## 11.4. Calibration Certificate for Dipole

This sub-section contains Cal Certificates for Dipoles and is not included in the total number of pages for this report.

Checked M.Nalcen 23/03/2023

PRE0253912
ULEID #234730

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

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S Swiss Calibration Service

Accredited by the Swiss Accreditation Service (SAS)
**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** UL UK

**Certificate No: D2450V2-1097_Feb23**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | D2450V2 - SN:1097 |
| Calibration procedure(s) | QA CAL-05.v12<br>Calibration Procedure for SAR Validation Sources between 0.7-3 GHz |
| Calibration date: | February 02, 2023 |

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 (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter NRP | SN: 104778 | 04-Apr-22 (No. 217-03525/03524) | Apr-23 |
| Power sensor NRP-Z91 | SN: 103244 | 04-Apr-22 (No. 217-03524) | Apr-23 |
| Power sensor NRP-Z91 | SN: 103245 | 04-Apr-22 (No. 217-03525) | Apr-23 |
| Reference 20 dB Attenuator | SN: BH9394 (20k) | 04-Apr-22 (No. 217-03527) | Apr-23 |
| Type-N mismatch combination | SN: 310982 / 06327 | 04-Apr-22 (No. 217-03528) | Apr-23 |
| Reference Probe EX3DV4 | SN: 7349 | 10-Jan-23 (No. EX3-7349_Jan23) | Jan-24 |
| DAE4 | SN: 601 | 19-Dec-22 (No. DAE4-601_Dec22) | Dec-23 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| Power meter E4419B | SN: GB39512475 | 30-Oct-14 (in house check Oct-22) | In house check: Oct-24 |
| Power sensor HP 8481A | SN: US37292783 | 07-Oct-15 (in house check Oct-22) | In house check: Oct-24 |
| Power sensor HP 8481A | SN: MY41093315 | 07-Oct-15 (in house check Oct-22) | In house check: Oct-24 |
| RF generator R&S SMT-06 | SN: 100972 | 15-Jun-15 (in house check Oct-22) | In house check: Oct-24 |
| Network Analyzer Agilent E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-22) | In house check: Oct-24 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Paulo Pina | Laboratory Technician | |
| Approved by: | Sven Kühn | Technical Manager | |

Issued: February 3, 2023

**Calibration Laboratory of**
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**Accreditation No.: SCS 0108**

## Glossary:

| | |
|---|---|
| TSL | tissue simulating liquid |
| ConvF | sensitivity in TSL / NORM x,y,z |
| 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-Worn 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) DASY 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 source is mounted in a touch configuration below the center marking of the flat phantom.
- *Return Loss:* This parameter is measured with the source positioned under the liquid filled phantom (as described in the measurement condition clause). The Return Loss ensures low reflected power. 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** | Modular Flat Phantom | |
| **Distance Dipole Center - TSL** | 10 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy, dz = 5 mm | |
| **Frequency** | 2450 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 39.2 | 1.80 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 39.3 ± 6 % | 1.85 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 13.0 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **51.4 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 6.05 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **24.0 W/kg ± 16.5 % (k=2)** |

## Appendix (Additional assessments outside the scope of SCS 0108)

### Antenna Parameters with Head TSL

| | |
|---|---|
| Impedance, transformed to feed point | 52.9 Ω + 3.3 jΩ |
| Return Loss | - 27.4 dB |

### General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.155 ns |

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint 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 feedpoint may be damaged.

