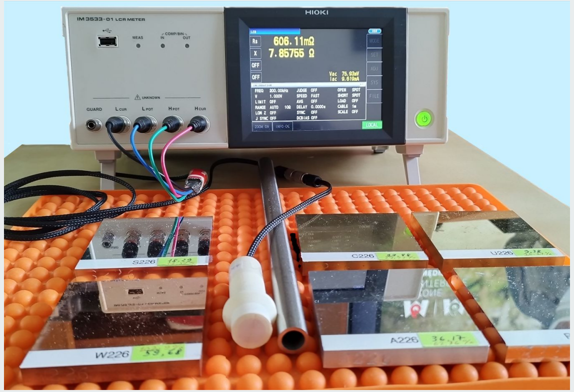
CONDUCSENS™

Eddy Current Non Destructive Testing System

User's guide v.0 - Sciensoria sarl - https://www.sciensoria.fr



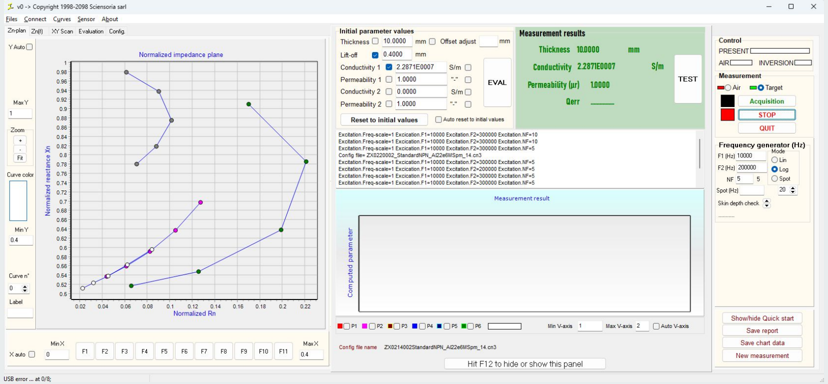
Summary

1.1 - What is ConducSens(™)

ConducSens™ is a Non Desctructive Testing system made by Sciensoria sarl (https://www.sciensoria.fr). It is composed of an impedance meter, an Eddy Current probe, and, the most important, the EddySens™ software made by Sciensoria. EddySens(™) is a multi-function software that allows users to acquire multifrequency material signature, predict impedance signature with supposed material parameters (simulation), and compute material parameters using acquired multifrequency material signature.

Impedance meter

Eddy current probe



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Max Y: 1
Min Y: 0.4
Curve n°: 0
X auto ☐ Min X: 0
Max X: 0.4

Initial parameter values
Thickness ☐ 10.0000 mm ☐ Offset adjust mm
Lift-off ☑ 0.4000 mm
Conductivity 1 ☑ 2.2871E0007 S/m ☐
Permeability 1 ☐ 1.0000 "-" ☐
Conductivity 2 ☐ 0.0000 S/m ☐
Permeability 2 ☐ 1.0000 "-" ☐
☐ Auto reset to initial values

Measurement results
Thickness 10.0000 mm
Conductivity 2.2871E0007 S/m
Permeability (µr) 1.0000
Qerr ....

○ Air ● Target

Frequency generator (Hz)
F1 (Hz) 10000
F2 (Hz) 200000
NF 5 5
Spot (Hz) 20
Mode: ○ Lin ● Log ○ Spot
Skin depth check
....

```
Excitation.Freq-scale=1 Excication.F1=10000 Excitation.F2=300000 Excitation.NF=10
Excitation.Freq-scale=1 Excication.F1=10000 Excitation.F2=300000 Excitation.NF=10
Excitation.Freq-scale=1 Excication.F1=10000 Excitation.F2=300000 Excitation.NF=5
Config file= ZX0220002_StandardNPN_Al22e6MSpm_14.cn3
Excitation.Freq-scale=1 Excication.F1=10000 Excitation.F2=300000 Excitation.NF=5
Excitation.Freq-scale=1 Excication.F1=10000 Excitation.F2=200000 Excitation.NF=5
Excitation.Freq-scale=1 Excication.F1=10000 Excitation.F2=300000 Excitation.NF=5
Excitation.Freq-scale=1 Excication.F1=10000 Excitation.F2=300000 Excitation.NF=5
```

Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0214002StandardNPN_Al22e6MSpm_14.cn3

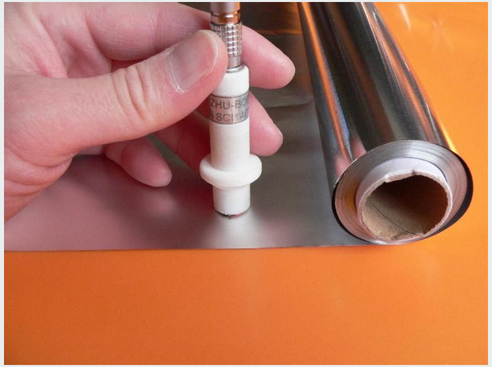
USB error ... at 0/8;

EddySens™ software

Applications of ConducSens™

Measurement electrical conductivity of carbon composite materials (CFRP)

Measurement of tube thickness

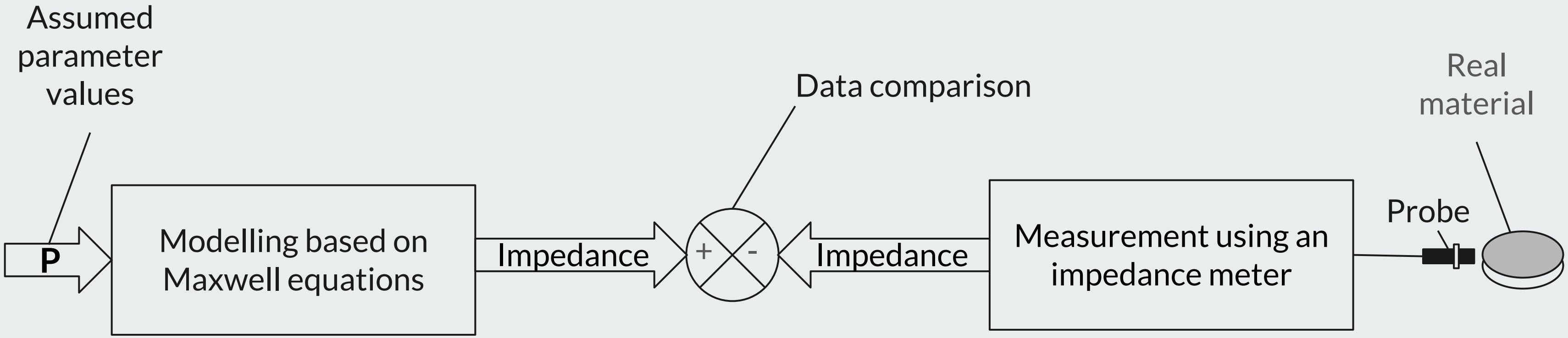


Measurement electrical conductivity of carbon composite materials (CFRP)

Measurement electrical conductivity of graphite

1.2 - Why use an impedance meter?

An impedance meter allows easy correlation between real measurements and physical models. Impedance is the ratio of voltage across the probe coil to the current flowing through it. For linear materials, it depends on the excitation frequency, material, and probe coil properties but not on the magnitude of the excitation voltage or current.



1.3 - Material list

1. Hioki LCR meter (models IM3533-01, IM3536, IM3570) with accessories :
    1. Power cord
    2. USB cable
2. Kelvin cable or Sciensoria's special 4-point to male Binder-712 cable
3. A bare coil or a Sciensoria's eddy current probe, for example
    1. 10 mm-diameter probe (ZX0210002)
    2. 12 mm-diameter probe (ZX0212002)
    3. 14 mm-diameter probe (ZX0214002)
    4. 20 mm-diameter probe (ZX0220002)
    5. 40 mm-diameter probe (ZX0240002)
4. Personal computer running Windows 10 or 11
5. *Optional: IntelliSW™ control USB box for continuous measurement operations*
6. EDDYSENS(L) software
    1. Download link: see delivery email

IntelliSW™ control box

1.4 - Installing the IM3536 Impedance Meter

- Place the IM3536 impedance meter on a flat and stable surface, away from heat and humidity sources.
- If the package was shipped from outside, wait at least 1 hour after unpacking before powering on the device.
- Connect the IM3536 power cord to the mains.
- Connect the USB cable between the IM3536 and the computer.
- Plug the computer’s power adapter into the mains.
- Connect an external monitor to the computer’s HDMI port.
- Start the computer and check that the keyboard and mouse are functioning properly.
- Connect the Sciensoria’s 4xBNC-to-Binder 712 probe cable, ensuring the correct correspondence of the BNC connectors (*Hcur, Hpot, Lpot, Lcur*) with the labels on the cables.
- Connect a probe: push the male and female connectors together until they make contact, then screw the locking caps to secure the cables.
- Connect the IntelliSW™ control box to a USB port
- Power on the IM3536.
- Locate the Conducsens™ folder in the Downloads directory. Open the EXE subdirectory and double-click on EddySens.exe to launch the program.

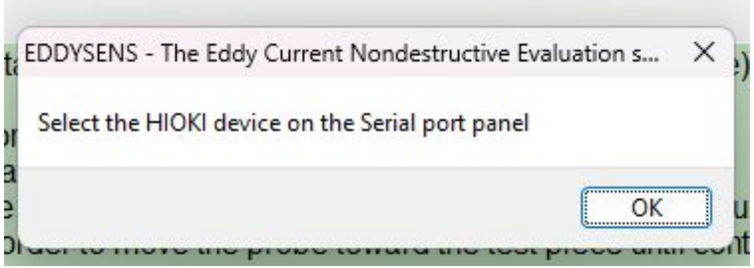
1.5 - Connecting the Measurement Cable

H_{CUR} : red cable
H_{POT} : green cable
L_{POT} : blue cable
L_{CUR} : black cable

1.6 - Launching EddySens

When launching EddySens, the main window appears (see Figure 1 on the next page). A message prompts you to connect the IM3536 device.

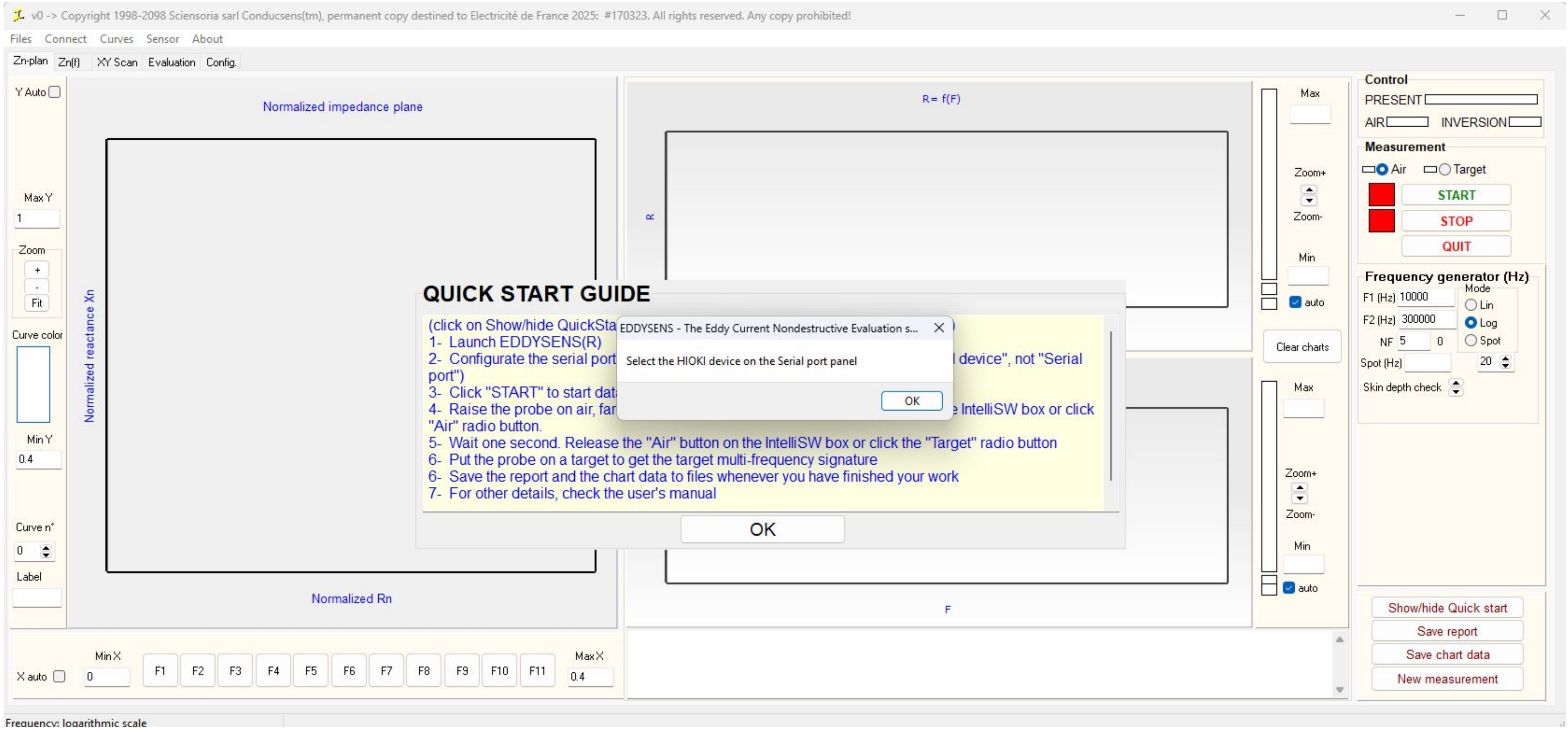
Click OK.



EDDYSENS - The Eddy Current Nondestructive Evaluation s...

Select the HIOKI device on the Serial port panel

1.7 - Startup screen



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Max Y 1

Min Y 0.4

Curve n° 0

Min X 0

Max X 0.4

F1 (Hz) 10000

F2 (Hz) 300000

NF 5 0

Mode: ○ Lin ● Log ○ Spot

Spot (Hz) 20

Measurement: ● Air ○ Target

QUICK START GUIDE

(click on Show/hide QuickSta

1- Launch EDDYSENS(R)

2- Configurate the serial port device", not "Serial port")

3- Click "START" to start dat

4- Raise the probe on air, far e IntelliSW box or click "Air" radio button.

5- Wait one second. Release the "Air" button on the IntelliSW box or click the "Target" radio button

6- Put the probe on a target to get the target multi-frequency signature

6- Save the report and the chart data to files whenever you have finished your work

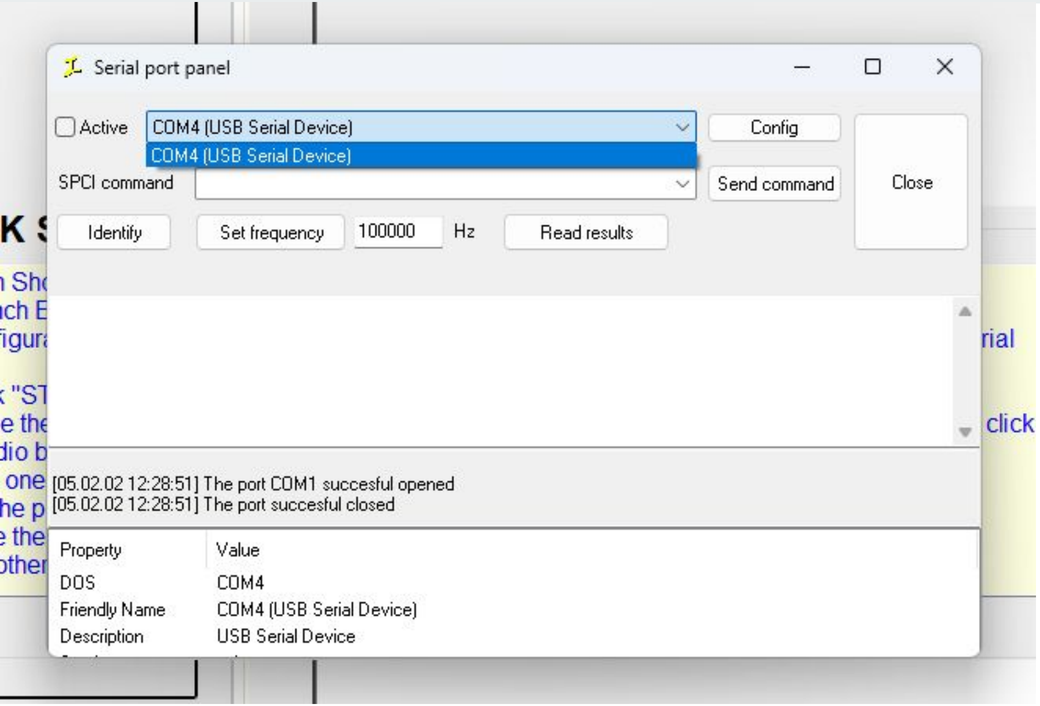
7- For other details, check the user's manual

EDDYSENS - The Eddy Current Nondestructive Evaluation s...

