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

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Swiss Calibration Service

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Accreditation No.: SCS 0108

Client **Audix (Auden)**

Certificate No: 5G-Veri10-2014_Dec22

CALIBRATION CERTIFICATE

Object	5G Verification Source 10 GHz - SN: 2014
Calibration procedure(s)	QA CAL-45.v4 Calibration procedure for sources in air above 6 GHz
Calibration date:	December 07, 2022

This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI).
The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature (22 ± 3)°C and humidity < 70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration
Reference Probe EUmmWV3	SN: 9374	2021-12-21(No. EUmmWV3-9374_Dec21)	Dec-22
DAE4ip	SN: 1602	2022-06-27 (No. DAE4ip-1602_Jun22)	Jun-23

Secondary Standards	ID #	Check Date (in house)	Scheduled Check
RF generator R&S SMF100A	SN: 100184	19-May-22 (in house check Nov-22)	In house check: Nov-23
Power sensor R&S NRP18S-10	SN: 101258	31-May-22 (in house check Nov-22)	In house check: Nov-23

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

Issued: December 13, 2022

Glossary

CW	Continuous wave

Calibration is Performed According to the Following Standards

- Internal procedure QA CAL-45, Calibration procedure for sources in air above 6 GHz.
- IEC/IEEE 63195-1, "Assessment of power density of human exposure to radio frequency fields from wireless devices in close proximity to the head and body (frequency range of 6 GHz to 300 GHz)", May 2022

Methods Applied and Interpretation of Parameters

- *Coordinate System:* z-axis in the waveguide horn boresight, x-axis is in the direction of the E-field, y-axis normal to the others in the field scanning plane parallel to the horn flare and horn flange.
- *Measurement Conditions: (1) 10 GHz:* The radiated power is the forward power to the horn antenna minus ohmic and mismatch loss. The forward power is measured prior and after the measurement with a power sensor. During the measurements, the horn is directly connected to the cable and the antenna ohmic and mismatch losses are determined by far-field measurements. *(2) 30, 45, 60 and 90 GHz*: The verification sources are switched on for at least 30 minutes. Absorbers are used around the probe cub and at the ceiling to minimize reflections.
- *Horn Positioning:* The waveguide horn is mounted vertically on the flange of the waveguide source to allow vertical positioning of the EUmmW probe during the scan. The plane is parallel to the phantom surface. Probe distance is verified using mechanical gauges positioned on the flare of the horn.
- *E- field distribution:* E field is measured in two x-y-plane (10mm, 10mm + λ/4) with a vectorial E-field probe. The E-field value stated as calibration value represents the E-field-maxima and the averaged (1cm^2 and 4cm^2) power density values at 10mm in front of the horn.
- *Field polarization:* Above the open horn, linear polarization of the field is expected. This is verified graphically in the field representation.

Calibrated Quantity

- Local peak E-field (V/m) and average of peak spatial components of the poynting vector (W/m^2) averaged over the surface area of 1 cm^2 and 4cm^2 at the nominal operational frequency of the verification source. Both square and circular averaging results are listed.

The reported uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95%.

Measurement Conditions

DASY system configuration, as far as not given on page 1.

DASY Version	DASY8 Module mmWave	V3.0
Phantom	5G Phantom	
Distance Horn Aperture - plane	10 mm	
XY Scan Resolution	dx, dy = 7.5 mm	
Number of measured planes	2 (10mm, 10mm + λ/4)	
Frequency	10 GHz ± 10 MHz	

Calibration Parameters, 10 GHz

Circular Averaging

Distance Horn Aperture to Measured Plane	***Prad*[1] *(mW)***	**Max E-field (V/m)**	Uncertainty (k = 2)	Avg Power Density Avg (psPDn+, psPDtot+, psPDmod+) (W/m^2)		Uncertainty (k = 2)
				1 cm^2	**4** cm^2	
10 mm	124	**270**	1.27 dB	**188**	**152**	1.28 dB

Square Averaging

Distance Horn Aperture to Measured Plane	***Prad*[1] *(mW)***	**Max E-field (V/m)**	Uncertainty (k = 2)	Avg Power Density Avg (psPDn+, psPDtot+, psPDmod+) (W/m^2)		Uncertainty (k = 2)
				1 cm^2	**4** cm^2	
10 mm	124	**270**	1.27 dB	**190**	**152**	1.28 dB

