Calibration Laboratory of
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Accreditation No.: SCS 0108

Client **UL**
Fremont, USA

Certificate No. **EX-7810_May25**

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7810
Calibration procedure(s)	QA CAL-01.v10, QA CAL-12.v10, QA CAL-14.v7, QA CAL-23.v6, QA CAL-25.v8 Calibration procedure for dosimetric E-field probes
Calibration date	May 08, 2025

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	Calibration Date (Certificate No.)	Sched. Cal.
Power Sensor R&S NRP-33T	SN: 100967	26-Mar-25 (No. 217-04290)	Mar-26
Type-N mismatch combination	SN: L1119	26-Mar-25 (No. 217-04292)	Mar-26
OCP DAK-12	SN: 1016	24-Sept-24 (No. OCP-DAK12-1016_Sep24)	Sep-25
OCP DAK-3.5	SN: 1249	23-Sept-24 (No. OCP-DAK3.5-1249_Sep24)	Sep-25
Reference Probe EX3DV4	SN: 7349	10-Jan-25 (No. EX3-7349_Jan25)	Jan-26
DAE4	SN: 1301	07-Nov-24 (No. DAE4-1301_Nov24)	Nov-25

Secondary Standards	ID	Check Date (in house)	Sched. Check
ACAP 2020 Setup 1	SN: L1404	30-Sept-24 (No. Report_ACAP2020E-Cave_20240930s)	Sep-25

	Name	Function	Signature
Calibrated by	Aidonia Georgiadou	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	

Issued: May 08, 2025

Glossary

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
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

Calibration is Performed According to the Following Standards:

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

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z*: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * 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.
- *DCPx,y,z*: 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
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: 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 *NORMx,y,z * 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 ±50 MHz to ±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 *NORMx* (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:7810

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$) [A]	0.59	0.69	0.65	±10.1%
DCP (mV) [B]	110.1	107.0	106.4	±4.7%

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	143.7	±1.2%	±4.7%
		Y	0.00	0.00	1.00		130.4		
		Z	0.00	0.00	1.00		149.4		
10352	Pulse Waveform (200Hz, 10%)	X	1.63	60.95	6.48	10.00	60.0	±2.6%	±9.6%
		Y	1.40	60.00	5.96		60.0		
		Z	1.47	60.43	6.35		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	0.84	60.00	4.91	6.99	80.0	±2.4%	±9.6%
		Y	0.81	60.00	4.80		80.0		
		Z	46.00	80.00	11.00		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	0.45	60.00	3.73	3.98	95.0	±2.7%	±9.6%
		Y	0.01	125.28	0.33		95.0		
		Z	0.16	140.59	0.19		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	10.11	89.44	0.01	2.22	120.0	±1.7%	±9.6%
		Y	5.95	159.98	1.45		120.0		
		Z	6.49	160.00	15.35		120.0		
10387	QPSK Waveform, 1 MHz	X	0.49	64.70	13.41	1.00	150.0	±3.1%	±9.6%
		Y	0.45	62.15	11.58		150.0		
		Z	0.58	65.39	13.98		150.0		
10388	QPSK Waveform, 10 MHz	X	1.31	67.40	14.22	0.00	150.0	±1.0%	±9.6%
		Y	1.21	65.18	13.33		150.0		
		Z	1.42	67.34	14.78		150.0		
10396	64-QAM Waveform, 100 kHz	X	1.77	65.53	16.12	3.01	150.0	±1.1%	±9.6%
		Y	1.60	63.78	15.63		150.0		
		Z	1.65	64.26	16.05		150.0		
10399	64-QAM Waveform, 40 MHz	X	2.77	67.03	15.36	0.00	150.0	±1.5%	±9.6%
		Y	2.71	65.99	14.88		150.0		
		Z	2.84	66.65	15.41		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	3.63	66.58	15.33	0.00	150.0	±2.5%	±9.6%
		Y	3.80	66.44	15.38		150.0		
		Z	3.92	66.81	15.73		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%.

[A] The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5 and 6).
[B] Linearization parameter uncertainty for maximum specified field strength.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Parameters of Probe: EX3DV4 - SN:7810

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	7.3	50.94	31.44	3.84	0.00	4.90	0.64	0.00	1.00
y	8.6	62.10	33.06	2.90	0.00	4.90	0.28	0.00	1.00
z	8.9	64.32	33.53	2.32	0.00	4.90	0.30	0.00	1.00

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	63.5°
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

Note: Measurement distance from surface can be increased to 3–4 mm for an *Area Scan* job.

Parameters of Probe: EX3DV4 - SN:7810

Calibration Parameter Determined in HSL

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
750	41.9	0.89	9.62	9.50	9.76	0.36	1.27	±11.0%
900	41.5	0.97	9.08	8.97	9.21	0.36	1.27	±11.0%
1450	40.5	1.20	7.93	7.83	8.05	0.36	1.27	±11.0%
1640	40.2	1.31	7.74	7.65	7.86	0.36	1.27	±11.0%
1750	40.1	1.37	7.81	7.72	7.93	0.36	1.27	±11.0%
1900	40.0	1.40	7.72	7.63	7.84	0.36	1.27	±11.0%
2100	39.8	1.49	7.51	7.42	7.62	0.36	1.27	±11.0%
2300	39.5	1.67	7.51	7.42	7.62	0.36	1.27	±11.0%
2450	39.2	1.80	7.31	7.22	7.42	0.36	1.27	±11.0%
2600	39.0	1.96	7.16	7.08	7.27	0.36	1.27	±11.0%
3300	38.2	2.71	6.31	6.23	6.40	0.37	1.27	±13.1%
3500	37.9	2.91	6.38	6.30	6.47	0.37	1.27	±13.1%
3700	37.7	3.12	6.37	6.29	6.46	0.37	1.27	±13.1%
3900	37.5	3.32	6.21	6.14	6.30	0.37	1.27	±13.1%
4100	37.2	3.53	6.08	6.00	6.17	0.37	1.27	±13.1%
4200	37.1	3.63	6.14	6.07	6.23	0.37	1.27	±13.1%
4400	36.9	3.84	5.95	5.88	6.04	0.37	1.27	±13.1%
4600	36.7	4.04	5.84	5.77	5.93	0.37	1.27	±13.1%
4800	36.4	4.25	6.00	5.93	6.09	0.37	1.27	±13.1%
4950	36.3	4.40	5.88	5.81	5.97	0.35	1.27	±13.1%
5250	35.9	4.71	5.71	5.64	5.79	0.32	1.27	±13.1%
5600	35.5	5.07	5.28	5.22	5.36	0.29	1.27	±13.1%
5750	35.4	5.22	5.23	5.16	5.31	0.27	1.27	±13.1%
5850	35.2	5.32	5.36	5.29	5.44	0.26	1.27	±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] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±5% from the target values (typically better than ±3%) and are valid for TSL with deviations of up to ±10% if SAR correction is applied.

[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.

[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

Parameters of Probe: EX3DV4 - SN:7810

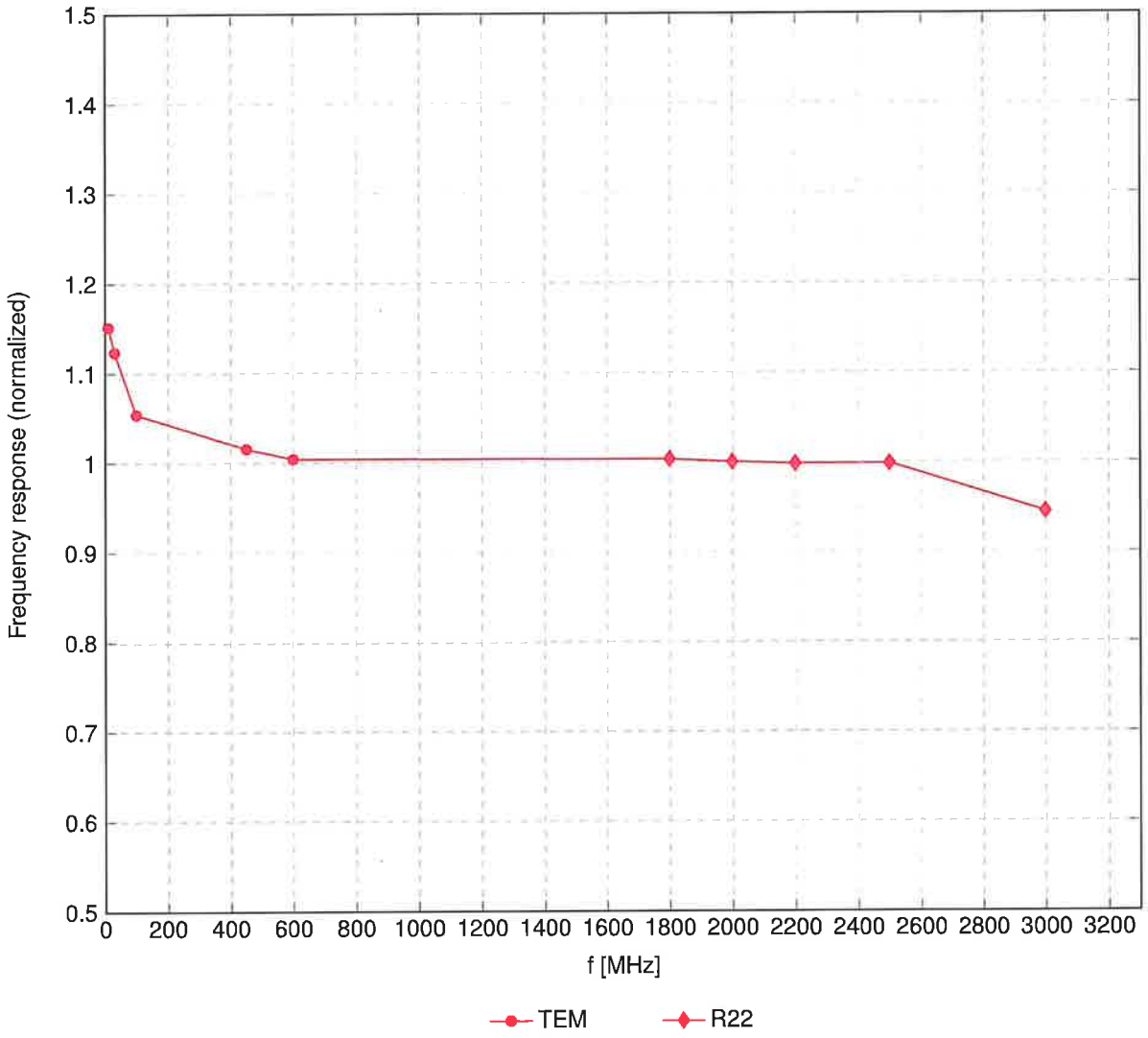
Calibration Parameter Determined in HSL

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
6500	34.5	6.07	5.17	5.11	5.25	0.20	1.27	±18.6%

[C] Frequency validity is −600/+700 MHz at 6.5 GHz, ±700 MHz at or above 7 GHz, and ±150 MHz at 9.85 GHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±10% from the target values (typically better than ±6%) and are valid for TSL with deviations of up to ±10%.
[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; below ±2% for frequencies between 3–6 GHz; and below ±4% for frequencies between 6–10 GHz at any distance larger than half the probe tip diameter from the boundary.
[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

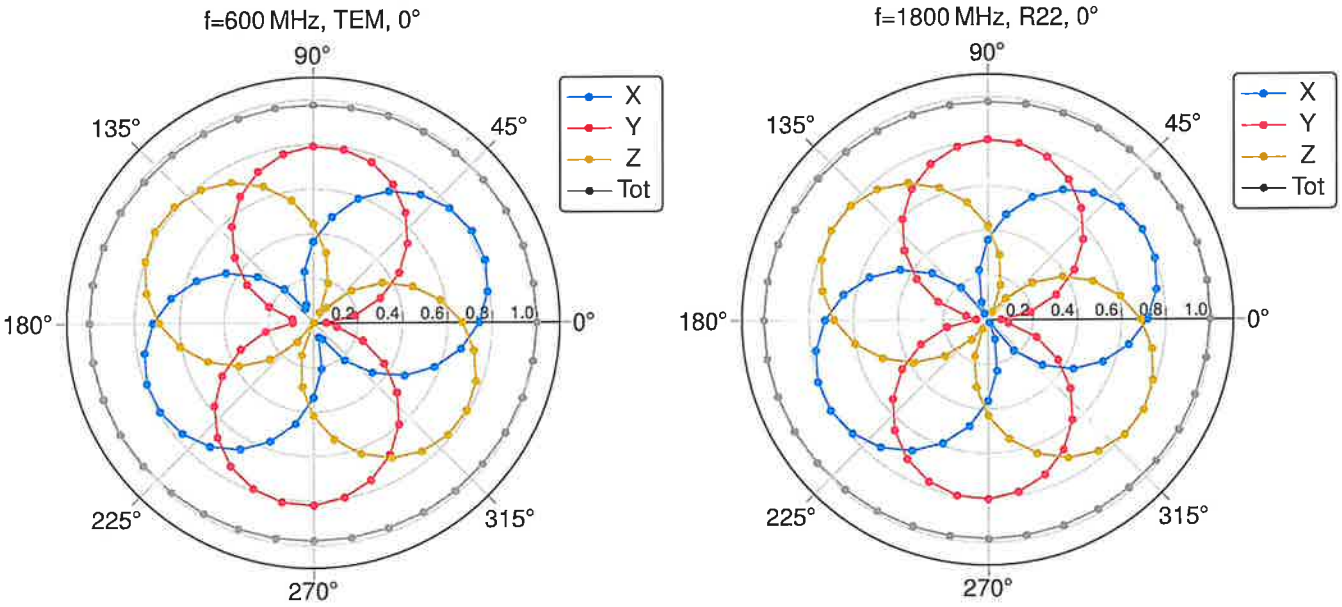
Frequency Response of E-Field

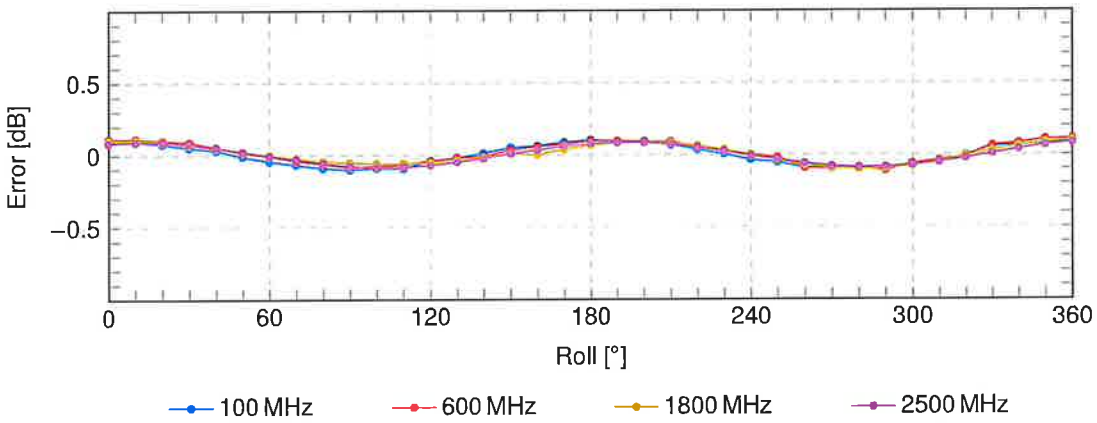
(TEM-Cell:ifi110 EXX, Waveguide:R22)



Uncertainty of Frequency Response of E-field: ±6.3% (k=2)

Receiving Pattern (ϕ), $\vartheta = 0°$

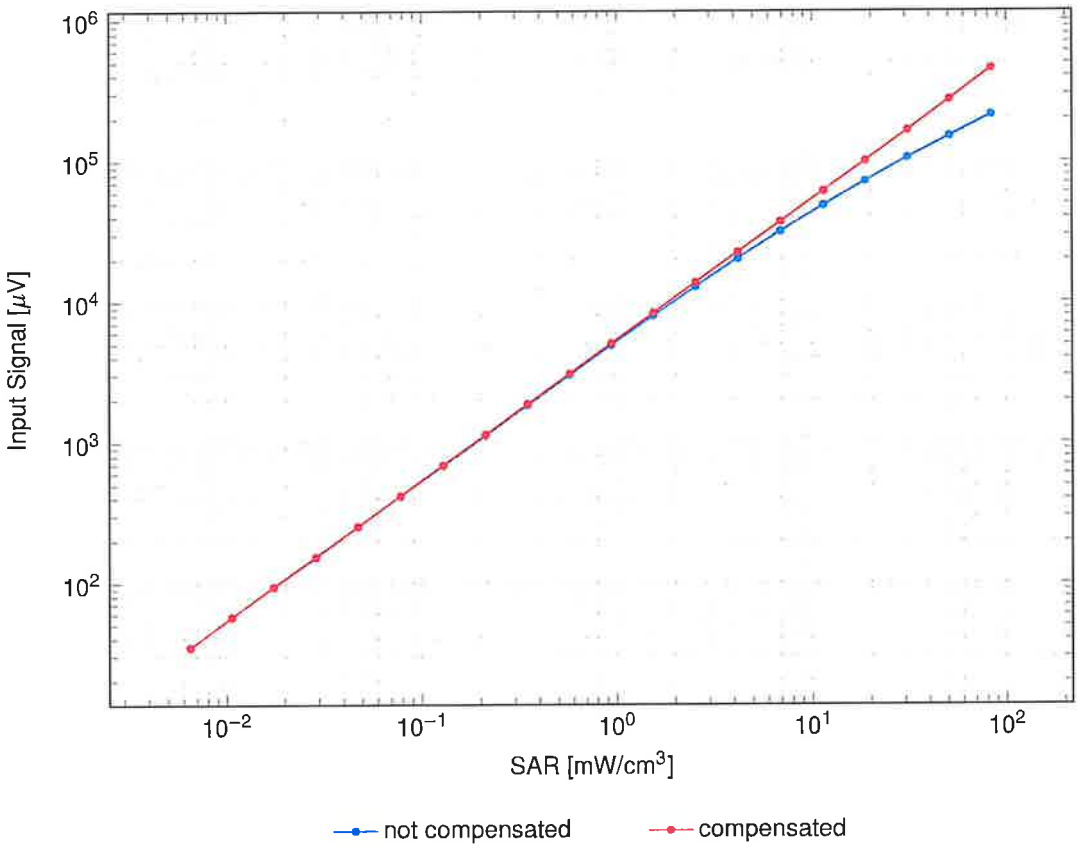


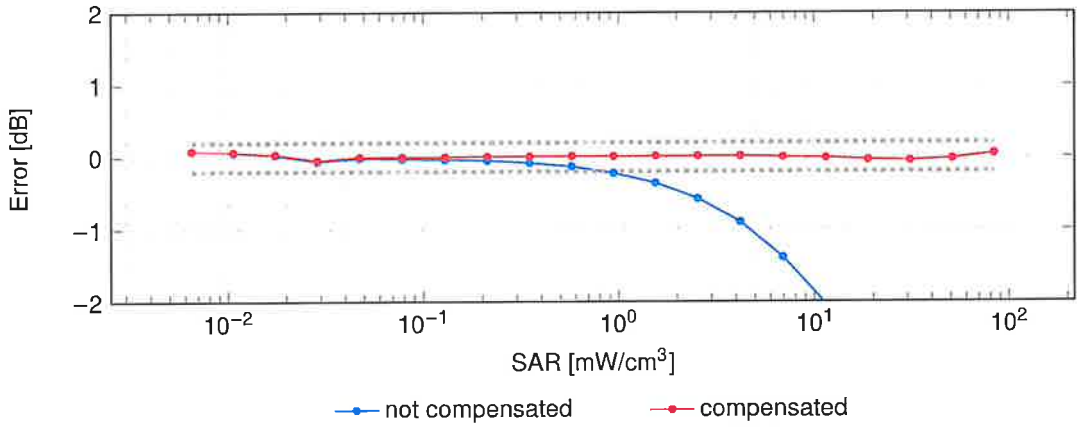


Uncertainty of Axial Isotropy Assessment: ±0.5% (k=2)

