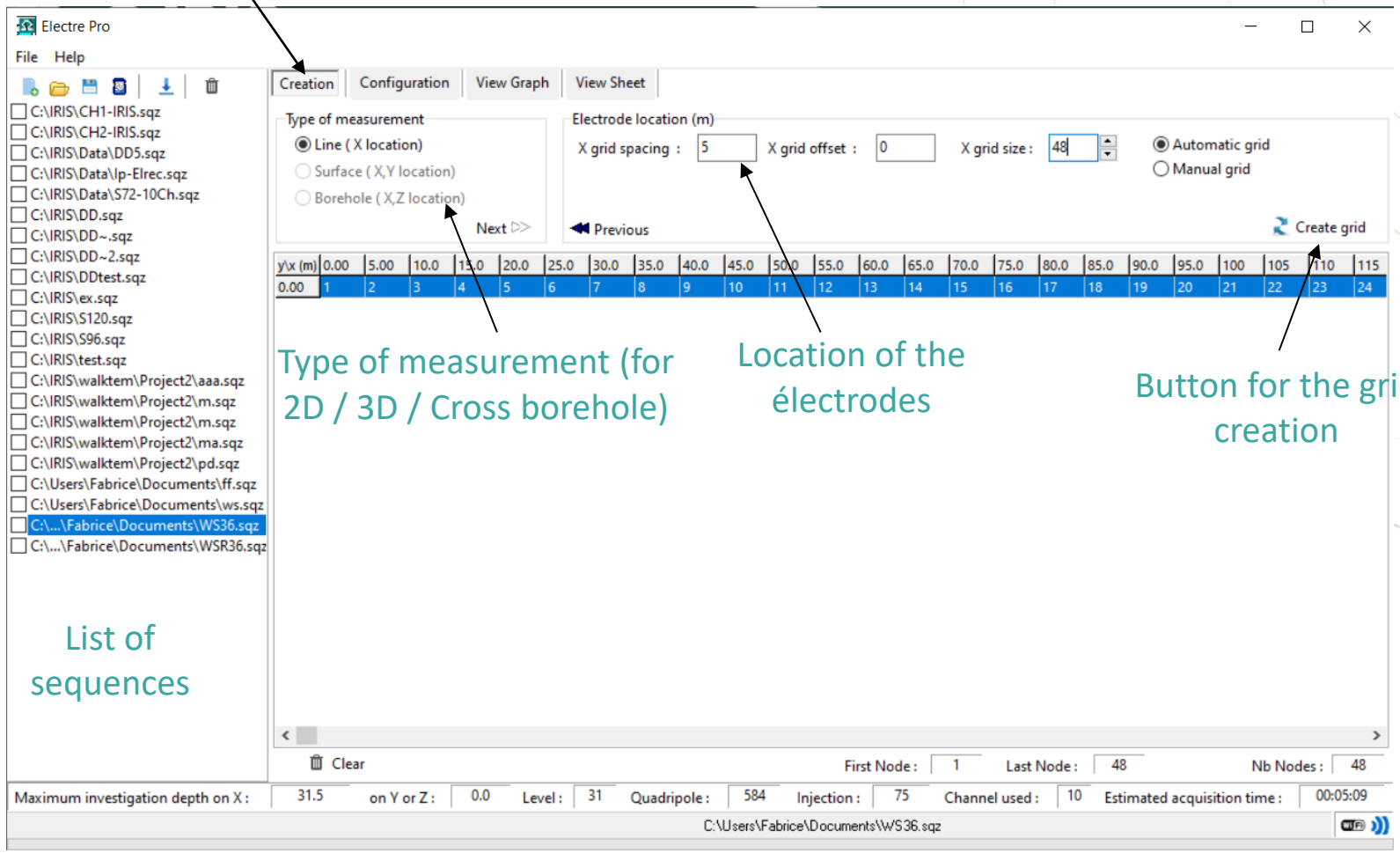
data



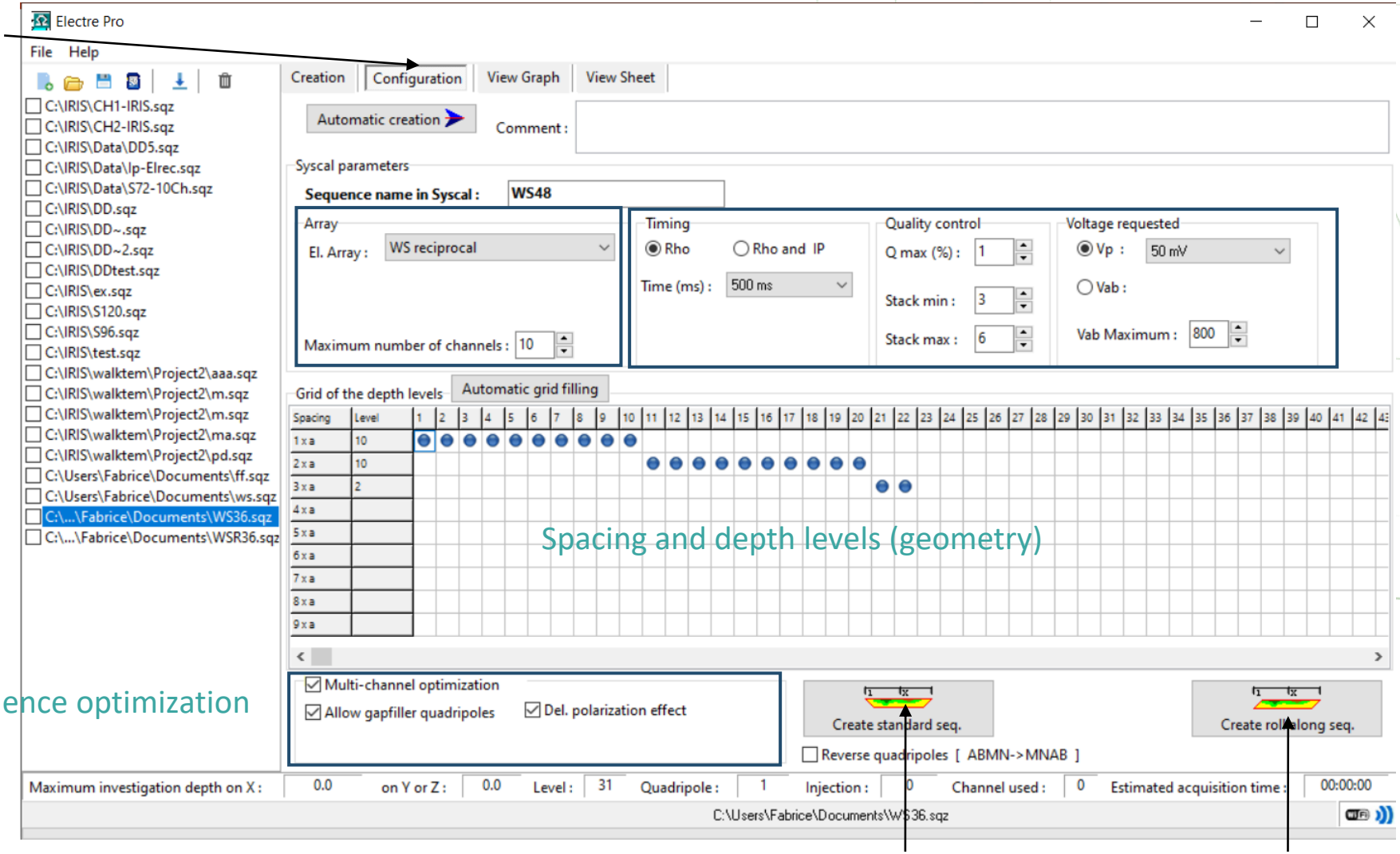
Interpretated Rho

In-the-field data

ERT concepts and state-of-the-art equipment



CONFIGURATION tab



Sequence optimization

Regular sequence creation

Roll Along sequence creation

6) Software Suite (ERT): ELECTRE PRO

Electrode arrays – Investigation depth

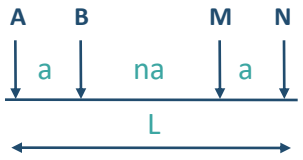
Order (1: best)	Penetration depth (in % of the line length)	Lateral resolution	Signal amplitude (Vmn reception)	Installation (# remote electrodes)
1	Pole-Pole (90%)	Dipole-Dipole	Pole-Pole	Schlumberger réciproque (0)
2	Pole-Dipole (35%)	Pole-Dipole	Schlumberger réciprocal	Dipôle-Dipôle (0)
3	Schlumberger réciprocal (20%)	Schlumberger réciprocal	Pole-Dipole	Pole-Dipole (1)
4	Dipole-Dipole (20%)	Pole-Pole	Dipole-Dipole	Pole-Pole (2)

The remote electrodes must be located at a distance of about 5 to 10 times the max length of the line (L)

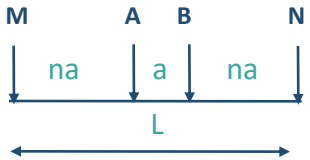
For optimized Pole-Pole array:

The remote is plugged into P2

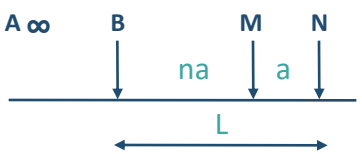
P2-P5-P8-P11… are strapped on the front panel



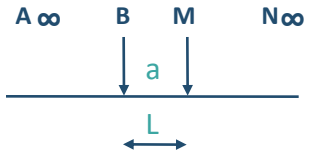
Depth: about 0.2 * L



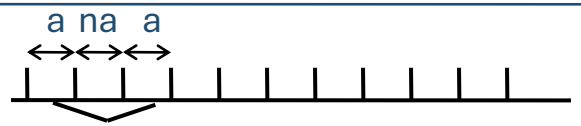
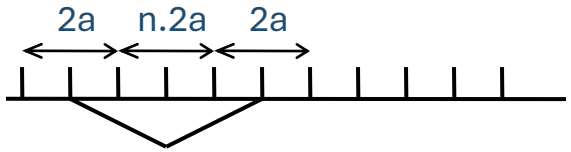
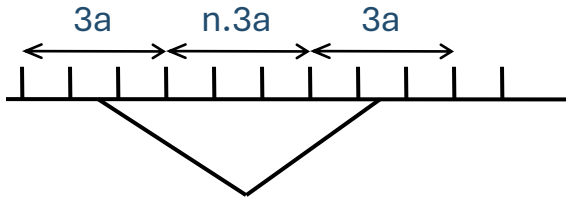
Depth: about 0.2 * L



Depth: about 0.35 * L



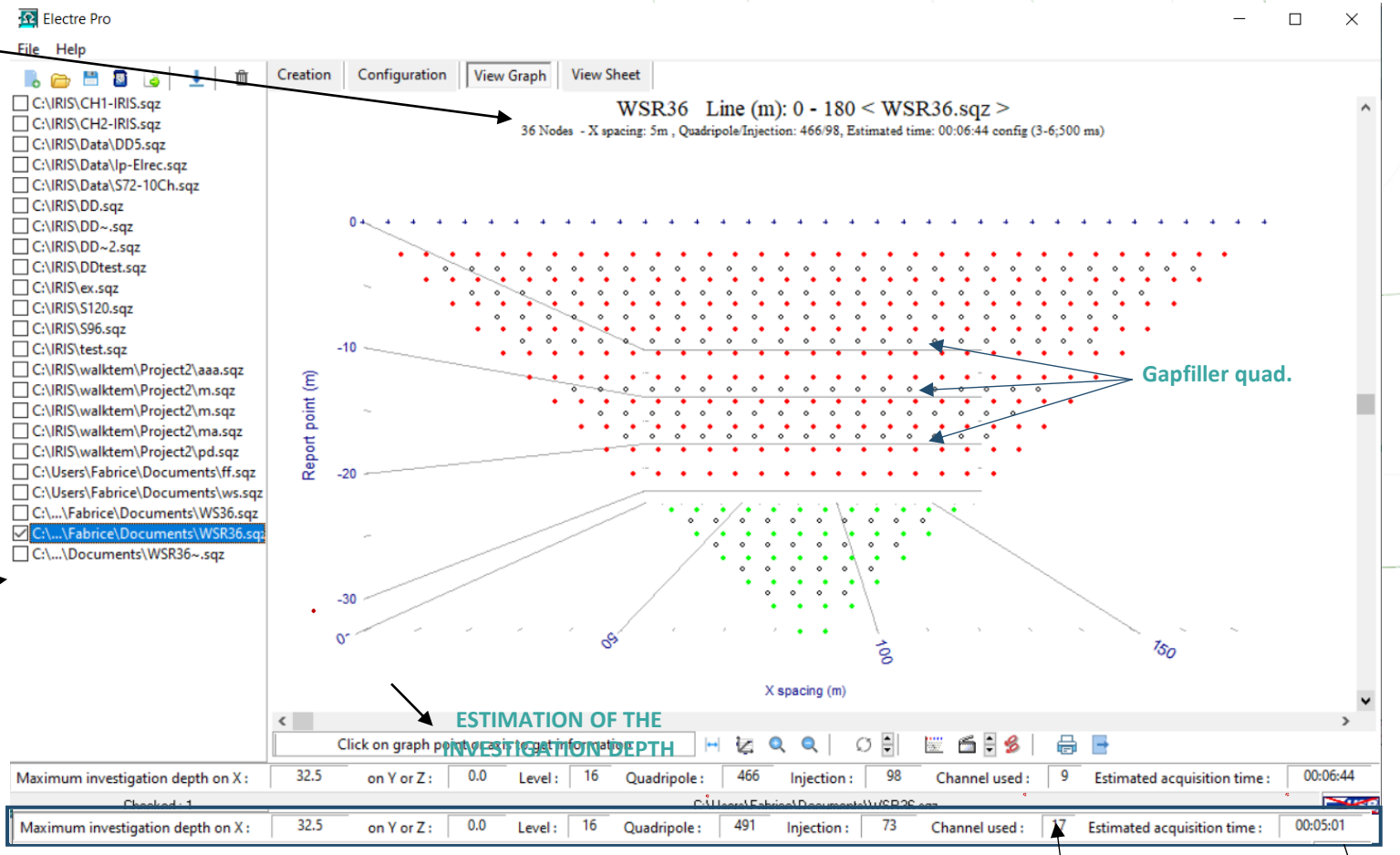
Depth: about 0.9 * L

Multi-spacing sequence	Electrodes combination	Depth levels
Spacing "a"		n = 1, 2, 3, 4, 5…
Spacing "2a"		n = 5/2, 3, 7/2…
Spacing "3a"		n = 7/3, 8/3, 3…

6) Software Suite (ERT): ELECTRE PRO

VIEW GRAPH tab

Possibility to visualize several sequences graphically (standard and roll-along)



VALIDATION OF THE SEQUENCE

ESTIMATION OF THE INVESTIGATION DEPTH

STATUS BAR

Nb of measurements

If optimization

Acq. time

6) Software Suite (ERT): ELECTRE PRO

VIEW SHEET Tab

ELECTRODES COORDINATES

Creation | Configuration | View Graph | View Sheet

# Node	X (m)	Y (m)	Z (m)
1	0.00	0.00	0.00
2	5.00	0.00	0.00
3	10.00	0.00	0.00
4	15.00	0.00	0.00
5	20.00	0.00	0.00
6	25.00	0.00	0.00
7	30.00	0.00	0.00
8	35.00	0.00	0.00
9	40.00	0.00	0.00
10	45.00	0.00	0.00
11	50.00	0.00	0.00
12	55.00	0.00	0.00
13	60.00	0.00	0.00
14	65.00	0.00	0.00
15	70.00	0.00	0.00
16	75.00	0.00	0.00
17	80.00	0.00	0.00
18	85.00	0.00	0.00
19	90.00	0.00	0.00
20	95.00	0.00	0.00
21	100.00	0.00	0.00
22	105.00	0.00	0.00
23	110.00	0.00	0.00

# Quad.	Ca	Cb	Pm	Pn	Spac. Coef	Level	Depth	K factor
1	2	3	1	4	1	1	2.62	31.42
2	3	4	1	6	1	2	4.60	94.25
3	3	4	2	5	1	1	2.62	31.42
4	4	5	1	8	1	3	6.56	188.50
5	4	5	3	6	1	1	2.62	31.42
6	4	5	6	2	0	-1	3.80	-47.12
7	4	5	2	7	1	2	4.60	94.25
8	5	6	1	10	1	4	8.52	314.16
9	5	6	4	7	1	1	2.62	31.42
10	5	6	7	3	0	-1	3.80	-47.12
11	5	6	3	8	1	2	4.60	94.25
12	5	6	8	2	0	-1	5.70	-125.66
13	5	6	2	9	1	3	6.56	188.50
14	6	7	1	12	1	5	10.46	471.24
15	6	7	5	8	1	1	2.62	31.42
16	6	7	8	4	0	-1	3.80	-47.12
17	6	7	4	9	1	2	4.60	94.25
18	6	7	9	3	0	-1	5.70	-125.66
19	6	7	3	10	1	3	6.56	188.50
20	6	7	10	2	0	-1	7.60	-235.62
21	6	7	2	11	1	4	8.52	314.16
22	7	8	1	14	1	6	12.40	659.73
23	7	8	6	9	1	1	2.62	31.42

The **Multi-Syscal** mode allows using simultaneously one Syscal as transmitter (Tx - injecting on A and B electrodes) and the other(s) as receiver (Rx, measuring voltage between M and N electrodes).
Note that it is not possible to inject or receive with two electrodes located on different Syscal devices.

