**Calibration Results**

Uncertainty limits (k=2) for the material measurements in the figures of Appendix A are represented with red dashed lines. These uncertainties contain - in addition to probe uncertainty - the uncertainty of the material target parameter determination.
The measurements show the results obtained from independent calibrations for the same material. The differences between the individual measurement curves give therefore an indication for the obtainable repeatability and shall lie within the uncertainties stated in the tables.

*Materials for DAK-3.5 calibration:*
*Appendix A with curves for Ethanol*, HBBL, and 0.05 mol/L NaCl solution (200 MHz - 6 GHz, optional 20 GHz), HS gel and low loss solid substrate are optional.*

** Effective immediately, methanol will be replaced with the safer and more environmentally-friendly ethanol as the validation liquid. Each batch of ethanol is calibrated using a methanol reference, ensuring that the validation process is both traceable and consistent with prior measurements.*



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# Appendix A: Detailed Results

## A.1 Probe appearance and calibration sequence

### A.1.1 Appearance

The OCP appearance is fully according to the expectations:

- the flange surface is intact

### A.1.2 Calibration sequence

The following sequence was repeated 3 times in the low frequency range from 200 – 300 MHz in 5 MHz steps and in the high frequency range from 300 to 6000 MHz in 50 MHz steps, and from 6 GHz to 20 GHz in 250 MHz steps.

| | |
|---|---|
| Air | |
| Short | 1 short, then immediate verification with a second short (with eventual repetition) |
| Water | De-ionized water, temperature measured and set in the software (for DAK-12 0.1 mol/L saline solution, temperature measured and set in the software) |
| Methanol | Pure methanol, temperature measured and set in the software |
| Ethanol | Pure ethanol, temperature measured and set in the software |
| Liquids | Measurement of further liquids (e.g. Head tissue simulating liquid and 0.05 mol/l saline) |
| Cleaning | Probe washed with water and isopropanol at the end of the sequence. |
| Shorts | 4 additional separate short measurements to determine the deviation from the original |
| Refresh | Refresh with Air |
| Solid | 4 separate solid low loss planar substrate measurements to determine one average (optional) |
| Semisolid | 4 separate head gel measurements on fresh intact surface to determine one average (optional) |
| Cleaning | Probe washed with water and isopropanol at the end of the sequence |

Evaluation of the additional shorts from the calibrated (ideal) short point at the left edge of the Smith Chart, represented as magnitude over the frequency range (fig. 2.1.x) and in polar representation (fig. 2.2.x).

Evaluation of the Liquid measurements and representation of the permittivity and conductivity deviation from their reference data at the measurement temperature. The results of each of the 3 calibrations is shown in the appendix for each material (fig. 3ff) in black, red, blue. The red dashed line shows the uncertainty of the reference material parameter determination.

Evaluation of the Semisolid measurements (optional) by representing the 3 average deviations (each resulting from the 4 separate measurements per set), equivalent to the liquid measurement. Representation of the permittivity and conductivity deviation from their reference data at the nominal temperature.

Evaluation of the Solid measurements (optional) by representing the 3 average deviations (each resulting from the 4 separate measurements per set), equivalent to the liquid measurement. Representation of the permittivity deviation from their reference data and the loss tangent at the nominal temperature.



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## A.2 Short residual magnitudes

After each of the 3 calibrations with a single short (as per the DAK software), 4 additional separate, short measurements were performed after the liquid measurements and evaluated from the S11 data. The residuals in the graphs represent the deviation from the ideal short point on the polar representation on the VNA screen.

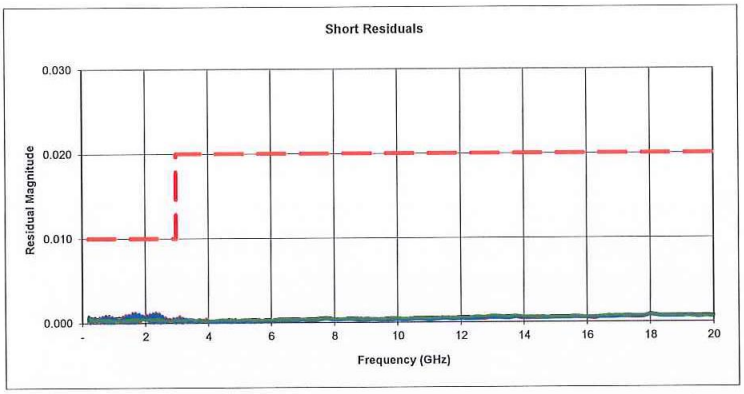


Fig. 2.1a Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration a)