[1] Assessed ohmic and mismatch loss plus numerical offset: 0.95 dB

DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

Name, Manufacturer	Dimensions [mm]	IMEI	DUT Type
5G Verification Source 10 GHz	100.0 x 100.0 x 100.0	SN: 2014	-

Exposure Conditions

Phantom Section	Position, Test Distance [mm]	Band	Group,	Frequency [MHz], Channel Number	Conversion Factor
5G -	10.0 mm	Validation band	CW	10000.0, 10000	1.0

Hardware Setup

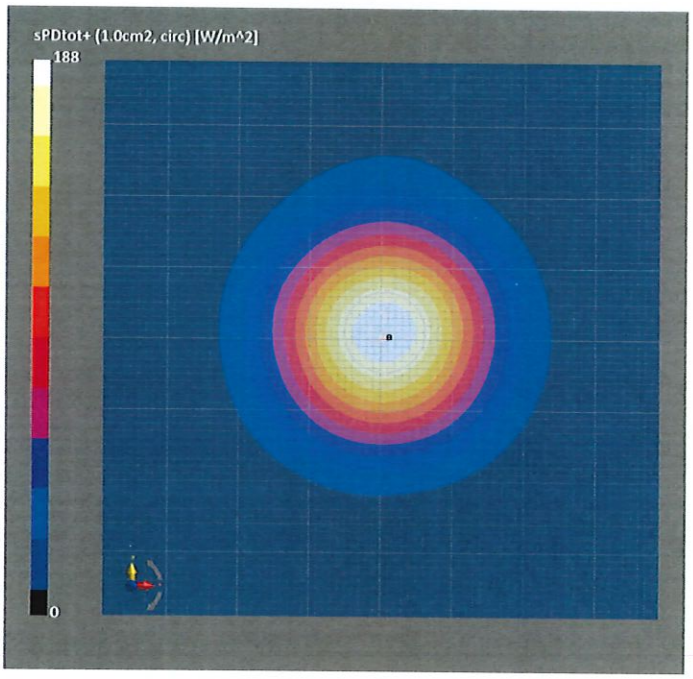
Phantom	Medium	Probe, Calibration Date	DAE, Calibration Date
mmWave Phantom - 1002	Air	EUmmWV3 - SN9374_F1-55GHz, 2021-12-21	DAE4ip Sn1602, 2022-06-27

Scan Setup

	5G Scan
Grid Extents [mm]	120.0 x 120.0
Grid Steps [lambda]	0.25 x 0.25
Sensor Surface [mm]	10.0
MAIA	MAIA not used

Measurement Results

	5G Scan
Date	2022-12-07, 15:57
Avg. Area [cm²]	1.00
psPDn+ [W/m²]	188
psPDtot+ [W/m²]	188
psPDmod+ [W/m²]	189
E_{max} [V/m]	270
Power Drift [dB]	-0.02



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

Name, Manufacturer	Dimensions [mm]	IMEI	DUT Type
5G Verification Source 10 GHz	100.0 x 100.0 x 100.0	SN: 2014	-

Exposure Conditions

Phantom Section	Position, Test Distance [mm]	Band	Group,	Frequency [MHz], Channel Number	Conversion Factor
5G -	10.0 mm	Validation band	CW	10000.0, 10000	1.0

Hardware Setup

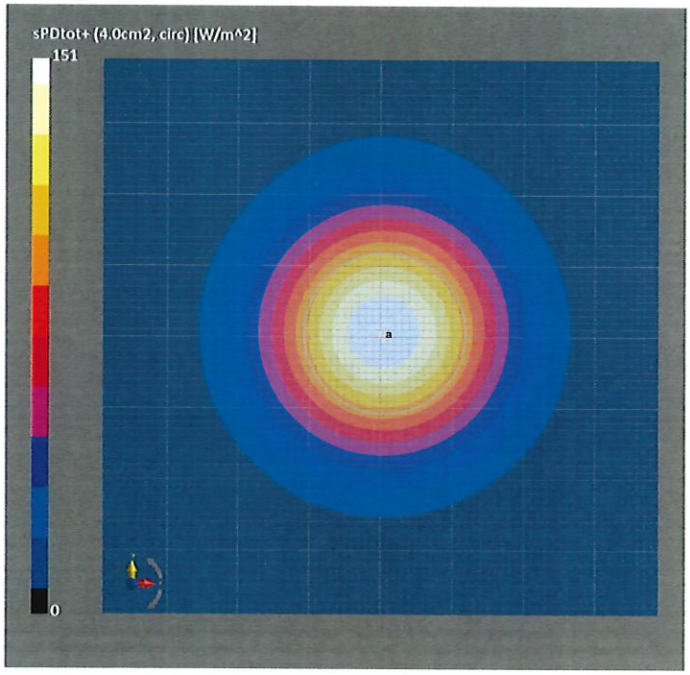
Phantom	Medium	Probe, Calibration Date	DAE, Calibration Date
mmWave Phantom - 1002	Air	EUmmWV3 - SN9374_F1-55GHz, 2021-12-21	DAE4ip Sn1602, 2022-06-27

