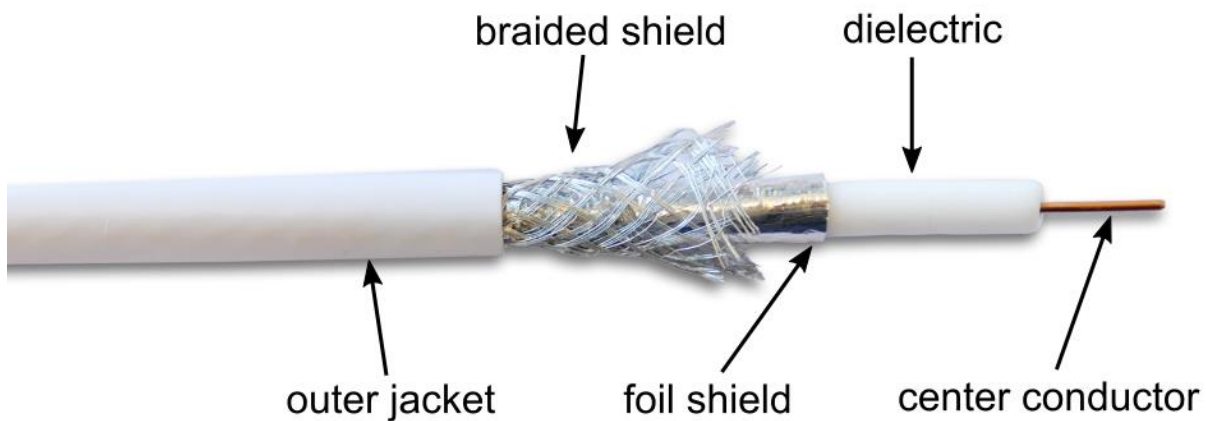


## SPECTANO 100 - Application Note

# Dielectric Parameters of a Coaxial Cable



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## Safety Instructions

### WARNING



#### Death or severe injury caused by high voltage or current

Before starting a measurement, read the safety rules and operation and connection instructions in the SPECTANO User Manual and observe the application specific safety instructions in this Application Note when performing measurements to protect yourself from high-voltage hazards.

**Note:** Basic procedures such as setting-up and adjusting the SPECTANO 100 are described in the SPECTANO 100 user manual. You can download the SPECTANO 100 user manual at: <https://www.omicron-lab.com/downloads/material-analysis/spectano-100/>

**Note:** All measurements in this application note have been performed with the SPECTANO Analyzer Suite V1.50. Use this version or a higher version to perform the measurements shown in this document. You can download the latest version at the SPECTANO 100 download area located at <https://www.omicron-lab.com/downloads/material-analysis/spectano-100/>

## 1 Abstract

This application note explains how to measure dielectric parameters such as the permittivity  $\epsilon_r$ , the capacitance C, the resistance R, the loss tangent  $\tan\delta$  (also called dissipation factor or power factor), the polarization and conductivity of coaxial cables.

Dielectric materials are used in different electrical application areas such as electrical insulation or protection. There are high demands on dielectric materials. Very important requirements are high creep resistance, dielectric strength, thermal stability or mechanical strength independent on environmental influences. For this reason, it is very important to analyze the dielectric material properties, in our example the coaxial cable dielectric.

These cable properties can be measured with different measurement methods supported by the SPECTANO 100:

- Time Domain Spectroscopy - measurement of polarization and depolarization current (PDC) from 20  $\mu$ Hz to 100 mHz
- Frequency Domain Spectroscopy (FDS) from 5  $\mu$ Hz to 5 kHz
- Combined mode (FDS and PDC) from 20  $\mu$ Hz to 5 kHz using a Fourier transformation to reduce measurement time up to 70 % compared to exclusive FDS measurements

Frequency band		Test duration
100 $\mu$ Hz to 1 kHz	FDS (only)	11 h
100 $\mu$ Hz to 1 kHz	PDC + FDS	3 h 

In most cases, a coaxial cable can be measured easily as it features a shielded setup. BNC or other coaxial plugs are available for most of the cable types which can be mounted in a simple way.

## 2 Measurement Tasks

Dielectric properties of a coaxial cable insulation are very important to ensure a perfect functionality of the cable. Depending on the usage of the cable and the environmental influences on the cable, parameters could change, and the cable may be destroyed.

For the development of new insulation materials, the dielectric properties are also an important indicator for the material characteristics and quality.

By analyzing the dielectric properties of coaxial cables, the following topics are covered:

- Some theory about the measurement of dielectric properties using SPECTANO 100.
- How to best connect a coaxially constructed cable.
- The advantages of measurement with the SPECTANO 100.

