

## Appendix C: System Calibration Certificate

# Calibration information for E-field probes



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CNAS L0570

Client **JYT**

Certificate No: **24J02Z001030**

## CALIBRATION CERTIFICATE

Object **EX3DV4 - SN : 7601**

Calibration Procedure(s) **FF-Z11-004-02**  
**Calibration Procedures for Dosimetric E-field Probes**

Calibration date: **January 15, 2025**

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)°C and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards        | ID #               | Cal Date(Calibrated by, Certificate No.)  | Scheduled Calibration |
|--------------------------|--------------------|-------------------------------------------|-----------------------|
| Power Meter NRP2         | 106277             | 18-Oct-24(CTTL, No.24J02X101459)          | Oct-25                |
| Power sensor NRP8S       | 104291             | 18-Oct-24(CTTL, No.24J02X101459)          | Oct-25                |
| Power sensor NRP8S       | 104292             | 18-Oct-24(CTTL, No.24J02X101459)          | Oct-25                |
| Reference 10dBAttenuator | 18N50W-10dB        | 19-Jan-23(CTTL, No.J23X00212)             | Jan-25                |
| Reference 20dBAttenuator | 18N50W-20dB        | 19-Jan-23(CTTL, No.J23X00211)             | Jan-25                |
| Reference Probe EX3DV4   | SN 7307            | 28-May-24(SPEAG, No.EX-7307_May24)        | May-25                |
| DAE4                     | SN 771             | 19-Jan-24(SPEAG, No.DAE4-771_Jan24)       | Jan-25                |
| DAE4                     | SN 1555            | 16-Aug-24(SPEAG, No. DAE4-1555_Aug24)     | Aug-25                |
| Secondary Standards      | ID #               | Cal Date(Calibrated by, Certificate No.)  | Scheduled Calibration |
| SignalGenerator MG3700A  | 6201052605         | 12-Jun-24(CTTL, No.24J02X005419)          | Jun-25                |
| SignalGenerator APSIN26G | 181-33A6D0700-1959 | 26-Mar-24(CTTL, No.24J02X002468)          | Mar-25                |
| Network Analyzer E5071C  | MY46110673         | 18-Dec-24(CTTL, No.24J02X103932)          | Dec-25                |
| Reference 10dBAttenuator | BT0520             | 11-May-23(CTTL, No.J23X04061)             | May-25                |
| Reference 20dBAttenuator | BT0267             | 11-May-23(CTTL, No.J23X04062)             | May-25                |
| OCP DAKS                 | SN 0015            | 09-Oct-24(SPEAG, No. OCP-DAKS-0015_Oct24) | Oct-25                |

|                | Name        | Function           | Signature |
|----------------|-------------|--------------------|-----------|
| Calibrated by: | Yu Zongying | SAR Test Engineer  |           |
| Reviewed by:   | Lin Jun     | SAR Test Engineer  |           |
| Approved by:   | Qi Dianyuan | SAR Project Leader |           |

Issued: January 17, 2025

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### Glossary:

|                       |                                                                                                                                             |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| TSL                   | tissue simulating liquid                                                                                                                    |
| NORM <sub>x,y,z</sub> | sensitivity in free space                                                                                                                   |
| ConvF                 | sensitivity in TSL / NORM <sub>x,y,z</sub>                                                                                                  |
| DCP                   | diode compression point                                                                                                                     |
| CF                    | crest factor (1/duty_cycle) of the RF signal                                                                                                |
| A,B,C,D               | modulation dependent linearization parameters                                                                                               |
| Polarization $\Phi$   | $\Phi$ rotation around probe axis                                                                                                           |
| Polarization $\theta$ | $\theta$ rotation around an axis that is in the plane normal to probe axis (at measurement center), i<br>$\theta=0$ is normal to probe axis |

Connector Angle information used in DASY system to align probe sensor X to the robot coordinate system

### Calibration is Performed According to the Following Standards:

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

### Methods Applied and Interpretation of Parameters:

- NORM<sub>x,y,z</sub>**: Assessed for E-field polarization  $\theta=0$  ( $f \leq 900\text{MHz}$  in TEM-cell;  $f > 1800\text{MHz}$ : waveguide). NORM<sub>x,y,z</sub> are only intermediate values, i.e., the uncertainties of NORM<sub>x,y,z</sub> does not effect the  $E^2$ -field uncertainty inside TSL (see below ConvF).
- NORM(f)<sub>x,y,z</sub>** = NORM<sub>x,y,z</sub> \* frequency\_response (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCPx,y,z**: DCP are numerical linearization parameters assessed based on the data of power sweep (no uncertainty required). DCP does not depend on frequency nor media.
- PAR**: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics.
- A<sub>x,y,z</sub>; B<sub>x,y,z</sub>; C<sub>x,y,z</sub>; VR<sub>x,y,z</sub>**: A,B,C are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters**: Assessed in flat phantom using E-field (or Temperature Transfer Standard for  $f \leq 800\text{MHz}$ ) and inside waveguide using analytical field distributions based on power measurements for  $f > 800\text{MHz}$ . The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty valued are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM<sub>x,y,z</sub>\* ConvF whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from  $\pm 50\text{MHz}$  to  $\pm 100\text{MHz}$ .
- Spherical isotropy (3D deviation from isotropy)**: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the NORM<sub>x</sub> (no uncertainty required).

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## DASY/EASY – Parameters of Probe: EX3DV4 – SN:7601

### Basic Calibration Parameters

|                                      | Sensor X | Sensor Y | Sensor Z | Unc ( $k=2$ ) |
|--------------------------------------|----------|----------|----------|---------------|
| Norm( $\mu V/(V/m)^2$ ) <sup>A</sup> | 0.70     | 0.64     | 0.74     | ±10.0%        |
| DCP(mV) <sup>B</sup>                 | 108.9    | 108.7    | 113.8    |               |

### Modulation Calibration Parameters

| UID | Communication System Name |   | A<br>dB | B<br>dB/μV | C   | D<br>dB | VR<br>mV | Unc <sup>E</sup><br>( $k=2$ ) |
|-----|---------------------------|---|---------|------------|-----|---------|----------|-------------------------------|
| 0   | CW                        | X | 0.0     | 0.0        | 1.0 | 0.00    | 227.1    | ±2.3%                         |
|     |                           | Y | 0.0     | 0.0        | 1.0 |         | 215.0    |                               |
|     |                           | Z | 0.0     | 0.0        | 1.0 |         | 237.8    |                               |

The reported uncertainty of measurement is stated as the standard uncertainty of Measurement multiplied by the coverage factor  $k=2$ , which for a normal distribution Corresponds to a coverage probability of approximately 95%.

<sup>A</sup> The uncertainties of Norm X, Y, Z do not affect the E<sup>2</sup>-field uncertainty inside TSL (see Page 4).

<sup>B</sup> Numerical linearization parameter: uncertainty not required.

<sup>E</sup> Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.



## DASY/EASY – Parameters of Probe: EX3DV4 – SN:7601

### Calibration Parameter Determined in Head Tissue Simulating Media

| f [MHz] <sup>C</sup> | Relative Permittivity <sup>F</sup> | Conductivity (S/m) <sup>F</sup> | ConvF X | ConvF Y | ConvF Z | Alpha <sup>G</sup> | Depth <sup>G</sup> (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 750                  | 41.9                               | 0.89                            | 10.65   | 10.65   | 10.65   | 0.08               | 1.71                    | ±12.7%      |
| 835                  | 41.5                               | 0.90                            | 10.25   | 10.25   | 10.25   | 0.09               | 1.60                    | ±12.7%      |
| 1750                 | 40.1                               | 1.37                            | 8.77    | 8.77    | 8.77    | 0.19               | 1.06                    | ±12.7%      |
| 1900                 | 40.0                               | 1.40                            | 8.42    | 8.42    | 8.42    | 0.18               | 1.14                    | ±12.7%      |
| 2100                 | 39.8                               | 1.49                            | 8.40    | 8.40    | 8.40    | 0.23               | 1.13                    | ±12.7%      |
| 2300                 | 39.5                               | 1.67                            | 8.12    | 8.12    | 8.12    | 0.54               | 0.70                    | ±12.7%      |
| 2450                 | 39.2                               | 1.80                            | 7.84    | 7.84    | 7.84    | 0.46               | 0.74                    | ±12.7%      |
| 2600                 | 39.0                               | 1.96                            | 7.66    | 7.66    | 7.66    | 0.54               | 0.70                    | ±12.7%      |
| 3300                 | 38.2                               | 2.71                            | 7.28    | 7.28    | 7.28    | 0.43               | 0.94                    | ±13.9%      |
| 3500                 | 37.9                               | 2.91                            | 7.15    | 7.15    | 7.15    | 0.41               | 1.01                    | ±13.9%      |
| 3700                 | 37.7                               | 3.12                            | 6.83    | 6.83    | 6.83    | 0.35               | 1.30                    | ±13.9%      |
| 3900                 | 37.5                               | 3.32                            | 6.70    | 6.70    | 6.70    | 0.35               | 1.50                    | ±13.9%      |
| 4100                 | 37.2                               | 3.53                            | 6.80    | 6.80    | 6.80    | 0.40               | 1.15                    | ±13.9%      |
| 5250                 | 35.9                               | 4.71                            | 5.52    | 5.52    | 5.52    | 0.40               | 1.52                    | ±13.9%      |
| 5600                 | 35.5                               | 5.07                            | 4.95    | 4.95    | 4.95    | 0.45               | 1.40                    | ±13.9%      |
| 5750                 | 35.4                               | 5.22                            | 5.07    | 5.07    | 5.07    | 0.45               | 1.40                    | ±13.9%      |

<sup>C</sup> Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

<sup>F</sup> At frequency up to 6 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

<sup>G</sup> Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

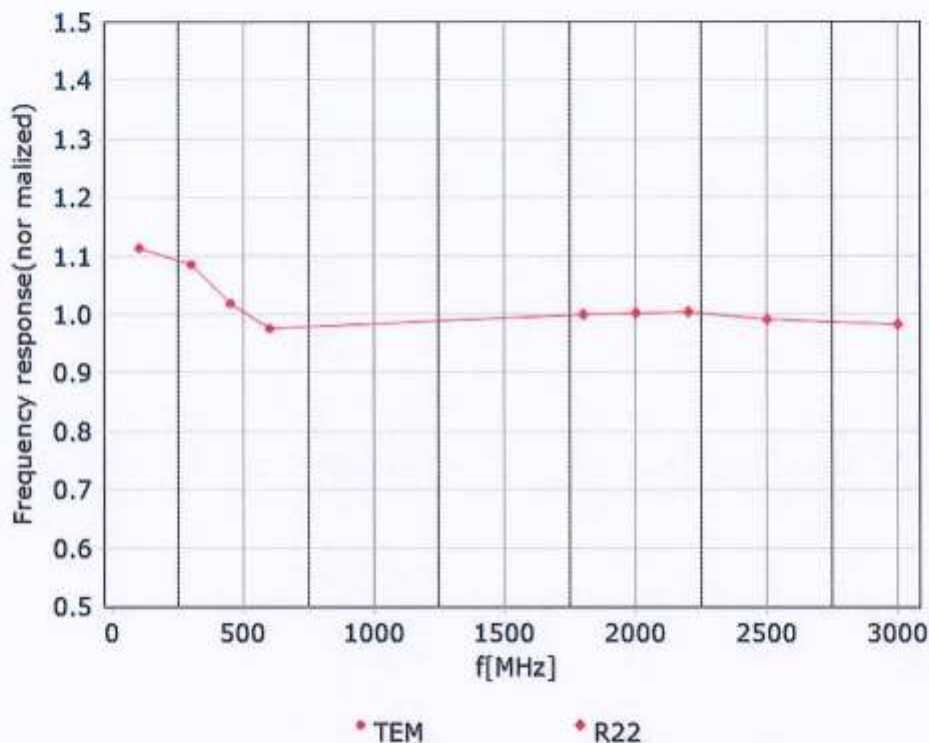


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## Frequency Response of E-Field (TEM-Cell: ifi110 EXX, Waveguide: R22)



