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

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

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Accreditation No.: SCS 0108

Client UL USA

Certificate No: EX3-7569_Apr22

CALIBRATION CERTIFICATE

Object: EX3DV4 - SN:7569

Calibration procedure(s): QA CAL-01.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7
Calibration procedure for dosimetric E-field probes

Calibration date: April 26, 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
Power meter NRP	SN: 104778	04-Apr-22 (No. 217-03525/03524)	Apr-23
Power sensor NRP-Z91	SN: 103244	04-Apr-22 (No. 217-03524)	Apr-23
Power sensor NRP-Z91	SN: 103245	04-Apr-22 (No. 217-03525)	Apr-23
Reference 20 dB Attenuator	SN: CC2552 (20x)	04-Apr-22 (No. 217-03527)	Apr-23
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Jeffrey Katzman	Laboratory Technician	J. Katz
Approved by:	Sven Kühn	Deputy Manager	S. Kü

Issued: April 27, 2022

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., ϑ = 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 ϑ = 0 (f ≤ 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 (no uncertainty required). 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 ≤ 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7569

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.63	0.62	0.62	± 10.1 %
DCP (mV)[B]	102.3	100.5	100.8	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	146.1	± 2.2 %	± 4.7 %
		Y	0.00	0.00	1.00		166.7		
		Z	0.00	0.00	1.00		169.0		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	20.00	92.92	22.03	10.00	60.0	± 2.7 %	± 9.6 %
		Y	20.00	90.99	20.83		60.0		
		Z	20.00	93.60	22.57		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	93.20	21.22	6.99	80.0	± 1.2 %	± 9.6 %
		Y	20.00	91.66	20.34		80.0		
		Z	20.00	93.48	21.52		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	95.80	21.21	3.98	95.0	± 1.0 %	± 9.6 %
		Y	20.00	94.64	20.65		95.0		
		Z	20.00	95.30	21.09		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	99.24	21.54	2.22	120.0	± 1.0 %	± 9.6 %
		Y	20.00	99.09	21.59		120.0		
		Z	20.00	97.69	20.94		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.60	64.90	14.26	1.00	150.0	± 2.2 %	± 9.6 %
		Y	1.63	65.42	14.54		150.0		
		Z	1.57	64.29	13.87		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.10	66.83	14.95	0.00	150.0	± 1.0 %	± 9.6 %
		Y	2.15	67.21	15.26		150.0		
		Z	2.05	66.11	14.53		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.96	70.50	18.58	3.01	150.0	± 0.8 %	± 9.6 %
		Y	2.92	70.80	19.02		150.0		
		Z	2.90	69.94	18.51		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.43	66.64	15.39	0.00	150.0	± 1.3 %	± 9.6 %
		Y	3.47	66.81	15.54		150.0		
		Z	3.41	66.30	15.19		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.84	65.43	15.30	0.00	150.0	± 3.0 %	± 9.6 %
		Y	4.85	65.55	15.42		150.0		
		Z	4.84	65.25	15.21		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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7569

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	48.9	360.02	34.64	21.73	0.20	5.10	1.51	0.20	1.01
Y	45.3	335.68	34.92	23.67	0.00	5.09	1.55	0.14	1.01
Z	49.3	368.74	35.48	22.91	0.28	5.10	1.26	0.24	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-88
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.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7569

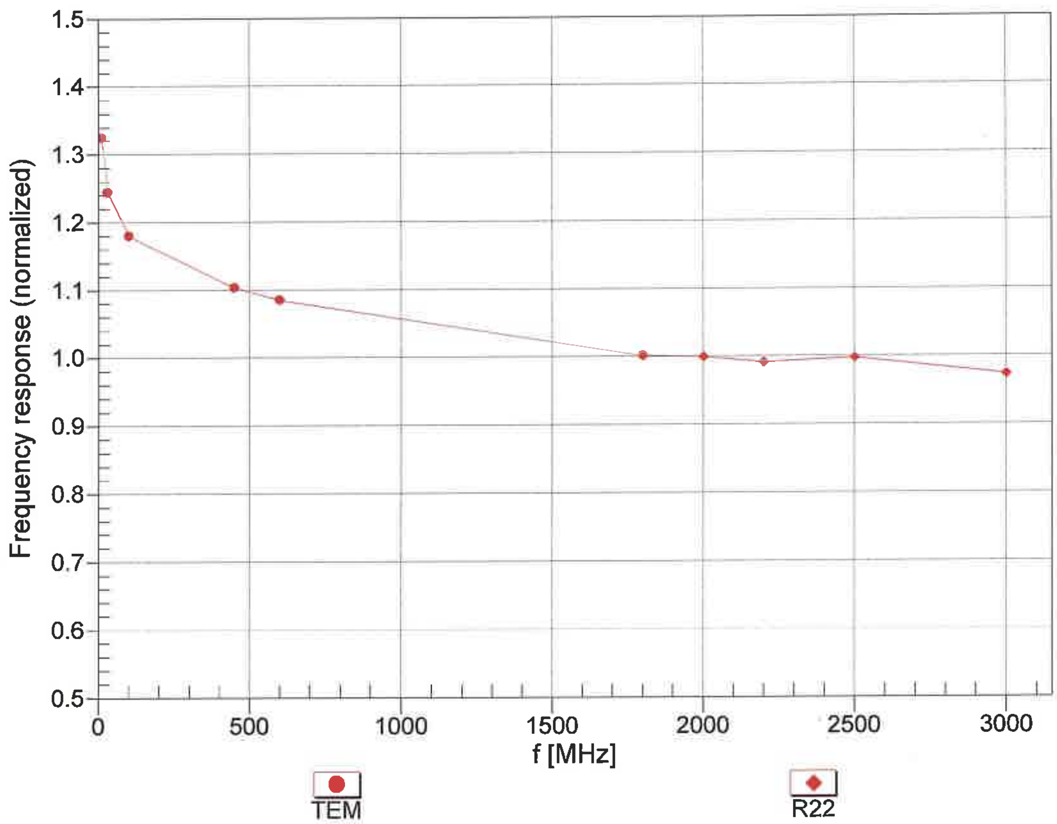
Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
750	41.9	0.89	10.48	10.48	10.48	0.57	0.80	± 12.0 %
900	41.5	0.97	10.01	10.01	10.01	0.39	0.98	± 12.0 %
1750	40.1	1.37	8.37	8.37	8.37	0.39	0.86	± 12.0 %
1900	40.0	1.40	8.02	8.02	8.02	0.35	0.86	± 12.0 %
2300	39.5	1.67	7.85	7.85	7.85	0.34	0.90	± 12.0 %
2450	39.2	1.80	7.58	7.58	7.58	0.41	0.90	± 12.0 %
2600	39.0	1.96	7.45	7.45	7.45	0.41	0.90	± 12.0 %
5250	35.9	4.71	5.30	5.30	5.30	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.73	4.73	4.73	0.40	1.80	± 13.1 %
5750	35.4	5.22	4.79	4.79	4.79	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

Frequency Response of E-Field

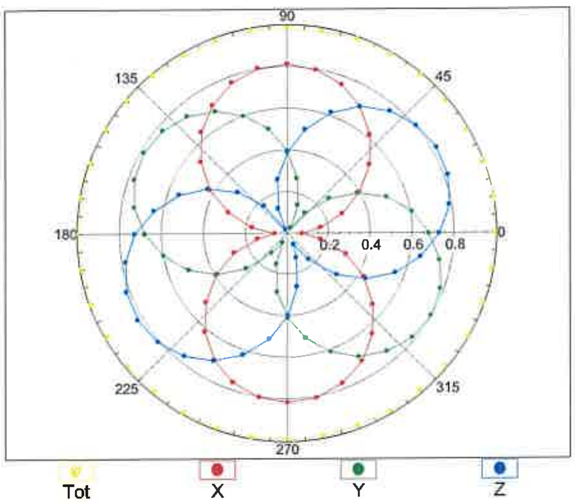
(TEM-Cell:ifi110 EXX, Waveguide: R22)



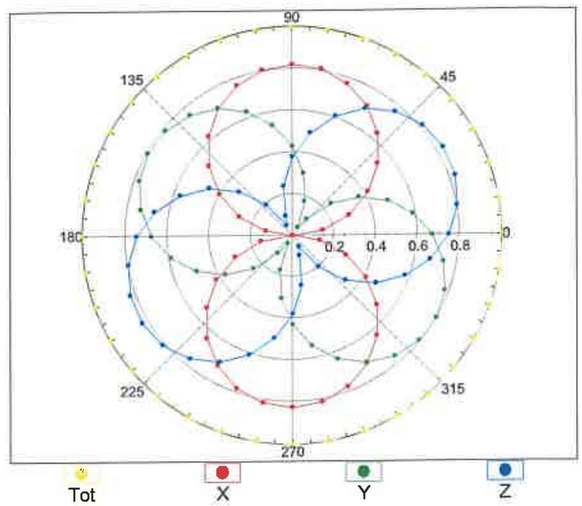
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

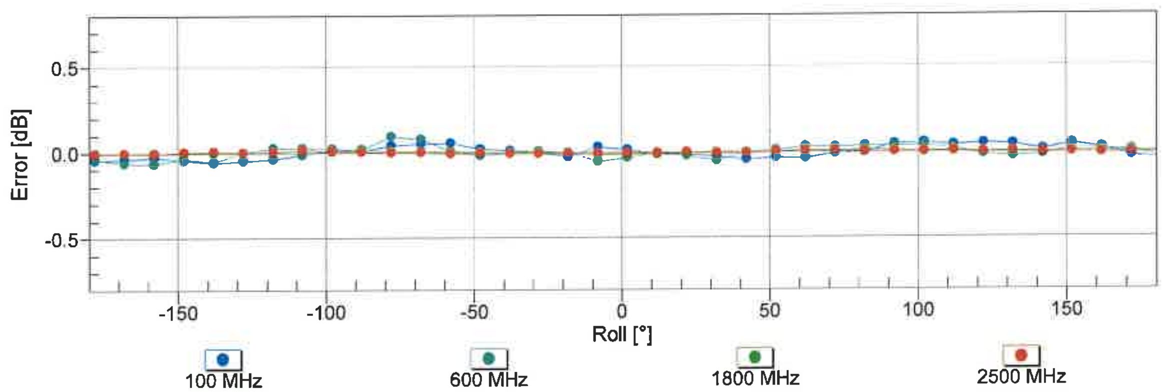
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



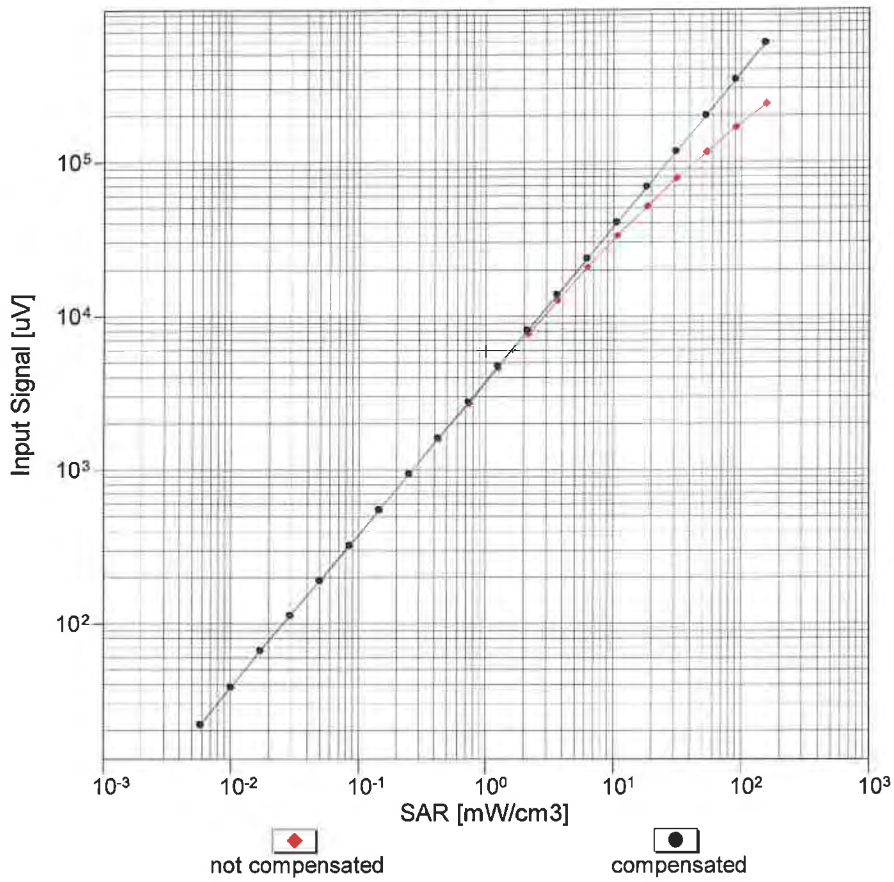
f=1800 MHz,R22

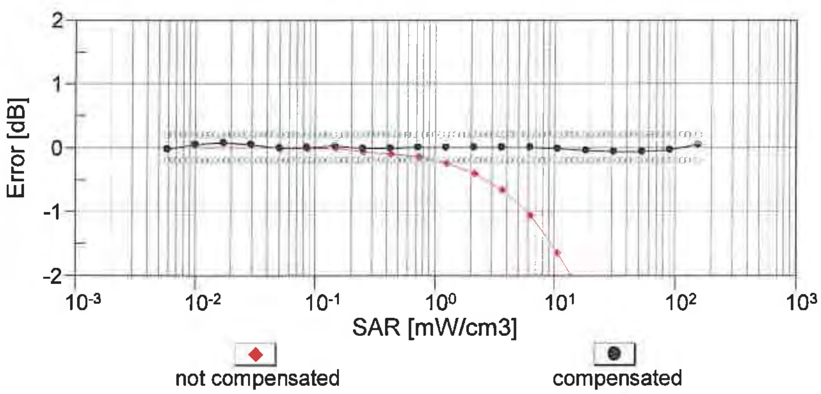




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

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

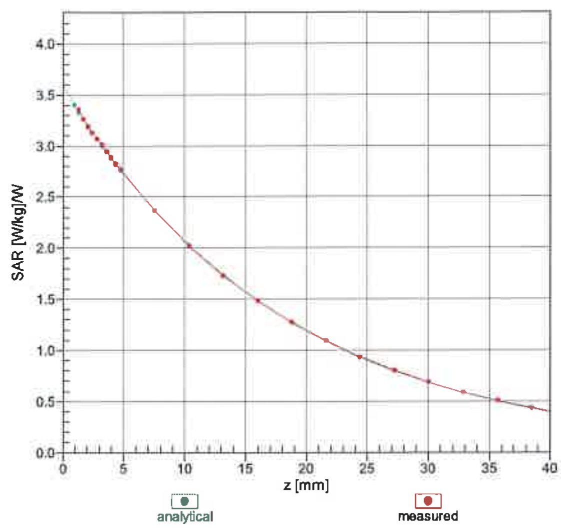




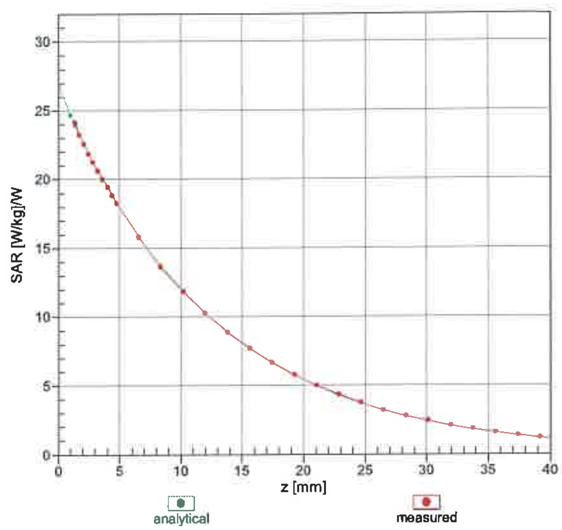
Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment

f = 900 MHz,WGLS R9 (H_convF)

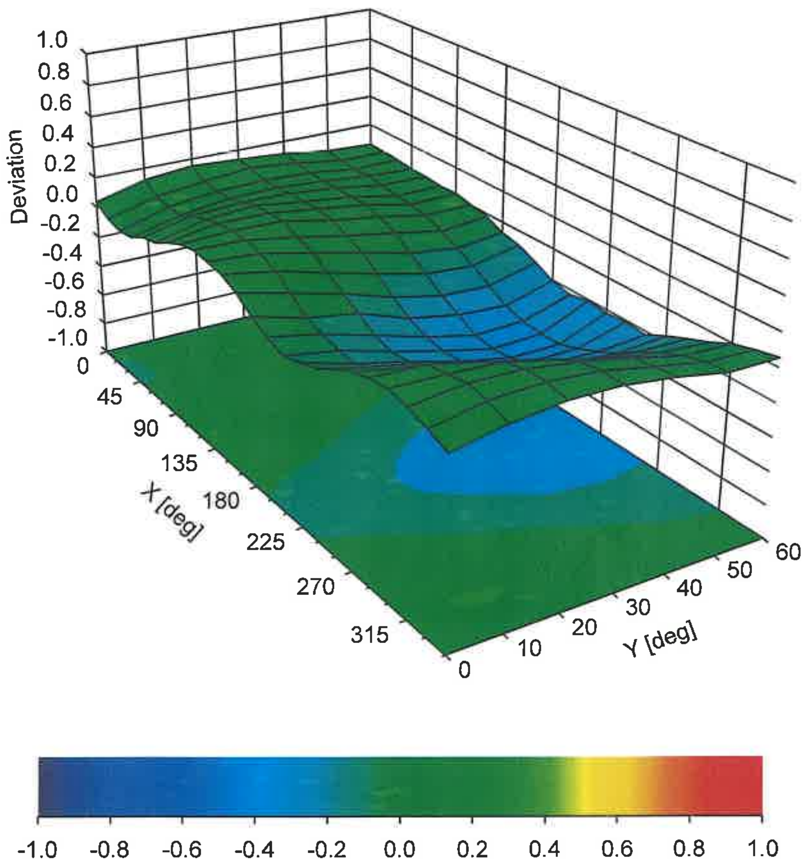


f = 1750 MHz,WGLS R22 (H_convF)



Deviation from Isotropy in Liquid

Error (ϕ, ϑ), f = 900 MHz



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

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Accreditation No.: SCS 0108

Client **UL USA**

Certificate No: EX3-7356_Mar22

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7356
Calibration procedure(s)	QA CAL-01.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	March 24, 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
Power meter NRP	SN: 104778	09-Apr-21 (No. 217-03291/03292)	Apr-22
Power sensor NRP-Z91	SN: 103244	09-Apr-21 (No. 217-03291)	Apr-22
Power sensor NRP-Z91	SN: 103245	09-Apr-21 (No. 217-03292)	Apr-22
Reference 20 dB Attenuator	SN: CC2552 (20x)	09-Apr-21 (No. 217-03343)	Apr-22
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Jeton Kastrati	Laboratory Technician	
Approved by:	Niels Kuster	Quality Manager	

Issued: March 28, 2022

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., ϑ = 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.
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Methods Applied and Interpretation of Parameters:

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- *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 (no uncertainty required). 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 ≤ 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.36	0.53	0.56	± 10.1 %
DCP (mV)[B]	105.2	101.2	99.6	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	151.6	± 2.7 %	± 4.7 %
		Y	0.00	0.00	1.00		165.0		
		Z	0.00	0.00	1.00		146.3		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	2.23	63.64	9.64	10.00	60.0	± 3.7 %	± 9.6 %
		Y	20.00	91.89	20.62		60.0		
		Z	20.00	93.92	22.44		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	1.45	63.10	8.22	6.99	80.0	± 2.5 %	± 9.6 %
		Y	20.00	95.01	21.09		80.0		
		Z	20.00	95.75	22.14		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	0.65	61.17	6.10	3.98	95.0	± 1.3 %	± 9.6 %
		Y	20.00	104.38	24.22		95.0		
		Z	20.00	99.87	22.62		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	0.30	60.00	4.55	2.22	120.0	± 1.0 %	± 9.6 %
		Y	20.00	120.71	30.20		120.0		
		Z	20.00	104.20	23.15		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.67	67.26	15.40	1.00	150.0	± 2.3 %	± 9.6 %
		Y	1.85	67.31	16.04		150.0		
		Z	1.75	65.65	14.98		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.26	68.97	16.19	0.00	150.0	± 0.9 %	± 9.6 %
		Y	2.52	69.85	16.84		150.0		
		Z	2.33	68.11	15.68		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.88	71.35	18.98	3.01	150.0	± 0.8 %	± 9.6 %
		Y	3.06	71.19	19.25		150.0		
		Z	2.94	69.32	18.17		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.52	67.58	16.00	0.00	150.0	± 1.3 %	± 9.6 %
		Y	3.68	67.82	16.31		150.0		
		Z	3.61	67.25	15.84		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.84	65.97	15.70	0.00	150.0	± 2.8 %	± 9.6 %
		Y	5.04	66.00	15.87		150.0		
		Z	5.05	65.81	15.66		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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

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	42.2	310.97	34.85	6.24	0.57	4.96	1.41	0.15	1.00
Y	52.1	394.35	36.48	11.34	0.00	5.08	1.05	0.30	1.01
Z	57.1	434.91	36.81	13.40	0.29	5.10	0.21	0.51	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	177.4
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.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

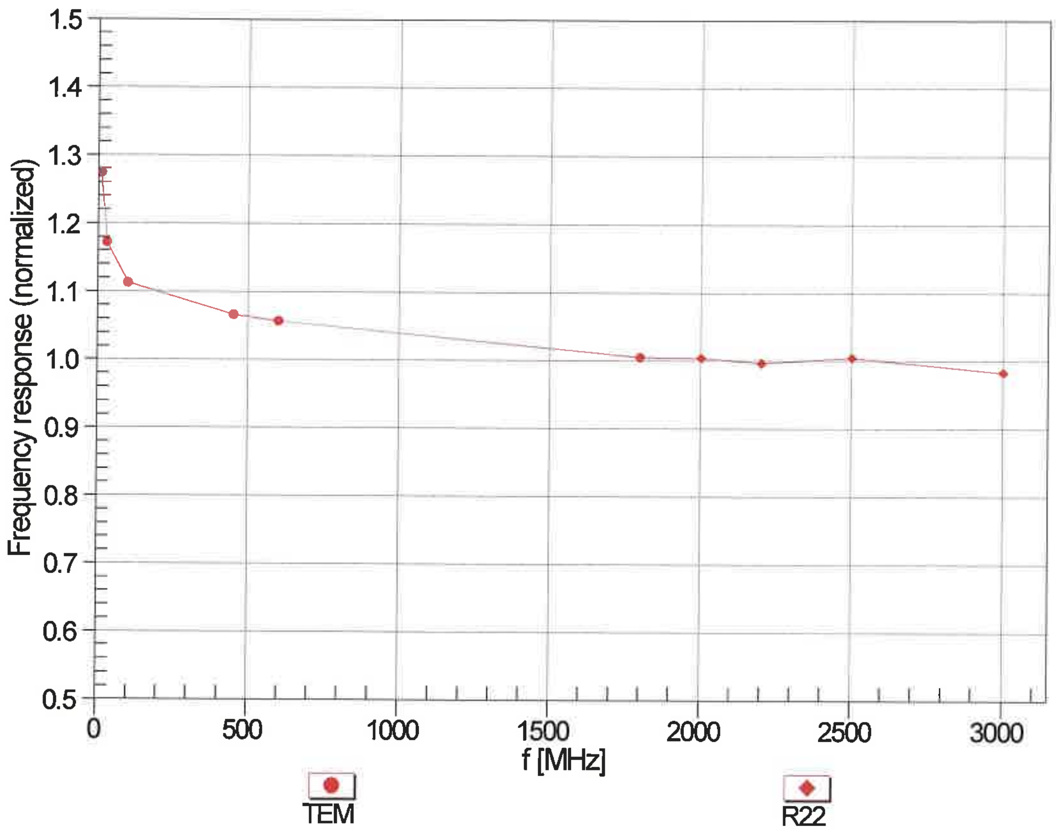
Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
750	41.9	0.89	10.70	10.70	10.70	0.58	0.80	± 12.0 %
900	41.5	0.97	10.31	10.31	10.31	0.53	0.84	± 12.0 %
1750	40.1	1.37	9.09	9.09	9.09	0.36	0.86	± 12.0 %
1900	40.0	1.40	8.85	8.85	8.85	0.37	0.86	± 12.0 %
2300	39.5	1.67	8.48	8.48	8.48	0.36	0.90	± 12.0 %
2450	39.2	1.80	8.17	8.17	8.17	0.38	0.90	± 12.0 %
2600	39.0	1.96	7.99	7.99	7.99	0.44	0.90	± 12.0 %
3300	38.2	2.71	7.70	7.70	7.70	0.30	1.35	± 13.1 %
3500	37.9	2.91	7.20	7.20	7.20	0.30	1.35	± 13.1 %
3700	37.7	3.12	7.15	7.15	7.15	0.30	1.35	± 13.1 %
3900	37.5	3.32	7.10	7.10	7.10	0.40	1.60	± 13.1 %
4100	37.2	3.53	7.03	7.03	7.03	0.40	1.60	± 13.1 %
4200	37.1	3.63	6.90	6.90	6.90	0.40	1.70	± 13.1 %
5250	35.9	4.71	5.59	5.59	5.59	0.40	1.80	± 13.1 %
5600	35.5	5.07	5.10	5.10	5.10	0.40	1.80	± 13.1 %
5750	35.4	5.22	5.19	5.19	5.19	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

