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CNAS L0570

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Client **Sporton**

Certificate No: **Z19-60057**

## CALIBRATION CERTIFICATE

Object **D1750V2 - SN: 1112**

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

Calibration date: **March 7, 2019**

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards       | ID #       | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
|-------------------------|------------|------------------------------------------|-----------------------|
| Power Meter NRP2        | 106277     | 20-Aug-18 (CTTL, No.J18X06862)           | Aug-19                |
| Power sensor NRP8S      | 104291     | 20-Aug-18 (CTTL, No.J18X06862)           | Aug-19                |
| Reference Probe EX3DV4  | SN 3617    | 31-Jan-19(SPEAG,No.EX3-3617_Jan19)       | Jan-20                |
| DAE4                    | SN 1331    | 06-Feb-19(SPEAG,No.DAE4-1331_Feb19)      | Feb-20                |
| Secondary Standards     | ID #       | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
| Signal Generator E4438C | MY49071430 | 23-Jan-19 (CTTL, No.J19X00336)           | Jan-20                |
| NetworkAnalyzer E5071C  | MY46110673 | 24-Jan-19 (CTTL, No.J19X00547)           | Jan-20                |

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

Issued: March 9, 2019

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### Glossary:

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

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

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Measurement procedure for assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices- Part 1: Device used next to the ear (Frequency range of 300MHz to 6GHz)", July 2016
- IEC 62209-2, "Procedure to measure the Specific Absorption Rate (SAR) For wireless communication devices used in close proximity to the human body (frequency range of 30MHz to 6GHz)", March 2010
- KDB865664, SAR Measurement Requirements for 100 MHz to 6 GHz

### Additional Documentation:

- DASY4/5 System Handbook

### Methods Applied and Interpretation of Parameters:

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

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



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## Measurement Conditions

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

|                              |                          |              |
|------------------------------|--------------------------|--------------|
| DASY Version                 | DASY52                   | 52.10.2.1495 |
| Extrapolation                | Advanced Extrapolation   |              |
| Phantom                      | Triple Flat Phantom 5.1C |              |
| Distance Dipole Center - TSL | 10 mm                    | with Spacer  |
| Zoom Scan Resolution         | dx, dy, dz = 5 mm        |              |
| Frequency                    | 1750 MHz $\pm$ 1 MHz     |              |

## Head TSL parameters

The following parameters and calculations were applied.

|                                         | Temperature         | Permittivity   | Conductivity         |
|-----------------------------------------|---------------------|----------------|----------------------|
| Nominal Head TSL parameters             | 22.0 °C             | 40.1           | 1.37 mho/m           |
| Measured Head TSL parameters            | (22.0 $\pm$ 0.2) °C | 41.1 $\pm$ 6 % | 1.39 mho/m $\pm$ 6 % |
| Head TSL temperature change during test | <1.0 °C             | ----           | ----                 |

## SAR result with Head TSL

|                                                         |                    |                              |
|---------------------------------------------------------|--------------------|------------------------------|
| SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL   | Condition          |                              |
| SAR measured                                            | 250 mW input power | 9.20 W/kg                    |
| SAR for nominal Head TSL parameters                     | normalized to 1W   | 36.7 W/kg $\pm$ 18.8 % (k=2) |
| SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL | Condition          |                              |
| SAR measured                                            | 250 mW input power | 4.87 W/kg                    |
| SAR for nominal Head TSL parameters                     | normalized to 1W   | 19.4 W/kg $\pm$ 18.7 % (k=2) |

## Body TSL parameters

The following parameters and calculations were applied.

|                                         | Temperature         | Permittivity   | Conductivity         |
|-----------------------------------------|---------------------|----------------|----------------------|
| Nominal Body TSL parameters             | 22.0 °C             | 53.4           | 1.49 mho/m           |
| Measured Body TSL parameters            | (22.0 $\pm$ 0.2) °C | 53.5 $\pm$ 6 % | 1.47 mho/m $\pm$ 6 % |
| Body TSL temperature change during test | <1.0 °C             | ----           | ----                 |

## SAR result with Body TSL

|                                                         |                    |                              |
|---------------------------------------------------------|--------------------|------------------------------|
| SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL   | Condition          |                              |
| SAR measured                                            | 250 mW input power | 9.25 W/kg                    |
| SAR for nominal Body TSL parameters                     | normalized to 1W   | 37.4 W/kg $\pm$ 18.8 % (k=2) |
| SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL | Condition          |                              |
| SAR measured                                            | 250 mW input power | 4.92 W/kg                    |
| SAR for nominal Body TSL parameters                     | normalized to 1W   | 19.8 W/kg $\pm$ 18.7 % (k=2) |



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

### Antenna Parameters with Head TSL

|                                      |                |
|--------------------------------------|----------------|
| Impedance, transformed to feed point | 48.8Ω- 1.87 jΩ |
| Return Loss                          | - 33.0 dB      |

### Antenna Parameters with Body TSL

|                                      |                |
|--------------------------------------|----------------|
| Impedance, transformed to feed point | 46.4Ω- 1.07 jΩ |
| Return Loss                          | - 28.3 dB      |

### General Antenna Parameters and Design

|                                  |          |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.080 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 |
|-----------------|-------|



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## DASY5 Validation Report for Head TSL

Date: 03.06.2019

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 1750 MHz; Type: D1750V2; Serial: D1750V2 - SN: 1112**

Communication System: UID 0, CW; Frequency: 1750 MHz; Duty Cycle: 1:1

Medium parameters used:  $f = 1750$  MHz;  $\sigma = 1.389$  S/m;  $\epsilon_r = 41.13$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Right Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3617; ConvF(8.38, 8.38, 8.38) @ 1750 MHz; Calibrated: 1/31/2019
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1331; Calibrated: 2/6/2019
- Phantom: MFP\_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (2); SEMCAD X Version 14.6.12 (7450)

**System Performance Check/Zoom Scan (7x7x7) (7x7x7)/Cube 0:** Measurement grid:

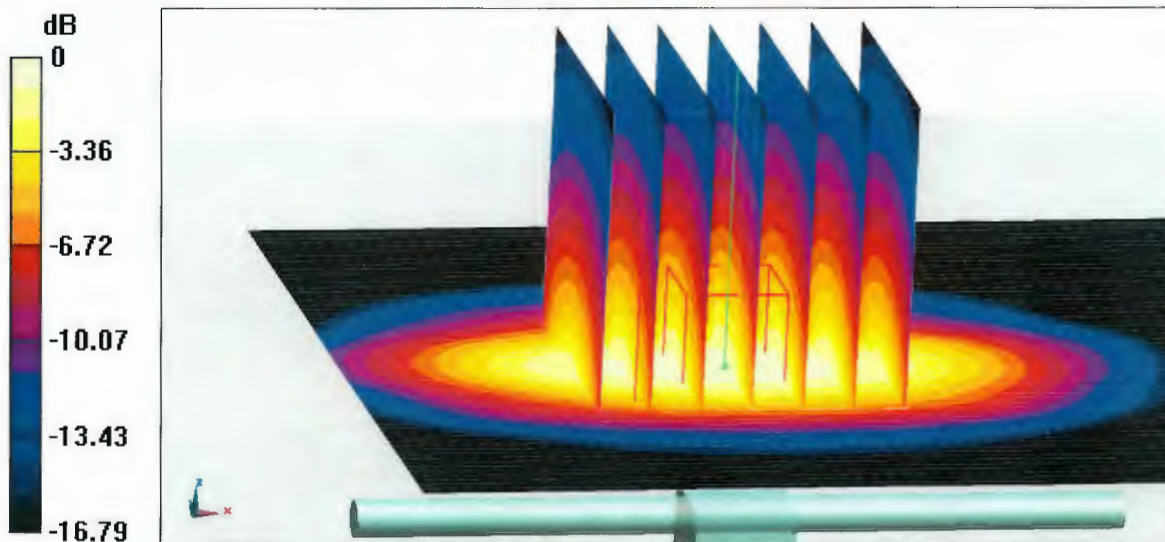
$dx=5$ mm,  $dy=5$ mm,  $dz=5$ mm

Reference Value = 93.87 V/m; Power Drift = 0.00 dB

Peak SAR (extrapolated) = 17.3 W/kg

**SAR(1 g) = 9.2 W/kg; SAR(10 g) = 4.87 W/kg**

Maximum value of SAR (measured) = 14.4 W/kg

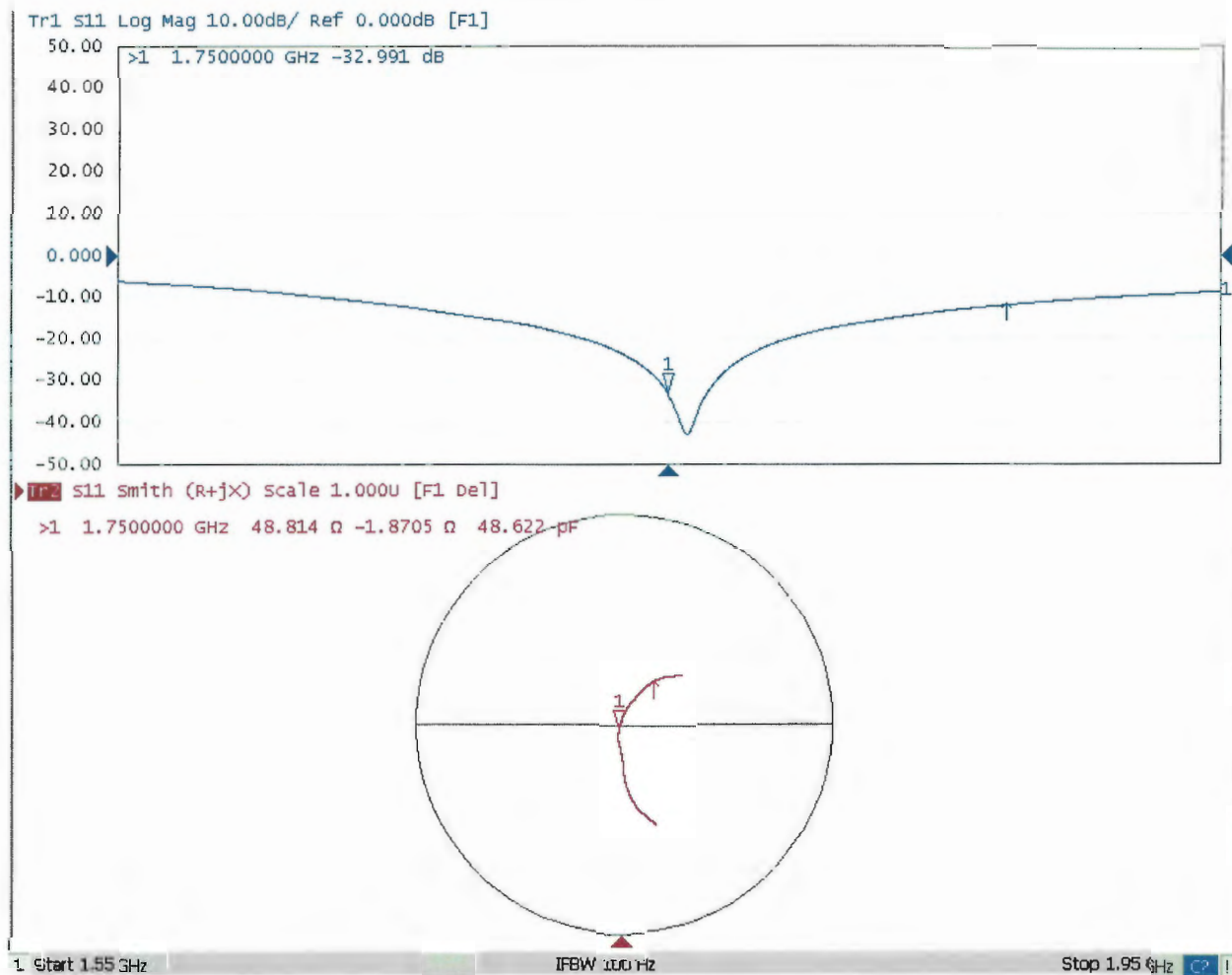


0 dB = 14.4 W/kg = 11.58 dBW/kg



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## Impedance Measurement Plot for Head TSL





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## DASY5 Validation Report for Body TSL

Date: 03.06.2019

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 1750 MHz; Type: D1750V2; Serial: D1750V2 - SN: 1112**

Communication System: UID 0, CW; Frequency: 1750 MHz; Duty Cycle: 1:1

Medium parameters used:  $f = 1750$  MHz;  $\sigma = 1.465$  S/m;  $\epsilon_r = 53.49$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Center Section

DASY5 Configuration:

- Probe: EX3DV4 - SN3617; ConvF(8.03, 8.03, 8.03) @ 1750 MHz; Calibrated: 1/31/2019
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1331; Calibrated: 2/6/2019
- Phantom: MFP\_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (2); SEMCAD X Version 14.6.12 (7450)