Uncertainty of Frequency Response of E-field:  $\pm 7.4\%$  ( $k=2$ )



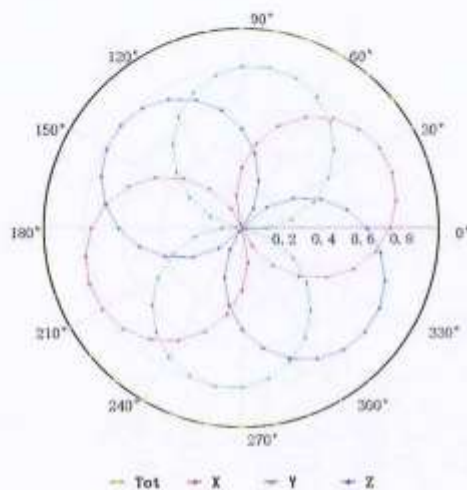
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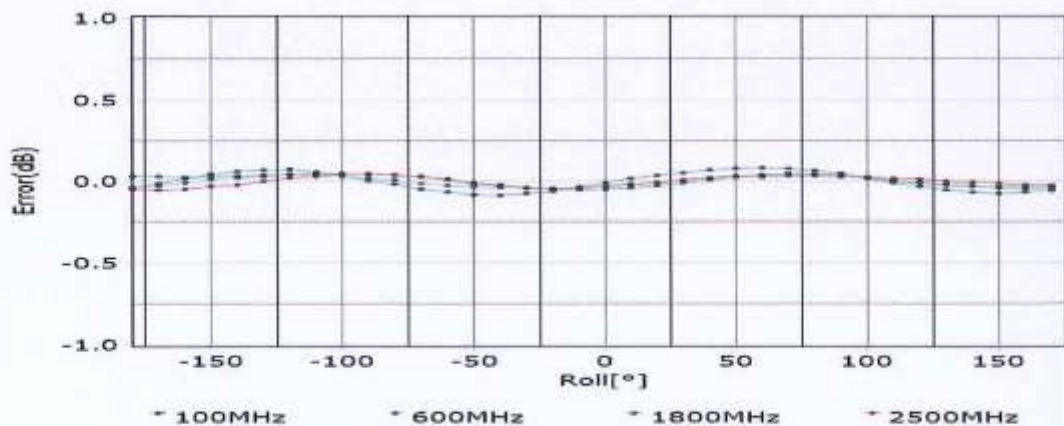
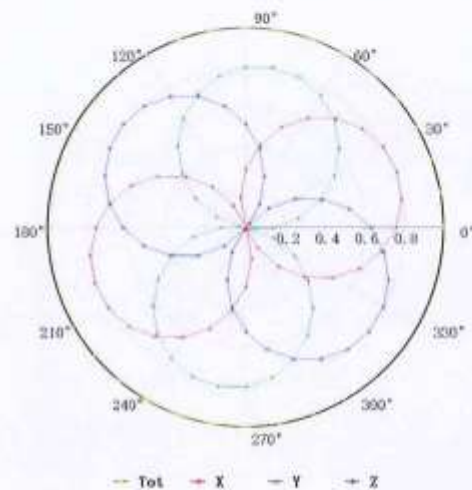
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## Receiving Pattern ( $\Phi$ ), $\theta=0^\circ$

**f=600 MHz, TEM**



**f=1800 MHz, R22**



Uncertainty of Axial Isotropy Assessment:  $\pm 1.2\%$  ( $k=2$ )

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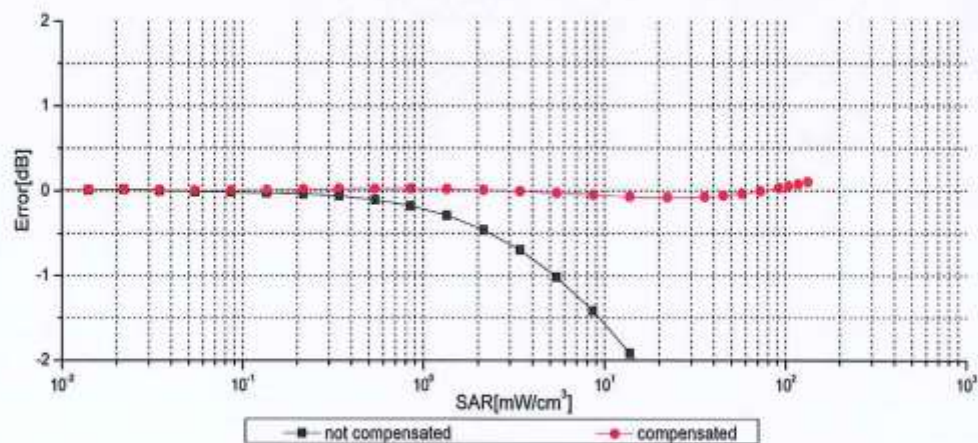
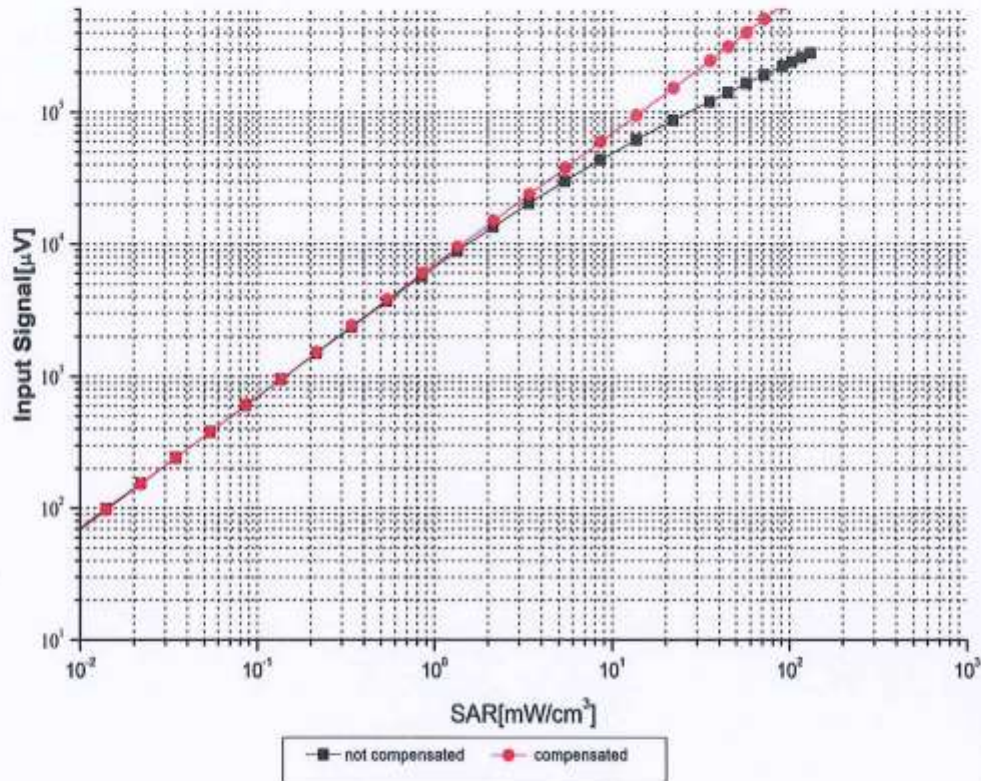
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## Dynamic Range $f(\text{SAR}_{\text{head}})$ (TEM cell, $f = 900 \text{ MHz}$ )



Uncertainty of Linearity Assessment:  $\pm 0.9\%$  ( $k=2$ )

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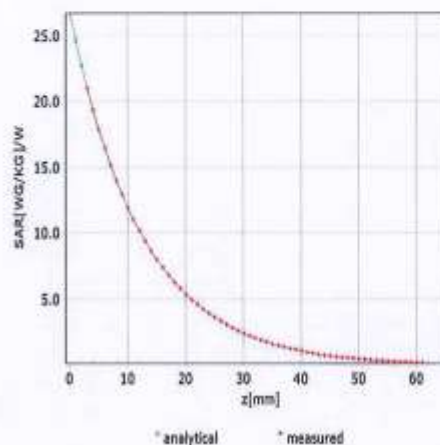
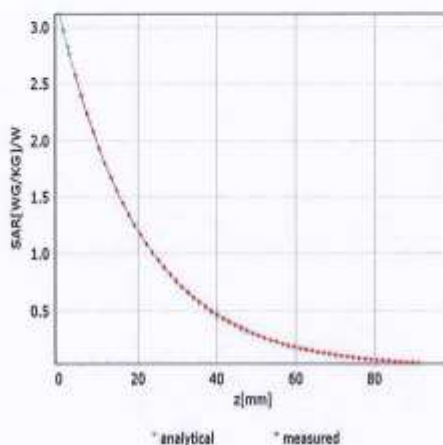


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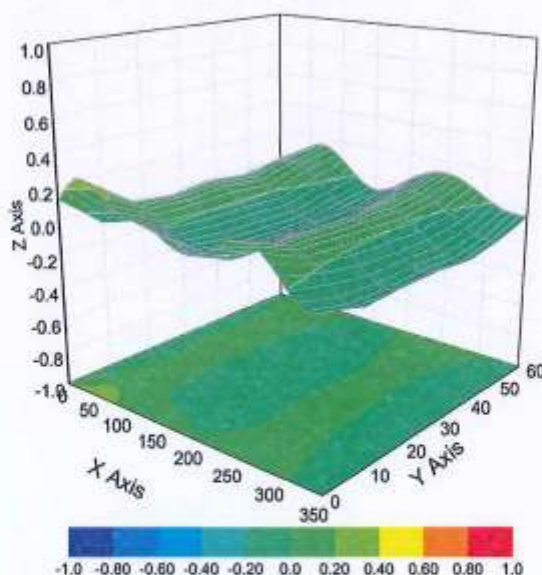
## Conversion Factor Assessment

**f=750 MHz,WGLS R9(H\_convF)**

**f=1750 MHz,WGLS R22(H\_convF)**



## Deviation from Isotropy in Liquid



**Uncertainty of Spherical Isotropy Assessment:  $\pm 3.2\%$  ( $k=2$ )**



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## DASY/EASY – Parameters of Probe: EX3DV4 – SN:7601

