



# *Broadband Electromagnetic Characterization of Materials*

## SCOPE

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Numerous research domains involving wave transmission rely on the knowledge of electromagnetic (EM) properties of materials: the dielectric permittivity, conductivity and magnetic permeability, - to understand how electromagnetic waves interact with materials.

Furthermore, these properties are directly related to secondary parameters, such as frequency, temperature, density and moisture content of the target material.

The patent protected EpsiMu® system is a user-friendly and autonomous device used to measure the electromagnetic properties of any type of non-metallic material, in a broad frequency range.

## APPLICATIONS

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- Antenna development
- Electronics and Instrumentation
- Aviation technologies
- Radar research
- Construction Industry
- Geology Research and Astrophysics
- Biomaterial development
- Food Processing Industry



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## SYSTEM OVERVIEW

The EpsiMu® coaxial transmission lines were developed to measure the complex electromagnetic parameters of a wide range of materials. More specifically, properties such as the complex dielectric permittivity, complex magnetic permeability, conductivity and loss tangent (or dielectric loss) can be determined on a wide frequency range, typically from a few tenths of MHz to a few tenths of GHz. The EpsiMu® PE13 & 7mm Complete Kit includes both of our most popular coaxial transmission lines, 7mm and PE13, as well as the dedicated software. This equipment was designed to be used with a calibrated Vector Network Analyzer (VNA).

Depending on the application, a few different transmission lines are available in the form of Measurement Kits.

### EpsiMu® 7mm

The EpsiMu® 7mm cell allows characterizing solid materials up to 18 GHz. When using EpsiMu® 7mm, the solid samples require an external diameter of 7 mm and an internal diameter of 3 mm; sample thickness should be higher than a few millimeters and inferior to  $\lambda/2$ . This coaxial line is an air-line type of cell, having two dissociable PC7 connectors, which allow a quick insertion of the solid sample.

### EpsiMu® PE13

EpsiMu® PE13 can be used to characterize any sort of materials up to 8 GHz. With the PE13 transmission line, solid materials need to be shaped into a washer of the same internal dimensions as the coaxial line. The external diameter of the propagation line's sample holder is 13 mm, and the internal diameter is 5.65 mm.



## EpsiMu® PE13 (cont.)

The thickness of the sample is not set, and it can be comprised between a few millimeters and the maximal length of the sample holder, either 6 mm, 12 mm, 24mm or 30mm. When measuring liquids or powdery materials, the sample holder must be completely filled to avoid any measurement errors due to air gaps. The detachable sample holder was conceived to contain any kind of material, due to the dielectric partitions that delimitate the confinement area.

## EpsiMu® PE25.4

The EpsiMu® PE25.4 is an individual cell with detachable sample holder. The outer conductor has a diameter of 25.4 mm and the inner conductor has a diameter of 11mm. It was especially conceived to measure the electromagnetic permittivity of soil core samples. Extraction stainless steel accessories, included in the EpsiMu® PE25.4mm Kit, provide an easy approach to extract and insert core samples into the sample-holder.

## EpsiMu® PE50 and PE100

The EpsiMu® PE50 and PE100 cells are extensions of the EpsiMu® PE13 cell. With an inner/outer diameter ratio of 21.7/50mm and 43.5/100mm, the PE50 and PE100 extensions are especially designed to measure large-granulate soils or granulated concrete, within low frequencies.

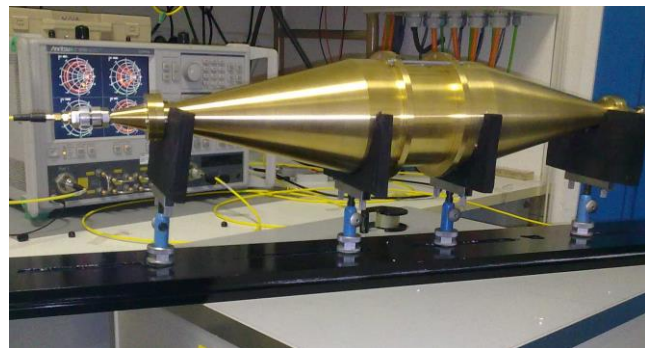


Image courtesy of P. Sabouroux, Institut Fresnel, Aix-Marseille University.