**System Performance Check/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid:**

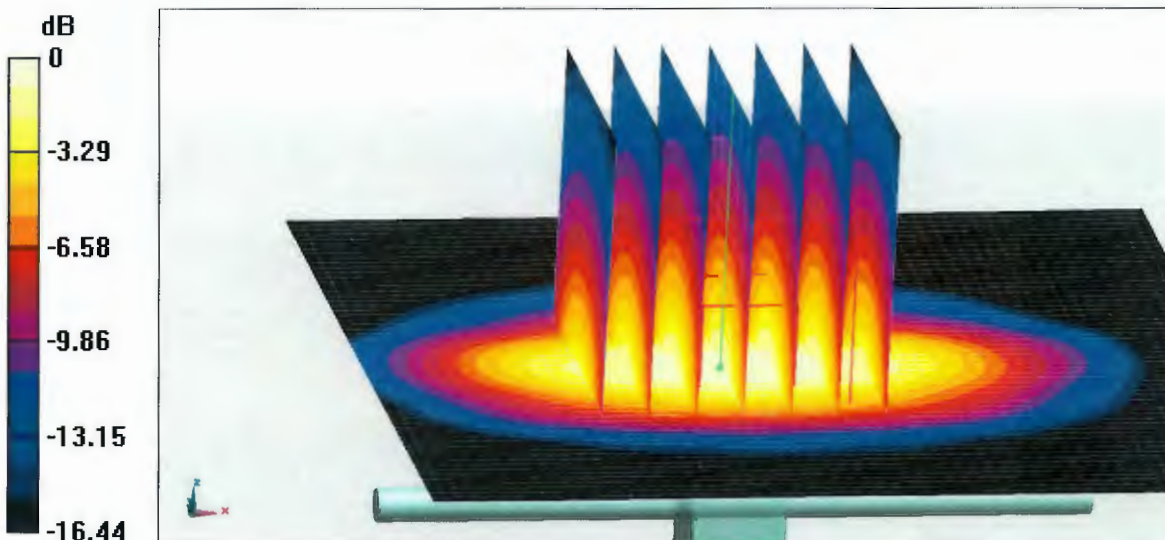
$dx=5$ mm,  $dy=5$ mm,  $dz=5$ mm

Reference Value = 91.64 V/m; Power Drift = 0.03 dB

Peak SAR (extrapolated) = 17.0 W/kg

**SAR(1 g) = 9.25 W/kg; SAR(10 g) = 4.92 W/kg**

Maximum value of SAR (measured) = 14.3 W/kg

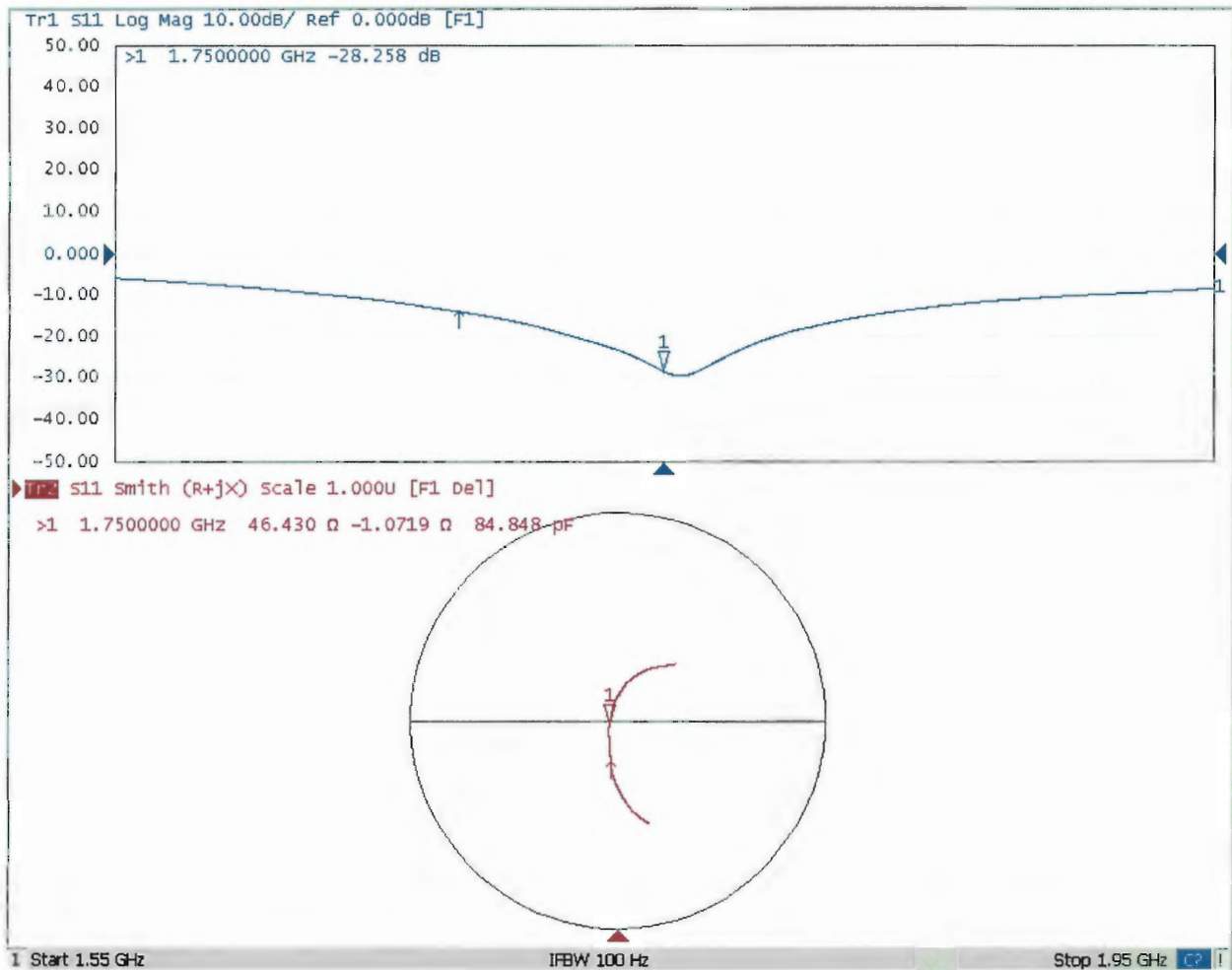


0 dB = 14.3 W/kg = 11.55 dBW/kg



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## Impedance Measurement Plot for Body TSL





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Client

**Sporton**

Certificate No:

**Z18-60324**

## CALIBRATION CERTIFICATE

Object **D1900V2 - SN: 5d041**

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

Calibration date: **September 11, 2018**

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards       | ID #       | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
|-------------------------|------------|------------------------------------------|-----------------------|
| Power Meter NRVD        | 102083     | 01-Nov-17 (CTTL, No.J17X08756)           | Oct-18                |
| Power sensor NRV-Z5     | 100542     | 01-Nov-17 (CTTL, No.J17X08756)           | Oct-18                |
| Reference Probe EX3DV4  | SN 7464    | 12-Sep-17(SPEAG,No.EX3-7464_Sep17)       | Sep-18                |
| DAE4                    | SN 1524    | 13-Sep-17(SPEAG,No.DAE4-1524_Sep17)      | Sep-18                |
| Secondary Standards     | ID #       | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
| Signal Generator E4438C | MY49071430 | 23-Jan-18 (CTTL, No.J18X00560)           | Jan-19                |
| NetworkAnalyzer E5071C  | MY46110673 | 24-Jan-18 (CTTL, No.J18X00561)           | Jan-19                |

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

Signature

Issued: September 15, 2018

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#### **lossary:**

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

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

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Measurement procedure for assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices- Part 1: Device used next to the ear (Frequency range of 300MHz to 6GHz)", July 2016
- IEC 62209-2, "Procedure to measure the Specific Absorption Rate (SAR) For wireless communication devices used in close proximity to the human body (frequency range of 30MHz to 6GHz)", March 2010
- KDB865664, SAR Measurement Requirements for 100 MHz to 6 GHz

#### **Additional Documentation:**

- DASY4/5 System Handbook

#### **Methods Applied and Interpretation of Parameters:**

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

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



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**Measurement Conditions**

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

|                                     |                          |              |
|-------------------------------------|--------------------------|--------------|
| <b>DASY Version</b>                 | DASY52                   | 52.10.1.1476 |
| <b>Extrapolation</b>                | Advanced Extrapolation   |              |
| <b>Phantom</b>                      | Triple Flat Phantom 5.1C |              |
| <b>Distance Dipole Center - TSL</b> | 10 mm                    | with Spacer  |
| <b>Zoom Scan Resolution</b>         | dx, dy, dz = 5 mm        |              |
| <b>Frequency</b>                    | 1900 MHz $\pm$ 1 MHz     |              |

**Head TSL parameters**

The following parameters and calculations were applied.

|                                                | Temperature         | Permittivity   | Conductivity         |
|------------------------------------------------|---------------------|----------------|----------------------|
| <b>Nominal Head TSL parameters</b>             | 22.0 °C             | 40.0           | 1.40 mho/m           |
| <b>Measured Head TSL parameters</b>            | (22.0 $\pm$ 0.2) °C | 40.4 $\pm$ 6 % | 1.44 mho/m $\pm$ 6 % |
| <b>Head TSL temperature change during test</b> | <1.0 °C             | ----           | ----                 |

**SAR result with Head TSL**

|                                                               |                    |                                                  |
|---------------------------------------------------------------|--------------------|--------------------------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Head TSL</b>   | Condition          |                                                  |
| SAR measured                                                  | 250 mW input power | 10.2 mW / g                                      |
| SAR for nominal Head TSL parameters                           | normalized to 1W   | <b>40.2 mW / g <math>\pm</math> 18.8 % (k=2)</b> |
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Head TSL</b> | Condition          |                                                  |
| SAR measured                                                  | 250 mW input power | 5.35 mW / g                                      |
| SAR for nominal Head TSL parameters                           | normalized to 1W   | <b>21.2 mW / g <math>\pm</math> 18.7 % (k=2)</b> |

**Body TSL parameters**

The following parameters and calculations were applied.

|                                                | Temperature         | Permittivity   | Conductivity         |
|------------------------------------------------|---------------------|----------------|----------------------|
| <b>Nominal Body TSL parameters</b>             | 22.0 °C             | 53.3           | 1.52 mho/m           |
| <b>Measured Body TSL parameters</b>            | (22.0 $\pm$ 0.2) °C | 53.3 $\pm$ 6 % | 1.49 mho/m $\pm$ 6 % |
| <b>Body TSL temperature change during test</b> | <1.0 °C             | ----           | ----                 |

**SAR result with Body TSL**

|                                                               |                    |                                                  |
|---------------------------------------------------------------|--------------------|--------------------------------------------------|
| <b>SAR averaged over 1 cm<sup>3</sup> (1 g) of Body TSL</b>   | Condition          |                                                  |
| SAR measured                                                  | 250 mW input power | 9.94 mW / g                                      |
| SAR for nominal Body TSL parameters                           | normalized to 1W   | <b>40.2 mW / g <math>\pm</math> 18.8 % (k=2)</b> |
| <b>SAR averaged over 10 cm<sup>3</sup> (10 g) of Body TSL</b> | Condition          |                                                  |
| SAR measured                                                  | 250 mW input power | 5.35 mW / g                                      |
| SAR for nominal Body TSL parameters                           | normalized to 1W   | <b>21.5 mW / g <math>\pm</math> 18.7 % (k=2)</b> |



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

### Antenna Parameters with Head TSL

|                                      |                            |
|--------------------------------------|----------------------------|
| Impedance, transformed to feed point | $52.9\Omega + 7.43j\Omega$ |
| Return Loss                          | - 22.3dB                   |

### Antenna Parameters with Body TSL

|                                      |                            |
|--------------------------------------|----------------------------|
| Impedance, transformed to feed point | $47.6\Omega + 6.80j\Omega$ |
| Return Loss                          | - 22.7dB                   |

### General Antenna Parameters and Design

|                                  |          |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.066 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 |
|-----------------|-------|



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## DASY5 Validation Report for Head TSL

Date: 09.10.2018

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d041**

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

Medium parameters used:  $f = 1900$  MHz;  $\sigma = 1.438$  S/m;  $\epsilon_r = 40.37$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Center Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(8.39, 8.39, 8.39) @ 1900 MHz; Calibrated: 9/12/2017
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1524; Calibrated: 9/13/2017
- Phantom: MFP\_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (1); SEMCAD X Version 14.6.11 (7439)

**System Performance Check/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid:**

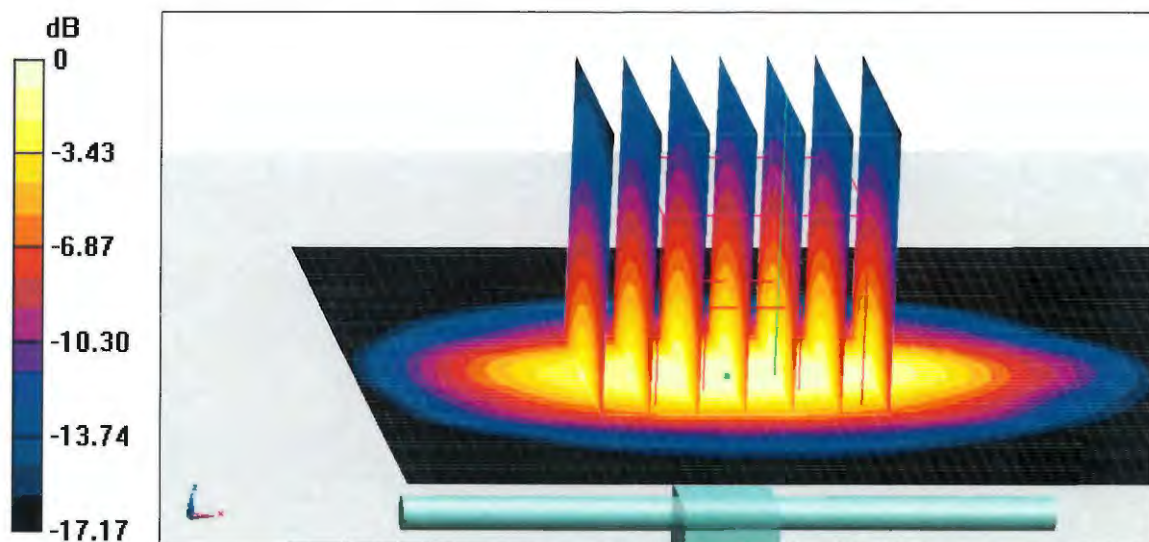
dx=5mm, dy=5mm, dz=5mm

Reference Value = 98.66 V/m; Power Drift = -0.02 dB

Peak SAR (extrapolated) = 19.1 W/kg

**SAR(1 g) = 10.2 W/kg; SAR(10 g) = 5.35 W/kg**

Maximum value of SAR (measured) = 15.7 W/kg



**0 dB = 15.7 W/kg = 11.96 dBW/kg**



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Add: No.51 Xueyuan Road, Haidian District, Beijing, 100191, China

