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

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

Accredited by the Swiss Accreditation Service (SAS)
**Accreditation No.: SCS 0108**

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

**Client** UL
Fremont, USA

**Certificate No.** D1900V2-5d140_Apr23

# CALIBRATION CERTIFICATE

Object: D1900V2 - SN:5d140

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

Calibration date: April 14, 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: BH9394 (20k) | 30-Mar-23 (No. 217-03809) | Mar-24 |
| Type-N mismatch combination | SN: 310982 / 06327 | 30-Mar-23 (No. 217-03810) | Mar-24 |
| Reference Probe EX3DV4 | SN: 7349 | 10-Jan-23 (No. EX3-7349_Jan23) | Jan-24 |
| DAE4 | SN: 601 | 19-Dec-22 (No. DAE4-601_Dec22) | Dec-23 |

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

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

Issued: April 21, 2023

## 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** | 1900 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 40.0 | 1.40 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 38.9 ± 6 % | 1.39 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 | 9.88 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **39.4 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 cm³ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 5.16 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **20.6 W/kg ± 16.5 % (k=2)** |

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

### Antenna Parameters with Head TSL

| | |
|---|---|
| Impedance, transformed to feed point | 52.1 Ω + 5.5 jΩ |
| Return Loss | - 24.9 dB |

### General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.204 ns |

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

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

### Additional EUT Data

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

Date: 14.04.2023

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN:5d140**

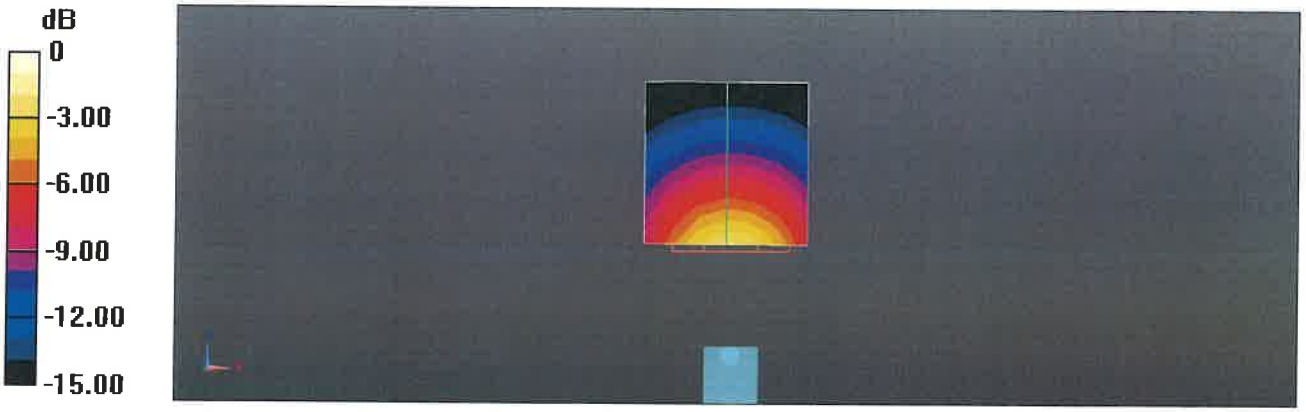
Communication System: UID 0 - CW; Frequency: 1900 MHz
Medium parameters used: f = 1900 MHz; $\sigma$ = 1.39 S/m; $\varepsilon_r$ = 38.9; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(8.35, 8.35, 8.35) @ 1900 MHz; Calibrated: 10.01.2023
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 19.12.2022
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

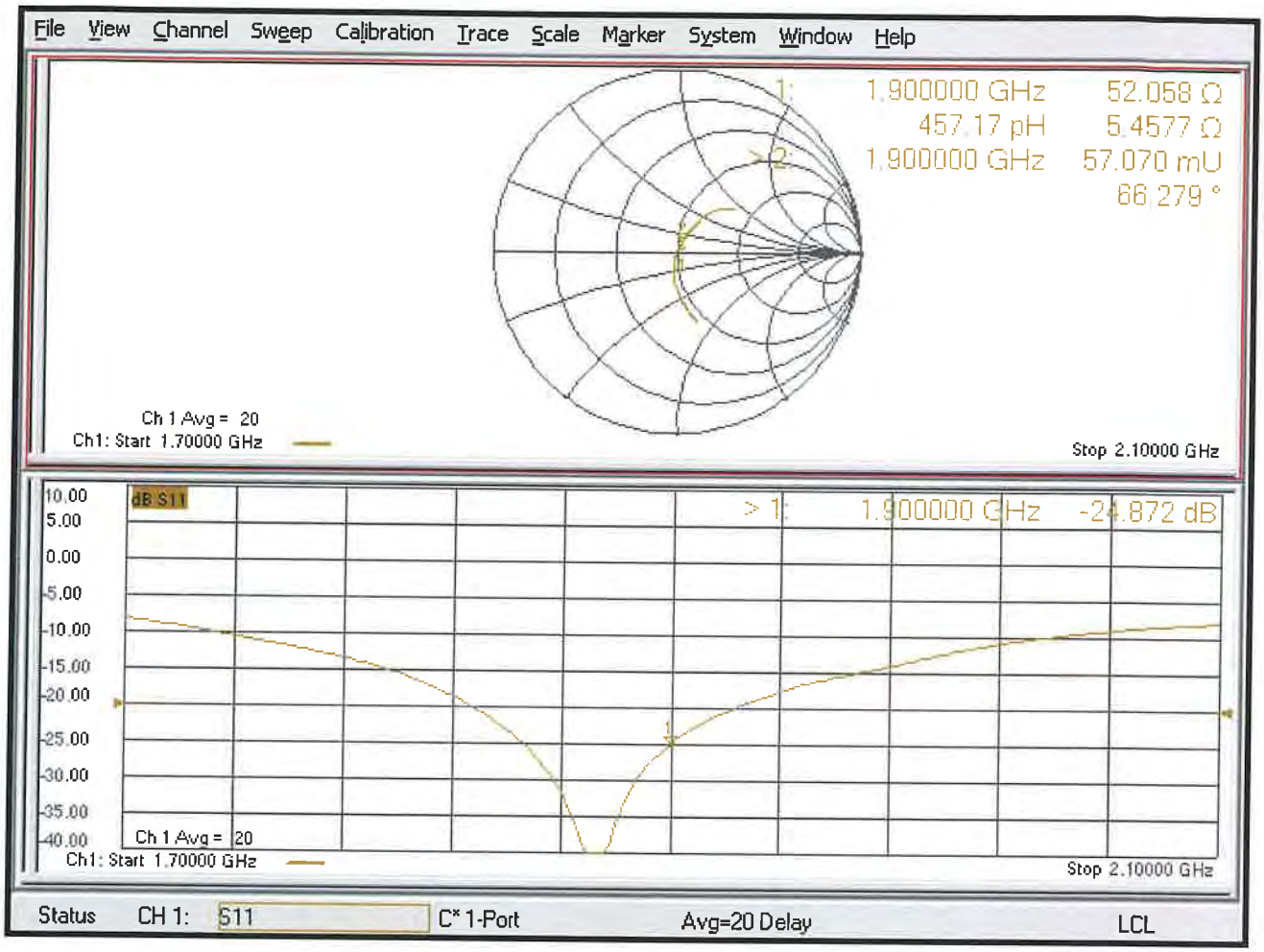
## Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 108.3 V/m; Power Drift = -0.02 dB
Peak SAR (extrapolated) = 18.0 W/kg
**SAR(1 g) = 9.88 W/kg; SAR(10 g) = 5.16 W/kg**
Smallest distance from peaks to all points 3 dB below = 10 mm
Ratio of SAR at M2 to SAR at M1 = 55.2%
Maximum value of SAR (measured) = 15.2 W/kg




0 dB = 15.2 W/kg = 11.81 dBW/kg

## Impedance Measurement Plot for Head TSL



# Dipole Impedance Measurement

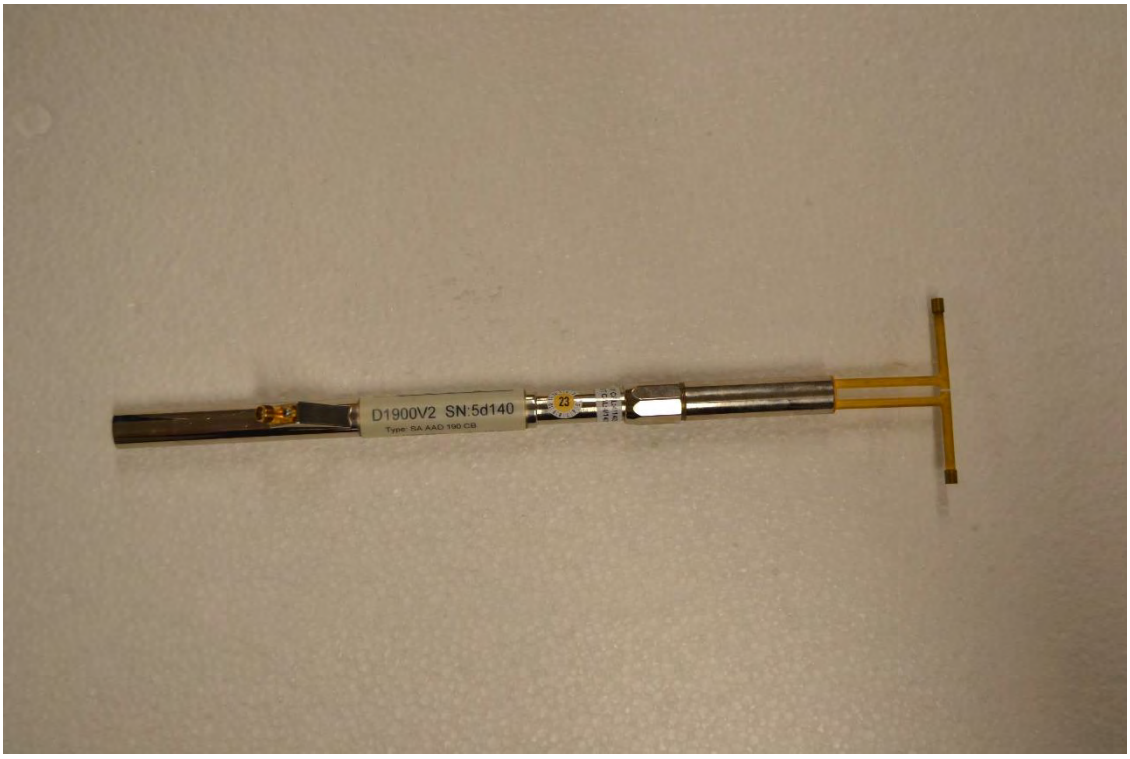
| Equipment Location | Equipment Name | Model Name | Date of Verification |
|---|---|---|---|
| UL Verification Services Inc.<br>47173 Benicia Street<br>Fremont, CA 94538, U.S.A. | Dipole Antenna | D1900V2-5d140 | April 14, 2023 |

| Number: | Check List: | Result: |
|---|---|---|
| 1 | Visual Inspection | Pass |
| 2 | Return/Loss and Impedance | Pass |
| 3 | Dipole Arms | Pass |

| Equipment List: | |
|---|---|
| Equipment Name: | Calibration Date: |
| R&S ZNLE6 Vector Network Analyzer | 03/05/2024 |
| ZV-Z135 Calibration Kit | 03/27/2024 |

# Dipole Impedance Measurement

1) Photo of Dipole




- The connector of dipole contains no abnormalities.

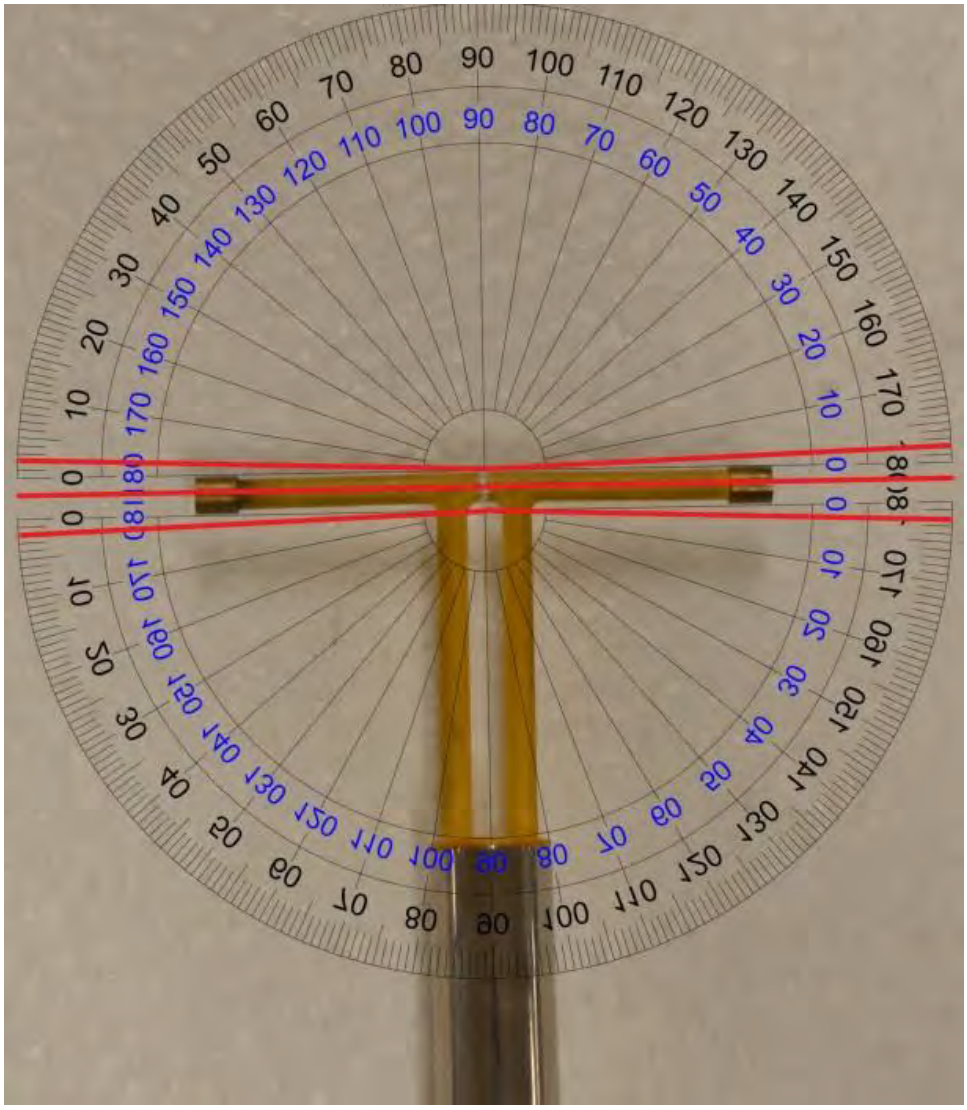
# Dipole Impedance Measurement

2) Impedance and Return/Loss

- Return/Loss is greater than the -20 dB cutoff and Impedance is within 5 Ω of previous value.

