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CNAS L0570

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Client

Sporton

Certificate No: **Z18-60259**

CALIBRATION CERTIFICATE

Object **D5GHzV2 - SN: 1167**

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

Calibration date: **August 03, 2018**

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

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

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	102083	01-Nov-17 (CTTL, No.J17X08756)	Oct-18
Power sensor NRP-Z91	100542	01-Nov-17 (CTTL, No.J17X08756)	Oct-18
ReferenceProbe EX3DV4	SN 7464	12-Sep-17(SPEAG,No.EX3-7464_Sep17)	Sep-18
DAE4	SN 1524	13-Sep-17(SPEAG,No.DAE4-1524_Sep17)	Sep-18
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Signal Generator E4438C	MY49071430	23-Jan-18 (CTTL, No.J18X00560)	Jan-19
NetworkAnalyzerE5071C	MY46110673	24-Jan-18 (CTTL, No.J18X00561)	Jan-19

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

Issued: August 6, 2018

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



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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 assessment of specific absorption rate of human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices- Part 1: Device used next to the ear (Frequency range of 300MHz to 6GHz)", July 2016
- IEC 62209-2, "Procedure to measure the Specific Absorption Rate (SAR) For wireless communication devices used in close proximity to the human body (frequency range of 30MHz to 6GHz)", March 2010
- KDB865664, SAR Measurement Requirements for 100 MHz to 6 GHz

Additional Documentation:

- DASY4/5 System Handbook

Methods Applied and Interpretation of Parameters:

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

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



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Measurement Conditions

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

DASY Version	DASY52	52.10.1.1476
Extrapolation	Advanced Extrapolation	
Phantom	Triple Flat Phantom 5.1C	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy = 4 mm, dz = 1.4 mm	Graded Ratio = 1.4 (Z direction)
Frequency	5250 MHz $\pm$ 1 MHz 5600 MHz $\pm$ 1 MHz 5750 MHz $\pm$ 1 MHz	

Head TSL parameters at 5250 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.9	4.71 mho/m
Measured Head TSL parameters	(22.0 $\pm$ 0.2) °C	35.9 $\pm$ 6 %	4.82 mho/m $\pm$ 6 %
Head TSL temperature change during test	<1.0 °C	----	----

SAR result with Head TSL at 5250 MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.69 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	77.0 mW / g $\pm$ 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.20 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	22.0 mW / g $\pm$ 24.2 % (k=2)



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Head TSL parameters at 5600 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.5	5.07 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	35.1 ± 6 %	5.18 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

SAR result with Head TSL at 5600 MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.09 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	80.8 mW / g ± 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.32 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	23.2 mW / g ± 24.2 % (k=2)

Head TSL parameters at 5750 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.4	5.22 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	34.9 ± 6 %	5.37 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

SAR result with Head TSL at 5750 MHz

SAR averaged over 1 cm ³ (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.70 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	76.9 mW / g ± 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.17 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	21.6 mW / g ± 24.2 % (k=2)



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Body TSL parameters at 5250 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.9	5.36 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.4 ± 6 %	5.32 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL at 5250 MHz

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.46 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	74.4 mW /g ± 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.10 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	20.9 mW /g ± 24.2 % (k=2)

Body TSL parameters at 5600 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.5	5.77 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	47.7 ± 6 %	5.79 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL at 5600 MHz

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.73 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	77.1 mW /g ± 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.16 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	21.5 mW /g ± 24.2 % (k=2)



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Body TSL parameters at 5750 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.3	5.94 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.5 ± 6 %	5.93 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

SAR result with Body TSL at 5750 MHz

SAR averaged over 1 cm ³ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.43 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	74.3 mW /g ± 24.4 % (k=2)
SAR averaged over 10 cm ³ (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.08 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	20.8 mW /g ± 24.2 % (k=2)



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Appendix (Additional assessments outside the scope of CNAS L0570)

Antenna Parameters with Head TSL at 5250 MHz

Impedance, transformed to feed point	50.3 Ω - 9.42j Ω
Return Loss	- 20.6dB

Antenna Parameters with Head TSL at 5600 MHz

Impedance, transformed to feed point	58.1 Ω - 7.15j Ω
Return Loss	- 20.0dB

Antenna Parameters with Head TSL at 5750 MHz

Impedance, transformed to feed point	53.5 Ω - 7.66j Ω
Return Loss	- 21.8dB

Antenna Parameters with Body TSL at 5250 MHz

Impedance, transformed to feed point	49.5 Ω - 7.40j Ω
Return Loss	- 22.6dB

Antenna Parameters with Body TSL at 5600 MHz

Impedance, transformed to feed point	58.0 Ω - 6.37j Ω
Return Loss	- 20.5dB

Antenna Parameters with Body TSL at 5750 MHz

Impedance, transformed to feed point	54.5 Ω - 7.07j Ω
Return Loss	- 21.9dB



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General Antenna Parameters and Design

Electrical Delay (one direction)	1.065 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: 07.27.2018

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1167

Communication System: CW; Frequency: 5250 MHz, Frequency: 5600 MHz,
Frequency: 5750 MHz,

Medium parameters used: $f = 5250$ MHz; $\sigma = 4.822$ S/m; $\epsilon_r = 35.92$; $\rho = 1000$ kg/m³, Medium parameters used: $f = 5600$ MHz; $\sigma = 5.184$ S/m; $\epsilon_r = 35.14$; $\rho = 1000$ kg/m³, Medium parameters used: $f = 5750$ MHz; $\sigma = 5.365$ S/m; $\epsilon_r = 34.88$; $\rho = 1000$ kg/m³,

Phantom section: Center Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(5.68, 5.68, 5.68) @ 5250 MHz; Calibrated: 9/12/2017, ConvF(4.98, 4.98, 4.98) @ 5600 MHz; Calibrated: 9/12/2017, ConvF(5.04, 5.04, 5.04) @ 5750 MHz; Calibrated: 9/12/2017,
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1524; Calibrated: 9/13/2017
- Phantom: MFP_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (1); SEMCAD X Version 14.6.11 (7439)

Dipole Calibration /Pin=100mW, d=10mm, f=5250 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 65.09 V/m; Power Drift = -0.02 dB
Peak SAR (extrapolated) = 32.4 W/kg
SAR(1 g) = 7.69 W/kg; SAR(10 g) = 2.2 W/kg
Maximum value of SAR (measured) = 18.0 W/kg

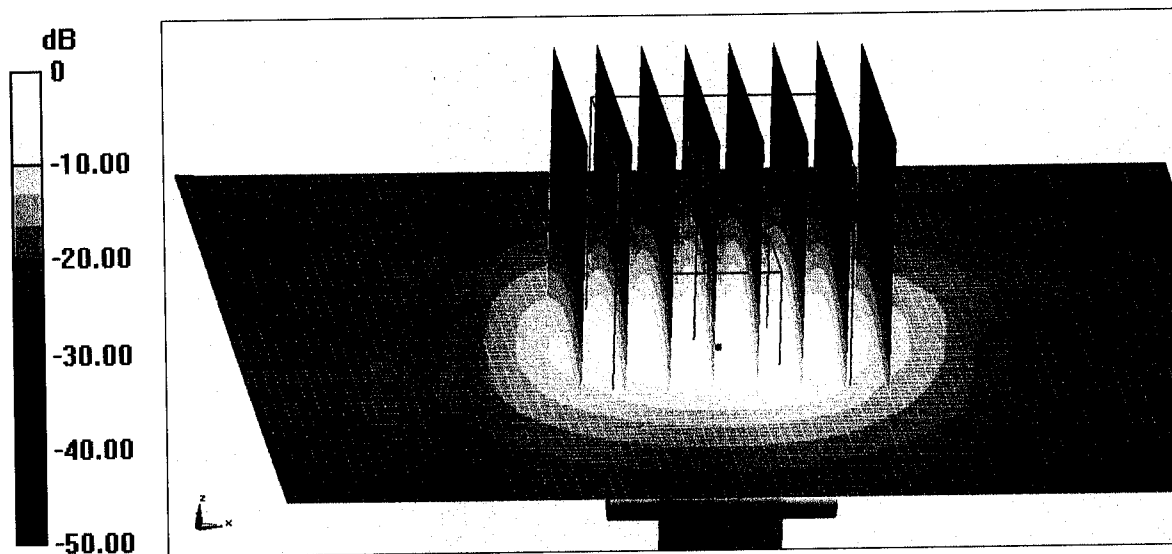
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Reference Value = 63.53 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 36.2 W/kg
SAR(1 g) = 8.09 W/kg; SAR(10 g) = 2.32 W/kg
Maximum value of SAR (measured) = 19.7 W/kg