### Other Probe Parameters

|                                               |            |
|-----------------------------------------------|------------|
| Sensor Arrangement                            | Triangular |
| Connector Angle (°)                           | 141.7      |
| Mechanical Surface Detection Mode             | enabled    |
| Optical Surface Detection Mode                | disable    |
| Probe Overall Length                          | 337mm      |
| Probe Body Diameter                           | 10mm       |
| Tip Length                                    | 9mm        |
| Tip Diameter                                  | 2.5mm      |
| Probe Tip to Sensor X Calibration Point       | 1mm        |
| Probe Tip to Sensor Y Calibration Point       | 1mm        |
| Probe Tip to Sensor Z Calibration Point       | 1mm        |
| Recommended Measurement Distance from Surface | 1.4mm      |

# Calibration information for Dipole



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Client **JYT**

Certificate No: **Z22-60210**

## CALIBRATION CERTIFICATE

Object **D835V2 - SN: 4d154**

Calibration Procedure(s) **FF-Z11-003-01**  
**Calibration Procedures for dipole validation kits**

Calibration date: **June 8, 2022**

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements (SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22±3)°C and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards       | ID #       | Cal Date (Calibrated by, Certificate No.) | Scheduled Calibration |
|-------------------------|------------|-------------------------------------------|-----------------------|
| Power Meter NRP2        | 106277     | 24-Sep-21 (CTTL, No.J21X08326)            | Sep-22                |
| Power sensor NRP8S      | 104291     | 24-Sep-21 (CTTL, No.J21X08326)            | Sep-22                |
| Reference Probe EX3DV4  | SN 7464    | 26-Jan-22(SPEAG,No.EX3-7464_Jan22)        | Jan-23                |
| DAE4                    | SN 1556    | 12-Jan-22(CTTL-SPEAG,No.Z22-60007)        | Jan-23                |
| Secondary Standards     | ID #       | Cal Date (Calibrated by, Certificate No.) | Scheduled Calibration |
| Signal Generator E4438C | MY49071430 | 13-Jan-22 (CTTL, No.J22X00409)            | Jan-23                |
| Network Analyzer E5071C | MY46110673 | 14-Jan-22 (CTTL, No.J22X00406)            | Jan-23                |

|                | Name        | Function           | Signature |
|----------------|-------------|--------------------|-----------|
| Calibrated by: | Zhao Jing   | SAR Test Engineer  |           |
| Reviewed by:   | Lin Hao     | SAR Test Engineer  |           |
| Approved by:   | Qi Dianyuan | SAR Project Leader |           |

Issued: June 13, 2022

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**Glossary:**

|       |                                            |
|-------|--------------------------------------------|
| TSL   | tissue simulating liquid                   |
| ConvF | sensitivity in TSL / NORM <sub>x,y,z</sub> |
| N/A   | not applicable or not measured             |

**Calibration is Performed According to the Following Standards:**

- a) IEC/IEEE 62209-1528, "Measurement Procedure for The Assessment of Specific Absorption Rate of Human Exposure to Radio Frequency Fields from Hand-held and Body-mounted Wireless Communication Devices- Part 1528: Human Models, Instrumentation and Procedures (Frequency range of 4 MHz to 10 GHz)", October 2020
- b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

**Additional Documentation:**

- c) DASY4/5 System Handbook

**Methods Applied and Interpretation of Parameters:**

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

The reported uncertainty of measurement is stated as the standard uncertainty of Measurement multiplied by the coverage factor  $k=2$ , which for a normal distribution Corresponds to a coverage probability of approximately 95%.

### Measurement Conditions

DASY system configuration, as far as not given on page 1.

|                              |                          |             |
|------------------------------|--------------------------|-------------|
| DASY Version                 | DASY52                   | V52.10.4    |
| Extrapolation                | Advanced Extrapolation   |             |
| Phantom                      | Triple Flat Phantom 5.1C |             |
| Distance Dipole Center - TSL | 15 mm                    | with Spacer |
| Zoom Scan Resolution         | dx, dy, dz = 5 mm        |             |
| Frequency                    | 835 MHz $\pm$ 1 MHz      |             |

### Head TSL parameters

The following parameters and calculations were applied.

|                                         | Temperature         | Permittivity   | Conductivity         |
|-----------------------------------------|---------------------|----------------|----------------------|
| Nominal Head TSL parameters             | 22.0 °C             | 41.5           | 0.90 mho/m           |
| Measured Head TSL parameters            | (22.0 $\pm$ 0.2) °C | 41.9 $\pm$ 6 % | 0.88 mho/m $\pm$ 6 % |
| Head TSL temperature change during test | <1.0 °C             | ----           | ----                 |

### SAR result with Head TSL

|                                                |                    |                                  |
|------------------------------------------------|--------------------|----------------------------------|
| SAR averaged over 1 $cm^3$ (1 g) of Head TSL   | Condition          |                                  |
| SAR measured                                   | 250 mW input power | 2.36 W/kg                        |
| SAR for nominal Head TSL parameters            | normalized to 1W   | 9.60 W/kg $\pm$ 18.8 % ( $k=2$ ) |
| SAR averaged over 10 $cm^3$ (10 g) of Head TSL | Condition          |                                  |
| SAR measured                                   | 250 mW input power | 1.53 W/kg                        |
| SAR for nominal Head TSL parameters            | normalized to 1W   | 6.20 W/kg $\pm$ 18.7 % ( $k=2$ ) |



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## Appendix (Additional assessments outside the scope of CNAS L0570)

### Antenna Parameters with Head TSL

|                                      |               |
|--------------------------------------|---------------|
| Impedance, transformed to feed point | 48.9Ω- 3.78jΩ |
| Return Loss                          | - 28.0dB      |

### General Antenna Parameters and Design

|                                  |          |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.310 ns |
|----------------------------------|----------|

After long term use with 100W radiated power, only a slight warming of the dipole near the feed-point can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard. No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feed-point may be damaged.

### Additional EUT Data

|                 |       |
|-----------------|-------|
| Manufactured by | SPEAG |
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### DASY5 Validation Report for Head TSL

Date: 2022-06-08

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 835 MHz; Type: D835V2; Serial: D835V2 - SN: 4d154**

Communication System: UID 0, CW; Frequency: 835 MHz; Duty Cycle: 1:1

Medium parameters used:  $f = 835$  MHz;  $\sigma = 0.882$  S/m;  $\epsilon_r = 41.9$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Right Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(9.96, 9.96, 9.96) @ 835 MHz; Calibrated: 2022-01-26
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1556; Calibrated: 2022-01-12
- Phantom: MFP\_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx; Serial: 1062
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

**Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 59.20 V/m; Power Drift = -0.01 dB

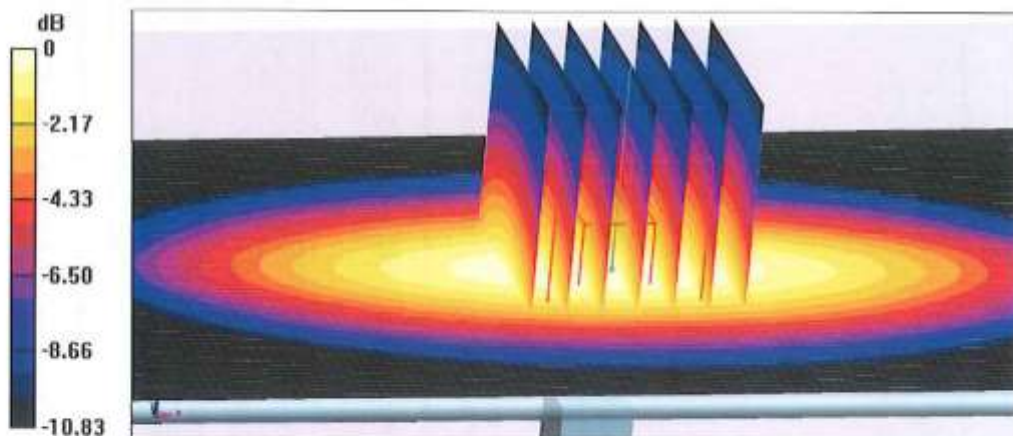
Peak SAR (extrapolated) = 3.58 W/kg

SAR(1 g) = 2.36 W/kg; SAR(10 g) = 1.53 W/kg

Smallest distance from peaks to all points 3 dB below = 18 mm

Ratio of SAR at M2 to SAR at M1 = 65.7%

Maximum value of SAR (measured) = 3.17 W/kg



0 dB = 3.17 W/kg = 5.01 dBW/kg

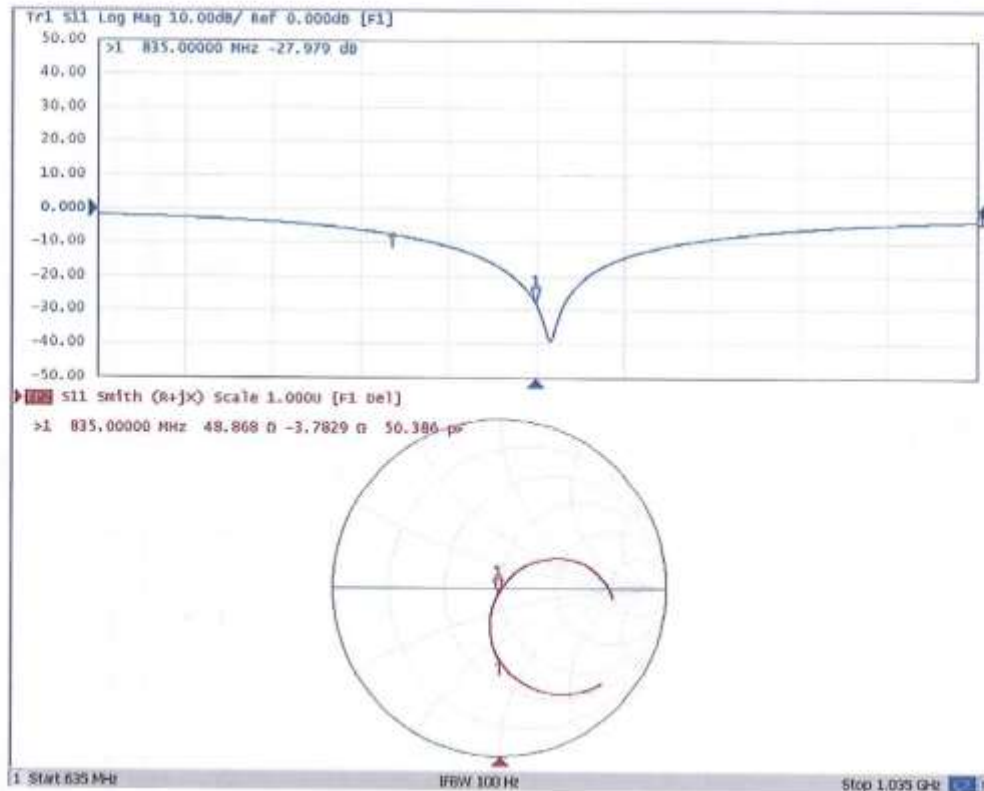


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### Impedance Measurement Plot for Head TSL