Frequency Response of E-Field

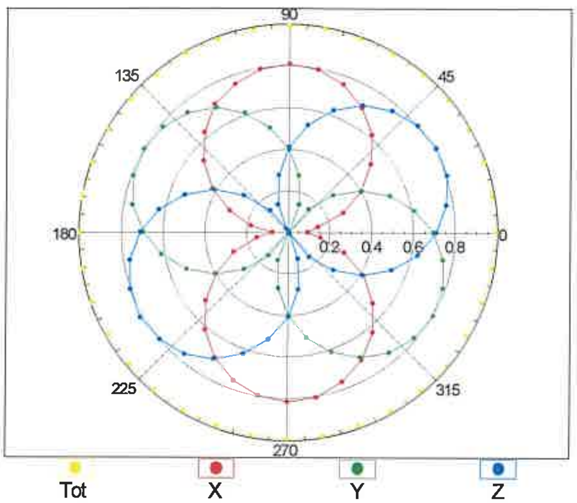
(TEM-Cell:ifi110 EXX, Waveguide: R22)



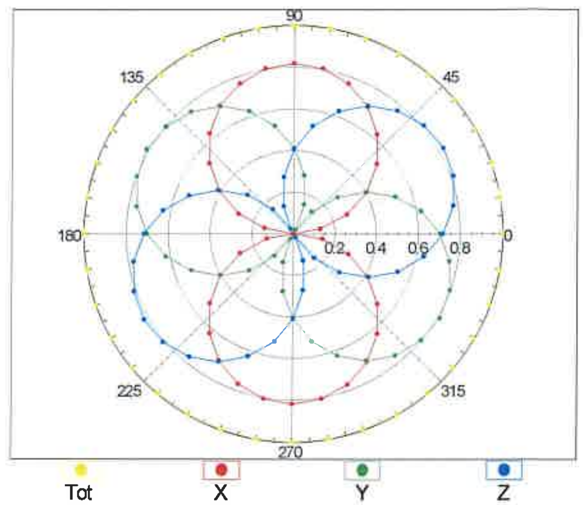
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

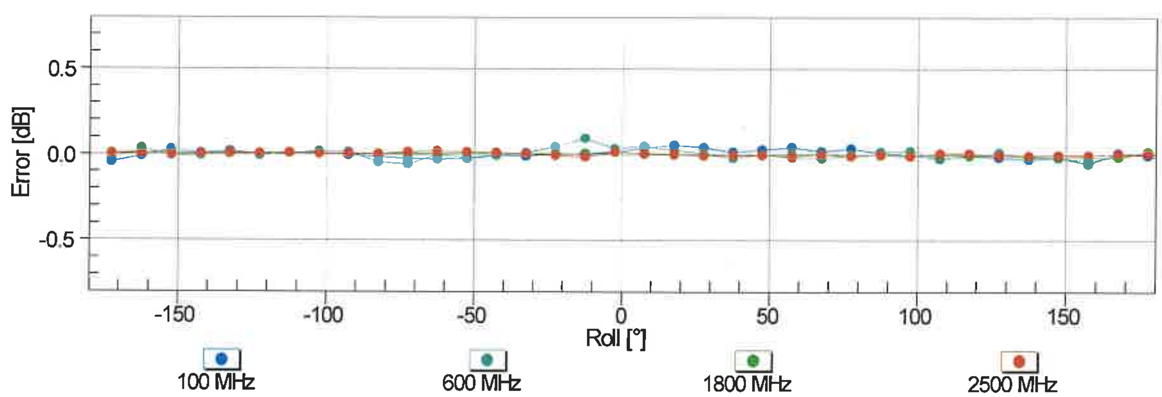
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



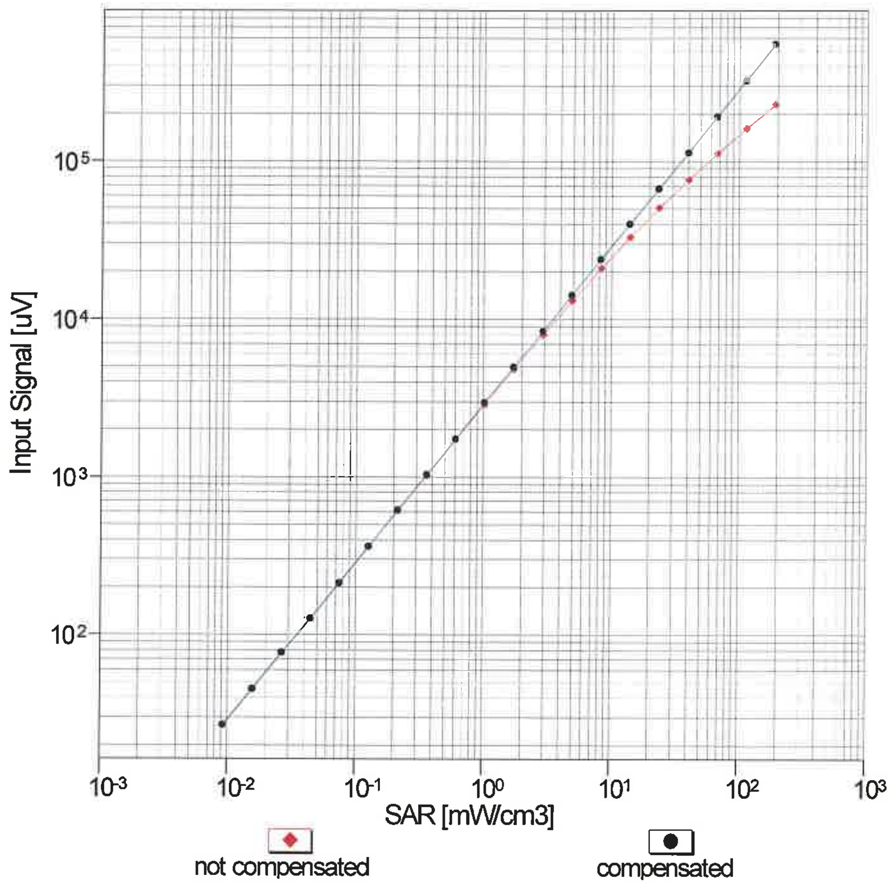
f=1800 MHz,R22

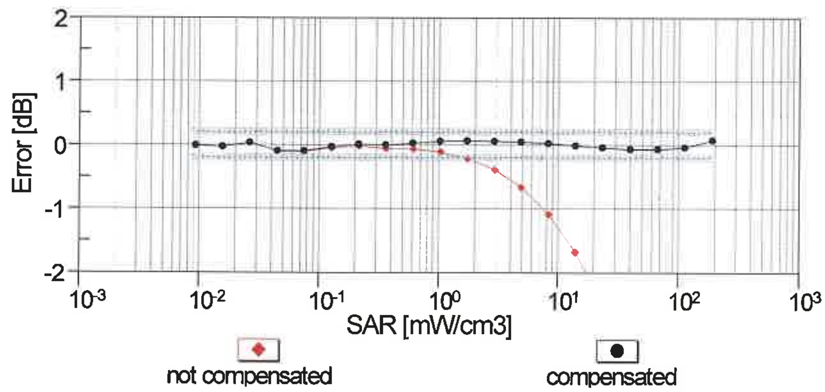




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

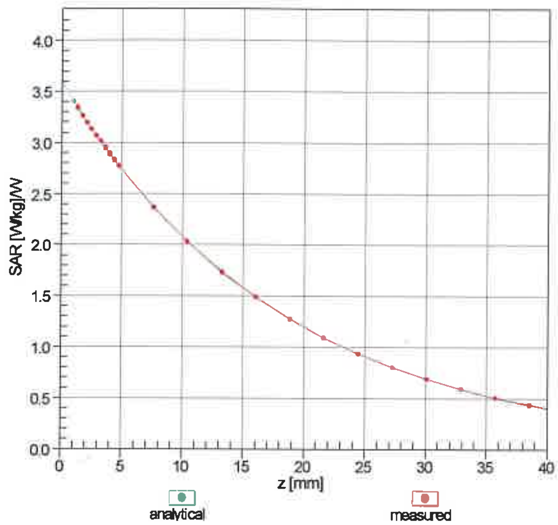
Dynamic Range f(SAR_{head})
(TEM cell , f_{eval}= 1900 MHz)

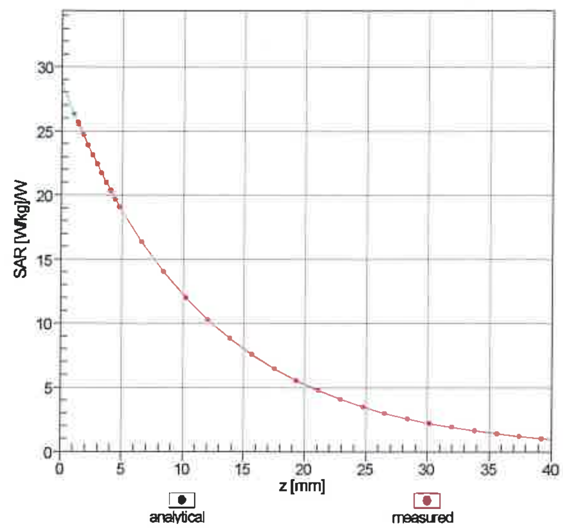




Uncertainty of Linearity Assessment: ± 0.6% (k=2)

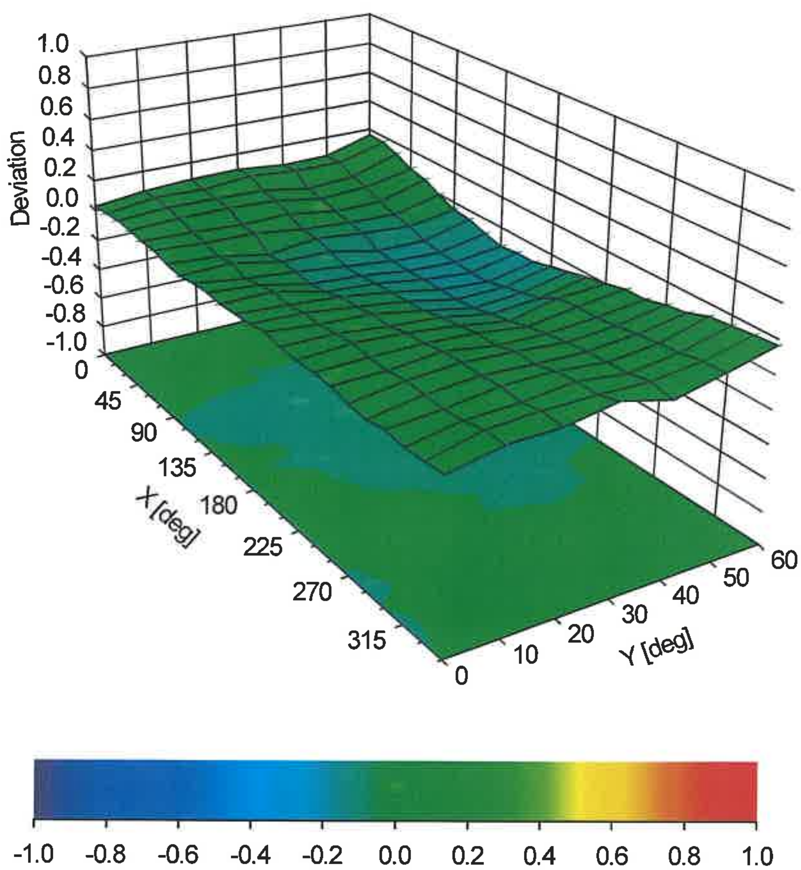
Conversion Factor Assessment





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
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 USA**

Certificate No: EX3-3929_Mar22

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3929
Calibration procedure(s)	QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	March 23, 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
Power meter NRP	SN: 104778	09-Apr-21 (No. 217-03291/03292)	Apr-22
Power sensor NRP-Z91	SN: 103244	09-Apr-21 (No. 217-03291)	Apr-22
Power sensor NRP-Z91	SN: 103245	09-Apr-21 (No. 217-03292)	Apr-22
Reference 20 dB Attenuator	SN: CC2552 (20x)	09-Apr-21 (No. 217-03343)	Apr-22
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Jeton Kastrati	Laboratory Technician	
Approved by:	Niels Kuster	Quality Manager	

Issued: March 28, 2022

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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 (no uncertainty required). 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3929

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.53	0.49	0.39	± 10.1 %
DCP (mV)[B]	100.6	99.2	100.8	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	166.6	± 2.7 %	± 4.7 %
		Y	0.00	0.00	1.00		152.1		
		Z	0.00	0.00	1.00		156.0		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	15.44	84.67	17.53	10.00	60.0	± 2.8 %	± 9.6 %
		Y	20.00	89.95	19.93		60.0		
		Z	20.00	88.50	18.92		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	87.87	17.52	6.99	80.0	± 1.7 %	± 9.6 %
		Y	20.00	90.85	19.02		80.0		
		Z	20.00	90.95	18.94		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	90.55	17.65	3.98	95.0	± 1.2 %	± 9.6 %
		Y	20.00	92.38	18.22		95.0		
		Z	20.00	99.15	21.44		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	95.80	19.02	2.22	120.0	± 1.1 %	± 9.6 %
		Y	20.00	92.87	17.13		120.0		
		Z	20.00	102.30	21.61		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.81	66.74	15.67	1.00	150.0	± 2.0 %	± 9.6 %
		Y	1.73	65.82	14.95		150.0		
		Z	1.83	68.03	16.11		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.43	69.15	16.43	0.00	150.0	± 0.9 %	± 9.6 %
		Y	2.31	68.17	15.70		150.0		
		Z	2.47	69.95	16.85		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	3.11	71.29	19.26	3.01	150.0	± 0.9 %	± 9.6 %
		Y	2.89	69.22	18.09		150.0		
		Z	2.58	68.94	18.17		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.65	67.59	16.14	0.00	150.0	± 1.3 %	± 9.6 %
		Y	3.61	67.32	15.87		150.0		
		Z	3.53	67.39	16.07		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	5.03	65.93	15.80	0.00	150.0	± 2.9 %	± 9.6 %
		Y	4.83	65.15	15.32		150.0		
		Z	4.83	65.60	15.63		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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3929

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	52.0	393.95	36.48	10.05	0.00	5.04	0.00	0.00	1.00
Y	53.7	409.44	36.83	8.90	0.31	5.05	0.17	0.50	1.01
Z	44.8	335.70	35.83	7.73	0.04	5.05	0.42	0.29	1.00

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	164.9
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.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3929

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
6	55.0	0.75	15.96	15.96	15.96	0.00	1.00	± 13.3 %
13	55.0	0.75	14.62	14.62	14.62	0.00	1.00	± 13.3 %
30	55.0	0.75	13.55	13.55	13.55	0.00	1.00	± 13.3 %
750	41.9	0.89	9.01	9.01	9.01	0.53	0.84	± 12.0 %
900	41.5	0.97	8.54	8.54	8.54	0.35	1.04	± 12.0 %
1750	40.1	1.37	8.14	8.14	8.14	0.38	0.86	± 12.0 %
1900	40.0	1.40	7.83	7.83	7.83	0.38	0.86	± 12.0 %
2300	39.5	1.67	7.34	7.34	7.34	0.31	0.90	± 12.0 %
2450	39.2	1.80	7.10	7.10	7.10	0.36	0.90	± 12.0 %
2600	39.0	1.96	6.98	6.98	6.98	0.37	0.90	± 12.0 %
3300	38.2	2.71	6.55	6.55	6.55	0.30	1.30	± 13.1 %
3500	37.9	2.91	6.50	6.50	6.50	0.30	1.30	± 13.1 %
3700	37.7	3.12	6.40	6.40	6.40	0.30	1.30	± 13.1 %
3900	37.5	3.32	6.34	6.34	6.34	0.40	1.60	± 13.1 %
4100	37.2	3.53	6.32	6.32	6.32	0.40	1.60	± 13.1 %
4200	37.1	3.63	6.20	6.20	6.20	0.40	1.60	± 13.1 %
4400	36.9	3.84	5.98	5.98	5.98	0.40	1.60	± 13.1 %
4600	36.7	4.04	5.89	5.89	5.89	0.40	1.80	± 13.1 %
4800	36.4	4.25	5.80	5.80	5.80	0.40	1.80	± 13.1 %
4950	36.3	4.40	5.57	5.57	5.57	0.40	1.80	± 13.1 %
5250	35.9	4.71	4.65	4.65	4.65	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.37	4.37	4.37	0.40	1.80	± 13.1 %
5750	35.4	5.22	4.29	4.29	4.29	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

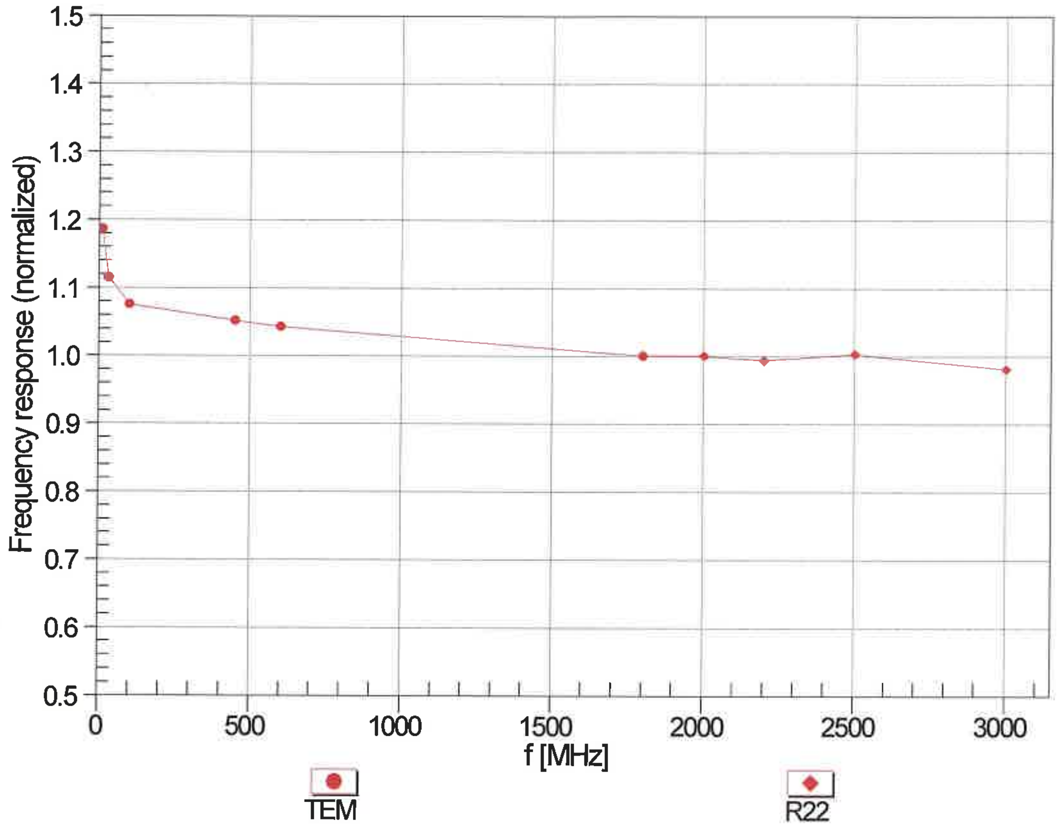
DASY/EASY - Parameters of Probe: EX3DV4 - SN:3929

Calibration Parameter Determined in Body Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
6500	34.5	6.07	5.25	5.25	5.25	0.20	2.50	± 18.6 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

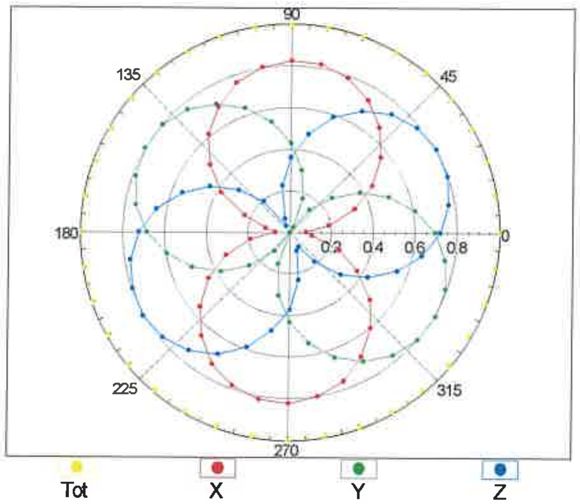
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)



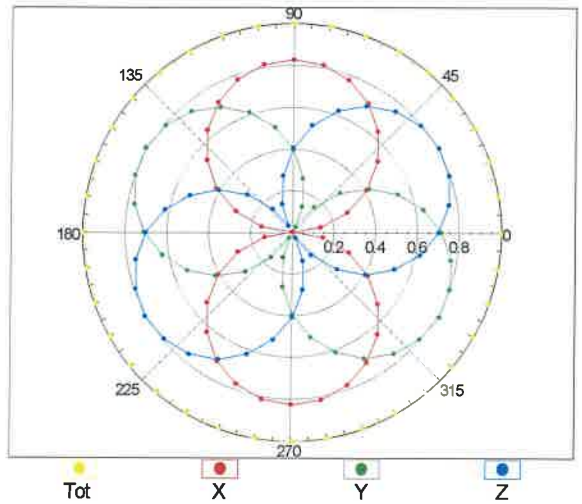
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

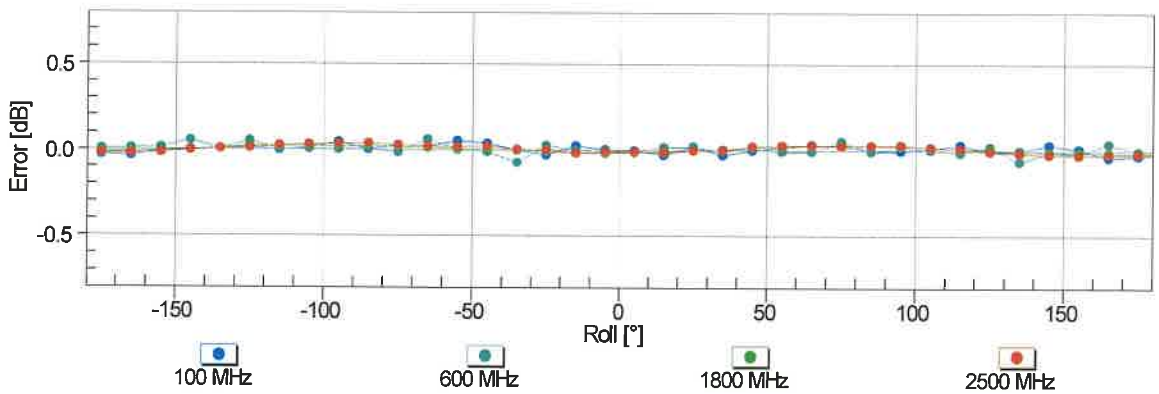
Receiving Pattern (ϕ), $\vartheta = 0°$

f=600 MHz,TEM



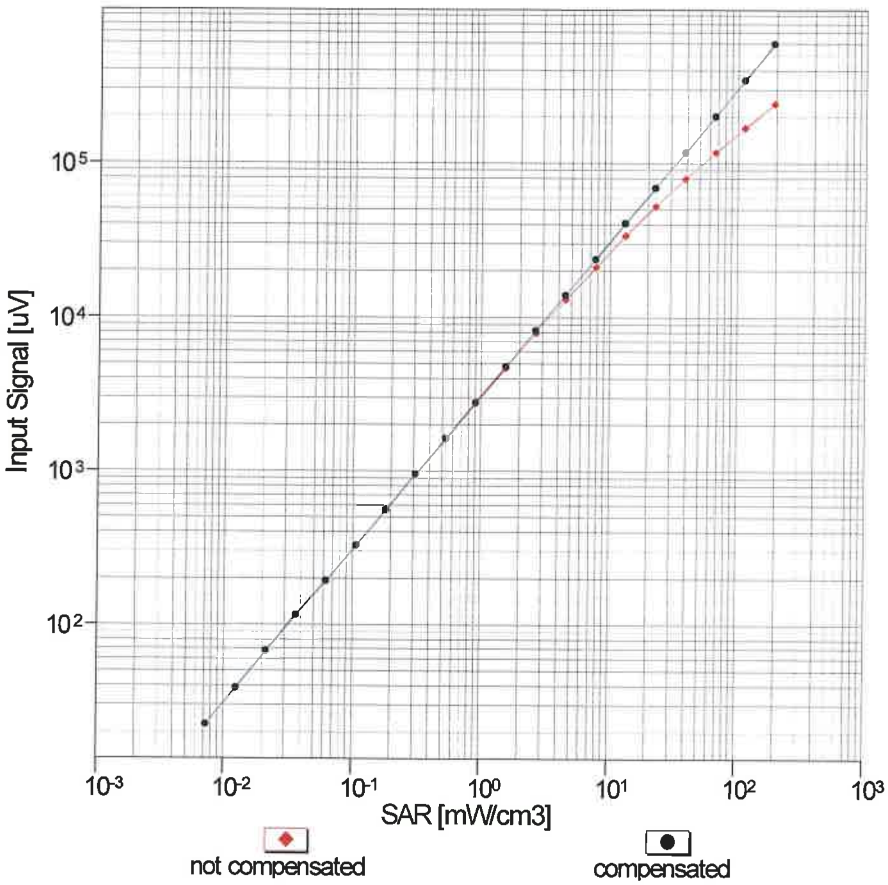
f=1800 MHz,R22

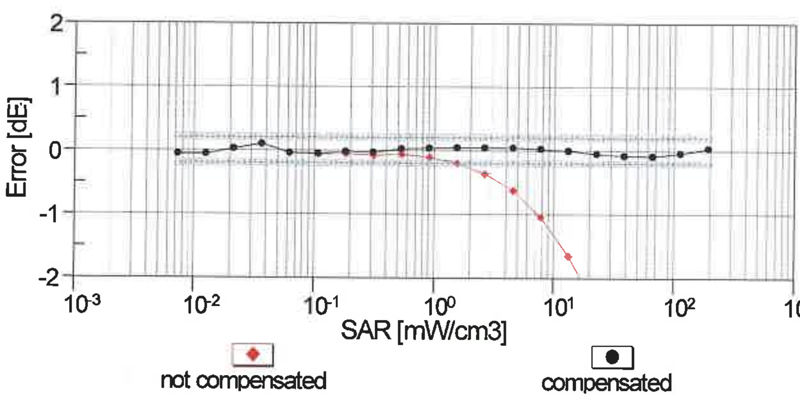




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

Dynamic Range f(SAR_{head})
(TEM cell , f_{eval}= 1900 MHz)