Dipole Calibration /Pin=100mW, d=10mm, f=5750 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.79 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 36.2 W/kg
SAR(1 g) = 7.7 W/kg; SAR(10 g) = 2.17 W/kg
Maximum value of SAR (measured) = 19.0 W/kg



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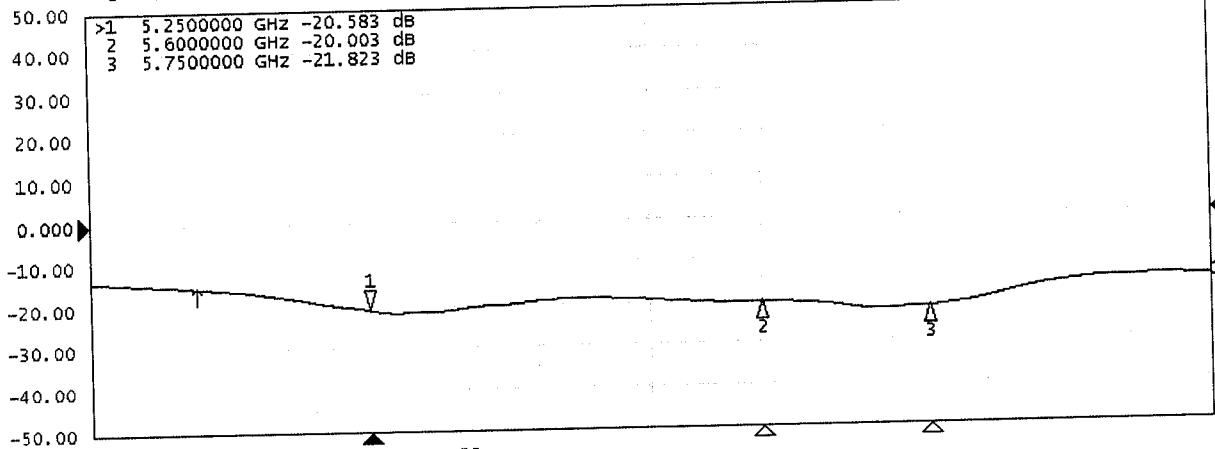
0 dB = 19.0 W/kg = 12.79 dBW/kg



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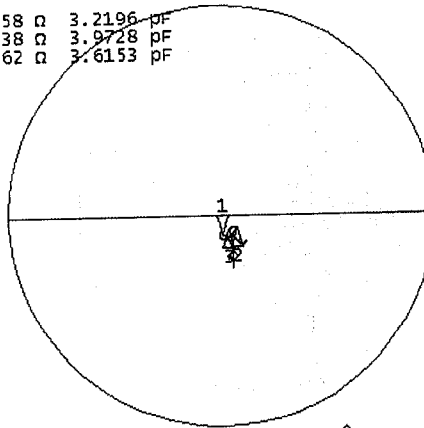
Impedance Measurement Plot for Head TSL

Tr1 S11 Log Mag 10.00dB/ Ref 0.000dB [F1]



Tr2 S11 Smith (R+jX) scale 1.000U [F1 Del]

>1	5.2500000 GHz	50.314 Ω	-9.4158 Ω	3.2196 pF
2	5.6000000 GHz	58.136 Ω	-7.1538 Ω	3.9728 pF
3	5.7500000 GHz	53.485 Ω	-7.6562 Ω	3.6153 pF





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Date: 08.02.2018

DASY5 Validation Report for Body TSL

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1167

Communication System: CW; Frequency: 5250 MHz, Frequency: 5600 MHz,
Frequency: 5750 MHz,

Medium parameters used: $f = 5250$ MHz; $\sigma = 5.316$ S/m; $\epsilon_r = 48.42$; $\rho = 1000$ kg/m³, Medium parameters used: $f = 5600$ MHz; $\sigma = 5.789$ S/m; $\epsilon_r = 47.7$; $\rho = 1000$ kg/m³, Medium parameters used: $f = 5750$ MHz; $\sigma = 5.926$ S/m; $\epsilon_r = 48.45$; $\rho = 1000$ kg/m³,

Phantom section: Right Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(5.29, 5.29, 5.29) @ 5250 MHz; Calibrated: 9/12/2017, ConvF(4.5, 4.5, 4.5) @ 5600 MHz; Calibrated: 9/12/2017, ConvF(4.59, 4.59, 4.59) @ 5750 MHz; Calibrated: 9/12/2017,
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1524; Calibrated: 9/13/2017
- Phantom: MFP_V5.1C ; Type: QD 000 P51CA; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (1); SEMCAD X Version 14.6.11 (7439)

Dipole Calibration /Pin=100mW, d=10mm, f=5250 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 64.14 V/m; Power Drift = 0.02 dB
Peak SAR (extrapolated) = 31.9 W/kg
SAR(1 g) = 7.46 W/kg; SAR(10 g) = 2.1 W/kg
Maximum value of SAR (measured) = 17.6 W/kg

Dipole Calibration /Pin=100mW, d=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 62.32 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 36.3 W/kg
SAR(1 g) = 7.73 W/kg; SAR(10 g) = 2.16 W/kg
Maximum value of SAR (measured) = 19.1 W/kg

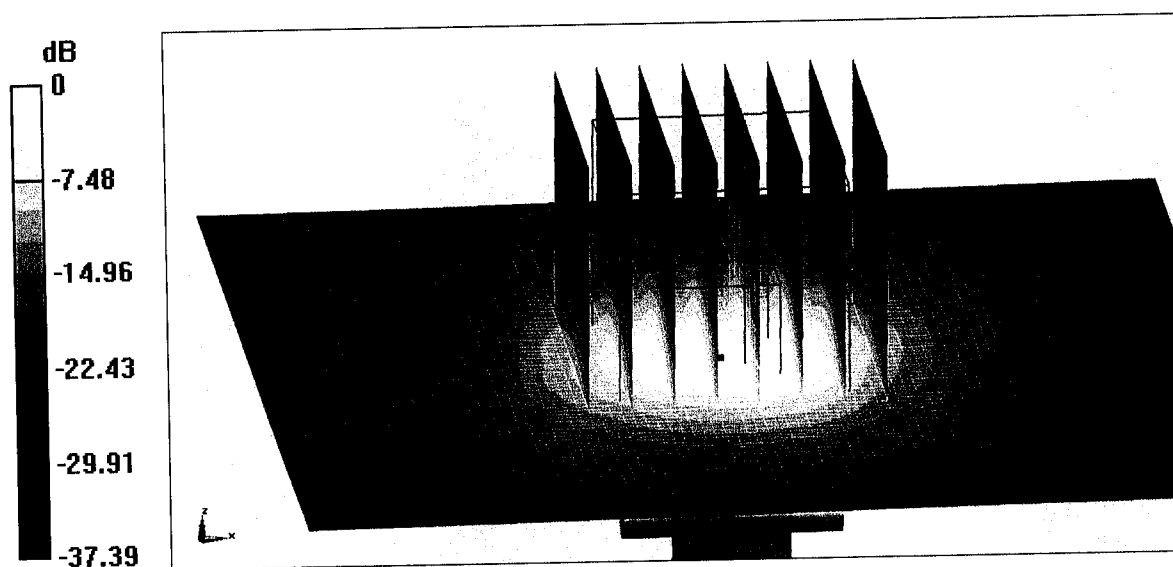
Dipole Calibration /Pin=100mW, d=10mm, f=5750 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.99 V/m; Power Drift = 0.02 dB
Peak SAR (extrapolated) = 35.2 W/kg
SAR(1 g) = 7.43 W/kg; SAR(10 g) = 2.08 W/kg
Maximum value of SAR (measured) = 18.0 W/kg