Dynamic Range f(SAR_{HSL})

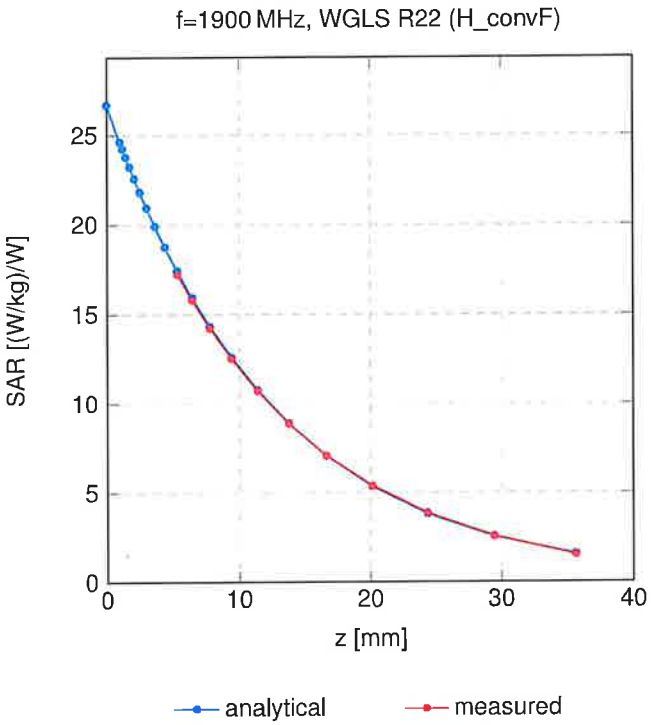
(TEM cell, f_{eval} = 1900 MHz)



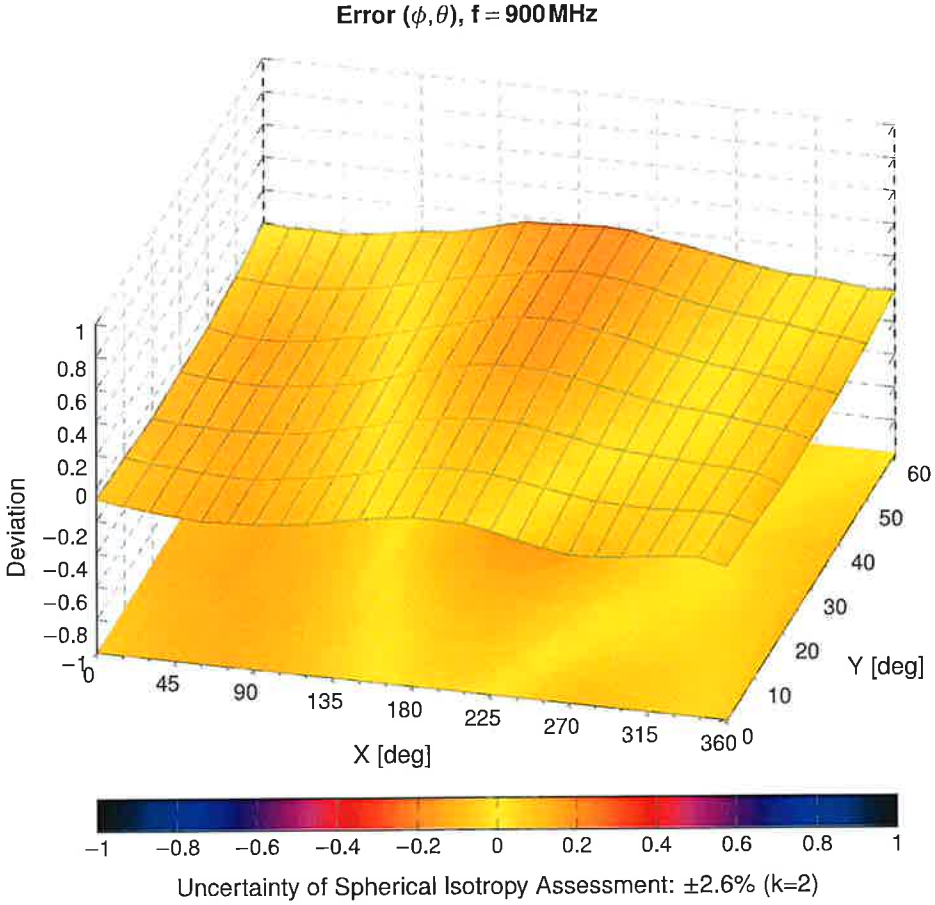


Uncertainty of Linearity Assessment: ±0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: ±2.6% (k=2)

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

Accreditation No.: SCS 0108

Client **UL**
Fremont, USA

Certificate No. **EX-3990_Feb25**

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3990
Calibration procedure(s)	QA CAL-01.v10, QA CAL-12.v10, QA CAL-14.v7, QA CAL-23.v6, QA CAL-25.v8 Calibration procedure for dosimetric E-field probes
Calibration date	February 07, 2025

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)

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Short [S6019i] + Attenuator [S6020i]	SN: L1119	26-Mar-24 (No. 217-04048)	Mar-25
OCP DAK-12	SN: 1016	24-Sept-24 (No. OCP-DAK12-1016_Sep24)	Sep-25
OCP DAK-3.5	SN: 1249	23-Sept-24 (No. OCP-DAK3.5-1249_Sep24)	Sep-25
Reference Probe EX3DV4	SN: 7349	10-Jan-25 (No. EX3-7349_Jan25)	Jan-26
DAE4	SN: 1301	07-Nov-24 (No. DAE4-1301_Nov24)	Nov-25

Secondary Standards	ID	Check Date (in house)	Sched. Check
ACAP 2020 Calibration Box	SN: L1404	30-Sept-24 (No. Report_ACAP2020E-Cave_20240930s)	Sep-25

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

Issued: February 07, 2025

Glossary

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
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

Calibration is Performed According to the Following Standards:

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

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z*: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * 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.
- *DCPx,y,z*: 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
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: 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 *NORMx,y,z * 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 ±50 MHz to ±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 *NORMx* (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:3990

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$) [A]	0.61	0.62	0.62	±10.1%
DCP (mV) [B]	100.7	100.5	99.6	±4.7%

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	145.2	±0.7%	±4.7%
		Y	0.00	0.00	1.00		141.1		
		Z	0.00	0.00	1.00		121.1		
10352	Pulse Waveform (200Hz, 10%)	X	84.00	108.00	25.00	10.00	60.0	±3.2%	±9.6%
		Y	20.00	89.32	19.50		60.0		
		Z	20.00	94.17	22.38		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	20.00	94.32	21.38	6.99	80.0	±1.5%	±9.6%
		Y	20.00	90.15	19.01		80.0		
		Z	20.00	98.86	23.69		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	20.00	98.72	22.24	3.98	95.0	±1.1%	±9.6%
		Y	20.00	91.78	18.66		95.0		
		Z	20.00	100.96	23.30		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	20.00	103.98	23.46	2.22	120.0	±1.1%	±9.6%
		Y	20.00	95.35	19.28		120.0		
		Z	20.00	105.45	24.08		120.0		
10387	QPSK Waveform, 1 MHz	X	1.65	65.31	14.46	1.00	150.0	±1.8%	±9.6%
		Y	1.69	65.94	14.79		150.0		
		Z	1.60	64.85	14.07		150.0		
10388	QPSK Waveform, 10 MHz	X	2.17	67.14	15.16	0.00	150.0	±1.2%	±9.6%
		Y	2.25	67.84	15.53		150.0		
		Z	2.11	66.59	14.80		150.0		
10396	64-QAM Waveform, 100 kHz	X	2.77	69.26	18.11	3.01	150.0	±0.7%	±9.6%
		Y	2.80	69.79	18.43		150.0		
		Z	2.66	68.61	17.83		150.0		
10399	64-QAM Waveform, 40 MHz	X	3.34	66.11	15.17	0.00	150.0	±1.0%	±9.6%
		Y	3.40	66.50	15.39		150.0		
		Z	3.30	65.81	14.97		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	4.74	65.05	15.14	0.00	150.0	±2.2%	±9.6%
		Y	4.78	65.27	15.27		150.0		
		Z	4.71	64.91	15.04		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%.

[A] The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5 and 6).
[B] Linearization parameter uncertainty for maximum specified field strength.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Parameters of Probe: EX3DV4 - SN:3990

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	46.4	342.58	34.81	15.50	0.01	5.09	0.95	0.25	1.01
y	45.6	337.22	34.81	18.01	0.00	5.05	0.91	0.24	1.01
z	44.9	333.81	35.15	14.24	0.00	5.10	0.82	0.25	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	-47.0°
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

Note: Measurement distance from surface can be increased to 3–4 mm for an *Area Scan* job.

Parameters of Probe: EX3DV4 - SN:3990

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[H] ($k = 2$)
750	41.9	0.89	9.29	10.11	9.10	0.37	1.27	±11.0%
900	41.5	0.97	8.87	9.65	8.69	0.37	1.27	±11.0%
1640	40.2	1.31	7.86	8.54	7.70	0.36	1.27	±11.0%
1750	40.1	1.37	7.89	8.58	7.73	0.36	1.27	±11.0%
1900	40.0	1.40	7.51	8.17	7.35	0.36	1.27	±11.0%
2100	39.8	1.49	7.39	8.04	7.24	0.36	1.27	±11.0%
2300	39.5	1.67	7.19	7.82	7.04	0.36	1.27	±11.0%
2450	39.2	1.80	6.94	7.55	6.80	0.36	1.27	±11.0%
2600	39.0	1.96	6.95	7.56	6.81	0.36	1.27	±11.0%
3300	38.2	2.71	6.44	7.00	6.31	0.35	1.27	±13.1%
3500	37.9	2.91	6.58	7.16	6.45	0.35	1.27	±13.1%
3700	37.7	3.12	6.46	7.03	6.33	0.35	1.27	±13.1%
3900	37.5	3.32	6.51	7.08	6.38	0.35	1.27	±13.1%
4100	37.2	3.53	6.45	7.02	6.32	0.34	1.27	±13.1%
4200	37.1	3.63	6.34	6.89	6.21	0.34	1.27	±13.1%
4400	36.9	3.84	6.16	6.70	6.03	0.34	1.27	±13.1%
4600	36.7	4.04	6.18	6.72	6.05	0.34	1.27	±13.1%
4800	36.4	4.25	6.30	6.85	6.17	0.34	1.27	±13.1%
4950	36.3	4.40	6.18	6.72	6.06	0.33	1.27	±13.1%
5250	35.9	4.71	5.44	5.92	5.33	0.30	1.27	±13.1%
5600	35.5	5.07	5.11	5.56	5.00	0.27	1.27	±13.1%
5750	35.4	5.22	4.94	5.37	4.84	0.26	1.27	±13.1%
5850	35.2	5.32	4.97	5.40	4.86	0.25	1.27	±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] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±5% from the target values (typically better than ±3%) and are valid for TSL with deviations of up to ±10% if SAR correction is applied.

[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.

[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

Parameters of Probe: EX3DV4 - SN:3990

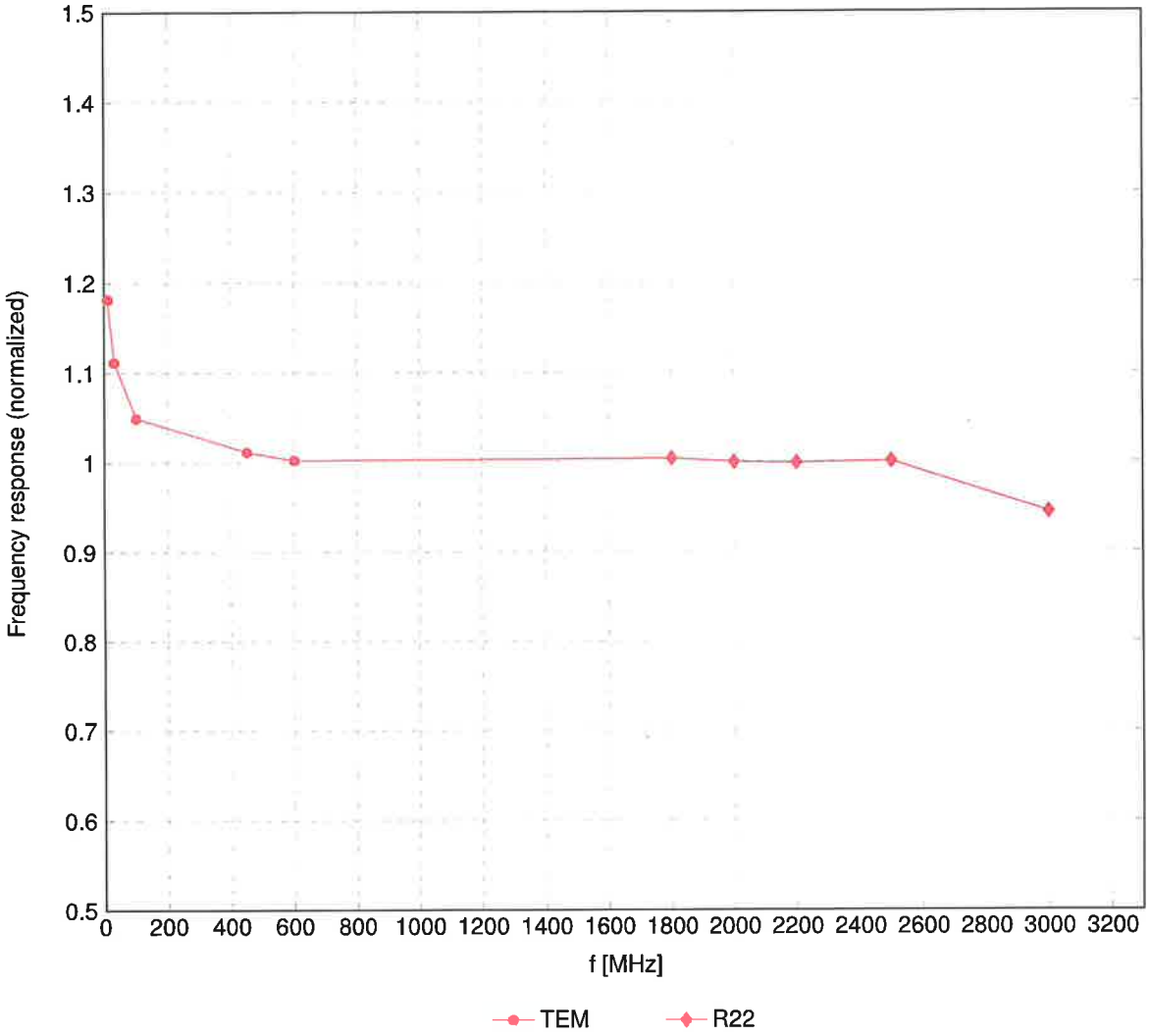
Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
6500	34.5	6.07	5.23	5.69	5.12	0.20	1.27	±18.6%

[C] Frequency validity at 6.5 GHz is −600/+700 MHz, and ±700 MHz at or above 7 GHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±10% from the target values (typically better than ±6%) and are valid for TSL with deviations of up to ±10%.
[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; below ±2% for frequencies between 3–6 GHz; and below ±4% for frequencies between 6–10 GHz at any distance larger than half the probe tip diameter from the boundary.
[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

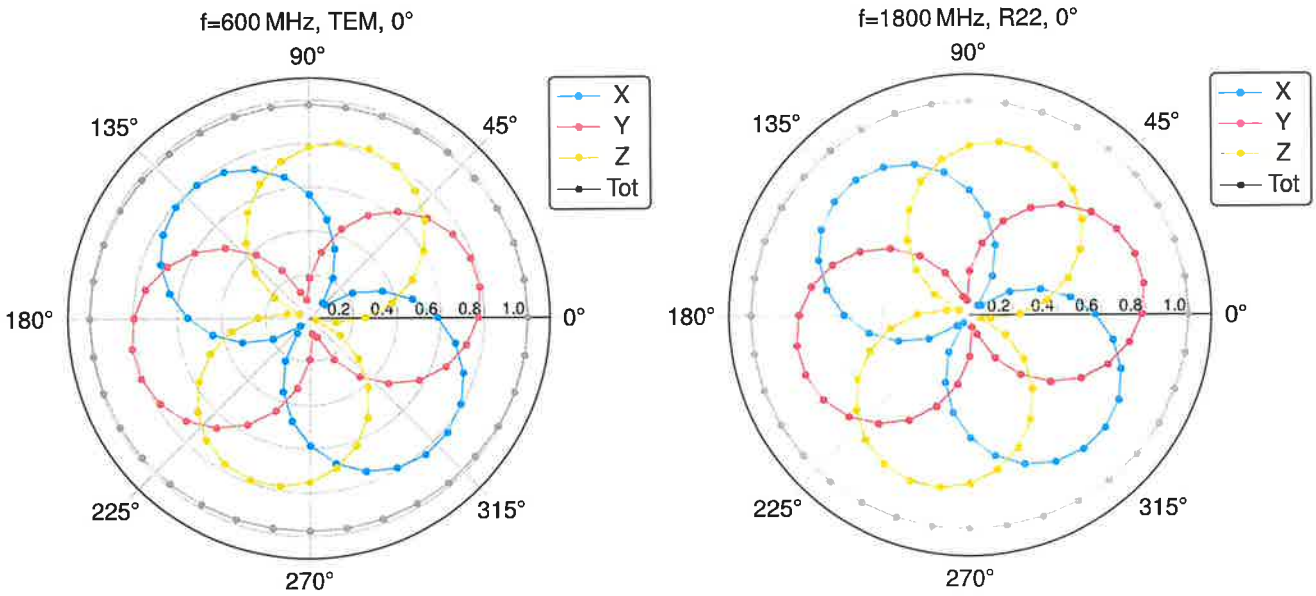
Frequency Response of E-Field

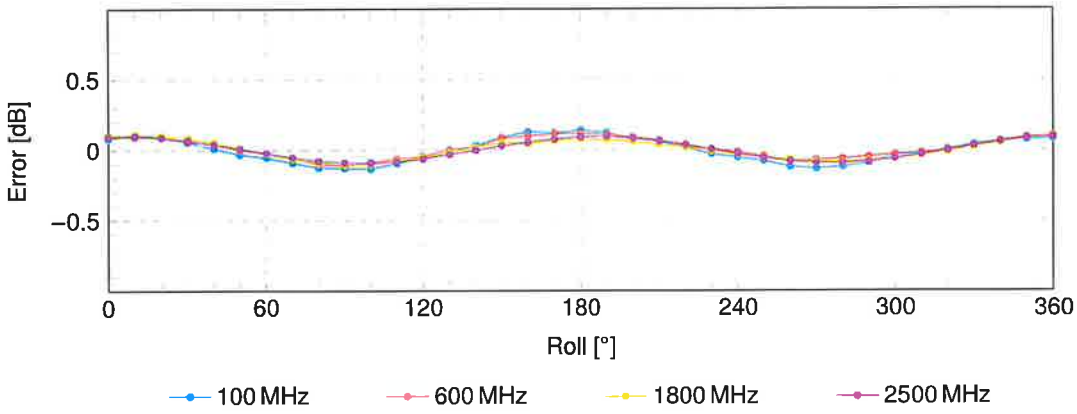
(TEM-Cell:ifi110 EXX, Waveguide:R22)