Certificate No: Z22-60210

Page 6 of 6

Dipole Impedance and Return Loss Check Report

Object: D835V2 - SN: 4d157

Check Date: June 03, 2024

Check reference: IEC/IEEE 62209-1528:2020, FCC KDB 865664 D01

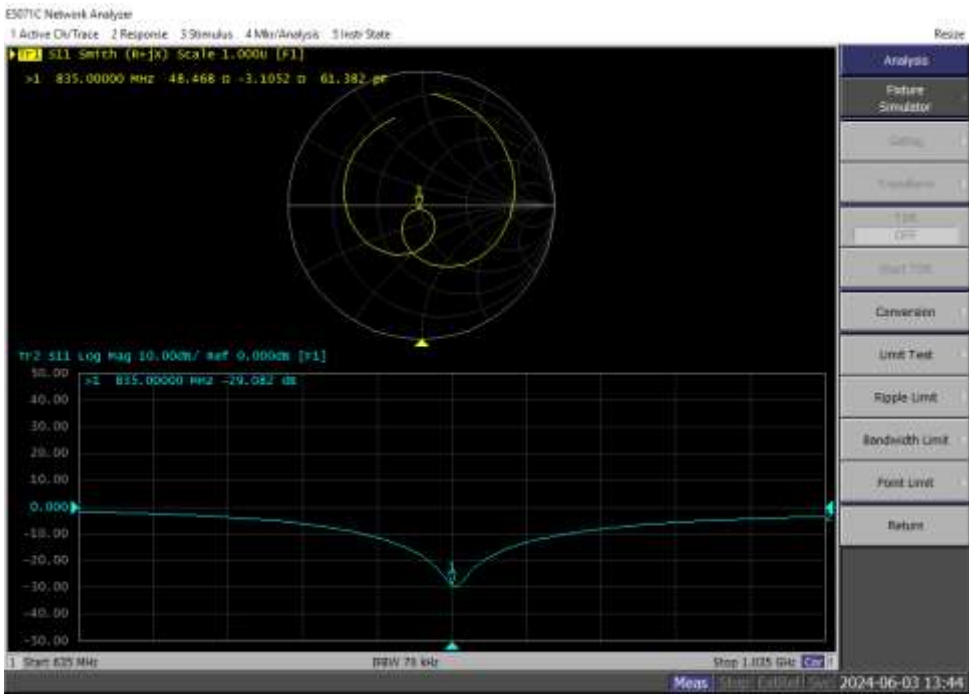
Checked By: Eric Wang (Eric Wang, SAR project engineer)

Reviewed By: Janet Wei (Janet Wei, manager)

Environment of Test Site

|                       |           |
|-----------------------|-----------|
| Temperature:          | 21 ~ 23°C |
| Humidity:             | 50~60% RH |
| Atmospheric Pressure: | 1011 mbar |

Test Data



Comparison with Original report

| Items                    | Checked By JYT In 2023 | Checked By JYT In 2024 | Deviation      | Limit                    |
|--------------------------|------------------------|------------------------|----------------|--------------------------|
| Impendence for Head TSL  | 49.63Ω -3.87jΩ         | 48.47Ω -3.11jΩ         | -1.16Ω -0.76jΩ | ±5Ω                      |
| Return Loss for Head TSL | -28.17                 | -29.09                 | 3.27%          | ±20%(No less than 20 dB) |

Result

Compliance



Client **JYT**

Certificate No: **Z22-60211**

## CALIBRATION CERTIFICATE

Object **D1900V2 - SN: 5d175**

Calibration Procedure(s) **FF-Z11-003-01**  
**Calibration Procedures for dipole validation kits**

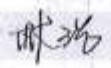
Calibration date: **June 7, 2022**

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements (SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22±3)°C and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards       | ID #       | Cal Date (Calibrated by, Certificate No.) | Scheduled Calibration |
|-------------------------|------------|-------------------------------------------|-----------------------|
| Power Meter NRP2        | 106277     | 24-Sep-21 (CTTL, No.J21X08326)            | Sep-22                |
| Power sensor NRP8S      | 104291     | 24-Sep-21 (CTTL, No.J21X08326)            | Sep-22                |
| Reference Probe EX3DV4  | SN 7464    | 26-Jan-22(SPEAG,No.EX3-7464_Jan22)        | Jan-23                |
| DAE4                    | SN 1556    | 12-Jan-22(CTTL-SPEAG,No.Z22-60007)        | Jan-23                |
| Secondary Standards     | ID #       | Cal Date (Calibrated by, Certificate No.) | Scheduled Calibration |
| Signal Generator E4438C | MY49071430 | 13-Jan-22 (CTTL, No.J22X00409)            | Jan-23                |
| Network Analyzer E5071C | MY46110673 | 14-Jan-22 (CTTL, No.J22X00406)            | Jan-23                |

|                | Name        | Function           | Signature                                                                             |
|----------------|-------------|--------------------|---------------------------------------------------------------------------------------|
| Calibrated by: | Zhao Jing   | SAR Test Engineer  |  |
| Reviewed by:   | Lin Hao     | SAR Test Engineer  |  |
| Approved by:   | Qi Dianyuan | SAR Project Leader |  |

Issued: June 13, 2022

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Certificate No: Z22-60211

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#### Glossary:

|       |                                            |
|-------|--------------------------------------------|
| TSL   | tissue simulating liquid                   |
| ConvF | sensitivity in TSL / NORM <sub>x,y,z</sub> |
| N/A   | not applicable or not measured             |

#### Calibration is Performed According to the Following Standards:

- IEC/IEEE 62209-1528, "Measurement Procedure for The Assessment of Specific Absorption Rate of Human Exposure to Radio Frequency Fields from Hand-held and Body-mounted Wireless Communication Devices- Part 1528: Human Models, Instrumentation and Procedures (Frequency range of 4 MHz to 10 GHz)", October 2020
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

#### Additional Documentation:

- DASY4/5 System Handbook

#### Methods Applied and Interpretation of Parameters:

- Measurement Conditions:** Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- Antenna Parameters with TSL:** The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- Feed Point Impedance and Return Loss:** These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- Electrical Delay:** One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- SAR measured:** SAR measured at the stated antenna input power.
- SAR normalized:** SAR as measured, normalized to an input power of 1 W at the antenna connector.
- SAR for nominal TSL parameters:** The measured TSL parameters are used to calculate the nominal SAR result.

The reported uncertainty of measurement is stated as the standard uncertainty of Measurement multiplied by the coverage factor  $k=2$ , which for a normal distribution Corresponds to a coverage probability of approximately 95%.



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### Measurement Conditions

DASY system configuration, as far as not given on page 1.

|                              |                          |             |
|------------------------------|--------------------------|-------------|
| DASY Version                 | DASY52                   | 52.10.4     |
| Extrapolation                | Advanced Extrapolation   |             |
| Phantom                      | Triple Flat Phantom 5.1C |             |
| Distance Dipole Center - TSL | 10 mm                    | with Spacer |
| Zoom Scan Resolution         | dx, dy, dz = 5 mm        |             |
| Frequency                    | 1900 MHz $\pm$ 1 MHz     |             |

### Head TSL parameters

The following parameters and calculations were applied.

|                                         | Temperature         | Permittivity   | Conductivity         |
|-----------------------------------------|---------------------|----------------|----------------------|
| Nominal Head TSL parameters             | 22.0 °C             | 40.0           | 1.40 mho/m           |
| Measured Head TSL parameters            | (22.0 $\pm$ 0.2) °C | 39.9 $\pm$ 6 % | 1.39 mho/m $\pm$ 6 % |
| Head TSL temperature change during test | <1.0 °C             | ----           | ----                 |

### SAR result with Head TSL

|                                                |                    |                              |
|------------------------------------------------|--------------------|------------------------------|
| SAR averaged over 1 $cm^3$ (1 g) of Head TSL   | Condition          |                              |
| SAR measured                                   | 250 mW input power | 9.93 W/kg                    |
| SAR for nominal Head TSL parameters            | normalized to 1W   | 39.9 W/kg $\pm$ 18.8 % (k=2) |
| SAR averaged over 10 $cm^3$ (10 g) of Head TSL | Condition          |                              |
| SAR measured                                   | 250 mW input power | 5.18 W/kg                    |
| SAR for nominal Head TSL parameters            | normalized to 1W   | 20.8 W/kg $\pm$ 18.7 % (k=2) |





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## Appendix (Additional assessments outside the scope of CNAS L0570)

### Antenna Parameters with Head TSL

|                                      |                            |
|--------------------------------------|----------------------------|
| Impedance, transformed to feed point | $51.7\Omega + 5.90j\Omega$ |
| Return Loss                          | - 24.4dB                   |

### General Antenna Parameters and Design

|                                  |          |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.110 ns |
|----------------------------------|----------|

After long term use with 100W radiated power, only a slight warming of the dipole near the feed-point can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard. No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feed-point may be damaged.

### Additional EUT Data

|                 |       |
|-----------------|-------|
| Manufactured by | SPEAG |
|-----------------|-------|



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### DASY5 Validation Report for Head TSL

Date: 2022-06-07

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d175**

Communication System: UID 0, CW; Frequency: 1900 MHz; Duty Cycle: 1:1

Medium parameters used:  $f = 1900$  MHz;  $\sigma = 1.385$  S/m;  $\epsilon_r = 39.85$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Right Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(8.18, 8.18, 8.18) @ 1900 MHz; Calibrated: 2022-01-26
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1556; Calibrated: 2022-01-12
- Phantom: MFP\_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx; Serial: 1062
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

**Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm**

Reference Value = 101.8 V/m; Power Drift = 0.00 dB

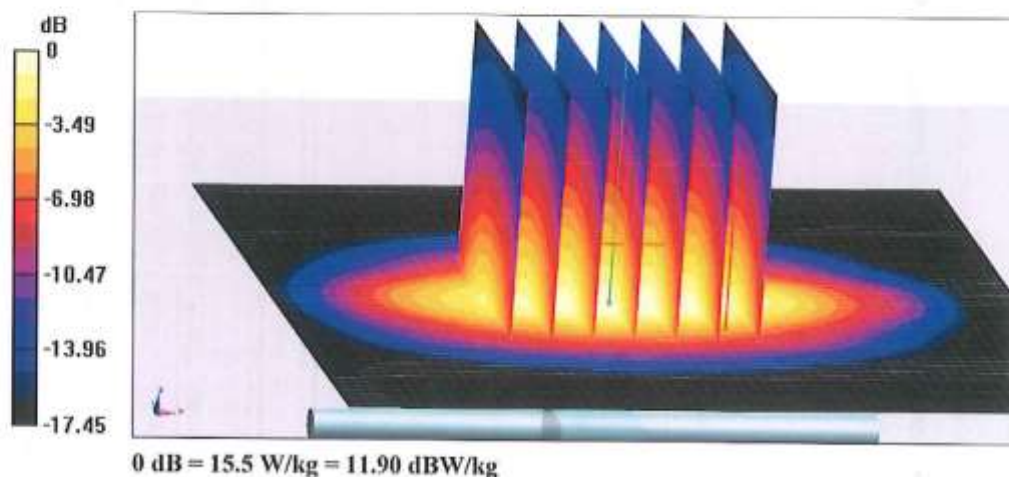
Peak SAR (extrapolated) = 18.5 W/kg

**SAR(1 g) = 9.93 W/kg; SAR(10 g) = 5.18 W/kg**

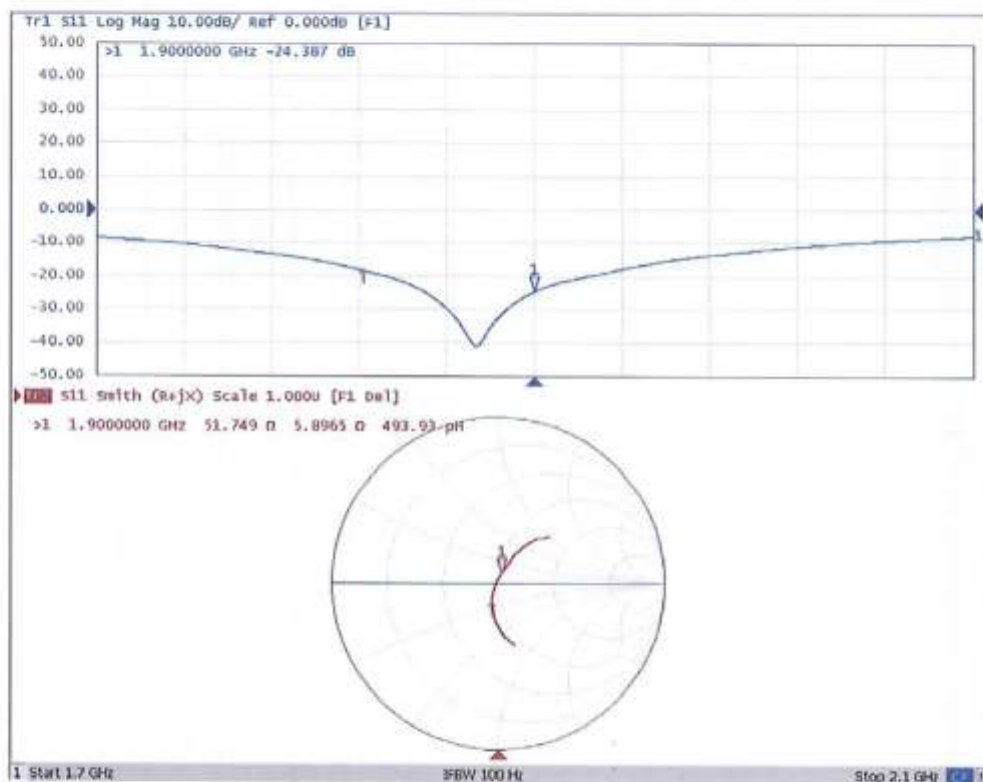
Smallest distance from peaks to all points 3 dB below = 10 mm

Ratio of SAR at M2 to SAR at M1 = 54.3%

Maximum value of SAR (measured) = 15.5 W/kg



### Impedance Measurement Plot for Head TSL





Dipole Impedance and Return Loss Check Report

Object: D1900V2 - SN: 5d175

Check Date: June 03, 2024

Check reference: IEC/IEEE 62209-1528:2020, FCC KDB 865664 D01

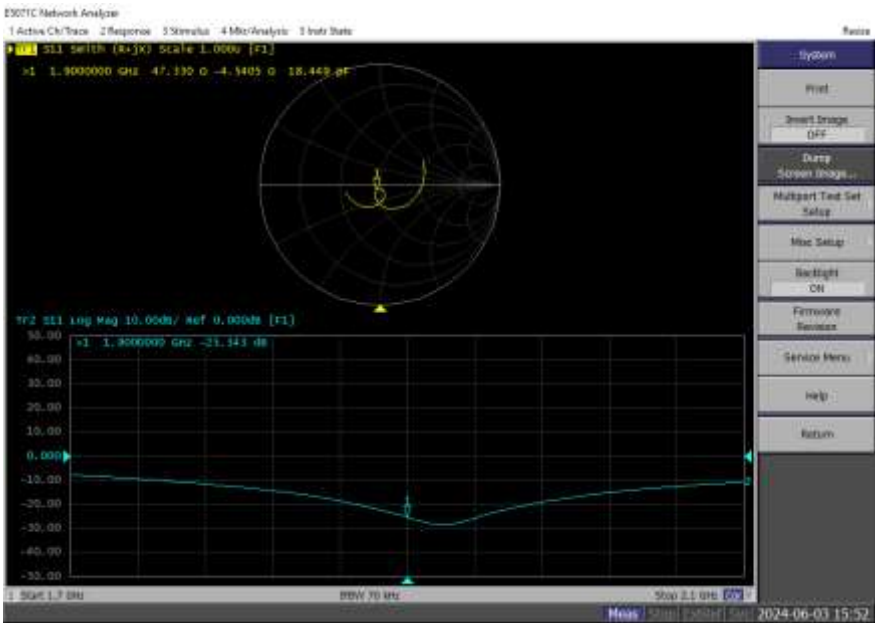
Checked By: Eric Wang (Eric Wang, SAR project engineer)

Reviewed By: Janet Wei (Janet Wei, manager)

Environment of Test Site

|                       |           |
|-----------------------|-----------|
| Temperature:          | 21 ~ 23°C |
| Humidity:             | 50~60% RH |
| Atmospheric Pressure: | 1011 mbar |

Test Data



Comparison with Original report

| Items                    | Checked By JYT In 2023 | Checked By JYT In 2024 | Deviation     | Limit                    |
|--------------------------|------------------------|------------------------|---------------|--------------------------|
| Impendence for Head TSL  | 49.30Ω-5.47jΩ          | 47.33Ω-4.54jΩ          | -1.97Ω+0.93jΩ | ±5Ω                      |
| Return Loss for Head TSL | -26.32                 | -25.34                 | -3.72%        | ±20%(No less than 20 dB) |

Result

Compliance

# Calibration information for DAE



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CNAS L0570

Client : **JYT**

Certificate No: **24J02Z001029**

## CALIBRATION CERTIFICATE

Object **DAE4 - SN: 1373**

Calibration Procedure(s) **FF-Z11-002-01**  
**Calibration Procedure for the Data Acquisition Electronics (DAEx)**

Calibration date: **December 31, 2024**

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards      | ID #    | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
|------------------------|---------|------------------------------------------|-----------------------|
| Process Calibrator 753 | 1971018 | 11-Jun-24 (CTTL, No.24J02X005147)        | Jun-25                |

|                | Name        | Function           | Signature |
|----------------|-------------|--------------------|-----------|
| Calibrated by: | Yu Zongying | SAR Test Engineer  |           |
| Reviewed by:   | Lin Jun     | SAR Test Engineer  |           |
| Approved by:   | Qi Dianyuan | SAR Project Leader |           |

Issued: January 02, 2025

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Certificate No: 24J02Z001029

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### Glossary:

DAE data acquisition electronics  
Connector angle information used in DASY system to align probe sensor X to the robot coordinate system.

### Methods Applied and Interpretation of Parameters:

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle:* The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The report provide only calibration results for DAE, it does not contain other performance test results.





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### DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1 $\mu$ V, full range = -100...+300 mV

Low Range: 1LSB = 61nV, full range = -1.....+3mV

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| Calibration Factors | X                         | Y                         | Z                         |
|---------------------|---------------------------|---------------------------|---------------------------|
| High Range          | 403.931 $\pm$ 0.15% (k=2) | 403.896 $\pm$ 0.15% (k=2) | 404.194 $\pm$ 0.15% (k=2) |
| Low Range           | 3.98546 $\pm$ 0.7% (k=2)  | 4.00739 $\pm$ 0.7% (k=2)  | 4.01092 $\pm$ 0.7% (k=2)  |

### Connector Angle

|                                           |                |
|-------------------------------------------|----------------|
| Connector Angle to be used in DASY system | 348° $\pm$ 1 ° |
|-------------------------------------------|----------------|

# Calibration information for DAE



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Client : JYT

Certificate No: 24J02Z001029

## CALIBRATION CERTIFICATE

Object DAE4 - SN: 1373

Calibration Procedure(s) FF-Z11-002-01  
Calibration Procedure for the Data Acquisition Electronics (DAEx)

Calibration date: December 31, 2024

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards      | ID #    | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
|------------------------|---------|------------------------------------------|-----------------------|
| Process Calibrator 753 | 1971018 | 11-Jun-24 (CTTL, No.24J02X005147)        | Jun-25                |

|                | Name        | Function           | Signature |
|----------------|-------------|--------------------|-----------|
| Calibrated by: | Yu Zongying | SAR Test Engineer  |           |
| Reviewed by:   | Lin Jun     | SAR Test Engineer  |           |
| Approved by:   | Qi Dianyuan | SAR Project Leader |           |

Issued: January 02, 2025

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### Glossary:

DAE data acquisition electronics  
Connector angle information used in DASY system to align probe sensor X to the robot coordinate system.

### Methods Applied and Interpretation of Parameters:

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle:* The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The report provide only calibration results for DAE, it does not contain other performance test results.





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### DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1μV, full range = -100...+300 mV

Low Range: 1LSB = 61nV, full range = -1.....+3mV

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| Calibration Factors | X                     | Y                     | Z                     |
|---------------------|-----------------------|-----------------------|-----------------------|
| High Range          | 403.931 ± 0.15% (k=2) | 403.896 ± 0.15% (k=2) | 404.194 ± 0.15% (k=2) |
| Low Range           | 3.98546 ± 0.7% (k=2)  | 4.00739 ± 0.7% (k=2)  | 4.01092 ± 0.7% (k=2)  |

### Connector Angle

|                                           |            |
|-------------------------------------------|------------|
| Connector Angle to be used in DASY system | 348° ± 1 ° |
|-------------------------------------------|------------|

# Calibration information for DAK3.5 probe

**Calibration Laboratory of  
Schmid & Partner  
Engineering AG**  
Zeughausstrasse 43, 8004 Zurich, Switzerland



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**C** Service suisse d'étalonnage  
**S** Servizio svizzero di taratura  
**S** Swiss Calibration Service

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The Swiss Accreditation Service is one of the signatories to the EA  
Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **JYT**  
**Shenzhen**

Certificate No: **OCP-DAK3.5-1119\_Feb25**

## CALIBRATION CERTIFICATE

Object **DAK-3.5 - SN: 1119**

Calibration procedure(s) **QA CAL-33.v3**  
**Calibration of dielectric parameter probes**

Calibration date: **February 17, 2025**

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).  
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature ( $22 \pm 3$ )°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards           | ID #     | Cal Date (Certificate No.)              | Scheduled Calibration |
|-----------------------------|----------|-----------------------------------------|-----------------------|
| OCP DAK-3.5 (weighted)      | SN: 1249 | 23-Sep-24 (OCP-DAK3.5-1249_Sep24)       | Sep-25                |
| Secondary Standards         | ID #     | Check Date (in house)                   | Scheduled Check       |
| Rohde & Schwarz ZVA67       | T4383    | 1-Oct-24 (in house check Oct-24)        | Oct-25                |
| Digital Thermometer DTM3000 | 4026     | 30-Jan-25 (DTM-4026_Jan25)              | Jan-26                |
| Methanol 99.9% Type 34860   | STBH5818 | 06-May-19 (bottle opened, check May-24) | May-25                |
| Ethanol 99.9% Type 1.0983   | 241014-1 | 14-Oct-20 (bottle opened, check Oct-24) | Oct-25                |
| Head Liquid, HBBL U16       | 200311-0 | 02-Feb-25 (in house check Feb-25)       | Feb-26                |
| 0.1 mol/L NaCl solution     | 190926-1 | 20-Sep-19 (in house check May-24)       | May-25                |
| 0.05 mol/L NaCl solution    | 190926-0 | 20-Sep-19 (in house check May-24)       | May-25                |
| Head Gel, SLAGH U08 AA-B    | 200227-1 | 07-Apr-20 (in house check Apr-24)       | Apr-25                |
| Eccostock0005               | 1507101  | 01-Jul-15 (in house check May-24)       | May-25                |

|                |              |                   |           |
|----------------|--------------|-------------------|-----------|
|                | Name         | Function          | Signature |
| Calibrated by: | Cindy Karina | External Engineer |           |
| Approved by:   | Sven Kühn    | Technical Manager |           |