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0 dB = 18.0 W/kg = 12.55 dBW/kg



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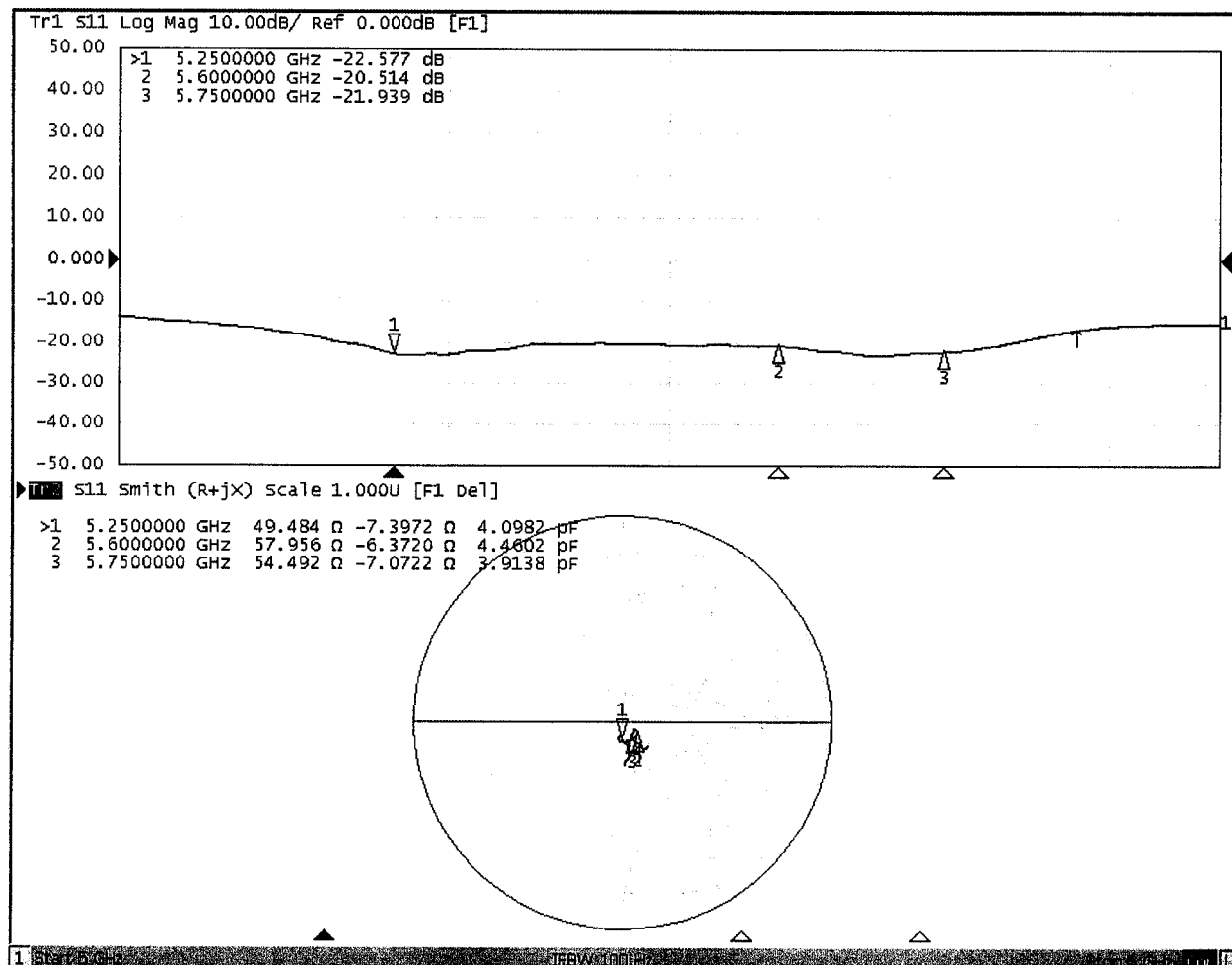
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Impedance Measurement Plot for Body TSL



D5GHzV3, Serial No. 1167 Extended Dipole Calibrations

Referring to KDB 865664 D01 v01r02, if dipoles are verified in return loss ($< -20\text{dB}$, within 20% of prior calibration), and in impedance (within 5 ohm of prior calibration), the annual calibration is not necessary and the calibration interval can be extended.

5250MHz

D5GHzV3 – serial no. 1167												
	5250 Head						5250 Body					
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
2018.08.03	-20.6		50.3		-9.42		-22.6		49.5		-7.40	
2019.10.30	-20.3	1.5	50.9	0.6	-9.72	-0.3	-22.4	0.9	48.2	-1.3	-7.25	0.15

5600MHz

D5GHzV3 – serial no. 1167												
	5600 Head						5600 Body					
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
2018.08.03	-20.0		58.1		-7.15		-20.5		58.0		-6.37	
2019.10.30	-20.1	-0.5	57.4	-0.7	-7.63	-0.48	-20.4	0.5	57.7	-0.3	-6.87	-0.5

5750MHz

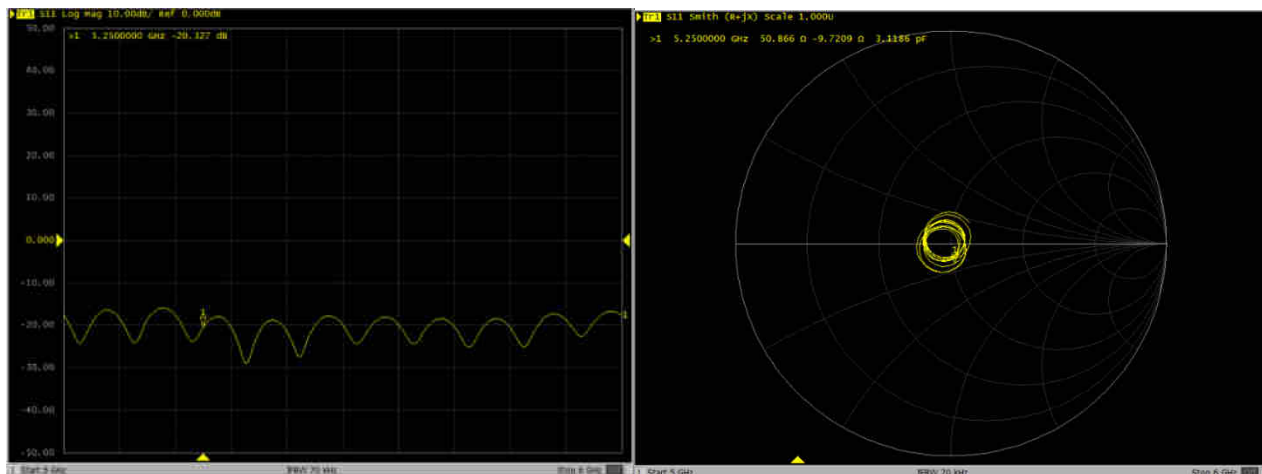
D5GHzV3 – serial no. 1167												
	5750 Head						5750 Body					
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
2018.08.03	-21.8		53.5		-7.66		-21.9		54.5		-7.07	
2019.10.30	-21.1	3.2	53.0	-0.5	-8.58	-0.92	-21.6	1.4	55.2	0.7	-7.04	0.03