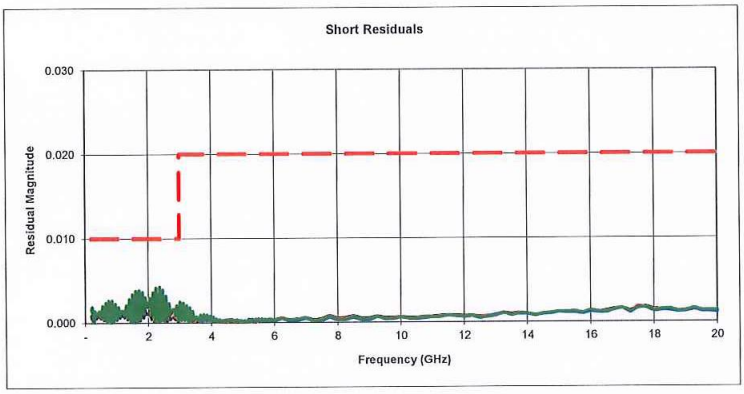


Fig. 2.1b Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration b)

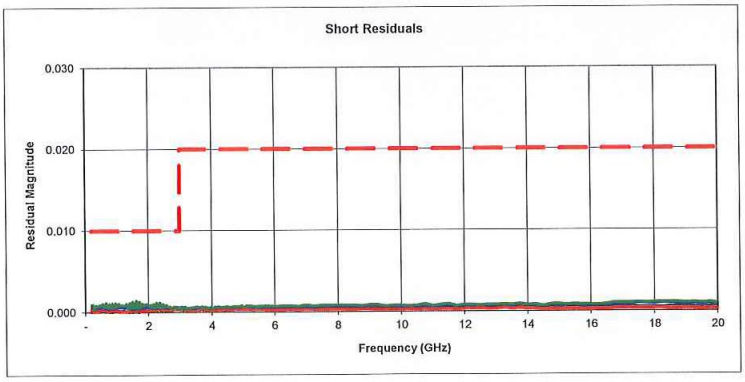


Fig. 2.1c Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration c)



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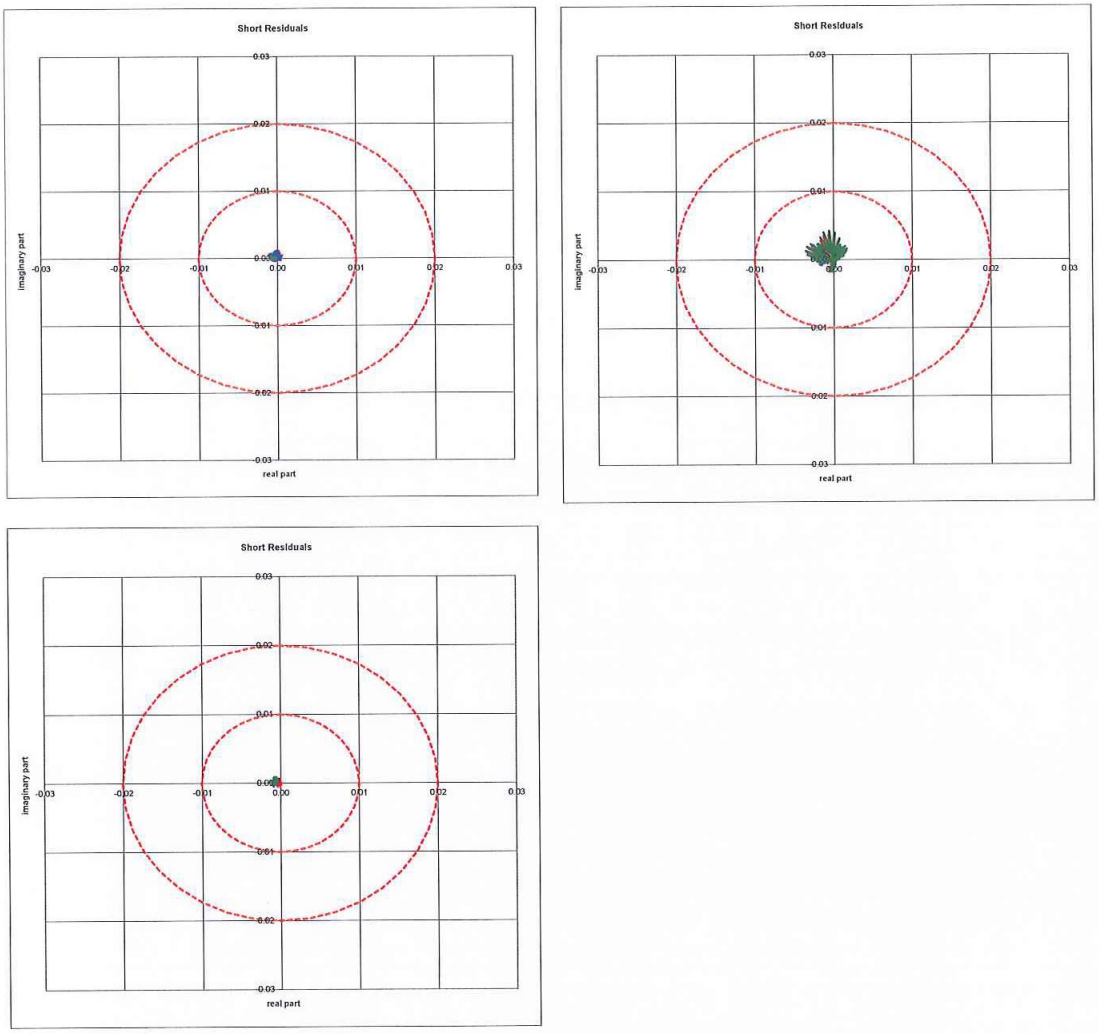


