

Parameters of Probe: EX3DV4 - SN:7678

Calibration Parameter Determined in Head Tissue Simulating Media

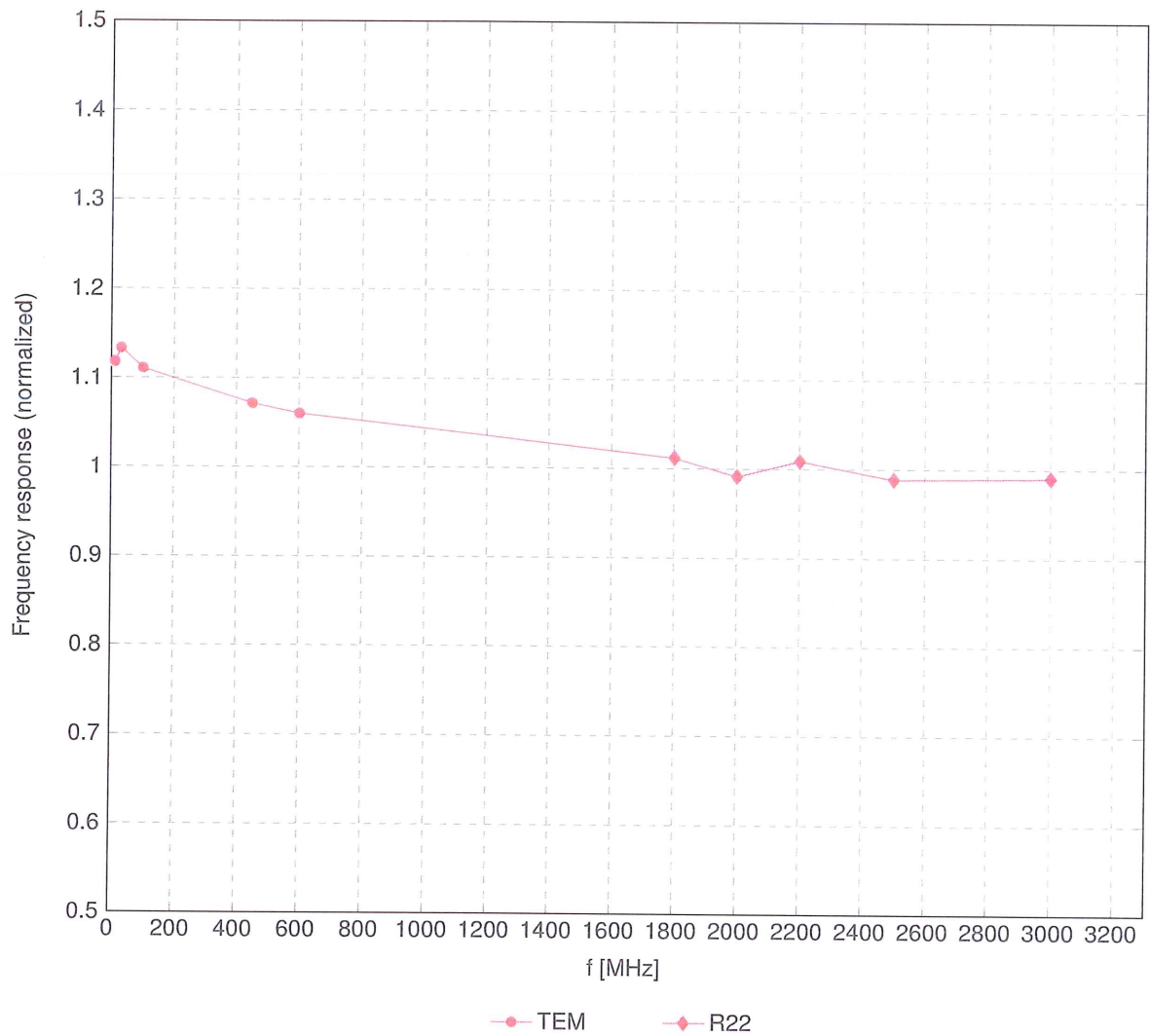
f (MHz) ^C	Relative Permittivity ^F	Conductivity ^F (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha ^G	Depth ^G (mm)	Unc (k = 2)
750	41.9	0.89	11.14	11.14	11.14	0.49	0.83	±12.0%
835	41.5	0.90	10.73	10.73	10.73	0.51	0.81	±12.0%
900	41.5	0.97	10.60	10.60	10.60	0.46	0.85	±12.0%
1750	40.1	1.37	8.63	8.63	8.63	0.41	0.86	±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%