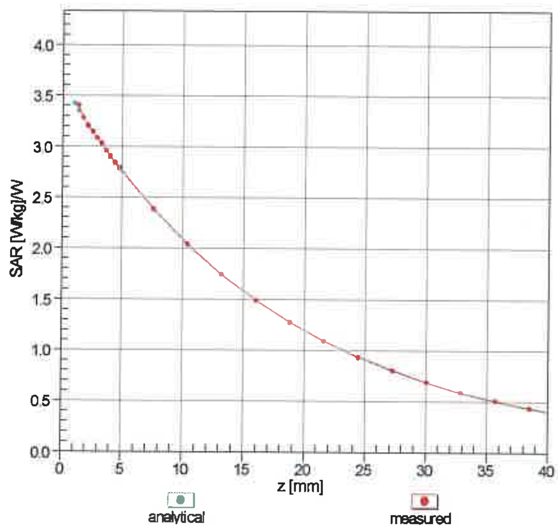




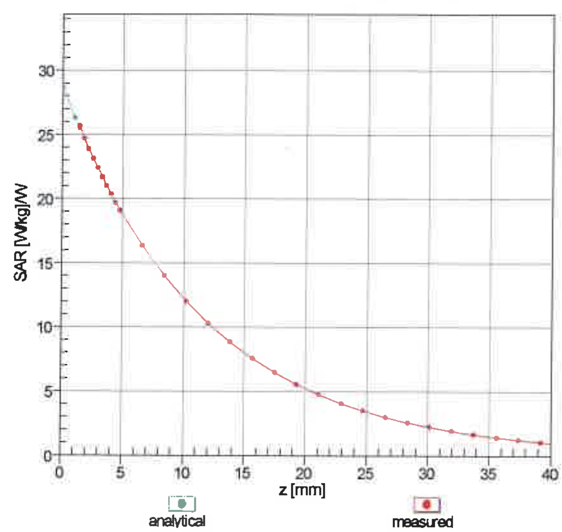
Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment

f = 900 MHz,WGLS R9 (H_convF)

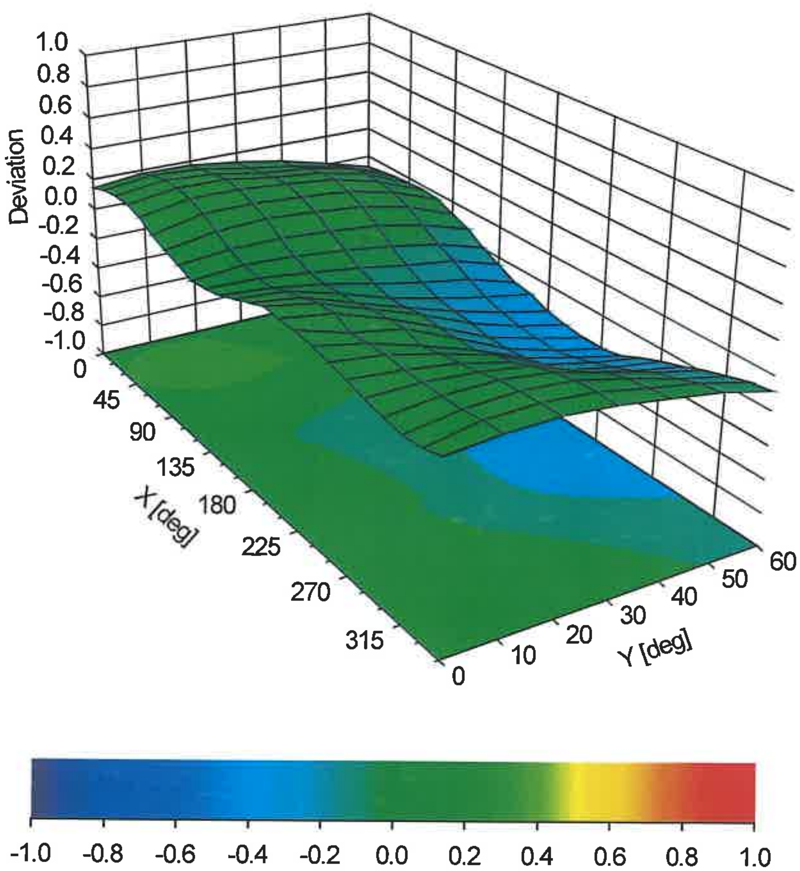


f = 1900 MHz,WGLS R22 (H_convF)



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
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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 USA

Certificate No: EX3-3990_Feb22

CALIBRATION CERTIFICATE

Object: EX3DV4 - SN:3990

Calibration procedure(s): QA CAL-01.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7
Calibration procedure for dosimetric E-field probes

Calibration date: February 25, 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
Power meter NRP	SN: 104778	09-Apr-21 (No. 217-03291/03292)	Apr-22
Power sensor NRP-Z91	SN: 103244	09-Apr-21 (No. 217-03291)	Apr-22
Power sensor NRP-Z91	SN: 103245	09-Apr-21 (No. 217-03292)	Apr-22
Reference 20 dB Attenuator	SN: CC2552 (20x)	09-Apr-21 (No. 217-03343)	Apr-22
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Aidonia Georgiadou	Laboratory Technician	
Approved by:	Niels Kuster	Quality Manager	

Issued: March 1, 2022

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**
Swiss Calibration Service

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Accreditation No.: SCS 0108

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., ϑ = 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 ϑ = 0 (f ≤ 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 (no uncertainty required). 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 ≤ 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).

DASY/EASY - 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]	0.59	0.63	0.59	± 10.1 %
DCP (mV)[B]	105.4	100.2	98.5	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	174.0	± 3.5 %	± 4.7 %
		Y	0.00	0.00	1.00		154.9		
		Z	0.00	0.00	1.00		178.3		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	20.00	92.23	21.23	10.00	60.0	± 3.6 %	± 9.6 %
		Y	20.00	92.24	21.04		60.0		
		Z	20.00	92.23	21.20		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	93.91	20.98	6.99	80.0	± 1.9 %	± 9.6 %
		Y	20.00	93.45	20.70		80.0		
		Z	20.00	93.25	20.60		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	96.80	20.95	3.98	95.0	± 1.0 %	± 9.6 %
		Y	20.00	96.98	21.19		95.0		
		Z	20.00	95.41	20.23		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	98.79	20.49	2.22	120.0	± 1.0 %	± 9.6 %
		Y	20.00	101.63	22.12		120.0		
		Z	20.00	96.28	19.28		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.58	65.14	14.23	1.00	150.0	± 2.5 %	± 9.6 %
		Y	1.70	66.10	14.91		150.0		
		Z	1.57	65.19	14.17		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.10	66.98	15.00	0.00	150.0	± 1.1 %	± 9.6 %
		Y	2.26	68.06	15.65		150.0		
		Z	2.09	66.96	14.98		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.85	69.54	18.18	3.01	150.0	± 0.8 %	± 9.6 %
		Y	2.89	70.15	18.64		150.0		
		Z	2.74	68.96	17.97		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.44	66.74	15.46	0.00	150.0	± 1.6 %	± 9.6 %
		Y	3.42	66.62	15.48		150.0		
		Z	3.45	66.76	15.47		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.85	65.54	15.41	0.00	150.0	± 3.2 %	± 9.6 %
		Y	4.78	65.29	15.31		150.0		
		Z	4.86	65.62	15.46		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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - 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	46.2	346.37	35.67	14.10	0.15	5.10	0.74	0.37	1.01
Y	46.5	345.70	35.20	15.90	0.00	5.09	0.79	0.30	1.01
Z	44.7	337.05	36.10	14.28	0.15	5.10	0.49	0.38	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	169.4
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.

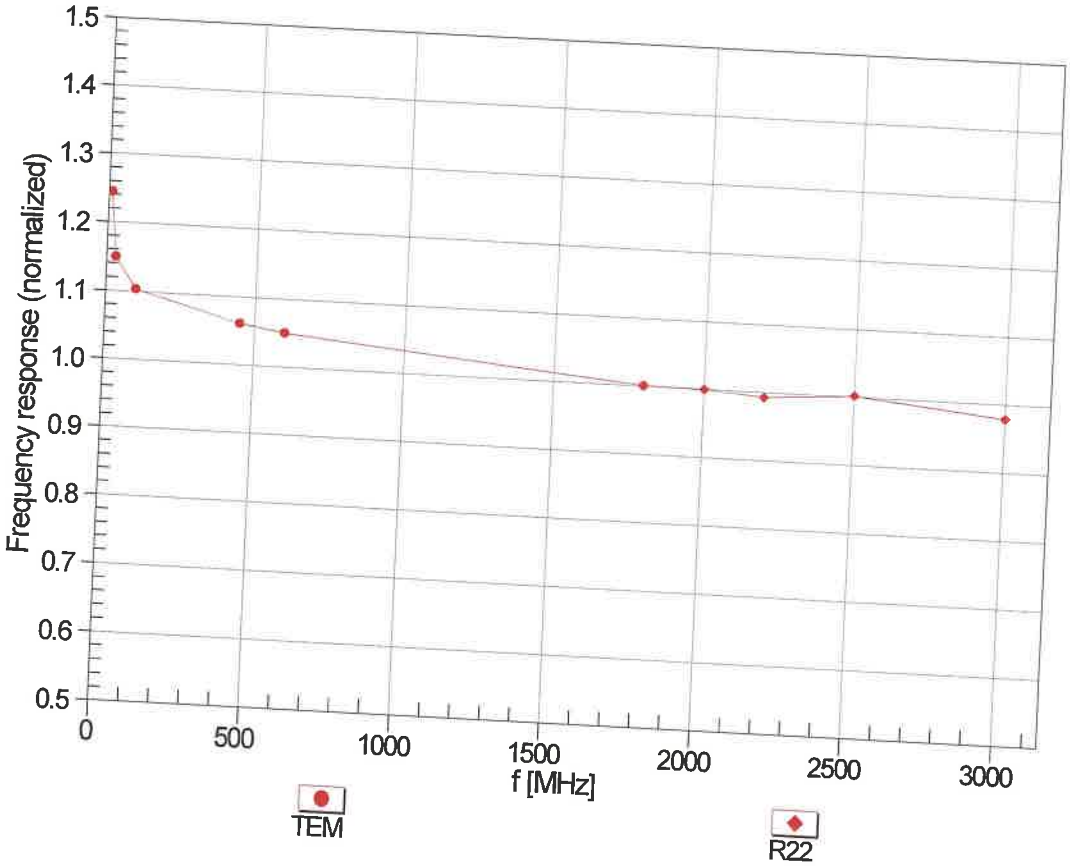
DASY/EASY - Parameters of Probe: EX3DV4 - SN:3990

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
750	41.9	0.89	10.08	10.08	10.08	0.52	0.88	± 12.0 %
900	41.5	0.97	9.70	9.70	9.70	0.55	0.80	± 12.0 %
1750	40.1	1.37	8.71	8.71	8.71	0.28	0.86	± 12.0 %
1900	40.0	1.40	8.18	8.18	8.18	0.30	0.86	± 12.0 %
2300	39.5	1.67	7.98	7.98	7.98	0.32	0.90	± 12.0 %
2450	39.2	1.80	7.70	7.70	7.70	0.31	0.90	± 12.0 %
2600	39.0	1.96	7.53	7.53	7.53	0.24	0.90	± 12.0 %
3300	38.2	2.71	7.05	7.05	7.05	0.35	1.30	± 13.1 %
3500	37.9	2.91	6.92	6.92	6.92	0.35	1.30	± 13.1 %
3700	37.7	3.12	6.90	6.90	6.90	0.35	1.30	± 13.1 %
3900	37.5	3.32	6.76	6.76	6.76	0.35	1.60	± 13.1 %
4100	37.2	3.53	6.69	6.69	6.69	0.35	1.60	± 13.1 %
4200	37.1	3.63	6.25	6.25	6.25	0.40	1.70	± 13.1 %
5250	35.9	4.71	5.54	5.54	5.54	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.85	4.85	4.85	0.40	1.80	± 13.1 %
5750	35.4	5.22	5.05	5.05	5.05	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

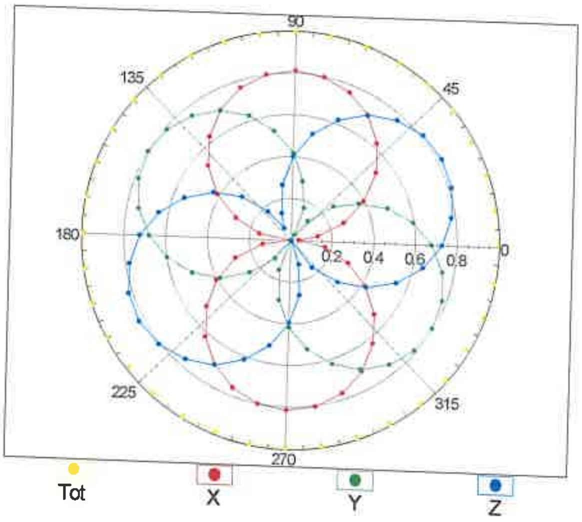
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)



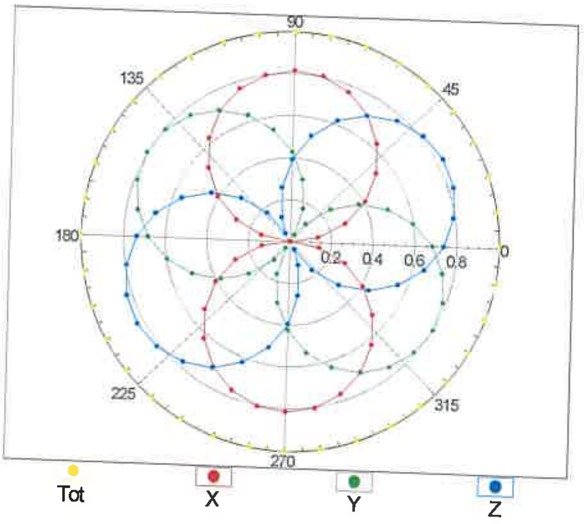
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

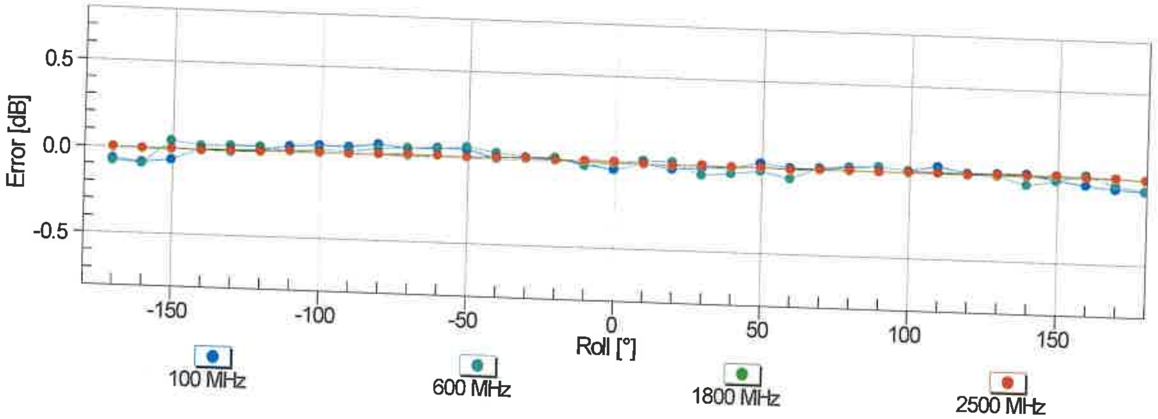
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



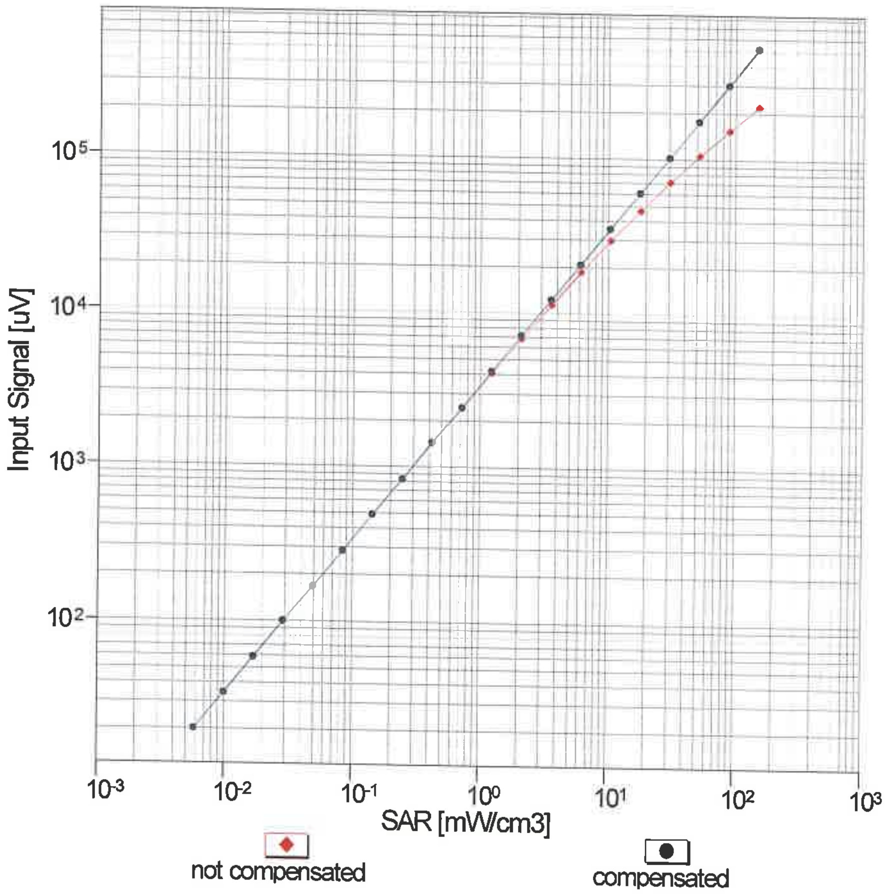
f=1800 MHz,R22

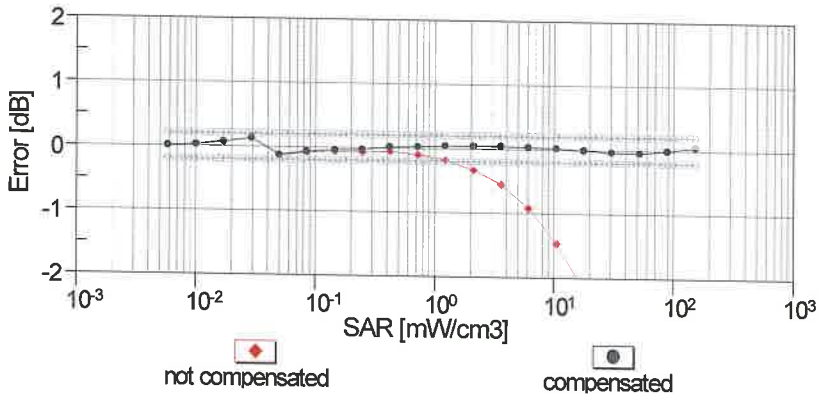




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

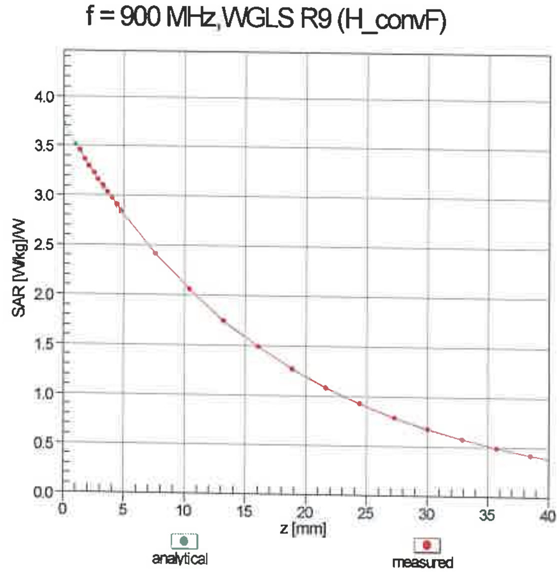
Dynamic Range f(SAR_{head})
(TEM cell , f_{eval}= 1900 MHz)

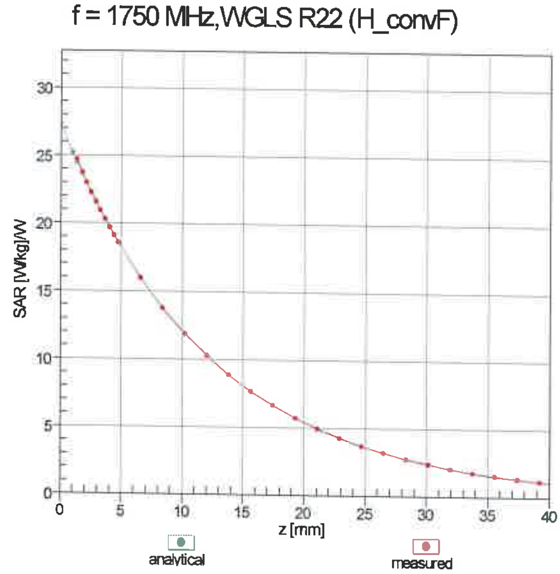




Uncertainty of Linearity Assessment: ± 0.6% (k=2)

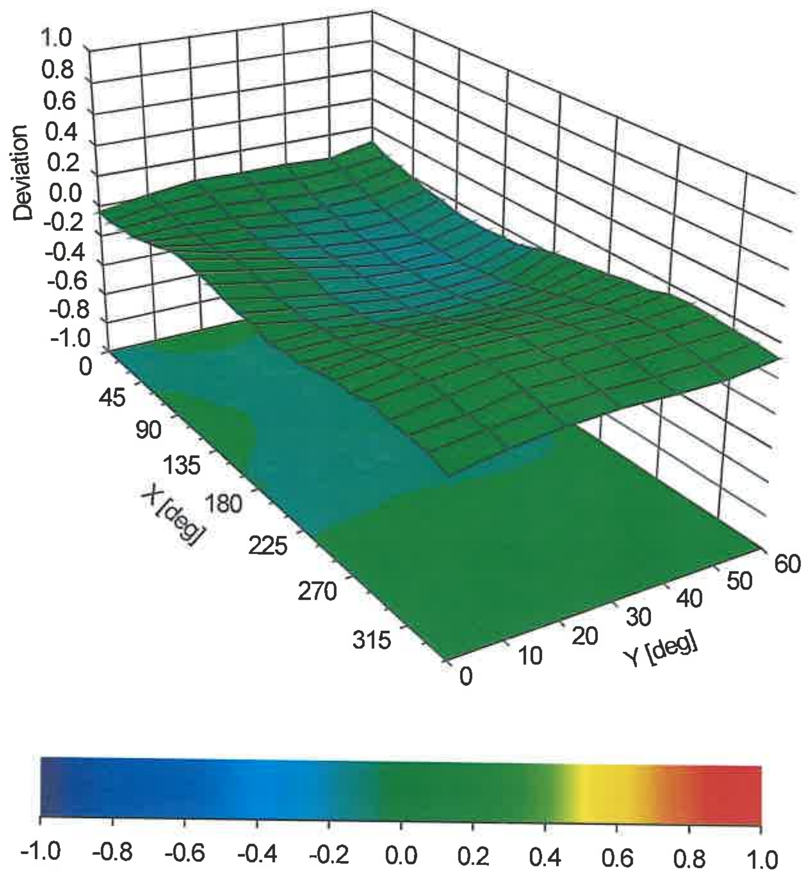
Conversion Factor Assessment





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
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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 USA**

Certificate No: EX3-3773_Feb22

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3773
Calibration procedure(s)	QA CAL-01.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	February 28, 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)

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DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
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Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Joanna Lleshaj	Laboratory Technician	
Approved by:	Niels Kuster	Quality Manager	

Issued: March 1, 2022

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 (no uncertainty required). 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3773

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.57	0.54	0.51	± 10.1 %
DCP (mV)[B]	98.5	100.4	99.7	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	140.0	± 2.7 %	± 4.7 %
		Y	0.00	0.00	1.00		144.2		
		Z	0.00	0.00	1.00		140.4		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	20.00	93.30	22.33	10.00	60.0	± 4.1 %	± 9.6 %
		Y	20.00	92.76	21.59		60.0		
		Z	20.00	94.04	23.01		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	94.65	21.77	6.99	80.0	± 2.1 %	± 9.6 %
		Y	20.00	92.91	20.79		80.0		
		Z	20.00	94.97	22.29		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	96.66	21.16	3.98	95.0	± 1.2 %	± 9.6 %
		Y	20.00	95.35	20.75		95.0		
		Z	20.00	97.00	21.73		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	96.76	19.72	2.22	120.0	± 1.0 %	± 9.6 %
		Y	20.00	98.77	21.09		120.0		
		Z	20.00	98.60	21.03		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.44	63.82	13.33	1.00	150.0	± 2.9 %	± 9.6 %
		Y	1.65	65.75	14.74		150.0		
		Z	1.50	64.04	13.63		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	1.91	65.43	14.14	0.00	150.0	± 1.0 %	± 9.6 %
		Y	2.20	67.69	15.50		150.0		
		Z	1.97	65.80	14.34		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.44	67.00	17.19	3.01	150.0	± 1.0 %	± 9.6 %
		Y	2.93	69.95	18.52		150.0		
		Z	3.03	70.24	18.55		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.29	65.86	14.96	0.00	150.0	± 2.0 %	± 9.6 %
		Y	3.50	66.99	15.68		150.0		
		Z	3.33	66.08	15.07		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.70	64.96	15.08	0.00	150.0	± 3.9 %	± 9.6 %
		Y	4.89	65.65	15.54		150.0		
		Z	4.76	65.09	15.12		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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3773

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	44.2	335.94	36.44	14.59	0.46	5.10	0.00	0.42	1.01
Y	46.9	352.33	35.90	21.10	0.12	5.10	0.76	0.37	1.01
Z	47.4	355.44	35.60	17.67	0.56	5.10	1.20	0.34	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	161
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.