Scan Setup

	5G Scan
Grid Extents [mm]	120.0 x 120.0
Grid Steps [lambda]	0.25 x 0.25
Sensor Surface [mm]	10.0
MAIA	MAIA not used

Measurement Results

	5G Scan
Date	2022-12-07, 15:57
Avg. Area [cm²]	4.00
psPDn+ [W/m²]	150
psPDtot+ [W/m²]	151
psPDmod+ [W/m²]	154
E_{max} [V/m]	270
Power Drift [dB]	-0.02



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

Name, Manufacturer	Dimensions [mm]	IMEI	DUT Type
5G Verification Source 10 GHz	100.0 x 100.0 x 100.0	SN: 2014	-

Exposure Conditions

Phantom Section	Position, Test Distance [mm]	Band	Group,	Frequency [MHz], Channel Number	Conversion Factor
5G -	10.0 mm	Validation band	CW	10000.0, 10000	1.0

Hardware Setup

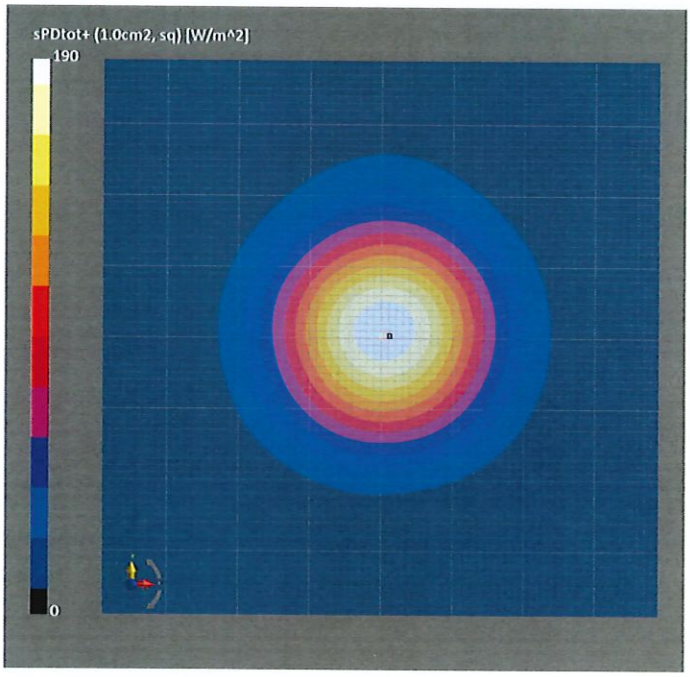
Phantom	Medium	Probe, Calibration Date	DAE, Calibration Date
mmWave Phantom - 1002	Air	EUmmWV3 - SN9374_F1-55GHz, 2021-12-21	DAE4ip Sn1602, 2022-06-27

Scan Setup

	5G Scan
Grid Extents [mm]	120.0 x 120.0
Grid Steps [lambda]	0.25 x 0.25
Sensor Surface [mm]	10.0
MAIA	MAIA not used

Measurement Results

	5G Scan
Date	2022-12-07, 15:57
Avg. Area [cm²]	1.00
psPDn+ [W/m²]	189
psPDtot+ [W/m²]	190
psPDmod+ [W/m²]	191
E_{max} [V/m]	270
Power Drift [dB]	-0.02



DASY Report

Measurement Report for 5G Verification Source 10 GHz, UID 0 -, Channel 10000 (10000.0MHz)

