

# Appendix C

## Calibration certificate

1. Dipole
D450V3 - SN1103(2021/04/21)
2. DAE
DAE4-SN 913(2021/04/21)
3. Probe
EX3DV4-SN 3798(2021/05/31)



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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 0108**

Client **SGS-CN (Auden)**

Certificate No: **D450V3-1103\_Apr21**

## CALIBRATION CERTIFICATE

Object **D450V3 - SN:1103**

Calibration procedure(s) **QA CAL-15.v9  
Calibration Procedure for SAR Validation Sources below 700 MHz**

Calibration date: **April 21, 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 ( $22 \pm 3$ )°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
Type-N mismatch combination	SN: 310982 / 06327	09-Apr-21 (No. 217-03344)	Apr-22
Reference Probe EX3DV4	SN: 3877	30-Dec-20 (No. EX3-3877_Dec20)	Dec-21
DAE4	SN: 654	26-Jun-20 (No. DAE4-654_Jun20)	Jun-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 Agilent E8358A	SN: US41080477	31-Mar-14 (in house check Oct-20)	In house check: Oct-21

Calibrated by: **Claudio Leubler**      Name: Claudio Leubler      Function: Laboratory Technician

Approved by: **Katja Pokovic**      Name: Katja Pokovic      Function: Technical Manager

Signature

Issued: April 23, 2021

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Accreditation No.: **SCS 0108**

### Glossary:

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

### Calibration is Performed According to the Following Standards:

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

### Additional Documentation:

- DASY4/5 System Handbook

### Methods Applied and Interpretation of Parameters:

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

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

## Measurement Conditions

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

DASY Version	DASY5	V52.10.4
Extrapolation	Advanced Extrapolation	
Phantom	ELI4 Flat Phantom	Shell thickness: $2 \pm 0.2$ mm
Distance Dipole Center - TSL	15 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	450 MHz $\pm$ 1 MHz	

## Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	43.5	0.87 mho/m
Measured Head TSL parameters	(22.0 $\pm$ 0.2) °C	43.1 $\pm$ 6 %	0.87 mho/m $\pm$ 6 %
Head TSL temperature change during test	< 0.5 °C	---	---

## SAR result with Head TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	1.14 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	4.55 W/kg $\pm$ 18.1 % (k=2)

SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	condition	
SAR measured	250 mW input power	0.767 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	3.06 W/kg $\pm$ 17.6 % (k=2)

## Appendix (Additional assessments outside the scope of SCS 0108)

### Antenna Parameters with Head TSL

Impedance, transformed to feed point	57.1 $\Omega$ - 2.8 j $\Omega$
Return Loss	- 23.0 dB

### General Antenna Parameters and Design

Electrical Delay (one direction)	1.346 ns
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After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.

No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

### Additional EUT Data

Manufactured by	SPEAG
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# DASY5 Validation Report for Head TSL

Date: 21.04.2021

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 450 MHz; Type: D450V3; Serial: D450V3 - SN:1103**

Communication System: UID 0 - CW; Frequency: 450 MHz

Medium parameters used:  $f = 450$  MHz;  $\sigma = 0.87$  S/m;  $\epsilon_r = 43.1$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Flat Section

Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EX3DV4 - SN3877; ConvF(10.64, 10.64, 10.64) @ 450 MHz; Calibrated: 30.12.2020
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn654; Calibrated: 26.06.2020
- Phantom: ELI v4.0; Type: QDOVA001BB; Serial: TP:1003
- DASY52 52.10.4(1527); SEMCAD X 14.6.14(7483)