Uncertainty of Frequency Response of E-field: ±6.3% (k=2)

Receiving Pattern (ϕ), $\vartheta = 0°$

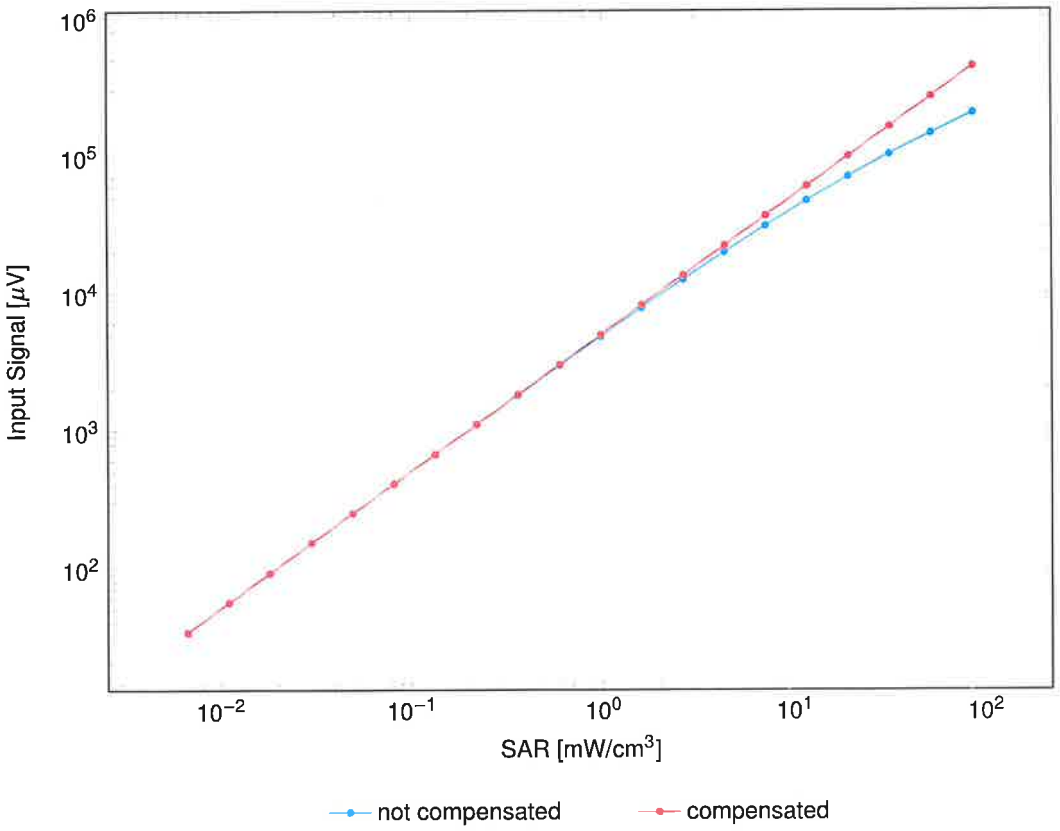


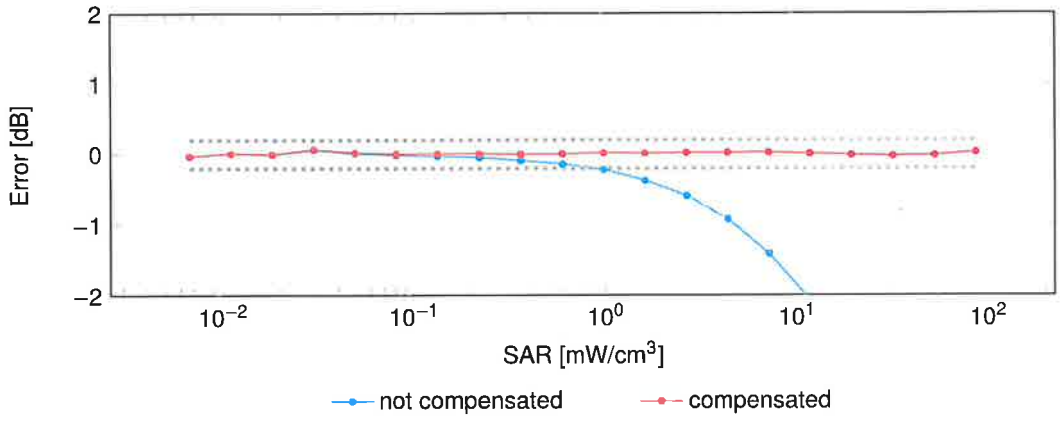


Uncertainty of Axial Isotropy Assessment: ±0.5% (k=2)

Dynamic Range f(SAR_{head})

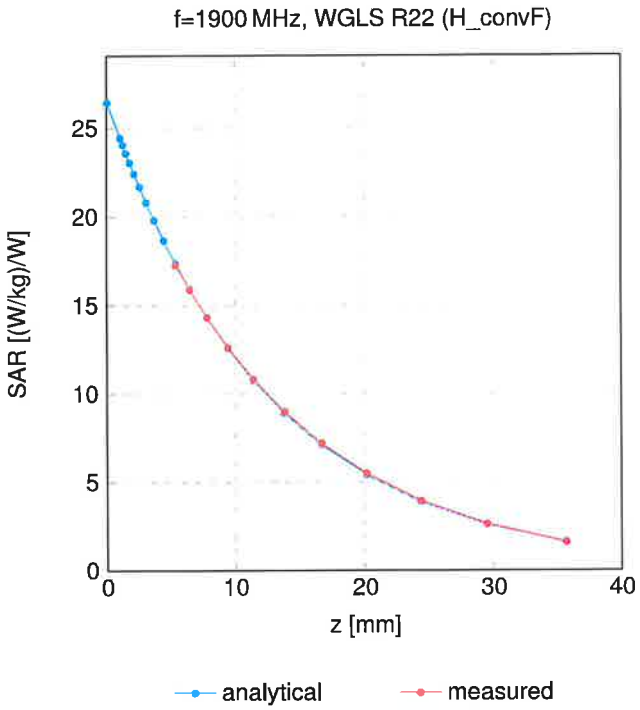
(TEM cell, f_{eval} = 1900 MHz)





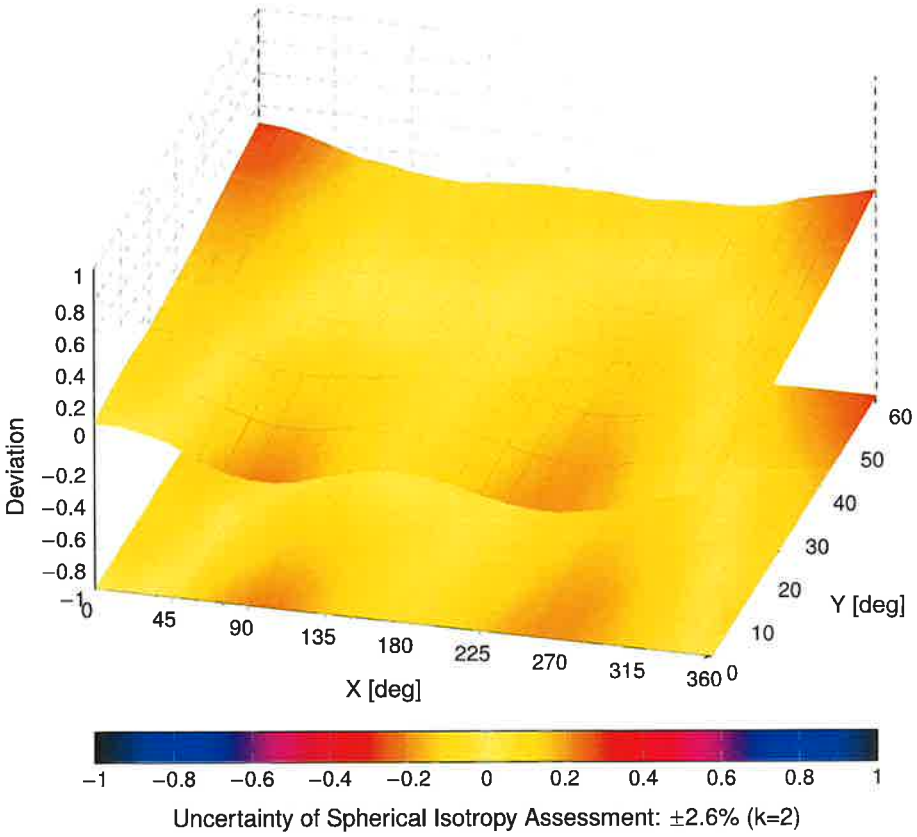
Uncertainty of Linearity Assessment: ±0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid

Error (ϕ,θ), f = 900 MHz



Uncertainty of Spherical Isotropy Assessment: ±2.6% (k=2)

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

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

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

Accreditation No.: SCS 0108

Client UL
Fremont, USA

Certificate No. EX-7915_Mar25

CALIBRATION CERTIFICATE

Object EX3DV4 - SN:7915

Calibration procedure(s) QA CAL-01.v10, QA CAL-12.v10, QA CAL-14.v7, QA CAL-23.v6, QA CAL-25.v8
Calibration procedure for dosimetric E-field probes

Calibration date March 21, 2025

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	Calibration Date (Certificate No.)	Sched. Cal.
Power Sensor R&S NRP-33T	SN: 100967	28-Mar-24 (No. 217-04038)	Mar-25
Short [S6019i] + Attenuator [S6020i]	SN: L1119	26-Mar-24 (No. 217-04048)	Mar-25
OCP DAK-12	SN: 1016	24-Sept-24 (No. OCP-DAK12-1016_Sep24)	Sep-25
OCP DAK-3.5	SN: 1249	23-Sept-24 (No. OCP-DAK3.5-1249_Sep24)	Sep-25
Reference Probe EX3DV4	SN: 7349	10-Jan-25 (No. EX3-7349_Jan25)	Jan-26
DAE4	SN: 1301	07-Nov-24 (No. DAE4-1301_Nov24)	Nov-25

Secondary Standards	ID	Check Date (in house)	Sched. Check
ACAP 2020 Calibration Box	SN: L1404	30-Sept-24 (No. Report_ACAP2020E-Cave_20240930s)	Sep-25

	Name	Function	Signature
Calibrated by	Aidonia Georgiadou	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	

Issued: March 26, 2025

Glossary

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
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

Calibration is Performed According to the Following Standards:

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

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z*: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * 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.
- *DCPx,y,z*: 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
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: 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 *NORMx,y,z * 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 ±50 MHz to ±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 *NORMx* (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:7915

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$) [A]	0.65	0.58	0.61	±10.1%
DCP (mV) [B]	104.2	105.9	107.1	±4.7%

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	122.3	±0.9%	±4.7%
		Y	0.00	0.00	1.00		146.4		
		Z	0.00	0.00	1.00		146.7		
10352	Pulse Waveform (200Hz, 10%)	X	1.48	60.42	6.34	10.00	60.0	±2.5%	±9.6%
		Y	1.48	60.40	6.22		60.0		
		Z	1.65	61.14	6.51		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	44.00	80.00	11.00	6.99	80.0	±2.3%	±9.6%
		Y	0.81	60.00	4.86		80.0		
		Z	22.00	74.00	9.00		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	0.07	130.69	0.59	3.98	95.0	±2.4%	±9.6%
		Y	0.08	127.37	0.08		95.0		
		Z	78.00	74.00	7.00		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	7.84	159.57	15.11	2.22	120.0	±1.6%	±9.6%
		Y	0.38	60.00	2.51		120.0		
		Z	9.80	127.52	4.55		120.0		
10387	QPSK Waveform, 1 MHz	X	0.57	62.99	12.01	1.00	150.0	±3.7%	±9.6%
		Y	0.55	62.72	11.56		150.0		
		Z	0.74	66.95	14.01		150.0		
10388	QPSK Waveform, 10 MHz	X	1.33	65.14	13.64	0.00	150.0	±1.2%	±9.6%
		Y	1.30	64.88	13.32		150.0		
		Z	1.51	67.24	14.83		150.0		
10396	64-QAM Waveform, 100 kHz	X	1.59	63.31	15.44	3.01	150.0	±1.1%	±9.6%
		Y	1.66	63.98	15.52		150.0		
		Z	1.78	65.60	16.57		150.0		
10399	64-QAM Waveform, 40 MHz	X	2.82	65.87	14.90	0.00	150.0	±1.8%	±9.6%
		Y	2.80	65.87	14.80		150.0		
		Z	2.95	66.82	15.43		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	3.99	66.34	15.48	0.00	150.0	±3.2%	±9.6%
		Y	3.81	65.64	15.04		150.0		
		Z	3.98	66.32	15.53		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%.

[A] The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Page 5).
[B] Linearization parameter uncertainty for maximum specified field strength.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Parameters of Probe: EX3DV4 - SN:7915

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	10.5	76.64	33.89	1.64	0.00	4.90	0.12	0.02	1.00
y	10.3	74.38	33.46	2.90	0.00	4.90	0.41	0.00	1.00
z	11.1	79.49	33.10	3.30	0.00	4.90	0.51	0.00	1.00

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	-3.7°
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

Note: Measurement distance from surface can be increased to 3–4 mm for an *Area Scan* job.

Parameters of Probe: EX3DV4 - SN:7915

Calibration Parameter Determined in HSL

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
750	41.9	0.89	9.54	9.48	9.60	0.35	1.27	±11.0%
900	41.5	0.97	9.21	9.16	9.27	0.35	1.27	±11.0%
1750	40.1	1.37	8.01	7.96	8.06	0.34	1.27	±11.0%
1900	40.0	1.40	7.75	7.71	7.81	0.34	1.27	±11.0%
2300	39.5	1.67	7.35	7.31	7.40	0.33	1.27	±11.0%
2450	39.2	1.80	7.20	7.16	7.25	0.33	1.27	±11.0%
2600	39.0	1.96	7.06	7.02	7.11	0.33	1.27	±11.0%
5250	35.9	4.71	5.87	5.83	5.91	0.29	1.27	±13.1%
5600	35.5	5.07	5.34	5.31	5.38	0.27	1.27	±13.1%
5750	35.4	5.22	5.52	5.49	5.56	0.26	1.27	±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.

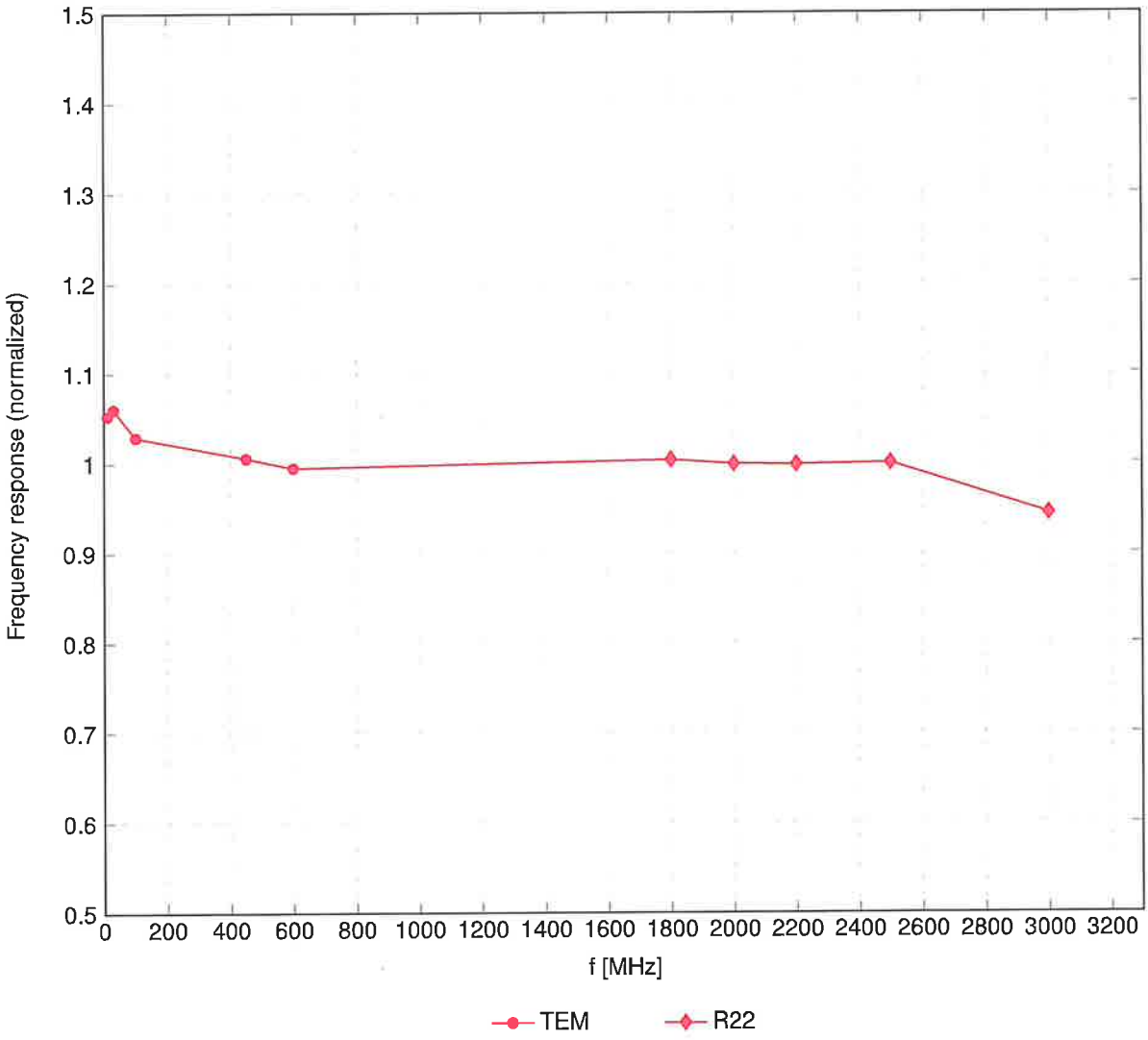
[F] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±5% from the target values (typically better than ±3%) and are valid for TSL with deviations of up to ±10% if SAR correction is applied.

[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.

