

Appendix C

Calibration certificate

1. Dipole
D2450V2-SN 733
2. DAE
DAE4-SN 1663
3. Probe
EX3DV4-SN 3838
4. dipole extend

Client **SGS**

Certificate No: Z22-60489

CALIBRATION CERTIFICATE

Object **D2450V2 - SN: 733**

Calibration Procedure(s) **FF-Z11-003-01**
 Calibration Procedures for dipole validation kits

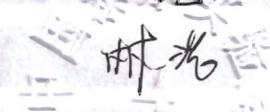
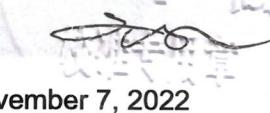
Calibration date: **November 2, 2022**

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 (Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	106276	10-May-22 (CTTL, No.J22X03103)	May-23
Power sensor NRP6A	101369	10-May-22 (CTTL, No.J22X03103)	May-23
Reference Probe EX3DV4	SN 7464	26-Jan-22(SPEAG, No.EX3-7464_Jan22)	Jan-23
DAE4	SN 1556	12-Jan-22(CTTL-SPEAG, No.Z22-60007)	Jan-23
Secondary Standards	ID #	Cal Date (Calibrated by, Certificate No.)	Scheduled Calibration
Signal Generator E4438C	MY49071430	13-Jan-22 (CTTL, No. J22X00409)	Jan-23
Network Analyzer E5071C	MY46110673	14-Jan-22 (CTTL, No.J22X00406)	Jan-23

Calibrated by:	Name	Function	Signature
	Zhao Jing	SAR Test Engineer	
Reviewed by:	Lin Hao	SAR Test Engineer	
Approved by:	Qi Dianyuan	SAR Project Leader	

Issued: November 7, 2022

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CAICT

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Glossary:

TSL	tissue simulating liquid
ConvF	sensitivity in TSL / NORMx,y,z
N/A	not applicable or not measured

Calibration is Performed According to the Following Standards:

- 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-mounted Wireless Communication Devices- Part 1528: Human Models, Instrumentation and Procedures (Frequency range of 4 MHz to 10 GHz)", October 2020
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Additional Documentation:

- DASY4/5 System Handbook

Methods Applied and Interpretation of Parameters:

- Measurement Conditions:** Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- Antenna Parameters with TSL:** The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- Feed Point Impedance and Return Loss:** These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- Electrical Delay:** One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- SAR measured:** SAR measured at the stated antenna input power.
- SAR normalized:** SAR as measured, normalized to an input power of 1 W at the antenna connector.
- SAR for nominal TSL parameters:** The measured TSL parameters are used to calculate the nominal SAR result.

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%.

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Measurement Conditions

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

DASY Version	DASY52	52.10.4
Extrapolation	Advanced Extrapolation	
Phantom	Triple Flat Phantom 5.1C	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	2450 MHz \pm 1 MHz	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	39.2	1.80 mho/m
Measured Head TSL parameters	(22.0 \pm 0.2) °C	39.4 \pm 6 %	1.79 mho/m \pm 6 %
Head TSL temperature change during test	<1.0 °C	---	---

SAR result with Head TSL

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	13.0 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	52.2 W/kg \pm 18.8 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Head TSL	Condition	
SAR measured	250 mW input power	6.07 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	24.3 W/kg \pm 18.7 % (k=2)



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Appendix (Additional assessments outside the scope of CNAS L0570)

Antenna Parameters with Head TSL

Impedance, transformed to feed point	50.2Ω+ 3.67jΩ
Return Loss	- 28.7dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.066 ns
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After long term use with 100W radiated power, only a slight warming of the dipole near the feed-point can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feed-point may be damaged.