<Justification of the extended calibration>

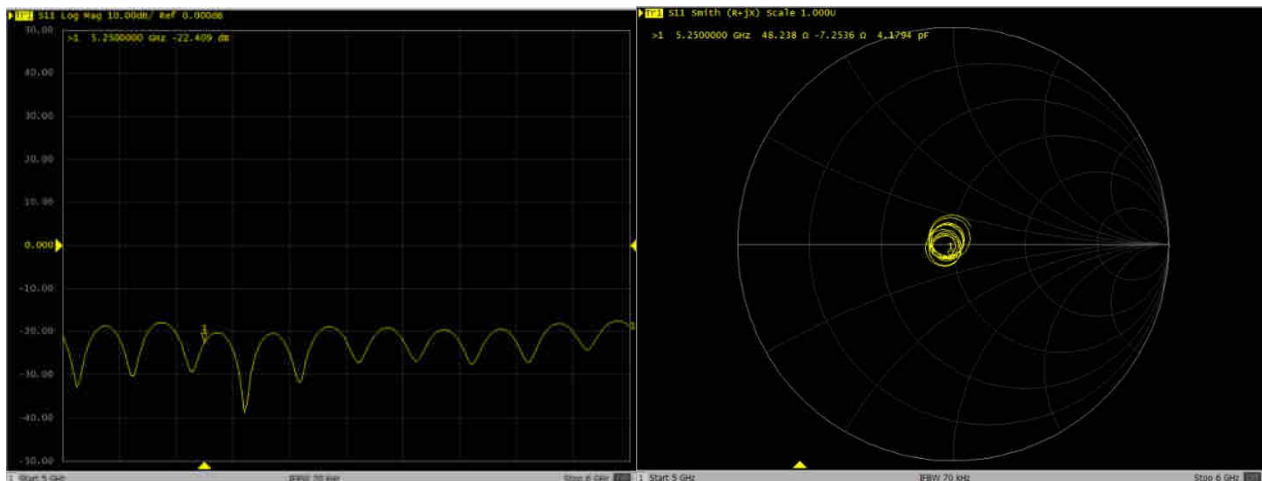
The return loss is $< -20\text{dB}$, within 20% of prior calibration; the impedance is within 5 ohm of prior calibration. Therefore the verification result should support extended calibration.

