

APPENDIX C: PROBE AND DIPOLE CALIBRATION CERTIFICATES



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Client **Element**
Columbia, USA

Certificate No. **CLA13-1002_Sep23**

CALIBRATION CERTIFICATE

Object **CLA13 - SN: 1002**

Calibration procedure(s) **QA CAL-15.v10
Calibration Procedure for SAR Validation Sources below 700 MHz**

*BNV
10-08-2023*

Calibration date: **September 12, 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 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: CC2552 (20x) | 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: 3877 | 06-Jan-23 (No. EX3-3877_Jan23) | Jan-24 |
| DAE4 | SN: 654 | 27-Jan-23 (No. DAE4-654_Jan23) | Jan-24 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---------------------------------|------------------|-----------------------------------|------------------------|
| Power meter NRP2 | SN: 107193 | 08-Nov-21 (in house check Dec-22) | In house check: Dec-24 |
| Power sensor NRP-Z91 | SN: 100922 | 15-Dec-09 (in house check Dec-22) | In house check: Dec-24 |
| Power sensor NRP-Z91 | SN: 100418 | 01-Jan-04 (in house check Dec-22) | In house check: Dec-24 |
| RF generator HP 8648C | SN: US3642U01700 | 04-Aug-99 (in house check Jun-22) | In house check: Jun-24 |
| Network Analyzer Agilent E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-22) | In house check: Oct-24 |

Calibrated by: **Jeffrey Katzman** *[Signature]* **Laboratory Technician**

Signature *[Signature]*

Approved by: **Sven Kühn** *[Signature]* **Technical Manager**

Issued: September 12, 2023

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



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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 | DASY5 | V52.10.4 |
| Extrapolation | Advanced Extrapolation | |
| Phantom | ELI4 Flat Phantom | Shell thickness: 2 ± 0.2 mm |
| EUT Positioning | Touch Position | |
| Zoom Scan Resolution | $dx, dy = 4.0$ mm, $dz = 1.4$ mm | Graded Ratio = 1.4 (Z direction) |
| Frequency | 13 MHz ± 1 MHz | |

Head TSL parameters

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|--|---------------------|----------------|------------------------|
| Nominal Head TSL parameters | 22.0 °C | 55.0 | 0.75 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 54.2 ± 6 % | 0.72 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL

| SAR averaged over 1 cm³ (1 g) of Head TSL | Condition | |
|---|------------------|---|
| SAR measured | 1 W input power | 0.508 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 0.523 W/kg ± 18.4 % (k=2) |

| SAR averaged over 10 cm³ (10 g) of Head TSL | condition | |
|---|------------------|---|
| SAR measured | 1 W input power | 0.318 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 0.327 W/kg ± 18.0 % (k=2) |

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

| | |
|--------------------------------------|------------------------------|
| Impedance, transformed to feed point | $54.6 \Omega + 14.7 j\Omega$ |
| Return Loss | - 16.7 dB |

Additional EUT Data

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

DASY5 Validation Report for Head TSL

Date: 12.09.2023

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: CLA13; Type: CLA13; Serial: CLA13 - SN: 1002

Communication System: UID 0 - CW; Frequency: 13 MHz

Medium parameters used: $f = 13$ MHz; $\sigma = 0.72$ S/m; $\epsilon_r = 54.2$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3877; ConvF(15.33, 15.33, 15.33) @ 13 MHz; Calibrated: 06.01.2023
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn654; Calibrated: 27.01.2023
- Phantom: ELI v6.0; Type: QDOVA003AA; Serial: TP:2034
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

CLA Calibration for HSL-LF Tissue/CLA-13, touch configuration, Pin=1W/Zoom Scan, dist=1.4mm (8x10x8)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 30.19 V/m; Power Drift = -0.01 dB

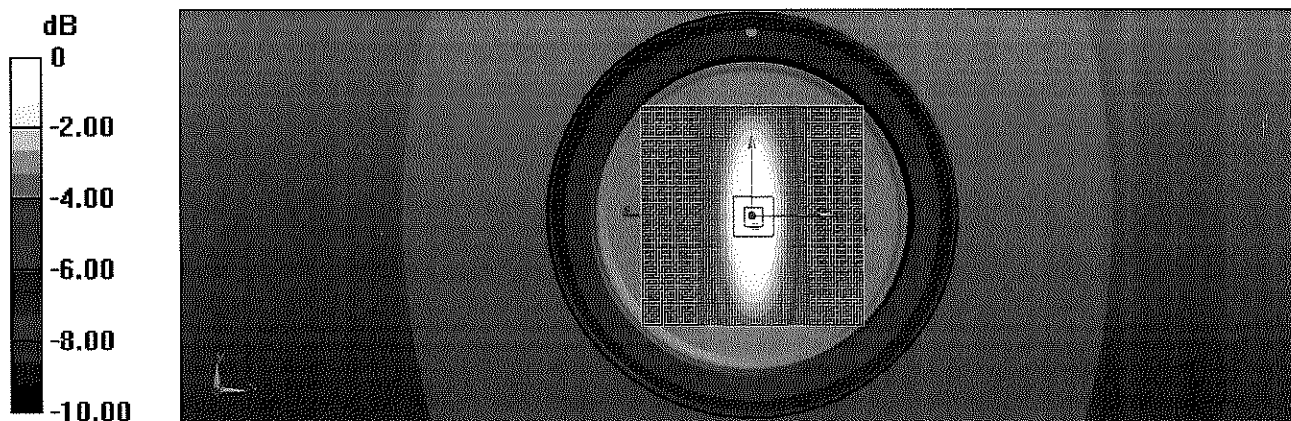
Peak SAR (extrapolated) = 1.03 W/kg

SAR(1 g) = 0.508 W/kg; SAR(10 g) = 0.318 W/kg

Smallest distance from peaks to all points 3 dB below = 23.3 mm

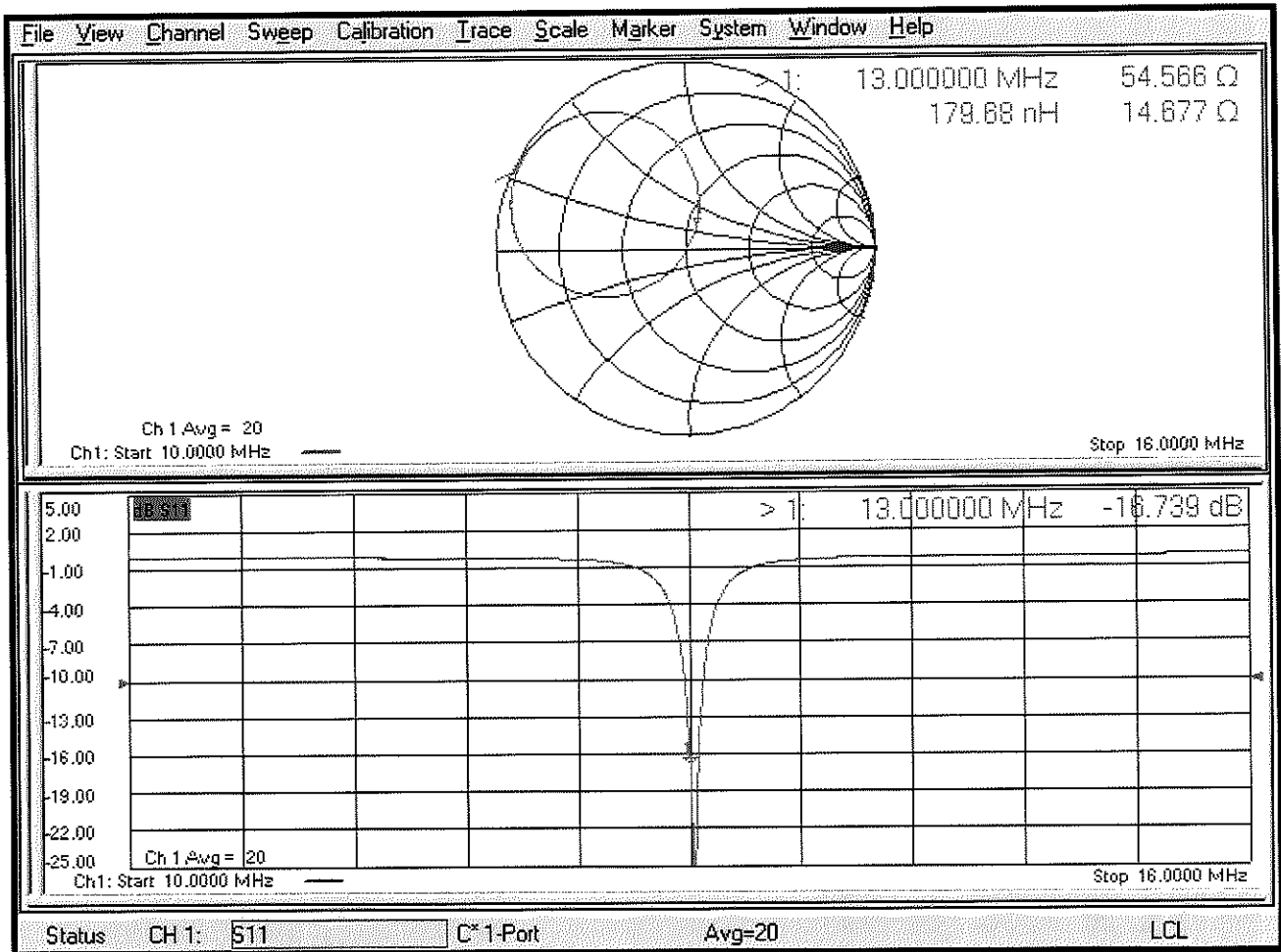
Ratio of SAR at M2 to SAR at M1 = 78.3%

Maximum value of SAR (measured) = 0.750 W/kg



0 dB = 0.750 W/kg = -1.25 dBW/kg

Impedance Measurement Plot for Head TSL





Accreditation No.: **SCS 0108**

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Client **PC Test**

Certificate No: **D2450V2-719_Aug21**

CALIBRATION CERTIFICATE

Object **D2450V2 - SN:719**

Calibration procedure(s) **QA CAL-05.v11
Calibration Procedure for SAR Validation Sources between 0.7-3 GHz**

Calibration date: **August 18, 2021**

BN[✓]
08-10-22

BN[✓]
9-3-2021

BN[✓]
08-27-23

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 | 09-Apr-21 (No. 217-03291/03292) | Apr-22 |
| Power sensor NRP-Z91 | SN: 103244 | 09-Apr-21 (No. 217-03291) | Apr-22 |
| Power sensor NRP-Z91 | SN: 103245 | 09-Apr-21 (No. 217-03292) | Apr-22 |
| Reference 20 dB Attenuator | SN: BH9394 (20k) | 09-Apr-21 (No. 217-03343) | Apr-22 |
| Type-N mismatch combination | SN: 310982 / 06327 | 09-Apr-21 (No. 217-03344) | Apr-22 |
| Reference Probe EX3DV4 | SN: 7349 | 28-Dec-20 (No. EX3-7349_Dec20) | Dec-21 |
| DAE4 | SN: 601 | 02-Nov-20 (No. DAE4-601_Nov20) | Nov-21 |
| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
| Power meter E4419B | SN: GB39512475 | 30-Oct-14 (in house check Oct-20) | In house check: Oct-22 |
| Power sensor HP 8481A | SN: US37292783 | 07-Oct-15 (in house check Oct-20) | In house check: Oct-22 |
| Power sensor HP 8481A | SN: MY41092317 | 07-Oct-15 (in house check Oct-20) | In house check: Oct-22 |
| RF generator R&S SMT-06 | SN: 100972 | 15-Jun-15 (in house check Oct-20) | In house check: Oct-22 |
| Network Analyzer Agilent E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-20) | In house check: Oct-21 |

| | | | |
|----------------|-------------------------------|--|---------------|
| Calibrated by: | Name Jeton Kastrati | Function Laboratory Technician | Signature |
| Approved by: | Name Katja Pokovic | Technical Manager | |

Issued: August 18, 2021

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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:

- 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.
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Additional Documentation:

- 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 | 37.9 ± 6 % | 1.87 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL

| SAR averaged over 1 cm³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 250 mW input power | 14.1 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 55.0 W/kg ± 17.0 % (k=2) |

| SAR averaged over 10 cm³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 250 mW input power | 6.53 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 25.7 W/kg ± 16.5 % (k=2) |

Body TSL parameters

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|--|-----------------|--------------|------------------|
| Nominal Body TSL parameters | 22.0 °C | 52.7 | 1.95 mho/m |
| Measured Body TSL parameters | (22.0 ± 0.2) °C | 52.0 ± 6 % | 2.03 mho/m ± 6 % |
| Body TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Body TSL

| SAR averaged over 1 cm³ (1 g) of Body TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 250 mW input power | 13.3 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | 52.0 W/kg ± 17.0 % (k=2) |

| SAR averaged over 10 cm³ (10 g) of Body TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 250 mW input power | 6.26 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | 24.7 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 | 55.9 Ω + 6.0 j Ω |
| Return Loss | - 22.0 dB |

Antenna Parameters with Body TSL

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 51.3 Ω + 8.4 j Ω |
| Return Loss | - 21.5 dB |

General Antenna Parameters and Design

| | |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.149 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 |
|-----------------|-------|

DASY5 Validation Report for Head TSL

Date: 17.08.2021

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN:719

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

Medium parameters used: $f = 2450$ MHz; $\sigma = 1.87$ S/m; $\epsilon_r = 37.9$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.96, 7.96, 7.96) @ 2450 MHz; Calibrated: 28.12.2020
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 02.11.2020
- 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 = 119.5 V/m; Power Drift = -0.06 dB

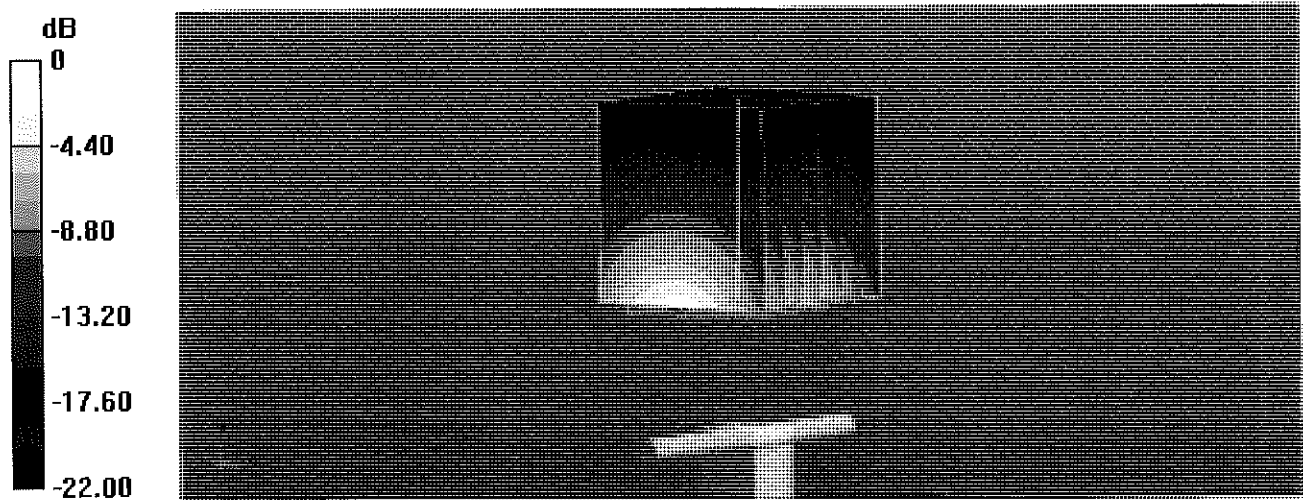
Peak SAR (extrapolated) = 28.1 W/kg

SAR(1 g) = 14.1 W/kg; SAR(10 g) = 6.53 W/kg

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

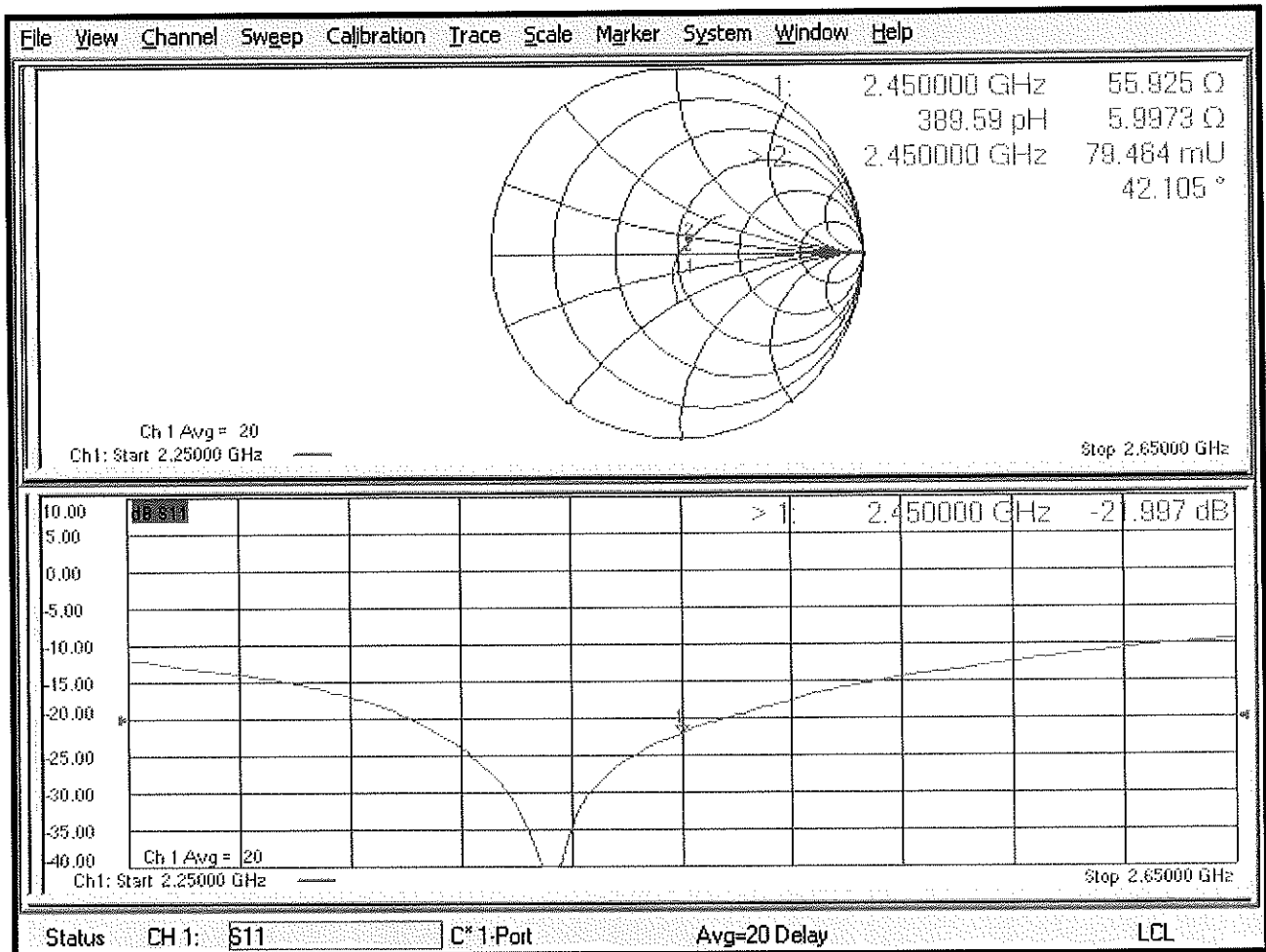
Ratio of SAR at M2 to SAR at M1 = 50.5%

Maximum value of SAR (measured) = 22.8 W/kg



0 dB = 22.8 W/kg = 13.58 dBW/kg

Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 18.08.2021

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN:719

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

Medium parameters used: $f = 2450$ MHz; $\sigma = 2.03$ S/m; $\epsilon_r = 52$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(8.12, 8.12, 8.12) @ 2450 MHz; Calibrated: 28.12.2020
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 02.11.2020
- Phantom: Flat Phantom 5.0 (back); Type: QD 000 P50 AA; Serial: 1002
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

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

Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 111.3 V/m; Power Drift = -0.03 dB