Additional EUT Data

Manufactured by	SPEAG
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DASY5 Validation Report for Head TSL

Date: 2022-11-02

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 733

Communication System: UID 0, CW; Frequency: 2450 MHz

Medium parameters used: $f = 2450$ MHz; $\sigma = 1.793$ S/m; $\epsilon_r = 39.42$; $\rho = 1000$ kg/m³

Phantom section: Right Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(7.77, 7.77, 7.77) @ 2450 MHz; Calibrated: 2022-01-26
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1556; Calibrated: 2022-01-12
- Phantom: MFP_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx; Serial: 1062
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0: Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 104.2 V/m; Power Drift = -0.07 dB

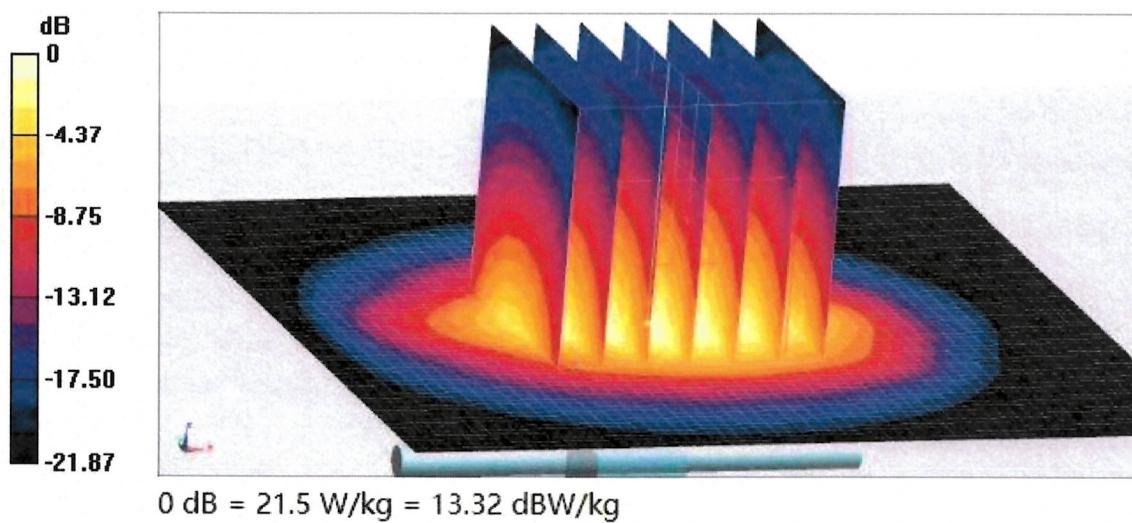
Peak SAR (extrapolated) = 26.6 W/kg

SAR(1 g) = 13 W/kg; SAR(10 g) = 6.07 W/kg

Smallest distance from peaks to all points 3 dB below = 9 mm

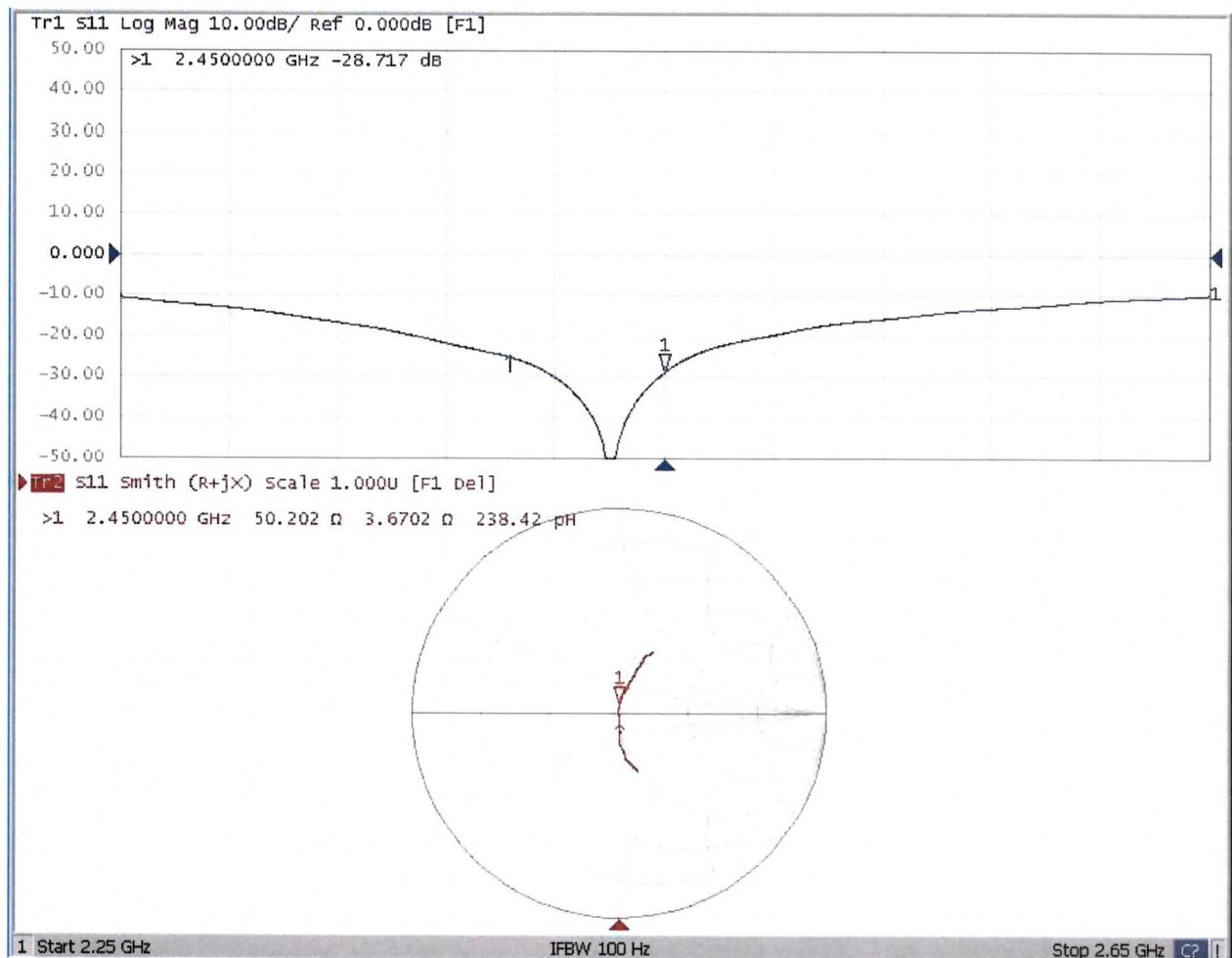
Ratio of SAR at M2 to SAR at M1 = 49.6%

Maximum value of SAR (measured) = 21.5 W/kg



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Impedance Measurement Plot for Head TSL



Client : **SGS**

Certificate No: J23Z60201

CALIBRATION CERTIFICATE

Object DAE4 - SN: 1663

Calibration Procedure(s) FF-Z11-002-01
 Calibration Procedure for the Data Acquisition Electronics
 (DAEx)

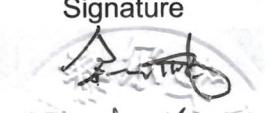
Calibration date: March 27, 2023

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(Calibrated by, Certificate No.)	Scheduled Calibration
Process Calibrator 753	1971018	14-Jun-22 (CTTL, No.J22X04180)	Jun-23

Calibrated by:	Name	Function	Signature
	Yu Zongying	SAR Test Engineer	
Reviewed by:	Lin Hao	SAR Test Engineer	
Approved by:	Qi Dianyuan	SAR Project Leader	

Issued: March 28, 2023

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Glossary:

DAE	data acquisition electronics
Connector angle	information used in DASY system to align probe sensor X to the robot coordinate system.

Methods Applied and Interpretation of Parameters:

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle:* The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The report provide only calibration results for DAE, it does not contain other performance test results.