Select the HIOKI device on the Serial port panel

Frequency: logarithmic scale

1.8 - LCR Meter Configuration



☐ Active COM4 (USB Serial Device)

COM4 (USB Serial Device)

SPCI command

100000 Hz

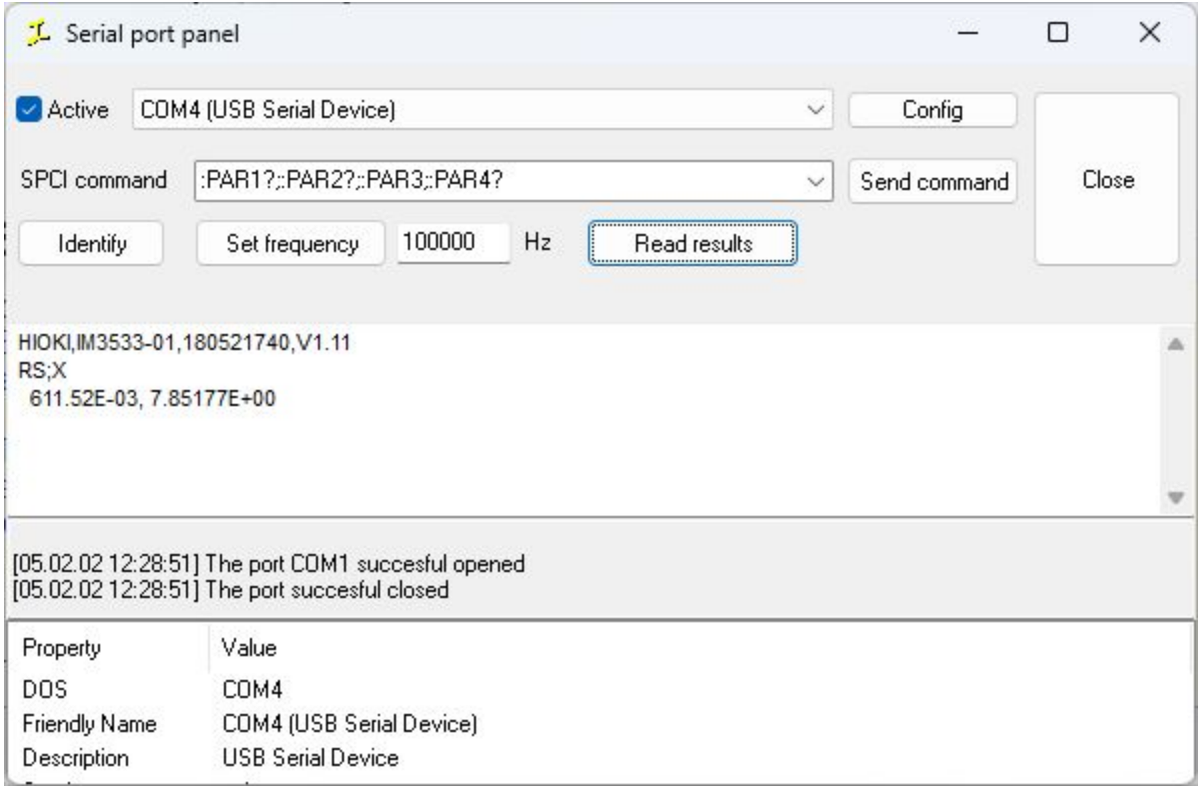
```
[05.02.02 12:28:51] The port COM1 succesful opened
[05.02.02 12:28:51] The port succesful closed
```

Property	Value
DOS	COM4
Friendly Name	COM4 (USB Serial Device)
Description	USB Serial Device

Configuring the USB Connection to the LCR Meter

1. Select the correct device: Choose (USB Serial Device) on COM5. Do not select (USB Serial Port) on COM8 if an external IntelliSW control box is connected.
2. Check port numbers: The assigned COM ports (e.g., COM5, COM8) may vary depending on the computer.
3. Enable communication: Check the "Active" box to establish the connection between the computer and the impedance meter.
4. Configure the virtual serial port: Click Config and adjust the settings to match the LCR meter’s COM port parameters. Refer to the LCR meter user manual for details.
5. Test the connection: Use the following buttons:
   - Identify – Detects the connected LCR meter.
   - Set frequency – Adjusts the measurement frequency.
   - Read results – Retrieves measurement data.
   - Send SCPI command – Manually send SCPI commands (refer to the LCR meter manual).
6. Using the SCPI command box: Type any SCPI command and press Enter or click Send command to execute it over USB.
7. Close the configuration window: Click the Close button when setup is complete.

1.9 - Example of a Successful Connection Window



☑ Active COM4 (USB Serial Device)

SPCI command :PAR1?;:PAR2?;:PAR3;:PAR4?

100000 Hz

```
HIOKI,IM3533-01,180521740,V1.11
RS;X
 611.52E-03, 7.85177E+00
```

```
[05.02.02 12:28:51] The port COM1 succesful opened
[05.02.02 12:28:51] The port succesful closed
```

Property	Value
DOS	COM4
Friendly Name	COM4 (USB Serial Device)
Description	USB Serial Device

The example on the side illustrates a successful connection.

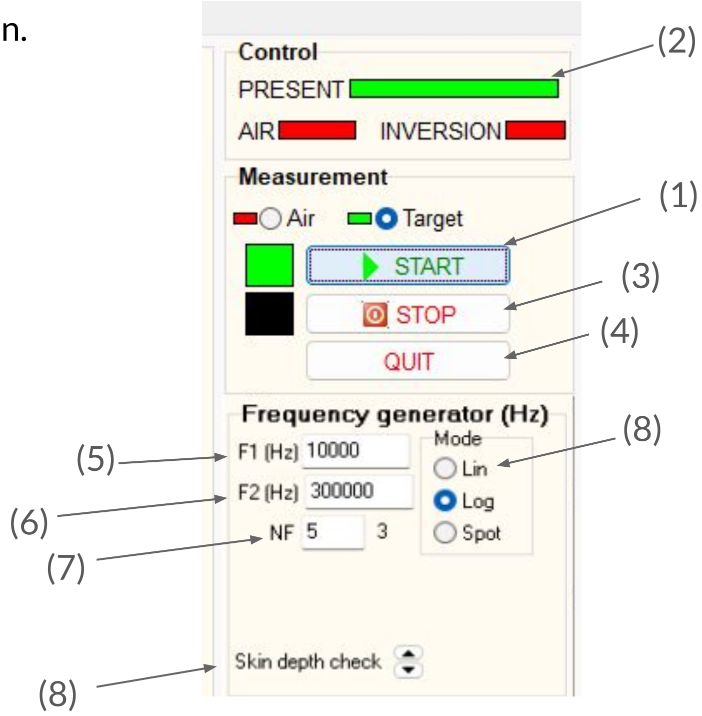
- Connection properties are displayed at the bottom of the window.
- LCR meter responses appear in the middle section of the display.
- When the SCPI composite command :PAR1?;:PAR2?;:PAR3?;:PAR4? is sent, the LCR meter responds with "RS;X", indicating that:
  - RS represents the serial resistance of the probe coil.
  - X represents the reactance of the probe coil.

1.10 - Starting Data Acquisition

- Click the START (1) button to begin data acquisition.
- If the IntelliSW™ control box is connected, the PRESENT (2) rectangle will turn green.
- To stop the acquisition, click on STOP (3).
- To exit EddySens™, click on QUIT (4).

Frequency Sweep:

- Start frequency (F1) (5)
- End frequency (F2) (6)
- Number of frequencies (NF) (7)
- Frequency distribution modes:
  - Linear (Lin)
  - Logarithmic (Log)
  - Single frequency (Spot)
- Skin depth check (8) : test the penetration depth for each used frequency



🟥 ○ Air 🟩 ● Target

F1 (Hz) 10000

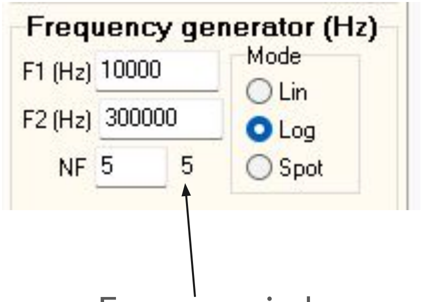
F2 (Hz) 300000

NF 5 3

Mode
○ Lin
● Log
○ Spot

1.11 - Multi-Frequency Acquisition - Normalized Impedance

- When the START button is pressed, the frequency sweep begins: the frequency sequentially takes the values defined in the frequency generator, and its index changes accordingly.
- If the index does not change, it indicates that an issue has occurred, and the acquisition is not proceeding as expected. This could be due to a problem such as the impedance meter not being properly connected to the computer.



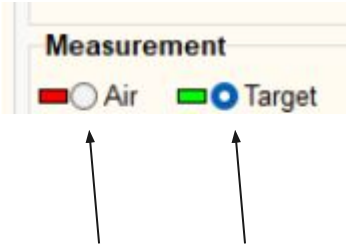
Frequency generator (Hz)

F1 (Hz) 10000
F2 (Hz) 300000
NF 5 5

Mode
○ Lin
● Log
○ Spot

Frequency index

- Normalization Relative to Air Impedance:
  It is very important to normalize the measured impedance relative to its value in air. This is because the EddySens™ calculations rely on the normalized impedance.
- To do this, lift the probe until it is about 10 cm away from any conductive objects, and press the green button on the IntelliSW™. Keep the probe in this position for 1 second after pressing the button.
- If the IntelliSW™ box is not present, check the Air button (1) to take air measurement. Keep the probe in air for 1 second, then check the Target (2) button.
- Then, bring the probe closer to the metallic object to be measured.



Measurement

🟥 ○ Air 🟩 ● Target

(1) (2)

1.12 - Graphical Display of Impedance

- As soon as the START button is clicked, the raw impedance *Z(f)* becomes available. After normalization is performed, the normalized impedance $Z_n(f)$ becomes available.
- The impedance plane Z_{plan} is a polar representation of $Z_n(f)$: the vertical axis represents the values of the imaginary part X_n of $Z_n(f)$, while the horizontal axis represents the values of its real part R_n. Each point corresponds to a pair of (R_n, X_n) at a given frequency

For reference:

$$Z(f) = R(f) + jX(f)$$

and

$$Z_n(f) = R_n(f) + jX_n(f)$$

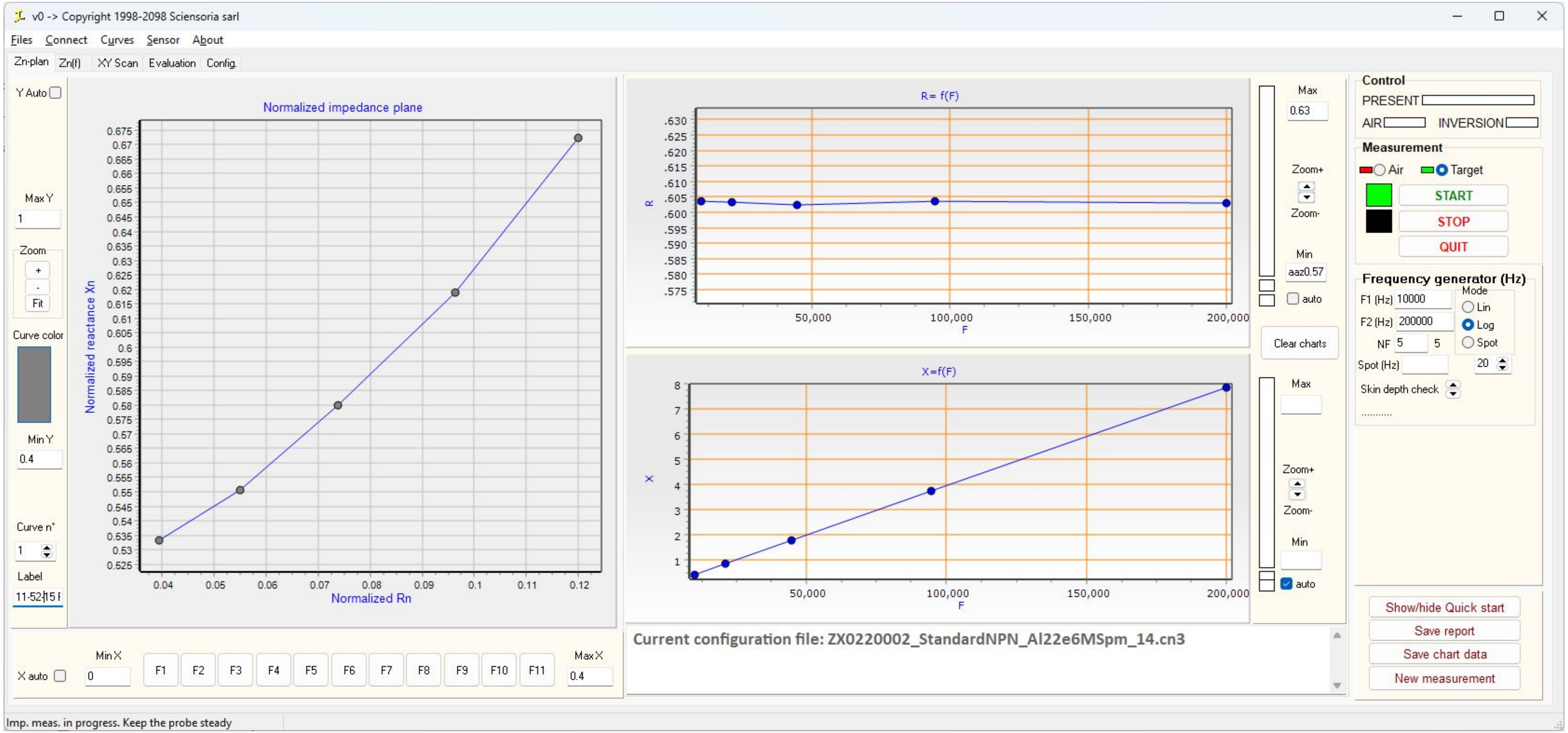
with

$$R_n = \frac{R(f) - R_{\text{air}}(f)}{X_{\text{air}}(f)}$$

and

$$X_n = \frac{X(f)}{X_{\text{air}}(f)}$$

1.13 - Impedance Plots



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Max Y: 1

Min Y: 0.4

Curve n°: 1

Label: 11-52-15 F

Min X: 0

Max X: 0.4

Max: 0.63

Min: aaz0.57

○ Air ● Target

Frequency generator (Hz)

F1 (Hz): 10000

F2 (Hz): 200000

NF: 5 5

Mode: ○ Lin ● Log ○ Spot

Spot (Hz): 20

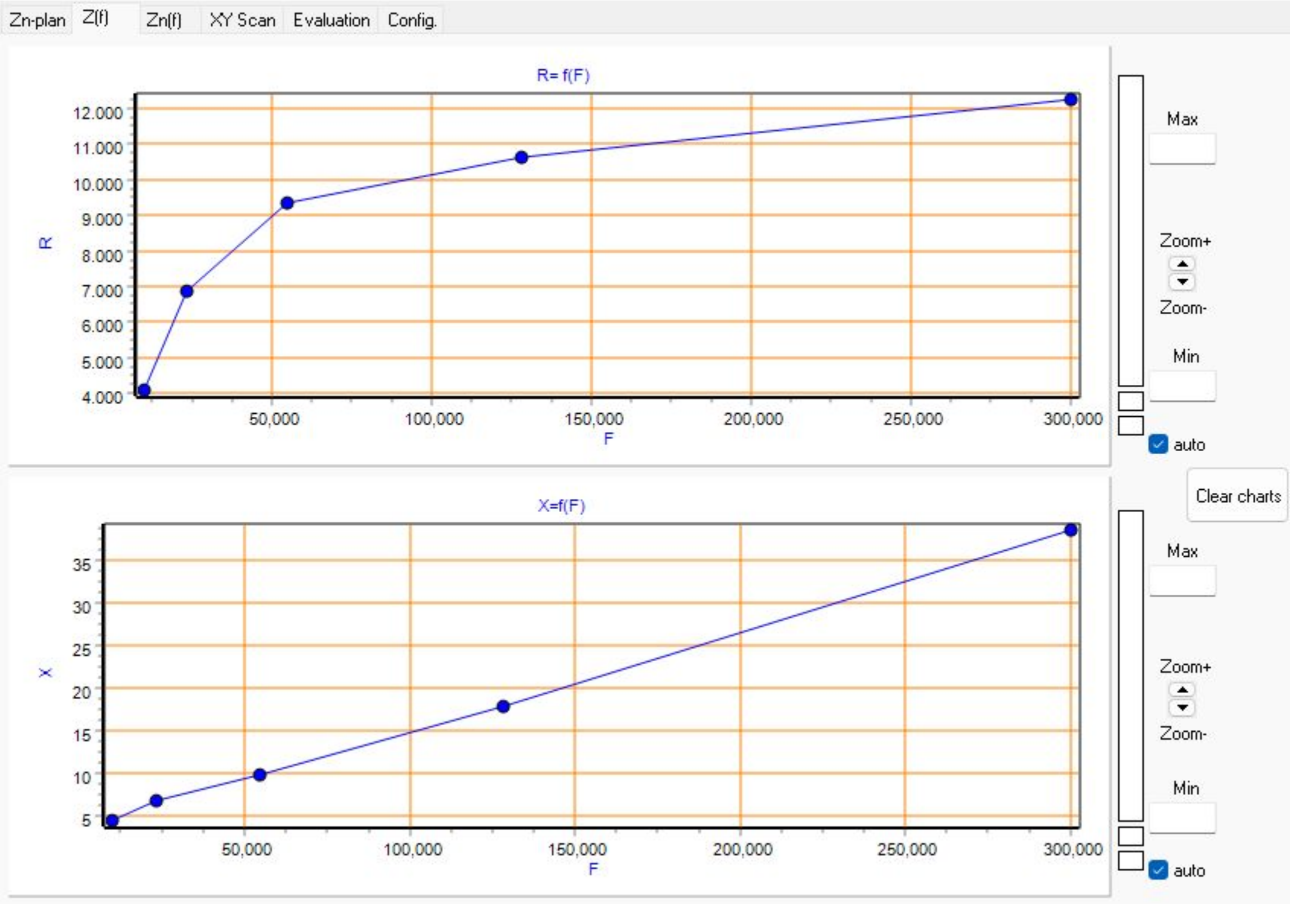
Skin depth check

....