# Dipole Impedance Measurement

3) Dipole Arms



- The center red line indicates that the arms of the dipole fall within $\pm 2°$

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**Accreditation No.: SCS 0108**

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**Client** **UL**
**Fremont, USA**

**Certificate No.** **D2300V2-1058_Oct23**

# CALIBRATION CERTIFICATE

Object: D2300V2 - SN:1058

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

Calibration date: October 13, 2023

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

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

Calibration Equipment used (M&TE critical for calibration)

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

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

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

Issued: October 16, 2023

## 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** | 2300 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 39.5 | 1.67 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 38.3 ± 6 % | 1.70 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 | 12.3 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **48.4 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 cm³ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 5.93 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **23.5 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 | 46.8 Ω - 3.5 jΩ |
| Return Loss | - 26.2 dB |

### General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.171 ns |

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

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

### Additional EUT Data

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

Date: 13.10.2023

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2300 MHz; Type: D2300V2; Serial: D2300V2 - SN:1058**

Communication System: UID 0 - CW; Frequency: 2300 MHz
Medium parameters used: f = 2300 MHz; $\sigma$ = 1.7 S/m; $\varepsilon_r$ = 38.3; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

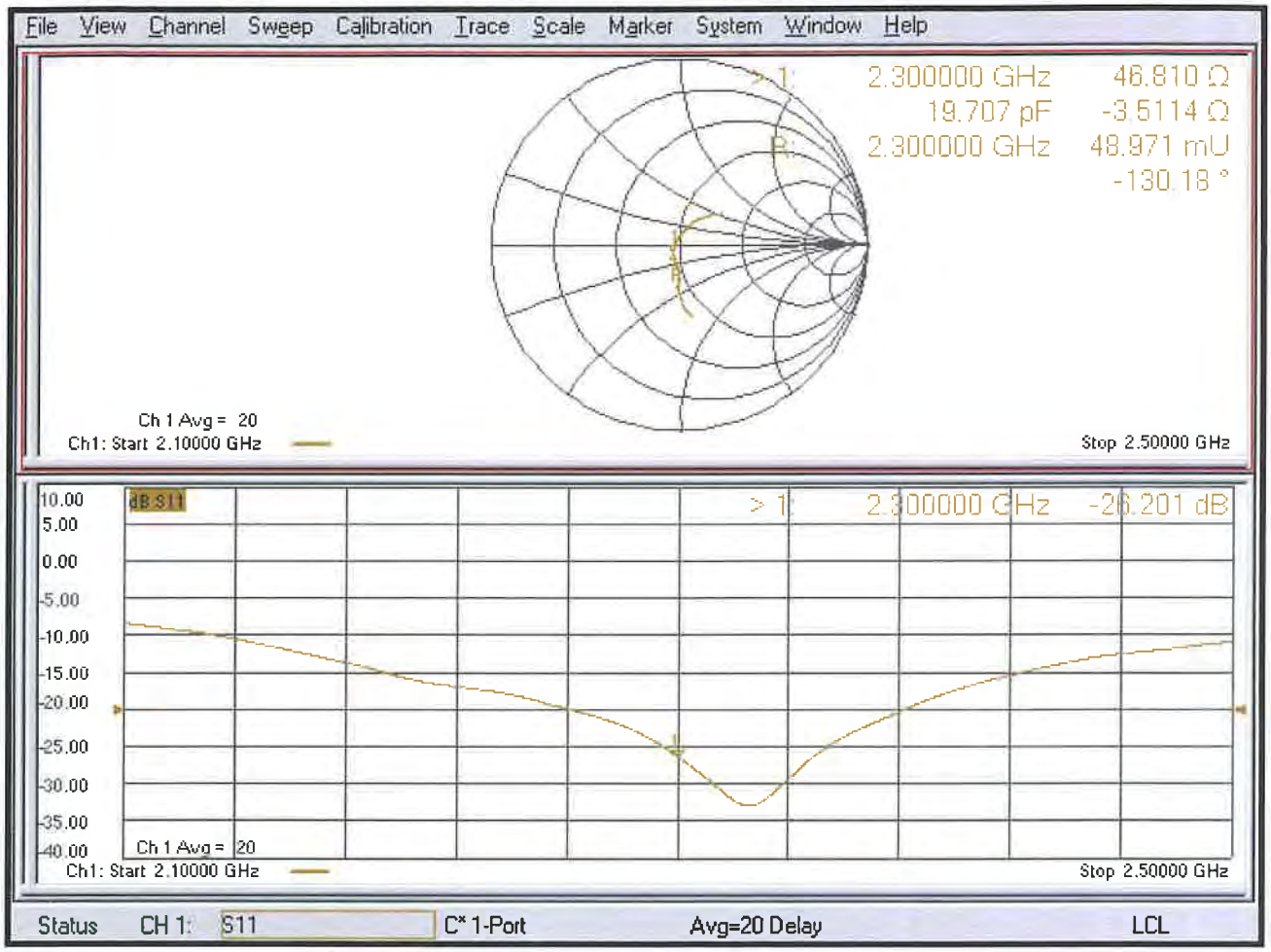
- Probe: EX3DV4 - SN7349; ConvF(7.98, 7.98, 7.98) @ 2300 MHz; Calibrated: 10.01.2023
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 03.10.2023
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

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

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 114.7 V/m; Power Drift = 0.08 dB
Peak SAR (extrapolated) = 22.4 W/kg
**SAR(1 g) = 12.3 W/kg; SAR(10 g) = 5.93 W/kg**
Smallest distance from peaks to all points 3 dB below = 9 mm
Ratio of SAR at M2 to SAR at M1 = 55.8%
Maximum value of SAR (measured) = 18.6 W/kg


0 dB = 18.6 W/kg = 12.68 dBW/kg

## Impedance Measurement Plot for Head TSL



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**S** Swiss Calibration Service

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**Accreditation No.: SCS 0108**

**Client** UL USA

**Certificate No: D2450V2-706_Jan23**

# CALIBRATION CERTIFICATE

Object: D2450V2 - SN:706

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

Calibration date: January 20, 2023

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

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

Calibration Equipment used (M&TE critical for calibration)

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

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

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

Issued: January 20, 2023

**Calibration Laboratory of**
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**C** Service suisse d'étalonnage
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**Accreditation No.: SCS 0108**

## Glossary:

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

## Calibration is Performed According to the Following Standards:

a) IEC/IEEE 62209-1528, "Measurement Procedure For The Assessment Of Specific Absorption Rate Of Human Exposure To Radio Frequency Fields From Hand-Held And Body-Worn Wireless Communication Devices - Part 1528: Human Models, Instrumentation And Procedures (Frequency Range of 4 MHz to 10 GHz)", October 2020.
b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Additional Documentation:

c) DASY System Handbook

## Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The source is mounted in a touch configuration below the center marking of the flat phantom.
- *Return Loss:* This parameter is measured with the source positioned under the liquid filled phantom (as described in the measurement condition clause). The Return Loss ensures low reflected power. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

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

## Measurement Conditions

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

| | | |
|---|---|---|
| **DASY Version** | DASY52 | V52.10.4 |
| **Extrapolation** | Advanced Extrapolation | |
| **Phantom** | Modular Flat Phantom | |
| **Distance Dipole Center - TSL** | 10 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy, dz = 5 mm | |
| **Frequency** | 2450 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 39.2 | 1.80 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 38.7 ± 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 | 13.4 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **52.3 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 cm³ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 6.19 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **24.5 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 | 51.6 Ω + 4.3 jΩ |
| Return Loss | - 26.8 dB |

### General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.142 ns |

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

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

### Additional EUT Data

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

Date: 20.01.2023

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN:706**

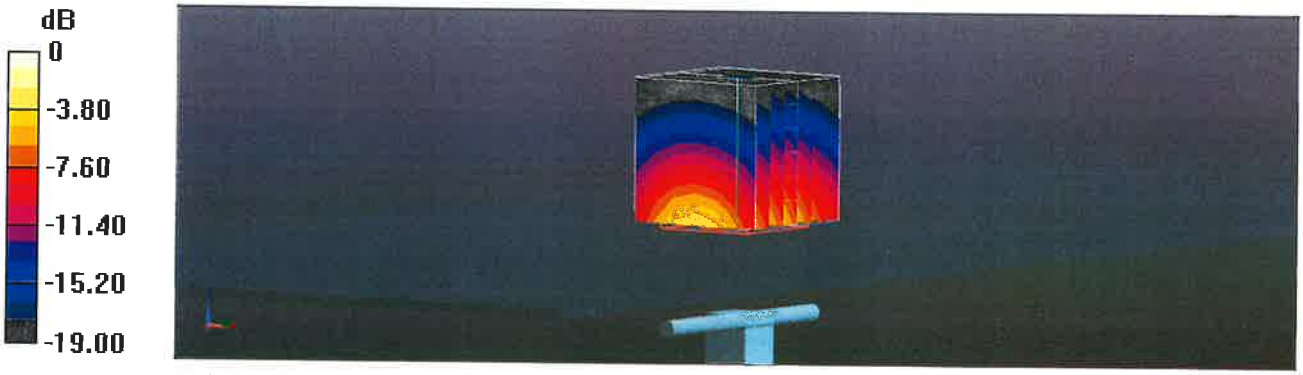
Communication System: UID 0 - CW; Frequency: 2450 MHz
Medium parameters used: f = 2450 MHz; $\sigma$ = 1.87 S/m; $\varepsilon_r$ = 38.7; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(7.96, 7.96, 7.96) @ 2450 MHz; Calibrated: 10.01.2023
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 19.12.2022
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

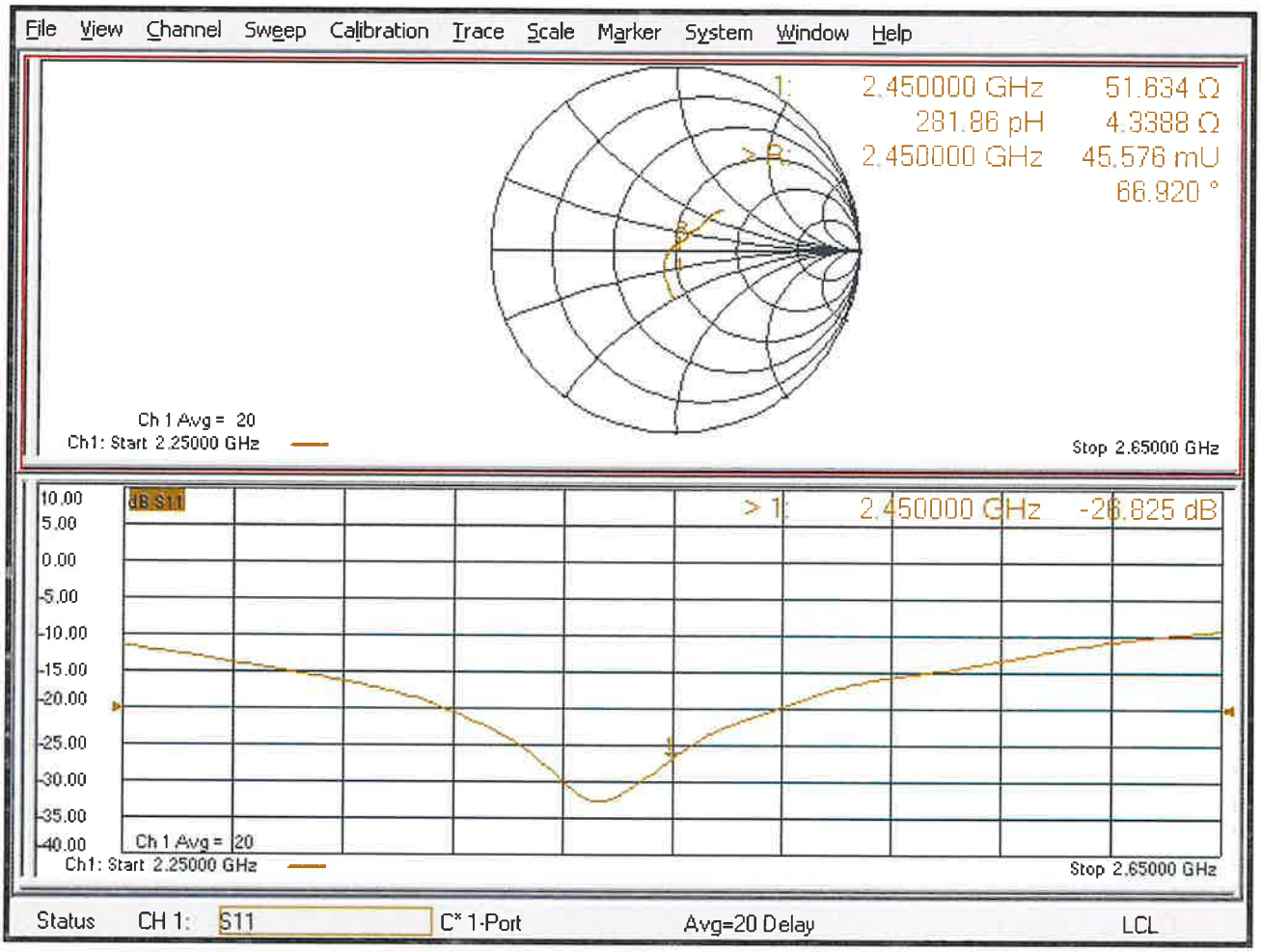
## Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 115.7 V/m; Power Drift = -0.05 dB
Peak SAR (extrapolated) = 26.5 W/kg
**SAR(1 g) = 13.4 W/kg; SAR(10 g) = 6.19 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) = 22.2 W/kg