Dipole Verification Data> D5GHzV3, serial no. 1167

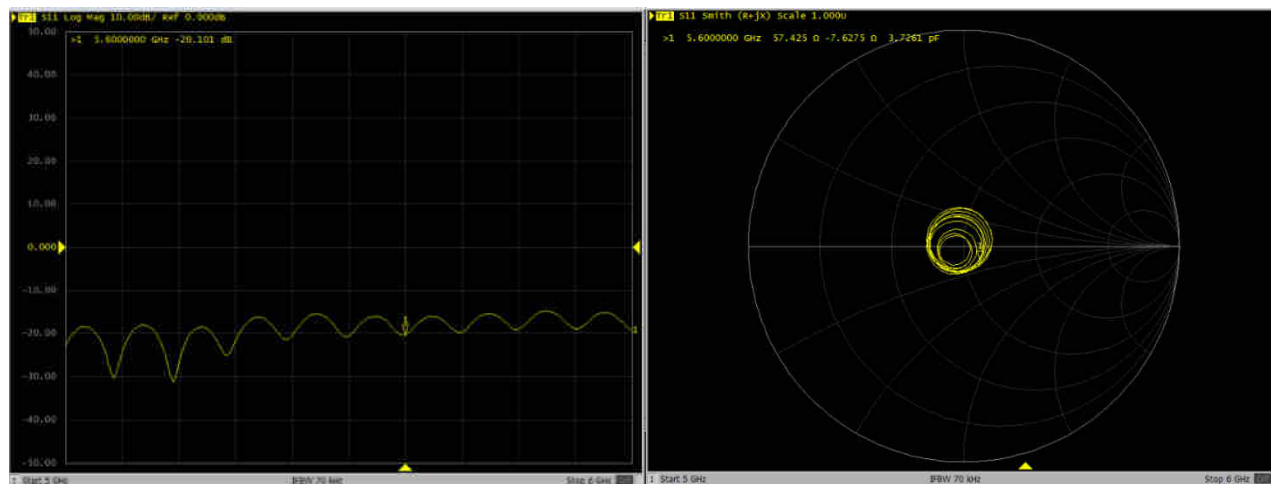
5250MHz - Head



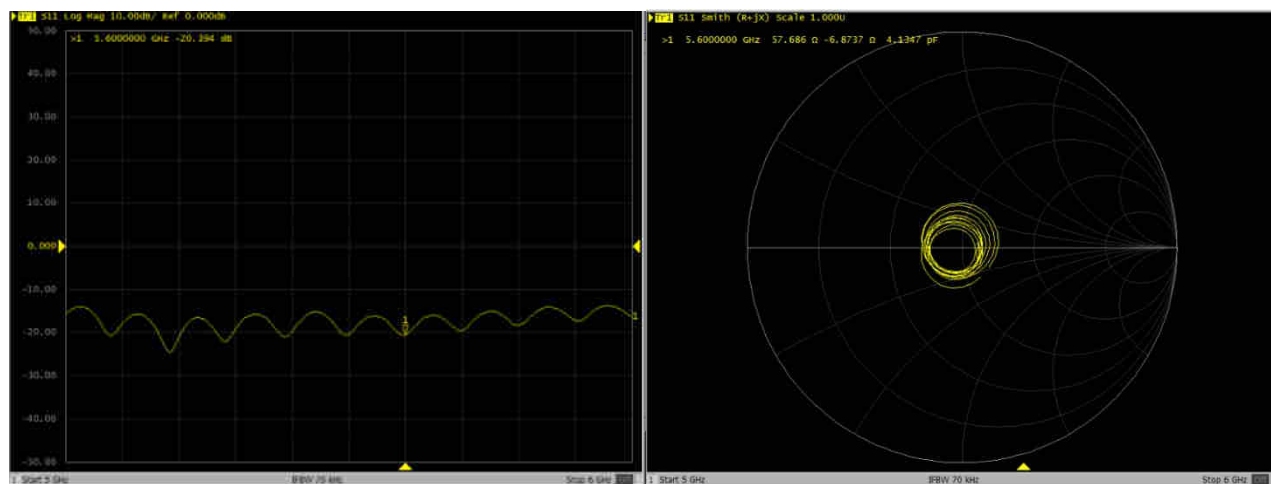
5250MHz – Body



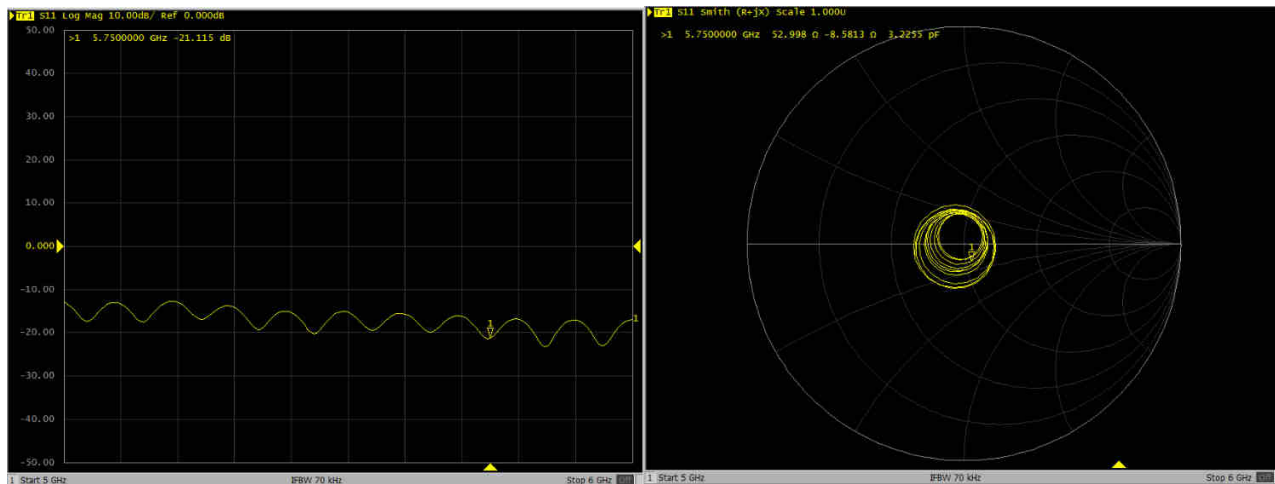
5600MHz – Head



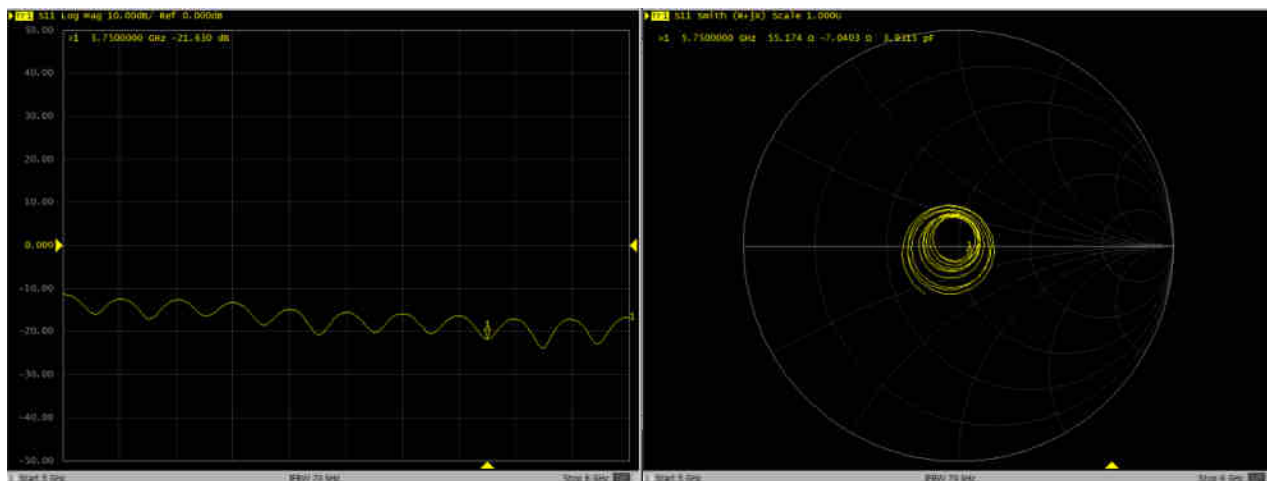
5600MHz – Body



5750MHz – Head



5750MHz – Body





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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

Sporton

Certificate No: **EX3-3819 Mar19**

CALIBRATION CERTIFICATE

Object

EX3DV4 - SN 3819

Calibration procedure(s)

QA CAL-01.v9, QA CAL-14.v5, QA CAL-23.v5, QA CAL-25.v7
Calibration procedure for dosimetric E-field probes

Calibration date:

March 1, 2019

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-18 (No. 217-02672/02673)	Apr-19
Power sensor NRP-Z91	SN: 103244	04-Apr-18 (No. 217-02672)	Apr-19
Power sensor NRP-Z91	SN: 103245	04-Apr-18 (No. 217-02673)	Apr-19
Reference 20 dB Attenuator	SN: S5277 (20x)	04-Apr-18 (No. 217-02682)	Apr-19
DAE4	SN: 660	19-Dec-18 (No. DAE4-660_Dec18)	Dec-19
Reference Probe ES3DV2	SN: 3013	31-Dec-18 (No. ES3-3013_Dec18)	Dec-19
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-18)	In house check: Jun-20
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-18)	In house check: Oct-19

	Name	Function	Signature
Calibrated by:	Michael Weber	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	
Issued: March 2, 2019			
This calibration certificate shall not be reproduced except in full without written approval of the laboratory.			



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Accreditation No.: **SCS 0108**

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 Multilateral Agreement for the recognition of calibration certificates

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., $\vartheta = 0$ 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_{x,y,z}**: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not affect the E^2 -field uncertainty inside TSL (see below ConvF).
- NORM(f)_{x,y,z}** = NORM_{x,y,z} * frequency_response (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCP_{x,y,z}**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (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_{x,y,z}; B_{x,y,z}; C_{x,y,z}; D_{x,y,z}; VR_{x,y,z}**: A, B, C, D are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters**: Assessed in flat phantom using E-field (or Temperature Transfer Standard for $f \leq 800$ MHz) and inside waveguide using analytical field distributions based on power measurements for $f > 800$ MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM_{x,y,z} * ConvF whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- Spherical isotropy (3D deviation from isotropy)**: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the NORM_x (no uncertainty required).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3819

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.46	0.40	0.46	± 10.1 %
DCP (mV) ^B	101.7	100.6	101.3	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB/ μV	C	D dB	VR mV	Max dev.	Unc ^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	149.0	±3.0 %	± 4.7 %
		Y	0.0	0.0	1.0		142.6		
		Y	0.0	0.0	1.0		155.7		

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.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3819

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	112.8
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	9 mm
Tip Diameter	2.5 mm
Probe Tip to Sensor X Calibration Point	1 mm
Probe Tip to Sensor Y Calibration Point	1 mm
Probe Tip to Sensor Z Calibration Point	1 mm
Recommended Measurement Distance from Surface	1.4 mm

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3819

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	10.00	10.00	10.00	0.42	1.05	± 12.0 %
835	41.5	0.90	9.57	9.57	9.57	0.55	0.89	± 12.0 %
900	41.5	0.97	9.43	9.43	9.43	0.41	1.05	± 12.0 %
1450	40.5	1.20	8.68	8.68	8.68	0.29	0.80	± 12.0 %
1750	40.1	1.37	8.54	8.54	8.54	0.40	0.89	± 12.0 %
1900	40.0	1.40	8.27	8.27	8.27	0.23	0.99	± 12.0 %
2000	40.0	1.40	8.20	8.20	8.20	0.35	0.86	± 12.0 %
2300	39.5	1.67	7.64	7.64	7.64	0.37	0.86	± 12.0 %
2450	39.2	1.80	7.21	7.21	7.21	0.34	0.92	± 12.0 %
2600	39.0	1.96	7.06	7.06	7.06	0.38	0.89	± 12.0 %
3300	38.2	2.71	6.91	6.91	6.91	0.29	1.20	± 14.0 %
3500	37.9	2.91	6.89	6.89	6.89	0.25	1.20	± 14.0 %
3700	37.7	3.12	6.67	6.67	6.67	0.25	1.25	± 14.0 %
5250	35.9	4.71	5.07	5.07	5.07	0.40	1.80	± 14.0 %
5600	35.5	5.07	4.70	4.70	4.70	0.40	1.80	± 14.0 %
5750	35.4	5.22	4.77	4.77	4.77	0.40	1.80	± 14.0 %