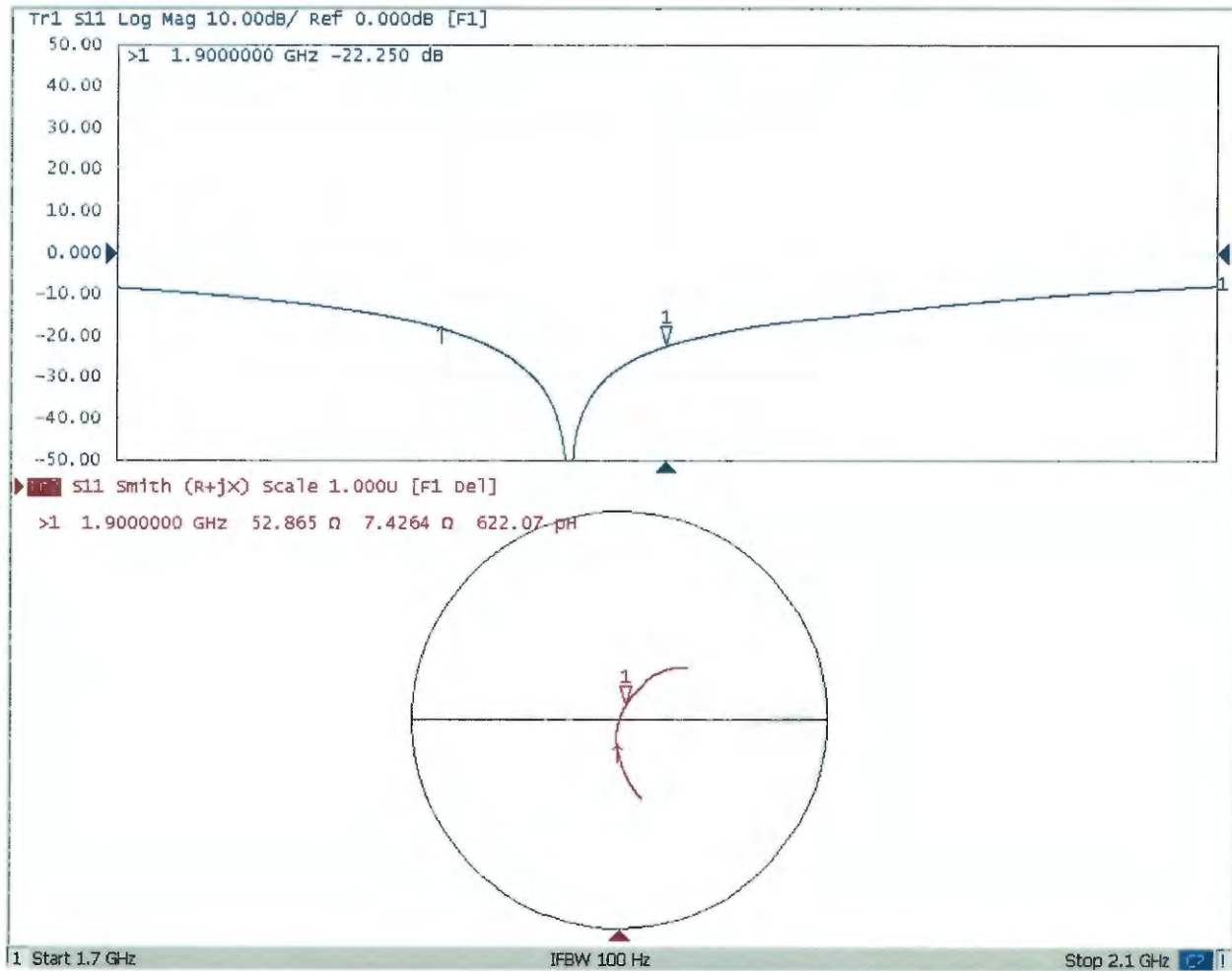
Tel: +86-10-62304633-2079

Fax: +86-10-62304633-2504

E-mail: cttl@chinattl.com

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## Impedance Measurement Plot for Head TSL





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## DASY5 Validation Report for Body TSL

Date: 09.10.2018

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d041**

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

Medium parameters used:  $f = 1900$  MHz;  $\sigma = 1.493$  S/m;  $\epsilon_r = 53.34$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Right Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(8.32, 8.32, 8.32) @ 1900 MHz; Calibrated: 9/12/2017
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1524; Calibrated: 9/13/2017
- Phantom: MFP\_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (1); SEMCAD X Version 14.6.11 (7439) )

**System Performance Check/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid:**

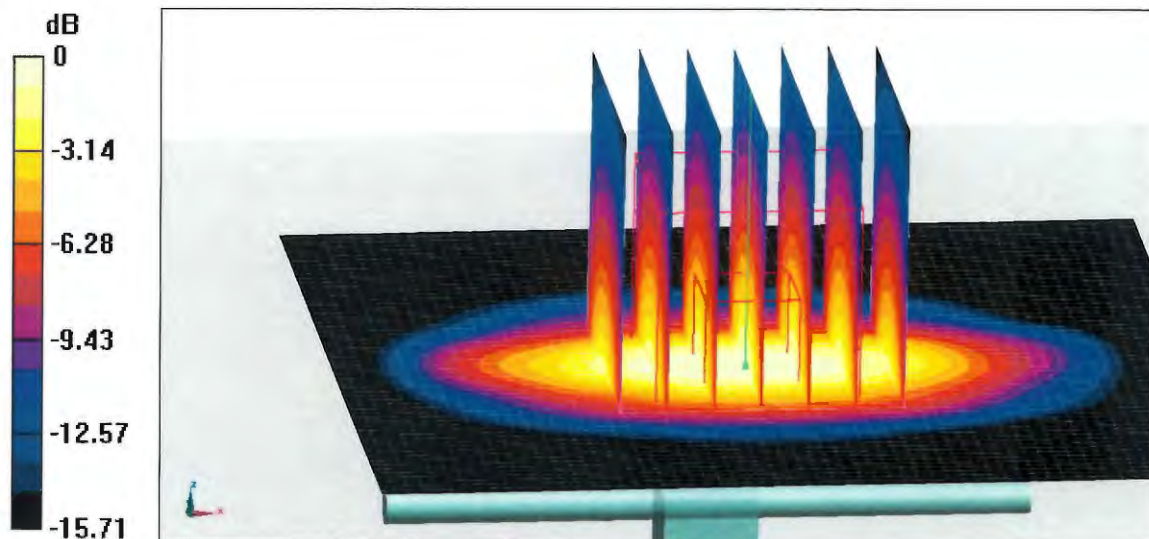
$dx=5$ mm,  $dy=5$ mm,  $dz=5$ mm

Reference Value = 94.03 V/m; Power Drift = -0.08 dB

Peak SAR (extrapolated) = 17.5 W/kg

**SAR(1 g) = 9.94 W/kg; SAR(10 g) = 5.35 W/kg**

Maximum value of SAR (measured) = 15.0 W/kg



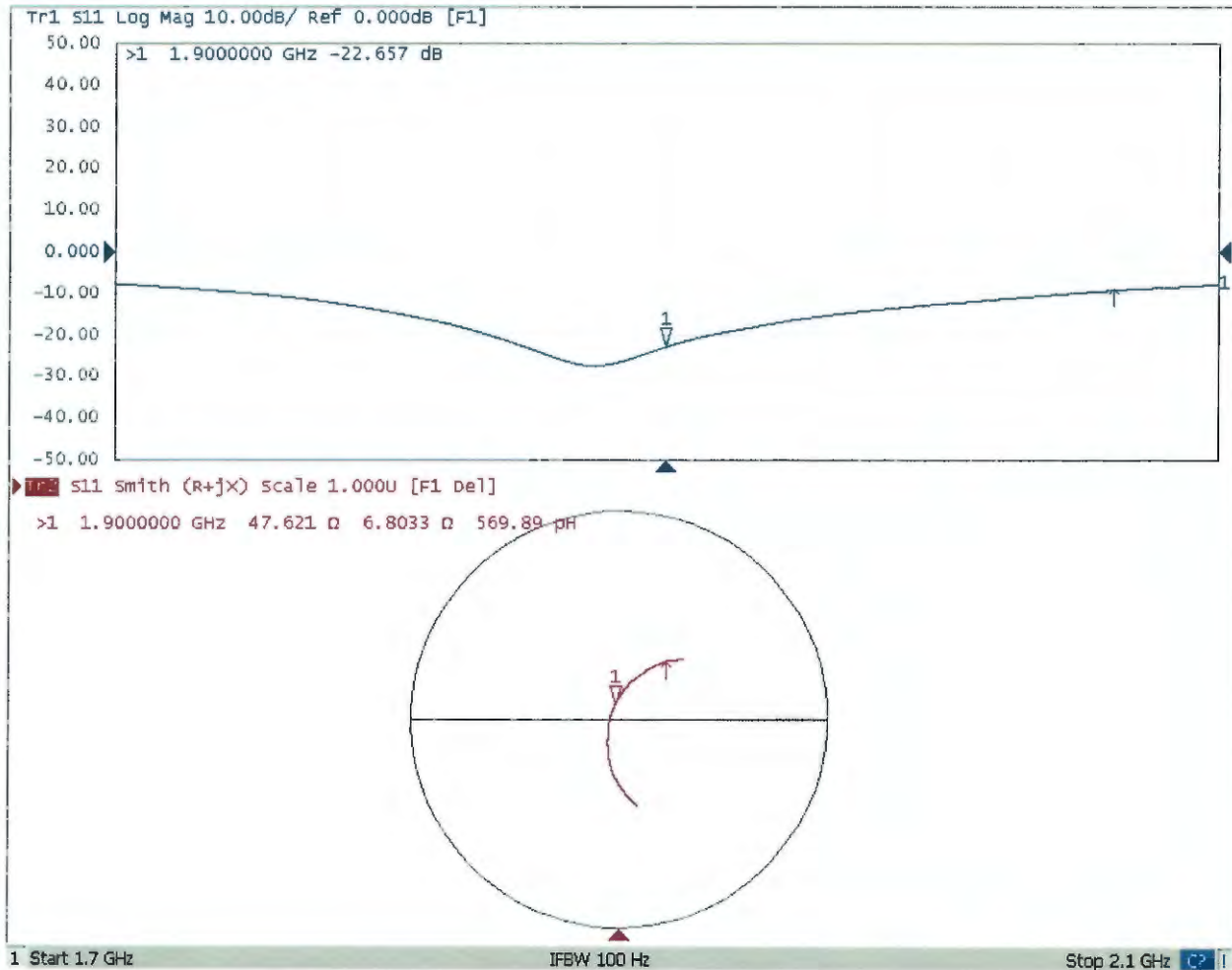
**0 dB = 15.0 W/kg = 11.76 dBW/kg**



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## Impedance Measurement Plot for Body TSL



## D1900V2, serial no. 5D041 Extended Dipole Calibrations

Referring to KDB 450824, if dipoles are verified in return loss ( $< -20\text{dB}$ , within 20% of prior calibration), and in impedance (within 5 ohm of prior calibration), the annual calibration is not necessary and the calibration interval can be extended.