^C 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.

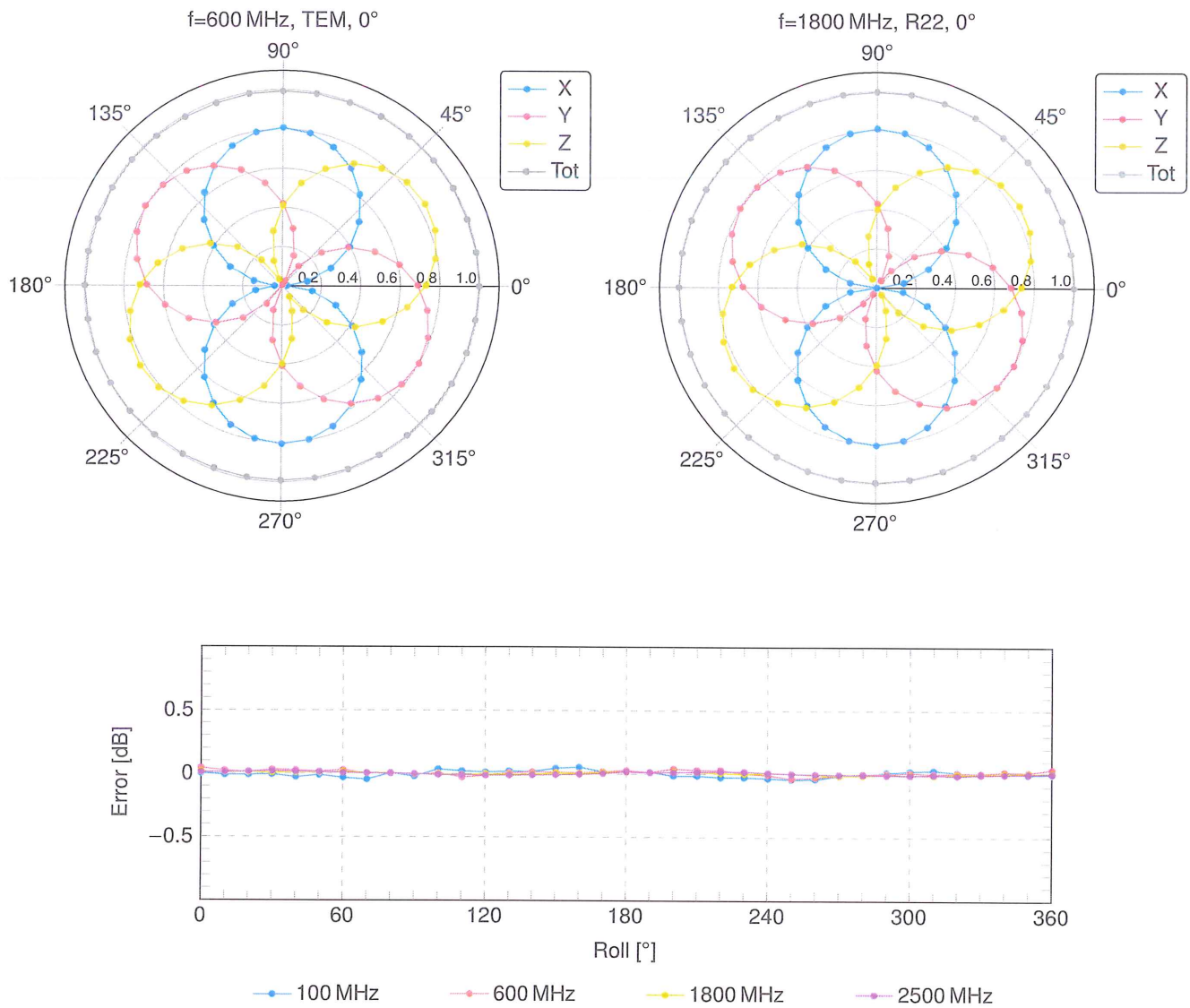
^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ±5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