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

^F 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:3819

Calibration Parameter Determined in Body Tissue Simulating Media

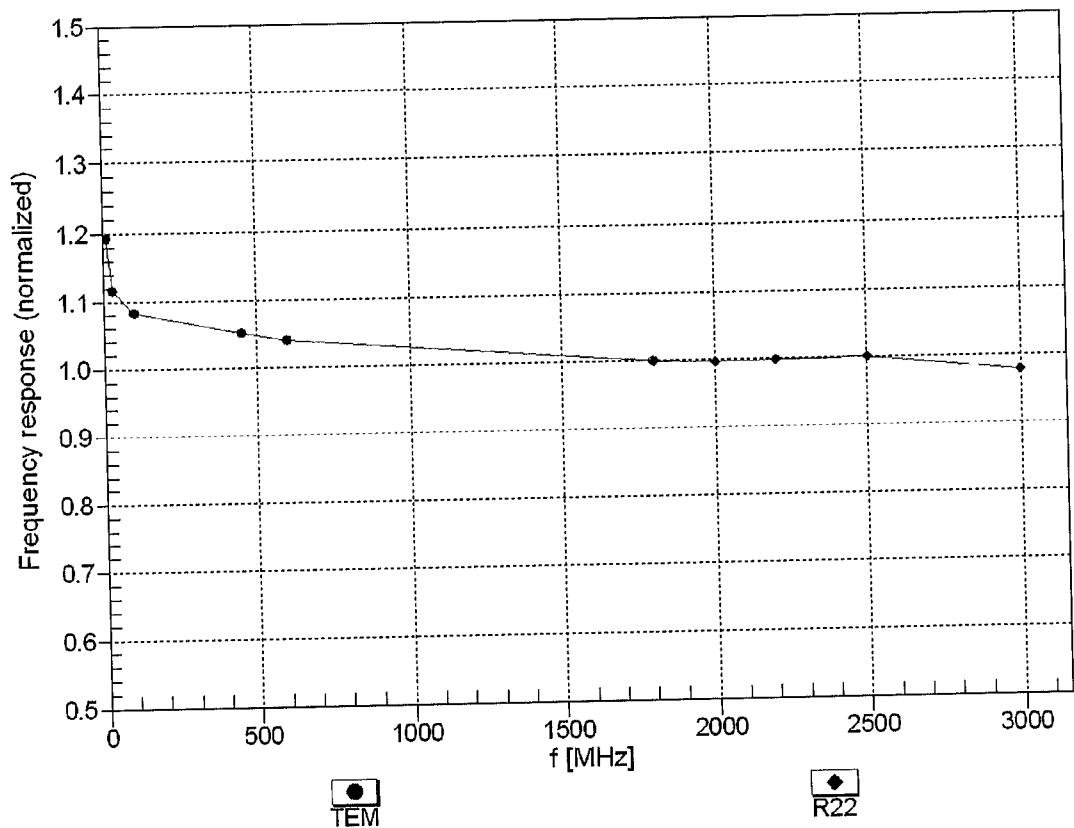
f (MHz) ^C	Relative Permittivity ^F	Conductivity (S/m) ^F	ConvF X	ConvF Y	ConvF Z	Alpha ^G	Depth ^G (mm)	Unc (k=2)
750	55.5	0.96	9.68	9.68	9.68	0.69	0.80	± 12.0 %
835	55.2	0.97	9.40	9.40	9.40	0.49	0.97	± 12.0 %
900	55.0	1.05	9.36	9.36	9.36	0.50	0.92	± 12.0 %
1750	53.4	1.49	8.06	8.06	8.06	0.33	0.85	± 12.0 %
1900	53.3	1.52	7.66	7.66	7.66	0.25	1.11	± 12.0 %
2300	52.9	1.81	7.49	7.49	7.49	0.32	0.96	± 12.0 %
2450	52.7	1.95	7.32	7.32	7.32	0.37	0.89	± 12.0 %
2600	52.5	2.16	7.04	7.04	7.04	0.34	0.95	± 12.0 %
3300	51.6	3.08	6.60	6.60	6.60	0.28	1.20	± 14.0 %
3500	51.3	3.31	6.57	6.57	6.57	0.25	1.20	± 14.0 %
3700	51.0	3.55	6.37	6.37	6.37	0.30	1.25	± 14.0 %
5250	48.9	5.36	4.46	4.46	4.46	0.50	1.90	± 14.0 %
5600	48.5	5.77	3.92	3.92	3.92	0.50	1.90	± 14.0 %
5750	48.3	5.94	4.07	4.07	4.07	0.50	1.90	± 14.0 %

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

^F 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.

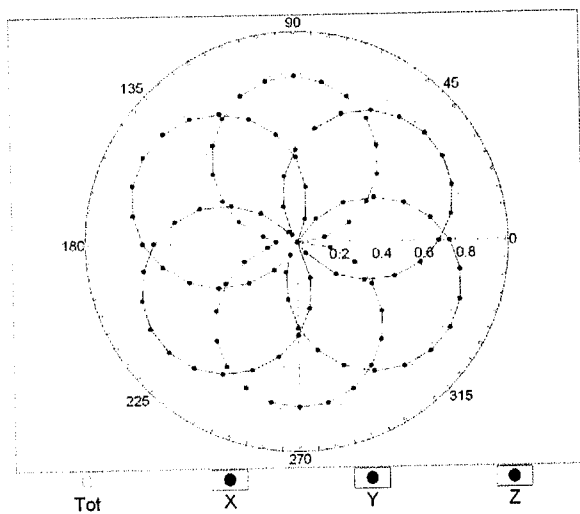
Frequency Response of E-Field
(TEM-Cell:ifi110 EXX, Waveguide: R22)



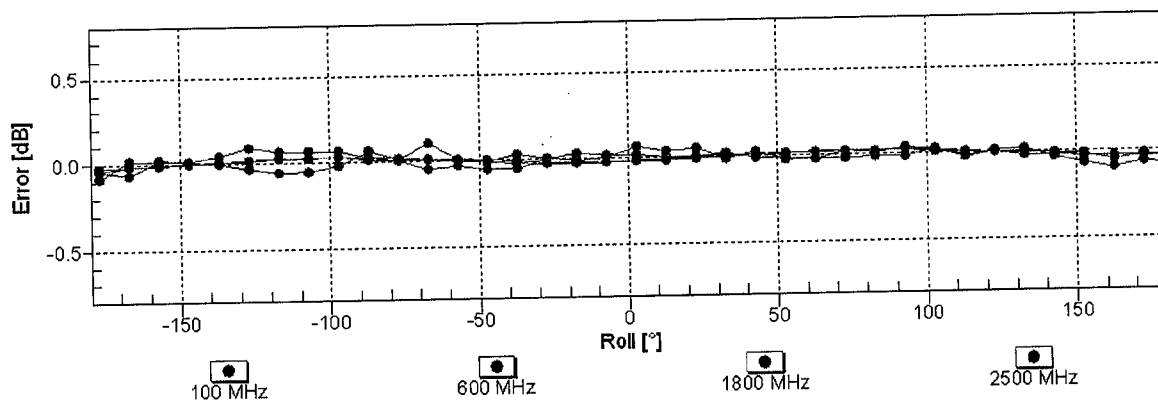
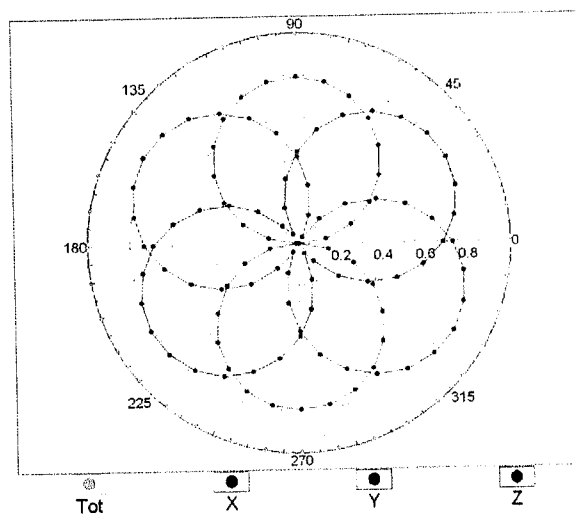
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