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DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = $6.1\mu\text{V}$, full range = $-100\ldots+300\text{ mV}$

Low Range: 1LSB = 61nV , full range = $-1\ldots+3\text{mV}$

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Calibration Factors	X	Y	Z
High Range	$405.048 \pm 0.15\% \text{ (k=2)}$	$405.004 \pm 0.15\% \text{ (k=2)}$	$404.684 \pm 0.15\% \text{ (k=2)}$
Low Range	$4.00278 \pm 0.7\% \text{ (k=2)}$	$3.98104 \pm 0.7\% \text{ (k=2)}$	$4.00564 \pm 0.7\% \text{ (k=2)}$

Connector Angle

Connector Angle to be used in DASY system	$53.5^\circ \pm 1^\circ$
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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **SGS**
 Shenzhen

Certificate No.

EX-7838_Sep23

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:7838**

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 **September 11, 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 $(22 \pm 3)^\circ\text{C}$ and humidity $< 70\%$.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID	Cal Date (Certificate No.)	Scheduled Calibration
Power meter NRP2	SN: 104778	30-Mar-23 (No. 217-03804/03805)	Mar-24
Power sensor NRP-Z91	SN: 103244	30-Mar-23 (No. 217-03804)	Mar-24
OCP DAK-3.5 (weighted)	SN: 1249	20-Oct-22 (OCP-DAK3.5-1249_Oct22)	Oct-23
OCP DAK-12	SN: 1016	20-Oct-22 (OCP-DAK12-1016_Oct22)	Oct-23
Reference 20 dB Attenuator	SN: CC2552 (20x)	30-Mar-23 (No. 217-03809)	Mar-24
DAE4	SN: 660	16-Mar-23 (No. DAE4-660_Mar23)	Mar-24
Reference Probe ES3DV2	SN: 3013	06-Jan-23 (No. ES3-3013_Jan23)	Jan-24

Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-22)	In house check: Jun-24
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-22)	In house check: Jun-24
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-22)	In house check: Jun-24
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-22)	In house check: Jun-24
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-22)	In house check: Oct-24

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

Issued: September 11, 2023

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Glossary

TS	tissue simulating liquid
NORM x,y,z	sensitivity in free space
ConvF	sensitivity in TSL / NORM x,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:

- 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.
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- NORM x,y,z** : Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORM x,y,z are only intermediate values, i.e., the uncertainties of NORM x,y,z does not affect the E²-field uncertainty inside TSL (see below *ConvF*).
- NORM(f) x,y,z = NORM x,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*.
- DCP x,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
- A x,y,z ; B x,y,z ; C x,y,z ; D x,y,z ; VR x,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 NORM x,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 NORM x (no uncertainty required).

Parameters of Probe: EX3DV4 - SN:7838

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k = 2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.70	0.69	0.77	$\pm 10.1\%$
DCP (mV) ^B	109.0	101.4	102.3	$\pm 4.7\%$

