

## Parameters of Probe: EX3DV4 - SN:7678

### Calibration Parameter Determined in Head Tissue Simulating Media

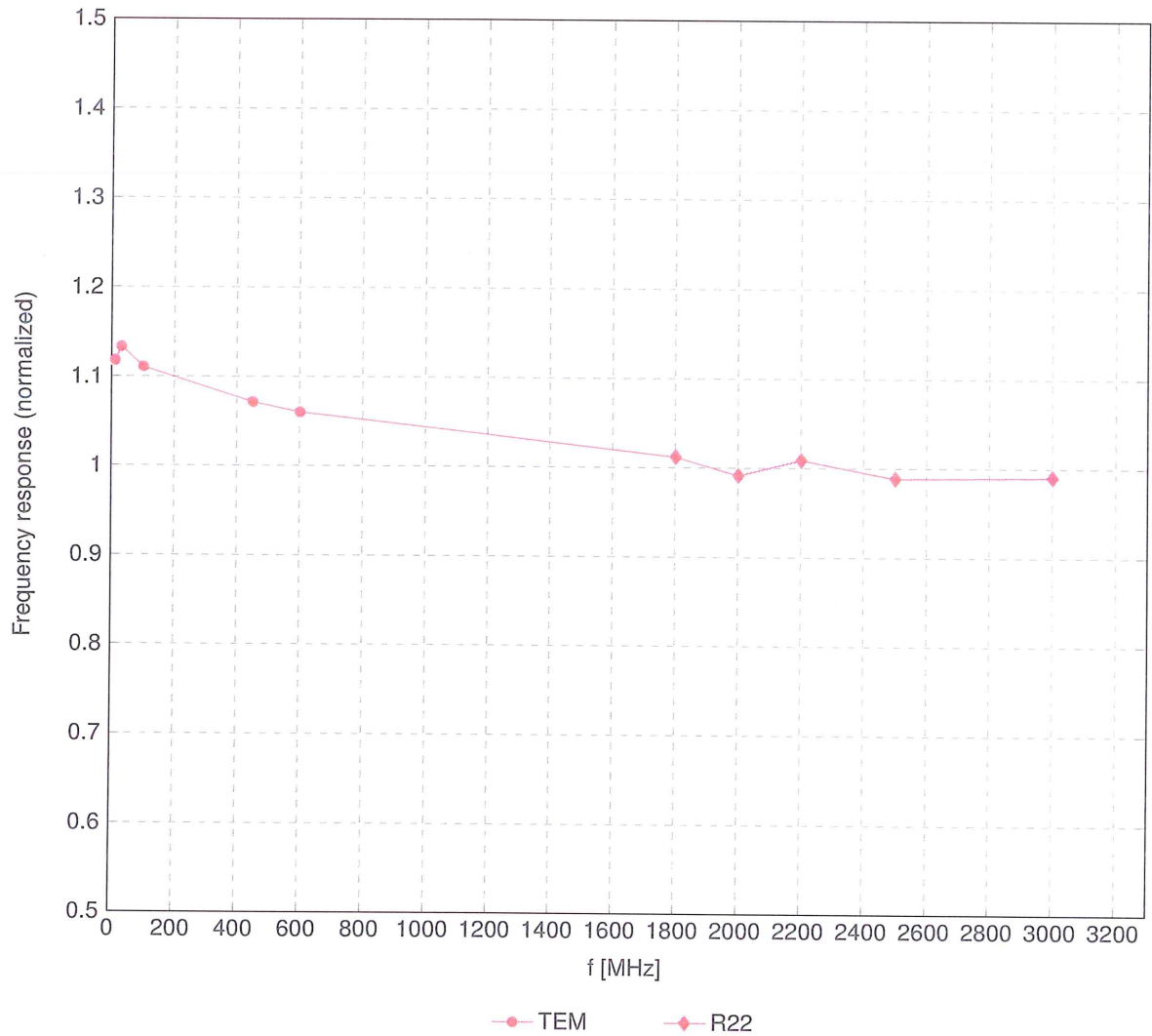
| f (MHz) <sup>C</sup> | Relative Permittivity <sup>F</sup> | Conductivity <sup>F</sup> (S/m) | ConvF X | ConvF Y | ConvF Z | Alpha <sup>G</sup> | Depth <sup>G</sup> (mm) | Unc (k = 2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 750                  | 41.9                               | 0.89                            | 11.14   | 11.14   | 11.14   | 0.49               | 0.83                    | ±12.0%      |
| 835                  | 41.5                               | 0.90                            | 10.73   | 10.73   | 10.73   | 0.51               | 0.81                    | ±12.0%      |
| 900                  | 41.5                               | 0.97                            | 10.60   | 10.60   | 10.60   | 0.46               | 0.85                    | ±12.0%      |
| 1750                 | 40.1                               | 1.37                            | 8.63    | 8.63    | 8.63    | 0.41               | 0.86                    | ±12.0%      |
| 1900                 | 40.0                               | 1.40                            | 8.55    | 8.55    | 8.55    | 0.41               | 0.86                    | ±12.0%      |
| 2300                 | 39.5                               | 1.67                            | 8.53    | 8.53    | 8.53    | 0.36               | 0.90                    | ±12.0%      |
| 2450                 | 39.2                               | 1.80                            | 8.34    | 8.34    | 8.34    | 0.34               | 0.90                    | ±12.0%      |
| 2600                 | 39.0                               | 1.96                            | 8.11    | 8.11    | 8.11    | 0.36               | 0.90                    | ±12.0%      |
| 3500                 | 37.9                               | 2.91                            | 7.10    | 7.10    | 7.10    | 0.30               | 1.35                    | ±13.1%      |
| 3700                 | 37.7                               | 3.12                            | 7.06    | 7.06    | 7.06    | 0.30               | 1.35                    | ±13.1%      |
| 5200                 | 36.0                               | 4.66                            | 5.67    | 5.67    | 5.67    | 0.40               | 1.80                    | ±13.1%      |
| 5300                 | 35.9                               | 4.76                            | 5.50    | 5.50    | 5.50    | 0.40               | 1.80                    | ±13.1%      |
| 5600                 | 35.5                               | 5.07                            | 4.95    | 4.95    | 4.95    | 0.40               | 1.80                    | ±13.1%      |
| 5800                 | 35.3                               | 5.27                            | 5.00    | 5.00    | 5.00    | 0.40               | 1.80                    | ±13.1%      |