f=600 MHz, TEM

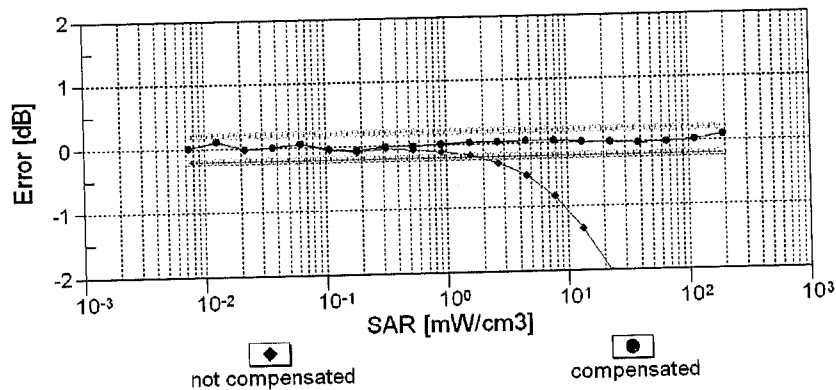
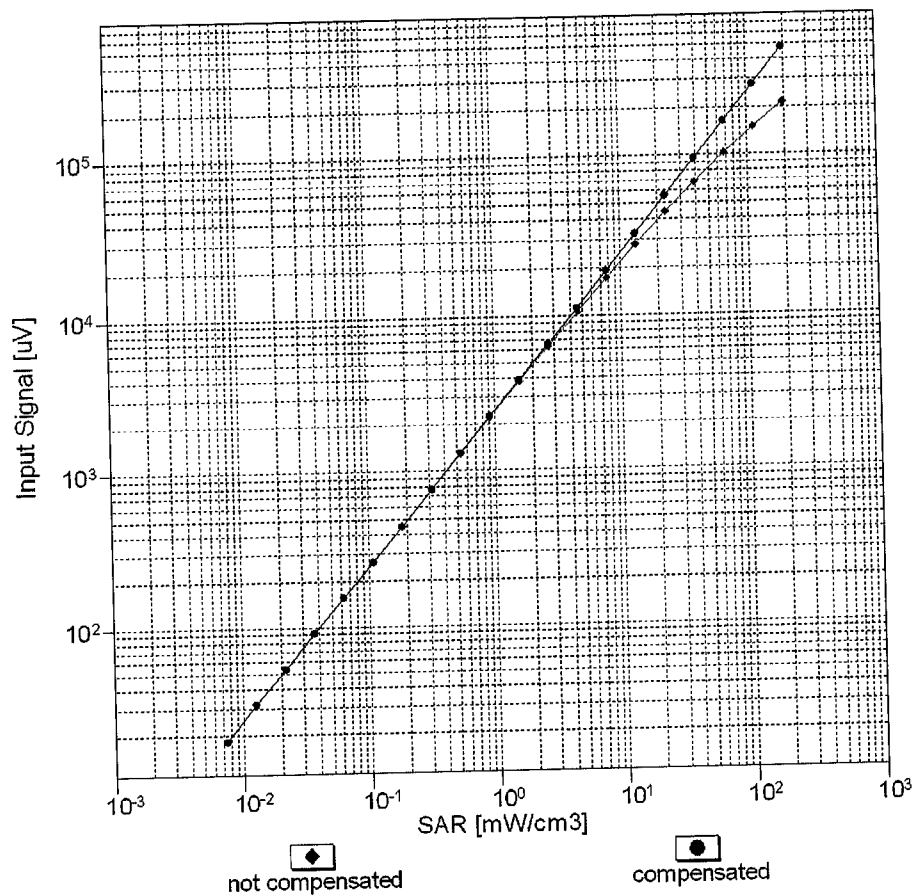


f=1800 MHz, R22



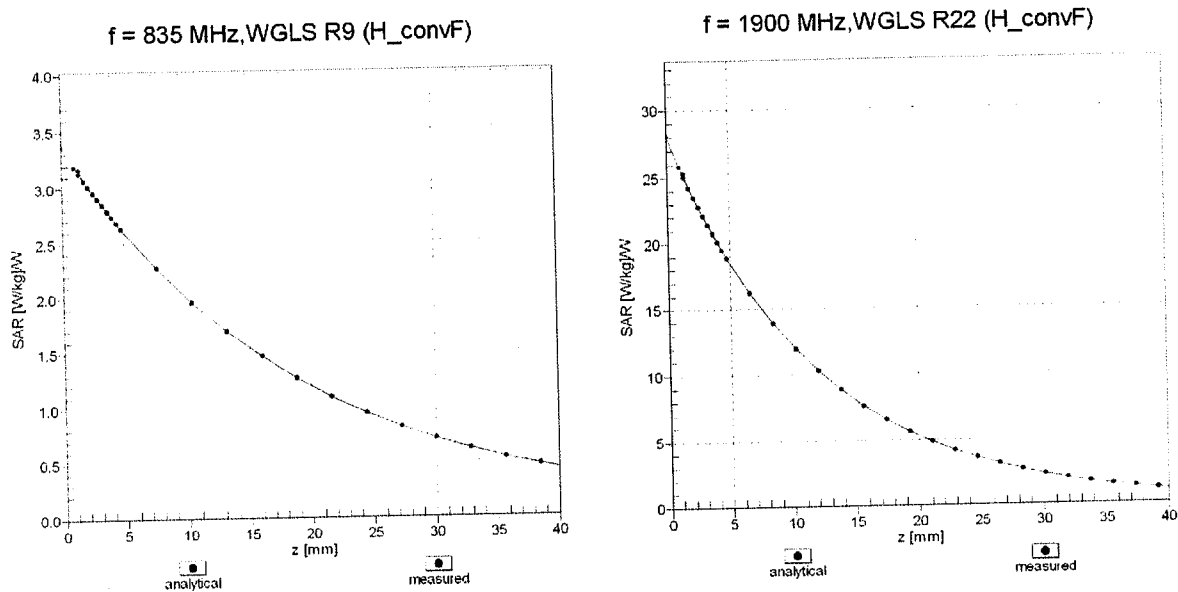
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ ($k=2$)

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

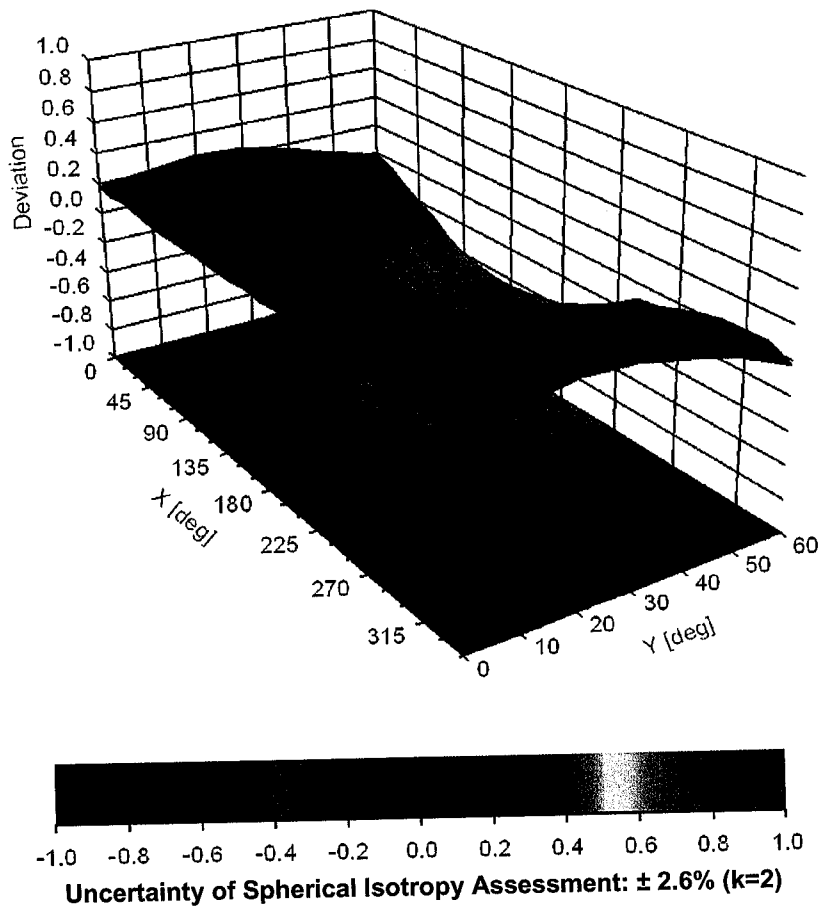


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid Error (ϕ, θ), f = 900 MHz