### Additional EUT Data

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

Date: 02.02.2023

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN:1097**

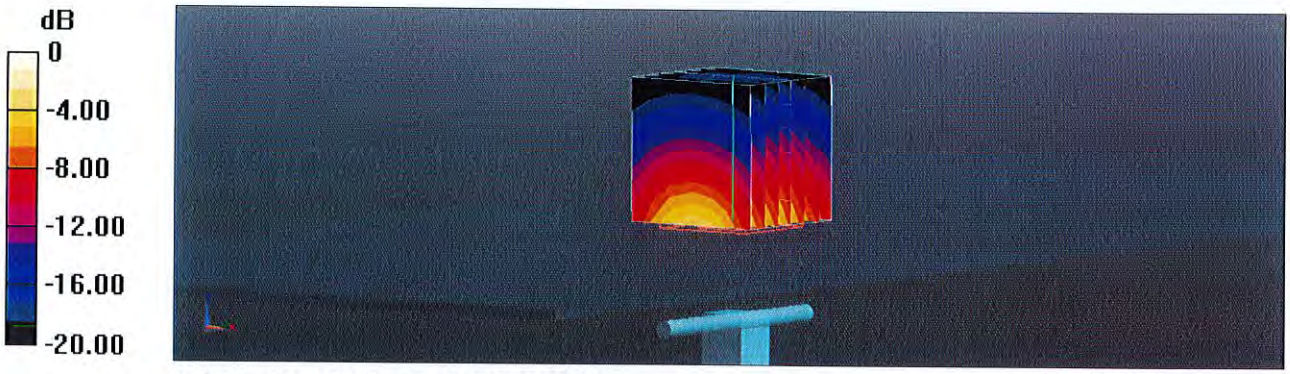
Communication System: UID 0 - CW; Frequency: 2450 MHz
Medium parameters used: f = 2450 MHz; $\sigma$ = 1.85 S/m; $\varepsilon_r$ = 39.3; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.88, 7.88, 7.88) @ 2450 MHz; Calibrated: 10.01.2023
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 19.12.2022
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

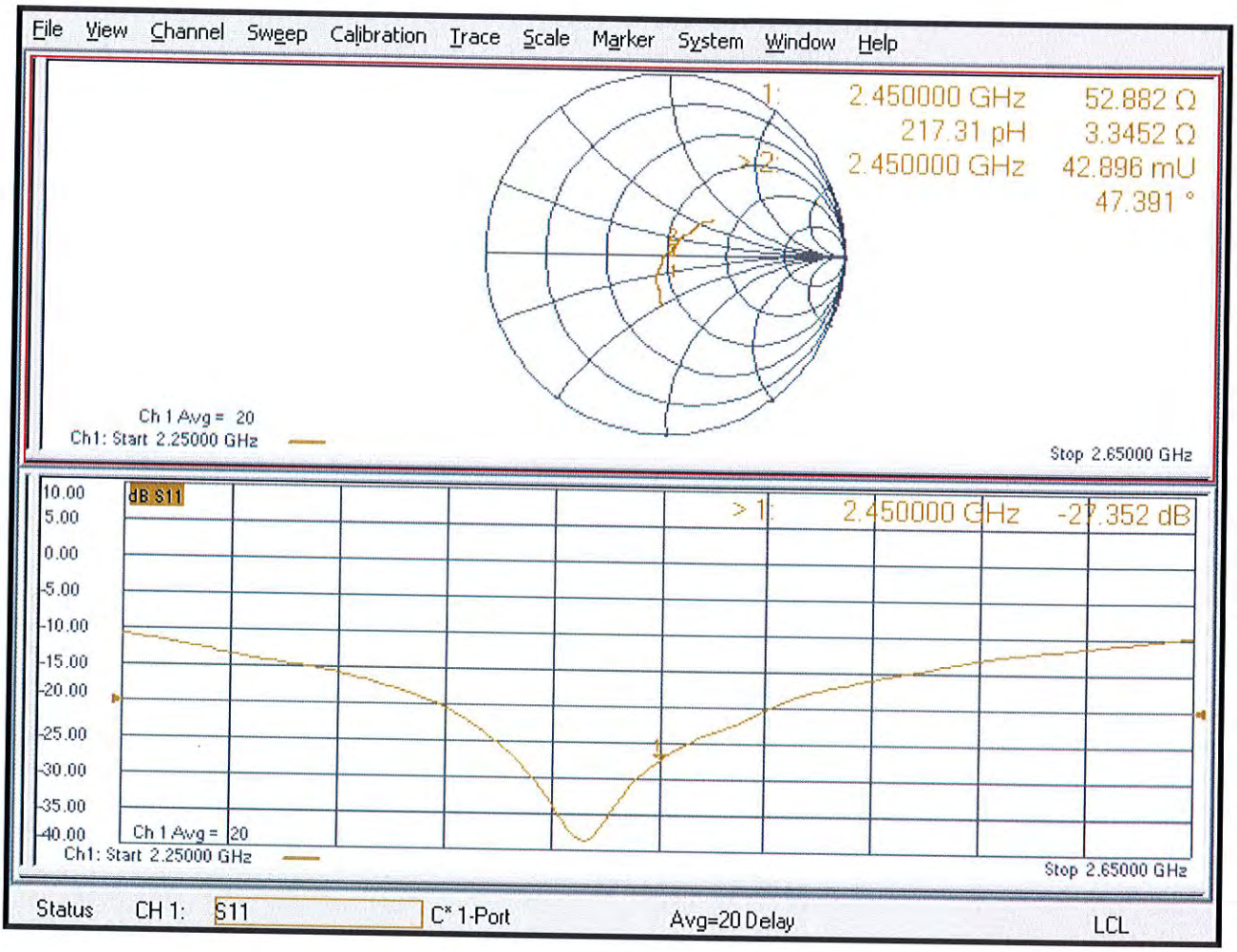
## Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 115.2 V/m; Power Drift = 0.04 dB
Peak SAR (extrapolated) = 25.7 W/kg
**SAR(1 g) = 13 W/kg; SAR(10 g) = 6.05 W/kg**
Smallest distance from peaks to all points 3 dB below = 9 mm
Ratio of SAR at M2 to SAR at M1 = 50.4%
Maximum value of SAR (measured) = 21.4 W/kg