## 3 Dielectric Measurement Methods

### 3.1 Time Domain Spectroscopy

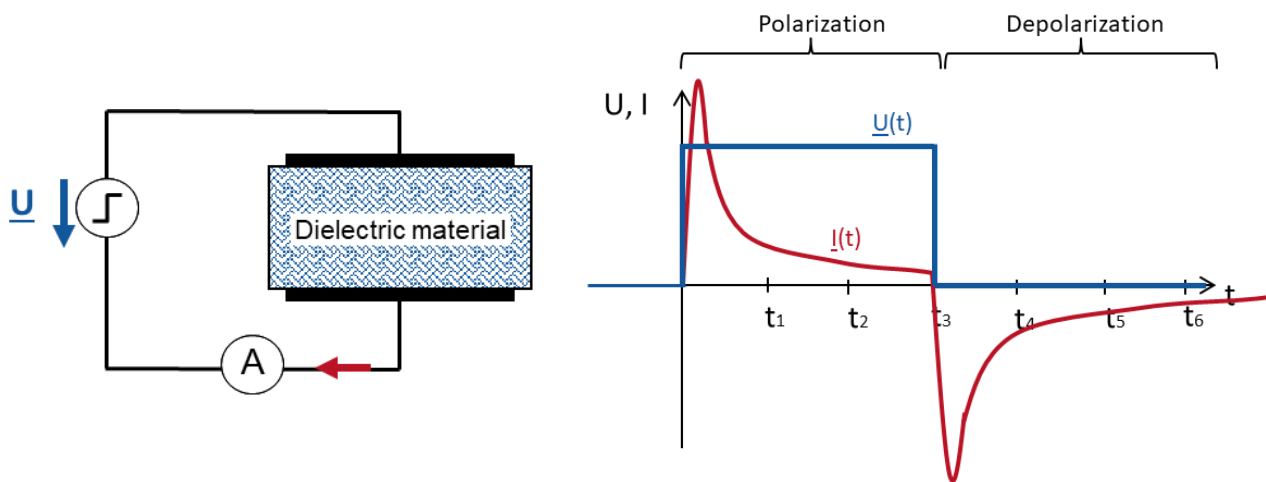
The time domain spectroscopy used in the SPECTANO 100 is called PDC measurement (Polarization Depolarization Current measurement)

The principle of the PDC method bases on applying a step voltage to a dielectric (insulation) material. The dielectric material under test acts as a capacitor in this case. It gets charged and the dielectric material (insulation between the electrode) is polarized.

The polarization current is recorded over time ( $t_0 \dots t_3$ ) as it is very specific for different dielectric materials and its condition. After this, the voltage source is removed, and the dielectric Material starts to depolarize ( $t_3 \dots t_6$ ).

This curve is specific for different dielectric materials and its condition.

The dielectric property curves in the frequency domain ( $\tan\delta$ , permittivity  $\epsilon_r$ , capacitance  $C$ , resistance  $R$  &  $X$ ) are calculated out of the polarization current results over time by using a Fourier transformation.



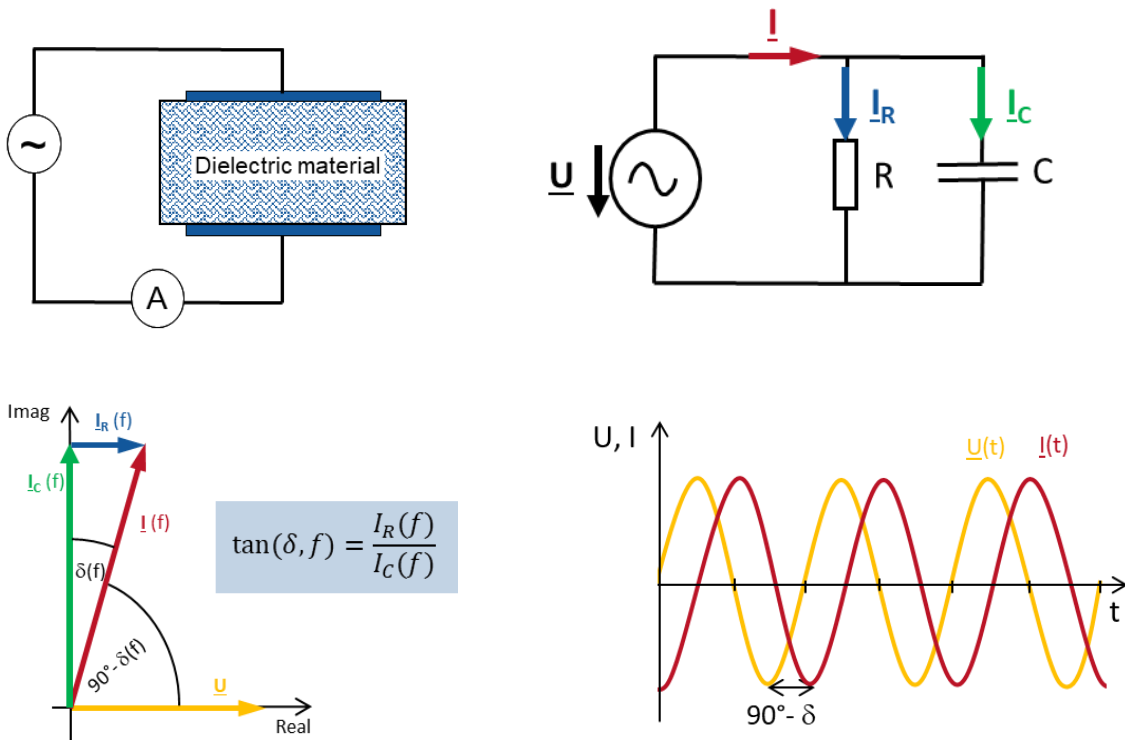
**Please note:** For this method the dielectric material to test must be fully depolarized. Remaining polarization will lead to inaccurate and sometimes negative results.