## Dipole Calibration for Head Tissue/ $d=15$ mm, Pin=250mW/Zoom Scan (7x7x7)/Cube 0:

Measurement grid:  $dx=5$ mm,  $dy=5$ mm,  $dz=5$ mm

Reference Value = 39.18 V/m; Power Drift = -0.08 dB

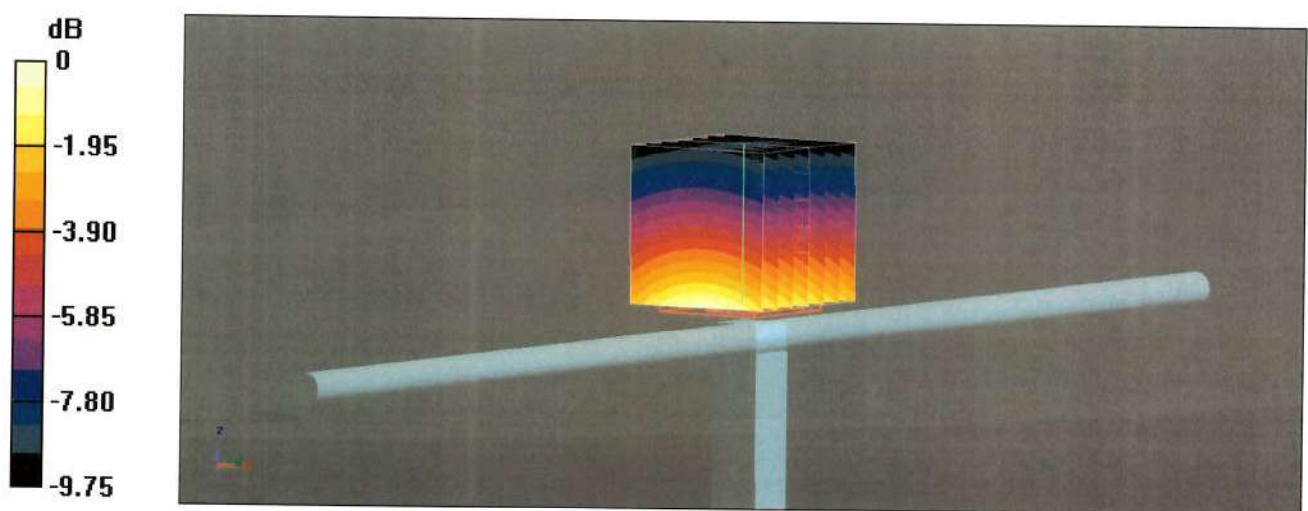
Peak SAR (extrapolated) = 1.76 W/kg

**SAR(1 g) = 1.14 W/kg; SAR(10 g) = 0.767 W/kg**

Smallest distance from peaks to all points 3 dB below: Larger than measurement grid