0 dB = 21.4 W/kg = 13.30 dBW/kg

## Impedance Measurement Plot for Head TSL



## 11.5. Tissues-Equivalent Media Recipes

The SPEAG Broadband Tissue Simulation Liquid HBBL600-10000V6 has been used for Head and Body testing. The composition of this fluid is undisclosed and proprietary to SPEAG.

Visual inspection is made to ensure air bubbles are not trapped during the mixing process. The mixture is calibrated to obtain proper dielectric constant (permittivity) and conductivity of the tissue.

## 11.6. Dielectric Property Measurements & System Check

### 11.6.1. Tissues-Equivalent Media Recipes

The SPEAG Broadband Tissue Simulation Liquid HBBL600-6000V6 has been used for Head and Body testing. The composition of this fluid is undisclosed and proprietary to SPEAG.

Visual inspection is made to ensure air bubbles are not trapped during the mixing process. The mixture is calibrated to obtain proper dielectric constant (permittivity) and conductivity of the tissue.

### 11.6.2. Tissue Dielectric Parameters

The temperature of the tissue-equivalent medium used during measurement must also be within 18°C to 25°C and within ± 2°C of the temperature when the tissue parameters are characterized.
The dielectric parameters must be measured before the tissue-equivalent medium is used in a series of SAR measurements. The parameters should be re-measured after each 3 – 4 days of use; or earlier if the dielectric parameters can become out of tolerance; for example, when the parameters are marginal at the beginning of the measurement series.
Tissue dielectric parameters were measured at the low, middle and high frequency of each operating frequency range of the test device.

**IEC 62209-1528**

| Target Frequency (MHz) | Head | |
|---|---|---|
| | $\varepsilon_r$ | $\sigma$ (S/m) |
| 4 | 55,0 | 0,75 |
| 13 | 55,0 | 0,75 |
| 30 | 55,0 | 0,75 |
| 150 | 52,3 | 0,76 |
| 300 | 45,3 | 0,87 |
| 450 | 43,5 | 0,87 |
| 750 | 41,9 | 0,89 |
| 835 | 41,5 | 0,90 |
| 900 | 41,5 | 0,97 |
| 1450 | 40,5 | 1,20 |
| 1800 | 40,0 | 1,40 |
| 1900 | 40,0 | 1,40 |
| 1950 | 40,0 | 1,40 |
| 2000 | 40,0 | 1,40 |
| 2100 | 39,8 | 1,49 |
| 2450 | 39,2 | 1,80 |
| 2600 | 39,0 | 1,96 |
| 3000 | 38,5 | 2,40 |
| 3500 | 37,9 | 2,91 |
| 4000 | 37,4 | 3,43 |
| 4500 | 36,8 | 3,94 |
| 5000 | 36,2 | 4,45 |
| 5200 | 36,0 | 4,66 |
| 5400 | 35,8 | 4,86 |
| 5600 | 35,5 | 5,07 |
| 5800 | 35,3 | 5,27 |
| 6000 | 35,1 | 5,48 |
| 6500 | 34,5 | 6,07 |
| 7000 | 33,9 | 6,65 |
| 7500 | 33,3 | 7,24 |
| 8000 | 32,7 | 7,84 |
| 8500 | 32,1 | 8,46 |
| 9000 | 31,6 | 9,08 |
| 9500 | 31,0 | 9,71 |
| 10000 | 30,4 | 10,40 |

**NOTE**: For convenience, permittivity and conductivity values are linearly interpolated for frequencies that are not a part of the original data from Drossos et al. [2]. They are shown in italics in Table 2. The italicized values are linearly interpolated (below 5 800 MHz) or extrapolated (above 5 800 MHz) from the non-italicized values that are immediately above and below these values.

