

Calibration Laboratory of
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Engineering AG
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Accreditation No.: SCS 0108

Glossary:

TSL	tissue simulating liquid
NORM _{x,y,z}	sensitivity in free space
ConvF	sensitivity in TSL / NORM _{x,y,z}
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C, D	modulation dependent linearization parameters
Polarization φ	φ rotation around probe axis
Polarization θ	θ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., $\theta = 0$ 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) 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
- b) 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
- c) 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
- d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- *NORM_{x,y,z}*: Assessed for E-field polarization $\theta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). *NORM_{x,y,z}* are only intermediate values, i.e., the uncertainties of *NORM_{x,y,z}* does not affect the E²-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORM_{x,y,z} * frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of *ConvF*.
- *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 *NORM_{x,y,z} * ConvF* whereby the uncertainty corresponds to that given for *ConvF*. A frequency dependent *ConvF* is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- *Spherical isotropy (3D deviation from isotropy)*: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- *Sensor Offset*: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle*: The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).



EX3DV4 – SN:7464

September 12, 2017

Probe EX3DV4

SN:7464

Manufactured: September 6, 2016
Calibrated: September 12, 2017

Calibrated for DASY/EASY Systems
(Note: non-compatible with DASY2 system!)



EX3DV4- SN:7464

September 12, 2017

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7464

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.45	0.43	0.45	$\pm 10.1 \%$
DCP (mV) ^B	101.6	99.3	99.7	

Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Unc ^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	150.5	$\pm 3.3 \%$
		Y	0.0	0.0	1.0		144.7	
		Z	0.0	0.0	1.0		147.0	

Note: For details on UID parameters see Appendix.

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	57.86	441.1	37.02	12.02	0.826	5.039	0.00	0.727	1.006
Y	59.82	453.4	36.65	14.84	0.468	5.100	0.25	0.626	1.007
Z	65.01	497.8	37.35	15.97	1.043	5.073	0.00	0.801	1.008

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 E²-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.



EX3DV4– SN:7464

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DASY/EASY - Parameters of Probe: EX3DV4 - SN:7464

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)
150	52.3	0.76	12.20	12.20	12.20	0.00	1.00	± 13.3 %
300	45.3	0.87	11.77	11.77	11.77	0.09	1.20	± 13.3 %
450	43.5	0.87	11.17	11.17	11.17	0.15	1.20	± 13.3 %
750	41.9	0.89	10.57	10.57	10.57	0.53	0.80	± 12.0 %
835	41.5	0.90	10.28	10.28	10.28	0.48	0.80	± 12.0 %
900	41.5	0.97	10.03	10.03	10.03	0.28	1.09	± 12.0 %
1450	40.5	1.20	9.05	9.05	9.05	0.37	0.80	± 12.0 %
1640	40.2	1.31	8.82	8.82	8.82	0.35	0.80	± 12.0 %
1750	40.1	1.37	8.70	8.70	8.70	0.38	0.80	± 12.0 %
1810	40.0	1.40	8.42	8.42	8.42	0.32	0.85	± 12.0 %
1900	40.0	1.40	8.39	8.39	8.39	0.35	0.80	± 12.0 %
2000	40.0	1.40	8.39	8.39	8.39	0.32	0.89	± 12.0 %
2100	39.8	1.49	8.54	8.54	8.54	0.27	0.86	± 12.0 %
2300	39.5	1.67	8.40	8.40	8.40	0.34	0.95	± 12.0 %
2450	39.2	1.80	7.89	7.89	7.89	0.34	0.93	± 12.0 %
2600	39.0	1.96	7.76	7.76	7.76	0.37	0.92	± 12.0 %
3500	37.9	2.91	7.40	7.40	7.40	0.41	0.94	± 13.1 %
3700	37.7	3.12	7.11	7.11	7.11	0.50	0.84	± 13.1 %
5200	36.0	4.66	5.82	5.82	5.82	0.35	1.80	± 13.1 %
5250	35.9	4.71	5.68	5.68	5.68	0.35	1.80	± 13.1 %
5300	35.9	4.76	5.53	5.53	5.53	0.35	1.80	± 13.1 %
5500	35.6	4.96	5.21	5.21	5.21	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.98	4.98	4.98	0.40	1.80	± 13.1 %
5750	35.4	5.22	5.04	5.04	5.04	0.40	1.80	± 13.1 %
5800	35.3	5.27	5.11	5.11	5.11	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. 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.