Ratio of SAR at M2 to SAR at M1 = 64.9%

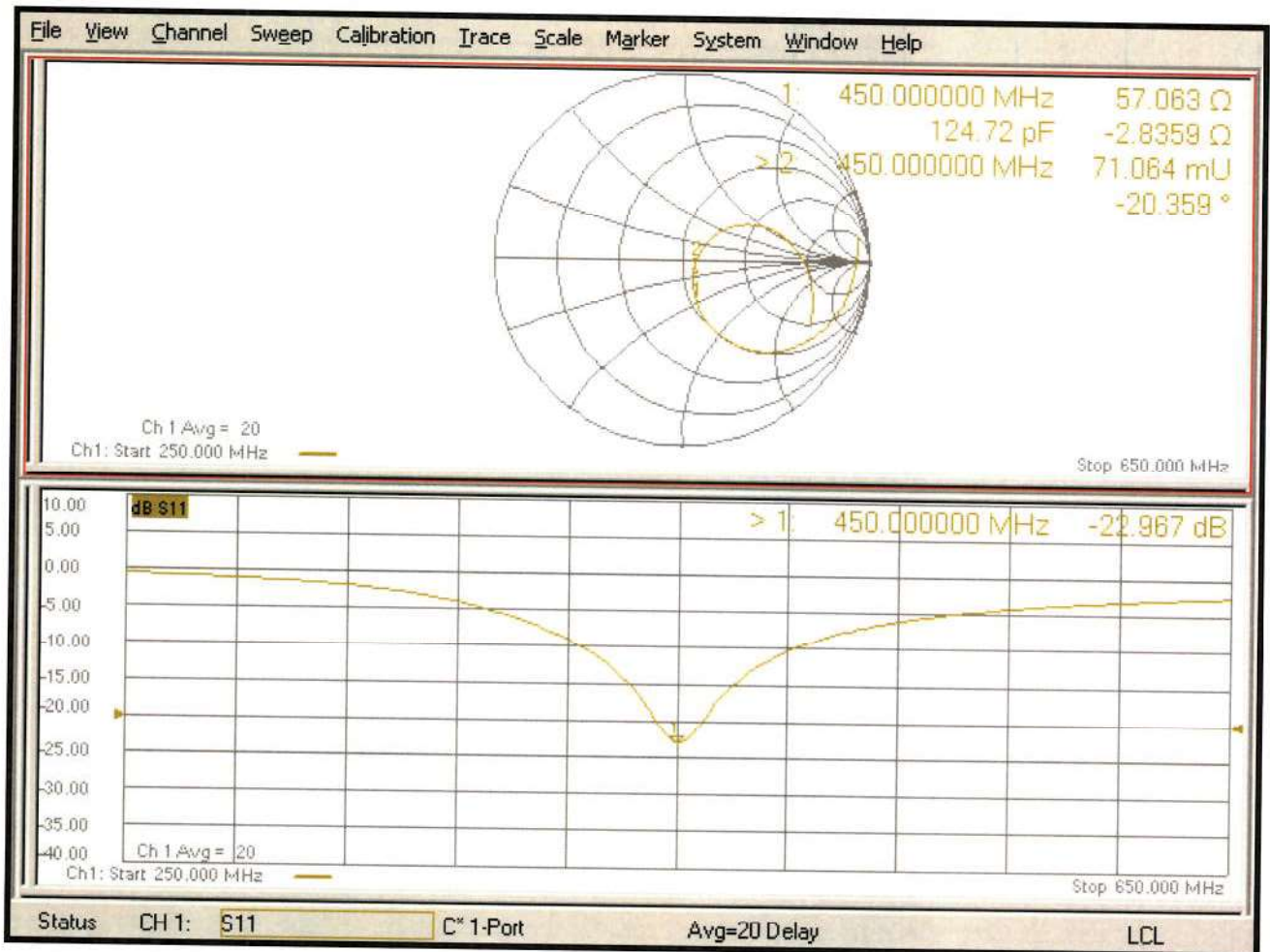
Maximum value of SAR (measured) = 1.53 W/kg



0 dB = 1.53 W/kg = 1.85 dBW/kg



# Impedance Measurement Plot for Head TSL





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Client : **Auden**

Certificate No: **Z21-60117**

## CALIBRATION CERTIFICATE

Object: **DAE4 - SN: 913**

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

Calibration date: **April 21, 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(Calibrated by, Certificate No.)	Scheduled Calibration
Process Calibrator 753	1971018	16-Jun-20 (CTTL, No.J20X04342)	Jun-21

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

Issued: April 23, 2021

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### **Glossary:**

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

### **Methods Applied and Interpretation of Parameters:**

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



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### DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1 $\mu$ V, full range = -100...+300 mV  
Low Range: 1LSB = 61nV, full range = -1.....+3mV

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

Calibration Factors	X	Y	Z
High Range	404.026 $\pm$ 0.15% (k=2)	404.421 $\pm$ 0.15% (k=2)	404.983 $\pm$ 0.15% (k=2)
Low Range	3.98555 $\pm$ 0.7% (k=2)	3.99415 $\pm$ 0.7% (k=2)	4.01890 $\pm$ 0.7% (k=2)

### Connector Angle

Connector Angle to be used in DASY system	184 $^{\circ}$ $\pm$ 1 $^{\circ}$
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Accreditation No.: **SCS 0108**

Client **SGS-CN (Auden)**

Certificate No: **EX3-3798\_May21**

## CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3798**

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: **May 31, 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 ( $22 \pm 3$ )°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-21

	Name	Function	Signature
Calibrated by:	Jeffrey Katzman	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	
			Issued: June 1, 2021
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Accredited by the Swiss Accreditation Service (SAS)

Accreditation No.: **SCS 0108**

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### Glossary:

TSL	tissue simulating liquid
NORM <sub>x,y,z</sub>	sensitivity in free space
ConvF	sensitivity in TSL / NORM <sub>x,y,z</sub>
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C, D	modulation dependent linearization parameters
Polarization $\varphi$	$\varphi$ rotation around probe axis
Polarization $\vartheta$	$\vartheta$ 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:

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
- IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

