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Accreditation No.: **SCS 0108**

Client **Sporton**

Certificate No: **5G-Veri30-1007\_Nov19**

## CALIBRATION CERTIFICATE

Object **5G Verification Source 30 GHz - SN: 1007**

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

Calibration date: **November 19, 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 |
|-------------------------|----------|------------------------------------|-----------------------|
| Reference Probe EUmmWV3 | SN: 9374 | 31-Dec-18 (No. EUmmWV3-9374_Dec18) | Dec-19                |
| DAE4ip                  | SN: 1602 | 01-Oct-19 (No. DAE4ip-1602_Oct19)  | Oct-20                |

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

|                | Name          | Function              | Signature |
|----------------|---------------|-----------------------|-----------|
| Calibrated by: | Leif Klysner  | Laboratory Technician |           |
| Approved by:   | Katja Pokovic | Technical Manager     |           |

Issued: November 20, 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 and the antenna ohmic and mismatch losses are determined by far-field measurements. (2) 30, 45, 60 and 90 GHz: The verification sources are switched on for at least 30 minutes. Absorbers are used around the probe cub and at the ceiling to minimize reflections.
- *Horn Positioning:* The waveguide horn is mounted vertically on the flange of the waveguide source to allow vertical positioning of the EUmmW probe during the scan. The plane is parallel to the phantom surface. Probe distance is verified using mechanical gauges positioned on the flare of the horn.
- *E- field distribution:* E field is measured in two x-y-plane (10mm, 10mm +  $\lambda/4$ ) with a vectorial E-field probe. The E-field value stated as calibration value represents the E-field-maxima and the averaged (1cm<sup>2</sup> and 4cm<sup>2</sup>) 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  $n \cdot \text{Re}\{S\}$  averaged over the surface area of 1 cm<sup>2</sup> ( $pS_{\text{totavg}1\text{cm}^2}$  and  $pS_{n\text{avg}1\text{cm}^2}$ ) and 4cm<sup>2</sup> ( $pS_{\text{totavg}4\text{cm}^2}$  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          | V2.0 |
| <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>Prad</i><sup>1</sup></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                                       | 30.3                                          | <b>131</b>                         | 1.27 dB                | <b>39.0, 39.4</b>                                            | <b>33.7, 34.1</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: 1007 | -        |

### Exposure Conditions

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

### Hardware Setup

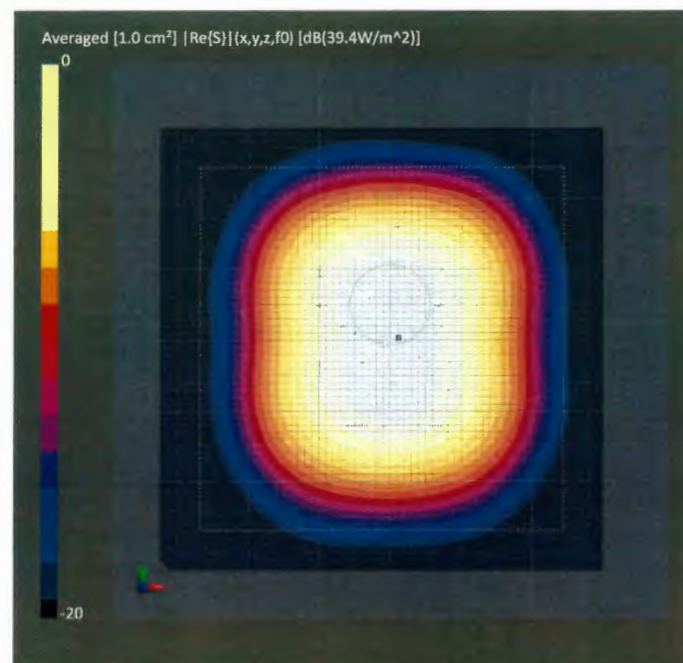
| Phantom               | Medium | Probe, Calibration Date      | DAE, Calibration Date     |
|-----------------------|--------|------------------------------|---------------------------|
| mmWave Phantom - 1002 | Air    | EUmmWV3 - SN9374, 2018-12-31 | DAE4ip Sn1602, 2019-10-01 |

