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Accreditation No.: SCS 0108

Client UL
Research Triangle Park, USA

Certificate No. EUmm-9619_Mar25

CALIBRATION CERTIFICATE

Object	EUmmWV4 - SN:9619
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	March 05, 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: March 05, 2025

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:9619

Basic Calibration Parameters

	Sensor X	Sensor Y	Unc ($k = 2$)
Norm ($\mu V/(V/m)^2$)	0.02284	0.02510	±10.1%
DCP (mV) [B]	106.0	105.0	±4.7%
Equivalent Sensor Angle	-55.0	34.5	

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	−0.22	−0.30	±0.43
1.8	140.4	−0.03	−0.02	±0.43
2.0	133.0	0.12	0.16	±0.43
2.2	124.8	−0.06	−0.05	±0.43
2.5	123.0	0.10	0.13	±0.43
3.5	256.2	−0.09	−0.09	±0.43
3.7	249.8	0.06	0.05	±0.43
6.6	63.4	−0.21	−0.24	±0.98
8.0	58.5	−0.11	−0.09	±0.98
10.0	58.0	0.01	0.01	±0.98
15.0	45.7	0.27	0.19	±0.98
26.6	115.1	0.19	0.17	±0.98
30.0	125.1	−0.00	−0.00	±0.98
35.0	123.5	−0.17	−0.13	±0.98
40.0	101.8	−0.25	−0.22	±0.98
50.0	60.8	0.05	0.07	±0.98
55.0	73.7	0.02	−0.02	±0.98
60.0	76.4	−0.00	0.01	±0.98
65.0	72.0	0.12	0.13	±0.98
70.0	68.5	0.12	0.11	±0.98
75.0	67.9	0.02	−0.04	±0.98
75.0	89.9	−0.01	−0.04	±0.98
80.0	88.2	−0.13	−0.12	±0.98
85.0	54.3	−0.06	−0.08	±0.98
90.0	80.6	0.00	0.02	±0.98
92.0	80.8	0.03	0.02	±0.98
95.0	73.2	0.01	−0.04	±0.98
97.0	65.9	0.01	−0.04	±0.98
100.0	63.4	0.06	0.05	±0.98
105.0	63.2	−0.13	−0.10	±0.98
110.0	72.1	0.04	0.04	±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:9619

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	135.2	±2.2%	±4.7%
		Y	0.00	0.00	1.00		102.7		
10352	Pulse Waveform (200Hz, 10%)	X	2.76	60.00	14.91	10.00	6.0	±1.1%	±9.6%
		Y	2.68	60.00	15.22		6.0		
10353	Pulse Waveform (200Hz, 20%)	X	2.14	61.22	14.22	6.99	12.0	±0.8%	±9.6%
		Y	1.86	60.00	14.11		12.0		
10354	Pulse Waveform (200Hz, 40%)	X	1.33	61.59	13.12	3.98	23.0	±1.3%	±9.6%
		Y	1.12	60.00	12.90		23.0		
10355	Pulse Waveform (200Hz, 60%)	X	0.68	60.00	11.79	2.22	27.0	±0.9%	±9.6%
		Y	0.68	60.00	12.19		27.0		
10387	QPSK Waveform, 1 MHz	X	1.24	60.00	12.34	1.00	22.0	±1.4%	±9.6%
		Y	1.27	60.00	12.46		22.0		
10388	QPSK Waveform, 10 MHz	X	1.27	60.00	12.04	0.00	22.0	±0.7%	±9.6%
		Y	1.30	60.00	12.11		22.0		
10396	64-QAM Waveform, 100 kHz	X	3.20	64.65	15.57	3.01	17.0	±0.8%	±9.6%
		Y	4.08	67.47	16.81		17.0		
10399	64-QAM Waveform, 40 MHz	X	2.07	60.00	12.48	0.00	19.0	±0.8%	±9.6%
		Y	2.08	60.00	12.58		19.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	3.23	60.00	12.89	0.00	12.0	±1.0%	±9.6%
		Y	3.21	60.00	12.99		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:9619

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	0.03	0.10	±0.2
0.9	100.0	0.02	0.00	±0.2
0.9	500.0	−0.00	−0.02	±0.2
0.9	1000.0	0.01	0.00	±0.2
0.9	1500.0	0.01	0.00	±0.2
0.9	2100.0	−0.01	−0.01	±0.2