<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.

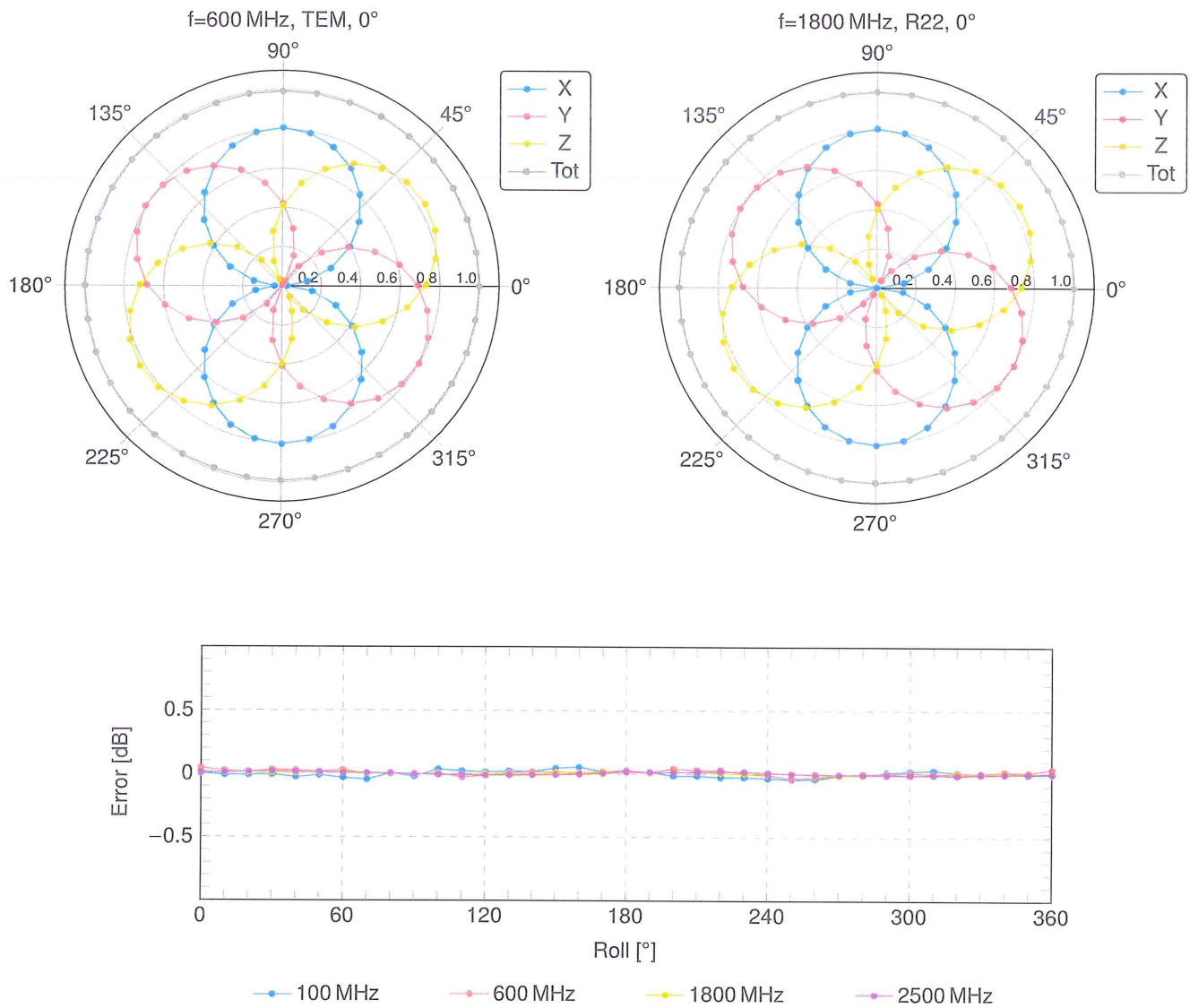
<sup>F</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to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

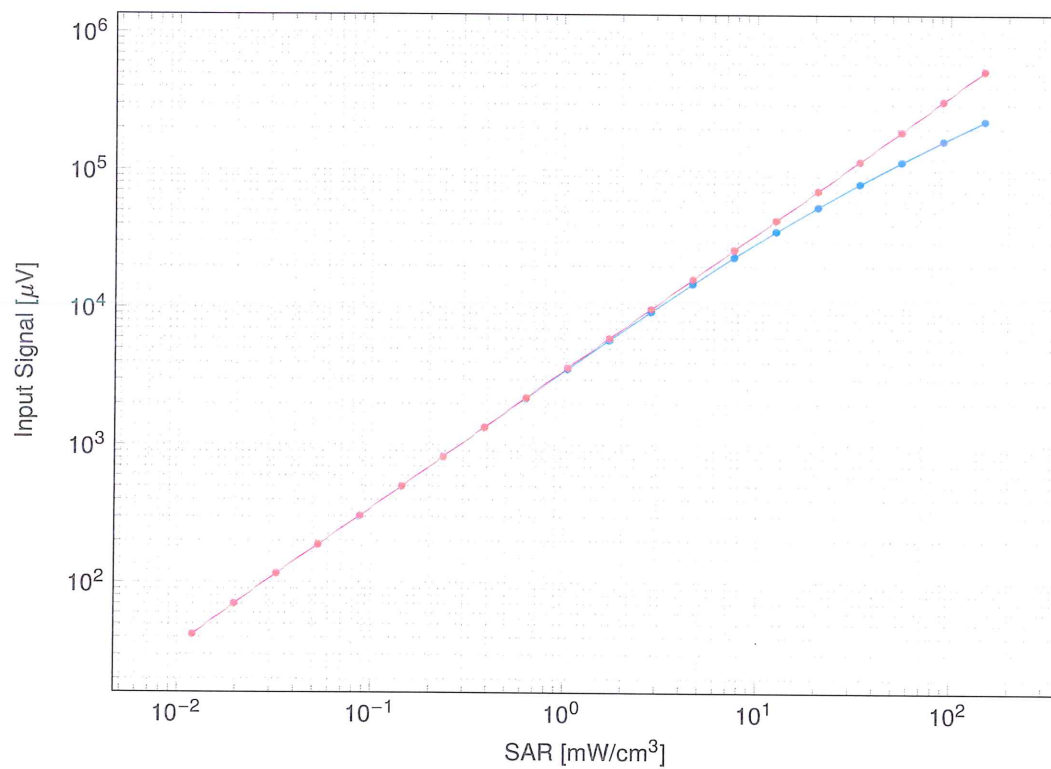
<sup>G</sup> Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ±1% for frequencies below 3 GHz and below ±2% for frequencies between 3–6 GHz at any distance larger than half the probe tip diameter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