Fig. 2.2a-c Complex representation of the residuals of the shorts, 200 MHz - 20 GHz, after calibrations a)-b) in the top and c) in the bottom

All shorts have good quality. Some minor deviations might be visible from contact quality (left - right).



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### A.3 Ethanol

Ethanol (99.9% pure) was measured at a temperature of 22 +/- 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the reference data for this material. Those parameters have been evaluated from multiple measurements on the used bath with precision reference OCP and further methods. For the measurements the Noise Filter was activated in the software.

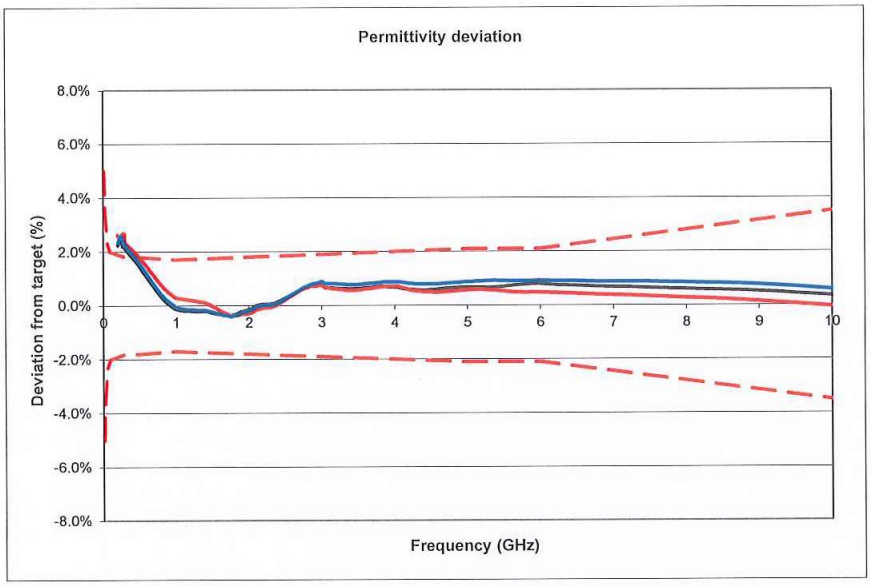


Fig. 3.1 Ethanol permittivity deviation from target, 200 MHz – 10 GHz

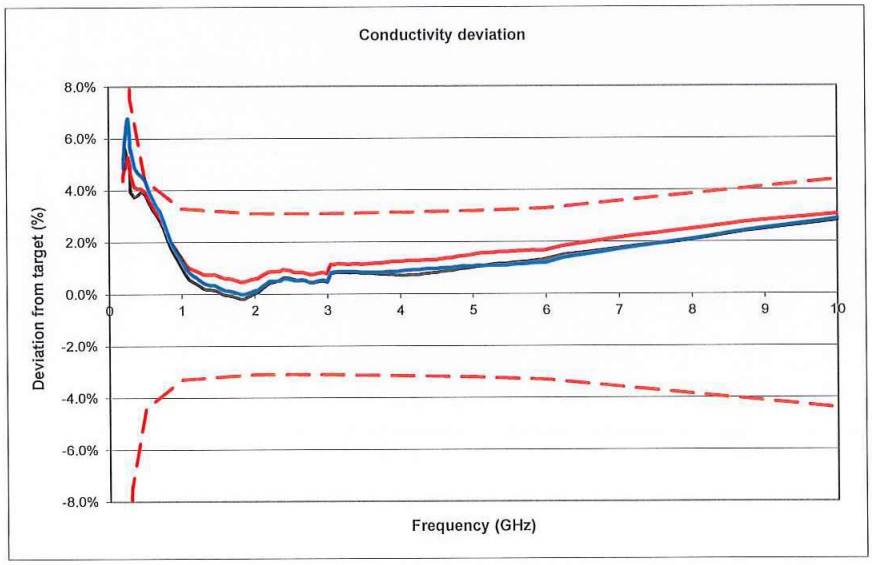


Fig. 3.2 Ethanol conductivity deviation from target, 200 MHz – 10 GHz

**Note:** Conductivity error can be high at low frequencies due to the low absolute conductivity values.



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## A.4 Head Tissue

Broadband head simulating liquid was measured at a temperature of 22 +/- 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the reference data for this material. Those parameters have been evaluated from multiple measurements on the used bath with precision reference OCP and further methods. For the measurements the Noise Filter was activated in the software.