### Methods Applied and Interpretation of Parameters:

- NORM<sub>x,y,z</sub>**: Assessed for E-field polarization  $\vartheta = 0$  ( $f \leq 900$  MHz in TEM-cell;  $f > 1800$  MHz: R22 waveguide). NORM<sub>x,y,z</sub> are only intermediate values, i.e., the uncertainties of NORM<sub>x,y,z</sub> does not affect the E<sup>2</sup>-field uncertainty inside TSL (see below ConvF).
- NORM(f)<sub>x,y,z</sub>** = NORM<sub>x,y,z</sub> \* frequency\_response (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCP<sub>x,y,z</sub>**: 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
- A<sub>x,y,z</sub>; B<sub>x,y,z</sub>; C<sub>x,y,z</sub>; D<sub>x,y,z</sub>; VR<sub>x,y,z</sub>**: A, B, C, D are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters**: Assessed in flat phantom using E-field (or Temperature Transfer Standard for  $f \leq 800$  MHz) and inside waveguide using analytical field distributions based on power measurements for  $f > 800$  MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM<sub>x,y,z</sub> \* 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  $\pm 50$  MHz to  $\pm 100$  MHz.
- Spherical isotropy (3D deviation from isotropy)**: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the NORM<sub>x</sub> (no uncertainty required).

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3798

### Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup>	0.52	0.50	0.58	$\pm 10.1 \%$
DCP (mV) <sup>B</sup>	101.2	101.9	98.4	

### Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Max dev.	Unc <sup>E</sup> (k=2)
0	CW	X	0.0	0.0	1.0	0.00	143.9	$\pm 2.5 \%$	$\pm 4.7 \%$
		Y	0.0	0.0	1.0		139.2		
		Z	0.0	0.0	1.0		134.6		

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%.

<sup>A</sup> The uncertainties of Norm X,Y,Z do not affect the  $E^2$ -field uncertainty inside TSL (see Page 5).

<sup>B</sup> Numerical linearization parameter; uncertainty not required.

<sup>E</sup> 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:3798

### Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-41.1
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:3798