0 dB = 22.2 W/kg = 13.47 dBW/kg

## Impedance Measurement Plot for Head TSL



# Dipole Impedance Measurement

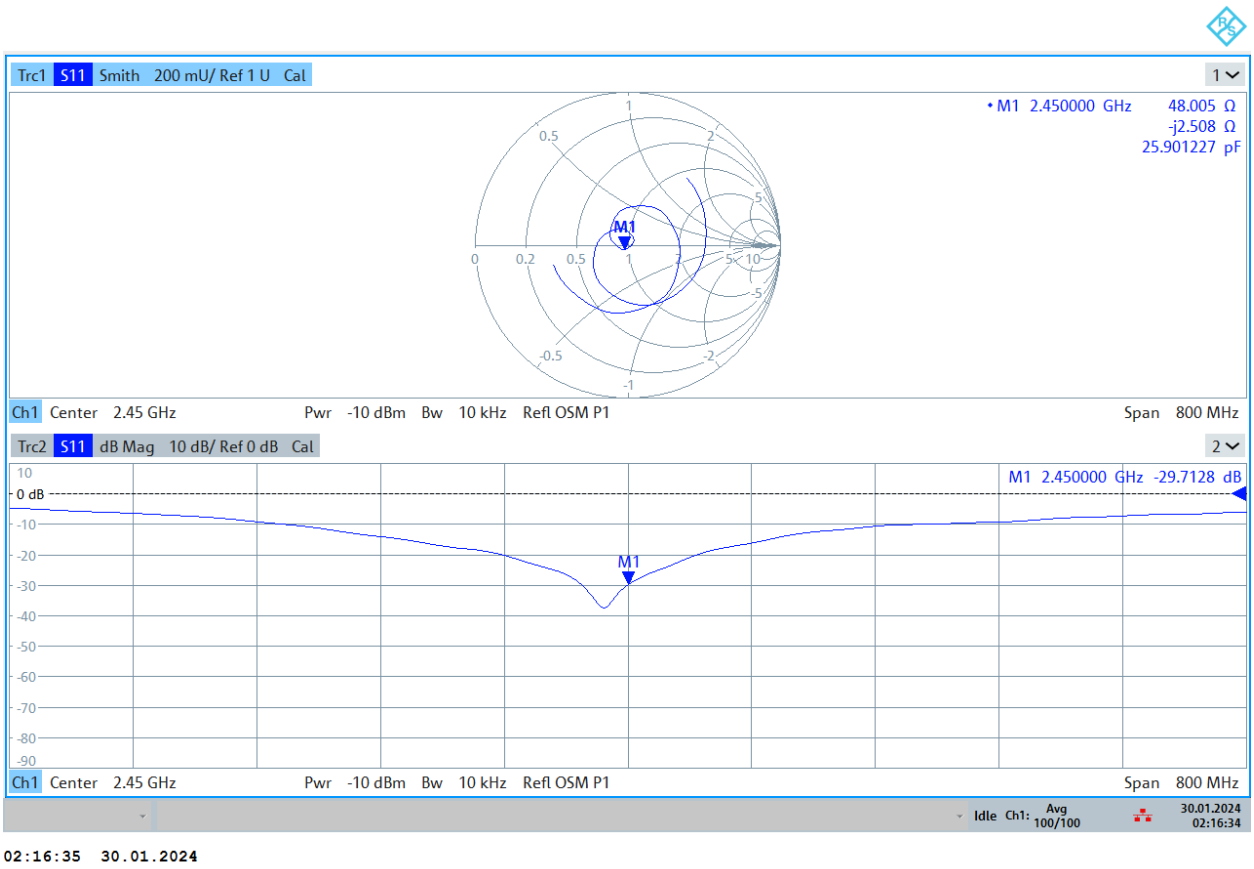
| Equipment Location | Equipment Name | Model Name | Date of Verification |
|---|---|---|---|
| UL Verification Services Inc.<br>47173 Benicia Street<br>Fremont, CA 94538, U.S.A. | Dipole Antenna | D2450V2-706 | January 29, 2024 |

| Number: | Check List: | Result: |
|---|---|---|
| 1 | Return/Loss and Impedance | Pass |
| 2 | Dipole Arms | Pass |

| Equipment List: | |
|---|---|
| Equipment Name: | Calibration Date: |
| R&S ZNLE6 Vector Network Analyzer | 02/28/2025 |
| ZV-Z135 Calibration Kit | 03/31/2024 |

# Dipole Impedance Measurement

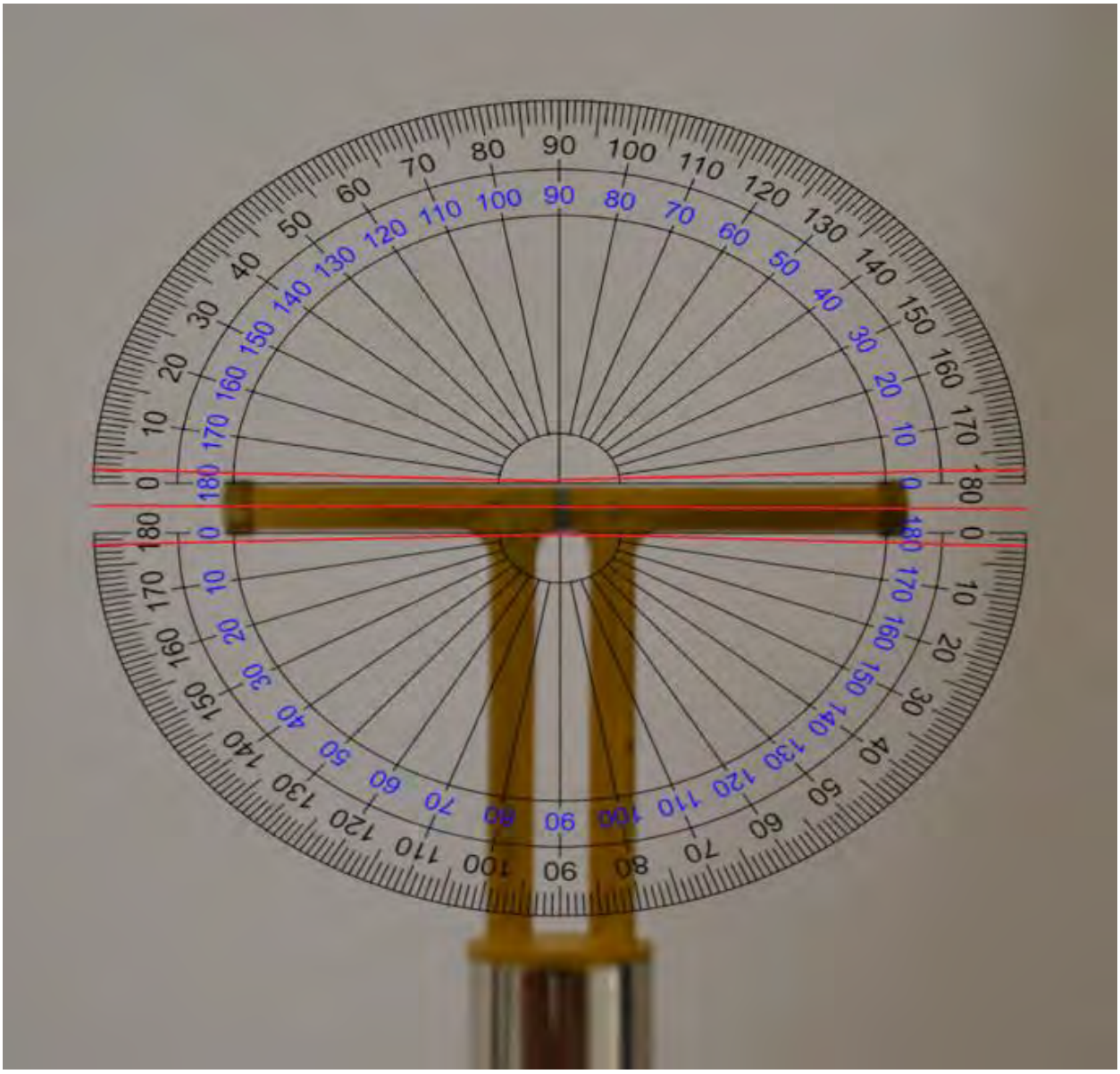
1) Impedance and Return/Loss




- Return/Loss is greater than the -20 dB cutoff and Impedance is within 5 Ω of previous value.

# Dipole Impedance Measurement

2) Dipole Arms



- The center red line indicates that the arms of the dipole fall within $\pm 2°$

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**Accreditation No.: SCS 0108**

**Client** UL USA

**Certificate No: D2450V2-748_Feb23**

# CALIBRATION CERTIFICATE

Object: D2450V2 - SN:748

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

Calibration date: February 08, 2023

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

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

Calibration Equipment used (M&TE critical for calibration)

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

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

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

Issued: February 9, 2023

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**Accreditation No.: SCS 0108**

## Glossary:

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

## Calibration is Performed According to the Following Standards:

a) IEC/IEEE 62209-1528, "Measurement Procedure For The Assessment Of Specific Absorption Rate Of Human Exposure To Radio Frequency Fields From Hand-Held And Body-Worn Wireless Communication Devices - Part 1528: Human Models, Instrumentation And Procedures (Frequency Range of 4 MHz to 10 GHz)", October 2020.
b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Additional Documentation:

c) DASY System Handbook

## Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The source is mounted in a touch configuration below the center marking of the flat phantom.
- *Return Loss:* This parameter is measured with the source positioned under the liquid filled phantom (as described in the measurement condition clause). The Return Loss ensures low reflected power. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

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

## Measurement Conditions

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

| | | |
|---|---|---|
| **DASY Version** | DASY52 | V52.10.4 |
| **Extrapolation** | Advanced Extrapolation | |
| **Phantom** | Modular Flat Phantom | |
| **Distance Dipole Center - TSL** | 10 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy, dz = 5 mm | |
| **Frequency** | 2450 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

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

## SAR result with Head TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 13.1 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **51.7 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 6.08 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **24.2 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 | 54.1 Ω - 0.6 jΩ |
| Return Loss | - 27.9 dB |

### General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.156 ns |

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

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

### Additional EUT Data

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

Date: 08.02.2023

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN:748**

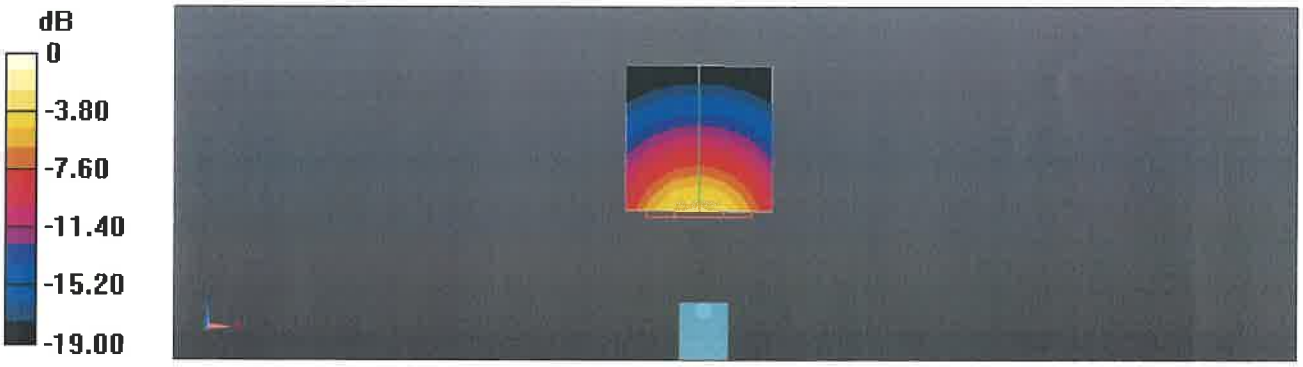
Communication System: UID 0 - CW; Frequency: 2450 MHz
Medium parameters used: f = 2450 MHz; $\sigma$ = 1.85 S/m; $\varepsilon_r$ = 39.3; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

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

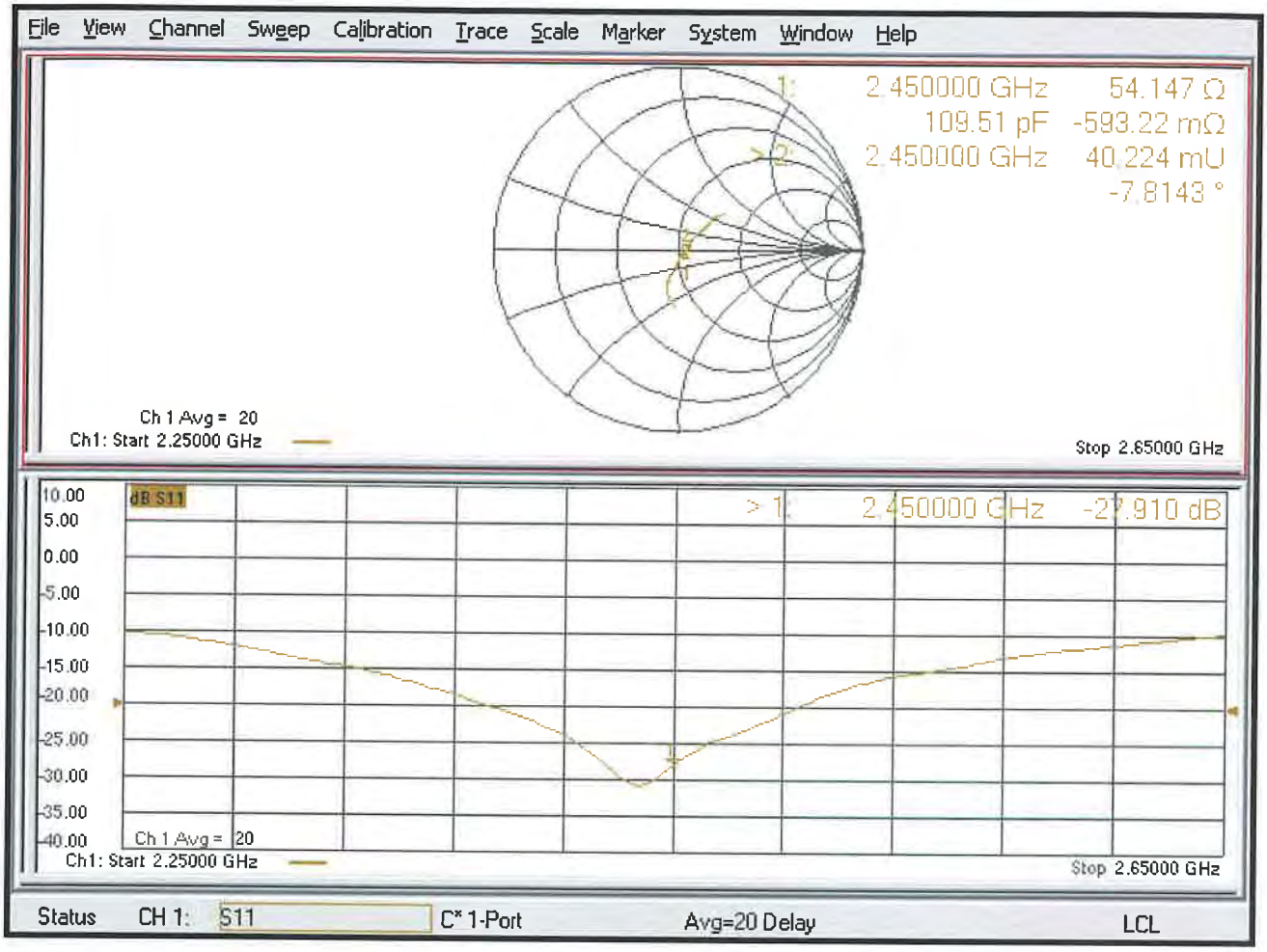
## Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 115.0 V/m; Power Drift = 0.05 dB
Peak SAR (extrapolated) = 26.0 W/kg
**SAR(1 g) = 13.1 W/kg; SAR(10 g) = 6.08 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) = 21.5 W/kg