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DASY/EASY - Parameters of Probe: EX3DV4 - SN:7464

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)
150	61.9	0.80	12.19	12.19	12.19	0.00	1.00	± 13.3 %
300	58.2	0.92	11.32	11.32	11.32	0.06	1.20	± 13.3 %
450	56.7	0.94	11.05	11.05	11.05	0.09	1.20	± 13.3 %
750	55.5	0.96	10.63	10.63	10.63	0.49	0.88	± 12.0 %
835	55.2	0.97	10.21	10.21	10.21	0.45	0.80	± 12.0 %
900	55.0	1.05	10.17	10.17	10.17	0.42	0.80	± 12.0 %
1450	54.0	1.30	9.18	9.18	9.18	0.36	0.80	± 12.0 %
1640	53.7	1.42	9.12	9.12	9.12	0.38	0.80	± 12.0 %
1750	53.4	1.49	8.60	8.60	8.60	0.44	0.80	± 12.0 %
1810	53.3	1.52	8.45	8.45	8.45	0.41	0.80	± 12.0 %
1900	53.3	1.52	8.32	8.32	8.32	0.42	0.80	± 12.0 %
2000	53.3	1.52	8.24	8.24	8.24	0.39	0.80	± 12.0 %
2100	53.2	1.62	8.38	8.38	8.38	0.40	0.80	± 12.0 %
2300	52.9	1.81	8.30	8.30	8.30	0.42	0.93	± 12.0 %
2450	52.7	1.95	8.09	8.09	8.09	0.34	0.95	± 12.0 %
2600	52.5	2.16	7.84	7.84	7.84	0.30	0.97	± 12.0 %
3500	51.3	3.31	7.06	7.06	7.06	0.68	0.70	± 13.1 %
3700	51.0	3.55	6.99	6.99	6.99	0.85	0.60	± 13.1 %
5200	49.0	5.30	5.39	5.39	5.39	0.35	1.90	± 13.1 %
5250	48.9	5.36	5.29	5.29	5.29	0.35	1.90	± 13.1 %
5300	48.9	5.42	5.19	5.19	5.19	0.35	1.90	± 13.1 %
5500	48.6	5.65	4.61	4.61	4.61	0.40	1.90	± 13.1 %
5600	48.5	5.77	4.50	4.50	4.50	0.40	1.90	± 13.1 %
5750	48.3	5.94	4.59	4.59	4.59	0.40	1.90	± 13.1 %
5800	48.2	6.00	4.67	4.67	4.67	0.40	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. Above 5 GHz frequency validity can be extended to ± 110 MHz.

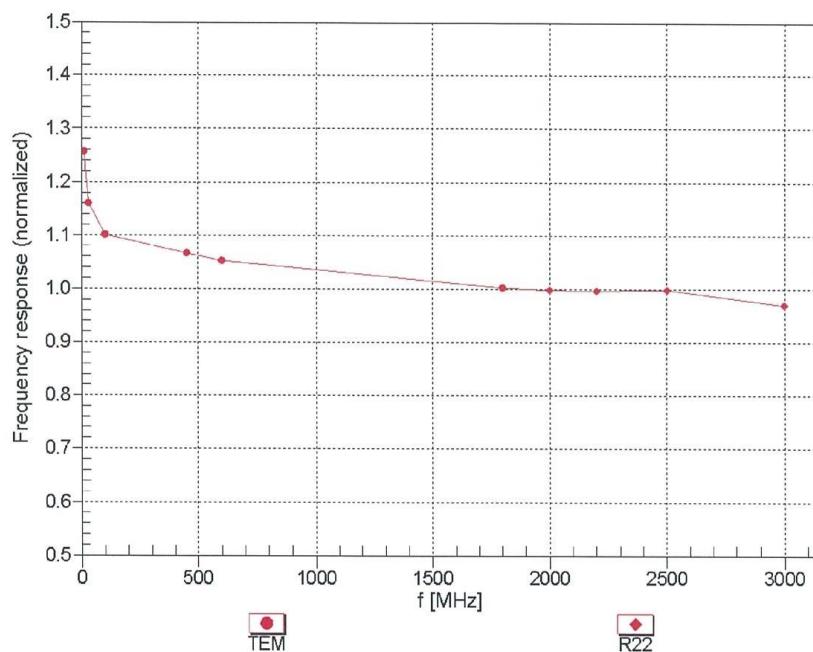
^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty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