Issued: February 18, 2025

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Certificate No: OCP-DAK3.5-1119\_Feb25

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## References

- [1] IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- [2] IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
- [3] IEC 62209-2 Ed.1, "Human Exposure to Radio Frequency Fields from Handheld and Body-Mounted Wireless Communication Devices – Human models, Instrumentation, and Procedures Part 2: Procedure to determine the specific absorption rate (SAR) for mobile wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- [4] A. P. Gregory and R. N. Clarke, "NPL Report MAT 23", January 2012
- [5] Tables of the Complex Permittivity of Dielectric Reference Liquids at Frequencies up to 5 GHz
- [6] DAK Professional Handbook, SPEAG, September 2018
- [7] A. Toropainen et al, "Method for accurate measurement of complex permittivity of tissue equivalent liquids", Electronics Letters 36 (1) 2000 pp32-34
- [8] J. Hilland, "Simple sensor system for measuring the dielectric properties of saline solutions", Meas. Sci. Technol. 8 pp901-910 (1997)
- [9] K. Nörtemann, J. Hilland and U. Kaatz, "Dielectric Properties of Aqueous NaCl Solutions at Microwave Frequencies", J. Phys. Chem. A 101 pp6864-6869 (1997)
- [9] R. Buchner, G. T. Hefter and Peter M. May, "Dielectric Relaxation of Aqueous NaCl Solutions", J. Phys. Chem. A 103 (1) (1999)

## Description of the dielectric probe

Dielectric probes are used to measure the dielectric parameters of tissue simulating media in a wide frequency range. The complex permittivity  $\epsilon_r^* = (\epsilon'/\epsilon_0) - j(\epsilon''/\epsilon_0)$  is determined from the S parameters measured with a vector network analyzer (VNA) with software specific to the probe type. The parameters of interest e.g. in standards [1, 2, 3] and for other applications are presented are calculated as follows:

(Relative) permittivity  $\epsilon'$  (real part of  $\epsilon_r^* = (\epsilon'/\epsilon_0) - j(\epsilon''/\epsilon_0)$  where  $\epsilon_0 = 8.854 \text{ pF/m}$  is the permittivity in free space)

Conductivity  $\sigma = 2 \pi f \epsilon'' \epsilon_0$ ,

Loss Tangent =  $(\epsilon''/\epsilon')$

The **OCP** (open ended coaxial) is a cut off section of 50 Ohm transmission line, similar to the system described in [1, 2, 3, 5], used for contact measurement. The material is measured either by touching the probe to the surface of a solid/gel or by immersing it into a liquid media. The electromagnetic fields at the probe end fringe into the material to be measured, and its parameters are determined from the change of the  $S_{11}$  parameters. With larger diameter of the dielectrics, the probe can be used down to lower frequencies.

The flange surrounding the active area shapes the near field similar to a semi-infinite geometry and is inserted fully into the measured lossy liquid.



The probe is connected with a phase and amplitude stable cable to a VNA which is then calibrated with Open, Short and a Liquid with well-known parameters.  
All parts in the setup influencing the amplitude and phase of the signal are important and shall remain stable.

#### Handling of the item

Before usage, the active probe area has to be cleaned from any material residuals potentially contaminating the reference standards. The metal and dielectric surface must be protected to keep the precision of the critical mechanical dimensions. The connector and cable quality are critical; any movements between calibration and measurement shall be avoided.  
The temperature must be stable and must not differ from the material temperature.

#### Methods Applied and Interpretation of Parameters

The calibration of the dielectric probe system is done in the steps described below for the desired frequency range and calibration package (SAR/MRI liquids, Semi-solid/solid material). Because the standard calibration in step 3 is critical for the results in steps 4 to 8, the sequence 3 to 8 is repeated 3 times. As a result, the result from these 3 sets is represented.

1. Configuration and mechanical / optical status.
2. Measurement resolution is 5 MHz from 10 to 300 MHz, 50 MHz from 300 to 6000 MHz and 250 MHz from 6 to 20 GHz.
3. Standard calibration uses Air / Short / Liquid. 1 liter liquid quantity is used to reduce the influence the reflections. The liquid type is selected depending on the lowest frequency and probe diameter:  
DAK-1.2, DAK-3.5, Agilent OCP: de-ionized water (approx. 22 °C)  
DAK-12: saline solution with static conductivity 1 S/m (approx. 22 °C)  
NPL OCP: pure ethanol (approx. 22 °C)
4. The cable used in the setup stays in a fixed position, i.e. the probe is fixed and measuring from the top in an angle of typ. 20° from the vertical axis. For DAK and Agilent probes, the refresh function (air standard) is used previous to the individual measurements in order to compensate for possible deviations from cable movements. After insertion of the probe into a liquid, the possible air bubbles are removed from the active surface.
5. Measurement of multiple shorts if not already available from the calibration in the previous step (NPL). Evaluation of the deviation from the previous calibration short with graphical representation of the complex quantities and magnitude over the frequency range. Probe specific short is used. This assessment shows ability to define a short circuit at the end of the probe for the VNA calibration in the setup which is essential at high frequencies and depends on the probe surface quality.
6. Measurement of validation liquids in a quantity of 1 liter at well defined temperature. Evaluation of the deviations from the target. The targets base on traceable data from reference sources. The deviation of the measurement is graphically presented for permittivity and conductivity (for lossy liquids) or loss tangent (for low losses at low frequencies).
7. Measurement of lossy liquids in a quantity of 1 liter at well defined temperature. Head tissue simulating liquid or saline solution with 0.5 S/m static conductivity are representative. The target data base on traceable data from reference sources or from multiple measurements with precision reference probes or different evaluations such as transmission line or slotted line methods. Evaluation of the deviation from the target and graphical representation for permittivity and conductivity over the frequency range
8. Semi-solid / solid material calibration:  
Measurements of an elastic lossy broadband semi-solid gel with parameters close to the head tissue target. Measurements of a planar very low loss solid microwave-substrate. The average of 4 measurements of the same sample at different location is shown as a single result. The deviation of the permittivity and conductivity from the reference data is evaluated.  
Measurements of a planar very low loss solid microwave-substrate. The average of 4 measurements of the same sample at different location is shown as a single result. The relative deviation of the permittivity and the absolute deviation of the loss tangent is evaluated.  
The targets base on multiple measurements (on the same material batch at identical temperature) on convex and planar surfaces with precision reference OCP.

- The measurement on semi-solid / solid materials is sensitive to the quality and planarity of the probe contact area, such as air gaps due to imperfect probes (resulting lower permittivity values).
9. Table for the probe uncertainty: The uncertainty of the probe depending on probe type, size, material parameter range and frequency is given in a table. It represents the best measurement capability of the specific probe but does not include the material (deviation from the target values).
  10. Appendix with detailed results of all measurements with the uncertainties for the specific measurement. In addition to the probe uncertainty (see above), it includes the uncertainty of the reference material used for the measurement. A set of results from independent calibrations represents the capability of the setup and the lossy materials used, including the precision of the measured material and the influence of temperature deviations. Temperature and operator influence was minimized and gives a good indication of the achievable repeatability of a measurement.
  11. Summary assessment of the measured deviations and detailed comments if not typical for the probe type.

#### Dielectric probe identification and configuration data

##### Item description

|                  |                                                                                                                                                   |
|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Probe type       | OCP Open-ended coaxial probe                                                                                                                      |
| Probe name       | SPEAG Dielectric Assessment Kit DAK-3.5                                                                                                           |
| Type No          | SM DAK 040 CA                                                                                                                                     |
| Serial No        | 1119                                                                                                                                              |
| Description      | Open-ended coaxial probe with flange<br>Flange diameter: 19.0 mm<br>Dielectric diameter: 3.5 mm<br>Material: stainless steel                      |
| Connector 1      | PC 3.5 pos.                                                                                                                                       |
| Software version | DAK Measurement Solver 3.0.6.34<br>Calibration Type: Air / short / water (set to measured water temp.)<br>Probe type: "DAK3.5" (software setting) |
| Further settings | VNA bandwidth setting: 50 Hz                                                                                                                      |

##### SCS 0108 Accessories used for customer probe calibration

|       |                                                                                           |
|-------|-------------------------------------------------------------------------------------------|
| Cable | Huber & Suhner Sucoflex 100, SN: 512046/126, length 1 m,<br>PC3.5 neg. – PC3.5 neg.       |
| Short | DAK-3.5 shorting block, type SM DAK 200 BA<br>Contact area covered with cleaned Cu stripe |

##### Additional items used during measurements

|           |                                      |
|-----------|--------------------------------------|
| Adapter 1 | PC3.5 pos. – PC1.85 (VNA side)       |
| Adapter 2 | PC3.5 pos. – PC3.5 neg. (probe side) |

#### Notes

- Before the calibration, the connectors of the probe and cable were inspected and cleaned.
- Probe visual inspection: according to requirements
- Short inspection: according to the requirements



### Probe Uncertainty

The following tables provide material and frequency specific uncertainties (k=2) for the dielectric probe. The values in the tables represent the measurement capability for the probe when measuring a material in the indicated parameter range. They include all uncertainties of

- probe system
- possible systematic errors due to the design
- calibration
- temperature differences during the calibration and measurements, as described,
- VNA noise

Apart from the material used for the calibration (de-ionized water), material uncertainties of the reference materials used during the measurement in Appendix A are not included in these tables.