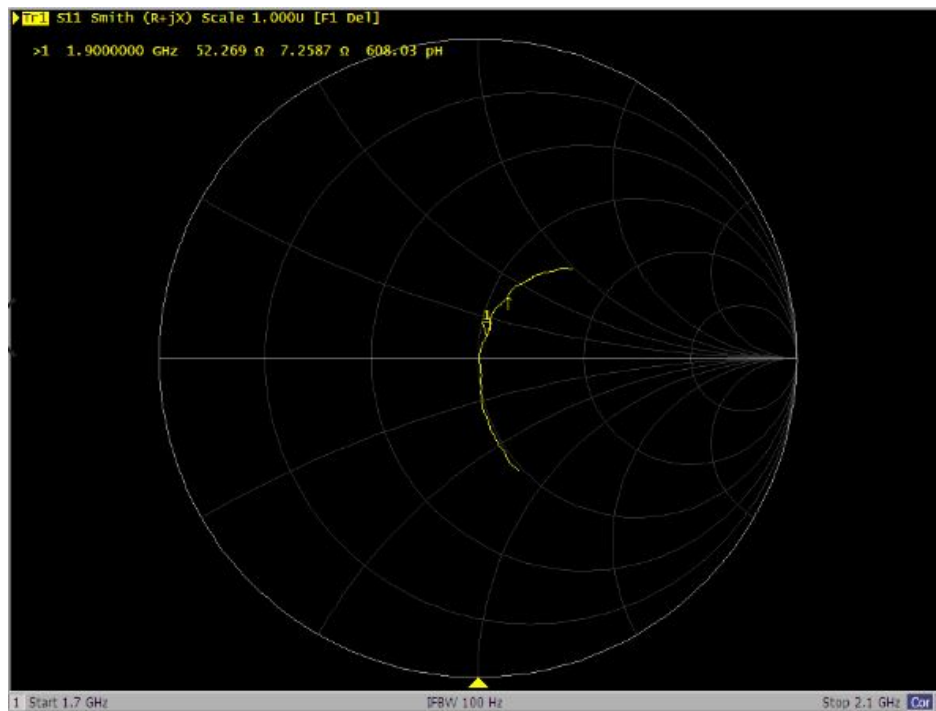
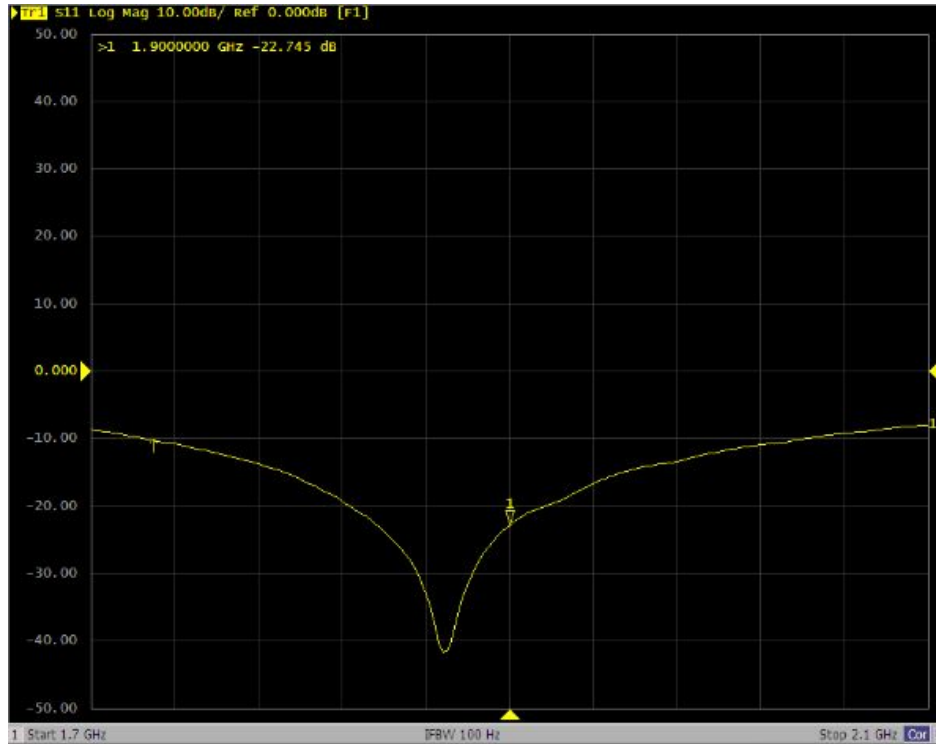
### <Justification of the extended calibration>

| D1900V2 – serial no. 5D041 |                  |           |                      |             |                           |             |
|----------------------------|------------------|-----------|----------------------|-------------|---------------------------|-------------|
|                            | 1900 Head        |           |                      |             |                           |             |
| Date of Measurement        | Return-Loss (dB) | Delta (%) | Real Impedance (ohm) | Delta (ohm) | Imaginary Impedance (ohm) | Delta (ohm) |
| 09.11.2018                 | -22.25           |           | 52.865               |             | 7.4264                    |             |
| 09.10.2019                 | -22.745          | 2.176     | 52.269               | -0.596      | 7.2587                    | -0.1677     |

The return loss is  $< -20\text{dB}$ , within 20% of prior calibration; the impedance is within 5 ohm of prior calibration. Therefore the verification result should support extended calibration.

<Dipole Verification Data> - D1900 V2, serial no. 5D041 (Data of Measurement : 9.10.2019)

1900 MHz - Head





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Client **Sporton**

Certificate No: **5G-Veri30-1009\_May19**

## CALIBRATION CERTIFICATE

Object **5G Verification Source 30 GHz - SN: 1009**

Calibration procedure(s) **QA CAL-45.v2  
Calibration procedure for sources in air above 6 GHz**

Calibration date: **May 03, 2019**

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 |
|-------------------------|----------|------------------------------------|-----------------------|
| Reference Probe EUMmWV3 | SN: 9374 | 31-Dec-18 (No. EUMmWV3-9374_Dec18) | Dec-19                |
| DAE4                    | SN: 1215 | 22-Feb-19 (No. DAE4-1215_Feb19)    | Feb-20                |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---------------------|------|-----------------------|-----------------|
|---------------------|------|-----------------------|-----------------|

|                |                |                       |           |
|----------------|----------------|-----------------------|-----------|
|                | Name           | Function              | Signature |
| Calibrated by: | Jeton Kastrati | Laboratory Technician |           |

|              |               |                   |  |
|--------------|---------------|-------------------|--|
| Approved by: | Katja Pokovic | Technical Manager |  |
|--------------|---------------|-------------------|--|

Issued: May 6, 2019

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## Glossary

CW                      Continuous wave

## Calibration is Performed According to the Following Standards

- Internal procedure QA CAL-45-5Gsources
- IEC TR 63170 ED1, "Measurement procedure for the evaluation of power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 100 GHz", January 2018

## 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 forward power to the horn antenna is measured prior and after the measurement with a power sensor. During the measurements, the horn is directly connected to the cable taking into account the 0.2dB horn loss. (2) 30, 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 ( $1\text{cm}^2$  and  $4\text{cm}^2$ ) 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 peak values of the total and normal component of the poynting vector  $|\text{Re}\{S\}|$  and  $n.\text{Re}\{S\}$  averaged over the surface area of  $1\text{cm}^2$  ( $pS_{\text{tot,avg}1\text{cm}^2}$  and  $pS_{n,\text{avg}1\text{cm}^2}$ ) and  $4\text{cm}^2$  ( $pS_{\text{tot,avg}4\text{cm}^2}$  and  $pS_{n,\text{avg}4\text{cm}^2}$ ) at the nominal operational frequency of the verification source.

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.

|                                       |                               |      |
|---------------------------------------|-------------------------------|------|
| <b>DASY Version</b>                   | cDASY6 Module mmWave          | V1.6 |
| <b>Phantom</b>                        | 5G Phantom                    |      |
| <b>Distance Horn Aperture - plane</b> | 10 mm                         |      |
| <b>XY Scan Resolution</b>             | dx, dy = 2.5 mm               |      |
| <b>Number of measured planes</b>      | 2 (10mm, 10mm + $\lambda/4$ ) |      |
| <b>Frequency</b>                      | 30 GHz $\pm$ 10 MHz           |      |

## Calibration Parameters, 30 GHz

| Distance Horn Aperture<br>to Measured Plane | <b><i>Prad1</i></b><br><b>(mW)</b> | <b>Max E-field</b><br><b>(V/m)</b> | Uncertainty<br>(k = 2) | Avg Power Density<br>n.Re{S},  Re{S} <br>(W/m <sup>2</sup> ) |                         | Uncertainty<br>(k = 2) |
|---------------------------------------------|------------------------------------|------------------------------------|------------------------|--------------------------------------------------------------|-------------------------|------------------------|
|                                             |                                    |                                    |                        | <b>1 cm<sup>2</sup></b>                                      | <b>4 cm<sup>2</sup></b> |                        |
| 10 mm                                       | 44.9                               | <b>154</b>                         | 1.27 dB                | <b>54.4, 54.9</b>                                            | <b>48.0, 48.5</b>       | 1.28 dB                |

<sup>1</sup> 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: 1009 | -        |

### 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   |
|------------|--------|------------------------------|-------------------------|
| 5G Phantom | Air    | EUmmWV3 - SN9374, 2018-12-31 | DAE4 Sn1215, 2019-02-22 |

### Scan Setup

|                     | 5G Scan       |
|---------------------|---------------|
| Grid Extents [mm]   | 60.0 x 60.0   |
| Grid Steps [lambda] | 0.25 x 0.25   |
| Sensor Surface [mm] | 5.55          |
| MAIA                | MAIA not used |

### Measurement Results

|                                           | 5G Scan           |
|-------------------------------------------|-------------------|
| Date                                      | 2019-05-03, 18:49 |
| Avg. Area [cm <sup>2</sup> ]              | 1.00              |
| pS <sub>tot</sub> avg [W/m <sup>2</sup> ] | 54.9              |
| pS <sub>n</sub> avg [W/m <sup>2</sup> ]   | 54.4              |
| E <sub>peak</sub> [V/m]                   | 154               |
| Power Drift [dB]                          | -0.02             |





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Client **Sporton**

Certificate No: **DAE4-778\_May19**

## CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 778**

Calibration procedure(s) **QA CAL-06.v29**  
**Calibration procedure for the data acquisition electronics (DAE)**

Calibration date: **May 21, 2019**

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards             | ID #               | Cal Date (Certificate No.) | Scheduled Calibration  |
|-------------------------------|--------------------|----------------------------|------------------------|
| Keithley Multimeter Type 2001 | SN: 0810278        | 03-Sep-18 (No:23488)       | Sep-19                 |
| Secondary Standards           | ID #               | Check Date (in house)      | Scheduled Check        |
| Auto DAE Calibration Unit     | SE UWS 053 AA 1001 | 07-Jan-19 (in house check) | In house check: Jan-20 |
| Calibrator Box V2.1           | SE UMS 006 AA 1002 | 07-Jan-19 (in house check) | In house check: Jan-20 |

|                |                        |                                   |               |
|----------------|------------------------|-----------------------------------|---------------|
| Calibrated by: | Name<br>Adrian Gehring | Function<br>Laboratory Technician | Signature<br> |
| Approved by:   | Sven Kühn              | Deputy Manager                    |               |

Issued: May 21, 2019

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Accreditation No.: **SCS 0108**

## Glossary

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

## Methods Applied and Interpretation of Parameters

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle:* The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
  - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
  - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
  - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
  - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
  - *Input Offset Measurement:* Output voltage and statistical results over a large number of zero voltage measurements.
  - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
  - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
  - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
  - *Power consumption:* Typical value for information. Supply currents in various operating modes.

## DC Voltage Measurement

A/D - Converter Resolution nominal

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

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

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

| Calibration Factors | X                         | Y                         | Z                         |
|---------------------|---------------------------|---------------------------|---------------------------|
| High Range          | 404.724 $\pm$ 0.02% (k=2) | 403.523 $\pm$ 0.02% (k=2) | 405.080 $\pm$ 0.02% (k=2) |
| Low Range           | 3.98714 $\pm$ 1.50% (k=2) | 3.96425 $\pm$ 1.50% (k=2) | 4.00091 $\pm$ 1.50% (k=2) |

## Connector Angle

|                                           |                   |
|-------------------------------------------|-------------------|
| Connector Angle to be used in DASY system | 269.5 ° $\pm$ 1 ° |
|-------------------------------------------|-------------------|

## Appendix (Additional assessments outside the scope of SCS0108)

### 1. DC Voltage Linearity

| High Range        | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 199997.18                 | 3.13                         | 0.00      |
| Channel X + Input | 20003.93                  | 2.54                         | 0.01      |
| Channel X - Input | -20000.18                 | 1.44                         | -0.01     |
| Channel Y + Input | 199995.82                 | 1.88                         | 0.00      |
| Channel Y + Input | 20003.10                  | 1.74                         | 0.01      |
| Channel Y - Input | -19999.94                 | 1.75                         | -0.01     |
| Channel Z + Input | 199997.86                 | 3.59                         | 0.00      |
| Channel Z + Input | 20000.46                  | -0.95                        | -0.00     |
| Channel Z - Input | -20005.38                 | -3.70                        | 0.02      |

| Low Range         | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 2000.87                   | 0.06                         | 0.00      |
| Channel X + Input | 201.00                    | -0.20                        | -0.10     |
| Channel X - Input | -198.59                   | 0.11                         | -0.05     |
| Channel Y + Input | 2000.10                   | -0.63                        | -0.03     |
| Channel Y + Input | 202.04                    | 0.88                         | 0.44      |
| Channel Y - Input | -199.00                   | -0.21                        | 0.10      |
| Channel Z + Input | 2001.05                   | 0.38                         | 0.02      |
| Channel Z + Input | 198.96                    | -2.14                        | -1.07     |
| Channel Z - Input | -199.86                   | -0.97                        | 0.49      |

### 2. Common mode sensitivity

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

|           | Common mode Input Voltage (mV) | High Range Average Reading ( $\mu\text{V}$ ) | Low Range Average Reading ( $\mu\text{V}$ ) |
|-----------|--------------------------------|----------------------------------------------|---------------------------------------------|
| Channel X | 200                            | -4.60                                        | -5.60                                       |
|           | - 200                          | 5.42                                         | 4.64                                        |
| Channel Y | 200                            | -0.35                                        | -1.21                                       |
|           | - 200                          | -0.14                                        | 0.05                                        |
| Channel Z | 200                            | -12.41                                       | -12.20                                      |
|           | - 200                          | 9.83                                         | 10.24                                       |

### 3. Channel separation

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

|           | Input Voltage (mV) | Channel X ( $\mu\text{V}$ ) | Channel Y ( $\mu\text{V}$ ) | Channel Z ( $\mu\text{V}$ ) |
|-----------|--------------------|-----------------------------|-----------------------------|-----------------------------|
| Channel X | 200                | -                           | -0.41                       | -2.24                       |
| Channel Y | 200                | 8.92                        | -                           | 0.13                        |
| Channel Z | 200                | 4.06                        | 7.55                        | -                           |

#### 4. AD-Converter Values with inputs shorted

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

|           | High Range (LSB) | Low Range (LSB) |
|-----------|------------------|-----------------|
| Channel X | 16054            | 16756           |
| Channel Y | 16192            | 17734           |
| Channel Z | 16436            | 15674           |