0 dB = 21.5 W/kg = 13.32 dBW/kg

## Impedance Measurement Plot for Head TSL



# Dipole Impedance Measurement

| Equipment Location | Equipment Name | Model Name | Date of Verification |
|---|---|---|---|
| UL Verification Services Inc.<br>47173 Benicia Street<br>Fremont, CA 94538, U.S.A. | Dipole Antenna | D2450V2-748 | February 08, 2023 |

| Number: | Check List: | Result: |
|---|---|---|
| 1 | Visual Inspection | Pass |
| 2 | Return/Loss and Impedance | Pass |
| 3 | Dipole Arms | Pass |

| Equipment List: | |
|---|---|
| Equipment Name: | Calibration Date: |
| R&S ZNLE6 Vector Network Analyzer | 03/05/2024 |
| ZV-Z135 Calibration Kit | 03/27/2024 |

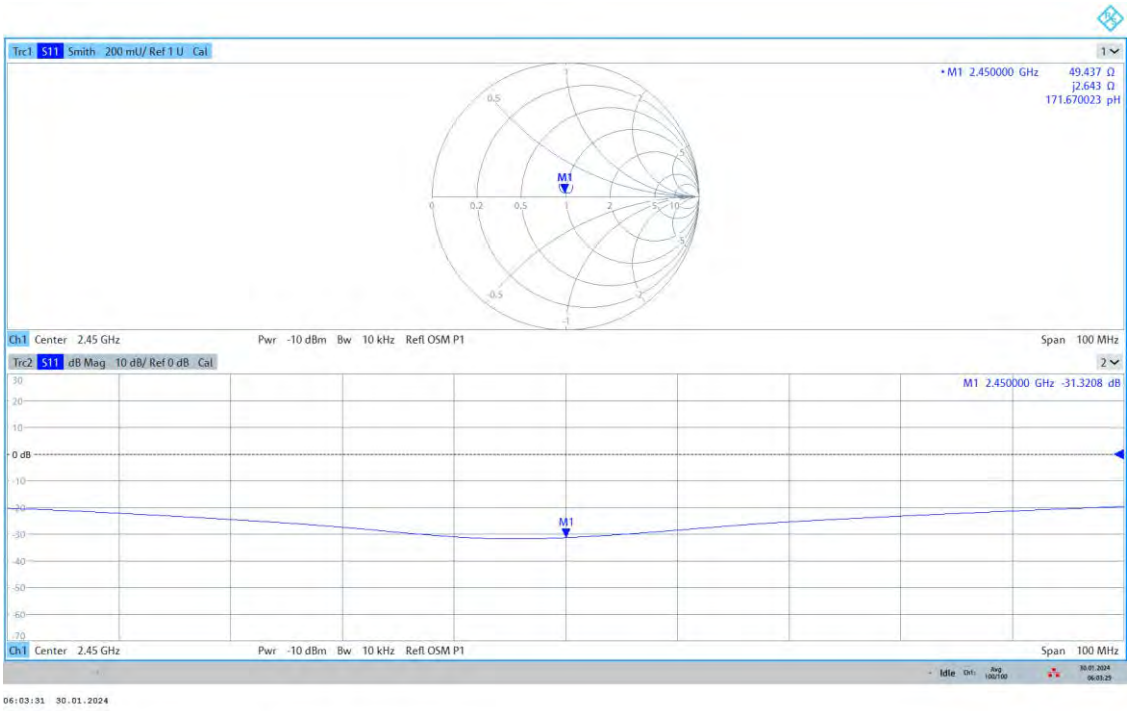
# Dipole Impedance Measurement

1) Photo of Dipole


- The connector of dipole contains no abnormalities.

# Dipole Impedance Measurement

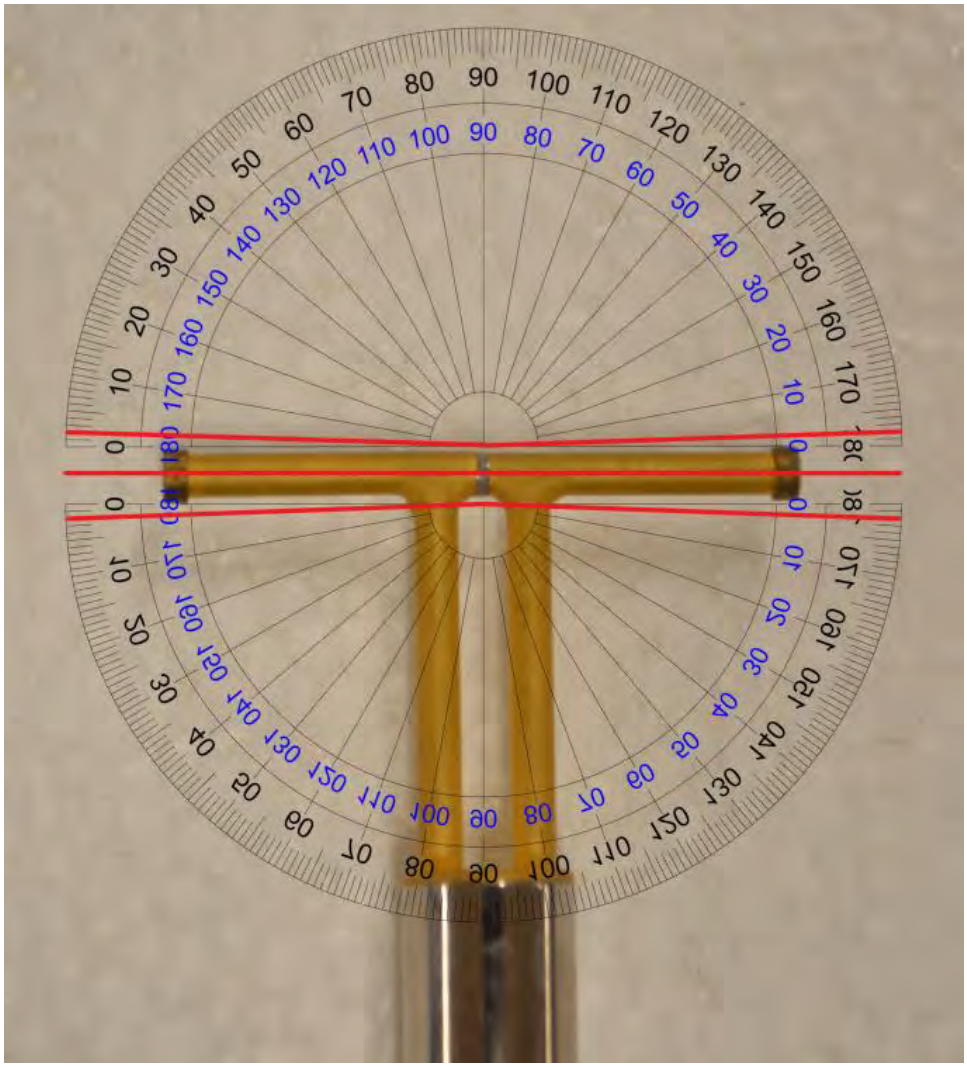
## 2) Impedance and Return/Loss




- Return/Loss is greater than the -20 dB cutoff and Impedance is within 5 Ω of previous value.

# Dipole Impedance Measurement

3) Dipole Arms



- The center red line indicates that the arms of the dipole fall within $\pm 2°$

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**Accreditation No.: SCS 0108**

**Client** UL USA

**Certificate No: D5GHzV2-1003_Feb23**

# CALIBRATION CERTIFICATE

Object: D5GHzV2 - SN:1003

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

Calibration date: February 22, 2023

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter NRP | SN: 104778 | 04-Apr-22 (No. 217-03525/03524) | Apr-23 |
| Power sensor NRP-Z91 | SN: 103244 | 04-Apr-22 (No. 217-03524) | Apr-23 |
| Power sensor NRP-Z91 | SN: 103245 | 04-Apr-22 (No. 217-03525) | Apr-23 |
| Reference 20 dB Attenuator | SN: BH9394 (20k) | 04-Apr-22 (No. 217-03527) | Apr-23 |
| Type-N mismatch combination | SN: 310982 / 06327 | 04-Apr-22 (No. 217-03528) | Apr-23 |
| Reference Probe EX3DV4 | SN: 3503 | 08-Mar-22 (No. EX3-3503_Mar22) | Mar-23 |
| DAE4 | SN: 601 | 19-Dec-22 (No. DAE4-601_Dec22) | Dec-23 |

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

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Paulo Pina | Laboratory Technician | |
| Approved by: | Niels Kuster | Quality Manager | |

Issued: February 22, 2023

## 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 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<br>5600 MHz ± 1 MHz<br>5750 MHz ± 1 MHz<br>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 | 36.0 ± 6 % | 4.67 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 | 8.03 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **80.3 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 cm³ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.29 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **22.9 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 | 35.9 ± 6 % | 5.06 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 | 8.28 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 | 2.36 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **23.7 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 | 35.7 ± 6 % | 5.17 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5750 MHz

| **SAR averaged over 1 cm³ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.92 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **79.3 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 cm³ (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 | **22.4 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 | 35.4 ± 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 cm³ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.13 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **81.3 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 cm³ (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 | **23.1 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 | 48.6 Ω - 5.6 jΩ |
| Return Loss | - 24.7 dB |

### Antenna Parameters with Head TSL at 5600 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 55.3 Ω + 0.9 jΩ |
| Return Loss | - 25.8 dB |

### Antenna Parameters with Head TSL at 5750 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 56.1 Ω - 2.9 jΩ |
| Return Loss | - 24.0 dB |

### Antenna Parameters with Head TSL at 5850 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 60.4 Ω - 3.7 jΩ |
| Return Loss | - 20.1 dB |

### General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.204 ns |

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

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

### Additional EUT Data

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

Date: 22.02.2023

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole D5GHzV2; Type: D5GHzV2; Serial: D5GHzV2 - SN:1003**

Communication System: UID 0 - CW; Frequency: 5250 MHz, Frequency: 5600 MHz, Frequency: 5750 MHz, Frequency: 5850 MHz
Medium parameters used: f = 5250 MHz; $\sigma$ = 4.67 S/m; $\varepsilon_r$ = 36; $\rho$ = 1000 kg/m$^3$

Medium parameters used: f = 5600 MHz; $\sigma$ = 5.06 S/m; $\varepsilon_r$ = 35.9; $\rho$ = 1000 kg/m$^3$

Medium parameters used: f = 5750 MHz; $\sigma$ = 5.17 S/m; $\varepsilon_r$ = 35.7; $\rho$ = 1000 kg/m$^3$

Medium parameters used: f = 5850 MHz; $\sigma$ = 5.25 S/m; $\varepsilon_r$ = 35.4; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

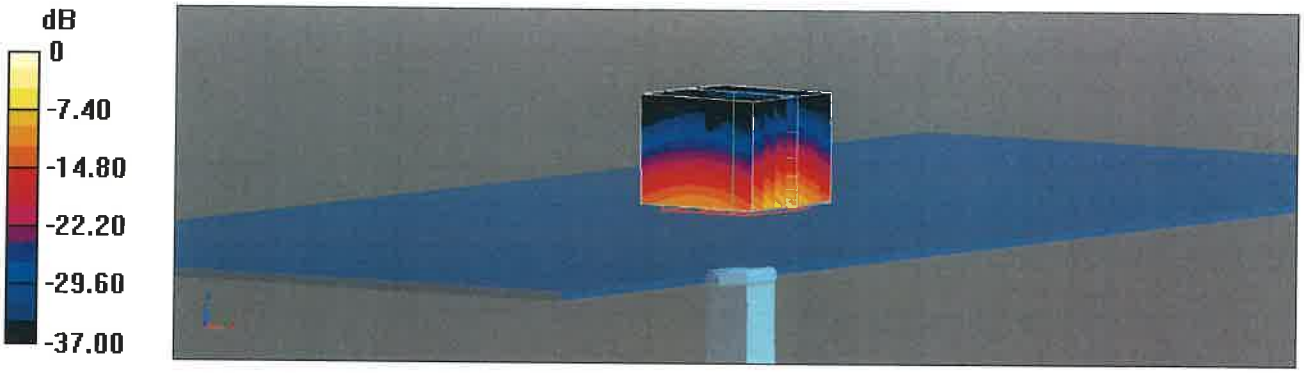
- Probe: EX3DV4 - SN3503; ConvF(5.5, 5.5, 5.5) @ 5250 MHz, ConvF(5.1, 5.1, 5.1) @ 5600 MHz, ConvF(5.08, 5.08, 5.08) @ 5750 MHz, ConvF(4.99, 4.99, 4.99) @ 5850 MHz; Calibrated: 08.03.2022
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 19.12.2022
- Phantom: Flat Phantom 5.0 (front); Type: QD 000 P50 AA; Serial: 1001
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

**Dipole Calibration for Head Tissue/Pin=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 = 75.24 V/m; Power Drift = -0.02 dB
Peak SAR (extrapolated) = 27.1 W/kg
**SAR(1 g) = 8.03 W/kg; SAR(10 g) = 2.29 W/kg**
Smallest distance from peaks to all points 3 dB below = 6.8 mm
Ratio of SAR at M2 to SAR at M1 = 70.7%
Maximum value of SAR (measured) = 17.8 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 = 74.53 V/m; Power Drift = -0.03 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 = 7.2 mm
Ratio of SAR at M2 to SAR at M1 = 67.8%
Maximum value of SAR (measured) = 18.9 W/kg