[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

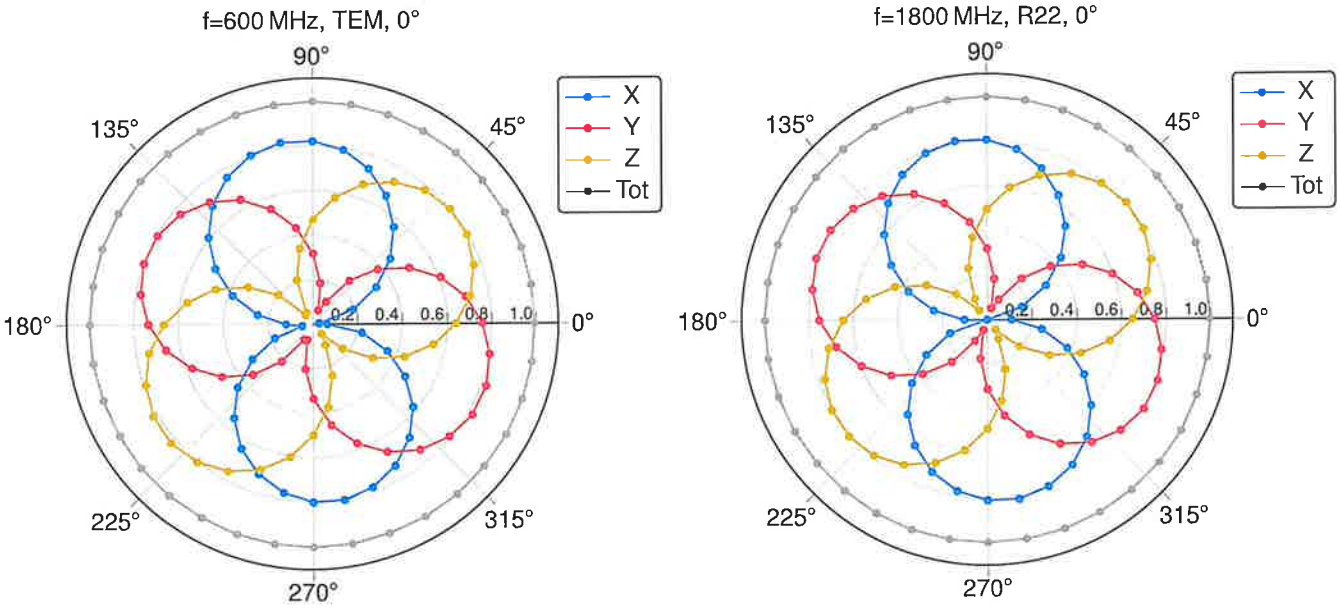
Frequency Response of E-Field

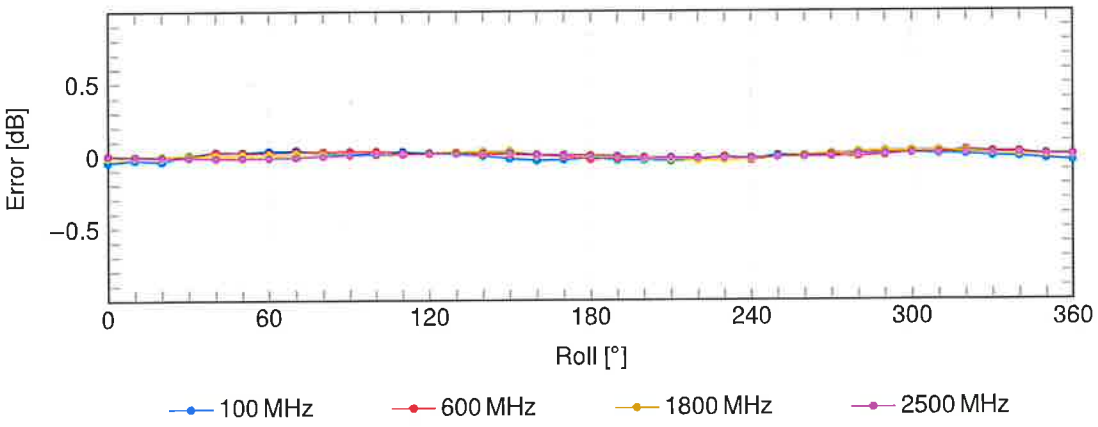
(TEM-Cell:ifi110 EXX, Waveguide:R22)



Uncertainty of Frequency Response of E-field: ±6.3% (k=2)

Receiving Pattern (ϕ), $\vartheta = 0°$

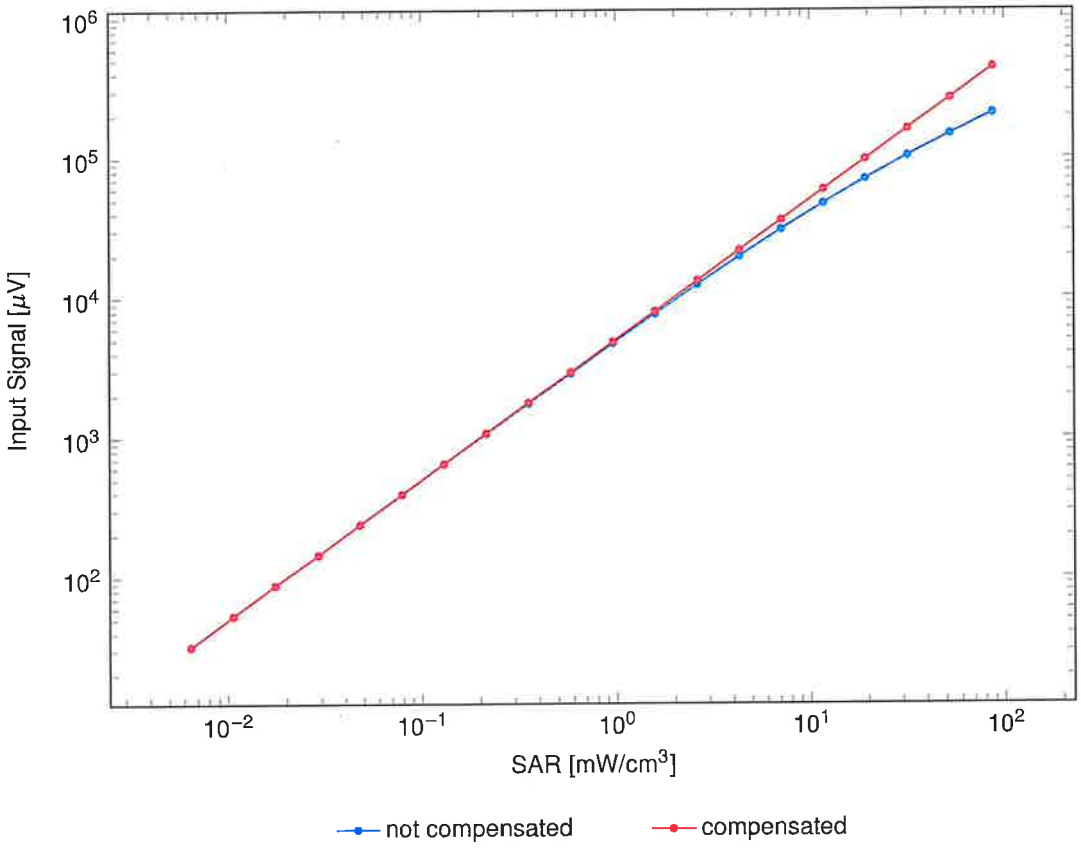


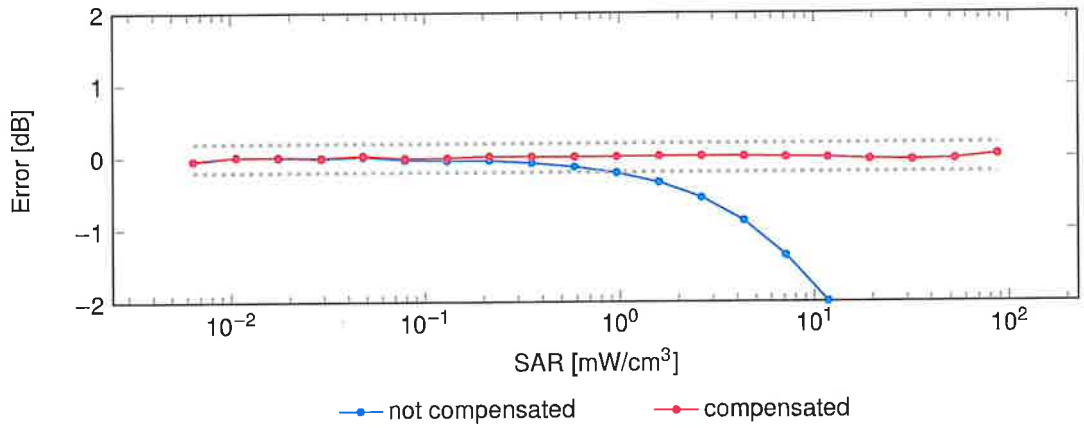


Uncertainty of Axial Isotropy Assessment: ±0.5% (k=2)

Dynamic Range f(SAR_{HSL})

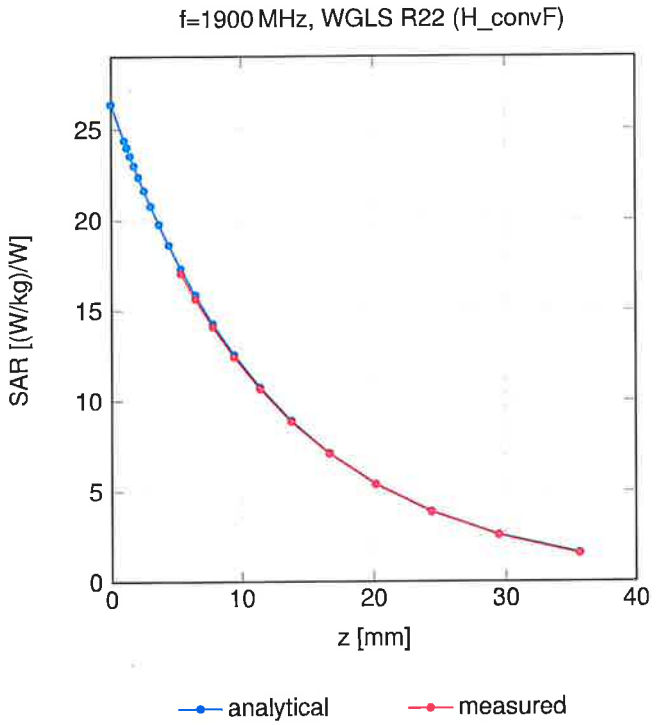
(TEM cell, f_{eval} = 1900 MHz)



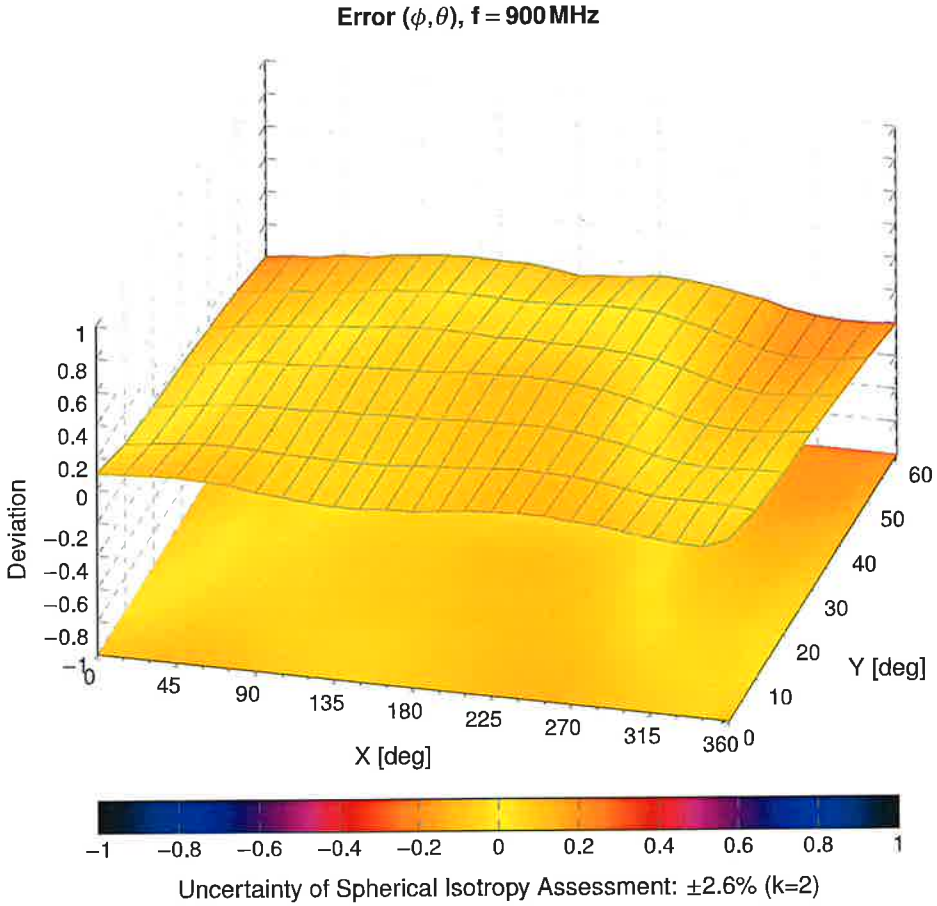


Uncertainty of Linearity Assessment: ±0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: ±2.6% (k=2)

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

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

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

Accreditation No.: SCS 0108

Client **UL**
Fremont, USA

Certificate No. **EX-7808_Mar25**

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7808
Calibration procedure(s)	QA CAL-01.v10, QA CAL-12.v10, QA CAL-14.v7, QA CAL-23.v6, QA CAL-25.v8 Calibration procedure for dosimetric E-field probes
Calibration date	March 12, 2025

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	Calibration Date (Certificate No.)	Sched. Cal.
Power Sensor R&S NRP-33T	SN: 100967	28-Mar-24 (No. 217-04038)	Mar-25
Short [S6019i] + Attenuator [S6020i]	SN: L1119	26-Mar-24 (No. 217-04048)	Mar-25
OCP DAK-12	SN: 1016	24-Sep-24 (No. OCP-DAK12-1016_Sep24)	Sep-25
OCP DAK-3.5	SN: 1249	23-Sep-24 (No. OCP-DAK3.5-1249_Sep24)	Sep-25
Reference Probe EX3DV4	SN: 7349	10-Jan-25 (No. EX3-7349_Jan25)	Jan-26
DAE4	SN: 1301	07-Nov-24 (No. DAE4-1301_Nov24)	Nov-25

Secondary Standards	ID	Check Date (in house)	Sched. Check
ACAP 2020 Calibration Box	SN: L1404	30-Sep-24 (No. Report_ACAP2020E-Cave_20240930s)	Sep-25

	Name	Function	Signature
Calibrated by	Krešimir Franjić	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	

Issued: March 12, 2025

Glossary

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
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

Calibration is Performed According to the Following Standards:

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

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z*: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * 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.
- *DCPx,y,z*: 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
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: 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 *NORMx,y,z * 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 ±50 MHz to ±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 *NORMx* (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:7808

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$) [A]	0.61	0.70	0.70	±10.1%
DCP (mV) [B]	108.4	103.9	104.3	±4.7%

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	145.5	±1.5%	±4.7%
		Y	0.00	0.00	1.00		132.8		
		Z	0.00	0.00	1.00		128.4		
10352	Pulse Waveform (200Hz, 10%)	X	2.00	62.00	7.00	10.00	60.0	±2.9%	±9.6%
		Y	1.57	60.77	6.45		60.0		
		Z	1.61	61.02	6.60		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	10.00	72.00	9.00	6.99	80.0	±2.1%	±9.6%
		Y	0.78	60.00	4.85		80.0		
		Z	0.78	60.00	4.92		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	0.40	60.00	4.01	3.98	95.0	±2.4%	±9.6%
		Y	0.00	125.12	0.64		95.0		
		Z	0.28	152.25	1.36		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	11.26	91.99	0.54	2.22	120.0	±1.7%	±9.6%
		Y	6.17	159.97	2.70		120.0		
		Z	8.18	123.15	10.14		120.0		
10387	QPSK Waveform, 1 MHz	X	0.51	64.72	13.70	1.00	150.0	±2.8%	±9.6%
		Y	0.51	62.94	12.03		150.0		
		Z	0.49	63.98	13.14		150.0		
10388	QPSK Waveform, 10 MHz	X	1.31	67.33	14.10	0.00	150.0	±0.8%	±9.6%
		Y	1.29	65.45	13.60		150.0		
		Z	1.28	66.63	13.89		150.0		
10396	64-QAM Waveform, 100 kHz	X	1.77	65.29	16.19	3.01	150.0	±1.4%	±9.6%
		Y	1.66	64.07	15.53		150.0		
		Z	1.54	63.29	15.55		150.0		
10399	64-QAM Waveform, 40 MHz	X	2.79	67.10	15.42	0.00	150.0	±1.4%	±9.6%
		Y	2.79	66.11	14.99		150.0		
		Z	2.76	66.66	15.29		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	3.64	66.72	15.38	0.00	150.0	±2.4%	±9.6%
		Y	3.75	65.83	15.15		150.0		
		Z	3.62	66.25	15.27		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%.

[A] The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5 to 7).
[B] Linearization parameter uncertainty for maximum specified field strength.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Parameters of Probe: EX3DV4 - SN:7808

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	6.8	48.19	32.24	2.78	0.00	4.90	0.51	0.00	1.00
y	9.2	66.87	33.66	1.24	0.00	4.90	0.48	0.00	1.00
z	7.4	53.66	33.78	1.85	0.00	4.90	0.00	0.01	1.00

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	4.4°
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

Note: Measurement distance from surface can be increased to 3–4 mm for an *Area Scan* job.

Parameters of Probe: EX3DV4 - SN:7808

Calibration Parameter Determined in HSL

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
6	55.0	0.75	18.51	18.83	17.73	0.00	1.25	±13.3%
13	55.0	0.75	18.27	18.58	17.50	0.00	1.25	±13.3%
30	55.0	0.75	16.78	17.06	16.06	0.00	1.25	±13.3%
64	54.2	0.75	14.41	14.65	13.79	0.00	1.25	±13.3%
450	43.5	0.87	10.91	10.91	10.91	0.16	1.30	±13.3%
750	41.9	0.89	9.80	9.74	9.36	0.37	1.27	±11.0%
900	41.5	0.97	9.43	9.37	9.01	0.37	1.27	±11.0%
1450	40.5	1.20	8.36	8.31	7.99	0.36	1.27	±11.0%
1640	40.2	1.31	8.21	8.16	7.85	0.36	1.27	±11.0%
1750	40.1	1.37	8.07	8.02	7.71	0.36	1.27	±11.0%
1900	40.0	1.40	7.88	7.84	7.53	0.36	1.27	±11.0%
2100	39.8	1.49	7.69	7.64	7.34	0.36	1.27	±11.0%
2300	39.5	1.67	7.48	7.44	7.15	0.36	1.27	±11.0%
2450	39.2	1.80	7.32	7.27	6.99	0.36	1.27	±11.0%
2600	39.0	1.96	7.16	7.12	6.84	0.36	1.27	±11.0%
3300	38.2	2.71	6.61	6.57	6.32	0.35	1.27	±13.1%
3500	37.9	2.91	6.52	6.48	6.23	0.35	1.27	±13.1%
3700	37.7	3.12	6.45	6.41	6.16	0.35	1.27	±13.1%
3900	37.5	3.32	6.40	6.36	6.11	0.35	1.27	±13.1%
4100	37.2	3.53	6.30	6.27	6.02	0.35	1.27	±13.1%
4200	37.1	3.63	6.25	6.21	5.97	0.35	1.27	±13.1%
4400	36.9	3.84	6.16	6.12	5.88	0.35	1.27	±13.1%
4600	36.7	4.04	6.06	6.02	5.79	0.34	1.27	±13.1%
4800	36.4	4.25	6.00	5.96	5.73	0.34	1.27	±13.1%
4950	36.3	4.40	5.88	5.85	5.62	0.33	1.27	±13.1%
5250	35.9	4.71	5.68	5.65	5.43	0.30	1.27	±13.1%
5600	35.5	5.07	5.26	5.23	5.02	0.28	1.27	±13.1%
5750	35.4	5.22	5.36	5.33	5.12	0.26	1.27	±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] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±5% from the target values (typically better than ±3%) and are valid for TSL with deviations of up to ±10% if SAR correction is applied.

