

## Dielectric Measurements of Samples Available in Limited Size or Volume

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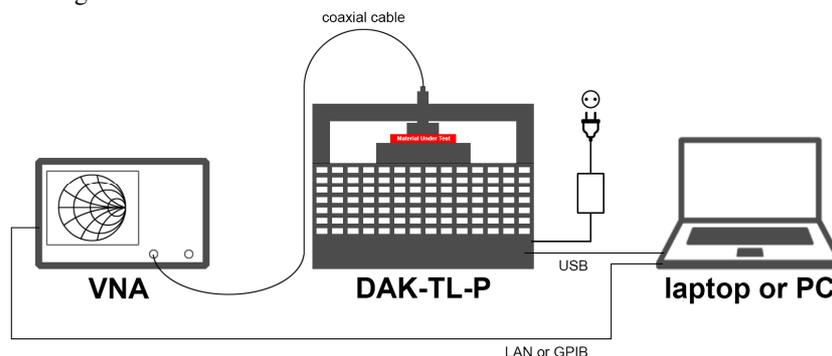
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### Summary

To precisely calculate the effects on the human body reliable dielectric tissue data are necessary. Open coaxial probes, attached to a Vector Network Analyzer (VNA), are well suited to perform dielectric measurements on biological tissues and has been extensively used for material characterization [1]. Although a successful method, it has its own limitations. The samples need to be sufficiently large such that the reflections at the boundaries can be neglected. This condition cannot always be fulfilled, since tissues like skin, blood vessels or gastrointestinal walls are limited in size. To deal with the limitations we implemented a modified open coaxial probe system, based on the formulation of [2]. It inherits the broadband nature of the open coaxial probes and allows the complex dielectric properties evaluation of samples with limited size.

Samples with finite thickness are placed on a metallic plate, and are in direct contact with the probe flange. First, the sample thickness is automatically measured by mechanical force detection. The complex dielectric parameters are calculated from the complex reflection coefficient measured with the VNA. The measured sample thickness and the reflection from the metallic plate are taken into account in the algorithms and the complex dielectric properties are derived. This is the first time that the full-wave analysis of the open coaxial probe geometry was inverted (complex dielectric parameter is calculated from reflection coefficient) and the improper integrals of complex functions were programmed [2]. The calculation is done automatically in the controlling software.



**Figure 1.** Schematic of the measurement system, DAK-TL-P. The system is connected to a laptop or a PC, which controls the data acquisition on the VNA and the movement of the test fixture. The red bar indicates the small sized sample.

The modified open coaxial probe was tested on solid materials with known dielectric properties, results are shown in Table 1.

**Table 1.** Reference materials samples with 2 mm-thickness, measured in the proposed modified open coaxial probe setup.

Material	Measured Permittivity (200 MHz – 20 GHz)	Reference Permittivity
Teflon	2.06, meas. unc. (k = 2) 3.2%	2.07
Boron Nitride	4.38, meas. unc. (k = 2) 3.2%	4.40
MACOR ceramics	5.64, meas. unc. (k = 2) 3.2%	5.67

### References

1 S. Gabriel, R. W. Lau, and C. Gabriel, “The dielectric properties of biological tissues: II. Measurements in the frequency range 10 Hz to 20 GHz”, *Physics in Medicine and Biology*, **41**, 11, April 1996, pp. 2251–2269, doi: <https://doi.org/10.1088/0031-9155/41/11/002>.

2 J. Baker-Jarvis, M. D. Janezic, P. D. Domich, and R. Geyer, “Analysis of an Open-Ended Coaxial Probe with Lift-Off for Nondestructive Testing”, *IEEE Transactions on Instrumentation and Measurement*, **43**, 5, October 1994, pp. 711-718, doi: 10.1109/19.328897