Advantage of PDC: Fast and accurate at low frequencies

Disadvantage of PDC: Inaccurate at high frequencies

### 3.2 Frequency Domain Spectroscopy (FDS)

The principle of FDS is to measure the current at different frequencies by applying a sinusoidal voltage at different frequencies  $f_1, f_2, \dots$  to a dielectric material for example located in a parallel electrodes test cell and then to calculate the dielectric properties as  $\tan\delta$  or permittivity  $\epsilon_r$  out of the measured current.



Advantage of FDS: Fast and accurate at high frequencies, resistant to disturbances

Disadvantage of FDS: Very slow at low frequencies

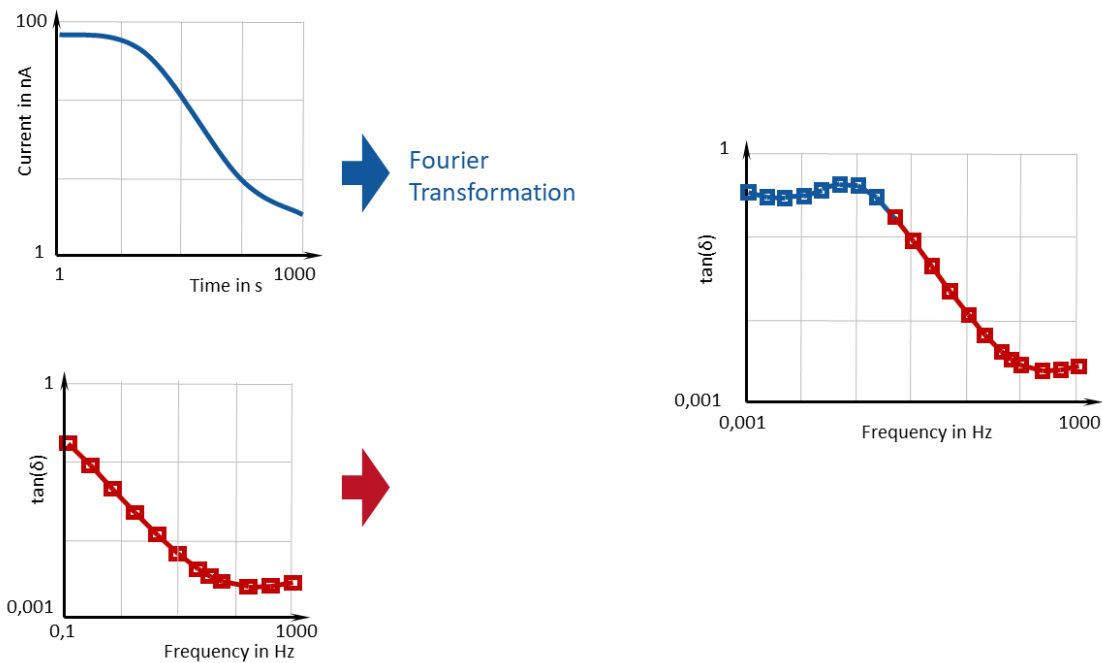
Frequency	Duration of 1 sine wave
5000 Hz	0,2 ms
1000 Hz	1 ms
50 Hz	20 ms
1 Hz	1 s
0.1 Hz	10 s
10 mHz	100 s
1 mHz	16,7 min
0.1 mHz	2,7 h
10 µHz	27 h

### 3.3 Combination of FDS and PDC

The PDC curve is transformed via a Fourier transformation to the frequency domain and combined with the measured FDS part. The overall curve can now be used for analysis of the dielectric properties of an insulation material.