The idea of the **Multi-Syscal** acquisition is to perform an ERT measurement with one unique Syscal first (the one of the left), then, to perform a second measurement with another unique Syscal (the one of the right) and finally an ERT measurement with the combination of the two Syscal devices (left and right). This “cross measurement” is sensitive to a volume located under the road.
This dataset, inverted conjointly with the two single ERT lines will allow the generation of a complete 3D model of the area.

A second possibility offered by the system to speed up measurement, especially when more than 2 Syscal devices are used, is to perform **Multi-Tx** measurements. In this case, two (or more) Syscal devices can inject at the same time (between A_1 and B_1 for the Syscal n°1 and A_2 and B_2 for the Syscal n°2). Both Syscal can also receive at the same time (between M_1 and N_1 for the Syscal n°1 and M_2 and N_2 for the Syscal n°2). Note that the drawing shows the measurement on 1 channel but that the system can measure on up to 20 channels.

In this case, the Syscal device n°1, will measure on M_1-N_1 a total voltage which is actually the contribution of the injection of the Syscal n°1 on A_1 and B_1 and of the Syscal n°2 on A_2 and B_2. During the exact same time, the Syscal device n°2, will measure on M_2-N_2 a total voltage which is actually the contribution of the injection of the Syscal n°1 on A_1 and B_1 and of the Syscal n°2 on A_2 and B_2.

Therefore, during one injection, the **Multi-Tx** measurement performs the equivalent of 4 measurements. If we now consider the 20 measurement channels on each device, during 1 injection the system performs 40 measurements, that contain the equivalent of 80 measurements (40 in line plus 40 cross measurements).

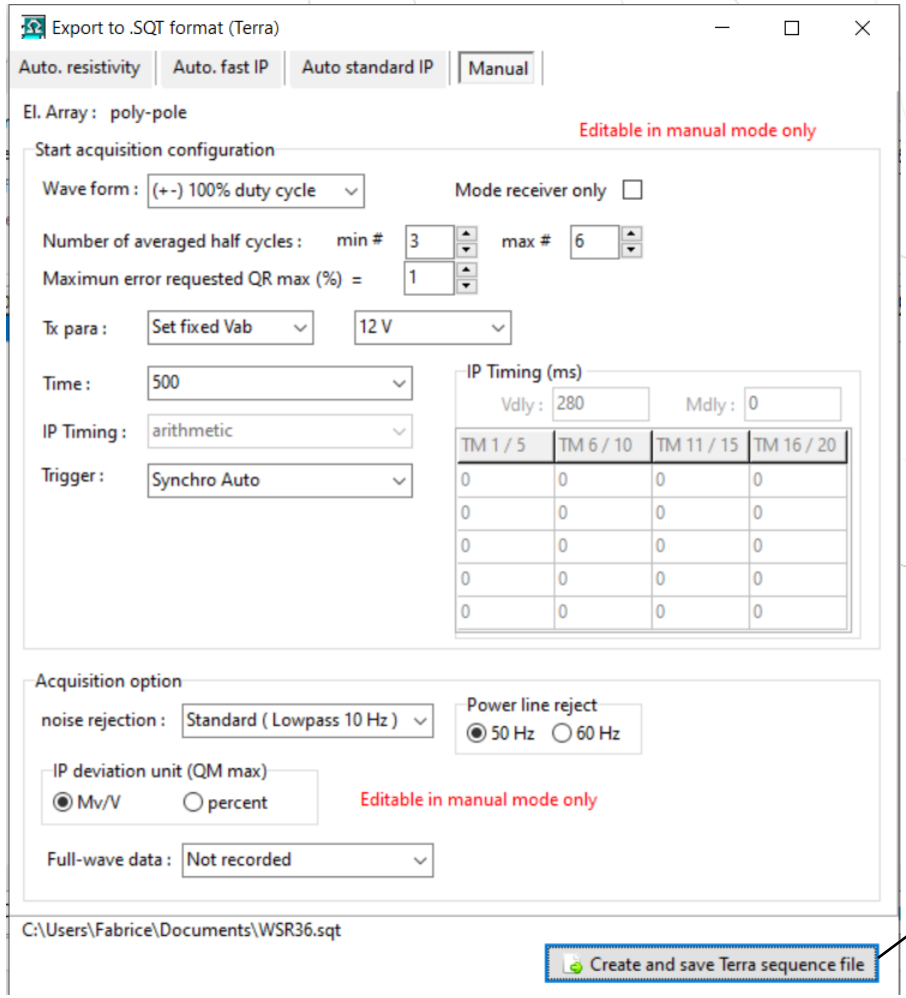
If you consider now 4 Syscal Terra devices, during one injection the system perform 80 measurements, that contain the equivalent of 320 measurements (20 in line plus 60 cross measurements for each system).

This type of dataset cannot be inverted by standard inversion software and must use ERTLab software with the Multi-Tx module.

6) Software Suite (ERT): ELECTRE PRO

Export Sequence into the SYSCAL TERRA Unit

« File | Export to SQT format »



Same parameters than the ones offered directly into the unit:

- PRESET parameters (based on a min. reception voltage value):
  - Auto Resistivity (100 % Duty Cycle and Vab regulated)
  - Auto fast IP (rising IP) (50 % Duty Cycle and Iab regulated)
  - Auto standard IP (decay IP) (50 % Duty Cycle and Vab regulated)

- Parameters manually defined

Load the « Sqt » file into the unit by:

- USB Cable
- USB Dongle
- WIFI

« Sqt » file saved

MAIN RECOMMANDATIONS

- Recharge the internal batteries before each day survey

- Use an external 12V battery in good condition for the Tx part - If the battery is fully discharged, the Syscal will draw the max. possible energy to run the acquisition

  The battery may be dead before the end of the acquisition

- Try to have some low grounding resistance values (digging properly the electrodes / pouring salt water…) for a max. injected current:

  $I_{AB} = V_{AB} / R_{AB}$

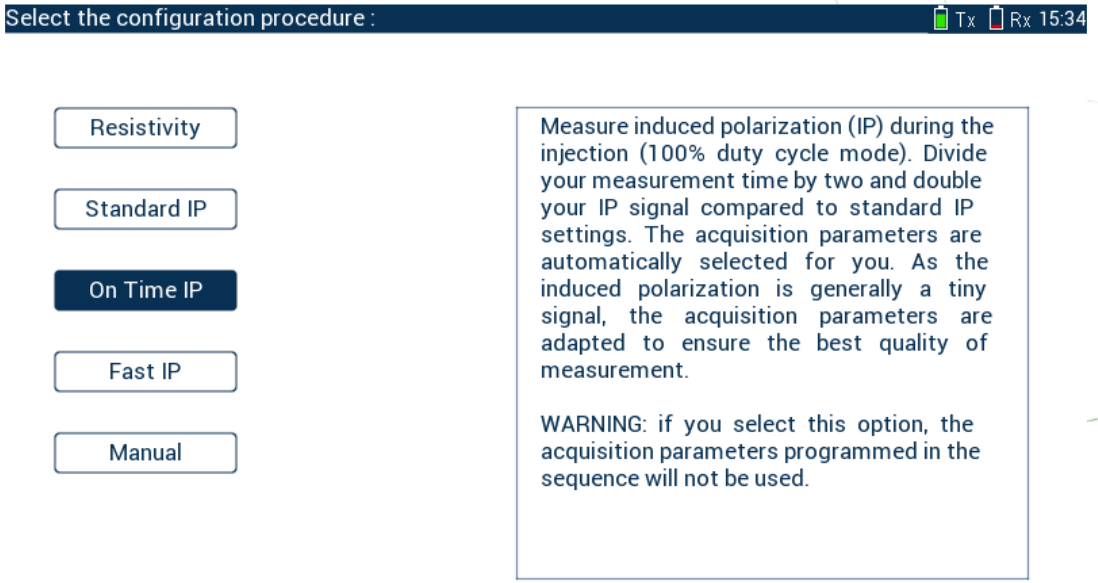
- Reception voltage (V_{MN}) directly in relation with the injected signal (I_{AB}) but also in relation with the type of ground layers (resistivity) and noise (ambient / electronic):

  V_{MN} higher than a few mV (classically) for a good reliability

- Quality factors: the standard deviation of the V_{MN} / I_{AB} ratio and of the M value (chargeability) should be lower than about 5% in standard conditions to get reliable data

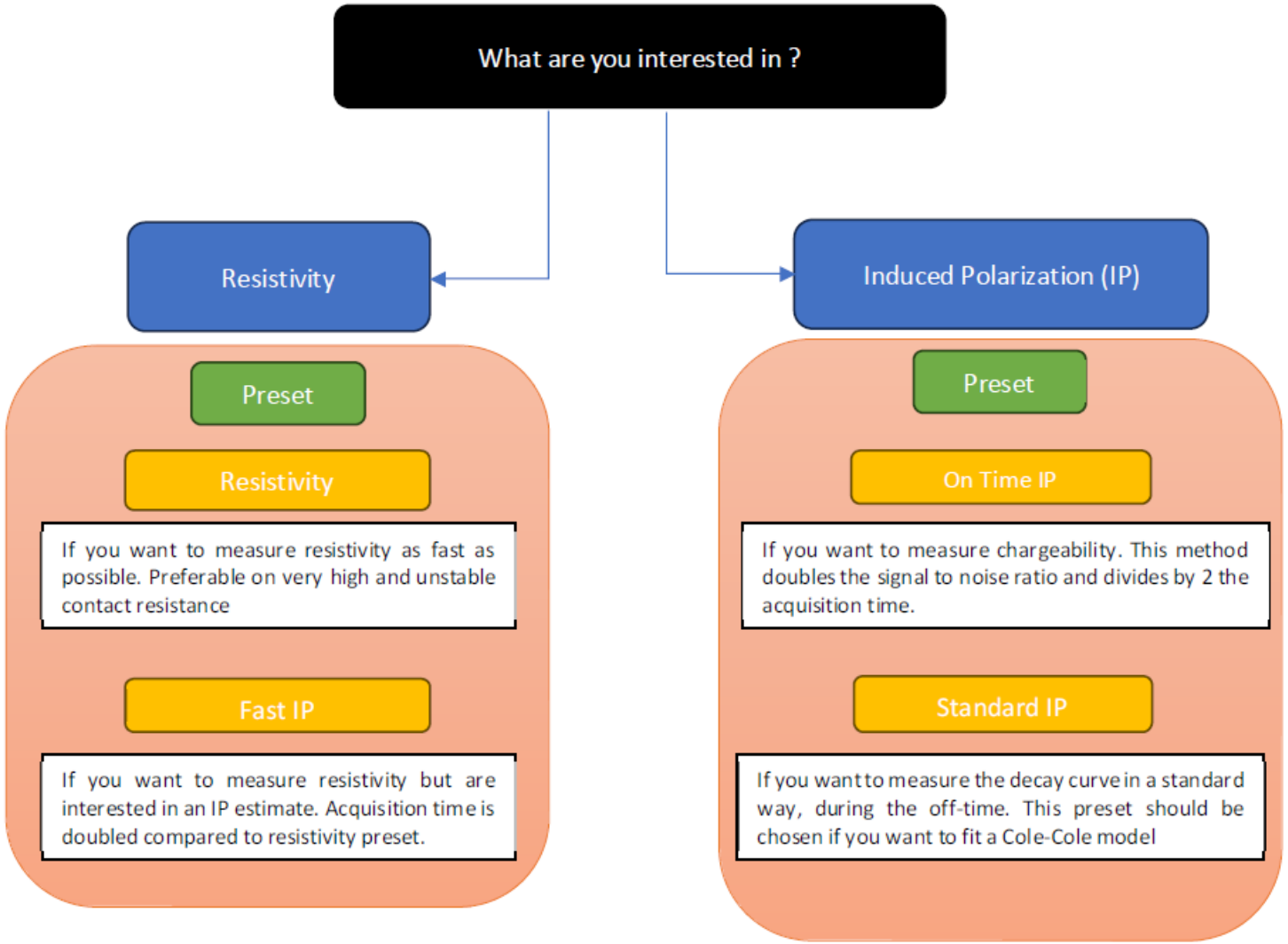
INJECTION PARAMETERS

To simplify the choice of the Tx parameters, IRIS Instruments offers presets named **Resistivity**, **Standard IP**, **On Time IP** and **Fast IP**. If the user knows exactly which parameters to set, he may use the **Manual** button and set the parameters manually.



Hereafter, a decision tree to help you choosing the best preset. Once the preset is selected, feel free to change the number of stacks to adapt the acquisition to your schedule and to the signal/noise level ratio.

ERT concepts and state-of-the-art equipment



Optimal Tx parameters are automatically proposed. The user can decide to change them anyway to adapt to their specific survey (number of stacks for example). After choosing a preset of pressing the **Manual** button, the user will come to this screen:

The Syscal Terra features several modes of injection. Indeed, the system can impose either a fixed current or a fixed voltage between A and B electrodes.
By default, the simplest way is to fix the voltage between A and B. The current injected will be

$$Iab = Vab/Rab$$

Where is varying over time because the contact resistance is changing (heating effect, IP, etc…). Consequently, the current is not stable in this mode. Whatever, it is measured by the Syscal and the ratio / remains correct.
The Syscal can also impose a fixed current. In this mode, the Syscal injects a current taking 15% of margin on the contact resistance (the contact resistance can vary by 15% until the Syscal reaches the maximum power or voltage of the system). Indeed, the Syscal will have to adapt the voltage between A and B to compensate for the resistance variation during the injection.
If the resistance varies for more than 15%, the Syscal will not be able to regulate current anymore and will continue injecting a non-regulated (non-stable) current. The absence of regulation is recorded in the data.

On these two modes the user can decided whether he wants to inject a constant value fixed by himself or if he wants to let the Syscal decide for him. We strongly advise to let the Syscal decide for him as it guarantees a minimum reception voltage on the weakest channel (15 mV for resistivity and 50 mV for IP), avoids overloading the channels and save battery life.

The current regulation is only interesting for on-time IP measurement where the current must be very stable so that the voltage variation measured at the reception is only due to the IP effect. Note that this mode takes 15% of margin so will slightly reduce the current injected compare to Vab regulation and may failed to regulate if the value change for more than 15%. This may happen on difficult context with high and unstable contact resistance. Avoid using current regulation in this context.

For very specific reasons (laboratory measurement), the user may want to inject a fixed voltage (12V to 800V or a specific current 50 to 2500 mA).

To summarize,

To summarize, choose between:

- **Vab regulated**: automatic injection voltage regulation: then select the “Input Signal lvl” and the “Vab Max (V)” value
- **Iab regulated**: automatic injection current regulation: then select the “Input Signal lvl” and the “Vab Max (V)” value

Note about the “Input Signal lvl”:

Rho Level: corresponds to a level of reception voltage of about 15 mV (for the channel receiving the lowest signal)
IP Level: corresponds to a level of reception voltage of about 50 mV (for the channel receiving the lowest signal)

- Advanced:

  - **Set fixed Vab**: constant injection voltage: then select the voltage value
  - **Set fixed Iab**: constant injection current: then enter the current value and define the max. Vab value allowed
  - **External DC**: in case of using an external 1200W converter

THANKS!

IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System
(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-Mission 4 “Education and Research” - Component 2: “From research to business” - Investment 3.1: “Fund for the realisation of an integrated system of research and innovation infrastructures”

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani

ERT concepts and state-of-the-art equipment

Gianfranco Morelli – Stefano Del Ghianda (Geostudi Astier srl)

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Finanziato dall'Unione europea NextGenerationEU
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Italiadomani

Recent Advances in 3D Electrical Resistivity Tomography, from Multi-transmitter Measurements to Improved Data Processing Strategies

ERT Multi-transmitter Measurements

New **MULTI-TRANSMITTER (Tx)** resistivity-meters => Key improvements

- capability of injecting current simultaneously with different dipoles
- reduced logistics required to operate long spreads in rough terrains.
- transmitting and receiving with short isolated wires
- reduced inductive and capacitive coupling in cables and multiplexers.
- modular systems based on stand-alone units with radio or GPS syncronization
- all the above infer **HIGHER DATA QUALITY** and **NEW APPLICATIONS OF 3d ERT**

Multi-TX resistivity measurements : recent history

2012 : *Application of the Multisource Approach to Deep Resistivity Surveys* -D. LaBrecque, MPT – Nevada - **PATENT**

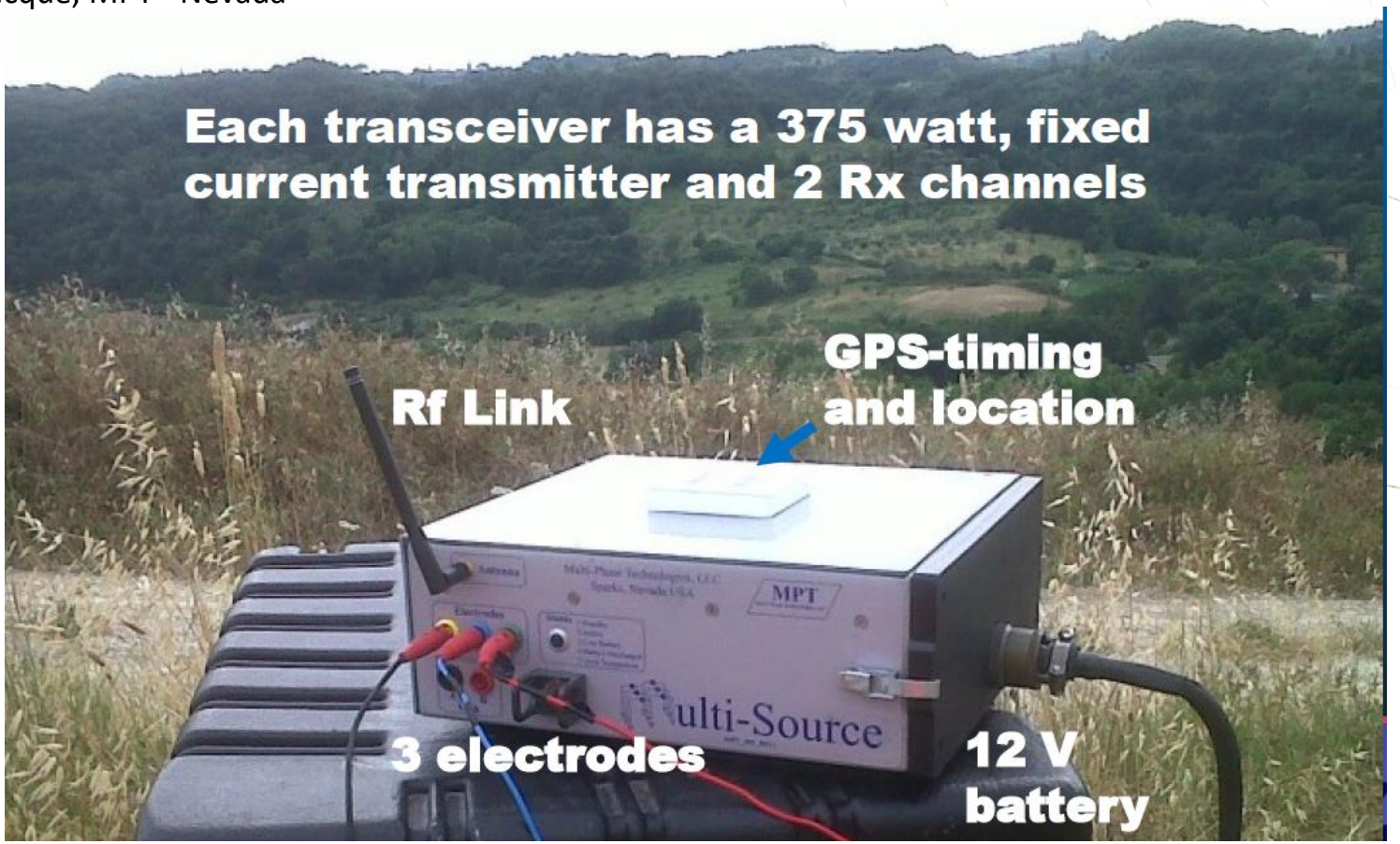
2018 : *Using the Multi-Source Induced Polarization System for Gold Exploration in Azerbaijan* – Morelli, Jalilov, LaBrecque

2021 : *The impact of multiple transmitters on signal strength in Deep Electrical Resistivity Tomography data: an experiment in the Vajont valley (north-eastern Italy)* - Bocchia et al., University of Parma

2023-> present : development of the new SYSCAL TERRA by IRIS INSTRUMENTS => MULTI-TX

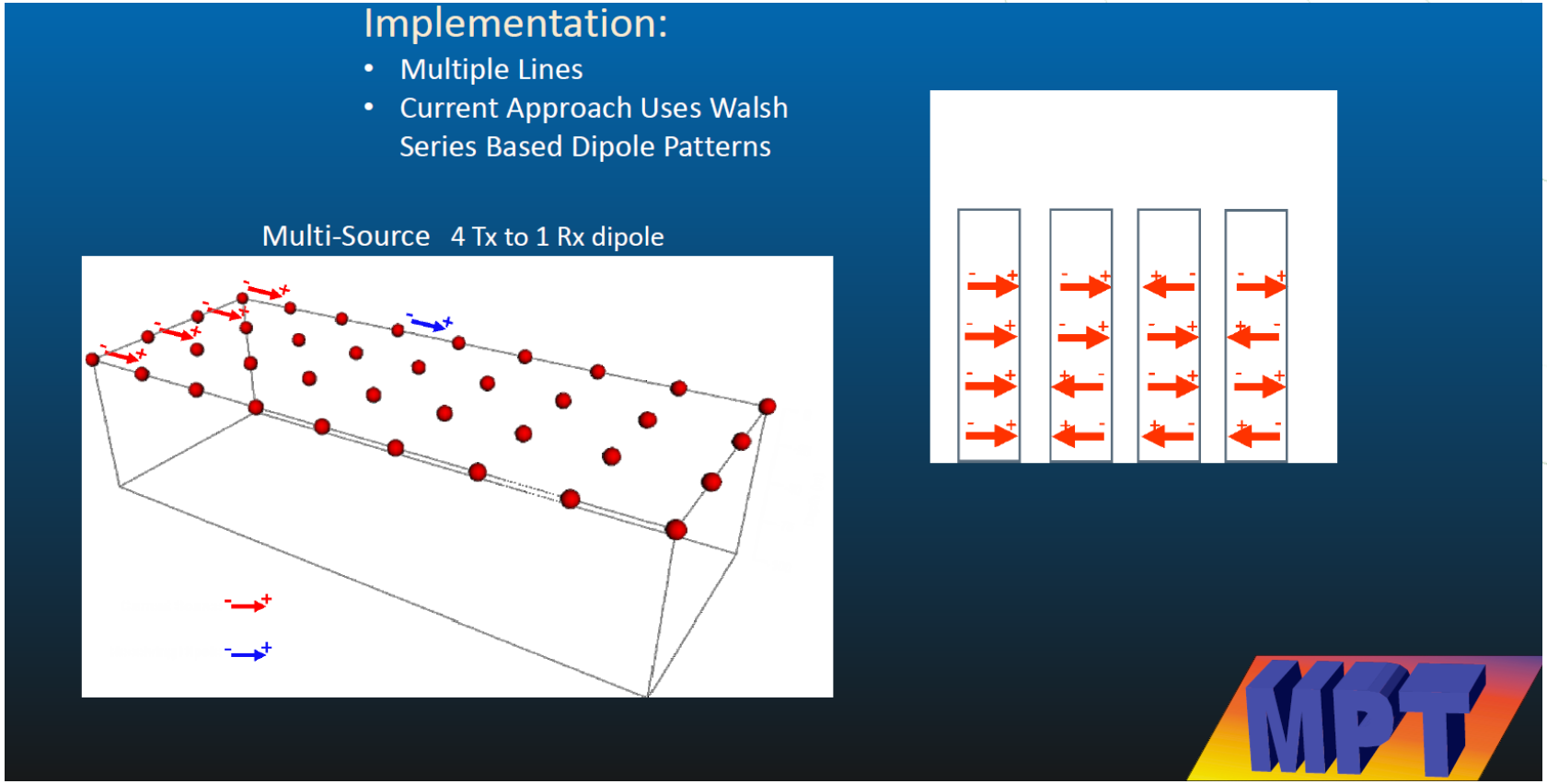
Multi-TX resistivity measurements : recent history

2012 : *Multisource system* - D. LaBrecque, MPT - Nevada



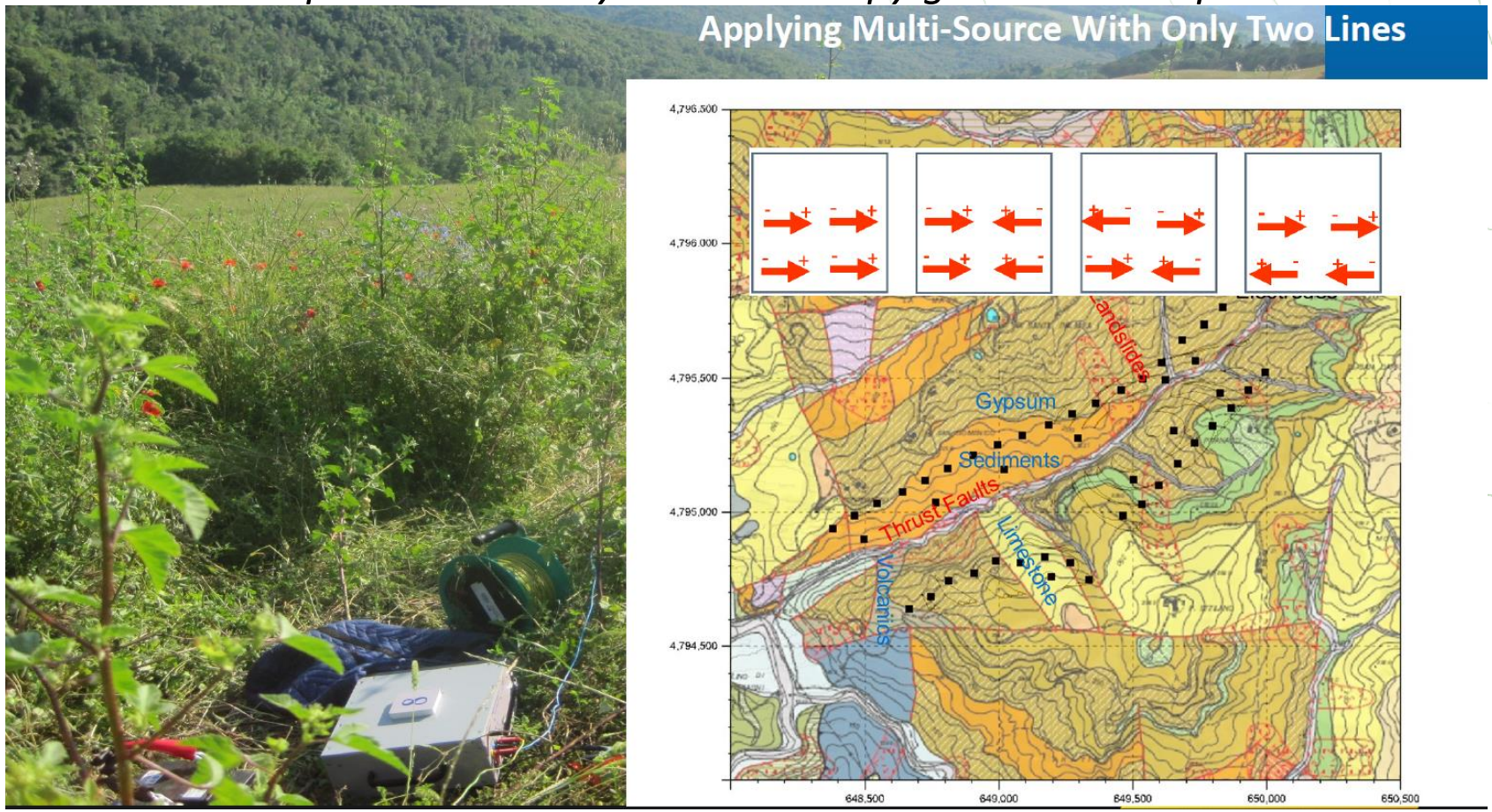
Multi-TX resistivity measurements : recent history

2012 : *Multisource system* - D. LaBrecque, MPT - Nevada



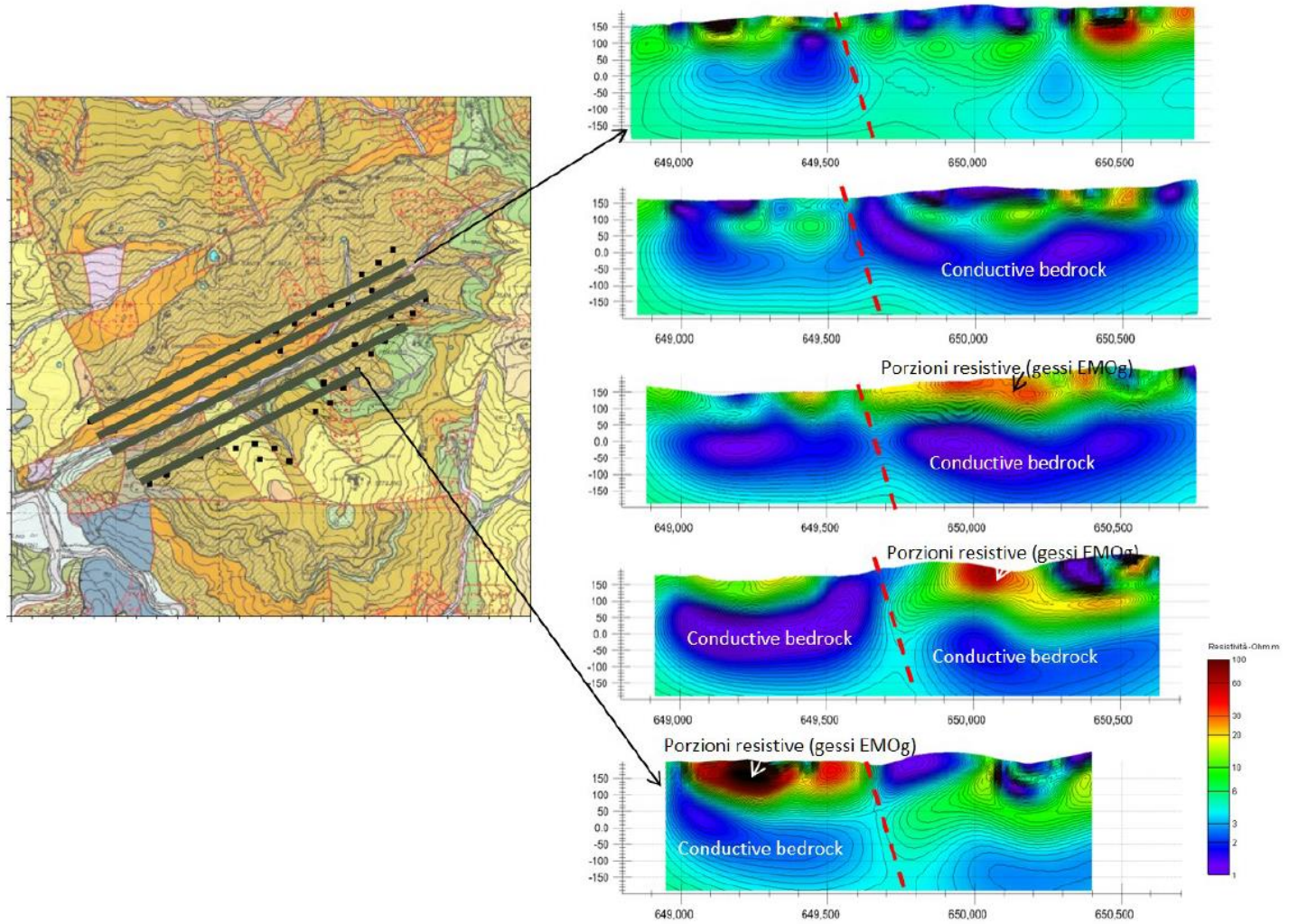
Multi-TX resistivity measurements : recent history