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



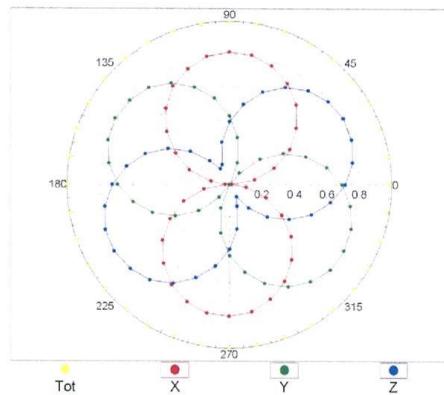
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ ($k=2$)

EX3DV4– SN:7464

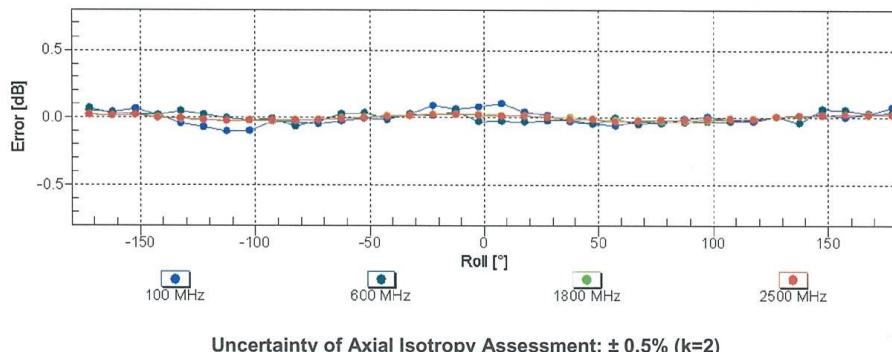
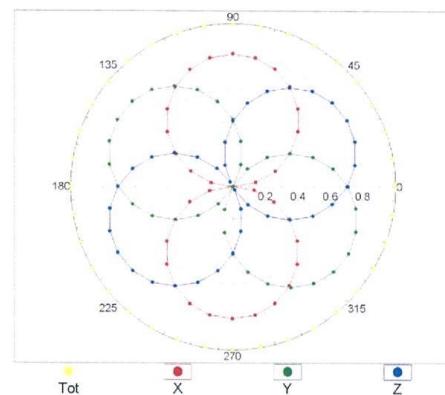
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Receiving Pattern (ϕ), $\theta = 0^\circ$