#### 5. Input Offset Measurement

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

Input 10M $\Omega$

|           | Average ( $\mu$ V) | min. Offset ( $\mu$ V) | max. Offset ( $\mu$ V) | Std. Deviation ( $\mu$ V) |
|-----------|--------------------|------------------------|------------------------|---------------------------|
| Channel X | -0.17              | -1.48                  | 0.79                   | 0.43                      |
| Channel Y | 0.39               | -1.44                  | 2.48                   | 0.63                      |
| Channel Z | -0.48              | -1.80                  | 0.97                   | 0.51                      |

#### 6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

#### 7. Input Resistance (Typical values for information)

|           | Zeroing (kOhm) | Measuring (MOhm) |
|-----------|----------------|------------------|
| Channel X | 200            | 200              |
| Channel Y | 200            | 200              |
| Channel Z | 200            | 200              |

#### 8. Low Battery Alarm Voltage (Typical values for information)

| Typical values | Alarm Level (VDC) |
|----------------|-------------------|
| Supply (+ Vcc) | +7.9              |
| Supply (- Vcc) | -7.6              |

#### 9. Power Consumption (Typical values for information)

| Typical values | Switched off (mA) | Stand by (mA) | Transmitting (mA) |
|----------------|-------------------|---------------|-------------------|
| Supply (+ Vcc) | +0.01             | +6            | +14               |
| Supply (- Vcc) | -0.01             | -8            | -9                |



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Accreditation No.: **SCS 0108**

Client **Sporton**

Certificate No: **DAE4-854\_May19**

## CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 854**

Calibration procedure(s) **QA CAL-06.v29**  
**Calibration procedure for the data acquisition electronics (DAE)**

Calibration date: **May 21, 2019**

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  |
|-------------------------------|--------------------|----------------------------|------------------------|
| Keithley Multimeter Type 2001 | SN: 0810278        | 03-Sep-18 (No:23488)       | Sep-19                 |
| Secondary Standards           | ID #               | Check Date (in house)      | Scheduled Check        |
| Auto DAE Calibration Unit     | SE UWS 053 AA 1001 | 07-Jan-19 (in house check) | In house check: Jan-20 |
| Calibrator Box V2.1           | SE UMS 006 AA 1002 | 07-Jan-19 (in house check) | In house check: Jan-20 |

|                |                |                       |           |
|----------------|----------------|-----------------------|-----------|
| Calibrated by: | Name           | Function              | Signature |
|                | Adrian Gehring | Laboratory Technician |           |

|              |           |                |
|--------------|-----------|----------------|
| Approved by: | Sven Kühn | Deputy Manager |
|--------------|-----------|----------------|

Issued: May 21, 2019

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## Glossary

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

## Methods Applied and Interpretation of Parameters

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle:* The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
  - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
  - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
  - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
  - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
  - *Input Offset Measurement:* Output voltage and statistical results over a large number of zero voltage measurements.
  - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
  - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
  - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
  - *Power consumption:* Typical value for information. Supply currents in various operating modes.

## DC Voltage Measurement

A/D - Converter Resolution nominal

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

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

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

| Calibration Factors | X                         | Y                         | Z                         |
|---------------------|---------------------------|---------------------------|---------------------------|
| High Range          | 404.909 $\pm$ 0.02% (k=2) | 404.692 $\pm$ 0.02% (k=2) | 405.783 $\pm$ 0.02% (k=2) |
| Low Range           | 3.97164 $\pm$ 1.50% (k=2) | 3.94913 $\pm$ 1.50% (k=2) | 3.99482 $\pm$ 1.50% (k=2) |

## Connector Angle

|                                           |                   |
|-------------------------------------------|-------------------|
| Connector Angle to be used in DASY system | 325.0 ° $\pm$ 1 ° |
|-------------------------------------------|-------------------|

## Appendix (Additional assessments outside the scope of SCS0108)

### 1. DC Voltage Linearity

| High Range        | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 199994.47                 | 0.40                         | 0.00      |
| Channel X + Input | 20000.57                  | -0.74                        | -0.00     |
| Channel X - Input | -19999.89                 | 1.86                         | -0.01     |
| Channel Y + Input | 199996.63                 | 2.65                         | 0.00      |
| Channel Y + Input | 19998.60                  | -2.61                        | -0.01     |
| Channel Y - Input | -20002.11                 | -0.26                        | 0.00      |
| Channel Z + Input | 199993.70                 | -0.37                        | -0.00     |
| Channel Z + Input | 19998.50                  | -2.78                        | -0.01     |
| Channel Z - Input | -20002.17                 | -0.31                        | 0.00      |

| Low Range         | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 2000.92                   | 0.14                         | 0.01      |
| Channel X + Input | 201.80                    | 0.54                         | 0.27      |
| Channel X - Input | -198.07                   | 0.52                         | -0.26     |
| Channel Y + Input | 2000.75                   | -0.14                        | -0.01     |
| Channel Y + Input | 200.51                    | -0.64                        | -0.32     |
| Channel Y - Input | -199.85                   | -1.04                        | 0.52      |
| Channel Z + Input | 2000.81                   | 0.06                         | 0.00      |
| Channel Z + Input | 200.50                    | -0.57                        | -0.28     |
| Channel Z - Input | -199.70                   | -0.76                        | 0.38      |

### 2. Common mode sensitivity

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

|           | Common mode Input Voltage (mV) | High Range Average Reading ( $\mu\text{V}$ ) | Low Range Average Reading ( $\mu\text{V}$ ) |
|-----------|--------------------------------|----------------------------------------------|---------------------------------------------|
| Channel X | 200                            | -11.53                                       | -13.11                                      |
|           | - 200                          | 15.52                                        | 13.66                                       |
| Channel Y | 200                            | -8.40                                        | -8.84                                       |
|           | - 200                          | 7.27                                         | 6.80                                        |
| Channel Z | 200                            | 16.75                                        | 16.91                                       |
|           | - 200                          | -18.58                                       | -18.86                                      |

### 3. Channel separation

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

|           | Input Voltage (mV) | Channel X ( $\mu\text{V}$ ) | Channel Y ( $\mu\text{V}$ ) | Channel Z ( $\mu\text{V}$ ) |
|-----------|--------------------|-----------------------------|-----------------------------|-----------------------------|
| Channel X | 200                | -                           | 1.02                        | -3.37                       |
| Channel Y | 200                | 7.97                        | -                           | 3.67                        |
| Channel Z | 200                | 9.63                        | 4.81                        | -                           |

#### 4. AD-Converter Values with inputs shorted

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

|           | High Range (LSB) | Low Range (LSB) |
|-----------|------------------|-----------------|
| Channel X | 16127            | 15569           |
| Channel Y | 15969            | 16516           |
| Channel Z | 15864            | 16505           |

#### 5. Input Offset Measurement

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

Input 10M $\Omega$

|           | Average ( $\mu$ V) | min. Offset ( $\mu$ V) | max. Offset ( $\mu$ V) | Std. Deviation ( $\mu$ V) |
|-----------|--------------------|------------------------|------------------------|---------------------------|
| Channel X | 0.80               | 0.09                   | 2.25                   | 0.35                      |
| Channel Y | -0.13              | -1.04                  | 0.67                   | 0.35                      |
| Channel Z | -0.21              | -1.03                  | 0.51                   | 0.33                      |

#### 6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

#### 7. Input Resistance (Typical values for information)

|           | Zeroing (kOhm) | Measuring (MOhm) |
|-----------|----------------|------------------|
| Channel X | 200            | 200              |
| Channel Y | 200            | 200              |
| Channel Z | 200            | 200              |

#### 8. Low Battery Alarm Voltage (Typical values for information)

| Typical values | Alarm Level (VDC) |
|----------------|-------------------|
| Supply (+ Vcc) | +7.9              |
| Supply (- Vcc) | -7.6              |

#### 9. Power Consumption (Typical values for information)

| Typical values | Switched off (mA) | Stand by (mA) | Transmitting (mA) |
|----------------|-------------------|---------------|-------------------|
| Supply (+ Vcc) | +0.01             | +6            | +14               |
| Supply (- Vcc) | -0.01             | -8            | -9                |



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Accreditation No.: **SCS 0108**

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 Multilateral Agreement for the recognition of calibration certificates

Client **Sporton**

Certificate No: **EX3-3931\_Sep19**

## CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3931**

Calibration procedure(s) **QA CAL-01.v9, QA CAL-14.v5, QA CAL-23.v5, QA CAL-25.v7**  
 Calibration procedure for dosimetric E-field probes

Calibration date: **September 26, 2019**

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards          | ID               | Cal Date (Certificate No.)        | Scheduled Calibration  |
|----------------------------|------------------|-----------------------------------|------------------------|
| Power meter NRP            | SN: 104778       | 03-Apr-19 (No. 217-02892/02893)   | Apr-20                 |
| Power sensor NRP-Z91       | SN: 103244       | 03-Apr-19 (No. 217-02892)         | Apr-20                 |
| Power sensor NRP-Z91       | SN: 103245       | 03-Apr-19 (No. 217-02893)         | Apr-20                 |
| Reference 20 dB Attenuator | SN: S5277 (20x)  | 04-Apr-19 (No. 217-02894)         | Apr-20                 |
| DAE4                       | SN: 660          | 19-Dec-18 (No. DAE4-660_Dec18)    | Dec-19                 |
| Reference Probe ES3DV2     | SN: 3013         | 31-Dec-18 (No. ES3-3013_Dec18)    | Dec-19                 |
| Secondary Standards        | ID               | Check Date (in house)             | Scheduled Check        |
| Power meter E4419B         | SN: GB41293874   | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A        | SN: MY41498087   | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A        | SN: 000110210    | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| RF generator HP 8648C      | SN: US3642U01700 | 04-Aug-99 (in house check Jun-18) | In house check: Jun-20 |
| Network Analyzer E8358A    | SN: US41080477   | 31-Mar-14 (in house check Oct-18) | In house check: Oct-19 |

|                                                                                                                 |                       |                                   |               |
|-----------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------------------|---------------|
| Calibrated by:                                                                                                  | Name<br>Michael Weber | Function<br>Laboratory Technician | Signature<br> |
| Approved by:                                                                                                    | Katja Pokovic         | Technical Manager                 |               |
| Issued: October 1, 2019                                                                                         |                       |                                   |               |
| This calibration certificate shall not be reproduced except in full without written approval of the laboratory. |                       |                                   |               |



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Accreditation No.: **SCS 0108**

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

## Glossary:

|                          |                                                                                                                                                         |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| TSL                      | tissue simulating liquid                                                                                                                                |
| NORM <sub>x,y,z</sub>    | sensitivity in free space                                                                                                                               |
| ConvF                    | sensitivity in TSL / NORM <sub>x,y,z</sub>                                                                                                              |
| DCP                      | diode compression point                                                                                                                                 |
| CF                       | crest factor (1/duty_cycle) of the RF signal                                                                                                            |
| A, B, C, D               | modulation dependent linearization parameters                                                                                                           |
| Polarization $\varphi$   | $\varphi$ rotation around probe axis                                                                                                                    |
| Polarization $\vartheta$ | $\vartheta$ rotation around an axis that is in the plane normal to probe axis (at measurement center),<br>i.e., $\vartheta = 0$ is normal to probe axis |
| Connector Angle          | information used in DASY system to align probe sensor X to the robot coordinate system                                                                  |

## Calibration is Performed According to the Following Standards:

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

## Methods Applied and Interpretation of Parameters:

- NORM<sub>x,y,z</sub>**: Assessed for E-field polarization  $\vartheta = 0$  ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide). NORM<sub>x,y,z</sub> are only intermediate values, i.e., the uncertainties of NORM<sub>x,y,z</sub> does not affect the  $E^2$ -field uncertainty inside TSL (see below **ConvF**).
- NORM(f)<sub>x,y,z</sub> = NORM<sub>x,y,z</sub> \* frequency\_response** (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of **ConvF**.
- DCP<sub>x,y,z</sub>**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- PAR**: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- A<sub>x,y,z</sub>; B<sub>x,y,z</sub>; C<sub>x,y,z</sub>; D<sub>x,y,z</sub>; VR<sub>x,y,z</sub>**: A, B, C, D are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters**: Assessed in flat phantom using E-field (or Temperature Transfer Standard for  $f \leq 800$  MHz) and inside waveguide using analytical field distributions based on power measurements for  $f > 800$  MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to **NORM<sub>x,y,z</sub> \* ConvF** whereby the uncertainty corresponds to that given for **ConvF**. A frequency dependent **ConvF** is used in DASY version 4.4 and higher which allows extending the validity from  $\pm 50$  MHz to  $\pm 100$  MHz.
- Spherical isotropy (3D deviation from isotropy)**: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the **NORM<sub>x</sub>** (no uncertainty required).