Sensor Frequency Model Parameters (750 MHz – 55 GHz)

	Sensor X	Sensor Y
R (Ω)	91.39	87.77
R_p (Ω)	121.46	118.45
L (nH)	0.08293	0.07102
C (pF)	0.1953	0.2644
C_p (pF)	0.0714	0.0797

Sensor Frequency Model Parameters (55 GHz – 110 GHz)

	Sensor X	Sensor Y
R (Ω)	14.25	14.54
R_p (Ω)	78.92	82.25
L (nH)	0.04322	0.04507
C (pF)	0.0943	0.0929
C_p (pF)	0.1144	0.1155

Sensor Model Parameters

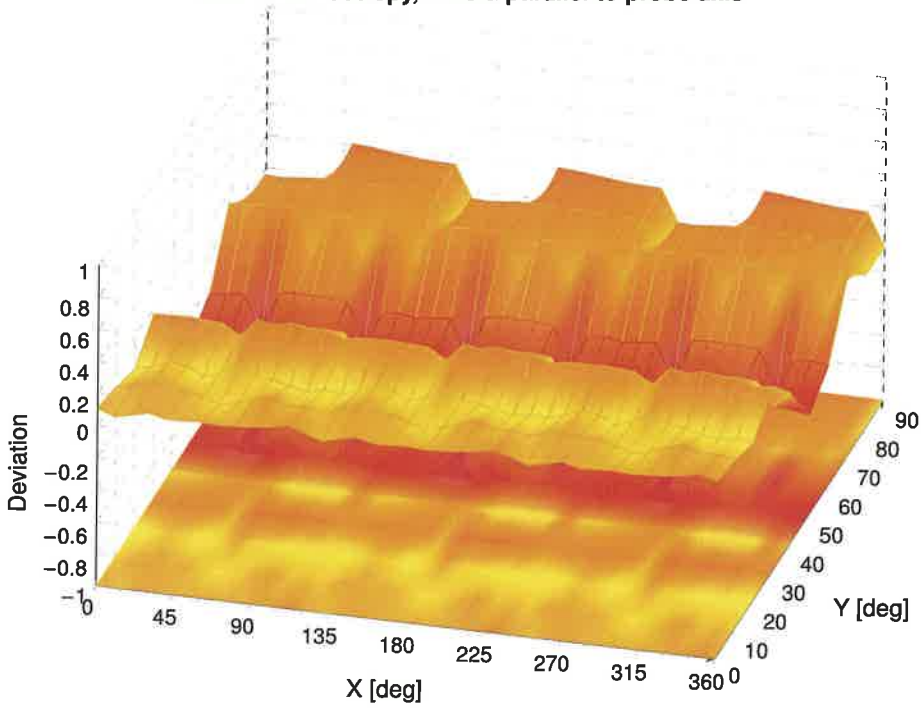
	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	60.4	434.99	33.29	0.92	7.13	5.01	0.00	1.83	1.01
y	61.9	447.19	33.52	0.92	7.25	5.01	0.00	2.00	1.01