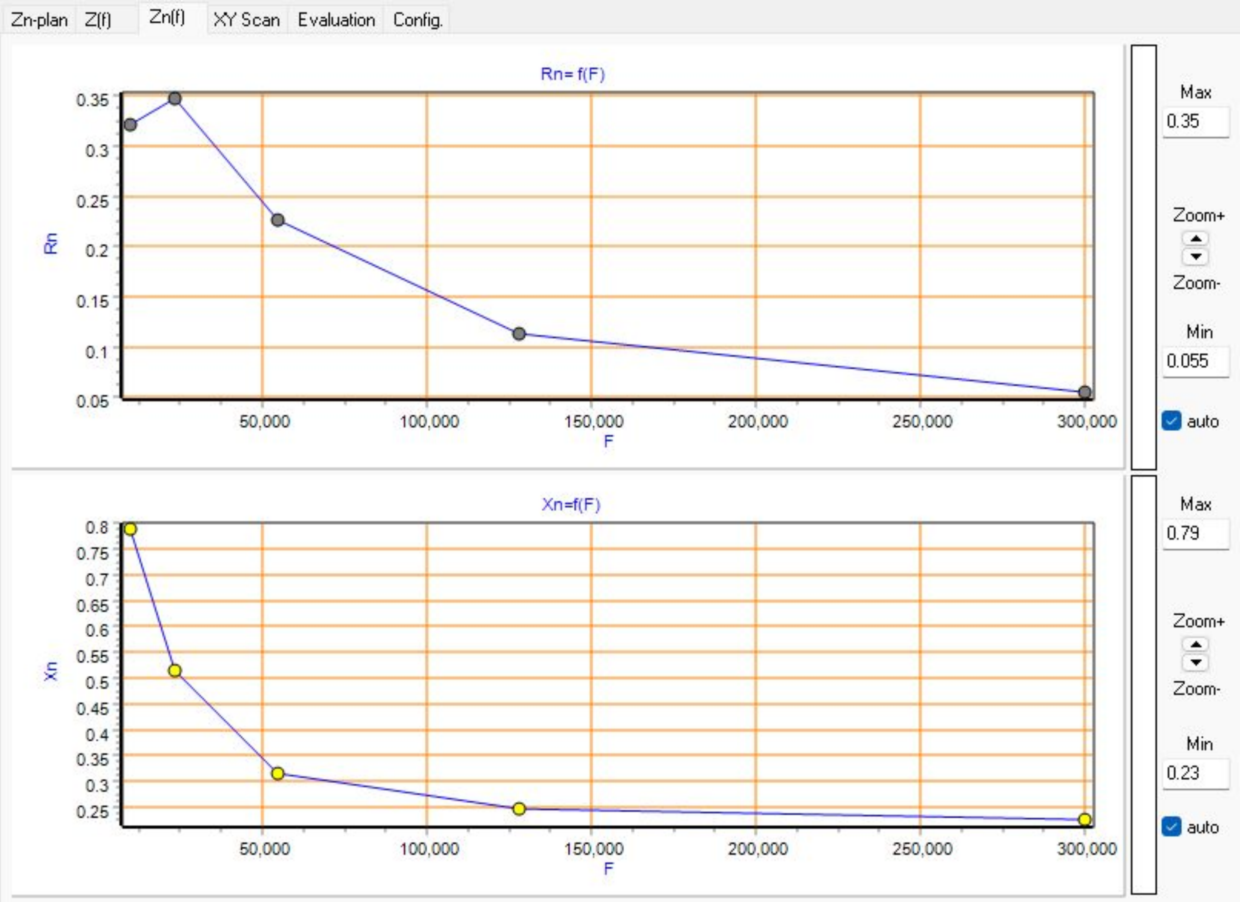
Current configuration file: ZX0220002_StandardNPN_Al22e6MSpm_14.cn3

Imp. meas. in progress. Keep the probe steady

1.14 - Impedance Z(f) vs. frequency



1.15 - Normalized impedance Zn(f) vs. frequency



Max 0.35

Min 0.055

☑ auto

Max 0.79

Min 0.23

☑ auto

1.16 - Normalized Impedance Plane

Check to set the Y-axis to automatic (adjusted to the signal)

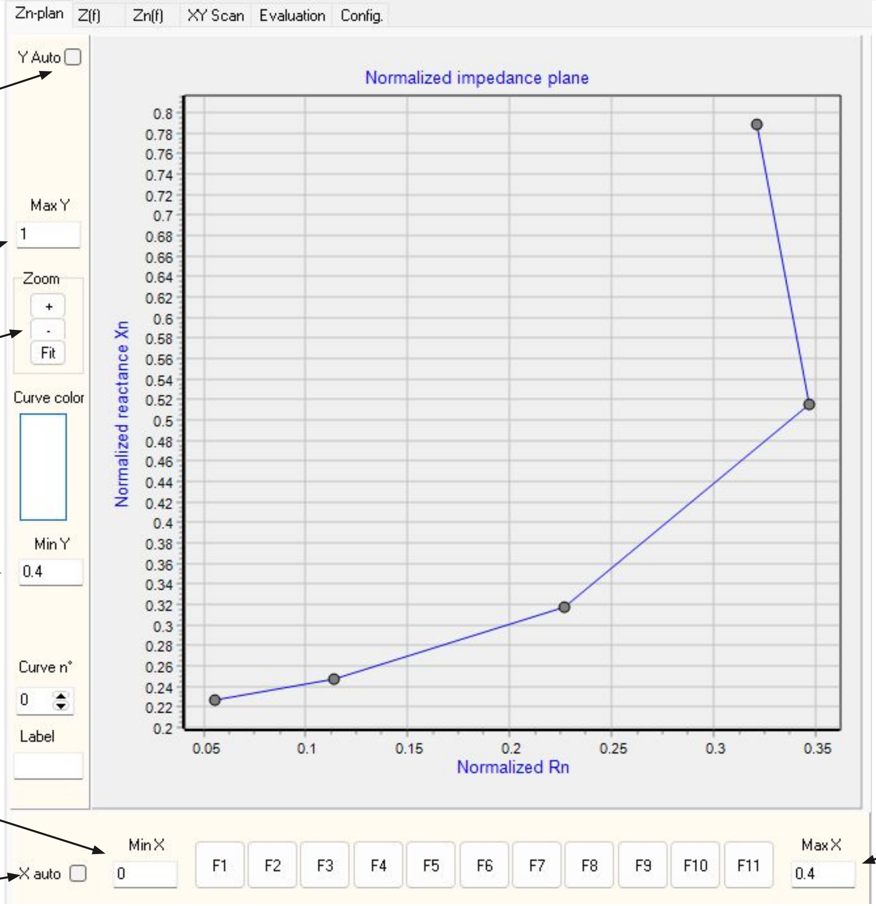
Set the maximum value of the Y-axis

Zoom: zoom in (+), zoom out (-), and fit (Fit)

Set the minimum value of the Y-axis

Set the minimum value of the Y-axis

Check to set the X-axis to automatic (adjusted to the signal)



Tips:

- Double-click the F1 button: adjust the curves on the screen, then freeze the axes.
- Press F2: clear all curves.
- Press F4: zoom in on the display.
- Press F5: zoom out on the display.

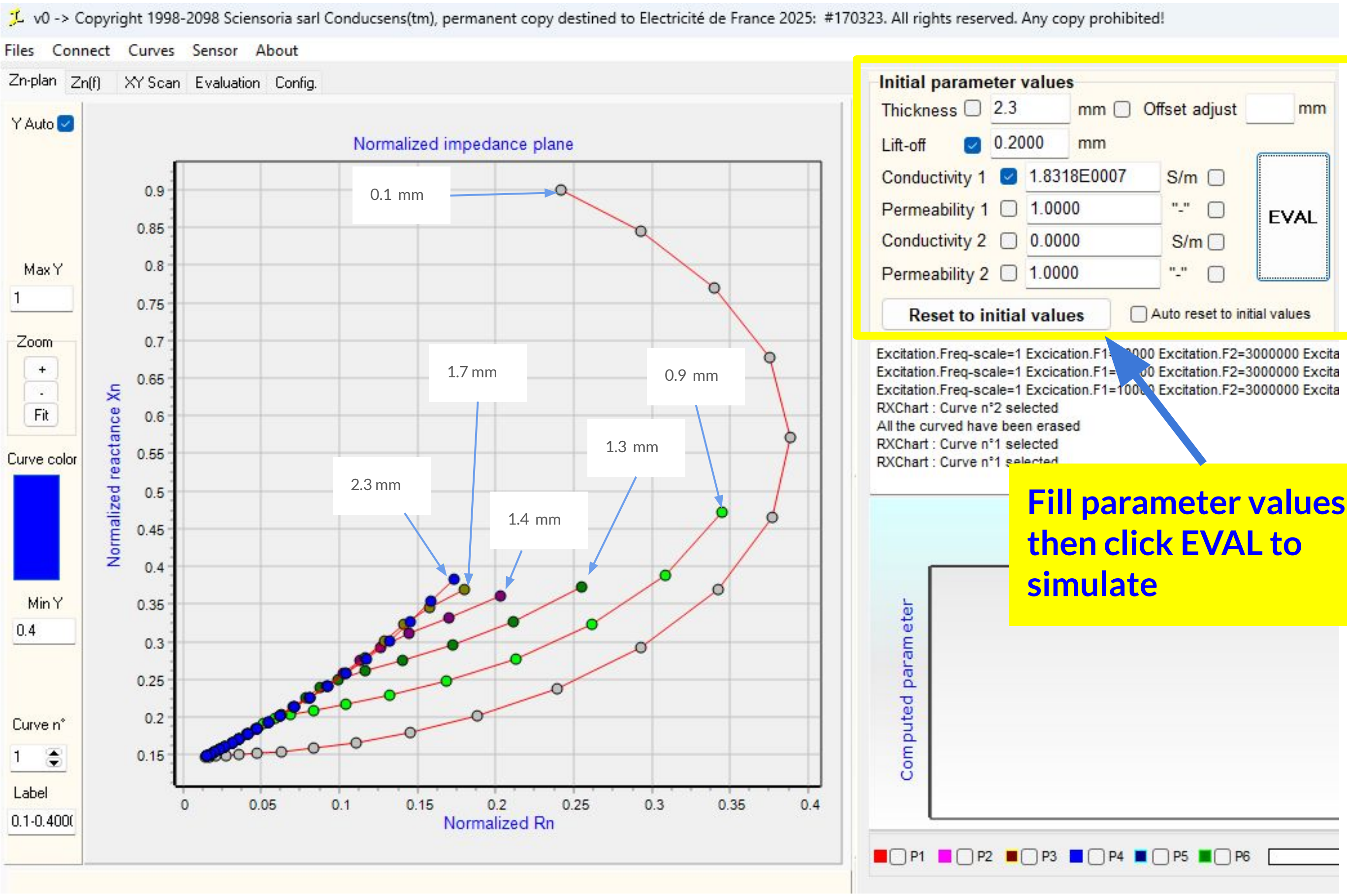
2.1 - Simulation of the Impedance Plane

Important: hit F2 to show the measurement panel.

Normalized impedance plane evolution for different *aluminum alloy sheet thicknesses.*

<u>Frequency:</u>
20 logarithmically spaced values from 10 kHz to 3 MHz

<u>Probe coil:</u>
D_{int} = 2 mm
D_{ext} = 10 mm
Height= 0.2 mm



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Initial parameter values

Thickness ☐ 2.3 mm ☐ Offset adjust mm

Lift-off ☑ 0.2000 mm

Conductivity 1 ☑ 1.8318E0007 S/m ☐

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

EVAL

Reset to initial values

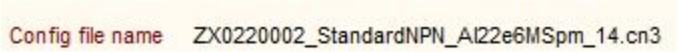
☐ Auto reset to initial values

```
Excitation.Freq-scale=1 Excication.F1=[illegible] Excitation.F2=3000000 Excita
Excitation.Freq-scale=1 Excication.F1=[illegible] Excitation.F2=3000000 Excita
Excitation.Freq-scale=1 Excication.F1=100[illegible] Excitation.F2=3000000 Excita
RXChart : Curve n°2 selected
All the curved have been erased
RXChart : Curve n°1 selected
RXChart : Curve n°1 selected
```

Fill parameter values, then click EVAL to simulate

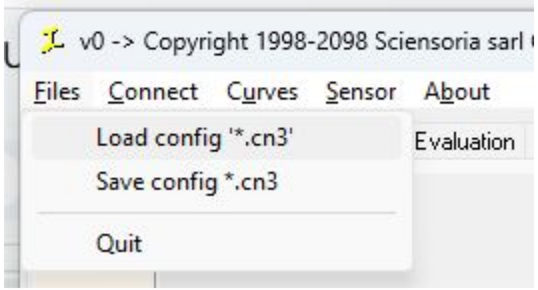
2.2 - Loading a Configuration File

When the program starts, it automatically loads a default configuration file, **ZX0220002_StandardNPN_Al22e6MSpm_14.cn3**.



Config file name ZX0220002_StandardNPN_Al22e6MSpm_14.cn3

To load a configuration file that matches the probe in use, go to Files → Load config (*.cn3) in the top menu bar.



This allows you to select the probe's characteristics and define the material parameters. These parameters should closely match those of the material being measured.

For example, if the material is a solid aluminum alloy block, you should load a configuration file with:

- Thickness: 10 mm
- Electrical conductivity: 22.643 MS/m
- Relative magnetic permeability: 1

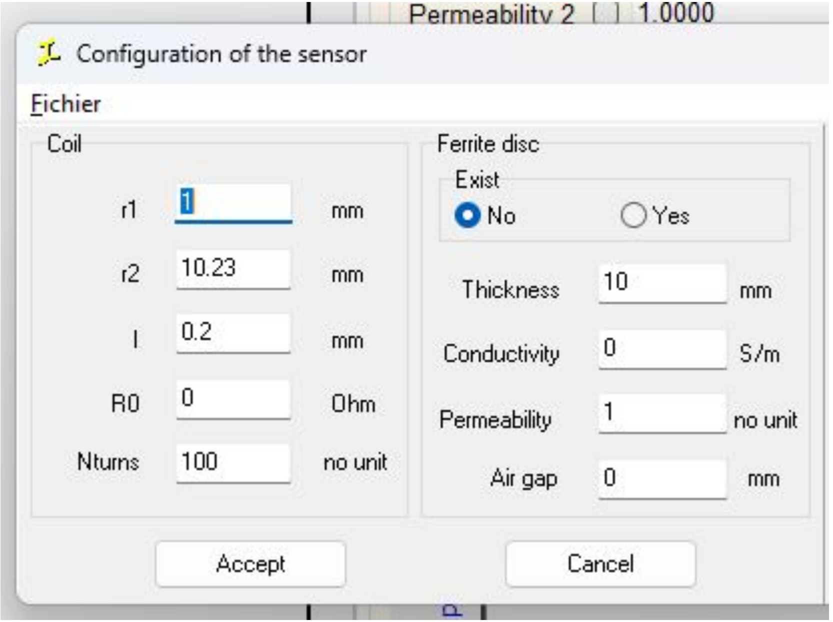
2.3 - Configuration File Parameters (continued)

Probe-Related Parameters:

- Internal radius of the coil (r1)
- External radius of the coil (r2)
- Length of the coil (l)
- Ohmic resistance of the coil (R0)
- Number of turns of the coil (Nturns)

If the probe includes a ferrite disc (Exist = Yes), the following disc parameters must be defined:

- Disc thickness (Thickness)
- Electrical conductivity of the disc (Conductivity)
- Magnetic permeability of the disc (Permeability)
- Thickness between the coil and the disc (Air gap)



Coil

r1	1	mm
r2	10.23	mm
l	0.2	mm
R0	0	Ohm
Nturns	100	no unit

Ferrite disc

Exist: ● No ○ Yes

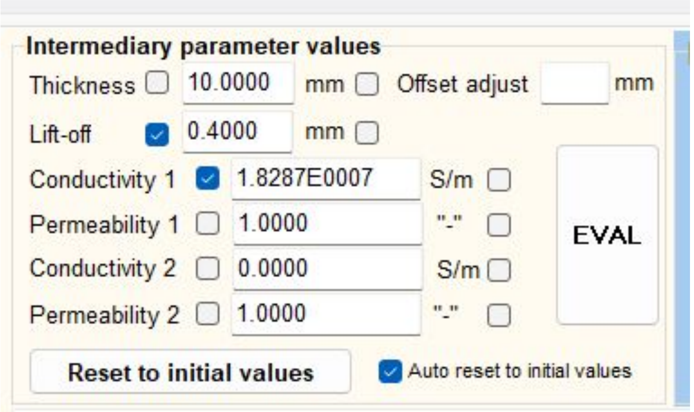
Thickness	10	mm
Conductivity	0	S/m
Permeability	1	no unit
Air gap	0	mm

2.4 - Configuration File Parameters

Material-Related Parameters:

- Thickness (Épaisseur)
- Coating Electrical Conductivity (Conductivity 1)
- Coating Relative Magnetic Permeability (Permeability 1)
- Base Electrical Conductivity (Conductivity 2)
- Base Relative Magnetic Permeability (Permeability 2)

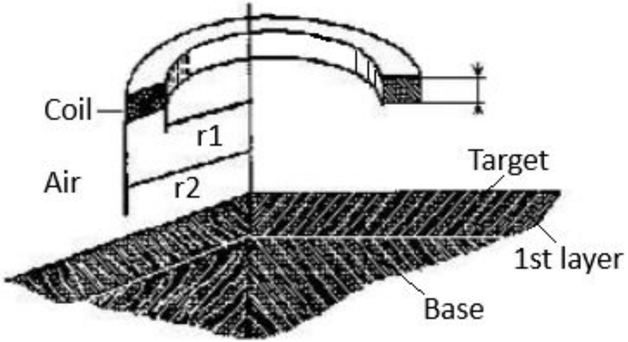
The base is considered infinitely thick.