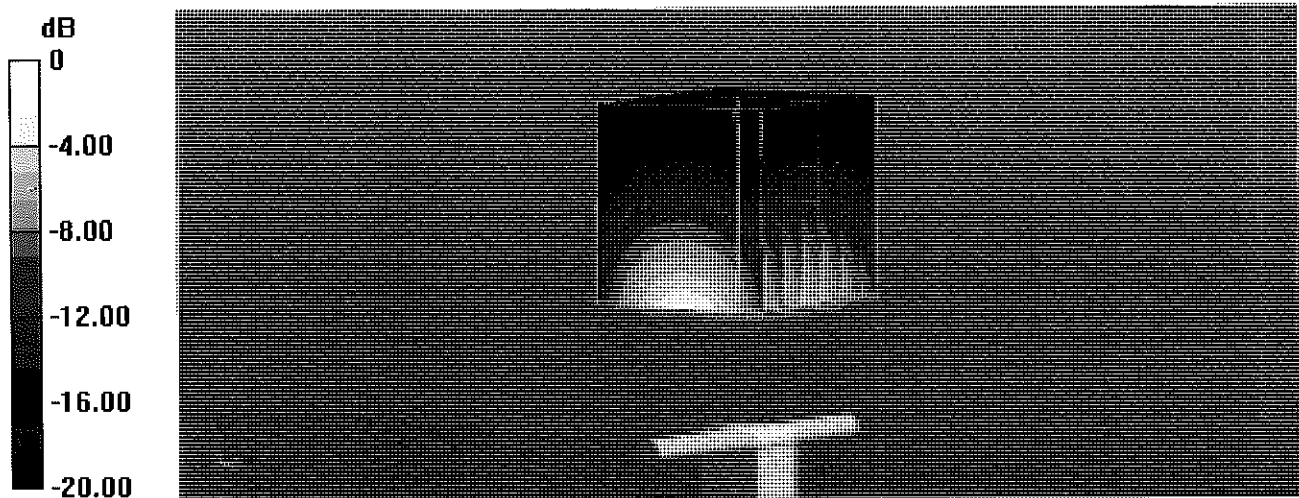
Peak SAR (extrapolated) = 24.8 W/kg

SAR(1 g) = 13.3 W/kg; SAR(10 g) = 6.26 W/kg

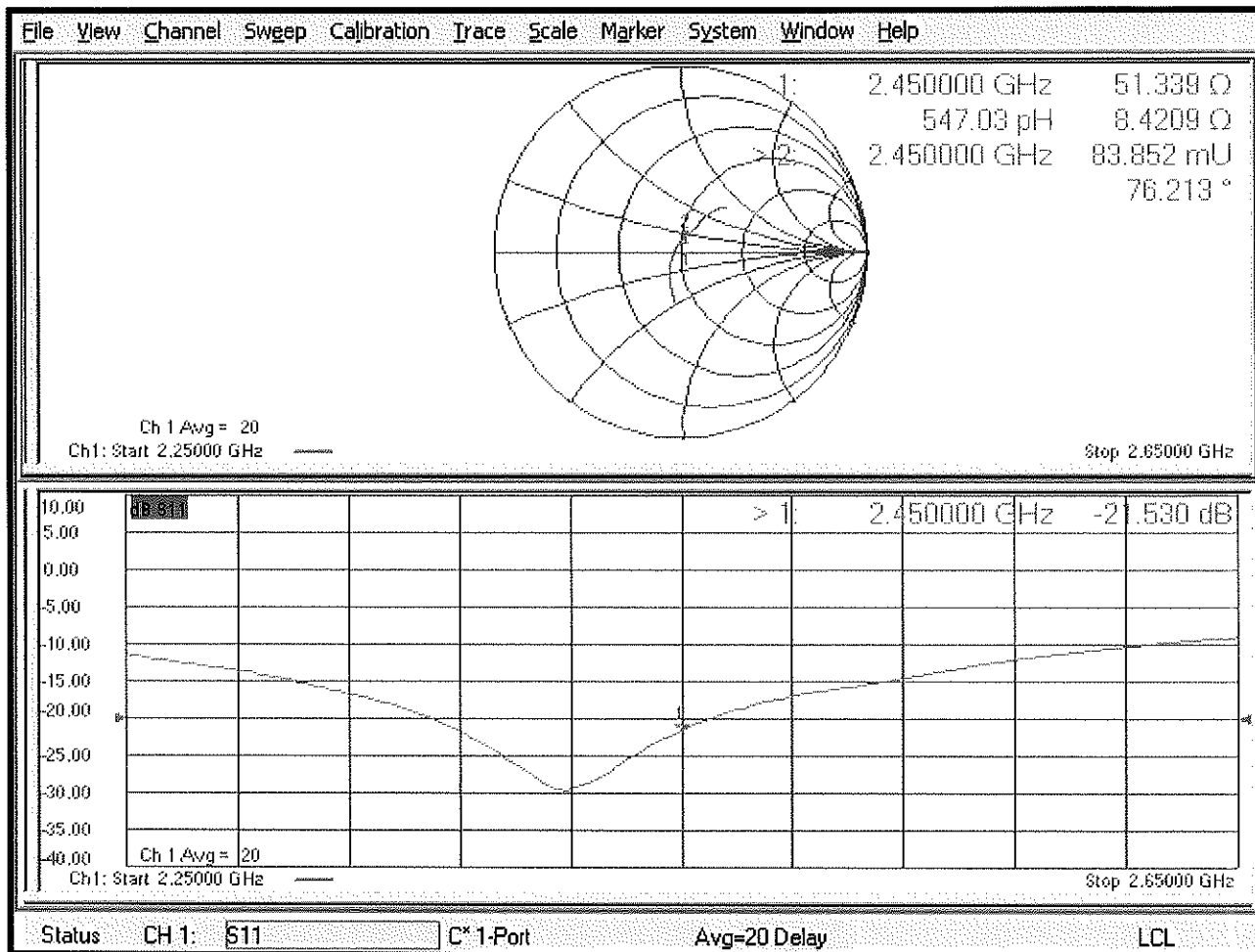
Smallest distance from peaks to all points 3 dB below = 8.2 mm

Ratio of SAR at M2 to SAR at M1 = 54.6%

Maximum value of SAR (measured) = 21.1 W/kg



Impedance Measurement Plot for Body TSL



Certification of Calibration

Object: D2450V2 – SN: 719
 Calibration procedure(s): Procedure for Calibration Extension for SAR Dipoles.
 Extension Calibration date: 08/10/2022
 Description: SAR Validation Dipole at 2450 MHz.

Calibration Equipment used:

| Manufacturer | Model | Description | Cal Date | Cal Interval | Cal Due | Serial Number |
|-----------------------|---------------|---|------------|--------------|------------|---------------|
| Agilent | N5182A | MXG Vector Signal Generator | 6/21/2022 | Annual | 6/21/2023 | MY47420651 |
| Amplifier Research | 15S1G6 | Amplifier | CBT | N/A | CBT | 343971 |
| Anritsu | MA2411B | Pulse Power Sensor | 9/21/2021 | Annual | 9/21/2022 | 1339008 |
| Anritsu | MA2411B | Pulse Power Sensor | 10/21/2021 | Annual | 10/21/2022 | 1339027 |
| Anritsu | ML2496A | Power Meter | 11/29/2021 | Annual | 11/29/2022 | 1840005 |
| Control Company | 4040 | Therm./ Clock/ Humidity Monitor | 3/12/2021 | Biennial | 3/12/2023 | 210202100 |
| Control Company | 4352 | Ultra Long Stem Thermometer | 10/25/2021 | Annual | 10/25/2022 | 200645916 |
| Control Company | 4353 | Long Stem Thermometer | 10/28/2020 | Biennial | 10/28/2022 | 200670653 |
| MiniCircuits | VLF-6000+ | Low Pass Filter | CBT | N/A | CBT | N/A |
| Mini-Circuits | BW-N20W5+ | DC to 18 GHz Precision Fixed 20 dB Attenuator | CBT | N/A | CBT | N/A |
| Mini-Circuits | NLP-2950+ | Low Pass Filter DC to 2700 MHz | CBT | N/A | CBT | N/A |
| Narda | 4772-3 | Attenuator (3dB) | CBT | N/A | CBT | 9406 |
| Pasternack | NC-100 | Torque Wrench | 3/19/2022 | Annual | 3/19/2023 | N/A |
| Mini-Circuits | ZHDC-16-63-S+ | Coupler | CBT | N/A | CBT | N/A |
| Rohde & Schwarz | ZNLE6 | Vector Network Analyzer | 10/20/2021 | Annual | 10/20/2022 | 101307 |
| SPEAG | DAK-3.5 | Dielectric Assessment Kit | 8/18/2021 | Annual | 8/18/2022 | 1041 |
| Keysight Technologies | 85033E | Standard Mechanical Calibration Kit (DC to 9GHz, 3.5mm) | 9/27/2021 | Annual | 9/27/2022 | MY53401181 |
| SPEAG | EX3DV4 | SAR Probe | 2/22/2022 | Annual | 2/22/2023 | 7417 |
| SPEAG | DAE4 | Dasy Data Acquisition Electronics | 2/22/2022 | Annual | 2/22/2023 | 665 |

Measurement Uncertainty = $\pm 23\%$ (k=2)

| | Name | Function | Signature |
|----------------|---------------------|--------------------------|-----------|
| Calibrated By: | Bizunesh Baldinazzo | Test Engineer | BB |
| Approved By: | Kaitlin O'Keefe | Senior Technical Manager | KOK |

DIPOLE CALIBRATION EXTENSION

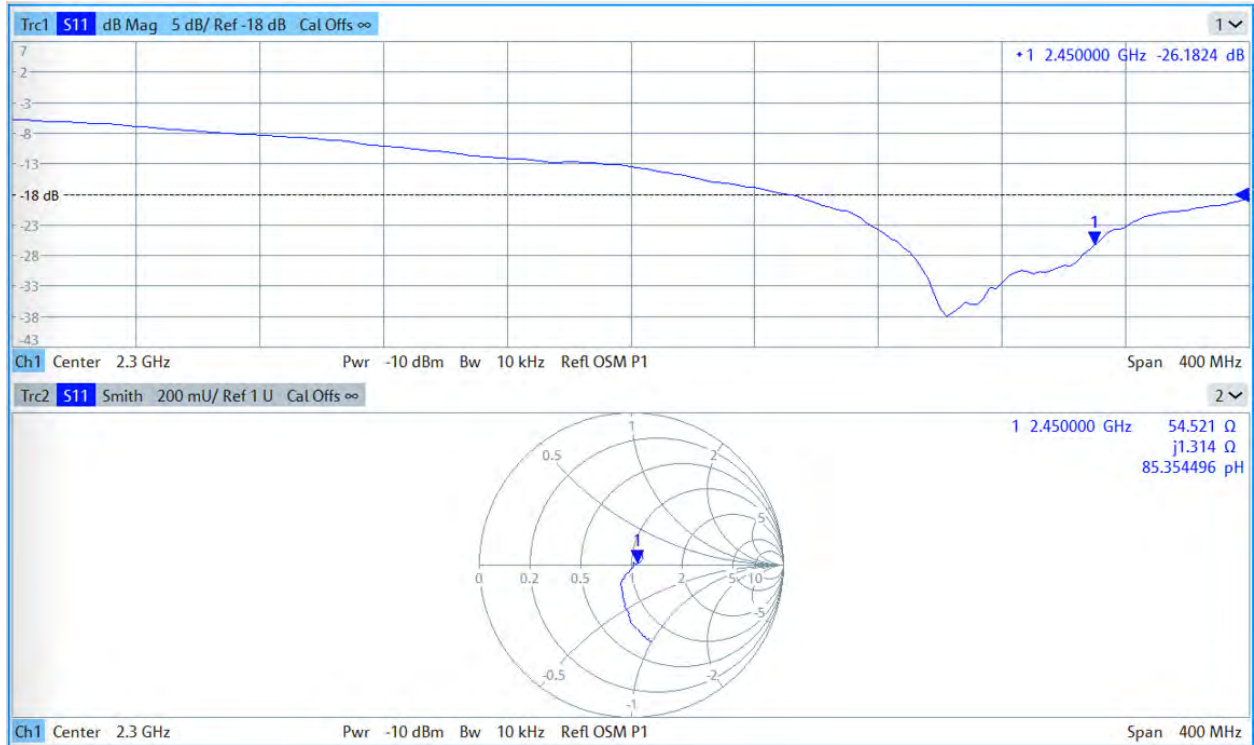
Per KDB 865664 D01, calibration intervals of up to three years may be considered for reference dipoles when it is demonstrated that the SAR target, impedance and return loss of a dipole have remained stable according to the following requirements:

1. The measured SAR does not deviate more than 10% from the target on the calibration certificate.
2. The return-loss does not deviate more than 20% from the previous measurement and meets the required 20dB minimum return-loss requirement.
3. The measurement of real or imaginary parts of impedance does not deviate more than 5Ω from the previous measurement.

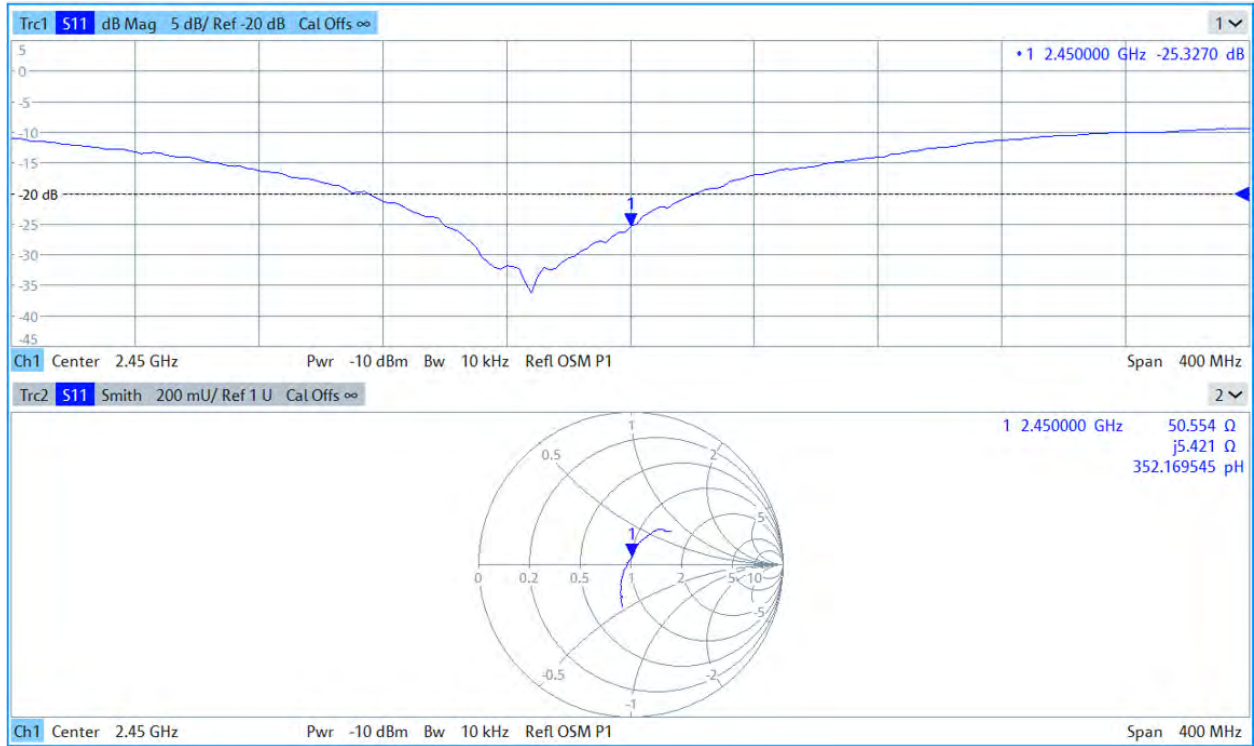
The following dipole was checked to pass the above 3 requirements to have 2-year calibration period from the calibration date:

| Calibration Date | Extension Date | Certificate Electrical Delay (ns) | Certificate SAR Target Head (1g) W/kg @ 20.0 dBm | Measured Head SAR (1g) W/kg @ 20.0 dBm | Deviation 1g (%) | Certificate SAR Target Head (10g) W/kg @ 20.0 dBm | Measured Head SAR (10g) W/kg @ 20.0 dBm | Deviation 10g (%) | Certificate Impedance Head (Ohm) Real | Measured Impedance Head (Ohm) Real | Difference (Ohm) Real | Certificate Impedance Head (Ohm) Imaginary | Measured Impedance Head (Ohm) Imaginary | Difference (Ohm) Imaginary | Certificate Return Loss Head (dB) | Measured Return Loss Head (dB) | Deviation (%) | PASS/FAIL |
|------------------|----------------|-----------------------------------|--|--|------------------|---|---|-------------------|---------------------------------------|------------------------------------|-----------------------|--|---|----------------------------|-----------------------------------|--------------------------------|---------------|-----------|
| 8/18/2021 | 8/10/2022 | 1.149 | 5.5 | 5.22 | -5.09% | 2.57 | 2.33 | -9.34% | 55.9 | 54.5 | 1.4 | 6 | 1.3 | 4.7 | -22 | -26.2 | -19.00% | PASS |
| Calibration Date | Extension Date | Certificate Electrical Delay (ns) | Certificate SAR Target Body (1g) W/kg @ 20.0 dBm | Measured Body SAR (1g) W/kg @ 20.0 dBm | Deviation 1g (%) | Certificate SAR Target Body (10g) W/kg @ 20.0 dBm | Measured Body SAR (10g) W/kg @ 20.0 dBm | Deviation 10g (%) | Certificate Impedance Body (Ohm) Real | Measured Impedance Body (Ohm) Real | Difference (Ohm) Real | Certificate Impedance Body (Ohm) Imaginary | Measured Impedance Body (Ohm) Imaginary | Difference (Ohm) Imaginary | Certificate Return Loss Body (dB) | Measured Return Loss Body (dB) | Deviation (%) | PASS/FAIL |
| 8/18/2021 | 8/10/2022 | 1.149 | 5.2 | 4.93 | -5.19% | 2.47 | 2.32 | -6.07% | 51.3 | 50.6 | 0.7 | 8.4 | 5.4 | 3 | -21.5 | -25.3 | -17.80% | PASS |

Impedance & Return-Loss Measurement Plot for Head TSL



Impedance & Return-Loss Measurement Plot for Body TSL



Certification of Calibration

Object: D2450V2 – SN: 719

Calibration procedure(s): Procedure for Calibration Extension for SAR Dipoles.

Extension Calibration date: 08/01/2023

Description: SAR Validation Dipole at 2450 MHz.