*Other sizes may be manufactured upon request*

# SOFTWARE

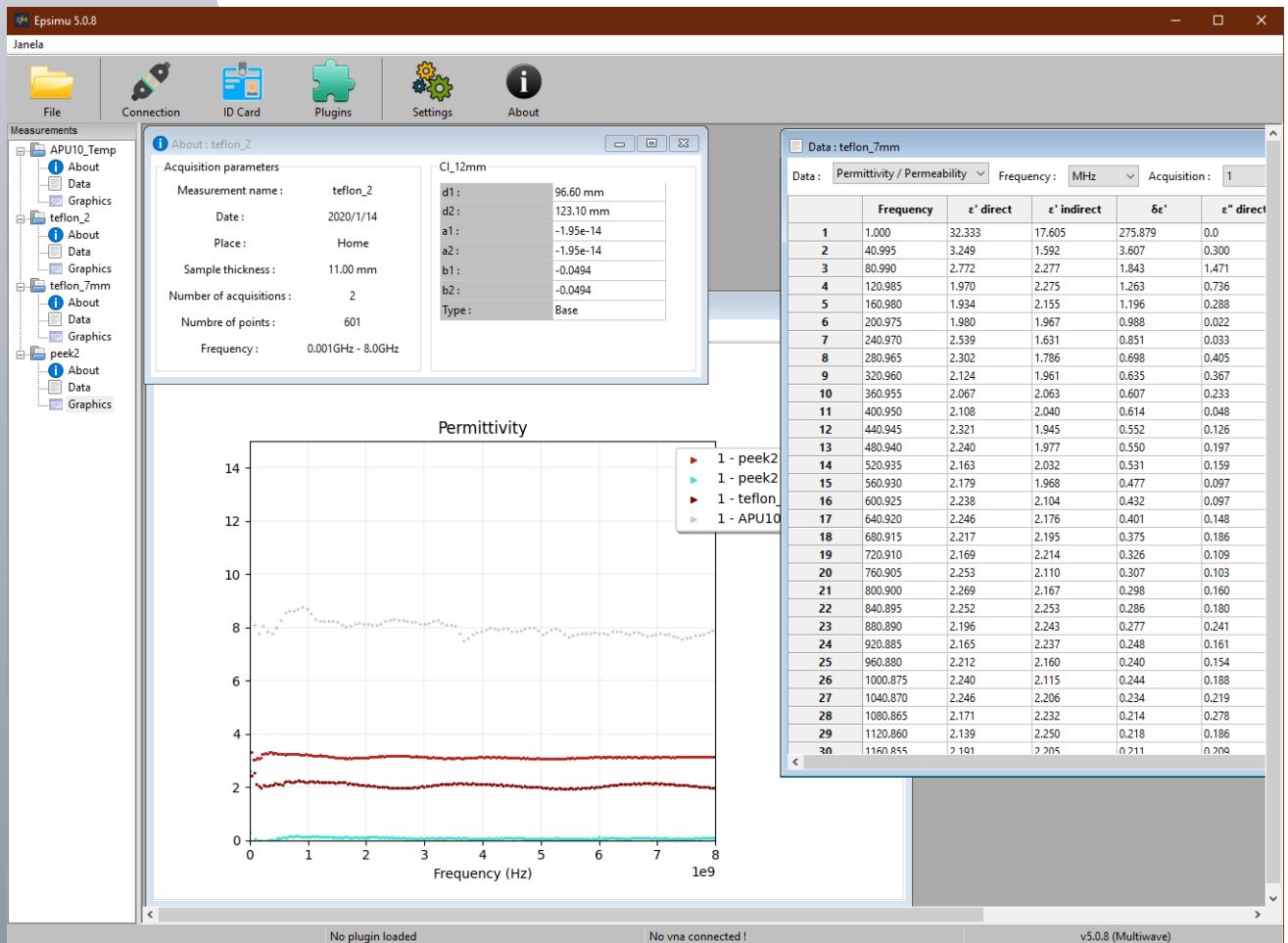
The EpsiMu® toolkits include a dedicated software (more information is available at [www.epsimu.com](http://www.epsimu.com)). The current version is EpsiMu® software v.5.0.10.

A multiple-measurement display allows comparing the four main parameters, as well as the S-Parameters of the transmission line and the sample.

The software recognizes direct acquisitions from a selected library of VNA brands and models. If your VNA is not on the list, we'll create your own dedicated plugin!

# VNA PLUGIN LIBRARY

- Anritsu MS20XX Series
- Anritsu Shockline™ Series
- Rhode & Schwarz ZVL, ZVA, ZNB
- Keysight N5222, E5071
- Keysight P937x Series
- Picotech PicoVNA