### 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                          | 2019-11-19, 08:47 |
| Avg. Area [cm <sup>2</sup> ]  | 1.00              |
| pStot avg [W/m <sup>2</sup> ] | 39.4              |
| pSn avg [W/m <sup>2</sup> ]   | 39.0              |
| E <sub>peak</sub> [V/m]       | 131               |
| Power Drift [dB]              | -0.00             |





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Accreditation No.: **SCS 0108**

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

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

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

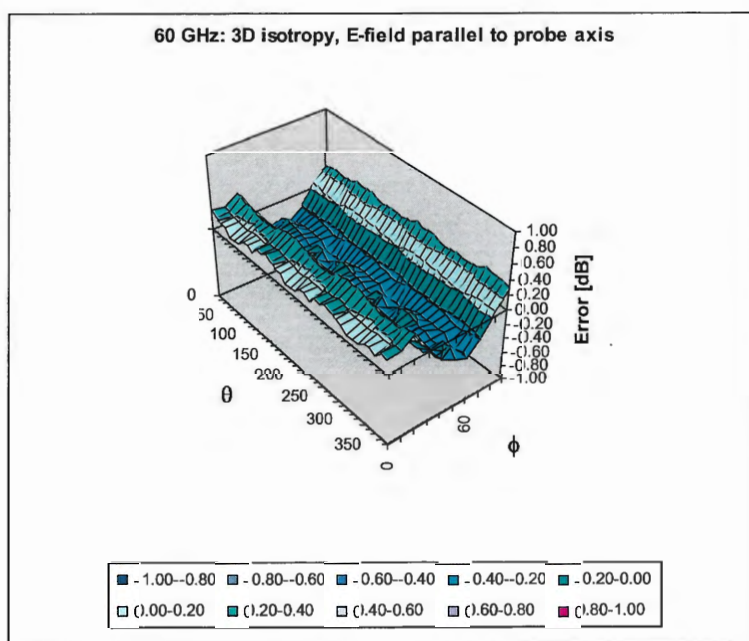
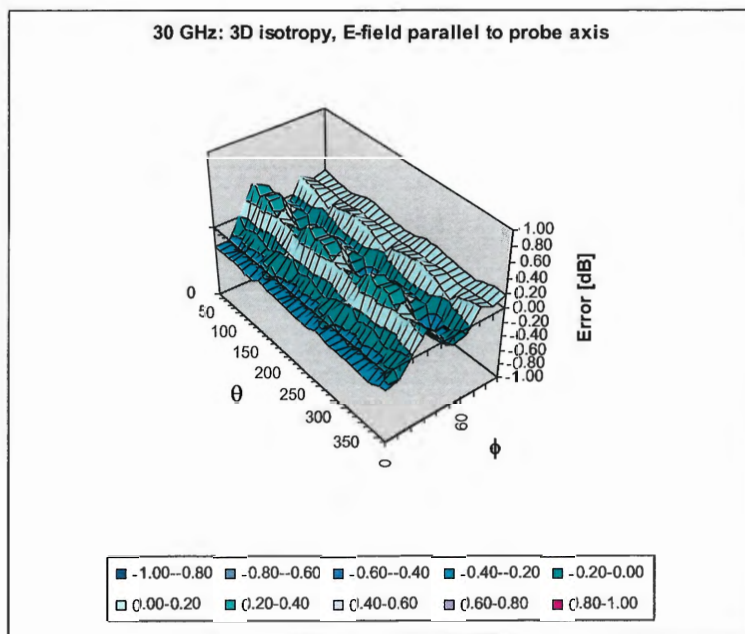
|   | C1<br>fF | C2<br>fF | $\alpha$<br>$V^{-1}$ | T1<br>$ms.V^{-2}$ | T2<br>$ms.V^{-1}$ | T3<br>ms | T4<br>$V^{-2}$ | T5<br>$V^{-1}$ | T6   |
|---|----------|----------|----------------------|-------------------|-------------------|----------|----------------|----------------|------|
| X | 24.1     | 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  $\pm 0.40 \text{ dB}$