Calibration Equipment used:

| Manufacturer | Model | Description | Cal Date | Cal Interval | Cal Due | Serial Number |
|-----------------------|---------------|---|------------|--------------|------------|---------------|
| Agilent | N5182A | MXG Vector Signal Generator | 11/30/2022 | Annual | 11/30/2023 | MY47420603 |
| Amplifier Research | 15S1G6 | Amplifier | CBT | N/A | CBT | 343971 |
| Anritsu | MA2411B | Pulse Power Sensor | 10/21/2022 | Annual | 10/21/2023 | 1207364 |
| Anritsu | ML2496A | Power Meter | 8/16/2022 | Annual | 8/16/2023 | 1351001 |
| Control Company | 4040 | Therm./ Clock/ Humidity Monitor | 1/17/2023 | Biennial | 1/17/2024 | 160574418 |
| Control Company | 4352 | Long Stem Thermometer | 9/10/2021 | Biennial | 9/10/2023 | 210774678 |
| Mini-Circuits | BW-N20W5+ | DC to 18 GHz Precision Fixed 20 dB Attenuator | CBT | N/A | CBT | N/A |
| Mini-Circuits | NLP-2950+ | Low Pass Filter DC to 2700 MHz | CBT | N/A | CBT | N/A |
| Narda | 4772-3 | Attenuator (3dB) | CBT | N/A | CBT | 9406 |
| Pasternack | PE5011-1 | Torque Wrench | 12/21/2021 | Biennial | 12/21/2023 | 82475 |
| Mini-Circuits | ZHDC-16-63-S+ | Coupler | CBT | N/A | CBT | N/A |
| Rohde & Schwarz | ZNLE6 | Vector Network Analyzer | 10/21/2022 | Annual | 10/21/2023 | 101307 |
| SPEAG | DAK-3.5 | Dielectric Assessment Kit | 11/14/2022 | Annual | 11/14/2023 | 1277 |
| Keysight Technologies | 85033E | Standard Mechanical Calibration Kit (DC to 9GHz, 3.5mm) | 11/11/2022 | Annual | 11/11/2023 | MY53401181 |
| SPEAG | EX3DV4 | SAR Probe | 6/15/2023 | Annual | 6/15/2024 | 7409 |
| SPEAG | DAE4 | Dasy Data Acquisition Electronics | 6/15/2023 | Annual | 6/15/2024 | 1334 |

Measurement Uncertainty = $\pm 23\%$ (k=2)

| | Name | Function | Signature |
|----------------|-------------|--|--------------------|
| Calibrated By: | Tho Tong | Test Engineer | <i>Tho Tong</i> |
| Approved By: | Greg Snyder | Executive VP of Operations, Regulatory | <i>Greg Snyder</i> |

DIPOLE CALIBRATION EXTENSION

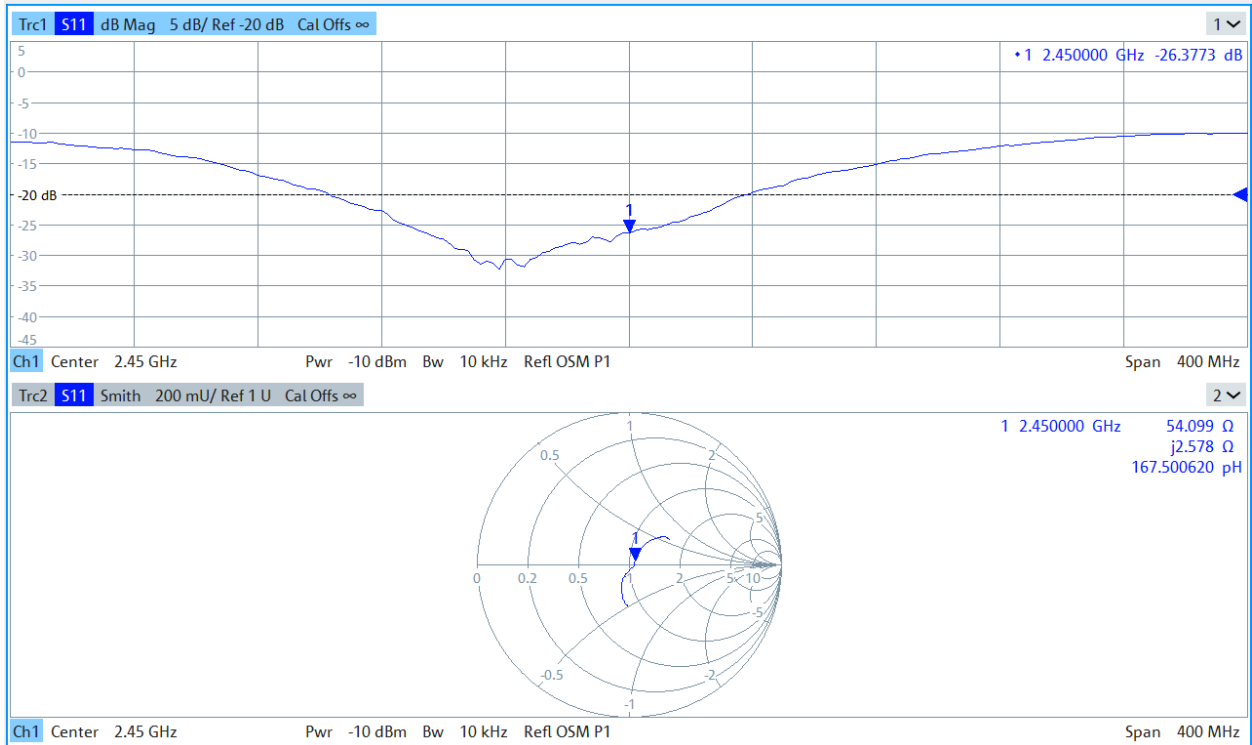
Per KDB 865664 D01, calibration intervals of up to three years may be considered for reference dipoles when it is demonstrated that the SAR target, impedance and return loss of a dipole have remained stable according to the following requirements:

1. The measured SAR does not deviate more than 10% from the target on the calibration certificate.
2. The return-loss does not deviate more than 20% from the previous measurement and meets the required 20dB minimum return-loss requirement.
3. The measurement of real or imaginary parts of impedance does not deviate more than 5Ω from the previous measurement.

The following dipole was checked to pass the above 3 requirements to have 3-year calibration period from the calibration date:

| Calibration Date | Extension Date | Certificate Electrical Delay (ns) | Certificate SAR Target Head (1g) W/kg @ 20.0 dBm | Measured Head SAR (1g) W/kg @ 20.0 dBm | Deviation 1g (%) | Certificate SAR Target Head (10g) W/kg @ 20.0 dBm | Measured Head SAR (10g) W/kg @ 20.0 dBm | Deviation 10g (%) | Certificate Impedance Head (Ohm) Real | Measured Impedance Head (Ohm) Real | Difference (Ohm) Real | Certificate Impedance Head (Ohm) Imaginary | Measured Impedance Head (Ohm) Imaginary | Difference (Ohm) Imaginary | Certificate Return Loss Head (dB) | Measured Return Loss Head (dB) | Deviation (%) | PASS/FAIL |
|------------------|----------------|-----------------------------------|--|--|------------------|---|---|-------------------|---------------------------------------|------------------------------------|-----------------------|--|---|----------------------------|-----------------------------------|--------------------------------|---------------|-----------|
| 8/19/2021 | 8/1/2023 | 1.149 | 5.5 | 5.34 | -2.81% | 2.57 | 2.49 | -3.11% | 55.9 | 54.1 | 1.8 | 6 | 2.6 | 3.4 | -22 | -26.4 | -19.50% | PASS |

Impedance & Return-Loss Measurement Plot for Head TSL





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 **PC Test**

Certificate No: **D2450V2-981_Nov21**

CALIBRATION CERTIFICATE

Object **D2450V2 - SN:981**

Calibration procedure(s) **QA CAL-05.v11
Calibration Procedure for SAR Validation Sources between 0.7-3 GHz**

Calibration date: **November 25, 2021**

*BN ✓
12-09-2021*

*BN ✓
11-25-22*

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)

S RS 01/03/24

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|-----------------------------|--------------------|---------------------------------|-----------------------|
| Power meter NRP | SN: 104778 | 09-Apr-21 (No. 217-03291/03292) | Apr-22 |
| Power sensor NRP-Z91 | SN: 103244 | 09-Apr-21 (No. 217-03291) | Apr-22 |
| Power sensor NRP-Z91 | SN: 103245 | 09-Apr-21 (No. 217-03292) | Apr-22 |
| Reference 20 dB Attenuator | SN: BH9394 (20k) | 09-Apr-21 (No. 217-03343) | Apr-22 |
| Type-N mismatch combination | SN: 310982 / 06327 | 09-Apr-21 (No. 217-03344) | Apr-22 |
| Reference Probe EX3DV4 | SN: 7349 | 28-Dec-20 (No. EX3-7349_Dec20) | Dec-21 |
| DAE4 | SN: 601 | 01-Nov-21 (No. DAE4-601_Nov21) | Nov-22 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---------------------------------|----------------|-----------------------------------|------------------------|
| Power meter E4419B | SN: GB39512475 | 30-Oct-14 (in house check Oct-20) | In house check: Oct-22 |
| Power sensor HP 8481A | SN: US37292783 | 07-Oct-15 (in house check Oct-20) | In house check: Oct-22 |
| Power sensor HP 8481A | SN: MY41092317 | 07-Oct-15 (in house check Oct-20) | In house check: Oct-22 |
| RF generator R&S SMT-06 | SN: 100972 | 15-Jun-15 (in house check Oct-20) | In house check: Oct-22 |
| Network Analyzer Agilent E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-20) | In house check: Oct-22 |

Calibrated by: **Jeffrey Katzman** Function: **Laboratory Technician**

Approved by: **Niels Kuster** Quality Manager

Signature

Issued: November 25, 2021

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



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**

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 | 39.1 ± 6 % | 1.87 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL

| SAR averaged over 1 cm³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 250 mW input power | 13.7 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 53.9 W/kg ± 17.0 % (k=2) |

| SAR averaged over 10 cm³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 250 mW input power | 6.42 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 25.4 W/kg ± 16.5 % (k=2) |

Body TSL parameters

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|--|-----------------|--------------|------------------|
| Nominal Body TSL parameters | 22.0 °C | 52.7 | 1.95 mho/m |
| Measured Body TSL parameters | (22.0 ± 0.2) °C | 51.2 ± 6 % | 2.01 mho/m ± 6 % |
| Body TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Body TSL

| SAR averaged over 1 cm³ (1 g) of Body TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 250 mW input power | 12.9 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | 50.3 W/kg ± 17.0 % (k=2) |

| SAR averaged over 10 cm³ (10 g) of Body TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 250 mW input power | 6.00 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | 23.7 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 | 53.8 Ω + 5.8 j Ω |
| Return Loss | - 23.6 dB |

Antenna Parameters with Body TSL

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 50.4 Ω + 8.5 j Ω |
| Return Loss | - 21.5 dB |

General Antenna Parameters and Design

| | |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.163 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 |
|-----------------|-------|

DASY5 Validation Report for Head TSL

Date: 25.11.2021

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 981

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

Medium parameters used: $f = 2450$ MHz; $\sigma = 1.87$ S/m; $\epsilon_r = 39.1$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.96, 7.96, 7.96) @ 2450 MHz; Calibrated: 28.12.2020
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 01.11.2021
- 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 = 118.7 V/m; Power Drift = -0.03 dB

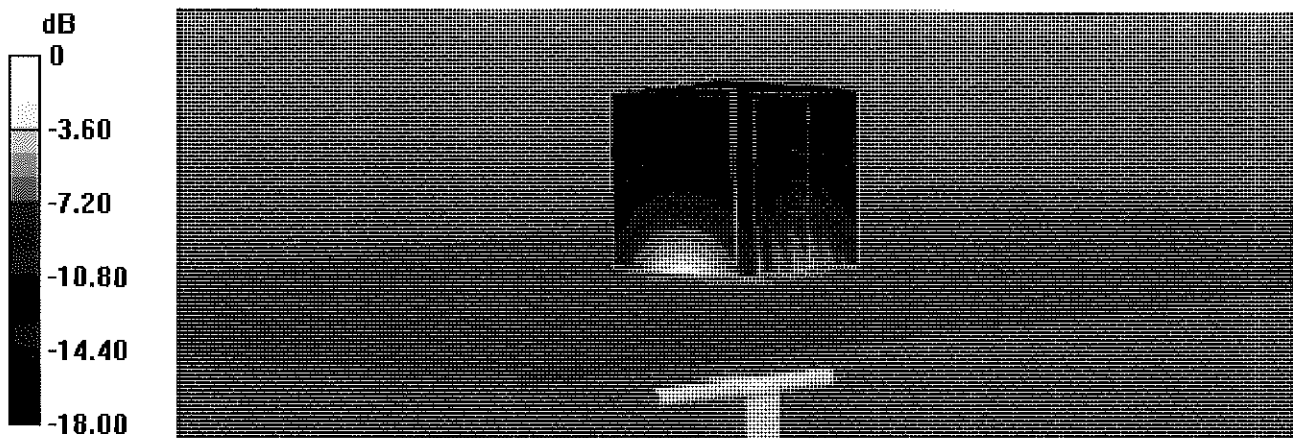
Peak SAR (extrapolated) = 27.1 W/kg

SAR(1 g) = 13.7 W/kg; SAR(10 g) = 6.42 W/kg

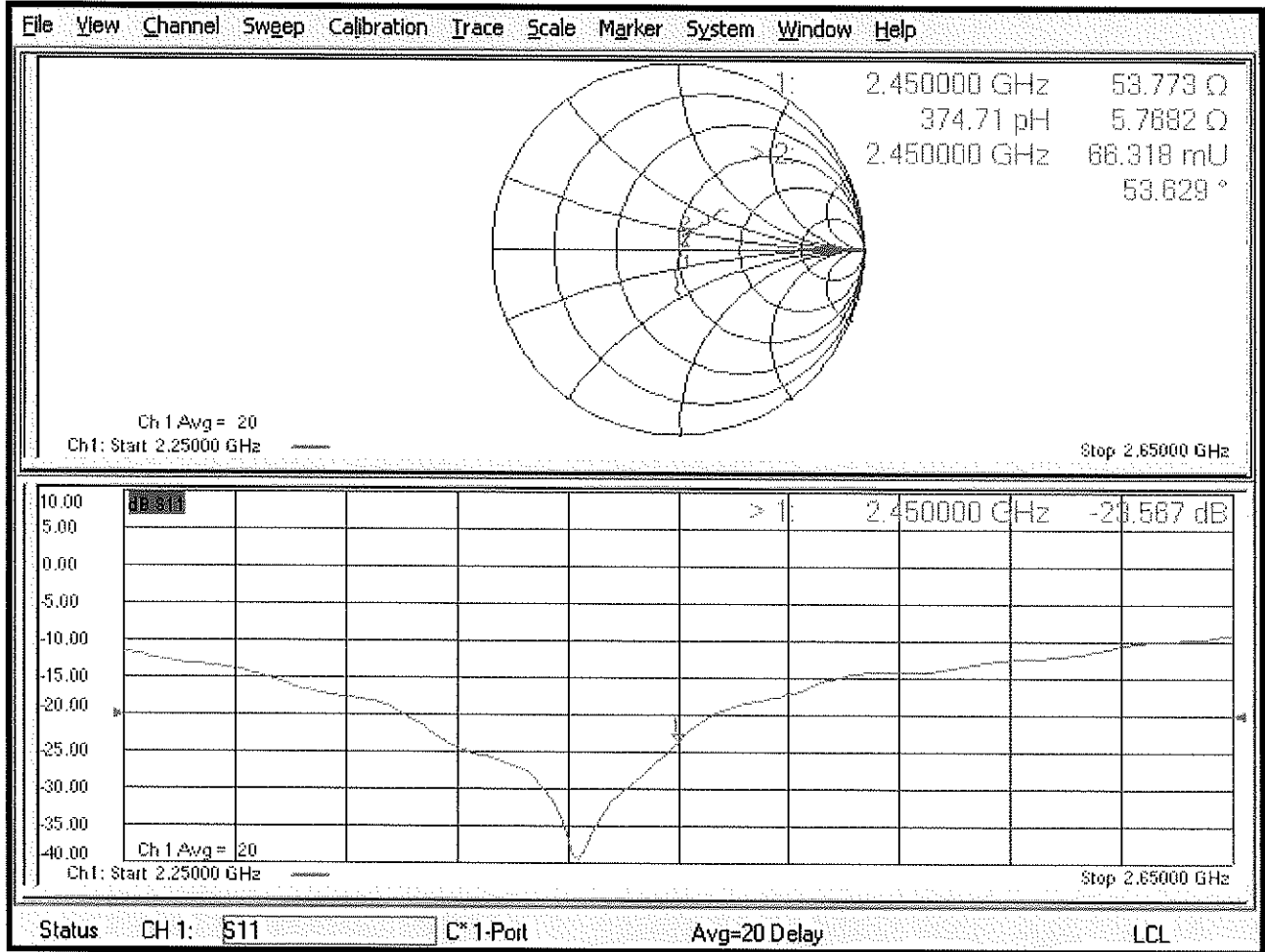
Smallest distance from peaks to all points 3 dB below = 9 mm

Ratio of SAR at M2 to SAR at M1 = 51.1%

Maximum value of SAR (measured) = 22.6 W/kg



Impedance Measurement Plot for Head TSL



DASY5 Validation Report for Body TSL

Date: 25.11.2021

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 981

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

Medium parameters used: $f = 2450$ MHz; $\sigma = 2.01$ S/m; $\epsilon_r = 51.2$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(8.12, 8.12, 8.12) @ 2450 MHz; Calibrated: 28.12.2020
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 01.11.2021
- Phantom: Flat Phantom 5.0 (back); Type: QD 000 P50 AA; Serial: 1002
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

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

Measurement grid: $dx=5$ mm, $dy=5$ mm, $dz=5$ mm

Reference Value = 108.0 V/m; Power Drift = -0.08 dB

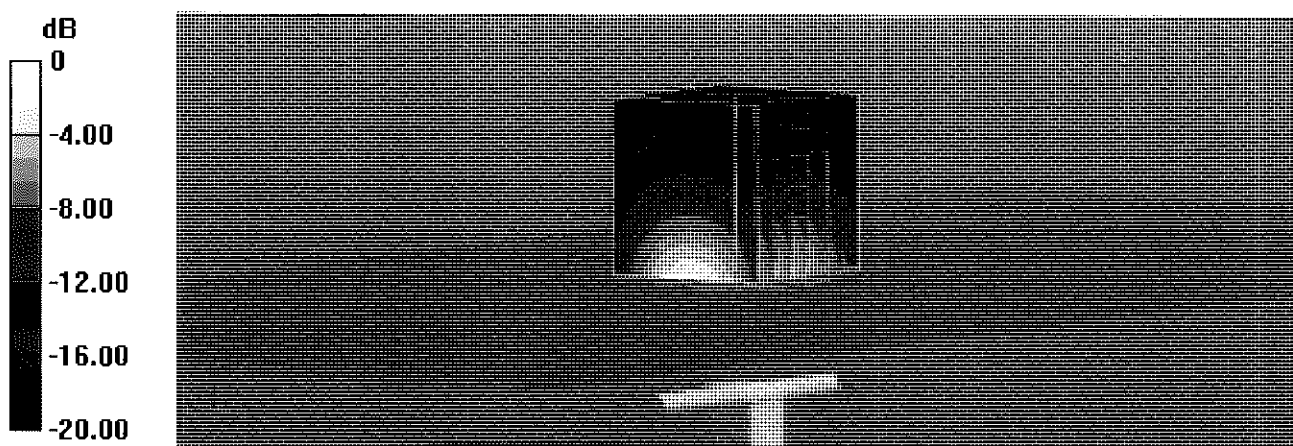
Peak SAR (extrapolated) = 24.3 W/kg

SAR(1 g) = 12.9 W/kg; SAR(10 g) = 6 W/kg

Smallest distance from peaks to all points 3 dB below = 8 mm

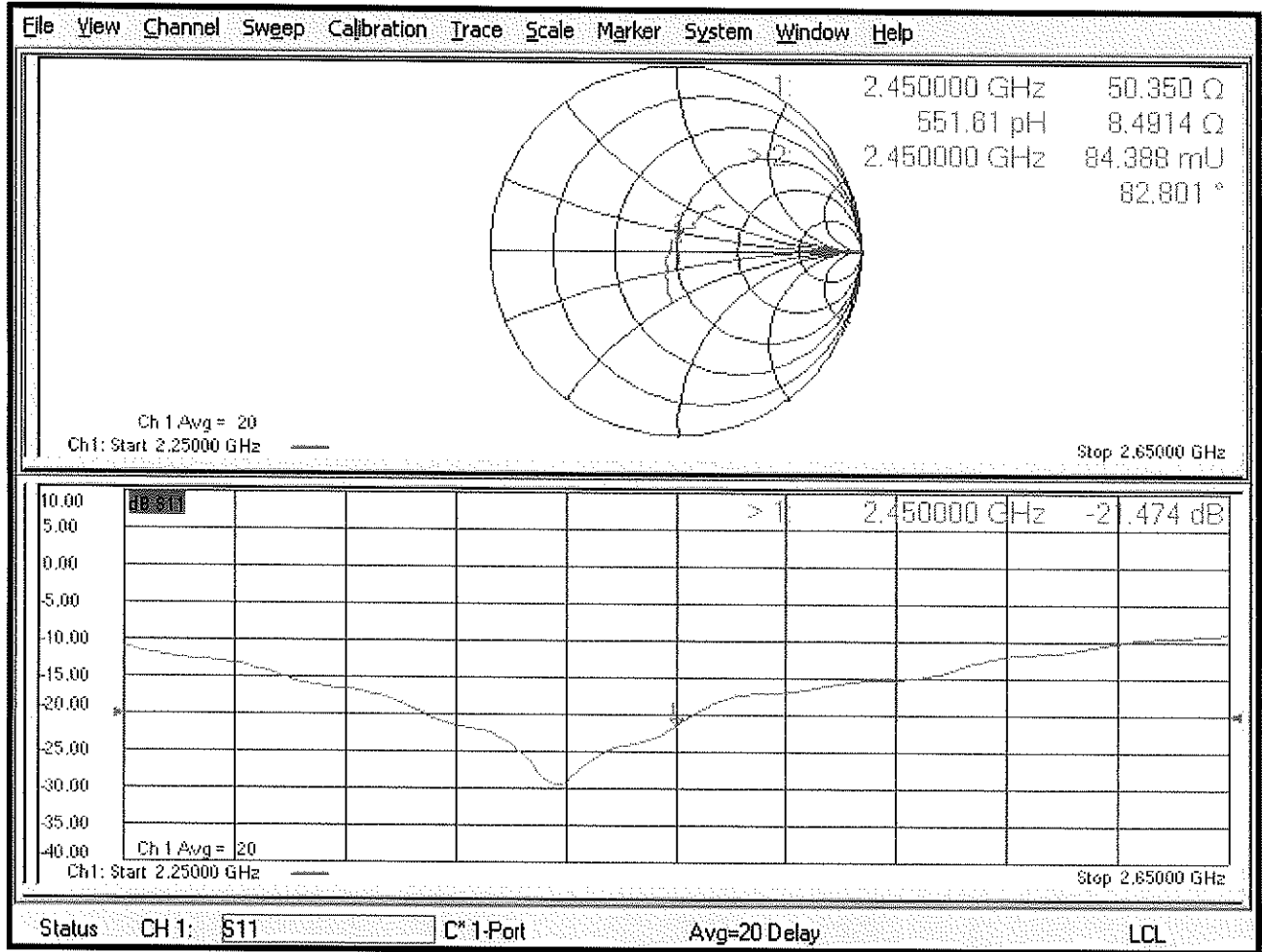
Ratio of SAR at M2 to SAR at M1 = 54.1%

Maximum value of SAR (measured) = 20.2 W/kg



0 dB = 20.2 W/kg = 13.05 dBW/kg

Impedance Measurement Plot for Body TSL



Certification of Calibration

Object: D2450V2 – SN: 981

Calibration procedure(s): Procedure for Calibration Extension for SAR Dipoles.