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3931

## Basic Calibration Parameters

|                                                           | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|-----------------------------------------------------------|----------|----------|----------|-----------|
| Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup> | 0.50     | 0.57     | 0.48     | ± 10.1 %  |
| DCP (mV) <sup>B</sup>                                     | 102.1    | 103.6    | 101.5    |           |

## Calibration Results for Modulation Response

| UID           | Communication System Name   |   | A<br>dB | B<br>dB $\sqrt{\mu\text{V}}$ | C     | D<br>dB | VR<br>mV | Max<br>dev. | Max<br>Unc <sup>E</sup><br>(k=2) |
|---------------|-----------------------------|---|---------|------------------------------|-------|---------|----------|-------------|----------------------------------|
| 0             | CW                          | X | 0.00    | 0.00                         | 1.00  | 0.00    | 137.4    | ± 3.0 %     | ± 4.7 %                          |
|               |                             | Y | 0.00    | 0.00                         | 1.00  |         | 158.3    |             |                                  |
|               |                             | Z | 0.00    | 0.00                         | 1.00  |         | 137.4    |             |                                  |
| 10352-<br>AAA | Pulse Waveform (200Hz, 10%) | X | 15.00   | 87.34                        | 19.77 | 10.00   | 60.0     | ± 2.4 %     | ± 9.6 %                          |
|               |                             | Y | 15.00   | 88.92                        | 21.71 |         | 60.0     |             |                                  |
|               |                             | Z | 15.00   | 88.27                        | 21.00 |         | 60.0     |             |                                  |
| 10353-<br>AAA | Pulse Waveform (200Hz, 20%) | X | 15.00   | 89.04                        | 19.16 | 6.99    | 80.0     | ± 1.1 %     | ± 9.6 %                          |
|               |                             | Y | 15.00   | 89.64                        | 20.91 |         | 80.0     |             |                                  |
|               |                             | Z | 15.00   | 88.37                        | 19.64 |         | 80.0     |             |                                  |
| 10354-<br>AAA | Pulse Waveform (200Hz, 40%) | X | 15.00   | 92.42                        | 19.01 | 3.98    | 95.0     | ± 1.1 %     | ± 9.6 %                          |
|               |                             | Y | 15.00   | 92.36                        | 20.80 |         | 95.0     |             |                                  |
|               |                             | Z | 15.00   | 88.86                        | 18.16 |         | 95.0     |             |                                  |
| 10355-<br>AAA | Pulse Waveform (200Hz, 60%) | X | 15.00   | 87.46                        | 14.88 | 2.22    | 120.0    | ± 1.4 %     | ± 9.6 %                          |
|               |                             | Y | 15.00   | 97.28                        | 21.80 |         | 120.0    |             |                                  |
|               |                             | Z | 15.00   | 87.00                        | 15.66 |         | 120.0    |             |                                  |
| 10387-<br>AAA | QPSK Waveform, 1 MHz        | X | 0.43    | 60.00                        | 5.51  | 0.00    | 150.0    | ± 3.6 %     | ± 9.6 %                          |
|               |                             | Y | 1.09    | 66.72                        | 12.69 |         | 150.0    |             |                                  |
|               |                             | Z | 0.59    | 60.62                        | 7.72  |         | 150.0    |             |                                  |
| 10388-<br>AAA | QPSK Waveform, 10 MHz       | X | 2.57    | 72.49                        | 18.21 | 0.00    | 150.0    | ± 1.3 %     | ± 9.6 %                          |
|               |                             | Y | 2.62    | 70.88                        | 17.20 |         | 150.0    |             |                                  |
|               |                             | Z | 2.18    | 68.21                        | 15.62 |         | 150.0    |             |                                  |
| 10396-<br>AAA | 64-QAM Waveform, 100 kHz    | X | 2.83    | 72.00                        | 20.42 | 3.01    | 150.0    | ± 1.0 %     | ± 9.6 %                          |
|               |                             | Y | 3.63    | 73.46                        | 20.08 |         | 150.0    |             |                                  |
|               |                             | Z | 3.10    | 70.61                        | 18.84 |         | 150.0    |             |                                  |
| 10399-<br>AAA | 64-QAM Waveform, 40 MHz     | X | 3.60    | 68.54                        | 16.82 | 0.00    | 150.0    | ± 2.1 %     | ± 9.6 %                          |
|               |                             | Y | 3.60    | 67.80                        | 16.22 |         | 150.0    |             |                                  |
|               |                             | Z | 3.50    | 67.31                        | 15.82 |         | 150.0    |             |                                  |
| 10414-<br>AAA | WLAN CCDF, 64-QAM, 40MHz    | X | 4.81    | 66.42                        | 16.25 | 0.00    | 150.0    | ± 4.1 %     | ± 9.6 %                          |
|               |                             | Y | 4.90    | 65.76                        | 15.65 |         | 150.0    |             |                                  |
|               |                             | Z | 4.89    | 65.90                        | 15.70 |         | 150.0    |             |                                  |

Note: For details on UID parameters see Appendix

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

<sup>A</sup> The uncertainties of Norm X,Y,Z do not affect the E<sup>2</sup>-field uncertainty inside TSL (see Page 5).

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

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

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3931

### Sensor Model Parameters

|   | C1<br>fF | C2<br>fF | $\alpha$<br>$V^{-1}$ | T1<br>$ms.V^{-2}$ | T2<br>$ms.V^{-1}$ | T3<br>ms | T4<br>$V^{-2}$ | T5<br>$V^{-1}$ | T6   |
|---|----------|----------|----------------------|-------------------|-------------------|----------|----------------|----------------|------|
| X | 34.0     | 262.55   | 38.03                | 9.56              | 0.59              | 5.10     | 0.00           | 0.39           | 1.01 |
| Y | 52.6     | 386.96   | 34.79                | 24.27             | 0.78              | 5.10     | 0.89           | 0.44           | 1.01 |
| Z | 45.7     | 349.94   | 37.08                | 17.58             | 0.95              | 5.10     | 0.00           | 0.61           | 1.01 |

### Other Probe Parameters

|                                               |            |
|-----------------------------------------------|------------|
| Sensor Arrangement                            | Triangular |
| Connector Angle (°)                           | 41         |
| Mechanical Surface Detection Mode             | enabled    |
| Optical Surface Detection Mode                | disabled   |
| Probe Overall Length                          | 337 mm     |
| Probe Body Diameter                           | 10 mm      |
| Tip Length                                    | 9 mm       |
| Tip Diameter                                  | 2.5 mm     |
| Probe Tip to Sensor X Calibration Point       | 1 mm       |
| Probe Tip to Sensor Y Calibration Point       | 1 mm       |
| Probe Tip to Sensor Z Calibration Point       | 1 mm       |
| Recommended Measurement Distance from Surface | 1.4 mm     |

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3931

### Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) <sup>C</sup> | Relative Permittivity <sup>F</sup> | Conductivity (S/m) <sup>F</sup> | ConvF X | ConvF Y | ConvF Z | Alpha <sup>G</sup> | Depth <sup>G</sup> (mm) | Unc (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-----------|
| 750                  | 41.9                               | 0.89                            | 9.99    | 9.99    | 9.99    | 0.68               | 0.80                    | ± 12.0 %  |
| 835                  | 41.5                               | 0.90                            | 9.80    | 9.80    | 9.80    | 0.58               | 0.85                    | ± 12.0 %  |
| 900                  | 41.5                               | 0.97                            | 9.49    | 9.49    | 9.49    | 0.57               | 0.91                    | ± 12.0 %  |
| 1450                 | 40.5                               | 1.20                            | 8.75    | 8.75    | 8.75    | 0.45               | 0.80                    | ± 12.0 %  |
| 1750                 | 40.1                               | 1.37                            | 8.66    | 8.66    | 8.66    | 0.39               | 0.86                    | ± 12.0 %  |
| 1900                 | 40.0                               | 1.40                            | 8.32    | 8.32    | 8.32    | 0.36               | 0.86                    | ± 12.0 %  |
| 2000                 | 40.0                               | 1.40                            | 8.30    | 8.30    | 8.30    | 0.32               | 0.86                    | ± 12.0 %  |
| 2300                 | 39.5                               | 1.67                            | 7.83    | 7.83    | 7.83    | 0.33               | 0.90                    | ± 12.0 %  |
| 2450                 | 39.2                               | 1.80                            | 7.61    | 7.61    | 7.61    | 0.39               | 0.90                    | ± 12.0 %  |
| 2600                 | 39.0                               | 1.96                            | 7.43    | 7.43    | 7.43    | 0.43               | 0.90                    | ± 12.0 %  |
| 3300                 | 38.2                               | 2.71                            | 7.07    | 7.07    | 7.07    | 0.30               | 1.35                    | ± 14.0 %  |
| 3500                 | 37.9                               | 2.91                            | 7.05    | 7.05    | 7.05    | 0.35               | 1.35                    | ± 14.0 %  |
| 3700                 | 37.7                               | 3.12                            | 6.97    | 6.97    | 6.97    | 0.30               | 1.35                    | ± 14.0 %  |
| 5250                 | 35.9                               | 4.71                            | 5.08    | 5.08    | 5.08    | 0.40               | 1.80                    | ± 14.0 %  |
| 5600                 | 35.5                               | 5.07                            | 4.49    | 4.49    | 4.49    | 0.40               | 1.80                    | ± 14.0 %  |
| 5750                 | 35.4                               | 5.22                            | 4.75    | 4.75    | 4.75    | 0.40               | 1.80                    | ± 14.0 %  |

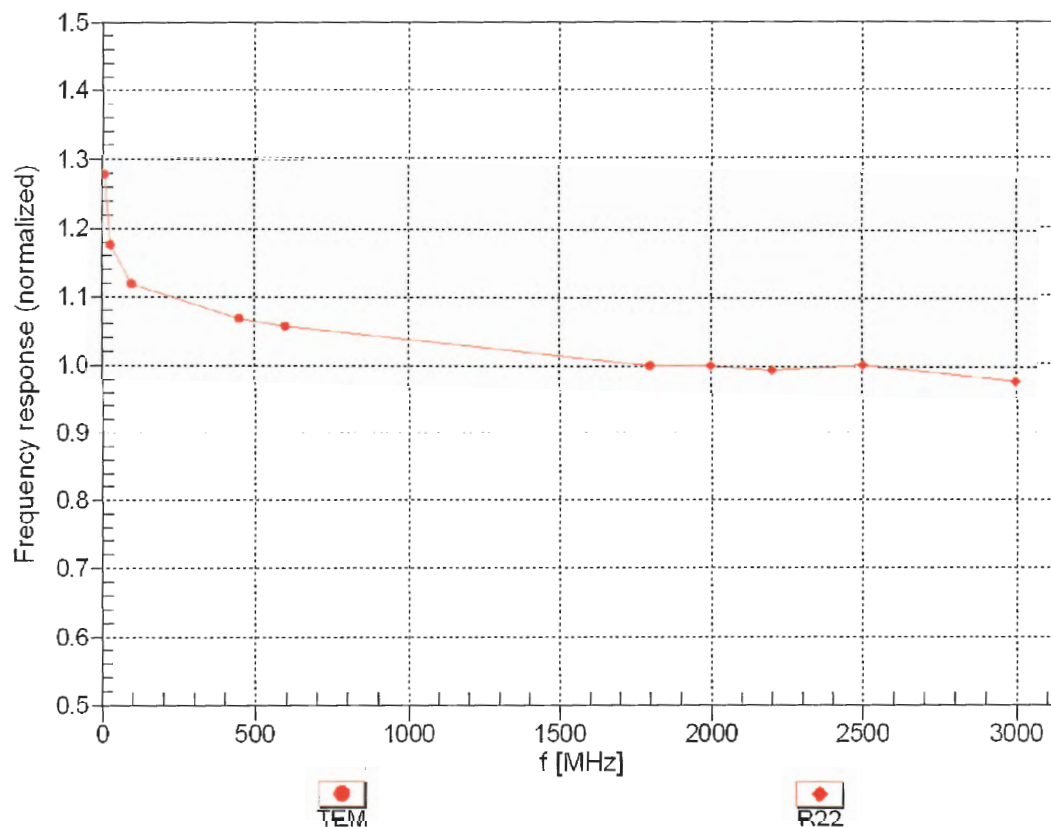
<sup>C</sup> Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.

<sup>F</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

## Frequency Response of E-Field

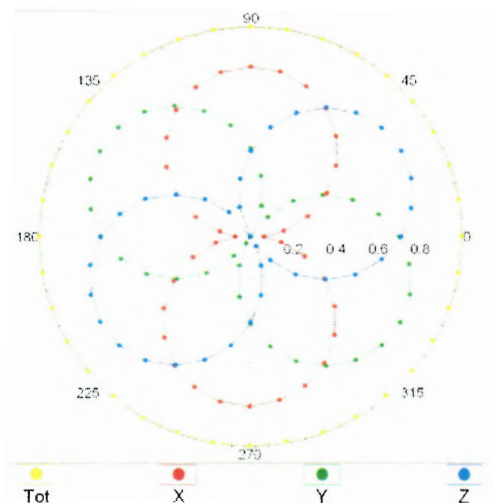
(TEM-Cell:ifi110 EXX, Waveguide: R22)



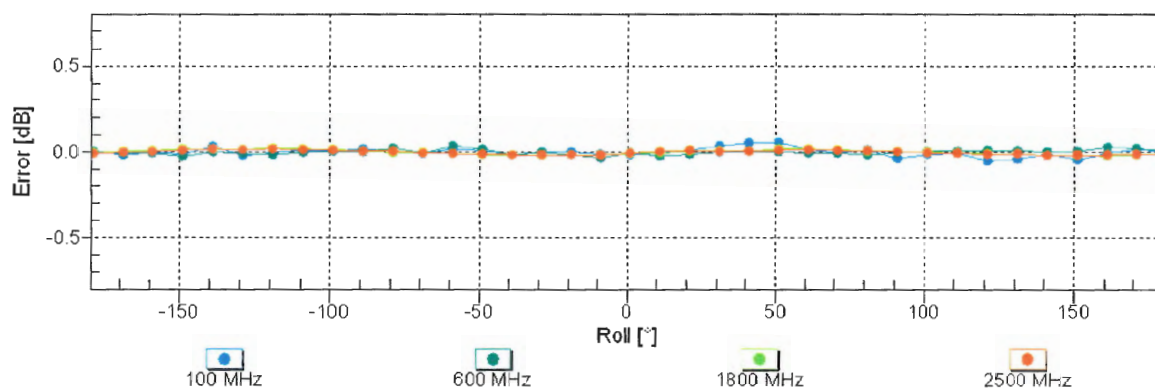
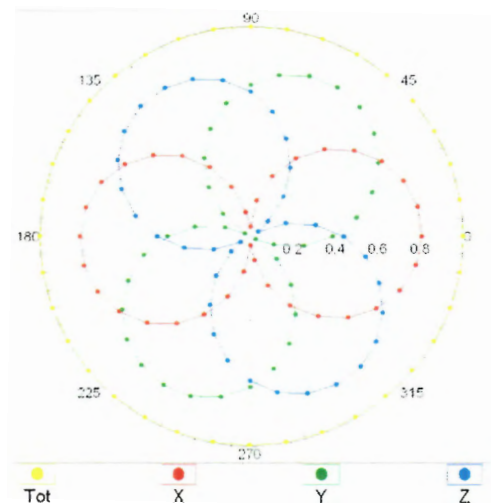
Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  ( $k=2$ )