Frequency Response of E-Field  
(TEM-Cell:ifi110 EXX, Waveguide:R22)

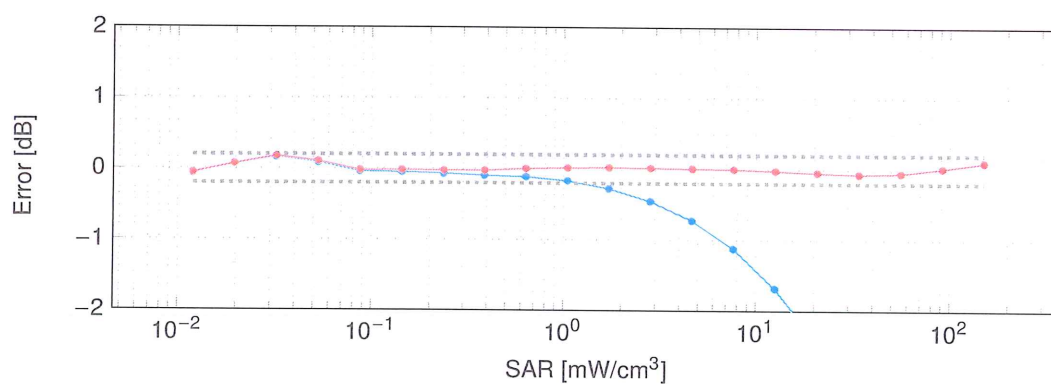


Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  ( $k=2$ )

Receiving Pattern ( $\phi$ ),  $\vartheta = 0^\circ$ Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  ( $k=2$ )

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

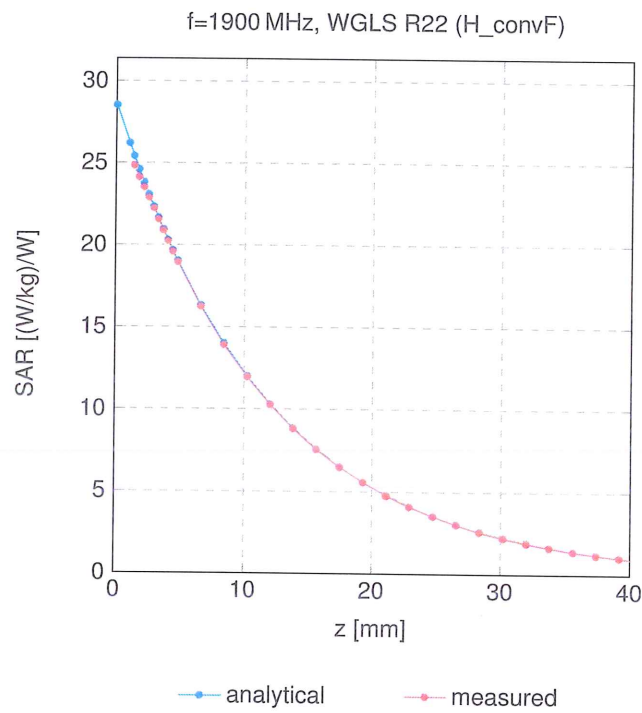
—●— not compensated      —●— compensated