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Accreditation No.: **SCS 0108**

Client **Sporton**

Certificate No: **DAE4-376\_Dec19**

## CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BJ - SN: 376**

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

Calibration date: **December 06, 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-19 (No:25949)       | Sep-20                 |
| 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 |
|-------------------|-----------------------|-----------|
| Dominique Steffen | Laboratory Technician |           |

Approved by: 

| Name      | Function       | Signature |
|-----------|----------------|-----------|
| Sven Kühn | Deputy Manager |           |

Issued: December 9, 2019

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



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

## Glossary

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          | 403.769 $\pm$ 0.02% (k=2) | 403.257 $\pm$ 0.02% (k=2) | 403.329 $\pm$ 0.02% (k=2) |
| Low Range           | 3.96196 $\pm$ 1.50% (k=2) | 3.93938 $\pm$ 1.50% (k=2) | 3.95372 $\pm$ 1.50% (k=2) |

## Connector Angle

|                                           |                   |
|-------------------------------------------|-------------------|
| Connector Angle to be used in DASY system | 215.5 ° $\pm$ 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 | 199996.34                 | 0.15                         | 0.00      |
| Channel X + Input | 20005.93                  | 3.53                         | 0.02      |
| Channel X - Input | -19996.90                 | 4.13                         | -0.02     |
| Channel Y + Input | 199996.81                 | 1.06                         | 0.00      |
| Channel Y + Input | 20003.51                  | 1.31                         | 0.01      |
| Channel Y - Input | -20000.90                 | 0.25                         | -0.00     |
| Channel Z + Input | 199997.40                 | 1.90                         | 0.00      |
| Channel Z + Input | 20001.76                  | -0.48                        | -0.00     |
| Channel Z - Input | -20001.01                 | 0.22                         | -0.00     |

| Low Range         | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 2003.26                   | 1.46                         | 0.07      |
| Channel X + Input | 202.23                    | 0.06                         | 0.03      |
| Channel X - Input | -197.79                   | -0.09                        | 0.04      |
| Channel Y + Input | 2002.55                   | 0.79                         | 0.04      |
| Channel Y + Input | 201.70                    | -0.26                        | -0.13     |
| Channel Y - Input | -198.58                   | -0.80                        | 0.41      |
| Channel Z + Input | 2002.01                   | 0.32                         | 0.02      |
| Channel Z + Input | 200.66                    | -1.16                        | -0.57     |
| Channel Z - Input | -199.39                   | -1.47                        | 0.74      |

### 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                            | 6.17                                         | 4.71                                        |
|           | - 200                          | -4.51                                        | -5.46                                       |
| Channel Y | 200                            | -0.99                                        | -1.23                                       |
|           | - 200                          | -0.48                                        | -0.54                                       |
| Channel Z | 200                            | 1.15                                         | 1.23                                        |
|           | - 200                          | -4.48                                        | -4.49                                       |

### 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                | -                           | 4.15                        | -2.03                       |
| Channel Y | 200                | 9.02                        | -                           | 3.40                        |
| Channel Z | 200                | 10.51                       | 7.61                        | -                           |

#### 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 | 15932            | 16255           |
| Channel Y | 16008            | 15888           |
| Channel Z | 16067            | 15143           |

#### 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 | 0.26               | -0.34                  | 0.82                   | 0.26                      |
| Channel Y | -1.26              | -2.30                  | 0.01                   | 0.46                      |
| Channel Z | -1.35              | -2.79                  | 0.93                   | 0.63                      |

#### 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                |