SPECTANO 100:

1. The FDS can be used for the whole frequency range of 5  $\mu$ Hz up to 5 kHz.
2. The measurement time is quite long (up to 11 hours). The PDC is practically restricted to frequencies below 100mHz (due to the transients after switching), but the measurement time is much shorter.
3. The combination of both methods used in SPECTANO 100 is decreasing the measurement time and delivers reliable results for the whole frequency range.



	Advantages	Disadvantages
PDC	☺ Fast and accurate at low frequencies	☹ Inaccurate at high frequencies
FDS	☺ Fast and accurate at high frequencies	☹ Very slow at low frequencies

### 3.4 Dielectric Parameters measured by SPECTANO 100

#### 3.4.1 Parameters from 5 $\mu$ Hz to 5 kHz

Complex permittivity $\epsilon_r$ <ul style="list-style-type: none"> <li>• <math>\epsilon_r'</math> real part of the complex permittivity</li> <li>• <math>\epsilon_r''</math> imaginary part of the complex permittivity</li> </ul>
Complex capacitance: <ul style="list-style-type: none"> <li>c' real part of the complex capacitance</li> <li>c'' imaginary part of the complex capacitance</li> </ul>
Tan $\delta$ (dissipation factor or power factor)
Impedance Z <ul style="list-style-type: none"> <li>•  Z  Absolute value</li> <li>• Phase of Z</li> </ul>
Admittance Y <ul style="list-style-type: none"> <li>•  Y  Absolute value</li> <li>• Phase of Y</li> </ul>
Parallel or series capacitance Cp/Cs
Parallel/series resistance Rp/Rs
Resistance R
Reactance X

#### 3.4.2 Additional PDC Parameters from 20 $\mu$ Hz to 100 mHz

Polarization current I <sub>pol</sub>
Depolarization current I <sub>depol</sub>
Electrical resistance R(t)
Electrical conductivity G(t)
For OMICRON Lab's DSH 100 and Disk electrode sample holder: <ul style="list-style-type: none"> <li>• Specific resistance <math>\rho(t)</math></li> <li>• Specific conductivity <math>\sigma(t)</math></li> </ul>

## 4 Measurement Setup & Results

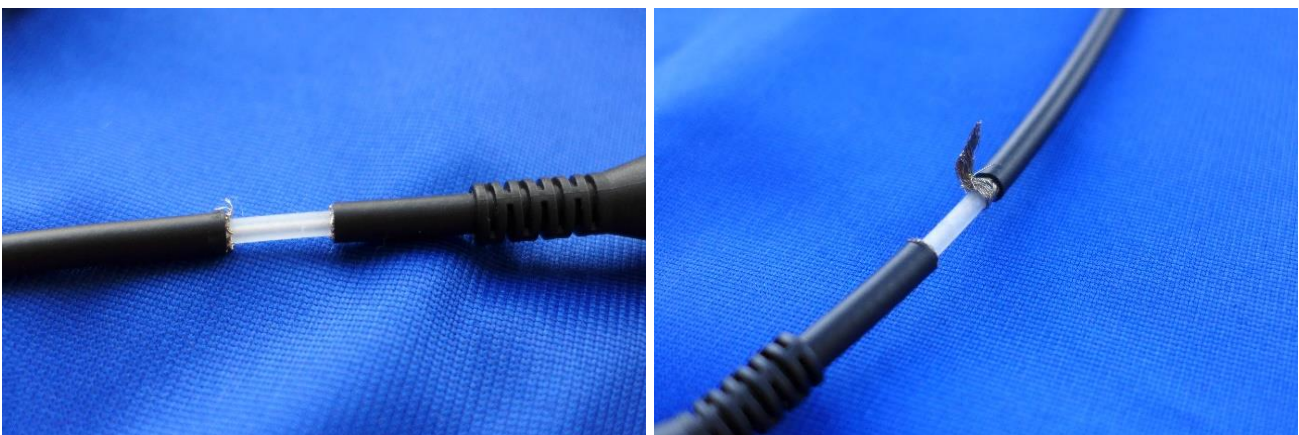
### 4.1 Measurement Setup and Cable Preparation

To measure a coaxial cable, you need the following equipment in addition to the SPECTANO 100:

- $\geq 1$  m of the cable that should be measured
- 2 BNC plugs with PTFE insulation
- mounting equipment for the BNC plugs
- 1 BNC “T” adapter with PTFE insulation
- a sharp knife
- a side cutter
- a “crocodile clamp” or similar
- 2 SPECTANO 100 triaxial cables, 1 triaxial to BNC adapter, 1 triaxial to 4 mm adapter cable

In our case we will measure an RG 58 cable with a nominal capacitance of 113 pF/m and a PE dielectric. The inner wire diameter is 0.9 mm and the dielectric diameter is 3 mm.

