Dielectric Assessment Kit

APPLICATION NOTE

Uncertainty of DAK12 between 4–10 MHz

speag

Uncertainty of DAK–12 between 4 and 10 MHz

1 Introduction

The SAR standard (Draft IEC 62209-U) has been recently extended to include testing of wireless power transfer (WPT) systems, which operate above 4 MHz. The perform compliance testing according to this standard, accurate dielectric measurements of the tissue simulating media (TSM) are required at the WPT operating frequencies. To achieve this by using the same instrumentations as for the higher frequencies, we have developed a novel algorithm for DAK–12 that reliably compensates for the effect of electrode polarization presents in liquids at these frequencies.

2 Objective

The objective of this document is provide the uncertainty budget for measurements of tissue simulating media and its verification for frequencies between 4 and 10 MHz with DAK–12.

3 Uncertainty Budget

The uncertainty of dielectric measurements with the DAK probes is composed of contributions which vary for probe type, frequency and material (under test) parameters. The significant factors contributing to the uncertainty include (among others):

- Probe Geometry and Mechanical tolerances
  - Inner / Outer diameter of the dielectric bead; bead permittivity
- VNA Errors
  - S11 noise; S11 phase linearity; S11 amplitude linearity
- Calibration errors
  - Open / Short quality; load homogeneity, temperature, position, electrode polarization effects.
- Numerical Errors
  - Numerical approximations (no. of modes)

The uncertainty budgets were assessed for liquids including saline and head and body simulating media for the frequency from 4 MHz - 10 MHz. The resulting expanded uncertainty (k=2) for DAK–12 is given in the table below:

f	**Head / Body Simulating liquid**		**0.1 mol Saline Solution**	
(MHz)	**Unc (k=2) %**		**Unc (k=2) %**	
	$\Delta\epsilon'$	$\Delta\sigma = \Delta\epsilon''$	$\Delta\epsilon'$	$\Delta\sigma = \Delta\epsilon''$
3.0	12.7%	3.3%	10.3%	3.2%
4.0	8.1%	3.3%	6.7%	3.2%
6.0	5.6%	3.3%	4.7%	3.2%
8.0	4.5%	3.3%	3.9%	3.2%
10.0	4.5%	3.3%	3.5%	3.0%

Table 1.1: Uncertainty budget for DAK–12 for TSM in range 4 MHz–10 MHz

4 Verification of Uncertainty Budget

4.1 Measurement Method

For the verification of the uncertainty budget, a series of saline solutions of varying concentrations as well as head tissue liquid were measured with two open co-axial probes (DAK–12 and a 10 mm OCP from Public Health England) and a static conductivity meter. Calibration of the setup was done by using 0.1 mol/l saline solution as load. The calibrated setups (probe & 8753ET VNA) for DAK–12 and 10 mm probe were verified by measuring methanol as reference liquid, prior to measurement of other liquids.

A list of equipment used is as follows:

- DAK–12 Probe
- Open Coaxial Probe (OCP) with 10 mm diameter
- VNA (HP 8753ET)
- Greisinger GMH 5430 conductivity meter

4.2 Static conductivity comparison for saline solutions

As per [1], saline solutions show frequency-independent, flat behavior below 200 MHz. The conductivity measured with the static conductivity meter is therefore taken as a reference, and the measurements with the two coaxial probes at 4 MHz are compared with those from the conductivity meter. Deviations of less than the uncertainty value are considered acceptable.
Table 1.2 shows the measured static conductivity with conductivity meter and the values from OCP measurements for various concentrations of saline solutions. It also contains the deviation between the two methods.

Electrode polarization effects were compensated for in the case of DAK–12. Possible polarization effects were not compensated for the 10 mm probe, however due to the flangeless design of the 10 mm probe, electrode polarization effects have been reported minimal.

The deviations in static conductivity measured by the two probes are within the uncertainty budget.

[1] A. Peyman, C. Gabriel and E. H. Grant, Complex Permittivity of Sodium Chloride Solutions at Microwave Frequencies, Bioelectromagnetics, Vol. 28, p. 264, 2007.

Conc. (mol/l)	**Temp (°)**	**Static cond. (S/m)**	**OCP cond. (S/m), 4 MHz**		**Deviation (%)**	
			DAK–12	**10mm OCP**	**DAK–12**	**10mm OCP**
0.010	22.00	0.111	0.116	0.111	-0.5 %	0.0 %
0.027	21.99	0.291	0.290	0.291	-0.4%	0.0%
0.050	22.03	0.518	0.516	0.513	-0.3%	-0.9%
0.080	21.99	0.809	0.809	0.803	0.0%	-0.7%
0.100	21.99	1.003	1.006	1.004	0.3%	0.2%

Table 1.2: Conductivity values measured with conductivity meter (static) and with two different open coaxial probes (at 4 MHz).

