



Broadband Electromagnetic Characterization of Materials

Product Data Sheet

Product Description

Product Overview

The *EpsiMu*[®] coaxial transmission lines integrate a kit for the complex electromagnetic parameter's measurement 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*[®] kit includes one of the coaxial transmission lines or both, as well as the dedicated software. This equipment was designed to be used with a calibrated Vector Network Analyzer (VNA).

Depending on the application, two different transmission lines are available. *EpsiMu*[®] 7mm allows characterizing solid materials up to 18 GHz; *EpsiMu*[®] PE13 can be used to characterize any sort of materials up to 8 GHz.

Concerning the precision of the system, the uncertainty analysis reported approximately 5% for the real part of permittivity and 10% for the imaginary part. In most cases, the uncertainty is less than reported. For magnetic materials, the

uncertainty analysis has not been plotted, since most of the tests done up to date are of weakly magnetic materials¹.

When using *EpsiMu*[®] 7mm, the solid samples required an external diameter of 7 mm and an internal diameter of 3 mm; the sample thickness is not fixed but should be higher than a few millimeters (inferior to $\lambda/2$). This coaxial line is an air-line type of cell, having two dissociable PC7 connectors, which allow an insertion of the solid sample.

With the *EpsiMu*[®] 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. 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, thanks to the dielectric partitions that delimitate the confinement area.



EpsiMu[®] 7 mm



The *EpsiMu*[®] complete kit



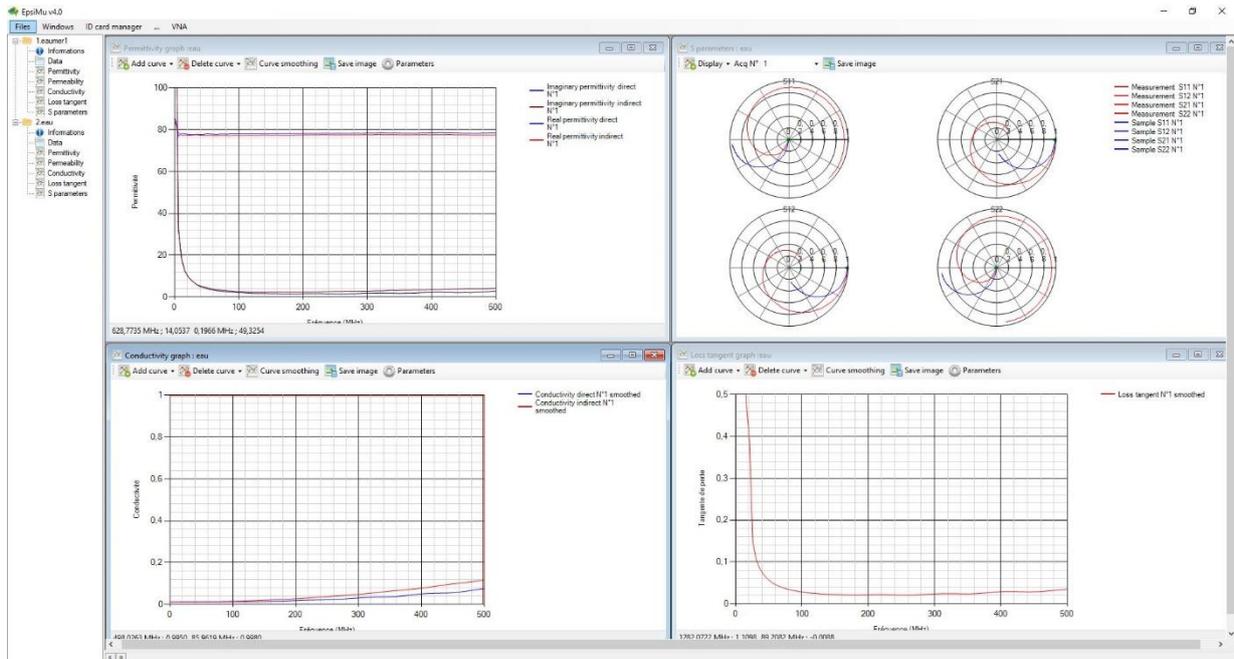
EpsiMu[®] PE13 with sample-holders

Software

The *EpsiMu*[®] toolkit includes a dedicated software (more information is available at www.epsimu.com). A multiple measurement display allows a comparison between the four main parameters as well as the S-Parameters of the transmission line and the sample.

¹Emerson and Cuming, ECCOSORB[®] SF, <http://www.eccosorb.com/Collateral/Documents/English-US/SF.pdf>

Additionally, the current version of the software, *EpsiMu*[®] 5.0, allows directly piloting all Anritsu MS20XX and MS46122 (ShockLine™), Rohde & Schwarz ZNB and ZVA, via a LAN interface. For other types of VNAs, the software can be used by import of S2P matrices of the S-Parameters.



Applications

The *EpsiMu*[®] coaxial transmission lines can be used for multiple applications, ranging from the biomedical domain to astrophysical exploration:

- Antenna development for multimedia and telecommunications
- Electronics and general instrumentation
- Aviation technologies
- Radar research (GPR, planetary and cometary exploration, etc.)
- Construction industry (moisture content in soil, concretes, etc.) and geology research
- Biomedical domain and biomaterial development
- Material characterization in the food processing industry (determination of water/alcohol content, quality control, PDO /PGI assessment)

A few documented references can be found at the end of this datasheet.