Extension Calibration date: 11/24/2022

Description: SAR Validation Dipole at 2450 MHz.

Calibration Equipment used:

| Manufacturer | Model | Description | Cal Date | Cal Interval | Cal Due | Serial Number |
|-----------------------|---------------|---|------------|--------------|------------|---------------|
| Agilent | N5182A | MXG Vector Signal Generator | 1/12/2022 | Annual | 1/12/2023 | MY47420837 |
| Amplifier Research | 15S1G6 | Amplifier | CBT | N/A | CBT | 343971 |
| Anritsu | MA2411B | Pulse Power Sensor | 3/28/2022 | Annual | 3/28/2023 | 1339007 |
| Anritsu | MA2411B | Pulse Power Sensor | 3/2/2022 | Annual | 3/2/2023 | 1126066 |
| Anritsu | ML2496A | Power Meter | 3/31/2022 | Annual | 3/31/2023 | 1138001 |
| Anritsu | ML2496A | Power Meter | 3/17/2022 | Annual | 3/17/2023 | 941001 |
| Control Company | 4040 | Therm./ Clock/ Humidity Monitor | 3/12/2021 | Biennial | 3/12/2023 | 210202100 |
| Control Company | 4352 | Ultra Long Stem Thermometer | 1/21/2022 | Annual | 1/21/2023 | 160508097 |
| Control Company | 4352 | Long Stem Thermometer | 9/10/2021 | Biennial | 9/10/2023 | 210774678 |
| Mini-Circuits | BW-N20W5+ | DC to 18 GHz Precision Fixed 20 dB Attenuator | CBT | N/A | CBT | N/A |
| Mini-Circuits | NLP-2950+ | Low Pass Filter DC to 2700 MHz | CBT | N/A | CBT | N/A |
| Narda | 4772-3 | Attenuator (3dB) | CBT | N/A | CBT | 9406 |
| Pasternack | PE5011-1 | Torque Wrench | 12/21/2021 | Biennial | 12/21/2023 | 82475 |
| Mini-Circuits | ZHDC-16-63-S+ | Coupler | CBT | N/A | CBT | N/A |
| Rohde & Schwarz | ZNLE6 | Vector Network Analyzer | 10/21/2022 | Annual | 10/21/2023 | 101307 |
| SPEAG | DAK-3.5 | Dielectric Assessment Kit | 5/12/2022 | Annual | 5/12/2023 | 1070 |
| Keysight Technologies | 85033E | Standard Mechanical Calibration Kit (DC to 9GHz, 3.5mm) | 6/21/2022 | Annual | 6/21/2023 | MY53402352 |
| SPEAG | EX3DV4 | SAR Probe | 2/21/2022 | Annual | 2/21/2023 | 7488 |
| SPEAG | DAE4 | Dasy Data Acquisition Electronics | 2/23/2022 | Annual | 2/23/2023 | 1415 |
| SPEAG | EX3DV4 | SAR Probe | 6/16/2022 | Annual | 6/16/2023 | 7409 |
| SPEAG | DAE4 | Dasy Data Acquisition Electronics | 6/14/2022 | Annual | 6/14/2023 | 1334 |

Measurement Uncertainty = $\pm 23\%$ (k=2)

| | Name | Function | Signature |
|----------------|-----------------|--------------------------|-----------------|
| Calibrated By: | Tho Tong | Test Engineer | <i>Tho Tong</i> |
| Approved By: | Kaitlin O'Keefe | Senior Technical Manager | <i>KOK</i> |

DIPOLE CALIBRATION EXTENSION

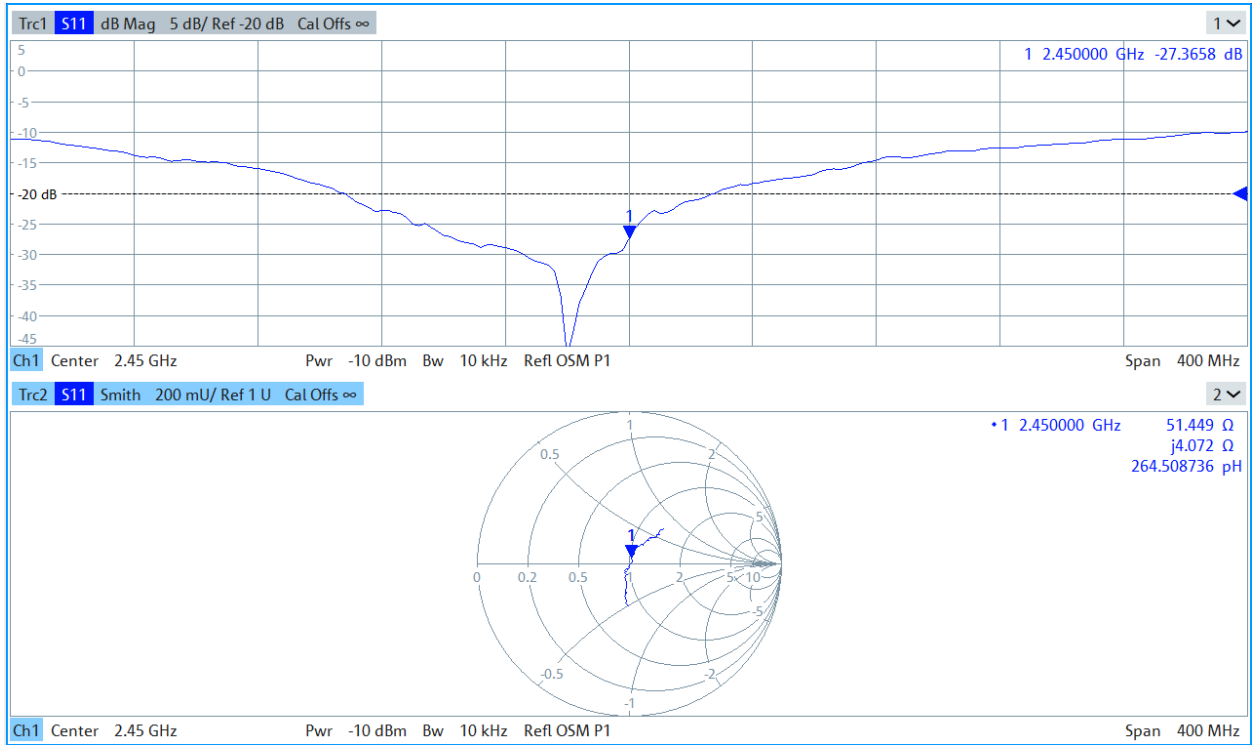
Per KDB 865664 D01, calibration intervals of up to three years may be considered for reference dipoles when it is demonstrated that the SAR target, impedance and return loss of a dipole have remained stable according to the following requirements:

1. The measured SAR does not deviate more than 10% from the target on the calibration certificate.
2. The return-loss does not deviate more than 20% from the previous measurement and meets the required 20dB minimum return-loss requirement.
3. The measurement of real or imaginary parts of impedance does not deviate more than 5Ω from the previous measurement.

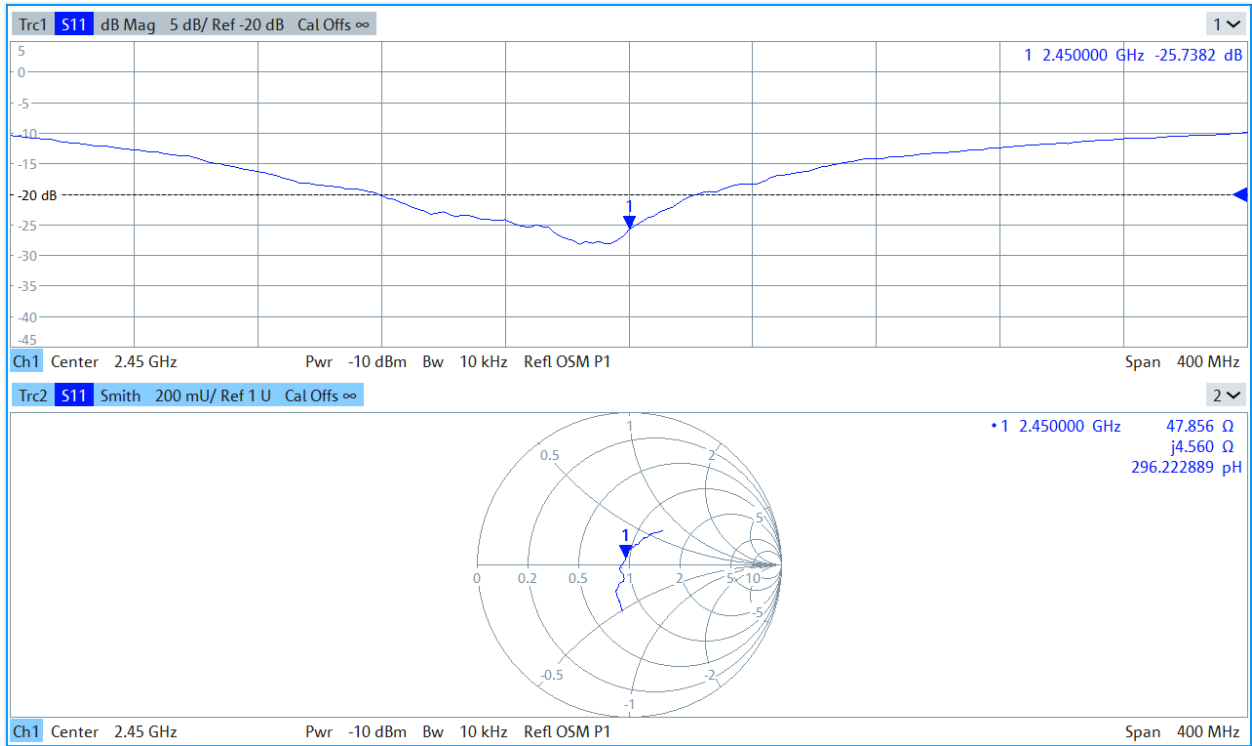
The following dipole was checked to pass the above 3 requirements to have 2-year calibration period from the calibration date:

| Calibration Date | Extension Date | Certificate Electrical Delay (ns) | Certificate SAR Target Head (1g) W/kg @ 20.0 dBm | Measured Head SAR (1g) W/kg @ 20.0 dBm | Deviation 1g (%) | Certificate SAR Target Head (10g) W/kg @ 20.0 dBm | Measured Head SAR (10g) W/kg @ 20.0 dBm | Deviation 10g (%) | Certificate Impedance Head (Ohm) Real | Measured Impedance Head (Ohm) Real | Difference (Ohm) Real | Certificate Impedance Head (Ohm) Imaginary | Measured Impedance Head (Ohm) Imaginary | Difference (Ohm) Imaginary | Certificate Return Loss Head (dB) | Measured Return Loss Head (dB) | Deviation (%) | PASS/FAIL |
|------------------|----------------|-----------------------------------|--|--|------------------|---|---|-------------------|---------------------------------------|------------------------------------|-----------------------|--|---|----------------------------|-----------------------------------|--------------------------------|---------------|-----------|
| 11/25/2021 | 11/24/2022 | 1.163 | 5.39 | 5.22 | -3.15% | 2.54 | 2.43 | -4.33% | 53.8 | 51.4 | 2.4 | 5.8 | 4.1 | 1.7 | -23.6 | -27.4 | -16.00% | PASS |
| Calibration Date | Extension Date | Certificate Electrical Delay (ns) | Certificate SAR Target Body (1g) W/kg @ 20.0 dBm | Measured Body SAR (1g) W/kg @ 20.0 dBm | Deviation 1g (%) | Certificate SAR Target Body (10g) W/kg @ 20.0 dBm | Measured Body SAR (10g) W/kg @ 20.0 dBm | Deviation 10g (%) | Certificate Impedance Body (Ohm) Real | Measured Impedance Body (Ohm) Real | Difference (Ohm) Real | Certificate Impedance Body (Ohm) Imaginary | Measured Impedance Body (Ohm) Imaginary | Difference (Ohm) Imaginary | Certificate Return Loss Body (dB) | Measured Return Loss Body (dB) | Deviation (%) | PASS/FAIL |
| 11/25/2021 | 11/24/2022 | 1.163 | 5.03 | 4.88 | -2.98% | 2.37 | 2.27 | -4.22% | 50.4 | 47.9 | 2.5 | 8.5 | 4.6 | 3.9 | -21.5 | -25.7 | -19.70% | PASS |

Impedance & Return-Loss Measurement Plot for Head TSL



Impedance & Return-Loss Measurement Plot for Body TSL



Certification of Calibration

Object: D2450V2 – SN: 981

Calibration procedure(s): Procedure for Calibration Extension for SAR Dipoles.

Extension Calibration date: 11/10/2023

Description: SAR Validation Dipole at 2450 MHz.

Calibration Equipment used:

| Manufacturer | Model | Description | Cal Date | Cal Interval | Cal Due | Serial Number |
|-----------------------|---------------|---|------------|--------------|------------|---------------|
| Agilent | N5182A | MXG Vector Signal Generator | 11/30/2022 | Annual | 11/30/2023 | MY47420603 |
| Amplifier Research | 15S1G6 | Amplifier | CBT | N/A | CBT | 343971 |
| Anritsu | MA2411B | Pulse Power Sensor | 1/10/2023 | Annual | 1/10/2024 | 1315051 |
| Anritsu | ML2496A | Power Meter | 6/15/2023 | Annual | 6/15/2024 | 1138001 |
| Control Company | 4040 | Therm./ Clock/ Humidity Monitor | 1/17/2023 | Biennial | 1/17/2024 | 160574418 |
| Control Company | 4353 | Long Stem Thermometer | 9/15/2022 | Biennial | 9/15/2024 | 221767767 |
| Mini-Circuits | BW-N20W5+ | DC to 18 GHz Precision Fixed 20 dB Attenuator | CBT | N/A | CBT | N/A |
| Mini-Circuits | NLP-2950+ | Low Pass Filter DC to 2700 MHz | CBT | N/A | CBT | N/A |
| Narda | 4772-3 | Attenuator (3dB) | CBT | N/A | CBT | 9406 |
| Pasternack | PE5011-1 | Torque Wrench | 12/21/2021 | Biennial | 12/21/2023 | 82475 |
| Mini-Circuits | ZHDC-16-63-S+ | Coupler | CBT | N/A | CBT | N/A |
| Anritsu | MS46322A | Vector Network Analyzer | 9/6/2023 | Biennial | 9/6/2025 | 82288 |
| SPEAG | DAK-3.5 | Dielectric Assessment Kit | 11/13/2023 | Annual | 11/13/2024 | 1277 |
| Keysight Technologies | 85033E | Standard Mechanical Calibration Kit (DC to 9GHz, 3.5mm) | 11/11/2022 | Annual | 11/11/2023 | MY53401181 |
| SPEAG | EX3DV4 | SAR Probe | 6/15/2023 | Annual | 6/15/2024 | 7409 |
| SPEAG | DAE4 | Dasy Data Acquisition Electronics | 6/15/2023 | Annual | 6/15/2024 | 1334 |

Measurement Uncertainty = ±23% (k=2)

| | Name | Function | Signature |
|----------------|-------------|--|--------------------|
| Calibrated By: | Tho Tong | Test Engineer | <i>Tho Tong</i> |
| Approved By: | Greg Snyder | Executive VP of Operations, Regulatory | <i>Greg Snyder</i> |

DIPOLE CALIBRATION EXTENSION

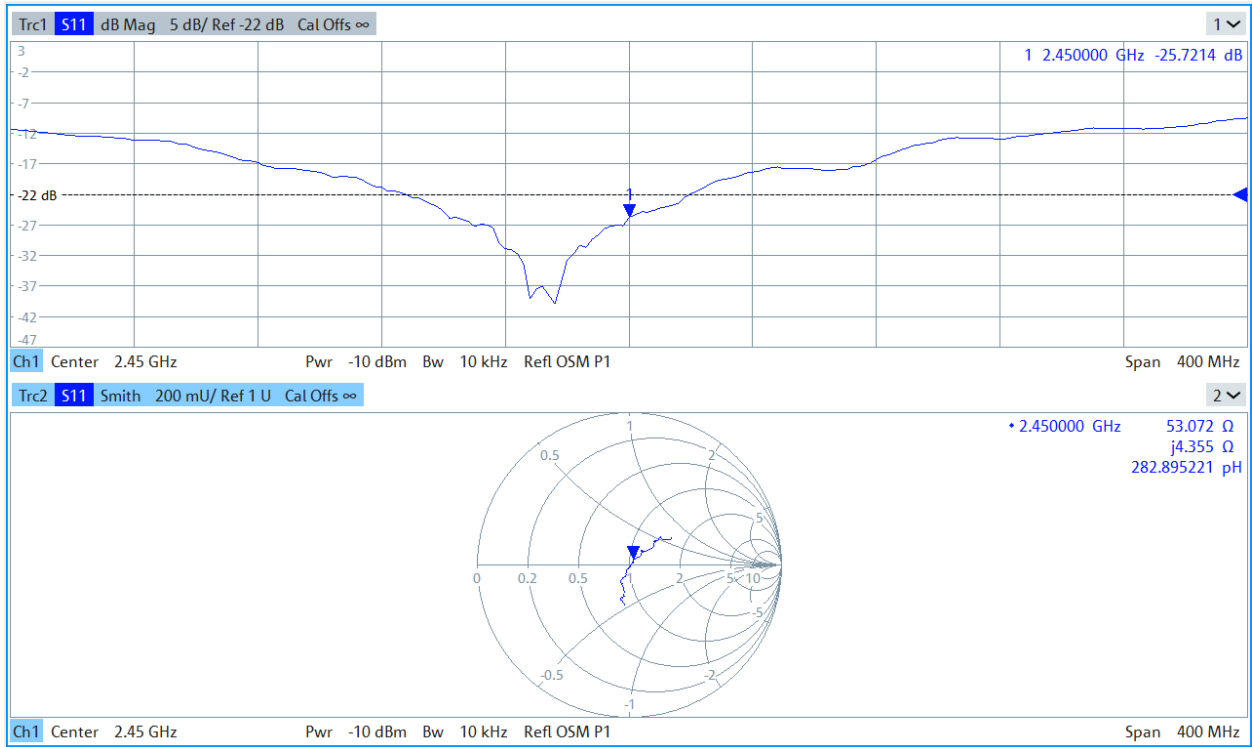
Per KDB 865664 D01, calibration intervals of up to three years may be considered for reference dipoles when it is demonstrated that the SAR target, impedance and return loss of a dipole have remained stable according to the following requirements:

1. The measured SAR does not deviate more than 10% from the target on the calibration certificate.
2. The return-loss does not deviate more than 20% from the previous measurement and meets the required 20dB minimum return-loss requirement.
3. The measurement of real or imaginary parts of impedance does not deviate more than 5Ω from the previous measurement.