4.3 Permittivity / Conductivity comparison with 50 MHz results for saline solutions

As per the reference 1, saline solutions show a frequency independent flat behaviour below 200 MHz.
Permittivity and Conductivity Comparison Between Probes for Head Tissue Liquid Measurements on broadband head tissue simulating liquid with the two coaxial probes are seen to give similar results: the curves with the 10 mm probe and DAK–12 are close. Figure 1.1 compares permittivity and conductivity measurements of broad band head liquid below 50 MHz.

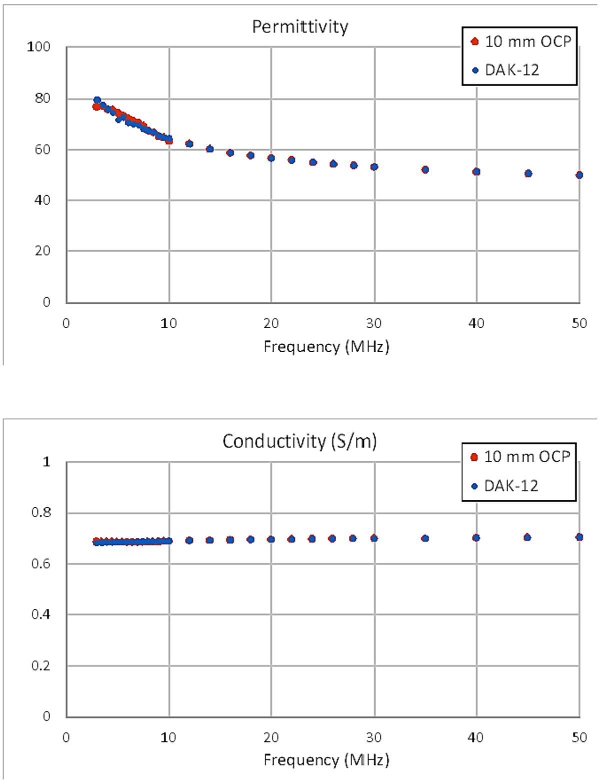

Figure 1.1: Permittivity and conductivity of broad band head liquid, measured with the 10 mm probe and DAK–12.

Permittivity			
Liquid	**10 mm probe** (4 MHz)	**Deviation**	**DAK–12** (4 MHz)
HBBL	75.77	-0.3 %	76.01

Conductivity			
Liquid	**10 mm probe** (4 MHz)	**Deviation**	**DAK–12** (4 MHz)
HBBL	0.6858	0.4 %	0.6833

Table 1.3: Permittivity and conductivity of liquids at 4 MHz, measured with the 10 mm probe and DAK–12. Deviation from DAK–12 is calculated.

The deviations between the two probes at 4 MHz, as shown in Table 1.3 above, are within the uncertainty budget and the permittivity smooth with frequency confirms that validity of the approach.

5 Conclusions

DAK–12 has been successfully extended down to 4 MHz for TSM by the developed algorithm for electro polarization compensation. The uncertainty budget has been assessed and verified. We will continue to evaluate and improve the algorithm for other liquids and materials.

6 Additional Information : Recommended Settings

Following measurement settings are recommended for low frequency measurements with DAK 12 probe: (Table 1.4)

Settings	**Value**
Frequency Segments	2.5 - 9.5 MHz : 0.5 MHz steps 10-295 MHz : 5.0 MHz steps 300-3000 MHz : 50.0 MHz steps
Averaging	3 traces
Filter	ON

Table 1.4: Recommended Settings for low frequency measurements with DAK 12 probe

Recommended VNA settings are shown in Figure 1.2 and Figure 1.3.