Other Probe Parameters

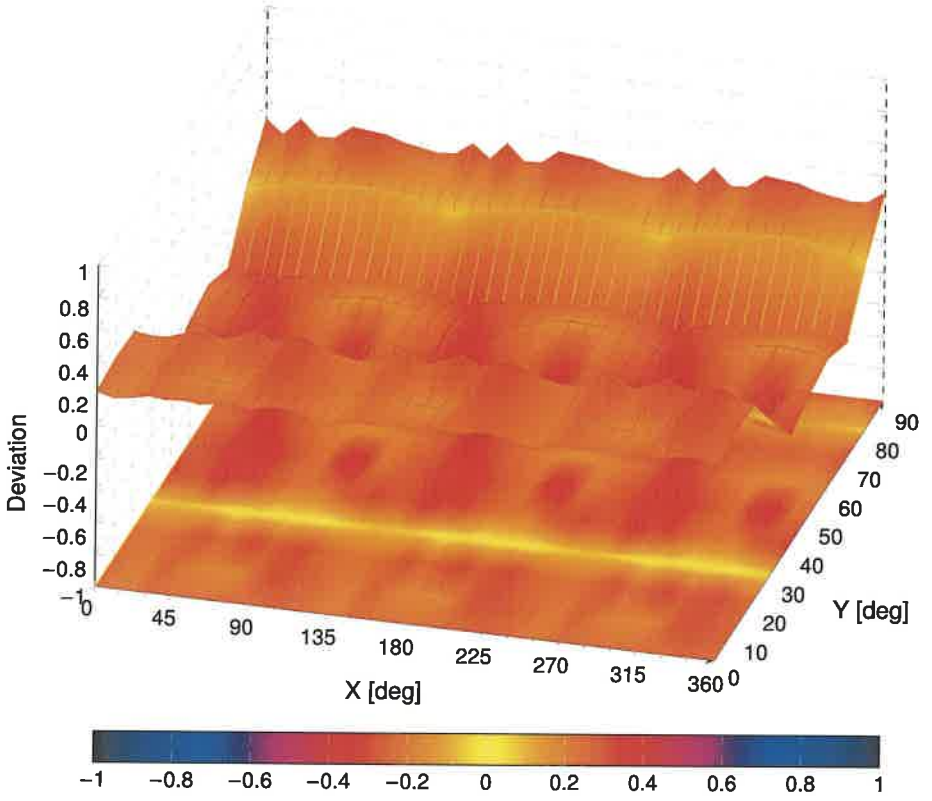
Sensor Arrangement	Rectangular
Connector Angle	-19.5°
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	320 mm
Probe Body Diameter	8 mm
Tip Length	23 mm
Tip Diameter	8.0 mm
Probe Tip to Sensor X Calibration Point	1.5 mm
Probe Tip to Sensor Y Calibration 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 ±0.34 dB
Parallel to the field propagation ($\psi = 0° - 90°$) at 60 GHz: deviation within ±0.35 dB

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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.
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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

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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

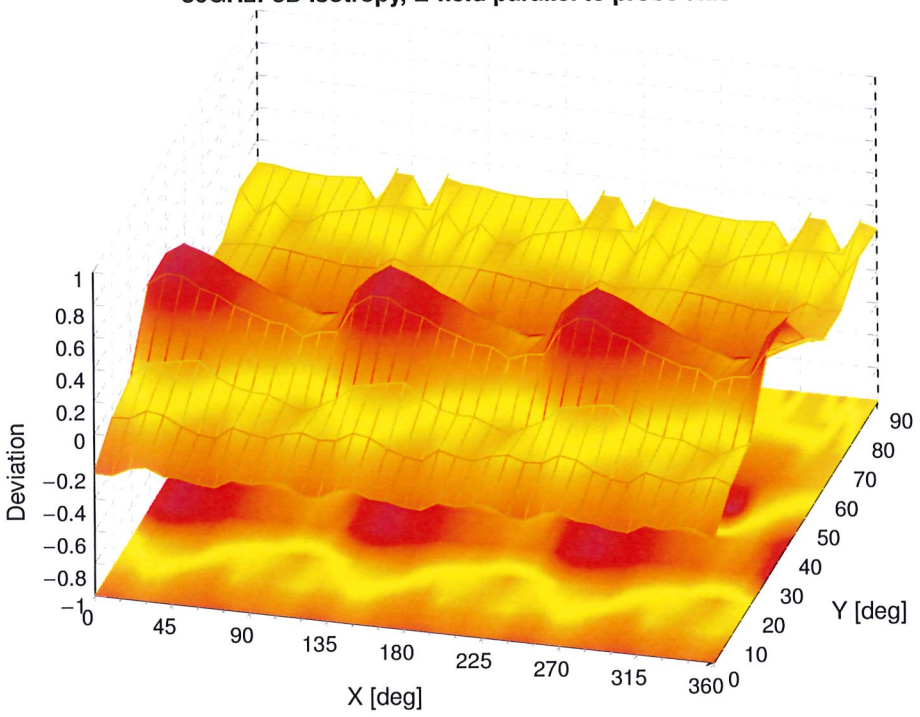
	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	50.7	363.96	33.11	0.92	5.71	5.00	0.00	1.45	1.01
y	46.2	331.69	33.08	0.92	5.07	5.03	0.00	1.81	1.01