The following dipole was checked to pass the above 3 requirements to have 3-year calibration period from the calibration date:

| Calibration Date | Extension Date | Certificate Electrical Delay (ns) | Certificate SAR Target Head (1g) W/kg @ 20.0 dBm | Measured Head SAR (1g) W/kg @ 20.0 dBm | Deviation 1g (%) | Certificate SAR Target Head (10g) W/kg @ 20.0 dBm | Measured Head SAR (10g) W/kg @ 20.0 dBm | Deviation 10g (%) | Certificate Impedance Head (Ohm) Real | Measured Impedance Head (Ohm) Real | Difference (Ohm) Real | Certificate Impedance Head (Ohm) Imaginary | Measured Impedance Head (Ohm) Imaginary | Difference (Ohm) Imaginary | Certificate Return Loss Head (dB) | Measured Return Loss Head (dB) | Deviation (%) | PASS/FAIL |
|------------------|----------------|-----------------------------------|--|--|------------------|---|---|-------------------|---------------------------------------|------------------------------------|-----------------------|--|---|----------------------------|-----------------------------------|--------------------------------|---------------|-----------|
| 11/25/2021 | 11/10/2023 | 1.163 | 5.39 | 5.53 | 2.80% | 2.54 | 2.56 | 0.79% | 53.8 | 53.1 | 0.7 | 5.8 | 4.4 | 1.4 | -23.6 | -25.7 | -9.00% | PASS |

Impedance & Return-Loss Measurement Plot for Head TSL





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Multilateral Agreement for the recognition of calibration certificates

Client **Element**
Columbia, USA

Certificate No. **D5GHzV2-1057_Feb24**

CALIBRATION CERTIFICATE

Object **D5GHzV2 - SN:1057**

SRS
0311124

Calibration procedure(s) **QA CAL-22.v7**
Calibration Procedure for SAR Validation Sources between 3-10 GHz

Calibration date: **February 21, 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 $(22 \pm 3)^\circ\text{C}$ 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: 3503 | 07-Mar-23 (No. EX3-3503_Mar23) | Mar-24 |
| DAE4 | SN: 601 | 30-Jan-24 (No. DAE4-601_Jan24) | Jan-25 |

| 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** Laboratory Technician
Approved by: **Niels Kuster** Quality Manager

Signature

Issued: February 26, 2024

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



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Multilateral Agreement for the recognition of calibration certificates

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) DASYS 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 V5.0 | |
| Distance Dipole Center - TSL | 10 mm | with Spacer |
| Zoom Scan Resolution | dx, dy = 4.0 mm, dz = 1.4 mm | Graded Ratio = 1.4 (Z direction) |
| Frequency | 5250 MHz ± 1 MHz 5600 MHz ± 1 MHz 5750 MHz ± 1 MHz 5850 MHz ± 1 MHz | |

Head TSL parameters at 5250 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|-----------------|--------------|------------------|
| Nominal Head TSL parameters | 22.0 °C | 35.9 | 4.71 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 36.2 ± 6 % | 4.61 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL at 5250 MHz

| SAR averaged over 1 cm ³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 7.93 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 79.4 W/kg ± 19.9 % (k=2) |

| SAR averaged over 10 cm ³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 2.27 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 22.7 W/kg ± 19.5 % (k=2) |

Head TSL parameters at 5600 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|-----------------|--------------|------------------|
| Nominal Head TSL parameters | 22.0 °C | 35.5 | 5.07 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 35.6 ± 6 % | 5.00 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL at 5600 MHz

| SAR averaged over 1 cm ³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 8.28 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 82.8 W/kg ± 19.9 % (k=2) |

| SAR averaged over 10 cm ³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 2.36 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 23.6 W/kg ± 19.5 % (k=2) |

Head TSL parameters at 5750 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|-----------------|--------------|------------------|
| Nominal Head TSL parameters | 22.0 °C | 35.4 | 5.22 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 35.3 ± 6 % | 5.16 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL at 5750 MHz

| SAR averaged over 1 cm ³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 7.99 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 79.8 W/kg ± 19.9 % (k=2) |

| SAR averaged over 10 cm ³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 2.27 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 22.7 W/kg ± 19.5 % (k=2) |

Head TSL parameters at 5850 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|-----------------|--------------|------------------|
| Nominal Head TSL parameters | 22.0 °C | 35.2 | 5.32 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 35.2 ± 6 % | 5.25 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL at 5850 MHz

| SAR averaged over 1 cm ³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 8.15 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 81.5 W/kg ± 19.9 % (k=2) |

| SAR averaged over 10 cm ³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 2.31 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 23.0 W/kg ± 19.5 % (k=2) |

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL at 5250 MHz

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 48.7 Ω - 3.4 j Ω |
| Return Loss | - 28.6 dB |

Antenna Parameters with Head TSL at 5600 MHz

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 55.9 Ω - 0.3 j Ω |
| Return Loss | - 25.0 dB |

Antenna Parameters with Head TSL at 5750 MHz

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 53.5 Ω + 4.0 j Ω |
| Return Loss | - 25.8 dB |

Antenna Parameters with Head TSL at 5850 MHz

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 52.2 Ω - 2.2 j Ω |
| Return Loss | - 30.4 dB |

General Antenna Parameters and Design

| | |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.202 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 |
|-----------------|-------|

DASY5 Validation Report for Head TSL

Date: 21.02.2024

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN:1057

Communication System: UID 0 - CW; Frequency: 5250 MHz, Frequency: 5600 MHz, Frequency: 5750 MHz, Frequency: 5850 MHz

Medium parameters used: $f = 5250$ MHz; $\sigma = 4.61$ S/m; $\epsilon_r = 36.2$; $\rho = 1000$ kg/m³,

Medium parameters used: $f = 5600$ MHz; $\sigma = 5.00$ S/m; $\epsilon_r = 35.6$; $\rho = 1000$ kg/m³,

Medium parameters used: $f = 5750$ MHz; $\sigma = 5.16$ S/m; $\epsilon_r = 35.3$; $\rho = 1000$ kg/m³,

Medium parameters used: $f = 5850$ MHz; $\sigma = 5.25$ S/m; $\epsilon_r = 35.2$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.5, 5.5, 5.5) @ 5250 MHz, ConvF(5.1, 5.1, 5.1) @ 5600 MHz, ConvF(5.08, 5.08, 5.08) @ 5750 MHz, ConvF(4.99, 4.99, 4.99) @ 5850 MHz; Calibrated: 07.03.2023
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 30.01.2024
- 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=100mW, dist=10mm, f=5250 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 71.92 V/m; Power Drift = 0.08 dB

Peak SAR (extrapolated) = 26.9 W/kg

SAR(1 g) = 7.93 W/kg; SAR(10 g) = 2.27 W/kg

Smallest distance from peaks to all points 3 dB below = 7.4 mm

Ratio of SAR at M2 to SAR at M1 = 70.5%

Maximum value of SAR (measured) = 18.1 W/kg

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 71.29 V/m; Power Drift = 0.07 dB

Peak SAR (extrapolated) = 30.4 W/kg

SAR(1 g) = 8.28 W/kg; SAR(10 g) = 2.36 W/kg

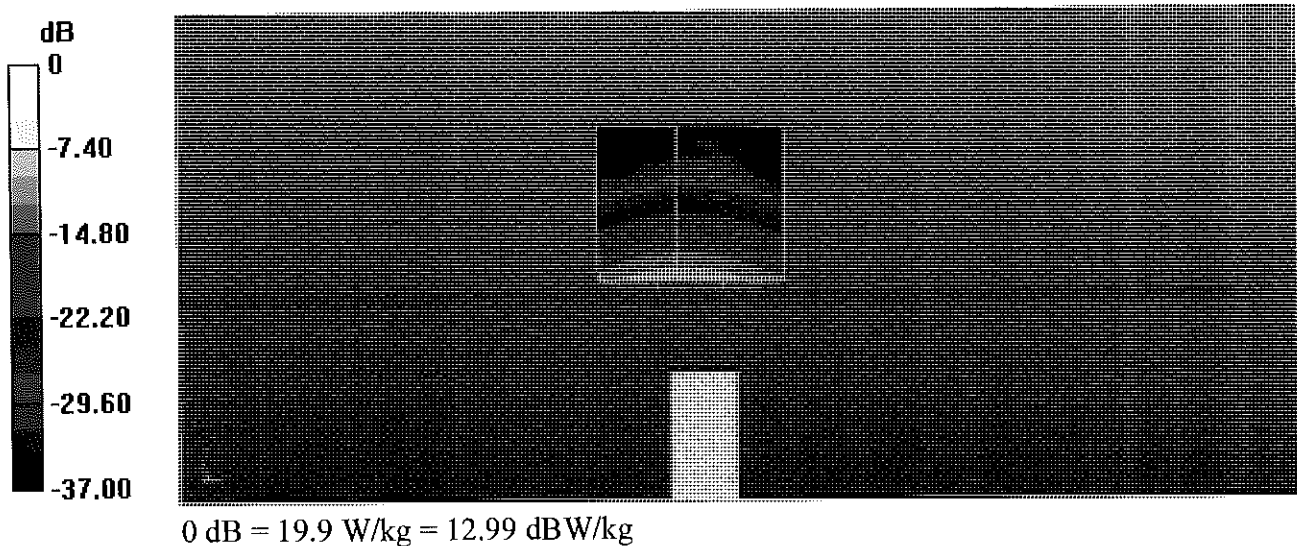
Smallest distance from peaks to all points 3 dB below = 7.5 mm

Ratio of SAR at M2 to SAR at M1 = 67.7%

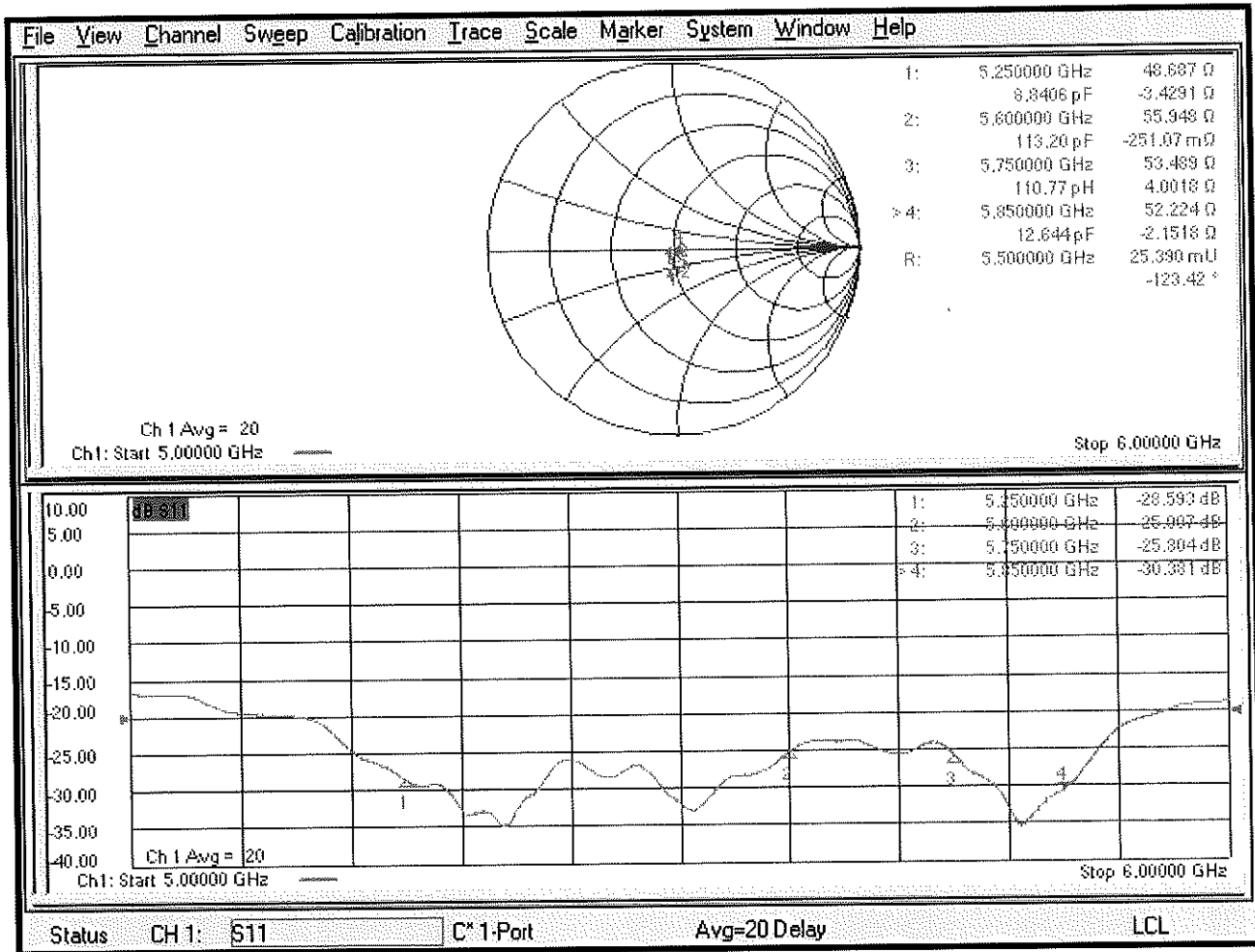
Maximum value of SAR (measured) = 19.4 W/kg

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5750 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 69.35 V/m; Power Drift = 0.09 dB
Peak SAR (extrapolated) = 31.1 W/kg
SAR(1 g) = 7.99 W/kg; SAR(10 g) = 2.27 W/kg
Smallest distance from peaks to all points 3 dB below = 7.5 mm
Ratio of SAR at M2 to SAR at M1 = 66%
Maximum value of SAR (measured) = 19.1 W/kg

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5850 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 68.94 V/m; Power Drift = 0.08 dB
Peak SAR (extrapolated) = 32.6 W/kg
SAR(1 g) = 8.15 W/kg; SAR(10 g) = 2.31 W/kg
Smallest distance from peaks to all points 3 dB below = 7.4 mm
Ratio of SAR at M2 to SAR at M1 = 65.2%
Maximum value of SAR (measured) = 19.9 W/kg



Impedance Measurement Plot for Head TSL





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Client **Element**
Columbia, USA

Certificate No. **D5GHzV2-1191_Jan24**

CALIBRATION CERTIFICATE

Object **D5GHzV2 - SN:1191**

SPS
01/30/24

Calibration procedure(s) **QA CAL-22.v7**
Calibration Procedure for SAR Validation Sources between 3-10 GHz

Calibration date: **January 17, 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)°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: 3503 | 07-Mar-23 (No. EX3-3503_Mar23) | Mar-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

Signature

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

Issued: January 18, 2024

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



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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:

- 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.
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Additional Documentation:

- 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 V5.0 | |
| Distance Dipole Center - TSL | 10 mm | with Spacer |
| Zoom Scan Resolution | dx, dy = 4.0 mm, dz = 1.4 mm | Graded Ratio = 1.4 (Z direction) |
| Frequency | 5250 MHz ± 1 MHz 5600 MHz ± 1 MHz 5750 MHz ± 1 MHz 5850 MHz ± 1 MHz | |

Head TSL parameters at 5250 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|--|-----------------|--------------|------------------|
| Nominal Head TSL parameters | 22.0 °C | 35.9 | 4.71 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 36.5 ± 6 % | 4.65 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL at 5250 MHz

| SAR averaged over 1 cm³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 7.87 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 78.9 W/kg ± 19.9 % (k=2) |

| SAR averaged over 10 cm³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 2.27 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 22.7 W/kg ± 19.5 % (k=2) |

Head TSL parameters at 5600 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|--|-----------------|--------------|------------------|
| Nominal Head TSL parameters | 22.0 °C | 35.5 | 5.07 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 36.1 ± 6 % | 5.04 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL at 5600 MHz

| SAR averaged over 1 cm³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 8.27 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 83.0 W/kg ± 19.9 % (k=2) |

| SAR averaged over 10 cm³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 2.38 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 23.9 W/kg ± 19.5 % (k=2) |

Head TSL parameters at 5750 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|-----------------|--------------|------------------|
| Nominal Head TSL parameters | 22.0 °C | 35.4 | 5.22 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 36.0 ± 6 % | 5.18 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL at 5750 MHz

| SAR averaged over 1 cm ³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 7.86 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 78.9 W/kg ± 19.9 % (k=2) |

| SAR averaged over 10 cm ³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 2.23 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 22.4 W/kg ± 19.5 % (k=2) |

Head TSL parameters at 5850 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|-----------------|--------------|------------------|
| Nominal Head TSL parameters | 22.0 °C | 35.2 | 5.32 mho/m |
| Measured Head TSL parameters | (22.0 ± 0.2) °C | 35.8 ± 6 % | 5.27 mho/m ± 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL at 5850 MHz

| SAR averaged over 1 cm ³ (1 g) of Head TSL | Condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 7.86 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 78.8 W/kg ± 19.9 % (k=2) |

| SAR averaged over 10 cm ³ (10 g) of Head TSL | condition | |
|---|--------------------|---------------------------------|
| SAR measured | 100 mW input power | 2.24 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 22.5 W/kg ± 19.5 % (k=2) |

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL at 5250 MHz

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 51.7 Ω - 8.5 j Ω |
| Return Loss | - 21.5 dB |

Antenna Parameters with Head TSL at 5600 MHz

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 54.9 Ω - 7.9 j Ω |
| Return Loss | - 21.1 dB |

Antenna Parameters with Head TSL at 5750 MHz

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 55.2 Ω - 1.6 j Ω |
| Return Loss | - 25.8 dB |

Antenna Parameters with Head TSL at 5850 MHz

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 51.3 Ω - 5.5 j Ω |
| Return Loss | - 25.0 dB |

General Antenna Parameters and Design

| | |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.203 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 |
|-----------------|-------|

DASY5 Validation Report for Head TSL

Date: 17.01.2024

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN:1191

Communication System: UID 0 - CW; Frequency: 5250 MHz, Frequency: 5600 MHz, Frequency: 5750 MHz, Frequency: 5850 MHz

Medium parameters used: $f = 5250$ MHz; $\sigma = 4.65$ S/m; $\epsilon_r = 36.5$; $\rho = 1000$ kg/m³

Medium parameters used: $f = 5600$ MHz; $\sigma = 5.04$ S/m; $\epsilon_r = 36.1$; $\rho = 1000$ kg/m³

Medium parameters used: $f = 5750$ MHz; $\sigma = 5.18$ S/m; $\epsilon_r = 36.0$; $\rho = 1000$ kg/m³

Medium parameters used: $f = 5850$ MHz; $\sigma = 5.27$ S/m; $\epsilon_r = 35.8$; $\rho = 1000$ kg/m³

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.5, 5.5, 5.5) @ 5250 MHz, ConvF(5.1, 5.1, 5.1) @ 5600 MHz, ConvF(5.08, 5.08, 5.08) @ 5750 MHz, ConvF(4.99, 4.99, 4.99) @ 5850 MHz; Calibrated: 07.03.2023
- 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=100mW, dist=10mm, f=5250 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 73.66 V/m; Power Drift = 0.01 dB

Peak SAR (extrapolated) = 26.6 W/kg

SAR(1 g) = 7.87 W/kg; SAR(10 g) = 2.27 W/kg

Smallest distance from peaks to all points 3 dB below = 7.2 mm

Ratio of SAR at M2 to SAR at M1 = 71%

Maximum value of SAR (measured) = 18.2 W/kg

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 73.16 V/m; Power Drift = 0.09 dB

Peak SAR (extrapolated) = 30.3 W/kg

SAR(1 g) = 8.27 W/kg; SAR(10 g) = 2.38 W/kg

Smallest distance from peaks to all points 3 dB below = 7.4 mm

Ratio of SAR at M2 to SAR at M1 = 68%

Maximum value of SAR (measured) = 19.7 W/kg

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5750 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 70.39 V/m; Power Drift = 0.08 dB

Peak SAR (extrapolated) = 30.6 W/kg

SAR(1 g) = 7.86 W/kg; SAR(10 g) = 2.23 W/kg

Smallest distance from peaks to all points 3 dB below = 7.2 mm

Ratio of SAR at M2 to SAR at M1 = 66.2%

Maximum value of SAR (measured) = 19.3 W/kg

Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5850 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm

Reference Value = 70.63 V/m; Power Drift = 0.08 dB

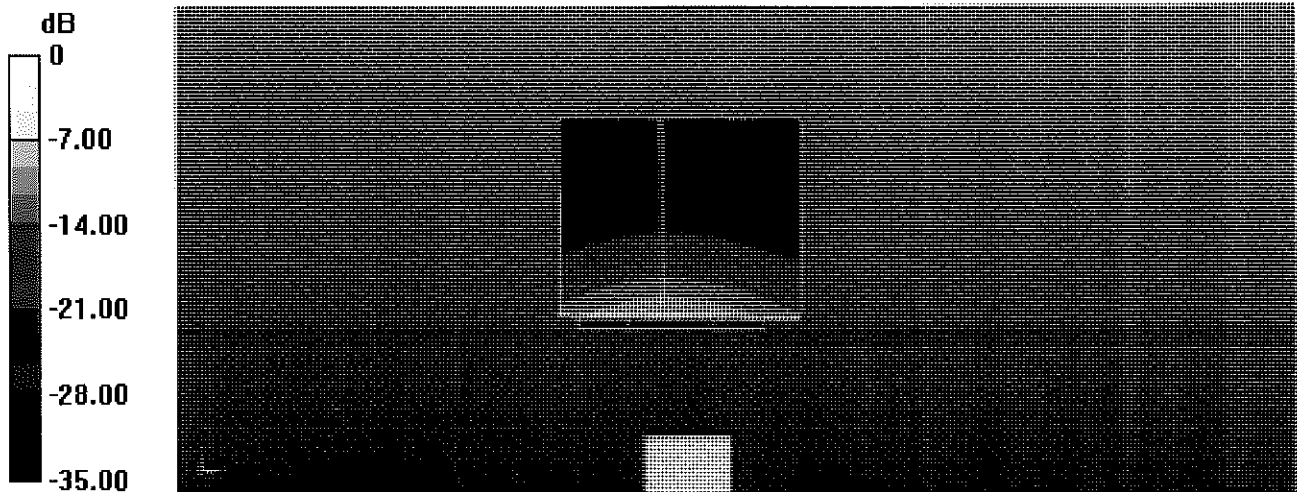
Peak SAR (extrapolated) = 31.1 W/kg

SAR(1 g) = 7.86 W/kg; SAR(10 g) = 2.24 W/kg

Smallest distance from peaks to all points 3 dB below = 7.2 mm

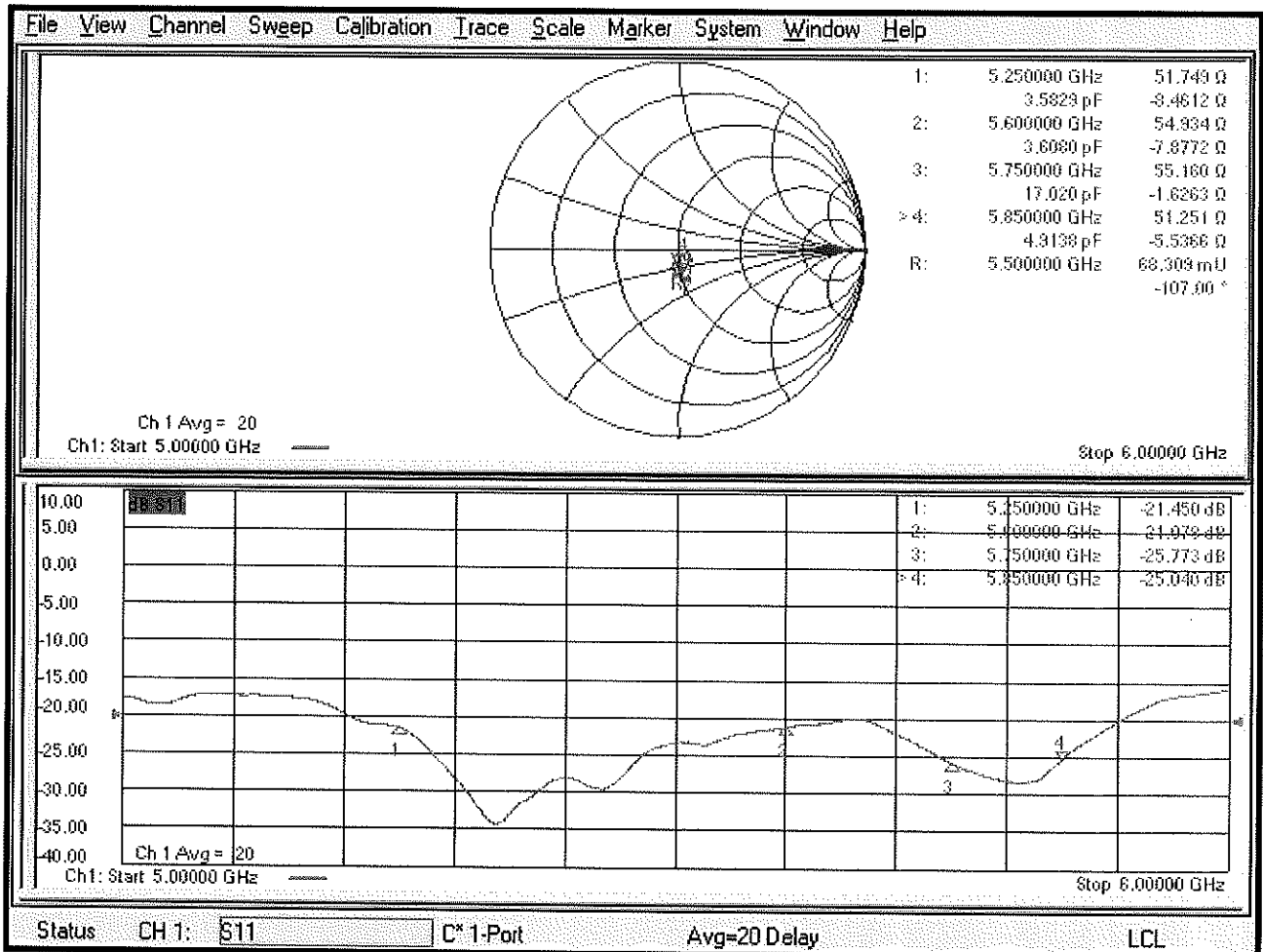
Ratio of SAR at M2 to SAR at M1 = 65.5%

Maximum value of SAR (measured) = 19.4 W/kg



0 dB = 19.7 W/kg = 12.94 dBW/kg

Impedance Measurement Plot for Head TSL





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 **Element**
Columbia, USA

Certificate No. **D6.5GHzV2-1018_Jan24**

CALIBRATION CERTIFICATE

Object **D6.5GHzV2 - SN:1018** SRS
01/30/24

Calibration procedure(s) **QA CAL-22.v7
Calibration Procedure for SAR Validation Sources between 3-10 GHz**

Calibration date: **January 10, 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)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|----------------------------|------------------|--------------------------------|-----------------------|
| Power sensor R&S NRP33T | SN: 100967 | 03-Apr-23 (No. 217-03806) | Apr-24 |
| Reference 20 dB Attenuator | SN: BH9394 (20k) | 30-Mar-23 (No. 217-03809) | Mar-24 |
| Mismatch combination | SN: 84224 / 360D | 03-Apr-23 (No. 217-03812) | Apr-24 |
| Reference Probe EX3DV4 | SN: 7405 | 12-Jun-23 (No. EX3-7405_Jun23) | Jun-24 |
| DAE4 | SN: 908 | 03-Jul-23 (No. DAE4-908_Jul23) | Jul-24 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|----------------------------------|---------------|-----------------------------------|------------------------|
| RF generator Anapico APSIN20G | SN: 827 | 18-Dec-18 (in house check Jan-24) | In house check: Jan-25 |
| Power sensor NRP-Z23 | SN: 100169 | 10-Jan-19 (in house check Jan-24) | In house check: Jan-25 |
| Power sensor NRP-18T | SN: 100950 | 28-Sep-22 (in house check Jan-24) | In house check: Jan-25 |
| Network Analyzer Keysight E5063A | SN:MY54504221 | 31-Oct-19 (in house check Oct-22) | In house check: Oct-25 |

| | | | |
|----------------|--------------------------------|--|---------------|
| Calibrated by: | Name Jeffrey Katzman | Function Laboratory Technician | Signature |
| Approved by: | Name Sven Kühn | Function Technical Manager | |

Issued: January 16, 2024

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



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.

Additional Documentation:

- b) DASYS 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 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 absorbed power density (APD):* The absorbed power density is evaluated according to Samaras T, Christ A, Kuster N, "Compliance assessment of the epithelial or absorbed power density above 6 GHz using SAR measurement systems", Bioelectromagnetics, 2021 (submitted). The additional evaluation uncertainty of 0.55 dB (rectangular distribution) is considered.

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 | DASY6 | V16.2 |
| Extrapolation | Advanced Extrapolation | |
| Phantom | Modular Flat Phantom | |
| Distance Dipole Center - TSL | 5 mm | with Spacer |
| Zoom Scan Resolution | dx, dy = 3.4 mm, dz = 1.4 mm | Graded Ratio = 1.4 (Z direction) |
| Frequency | 6500 MHz \pm 1 MHz | |

Head TSL parameters

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|--|---------------------|----------------|----------------------|
| Nominal Head TSL parameters | 22.0 °C | 34.5 | 6.07 mho/m |
| Measured Head TSL parameters | (22.0 \pm 0.2) °C | 34.9 \pm 6 % | 6.17 mho/m \pm 6 % |
| Head TSL temperature change during test | < 0.5 °C | ---- | ---- |

SAR result with Head TSL

| SAR averaged over 1 cm³ (1 g) of Head TSL | Condition | |
|---|--------------------|---|
| SAR measured | 100 mW input power | 29.2 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 293 W/kg \pm 24.7 % (k=2) |

| SAR averaged over 8 cm³ (8 g) of Head TSL | Condition | |
|---|--------------------|--|
| SAR measured | 100 mW input power | 6.55 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 65.7 W/kg \pm 24.4 % (k=2) |

| SAR averaged over 10 cm³ (10 g) of Head TSL | condition | |
|---|--------------------|--|
| SAR measured | 100 mW input power | 5.37 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 53.9 W/kg \pm 24.4 % (k=2) |

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 49.6 Ω - 4.1 j Ω |
| Return Loss | - 27.7 dB |

APD (Absorbed Power Density)

| APD averaged over 1 cm ² | Condition | |
|-------------------------------------|--------------------|---|
| APD measured | 100 mW input power | 292 W/m ² |
| APD measured | normalized to 1W | 2920 W/m² \pm 29.2 % (k=2) |

| APD averaged over 4 cm ² | condition | |
|-------------------------------------|--------------------|---|
| APD measured | 100 mW input power | 131 W/m ² |
| APD measured | normalized to 1W | 1310 W/m² \pm 28.9 % (k=2) |

*The reported APD values have been derived using the psSAR1g and psSAR8g.

General Antenna Parameters and Design

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 |
|-----------------|-------|

DASY6 Validation Report for Head TSL

Measurement Report for D6.5GHz-1018, UID 0 -, Channel 6500 (6500.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|--------------------|--------------------|----------|----------|
| D6.5GHz | 16.0 x 6.0 x 300.0 | SN: 1018 | - |

Exposure Conditions

| Phantom Section, TSL | Position, Test Distance [mm] | Band | Group, UID | Frequency [MHz] | Conversion Factor | TSL Cond. [5/m] | TSL Permittivity |
|----------------------|------------------------------|------|------------|-----------------|-------------------|-----------------|------------------|
| Flat, HSL | 5.00 | Band | CW, | 6500 | 5.50 | 6.17 | 34.9 |

Hardware Setup

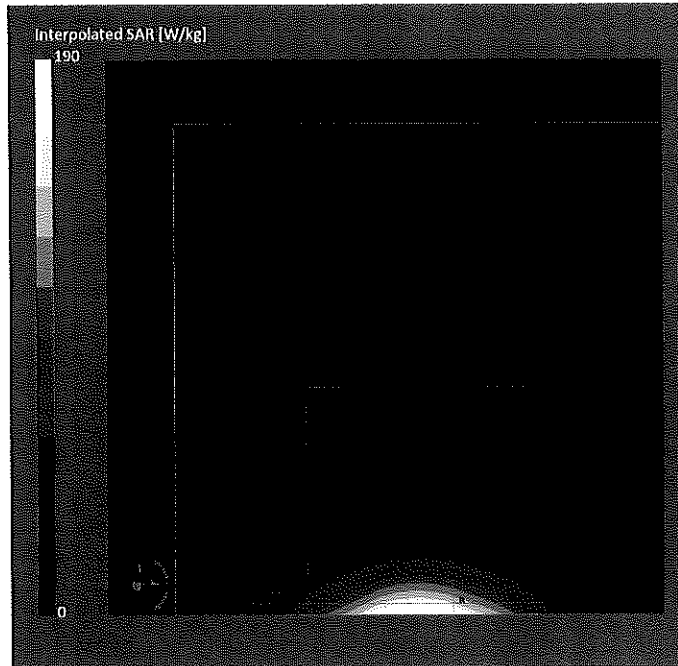
| Phantom | TSL | Probe, Calibration Date | DAE, Calibration Date |
|------------------------|-----------------|-----------------------------|------------------------|
| MFP V8.0 Center - 1182 | HBBL600-10000V6 | EX3DV4 - SN7405, 2023-06-12 | DAE4 Sn908, 2023-07-03 |

Scan Setup

| | Zoom Scan |
|---------------------|--------------------|
| Grid Extents [mm] | 22.0 x 22.0 x 22.0 |
| Grid Steps [mm] | 3.4 x 3.4 x 1.4 |
| Sensor Surface [mm] | 1.4 |
| Graded Grid | Yes |
| Grading Ratio | 1.4 |
| MAIA | N/A |
| Surface Detection | VMS + 6p |
| Scan Method | Measured |

Measurement Results

| | Zoom Scan |
|---------------------|-------------------|
| Date | 2024-01-10, 13:38 |
| psSAR1g [W/Kg] | 29.2 |
| psSAR8g [W/Kg] | 6.55 |
| psSAR10g [W/Kg] | 5.37 |
| Power Drift [dB] | 0.02 |
| Power Scaling | Disabled |
| Scaling Factor [dB] | |
| TSL Correction | No correction |
| M2/M1 [%] | 49.6 |
| Dist 3dB Peak [mm] | 4.6 |

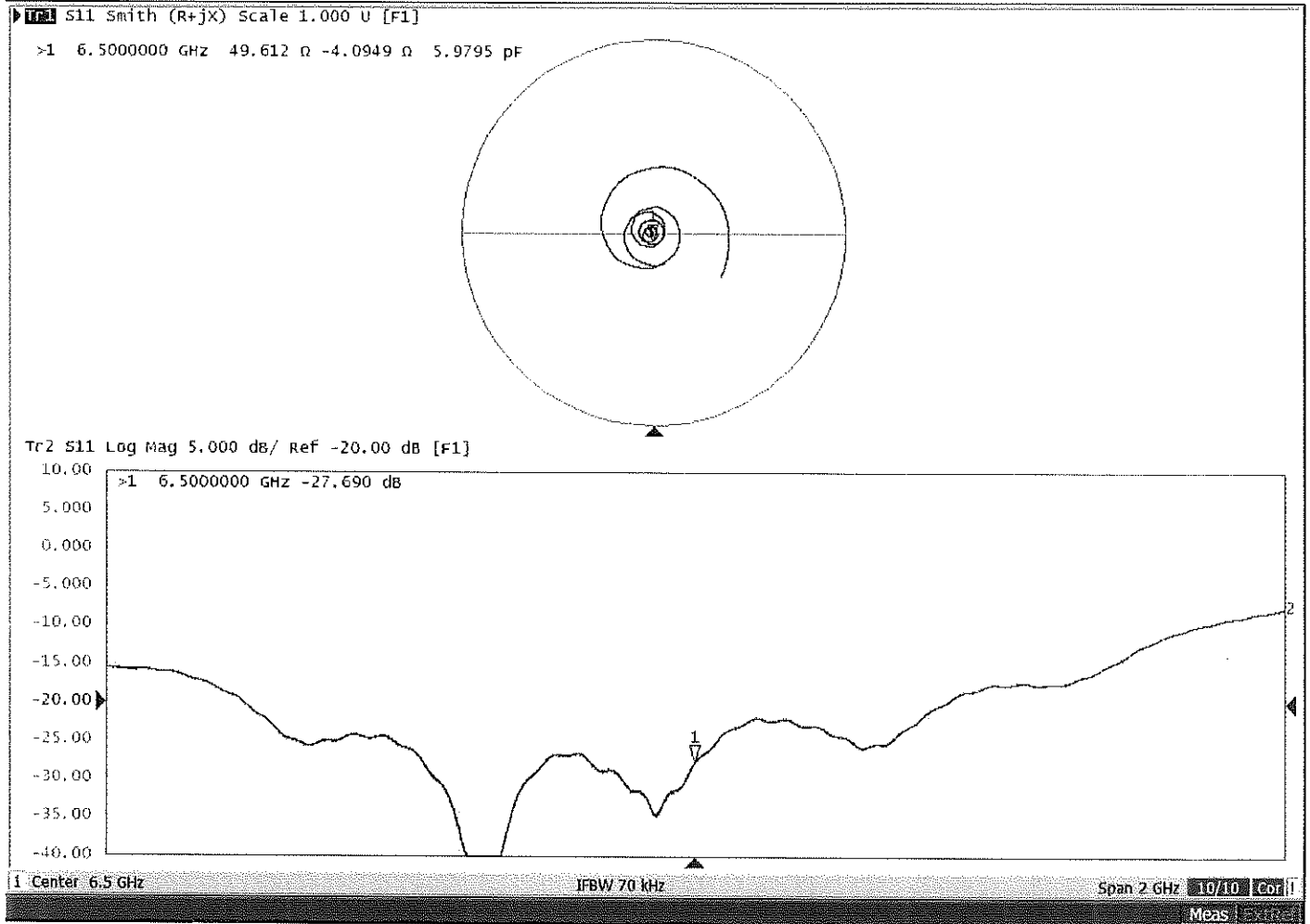


Impedance Measurement Plot for Head TSL

E5063A Network Analyzer

1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State

Resize





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 **Element**
Yongin, Republic of Korea

Certificate No. **D6.5GHzV2-1020_Jan24**

CALIBRATION CERTIFICATE

Object **D6.5GHzV2 - SN:1020**

Calibration procedure(s) **QA CAL-22.v7
Calibration Procedure for SAR Validation Sources between 3-10 GHz**

Calibration date: **January 10, 2024**

| 실무자 | 기술책임자 |
|-----|-------|
| | |

11/31-2024

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)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|----------------------------------|------------------|-----------------------------------|------------------------|
| Power sensor R&S NRP33T | SN: 100967 | 03-Apr-23 (No. 217-03806) | Apr-24 |
| Reference 20 dB Attenuator | SN: BH9394 (20k) | 30-Mar-23 (No. 217-03809) | Mar-24 |
| Mismatch combination | SN: 84224 / 360D | 03-Apr-23 (No. 217-03812) | Apr-24 |
| Reference Probe EX3DV4 | SN: 7405 | 12-Jun-23 (No. EX3-7405_Jun23) | Jun-24 |
| DAE4 | SN: 908 | 03-Jul-23 (No. DAE4-908_Jul23) | Jul-24 |
| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
| RF generator Anapico APSIN20G | SN: 827 | 18-Dec-18 (in house check Jan-24) | In house check: Jan-25 |
| Power sensor NRP-Z23 | SN: 100169 | 10-Jan-19 (in house check Jan-24) | In house check: Jan-25 |
| Power sensor NRP-18T | SN: 100950 | 28-Sep-22 (in house check Jan-24) | In house check: Jan-25 |
| Network Analyzer Keysight E5063A | SN:MY54504221 | 31-Oct-19 (in house check Oct-22) | In house check: Oct-25 |

Calibrated by: **Jeffrey Katzman** Name: Jeffrey Katzman Function: Laboratory Technician

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

Signature

Issued: January 16, 2024

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



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.

Additional Documentation:

- b) 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 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 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 absorbed power density (APD):* The absorbed power density is evaluated according to Samaras T, Christ A, Kuster N, "Compliance assessment of the epithelial or absorbed power density above 6 GHz using SAR measurement systems", Bioelectromagnetics, 2021 (submitted). The additional evaluation uncertainty of 0.55 dB (rectangular distribution) is considered.

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 | DASY6 | V16.2 |
| Extrapolation | Advanced Extrapolation | |
| Phantom | Modular Flat Phantom | |
| Distance Dipole Center - TSL | 5 mm | with Spacer |
| Zoom Scan Resolution | dx, dy = 3.4 mm, dz = 1.4 mm | Graded Ratio = 1.4 (Z direction) |
| Frequency | 6500 MHz \pm 1 MHz | |

Head TSL parameters

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---------------------|----------------|----------------------|
| Nominal Head TSL parameters | 22.0 °C | 34.5 | 6.07 mho/m |
| Measured Head TSL parameters | (22.0 \pm 0.2) °C | 34.9 \pm 6 % | 6.17 mho/m \pm 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 | 100 mW input power | 29.1 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 292 W/kg \pm 24.7 % (k=2) |

| SAR averaged over 8 cm ³ (8 g) of Head TSL | Condition | |
|---|--------------------|--|
| SAR measured | 100 mW input power | 6.55 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 65.7 W/kg \pm 24.4 % (k=2) |

| SAR averaged over 10 cm ³ (10 g) of Head TSL | condition | |
|---|--------------------|--|
| SAR measured | 100 mW input power | 5.37 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | 53.9 W/kg \pm 24.4 % (k=2) |

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters with Head TSL

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 50.6 Ω - 1.9 j Ω |
| Return Loss | - 33.8 dB |

APD (Absorbed Power Density)

| APD averaged over 1 cm ² | Condition | |
|-------------------------------------|--------------------|---|
| APD measured | 100 mW input power | 291 W/m ² |
| APD measured | normalized to 1W | 2910 W/m² \pm 29.2 % (k=2) |

| APD averaged over 4 cm ² | condition | |
|-------------------------------------|--------------------|---|
| APD measured | 100 mW input power | 131 W/m ² |
| APD measured | normalized to 1W | 1310 W/m² \pm 28.9 % (k=2) |

*The reported APD values have been derived using the psSAR1g and psSAR8g.