$f=600$ MHz, TEM



$f=1800$ MHz, R22

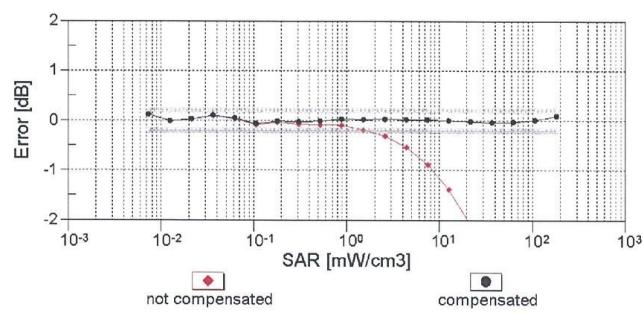
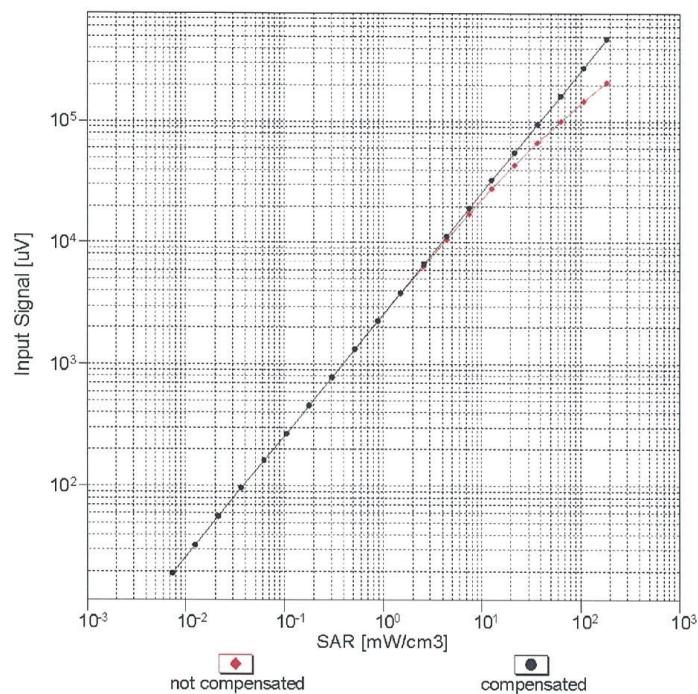


Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ ($k=2$)

EX3DV4– SN:7464

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

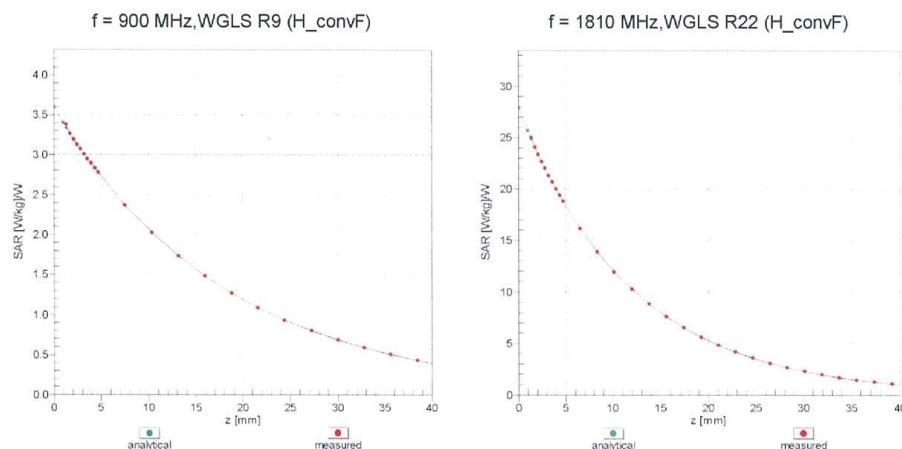


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

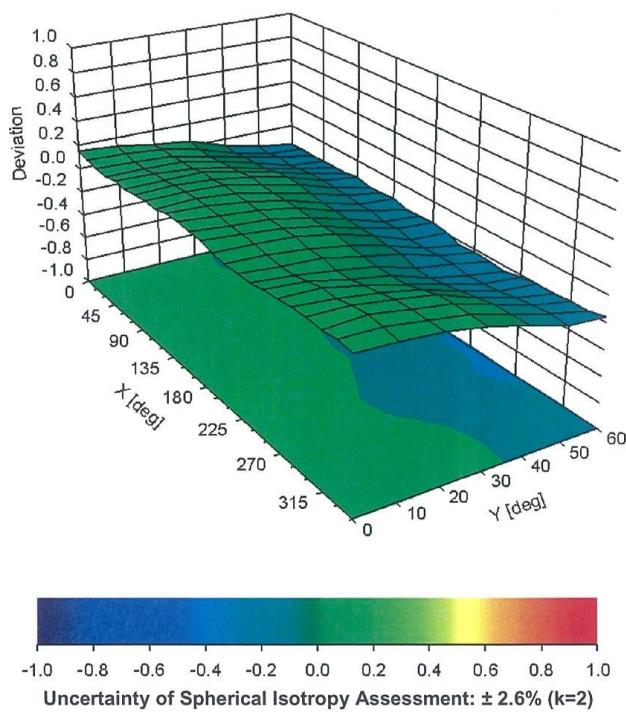
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Conversion Factor Assessment