Intermediary parameter values

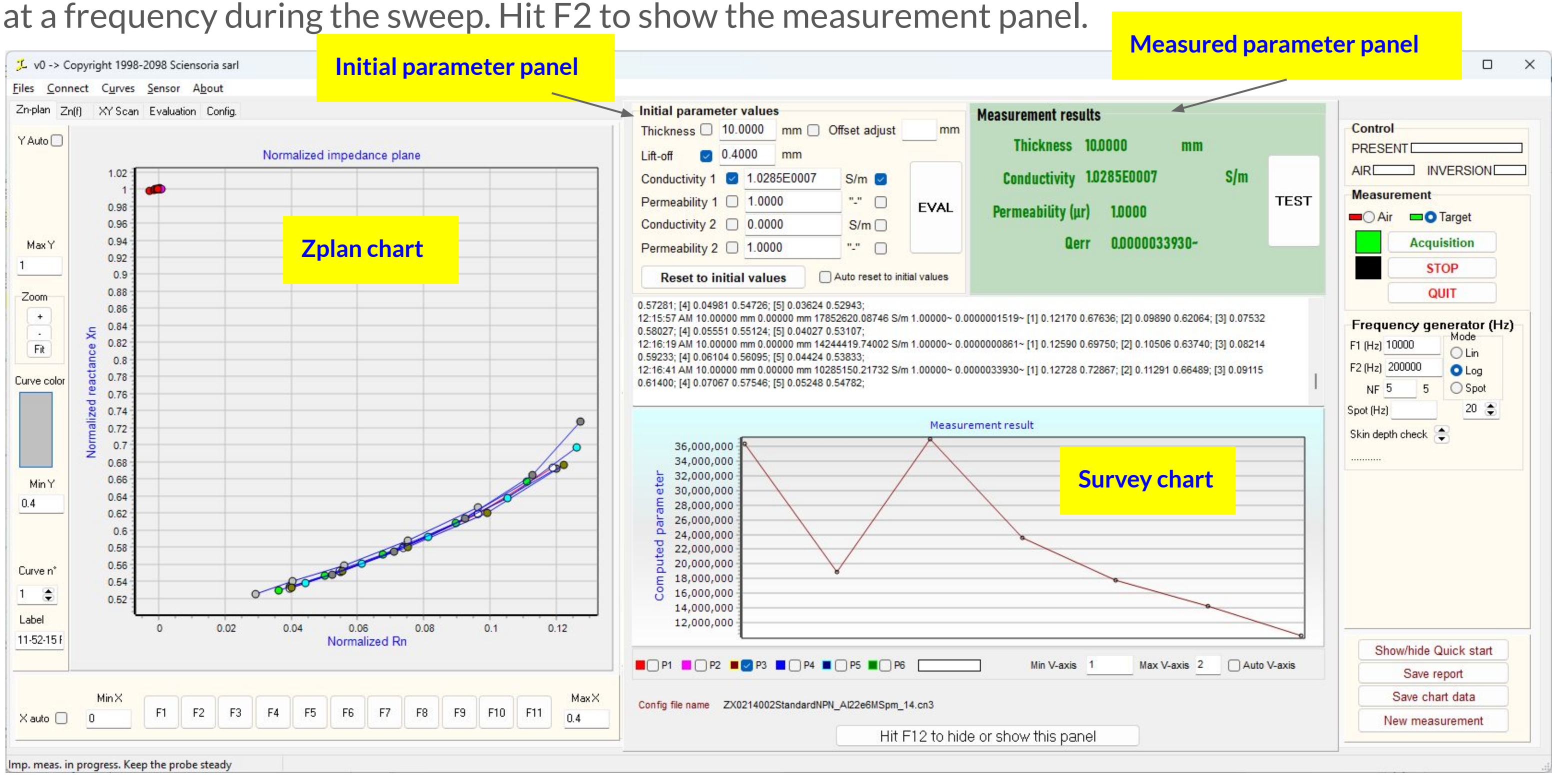
Thickness ☐	10.0000	mm ☐	Offset adjust	mm
Lift-off ☑	0.4000	mm ☐		
Conductivity 1 ☑	1.8287E0007	S/m ☐		
Permeability 1 ☐	1.0000	"-" ☐		
Conductivity 2 ☐	0.0000	S/m ☐		
Permeability 2 ☐	1.0000	"-" ☐		

☑ Auto reset to initial values



2.5 - Measurement of material parameters

Once a normalized impedance curve has been obtained, as shown on the screen below, you can proceed with the measurement of parameters. The curve consists of several points, each representing the complex normalized impedance acquired at a frequency during the sweep. Hit F2 to show the measurement panel.



Initial parameter values

Thickness ☐ 10.0000 mm ☐ Offset adjust mm

Lift-off ☑ 0.4000 mm

Conductivity 1 ☑ 1.0285E0007 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

Measurement results

Thickness 10.0000 mm

Conductivity 1.0285E0007 S/m

Permeability (µr) 1.0000

Qerr 0.0000033930~

```
0.57281; [4] 0.04981 0.54726; [5] 0.03624 0.52943;
12:15:57 AM 10.00000 mm 0.00000 mm 17852620.08746 S/m 1.00000~ 0.0000001519~ [1] 0.12170 0.67636; [2] 0.09890 0.62064; [3] 0.07532
0.58027; [4] 0.05551 0.55124; [5] 0.04027 0.53107;
12:16:19 AM 10.00000 mm 0.00000 mm 14244419.74002 S/m 1.00000~ 0.0000000861~ [1] 0.12590 0.69750; [2] 0.10506 0.63740; [3] 0.08214
0.59233; [4] 0.06104 0.56095; [5] 0.04424 0.53833;
12:16:41 AM 10.00000 mm 0.00000 mm 10285150.21732 S/m 1.00000~ 0.0000033930~ [1] 0.12728 0.72867; [2] 0.11291 0.66489; [3] 0.09115
0.61400; [4] 0.07067 0.57546; [5] 0.05248 0.54782;
```

Max Y 1 · Min Y 0.4 · Curve n° 1 · Label 11-52-15 · X auto ☐ · Min X 0 · Max X 0.4

☑ P3 · Min V-axis 1 · Max V-axis 2 · ☐ Auto V-axis

Config file name ZX0214002StandardNPN_Al22e6MSpm_14.cn3

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 200000

NF 5 5

Spot (Hz)

Mode: ○ Lin ● Log ○ Spot

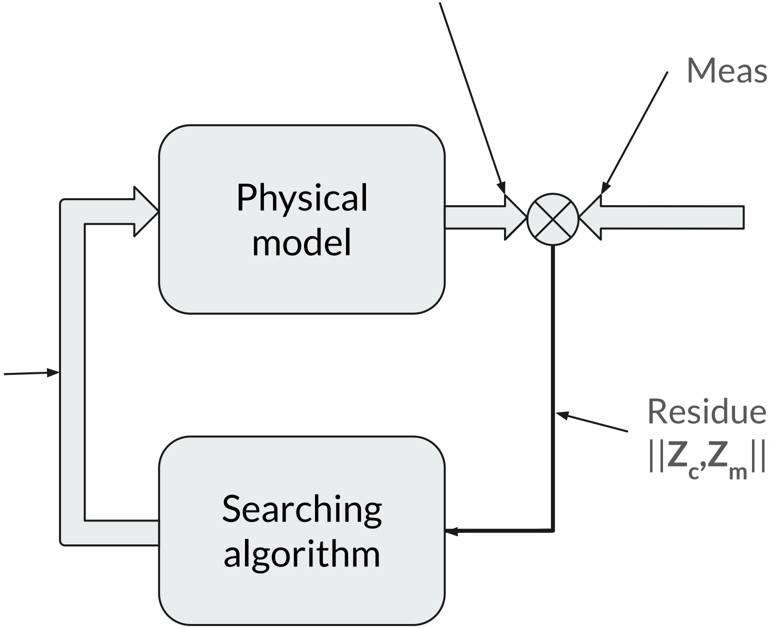
20

Skin depth check

Imp. meas. in progress. Keep the probe steady

3.1 - Operating principle of Conducsens™

Iterative algorithm for finding target parameters using a physical model of the probe-target system



Computed impedance $\mathbf{Z}_c$

Measured Impedance $\mathbf{Z}_m$

Physical model

Estimated parameters **P**

Residue **ε** (difference $||\mathbf{Z}_c, \mathbf{Z}_m||$)

Searching algorithm

The search continues until the residual ε is sufficiently small or no longer decreases. The amplitude of the residual allows for evaluating the quality of the search.

3.2 - Operating principle of ConducSens™ (continued)

Once the inversion process is started, the software will attempt to match the measured impedance curve to the target curve by adjusting the parameters iteratively. The system uses the defined physical model and the initial parameters to calculate the optimal values for the target material.

During this process, the parameters may be adjusted until the impedance curve from the physical model closely matches the measured impedance curve. Once the curves align sufficiently, the process is considered complete, and the parameters are updated accordingly.

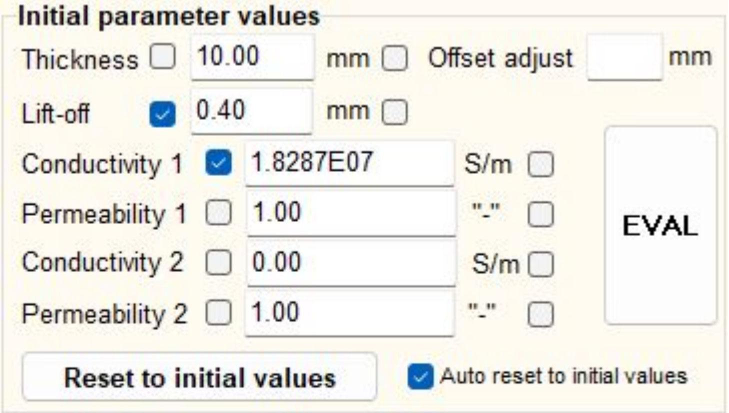
The residue characterizes Qerr represents the quality of the search process. It is the difference between the measured impedance and the calculated impedance based on the current parameters. A smaller residue indicates that the current parameter values are closer to the optimal solution, while a larger residue suggests that further iterations or adjustments are needed to improve the accuracy of the model. The goal of the iterative algorithm is to minimize the residue to achieve the best match between the measured and calculated impedance.

3.3 - Providing the initial values

The measurement principle is based on the iterative search for an optimal solution using a physical model of the probe-target system. When the multi-frequency impedance measured is sufficiently close to that calculated by the model, the solution is considered to be found.

To begin, the initial values of the target parameters (measured material) must be entered. The target is represented by 6 parameters:

- Thickness (coating layer thickness) (denoted by P1)
- Lift-off: probe-target distance (denoted by P2)
- Conductivity 1: electrical conductivity of the coating (denoted by P3)
- Permeability 1: relative magnetic permeability of the coating (denoted by P4)
- Conductivity 2: electrical conductivity of the base (denoted by P5)
- Permeability 2: relative magnetic permeability of the base (denoted by P6)



Initial parameter values

Thickness ☐ 10.00 mm ☐ Offset adjust mm
Lift-off ☑ 0.40 mm ☐
Conductivity 1 ☑ 1.8287E07 S/m ☐
Permeability 1 ☐ 1.00 "-" ☐
Conductivity 2 ☐ 0.00 S/m ☐
Permeability 2 ☐ 1.00 "-" ☐
☑ Auto reset to initial values

Important: Check the boxes preceding the parameters to define them as variables. Otherwise, they will be considered constant and will not be included in the calculation. Also check the case following a parameter to include it to the Survey chart underneath.

In the example shown in the image, electrical conductivity and probe-to-target distance are defined as variables.

The "Reset to initial values" button allows you to restore the parameter values to the initial values recorded in the configuration file. The EVAL button calculates the normalized impedance curve corresponding to the specified initial values.

3.4 - The Importance of Initial Values

Important : the initial parameter values must be sufficiently close to the target parameters; otherwise, the search may not converge.

<u>Note:</u>

- Blue parameters are variables.
- Black parameters are constants.

Examples of Initial Values:

1️⃣Measuring the conductivity of solid aluminum

- P1 = 10 mm, P2 = 0.5 mm, P3 = 20×10^{6} S/m, P4 = 1, P5 = 0, P6 = 1
- Justification: Due to the limited penetration of eddy currents, a thickness of 10 mm is representative of a solid aluminum block.

2️⃣Measuring the conductivity of solid 316L stainless steel

- P1 = 10 mm, P2 = 0.5 mm, P3 = 1×10^{6} S/m, P4 = 1, P5 = 0, P6 = 1

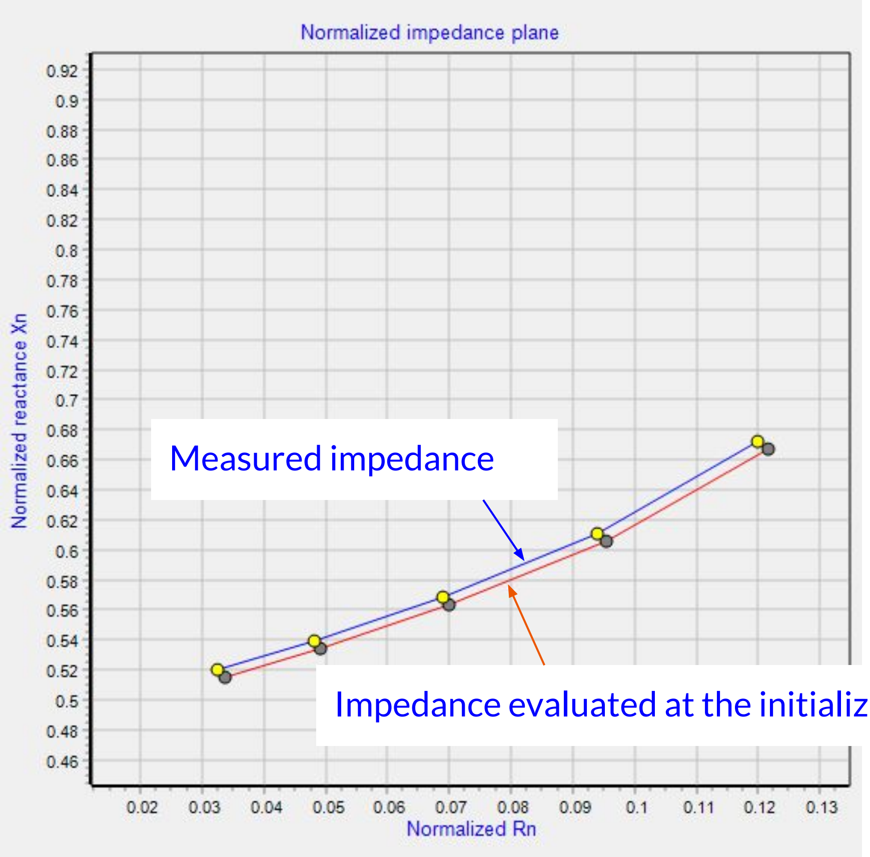
3️⃣Measuring the conductivity and permeability of solid 316L stainless steel

- P1 = 200 mm, P2 = 0.5 mm, P3 = 1×10^{6} S/m, P4 = 1, P5 = 0, P6 = 1
- Justification: Since 316L stainless steel is less conductive than aluminum, a 200 mm thickness represents a solid block.

4️⃣Measuring the thickness and conductivity of a 316L stainless steel tube with a nominal thickness of 1.8 mm

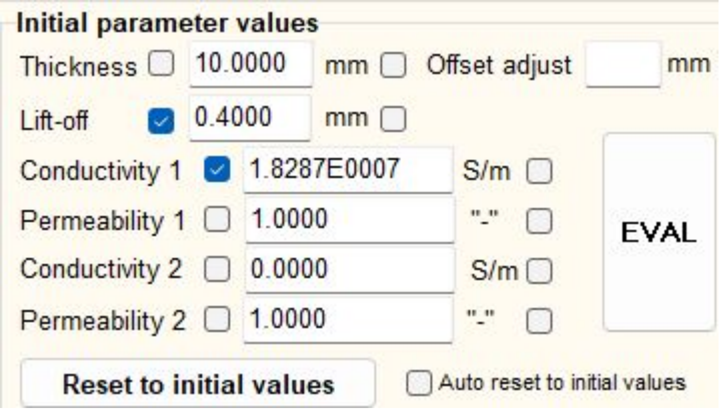
- P1 = 1,8 mm, P2 = 0.5 mm, P3 = 1×10^{6} S/m, P4 = 1, P5 = 0, P6 = 1
- Justification: The thickness is initially set to the nominal tube value to determine the actual thickness after wear or corrosion. The real thickness will always be smaller. Setting P1 to 10 mm (as in the solid block case) would mislead the algorithm, as eddy current signals have low sensitivity to thickness variations at that depth.