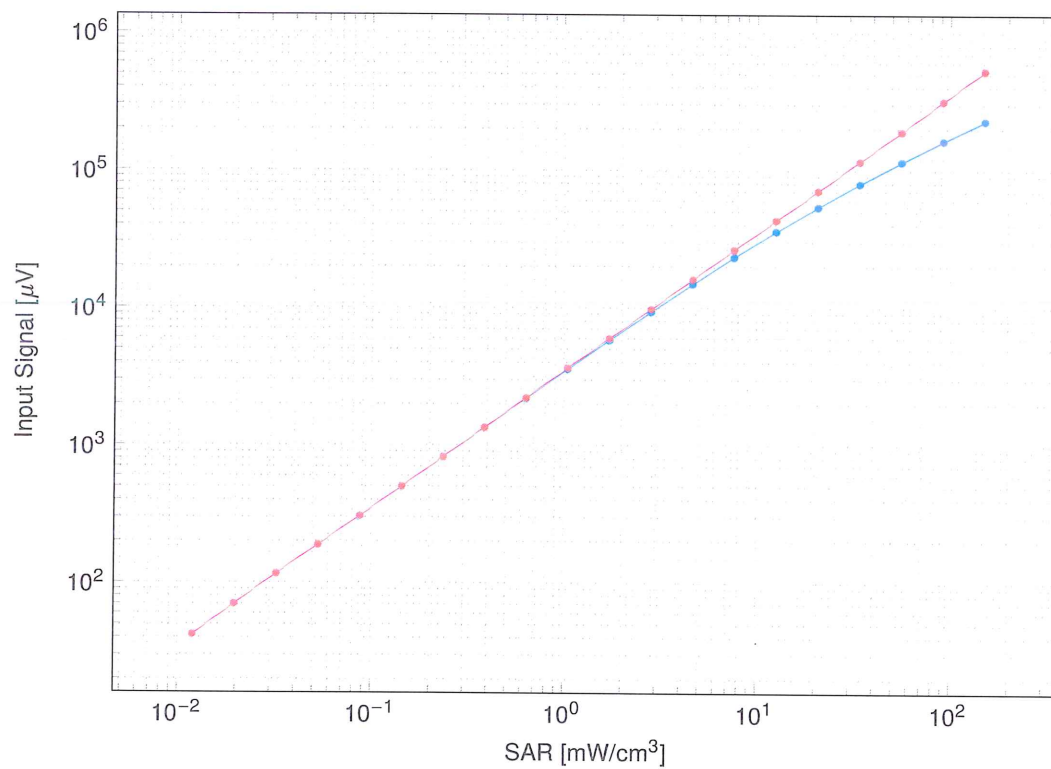
^G Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ±1% for frequencies below 3 GHz and below ±2% for frequencies between 3–6 GHz at any distance larger than half the probe tip diameter from the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