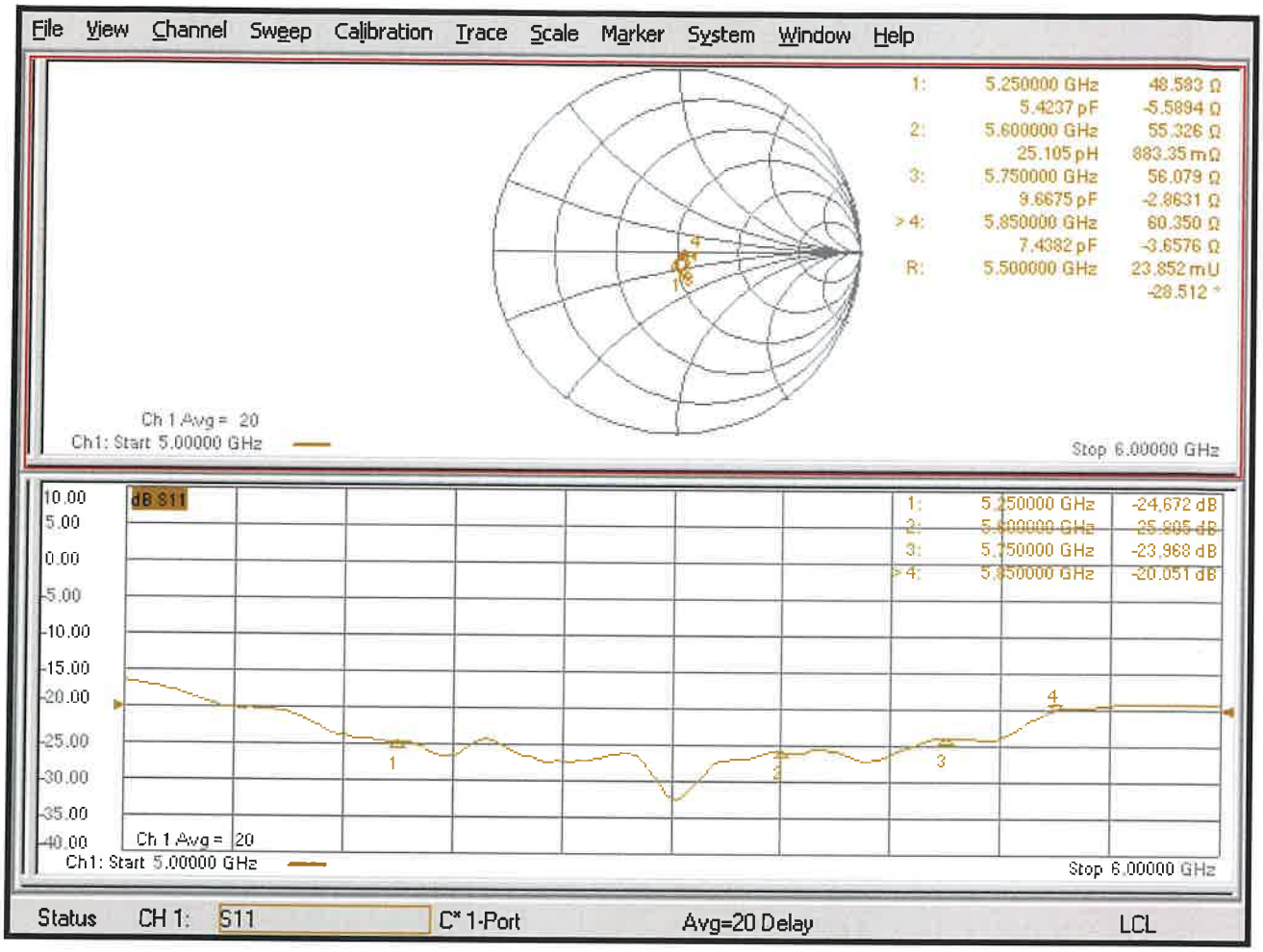
**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5750 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 72.42 V/m; Power Drift = -0.03 dB
Peak SAR (extrapolated) = 30.7 W/kg
**SAR(1 g) = 7.92 W/kg; SAR(10 g) = 2.24 W/kg**
Smallest distance from peaks to all points 3 dB below = 7.2 mm
Ratio of SAR at M2 to SAR at M1 = 66%
Maximum value of SAR (measured) = 18.5 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 = 72.25 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 32.4 W/kg
**SAR(1 g) = 8.13 W/kg; SAR(10 g) = 2.31 W/kg**
Smallest distance from peaks to all points 3 dB below = 7.2 mm
Ratio of SAR at M2 to SAR at M1 = 65.2%
Maximum value of SAR (measured) = 19.1 W/kg




0 dB = 19.1 W/kg = 12.80 dBW/kg

## Impedance Measurement Plot for Head TSL



# Dipole Impedance Measurement

| Equipment Location | Equipment Name | Model Name | Date of Verification |
|---|---|---|---|
| UL Verification Services Inc.<br>47173 Benicia Street<br>Fremont, CA 94538, U.S.A. | Dipole Antenna | D5GHzV2-1003 | February 22, 2023 |

| Number: | Check List: | Result: |
|---|---|---|
| 1 | Visual Inspection | Pass |
| 2 | Return/Loss and Impedance | Pass |
| 3 | Dipole Arms | Pass |

| Equipment List: | |
|---|---|
| Equipment Name: | Calibration Date: |
| R&S ZNLE6 Vector Network Analyzer | 03/05/2024 |
| ZV-Z135 Calibration Kit | 03/27/2024 |

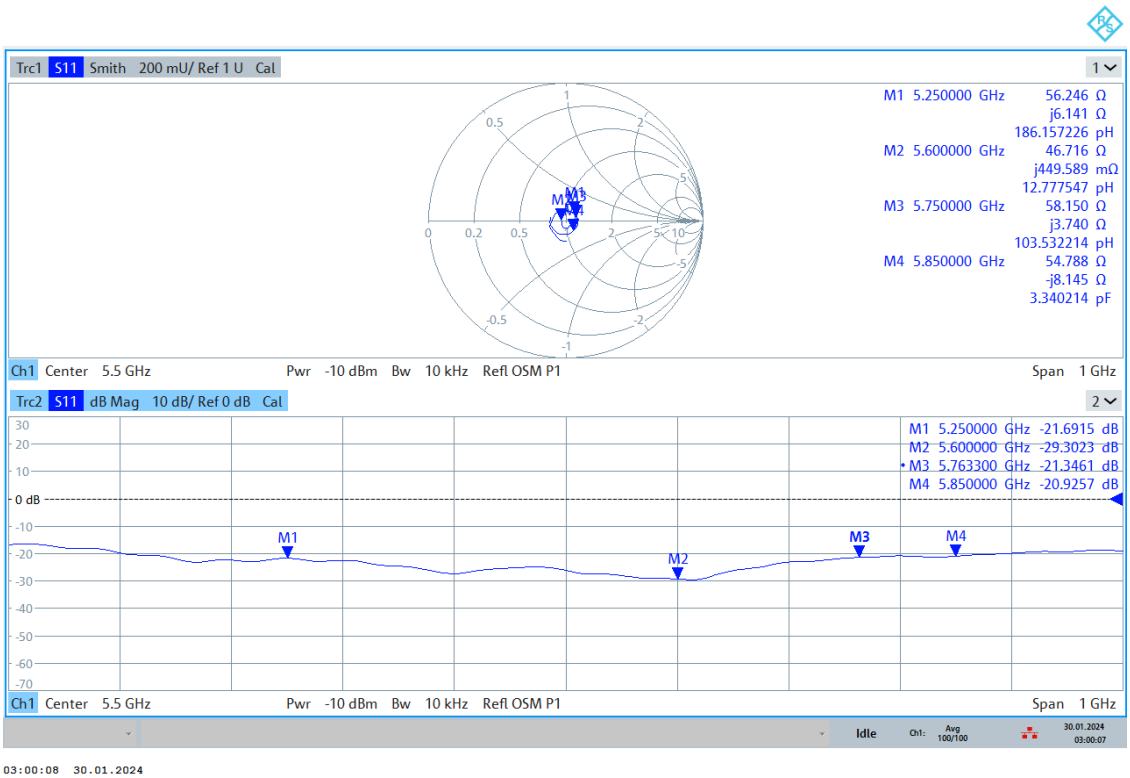
# Dipole Impedance Measurement

1) Photo of Dipole


- The connector of dipole contains no abnormalities.

# Dipole Impedance Measurement

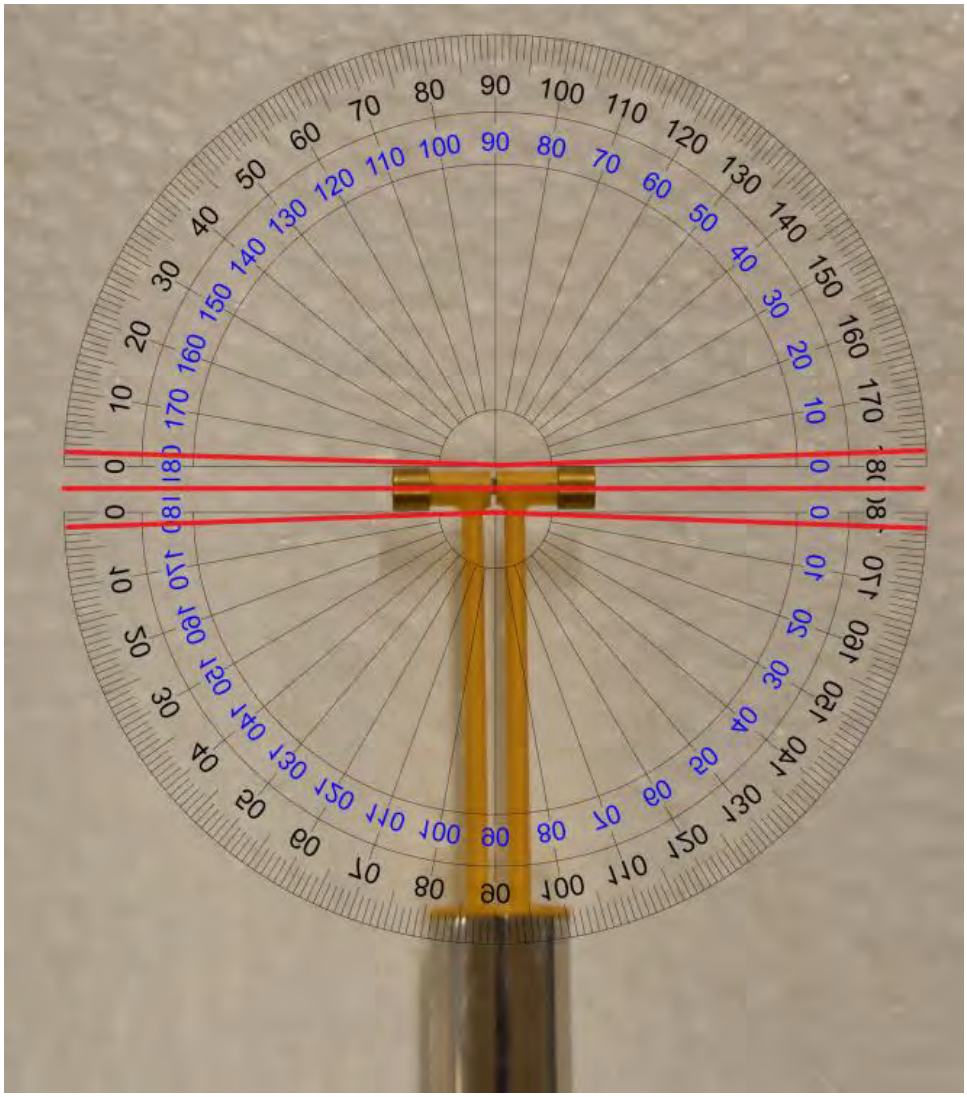
## 2) Impedance and Return/Loss




- Return/Loss is greater than the -20 dB cutoff and Impedance is within 5 Ω of previous value.

# Dipole Impedance Measurement

3) Dipole Arms



- The center red line indicates that the arms of the dipole fall within $\pm 2°$

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

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

Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

**Client** **UL USA**
**Fremont, USA**

**Certificate No: D6.5GHzV2-1033_Mar23**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | D6.5GHzV2 - SN:1033 |
| Calibration procedure(s) | QA CAL-22.v7<br>Calibration Procedure for SAR Validation Sources between 3-10 GHz |
| Calibration date: | March 15, 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 sensor R&S NRP33T | SN: 100967 | 01-Apr-22 (No. 217-03526) | Apr-23 |
| Reference 20 dB Attenuator | SN: BH9394 (20k) | 04-Apr-22 (No. 217-03527) | Apr-23 |
| Mismatch combination | SN: 84224 / 360D | 26-Apr-22 (No. 217-03545) | Apr-23 |
| Reference Probe EX3DV4 | SN: 7405 | 02-Jun-22 (No. EX3-7405_Jun22) | Jun-23 |
| DAE4 | SN: 908 | 27-Jun-22 (No. DAE4-908_Jun22) | Jun-23 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| RF generator Anapico APSIN20G | SN: 827 | 18-Dec-18 (in house check Dec-21) | In house check: Dec-23 |
| Network Analyzer Keysight E5063A | SN:MY54504221 | 31-Oct-19 (in house check Oct-22) | In house check: Oct-25 |

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

Issued: March 16, 2023

## 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 impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *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 ± 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 ± 0.2) °C | 34.3 ± 6 % | 6.02 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 | 100 mW input power | 28.9 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **288 W/kg ± 24.7 % (k=2)** |

| **SAR averaged over 8 cm³ (8 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 6.48 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **64.7 W/kg ± 24.4 % (k=2)** |

| **SAR averaged over 10 cm³ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 5.31 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **53.1 W/kg ± 24.4 % (k=2)** |

## Appendix

### Antenna Parameters with Head TSL

| | |
|---|---|
| Impedance, transformed to feed point | 49.2 Ω - 3.4 jΩ |
| Return Loss | - 29.0 dB |

### APD (Absorbed Power Density)

| **APD averaged over 1 cm²** | Condition | |
|---|---|---|
| APD measured | 100 mW input power | 288 W/m² |
| APD measured | normalized to 1W | **2880 W/m² ± 29.2 % (k=2)** |

| **APD averaged over 4 cm²** | condition | |
|---|---|---|
| APD measured | 100 mW input power | 130 W/m² |
| APD measured | normalized to 1W | **1300 W/m² ± 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-1033, 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: 1033 | - |