2013: *First Multi-TX experiment in Italy – low-enthalpy geothermal exploration*



Multi-TX resistivity measurements : recent history

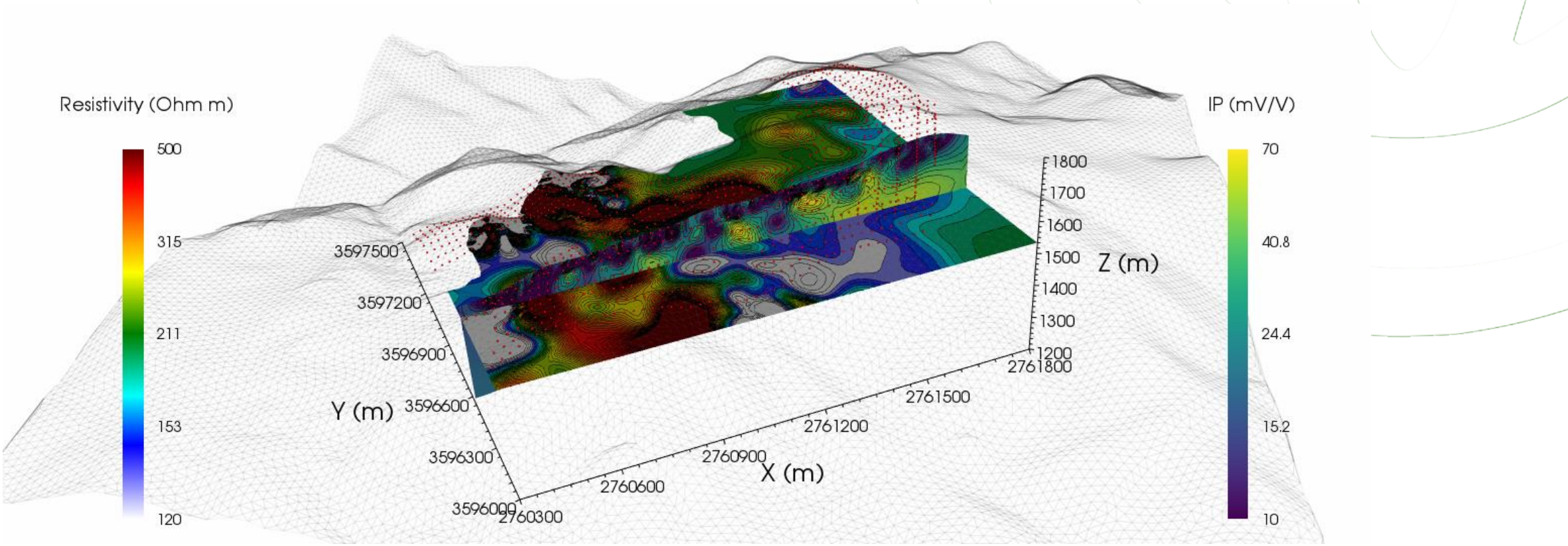
2013: *First Multi-TX experiment in Italy*



low-enthalpy geothermal exploration

Multi-TX resistivity measurements : recent history

2016->2020: *Multi-Source Induced Polarization measurements for mining Exploration in Azerbaijan*

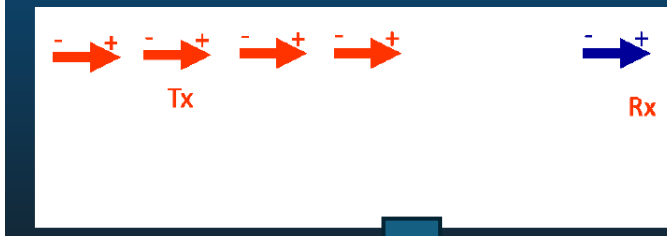


Multi-TX resistivity measurements : recent history

MPT Multi-Source system : LIMITATIONS

Limitations for Single Lines:

Multi-source, at least with the methods we are using, doesn't add much signal strength or resolution when applied on individual lines. The problem is that for collinear sources and receivers the closet receiver-transmitter pair tends to dominate the response.

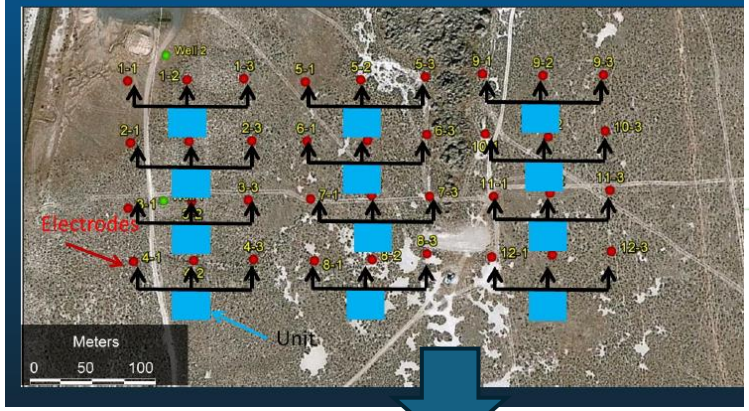


Communications:

Using Unlicensed ISM Band Communication can be Difficult in Europe on Sites Spanning Several Km. Workarounds include using Node-to-Node data transfer, getting the antenna off the ground, and designing the system to be tolerant of slow communications.

The Coverage Gap:

The standard layout leaves gaps between some adjacent dipoles. The typical workaround is to either live with the gap or shift the survey equipment and repeat.

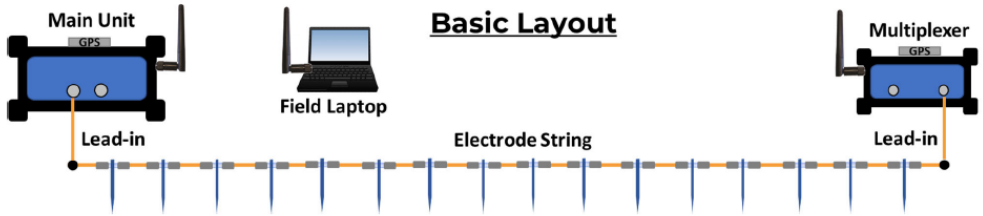


=>Focus on 3D arrays, GPS synchronization and multi-electrode

Multi-TX resistivity measurements : recent history

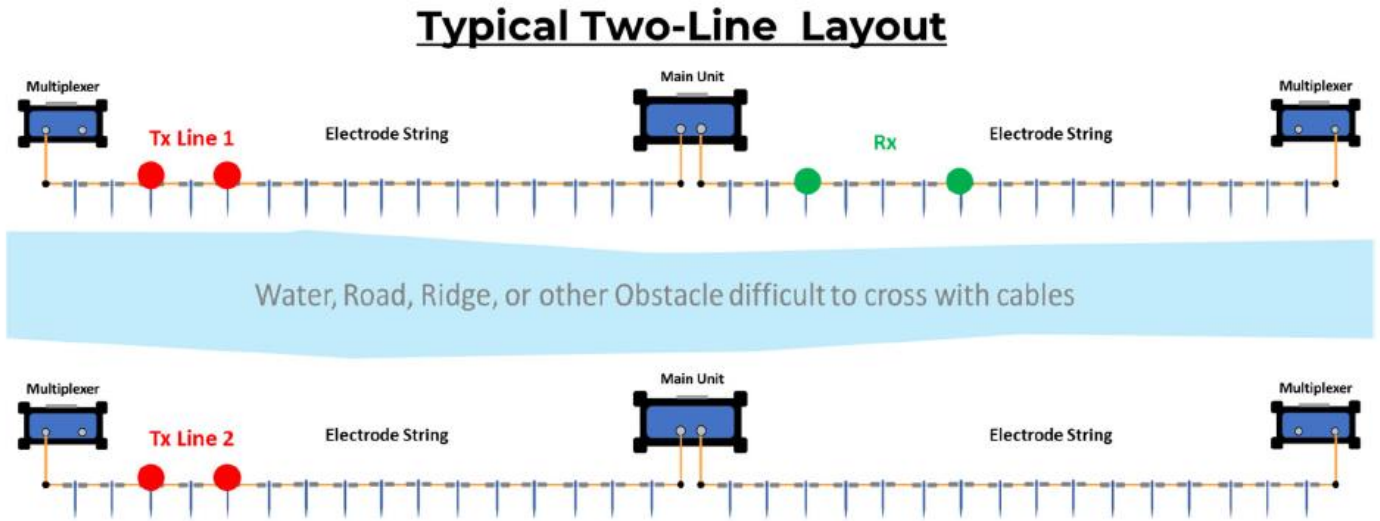
2021-2023: *development of MULTI-ELECTRODE – MULTI-TX systems.*

MPT and IRIS INSTRUMENTS



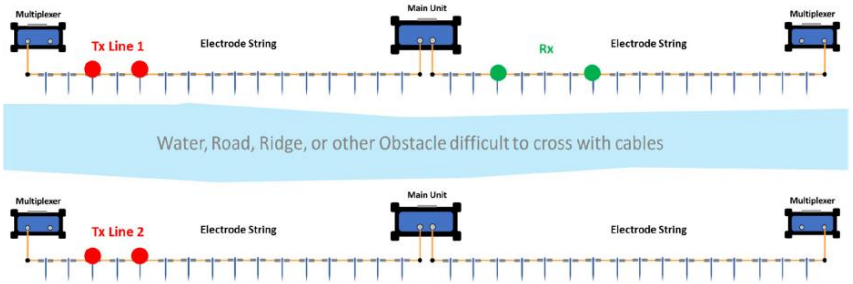
MPT-IRIS Inc.

www.mptech3d.com



Multi-TX resistivity measurements : recent history

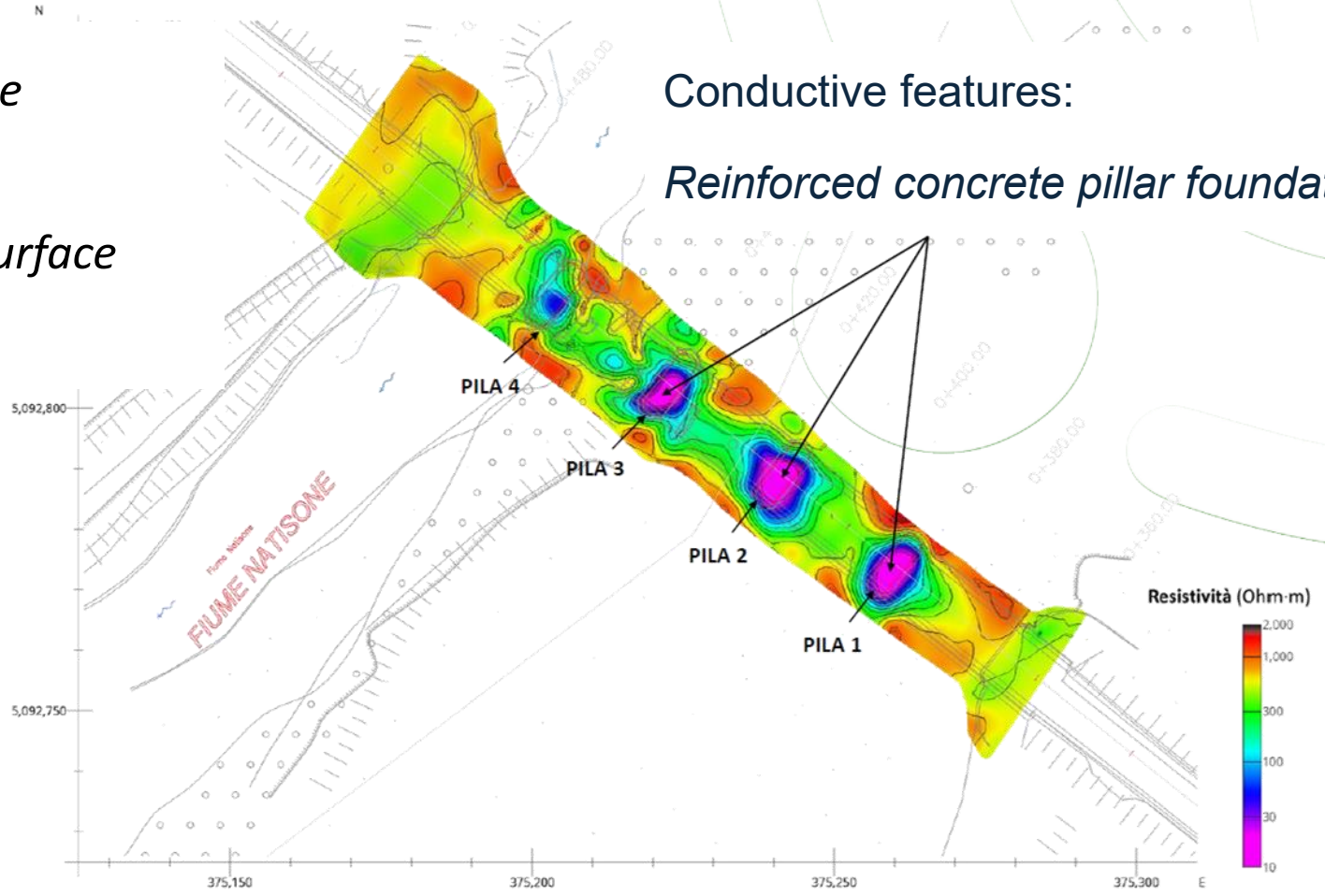
2022: *DAS-M multi-TX measurements at the Natisone historical BRIDGE - Italy*



Multi-TX resistivity measurements : recent history

2022: *DAS-M multi-TX ERT at the Natisone BRIDGE:*

ISODEPTH surface at 4 m from surface



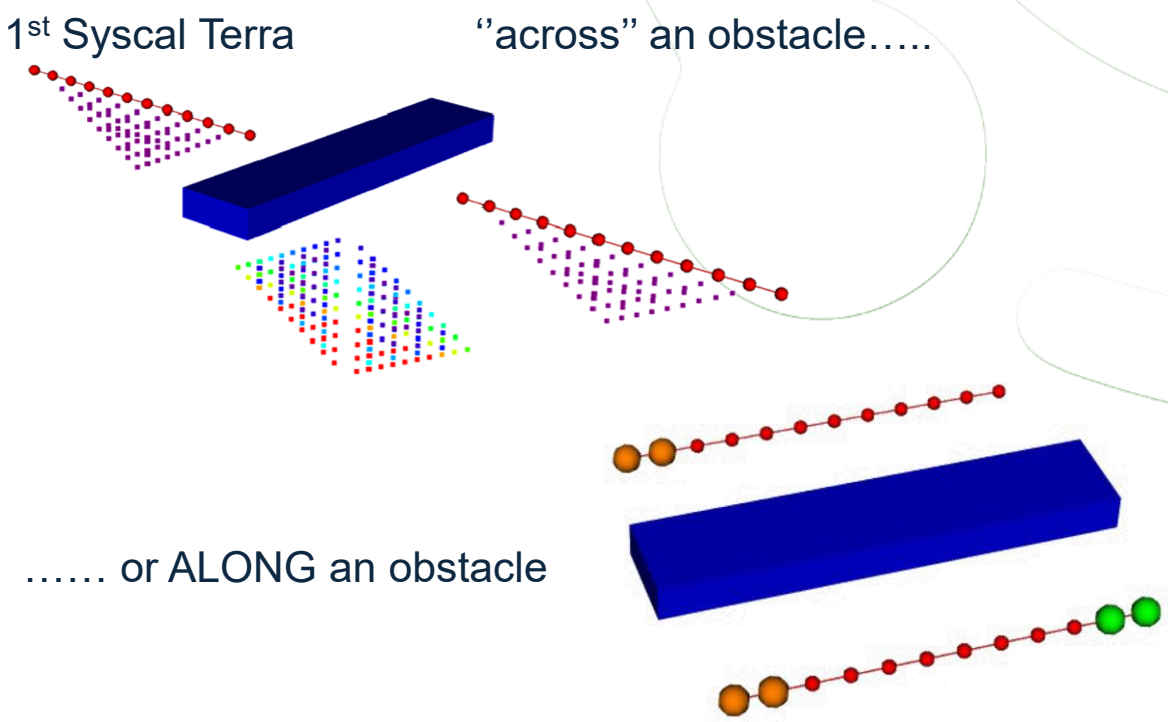
Conductive features:

Reinforced concrete pillar foundations

Multi-TX resistivity measurements : recent history

2024-2025: ***development of MULTI-ELECTRODE – MULTI-TX system – SYSCAL TERRA***

IRIS INSTRUMENTS



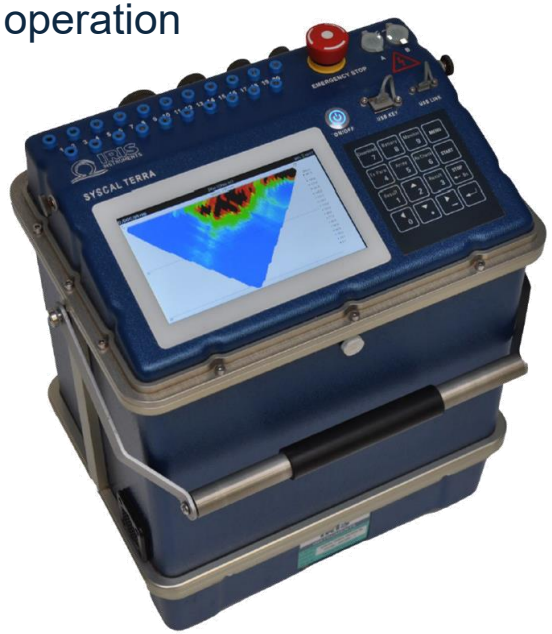
Multi-TX resistivity measurements : recent history

2024-2025: *development of MULTI-ELECTRODE – MULTI-TX systems .*

IRIS INSTRUMENTS

Syscal Terra:

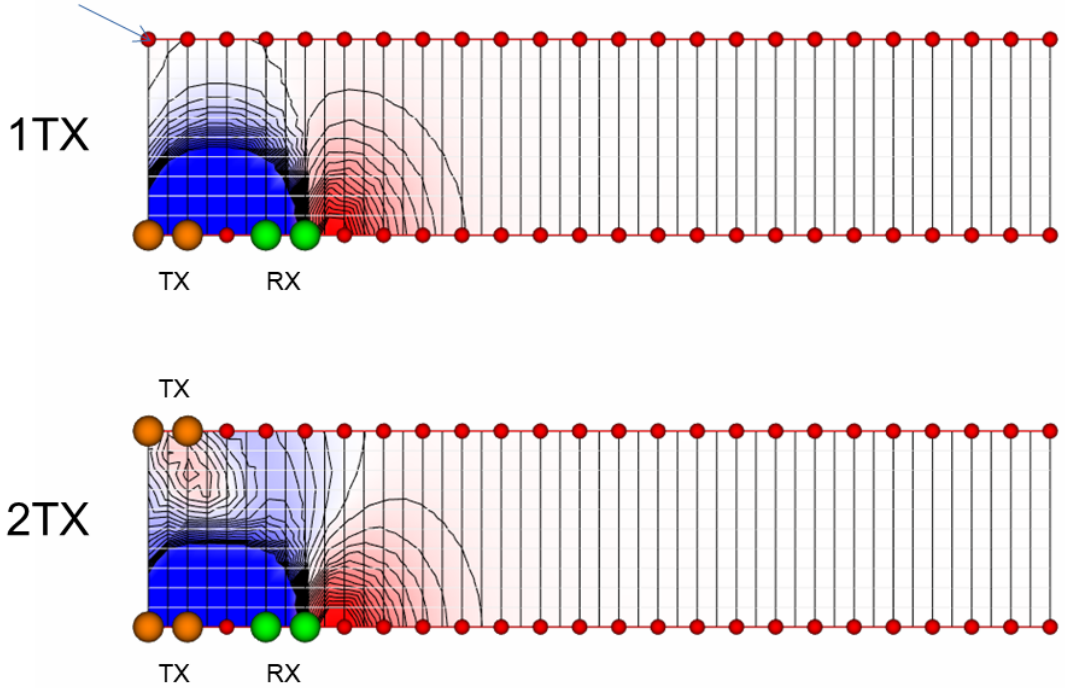
- evolution of the Syscal Pro => 20-channel RX
- Scalable multiplexer
- 2 Tx multiple TX operation



Multi-TX resistivity measurements : key concepts

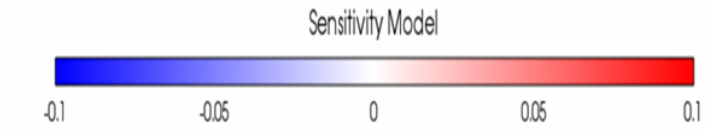
2 TX vs 1 TX

Sensitivity distribution : single measurement



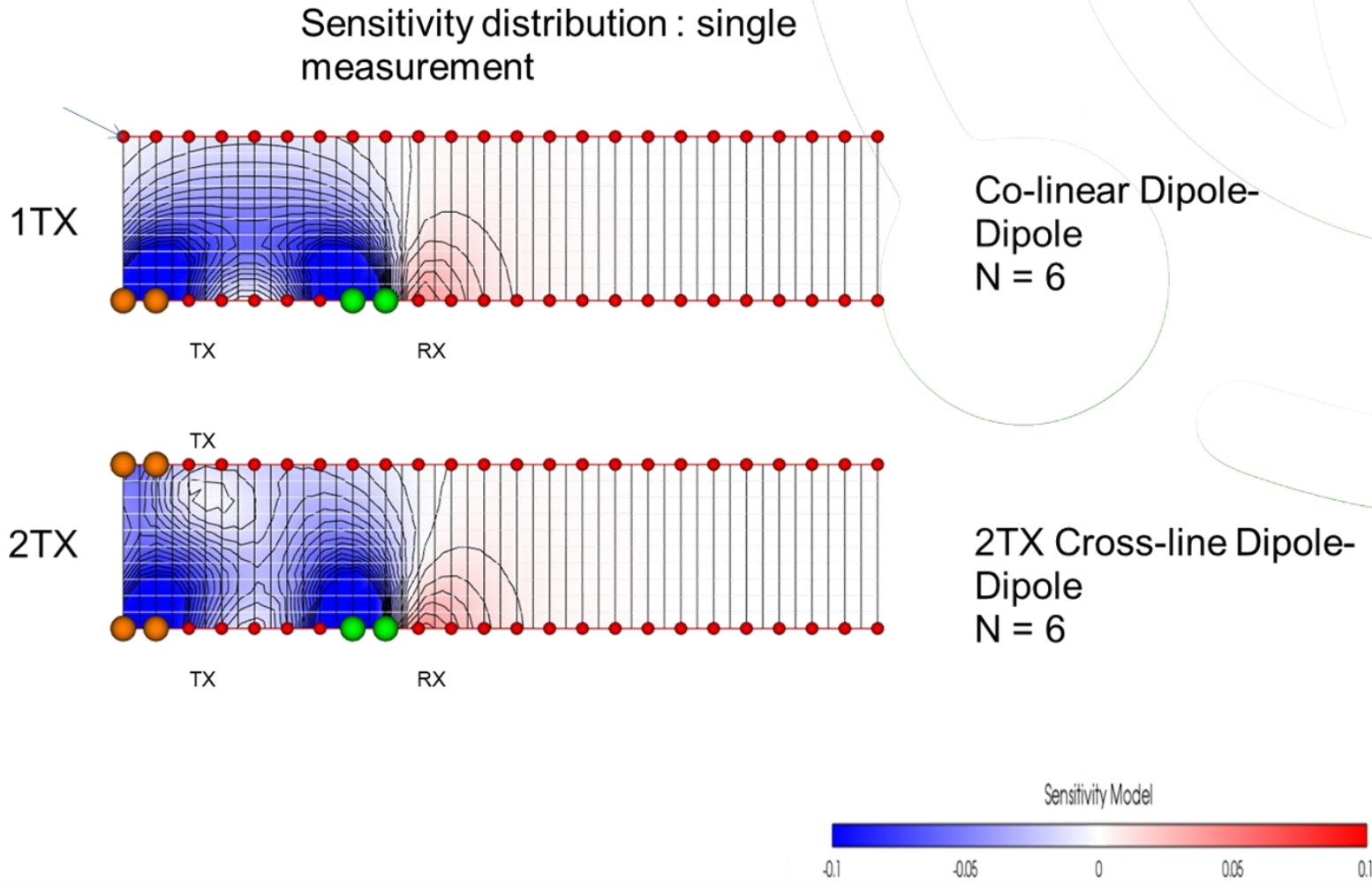
Co-linear Dipole-Dipole
N = 2

2TX Cross-line Dipole-Dipole
N = 2



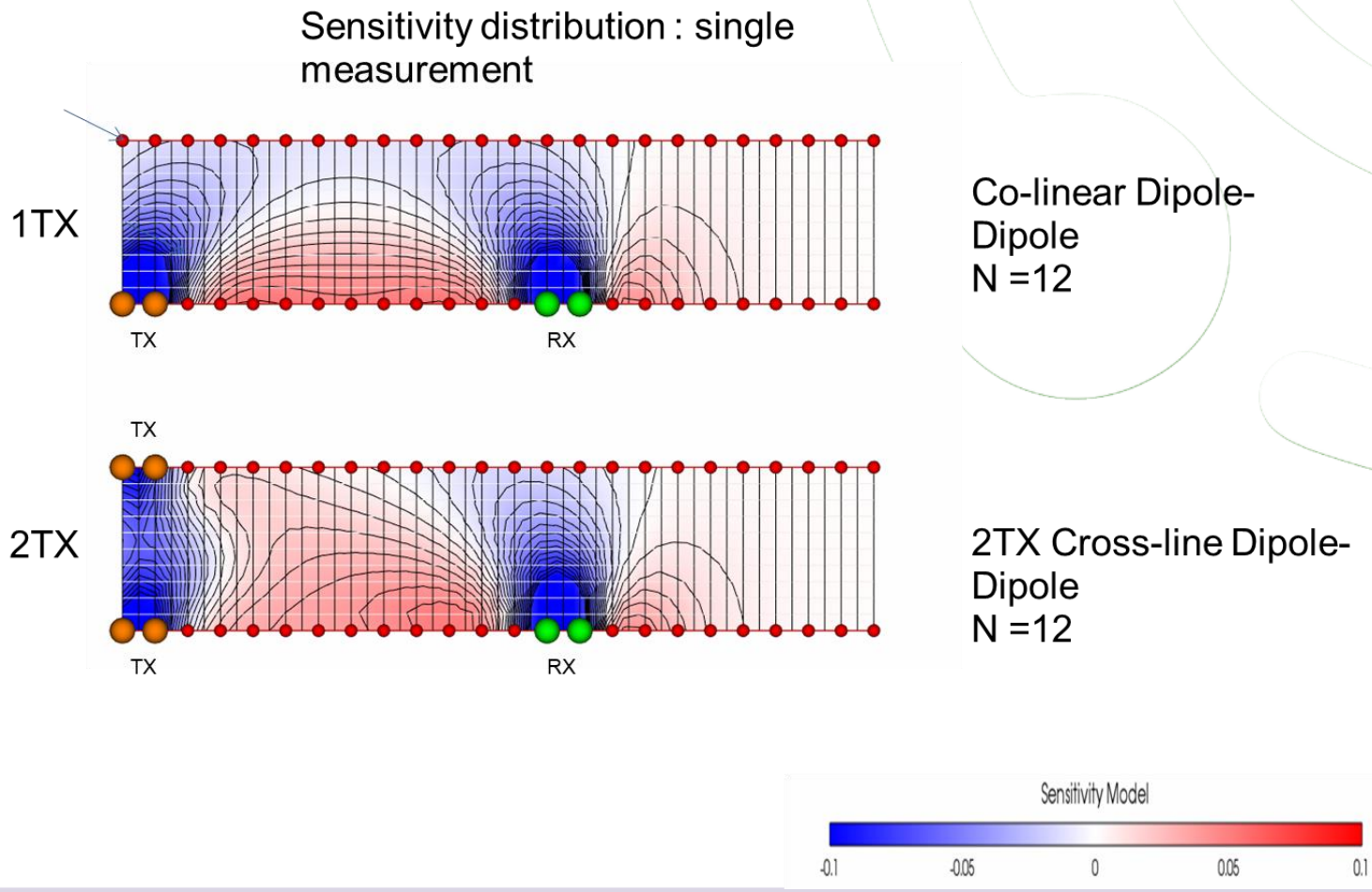
Multi-TX resistivity measurements : key concepts

2 TX vs 1 TX



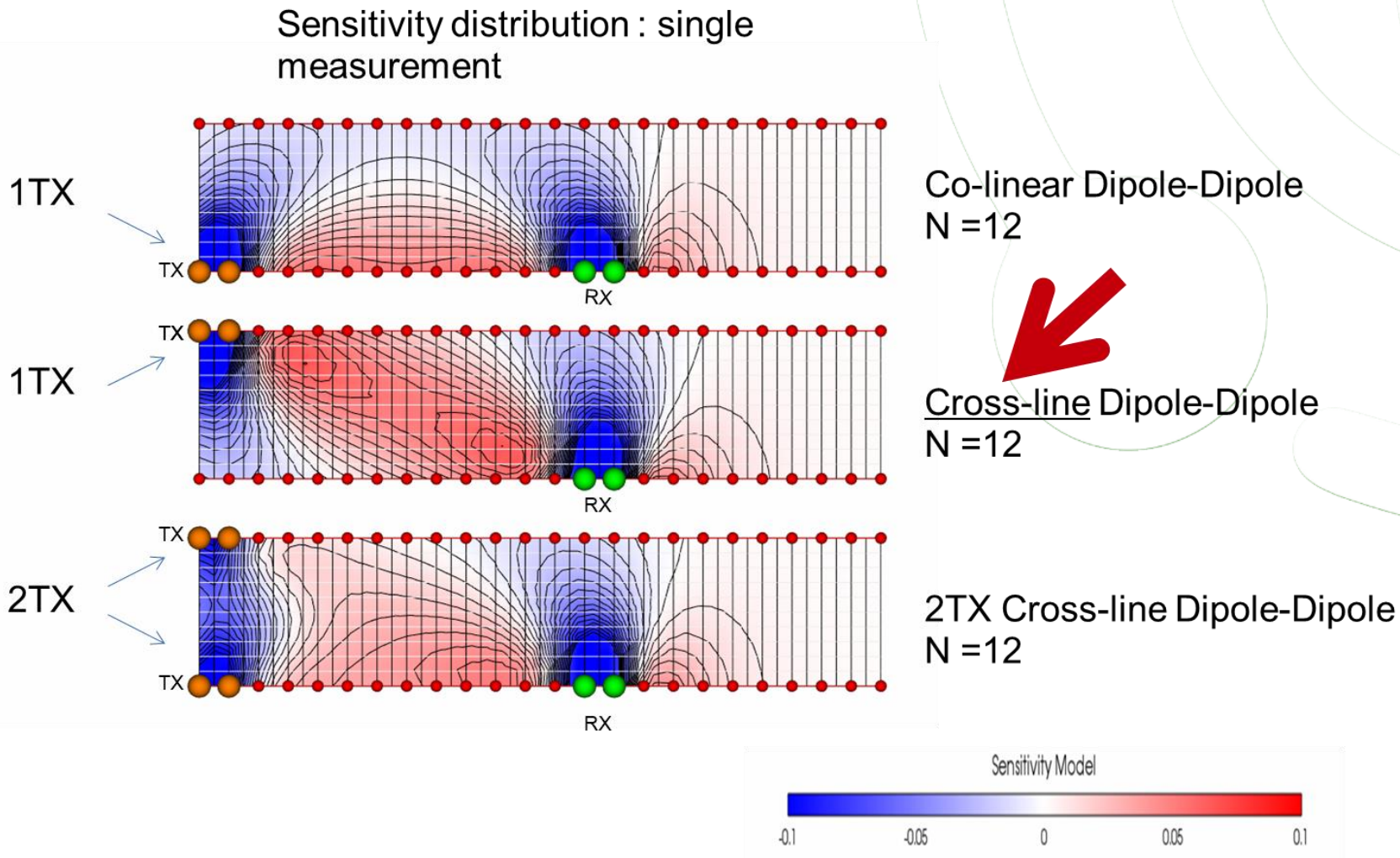
Multi-TX resistivity measurements : key concepts