General Antenna Parameters and Design

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 |
|-----------------|-------|

DASY6 Validation Report for Head TSL

Measurement Report for D6.5GHz-1020, UID 0 -, Channel 6500 (6500.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|--------------------|--------------------|----------|----------|
| D6.5GHz | 16.0 x 6.0 x 300.0 | SN: 1020 | - |

Exposure Conditions

| Phantom Section, TSL | Position, Test Distance [mm] | Band | Group, UID | Frequency [MHz] | Conversion Factor | TSL Cond. [S/m] | TSL Permittivity |
|----------------------|------------------------------|------|------------|-----------------|-------------------|-----------------|------------------|
| Flat, HSL | 5.00 | Band | CW, | 6500 | 5.50 | 6.17 | 34.9 |

Hardware Setup

| Phantom | TSL | Probe, Calibration Date | DAE, Calibration Date |
|------------------------|-----------------|-----------------------------|------------------------|
| MFP V8.0 Center - 1182 | HBBL600-10000V6 | EX3DV4 - SN7405, 2023-06-12 | DAE4 Sn908, 2023-07-03 |

Scan Setup

| | Zoom Scan |
|---------------------|--------------------|
| Grid Extents [mm] | 22.0 x 22.0 x 22.0 |
| Grid Steps [mm] | 3.4 x 3.4 x 1.4 |
| Sensor Surface [mm] | 1.4 |
| Graded Grid | Yes |
| Grading Ratio | 1.4 |
| MAIA | N/A |
| Surface Detection | VMS + 6p |
| Scan Method | Measured |

Measurement Results

| | Zoom Scan |
|---------------------|-------------------|
| Date | 2024-01-10, 15:09 |
| psSAR1g [W/Kg] | 29.1 |
| psSAR8g [W/Kg] | 6.55 |
| psSAR10g [W/Kg] | 5.37 |
| Power Drift [dB] | 0.02 |
| Power Scaling | Disabled |
| Scaling Factor [dB] | |
| TSL Correction | No correction |
| M2/M1 [%] | 50.1 |
| Dist 3dB Peak [mm] | 4.8 |



Impedance Measurement Plot for Head TSL

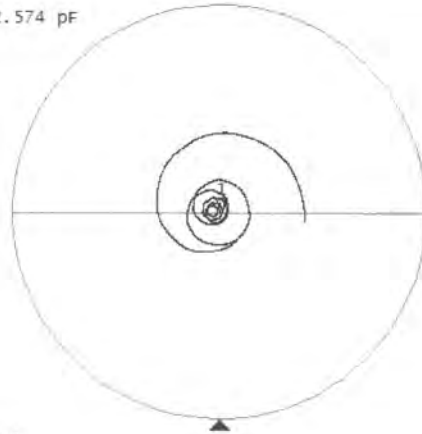
E5063A Network Analyzer

1 Active Ch/Trace 2 Response 3 Stimulus 4 Mkr/Analysis 5 Instr State

Resize

Tr1 S11 Smith (R+jX) scale 1.000 U [F1]

>1 6.5000000 GHz 50.631 Ω -1.9473 Ω 12.574 pF



Tr2 S11 Log Mag 5.000 dB/ Ref -20.00 dB [F1]

>1 6.5000000 GHz -33.834 dB



1 Center 6.5 GHz

IFBW 70 kHz

Span 2 GHz 10/10 Cor

Meas ExtrRef



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 **Element**
Columbia, USA

Certificate No. **5G-Veri10-1004_Aug23**

CALIBRATION CERTIFICATE

Object **5G Verification Source 10 GHz - SN: 1004**

Calibration procedure(s) **QA CAL-45.v4**
Calibration procedure for sources in air above 6 GHz

MAR
14/4/23

Calibration date: **August 11, 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 |
|----------------------------------|----------------|-----------------------------------|------------------------|
| Reference Probe EUmmWV3 | SN: 9374 | 22-May-23 (No. EUmm-9374_May23) | May-24 |
| DAE4ip | SN: 1602 | 05-Jul-23 (No. DAE4ip-1602_Jul23) | Jul-24 |
| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
| RF generator R&S SMF100A | SN: 100184 | 19-May-22 (in house check Nov-22) | In house check: Nov-23 |
| Power sensor R&S NRP18S-10 | SN: 101258 | 31-May-22 (in house check Nov-22) | In house check: Nov-23 |
| Network Analyzer Keysight E5063A | SN: MY54504221 | 31-Oct-19 (in house check Oct-22) | In house check: Oct-25 |

| | | |
|----------------|------------------------|-----------------------------------|
| Calibrated by: | Name Joanna Lleshaj | Function Laboratory Technician |
| Approved by: | Name Niels Kuster | Function Quality Manager |

Signature

Issued: August 14, 2023

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



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**

Glossary

CW Continuous wave

Calibration is Performed According to the Following Standards

- Internal procedure QA CAL-45, Calibration procedure for sources in air above 6 GHz.
- IEC/IEEE 63195-1, "Assessment of power density of human exposure to radio frequency fields from wireless devices in close proximity to the head and body (frequency range of 6 GHz to 300 GHz)", May 2022

Methods Applied and Interpretation of Parameters

- *Coordinate System:* z-axis in the waveguide horn boresight, x-axis is in the direction of the E-field, y-axis normal to the others in the field scanning plane parallel to the horn flare and horn flange.
- *Measurement Conditions: (1) 10 GHz:* The radiated power is the forward power to the horn antenna minus ohmic and mismatch loss. The forward power is measured prior and after the measurement with a power sensor. During the measurements, the horn is directly connected to the cable and the antenna ohmic and mismatch losses are determined by far-field measurements. *(2) 30, 45, 60 and 90 GHz:* The verification sources are switched on for at least 30 minutes. Absorbers are used around the probe cub and at the ceiling to minimize reflections.
- *Horn Positioning:* The waveguide horn is mounted vertically on the flange of the waveguide source to allow vertical positioning of the EUmmW probe during the scan. The plane is parallel to the phantom surface. Probe distance is verified using mechanical gauges positioned on the flare of the horn.
- *E- field distribution:* E field is measured in two x-y-plane (10mm, 10mm + $\lambda/4$) with a vectorial E-field probe. The E-field value stated as calibration value represents the E-field-maxima and the averaged (1cm² and 4cm²) power density values at 10mm in front of the horn.
- *Field polarization:* Above the open horn, linear polarization of the field is expected. This is verified graphically in the field representation.

Calibrated Quantity

- Local peak E-field (V/m) and average of peak spatial components of the poynting vector (W/m²) averaged over the surface area of 1 cm² and 4cm² at the nominal operational frequency of the verification source. Both square and circular averaging results are listed.

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 | DASY8 Module mmWave | V3.2 |
| Phantom | 5G Phantom | |
| Distance Horn Aperture - plane | 10 mm | |
| Number of measured planes | 2 (10mm, 10mm + $\lambda/4$) | |
| Frequency | 10 GHz \pm 10 MHz | |

Calibration Parameters, 10 GHz

Circular Averaging

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Avg Power Density Avg (psPDn+, psPDtot+, psPDmod+) (W/m ²) | | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|-------------------|---------------------|
| | | | | 1 cm ² | 4 cm ² | |
| 10 mm | 93.3 | 156 | 1.27 dB | 60.3 | 56.1 | 1.28 dB |

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Power Density psPDn+, psPDtot+, psPDmod+ (W/m ²) | | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|-------------------|---------------------|
| | | | | 1 cm ² | 4 cm ² | |
| 10 mm | 93.3 | 156 | 1.27 dB | 60.1, 60.3, 60.5 | 55.8, 56.1, 56.4 | 1.28 dB |

Square Averaging

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Avg Power Density Avg (psPDn+, psPDtot+, psPDmod+) (W/m ²) | | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|-------------------|---------------------|
| | | | | 1 cm ² | 4 cm ² | |
| 10 mm | 93.3 | 156 | 1.27 dB | 60.3 | 56.0 | 1.28 dB |

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Power Density psPDn+, psPDtot+, psPDmod+ (W/m ²) | | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|-------------------|---------------------|
| | | | | 1 cm ² | 4 cm ² | |
| 10 mm | 93.3 | 156 | 1.27 dB | 60.2, 60.3, 60.5 | 55.7, 56.0, 56.3 | 1.28 dB |

Max Power Density

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Max Power Density Sn, Stot, Stot (W/m ²) | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|---------------------|
| | | | | 61.7, 61.8, 62.0 | |
| 10 mm | 93.3 | 156 | 1.27 dB | 61.7, 61.8, 62.0 | 1.28 dB |

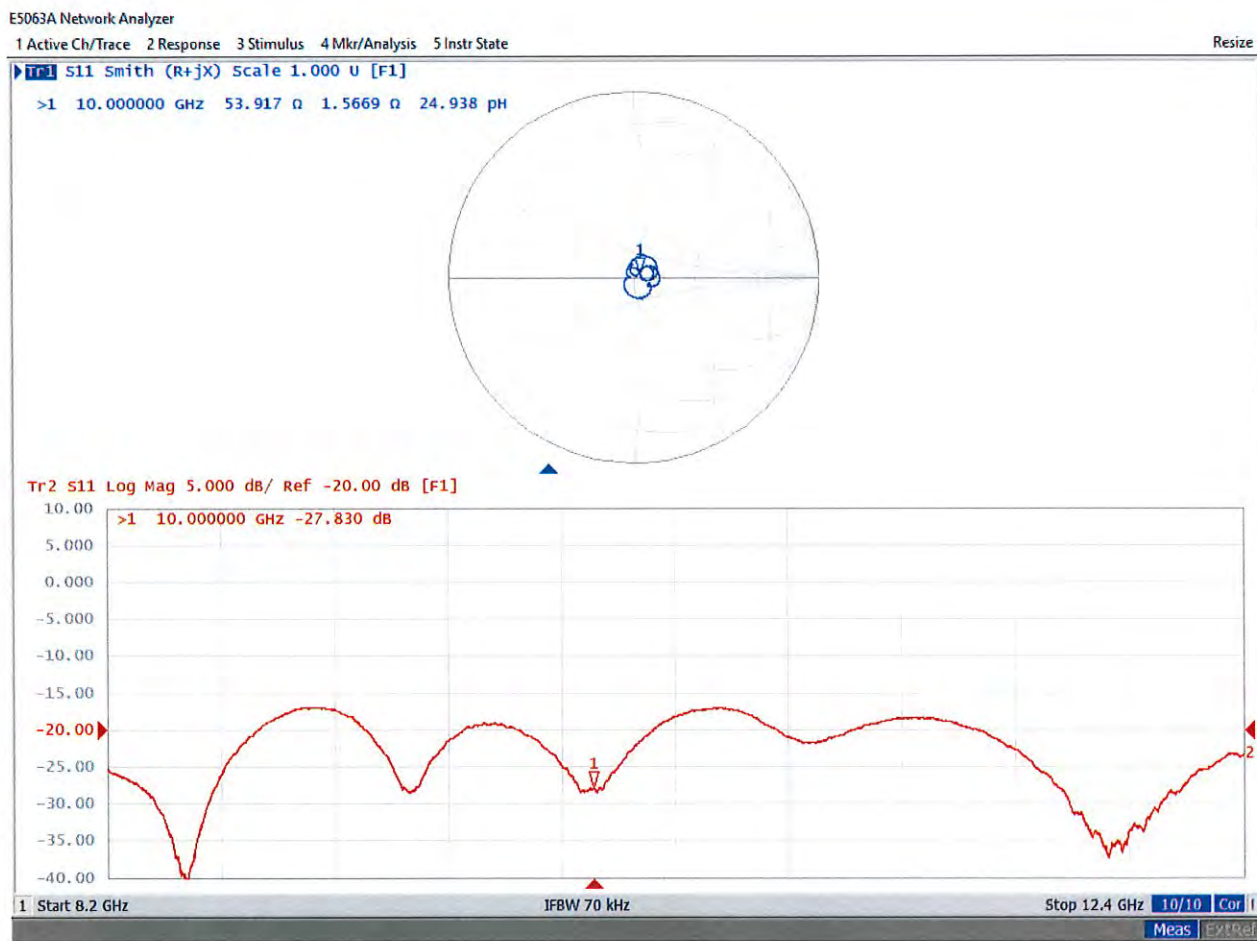
¹ Assessed ohmic and mismatch loss plus numerical offset: 0.30 dB

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters

| | |
|--------------------------------------|--------------------------------|
| Impedance, transformed to feed point | 53.9 Ω + 1.6 j Ω |
| Return Loss | - 27.8 dB |

Impedance Measurement Plot



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|-------------------------------|-----------------------|----------|----------|
| 5G Verification Source 10 GHz | 100.0 x 100.0 x 172.0 | SN: 1004 | - |

Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|-----------------|------------------------------|-----------------|--------|---------------------------------|-------------------|
| 5G - | 10.0 mm | Validation band | CW | 10000.0, 10000 | 1.0 |

Hardware Setup

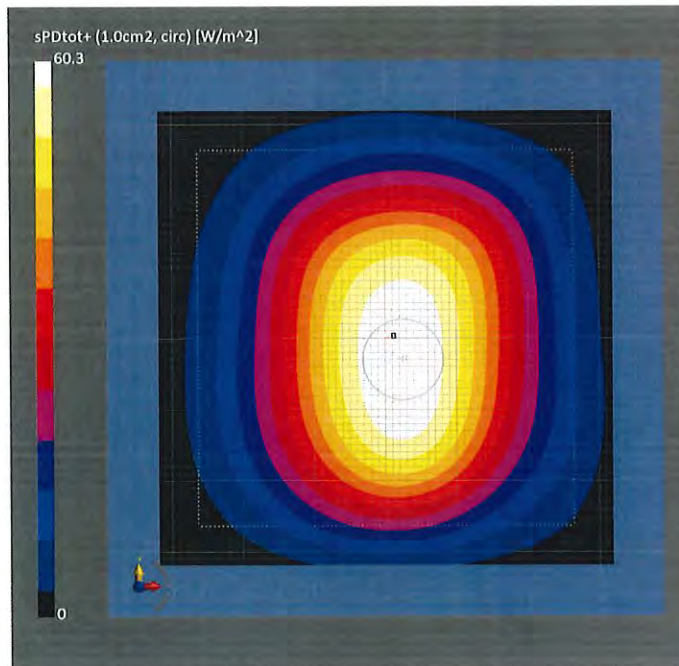
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|-----------------------|--------|---------------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

Scan Setup

| Sensor Surface [mm] | 5G Scan |
|---------------------|-----------------------|
| MAIA | 10.0 MAIA not used |

Measurement Results

| | 5G Scan |
|---------------------------------|--------------------|
| Date | 2023-08-11, 11:52 |
| Avg. Area [cm ²] | 1.00 |
| Avg. Type | Circular Averaging |
| psPDn+ [W/m ²] | 60.1 |
| psPDtot+ [W/m ²] | 60.3 |
| psPDmod+ [W/m ²] | 60.5 |
| Max(Sn) [W/m ²] | 61.7 |
| Max(Stot) [W/m ²] | 61.8 |
| Max(Stot) [W/m ²] | 62.0 |
| E _{max} [V/m] | 156 |
| Power Drift [dB] | -0.02 |



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|-------------------------------|-----------------------|----------|----------|
| 5G Verification Source 10 GHz | 100.0 x 100.0 x 172.0 | SN: 1004 | - |

Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|-----------------|------------------------------|-----------------|--------|---------------------------------|-------------------|
| 5G - | 10.0 mm | Validation band | CW | 10000.0, 10000 | 1.0 |

Hardware Setup

| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|-----------------------|--------|---------------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

Scan Setup

| Sensor Surface [mm] | 5G Scan |
|---------------------|-----------------------|
| MAIA | 10.0 MAIA not used |

Measurement Results

| Date | 5G Scan |
|---------------------------------|--------------------|
| 2023-08-11, 11:52 | 2023-08-11, 11:52 |
| Avg. Area [cm ²] | 4.00 |
| Avg. Type | Circular Averaging |
| psPDn+ [W/m ²] | 55.8 |
| psPDtot+ [W/m ²] | 56.1 |
| psPDmod+ [W/m ²] | 56.4 |
| Max(Sn) [W/m ²] | 61.7 |
| Max(Stot) [W/m ²] | 61.8 |
| Max(Stot) [W/m ²] | 62.0 |
| E _{max} [V/m] | 156 |
| Power Drift [dB] | -0.02 |



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|-------------------------------|-----------------------|----------|----------|
| 5G Verification Source 10 GHz | 100.0 x 100.0 x 172.0 | SN: 1004 | - |

Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|-----------------|------------------------------|-----------------|--------|---------------------------------|-------------------|
| 5G - | 10.0 mm | Validation band | CW | 10000.0, 10000 | 1.0 |

Hardware Setup

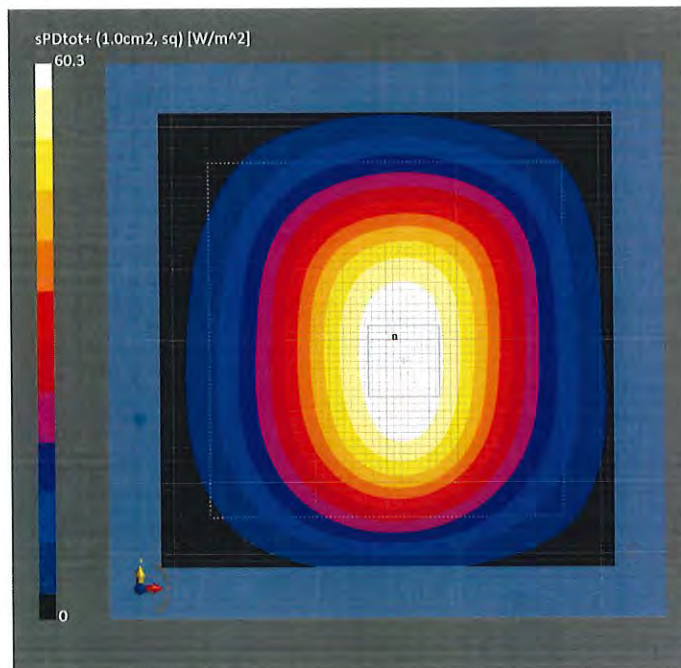
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|-----------------------|--------|---------------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

Scan Setup

| Sensor Surface [mm] | 5G Scan |
|---------------------|-----------------------|
| MAIA | 10.0 MAIA not used |

Measurement Results

| | 5G Scan |
|---------------------------------|-------------------|
| Date | 2023-08-11, 11:52 |
| Avg. Area [cm ²] | 1.00 |
| Avg. Type | Square Averaging |
| psPDn+ [W/m ²] | 60.2 |
| psPDtot+ [W/m ²] | 60.3 |
| psPDmod+ [W/m ²] | 60.5 |
| Max{Sn} [W/m ²] | 61.7 |
| Max{Stot} [W/m ²] | 61.8 |
| Max(Stot) [W/m ²] | 62.0 |
| E _{max} [V/m] | 156 |
| Power Drift [dB] | -0.02 |



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|-------------------------------|-----------------------|----------|----------|
| 5G Verification Source 10 GHz | 100.0 x 100.0 x 172.0 | SN: 1004 | - |

Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|-----------------|------------------------------|-----------------|--------|---------------------------------|-------------------|
| 5G - | 10.0 mm | Validation band | CW | 10000.0, 10000 | 1.0 |