Technical Properties

	<i>EpsiMu</i> [®] 7mm	<i>EpsiMu</i> [®] PE13
Frequency Range	1 MHz to 18 GHz	1 MHz to 8 GHz
Temperature Range	-30°C to 85°C	-30°C to 85°C
Connectors (by default)	N _{male} -PC7/ N _{female} -PC7	N _{male} -PC7/ N _{female} -PC7
Inner conductor diameter/ outer conductor diameter (mm)	3.04/7	5.65/13
Sample type	Washer-shaped solids	Solids, powders, liquids, etc.
Sample length range (mm)	2 to a few mm ($< \frac{\lambda}{2}$)	2 to sample holder length (6, 12, 24 or 30 mm)
Sample holder volume (cm³)	-	6 mm: 0.65; 12 mm: 1.29
Sample holder maximal Pressure	-	2 ton/cm ² on the sample
Impedance	50 Ω	50 Ω
Accuracy	$\frac{\Delta \epsilon'}{\epsilon'} < 5\%$; $\frac{\Delta \epsilon''}{\epsilon''} < 10\%$	$\frac{\Delta \epsilon'}{\epsilon'} < 5\%$; $\frac{\Delta \epsilon''}{\epsilon''} < 10\%$

Equipment and 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-measurement only *EpsiMu*[®] 7mm, the *EpsiMu*[®] PE13 with detachable and watertight sample holder allows measuring much more than just washer-shaped solid samples. For instance, several sample holder sizes are currently available, in terms of diameters or length, depending on the target application. We take pride in being able to propose to our customer's the possibility to completely customize their *EpsiMu*[®] kits. For more information on our customization possibilities, please contact epsimu@multiwave.fr. Modifications or custom orders of either the hardware or software may sustain a further delay.

Accessories

Outside any custom accessories, a few operational accessories are already available upon request:

- Liquid access sample holder for PE13 system, any length.
- Temperature control system for PE13 24 mm, PE30 mm sample holders or the EpsiMu 7mm cell.
- 1-inch, 50 mm and 100 mm diameter sample holders are available upon request, as well as the corresponding extension to the PE13 conical cell. Other sizes may be manufactured on request.

Replacement Parts

All pieces included in the kit 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

After-sales Service

Since all components, hardware and software, are made-in France (Marseille), all posterior alterations can be possible.

Warranty

The *EpsiMu*[®] toolkit has 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.

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

- M. W. Ben Ayoub, E. Georget, J.-F. Rochas, S. Hubert, R. Aro, A. L. Neves, P. Sabouroux. Quantitative determination of bound water in cardboard by dielectric permittivity measurement. *Measurement Science and Technology*, 2018.
- Hurshkainen, A. Nikulin, E. Georget, B. Larrat, D. Berrahou, L. Neves, P. Sabouroux, S. Enoch, I. Melchakova, P. Belov, S. Glybovski. A Novel Metamaterial-Inspired RF-coil for Preclinical Dual-Nuclei MRI, arXiv preprint, arXiv:1709.04761, 2017.=
- A.L. Neves, E. Georget, N. Cochinaire, P. Sabouroux. Real - Time Microwave Sensor System for Detection of Polluting Substances in Pure Water, *Review of Scientific Instruments*, 88 (084706); doi: 10.1063/1.4998982, 2017.
- A.L. Neves, L. Leroi, Z. Raolison, N. Cochinaire, T. Letertre, R. Abdeddaim, S. Enoch, J. Wenger, J. Berthelot, AL Adenot-Engelvin, N. Malléjac, F. Mauconduit, A. Vignaud, P. Sabouroux. Compressed Perovskite Aqueous Mixtures Near Their Phase Transitions Show Very High Permittivities: New prospects for High Field MRI Dielectric Shimming. *Magnetic Resonance in Medicine*; doi:10.1002/mrm.26771, 2017.
- A.L. Neves, L. Leroi, N. Cochinaire, R. Abdeddaim, P. Sabouroux, A. Vignaud. Mimicking the Electromagnetic Distribution in the Human Brain: A Multi-frequency MRI Head Phantom. *Applied Magnetic Resonance* 3(48), 213-226; doi: 10.1007/s00723-017-0862-4, 2016.
- Y. Brouet, L. Neves, P. Sabouroux, A.C. Levasseur-Regourd, O. Poch, P. Encrenaz, A. Pommerol, N. Thomas, W. Kofman. Characterization of the permittivity of controlled porous water ice/dust mixtures to support the radar exploration of icy bodies. *Journal of Geophysical Research: Planets* 121(12):2426–2443; doi: 10.1002/2016JE005045, 2016.
- Y. Brouet, A.C. Levasseur-Regourd, P. Sabouroux, L. Neves, P. Encrenaz, O. Poch, A. Pommerol, N. Thomas, W. Kofman, A. Le Gall, V. Ciarletti, A. Hérique, A. Lethuillier. A porosity gradient in 67P/C-G nucleus suggested from CONSERT and SESAME-PP results: an interpretation based on new laboratory permittivity measurements of porous icy analogues. *Monthly Notices of the royal Astronomical Society*, stw2151, doi: 10.1093/mnras/stw215, 2016.
- Georget, R. Abdeddaim, P. Sabouroux. A quasi-universal method to measure the electromagnetic characteristics of usual materials in the microwave range. *Comptes Rendus Physique* 15.5: 448-457, 2014.
- Ba, P. Sabouroux. EpsiMu, a Toolkit for permittivity and permeability measurement in microwave domain at real time of all materials: Applications to solid and semisolid materials. *Microwave and optical technology letters* 52.12, : 2643-2648, 2010.