—●— not compensated      —●— compensated

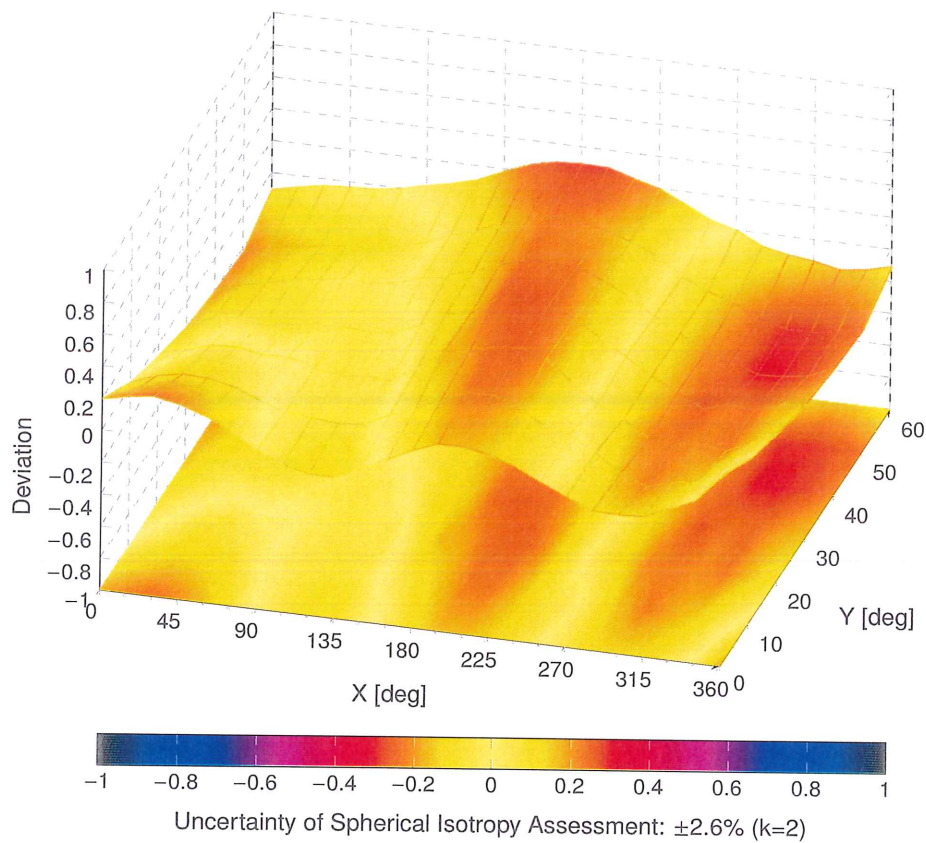
Uncertainty of Linearity Assessment:  $\pm 0.6\%$  ( $k=2$ )

Conversion Factor Assessment



Deviation from Isotropy in Liquid

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





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

**Accreditation No.: SCS 0108**

**Client**

**BTL**

**Certificate No**

**EUmm-9583\_Sep22**

## CALIBRATION CERTIFICATE

**Object**

**EUmmWV4 - SN:9583**

**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**

**September 27, 2022**

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 sensor NRP110T    | SN: 101244 | 14-Mar-22 (No. 20A1037915)         | Mar-23                |
| Spectrum analyzer FSV40 | SN: 101832 | 25-Jan-22 (No. 4030-315003399)     | Jan-25                |
| Ref. Probe EUmmWV3      | SN: 9374   | 21-Dec-21 (No. EUmmWV3-9374_Dec21) | Dec-22                |
| DAE4                    | SN: 789    | 24-Dec-21 (No. DAE4-789_Dec21)     | Dec-22                |

| Secondary Standards      | ID             | Check Date (in house)             | Scheduled Check        |
|--------------------------|----------------|-----------------------------------|------------------------|
| Generator APSIN26G       | SN: 669        | 28-Mar-17 (in house check May-22) | In house check: May-23 |
| Generator Agilent E8251A | SN: US41140111 | 28-Mar-17 (in house check May-22) | In house check: May-23 |