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

f=600 MHz, TEM

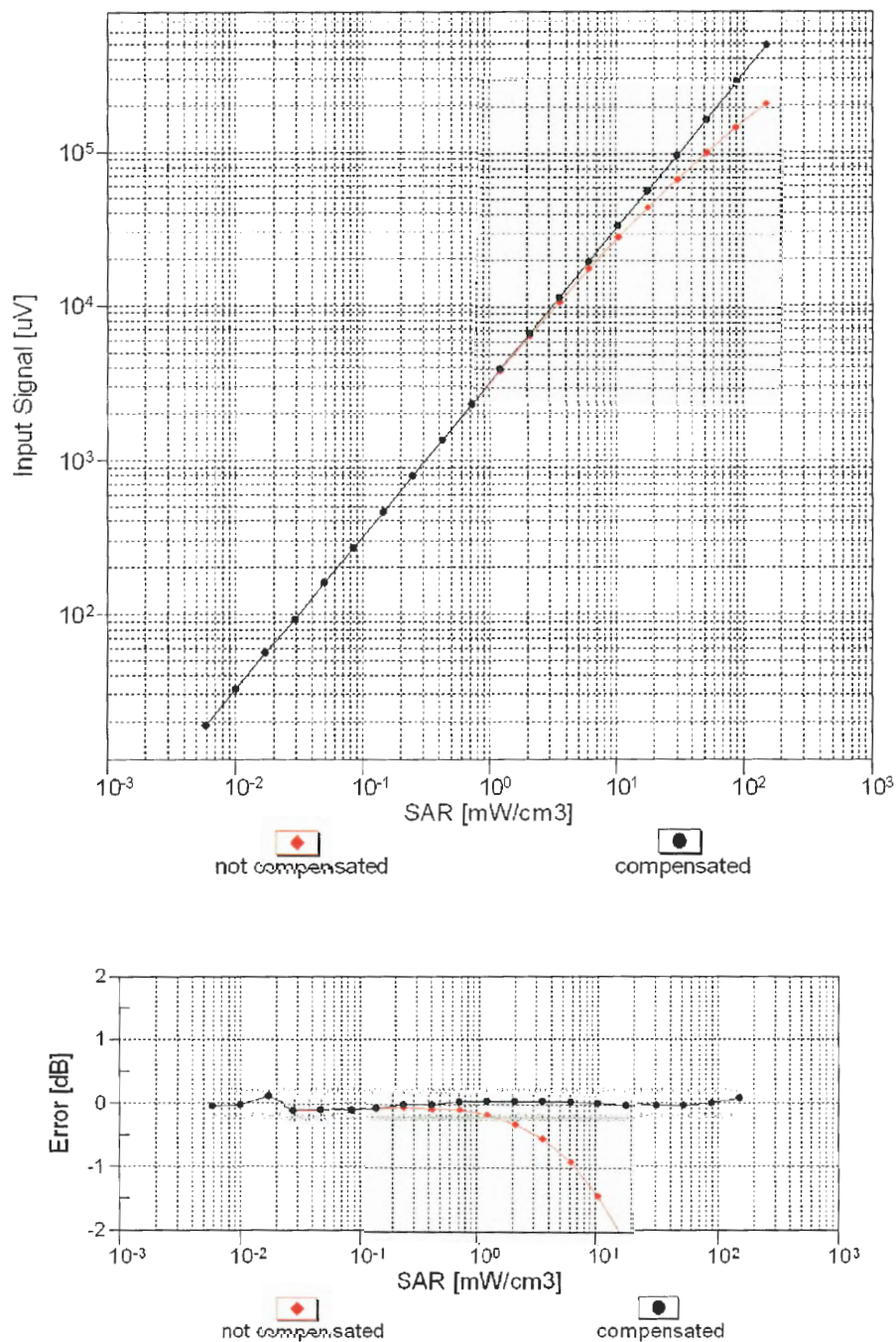


f=1800 MHz, R22



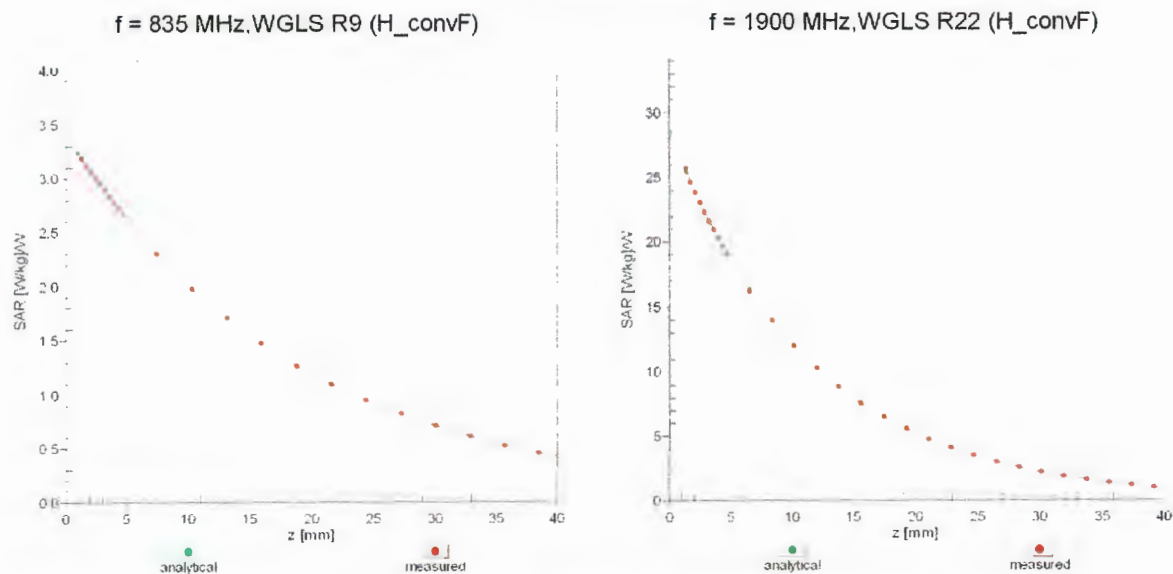
Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  ( $k=2$ )

## Dynamic Range $f(\text{SAR}_{\text{head}})$ (TEM cell , $f_{\text{eval}} = 1900 \text{ MHz}$ )



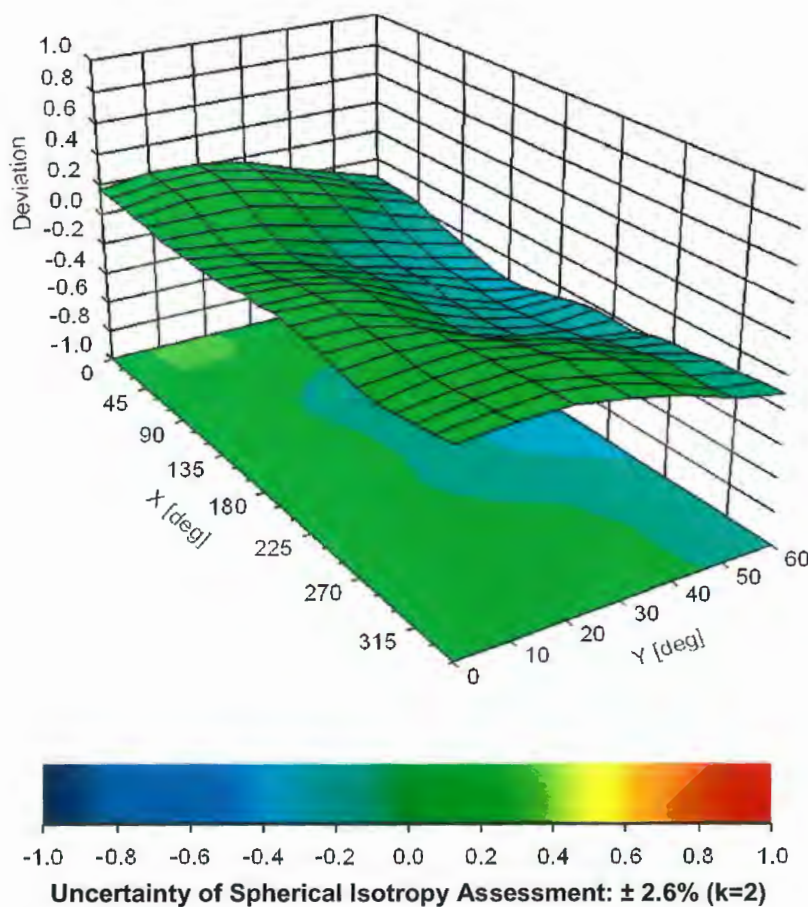
Uncertainty of Linearity Assessment:  $\pm 0.6\%$  ( $k=2$ )

## Conversion Factor Assessment



## Deviation from Isotropy in Liquid

Error ( $\phi, \theta$ ),  $f = 900 \text{ MHz}$





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 **Sporton**

Certificate No: **EUmmWV4-9461\_Nov19**

## CALIBRATION CERTIFICATE

Object **EUmmWV4 - SN:9461**

Calibration procedure(s) **QA CAL-02.v9, QA CAL-25.v7, QA CAL-42.v2**  
 Calibration procedure for E-field probes optimized for close near field  
 evaluations in air

Calibration date: **November 5, 2019**

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 NRP            | SN: 104778       | 03-Apr-19 (No. 217-02892/02893)   | Apr-20                 |
| Power sensor NRP-Z91       | SN: 103244       | 03-Apr-19 (No. 217-02892)         | Apr-20                 |
| Power sensor NRP-Z91       | SN: 103245       | 03-Apr-19 (No. 217-02893)         | Apr-20                 |
| Reference 20 dB Attenuator | SN: S5277 (20x)  | 04-Apr-19 (No. 217-02894)         | Apr-20                 |
| Reference Probe ER3DV6     | SN: 2328         | 05-Oct-19 (No. ER3-2328_Oct19)    | Oct-20                 |
| DAE4                       | SN: 789          | 14-Jan-19 (No. DAE4-789_Jan19)    | Jan-20                 |
| Secondary Standards        | ID               | Check Date (in house)             | Scheduled Check        |
| Power meter E4419B         | SN: GB41293874   | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A        | SN: MY41498087   | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A        | SN: 000110210    | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| RF generator HP 8648C      | SN: US3642U01700 | 04-Aug-99 (in house check Jun-18) | In house check: Jun-20 |
| Network Analyzer HP 8753E  | SN: US37390585   | 18-Oct-01 (in house check Oct-19) | In house check: Oct-20 |

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

Issued: November 5, 2019

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:

|                          |                                                                                                                                                         |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| NORM <sub>x,y,z</sub>    | sensitivity in free space                                                                                                                               |
| DCP                      | diode compression point                                                                                                                                 |
| CF                       | crest factor (1/duty_cycle) of the RF signal                                                                                                            |
| A, B, C, D               | modulation dependent linearization parameters                                                                                                           |
| Polarization $\phi$      | $\phi$ rotation around probe axis                                                                                                                       |
| Polarization $\vartheta$ | $\vartheta$ rotation around an axis that is in the plane normal to probe axis (at measurement center),<br>i.e., $\vartheta = 0$ is normal to probe axis |
| Connector Angle          | information used in DASY system to align probe sensor X to the robot coordinate system                                                                  |
| Sensor Angles<br>$k$     | sensor deviation from the probe axis, used to calculate the field orientation and polarization<br>is the wave propagation direction                     |

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

- IEEE Std 1309-2005, "IEEE Standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz", December 2005

### Methods Applied and Interpretation of Parameters:

- NORM<sub>x,y,z</sub>**: Assessed for E-field polarization  $\vartheta = 0$  for XY sensors and  $\vartheta = 90$  for Z sensor ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide). For frequencies  $> 6$  GHz, the far field in front of waveguide horn antennas is measured for a set of frequencies in various waveguide bands up to 110 GHz.
- DCP<sub>x,y,z</sub>**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- PAR**: PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- The frequency sensor model parameters are determined prior to calibration based on a frequency sweep (sensor model involving resistors R, R<sub>p</sub>, inductance L and capacitors C, C<sub>p</sub>).
- A<sub>x,y,z</sub>; B<sub>x,y,z</sub>; C<sub>x,y,z</sub>; D<sub>x,y,z</sub>; VR<sub>x,y,z</sub>; A, B, C, D** are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- Sensor Offset**: The sensor offset corresponds to the mechanical from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the NORM<sub>x</sub> (no uncertainty required).
- Equivalent Sensor Angle**: The two probe sensors are mounted in the same plane at different angles. The angles are assessed using the information gained by determining the NORM<sub>x</sub> (no uncertainty required).
- Spherical isotropy (3D deviation from isotropy)**: in a locally homogeneous field realized using an open waveguide / horn setup.