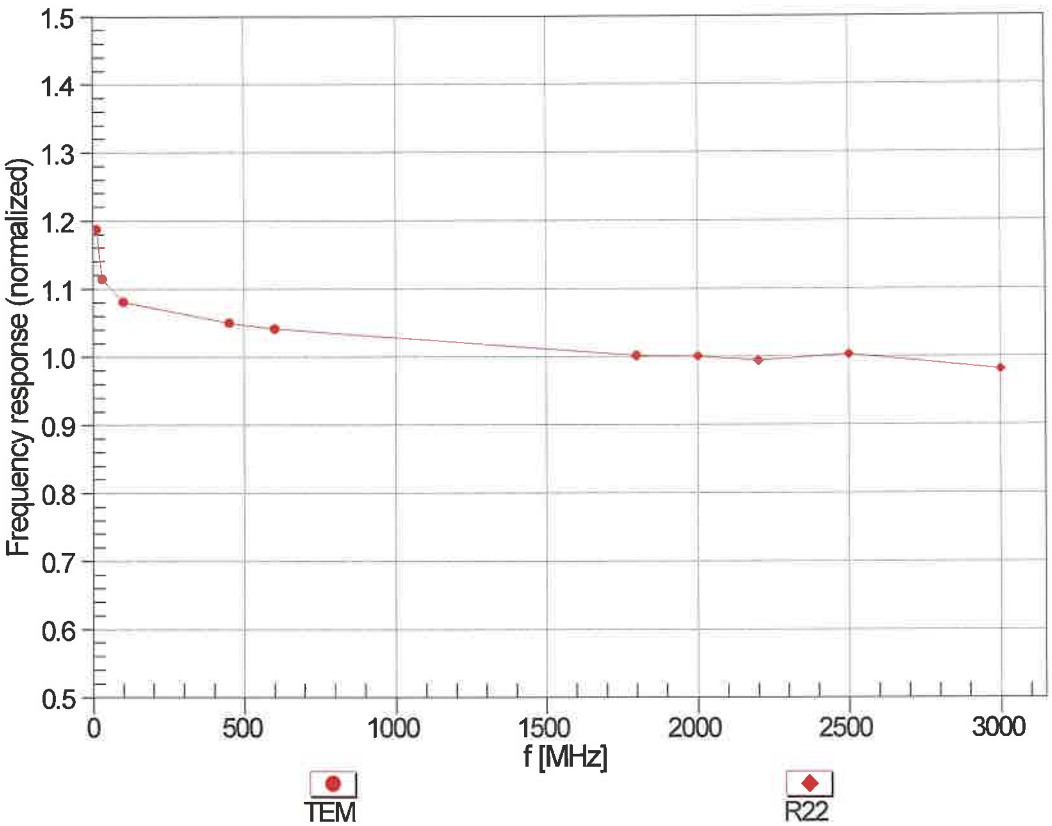
DASY/EASY - Parameters of Probe: EX3DV4 - SN:3773

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
750	41.9	0.89	9.41	9.41	9.41	0.52	0.80	± 12.0 %
900	41.5	0.97	8.74	8.74	8.74	0.51	0.80	± 12.0 %
1750	40.1	1.37	7.93	7.93	7.93	0.31	0.86	± 12.0 %
1900	40.0	1.40	7.67	7.67	7.67	0.31	0.86	± 12.0 %
2300	39.5	1.67	7.35	7.35	7.35	0.32	0.90	± 12.0 %
2450	39.2	1.80	7.17	7.17	7.17	0.19	0.90	± 12.0 %
2600	39.0	1.96	7.08	7.08	7.08	0.27	0.90	± 12.0 %
5250	35.9	4.71	4.66	4.66	4.66	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.30	4.30	4.30	0.40	1.80	± 13.1 %
5750	35.4	5.22	4.50	4.50	4.50	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

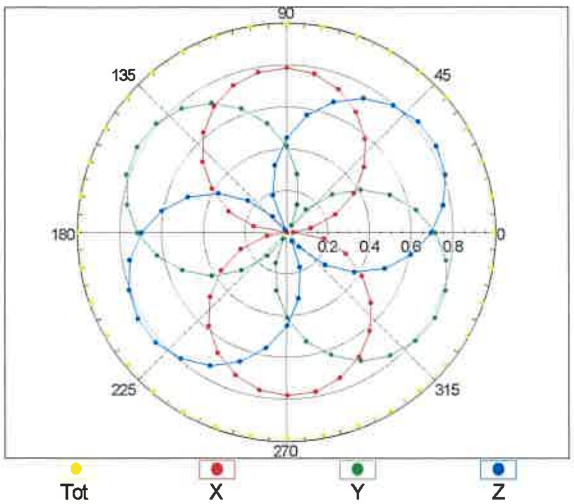
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)



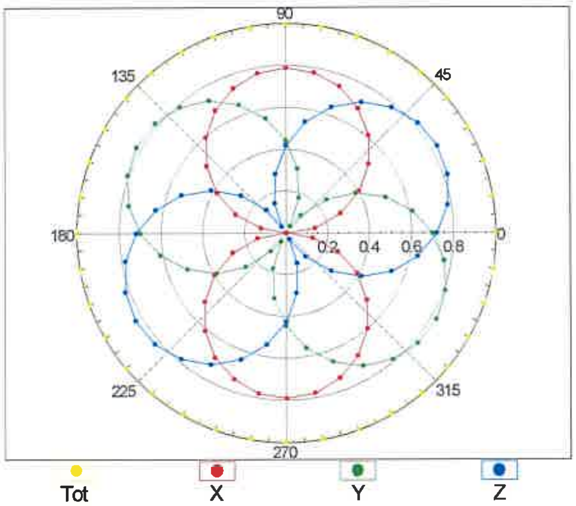
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

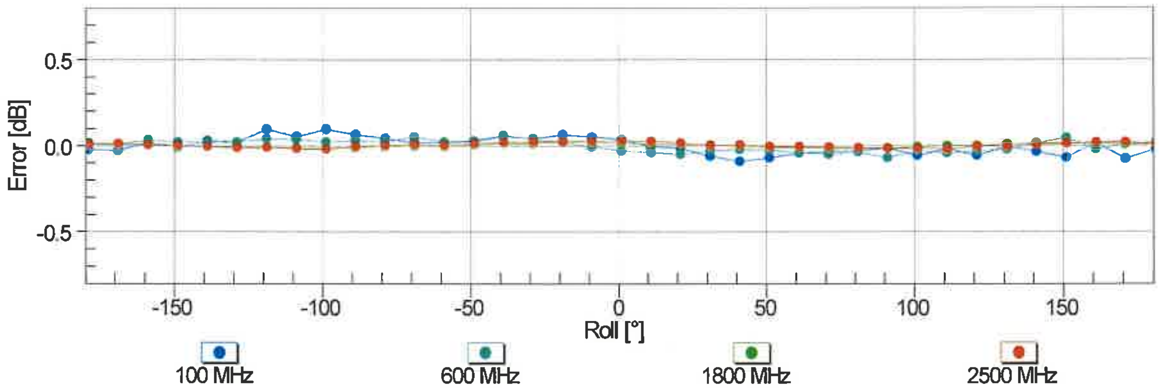
Receiving Pattern (ϕ), $\vartheta = 0°$

f=600 MHz,TEM



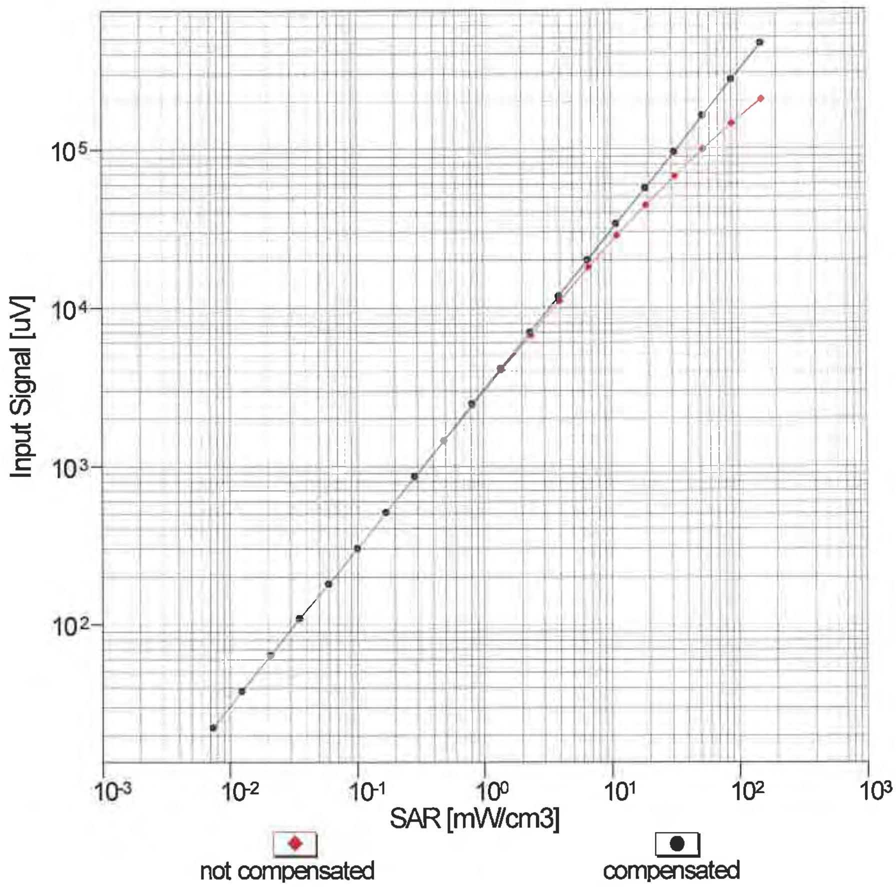
f=1800 MHz,R22

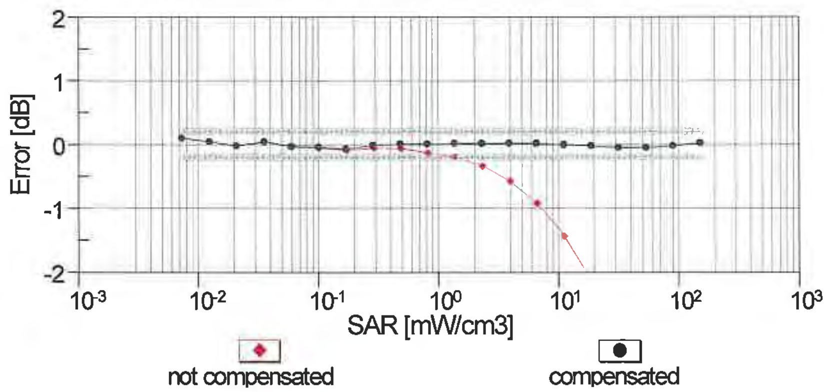




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

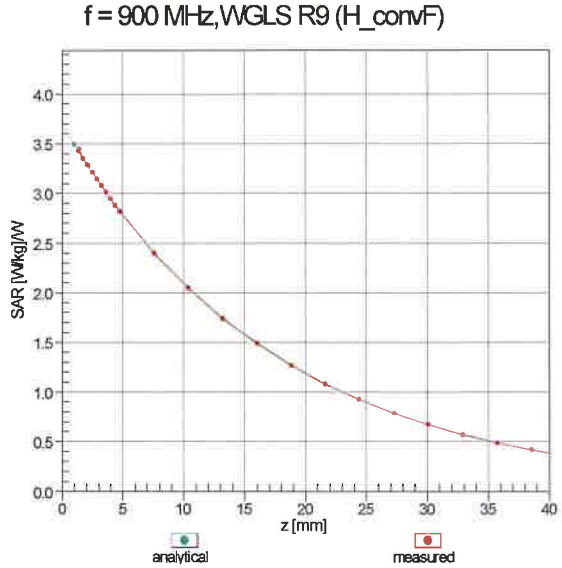
Dynamic Range f(SAR_{head})
(TEM cell , f_{eval}= 1900 MHz)

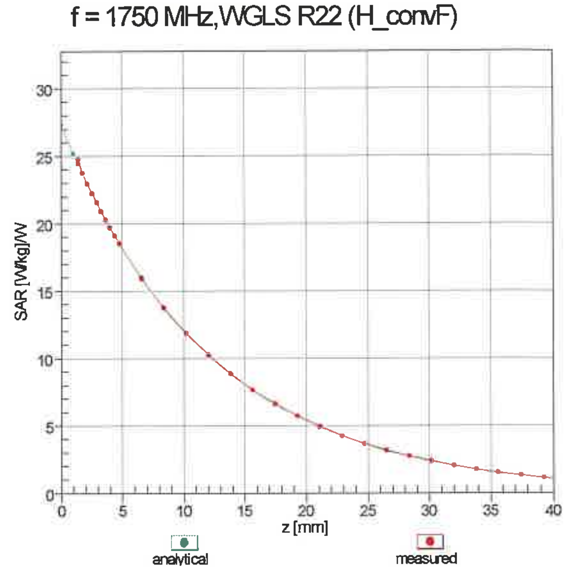




Uncertainty of Linearity Assessment: ± 0.6% (k=2)

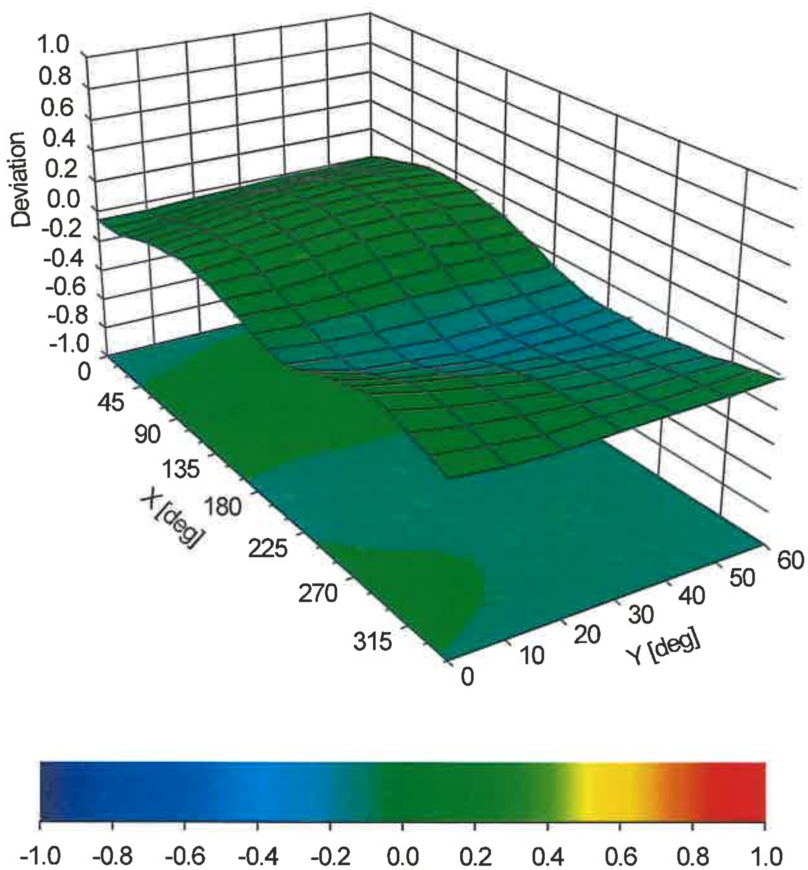
Conversion Factor Assessment





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**
Swiss Calibration Service

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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 **UL USA**

Certificate No: EX3-3989_Jan22

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3989
Calibration procedure(s)	QA CAL-01.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	January 19, 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
Power meter NRP	SN: 104778	09-Apr-21 (No. 217-03291/03292)	Apr-22
Power sensor NRP-Z91	SN: 103244	09-Apr-21 (No. 217-03291)	Apr-22
Power sensor NRP-Z91	SN: 103245	09-Apr-21 (No. 217-03292)	Apr-22
Reference 20 dB Attenuator	SN: CC2552 (20x)	09-Apr-21 (No. 217-03343)	Apr-22
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Jeffrey Katzman	Laboratory Technician	
Approved by:	Sven Kühn	Deputy Manager	

Issued: January 23, 2022

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 (no uncertainty required). 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3989

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.54	0.51	0.46	± 10.1 %
DCP (mV)[B]	101.7	99.1	101.1	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	140.0	± 2.7 %	± 4.7 %
		Y	0.00	0.00	1.00		142.5		
		Z	0.00	0.00	1.00		151.0		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	20.00	91.00	20.65	10.00	60.0	± 4.1 %	± 9.6 %
		Y	20.00	91.63	20.60		60.0		
		Z	20.00	90.66	20.56		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	92.42	20.15	6.99	80.0	± 2.5 %	± 9.6 %
		Y	20.00	93.05	20.36		80.0		
		Z	20.00	91.37	19.62		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	95.43	20.11	3.98	95.0	± 1.4 %	± 9.6 %
		Y	20.00	97.30	21.14		95.0		
		Z	20.00	92.30	18.48		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	97.36	19.61	2.22	120.0	± 1.1 %	± 9.6 %
		Y	20.00	101.93	21.94		120.0		
		Z	20.00	90.38	16.17		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.55	64.83	14.16	1.00	150.0	± 2.6 %	± 9.6 %
		Y	1.70	66.01	15.05		150.0		
		Z	1.58	65.55	14.44		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.05	66.69	14.88	0.00	150.0	± 0.8 %	± 9.6 %
		Y	2.28	68.27	15.81		150.0		
		Z	2.14	67.59	15.27		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	3.02	70.92	18.83	3.01	150.0	± 0.7 %	± 9.6 %
		Y	3.09	71.03	19.13		150.0		
		Z	2.90	70.01	18.39		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.37	66.48	15.33	0.00	150.0	± 2.1 %	± 9.6 %
		Y	3.54	67.20	15.83		150.0		
		Z	3.45	66.97	15.58		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.78	65.30	15.27	0.00	150.0	± 3.9 %	± 9.6 %
		Y	4.93	65.66	15.57		150.0		
		Z	4.85	65.65	15.48		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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3989

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	47.9	355.69	35.16	12.30	0.28	5.08	1.46	0.24	1.01
Y	51.3	386.77	36.15	15.82	0.00	5.10	0.88	0.36	1.01
Z	47.5	356.18	35.72	11.65	0.40	5.09	0.52	0.42	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-100.3
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.

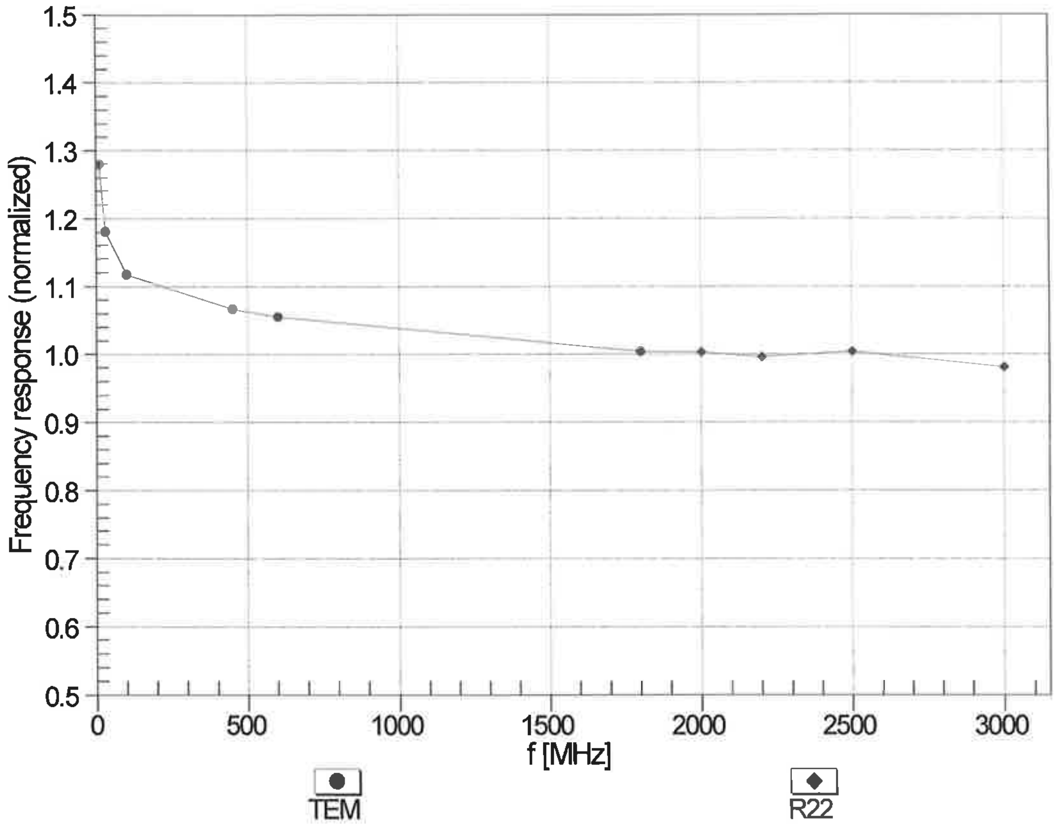
DASY/EASY - Parameters of Probe: EX3DV4 - SN:3989

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
750	41.9	0.89	10.59	10.59	10.59	0.44	0.80	± 12.0 %
900	41.5	0.97	10.18	10.18	10.18	0.44	0.80	± 12.0 %
1750	40.1	1.37	8.80	8.80	8.80	0.41	0.86	± 12.0 %
1900	40.0	1.40	8.43	8.43	8.43	0.42	0.86	± 12.0 %
2300	39.5	1.67	8.37	8.37	8.37	0.32	0.90	± 12.0 %
2450	39.2	1.80	8.04	8.04	8.04	0.39	0.90	± 12.0 %
2600	39.0	1.96	7.94	7.94	7.94	0.42	0.90	± 12.0 %
3300	38.2	2.71	7.30	7.30	7.30	0.30	1.35	± 13.1 %
3500	37.9	2.91	7.12	7.12	7.12	0.30	1.35	± 13.1 %
3700	37.7	3.12	7.05	7.05	7.05	0.30	1.35	± 13.1 %
3900	37.5	3.32	6.90	6.90	6.90	0.40	1.60	± 13.1 %
4100	37.2	3.53	6.70	6.70	6.70	0.40	1.60	± 13.1 %
4200	37.1	3.63	6.65	6.65	6.65	0.40	1.70	± 13.1 %
5250	35.9	4.71	5.35	5.35	5.35	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.80	4.80	4.80	0.40	1.80	± 13.1 %
5750	35.4	5.22	5.06	5.06	5.06	0.40	1.80	± 13.1 %

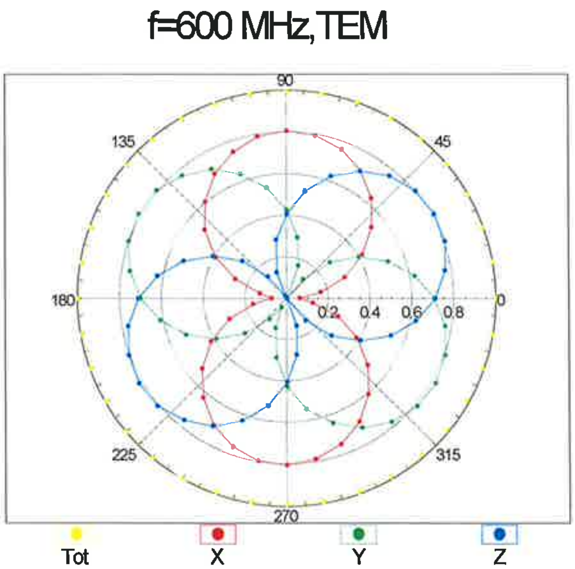
[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