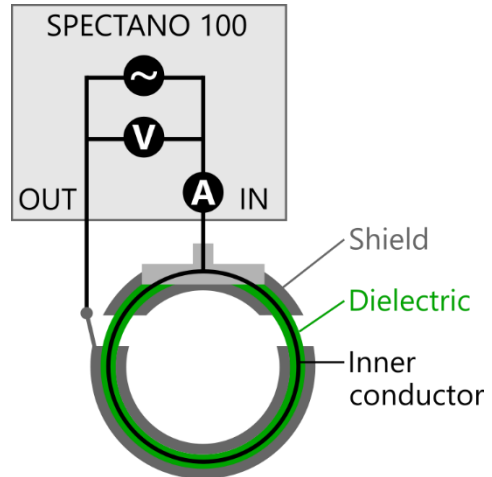
If the cable does not have mounted plugs, mount the BNC plugs on both sides of the cable. To avoid surface currents, cut the outer insulation of the cable about 5 cm from the plugs and remove about 1 cm of the outer jacket. Afterwards remove the screen (shield) in this area. Take care not to cut the dielectric.



Cut a small section of the outer insulation towards the middle section so that the screen of the middle section can be contacted (e.g. using crocodile clips). Ensure that the pressure of the clips does not deform the cable.



Connect the two BNC plugs of the sample cable to the “T” adapter. Then, connect the adapter to the measurement channel (IN) of the SPECTANO 100. Connect the crocodile clamp to the output of the SPECTANO 100 using the 4 mm adapter cable. Don't connect the 4 mm pin of guard and ground.



The picture below shows the completed setup. The output of the SPECTANO 100 drives the shield of the circular section of the cable. The measurement channel is connected to the inner conductor of the cable receiving the currents that pass through the insulator. Surface currents are guarded via the screen of the BNC connectors.



## 4.2 Configure the Measurement

After connecting the SPECTANO 100 to a computer and having started the Spectano Analyzer Suite, the following settings are applied:

### 4.2.1 Test cell settings

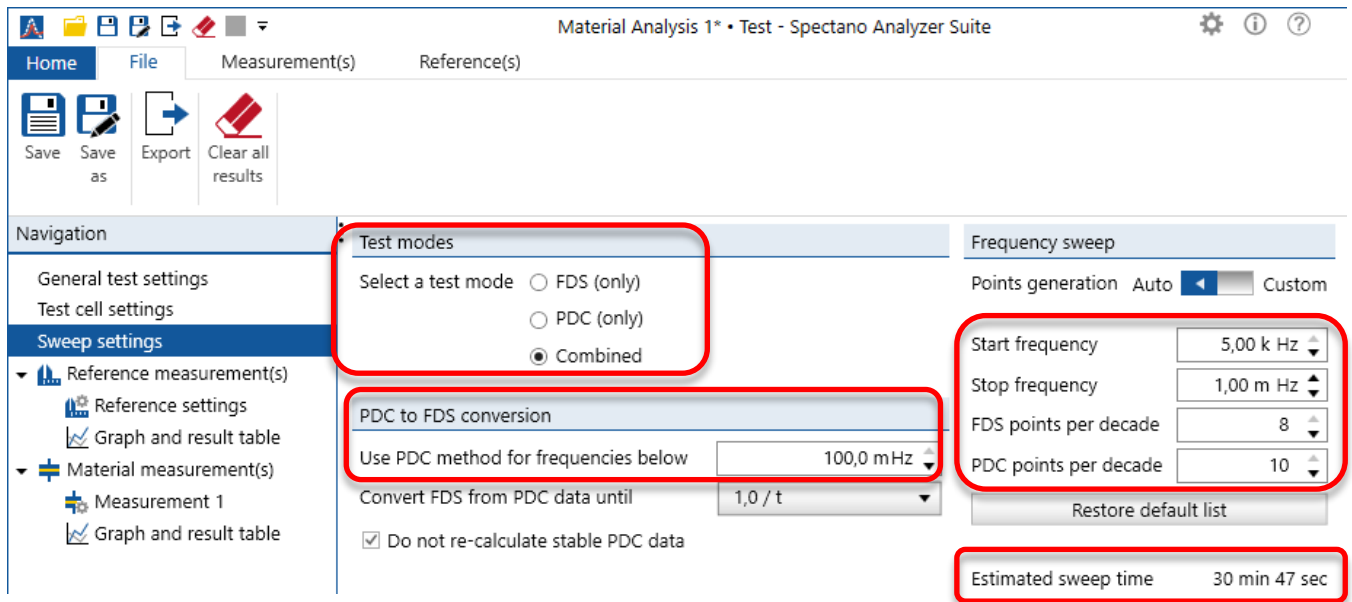
In the **Test cell settings** area, select the cylindrical electrodes and enter the parameters of the cable as shown below:

The Cylindrical electrode geometry is like the geometry of a coaxial cable. Therefore, it can directly be used to measure the permittivity of the insulator in the coaxial cable. The inner diameter (diameter of the conductor) and the outer diameter (diameter of the cable-dielectric) must be entered. The electrode length equals the cable-length and the guard gap is set to 12 mm as shown in the picture to the right.