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

Issued: September 28, 2022

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



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

**Accreditation No.: SCS 0108**

## Glossary

|                          |                                                                                                                                                      |
|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| NORM <sub>x,y</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 $\varphi$   | $\varphi$ rotation around probe axis                                                                                                                 |
| Polarization $\vartheta$ | $\vartheta$ rotation around an axis that is in the plane normal to probe axis (at measurement center), 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            | sensor deviation from the probe axis, used to calculate the field orientation and polarization                                                       |
| $\vec{k}$                | is the wave propagation direction                                                                                                                    |

## Calibration is Performed According to the Following Standards:

- a) 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</sub>**: Assessed for E-field polarization  $\vartheta = 0$  ( $f \leq 900$  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</sub>**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal. 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</sub>; B<sub>x,y</sub>; C<sub>x,y</sub>; D<sub>x,y</sub>; VR<sub>x,y</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 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).
- **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.

## Parameters of Probe: EUmmWV4 - SN:9583

### Basic Calibration Parameters

|                                              | Sensor X | Sensor Y | Unc ( $k = 2$ ) |
|----------------------------------------------|----------|----------|-----------------|
| Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) | 0.01865  | 0.02030  | $\pm 10.1\%$    |
| DCP (mV) <sup>B</sup>                        | 106.0    | 105.0    | $\pm 4.7\%$     |
| Equivalent Sensor Angle                      | -60.7    | 35.8     |                 |

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

| Frequency MHz | Target E-Field V/m | Deviation Sensor X dB | Deviation Sensor Y dB | Unc ( $k = 2$ ) dB |
|---------------|--------------------|-----------------------|-----------------------|--------------------|
| 0.75          | 77.2               | -0.24                 | -0.10                 | $\pm 0.43$         |
| 1.8           | 140.4              | -0.02                 | 0.01                  | $\pm 0.43$         |
| 2.0           | 133.0              | 0.13                  | 0.16                  | $\pm 0.43$         |
| 2.2           | 124.8              | -0.06                 | -0.06                 | $\pm 0.43$         |
| 2.5           | 123.0              | 0.06                  | 0.07                  | $\pm 0.43$         |
| 3.5           | 256.2              | -0.21                 | -0.33                 | $\pm 0.43$         |
| 3.7           | 249.8              | -0.12                 | -0.26                 | $\pm 0.43$         |
|               |                    |                       |                       |                    |
| 6.6           | 76.1               | -0.20                 | -0.30                 | $\pm 0.98$         |
| 8.0           | 68.3               | -0.20                 | -0.19                 | $\pm 0.98$         |
| 10.0          | 67.5               | 0.00                  | 0.01                  | $\pm 0.98$         |
| 15.0          | 55.3               | 0.41                  | 0.40                  | $\pm 0.98$         |
|               |                    |                       |                       |                    |
| 26.6          | 114.9              | -0.03                 | -0.04                 | $\pm 0.98$         |
| 30.0          | 121.2              | -0.02                 | -0.02                 | $\pm 0.98$         |
| 35.0          | 119.8              | 0.06                  | 0.08                  | $\pm 0.98$         |
| 40.0          | 105.8              | 0.07                  | 0.08                  | $\pm 0.98$         |
|               |                    |                       |                       |                    |
| 50.0          | 60.5               | 0.12                  | 0.20                  | $\pm 0.98$         |
| 55.0          | 75.8               | -0.07                 | -0.11                 | $\pm 0.98$         |
| 60.0          | 80.0               | 0.01                  | 0.01                  | $\pm 0.98$         |
| 65.0          | 77.7               | -0.06                 | -0.01                 | $\pm 0.98$         |
| 70.0          | 73.8               | 0.06                  | 0.08                  | $\pm 0.98$         |
| 75.0          | 73.2               | -0.13                 | -0.14                 | $\pm 0.98$         |
|               |                    |                       |                       |                    |
| 75.0          | 80.8               | 0.19                  | 0.18                  | $\pm 0.98$         |
| 80.0          | 79.9               | -0.22                 | -0.19                 | $\pm 0.98$         |
| 85.0          | 47.6               | -0.22                 | -0.24                 | $\pm 0.98$         |
| 90.0          | 72.3               | 0.00                  | 0.00                  | $\pm 0.98$         |
| 92.0          | 72.0               | 0.12                  | 0.12                  | $\pm 0.98$         |
| 95.0          | 66.6               | 0.10                  | 0.12                  | $\pm 0.98$         |
| 97.0          | 57.0               | 0.15                  | 0.12                  | $\pm 0.98$         |
| 100.0         | 55.0               | 0.05                  | 0.09                  | $\pm 0.98$         |
| 105.0         | 53.0               | -0.22                 | -0.16                 | $\pm 0.98$         |
| 110.0         | 61.1               | -0.02                 | -0.09                 | $\pm 0.98$         |