**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 | 6.02 | 34.3 |

**Hardware Setup**

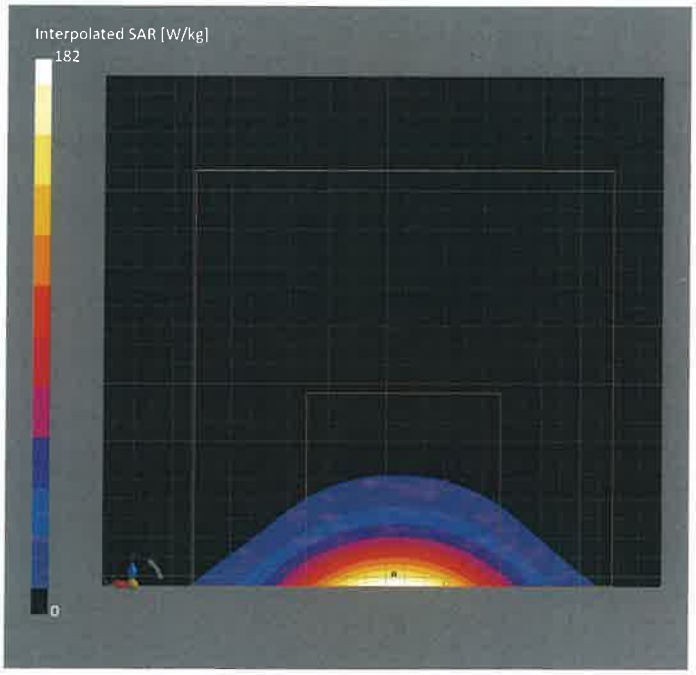
| Phantom | TSL | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| MFP V8.0 Center - 1182 | HBBL600-10000V6 | EX3DV4 - SN7405, 2022-06-02 | DAE4 Sn908, 2022-06-27 |

**Scan Setup**

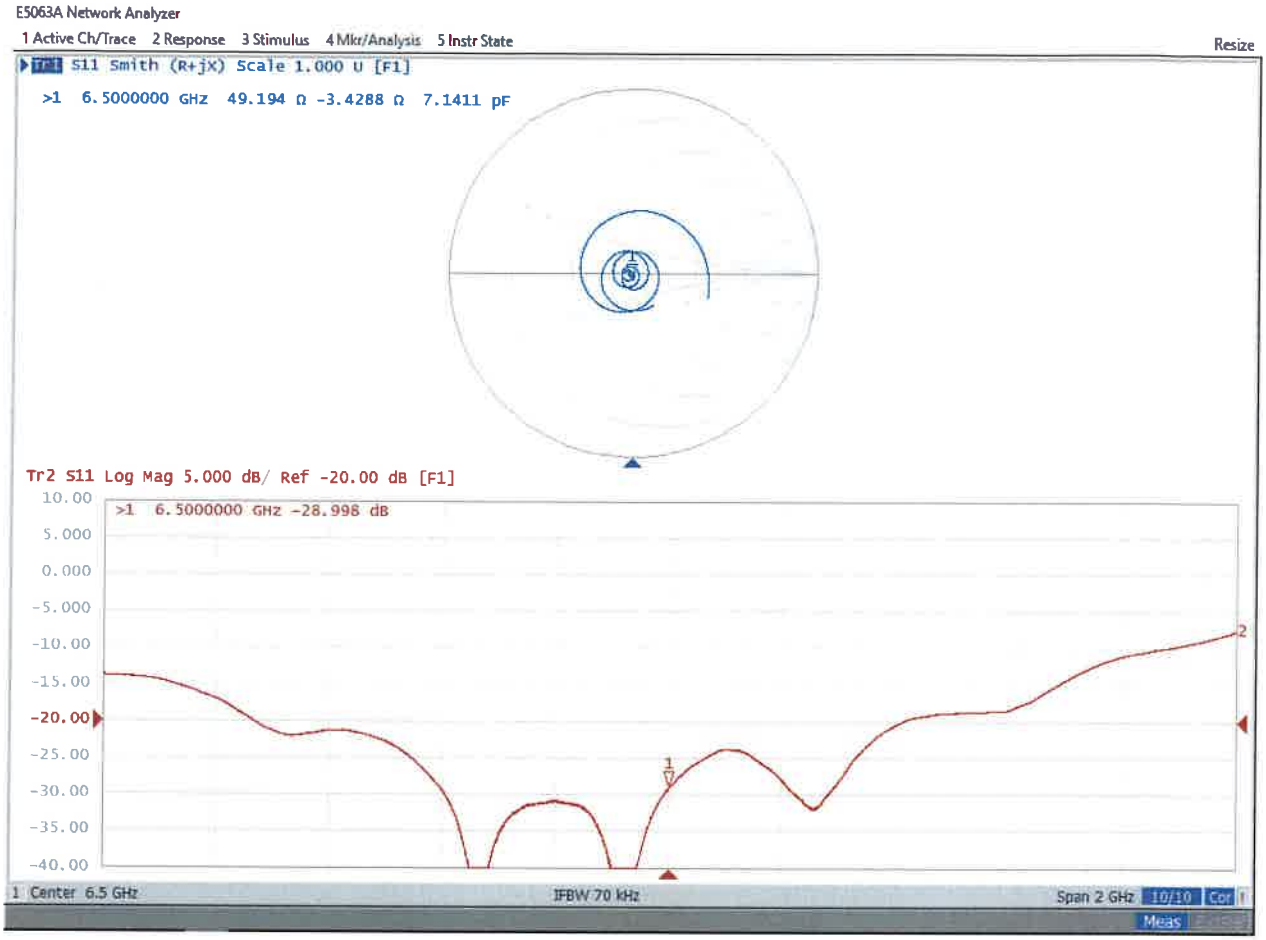
| | Zoom Scan |
|---|---|
| Grid Extents [mm] | 22.0 x 22.0 x 22.0 |
| Grid Steps [mm] | 3.4 x 3.4 x 1.4 |
| Sensor Surface [mm] | 1.4 |
| Graded Grid | Yes |
| Grading Ratio | 1.4 |
| MAIA | N/A |
| Surface Detection | VMS + 6p |
| Scan Method | Measured |

**Measurement Results**

| | Zoom Scan |
|---|---|
| Date | 2023-03-15, 12:39 |
| psSAR1g [W/Kg] | 28.9 |
| psSAR8g [W/Kg] | 6.48 |
| psSAR10g [W/Kg] | 5.31 |
| Power Drift [dB] | 0.01 |
| Power Scaling | Disabled |
| Scaling Factor [dB] | |
| TSL Correction | No correction |
| M2/M1 [%] | 55.2 |
| Dist 3dB Peak [mm] | 4.7 |



## Impedance Measurement Plot for Head TSL



# Dipole Impedance Measurement

| Equipment Location | Equipment Name | Model Name | Date of Verification |
|---|---|---|---|
| UL Verification Services Inc.<br>47173 Benicia Street<br>Fremont, CA 94538, U.S.A. | Dipole Antenna | D6.55GHzV2-1033 | March 15, 2024 |

| Number: | Check List: | Result: |
|---|---|---|
| 1 | Visual Inspection | Pass |
| 2 | Return/Loss and Impedance | Pass |
| 3 | Dipole Arms | Pass |

| Equipment List: | |
|---|---|
| Equipment Name: | Calibration Date: |
| R&S ZNLE6 Vector Network Analyzer | 03/05/2024 |
| ZV-Z135 Calibration Kit | 03/27/2024 |

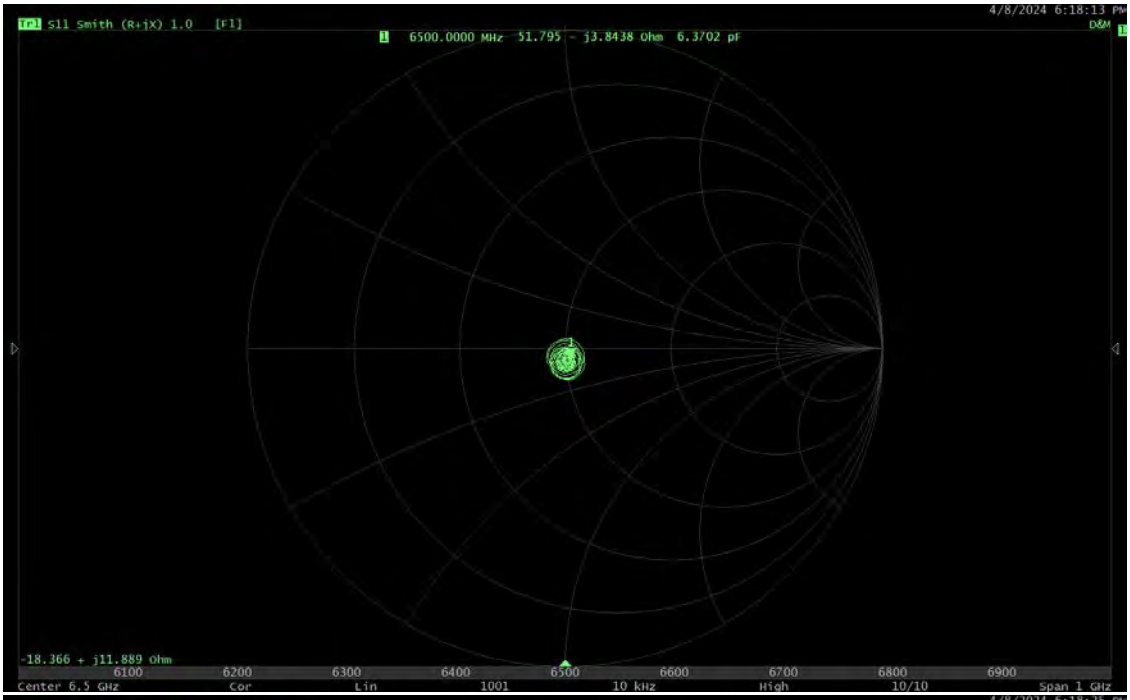
# Dipole Impedance Measurement

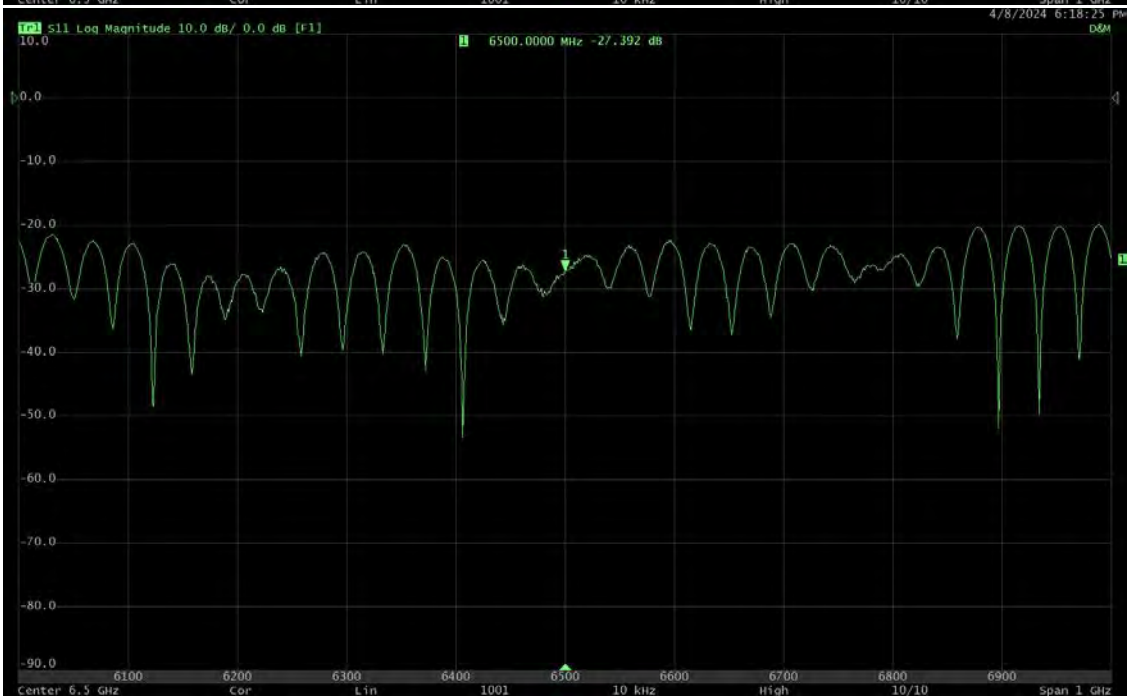
1) Photo of Dipole


- The connector of dipole contains no abnormalities.

# Dipole Impedance Measurement

## 2) Impedance and Return/Loss

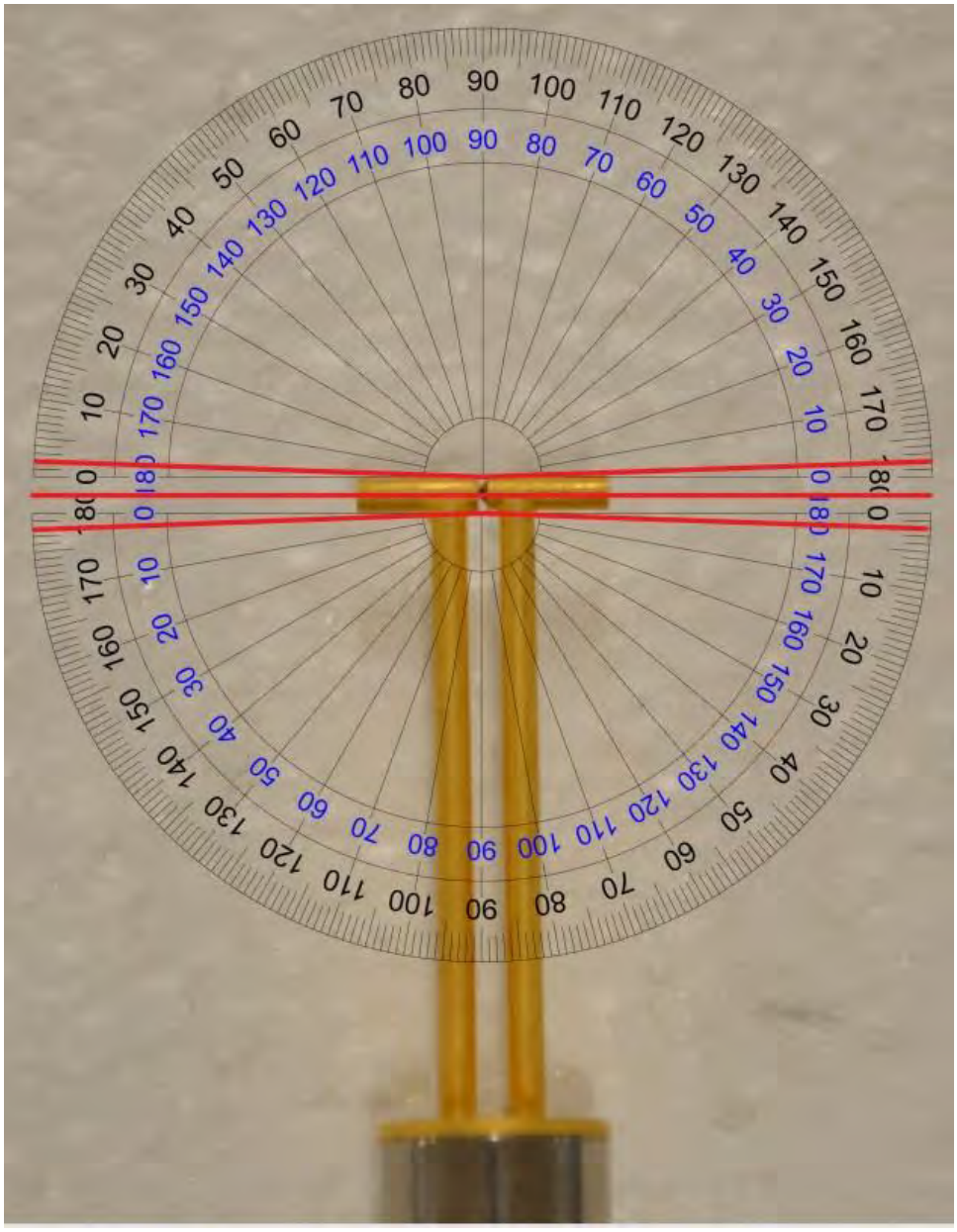



- Return/Loss is greater than the -20 dB cutoff and Impedance is within 5 Ω of previous value.