| DAK-3.5                  |          |                 |                      |            |
|--------------------------|----------|-----------------|----------------------|------------|
| Permittivity range       |          | Frequency range | (sigma / LT range)   | Unc. (k=2) |
|                          | 1 – 15   | 200 MHz - 3 GHz | LT < 0.1             | 2.4%       |
|                          |          | 3 GHz - 6 GHz   | LT < 0.1             | 2.0%       |
|                          |          | 6 GHz - 20 GHz  | LT < 0.1             | 2.1%       |
|                          |          | 6 GHz - 20 GHz  | sigma > 1            | 3.5%       |
|                          |          |                 |                      |            |
|                          | 10 – 40  | 200 MHz - 3 GHz | sigma : 1 – 10 S/m   | 1.9%       |
|                          |          | 3 GHz - 6 GHz   | sigma : 1 – 10 S/m   | 2.3%       |
|                          |          | 6 GHz - 20 GHz  | sigma > 10 S/m       | 3.5%       |
|                          |          |                 |                      |            |
|                          | 35 – 100 | 200 MHz - 3 GHz | sigma : 1 – 10 S/m   | 1.8%       |
|                          |          | 3 GHz - 6 GHz   | sigma : 1 – 10 S/m   | 1.9%       |
|                          |          | 6 GHz - 20 GHz  | sigma > 10 S/m       | 2.4%       |
|                          |          |                 |                      |            |
| Conductivity range (S/m) |          | Frequency range | (epsilon / LT range) | Unc. (k=2) |
|                          | 1 – 10   | 200 MHz - 3 GHz | eps : 35 - 100       | 2.7%       |
|                          |          | 3 GHz - 6 GHz   | eps : 35 - 100       | 3.0%       |
|                          |          | 6 GHz - 20 GHz  | eps : 10 - 40        | 3.0%       |
|                          |          |                 |                      |            |
| Loss tangent range       |          | Frequency range | (epsilon / LT range) | Unc. (k=2) |
|                          | < 0.1    | 200 MHz - 3 GHz | eps : 1 - 15         | 0.03       |
|                          |          | 3 GHz - 6 GHz   | eps : 1 - 15         | 0.03       |
|                          |          | 6 GHz - 20 GHz  | eps : 1 - 15         | 0.03       |



### 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.*

## 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.

## 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.

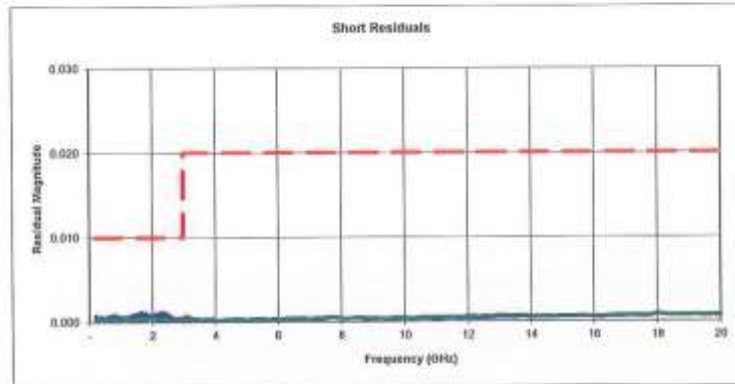


Fig. 2.1a Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration a)

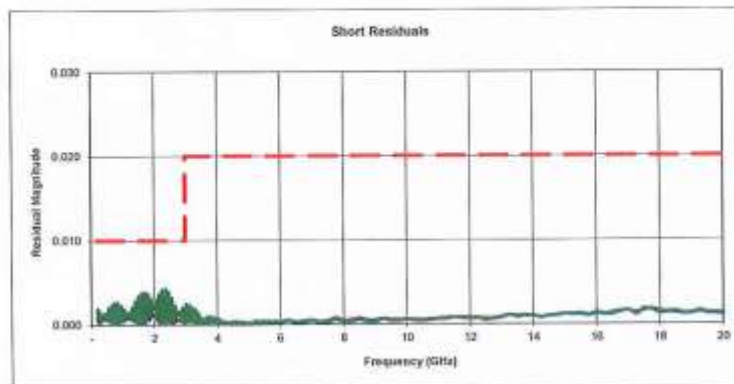


Fig. 2.1b Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration b)

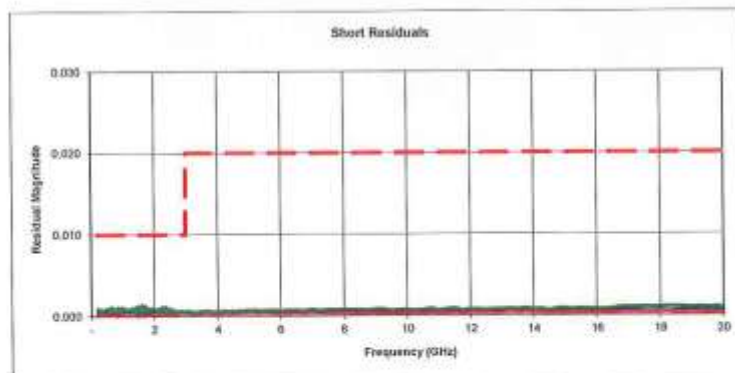


Fig. 2.1c Magnitude of the residual of the shorts, 200 MHz – 20 GHz, after calibration c)



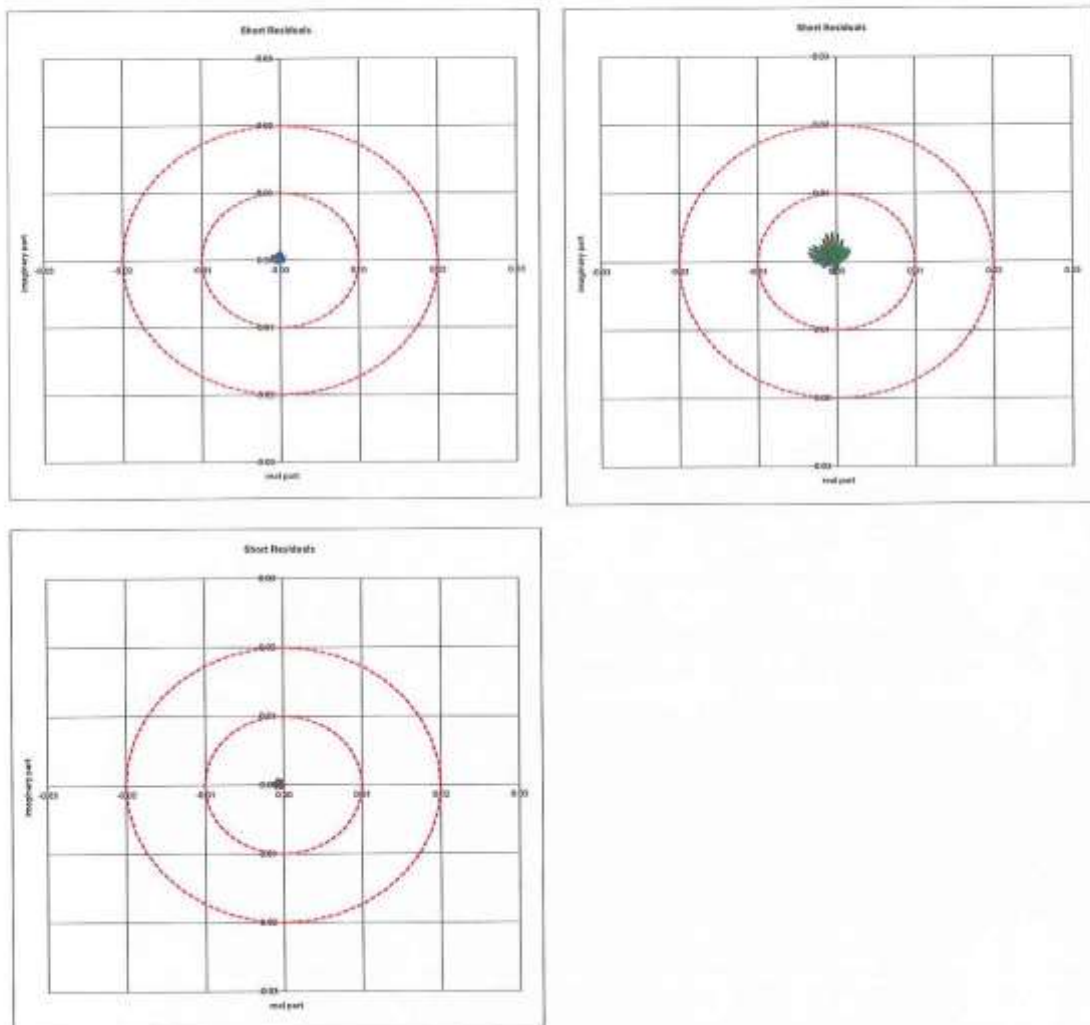


Fig. 2.2a-c Complex representation of the residuals of the shorts, 200 MHz - 20 GHz, after calibrations a)-b) in the top and c) in the bottom

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

### A.3 Ethanol

Ethanol (99.9% pure) was measured at a temperature of  $22 \pm 2$  °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.

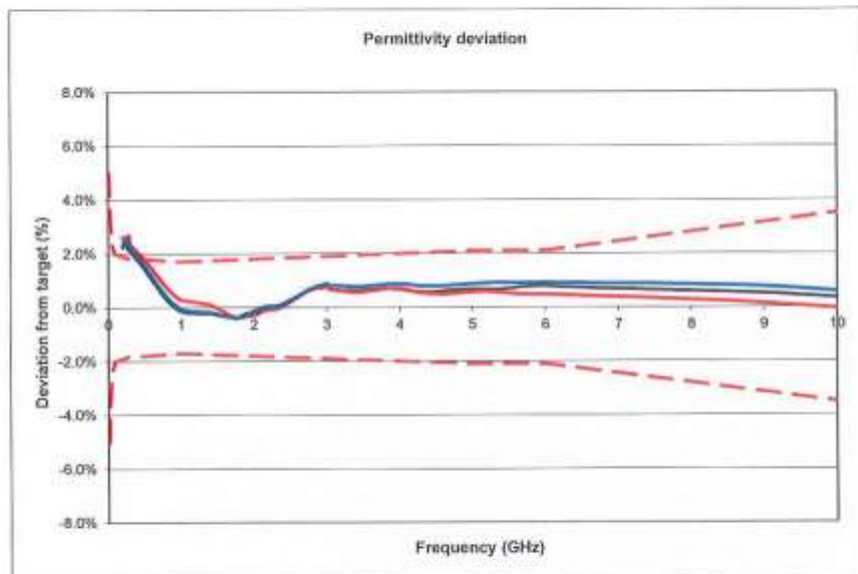


Fig. 3.1 Ethanol permittivity deviation from target, 200 MHz – 10 GHz

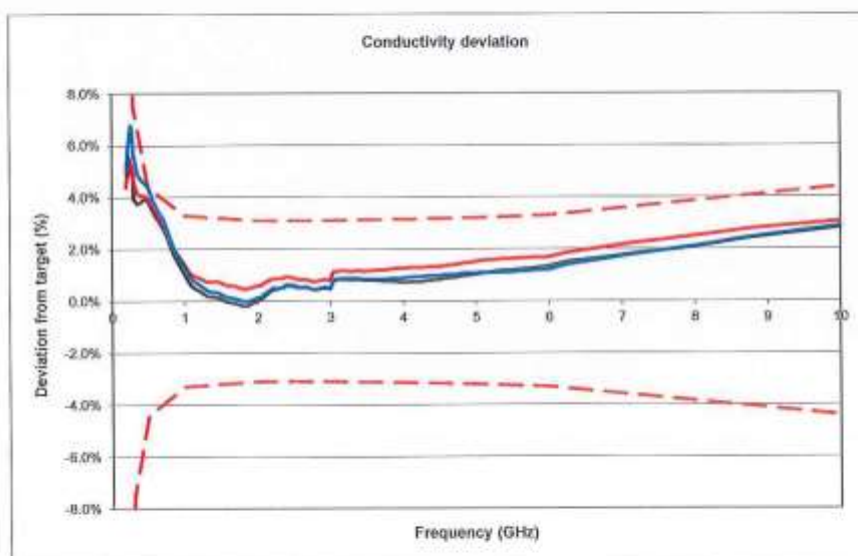


Fig. 3.2 Ethanol conductivity deviation from target, 200 MHz – 10 GHz

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

#### A.4 Head Tissue

Broadband head simulating liquid was measured at a temperature of  $22 \pm 2$  °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.