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> Linearization parameter uncertainty for maximum specified field strength.

## Parameters of Probe: EUMmWV4 - SN:9583

### 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    | 131.8    | ±2.7%       | ±4.7%                            |
|       |                             | Y | 0.00    | 0.00                   | 1.00  |         | 68.6     |             |                                  |
| 10352 | Pulse Waveform (200Hz, 10%) | X | 3.08    | 60.00                  | 14.70 | 10.00   | 6.0      | ±1.5%       | ±9.6%                            |
|       |                             | Y | 3.47    | 60.00                  | 14.96 |         | 6.0      |             |                                  |
| 10353 | Pulse Waveform (200Hz, 20%) | X | 2.16    | 60.00                  | 13.47 | 6.99    | 12.0     | ±1.1%       | ±9.6%                            |
|       |                             | Y | 2.32    | 60.00                  | 13.95 |         | 12.0     |             |                                  |
| 10354 | Pulse Waveform (200Hz, 40%) | X | 1.33    | 60.32                  | 12.26 | 3.98    | 23.0     | ±1.6%       | ±9.6%                            |
|       |                             | Y | 1.35    | 60.00                  | 12.76 |         | 23.0     |             |                                  |
| 10355 | Pulse Waveform (200Hz, 60%) | X | 0.75    | 60.00                  | 11.40 | 2.22    | 27.0     | ±1.2%       | ±9.6%                            |
|       |                             | Y | 0.86    | 60.00                  | 11.78 |         | 27.0     |             |                                  |
| 10387 | QPSK Waveform, 1 MHz        | X | 1.25    | 60.00                  | 12.16 | 1.00    | 22.0     | ±1.4%       | ±9.6%                            |
|       |                             | Y | 1.33    | 60.00                  | 12.20 |         | 22.0     |             |                                  |
| 10388 | QPSK Waveform, 10 MHz       | X | 1.29    | 60.00                  | 11.83 | 0.00    | 22.0     | ±0.8%       | ±9.6%                            |
|       |                             | Y | 1.40    | 60.00                  | 11.75 |         | 22.0     |             |                                  |
| 10396 | 64-QAM Waveform, 100 kHz    | X | 3.17    | 64.46                  | 15.48 | 3.01    | 17.0     | ±0.7%       | ±9.6%                            |
|       |                             | Y | 20.00   | 85.89                  | 22.26 |         | 17.0     |             |                                  |
| 10399 | 64-QAM Waveform, 40 MHz     | X | 2.10    | 60.00                  | 12.34 | 0.00    | 19.0     | ±0.9%       | ±9.6%                            |
|       |                             | Y | 2.17    | 60.00                  | 12.38 |         | 19.0     |             |                                  |
| 10414 | WLAN CCDF, 64-QAM, 40 MHz   | X | 3.27    | 60.00                  | 12.78 | 0.00    | 12.0     | ±0.9%       | ±9.6%                            |
|       |                             | Y | 3.31    | 60.00                  | 12.86 |         | 12.0     |             |                                  |

Note: For details on UID parameters see Appendix

<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.