3.5 - Testing the Initial Values



Measured impedance

Impedance evaluated at the initialization point


Initial parameter values

Thickness ☐ 10.0000 mm ☐ Offset adjust mm

Lift-off ☑ 0.4000 mm ☐

Conductivity 1 ☑ 1.8287E0007 S/m ☐

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

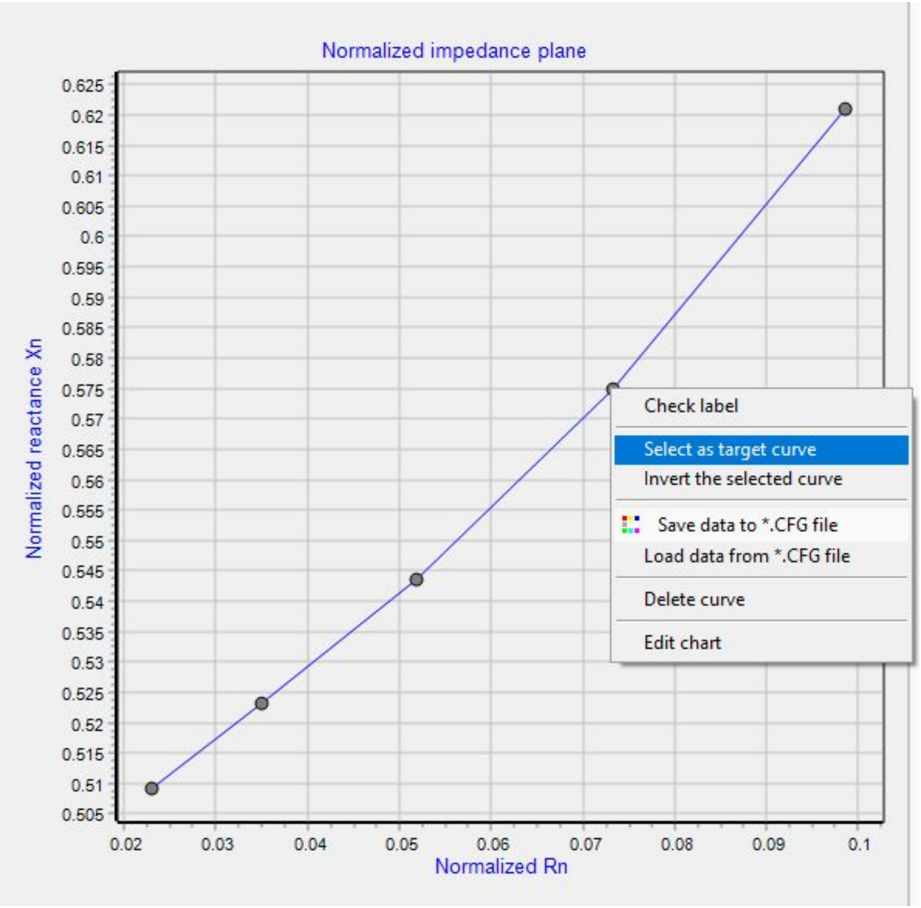
Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

After entering the initial values of the target parameters, press the EVAL button to compute the impedance corresponding to this initialization point.

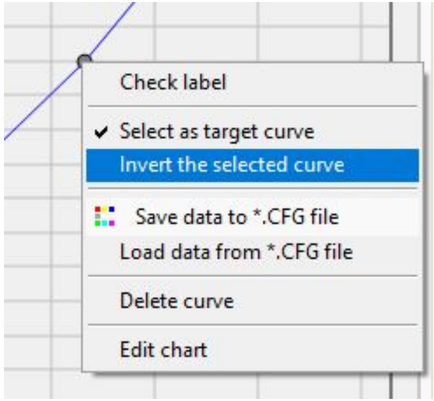
In the example shown in the image on the left, the initialization appears to be very close to reality, making it favorable.

3.6 - Inversion of measured impedance - Manual inversion

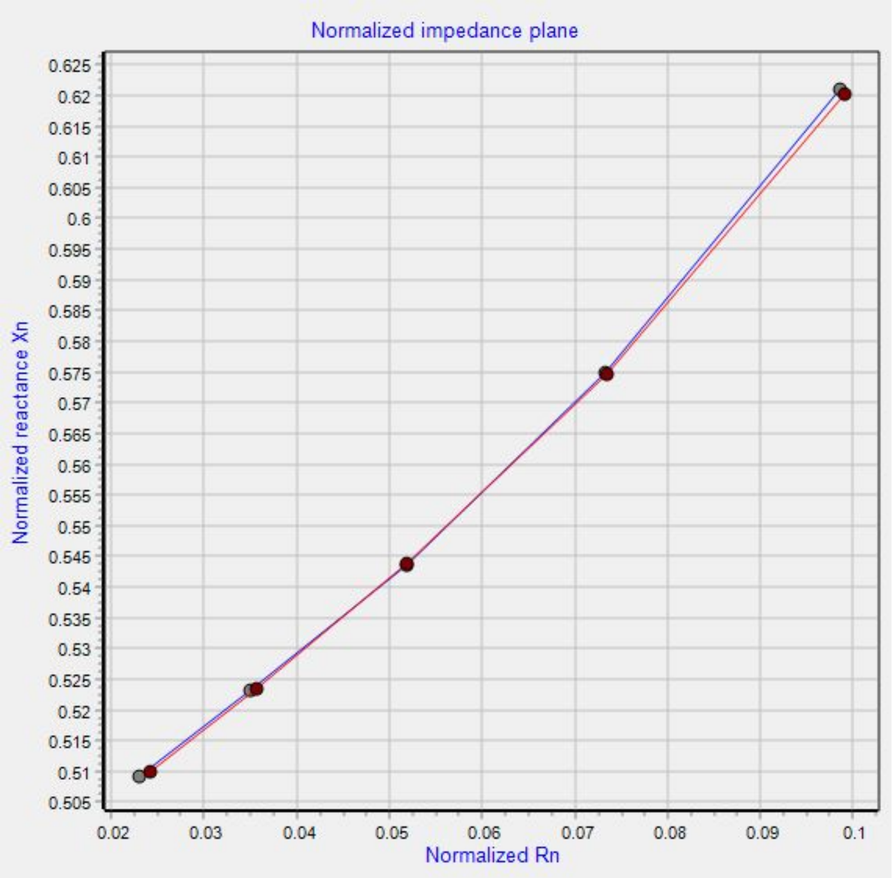


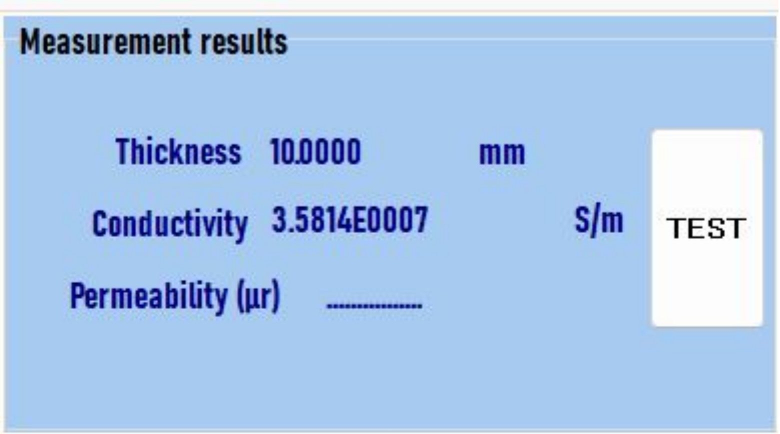
Manual inversion:

1. Stop the acquisition to freeze the curve by clicking the STOP button or pressing the Esc key on the keyboard.
2. Right-click on the frozen impedance curve displayed on the screen, then select the "Select as target curve" option.
3. Right-click again and choose the "Invert the selected curve" command as shown below. The inversion process will begin.



3.7 - Manual inversion (continued)





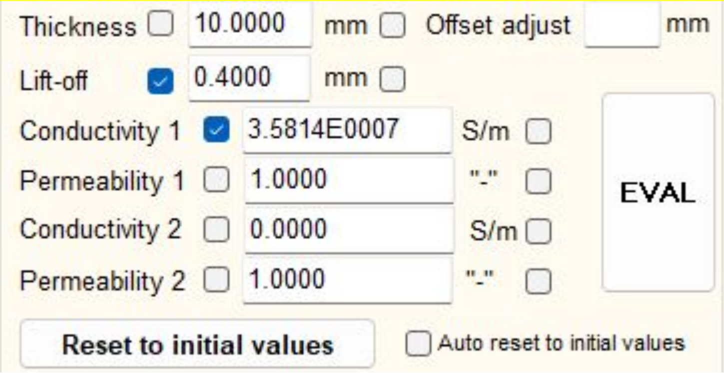
Measurement results

Thickness 10.0000 mm

Conductivity 3.5814E0007 S/m

Permeability (µr) ....

Note: do not forget to configure beforehand (as shown below).



Thickness ☐ 10.0000 mm ☐ Offset adjust mm

Lift-off ☑ 0.4000 mm ☐

Conductivity 1 ☑ 3.5814E0007 S/m ☐

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

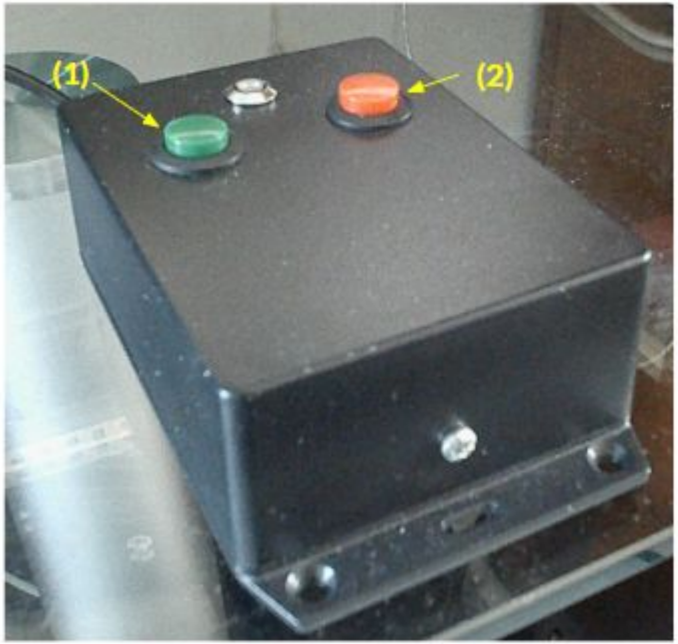
3.8 - Continuous Inversion with IntelliSW™

⇨ Manual inversion requires stopping the acquisition, selecting the impedance curve, and then initiating the inversion with the mouse.

➡ Continuous inversion allows for the continuous calculation of the target parameters by pressing the red button (2) on the IntelliSW™ box. This enables the inspection of different points on the target continuously, making it easier to observe variations.

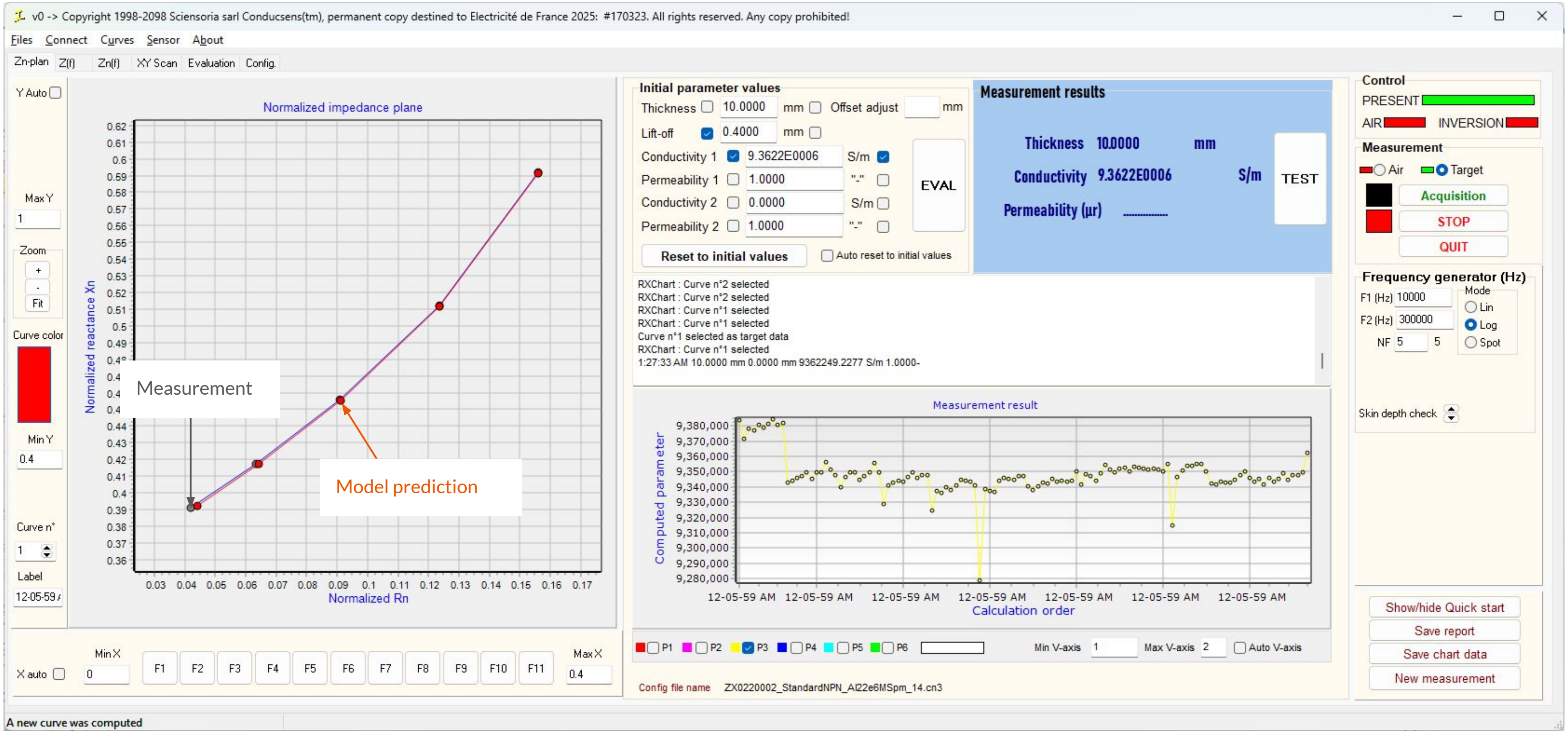
To perform continuous inversion, press the "Inversion" button (red button) on the IntelliSW™ box while the probe is positioned in front of the target.

<u>Note:</u> **It is recommended to lift the probe into the air and press the "Air" button (green button) (1) on the IntelliSW™ box beforehand to eliminate any low-frequency drift from the impedance meter.**



IntelliSW™ control box

3.9 - Measurement on a NPL's standard (16.17% IACS 9.38 MS/m)



Measurement

Model prediction

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Initial parameter values

Thickness ☐ 10.0000 mm ☐ Offset adjust mm

Lift-off ☑ 0.4000 mm ☐

Conductivity 1 ☑ 9.3622E0006 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

Measurement results

Thickness 10.0000 mm

Conductivity 9.3622E0006 S/m

Permeability (µr) ....

```
RXChart : Curve n°2 selected
RXChart : Curve n°2 selected
RXChart : Curve n°1 selected
RXChart : Curve n°1 selected
Curve n°1 selected as target data
RXChart : Curve n°1 selected
1:27:33 AM 10.0000 mm 0.0000 mm 9362249.2277 S/m 1.0000-
```

Measurement: ○ Air ● Target

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 300000

NF 5 5

Mode: ○ Lin ● Log ○ Spot

Y Auto ☐

Max Y 1

Min Y 0.4

Curve n° 1

Label 12-05-59 /

X auto ☐ Min X 0 Max X 0.4

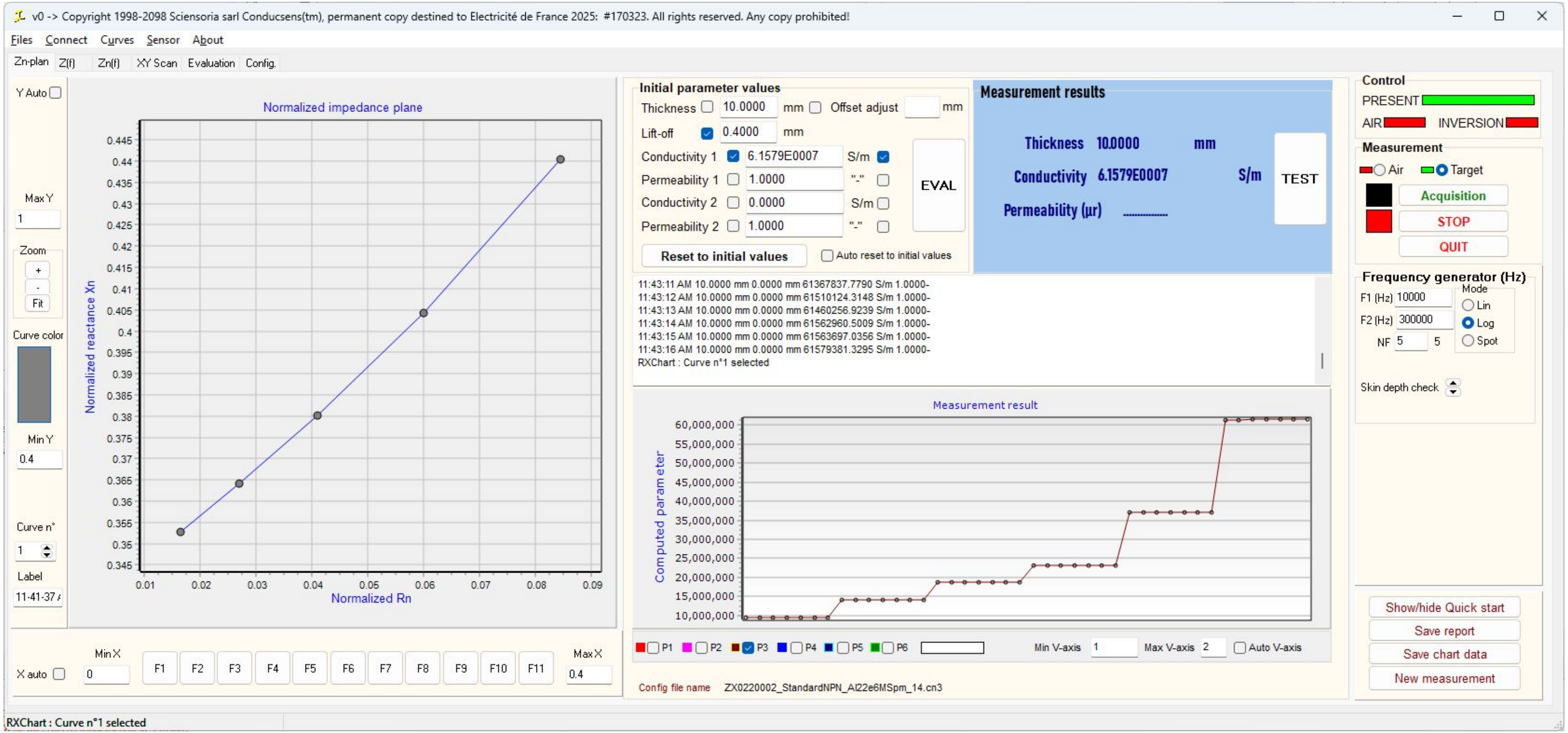
☐ P1 ☐ P2 ☑ P3 ☐ P4 ☐ P5 ☐ P6

Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0220002_StandardNPN_Al22e6MSpm_14.cn3