## DASY - Parameters of Probe: EUmmWV4 - SN:9461

### Basic Calibration Parameters

|                                              | Sensor X | Sensor Y | Unc (k=2)     |
|----------------------------------------------|----------|----------|---------------|
| Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) | 0.02153  | 0.02252  | $\pm 10.1 \%$ |
| DCP (mV) <sup>B</sup>                        | 100.0    | 112.0    |               |
| Equivalent Sensor Angle                      | -60.6    | 35.0     |               |

### Calibration results for Frequency Response (750 MHz – 110 GHz)

| Frequency GHz | Target E-Field V/m | Deviation Sensor X dB | Deviation Sensor Y dB | Unc (k=2) dB  |
|---------------|--------------------|-----------------------|-----------------------|---------------|
| 0.75          | 77.2               | -0.16                 | 0.17                  | $\pm 0.43$ dB |
| 1.8           | 140.4              | 0.10                  | 0.13                  | $\pm 0.43$ dB |
| 2             | 133.0              | 0.03                  | 0.07                  | $\pm 0.43$ dB |
| 2.2           | 124.8              | 0.03                  | 0.04                  | $\pm 0.43$ dB |
| 2.5           | 123.0              | -0.05                 | -0.09                 | $\pm 0.43$ dB |
| 3.5           | 256.2              | 0.07                  | -0.12                 | $\pm 0.43$ dB |
| 3.7           | 249.8              | 0.13                  | -0.10                 | $\pm 0.43$ dB |
| 6.6           | 41.8               | 0.13                  | 0.52                  | $\pm 0.98$ dB |
| 8             | 48.4               | -0.21                 | -0.20                 | $\pm 0.98$ dB |
| 10            | 54.4               | -0.03                 | 0.00                  | $\pm 0.98$ dB |
| 15            | 71.5               | 0.36                  | -0.25                 | $\pm 0.98$ dB |
| 18            | 85.3               | -0.34                 | -0.02                 | $\pm 0.98$ dB |
| 26.6          | 96.9               | 0.02                  | 0.02                  | $\pm 0.98$ dB |
| 30            | 92.6               | 0.19                  | 0.10                  | $\pm 0.98$ dB |
| 35            | 93.7               | -0.29                 | -0.16                 | $\pm 0.98$ dB |
| 40            | 91.5               | -0.77                 | -0.57                 | $\pm 0.98$ dB |
| 50            | 19.6               | -0.05                 | 0.12                  | $\pm 0.98$ dB |
| 55            | 22.4               | 0.44                  | 0.40                  | $\pm 0.98$ dB |
| 60            | 23.0               | -0.04                 | -0.04                 | $\pm 0.98$ dB |
| 65            | 27.4               | -0.22                 | -0.01                 | $\pm 0.98$ dB |
| 70            | 23.9               | 0.21                  | -0.10                 | $\pm 0.98$ dB |
| 75            | 20.0               | 0.04                  | -0.04                 | $\pm 0.98$ dB |
| 75            | 14.8               | 0.20                  | 0.35                  | $\pm 0.98$ dB |
| 80            | 22.5               | 0.14                  | 0.28                  | $\pm 0.98$ dB |
| 85            | 22.8               | 0.01                  | 0.05                  | $\pm 0.98$ dB |
| 90            | 23.8               | 0.03                  | 0.03                  | $\pm 0.98$ dB |
| 92            | 23.9               | -0.11                 | -0.15                 | $\pm 0.98$ dB |
| 95            | 20.5               | -0.19                 | -0.15                 | $\pm 0.98$ dB |
| 97            | 24.4               | -0.08                 | -0.10                 | $\pm 0.98$ dB |
| 100           | 22.6               | 0.09                  | -0.01                 | $\pm 0.98$ dB |
| 105           | 22.7               | 0.03                  | 0.03                  | $\pm 0.98$ dB |
| 110           | 19.7               | 0.06                  | 0.17                  | $\pm 0.98$ dB |

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

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

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

## DASY - Parameters of Probe: EUMmWV4 - SN:9461

### Calibration Results for Modulation Response

| UID           | Communication System Name   |   | A<br>dB | B<br>dB $\sqrt{\mu V}$ | C     | D<br>dB | VR<br>mV | Max<br>dev.  | Max<br>Unc <sup>E</sup><br>(k=2) |
|---------------|-----------------------------|---|---------|------------------------|-------|---------|----------|--------------|----------------------------------|
| 0             | CW                          | X | 0.00    | 0.00                   | 1.00  | 0.00    | 111.3    | $\pm 3.8 \%$ | $\pm 4.7 \%$                     |
|               |                             | Y | 0.00    | 0.00                   | 1.00  |         | 88.6     |              |                                  |
| 10352-<br>AAA | Pulse Waveform (200Hz, 10%) | X | 1.51    | 60.00                  | 12.61 | 10.00   | 6.0      | $\pm 1.5 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 2.31    | 60.00                  | 12.97 |         | 6.0      |              |                                  |
| 10353-<br>AAA | Pulse Waveform (200Hz, 20%) | X | 0.92    | 60.00                  | 11.74 | 6.99    | 12.0     | $\pm 0.9 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 14.00   | 78.00                  | 17.00 |         | 12.0     |              |                                  |
| 10354-<br>AAA | Pulse Waveform (200Hz, 40%) | X | 0.51    | 60.00                  | 10.67 | 3.98    | 23.0     | $\pm 1.1 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 0.73    | 60.00                  | 11.46 |         | 23.0     |              |                                  |
| 10355-<br>AAA | Pulse Waveform (200Hz, 60%) | X | 0.33    | 60.00                  | 9.70  | 2.22    | 27.0     | $\pm 0.7 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 0.48    | 60.00                  | 10.79 |         | 27.0     |              |                                  |
| 10387-<br>AAA | QPSK Waveform, 1 MHz        | X | 0.11    | 101.24                 | 0.22  | 0.00    | 22.0     | $\pm 1.2 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 2.53    | 81.91                  | 0.54  |         | 22.0     |              |                                  |
| 10388-<br>AAA | QPSK Waveform, 10 MHz       | X | 1.26    | 60.00                  | 11.42 | 0.00    | 22.0     | $\pm 0.7 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 1.20    | 60.00                  | 11.92 |         | 22.0     |              |                                  |
| 10396-<br>AAA | 64-QAM Waveform, 100 kHz    | X | 1.88    | 60.00                  | 13.67 | 3.01    | 17.0     | $\pm 0.6 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 1.94    | 60.52                  | 13.93 |         | 17.0     |              |                                  |
| 10399-<br>AAA | 64-QAM Waveform, 40 MHz     | X | 2.14    | 60.00                  | 12.11 | 0.00    | 19.0     | $\pm 0.7 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 1.97    | 60.00                  | 12.44 |         | 19.0     |              |                                  |
| 10414-<br>AAA | WLAN CCDF, 64-QAM, 40MHz    | X | 3.17    | 60.00                  | 12.58 | 0.00    | 12.0     | $\pm 0.8 \%$ | $\pm 9.6 \%$                     |
|               |                             | Y | 2.90    | 60.00                  | 12.86 |         | 12.0     |              |                                  |

Note: For details on all calibrated UID parameters see Appendix

### Calibration Results for Linearity Response

| Frequency<br>GHz | Target E-Field<br>V/m | Deviation Sensor X dB | Deviation Sensor Y dB | Unc (k=2)<br>dB |
|------------------|-----------------------|-----------------------|-----------------------|-----------------|
| 0.9              | 50.0                  | 0.09                  | -0.09                 | $\pm 0.2$ dB    |
| 0.9              | 100.0                 | 0.04                  | 0.09                  | $\pm 0.2$ dB    |
| 0.9              | 500.0                 | -0.01                 | -0.02                 | $\pm 0.2$ dB    |
| 0.9              | 1000.0                | 0.01                  | 0.01                  | $\pm 0.2$ dB    |
| 0.9              | 1500.0                | 0.00                  | 0.01                  | $\pm 0.2$ dB    |
| 0.9              | 2000.0                | -0.04                 | 0.01                  | $\pm 0.2$ dB    |

### Sensor Frequency Model Parameters (750 MHz – 78 GHz)

|                             | Sensor X | Sensor Y |
|-----------------------------|----------|----------|
| R ( $\Omega$ )              | 42.91    | 43.78    |
| R <sub>p</sub> ( $\Omega$ ) | 94.99    | 91.70    |
| L (nH)                      | 0.04383  | 0.04084  |
| C (pF)                      | 0.2089   | 0.2543   |
| C <sub>p</sub> (pF)         | 0.1087   | 0.1140   |

### Sensor Frequency Model Parameters (55 GHz – 110 GHz)

|                             | Sensor X | Sensor Y |
|-----------------------------|----------|----------|
| R ( $\Omega$ )              | 28.99    | 29.33    |
| R <sub>p</sub> ( $\Omega$ ) | 99.67    | 97.13    |
| L (nH)                      | 0.03854  | 0.03920  |
| C (pF)                      | 0.1439   | 0.1488   |
| C <sub>p</sub> (pF)         | 0.1219   | 0.1187   |

## DASY - Parameters of Probe: EUmmWV4 - SN:9461

### Sensor Model Parameters

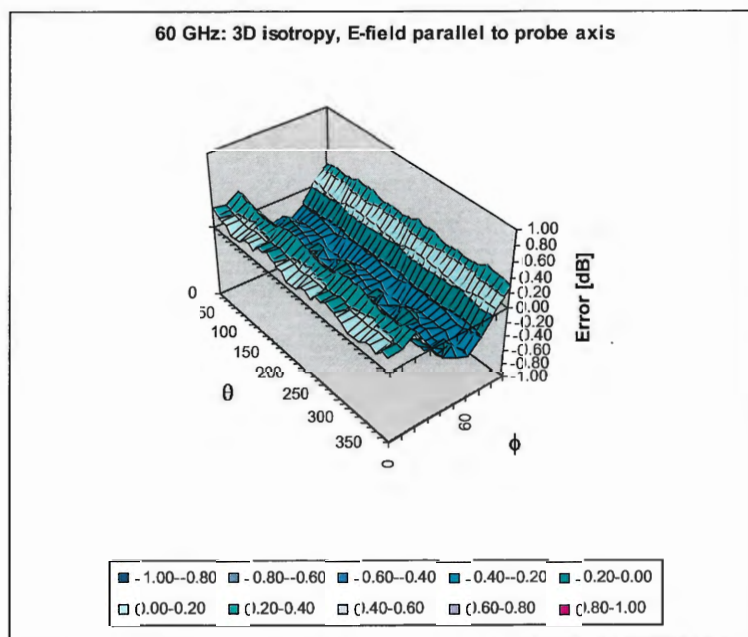
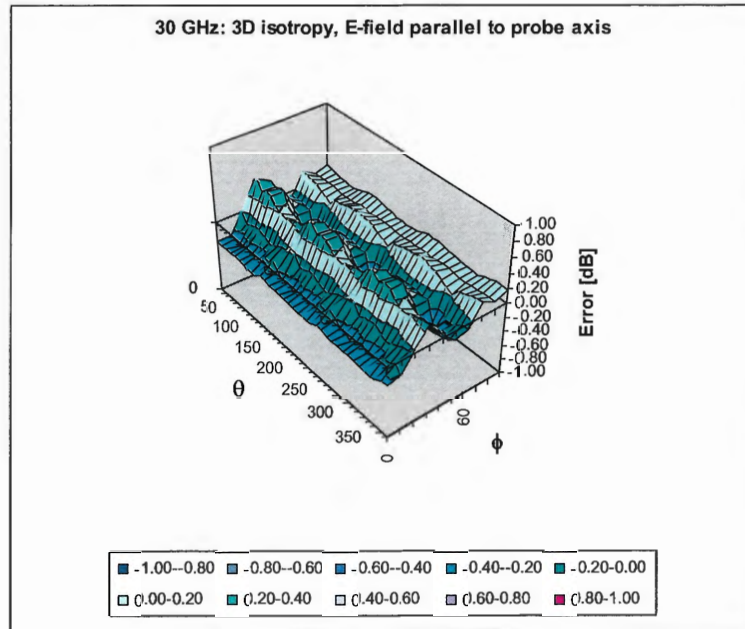
|   | C1<br>fF | C2<br>fF | $\alpha$<br>$V^{-1}$ | T1<br>$ms.V^{-2}$ | T2<br>$ms.V^{-1}$ | T3<br>ms | T4<br>$V^{-2}$ | T5<br>$V^{-1}$ | T6   |
|---|----------|----------|----------------------|-------------------|-------------------|----------|----------------|----------------|------|
| X | 24.1     | 182.58   | 36.01                | 0.00              | 1.73              | 5.00     | 0.00           | 0.98           | 1.01 |
| Y | 28.1     | 195.63   | 31.32                | 0.92              | 3.12              | 4.97     | 0.00           | 1.15           | 1.01 |

### Other Probe Parameters

|                                         |             |
|-----------------------------------------|-------------|
| Sensor Arrangement                      | Rectangular |
| Connector Angle (°)                     | 68.8        |
| Mechanical Surface Detection Mode       | enabled     |
| Optical Surface Detection Mode          | disabled    |
| Probe Overall Length                    | 320 mm      |
| Probe Body Diameter                     | 8 mm        |
| Tip Length                              | 23 mm       |
| Tip Diameter                            | 8.0 mm      |
| Probe Tip to Sensor X Calibration Point | 1.5 mm      |
| Probe Tip to Sensor Y Calibration Point | 1.5 mm      |

## Deviation from Isotropy in Air

$f = 30, 60 \text{ GHz}$



Probe isotropy for  $E_{\text{tot}}$ : probe rotated  $\phi = 0^\circ$  to  $360^\circ$ , tilted from field propagation direction  $\vec{k}$   
 Parallel to the field propagation ( $\psi = 0^\circ - 90^\circ$ ) at 30 GHz: deviation within  $\pm 0.40 \text{ dB}$   
 Parallel to the field propagation ( $\psi = 0^\circ - 90^\circ$ ) at 60 GHz: deviation within  $\pm 0.40 \text{ dB}$