Deviation from Isotropy in Liquid Error (ϕ, θ), $f = 900 \text{ MHz}$





EX3DV4- SN:7464

September 12, 2017

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7464

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	27.6
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

ANNEX H Dipole Calibration Certificate

750 MHz Dipole Calibration Certificate

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Accreditation No.: **SCS 0108**

Client **CTTL-BJ (Auden)**

Certificate No: **D750V3-1017_Jul17**

CALIBRATION CERTIFICATE

Object	D750V3 - SN:1017					
Calibration procedure(s)	QA CAL-05.v9 Calibration procedure for dipole validation kits above 700 MHz					
Calibration date:	July 19, 2017					
This calibration certificate documents the traceability to national standards, which realize the physical units of measurements (SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.						
All calibrations have been conducted in the closed laboratory facility: environment temperature $(22 \pm 3)^\circ\text{C}$ and humidity < 70%.						
Calibration Equipment used (M&TE critical for calibration)						
Primary Standards	ID #	Cal Date (Certificate No.)	Scheduled Calibration			
Power meter NRP	SN: 104778	04-Apr-17 (No. 217-02521/02522)	Apr-18			
Power sensor NRP-Z91	SN: 103244	04-Apr-17 (No. 217-02521)	Apr-18			
Power sensor NRP-Z91	SN: 103245	04-Apr-17 (No. 217-02522)	Apr-18			
Reference 20 dB Attenuator	SN: 5058 (20k)	07-Apr-17 (No. 217-02528)	Apr-18			
Type-N mismatch combination	SN: 5047.2 / 06327	07-Apr-17 (No. 217-02529)	Apr-18			
Reference Probe EX3DV4	SN: 7349	31-May-17 (No. EX3-7349_May17)	May-18			
DAE4	SN: 601	28-Mar-17 (No. DAE4-601_Mar17)	Mar-18			
Secondary Standards	ID #	Check Date (in house)	Scheduled Check			
Power meter EPM-442A	SN: GB37480704	07-Oct-15 (in house check Oct-16)	In house check: Oct-18			
Power sensor HP 8481A	SN: US37292783	07-Oct-15 (in house check Oct-16)	In house check: Oct-18			
Power sensor HP 8481A	SN: MY41092317	07-Oct-15 (in house check Oct-16)	In house check: Oct-18			
RF generator R&S SMT-06	SN: 100972	15-Jun-15 (in house check Oct-16)	In house check: Oct-18			
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-16)	In house check: Oct-17			
Calibrated by:	Name Johannes Kurikka	Function Laboratory Technician	Signature 			
Approved by:	Katja Pokovic	Technical Manager				
Issued: July 20, 2017 This calibration certificate shall not be reproduced except in full without written approval of the laboratory.						

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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:

- a) 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
- b) 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
- c) 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
- d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Additional Documentation:

- e) 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	V52.10.0
Extrapolation	Advanced Extrapolation	
Phantom	Modular Flat Phantom	
Distance Dipole Center - TSL	15 mm	with Spacer
Zoom Scan Resolution	$dx, dy, dz = 5 \text{ mm}$	
Frequency	$750 \text{ MHz} \pm 1 \text{ MHz}$	

Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	41.9	0.89 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	41.0 ± 6 %	0.89 mho/m ± 6 %
Head TSL temperature change during test	< 0.5 °C	---	----

SAR result with Head TSL

SAR averaged over 1 cm³ (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	2.09 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	8.32 W/kg ± 17.0 % (k=2)