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

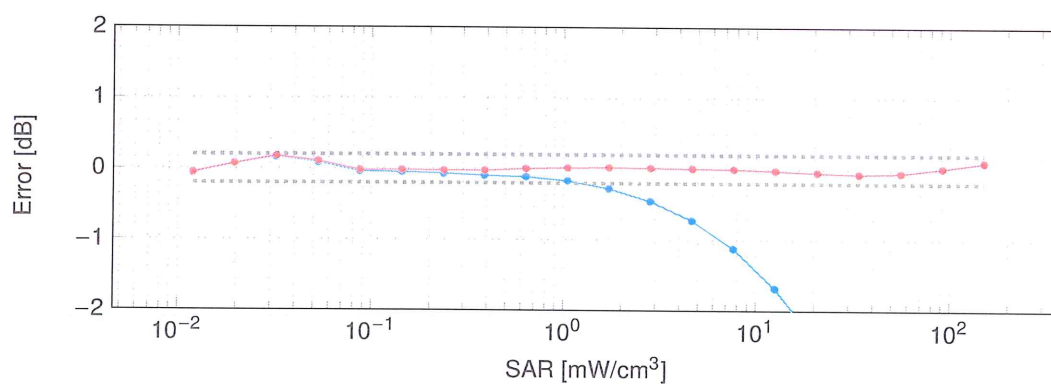


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ ($k=2$)