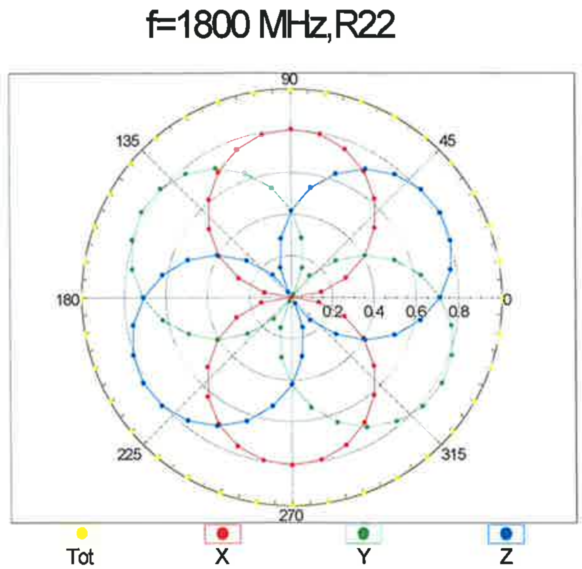
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)

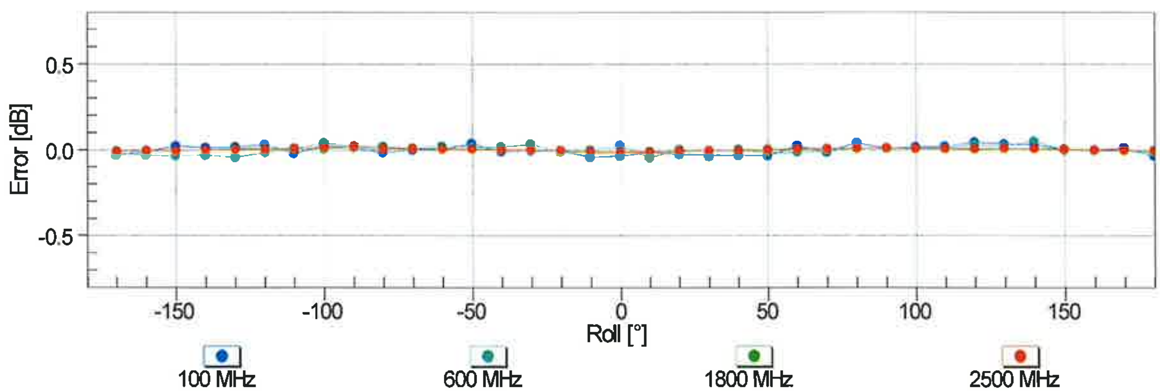


Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

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

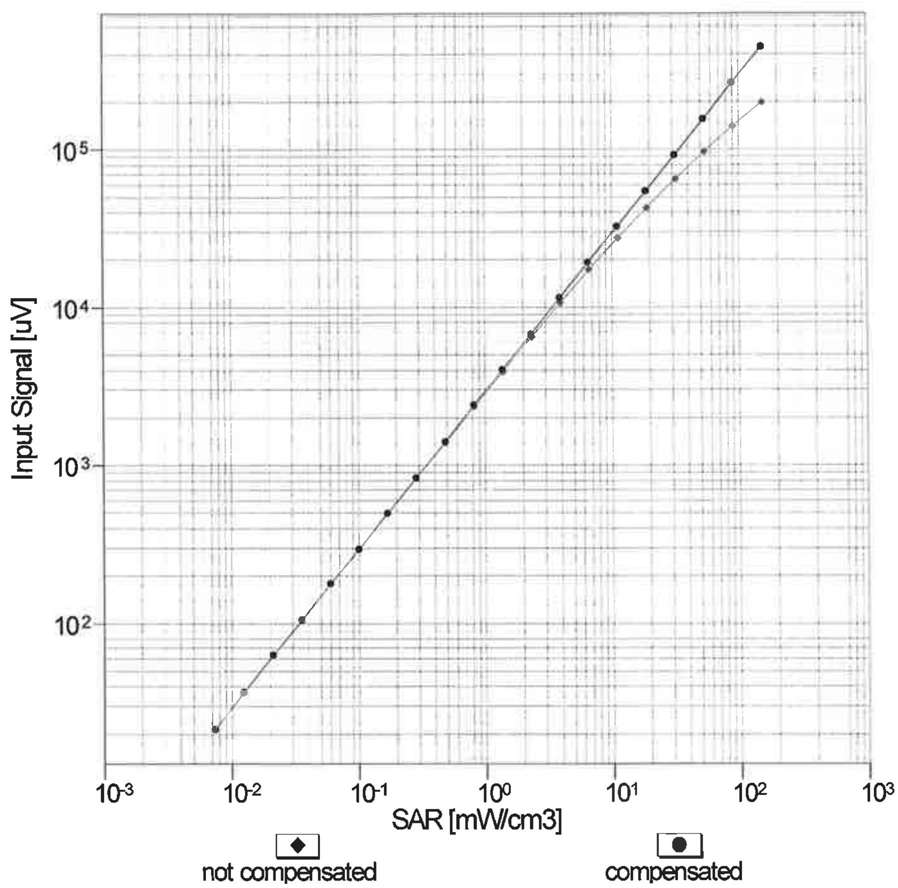


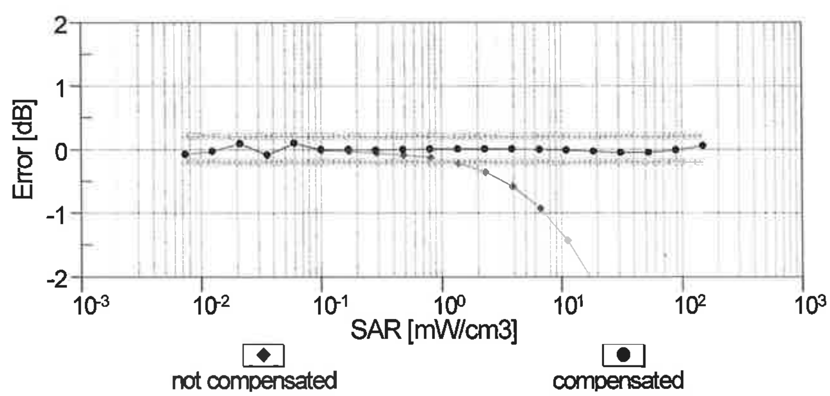




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

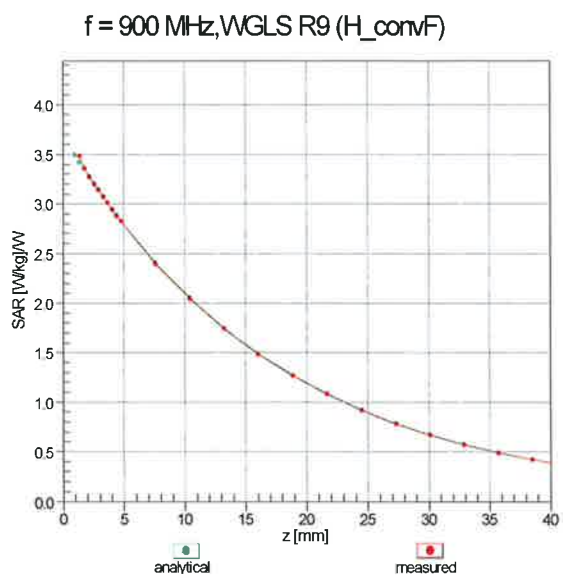
Dynamic Range f(SAR_{head})
(TEM cell , f_{eval}= 1900 MHz)

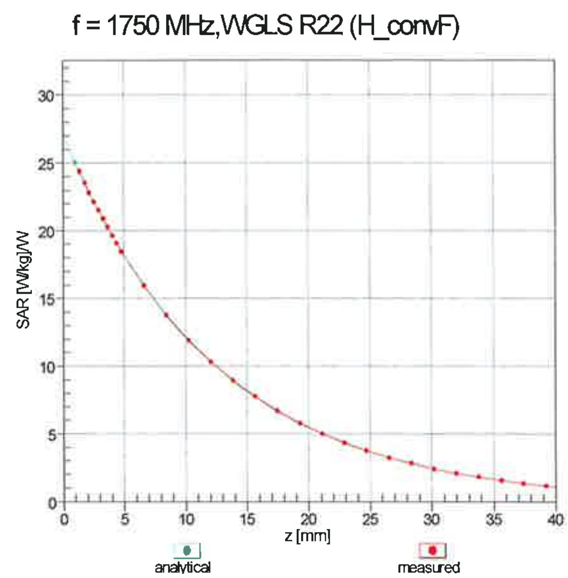




Uncertainty of Linearity Assessment: ± 0.6% (k=2)

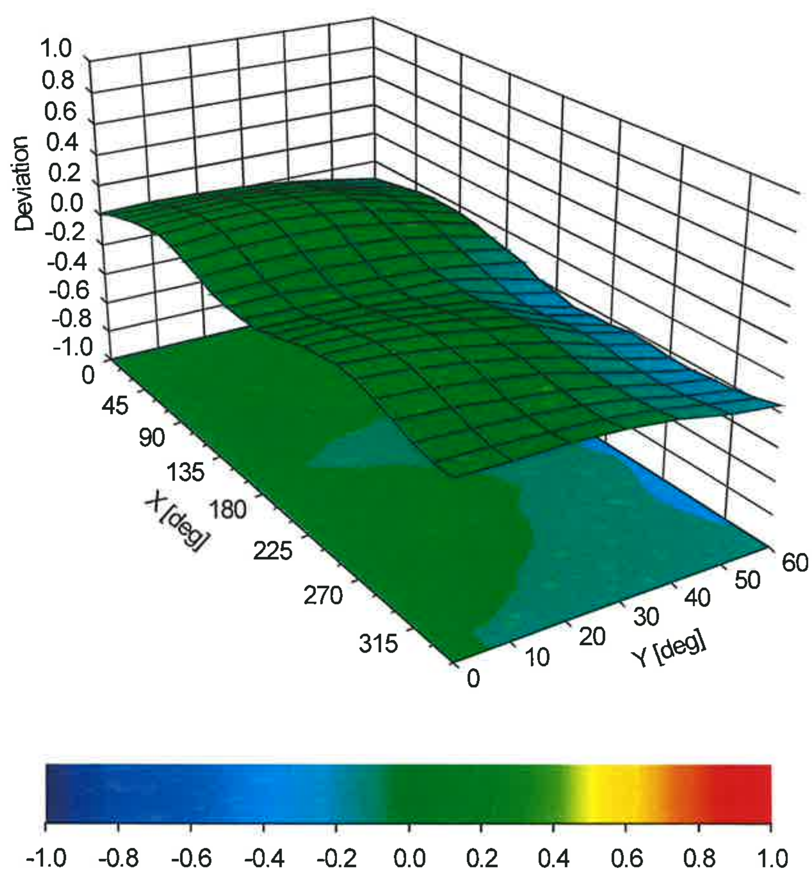
Conversion Factor Assessment





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**
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 USA**

Certificate No: EX3-7482_Apr22

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7482
Calibration procedure(s)	QA CAL-01.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	April 26, 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
Power meter NRP	SN: 104778	04-Apr-22 (No. 217-03525/03524)	Apr-23
Power sensor NRP-Z91	SN: 103244	04-Apr-22 (No. 217-03524)	Apr-23
Power sensor NRP-Z91	SN: 103245	04-Apr-22 (No. 217-03525)	Apr-23
Reference 20 dB Attenuator	SN: CC2552 (20x)	04-Apr-22 (No. 217-03527)	Apr-23
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Jeffrey Katzman	Laboratory Technician	
Approved by:	Sven Kühn	Deputy Manager	

Issued: April 27, 2022

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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., ϑ = 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 ϑ = 0 (f ≤ 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 (no uncertainty required). 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 ≤ 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7482

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.47	0.58	0.59	± 10.1 %
DCP (mV)[B]	97.2	97.8	98.2	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	155.5	± 2.7 %	± 4.7 %
		Y	0.00	0.00	1.00		157.7		
		Z	0.00	0.00	1.00		156.5		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	20.00	88.00	18.34	10.00	60.0	± 3.6 %	± 9.6 %
		Y	1.85	62.07	7.85		60.0		
		Z	15.16	85.53	17.76		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	89.60	17.72	6.99	80.0	± 2.4 %	± 9.6 %
		Y	1.15	60.78	6.45		80.0		
		Z	20.00	89.41	17.82		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	91.93	17.23	3.98	95.0	± 1.4 %	± 9.6 %
		Y	0.63	60.00	5.49		95.0		
		Z	20.00	92.42	17.87		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	90.16	15.13	2.22	120.0	± 1.1 %	± 9.6 %
		Y	0.38	60.00	5.21		120.0		
		Z	20.00	94.57	17.68		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.58	66.83	14.85	1.00	150.0	± 2.9 %	± 9.6 %
		Y	1.63	66.15	14.91		150.0		
		Z	1.61	65.22	14.23		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.13	67.89	15.70	0.00	150.0	± 1.1 %	± 9.6 %
		Y	2.16	67.57	15.60		150.0		
		Z	2.14	66.96	14.99		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.34	67.31	17.45	3.01	150.0	± 1.1 %	± 9.6 %
		Y	2.30	66.61	17.14		150.0		
		Z	2.59	67.95	17.51		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.47	67.10	15.83	0.00	150.0	± 1.6 %	± 9.6 %
		Y	3.46	66.87	15.70		150.0		
		Z	3.33	65.99	15.10		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.79	65.77	15.69	0.00	150.0	± 3.3 %	± 9.6 %
		Y	4.79	65.48	15.49		150.0		
		Z	4.71	64.94	15.11		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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7482

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	36.3	277.97	37.19	5.19	0.00	5.06	0.00	0.34	1.01
Y	41.3	310.41	35.89	13.97	0.00	4.94	0.00	0.33	1.01
Z	44.8	338.32	36.08	7.93	0.00	5.04	0.27	0.37	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-100.7
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.

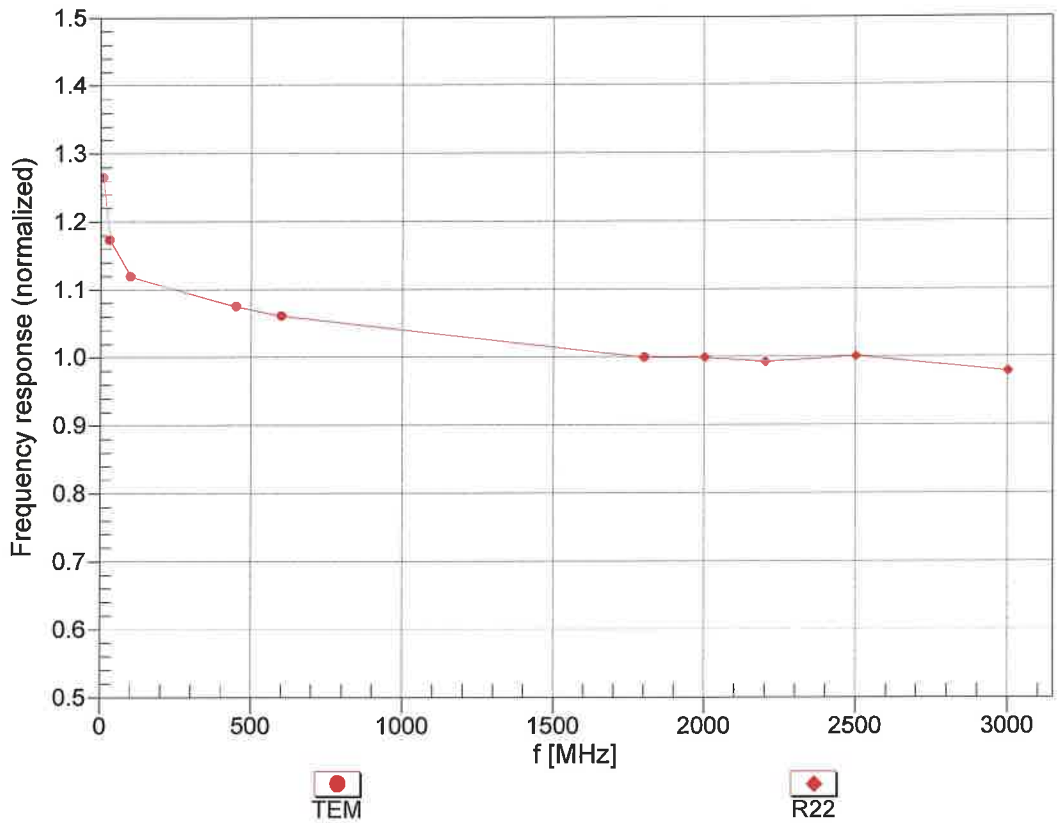
DASY/EASY - Parameters of Probe: EX3DV4 - SN:7482

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
750	41.9	0.89	9.44	9.44	9.44	0.44	0.92	± 12.0 %
900	41.5	0.97	9.01	9.01	9.01	0.34	1.03	± 12.0 %
1750	40.1	1.37	8.39	8.39	8.39	0.29	0.86	± 12.0 %
1900	40.0	1.40	8.12	8.12	8.12	0.33	0.86	± 12.0 %
2300	39.5	1.67	7.52	7.52	7.52	0.32	0.90	± 12.0 %
2450	39.2	1.80	7.23	7.23	7.23	0.41	0.90	± 12.0 %
2600	39.0	1.96	7.06	7.06	7.06	0.39	0.90	± 12.0 %
5250	35.9	4.71	5.54	5.54	5.54	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.66	4.66	4.66	0.40	1.80	± 13.1 %
5750	35.4	5.22	4.90	4.90	4.90	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

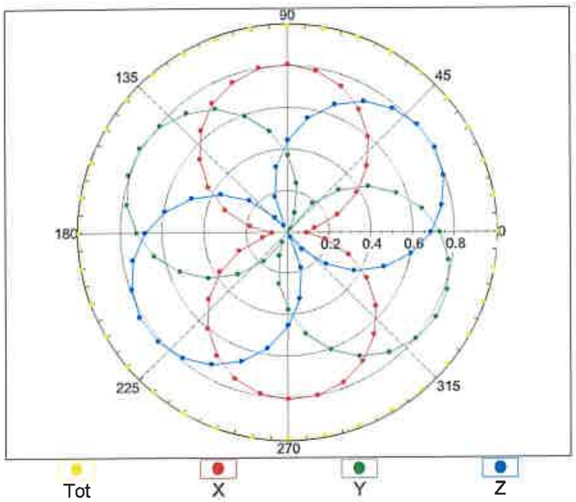
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)



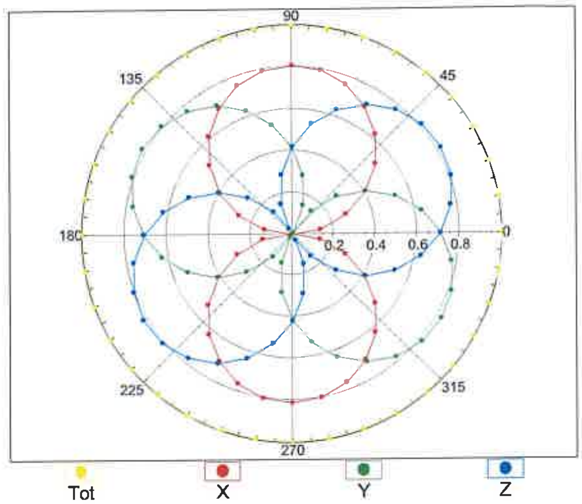
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

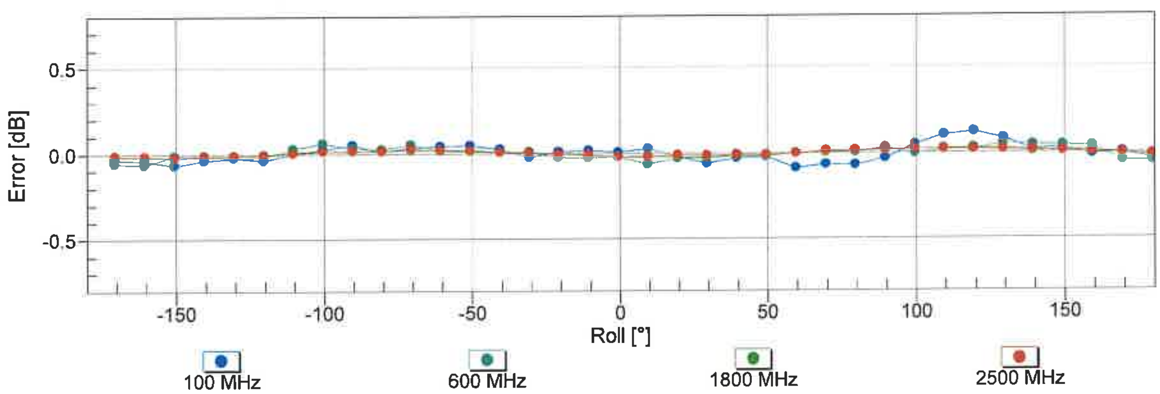
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



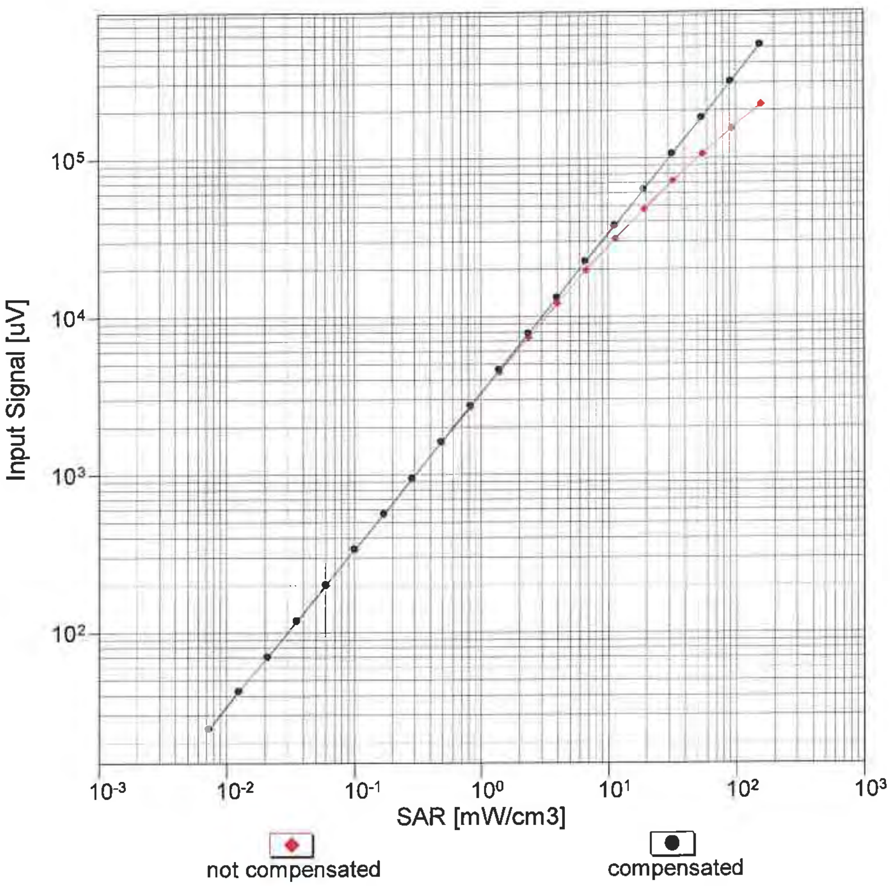
f=1800 MHz,R22

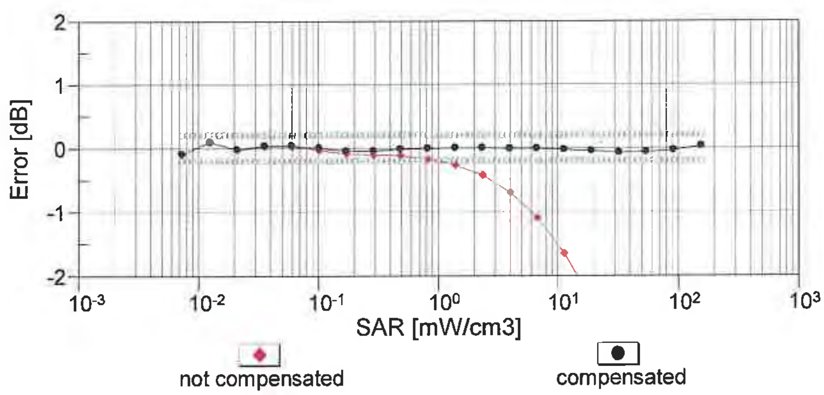




Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

Dynamic Range f(SAR_{head})
(TEM cell , f_{eval}= 1900 MHz)

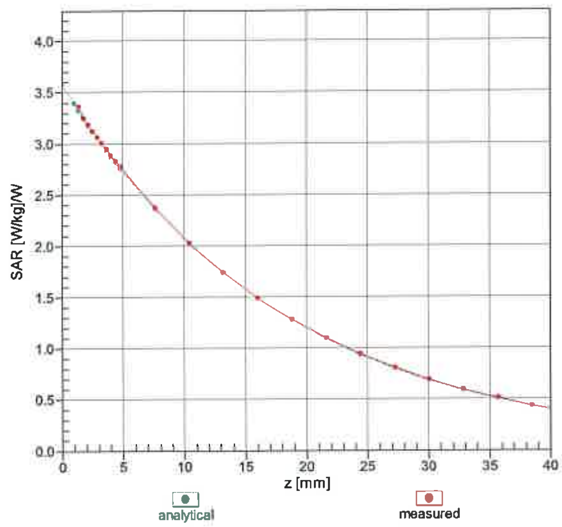




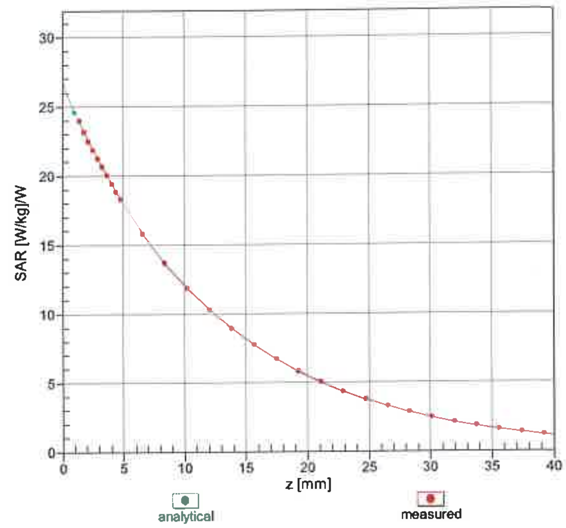
Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment

f = 900 MHz,WGLS R9 (H_convF)