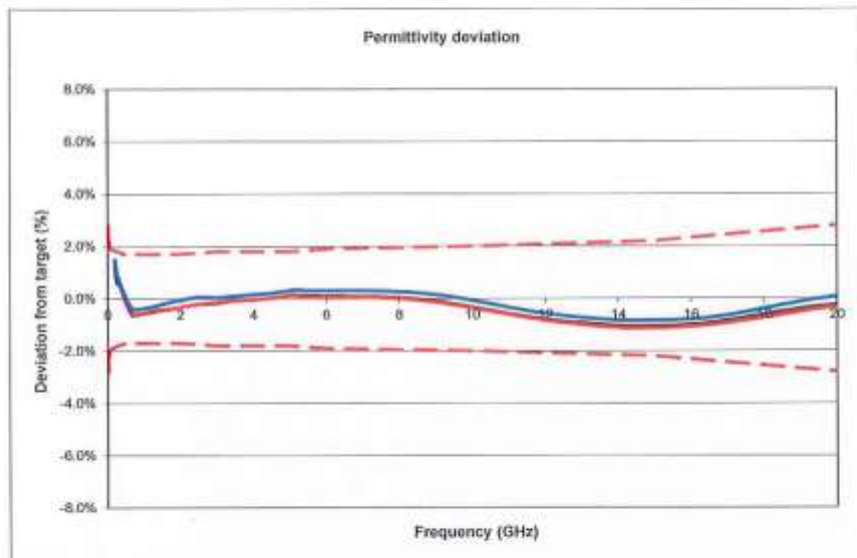


Fig. 4.1 HBBL permittivity deviation from target, 200 MHz – 20 GHz

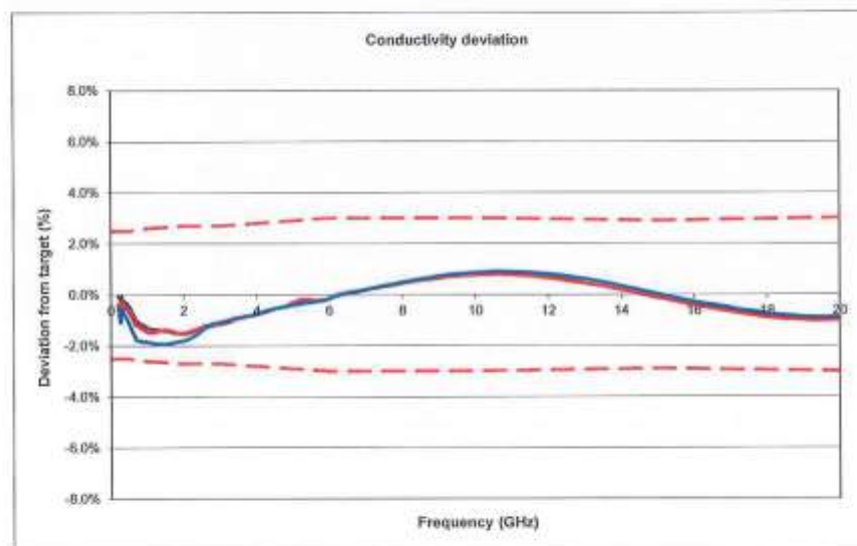


Fig. 4.2 HBBL conductivity deviation from target, 200 MHz – 20 GHz



#### 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  $22 \pm 2$  °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.

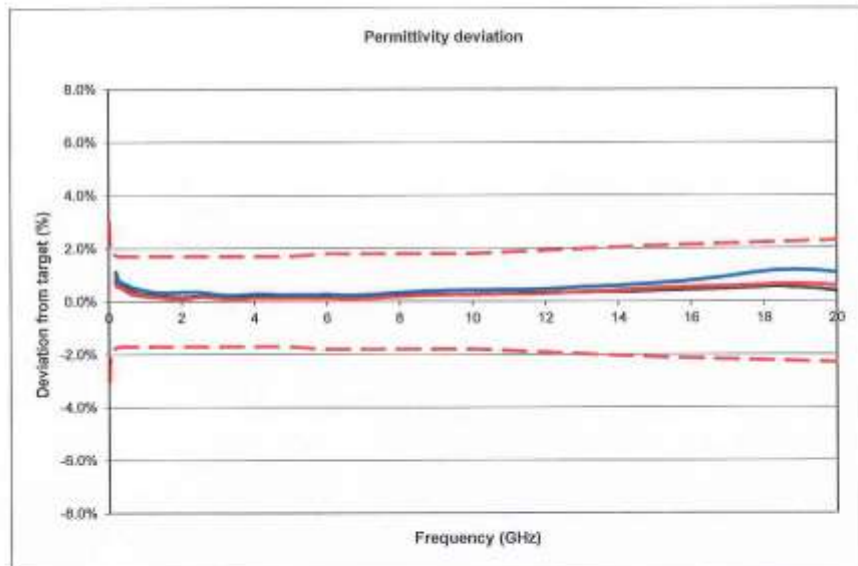


Fig. 5.1 0.05 mol/L solution permittivity deviation from target, 200 MHz – 20 GHz

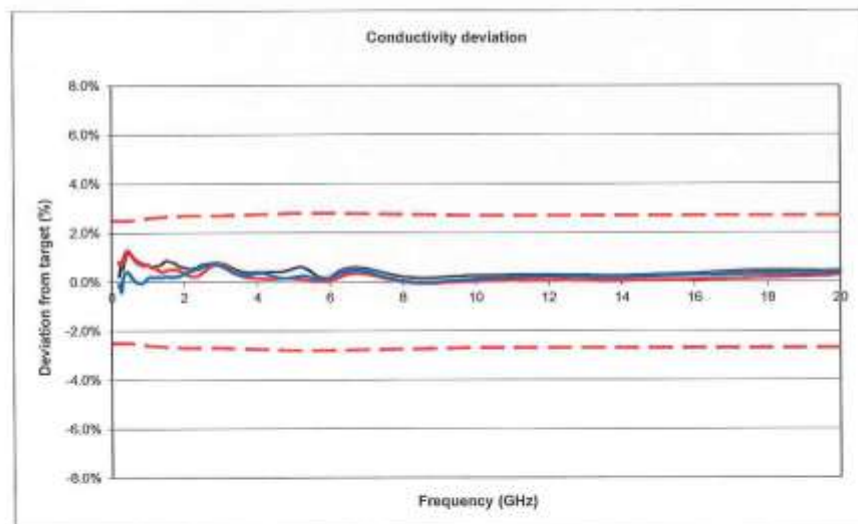


Fig. 5.2 0.05 mol/L solution conductivity deviation from target, 200 MHz – 20 GHz

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

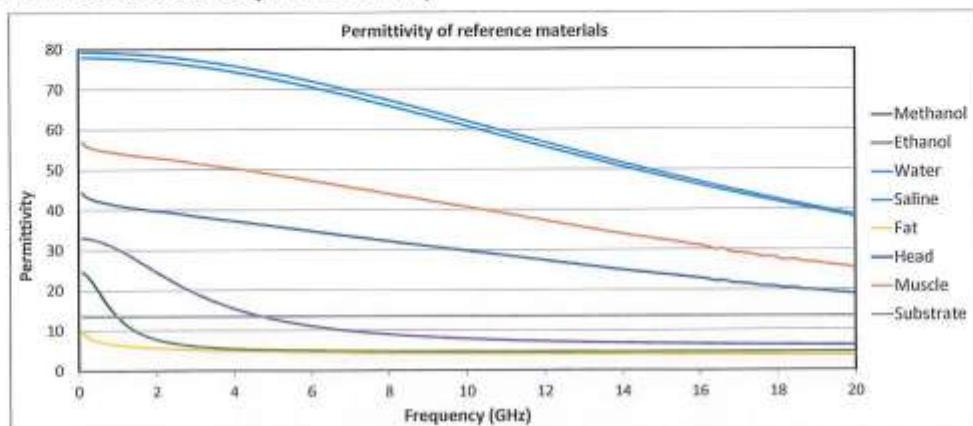


Fig. B.1 Permittivity of reference materials

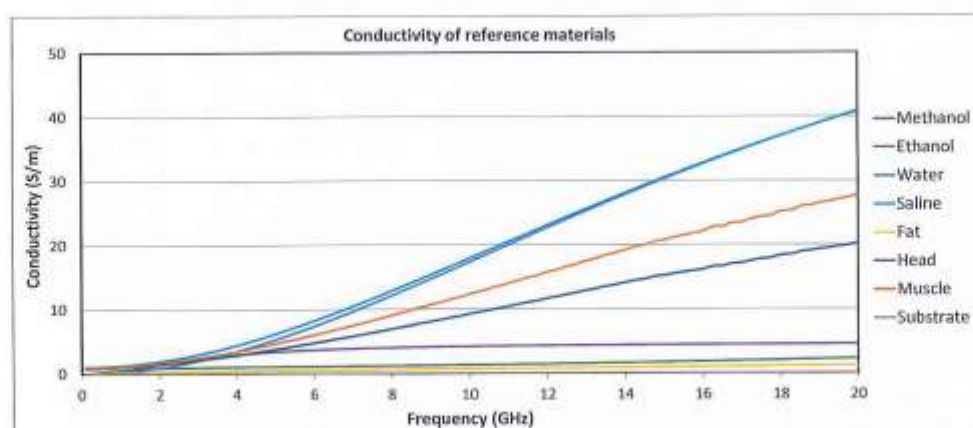


Fig. B.2 Conductivity of reference materials

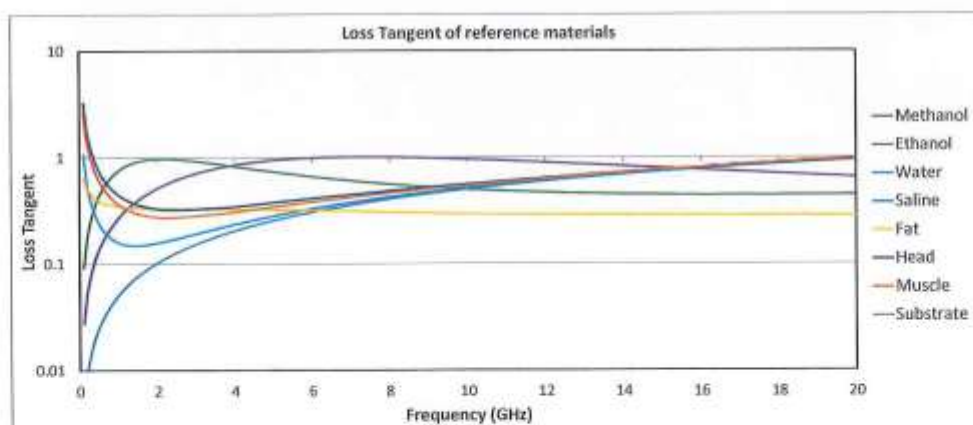


Fig. B.3 Loss tangent of reference materials

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