A new curve was computed

3.10 - Measurement of electrical conductivity on NPL's standards



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Initial parameter values

Thickness ☐ 10.0000 mm ☐ Offset adjust mm

Lift-off ☑ 0.4000 mm

Conductivity 1 ☑ 6.1579E0007 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

Measurement results

Thickness 10.0000 mm

Conductivity 6.1579E0007 S/m

Permeability (µr) ....

```
11:43:11 AM 10.0000 mm 0.0000 mm 61367837.7790 S/m 1.0000-
11:43:12 AM 10.0000 mm 0.0000 mm 61510124.3148 S/m 1.0000-
11:43:13 AM 10.0000 mm 0.0000 mm 61460256.9239 S/m 1.0000-
11:43:14 AM 10.0000 mm 0.0000 mm 61562960.5009 S/m 1.0000-
11:43:15 AM 10.0000 mm 0.0000 mm 61563697.0356 S/m 1.0000-
11:43:16 AM 10.0000 mm 0.0000 mm 61579381.3295 S/m 1.0000-
RXChart : Curve n°1 selected
```

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 300000

NF 5 5

Mode: ○ Lin ● Log ○ Spot

Measurement: ○ Air ● Target

Y Auto ☐ Max Y 1 Min Y 0.4 Curve n° 1 Label 11-41-37

X auto ☐ Min X 0 Max X 0.4

Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

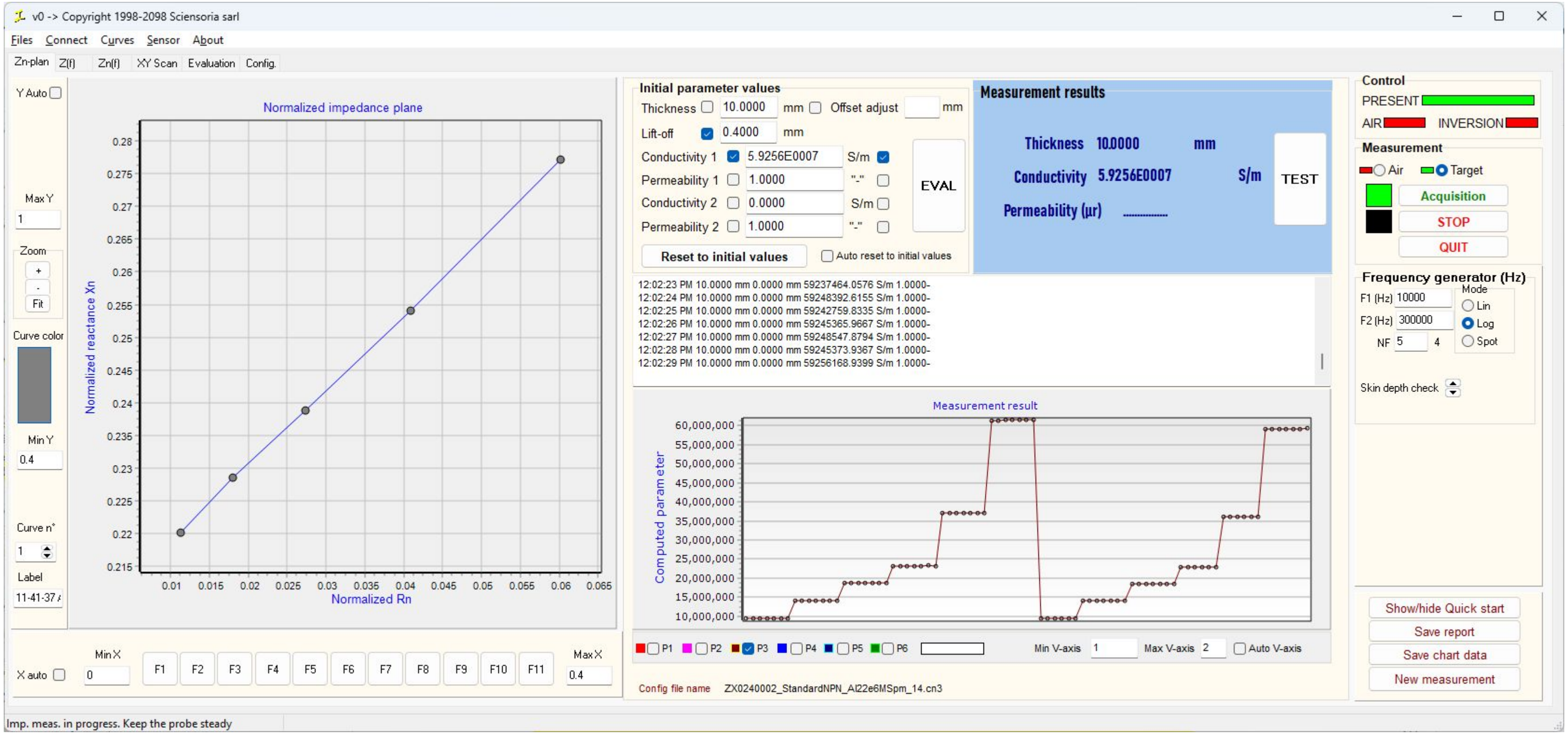
☐ P1 ☐ P2 ☑ P3 ☐ P4 ☐ P5 ☐ P6

Config file name ZX0220002_StandardNPN_Al22e6MSpm_14.cn3

RXChart : Curve n°1 selected

Probe ZX0220002-EDF2024-1

3.11 - Measurement of electrical conductivity on NPL's standards using two different probes



Max Y: 1

Min Y: 0.4

Curve n°: 1

Label: 11-41-37

X auto ☐ Min X: 0 Max X: 0.4

Initial parameter values

Thickness ☐ 10.0000 mm ☐ Offset adjust mm

Lift-off ☑ 0.4000 mm

Conductivity 1 ☑ 5.9256E0007 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

Measurement results

Thickness 10.0000 mm

Conductivity 5.9256E0007 S/m

Permeability (µr) ....

```
12:02:23 PM 10.0000 mm 0.0000 mm 59237464.0576 S/m 1.0000-
12:02:24 PM 10.0000 mm 0.0000 mm 59248392.6155 S/m 1.0000-
12:02:25 PM 10.0000 mm 0.0000 mm 59242759.8335 S/m 1.0000-
12:02:26 PM 10.0000 mm 0.0000 mm 59245365.9667 S/m 1.0000-
12:02:27 PM 10.0000 mm 0.0000 mm 59248547.8794 S/m 1.0000-
12:02:28 PM 10.0000 mm 0.0000 mm 59245373.9367 S/m 1.0000-
12:02:29 PM 10.0000 mm 0.0000 mm 59256168.9399 S/m 1.0000-
```

Measurement

○ Air ● Target

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 300000

NF 5 4

Mode: ○ Lin ● Log ○ Spot

Skin depth check

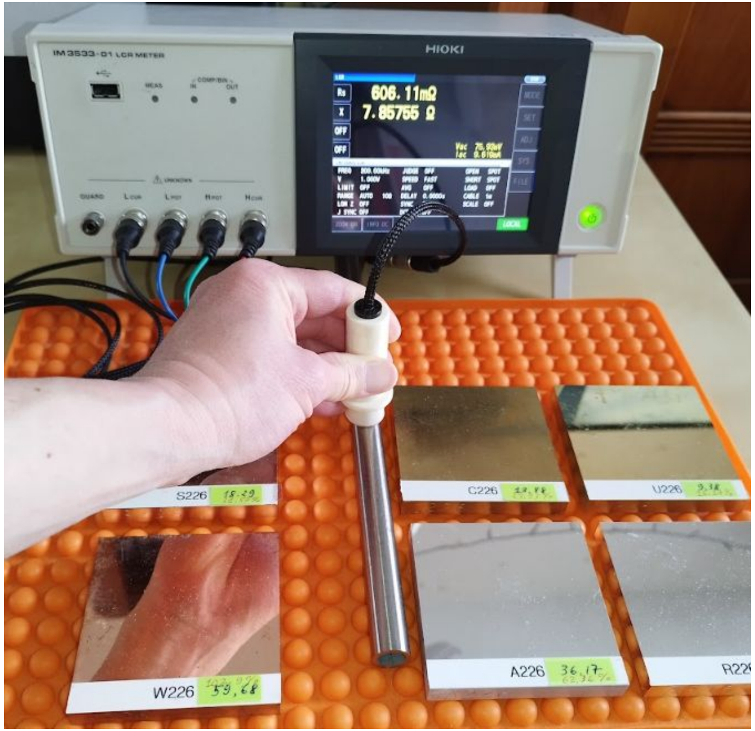
Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0240002_StandardNPN_Al22e6MSpm_14.cn3

Imp. meas. in progress. Keep the probe steady

Probes ZX0220002-EDF2024-1 and ZX0240002-EDF2024-1

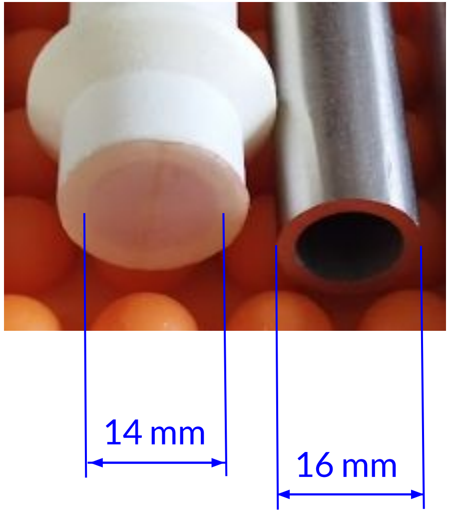
Measuring thickness of tubes and other curved surfaces



<u>Example n°1:</u> Measuring Thickness and Conductivity of an Unknown Non-Magnetic Stainless Steel Tube (Nominal ID = 14 mm, OD = 2 mm)

- The tube's surface is curved rather than flat, which can introduce measurement errors. Additionally, the outer radius (8 mm) is relatively small compared to the probe diameter (14 mm), further complicating the measurement process.
- Since the probe position is not stable, the lift-off is always considered a variable.
- Simultaneous measurement of thickness and conductivity is challenging because these parameters are strongly correlated at certain frequency ranges. Due to convergence difficulties, a partial 2-parameter inversion is used instead of a full 3-parameter inversion to improve stability and accuracy.

Measuring tube thickness - Example n°1



Probe diameter vs tube diameter

Example n°1 - Inversion strategies

To avoid divergence, a sequential inversion strategy is utilized. This approach, referred to as *Alternating Parameter Inversion* (or *Cyclic Partial Inversion*), involves solving the inverse problem by varying only two out of the three unknown parameters at each step while keeping the third fixed.

The process iterates cyclically, updating different parameter subsets until global convergence is achieved for all three parameters.

Example n°1 - Partial Inversion - Convergence of electrical conductivity

Y Auto ☐

Max Y 1

Min Y 0.4

Curve n° 0

X auto ☐ Min X 0 Max X 0.4

Initial parameter values

Thickness ☑ 2.2456 mm ☑ Offset adjust mm

Lift-off ☑ 0.4000 mm

Conductivity 1 ☐ 9.4821E0005 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

Reset to initial values ☐ Auto reset to initial values

Measurement results

Thickness 2.2456 mm

Conductivity 9.4821E0005 S/m

Permeability (µr) 1.0000

Qerr 0.0000047429-

```
0.08996 0.81511; [5] 0.07228 0.77690;
12:09:06 AM 2.24273 mm 0.00000 mm 946970.00000 S/m 1.00000~ 0.0000033788~ [1] 0.06357 0.97726; [2] 0.09356 0.93515; [3] 0.10308 0.87259; [4]
0.08944 0.81599; [5] 0.07199 0.77755;
12:09:19 AM 2.24270 mm 0.00000 mm 948207.12342 S/m 1.00000~ 0.0000033394~ [1] 0.06408 0.97705; [2] 0.09312 0.93558; [3] 0.10351 0.87174; [4]
0.08986 0.81554; [5] 0.07202 0.77742;
12:09:30 AM 2.24563 mm 0.00000 mm 948210.00000 S/m 1.00000~ 0.0000047429~ [1] 0.06489 0.97782; [2] 0.09352 0.93534; [3] 0.10319 0.87178; [4]
0.08974 0.81585; [5] 0.07193 0.77746;
```

○ Air ● Target

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 200000

NF 5 5

Mode ○ Lin ● Log ○ Spot

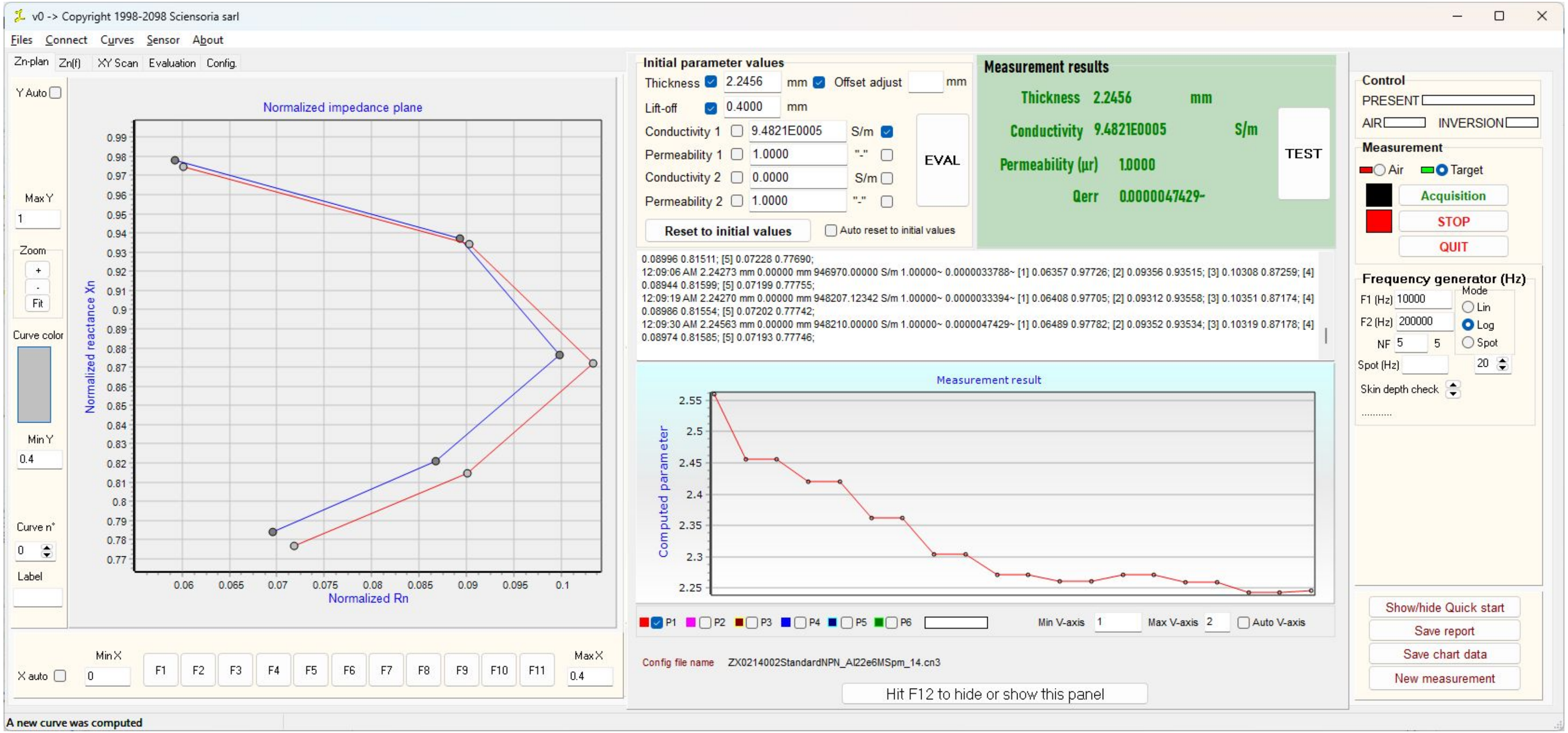
Spot (Hz) 20

☐ P1 ☐ P2 ☑ P3 ☐ P4 ☐ P5 ☐ P6 Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0214002StandardNPN_Al22e6MSpm_14.cn3

A new curve was computed

Example n°1 - Partial Inversion - Convergence of thickness



Y Auto ☐

Max Y: 1

Min Y: 0.4

Curve n°: 0

X auto ☐ Min X: 0 Max X: 0.4

Initial parameter values

Thickness ☑ 2.2456 mm ☑ Offset adjust mm

Lift-off ☑ 0.4000 mm

Conductivity 1 ☐ 9.4821E0005 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

Measurement results

Thickness 2.2456 mm

Conductivity 9.4821E0005 S/m

Permeability (µr) 1.0000

Qerr 0.0000047429~

```
0.08996 0.81511; [5] 0.07228 0.77690;
12:09:06 AM 2.24273 mm 0.00000 mm 946970.00000 S/m 1.00000~ 0.0000033788~ [1] 0.06357 0.97726; [2] 0.09356 0.93515; [3] 0.10308 0.87259; [4]
0.08944 0.81599; [5] 0.07199 0.77755;
12:09:19 AM 2.24270 mm 0.00000 mm 948207.12342 S/m 1.00000~ 0.0000033394~ [1] 0.06408 0.97705; [2] 0.09312 0.93558; [3] 0.10351 0.87174; [4]
0.08986 0.81554; [5] 0.07202 0.77742;
12:09:30 AM 2.24563 mm 0.00000 mm 948210.00000 S/m 1.00000~ 0.0000047429~ [1] 0.06489 0.97782; [2] 0.09352 0.93534; [3] 0.10319 0.87178; [4]
0.08974 0.81585; [5] 0.07193 0.77746;
```

🟥 ☑ P1 ☐ P2 ☐ P3 ☐ P4 ☐ P5 ☐ P6 Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0214002StandardNPN_Al22e6MSpm_14.cn3

○ Air ● Target

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 200000

NF 5 5

Mode: ○ Lin ● Log ○ Spot

Spot (Hz) 20

Skin depth check

A new curve was computed

Example n°1 - Global Inversion

In contrast with sequential partial inversion, global inversion attempts to solve for all three parameters simultaneously, which can be more challenging and prone to divergence if initial values are poorly selected.