# Dipole Impedance Measurement

3) Dipole Arms



- The center red line indicates that the arms of the dipole fall within $\pm 2°$

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

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

Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

**Client** **UL**
**Fremont, USA**

**Certificate No.** **5G-Veri10-1015_Sep23**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | 5G Verification Source 10 GHz - SN: 1015 |
| Calibration procedure(s) | QA CAL-45.v4<br>Calibration procedure for sources in air above 6 GHz |
| Calibration date: | September 05, 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 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Joanna Lleshaj | Laboratory Technician | |
| Approved by: | Sven Kühn | Technical Manager | |

Issued: September 8, 2023

## 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 (1cm$^2$ and 4cm$^2$) 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/m$^2$) averaged over the surface area of 1 cm$^2$ and 4cm$^2$ 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 + λ/4) | |
| **Frequency** | 10 GHz ± 10 MHz | |

## Calibration Parameters, 10 GHz

### Circular Averaging

| Distance Horn Aperture to Measured Plane | ***Prad*[1] *(mW)*** | **Max E-field (V/m)** | Uncertainty (k = 2) | Avg Power Density Avg (psPDn+, psPDtot+, psPDmod+) (W/m²) | | Uncertainty (k = 2) |
|---|---|---|---|---|---|---|
| | | | | **1** cm² | **4** cm² | |
| 10 mm | 93.3 | **155** | 1.27 dB | **60.5** | **56.2** | 1.28 dB |

| Distance Horn Aperture to Measured Plane | ***Prad*[1] *(mW)*** | **Max E-field (V/m)** | Uncertainty (k = 2) | Power Density psPDn+, psPDtot+, psPDmod+ (W/m²) | | Uncertainty (k = 2) |
|---|---|---|---|---|---|---|
| | | | | **1** cm² | **4** cm² | |
| 10 mm | 93.3 | **155** | 1.27 dB | **60.3, 60.5, 60.6** | **56.0, 56.2, 56.4** | 1.28 dB |

### Square Averaging

| Distance Horn Aperture to Measured Plane | ***Prad*[1] *(mW)*** | **Max E-field (V/m)** | Uncertainty (k = 2) | Avg Power Density Avg (psPDn+, psPDtot+, psPDmod+) (W/m²) | | Uncertainty (k = 2) |
|---|---|---|---|---|---|---|
| | | | | **1** cm² | **4** cm² | |
| 10 mm | 93.3 | **155** | 1.27 dB | **60.5** | **56.1** | 1.28 dB |

| Distance Horn Aperture to Measured Plane | ***Prad*[1] *(mW)*** | **Max E-field (V/m)** | Uncertainty (k = 2) | Power Density psPDn+, psPDtot+, psPDmod+ (W/m²) | | Uncertainty (k = 2) |
|---|---|---|---|---|---|---|
| | | | | **1** cm² | **4** cm² | |
| 10 mm | 93.3 | **155** | 1.27 dB | **60.4, 60.5, 60.6** | **55.9, 56.1, 56.4** | 1.28 dB |

### Max Power Density

| Distance Horn Aperture to Measured Plane | ***Prad*[1] *(mW)*** | **Max E-field (V/m)** | Uncertainty (k = 2) | Max Power Density Sn, Stot, \|Stot\| (W/m²) | Uncertainty (k = 2) |
|---|---|---|---|---|---|
| 10 mm | 93.3 | **155** | 1.27 dB | **62.1, 62.1, 62.2** | 1.28 dB |

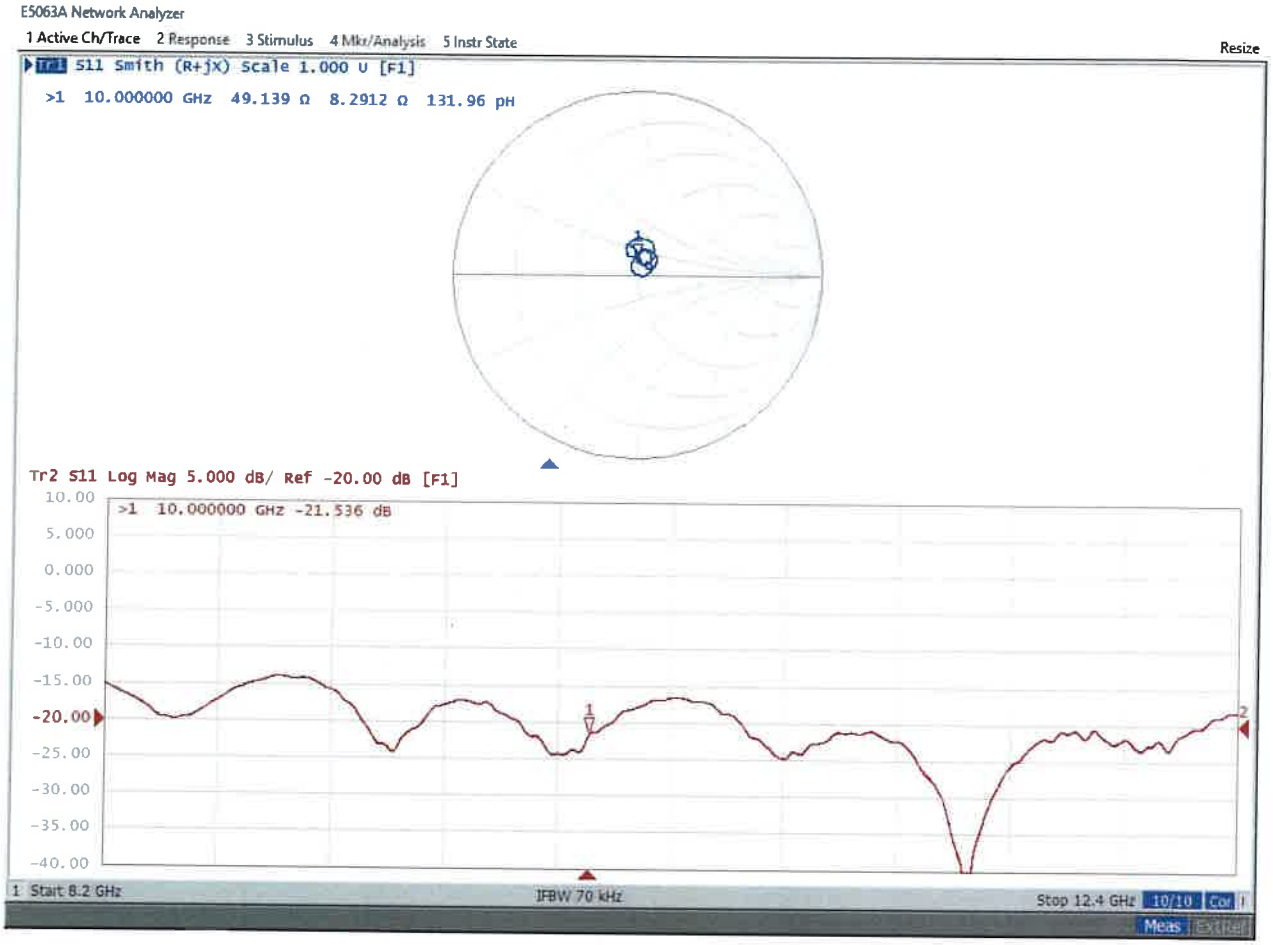
[1] Assessed ohmic and mismatch loss plus numerical offset: 0.30 dB

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

### Antenna Parameters

| | |
|---|---|
| Impedance, transformed to feed point | 49.1 Ω + 8.3 jΩ |
| Return Loss | - 21.5 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: 1015 | - |

### 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

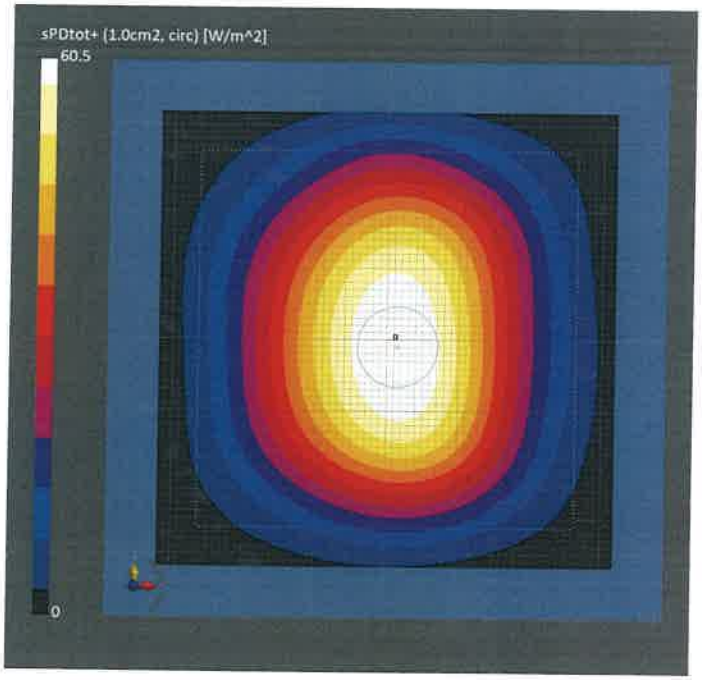
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

### Scan Setup

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

### Measurement Results

| | 5G Scan |
|---|---|
| Date | 2023-09-05, 16:21 |
| Avg. Area [cm²] | 1.00 |
| Avg. Type | Circular Averaging |
| psPDn+ [W/m²] | 60.3 |
| psPDtot+ [W/m²] | 60.5 |
| psPDmod+ [W/m²] | 60.6 |
| Max(Sn) [W/m²] | 62.1 |
| Max(Stot) [W/m²] | 62.1 |
| Max(\|Stot\|) [W/m²] | 62.2 |
| $E_{max}$ [V/m] | 155 |
| Power Drift [dB] | 0.01 |



# 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: 1015 | - |

### 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

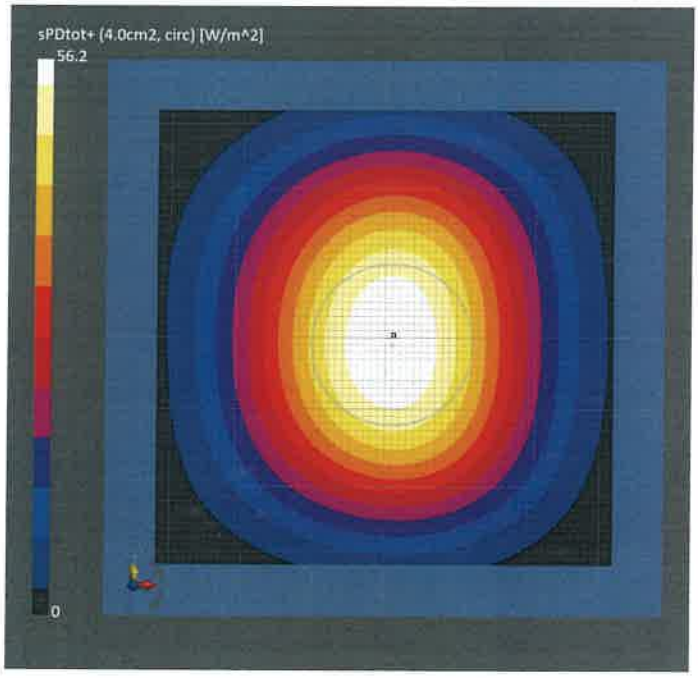
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

### Scan Setup

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

### Measurement Results

| | 5G Scan |
|---|---|
| Date | 2023-09-05, 16:21 |
| Avg. Area [cm²] | 4.00 |
| Avg. Type | Circular Averaging |
| psPDn+ [W/m²] | 56.0 |
| psPDtot+ [W/m²] | 56.2 |
| psPDmod+ [W/m²] | 56.4 |
| Max(Sn) [W/m²] | 62.1 |
| Max(Stot) [W/m²] | 62.1 |
| Max(\|Stot\|) [W/m²] | 62.2 |
| $E_{max}$ [V/m] | 155 |
| Power Drift [dB] | 0.01 |



# 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: 1015 | - |

### 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

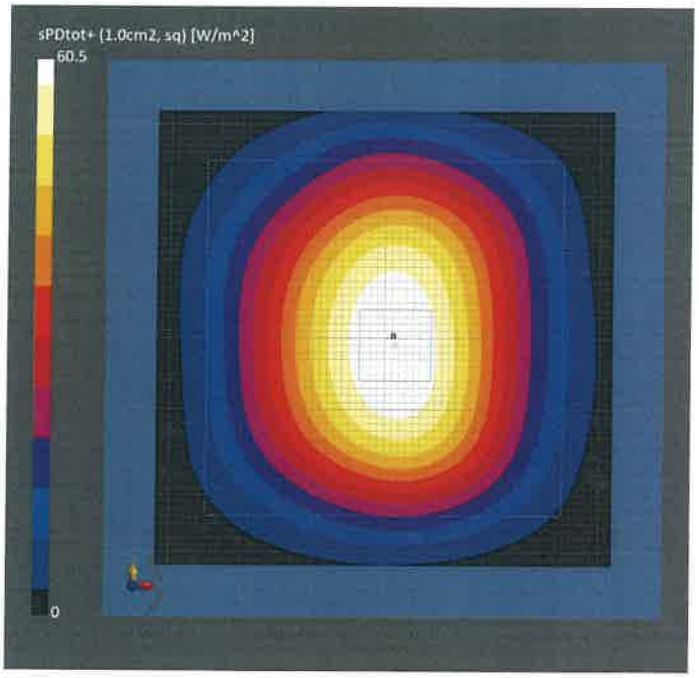
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