### Calibration Parameter Determined in Head Tissue Simulating Media

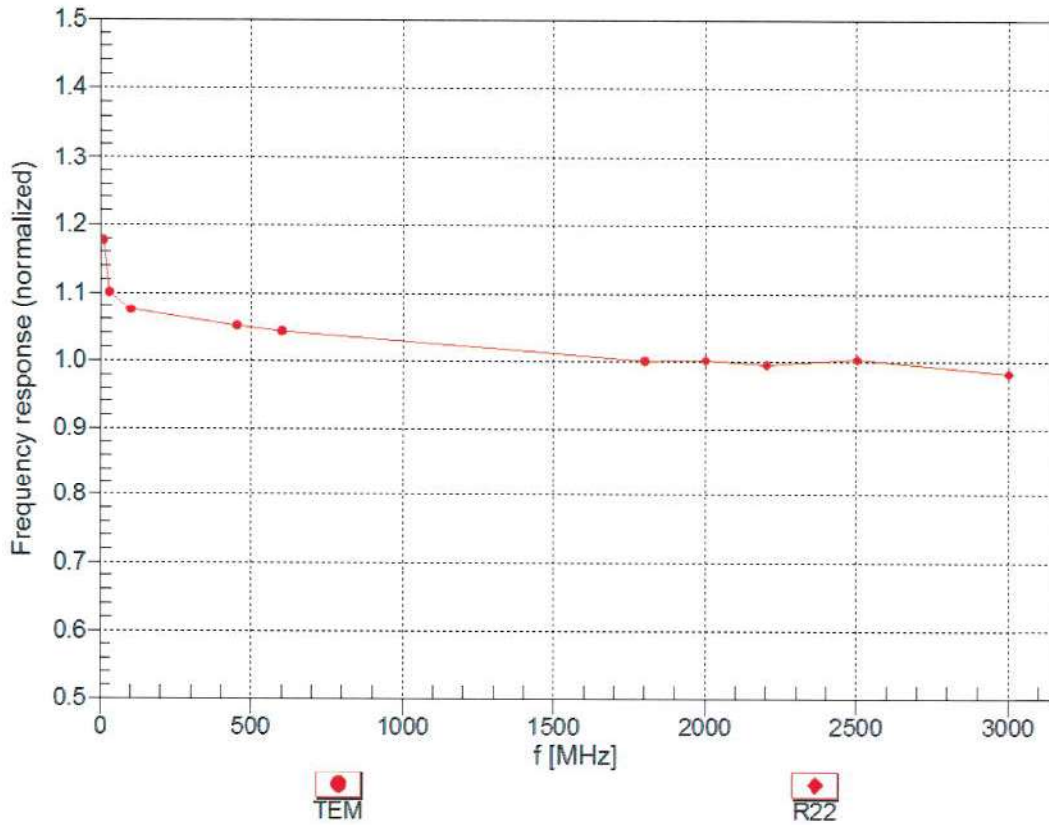
f (MHz) <sup>C</sup>	Relative Permittivity <sup>F</sup>	Conductivity (S/m) <sup>F</sup>	ConvF X	ConvF Y	ConvF Z	Alpha <sup>G</sup>	Depth <sup>G</sup> (mm)	Unc (k=2)
150	52.3	0.76	10.97	10.97	10.97	0.00	1.00	± 13.3 %
450	43.5	0.87	10.18	10.18	10.18	0.15	1.30	± 13.3 %
750	41.9	0.89	9.78	9.78	9.78	0.49	0.80	± 12.0 %
835	41.5	0.90	9.52	9.52	9.52	0.47	0.80	± 12.0 %
1750	40.1	1.37	8.22	8.22	8.22	0.34	0.86	± 12.0 %
1900	40.0	1.40	7.89	7.89	7.89	0.33	0.86	± 12.0 %
2100	39.8	1.49	7.85	7.85	7.85	0.29	0.86	± 12.0 %
2300	39.5	1.67	7.63	7.63	7.63	0.32	0.90	± 12.0 %
2450	39.2	1.80	7.33	7.33	7.33	0.31	0.90	± 12.0 %
2600	39.0	1.96	7.13	7.13	7.13	0.39	0.90	± 12.0 %
5200	36.0	4.66	4.85	4.85	4.85	0.40	1.80	± 13.1 %
5300	35.9	4.76	4.75	4.75	4.75	0.40	1.80	± 13.1 %
5500	35.6	4.96	4.65	4.65	4.65	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.50	4.50	4.50	0.40	1.80	± 13.1 %
5800	35.3	5.27	4.60	4.60	4.60	0.40	1.80	± 13.1 %

<sup>C</sup> 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.

<sup>F</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) 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 ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

<sup>G</sup> 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.

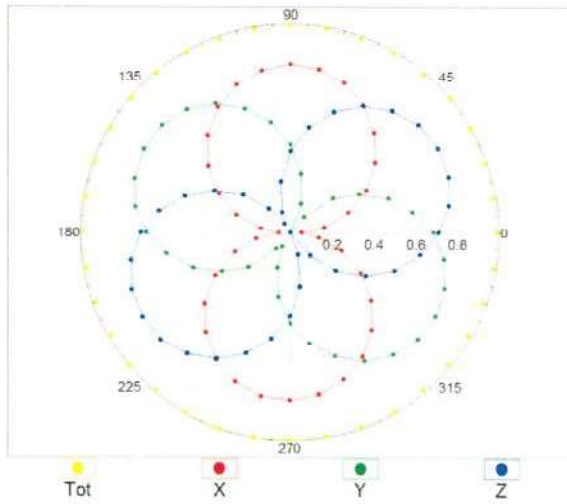
### Frequency Response of E-Field (TEM-Cell:ifi110 EXX, Waveguide: R22)