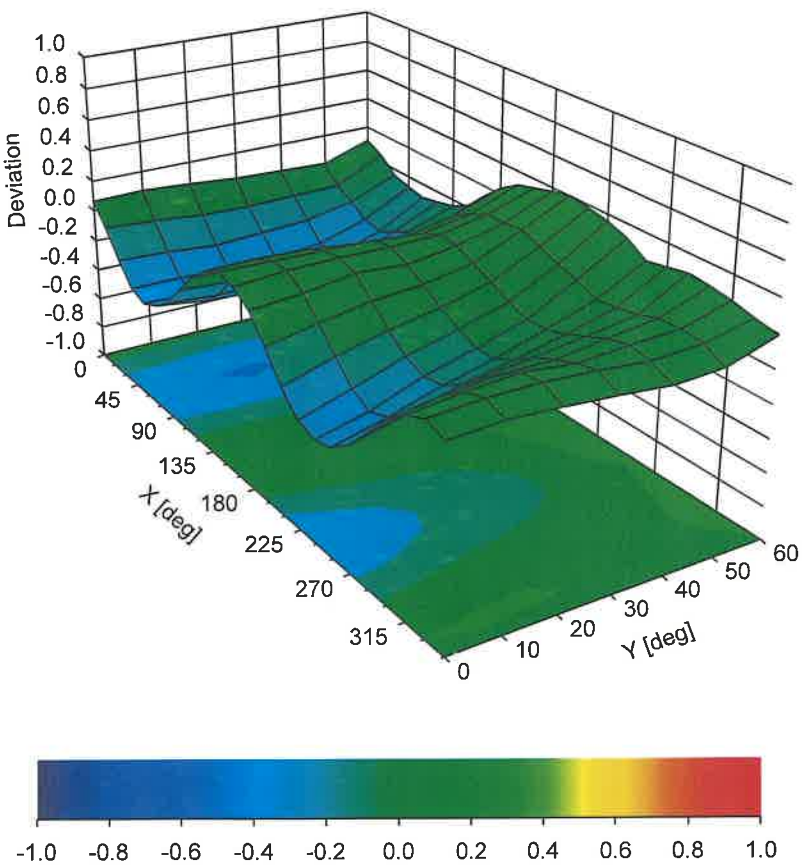


f = 1750 MHz,WGLS R22 (H_convF)



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**
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 USA**

Certificate No: EX3-3686_Jan22

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3686
Calibration procedure(s)	QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	January 18, 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
Power meter NRP	SN: 104778	09-Apr-21 (No. 217-03291/03292)	Apr-22
Power sensor NRP-Z91	SN: 103244	09-Apr-21 (No. 217-03291)	Apr-22
Power sensor NRP-Z91	SN: 103245	09-Apr-21 (No. 217-03292)	Apr-22
Reference 20 dB Attenuator	SN: CC2552 (20x)	09-Apr-21 (No. 217-03343)	Apr-22
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

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

Issued: January 23, 2022

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 (no uncertainty required). 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3686

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm (µV/(V/m)²)[A]	0.33	0.40	0.40	± 10.1 %
DCP (mV)[B]	105.1	101.7	99.5	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√µV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	142.8	± 3.3 %	± 4.7 %
		Y	0.00	0.00	1.00		138.5		
		Z	0.00	0.00	1.00		133.4		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	10.00	80.00	17.00	10.00	60.0	± 3.2 %	± 9.6 %
		Y	20.00	92.35	21.49		60.0		
		Z	74.00	110.00	27.00		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	3.43	70.25	12.20	6.99	80.0	± 1.8 %	± 9.6 %
		Y	20.00	94.44	21.48		80.0		
		Z	20.00	92.53	20.94		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	1.81	67.41	9.74	3.98	95.0	± 1.1 %	± 9.6 %
		Y	20.00	99.11	22.29		95.0		
		Z	20.00	92.69	19.37		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	0.44	60.72	5.74	2.22	120.0	± 1.0 %	± 9.6 %
		Y	20.00	98.03	20.37		120.0		
		Z	20.00	91.37	17.25		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.34	64.93	13.56	1.00	150.0	± 3.3 %	± 9.6 %
		Y	1.67	66.46	15.00		150.0		
		Z	1.51	64.97	13.92		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	1.82	66.09	14.51	0.00	150.0	± 0.9 %	± 9.6 %
		Y	2.26	68.43	15.81		150.0		
		Z	2.03	66.77	14.79		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.57	68.60	17.56	3.01	150.0	± 0.7 %	± 9.6 %
		Y	2.79	69.48	18.28		150.0		
		Z	2.84	68.99	17.92		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.34	66.94	15.47	0.00	150.0	± 2.7 %	± 9.6 %
		Y	3.55	67.44	15.87		150.0		
		Z	3.38	66.58	15.34		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.67	65.72	15.42	0.00	150.0	± 4.6 %	± 9.6 %
		Y	4.73	65.28	15.32		150.0		
		Z	4.80	65.51	15.39		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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3686

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	36.0	264.51	34.41	11.35	0.91	5.01	0.73	0.33	1.01
Y	45.3	336.89	35.22	15.93	0.26	5.10	0.26	0.41	1.01
Z	45.0	340.05	36.25	16.37	0.79	5.10	0.00	0.56	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-114.4
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.

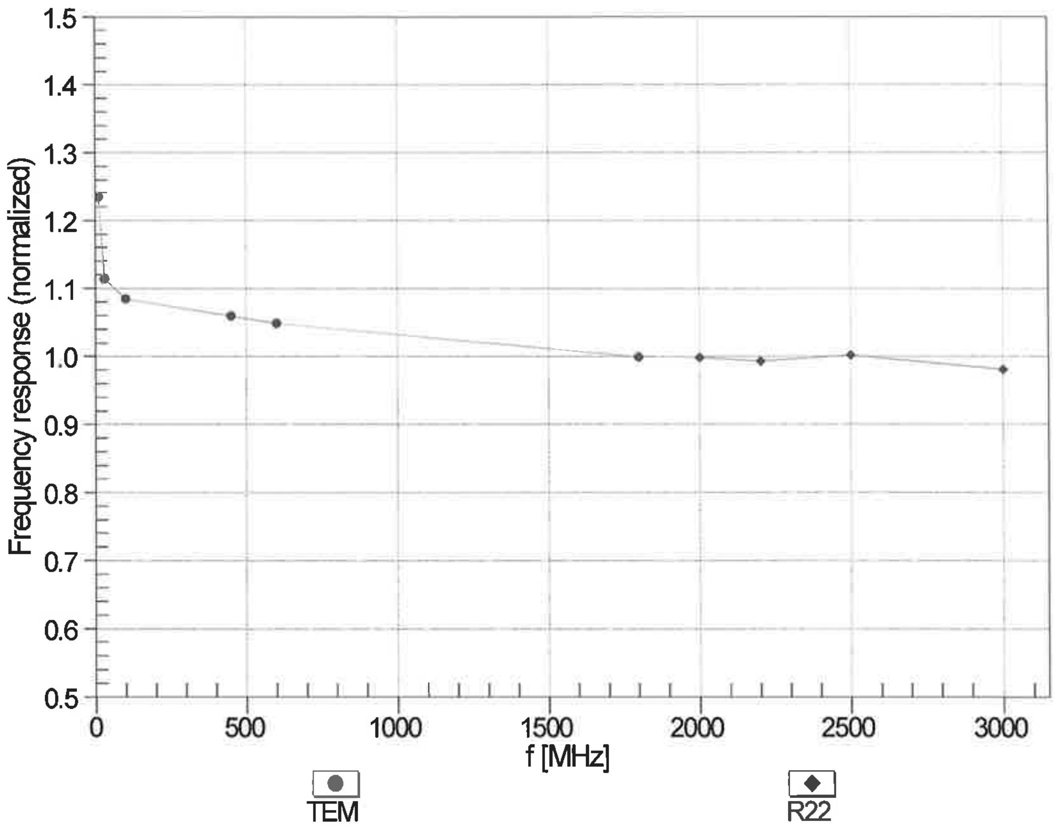
DASY/EASY - Parameters of Probe: EX3DV4 - SN:3686

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
450	43.5	0.87	9.70	9.70	9.70	0.16	1.30	± 13.3 %
750	41.9	0.89	9.75	9.75	9.75	0.45	0.80	± 12.0 %
900	41.5	0.97	9.20	9.20	9.20	0.52	0.80	± 12.0 %
1450	40.5	1.20	7.76	7.76	7.76	0.24	0.80	± 12.0 %
1640	40.2	1.31	7.68	7.68	7.68	0.37	0.86	± 12.0 %
1750	40.1	1.37	7.67	7.67	7.67	0.33	0.86	± 12.0 %
1900	40.0	1.40	7.52	7.52	7.52	0.28	0.86	± 12.0 %
2300	39.5	1.67	7.31	7.31	7.31	0.36	0.95	± 12.0 %
2450	39.2	1.80	7.09	7.09	7.09	0.29	0.95	± 12.0 %
2600	39.0	1.96	6.99	6.99	6.99	0.36	0.95	± 12.0 %
5250	35.9	4.71	5.15	5.15	5.15	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.55	4.55	4.55	0.40	1.80	± 13.1 %
5750	35.4	5.22	4.50	4.50	4.50	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

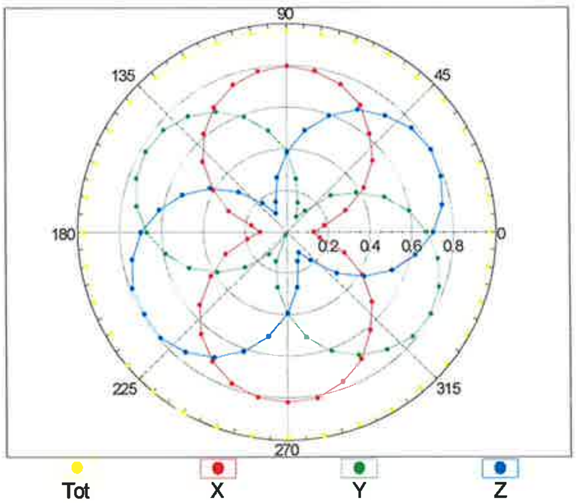
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)



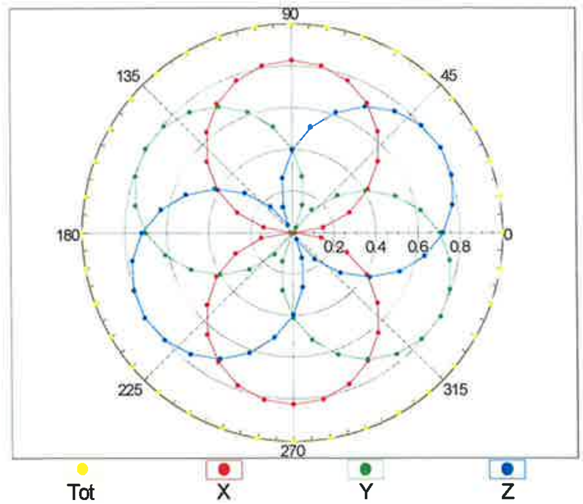
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

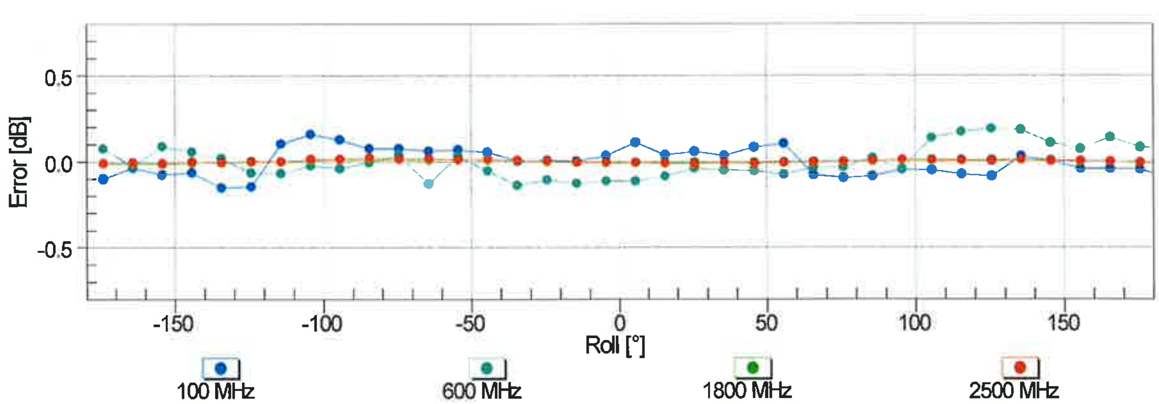
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



f=1800 MHz,R22

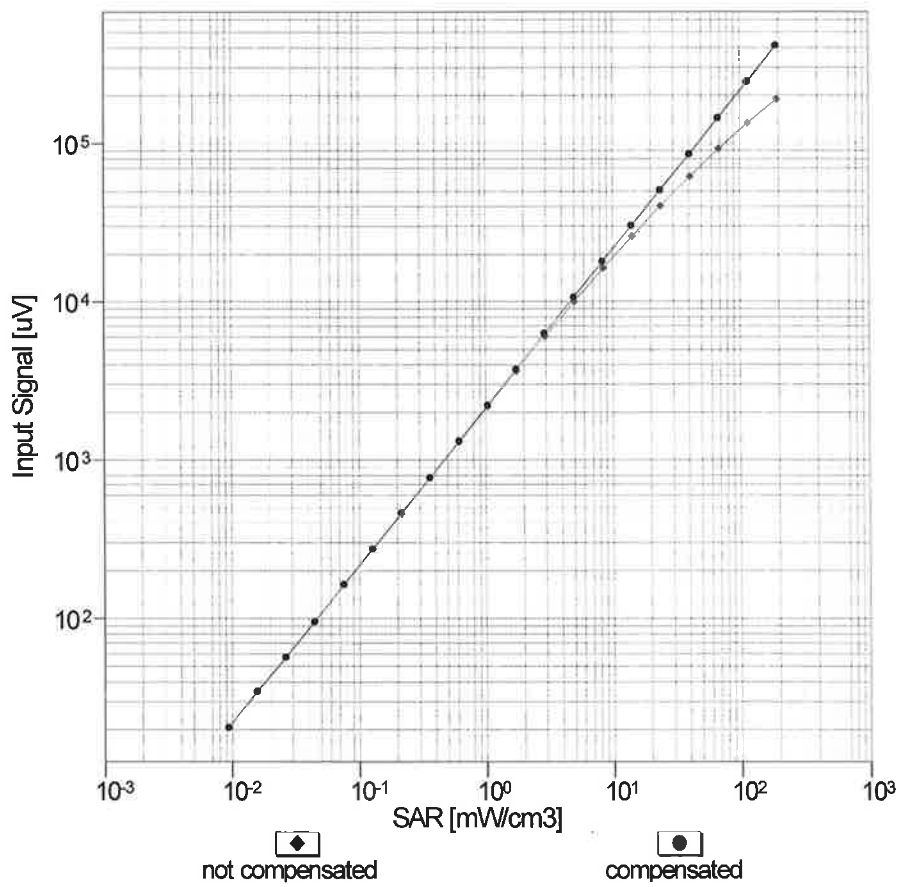


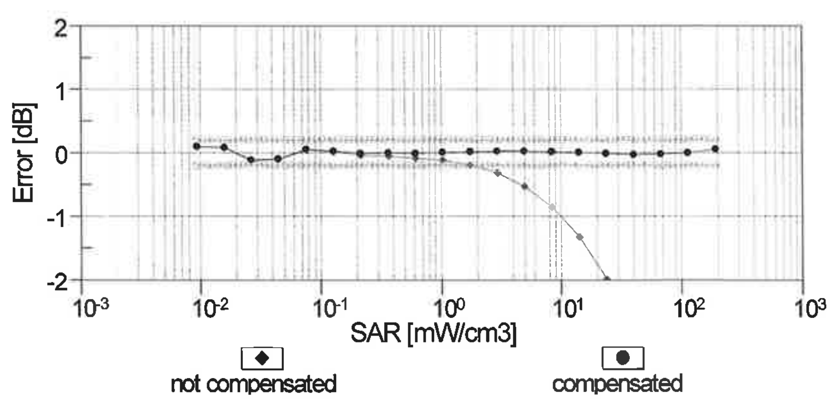


Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

Dynamic Range f(SAR_{head})

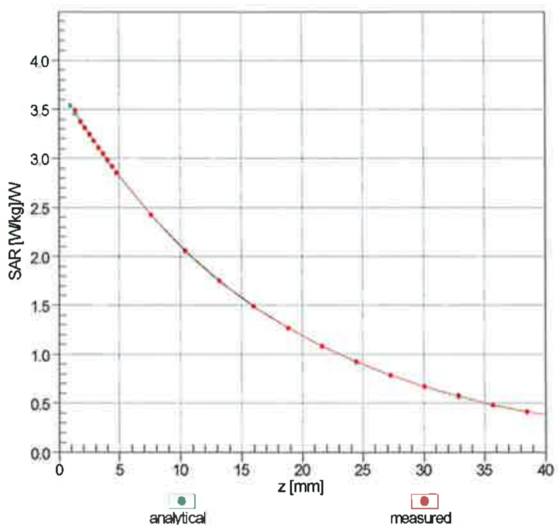
(TEM cell , f_{eval}= 1900 MHz)

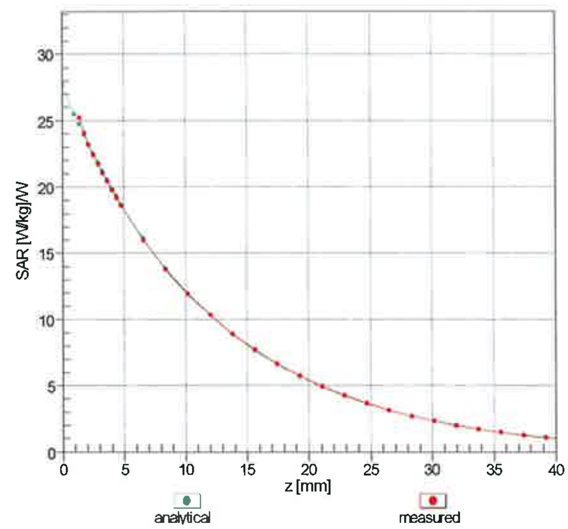




Uncertainty of Linearity Assessment: ± 0.6% (k=2)

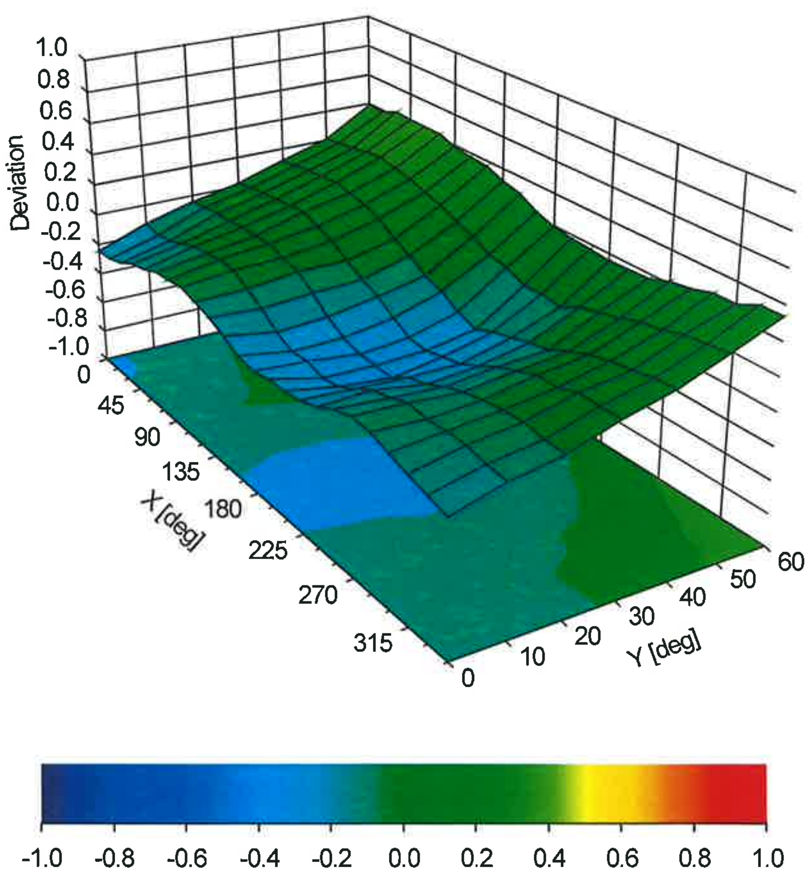
Conversion Factor Assessment





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
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 USA

Certificate No: EX3-7589_Apr22

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:7589
Calibration procedure(s)	QA CAL-01.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	April 28, 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
Power meter NRP	SN: 104778	04-Apr-22 (No. 217-03525/03524)	Apr-23
Power sensor NRP-Z91	SN: 103244	04-Apr-22 (No. 217-03524)	Apr-23
Power sensor NRP-Z91	SN: 103245	04-Apr-22 (No. 217-03525)	Apr-23
Reference 20 dB Attenuator	SN: CC2552 (20x)	04-Apr-22 (No. 217-03527)	Apr-23
DAE4	SN: 660	13-Oct-21 (No. DAE4-660_Oct21)	Oct-22
Reference Probe ES3DV2	SN: 3013	27-Dec-21 (No. ES3-3013_Dec21)	Dec-22
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

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

Issued: April 28, 2022

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., ϑ = 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 ϑ = 0 (f ≤ 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 (no uncertainty required). 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 ≤ 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7589

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm (µV/(V/m)^2)[A]	0.65	0.53	0.62	± 10.1 %
DCP (mV)[B]	101.0	100.0	97.0	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√µV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	166.3	± 2.2 %	± 4.7 %
		Y	0.00	0.00	1.00		153.4		
		Z	0.00	0.00	1.00		158.7		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	20.00	92.61	21.96	10.00	60.0	± 3.0 %	± 9.6 %
		Y	16.98	85.33	17.80		60.0		
		Z	20.00	92.42	21.35		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	93.47	21.35	6.99	80.0	± 1.7 %	± 9.6 %
		Y	20.00	87.22	17.46		80.0		
		Z	20.00	94.75	21.43		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	96.54	21.51	3.98	95.0	± 1.0 %	± 9.6 %
		Y	20.00	89.24	17.35		95.0		
		Z	20.00	99.31	22.26		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	100.53	22.05	2.22	120.0	± 0.9 %	± 9.6 %
		Y	20.00	93.01	18.10		120.0		
		Z	20.00	103.14	22.70		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.70	64.93	14.59	1.00	150.0	± 2.4 %	± 9.6 %
		Y	1.77	66.44	15.24		150.0		
		Z	1.61	64.27	14.01		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.23	67.34	15.23	0.00	150.0	± 1.0 %	± 9.6 %
		Y	2.37	68.57	15.98		150.0		
		Z	2.09	66.20	14.65		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	3.24	70.74	18.74	3.01	150.0	± 1.2 %	± 9.6 %
		Y	2.50	67.27	17.36		150.0		
		Z	2.90	69.48	18.30		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.52	66.86	15.55	0.00	150.0	± 1.4 %	± 9.6 %
		Y	3.50	66.86	15.67		150.0		
		Z	3.45	66.31	15.28		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.97	65.50	15.40	0.00	150.0	± 2.9 %	± 9.6 %
		Y	4.88	65.45	15.47		150.0		
		Z	4.88	65.20	15.27		150.0		

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] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7589

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	59.0	440.74	35.51	20.17	0.23	5.10	0.92	0.44	1.01
Y	48.9	368.31	36.03	19.77	0.00	5.04	0.00	0.42	1.01
Z	52.1	397.53	36.71	14.36	0.00	5.09	1.09	0.31	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-123.2
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.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7589