# TECHNICAL PROPERTIES

	EpsiMu® 7mm	EpsiMu® PE13	EpsiMu® PE25.4 (1 inch)	EpsiMu® PE50	EpsiMu® PE100
<b>Frequency Range</b>	1 MHz to 18 GHz	1 MHz to 8 GHz	1 MHz to 4.5 GHz	1 MHz to 1.5 GHz	1 MHz to 500 MHz
<b>Temperature Range</b>	-30°C to 85°C	-30°C to 85°C	N.A	N.A	N.A
<b>Connectors (by default)</b>	N <sub>male</sub> -PC7/ N <sub>female</sub> -PC7				
<b>Inner conductor diameter (mm)</b>	3.04	5.65	11	21.7	43.5
<b>Outer conductor diameter (mm)</b>	7	13	25.4	50	100
<b>Sample type</b>	Washer-shaped solids	Solids, powders, liquids, etc.			
<b>Metallic samples</b>	No				
<b>Inhomogeneous samples</b>	No	No	Yes if grain size <3mm	Yes if grain size <5mm	Yes if grain size <10mm
<b>Sample length range (mm)</b>	2 to a few mm ( $\leq \frac{\lambda}{2}$ )	2 to sample holder length (6, 12, 24 or 30 mm)	Max. 50 mm	Max. 40 mm	Max. 60mm
<b>Sample holder volume (cm<sup>3</sup>)</b>	N.A.	6 mm: 0.65 12 mm: 1.29 24 mm: 2.58 30 mm: 3.23	20.6	63.7	382.1
<b>Sample holder maximal Pressure</b>	N.A.	2 ton/cm <sup>2</sup> on the sample	-	-	-
<b>Cell Impedance</b>	50 Ω				
<b>Accuracy</b>	$\frac{\Delta\epsilon'}{\epsilon'} < 5\%; \frac{\Delta\epsilon''}{\epsilon''} < 10\%$	$\frac{\Delta\epsilon'}{\epsilon'} < 5\%; \frac{\Delta\epsilon''}{\epsilon''} < 10\%$	$\frac{\Delta\epsilon'}{\epsilon'} < 5\%; \frac{\Delta\epsilon''}{\epsilon''} < 15\%$	$\frac{\Delta\epsilon'}{\epsilon'} < 5\%; \frac{\Delta\epsilon''}{\epsilon''} < 15\%$	$\frac{\Delta\epsilon'}{\epsilon'} < 5\%; \frac{\Delta\epsilon''}{\epsilon''} < 15\%$
<b>EpsiMu Software Extraction Algorithms</b>	NRW	NRW, HPM, TRL	HPM	HPM	HPM
<b>Type</b>	Individual cell	Individual cell	Individual cell	Extension of EpsiMu® PE13	Extension of EpsiMu® PE13

## ACCESSORIES

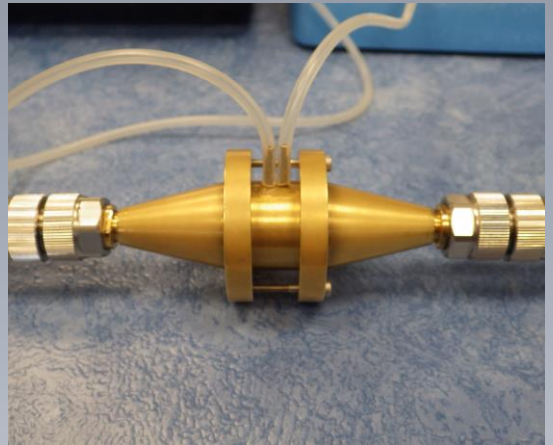
The EpsiMu® PE13 has been, since its first prototype, a technology molded to answer a need of versatility. As a complement to the solid-restricted EpsiMu® 7mm, the EpsiMu® PE13 with detachable and watertight sample holder measures much more than just washer-shaped solid samples. For instance, a water-dedicated sample holder has been developed to allow the measurement of continuously changing liquids (in terms of concentration, temperature, etc.).

Furthermore, a Temperature Control system is today available as a complement of the EpsiMu® PE13 & 7mm complete kit, supporting the measurement of EM properties of materials as function of not only frequency, but of temperature as well.

We take pride in being able to propose a complete customization of our EpsiMu® kits. For more information on our customization possibilities, please contact [epsimu@multiwave.fr](mailto:epsimu@multiwave.fr)

Modifications or custom orders of either the hardware or software may sustain a further delay.

## Liquid Access Sample-holder



- PE13's detachable sample-holder
- Available in lengths 12 mm or 24mm

## Temperature Control System



- From room temperature up to 85°C
- Adaptable to EpsiMu® 7mm or PE13 cells
- Low Temperature Control System coming in 2022!

## REPLACEMENT PARTS

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All parts included in the kits are available as replacement parts. The parts that need to be replaced relatively often are the Teflon partitions, the sample holder internal conductor, and internal and external bolts.

## MAINTENANCE AND FOLLOW-UP

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### AFTER-SALES SERVICE

The EpsiMu® team will accompany you from software installation and VNA connection, to setting up the system and carrying out the first measurements. We also provide measurement advice and measurement verification, if requested.

### WARRANTY

The EpsiMu® toolkits have a 2-year warranty over manufacturing defects. The warranty does not cover damage caused by accident, improper care, negligence, or by the use of corrosive or other damaging materials. Upon termination of the 2-year warranty period, an annually extension of the warranty can be acquired, which covers the replacement of damaged parts and/or measurement confirmation service/reports. All parts of the EpsiMu® toolkits are replaceable.

### DELIVERY

Shipment is assured within 1 month from receiving the order form, if the products are in stock, or 3 months if the products are out of stock. Modifications or custom orders of either the hardware or software may sustain a further delay.

## REFERENCES

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