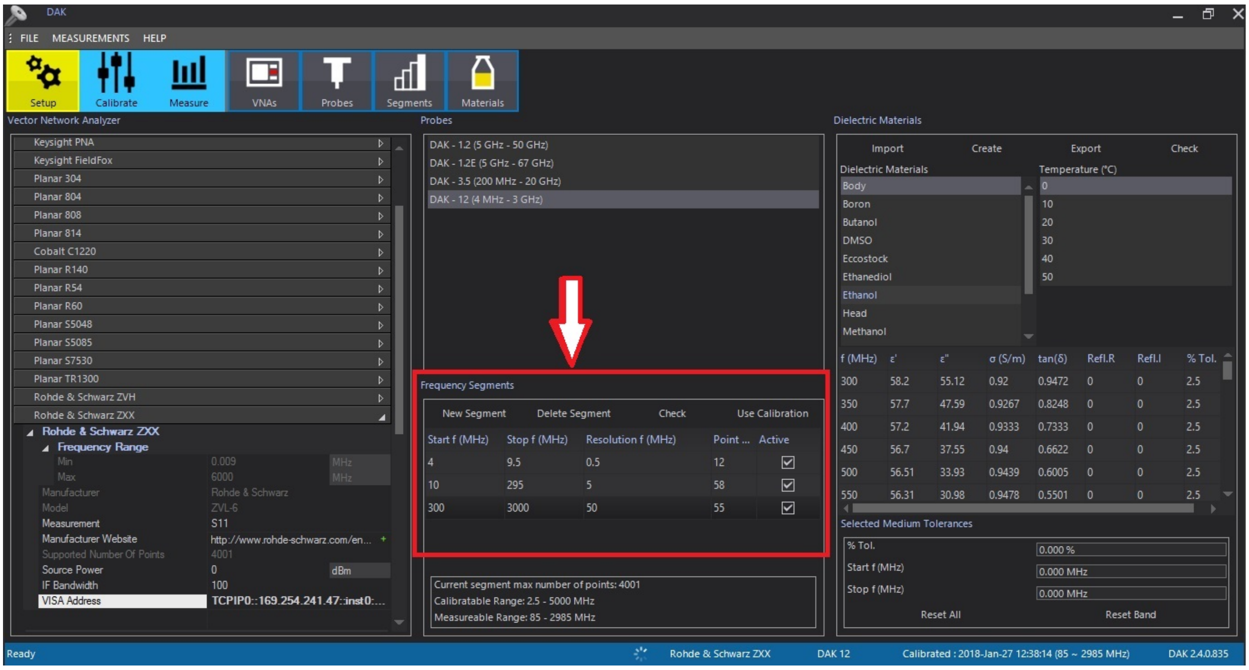

Figure 1.2: Recommended Frequency Segments

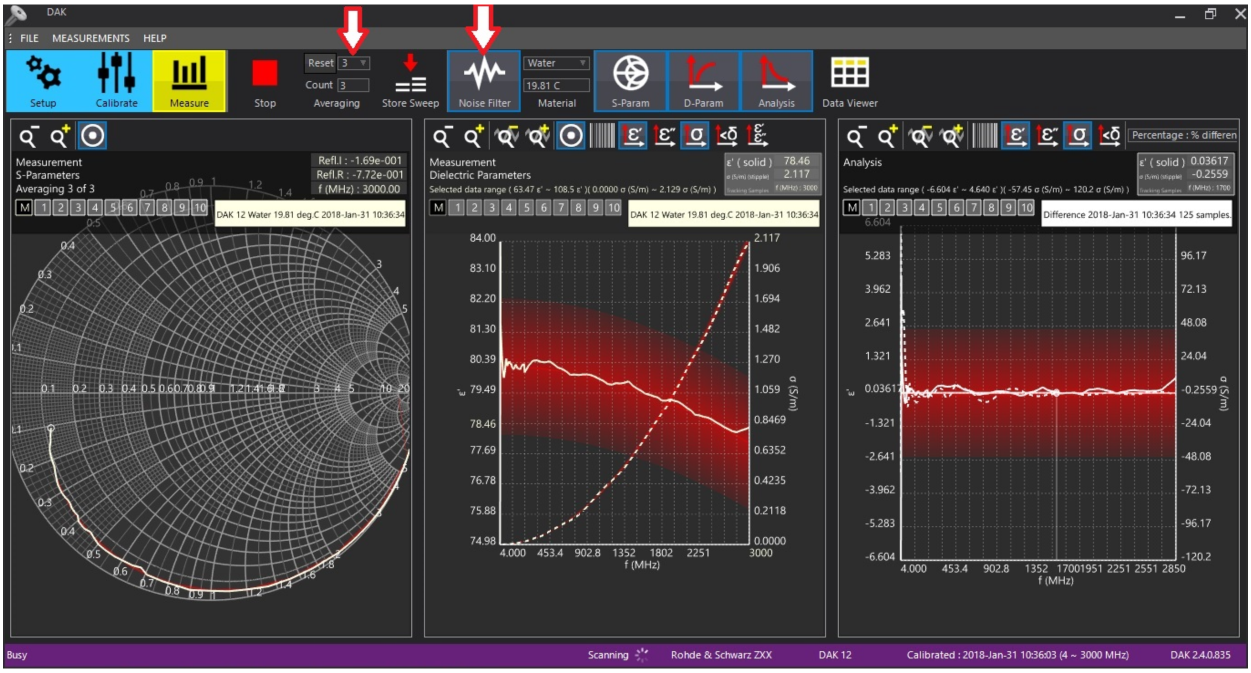

Figure 1.3: Recommended VNA Settings