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

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

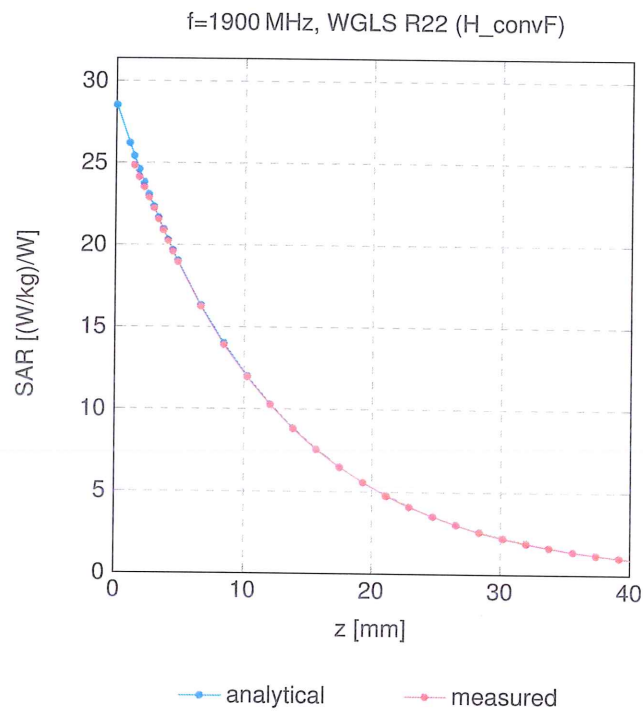
—●— not compensated —●— compensated



—●— not compensated —●— compensated

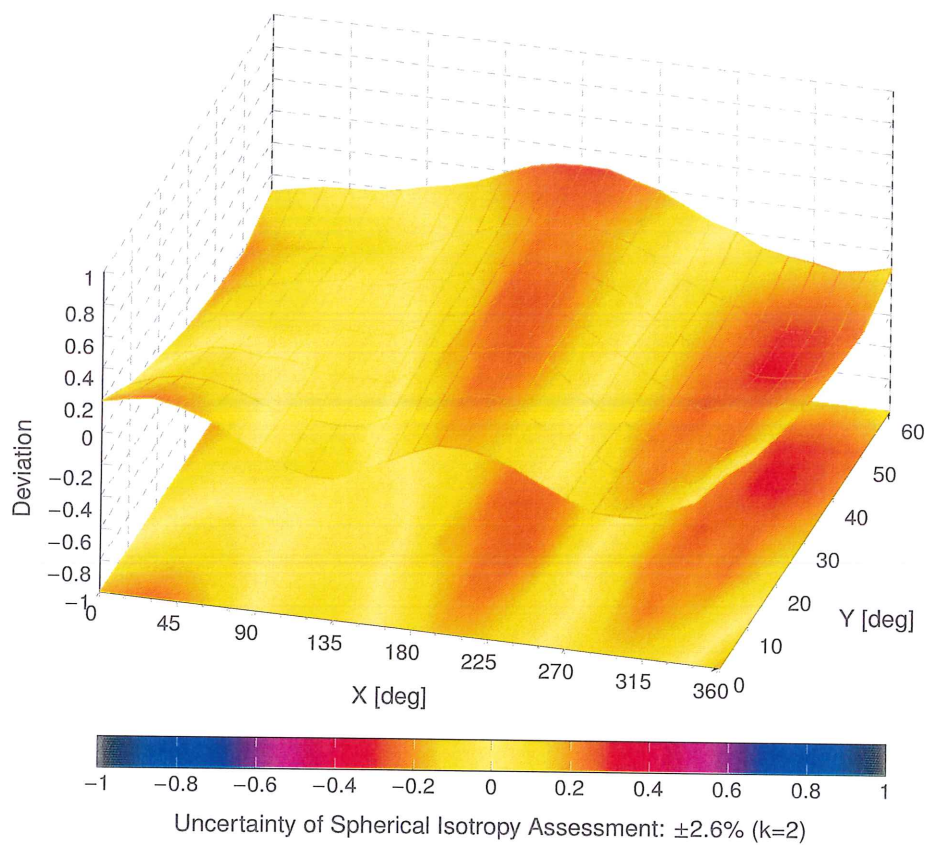
Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

Conversion Factor Assessment



Deviation from Isotropy in Liquid

Error (ϕ, θ), f = 900MHz





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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.



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Accreditation No.: SCS 0108

Glossary

NORM _{x,y}	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 φ	φ rotation around probe axis
Polarization ϑ	ϑ 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_{x,y}**: 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_{x,y}**: 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_p, inductance L and capacitors C, C_p).
- **A_{x,y}; B_{x,y}; C_{x,y}; D_{x,y}; VR_{x,y}**: 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_x** (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_x** (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) ^B	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	± 0.43
1.8	140.4	-0.02	0.01	± 0.43
2.0	133.0	0.13	0.16	± 0.43
2.2	124.8	-0.06	-0.06	± 0.43
2.5	123.0	0.06	0.07	± 0.43
3.5	256.2	-0.21	-0.33	± 0.43
3.7	249.8	-0.12	-0.26	± 0.43
6.6	76.1	-0.20	-0.30	± 0.98
8.0	68.3	-0.20	-0.19	± 0.98
10.0	67.5	0.00	0.01	± 0.98
15.0	55.3	0.41	0.40	± 0.98
26.6	114.9	-0.03	-0.04	± 0.98
30.0	121.2	-0.02	-0.02	± 0.98
35.0	119.8	0.06	0.08	± 0.98
40.0	105.8	0.07	0.08	± 0.98
50.0	60.5	0.12	0.20	± 0.98
55.0	75.8	-0.07	-0.11	± 0.98
60.0	80.0	0.01	0.01	± 0.98
65.0	77.7	-0.06	-0.01	± 0.98
70.0	73.8	0.06	0.08	± 0.98
75.0	73.2	-0.13	-0.14	± 0.98
75.0	80.8	0.19	0.18	± 0.98
80.0	79.9	-0.22	-0.19	± 0.98
85.0	47.6	-0.22	-0.24	± 0.98
90.0	72.3	0.00	0.00	± 0.98
92.0	72.0	0.12	0.12	± 0.98
95.0	66.6	0.10	0.12	± 0.98
97.0	57.0	0.15	0.12	± 0.98
100.0	55.0	0.05	0.09	± 0.98
105.0	53.0	-0.22	-0.16	± 0.98
110.0	61.1	-0.02	-0.09	± 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%.

^B Linearization parameter uncertainty for maximum specified field strength.

Parameters of Probe: EUMmWV4 - SN:9583

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB $\sqrt{\mu V}$	C	D dB	VR mV	Max dev.	Max Unc ^E 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

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