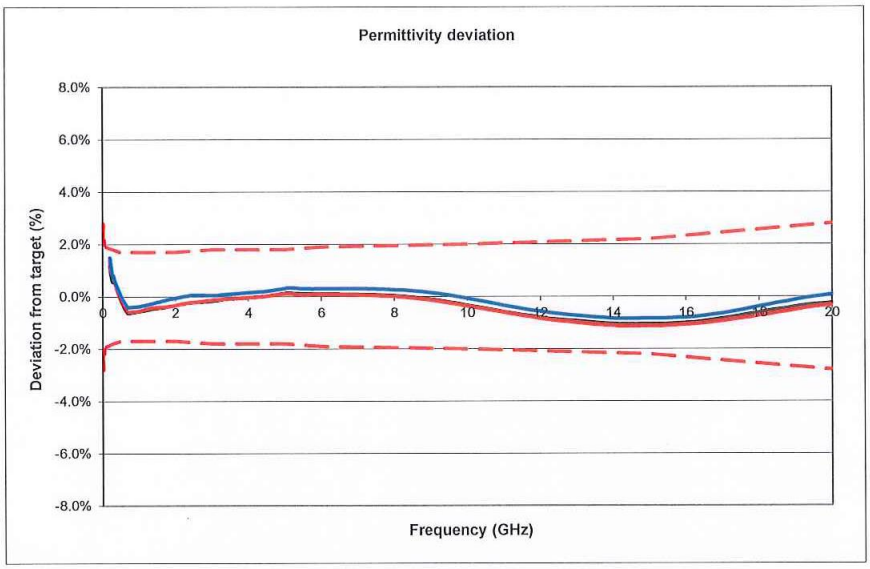


Fig. 4.1 HBBL permittivity deviation from target, 200 MHz – 20 GHz

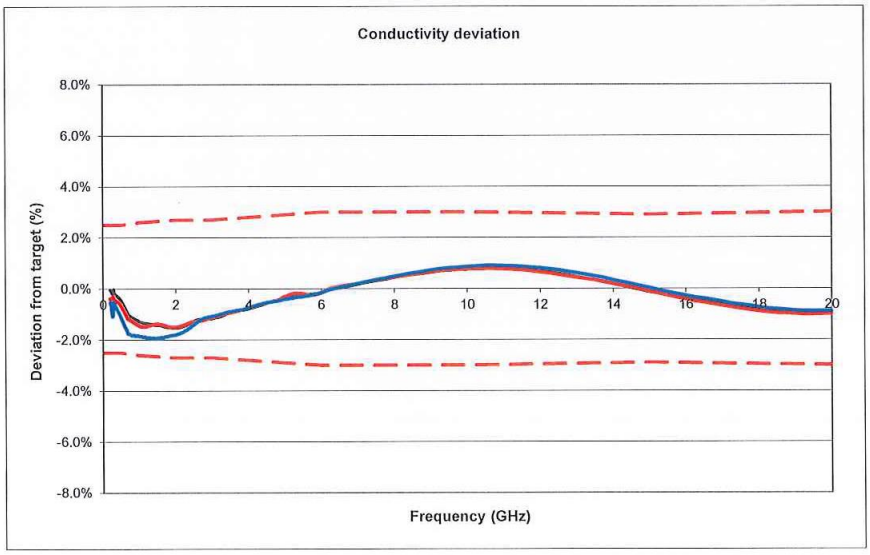


Fig. 4.2 HBBL conductivity deviation from target, 200 MHz – 20 GHz



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### A.5 0.05 mol/L NaCl solution

0.05 mol/L NaCl / water solution has a static conductivity of 0.5 S/m, similar to MRI HCL (High Conductivity Liquid). It was measured at a temperature of 22 +/- 2 °C. The liquid temperature was stabilized within 0.05 °C of the desired temperature. Deviations are presented