2 TX vs 1 TX



Multi-TX resistivity measurements : key concepts

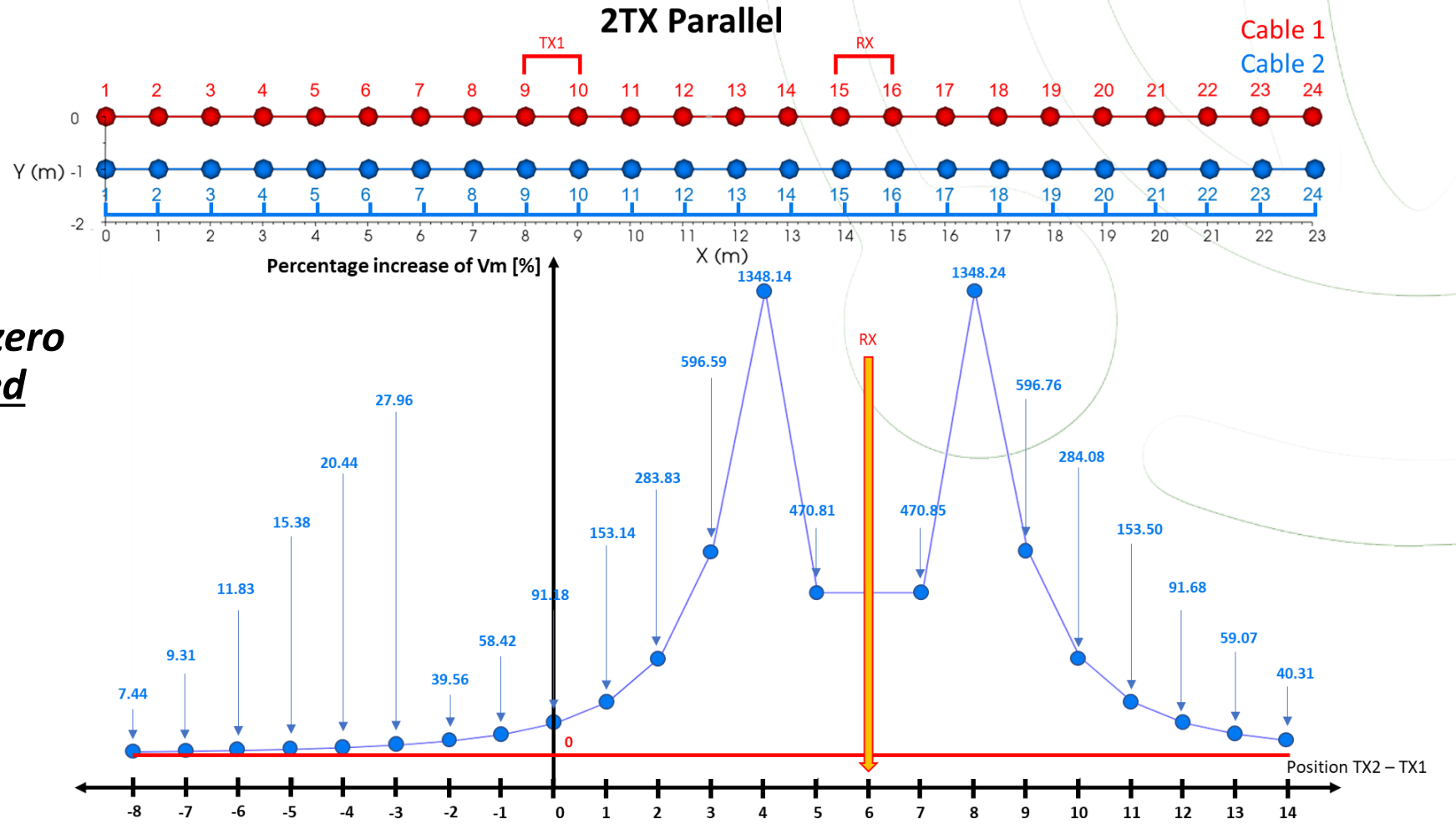
2 TX vs 1 TX



Multi-TX resistivity measurements : key concepts

2 TX vs 1 TX

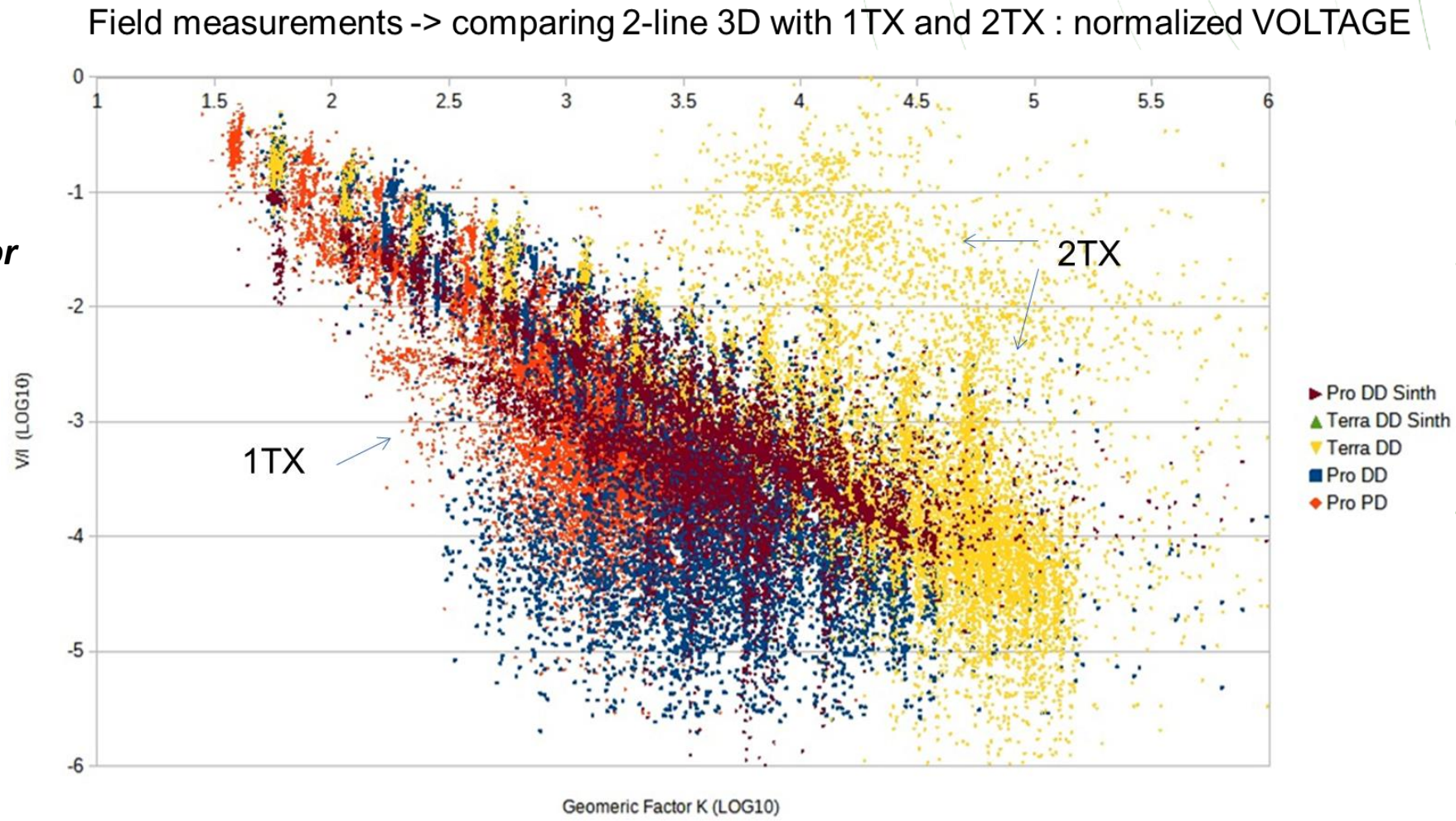
If TX1 and TX2 have zero offset the V is doubled