[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.

[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

Parameters of Probe: EX3DV4 - SN:7808

Calibration Parameter Determined in HSL

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
5850	35.2	5.32	5.43	5.40	5.19	0.25	1.27	±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.

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[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.

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Parameters of Probe: EX3DV4 - SN:7808

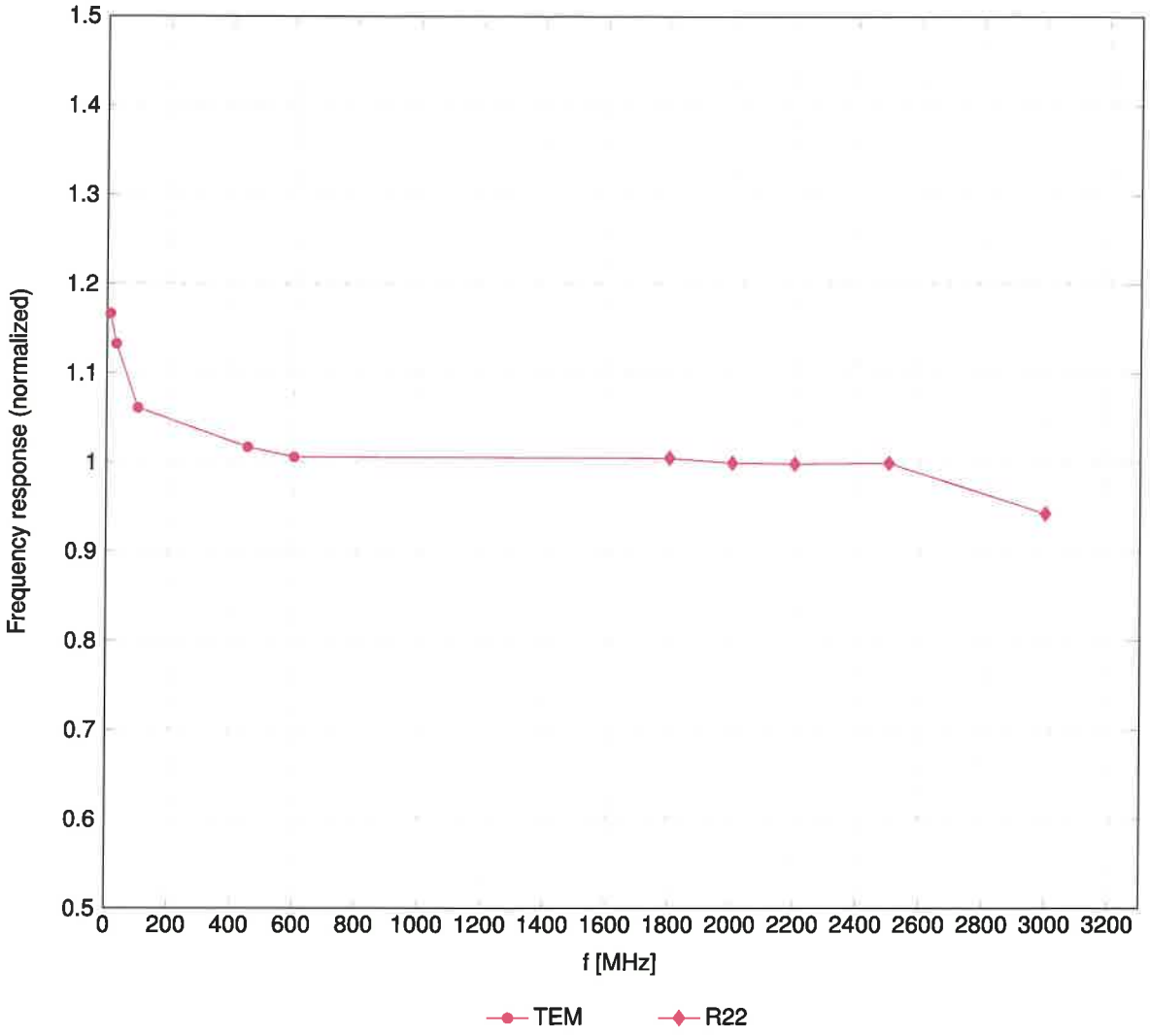
Calibration Parameter Determined in HSL

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
6500	34.5	6.07	5.37	5.34	5.13	0.20	1.27	±18.6%

[C] Frequency validity at 6.5 GHz is −600/+700 MHz, and ±700 MHz at or above 7 GHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±10% from the target values (typically better than ±6%) and are valid for TSL with deviations of up to ±10%.
[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; below ±2% for frequencies between 3–6 GHz; and below ±4% for frequencies between 6–10 GHz at any distance larger than half the probe tip diameter from the boundary.
[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

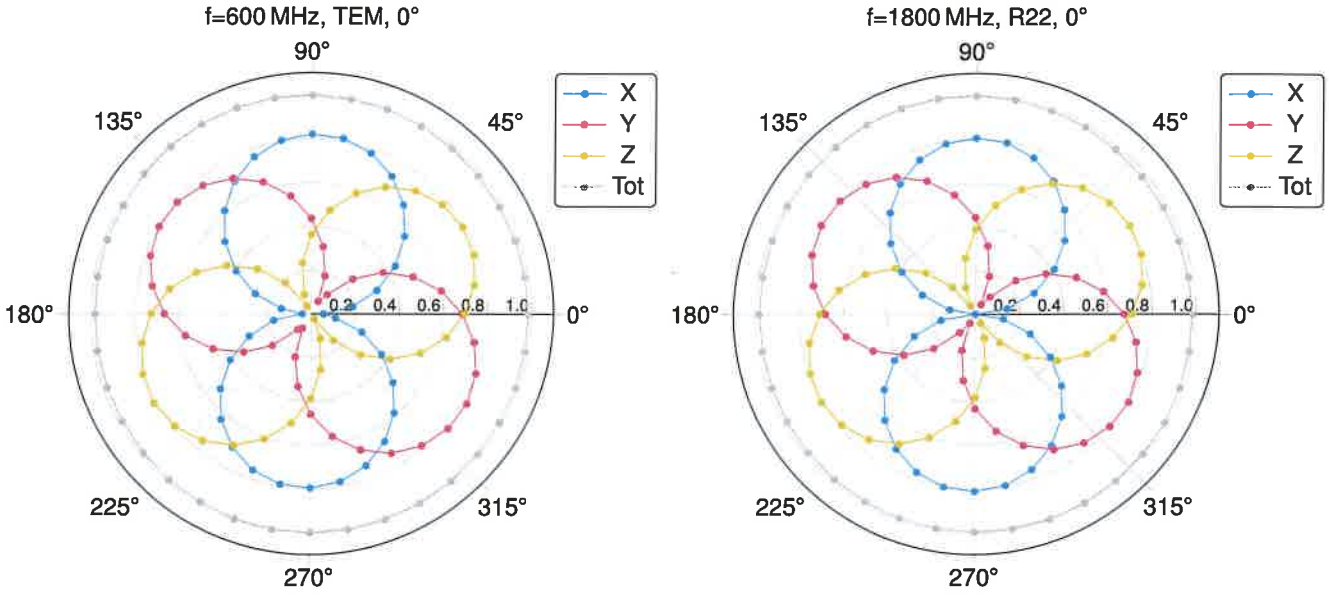
Frequency Response of E-Field

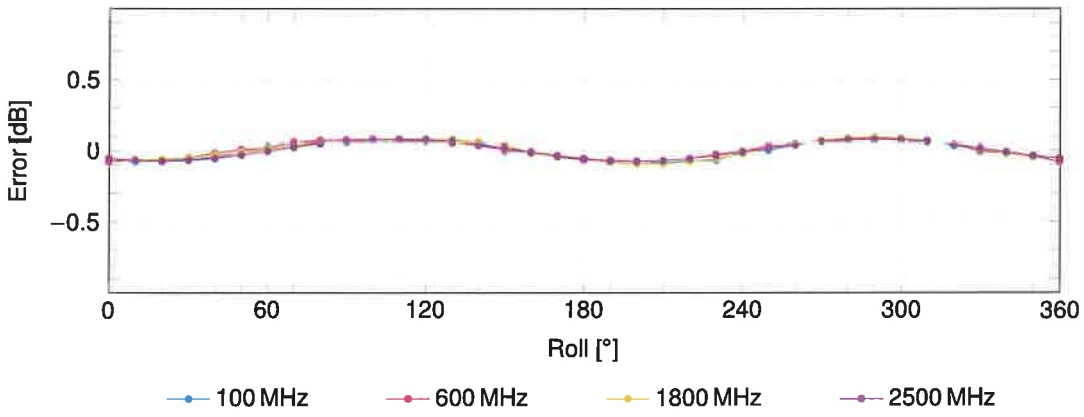
(TEM-Cell:ifi110 EXX, Waveguide:R22)



Uncertainty of Frequency Response of E-field: ±6.3% (k=2)

Receiving Pattern (ϕ), $\vartheta = 0°$

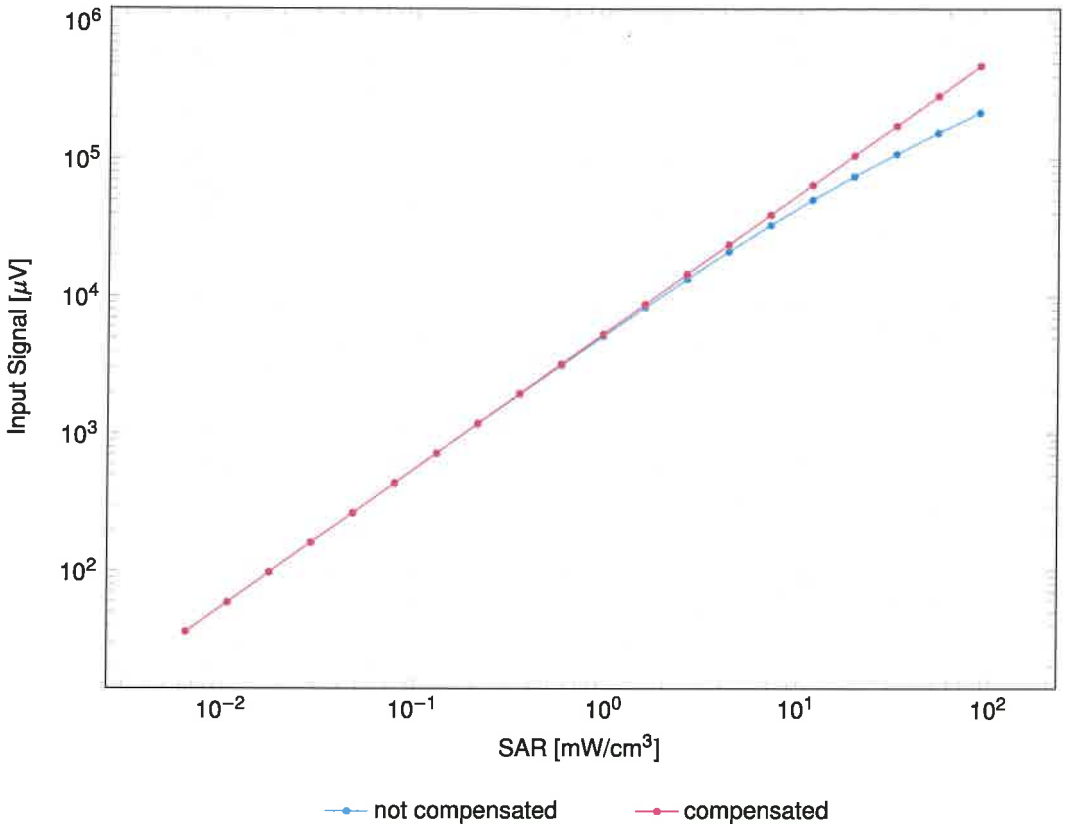


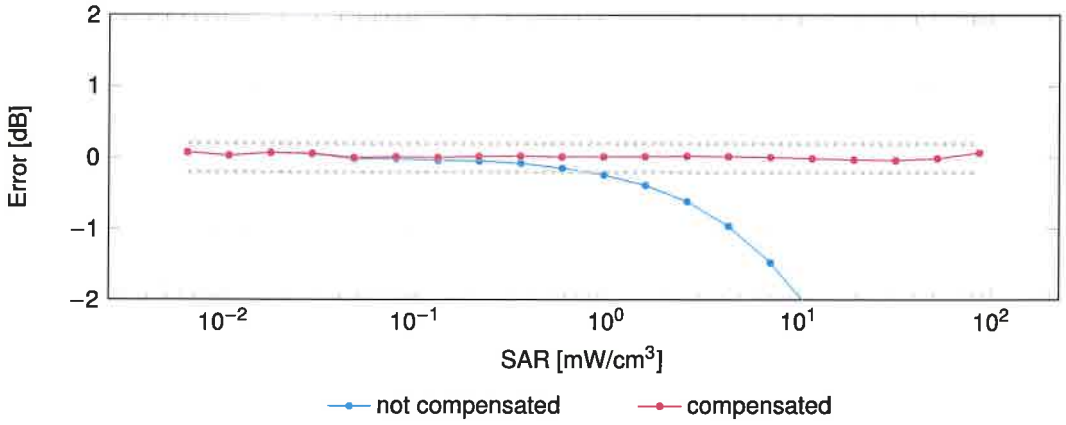


Uncertainty of Axial Isotropy Assessment: ±0.5% (k=2)

Dynamic Range f(SAR_{HSL})

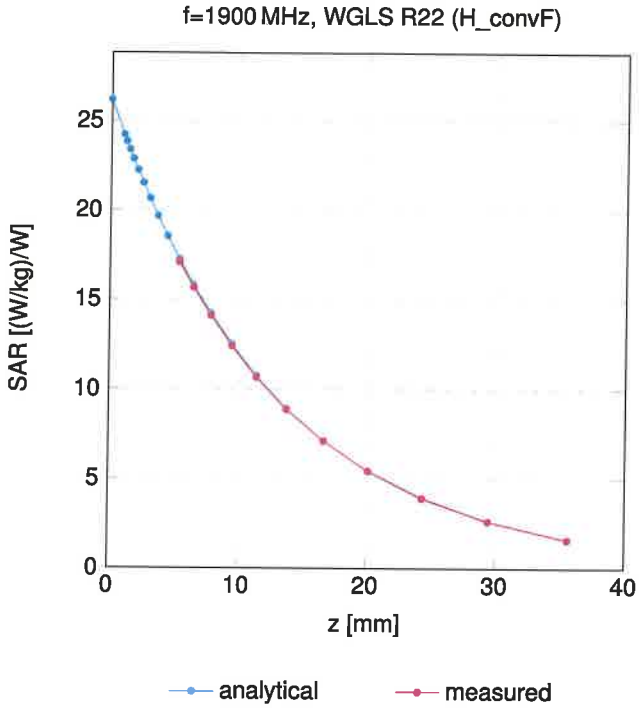
(TEM cell, f_{eval} = 1900 MHz)



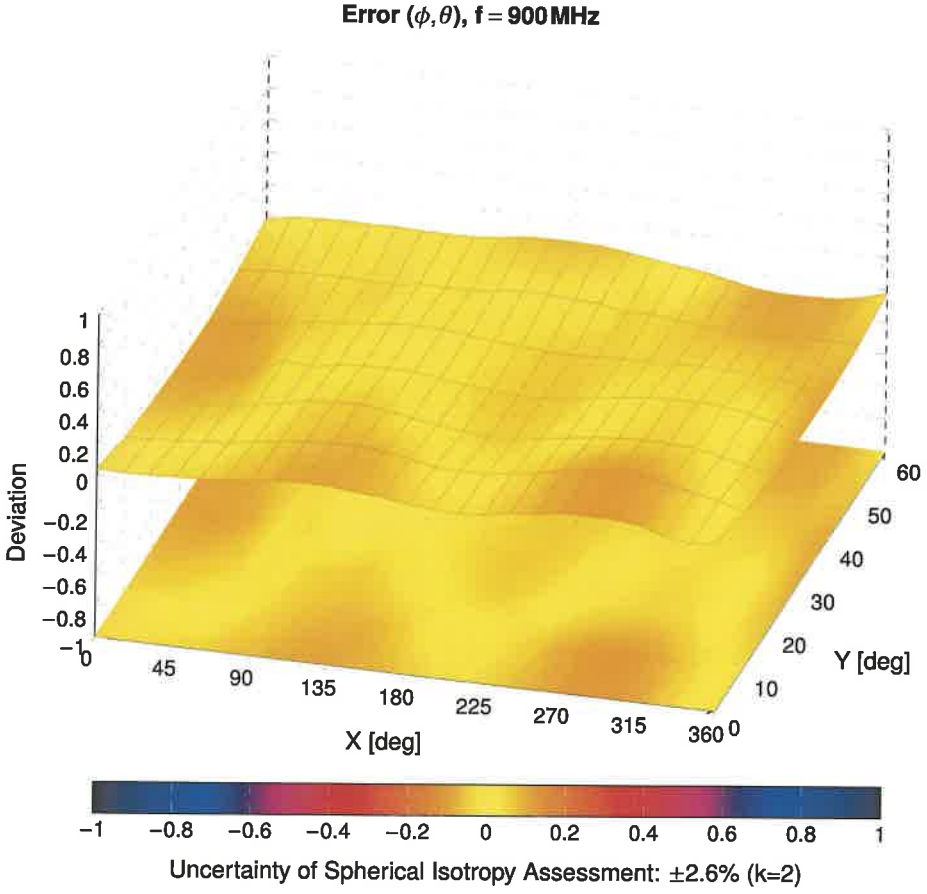


Uncertainty of Linearity Assessment: ±0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: ±2.6% (k=2)

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

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

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

Accreditation No.: SCS 0108

Client **UL**
Fremont, USA

Certificate No. **EX-3902_Mar25**

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3902
Calibration procedure(s)	QA CAL-01.v10, QA CAL-12.v10, QA CAL-14.v7, QA CAL-23.v6, QA CAL-25.v8 Calibration procedure for dosimetric E-field probes
Calibration date	March 10, 2025

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)

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OCP DAK-12	SN: 1016	24-Sep-24 (No. OCP-DAK12-1016_Sep24)	Sep-25
OCP DAK-3.5	SN: 1249	23-Sep-24 (No. OCP-DAK3.5-1249_Sep24)	Sep-25
Reference Probe EX3DV4	SN: 7349	10-Jan-25 (No. EX3-7349_Jan25)	Jan-26
DAE4	SN: 1301	07-Nov-24 (No. DAE4-1301_Nov24)	Nov-25

Secondary Standards	ID	Check Date (in house)	Sched. Check
ACAP 2020 Calibration Box	SN: L1404	30-Sep-24 (No. Report_ACAP2020E-Cave_20240930s)	Sep-25

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

Issued: March 10, 2025

Glossary

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
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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

Calibration is Performed According to the Following Standards:

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Methods Applied and Interpretation of Parameters:

- *NORMx,y,z*: Assessed for E-field polarization $\vartheta = 0$ ($f \le 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * 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.
- *DCPx,y,z*: 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
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: 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 $f \le 800$ 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 *NORMx,y,z * 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 ±50 MHz to ±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 *NORMx* (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:3902

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$) [A]	0.43	0.45	0.47	±10.1%
DCP (mV) [B]	104.5	100.6	101.5	±4.7%

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	144.7	±0.8%	±4.7%
		Y	0.00	0.00	1.00		121.0		
		Z	0.00	0.00	1.00		146.1		
10352	Pulse Waveform (200Hz, 10%)	X	20.00	93.04	22.24	10.00	60.0	±3.1%	±9.6%
		Y	64.00	106.00	25.00		60.0		
		Z	20.00	94.17	22.82		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	20.00	95.16	22.31	6.99	80.0	±1.3%	±9.6%
		Y	20.00	93.47	20.91		80.0		
		Z	20.00	96.80	23.25		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	20.00	101.30	24.02	3.98	95.0	±1.4%	±9.6%
		Y	20.00	96.93	21.11		95.0		
		Z	20.00	98.53	22.78		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	20.00	110.48	27.02	2.22	120.0	±1.4%	±9.6%
		Y	20.00	101.53	21.96		120.0		
		Z	20.00	105.10	24.65		120.0		
10387	QPSK Waveform, 1 MHz	X	1.72	67.09	15.49	1.00	150.0	±1.7%	±9.6%
		Y	1.62	64.98	14.34		150.0		
		Z	1.81	66.73	15.56		150.0		
10388	QPSK Waveform, 10 MHz	X	2.27	68.60	16.12	0.00	150.0	±1.0%	±9.6%
		Y	2.13	66.82	15.02		150.0		
		Z	2.42	69.01	16.29		150.0		
10396	64-QAM Waveform, 100 kHz	X	2.79	70.26	18.68	3.01	150.0	±0.7%	±9.6%
		Y	2.84	69.55	18.23		150.0		
		Z	2.93	69.98	18.62		150.0		
10399	64-QAM Waveform, 40 MHz	X	3.55	67.50	15.98	0.00	150.0	±0.8%	±9.6%
		Y	3.48	66.73	15.48		150.0		
		Z	3.52	67.05	15.80		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	4.70	65.35	15.36	0.00	150.0	±1.8%	±9.6%
		Y	4.69	64.83	15.04		150.0		
		Z	4.88	65.50	15.49		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%.