### 11.6.3. System Check

SAR system verification is required to confirm measurement accuracy, according to the tissue dielectric media, probe calibration points and other system operating parameters required for measuring the SAR of a test device. The system verification must be performed for each frequency band and within the valid range of each probe calibration point required for testing the device. The same SAR probe(s) and tissue-equivalent media combinations used with each specific SAR system for system verification must be used for device testing. When multiple probe calibration points are required to cover substantially large transmission bands, independent system verifications are required for each probe calibration point. A system verification must be performed before each series of SAR measurements using the same probe calibration point and tissue-equivalent medium. Additional system verification should be considered according to the conditions of the tissue-equivalent medium and measured tissue dielectric parameters, typically every three to four days when the liquid parameters are re-measured or sooner when marginal liquid parameters are used at the beginning of a series of measurements.

### 11.6.4. Numerical SAR Target Values

The numerical SAR target values are obtained from the reference standards. The measured values are normalised to 1 Watt.

| System Dipole | Freq. (MHz) | Numerical SAR Target Values (W/kg) | |
|---|---|---|---|
| | | 1g/10g | Head |
| D750V3 | 750 | 1g | 8.49 |
| | | 10g | 5.55 |
| D900V2 | 900 | 1g | 10.90 |
| | | 10g | 6.99 |
| D1800V2 | 1800 | 1g | 38.40 |
| | | 10g | 20.10 |
| D1900V2 | 1900 | 1g | 39.70 |
| | | 10g | 20.50 |
| D2000V2 | 2000 | 1g | 41.10 |
| | | 10g | 21.10 |
| D2100V2 | 2100 | 1g | 43.60 |
| | | 10g | 21.90 |
| D2300V2 | 2300 | 1g | 48.70 |
| | | 10g | 23.30 |
| D2450V2 | 2450 | 1g | 52.40 |
| | | 10g | 24.00 |
| D2600V2 | 2600 | 1g | 56.20 |
| | | 10g | 24.70 |
| D3300V2 | 3300 | 1g | 66.90 |
| | | 10g | 25.40 |
| D3500V2 | 3500 | 1g | 67.10 |
| | | 10g | 25.00 |
| D3700V2 | 3700 | 1g | 67.40 |
| | | 10g | 24.20 |
| D3900V2 | 3900 | 1g | 67.50 |
| | | 10g | 23.30 |
| D4200V2 | 4200 | 1g | 66.40 |
| | | 10g | 22.20 |
| D5GHzV2 | 5250 | 1g | 77.40 |
| | | 10g | 21.90 |
| | 5600 | 1g | 80.10 |
| | | 10g | 22.50 |
| | 5750 | 1g | 77.00 |
| | | 10g | 21.60 |
| D6500V2 | 6500 | 1g | 298.00 |
| | | 10g | 52.80 |
| D7000V2 | 7000 | 1g | 275.00 |
| | | 10g | 47.00 |
| D9000V2 | 9000 | 1g | 243.00 |
| | | 10g | 40.00 |

## 11.6.5. Dielectric Property Measurements & System Check Results

The 1-g SAR and 10-g SAR measured with a reference dipole, using the required tissue-equivalent medium at the test frequency, must be within ±10% of the manufacturer calibrated dipole SAR target and ±15% of the numerical target

**Site 67**

**2450 Head**
Date: 17 Oct 2023
Reference Dipole Antenna: D2450V2 - SN1097

| Simulant | Frequency (MHz) | Room Temp (℃) | Liquid Temp (℃) | Parameters | Measured Value | Target Type | Target Value | Deviation (%) | Limit (%) |
|---|---|---|---|---|---|---|---|---|---|
| Head | 2450 | 21.8 | 20.6 | $\varepsilon_r$ | 40.26 | Numerical | 39.20 | 2.71 | 10 |
| | | | | σ (S/m) | 1.84 | Numerical | 1.80 | 2.14 | 10 |
| | | | | 1g (W/kg) | 48.48 | Experimental | 51.40 | -5.67 | 10 |
| | | | | | | Numerical | 52.40 | -7.47 | 15 |
| | | | | 10g (W/kg) | 23.14 | Experimental | 24.00 | -3.56 | 10 |
| | | | | | | Numerical | 24.00 | -3.56 | 15 |

**END OF REPORT**