Device under Test Properties

Name, Manufacturer	Dimensions [mm]	IMEI	DUT Type
5G Verification Source 10 GHz	100.0 x 100.0 x 100.0	SN: 2014	-

Exposure Conditions

Phantom Section	Position, Test Distance [mm]	Band	Group,	Frequency [MHz], Channel Number	Conversion Factor
5G -	10.0 mm	Validation band	CW	10000.0, 10000	1.0

Hardware Setup

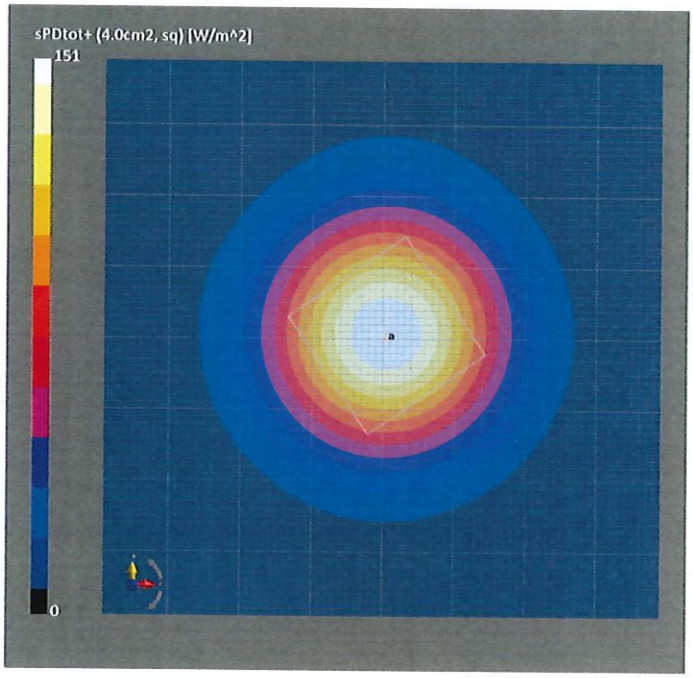
Phantom	Medium	Probe, Calibration Date	DAE, Calibration Date
mmWave Phantom - 1002	Air	EUmmWV3 - SN9374_F1-55GHz, 2021-12-21	DAE4ip Sn1602, 2022-06-27

Scan Setup

	5G Scan
Grid Extents [mm]	120.0 x 120.0
Grid Steps [lambda]	0.25 x 0.25
Sensor Surface [mm]	10.0
MAIA	MAIA not used

Measurement Results

	5G Scan
Date	2022-12-07, 15:57
Avg. Area [cm²]	4.00
psPDn+ [W/m²]	151
psPDtot+ [W/m²]	151
psPDmod+ [W/m²]	154
E_{max} [V/m]	270
Power Drift [dB]	-0.02



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Accreditation No.: SCS 0108

Client **Audix**
New Taipei City, Taiwan

Certificate No. **EUmm-9544_Apr23**

CALIBRATION CERTIFICATE

Object	EUmmWV4 - SN:9544
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	April 19, 2023

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	Cal Date (Certificate No.)	Scheduled Calibration
Power sensor NRP110T	SN: 101244	12-Apr-23 (No. 0001A300692178)	Apr-24
Spectrum analyzer FSV40	SN: 101832	23-Jan-23 (No. 4030-315005314)	Jan-24
Ref. Probe EUmmWV3	SN: 9374	03-Jan-23 (No. EUmmWV3-9374_Jan23)	Jan-24
DAE4	SN: 789	03-Jan-23 (No. DAE4-789_Jan23)	Jan-24

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

	Name	Function	Signature
Calibrated by	Leif Klysner	Laboratory Technician	
Approved by	Sven Kühn	Technical Manager	i.a.