[A] The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5 and 6).
[B] Linearization parameter uncertainty for maximum specified field strength.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Parameters of Probe: EX3DV4 - SN:3902

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	41.6	302.02	33.91	18.63	0.13	5.10	1.21	0.17	1.01
y	47.2	350.28	35.03	11.50	0.39	5.05	1.15	0.25	1.01
z	50.3	372.68	35.14	21.75	0.18	5.10	0.55	0.37	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	4.0°
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

Note: Measurement distance from surface can be increased to 3–4 mm for an *Area Scan* job.

Parameters of Probe: EX3DV4 - SN:3902

Calibration Parameter Determined in HSL

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
2450	39.2	1.80	8.17	7.71	7.26	0.31	1.27	±11.0%
5250	35.9	4.71	5.93	5.59	5.27	0.28	1.27	±13.1%
5600	35.5	5.07	5.49	5.18	4.88	0.26	1.27	±13.1%
5750	35.4	5.22	5.56	5.25	4.94	0.25	1.27	±13.1%
5850	35.2	5.32	5.60	5.28	4.98	0.24	1.27	±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] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±5% from the target values (typically better than ±3%) and are valid for TSL with deviations of up to ±10% if SAR correction is applied.

[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.

[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

Parameters of Probe: EX3DV4 - SN:3902

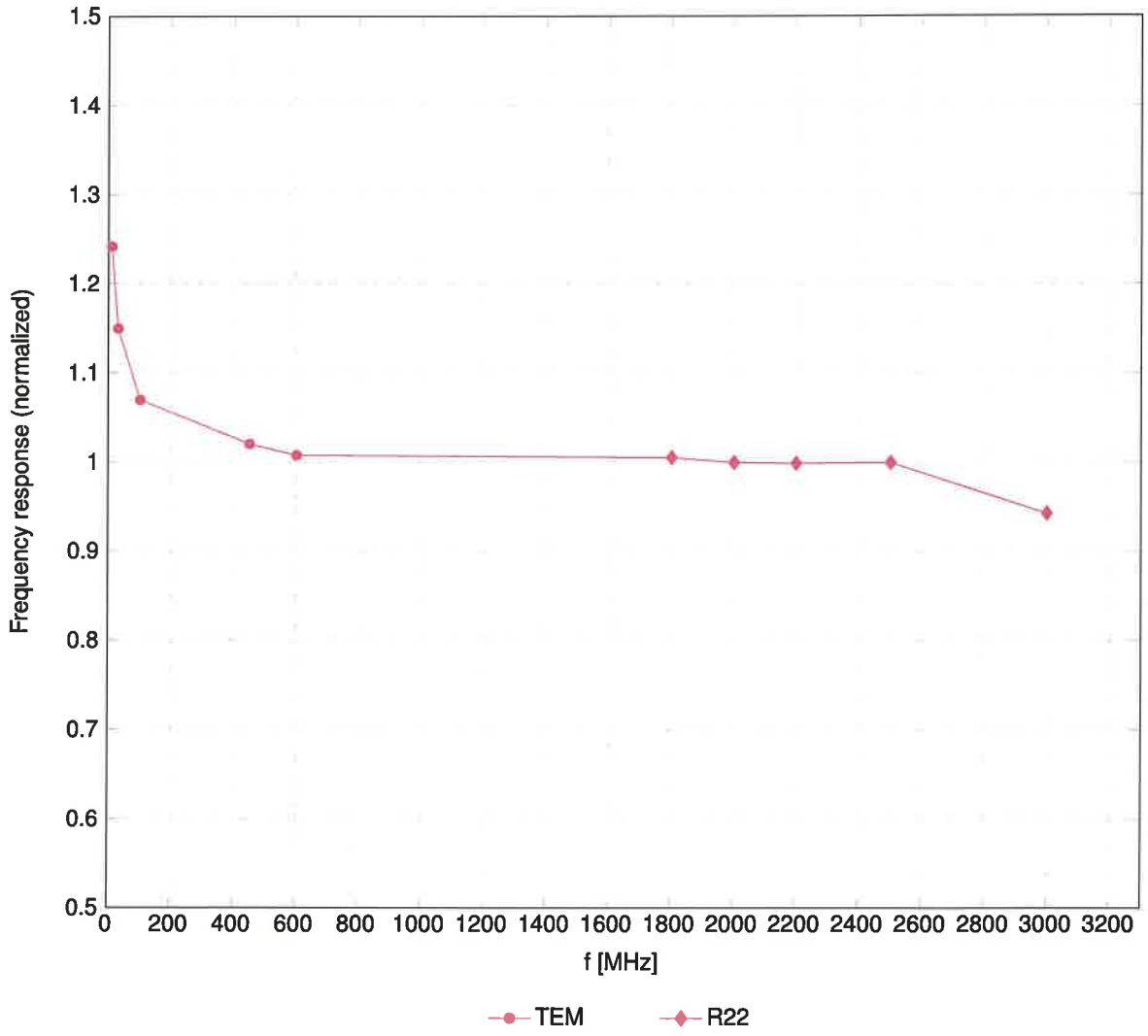
Calibration Parameter Determined in HSL

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
6500	34.5	6.07	5.74	5.42	5.10	0.20	1.27	±18.6%

[C] Frequency validity at 6.5 GHz is −600/+700 MHz, and ±700 MHz at or above 7 GHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±10% from the target values (typically better than ±6%) and are valid for TSL with deviations of up to ±10%.
[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; below ±2% for frequencies between 3–6 GHz; and below ±4% for frequencies between 6–10 GHz at any distance larger than half the probe tip diameter from the boundary.
[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

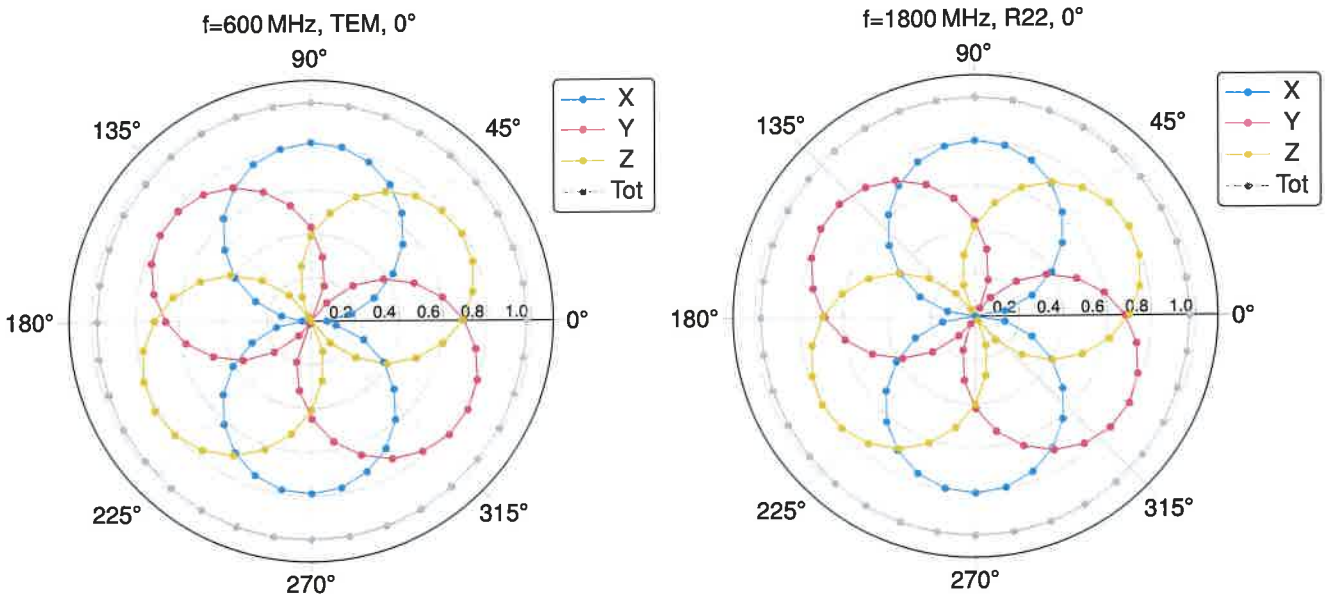
Frequency Response of E-Field

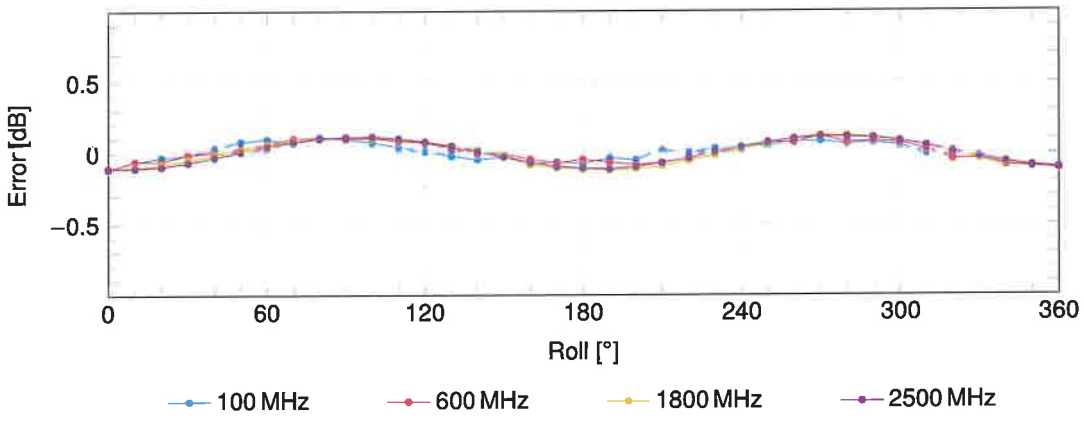
(TEM-Cell:ifi110 EXX, Waveguide:R22)



Uncertainty of Frequency Response of E-field: ±6.3% (k=2)

Receiving Pattern (ϕ), $\vartheta = 0°$

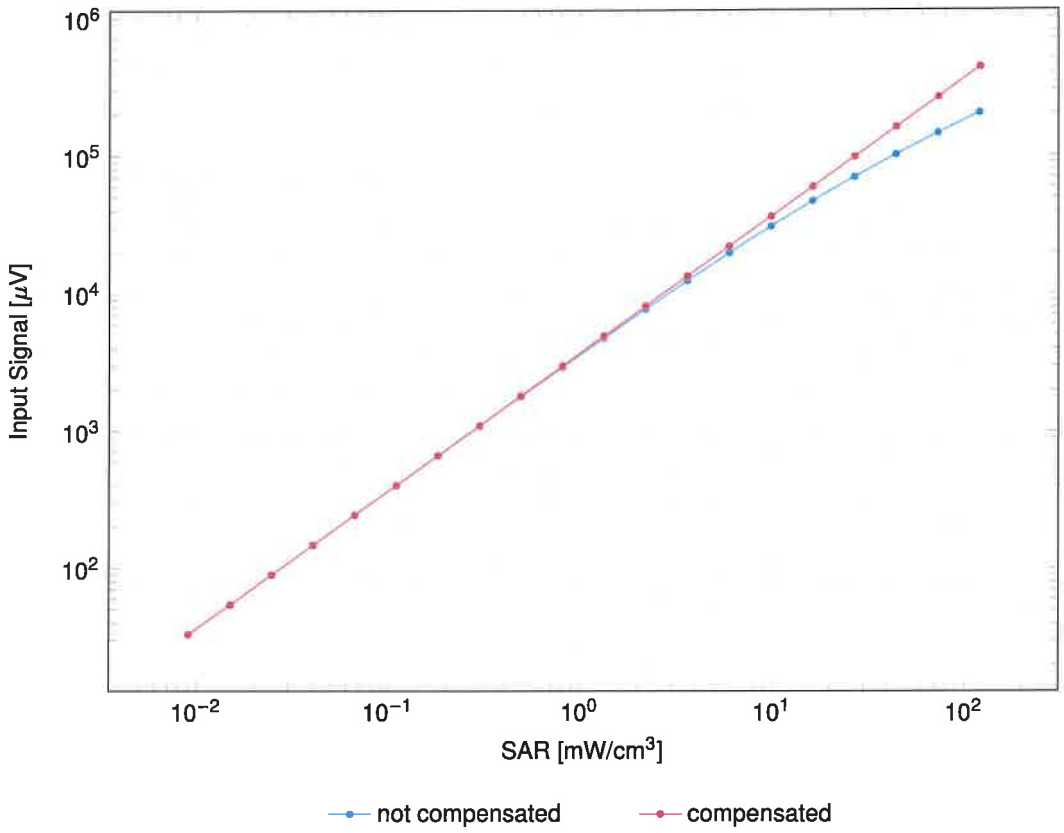


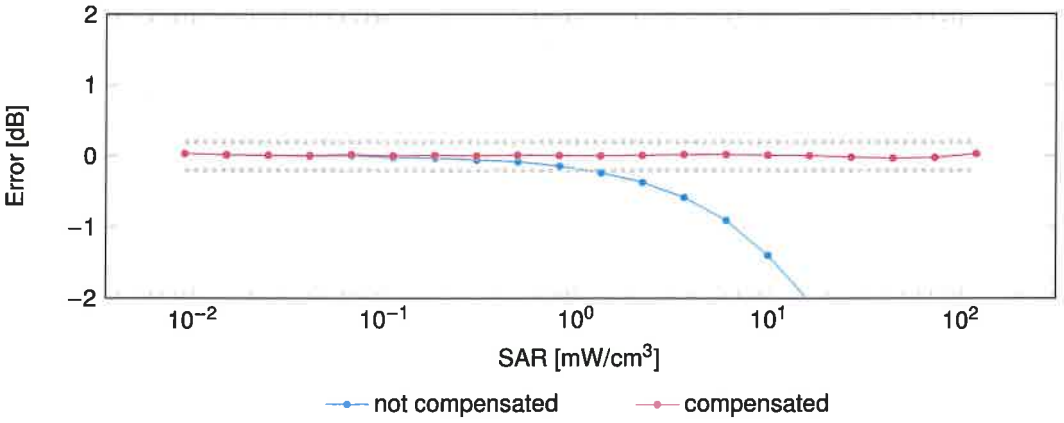


Uncertainty of Axial Isotropy Assessment: ±0.5% (k=2)

Dynamic Range f(SAR_{HSL})

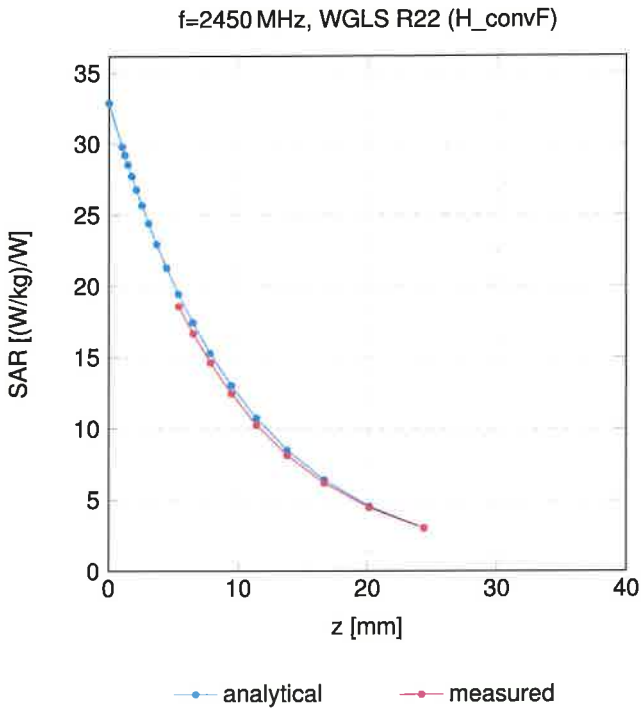
(TEM cell, f_{eval} = 1900 MHz)