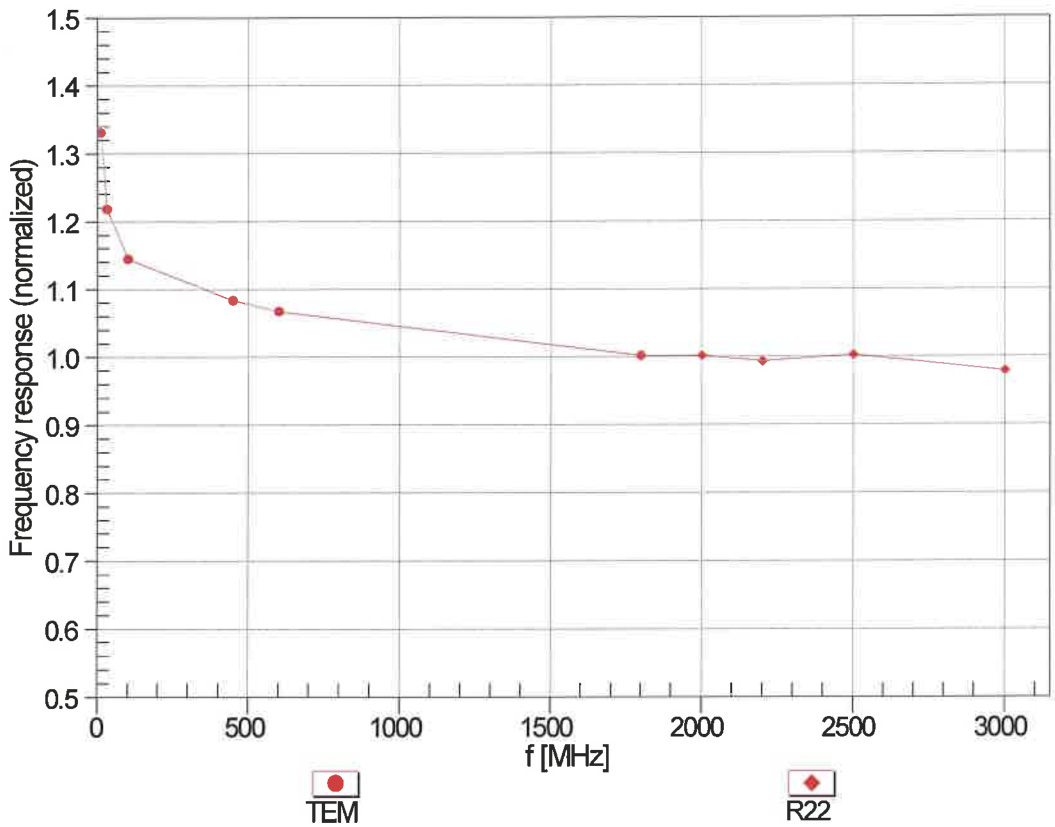
Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
750	41.9	0.89	10.63	10.63	10.63	0.42	0.90	± 12.0 %
900	41.5	0.97	10.09	10.09	10.09	0.51	0.80	± 12.0 %
1750	40.1	1.37	8.67	8.67	8.67	0.35	0.86	± 12.0 %
1900	40.0	1.40	8.35	8.35	8.35	0.30	0.86	± 12.0 %
2300	39.5	1.67	8.26	8.26	8.26	0.33	0.90	± 12.0 %
2450	39.2	1.80	7.91	7.91	7.91	0.38	0.90	± 12.0 %
2600	39.0	1.96	7.62	7.62	7.62	0.40	0.90	± 12.0 %
5250	35.9	4.71	5.59	5.59	5.59	0.40	1.80	± 13.1 %
5600	35.5	5.07	5.05	5.05	5.05	0.40	1.80	± 13.1 %
5750	35.4	5.22	5.13	5.13	5.13	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

Frequency Response of E-Field

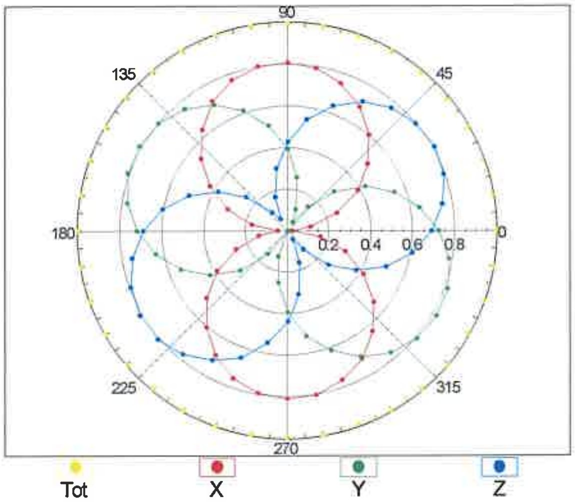
(TEM-Cell:ifi110 EXX, Waveguide: R22)



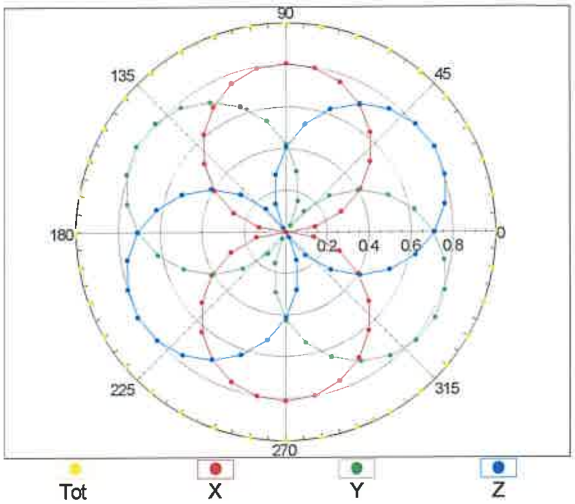
Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

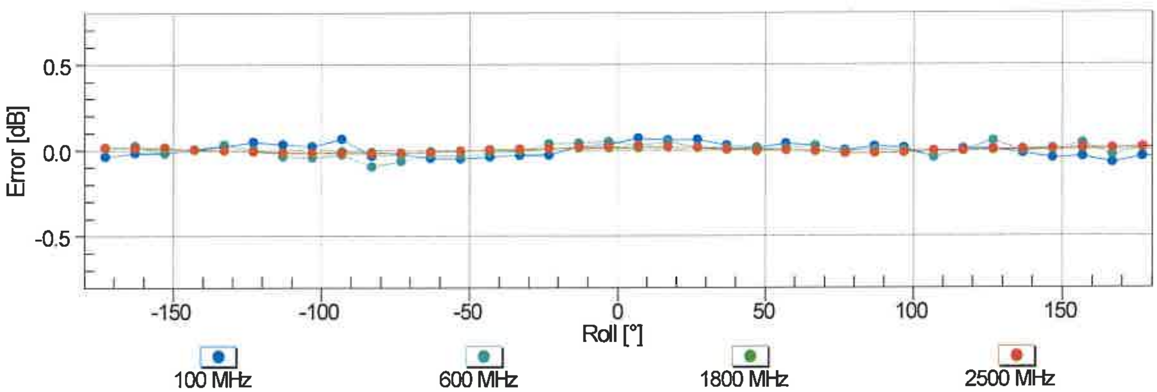
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



f=1800 MHz,R22

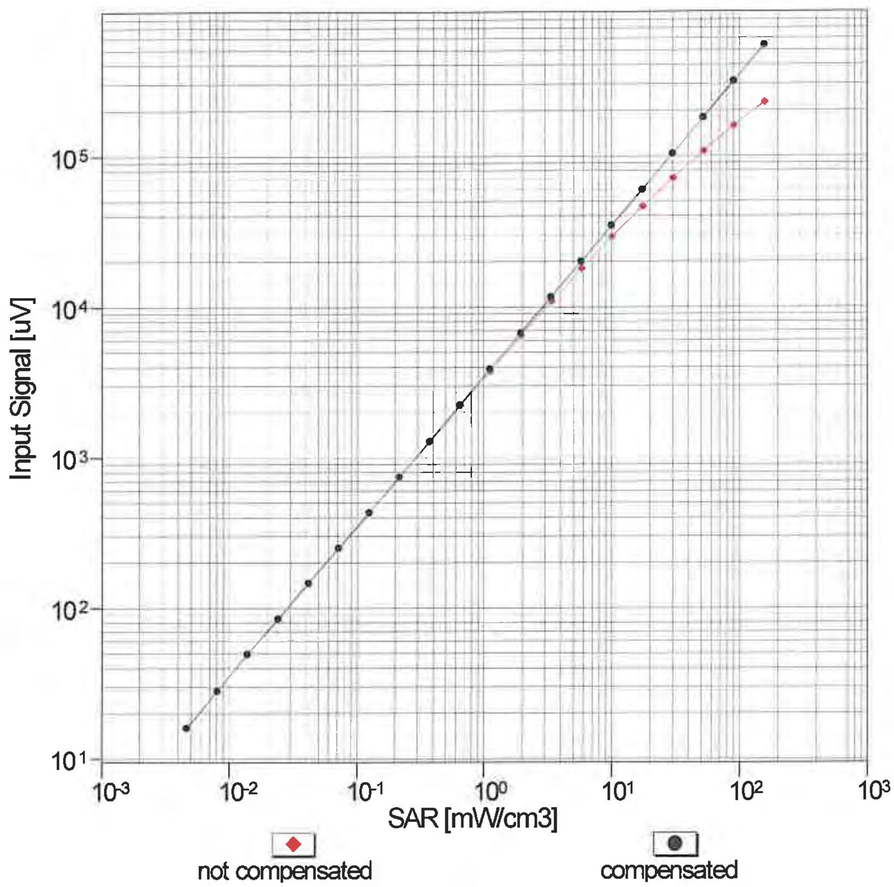


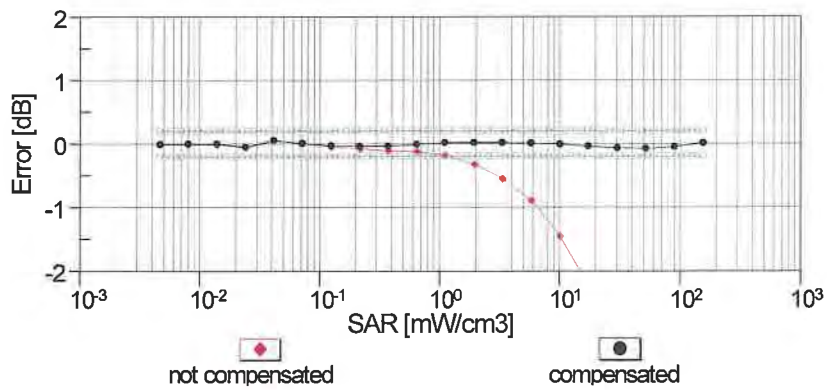


Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

Dynamic Range f(SAR_{head})

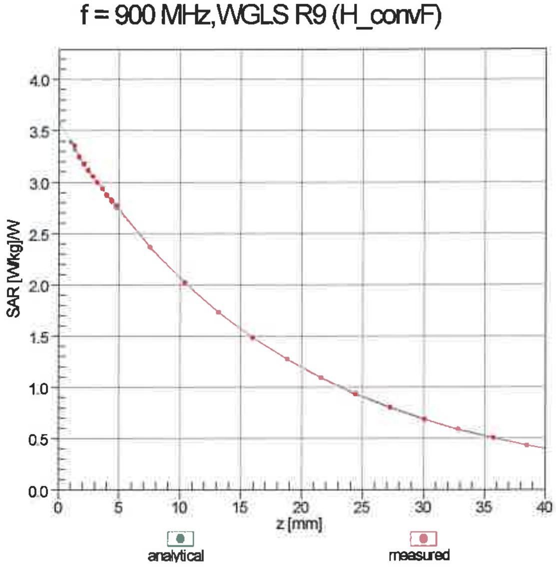
(TEM cell , f_{eval}= 1900 MHz)

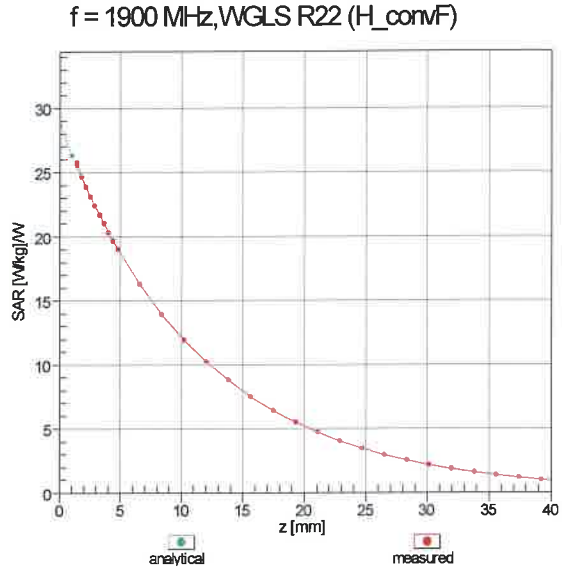




Uncertainty of Linearity Assessment: ± 0.6% (k=2)

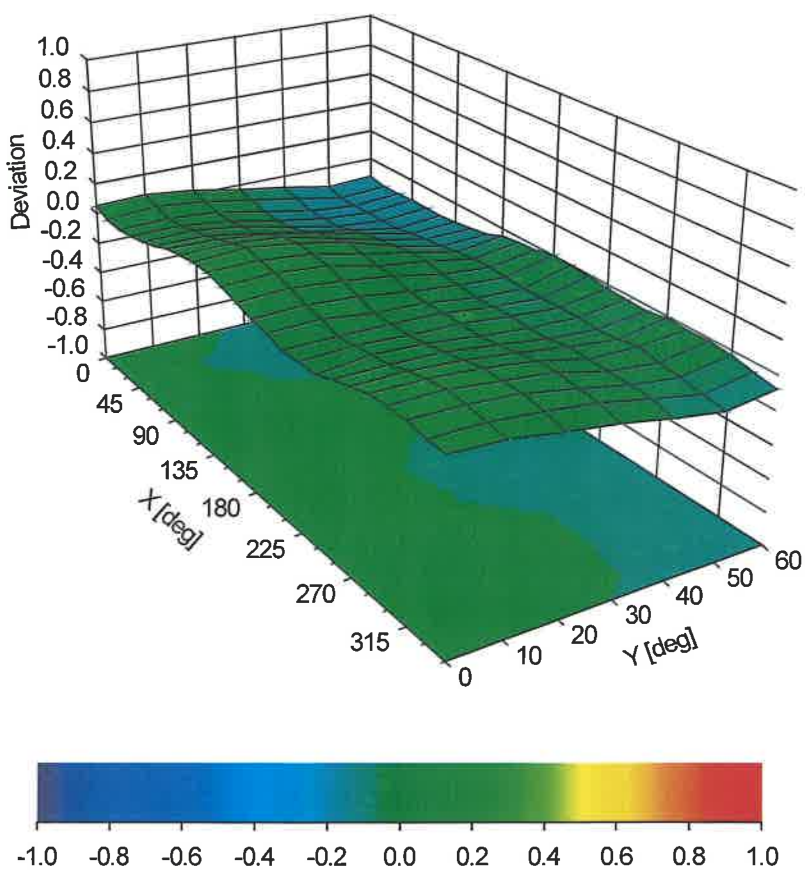
Conversion Factor Assessment





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**
Swiss Calibration Service

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Accreditation No.: SCS 0108

Client **Apple USA**

Certificate No: EX3-3988_Oct21

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3988
Calibration procedure(s)	QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	October 27, 2021

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 meter NRP	SN: 104778	09-Apr-21 (No. 217-03291/03292)	Apr-22
Power sensor NRP-Z91	SN: 103244	09-Apr-21 (No. 217-03291)	Apr-22
Power sensor NRP-Z91	SN: 103245	09-Apr-21 (No. 217-03292)	Apr-22
Reference 20 dB Attenuator	SN: CC2552 (20x)	09-Apr-21 (No. 217-03343)	Apr-22
DAE4	SN: 660	23-Dec-20 (No. DAE4-660_Dec20)	Dec-21
Reference Probe ES3DV2	SN: 3013	30-Dec-20 (No. ES3-3013_Dec20)	Dec-21
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Jeton Kastrati	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: October 29, 2021

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., ϑ = 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 ϑ = 0 (f ≤ 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 (no uncertainty required). 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 ≤ 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).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3988

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.37	0.43	0.27	± 10.1 %
DCP (mV)[B]	104.5	104.9	97.9	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	136.8	± 2.7 %	± 4.7 %
		Y	0.00	0.00	1.00		128.2		
		Z	0.00	0.00	1.00		129.3		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	20.00	90.99	20.85	10.00	60.0	± 3.1 %	± 9.6 %
		Y	10.05	81.83	18.04		60.0		
		Z	20.00	92.54	21.28		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	92.58	20.47	6.99	80.0	± 1.6 %	± 9.6 %
		Y	20.00	90.15	19.26		80.0		
		Z	20.00	96.56	22.03		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	97.63	21.57	3.98	95.0	± 1.2 %	± 9.6 %
		Y	20.00	91.96	18.70		95.0		
		Z	20.00	105.30	24.75		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	101.90	22.43	2.22	120.0	± 1.2 %	± 9.6 %
		Y	20.00	95.90	19.38		120.0		
		Z	20.00	116.32	28.44		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.74	66.87	15.29	1.00	150.0	± 1.7 %	± 9.6 %
		Y	1.63	65.60	14.62		150.0		
		Z	1.72	66.12	15.08		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.29	68.48	15.93	0.00	150.0	± 1.0 %	± 9.6 %
		Y	2.15	67.38	15.30		150.0		
		Z	2.27	67.91	15.76		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.76	70.26	18.45	3.01	150.0	± 0.8 %	± 9.6 %
		Y	3.01	71.27	18.85		150.0		
		Z	2.38	67.53	17.52		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.43	66.93	15.60	0.00	150.0	± 0.8 %	± 9.6 %
		Y	3.48	67.04	15.58		150.0		
		Z	3.42	66.48	15.52		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.77	65.60	15.37	0.00	150.0	± 1.6 %	± 9.6 %
		Y	4.66	65.08	15.09		150.0		
		Z	4.77	65.17	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, 6 and 7).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3988

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	295.39	32.52	12.72	0.35	5.02	2.00	0.01	1.00
Y	44.4	318.34	33.10	11.89	0.63	5.00	1.83	0.09	1.01
Z	45.2	338.41	35.72	8.30	0.08	5.06	0.69	0.18	1.00

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	164.5
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.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3988

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
600	42.7	0.88	10.59	10.59	10.59	0.10	1.25	± 13.3 %
750	41.9	0.89	10.44	10.44	10.44	0.46	0.92	± 12.0 %
835	41.5	0.90	10.36	10.36	10.36	0.42	0.80	± 12.0 %
900	41.5	0.97	10.00	10.00	10.00	0.26	1.30	± 12.0 %
1450	40.5	1.20	8.94	8.94	8.94	0.37	0.80	± 12.0 %
1640	40.2	1.31	8.77	8.77	8.77	0.31	0.86	± 12.0 %
1750	40.1	1.37	8.71	8.71	8.71	0.30	0.88	± 12.0 %
1900	40.0	1.40	8.44	8.44	8.44	0.32	0.88	± 12.0 %
2000	40.0	1.40	8.39	8.39	8.39	0.39	0.88	± 12.0 %
2300	39.5	1.67	8.03	8.03	8.03	0.34	0.90	± 12.0 %
2450	39.2	1.80	7.78	7.78	7.78	0.38	0.90	± 12.0 %
2600	39.0	1.96	7.54	7.54	7.54	0.44	0.90	± 12.0 %
3300	38.2	2.71	6.97	6.97	6.97	0.40	1.20	± 13.1 %
3500	37.9	2.91	6.83	6.83	6.83	0.35	1.20	± 13.1 %
3700	37.7	3.12	6.80	6.80	6.80	0.40	1.20	± 13.1 %
3900	37.5	3.32	6.60	6.60	6.60	0.45	1.60	± 13.1 %
4100	37.2	3.53	6.38	6.38	6.38	0.45	1.60	± 13.1 %
4200	37.1	3.63	6.25	6.25	6.25	0.45	1.60	± 13.1 %
4400	36.9	3.84	6.23	6.23	6.23	0.40	1.60	± 13.1 %
4600	36.7	4.04	6.10	6.10	6.10	0.40	1.70	± 13.1 %
4800	36.4	4.25	5.90	5.90	5.90	0.40	1.70	± 13.1 %
4950	36.3	4.40	5.78	5.78	5.78	0.40	1.70	± 13.1 %
5200	36.0	4.66	5.05	5.05	5.05	0.40	1.80	± 13.1 %
5300	35.9	4.76	5.20	5.20	5.20	0.40	1.80	± 13.1 %
5500	35.6	4.96	5.10	5.10	5.10	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.90	4.90	4.90	0.40	1.80	± 13.1 %
5800	35.3	5.27	5.00	5.00	5.00	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3988

Calibration Parameter Determined in Body Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
600	56.1	0.95	10.91	10.91	10.91	0.10	1.20	± 13.3 %
750	55.5	0.96	10.37	10.37	10.37	0.45	0.83	± 12.0 %
835	55.2	0.97	10.19	10.19	10.19	0.48	0.80	± 12.0 %
900	55.0	1.05	10.08	10.08	10.08	0.41	0.86	± 12.0 %
1450	54.0	1.30	8.88	8.88	8.88	0.29	0.80	± 12.0 %
1640	53.7	1.42	8.70	8.70	8.70	0.40	0.88	± 12.0 %
1750	53.4	1.49	8.34	8.34	8.34	0.43	0.88	± 12.0 %
1900	53.3	1.52	8.20	8.20	8.20	0.28	0.88	± 12.0 %
2000	53.3	1.52	8.12	8.12	8.12	0.30	0.88	± 12.0 %
2300	52.9	1.81	7.90	7.90	7.90	0.39	0.90	± 12.0 %
2450	52.7	1.95	7.86	7.86	7.86	0.30	0.90	± 12.0 %
2600	52.5	2.16	7.63	7.63	7.63	0.40	0.90	± 12.0 %
3300	51.6	3.08	6.65	6.65	6.65	0.40	1.30	± 13.1 %
3500	51.3	3.31	6.52	6.52	6.52	0.40	1.30	± 13.1 %
3700	51.0	3.55	6.47	6.47	6.47	0.40	1.30	± 13.1 %
3900	50.8	3.78	6.28	6.28	6.28	0.45	1.75	± 13.1 %
4100	50.5	4.01	6.13	6.13	6.13	0.45	1.75	± 13.1 %
4200	50.4	4.13	6.01	6.01	6.01	0.45	1.80	± 13.1 %
4400	50.1	4.37	5.98	5.98	5.98	0.40	1.80	± 13.1 %
4600	49.8	4.60	5.95	5.95	5.95	0.40	1.80	± 13.1 %
4800	49.6	4.83	5.40	5.40	5.40	0.50	1.90	± 13.1 %
4950	49.4	5.01	5.10	5.10	5.10	0.50	1.90	± 13.1 %
5200	49.0	5.30	4.85	4.85	4.85	0.50	1.90	± 13.1 %
5300	48.9	5.42	4.75	4.75	4.75	0.50	1.90	± 13.1 %
5500	48.6	5.65	4.30	4.30	4.30	0.50	1.90	± 13.1 %
5600	48.5	5.77	4.21	4.21	4.21	0.50	1.90	± 13.1 %
5800	48.2	6.00	4.38	4.38	4.38	0.50	1.90	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

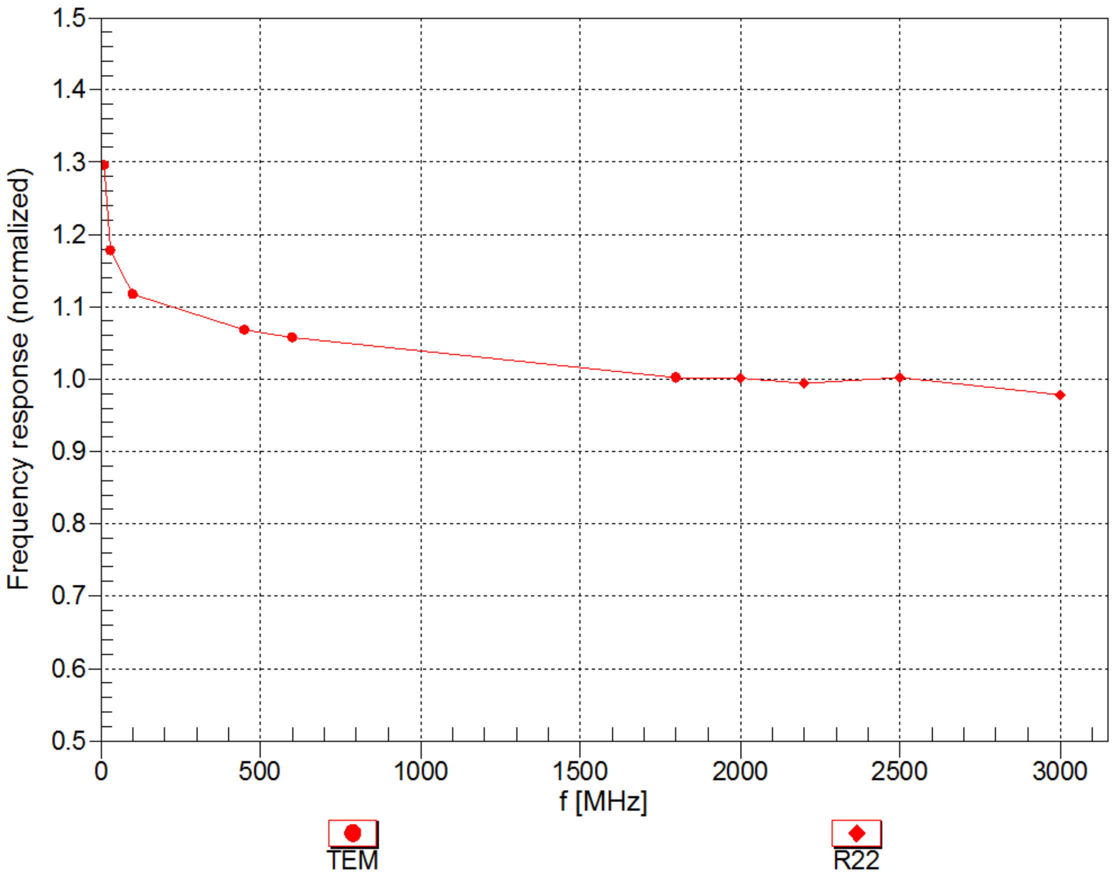
DASY/EASY - Parameters of Probe: EX3DV4 - SN:3988

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
6500	34.5	6.07	5.70	5.70	5.70	0.20	2.50	± 18.6 %

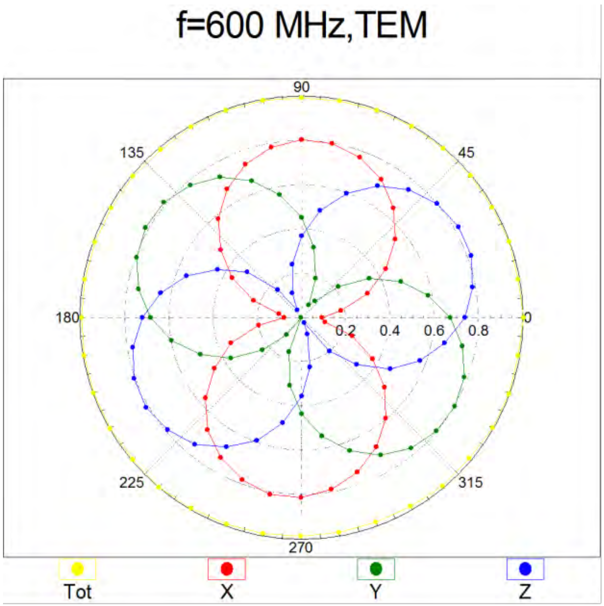
[C] Frequency validity above 6GHz is ± 700 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] At frequencies 6-10 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz; 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.