relative to the reference data for this material. These parameters have been derived from the theoretical model according to [7], matched to the measurements from reference probes and other sources.
A quantity of 1 liter was used for the measurement. For the measurements the Noise Filter was activated in the software.

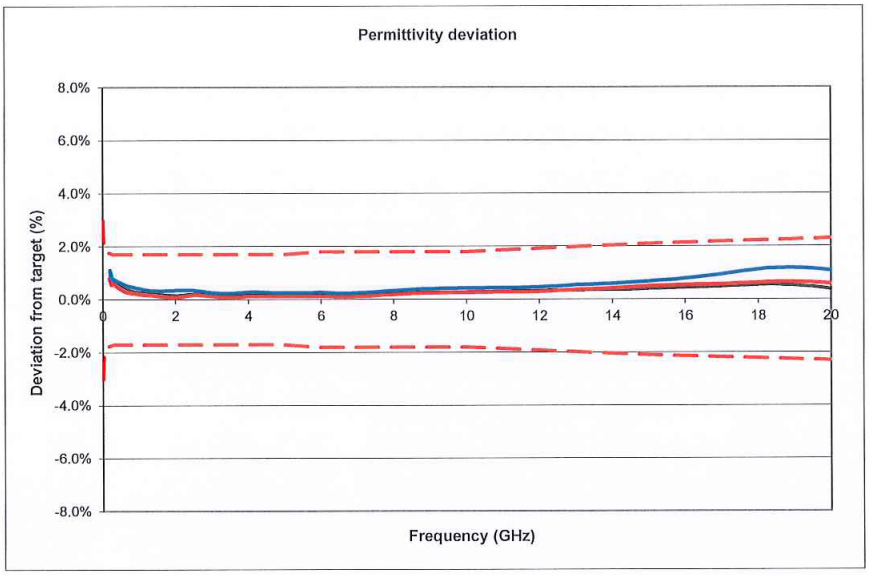


Fig. 5.1 0.05 mol/L solution permittivity deviation from target, 200 MHz – 20 GHz

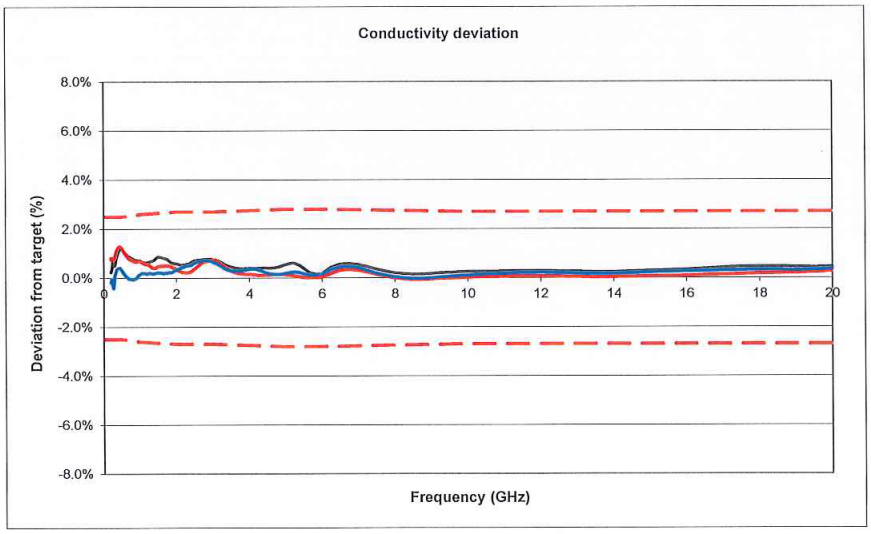


Fig. 5.2 0.05 mol/L solution conductivity deviation from target, 200 MHz – 20 GHz



