

**11.5. 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.



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Accreditation No.: **SCS 0108**

Client **UL**  
**Basingstoke, United Kingdom**

Certificate No. **D2450V2-725\_Oct23**

## CALIBRATION CERTIFICATE

Object **D2450V2 - SN:725**

Calibration procedure(s) **QA CAL-05.v12**  
**Calibration Procedure for SAR Validation Sources between 0.7-3 GHz**

Calibration date: **October 13, 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 ( $22 \pm 3$ )°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP2	SN: 104778	30-Mar-23 (No. 217-03804/03805)	Mar-24
Power sensor NRP-Z91	SN: 103244	30-Mar-23 (No. 217-03804)	Mar-24
Power sensor NRP-Z91	SN: 103245	30-Mar-23 (No. 217-03805)	Mar-24
Reference 20 dB Attenuator	SN: BH9394 (20k)	30-Mar-23 (No. 217-03809)	Mar-24
Type-N mismatch combination	SN: 310982 / 06327	30-Mar-23 (No. 217-03810)	Mar-24
Reference Probe EX3DV4	SN: 7349	10-Jan-23 (No. EX3-7349_Jan23)	Jan-24
DAE4	SN: 601	03-Oct-23 (No. DAE4-601_Oct23)	Oct-24
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

Calibrated by: **Paulo Pina**      Name: **Paulo Pina**      Function: **Laboratory Technician**

Approved by: **Sven Kühn**      Name: **Sven Kühn**      Function: **Technical Manager**

Issued: October 16, 2023

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.





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### 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 $\pm$ 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 $\pm$ 0.2) °C	37.7 $\pm$ 6 %	1.86 mho/m $\pm$ 6 %
Head TSL temperature change during test	< 0.5 °C	----	----

## SAR result with Head TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	13.6 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	<b>53.0 W/kg <math>\pm</math> 17.0 % (k=2)</b>

SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	condition	
SAR measured	250 mW input power	6.32 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	<b>24.9 W/kg <math>\pm</math> 16.5 % (k=2)</b>



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

### Antenna Parameters with Head TSL

Impedance, transformed to feed point	$52.0\ \Omega + 6.8\ j\Omega$
Return Loss	- 23.1 dB

### General Antenna Parameters and Design

Electrical Delay (one direction)	1.148 ns
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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
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# DASY5 Validation Report for Head TSL

Date: 13.10.2023

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN:725**

Communication System: UID 0 - CW; Frequency: 2450 MHz

Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.86$  S/m;  $\epsilon_r = 37.7$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.9, 7.9, 7.9) @ 2450 MHz; Calibrated: 10.01.2023
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 03.10.2023
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; 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 = 117.0 V/m; Power Drift = 0.05 dB