Multi-TX resistivity measurements : key concepts

2 TX vs 1 TX :

V/I as a function of the K geometric factor

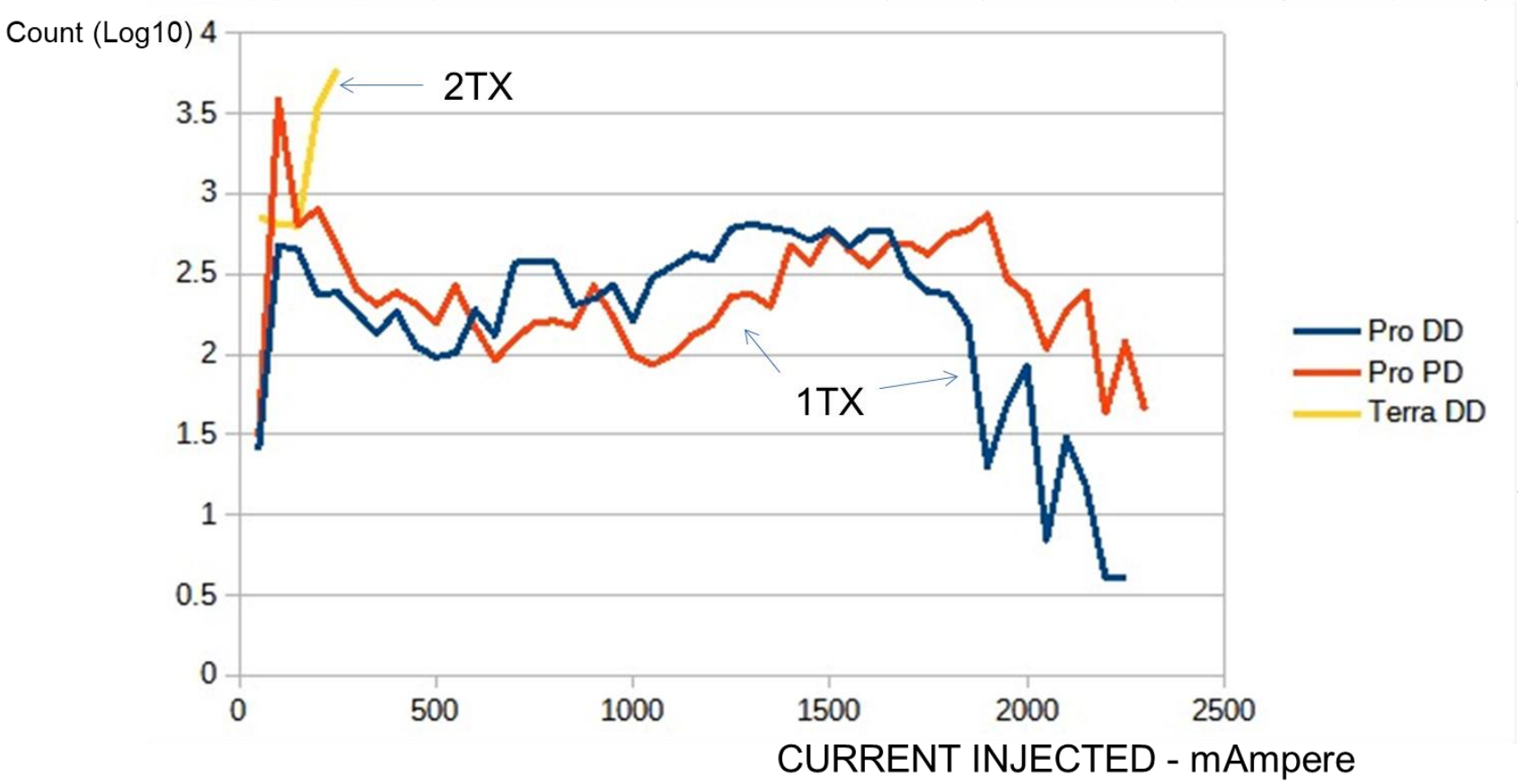


Multi-TX resistivity measurements : key concepts

2 TX vs 1 TX :

Efficiency of power consumption

Field measurements -> comparing 2-line 3D with 1TX and 2TX : CURRENTS

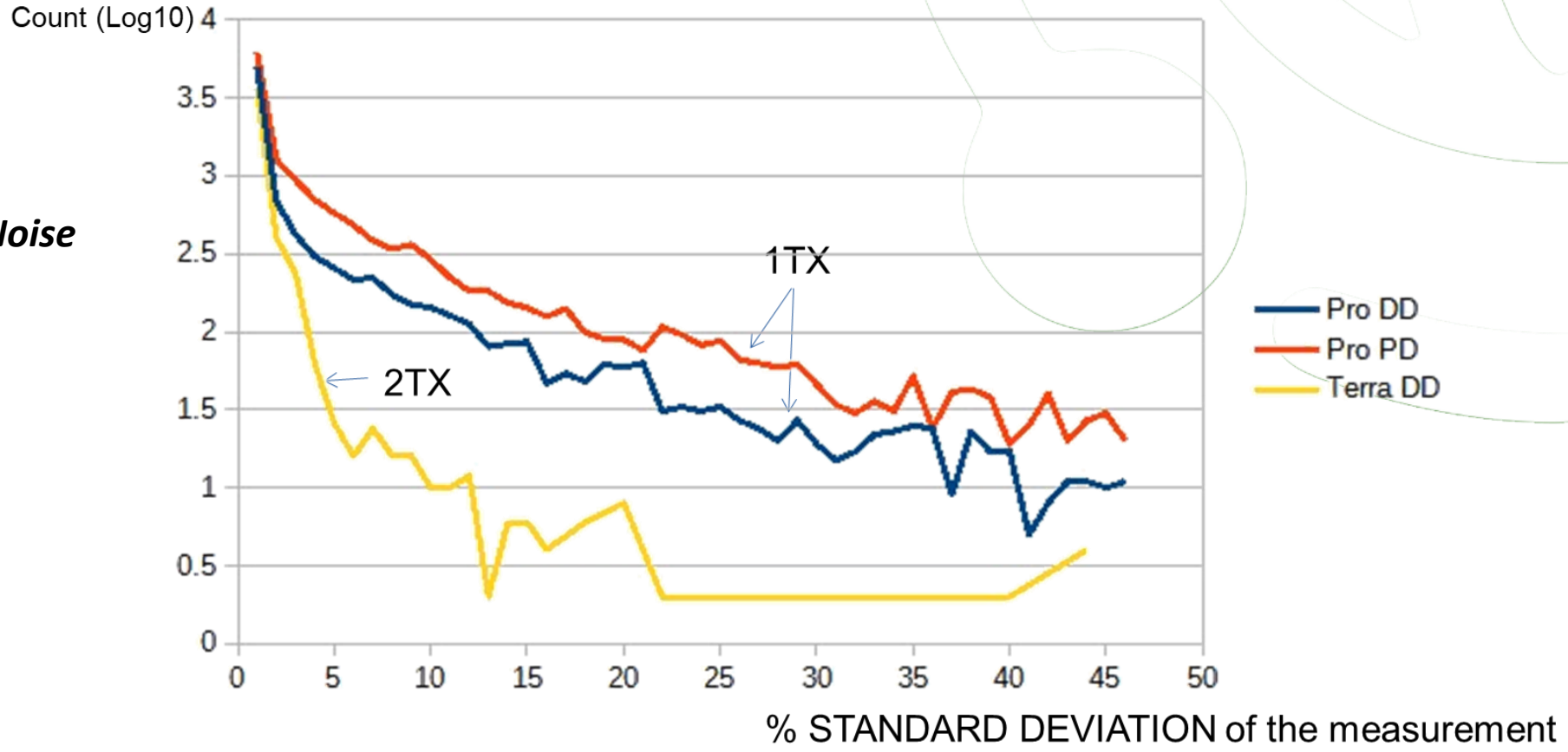


Multi-TX resistivity measurements : key concepts

2 TX vs 1 TX :

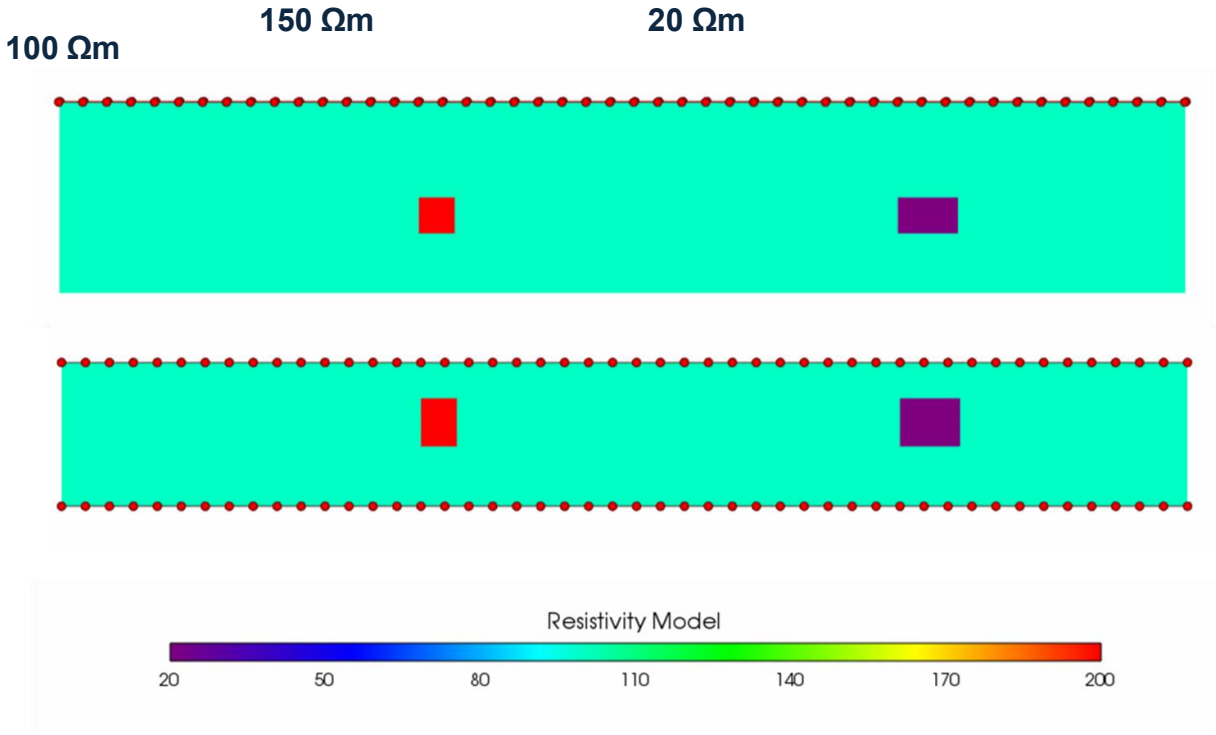
Improved Signal/Noise

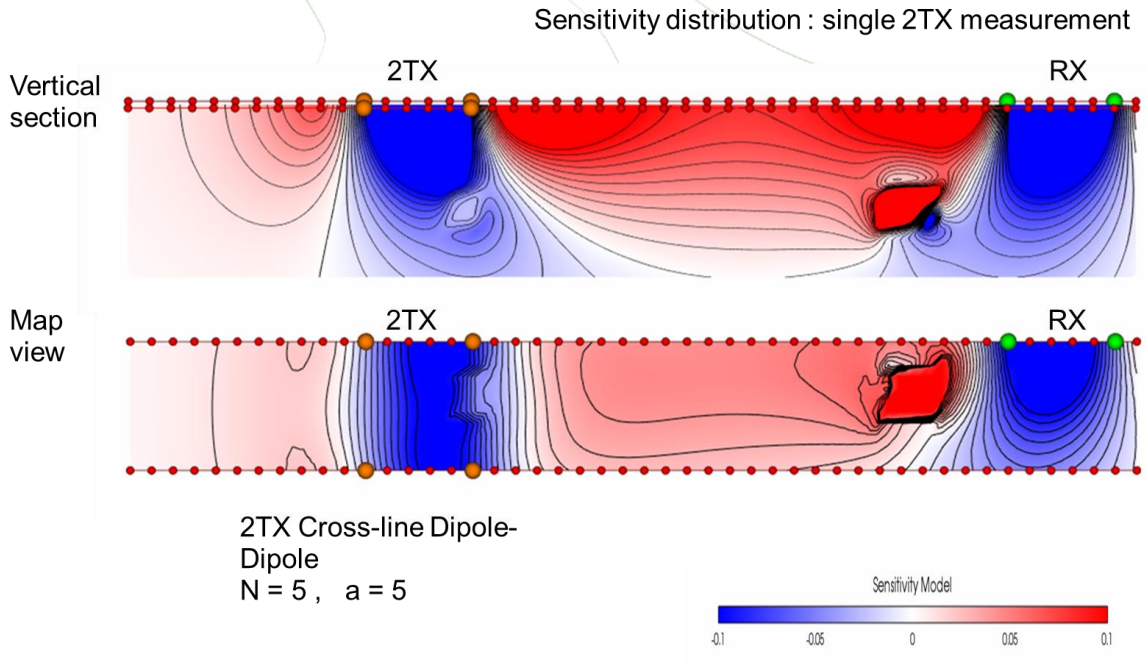
Field measurements -> comparing 2-line 3D with 1TX and 2TX : NOISE



Multi-TX resistivity measurements : key concepts

2 TX vs 1 TX : Sensitivity on targets – numerical simulations on resistive and conductive targets

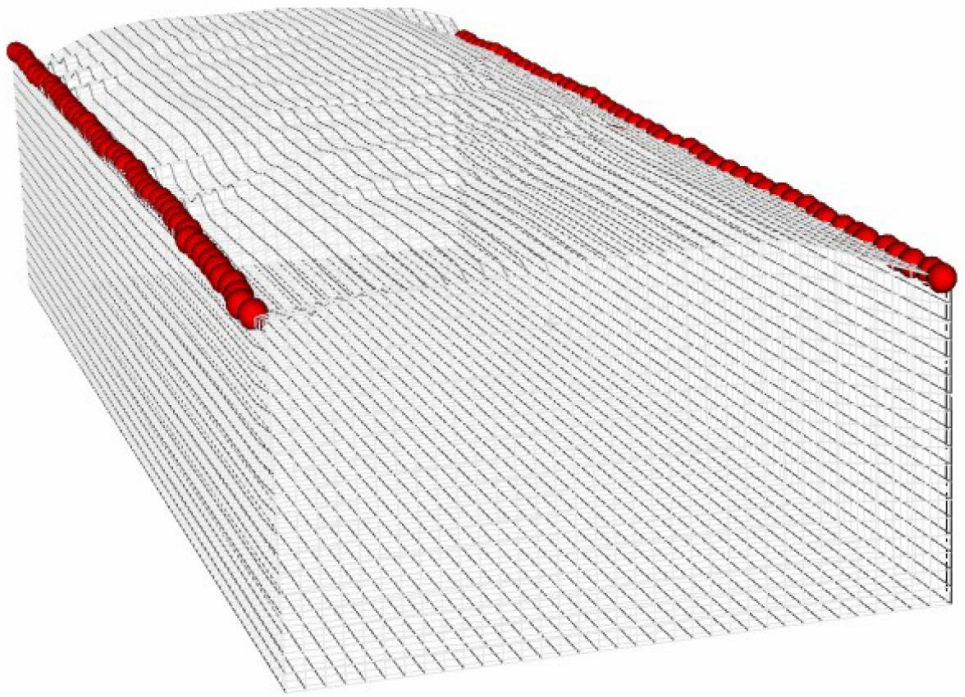




2-TX INFRASTRUCTURAL applications

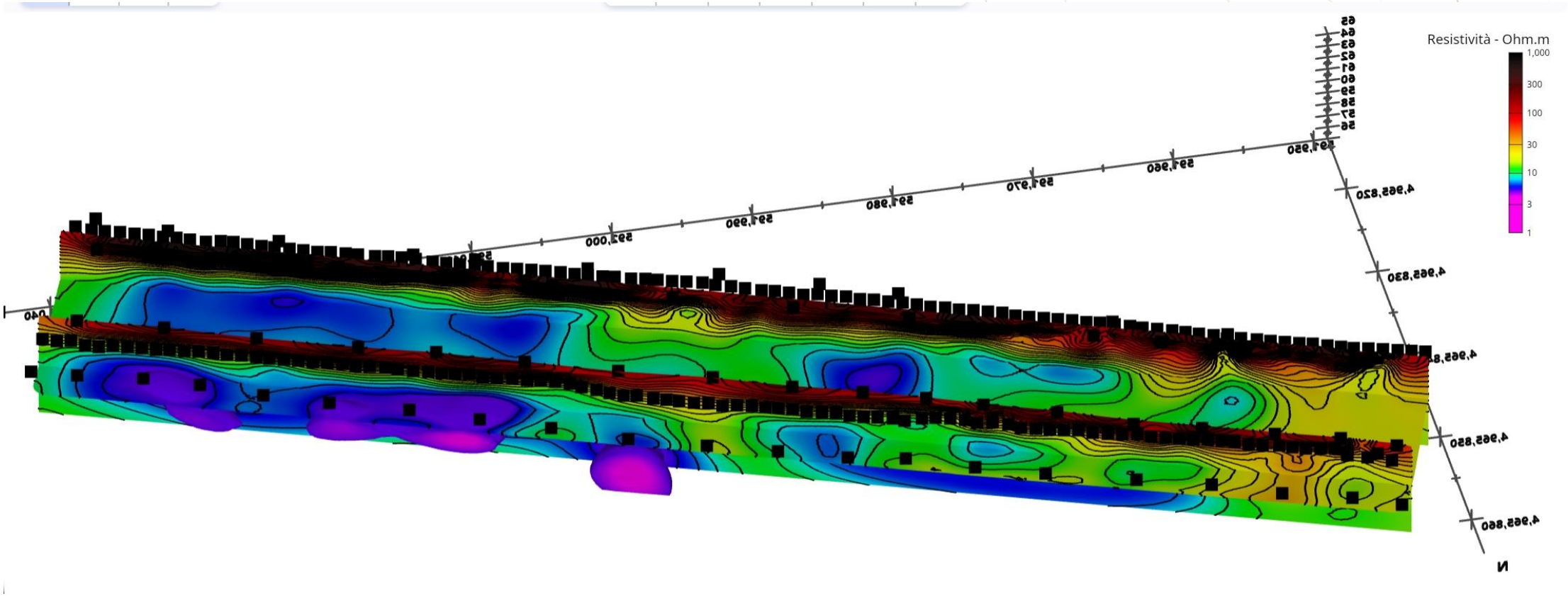
2-TX INFRASTRUCTURAL applications

TOPOGRAPHY IS FUNDAMENTAL IN 3D !!



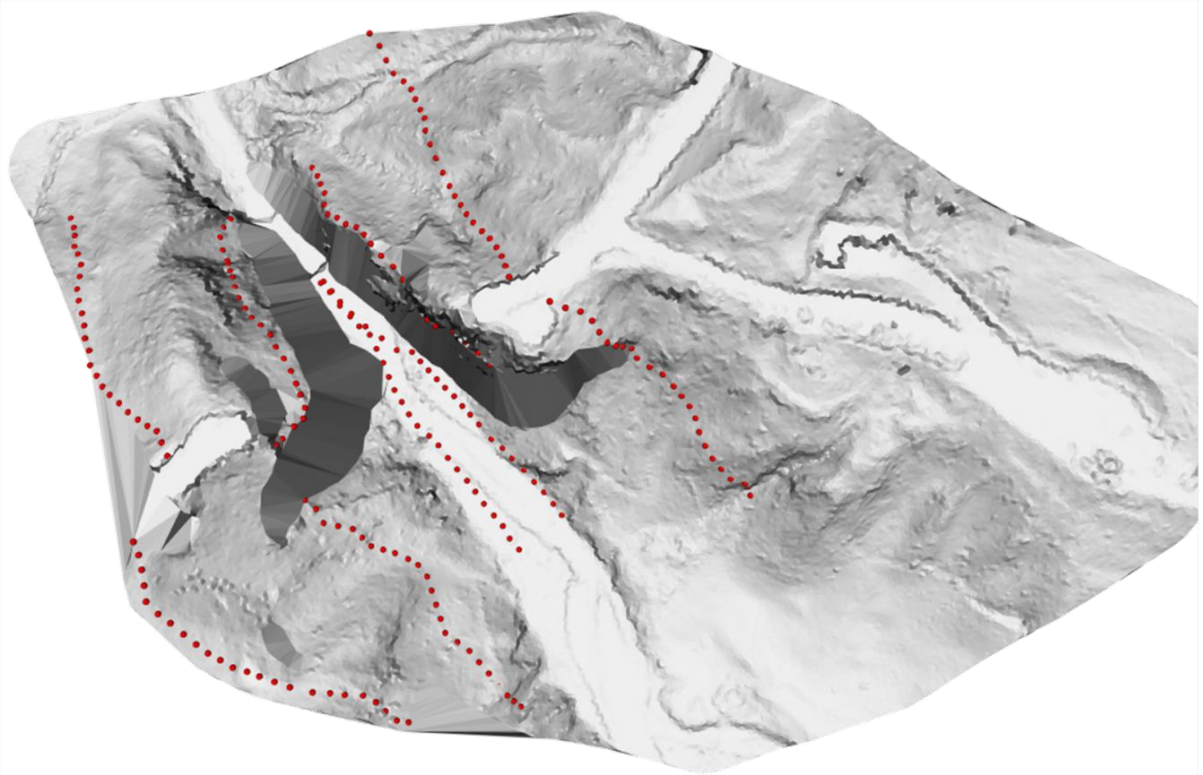
2-TX INFRASTRUCTURAL applications

- Italy , 2024: monitoring soil heterogeneity under railways

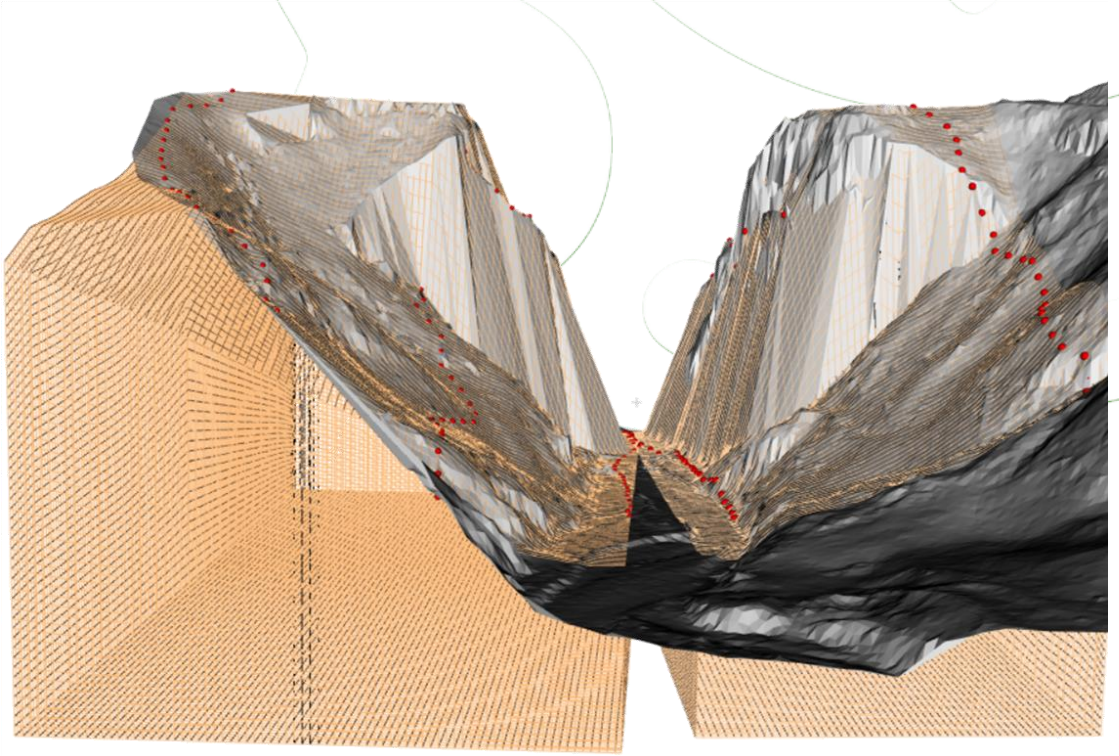


2-TX INFRASTRUCTURAL applications

Multiple simultaneous 3D arrays "top-bottom"