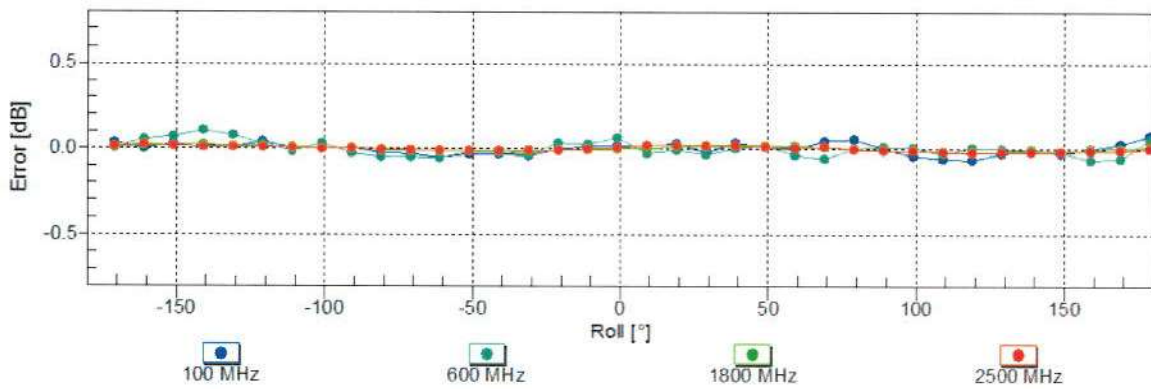
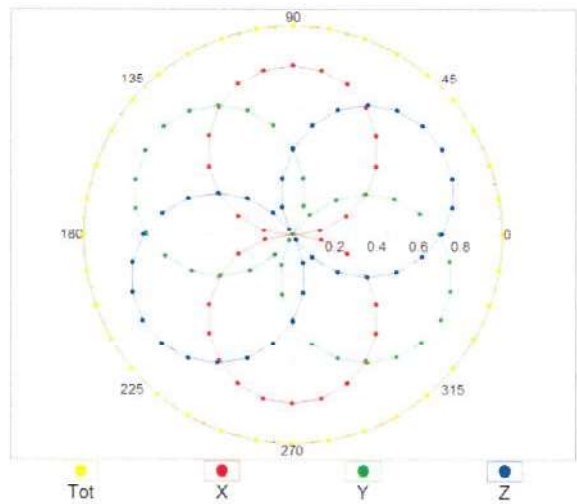
Uncertainty of Frequency Response of E-field:  $\pm 6.3\%$  (k=2)

### Receiving Pattern ( $\phi$ ), $\vartheta = 0^\circ$

f=600 MHz, TEM



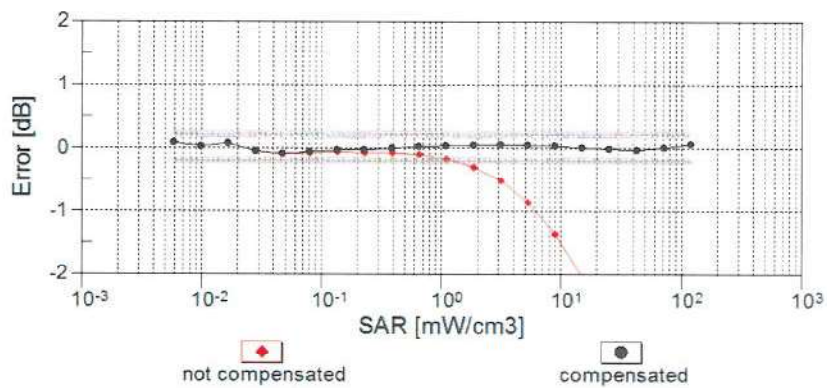
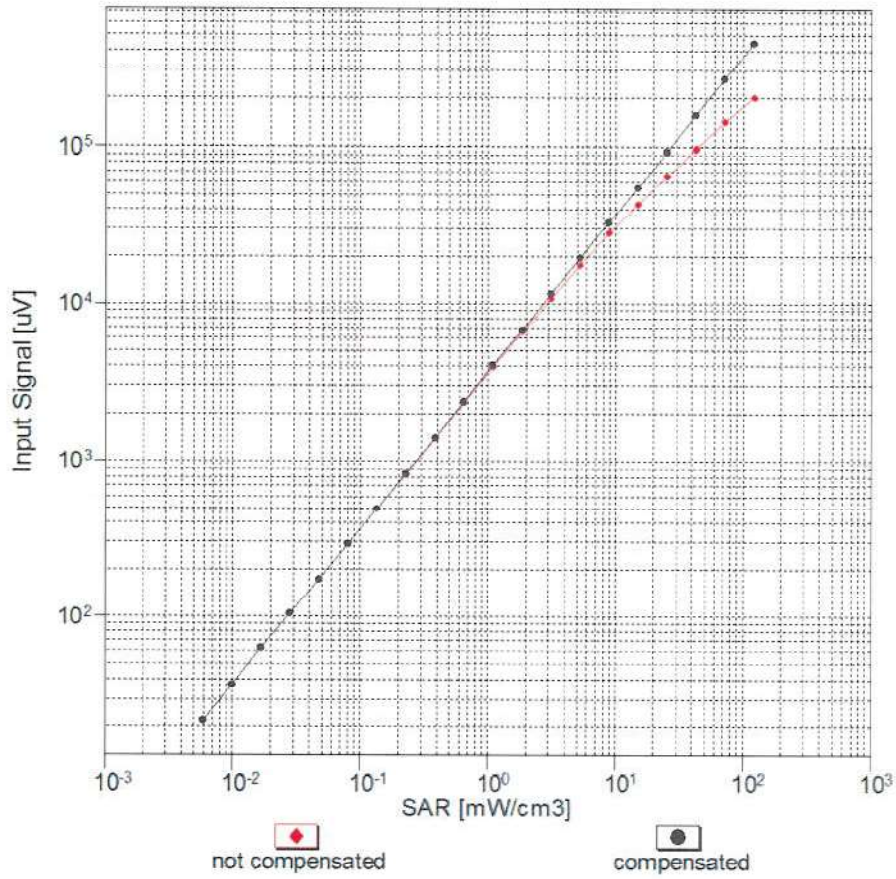
f=1800 MHz, R22



Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  ( $k=2$ )

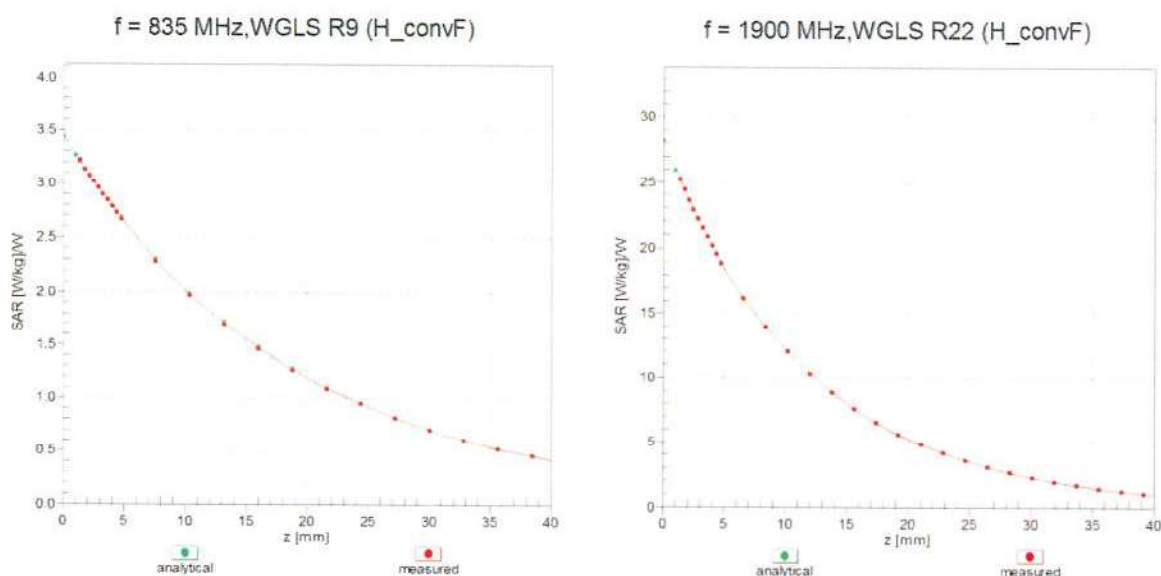


### Dynamic Range $f(SAR_{head})$ (TEM cell , $f_{eval} = 1900$ MHz)



Uncertainty of Linearity Assessment:  $\pm 0.6\%$  (k=2)

## Conversion Factor Assessment



## Deviation from Isotropy in Liquid Error ( $\phi, \vartheta$ ), f = 900 MHz