Other Probe Parameters

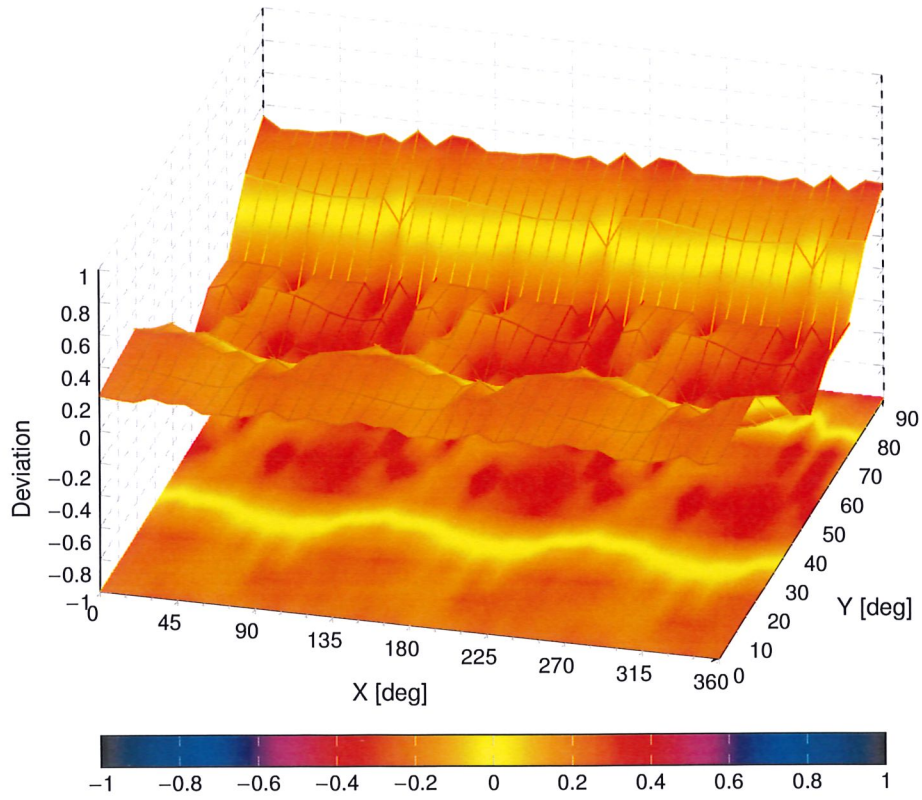
Sensor Arrangement	Rectangular
Connector Angle	-72.3°
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	320 mm
Probe Body Diameter	8 mm
Tip Length	23 mm
Tip Diameter	8.0 mm
Probe Tip to Sensor X Calibration Point	1.5 mm
Probe Tip to Sensor Y Calibration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

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**
Gyeonggi-do, Republic of Korea

Certificate No. **EUmm-9493_Jan25**

CALIBRATION CERTIFICATE

Object: EUmmWV4 - SN:9493

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: 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 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	25-Jan-24 (No. 4030-315007551)	Jan-25
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	Leif Klysner	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	

Issued: January 22, 2025

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:9493

Basic Calibration Parameters

	Sensor X	Sensor Y	Unc ($k = 2$)
Norm (μV/(V/m)^2)	0.02112	0.02396	±10.1%
DCP (mV) [B]	104.0	105.0	±4.7%
Equivalent Sensor Angle	-50.1	37.2	

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	−0.08	−0.17	±0.43
1.8	140.4	−0.02	−0.02	±0.43
2.0	133.0	0.15	0.15	±0.43
2.2	124.8	−0.08	−0.05	±0.43
2.5	123.0	0.07	0.12	±0.43
3.5	256.2	−0.22	−0.14	±0.43
3.7	249.8	−0.07	−0.01	±0.43
6.6	63.4	−0.40	−0.47	±0.98
8.0	58.6	−0.22	−0.20	±0.98
10.0	58.1	0.04	0.06	±0.98
15.0	45.8	0.15	0.33	±0.98
26.6	115.1	0.20	0.21	±0.98
30.0	125.1	−0.01	−0.01	±0.98
35.0	123.5	−0.21	−0.19	±0.98
40.0	101.8	−0.26	−0.28	±0.98
50.0	60.8	0.10	−0.02	±0.98
55.0	73.7	0.03	0.02	±0.98
60.0	76.4	−0.01	0.02	±0.98
65.0	72.0	0.10	0.09	±0.98
70.0	68.5	0.13	0.06	±0.98
75.0	67.9	−0.00	−0.03	±0.98
75.0	89.9	−0.00	−0.03	±0.98
80.0	88.2	−0.15	−0.10	±0.98
85.0	54.3	−0.05	−0.07	±0.98
90.0	80.6	0.01	0.01	±0.98
92.0	80.8	0.03	0.02	±0.98
95.0	73.2	0.00	−0.02	±0.98
97.0	65.9	0.00	−0.01	±0.98
100.0	63.4	0.04	0.05	±0.98
105.0	63.2	−0.17	−0.08	±0.98
110.0	72.1	0.10	0.01	±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:9493