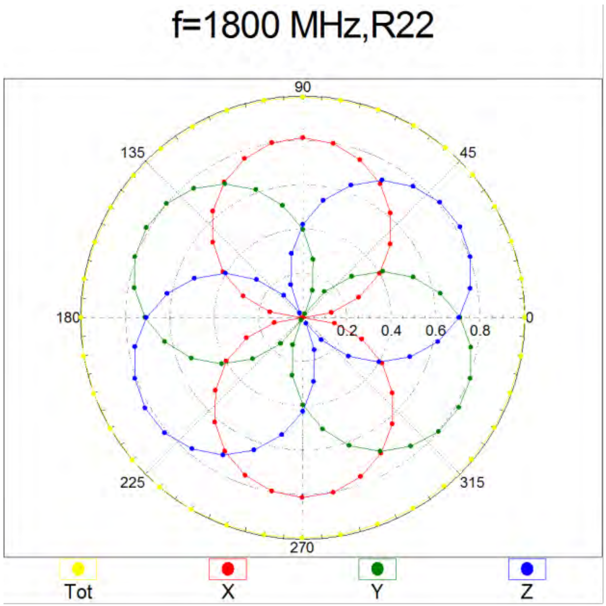
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)

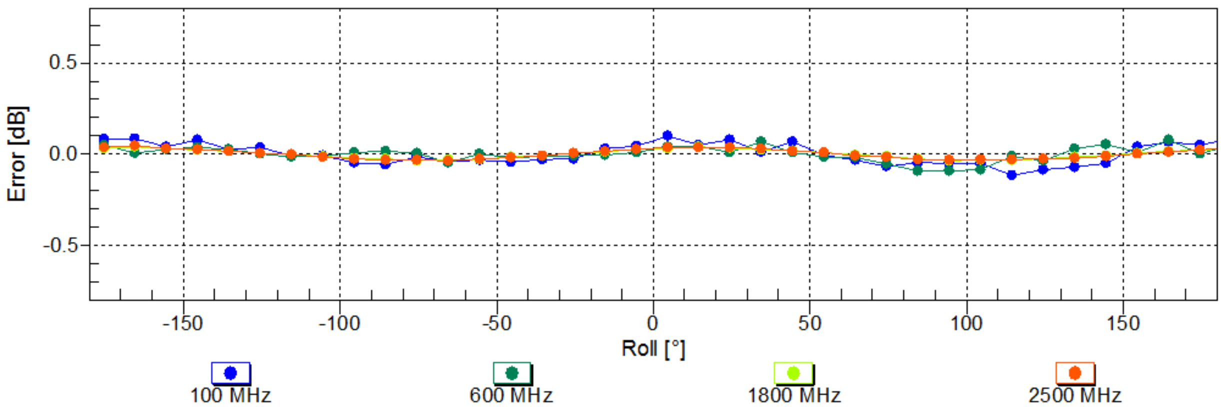


Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)

Receiving Pattern (ϕ), ϑ = 0°



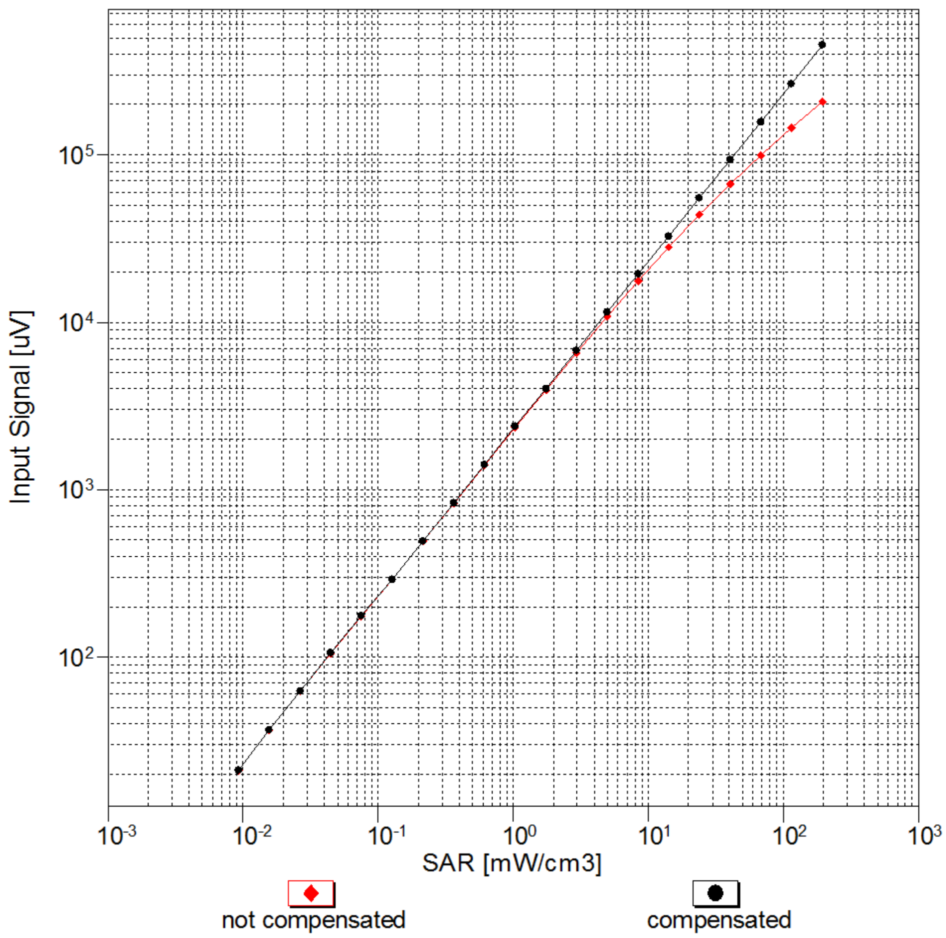


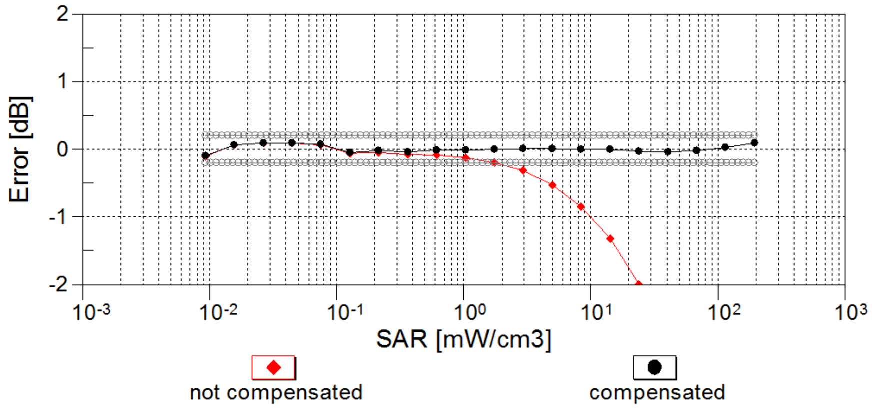


Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

Dynamic Range f(SAR_{head})

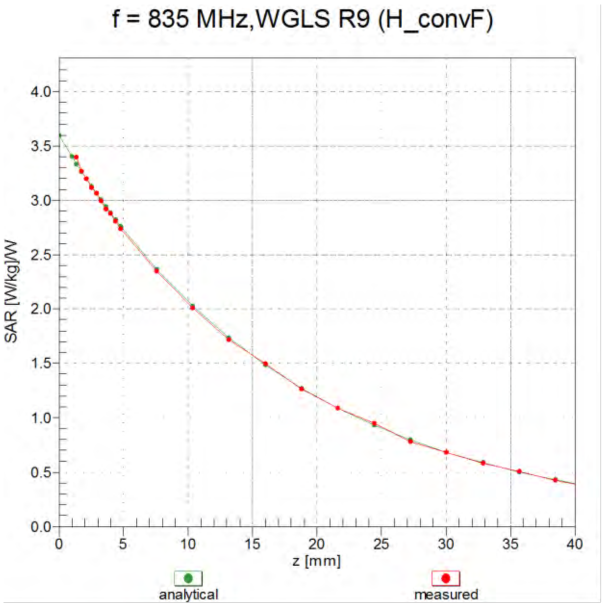
(TEM cell , f_{eval}= 1900 MHz)

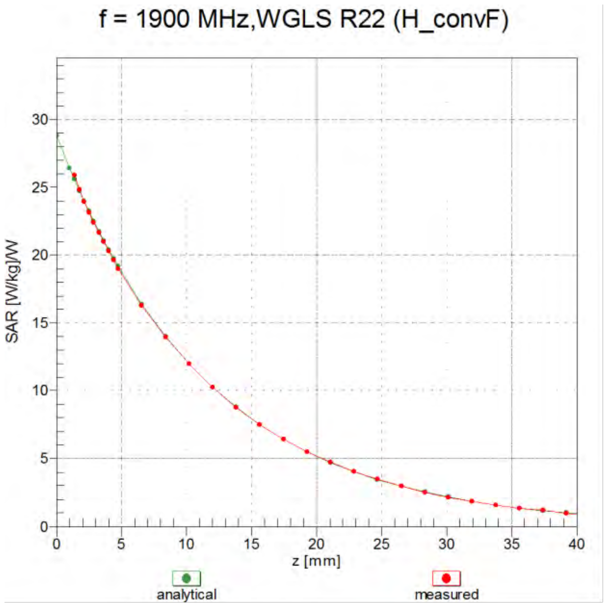




Uncertainty of Linearity Assessment: ± 0.6% (k=2)

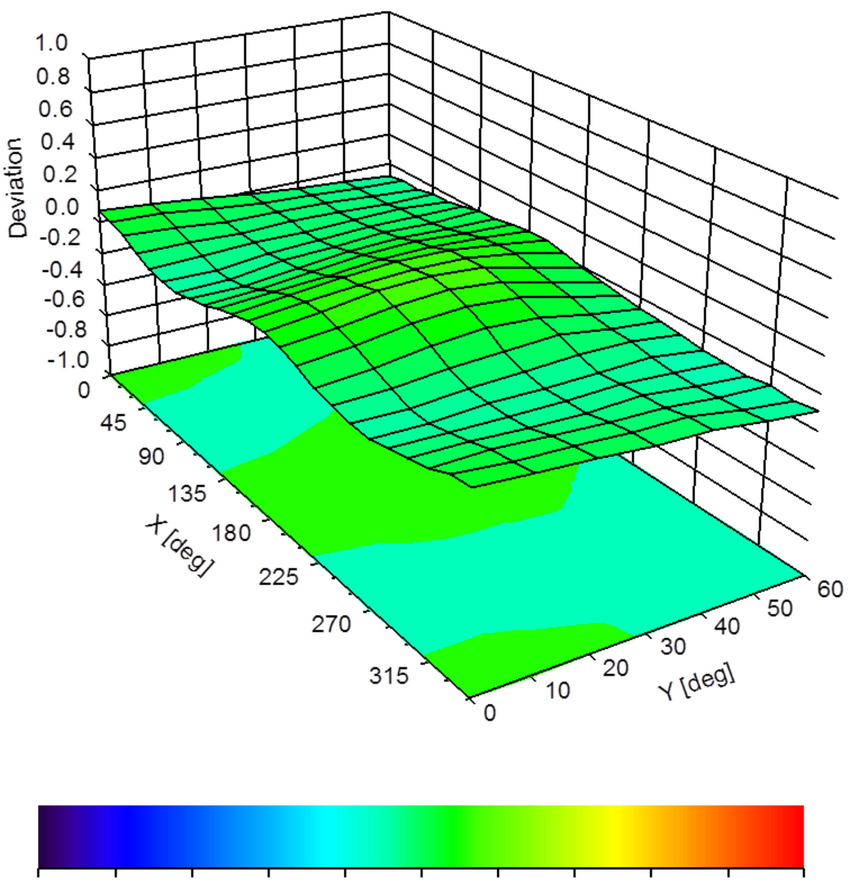
Conversion Factor Assessment





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
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 **Apple USA**

Certificate No: **EX3-3785_Oct21**

CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3785
Calibration procedure(s)	QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v6, QA CAL-23.v5, QA CAL-25.v7 Calibration procedure for dosimetric E-field probes
Calibration date:	October 27, 2021

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
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Power sensor NRP-Z91	SN: 103244	09-Apr-21 (No. 217-03291)	Apr-22
Power sensor NRP-Z91	SN: 103245	09-Apr-21 (No. 217-03292)	Apr-22
Reference 20 dB Attenuator	SN: CC2552 (20x)	09-Apr-21 (No. 217-03343)	Apr-22
DAE4	SN: 660	23-Dec-20 (No. DAE4-660_Dec20)	Dec-21
Reference Probe ES3DV2	SN: 3013	30-Dec-20 (No. ES3-3013_Dec20)	Dec-21
Secondary Standards	ID	Check Date (in house)	Scheduled Check
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Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-20)	In house check: Jun-22
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-20)	In house check: Jun-22
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-22

	Name	Function	Signature
Calibrated by:	Jeton Kastrati	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	

Issued: October 29, 2021

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3785

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu V/(V/m)^2$)[A]	0.47	0.41	0.53	± 10.1 %
DCP (mV)[B]	102.0	104.5	102.0	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Max Unc[E] (k=2)
0	CW	X	0.00	0.00	1.00	0.00	133.1	± 2.7 %	± 4.7 %
		Y	0.00	0.00	1.00		145.9		
		Z	0.00	0.00	1.00		144.4		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	20.00	90.84	20.04	10.00	60.0	± 4.0 %	± 9.6 %
		Y	14.43	85.71	18.66		60.0		
		Z	20.00	95.87	23.26		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	20.00	93.41	20.24	6.99	80.0	± 2.6 %	± 9.6 %
		Y	20.00	90.46	18.91		80.0		
		Z	20.00	99.24	23.96		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	20.00	100.40	22.30	3.98	95.0	± 1.3 %	± 9.6 %
		Y	20.00	93.43	18.88		95.0		
		Z	20.00	106.75	26.25		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	20.00	110.87	25.82	2.22	120.0	± 1.0 %	± 9.6 %
		Y	20.00	98.05	19.80		120.0		
		Z	20.00	114.93	28.66		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	1.66	66.99	15.25	1.00	150.0	± 2.4 %	± 9.6 %
		Y	1.46	65.70	14.15		150.0		
		Z	1.61	65.67	14.61		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.18	68.11	15.87	0.00	150.0	± 1.2 %	± 9.6 %
		Y	1.94	66.45	14.86		150.0		
		Z	2.11	67.05	15.27		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.73	70.23	18.85	3.01	150.0	± 0.7 %	± 9.6 %
		Y	2.64	69.97	18.52		150.0		
		Z	2.84	70.44	18.98		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.49	67.25	15.85	0.00	150.0	± 1.0 %	± 9.6 %
		Y	3.33	66.58	15.36		150.0		
		Z	3.46	66.78	15.57		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.81	65.83	15.62	0.00	150.0	± 2.2 %	± 9.6 %
		Y	4.64	65.54	15.34		150.0		
		Z	4.82	65.57	15.46		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] A The uncertainties of Norm X,Y,Z do not affect the E^2-field uncertainty inside TSL (see Pages 5, 6 and 7).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3785

Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
600	42.7	0.88	9.39	9.39	9.39	0.10	1.25	± 13.3 %
750	41.9	0.89	9.37	9.37	9.37	0.52	0.80	± 12.0 %
835	41.5	0.90	9.05	9.05	9.05	0.41	1.00	± 12.0 %
900	41.5	0.97	8.88	8.88	8.88	0.45	0.92	± 12.0 %
1450	40.5	1.20	7.97	7.97	7.97	0.50	0.80	± 12.0 %
1640	40.2	1.31	7.92	7.92	7.92	0.28	0.86	± 12.0 %
1750	40.1	1.37	7.75	7.75	7.75	0.37	0.86	± 12.0 %
1900	40.0	1.40	7.34	7.34	7.34	0.34	0.86	± 12.0 %
2000	40.0	1.40	7.34	7.34	7.34	0.33	0.86	± 12.0 %
2300	39.5	1.67	7.18	7.18	7.18	0.22	0.90	± 12.0 %
2450	39.2	1.80	6.75	6.75	6.75	0.34	0.90	± 12.0 %
2600	39.0	1.96	6.70	6.70	6.70	0.34	0.90	± 12.0 %
3300	38.2	2.71	6.45	6.45	6.45	0.35	1.30	± 13.1 %
3500	37.9	2.91	6.15	6.15	6.15	0.30	1.30	± 13.1 %
3700	37.7	3.12	6.10	6.10	6.10	0.45	1.30	± 13.1 %
3900	37.5	3.32	6.09	6.09	6.09	0.40	1.60	± 13.1 %
4100	37.2	3.53	5.80	5.80	5.80	0.40	1.60	± 13.1 %
4200	37.1	3.63	5.75	5.75	5.75	0.40	1.60	± 13.1 %
4400	36.9	3.84	5.73	5.73	5.73	0.40	1.60	± 13.1 %
4600	36.7	4.04	5.61	5.61	5.61	0.40	1.60	± 13.1 %
4800	36.4	4.25	5.50	5.50	5.50	0.40	1.80	± 13.1 %
4950	36.3	4.40	5.30	5.30	5.30	0.40	1.80	± 13.1 %
5200	36.0	4.66	4.75	4.75	4.75	0.40	1.80	± 13.1 %
5300	35.9	4.76	4.55	4.55	4.55	0.40	1.80	± 13.1 %
5500	35.6	4.96	4.40	4.40	4.40	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.31	4.31	4.31	0.40	1.80	± 13.1 %
5800	35.3	5.27	4.40	4.40	4.40	0.40	1.80	± 13.1 %

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.

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

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3785

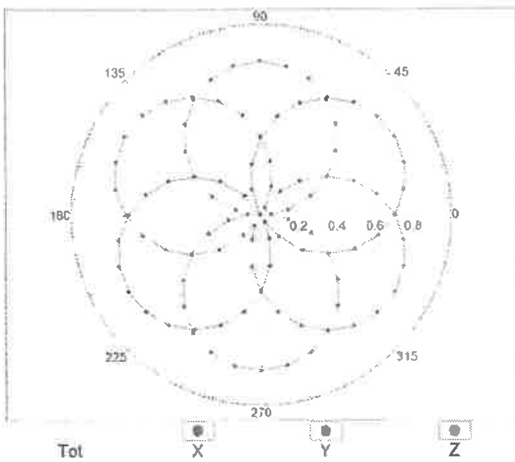
Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) [C]	Relative Permittivity [F]	Conductivity (S/m) [F]	ConvF X	ConvF Y	ConvF Z	Alpha [G]	Depth [G] (mm)	Unc (k=2)
6500	34.5	6.07	5.30	5.30	5.30	0.20	2.50	± 18.6 %

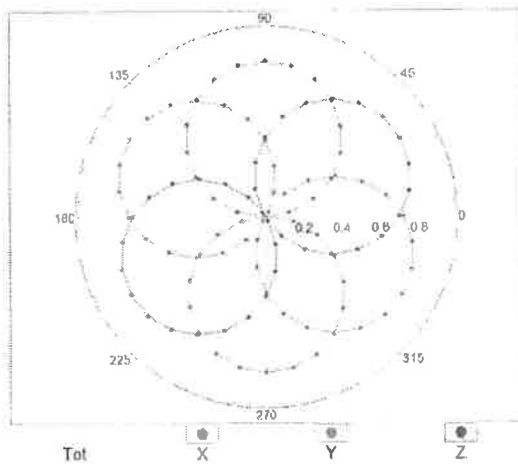
[C] Frequency validity above 6GHz is ± 700 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] At frequencies 6-10 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz; 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.

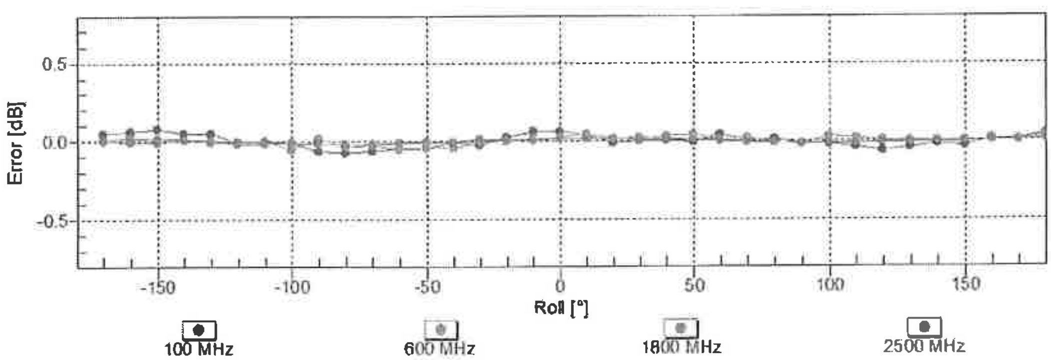
Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



f=1800 MHz,R22

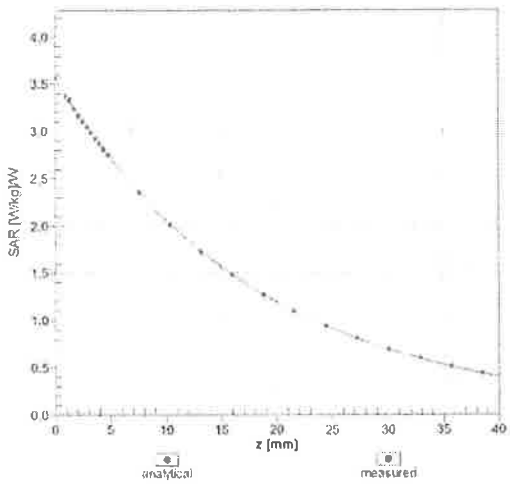




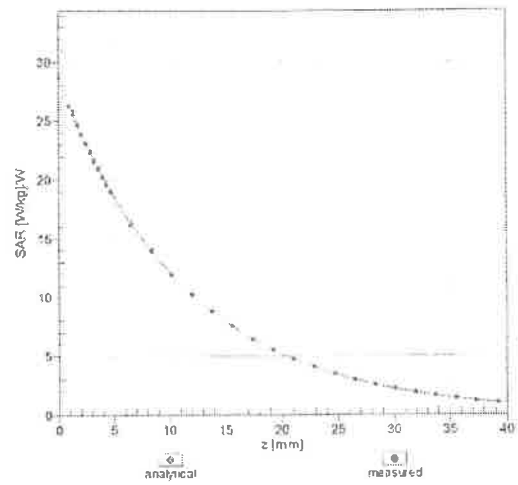
Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)

Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

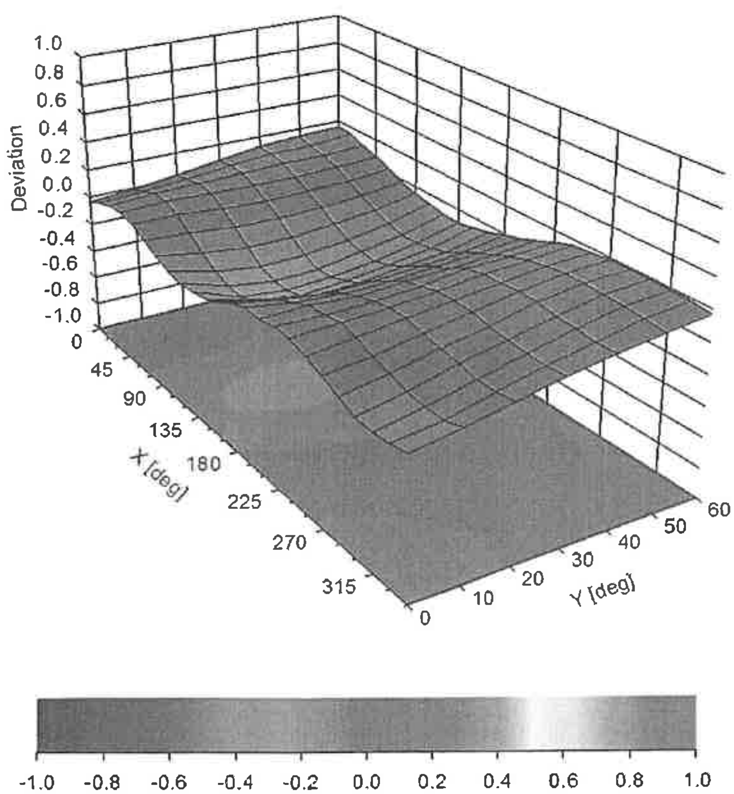


f = 1900 MHz,WGLS R22 (H_convF)



Deviation from Isotropy in Liquid

Error (ϕ, ϑ), f = 900 MHz



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