### Scan Setup

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

### Measurement Results

| | 5G Scan |
|---|---|
| Date | 2023-09-05, 16:21 |
| Avg. Area [cm²] | 1.00 |
| Avg. Type | Square Averaging |
| psPDn+ [W/m²] | 60.4 |
| psPDtot+ [W/m²] | 60.5 |
| psPDmod+ [W/m²] | 60.6 |
| Max(Sn) [W/m²] | 62.1 |
| Max(Stot) [W/m²] | 62.1 |
| Max(\|Stot\|) [W/m²] | 62.2 |
| $E_{max}$ [V/m] | 155 |
| Power Drift [dB] | 0.01 |



# 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: 1015 | - |

### 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

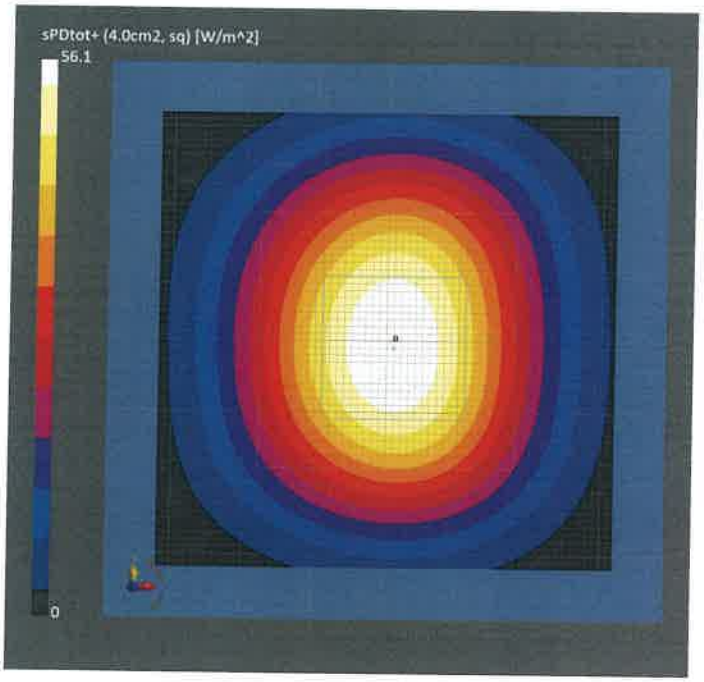
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F1-55GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

### Scan Setup

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

### Measurement Results

| | 5G Scan |
|---|---|
| Date | 2023-09-05, 16:21 |
| Avg. Area [cm²] | 4.00 |
| Avg. Type | Square Averaging |
| psPDn+ [W/m²] | 55.9 |
| psPDtot+ [W/m²] | 56.1 |
| psPDmod+ [W/m²] | 56.4 |
| Max(Sn) [W/m²] | 62.1 |
| Max(Stot) [W/m²] | 62.1 |
| Max(\|Stot\|) [W/m²] | 62.2 |
| $E_{max}$ [V/m] | 155 |
| Power Drift [dB] | 0.01 |



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

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

Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

**Client** **UL**
**Fremont, USA**

**Certificate No.** **5G-Veri30-1117_Sep23**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | 5G Verification Source 30 GHz - SN: 1117 |
| Calibration procedure(s) | QA CAL-45.v4<br>Calibration procedure for sources in air above 6 GHz |
| Calibration date: | September 20, 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 |
|---|---|---|---|
| | | | |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Joanna Lleshaj | Laboratory Technician | |
| Approved by: | Sven Kühn | Technical Manager | |

Issued: September 21, 2023

## 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. 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 (1cm$^2$ and 4cm$^2$) 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/m$^2$) averaged over the surface area of 1 cm$^2$ and 4cm$^2$ 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 + λ/4) | |
| **Frequency** | 30 GHz ± 10 MHz | |

## Calibration Parameters, 30 GHz

### Circular Averaging

| Distance Horn Aperture to Measured Plane | ***Prad*[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 | 74.1 | **201** | 1.27 dB | **92.3** | **80.4** | 1.28 dB |

| Distance Horn Aperture to Measured Plane | ***Prad*[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 | 74.1 | **201** | 1.27 dB | **91.5, 92.6, 92.8** | **79.4, 80.7, 81.0** | 1.28 dB |

### Square Averaging

| Distance Horn Aperture to Measured Plane | ***Prad*[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 | 74.1 | **201** | 1.27 dB | **92.5** | **80.1** | 1.28 dB |

| Distance Horn Aperture to Measured Plane | ***Prad*[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 | 74.1 | **201** | 1.27 dB | **91.7, 92.8, 93.0** | **79.1, 80.5, 80.7** | 1.28 dB |

### Max Power Density

| Distance Horn Aperture to Measured Plane | ***Prad*[1] *(mW)*** | **Max E-field (V/m)** | Uncertainty (k = 2) | Max Power Density Sn, Stot, \|Stot\| ($W/m^2$) | Uncertainty (k = 2) |
|---|---|---|---|---|---|
| 10 mm | 74.1 | **201** | 1.27 dB | **105, 106, 106** | 1.28 dB |

[1] Derived from far-field data

# DASY Report

## Measurement Report for 5G Verification Source 30 GHz, UID 0 -, Channel 30000 (30000.0MHz)

### Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|---|---|---|---|
| 5G Verification Source 30 GHz | 100.0 x 100.0 x 100.0 | SN: 1117 | - |

### Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|---|---|---|---|---|---|
| 5G - | 5.55 mm | Validation band | CW | 30000.0, 30000 | 1.0 |

### Hardware Setup

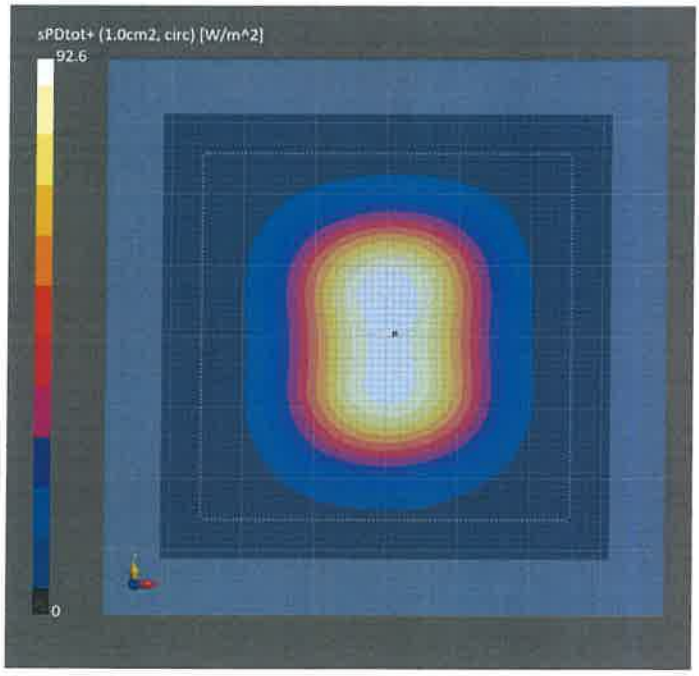
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F30GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

### Scan Setup

| | 5G Scan |
|---|---|
| **Sensor Surface [mm]** | 5.55 |
| **MAIA** | MAIA not used |

### Measurement Results

| | 5G Scan |
|---|---|
| Date | 2023-09-20, 16:02 |
| Avg. Area [cm²] | 1.00 |
| Avg. Type | Circular Averaging |
| psPDn+ [W/m²] | 91.5 |
| psPDtot+ [W/m²] | 92.6 |
| psPDmod+ [W/m²] | 92.8 |
| Max(Sn) [W/m²] | 105 |
| Max(Stot) [W/m²] | 106 |
| Max(\|Stot\|) [W/m²] | 106 |
| $E_{max}$ [V/m] | 201 |
| Power Drift [dB] | -0.04 |



# DASY Report

## Measurement Report for 5G Verification Source 30 GHz, UID 0 -, Channel 30000 (30000.0MHz)

### Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|---|---|---|---|
| 5G Verification Source 30 GHz | 100.0 x 100.0 x 100.0 | SN: 1117 | - |

### Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|---|---|---|---|---|---|
| 5G - | 5.55 mm | Validation band | CW | 30000.0, 30000 | 1.0 |

### Hardware Setup

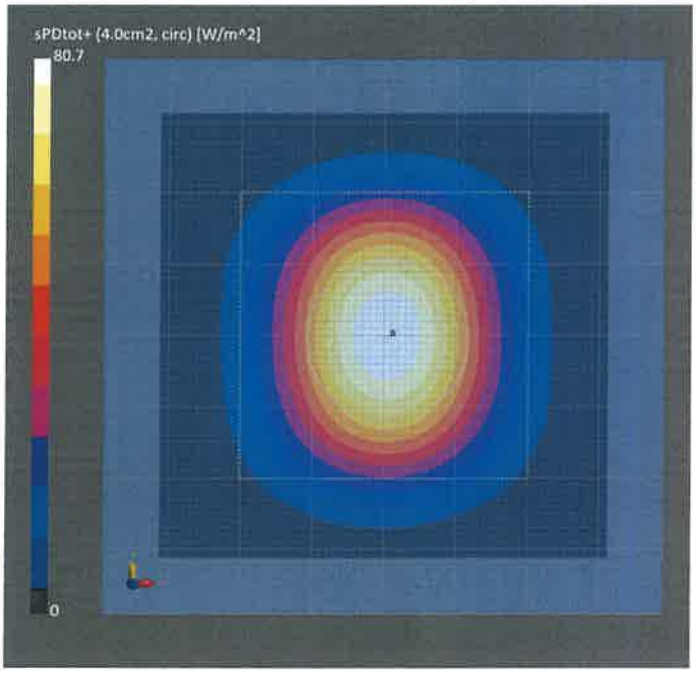
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F30GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

### Scan Setup

| | 5G Scan |
|---|---|
| **Sensor Surface [mm]** | 5.55 |
| **MAIA** | MAIA not used |

### Measurement Results

| | 5G Scan |
|---|---|
| Date | 2023-09-20, 16:02 |
| Avg. Area [cm²] | 4.00 |
| Avg. Type | Circular Averaging |
| psPDn+ [W/m²] | 79.4 |
| psPDtot+ [W/m²] | 80.7 |
| psPDmod+ [W/m²] | 81.0 |
| Max(Sn) [W/m²] | 105 |
| Max(Stot) [W/m²] | 106 |
| Max(\|Stot\|) [W/m²] | 106 |
| $E_{max}$ [V/m] | 201 |
| Power Drift [dB] | -0.04 |



# DASY Report

## Measurement Report for 5G Verification Source 30 GHz, UID 0 -, Channel 30000 (30000.0MHz)

### Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|---|---|---|---|
| 5G Verification Source 30 GHz | 100.0 x 100.0 x 100.0 | SN: 1117 | - |

### Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|---|---|---|---|---|---|
| 5G - | 5.55 mm | Validation band | CW | 30000.0, 30000 | 1.0 |

### Hardware Setup

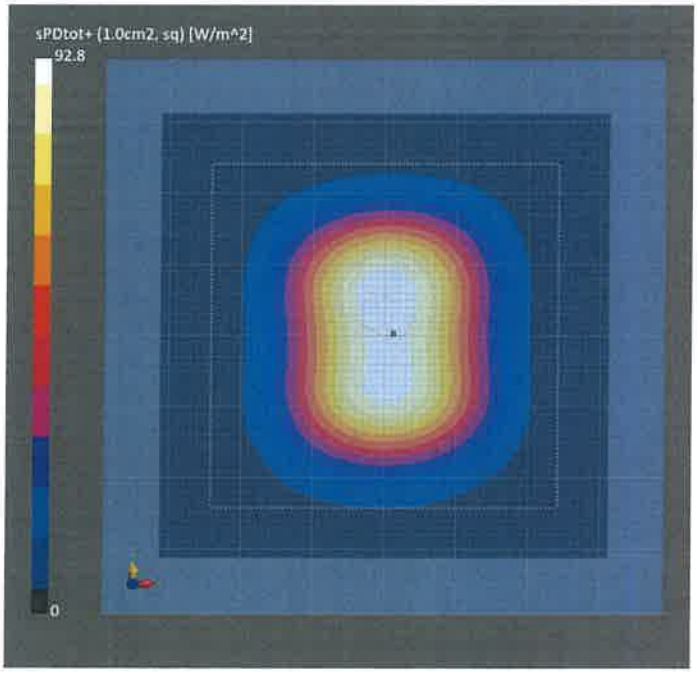
| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F30GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

### Scan Setup

| | 5G Scan |
|---|---|
| **Sensor Surface [mm]** | 5.55 |
| **MAIA** | MAIA not used |

### Measurement Results

| | 5G Scan |
|---|---|
| Date | 2023-09-20, 16:02 |
| Avg. Area [cm²] | 1.00 |
| Avg. Type | Square Averaging |
| psPDn+ [W/m²] | 91.7 |
| psPDtot+ [W/m²] | 92.8 |
| psPDmod+ [W/m²] | 93.0 |
| Max(Sn) [W/m²] | 105 |
| Max(Stot) [W/m²] | 106 |
| Max(\|Stot\|) [W/m²] | 106 |
| $E_{max}$ [V/m] | 201 |
| Power Drift [dB] | -0.04 |



# DASY Report

## Measurement Report for 5G Verification Source 30 GHz, UID 0 -, Channel 30000 (30000.0MHz)

### Device under Test Properties

| Name, Manufacturer | Dimensions [mm] | IMEI | DUT Type |
|---|---|---|---|
| 5G Verification Source 30 GHz | 100.0 x 100.0 x 100.0 | SN: 1117 | - |

### Exposure Conditions

| Phantom Section | Position, Test Distance [mm] | Band | Group, | Frequency [MHz], Channel Number | Conversion Factor |
|---|---|---|---|---|---|
| 5G - | 5.55 mm | Validation band | CW | 30000.0, 30000 | 1.0 |

### Hardware Setup

| Phantom | Medium | Probe, Calibration Date | DAE, Calibration Date |
|---|---|---|---|
| mmWave Phantom - 1002 | Air | EUmmWV3 - SN9374_F30GHz, 2023-05-22 | DAE4ip Sn1602, 2023-07-05 |

### Scan Setup

| | 5G Scan |
|---|---|
| **Sensor Surface [mm]** | 5.55 |
| **MAIA** | MAIA not used |

### Measurement Results

| | 5G Scan |
|---|---|
| Date | 2023-09-20, 16:02 |
| Avg. Area [cm²] | 4.00 |
| Avg. Type | Square Averaging |
| psPDn+ [W/m²] | 79.1 |
| psPDtot+ [W/m²] | 80.5 |
| psPDmod+ [W/m²] | 80.7 |
| Max(Sn) [W/m²] | 105 |
| Max(Stot) [W/m²] | 106 |
| Max(\|Stot\|) [W/m²] | 106 |
| $E_{max}$ [V/m] | 201 |
| Power Drift [dB] | -0.04 |