Calibration Results for Modulation Response

UID	Communication System Name	A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Max dev.	Max Unc ^E k = 2
0	CW	X 0.00	0.00	1.00	0.00	140.6	$\pm 1.9\%$	$\pm 4.7\%$
		Y 0.00	0.00	1.00		129.6		
		Z 0.00	0.00	1.00		117.4		
10352	Pulse Waveform (200Hz, 10%)	X 1.52	60.58	6.16	10.00	60.0	$\pm 3.3\%$	$\pm 9.6\%$
		Y 1.57	61.02	6.83		60.0		
		Z 1.43	60.00	6.05		60.0		
10353	Pulse Waveform (200Hz, 20%)	X 0.86	60.00	4.87	6.99	80.0	$\pm 2.6\%$	$\pm 9.6\%$
		Y 0.81	60.00	5.23		80.0		
		Z 0.92	60.00	5.03		80.0		
10354	Pulse Waveform (200Hz, 40%)	X 0.51	60.00	3.73	3.98	95.0	$\pm 2.2\%$	$\pm 9.6\%$
		Y 2.00	64.00	5.00		95.0		
		Z 70.00	78.00	9.00		95.0		
10355	Pulse Waveform (200Hz, 60%)	X 0.40	60.00	2.83	2.22	120.0	$\pm 1.9\%$	$\pm 9.6\%$
		Y 10.33	156.98	13.14		120.0		
		Z 0.33	60.00	3.31		120.0		
10387	QPSK Waveform, 1 MHz	X 0.57	66.02	13.91	1.00	150.0	$\pm 3.9\%$	$\pm 9.6\%$
		Y 0.86	64.77	12.49		150.0		
		Z 0.62	65.50	13.19		150.0		
10388	QPSK Waveform, 10 MHz	X 1.41	67.73	14.76	0.00	150.0	$\pm 1.0\%$	$\pm 9.6\%$
		Y 1.50	65.18	13.89		150.0		
		Z 1.42	66.89	14.37		150.0		
10396	64-QAM Waveform, 100 kHz	X 1.87	66.38	16.67	3.01	150.0	$\pm 1.2\%$	$\pm 9.6\%$
		Y 1.70	63.95	15.69		150.0		
		Z 1.90	66.56	16.83		150.0		
10399	64-QAM Waveform, 40 MHz	X 2.82	66.91	15.40	0.00	150.0	$\pm 2.4\%$	$\pm 9.6\%$
		Y 2.96	65.83	14.87		150.0		
		Z 2.88	66.76	15.29		150.0		
10414	WLAN CCDF, 64-QAM, 40 MHz	X 3.89	67.02	15.71	0.00	150.0	$\pm 4.2\%$	$\pm 9.6\%$
		Y 4.09	65.34	15.09		150.0		
		Z 3.86	66.32	15.40		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:7838

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	8.7	61.10	31.98	5.63	0.00	4.90	0.80	0.00	1.00
y	16.0	116.73	33.90	3.92	0.00	4.94	0.00	0.10	1.00
z	9.7	69.37	32.51	6.93	0.00	4.90	0.72	0.00	1.00

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle	40.8°
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:7838

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) ^C	Relative Permittivity ^F	Conductivity ^F (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha ^G	Depth ^G (mm)	Unc (k = 2)
750	41.9	0.89	9.75	9.68	9.67	0.39	1.27	±12.0%
835	41.5	0.90	9.30	9.34	9.27	0.38	1.27	±12.0%
1750	40.1	1.37	8.11	8.04	8.17	0.27	1.27	±12.0%
1900	40.0	1.40	7.82	7.76	7.85	0.29	1.27	±12.0%
2100	39.8	1.49	7.61	7.56	7.64	0.29	1.27	±12.0%
2300	39.5	1.67	7.56	7.47	7.57	0.31	1.27	±12.0%
2450	39.2	1.80	7.40	7.32	7.42	0.30	1.27	±12.0%
2600	39.0	1.96	7.31	7.23	7.33	0.29	1.27	±12.0%
5250	35.9	4.71	5.34	5.25	5.46	0.39	1.53	±14.0%
5600	35.5	5.07	4.77	4.64	4.79	0.38	1.67	±14.0%
5750	35.4	5.22	5.07	4.88	5.02	0.36	1.75	±14.0%

^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 TSL with deviations from the target of less than ±5% are used, the calibration uncertainties are 11.1% for 0.7 - 3 GHz and 13.1% for 3 - 6 GHz.

^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.

Parameters of Probe: EX3DV4 - SN:7838

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) ^C	Relative Permittivity ^F	Conductivity ^F (S/m)	ConvF X	ConvF Y	ConvF Z	Alpha ^G	Depth ^G (mm)	Unc (k = 2)
6500	34.5	6.07	5.07	4.99	5.15	0.20	2.50	±18.6%