When the convergence of thickness and conductivity is slow, it may indicate that the estimated values are close to the true solution. In such cases, one can attempt global inversion to obtain a quicker result.

Example n°1 - Global Inversion When Close to Target

Initial parameter values

Thickness ☑ 2.1712 mm ☑ Offset adjust mm

Lift-off ☑ 0.4000 mm

Conductivity 1 ☑ 9.5104E0005 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

Measurement results

Thickness 2.1712 mm

Conductivity 9.5104E0005 S/m

Permeability (µr) 1.0000

Qerr 0.0000014408~

```
0.08944 0.81599; [5] 0.07199 0.77755;
12:09:19 AM 2.24270 mm 0.00000 mm 948207.12342 S/m 1.00000~ 0.0000033394~ [1] 0.06408 0.97705; [2] 0.09312 0.93558; [3] 0.10351 0.87174; [4]
0.08986 0.81554; [5] 0.07202 0.77742;
12:09:30 AM 2.24563 mm 0.00000 mm 948210.00000 S/m 1.00000~ 0.0000047429~ [1] 0.06489 0.97782; [2] 0.09352 0.93534; [3] 0.10319 0.87178; [4]
0.08974 0.81585; [5] 0.07193 0.77746;
12:23:32 AM 2.17123 mm 0.00000 mm 951036.60784 S/m 1.00000~ 0.0000014408~ [1] 0.06049 0.97751; [2] 0.09244 0.93609; [3] 0.10328 0.87343; [4]
0.08990 0.81611; [5] 0.07161 0.77790;
```

Measurement: ○ Air ● Target

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 200000

NF 5 5

Mode: ○ Lin ● Log ○ Spot

Spot (Hz) 20

Skin depth check

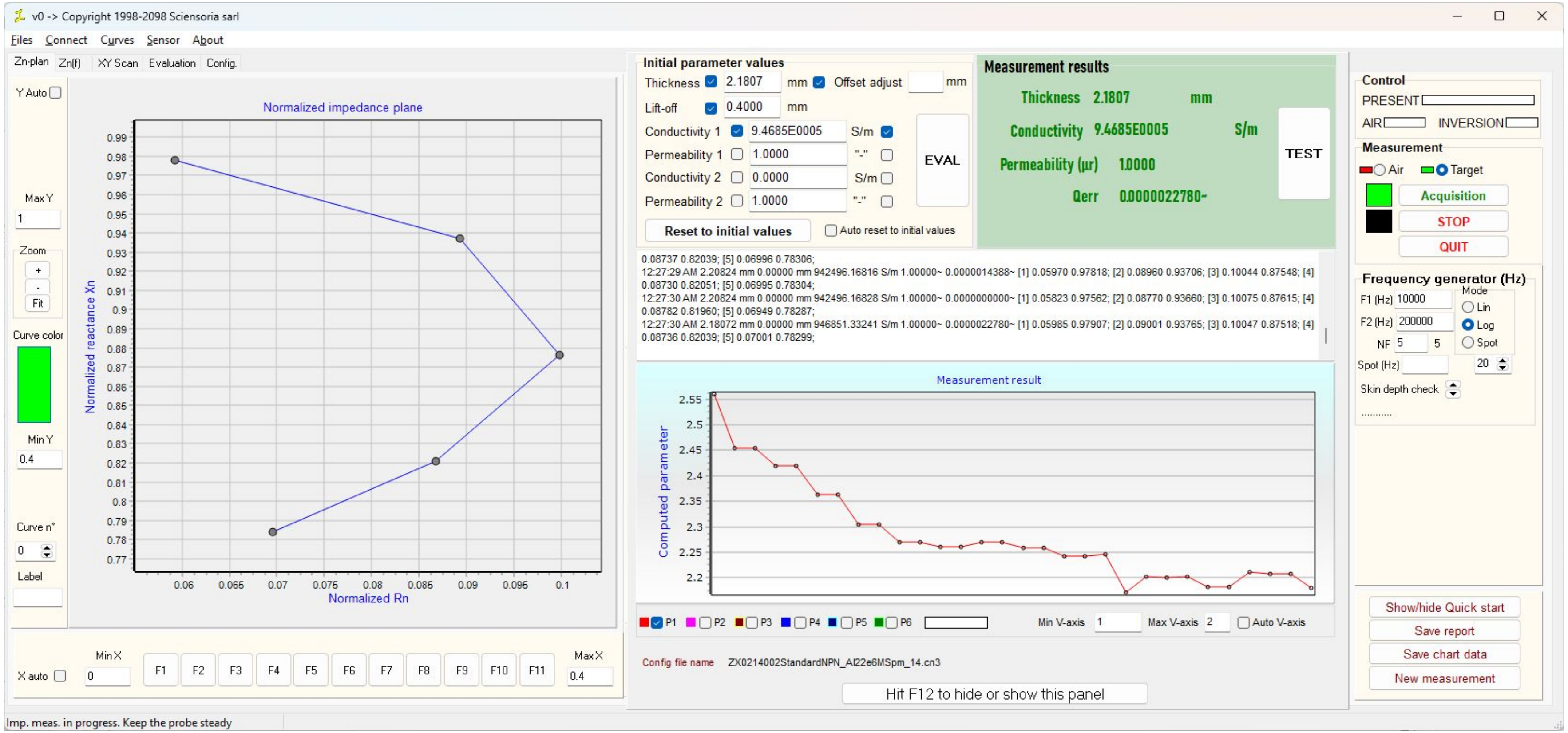
🟥 ☑ P1 ☐ P2 ☑ P3 ☐ P4 ☐ P5 ☐ P6

Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0214002StandardNPN_Al22e6MSpm_14.cn3

A new curve was computed

Global Inversion - Convergence of Thickness



Y Auto ☐

Max Y: 1

Min Y: 0.4

Curve n°: 0

X auto ☐ Min X: 0 Max X: 0.4

Initial parameter values

Thickness	☑ 2.1807	mm	☑ Offset adjust	mm
Lift-off	☑ 0.4000	mm		
Conductivity 1	☑ 9.4685E0005	S/m	☑	
Permeability 1	☐ 1.0000	"-"	☐	
Conductivity 2	☐ 0.0000	S/m	☐	
Permeability 2	☐ 1.0000	"-"	☐	

☐ Auto reset to initial values

Measurement results

Thickness 2.1807 mm

Conductivity 9.4685E0005 S/m

Permeability (µr) 1.0000

Qerr 0.0000022780~

```
0.08737 0.82039; [5] 0.06996 0.78306;
12:27:29 AM 2.20824 mm 0.00000 mm 942496.16816 S/m 1.00000~ 0.0000014388~ [1] 0.05970 0.97818; [2] 0.08960 0.93706; [3] 0.10044 0.87548; [4]
0.08730 0.82051; [5] 0.06995 0.78304;
12:27:30 AM 2.20824 mm 0.00000 mm 942496.16828 S/m 1.00000~ 0.0000000000~ [1] 0.05823 0.97562; [2] 0.08770 0.93660; [3] 0.10075 0.87615; [4]
0.08782 0.81960; [5] 0.06949 0.78287;
12:27:30 AM 2.18072 mm 0.00000 mm 946851.33241 S/m 1.00000~ 0.0000022780~ [1] 0.05985 0.97907; [2] 0.09001 0.93765; [3] 0.10047 0.87518; [4]
0.08736 0.82039; [5] 0.07001 0.78299;
```

🟥 ☑ P1 ☐ P2 ☐ P3 ☐ P4 ☐ P5 ☐ P6

Min V-axis: 1 Max V-axis: 2 ☐ Auto V-axis

Config file name: ZX0214002StandardNPN_Al22e6MSpm_14.cn3

Control

PRESENT

AIR INVERSION

Measurement

○ Air ● Target

Frequency generator (Hz)

F1 (Hz): 10000

F2 (Hz): 200000

NF: 5 5

Mode: ○ Lin ● Log ○ Spot

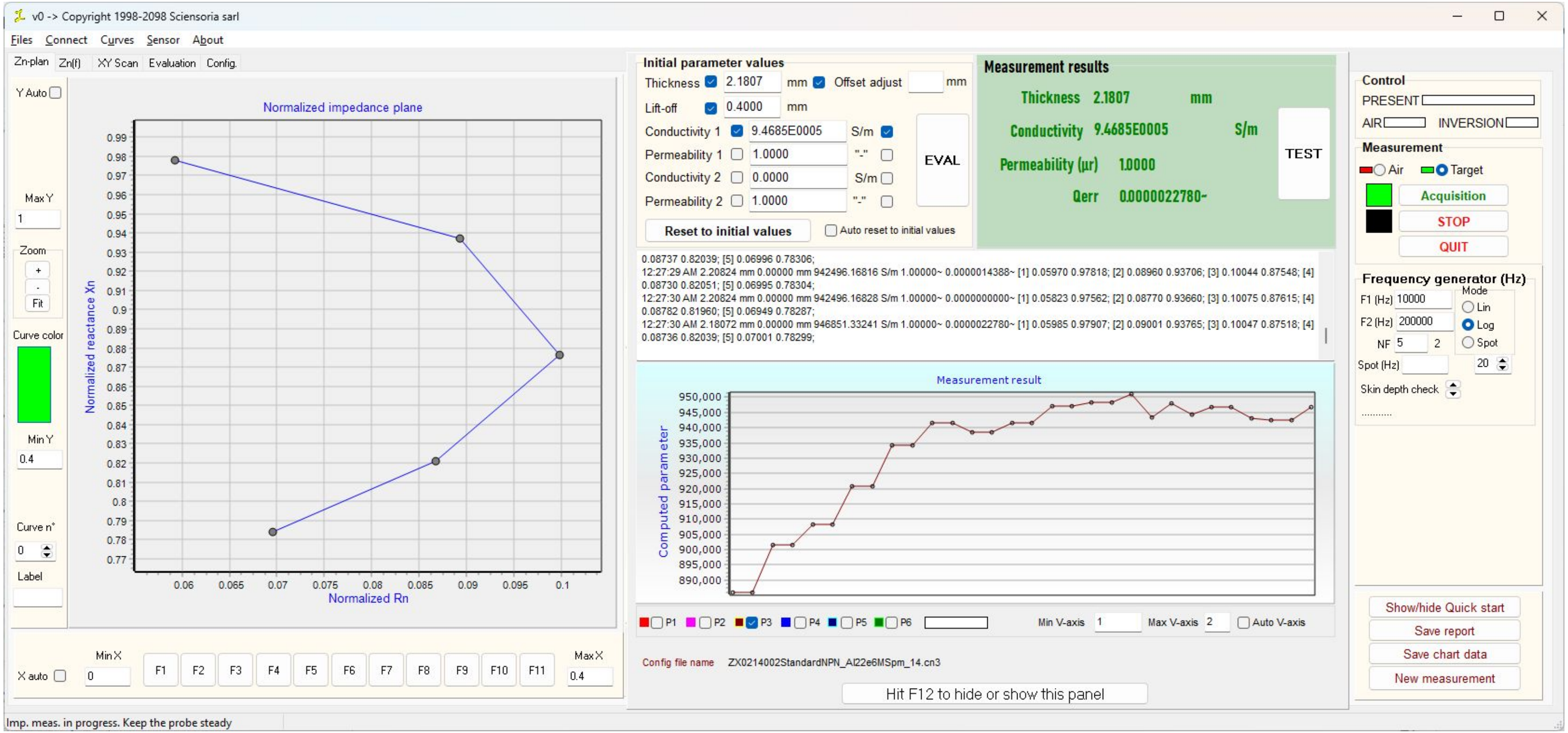
Spot (Hz): 20

Skin depth check

....

Imp. meas. in progress. Keep the probe steady

Global Inversion - Convergence of Electrical Conductivity



Y Auto ☐

Max Y 1

Min Y 0.4

Curve n° 0

X auto ☐ Min X 0 Max X 0.4

Initial parameter values

Thickness ☑ 2.1807 mm ☑ Offset adjust mm

Lift-off ☑ 0.4000 mm

Conductivity 1 ☑ 9.4685E0005 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

Measurement results

Thickness 2.1807 mm

Conductivity 9.4685E0005 S/m

Permeability (µr) 1.0000

Qerr 0.0000022780~

Measurement

○ Air ● Target

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 200000

NF 5 2

Mode ○ Lin ● Log ○ Spot

Spot (Hz) 20

```
0.08737 0.82039; [5] 0.06996 0.78306;
12:27:29 AM 2.20824 mm 0.00000 mm 942496.16816 S/m 1.00000~ 0.0000014388~ [1] 0.05970 0.97818; [2] 0.08960 0.93706; [3] 0.10044 0.87548; [4]
0.08730 0.82051; [5] 0.06995 0.78304;
12:27:30 AM 2.20824 mm 0.00000 mm 942496.16828 S/m 1.00000~ 0.0000000000~ [1] 0.05823 0.97562; [2] 0.08770 0.93660; [3] 0.10075 0.87615; [4]
0.08782 0.81960; [5] 0.06949 0.78287;
12:27:30 AM 2.18072 mm 0.00000 mm 946851.33241 S/m 1.00000~ 0.0000022780~ [1] 0.05985 0.97907; [2] 0.09001 0.93765; [3] 0.10047 0.87518; [4]
0.08736 0.82039; [5] 0.07001 0.78299;
```

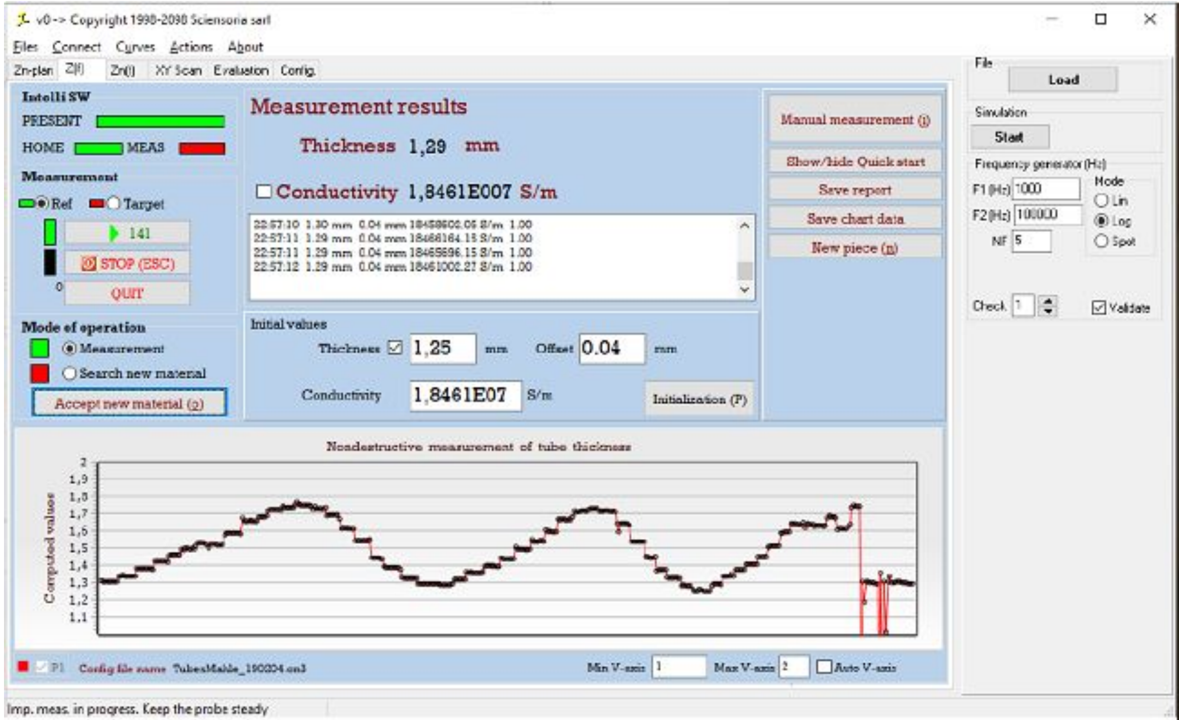
☑ P3

Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0214002StandardNPN_Al22e6MSpm_14.cn3