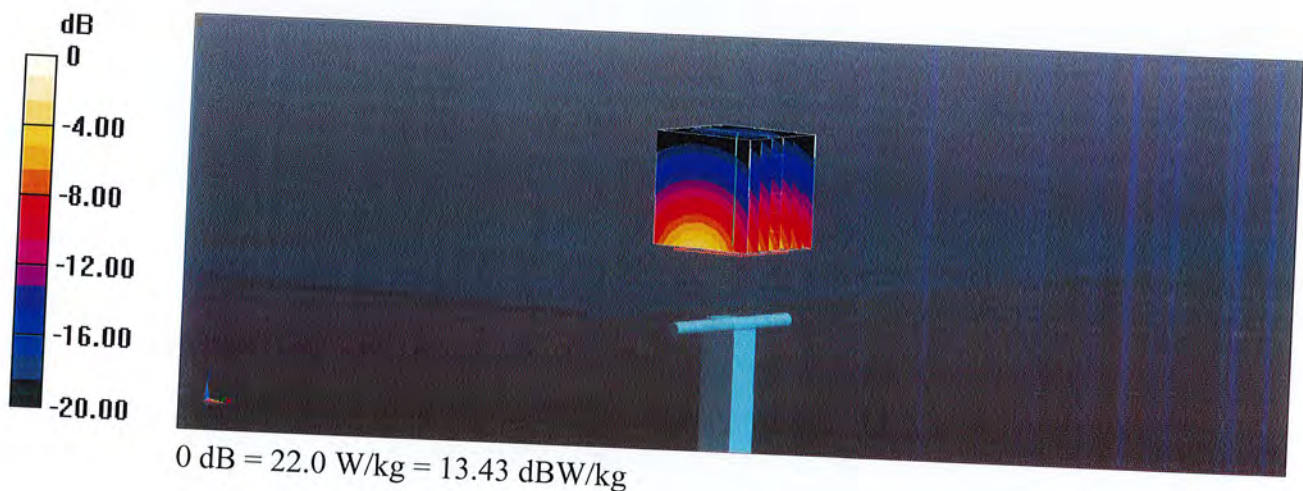
Peak SAR (extrapolated) = 26.9 W/kg

**SAR(1 g) = 13.6 W/kg; SAR(10 g) = 6.32 W/kg**

Smallest distance from peaks to all points 3 dB below = 9 mm

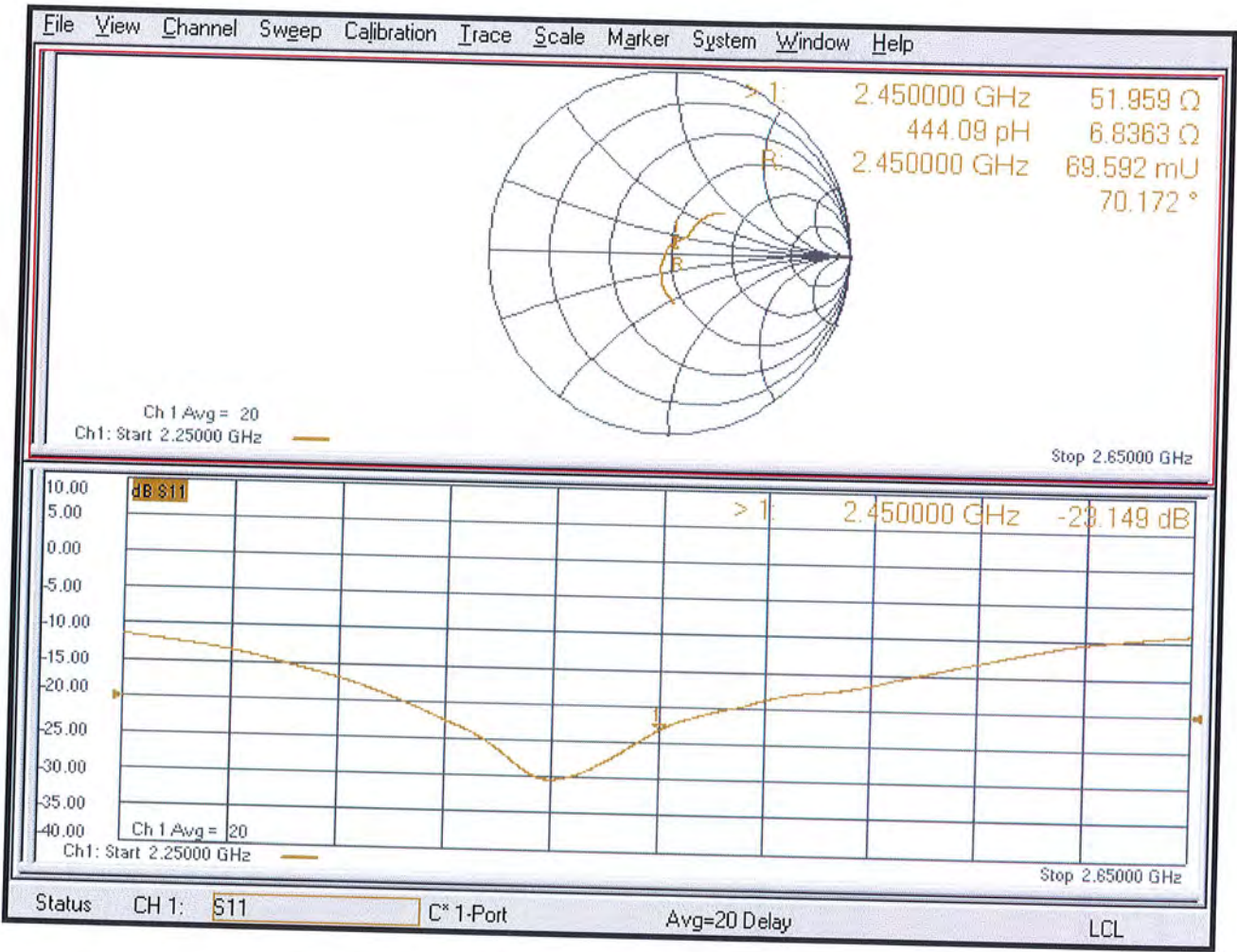
Ratio of SAR at M2 to SAR at M1 = 50.5%

Maximum value of SAR (measured) = 22.0 W/kg





Impedance Measurement Plot for Head TSL



**11.6. 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.



## **11.7. Dielectric Property Measurements & System Check**

### **11.7.1. 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.

### 11.7.2. Tissue Dielectric Parameters

The temperature of the tissue-equivalent medium used during measurement must also be within 18°C to 25°C and within  $\pm 2^\circ\text{C}$  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	
	$\epsilon_r$	$\sigma$ (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.

### 11.7.3. 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.



#### 11.7.4. 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

11.7.5. 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 59

2450 Head  
Date: 14 Dec 2023  
Reference Dipole Antenna: D2450V2 - SN725

Simulant	Frequency (MHz)	Room Temp (°C)	Liquid Temp (°C)	Parameters	Measured Value	Target Type	Target Value	Deviation (%)	Limit (%)
Head	2450	22.1	20.8	$\epsilon_r$	38.95	Numerical	39.20	-0.63	10
				$\sigma$ (S/m)	1.75	Numerical	1.80	-2.57	10
				1g (W/kg)	48.48	Experimental	53.05	-8.61	10
						Numerical	52.40	-7.47	15
				10g (W/kg)	22.95	Experimental	24.90	-7.85	10
						Numerical	24.00	-4.39	15

2450 Head  
Date: 18 Dec 2023  
Reference Dipole Antenna: D2450V2 - SN725

Simulant	Frequency (MHz)	Room Temp (°C)	Liquid Temp (°C)	Parameters	Measured Value	Target Type	Target Value	Deviation (%)	Limit (%)
Head	2450	22.1	21.0	$\epsilon_r$	38.84	Numerical	39.20	-0.91	10
				$\sigma$ (S/m)	1.78	Numerical	1.80	-0.87	10
				1g (W/kg)	49.28	Experimental	53.05	-7.10	10
						Numerical	52.40	-5.95	15
				10g (W/kg)	23.14	Experimental	24.90	-7.05	10
						Numerical	24.00	-3.56	15

Dielectric Property

Band / Mode	Channel	Frequency (MHz)	Parameters	Measured Value
Wi-Fi 2.4GHz	1	2412	$\epsilon_r$	38.90
			$\sigma$ (S/m)	1.76
	6	2437	$\epsilon_r$	38.90
			$\sigma$ (S/m)	1.78
	11	2462	$\epsilon_r$	38.80
			$\sigma$ (S/m)	1.79