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	138.1	±3.3%	±4.7%
		Y	0.00	0.00	1.00		79.9		
10352	Pulse Waveform (200Hz, 10%)	X	1.72	60.00	14.38	10.00	6.0	±1.5%	±9.6%
		Y	1.44	60.00	14.34		6.0		
10353	Pulse Waveform (200Hz, 20%)	X	1.19	60.00	13.26	6.99	12.0	±0.9%	±9.6%
		Y	0.95	60.00	13.51		12.0		
10354	Pulse Waveform (200Hz, 40%)	X	0.72	60.00	12.07	3.98	23.0	±1.2%	±9.6%
		Y	0.56	60.00	12.57		23.0		
10355	Pulse Waveform (200Hz, 60%)	X	0.44	60.00	11.52	2.22	27.0	±0.9%	±9.6%
		Y	0.40	60.00	11.71		27.0		
10387	QPSK Waveform, 1 MHz	X	1.03	60.00	11.80	1.00	22.0	±1.6%	±9.6%
		Y	0.94	60.00	11.70		22.0		
10388	QPSK Waveform, 10 MHz	X	1.25	60.00	11.99	0.00	22.0	±0.6%	±9.6%
		Y	1.25	60.00	12.04		22.0		
10396	64-QAM Waveform, 100 kHz	X	2.04	61.16	14.21	3.01	17.0	±0.7%	±9.6%
		Y	2.28	63.56	15.53		17.0		
10399	64-QAM Waveform, 40 MHz	X	2.08	60.00	12.43	0.00	19.0	±0.8%	±9.6%
		Y	2.02	60.00	12.58		19.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	3.14	60.00	12.85	0.00	12.0	±0.9%	±9.6%
		Y	2.97	60.00	13.00		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:9493

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	−0.00	±0.2
0.9	100.0	−0.00	0.00	±0.2
0.9	500.0	−0.00	−0.01	±0.2
0.9	1000.0	0.02	0.02	±0.2
0.9	1500.0	0.01	0.01	±0.2
0.9	2100.0	−0.02	−0.01	±0.2

Sensor Frequency Model Parameters (750 MHz – 55 GHz)

	Sensor X	Sensor Y
R (Ω)	69.25	73.86
R_p (Ω)	101.97	98.58
L (nH)	0.06810	0.06320
C (pF)	0.2196	0.2936
C_p (pF)	0.0860	0.0921

Sensor Frequency Model Parameters (55 GHz – 110 GHz)

	Sensor X	Sensor Y
R (Ω)	34.75	38.81
R_p (Ω)	194.77	210.31
L (nH)	0.10244	0.11360
C (pF)	0.0402	0.0371
C_p (pF)	0.0498	0.0436