Imp. meas. in progress. Keep the probe steady

Example n°2 - Measurement of aluminum tube wall thickness



Measurement results

Thickness 1,29 mm

☐ Conductivity 1,8461E007 S/m

```
22:57:10  1.30 mm  0.04 mm 18458602.06 S/m  1.00
22:57:11  1.29 mm  0.04 mm 18466164.15 S/m  1.00
22:57:11  1.29 mm  0.04 mm 18465696.15 S/m  1.00
22:57:12  1.29 mm  0.04 mm 18461002.27 S/m  1.00
```

Initial values

Thickness ☑ 1,25 mm Offset 0.04 mm

Conductivity 1,8461E07 S/m

F1 (Hz) 1000

F2 (Hz) 100000

NF 5

Check 1

☑ Validate

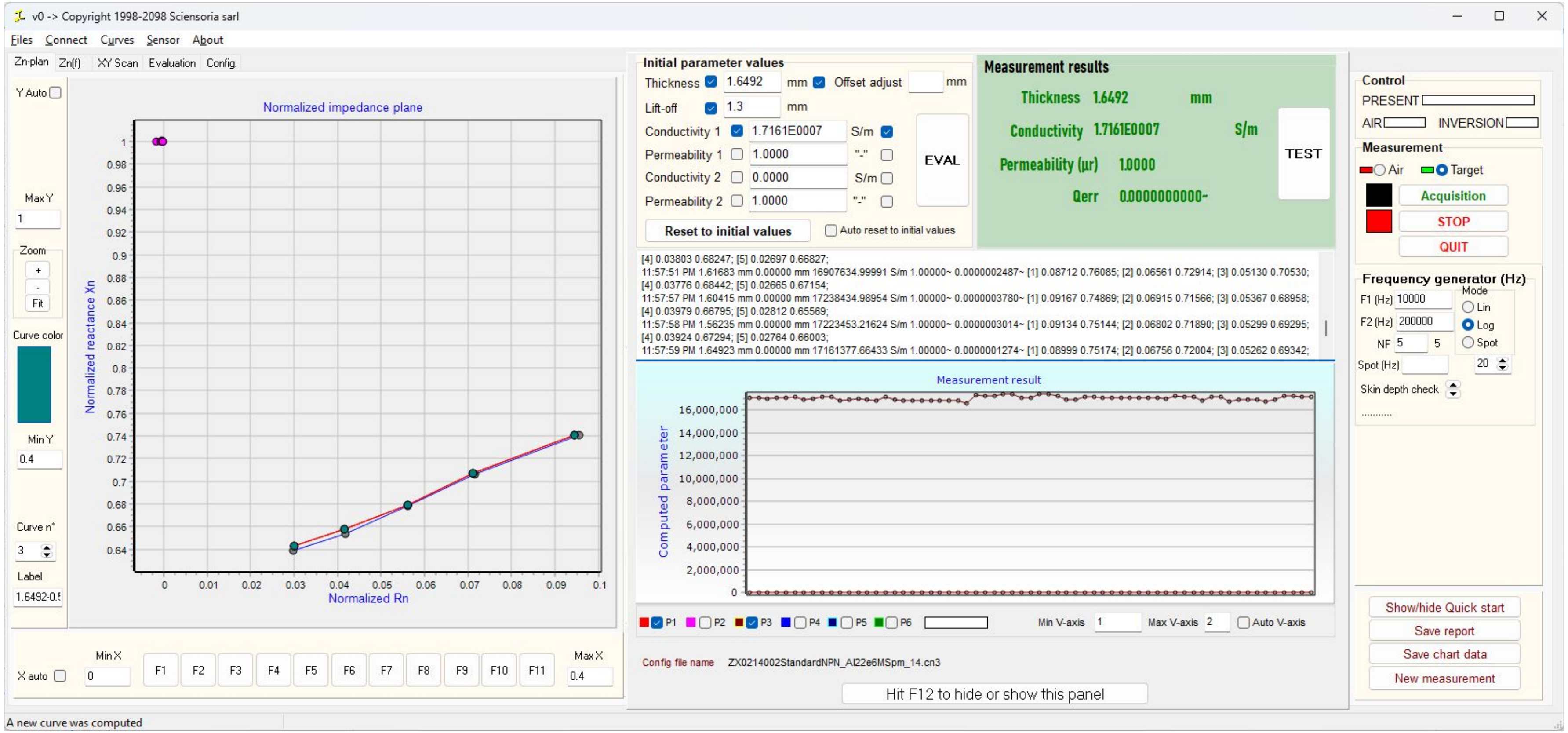
P1 Config file name TubesMable_190204.cn3

Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Imp. meas. in progress. Keep the probe steady

ConducSens™ has been used to assess the uniformity of the thickness of aluminum pistons.

Example n˚2 - EddySens™ screen



v0 -> Copyright 1998-2098 Sciensoria sarl

Y Auto ☐

Max Y: 1

Min Y: 0.4

Curve n°: 3

Label: 1.6492-0.!

X auto ☐

Min X: 0

Max X: 0.4

Initial parameter values

Thickness ☑ 1.6492 mm ☑ Offset adjust mm

Lift-off ☑ 1.3 mm

Conductivity 1 ☑ 1.7161E0007 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

☐ Auto reset to initial values

Measurement results

Thickness 1.6492 mm

Conductivity 1.7161E0007 S/m

Permeability (μr) 1.0000

Qerr 0.0000000000~

```
[4] 0.03803 0.68247; [5] 0.02697 0.66827;
11:57:51 PM 1.61683 mm 0.00000 mm 16907634.99991 S/m 1.00000~ 0.0000002487~ [1] 0.08712 0.76085; [2] 0.06561 0.72914; [3] 0.05130 0.70530;
[4] 0.03776 0.68442; [5] 0.02665 0.67154;
11:57:57 PM 1.60415 mm 0.00000 mm 17238434.98954 S/m 1.00000~ 0.0000003780~ [1] 0.09167 0.74869; [2] 0.06915 0.71566; [3] 0.05367 0.68958;
[4] 0.03979 0.66795; [5] 0.02812 0.65569;
11:57:58 PM 1.56235 mm 0.00000 mm 17223453.21624 S/m 1.00000~ 0.0000003014~ [1] 0.09134 0.75144; [2] 0.06802 0.71890; [3] 0.05299 0.69295;
[4] 0.03924 0.67294; [5] 0.02764 0.66003;
11:57:59 PM 1.64923 mm 0.00000 mm 17161377.66433 S/m 1.00000~ 0.0000001274~ [1] 0.08999 0.75174; [2] 0.06756 0.72004; [3] 0.05262 0.69342;
```

🟥 ☑ P1 🟪 ☐ P2 🟫 ☑ P3 🟦 ☐ P4 🟦 ☐ P5 🟩 ☐ P6

Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0214002StandardNPN_Al22e6MSpm_14.cn3

Control

PRESENT

AIR INVERSION

Measurement

🟥 ○ Air 🟩 ● Target

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 200000

NF 5 5

Mode: ○ Lin ● Log ○ Spot

Spot (Hz) 20

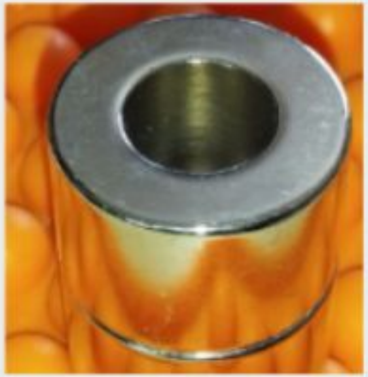
Skin depth check

....

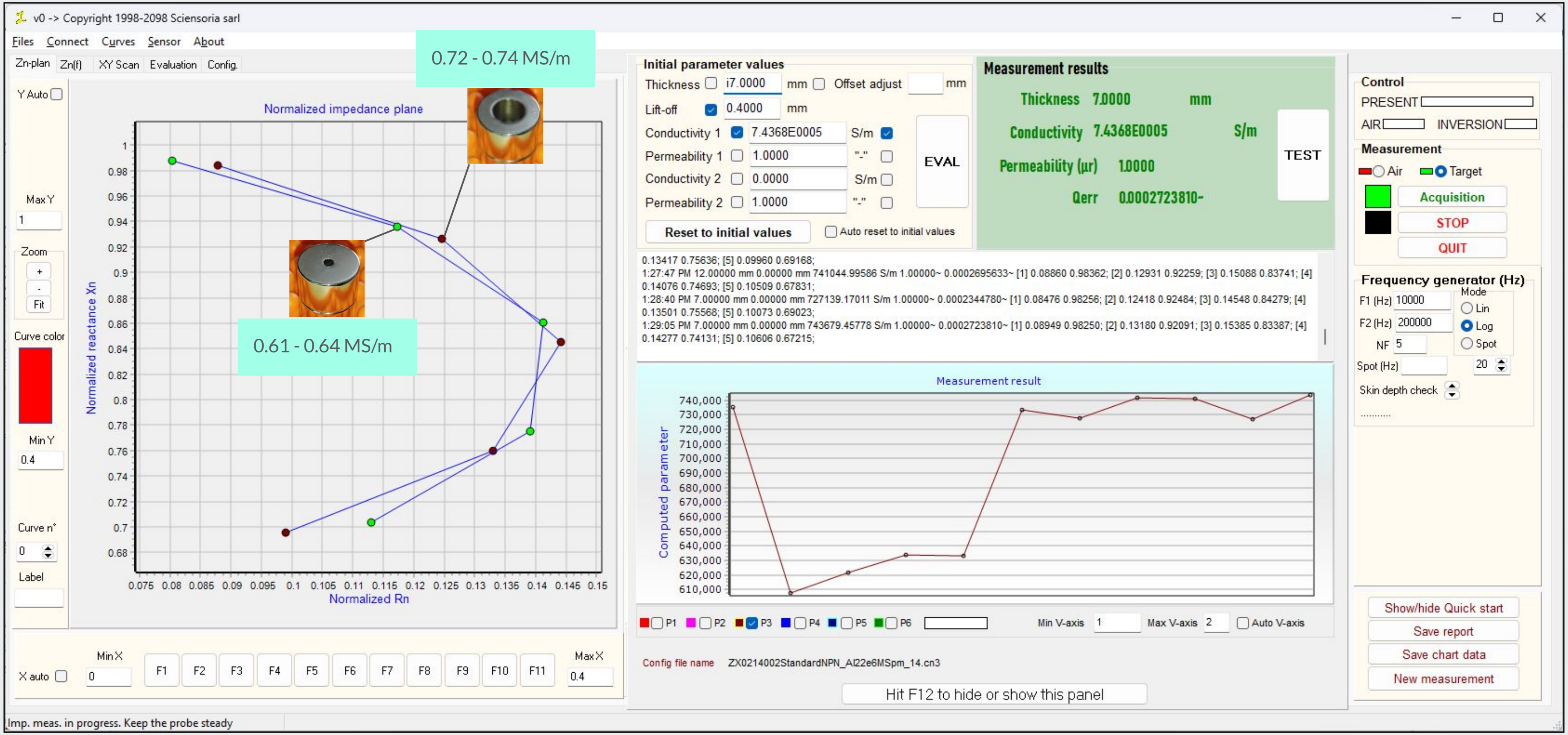
A new curve was computed

Measurement of Electrical Conductivity of Magnet

- In applications involving eddy currents (e.g., in motors, generators, and sensors), the conductivity of the magnet determines the level of eddy current losses.
- High conductivity can lead to higher energy dissipation (Joule heating), reducing efficiency in high-speed motors and electrical machines.
- Many magnets are used in electric machines (motors, generators) and inductive systems, where their electrical properties impact overall performance.
- Lower conductivity reduces undesirable eddy currents, improving energy efficiency.
- Conductivity influences a magnet's response to external electromagnetic fields.
- It affects how the magnet behaves under pulsed fields, such as in magnetization/demagnetization processes.
- Some magnets, especially neodymium magnets, are coated (Ni-Cu-Ni, epoxy, etc.) to prevent corrosion.
- Measuring conductivity can verify coating integrity and detect defects in protective layers.
- In applications like aerospace, medical devices, and high-temperature environments, knowing a magnet's conductivity helps engineers choose materials that best suit thermal and electromagnetic constraints.
- Magnets, especially rare-earth magnets like NdFeB (neodymium-iron-boron) and SmCo (samarium-cobalt), often contain metallic and non-metallic elements. Their conductivity provides insights into their composition, purity, and uniformity.
- Variations in conductivity can indicate manufacturing defects, contamination, or changes in alloy composition.



Example n°3 - Measuring conductivity of magnets



0.72 - 0.74 MS/m

0.61 - 0.64 MS/m

Y Auto ☐

Max Y 1

Min Y 0.4

Curve n° 0

Label

X auto ☐ Min X 0 Max X 0.4

Initial parameter values

Thickness ☐ 7.0000 mm ☐ Offset adjust mm

Lift-off ☑ 0.4000 mm

Conductivity 1 ☑ 7.4368E0005 S/m ☑

Permeability 1 ☐ 1.0000 "-" ☐

Conductivity 2 ☐ 0.0000 S/m ☐

Permeability 2 ☐ 1.0000 "-" ☐

Reset to initial values ☐ Auto reset to initial values

Measurement results

Thickness 7.0000 mm

Conductivity 7.4368E0005 S/m

Permeability (µr) 1.0000

Qerr 0.0002723810~

```
0.13417 0.75636; [5] 0.09960 0.69168;
1:27:47 PM 12.00000 mm 0.00000 mm 741044.99586 S/m 1.00000~ 0.0002695633~ [1] 0.08860 0.98362; [2] 0.12931 0.92259; [3] 0.15088 0.83741; [4]
0.14076 0.74693; [5] 0.10509 0.67831;
1:28:40 PM 7.00000 mm 0.00000 mm 727139.17011 S/m 1.00000~ 0.0002344780~ [1] 0.08476 0.98256; [2] 0.12418 0.92484; [3] 0.14548 0.84279; [4]
0.13501 0.75568; [5] 0.10073 0.69023;
1:29:05 PM 7.00000 mm 0.00000 mm 743679.45778 S/m 1.00000~ 0.0002723810~ [1] 0.08949 0.98250; [2] 0.13180 0.92091; [3] 0.15385 0.83387; [4]
0.14277 0.74131; [5] 0.10606 0.67215;
```

🟥☐ P1 ☐ P2 ☑ P3 ☐ P4 ☐ P5 ☐ P6 Min V-axis 1 Max V-axis 2 ☐ Auto V-axis

Config file name ZX0214002StandardNPN_Al22e6MSpm_14.cn3

Control

PRESENT

AIR INVERSION

Measurement

○ Air ● Target

Frequency generator (Hz)

F1 (Hz) 10000

F2 (Hz) 200000

NF 5

Mode: ○ Lin ● Log ○ Spot

Spot (Hz) 20

Skin depth check

Imp. meas. in progress. Keep the probe steady

Example n˚3 - Advantages of ConducSens™

ConducSens™ has several key advantages over traditional comparative conductivity measurement methods, particularly when it comes to magnets and other conductive materials. Here's why obtaining absolute values of electrical conductivity, rather than just comparative values, is crucial:

1. Accurate and Quantitative Material Characterization

- Comparative methods only allow relative assessment (e.g., determining whether one magnet is more or less conductive than another).
- ConducSens™ provides absolute values, enabling precise characterization of magnets, even when comparing different types (NdFeB, SmCo, AlNiCo, etc.).
- This is essential for quality control, research, and material certification.

2. Essential for Eddy Current Loss Analysis

- In motors, generators, and electromagnetic devices, eddy current losses are directly influenced by the electrical conductivity of the magnet.
- Absolute conductivity values allow engineers to accurately model and predict these losses, leading to better design optimization for high-efficiency motors.
- Comparative methods fail when materials have significantly different conductivity ranges.

Example n°3 - Advantages of ConducSens™

3. Reliable Evaluation of Coatings and Surface Treatments

- Many industrial magnets (especially NdFeB) have coatings (Ni-Cu-Ni, epoxy, etc.) to prevent corrosion.
- Absolute conductivity measurements enable precise assessment of coating thickness and integrity, which comparative methods cannot quantify.
- This ensures that coated magnets meet performance and durability requirements.

4. Identification of Manufacturing Variations & Defects

- Small changes in alloy composition, impurities, or processing conditions (e.g., sintering, heat treatment) affect electrical conductivity.
- Absolute measurements detect subtle variations in material properties that comparative tests might overlook.
- This helps manufacturers maintain consistency and avoid performance issues in large-scale production.

5. Compatibility with Multi-Frequency and Inversion Algorithms

- ConducSens™ operates with multi-frequency eddy current measurement, enabling deeper penetration into materials.
- Using inversion algorithms, it extracts absolute conductivity values, even when the material is coated.
- Traditional comparative techniques are usually single-frequency and depth-limited, making them unsuitable for complex structures.

Example n°3 - Advantages of ConducSens™

6. Eliminates Need for Reference Samples

- Comparative methods require reference materials with known conductivity, which may not always be available for specific magnet types.
- ConducSens™ does not rely on reference samples, making it more flexible and practical for analyzing custom or experimental magnetic materials.

7. More Versatile Across Different Magnetic Materials

- Conductivity values of magnets vary widely, from highly conductive AlNiCo (~30 MS/m) to relatively low conductivity NdFeB (~1-2 MS/m).
- Many comparative systems struggle with such variations, while ConducSens™ provides precise absolute values across a broad range.

Conclusion

The ability to measure absolute conductivity values instead of just making relative comparisons provides critical insights for:

✅ Motor & generator optimization (minimizing eddy current losses)
✅ Material quality control & process monitoring
✅ Predicting long-term stability & degradation
✅ Improved modeling for electromagnetic simulations