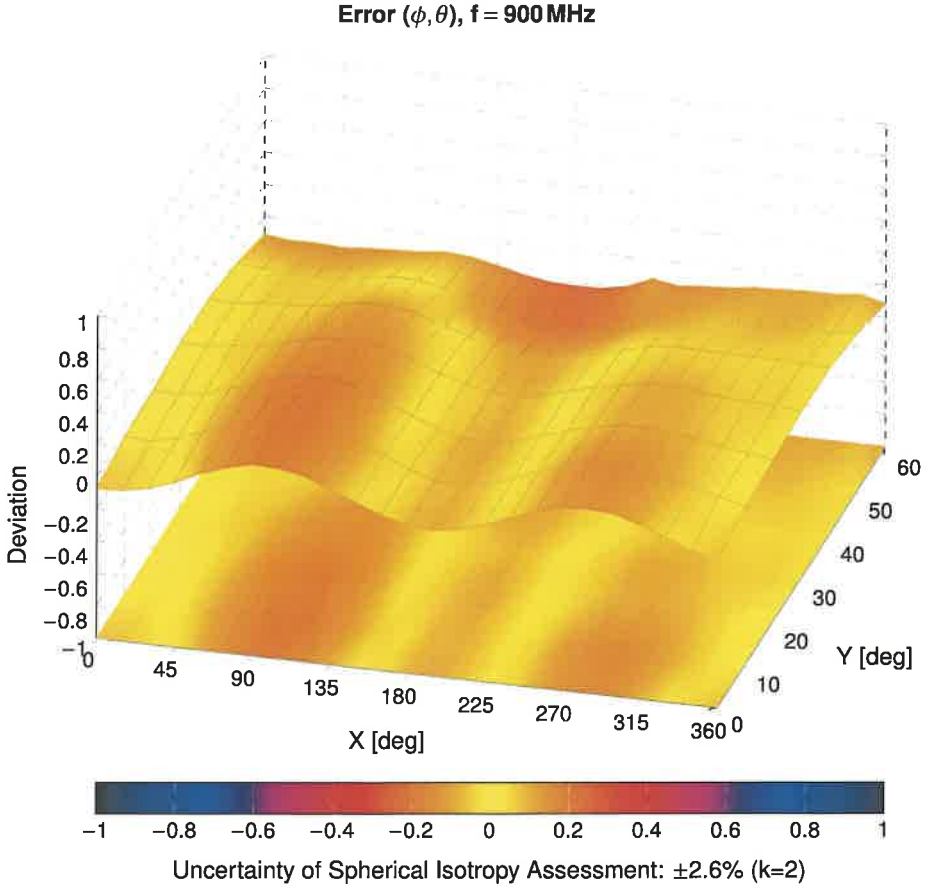


Uncertainty of Linearity Assessment: ±0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: ±2.6% (k=2)

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

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

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

Accreditation No.: SCS 0108

Client **UL**
Fremont, USA

Certificate No. **EX-7335_Jan25**

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7335
Calibration procedure(s)	QA CAL-01.v10, QA CAL-12.v10, QA CAL-14.v7, QA CAL-23.v6, QA CAL-25.v8 Calibration procedure for dosimetric E-field probes
Calibration date	January 13, 2025

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	Calibration Date (Certificate No.)	Sched. Cal.
Power Sensor R&S NRP-33T	SN: 100967	28-Mar-24 (No. 217-04038)	Mar-25
Short [S6019i] + Attenuator [S6020i]	SN: L1119	26-Mar-24 (No. 217-04048)	Mar-25
OCP DAK-12	SN: 1016	24-Sept-24 (No. OCP-DAK12-1016_Sep24)	Sep-25
OCP DAK-3.5	SN: 1249	23-Sept-24 (No. OCP-DAK3.5-1249_Sep24)	Sep-25
Reference Probe EX3DV4	SN: 7349	10-Jan-25 (No. EX3-7349_Jan25)	Jan-26
DAE4	SN: 1301	07-Nov-24 (No. DAE4-1301_Nov24)	Nov-25

Secondary Standards	ID	Check Date (in house)	Sched. Check
ACAP 2020 Calibration Box	SN: L1404	30-Sept-24 (No. Report_ACAP2020E-Cave_20240930s)	Sep-25

	Name	Function	Signature
Calibrated by	Aidonia Georgiadou	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	

Issued: January 13, 2025

Glossary

TSL	tissue simulating liquid
NORMx,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORMx,y,z
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

Calibration is Performed According to the Following Standards:

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

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z*: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the E^2-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * 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.
- *DCPx,y,z*: 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
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: 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 *NORMx,y,z * 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 ±50 MHz to ±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 *NORMx* (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:7335

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$) [A]	0.40	0.42	0.54	±10.1%
DCP (mV) [B]	104.6	102.2	99.1	±4.7%

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	134.8	±0.9%	±4.7%
		Y	0.00	0.00	1.00		145.2		
		Z	0.00	0.00	1.00		132.0		
10352	Pulse Waveform (200Hz, 10%)	X	6.79	75.38	14.23	10.00	60.0	±2.8%	±9.6%
		Y	8.73	79.99	16.99		60.0		
		Z	20.00	90.68	20.49		60.0		
10353	Pulse Waveform (200Hz, 20%)	X	20.00	86.85	16.80	6.99	80.0	±1.5%	±9.6%
		Y	20.00	90.32	18.88		80.0		
		Z	20.00	92.12	20.24		80.0		
10354	Pulse Waveform (200Hz, 40%)	X	20.00	92.35	18.28	3.98	95.0	±1.2%	±9.6%
		Y	20.00	93.76	19.02		95.0		
		Z	20.00	96.53	21.20		95.0		
10355	Pulse Waveform (200Hz, 60%)	X	20.00	108.49	24.63	2.22	120.0	±1.3%	±9.6%
		Y	20.00	100.26	20.81		120.0		
		Z	20.00	103.35	23.23		120.0		
10387	QPSK Waveform, 1 MHz	X	2.10	74.38	18.38	1.00	150.0	±2.3%	±9.6%
		Y	1.63	65.65	14.75		150.0		
		Z	1.79	66.07	15.28		150.0		
10388	QPSK Waveform, 10 MHz	X	2.20	70.02	17.15	0.00	150.0	±1.1%	±9.6%
		Y	2.14	67.28	15.41		150.0		
		Z	2.37	68.42	15.98		150.0		
10396	64-QAM Waveform, 100 kHz	X	1.92	65.71	16.67	3.01	150.0	±1.0%	±9.6%
		Y	2.79	70.22	18.66		150.0		
		Z	2.96	70.30	18.75		150.0		
10399	64-QAM Waveform, 40 MHz	X	3.43	67.83	16.32	0.00	150.0	±0.8%	±9.6%
		Y	3.48	66.90	15.65		150.0		
		Z	3.64	67.41	15.96		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	4.58	66.21	15.89	0.00	150.0	±1.7%	±9.6%
		Y	4.85	65.62	15.48		150.0		
		Z	4.85	65.18	15.33		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%.

[A] The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5 and 6).
[B] Linearization parameter uncertainty for maximum specified field strength.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

Parameters of Probe: EX3DV4 - SN:7335

Sensor Model Parameters

	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	24.4	175.23	33.34	11.37	0.00	5.00	0.38	0.10	1.00
y	43.7	321.67	34.60	7.12	0.45	4.99	1.70	0.09	1.01
z	53.4	399.50	35.71	17.88	0.00	5.07	1.03	0.28	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	-0.8°
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

Note: Measurement distance from surface can be increased to 3–4 mm for an *Area Scan* job.

Parameters of Probe: EX3DV4 - SN:7335

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[H] ($k = 2$)
750	41.9	0.89	9.91	10.10	9.53	0.37	1.27	±11.0%
900	41.5	0.97	9.25	9.44	8.89	0.37	1.27	±11.0%
1450	40.5	1.20	8.12	8.28	7.81	0.37	1.27	±11.0%
1640	40.2	1.31	8.16	8.32	7.84	0.38	1.27	±11.0%
1750	40.1	1.37	8.15	8.31	7.84	0.38	1.27	±11.0%
1900	40.0	1.40	8.05	8.21	7.74	0.38	1.27	±11.0%
2100	39.8	1.49	7.67	7.83	7.38	0.38	1.27	±11.0%
2300	39.5	1.67	7.60	7.75	7.31	0.38	1.27	±11.0%
2450	39.2	1.80	7.33	7.48	7.05	0.38	1.27	±11.0%
2600	39.0	1.96	7.41	7.56	7.13	0.38	1.27	±11.0%
3300	38.2	2.71	6.90	7.04	6.64	0.39	1.27	±13.1%
3500	37.9	2.91	6.78	6.92	6.52	0.39	1.27	±13.1%
3700	37.7	3.12	6.86	7.00	6.60	0.39	1.27	±13.1%
3900	37.5	3.32	6.64	6.78	6.39	0.39	1.27	±13.1%
4100	37.2	3.53	6.52	6.65	6.27	0.39	1.27	±13.1%
4200	37.1	3.63	6.72	6.86	6.46	0.39	1.27	±13.1%
4400	36.9	3.84	6.35	6.47	6.10	0.39	1.27	±13.1%
4600	36.7	4.04	6.43	6.56	6.19	0.39	1.27	±13.1%
4800	36.4	4.25	6.31	6.44	6.07	0.39	1.27	±13.1%
4950	36.3	4.40	6.08	6.20	5.84	0.38	1.27	±13.1%
5250	35.9	4.71	5.92	6.04	5.70	0.34	1.27	±13.1%
5600	35.5	5.07	5.37	5.48	5.17	0.30	1.27	±13.1%
5750	35.4	5.22	5.42	5.53	5.21	0.29	1.27	±13.1%
5850	35.2	5.32	5.40	5.50	5.19	0.27	1.27	±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] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±5% from the target values (typically better than ±3%) and are valid for TSL with deviations of up to ±10% if SAR correction is applied.

[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.

[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

Parameters of Probe: EX3DV4 - SN:7335

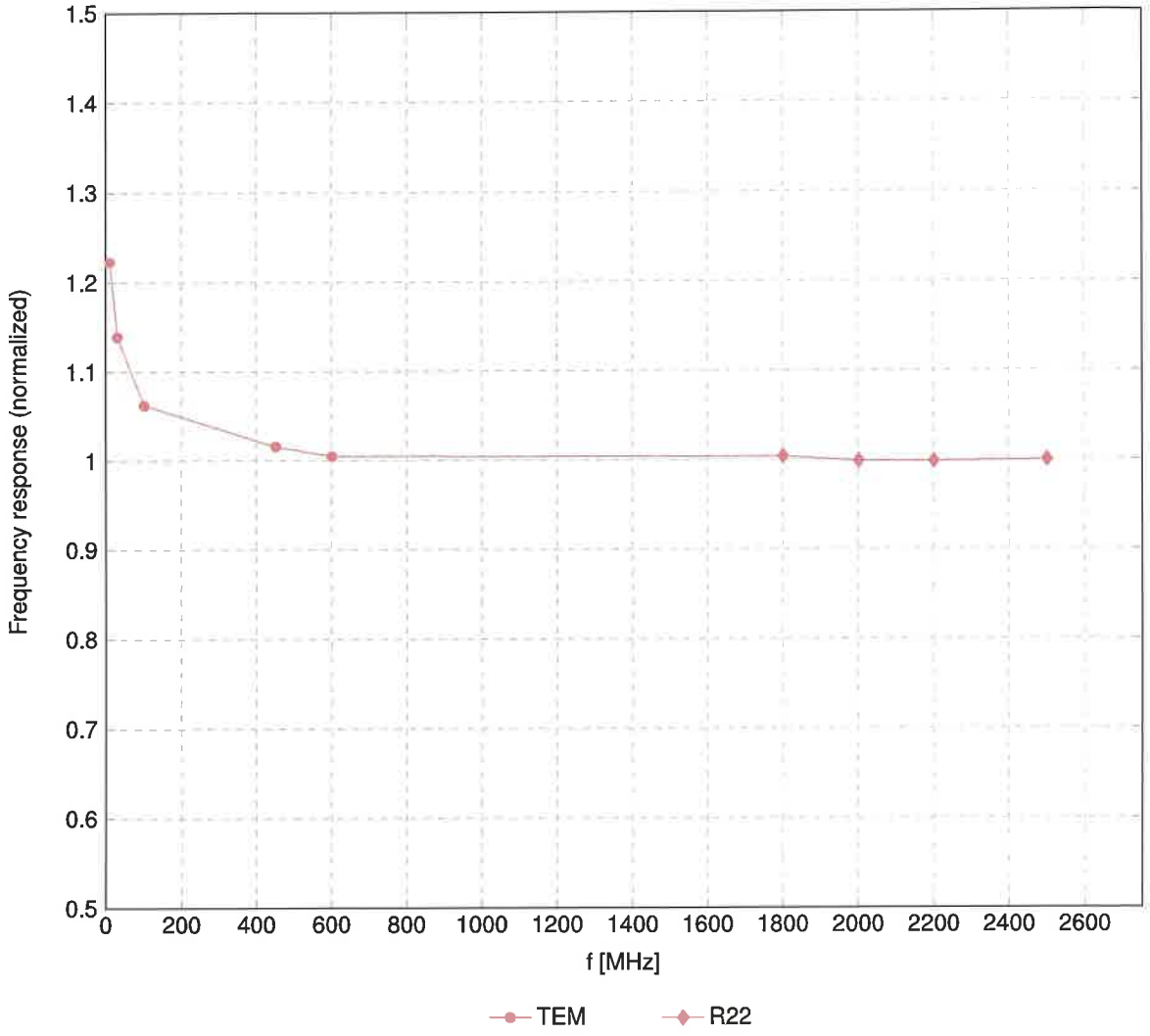
Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz)[C]	Relative Permittivity[F]	Conductivity[F] (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha[G]	Depth[G] (mm)	Unc[H] ($k = 2$)
6500	34.5	6.07	5.71	5.82	5.49	0.20	1.27	±18.6%

[C] Frequency validity at 6.5 GHz is −600/+700 MHz, and ±700 MHz at or above 7 GHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] The probes are calibrated using tissue simulating liquids (TSL) that deviate for ε and σ by less than ±10% from the target values (typically better than ±6%) and are valid for TSL with deviations of up to ±10%.
[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; below ±2% for frequencies between 3–6 GHz; and below ±4% for frequencies between 6–10 GHz at any distance larger than half the probe tip diameter from the boundary.
[H] The stated uncertainty is the total calibration uncertainty ($k = 2$) of Norm·ConvF. This is equivalent to the uncertainty component with the symbol CF in Table 9 of IEC/IEEE 62209-1528:2020.

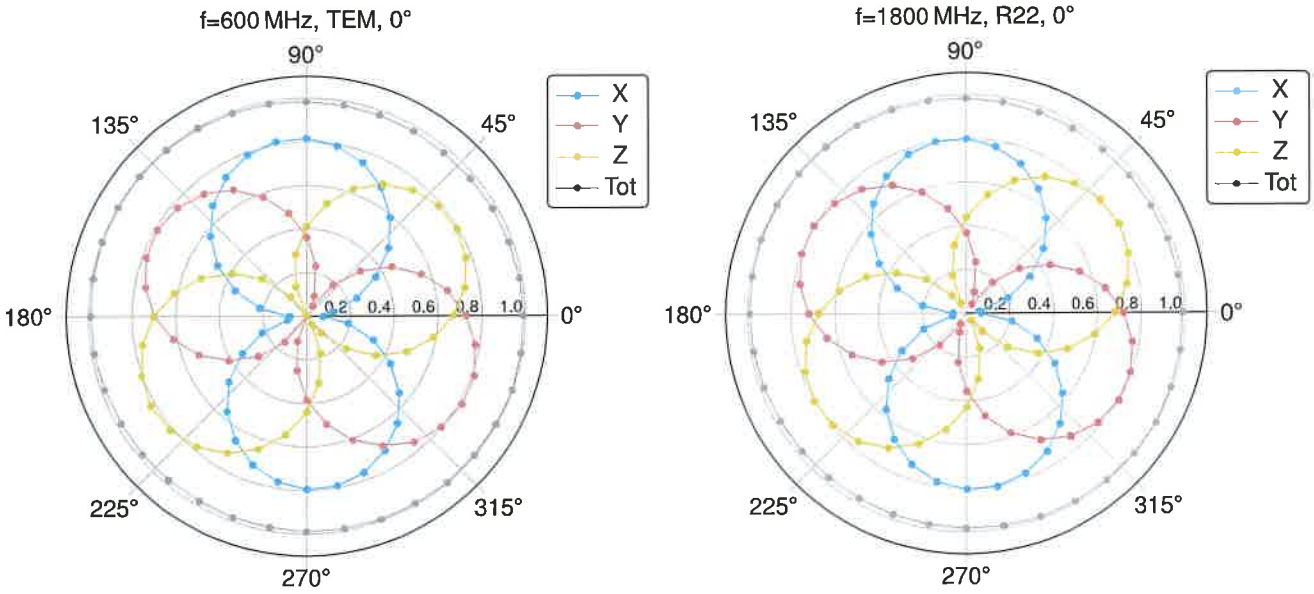
Frequency Response of E-Field

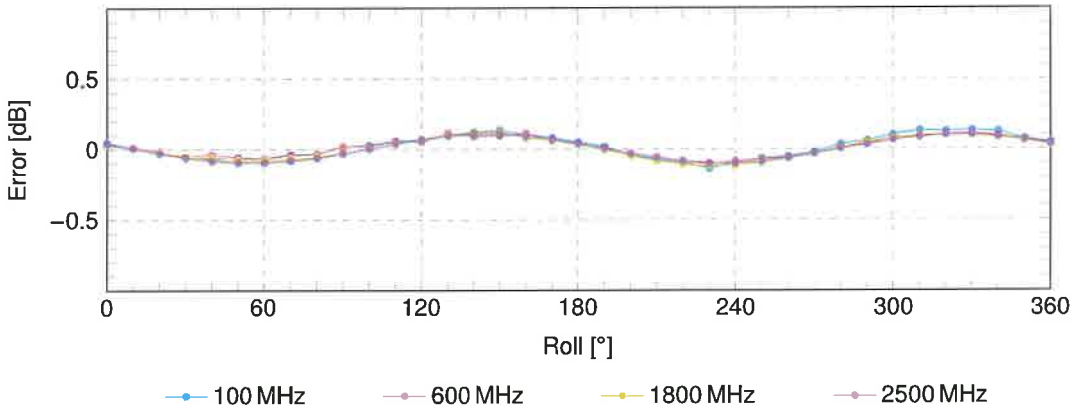
(TEM-Cell:ifi110 EXX, Waveguide:R22)



Uncertainty of Frequency Response of E-field: ±6.3% (k=2)