Sensor Model Parameters

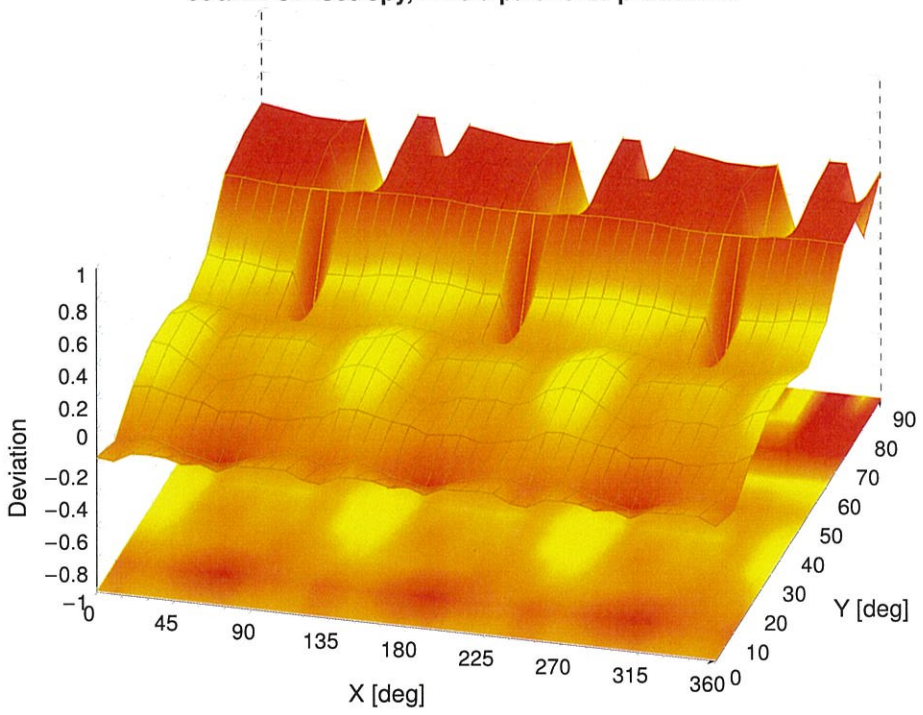
	C1 fF	C2 fF	α V^{-1}	T1 $ms\,V^{-2}$	T2 $ms\,V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
x	35.3	257.13	33.83	0.92	3.34	5.00	0.00	0.93	1.01
y	28.0	201.46	33.27	0.92	2.47	5.00	0.00	0.79	1.01

Other Probe Parameters

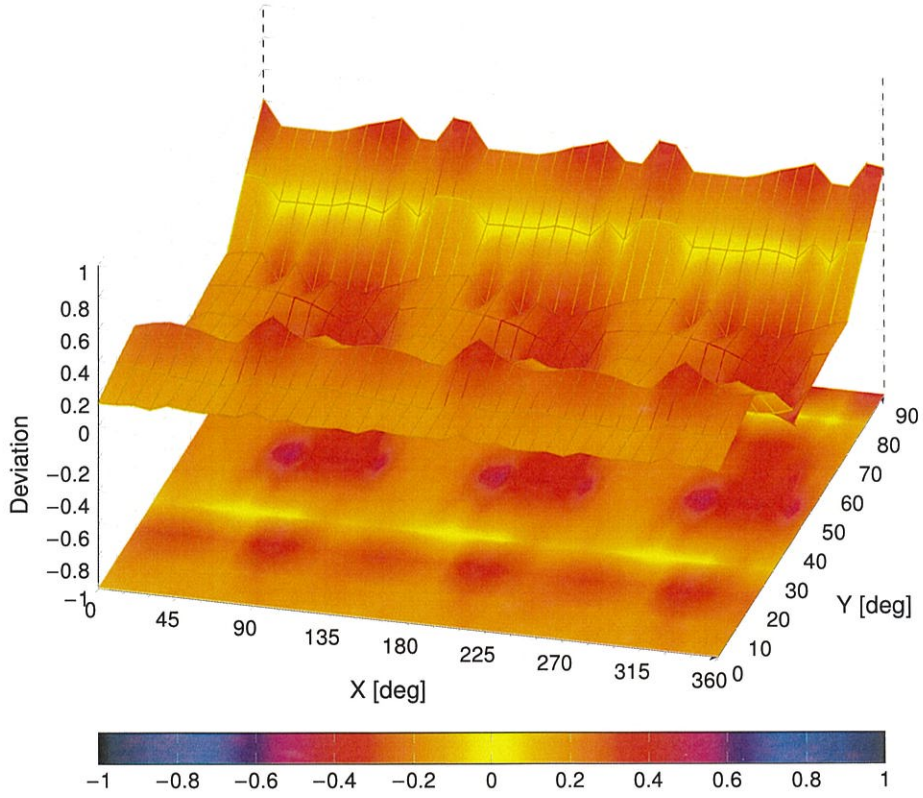
Sensor Arrangement	Rectangular
Connector Angle	-69.9°
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	320 mm
Probe Body Diameter	8 mm
Tip Length	23 mm
Tip Diameter	8.0 mm
Probe Tip to Sensor X Calibration Point	1.5 mm
Probe Tip to Sensor Y Calibration 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 ±0.42 dB
Parallel to the field propagation ($\psi = 0° - 90°$) at 60 GHz: deviation within ±0.46 dB