SAR averaged over 10 cm³ (10 g) of Head TSL	condition	
SAR measured	250 mW input power	1.36 W/kg
SAR for nominal Head TSL parameters	normalized to 1W	5.42 W/kg ± 16.5 % (k=2)

Body TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	55.5	0.96 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	55.0 ± 6 %	0.99 mho/m ± 6 %
Body TSL temperature change during test	< 0.5 °C	---	----

SAR result with Body TSL

SAR averaged over 1 cm³ (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	2.22 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	8.66 W/kg ± 17.0 % (k=2)

SAR averaged over 10 cm³ (10 g) of Body TSL	condition	
SAR measured	250 mW input power	1.45 W/kg
SAR for nominal Body TSL parameters	normalized to 1W	5.68 W/kg ± 16.5 % (k=2)

Appendix (Additional assessments outside the scope of SCS 0108)**Antenna Parameters with Head TSL**

Impedance, transformed to feed point	54.4 Ω +0.5 $j\Omega$
Return Loss	- 27.5 dB

Antenna Parameters with Body TSL

Impedance, transformed to feed point	49.3 Ω - 3.4 $j\Omega$
Return Loss	- 29.1 dB

General Antenna Parameters and Design

Electrical Delay (one direction)	1.033 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
Manufactured on	March 22, 2010

DASY5 Validation Report for Head TSL

Date: 19.07.2017

Test Laboratory: SPEAG, Zurich, Switzerland

DUT: Dipole 750 MHz; Type: D750V3; Serial: D750V3 - SN:1017

Communication System: UID 0 - CW; Frequency: 750 MHz

Medium parameters used: $f = 750 \text{ MHz}$; $\sigma = 0.89 \text{ S/m}$; $\epsilon_r = 41$; $\rho = 1000 \text{ kg/m}^3$

Phantom section: Flat Section

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

DASY52 Configuration:

- Probe: EX3DV4 - SN7349; ConvF(10.49, 10.49, 10.49); Calibrated: 31.05.2017;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 28.03.2017
- Phantom: Flat Phantom 4.9 (front); Type: QD 00L P49 AA; Serial: 1001
- DASY52 52.10.0(1446); SEMCAD X 14.6.10(7417)

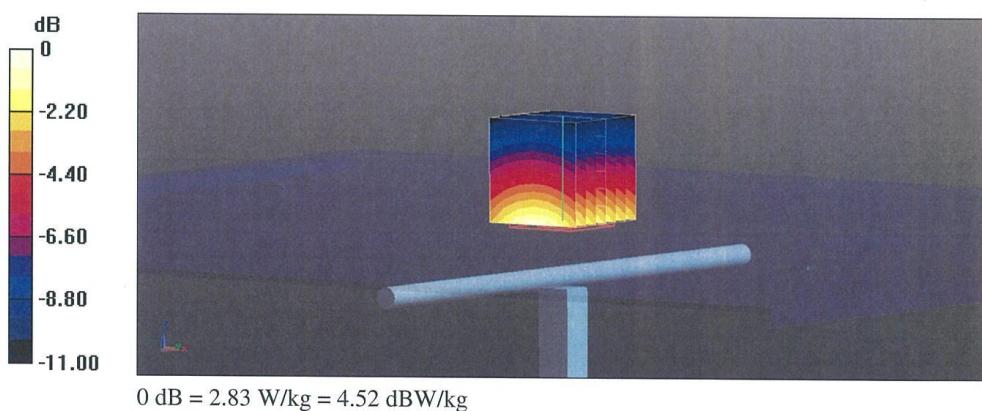
Dipole Calibration for Head Tissue/Pin=250 mW, d=15mm/Zoom Scan (7x7x7)/Cube 0:Measurement grid: $dx=5\text{mm}$, $dy=5\text{mm}$, $dz=5\text{mm}$

Reference Value = 58.85 V/m; Power Drift = 0.00 dB

Peak SAR (extrapolated) = 3.22 W/kg

SAR(1 g) = 2.09 W/kg; SAR(10 g) = 1.36 W/kg

Maximum value of SAR (measured) = 2.83 W/kg



Impedance Measurement Plot for Head TSL