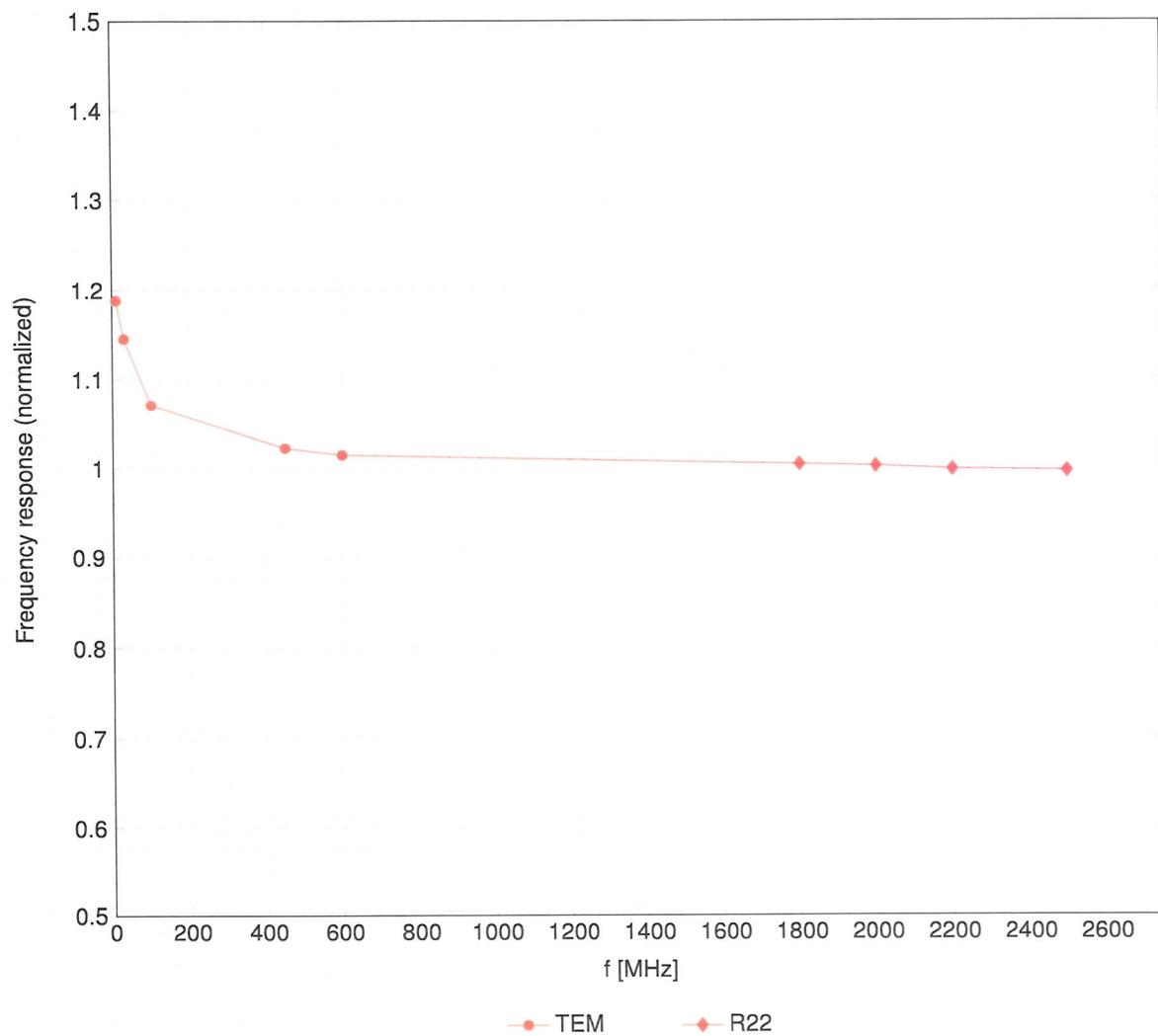
^C Frequency validity at 6.5 GHz is $-600/+700$ MHz, and ± 700 MHz at or above 7 GHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

^F The probes are calibrated using tissue simulating liquids (TSL) that deviate for ϵ and σ by less than $\pm 10\%$ from the target values (typically better than $\pm 6\%$) and are valid for TSL with deviations of up to $\pm 10\%$.

^G Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than $\pm 1\%$ for frequencies below 3 GHz; below $\pm 2\%$ for frequencies between 3–6 GHz; and below $\pm 4\%$ for frequencies between 6–10 GHz at any distance larger than half the probe tip diameter from the boundary.

Frequency Response of E-Field

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



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