Hardware Setup

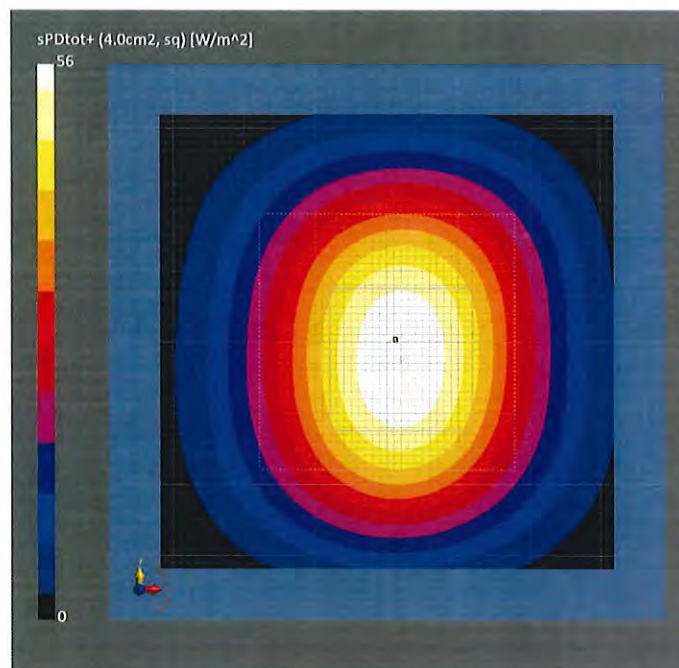
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|-----------------------|--------|---------------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

Scan Setup

| Sensor Surface [mm] | 5G Scan |
|---------------------|-----------------------|
| MAIA | 10.0 MAIA not used |

Measurement Results

| | 5G Scan |
|---------------------------------|-------------------|
| Date | 2023-08-11, 11:52 |
| Avg. Area [cm ²] | 4.00 |
| Avg. Type | Square Averaging |
| psPDn+ [W/m ²] | 55.7 |
| psPDtot+ [W/m ²] | 56.0 |
| psPDmod+ [W/m ²] | 56.3 |
| Max(Sn) [W/m ²] | 61.7 |
| Max(Stot) [W/m ²] | 61.8 |
| Max(Stot) [W/m ²] | 62.0 |
| E _{max} [V/m] | 156 |
| Power Drift [dB] | -0.02 |





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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **Element**
Columbia, USA

Certificate No. **5G-Veri10-1002_Mar24**

CALIBRATION CERTIFICATE

Object **5G Verification Source 10 GHz - SN: 1002** SPS 03/25/24

Calibration procedure(s) **QA CAL-45.v5**
Calibration procedure for sources in air above 6 GHz

Calibration date: **March 05, 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)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|----------------------------------|----------------|-----------------------------------|------------------------|
| Reference Probe EUmmWV3 | SN: 9374 | 04-Dec-23 (No. EUmm-9374_Dec23) | Dec-24 |
| DAE4ip | SN: 1602 | 08-Nov-23 (No. DAE4ip-1602_Nov23) | Nov-24 |
| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
| RF generator R&S SMF100A | SN: 100184 | 29-Nov-23 (in house check Nov-23) | In house check: Nov-24 |
| Power sensor R&S NRP18S-10 | SN: 101258 | 29-Nov-23 (in house check Nov-23) | In house check: Nov-24 |
| Network Analyzer Keysight E5063A | SN: MY54504221 | 31-Oct-19 (in house check Oct-22) | In house check: Oct-25 |

| | | | |
|----------------|----------------------|-----------------------------------|---------------|
| Calibrated by: | Name Leif Klysner | Function Laboratory Technician | Signature |
| Approved by: | Sven Kühn | Technical Manager | |

Issued: March 7, 2024

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



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Glossary

CW Continuous wave

Calibration is Performed According to the Following Standards

- Internal procedure QA CAL-45, Calibration procedure for sources in air above 6 GHz.
- IEC/IEEE 63195-1, "Assessment of power density of human exposure to radio frequency fields from wireless devices in close proximity to the head and body (frequency range of 6 GHz to 300 GHz)", May 2022

Methods Applied and Interpretation of Parameters

- *Coordinate System:* z-axis in the waveguide horn boresight, x-axis is in the direction of the E-field, y-axis normal to the others in the field scanning plane parallel to the horn flare and horn flange.
- *Measurement Conditions:* (1) 10 GHz: The radiated power is the forward power to the horn antenna minus ohmic and mismatch loss. The forward power is measured prior and after the measurement with a power sensor. During the measurements, the horn is directly connected to the cable and the antenna ohmic and mismatch losses are determined by far-field measurements. (2) 30, 45, 60 and 90 GHz: The verification sources are switched on for at least 30 minutes. Absorbers are used around the probe cub and at the ceiling to minimize reflections.
- *Horn Positioning:* The waveguide horn is mounted vertically on the flange of the waveguide source to allow vertical positioning of the EUmmW probe during the scan. The plane is parallel to the phantom surface. Probe distance is verified using mechanical gauges positioned on the flare of the horn.
- *E- field distribution:* E field is measured in two x-y-plane (10mm, 10mm + $\lambda/4$) with a vectorial E-field probe. The E-field value stated as calibration value represents the E-field-maxima and the averaged (1cm² and 4cm²) power density values at 10mm in front of the horn.
- *Field polarization:* Above the open horn, linear polarization of the field is expected. This is verified graphically in the field representation.

Calibrated Quantity

- Local peak E-field (V/m) and average of peak spatial components of the poynting vector (W/m²) averaged over the surface area of 1 cm² and 4cm² at the nominal operational frequency of the verification source. Both square and circular averaging results are listed.

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 | DASY8 Module mmWave | V3.2 |
| Phantom | 5G Phantom | |
| Distance Horn Aperture - plane | 10 mm | |
| Number of measured planes | 2 (10mm, 10mm + $\lambda/4$) | |
| Frequency | 10 GHz \pm 10 MHz | |

Calibration Parameters, 10 GHz

Circular Averaging

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Avg Power Density Avg (psPDn+, psPDtot+, psPDmod+) (W/m ²) | | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|-------------------|---------------------|
| | | | | 1 cm ² | 4 cm ² | |
| 10 mm | 93.3 | 151 | 1.27 dB | 58.7 | 54.9 | 1.28 dB |

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Power Density psPDn+, psPDtot+, psPDmod+ (W/m ²) | | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|-------------------|---------------------|
| | | | | 1 cm ² | 4 cm ² | |
| 10 mm | 93.3 | 151 | 1.27 dB | 58.5, 58.7, 58.8 | 54.6, 54.9, 55.1 | 1.28 dB |

Square Averaging

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Avg Power Density Avg (psPDn+, psPDtot+, psPDmod+) (W/m ²) | | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|-------------------|---------------------|
| | | | | 1 cm ² | 4 cm ² | |
| 10 mm | 93.3 | 151 | 1.27 dB | 58.7 | 54.8 | 1.28 dB |

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Power Density psPDn+, psPDtot+, psPDmod+ (W/m ²) | | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|-------------------|---------------------|
| | | | | 1 cm ² | 4 cm ² | |
| 10 mm | 93.3 | 151 | 1.27 dB | 58.5, 58.7, 58.8 | 54.5, 54.8, 55.0 | 1.28 dB |

Max Power Density

| Distance Horn Aperture to Measured Plane | <i>Prad</i> ¹ (mW) | Max E-field (V/m) | Uncertainty (k = 2) | Max Power Density Sn, Stot, Stot (W/m ²) | Uncertainty (k = 2) |
|--|-------------------------------|-------------------|---------------------|--|---------------------|
| 10 mm | 93.3 | 151 | 1.27 dB | 59.9, 60.0, 60.2 | 1.28 dB |

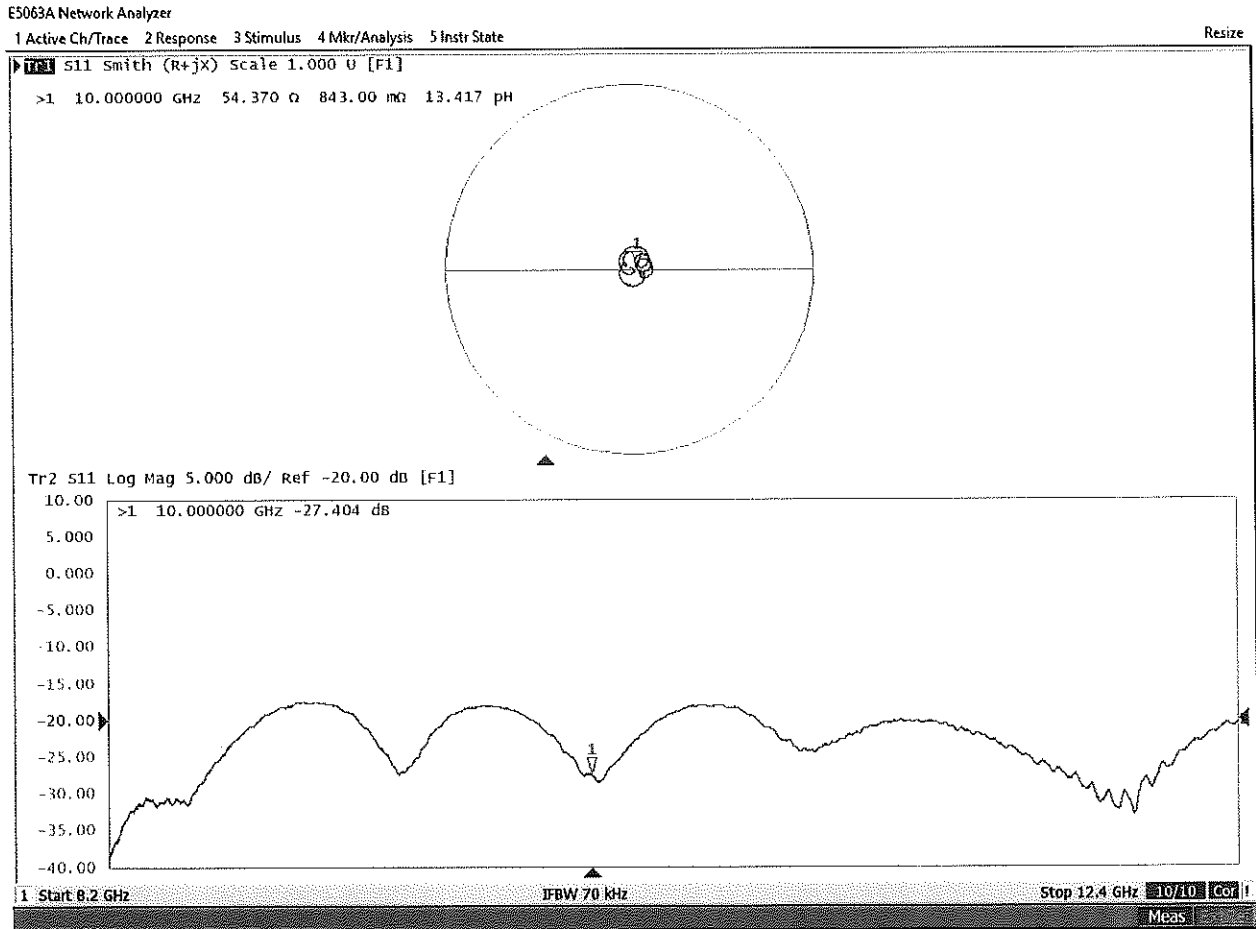
¹ Assessed ohmic and mismatch loss plus numerical offset: 0.30 dB

Appendix (Additional assessments outside the scope of SCS 0108)

Antenna Parameters

| | |
|--------------------------------------|-----------------------------|
| Impedance, transformed to feed point | $54.4 \Omega + 0.8 j\Omega$ |
| Return Loss | - 27.4 dB |

Impedance Measurement Plot



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|-------------------------------|-----------------------|----------|----------|
| 5G Verification Source 10 GHz | 100.0 x 100.0 x 172.0 | SN: 1002 | - |

Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|-----------------|------------------------------|-----------------|--------|---------------------------------|-------------------|
| 5G - | 10.0 mm | Validation band | CW | 10000.0, 10000 | 1.0 |

Hardware Setup

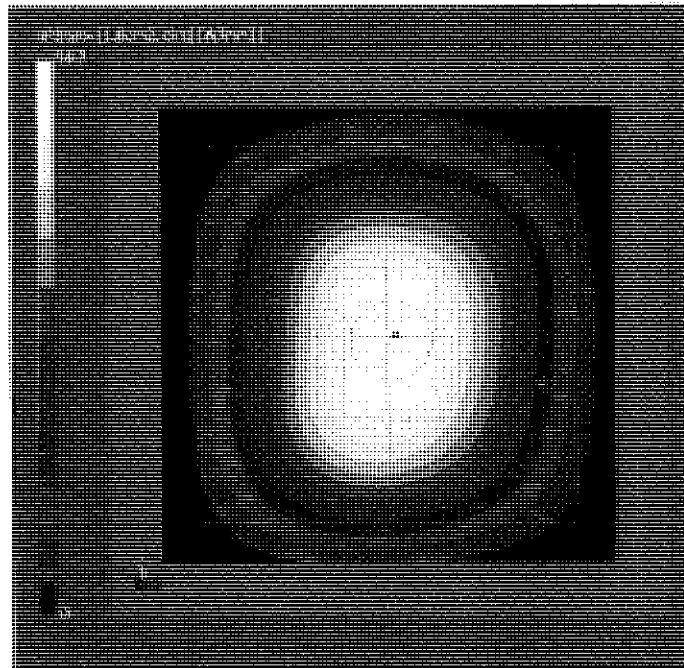
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|-----------------------|--------|---------------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-12-04 | DAE4ip Sn1602, 2023-11-08 |

Scan Setup

| Sensor Surface [mm] | 5G Scan |
|---------------------|-----------------------|
| MAiA | 10.0 MAiA not used |

Measurement Results

| Date | 5G Scan |
|---------------------------------|--------------------|
| 2024-03-05, 10:32 | 2024-03-05, 10:32 |
| Avg. Area [cm ²] | 1.00 |
| Avg. Type | Circular Averaging |
| psPDn+ [W/m ²] | 58.5 |
| psPDtot+ [W/m ²] | 58.7 |
| psPDmod+ [W/m ²] | 58.8 |
| Max(Sn) [W/m ²] | 59.9 |
| Max(Stot) [W/m ²] | 60.0 |
| Max(Stot) [W/m ²] | 60.2 |
| E _{max} [V/m] | 151 |
| Power Drift [dB] | -0.00 |



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|-------------------------------|-----------------------|----------|----------|
| 5G Verification Source 10 GHz | 100.0 x 100.0 x 172.0 | SN: 1002 | - |

Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|-----------------|------------------------------|-----------------|--------|---------------------------------|-------------------|
| 5G - | 10.0 mm | Validation band | CW | 10000.0, 10000 | 1.0 |

Hardware Setup

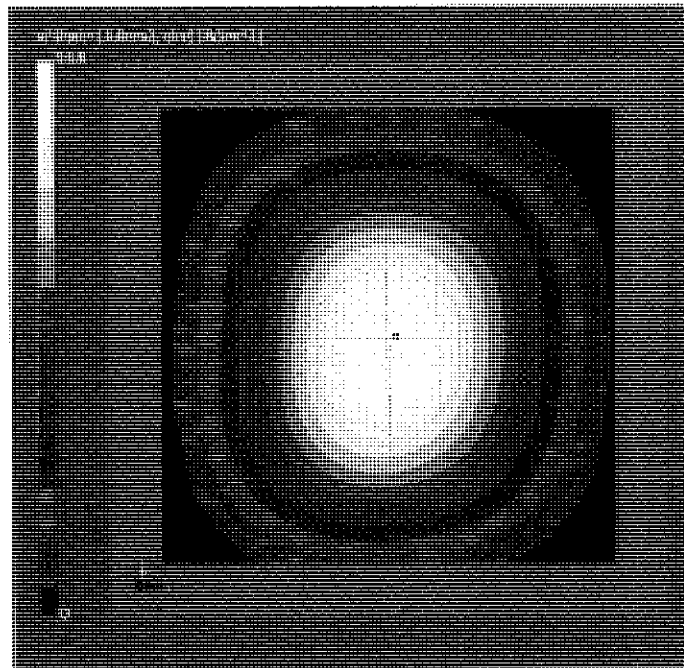
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|-----------------------|--------|---------------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-12-04 | DAE4ip Sn1602, 2023-11-08 |

Scan Setup

| Sensor Surface [mm] | 5G Scan |
|---------------------|-----------------------|
| MAIA | 10.0 MAIA not used |

Measurement Results

| | 5G Scan |
|---------------------------------|--------------------|
| Date | 2024-03-05, 10:32 |
| Avg. Area [cm ²] | 4.00 |
| Avg. Type | Circular Averaging |
| psPDn+ [W/m ²] | 54.6 |
| psPDtot+ [W/m ²] | 54.9 |
| psPDmod+ [W/m ²] | 55.1 |
| Max(Sn) [W/m ²] | 59.9 |
| Max(Stot) [W/m ²] | 60.0 |
| Max(Stot) [W/m ²] | 60.2 |
| E _{max} [V/m] | 151 |
| Power Drift [dB] | -0.00 |



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|-------------------------------|-----------------------|----------|----------|
| 5G Verification Source 10 GHz | 100.0 x 100.0 x 172.0 | SN: 1002 | - |

Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|-----------------|------------------------------|-----------------|--------|---------------------------------|-------------------|
| 5G - | 10.0 mm | Validation band | CW | 10000.0, 10000 | 1.0 |

Hardware Setup

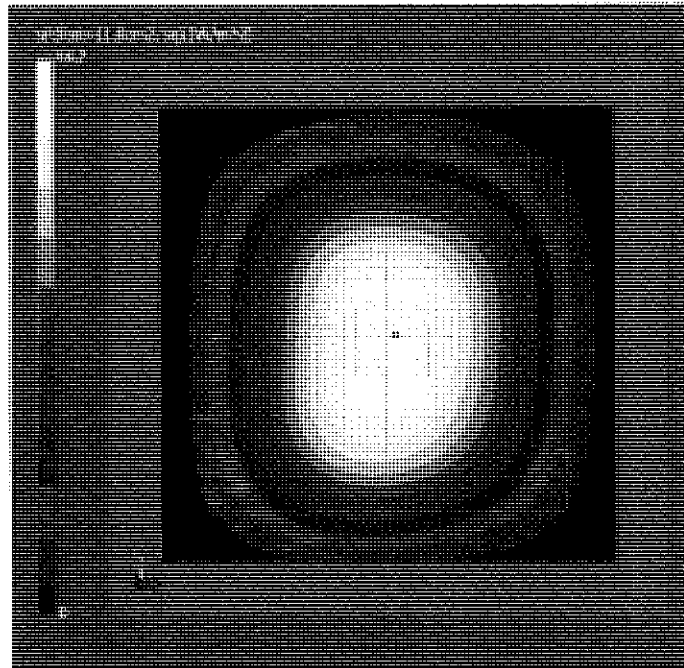
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|-----------------------|--------|---------------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-12-04 | DAE4ip Sn1602, 2023-11-08 |

Scan Setup

| Sensor Surface [mm] | 5G Scan |
|---------------------|-----------------------|
| MAIA | 10.0 MAIA not used |

Measurement Results

| Date | 5G Scan |
|---------------------------------|-------------------|
| 2024-03-05, 10:32 | 2024-03-05, 10:32 |
| Avg. Area [cm ²] | 1.00 |
| Avg. Type | Square Averaging |
| psPDn+ [W/m ²] | 58.5 |
| psPDtot+ [W/m ²] | 58.7 |
| psPDmod+ [W/m ²] | 58.8 |
| Max(Sn) [W/m ²] | 59.9 |
| Max(Stot) [W/m ²] | 60.0 |
| Max(Stot) [W/m ²] | 60.2 |
| E _{max} [V/m] | 151 |
| Power Drift [dB] | -0.00 |



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|-------------------------------|-----------------------|----------|----------|
| 5G Verification Source 10 GHz | 100.0 x 100.0 x 172.0 | SN: 1002 | - |

Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|-----------------|------------------------------|-----------------|--------|---------------------------------|-------------------|
| 5G - | 10.0 mm | Validation band | CW | 10000.0, 10000 | 1.0 |

Hardware Setup

| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|-----------------------|--------|---------------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-12-04 | DAE4ip Sn1602, 2023-11-08 |

Scan Setup

| Sensor Surface [mm] | 5G Scan |
|---------------------|-----------------------|
| MAIA | 10.0 MAIA not used |

Measurement Results

| Date | 5G Scan |
|---------------------------------|------------------|
| 2024-03-05, 10:32 | |
| Avg. Area [cm ²] | 4.00 |
| Avg. Type | Square Averaging |
| psPDn+ [W/m ²] | 54.5 |
| psPDtot+ [W/m ²] | 54.8 |
| psPDmod+ [W/m ²] | 55.0 |
| Max(Sn) [W/m ²] | 59.9 |
| Max(Stot) [W/m ²] | 60.0 |
| Max({Stot}) [W/m ²] | 60.2 |
| E _{max} [V/m] | 151 |
| Power Drift [dB] | -0.00 |