Issued: April 25, 2023

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:9544

Basic Calibration Parameters

	Sensor X	Sensor Y	Unc ($k = 2$)
Norm (μV/(V/m)^2)	0.01849	0.02029	±10.1%
DCP (mV) [B]	105.0	105.0	±4.7%
Equivalent Sensor Angle	-61.3	35.3	

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	−0.03	−0.35	±0.43
1.8	140.4	−0.04	−0.06	±0.43
2.0	133.0	0.12	0.14	±0.43
2.2	124.8	−0.07	−0.06	±0.43
2.5	123.0	0.09	0.14	±0.43
3.5	256.2	−0.18	−0.05	±0.43
3.7	249.8	0.03	0.13	±0.43
6.6	76.1	0.29	0.22	±0.98
8.0	68.3	0.14	0.05	±0.98
10.0	67.5	0.06	0.06	±0.98
15.0	55.3	0.37	0.23	±0.98
26.6	114.9	−0.04	−0.03	±0.98
30.0	121.2	−0.00	0.02	±0.98
35.0	119.8	0.14	0.11	±0.98
40.0	105.8	0.22	0.13	±0.98
50.0	60.5	0.54	0.57	±0.98
55.0	75.8	−0.06	−0.06	±0.98
60.0	80.0	0.09	0.08	±0.98
65.0	77.7	0.31	0.32	±0.98
70.0	73.8	0.29	0.25	±0.98
75.0	73.2	−0.20	−0.22	±0.98
75.0	80.8	0.10	0.09	±0.98
80.0	79.9	−0.41	−0.37	±0.98
85.0	47.6	−0.53	−0.50	±0.98
90.0	72.3	−0.30	−0.30	±0.98
92.0	72.0	−0.18	−0.17	±0.98
95.0	66.6	−0.01	−0.03	±0.98
97.0	57.0	0.04	0.03	±0.98
100.0	55.0	0.06	0.04	±0.98
105.0	53.0	−0.19	−0.18	±0.98
110.0	61.1	−0.03	−0.02	±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:9544

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	128.3	±3.5%	±4.7%
		Y	0.00	0.00	1.00		63.4		
10352	Pulse Waveform (200Hz, 10%)	X	2.39	60.00	14.56	10.00	6.0	±0.9%	±9.6%
		Y	1.47	60.00	16.32		6.0		
10353	Pulse Waveform (200Hz, 20%)	X	1.65	60.00	13.37	6.99	12.0	±1.0%	±9.6%
		Y	10.00	86.00	23.00		12.0		
10354	Pulse Waveform (200Hz, 40%)	X	0.98	60.00	12.07	3.98	23.0	±1.4%	±9.6%
		Y	0.69	60.00	13.88		23.0		
10355	Pulse Waveform (200Hz, 60%)	X	0.57	60.00	11.37	2.22	27.0	±1.1%	±9.6%
		Y	0.53	60.00	12.47		27.0		
10387	QPSK Waveform, 1 MHz	X	1.25	60.00	12.21	1.00	22.0	±1.5%	±9.6%
		Y	1.32	60.00	11.80		22.0		
10388	QPSK Waveform, 10 MHz	X	1.28	60.00	11.88	0.00	22.0	±0.9%	±9.6%
		Y	1.53	60.00	11.62		22.0		
10396	64-QAM Waveform, 100 kHz	X	3.42	65.98	16.24	3.01	17.0	±0.6%	±9.6%
		Y	2.16	60.00	13.90		17.0		
10399	64-QAM Waveform, 40 MHz	X	2.09	60.00	12.39	0.00	19.0	±1.1%	±9.6%
		Y	2.29	60.00	12.25		19.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X	3.27	60.00	12.82	0.00	12.0	±0.8%	±9.6%
		Y	3.43	60.00	12.71		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:9544

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	0.08	0.14	±0.2
0.9	100.0	−0.02	0.07	±0.2
0.9	500.0	−0.00	−0.03	±0.2
0.9	1000.0	0.03	−0.01	±0.2
0.9	1500.0	0.03	−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)	114.18	87.21
R_p (Ω)	124.58	97.49
L (nH)	0.15031	0.10470
C (pF)	0.1747	0.2822
C_p (pF)	0.0595	0.0784

Sensor Frequency Model Parameters (55 GHz – 110 GHz)

	Sensor X	Sensor Y
R (Ω)	25.25	47.36
R_p (Ω)	135.16	244.33
L (nH)	0.07195	0.13584
C (pF)	0.0584	0.0320
C_p (pF)	0.0673	0.0341

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	61.2	445.10	33.78	0.92	5.59	5.00	0.00	1.72	1.01
y	45.2	323.56	32.87	0.92	3.49	5.05	0.00	1.98	1.01

Other Probe Parameters

Sensor Arrangement	Rectangular
Connector Angle	-175.0°
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