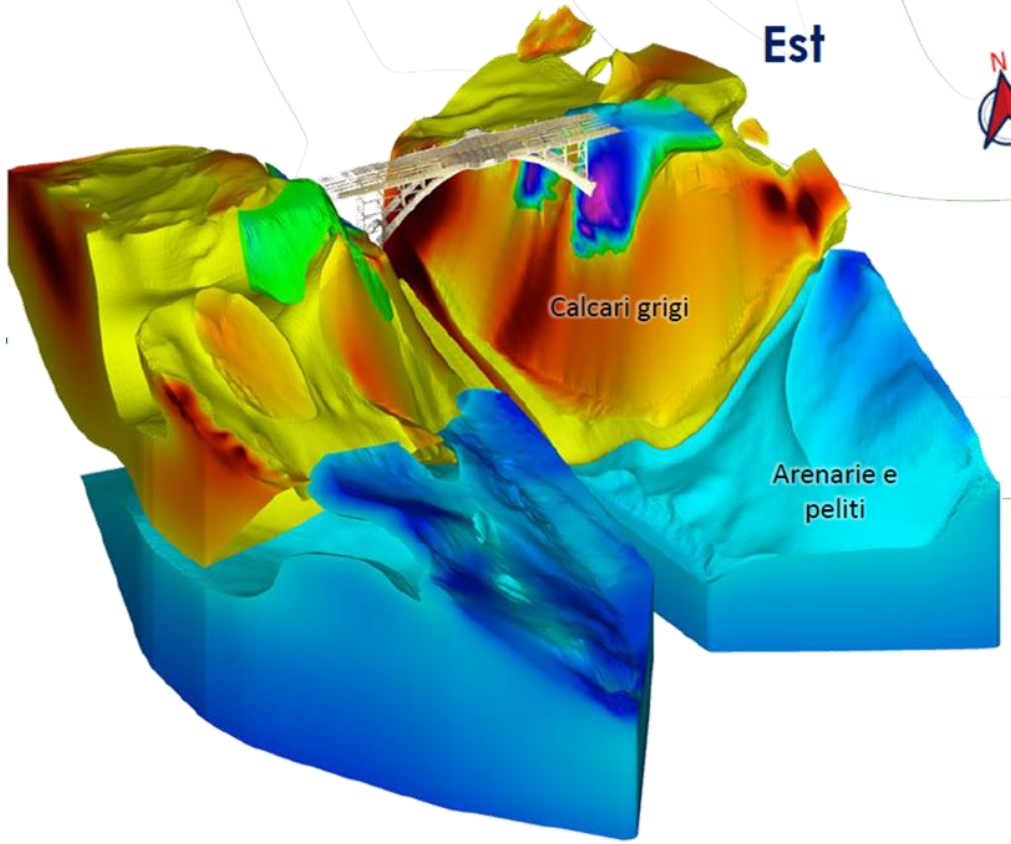


TOPOGRAPHY IS FUNDAMENTAL IN 3D !!



2-TX INFRASTRUCTURAL applications

TOPOGRAPHY IS FUNDAMENTAL IN 3D !!



2-TX most recent URBAN applications

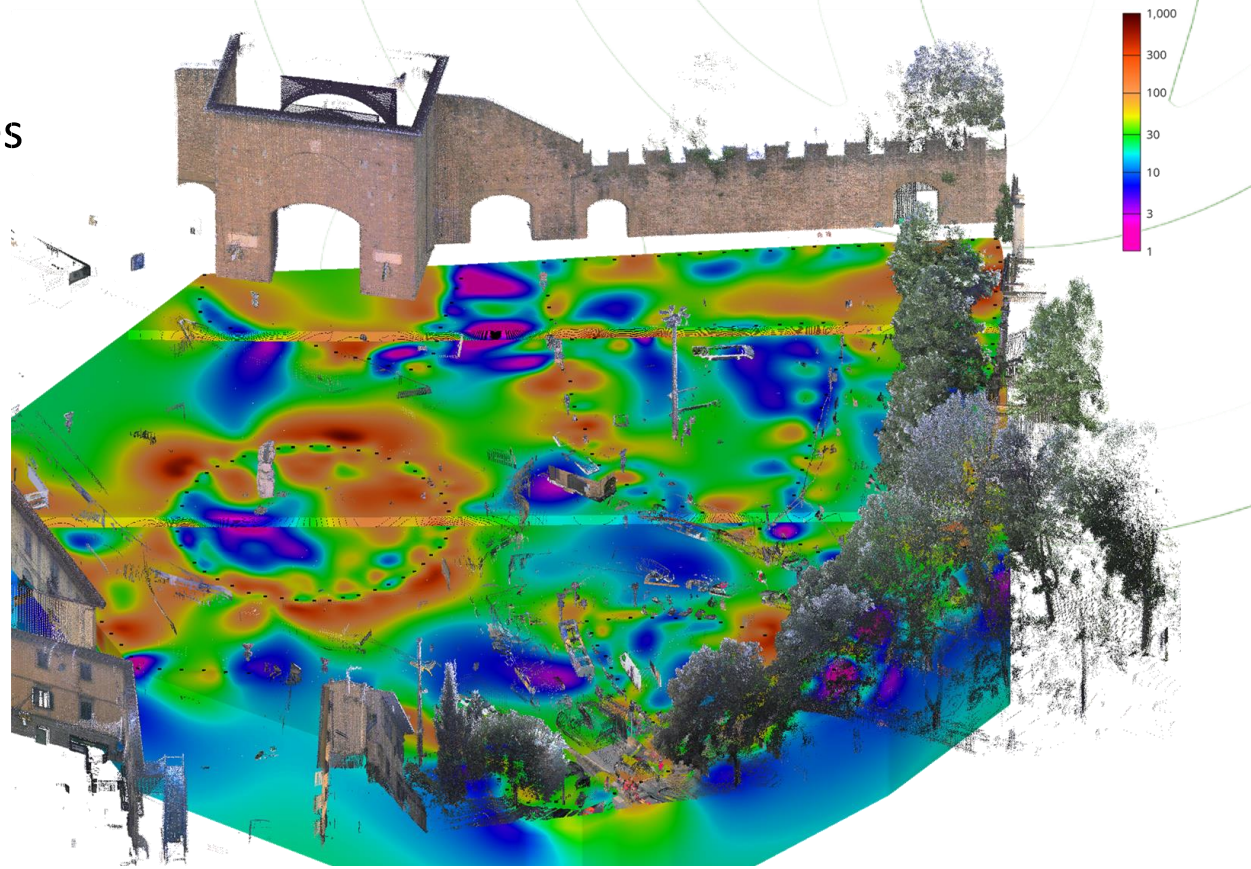
- Florence – Italy , May 2025

2-TX most recent URBAN applications

- Florence – Italy , May 2025

  1st Syscal Terra inside the roundabout

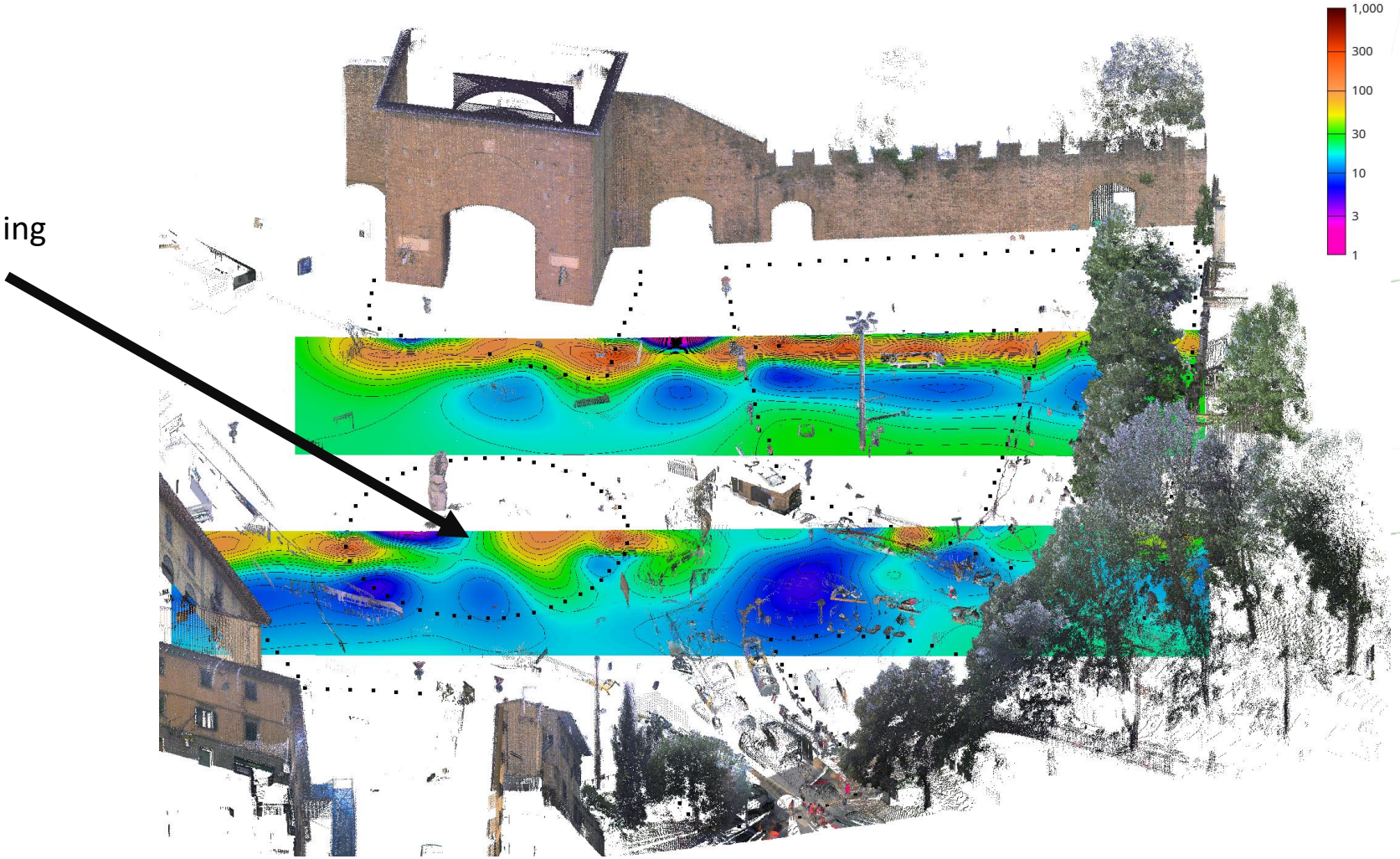
  2° Syscal Terra connected to surrounding sets of electrodes



2-TX most recent URBAN applications

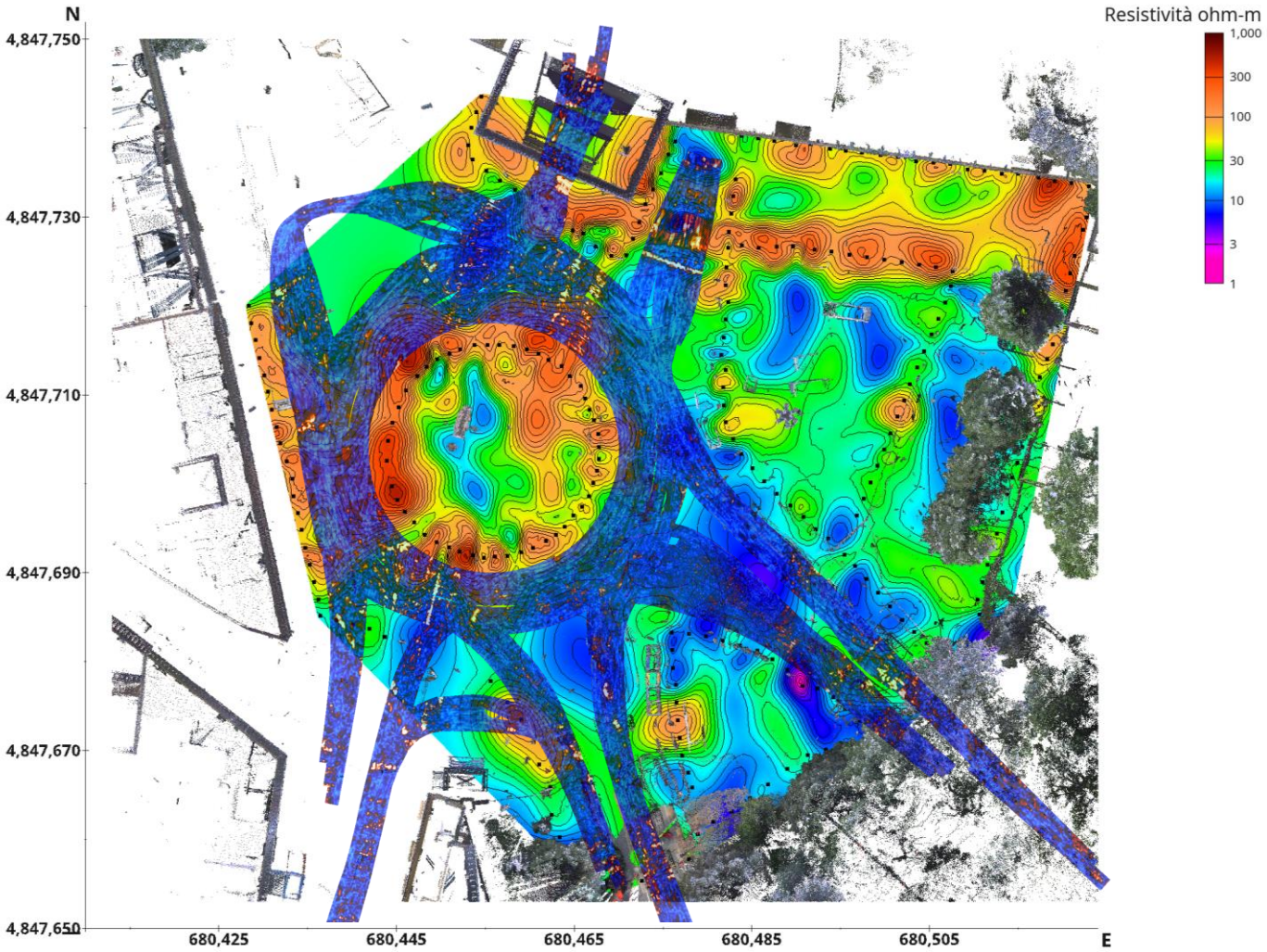
1st Syscal Terra to a circle of 48 el.

2° Syscal Terra connected to surrounding sets of 48 electrodes



2-TX most recent URBAN applications

3D ERT for urban surveys => effective complement to GPR



THANKS!

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