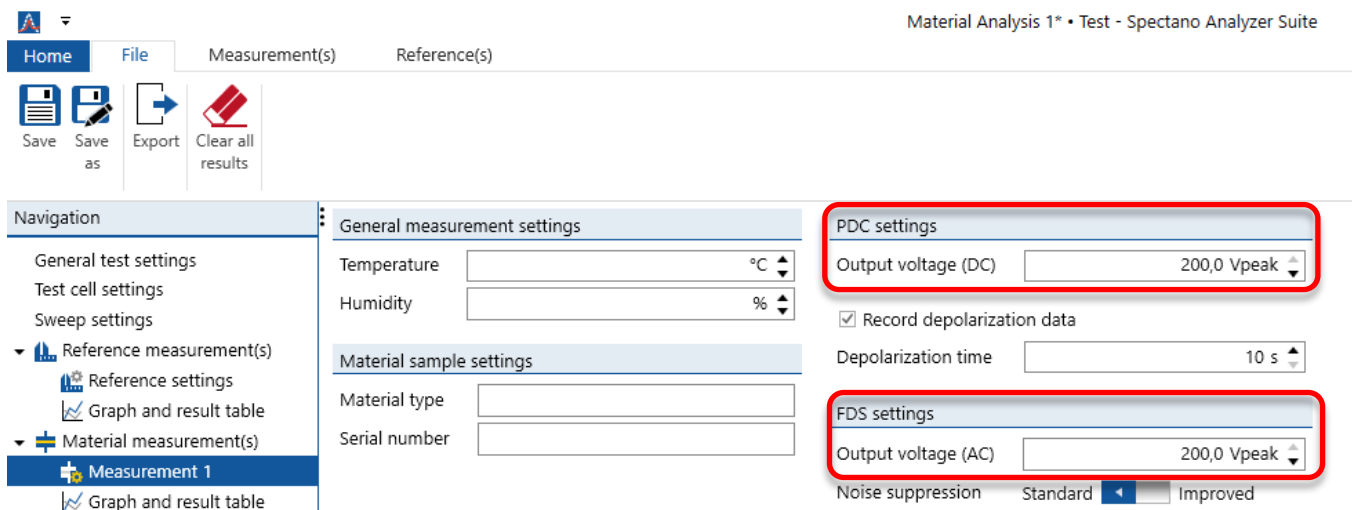
### 4.2.2 Sweep settings

In the **Sweep settings** area, select the test mode. In this case, the combined mode is used, and the measurement is selected to run from 5 kHz down to 1 mHz. The low frequency of 1 mHz results in an estimated sweep time of 30 minutes and 47 seconds. Below 100 mHz, the PDC method is used.



### 4.2.3 Measurement settings

After configuring the test cell geometry and the sweep, enter the **Measurement setting** area to configure the material thickness and the measurement voltage.



The measurement voltage was set to 200 Vpeak in the PDC measurement as well as in the FDS measurement. No pre-measurement checks were applied.

### 4.3 Performing the Measurement

Before starting the measurement, make sure to follow all safety rules.