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## Appendix B: Nominal parameters of reference materials used for calibration (additional assessments outside the scope of SCS0108)

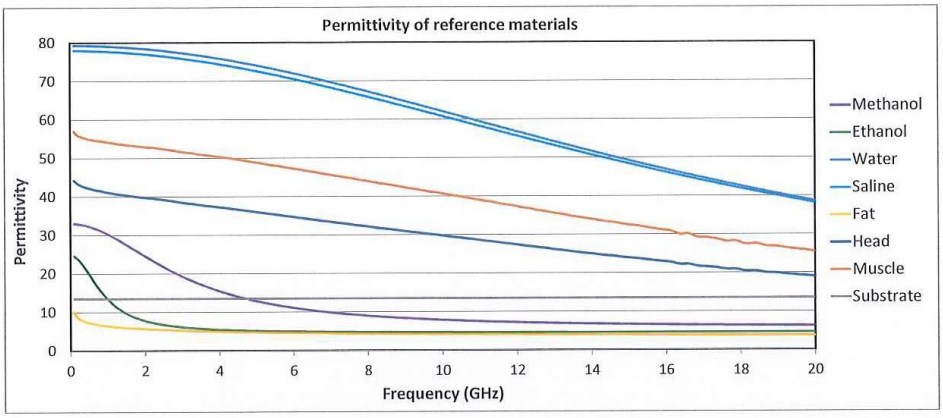


Fig. B.1 Permittivity of reference materials

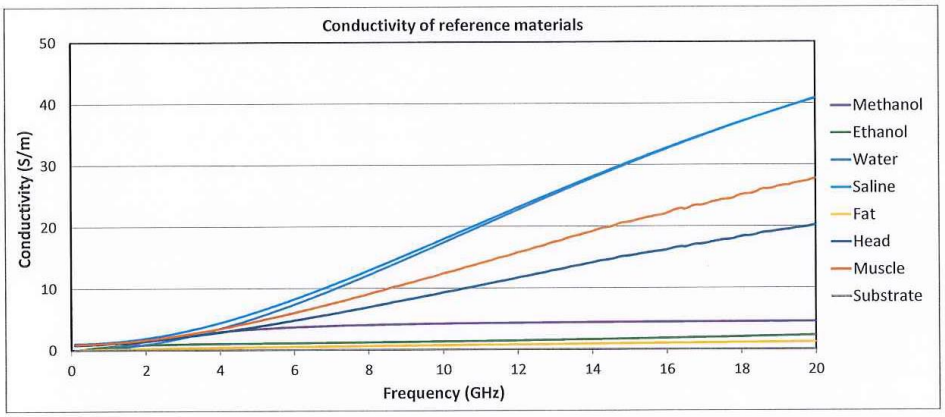


Fig. B.2 Conductivity of reference materials

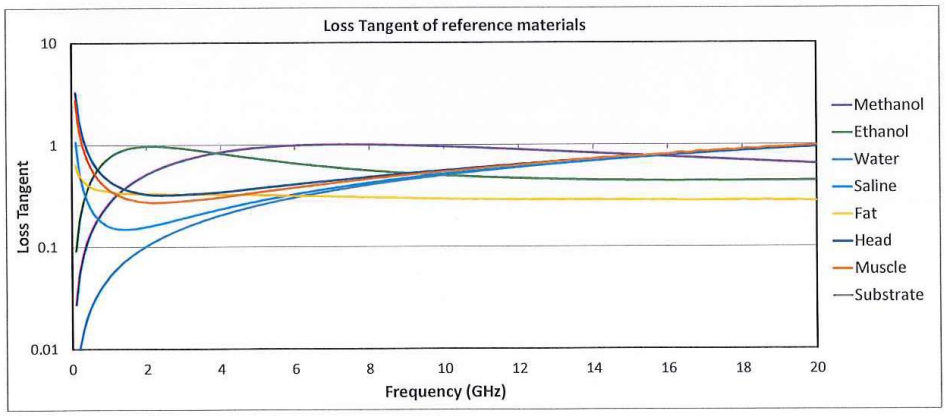


Fig. B.3 Loss tangent of reference materials



**------End of Report------**