Receiving Pattern (ϕ), $\vartheta = 0°$

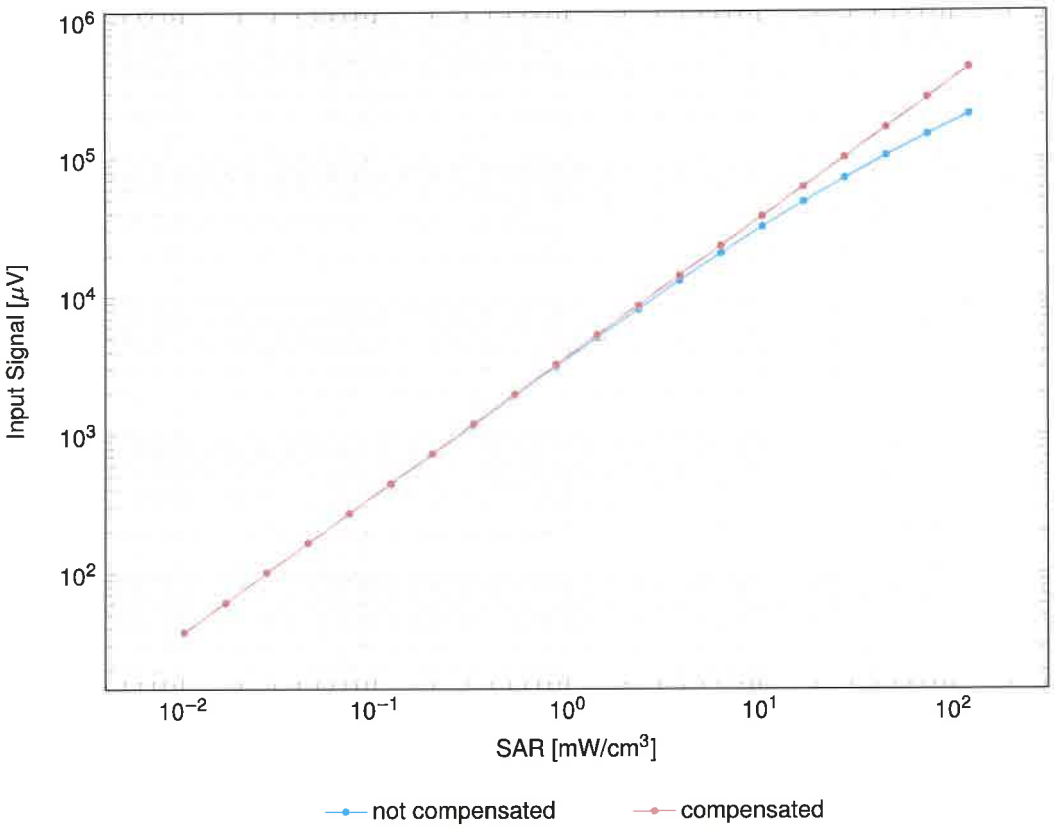


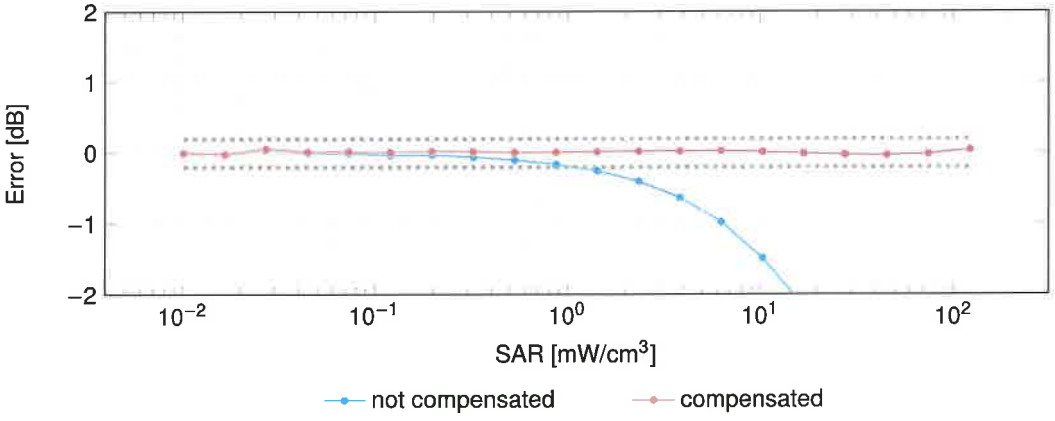


Uncertainty of Axial Isotropy Assessment: ±0.5% (k=2)

Dynamic Range f(SAR$_{head}$)

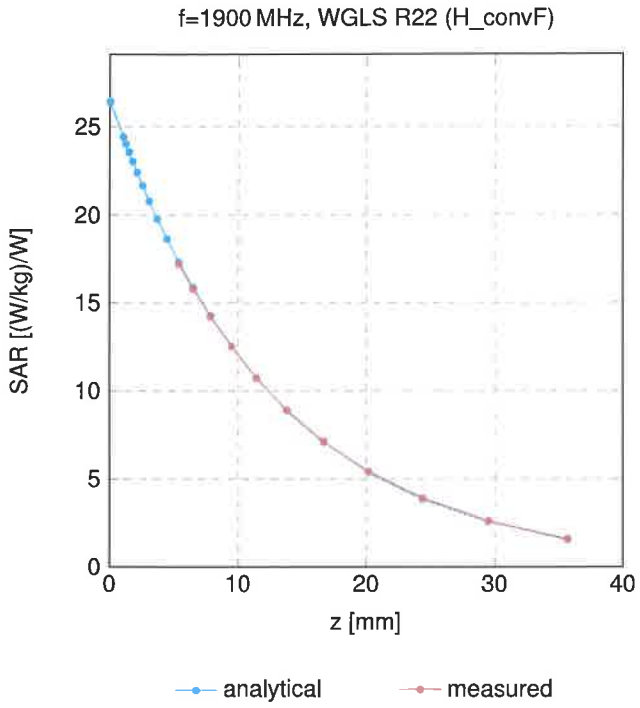
(TEM cell, f_{eval} = 1900 MHz)



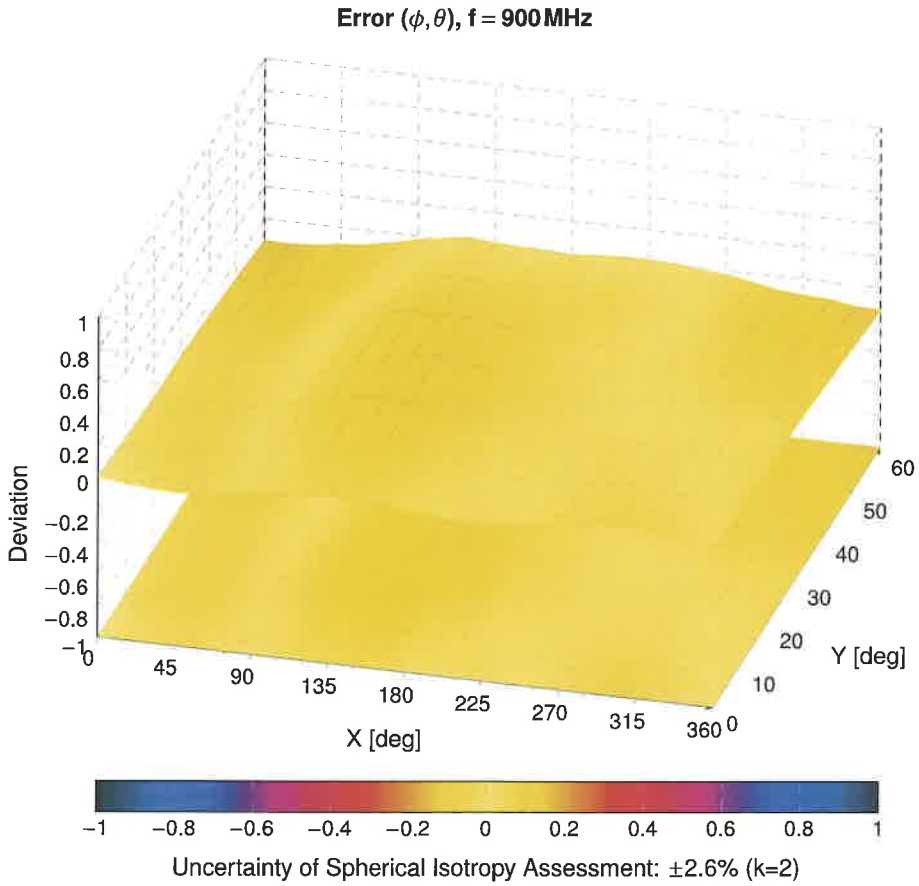


Uncertainty of Linearity Assessment: ±0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: ±2.6% (k=2)

Calibration Laboratory of
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S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
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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 **Apple**
Cupertino, USA

Certificate No. **EUmm-9532_Feb25**

CALIBRATION CERTIFICATE

Object	EUmmWV4 - SN:9532
Calibration procedure(s)	QA CAL-02.v9, QA CAL-25.v8, QA CAL-42.v3 Calibration procedure for E-field probes optimized for close near field evaluations in air
Calibration date	February 17, 2025

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	Calibration Date (Certificate No.)	Sched. Cal.
Power sensor NRP33T	SN: 100967	28-Mar-24 (No. 217-04038)	Mar-25
Power sensor NRP110T	SN: 101244	04-Apr-24 (No. 0001A300740056)	Apr-25
Spectrum analyzer FSV40	SN: 101832	29-Jan-25 (No. 4030A315009658)	Jan-26
Harmonic mixer FS-Z75	SN: 101566	11-Apr-24 (No. 0001A300740054)	Apr-25
Harmonic mixer FS-Z110	SN: 101633	05-Apr-24 (No. 0001A300740055)	Apr-25
Ref. Probe EUmmWV3	SN: 9374	28-Aug-24 (No. EUmm-9374_Aug24)	Aug-25
DAE4ip	SN: 1662	05-Nov-24 (No. DAE4ip-1662_Nov24)	Nov-25

Secondary Standards	ID	Check Date (in house)	Sched. Check
Generator APSIN26G	SN: 2023	30-Nov-21 (in house check Jun-24)	In house check: Jun-25
Power sensor NRP40T	SN: 101439	08-Nov-21 (in house check Jun-24)	In house check: Jun-25
Power sensor NRP110T	SN: 101226	15-Nov-21 (in house check Jun-24)	In house check: Jun-25

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

Issued: February 18, 2025

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

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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

NORMx,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:

- *NORMx,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.
- *DCPx,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.
  Note: As the field is measured with a diode detector sensor, it is warrantied that the probe response is linear (E^2) below the documented lowest calibrated value.
- *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).
- *Ax,y; Bx,y; Cx,y; Dx,y; VRx,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 *NORMx* (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 *NORMx* (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:9532

Basic Calibration Parameters

	Sensor X	Sensor Y	Unc ($k = 2$)
Norm (μV/(V/m)^2)	0.01753	0.02053	±10.1%
DCP (mV) [B]	106.0	105.0	±4.7%
Equivalent Sensor Angle	-59.2	35.8	

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	−0.34	−0.29	±0.43
1.8	140.4	−0.02	−0.04	±0.43
2.0	133.0	0.13	0.15	±0.43
2.2	124.8	−0.07	−0.04	±0.43
2.5	123.0	0.09	0.14	±0.43
3.5	256.2	−0.07	−0.06	±0.43
3.7	249.8	0.09	0.08	±0.43
6.6	63.4	−0.10	−0.27	±0.98
8.0	58.5	−0.07	−0.16	±0.98
10.0	57.9	−0.01	0.02	±0.98
15.0	45.6	0.19	0.21	±0.98
26.6	115.1	0.17	0.23	±0.98
30.0	125.1	0.01	0.01	±0.98
35.0	123.5	−0.15	−0.19	±0.98
40.0	101.8	−0.23	−0.32	±0.98
50.0	60.8	0.09	−0.02	±0.98
55.0	73.7	−0.09	−0.05	±0.98
60.0	76.4	0.01	0.03	±0.98
65.0	72.0	0.17	0.13	±0.98
70.0	68.5	0.12	0.07	±0.98
75.0	67.9	−0.04	−0.08	±0.98
75.0	89.9	−0.07	−0.07	±0.98
80.0	88.2	−0.14	−0.10	±0.98
85.0	54.3	−0.03	−0.05	±0.98
90.0	80.6	0.02	0.02	±0.98
92.0	80.8	−0.01	0.03	±0.98
95.0	73.2	−0.05	−0.02	±0.98
97.0	65.9	−0.03	−0.04	±0.98
100.0	63.4	0.03	0.05	±0.98
105.0	63.2	−0.10	−0.12	±0.98
110.0	72.1	0.07	0.05	±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:9532

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	123.9	±2.5%	±4.7%
		Y	0.00	0.00	1.00		69.0		
10352	Pulse Waveform (200Hz, 10%)	X	2.34	60.00	14.87	10.00	6.0	±1.0%	±9.6%
		Y	2.06	60.00	15.63		6.0		
10353	Pulse Waveform (200Hz, 20%)	X	1.62	60.00	13.75	6.99	12.0	±1.1%	±9.6%
		Y	1.42	60.00	14.64		12.0		
10354	Pulse Waveform (200Hz, 40%)	X	0.99	60.27	12.69	3.98	23.0	±1.5%	±9.6%
		Y	0.89	60.00	13.44		23.0		
10355	Pulse Waveform (200Hz, 60%)	X	0.58	60.00	12.08	2.22	27.0	±1.1%	±9.6%
		Y	0.63	60.00	12.37		27.0		
10387	QPSK Waveform, 1 MHz	X	1.15	60.00	12.44	1.00	22.0	±1.2%	±9.6%
		Y	1.27	60.00	12.04		22.0		
10388	QPSK Waveform, 10 MHz	X	1.23	60.00	12.30	0.00	22.0	±0.6%	±9.6%
		Y	1.45	60.00	11.85		22.0		
10396	64-QAM Waveform, 100 kHz	X	3.26	66.13	16.37	3.01	17.0	±0.6%	±9.6%
		Y	2.13	60.00	13.90		17.0		
10399	64-QAM Waveform, 40 MHz	X	2.02	60.00	12.67	0.00	19.0	±0.8%	±9.6%
		Y	2.20	60.00	12.43		19.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	3.16	60.17	13.12	0.00	12.0	±1.0%	±9.6%
		Y	3.29	60.00	12.87		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.

Parameters of Probe: EUmmWV4 - SN:9532

Calibration Results for Linearity Response

Frequency GHz	Target E-Field V/m	Deviation Sensor X dB	Deviation Sensor Y dB	Unc ($k = 2$) dB
0.9	50.0	−0.02	−0.13	±0.2
0.9	100.0	−0.02	0.01	±0.2
0.9	500.0	−0.01	−0.01	±0.2
0.9	1000.0	0.01	0.01	±0.2
0.9	1500.0	−0.00	0.01	±0.2
0.9	2100.0	−0.02	0.00	±0.2

Sensor Frequency Model Parameters (750 MHz – 55 GHz)

	Sensor X	Sensor Y
R (Ω)	61.95	93.28
R_p (Ω)	83.25	116.19
L (nH)	0.05692	0.07457
C (pF)	0.2808	0.2696
C_p (pF)	0.1065	0.0780

Sensor Frequency Model Parameters (55 GHz – 110 GHz)

	Sensor X	Sensor Y
R (Ω)	18.10	24.81
R_p (Ω)	102.72	127.19
L (nH)	0.05806	0.07297
C (pF)	0.0719	0.0599
C_p (pF)	0.0917	0.0704

Sensor Model Parameters

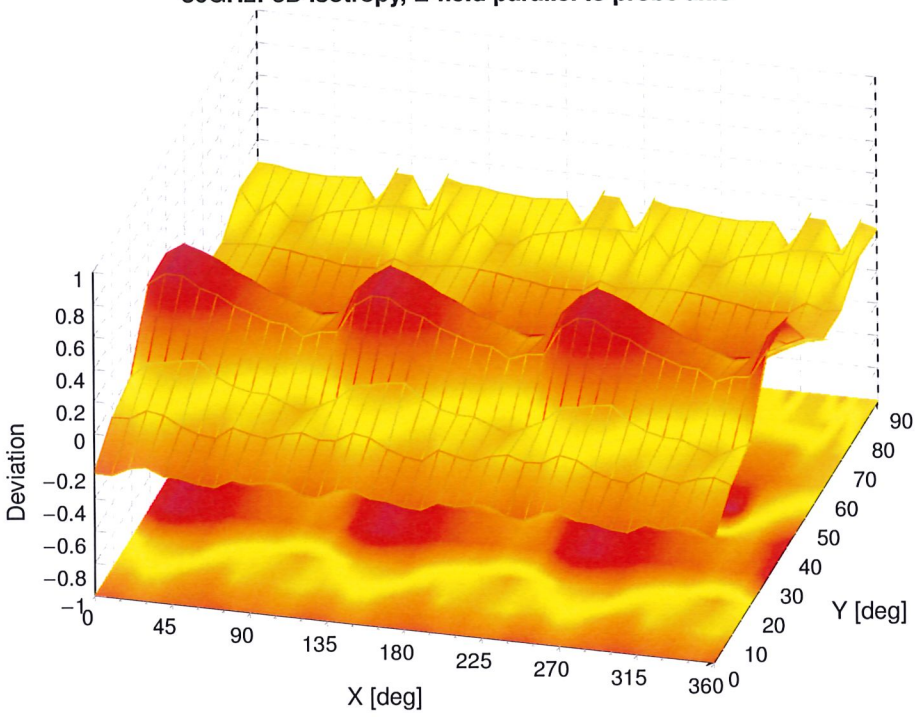
	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	50.7	363.96	33.11	0.92	5.71	5.00	0.00	1.45	1.01
y	46.2	331.69	33.08	0.92	5.07	5.03	0.00	1.81	1.01

Other Probe Parameters

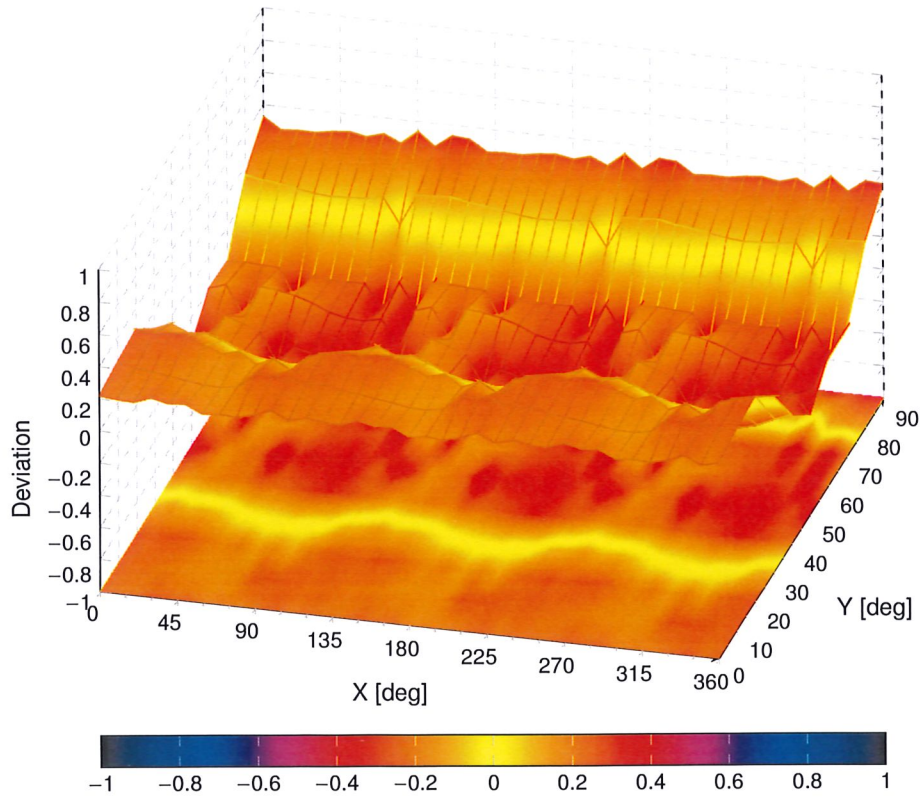
Sensor Arrangement	Rectangular
Connector Angle	-72.3°
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	320 mm
Probe Body Diameter	8 mm
Tip Length	23 mm
Tip Diameter	8.0 mm
Probe Tip to Sensor X Calibration Point	1.5 mm
Probe Tip to Sensor Y Calibration Point	1.5 mm

Deviation from Isotropy in Air

30GHz: 3D isotropy, E-field parallel to probe axis



60GHz: 3D isotropy, E-field parallel to probe axis



Probe isotropy for E_{tot}: probe rotated $\phi = 0°$ to 360°, tilted from field propagation direction $\vec{k}$
Parallel to the field propagation ($\psi = 0° - 90°$) at 30 GHz: deviation within ±0.49 dB
Parallel to the field propagation ($\psi = 0° - 90°$) at 60 GHz: deviation within ±0.38 dB