**WARNING**

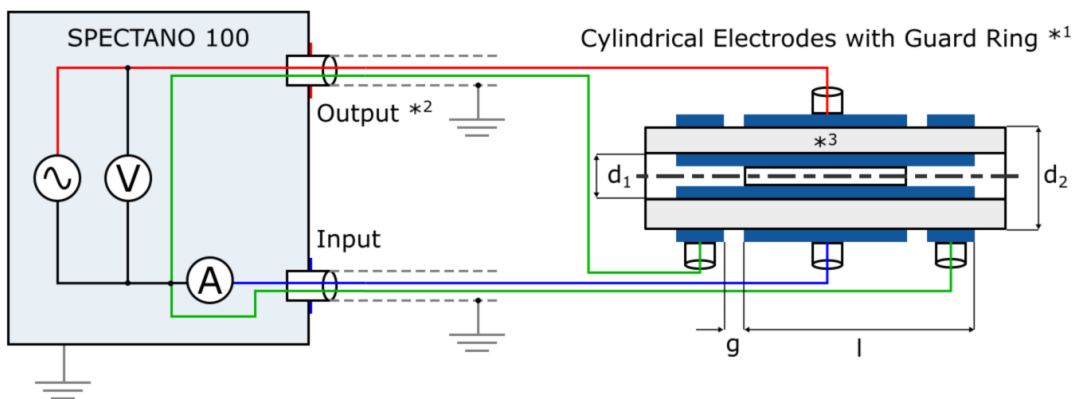


**Death or severe injury caused by high voltage or current**

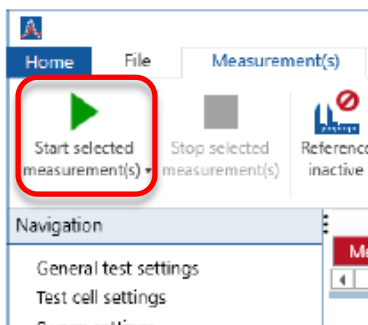
Before starting a measurement, read the safety rules and operation and connection instructions in the SPECTANO User Manual and observe the application specific safety instructions in this Application Note when performing measurements to protect yourself from high-voltage hazards.

Re-check the connection diagram and connection setup.

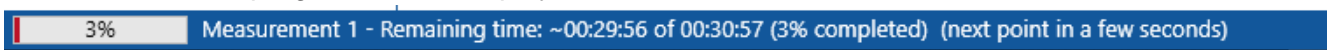
Connection diagram



Then, start a measurement by clicking on the “Start selected measurement(s)” icon:



The measurement progress will be displayed in the status bar:

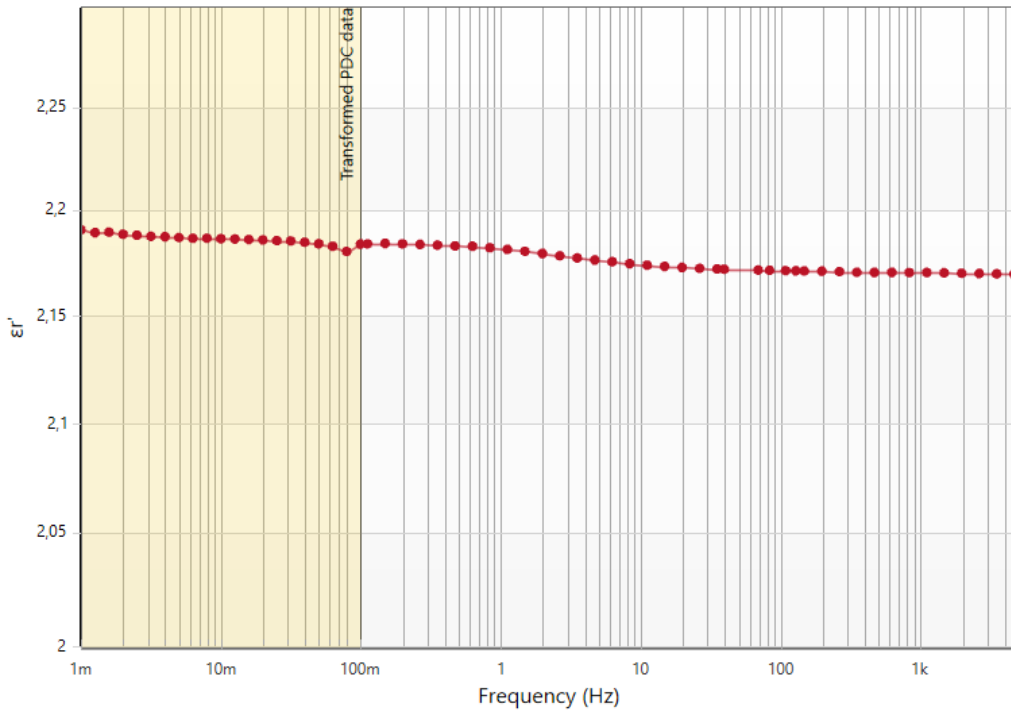


## 4.4 Measurement Result

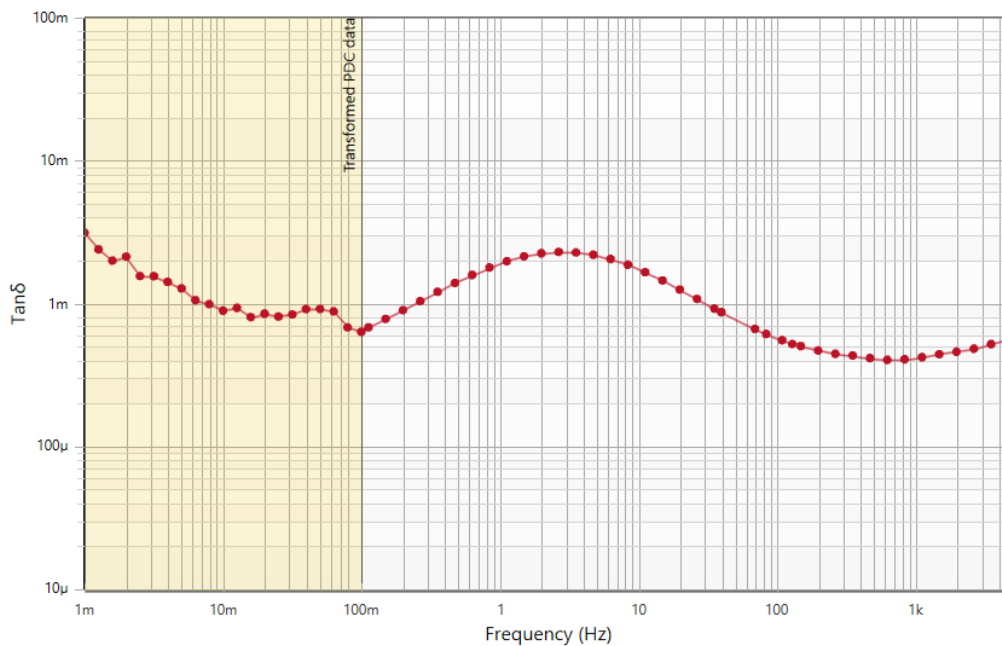
After the measurement has finished, switch to “Graph and result table” to analyze the result of the performed measurement in tabular or graphical form:

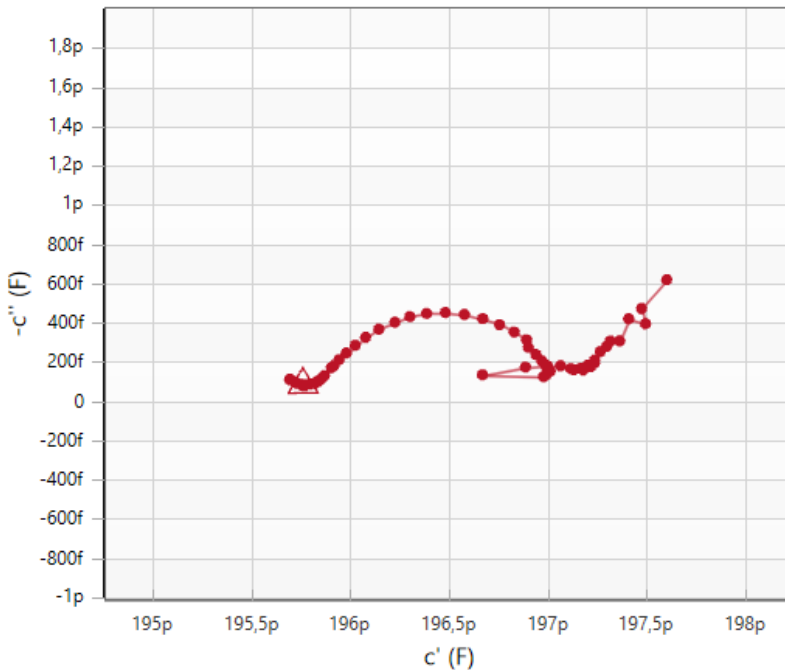
 Graph and result table

The following diagram shows the measured permittivity of the cable dielectric. The permittivity is at 2.17 at 5 kHz. At frequencies below 1 Hz, the permittivity rises slightly to nearly 2.19 at 1 mHz.



The  $\tan(\delta)$  is shown in the following diagram. It is at 0.00057 at 5 kHz and has its maximum of 0.0023 at around 3 Hz.





The real part of capacitance is at 196 pF, the complex part of the capacitance is < 400 fF which means the losses of the cable are very small, which is also reflected in the small  $\text{Tan}\delta$ .

The capacitance from the datasheet is 113 pF/m. In our case we measured 101 pF/m which is approximately 10% lower than the datasheet indicates.

## 5 Conclusion

SPECTANO 100 with the Spectano Analyzer Suite offers all necessary tools to perform measurements of dielectric parameters on coaxial cables. Important dielectric parameters can be measured and displayed easily. The Spectano Analyzer Suite offers all graphical possibilities to display the results, in linear and logarithmic axis scaling.



OMICRON Lab is a division of OMICRON electronics specialized in providing Smart Measurement Solutions to professionals such as scientists, engineers and teachers engaged in the field of electronics. It simplifies measurement tasks and provides its customers with more time to focus on their real business.

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