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Multilateral Agreement for the recognition of calibration certificates

Client **Sporton**

Certificate No: **ES3-3184_Sep19**

CALIBRATION CERTIFICATE

Object **ES3DV3 - SN:3184**

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

Calibration date: **September 25, 2019**

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	03-Apr-19 (No. 217-02892/02893)	Apr-20
Power sensor NRP-Z91	SN: 103244	03-Apr-19 (No. 217-02892)	Apr-20
Power sensor NRP-Z91	SN: 103245	03-Apr-19 (No. 217-02893)	Apr-20
Reference 20 dB Attenuator	SN: S5277 (20x)	04-Apr-19 (No. 217-02894)	Apr-20
DAE4	SN: 660	19-Dec-18 (No. DAE4-660_Dec18)	Dec-19
Reference Probe ES3DV2	SN: 3013	31-Dec-18 (No. ES3-3013_Dec18)	Dec-19
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-18)	In house check: Jun-20
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-18)	In house check: Oct-19

	Name	Function	Signature
Calibrated by:	Michael Weber	Laboratory Technician	
Approved by:	Katja Pokovic	Technical Manager	
Issued: September 26, 2019			
This calibration certificate shall not be reproduced except in full without written approval of the laboratory.			



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Accreditation No.: **SCS 0108**

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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., $\vartheta = 0$ 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_{x,y,z}**: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not affect the E²-field uncertainty inside TSL (see below ConvF).
- NORM(f)_{x,y,z}** = NORM_{x,y,z} * frequency_response (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCP_{x,y,z}**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (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_{x,y,z}; B_{x,y,z}; C_{x,y,z}; D_{x,y,z}; VR_{x,y,z}**: A, B, C, D are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters**: Assessed in flat phantom using E-field (or Temperature Transfer Standard for $f \leq 800$ MHz) and inside waveguide using analytical field distributions based on power measurements for $f > 800$ MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM_{x,y,z} * ConvF whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- Spherical isotropy (3D deviation from isotropy)**: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the NORM_x (no uncertainty required).

DASY/EASY - Parameters of Probe: ES3DV3 - SN:3184

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	1.21	1.33	1.21	± 10.1 %
DCP (mV) ^B	102.5	104.3	100.0	

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 ^E (k=2)
0	CW	X	0.0	0.0	1.0	0.00	211.1	±3.3 %	± 4.7 %
		Y	0.0	0.0	1.0		219.6		
		Y	0.0	0.0	1.0		207.0		

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 E²-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: ES3DV3 - SN:3184**Other Probe Parameters**

Sensor Arrangement	Triangular
Connector Angle (°)	107.9
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	337 mm
Probe Body Diameter	10 mm
Tip Length	10 mm
Tip Diameter	4 mm
Probe Tip to Sensor X Calibration Point	2 mm
Probe Tip to Sensor Y Calibration Point	2 mm
Probe Tip to Sensor Z Calibration Point	2 mm
Recommended Measurement Distance from Surface	3 mm

DASY/EASY - Parameters of Probe: ES3DV3 - SN:3184

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	6.61	6.61	6.61	0.80	1.15	± 12.0 %
835	41.5	0.90	6.41	6.41	6.41	0.71	1.21	± 12.0 %
900	41.5	0.97	6.30	6.30	6.30	0.73	1.21	± 12.0 %
1750	40.1	1.37	5.45	5.45	5.45	0.53	1.34	± 12.0 %
1900	40.0	1.40	5.23	5.23	5.23	0.51	1.42	± 12.0 %
2000	40.0	1.40	5.16	5.16	5.16	0.71	1.16	± 12.0 %
2300	39.5	1.67	4.96	4.96	4.96	0.61	1.35	± 12.0 %
2450	39.2	1.80	4.69	4.69	4.69	0.76	1.26	± 12.0 %
2600	39.0	1.96	4.49	4.49	4.49	0.75	1.28	± 12.0 %

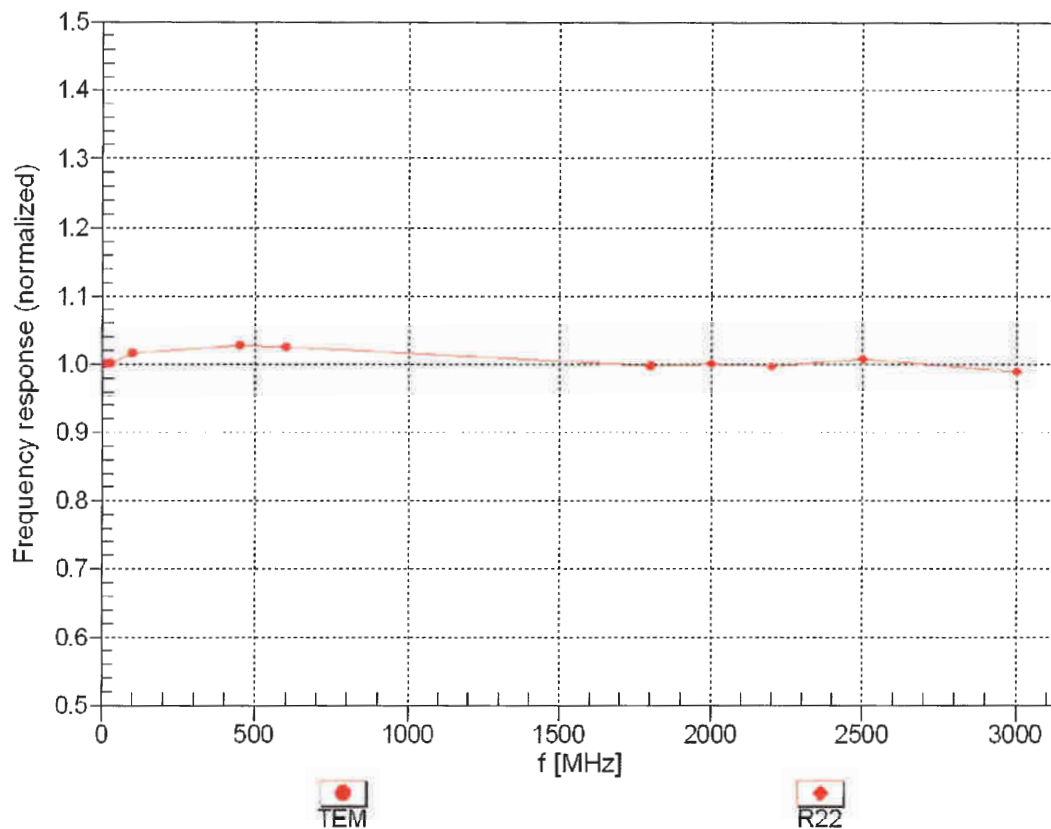
^C Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is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

^F 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

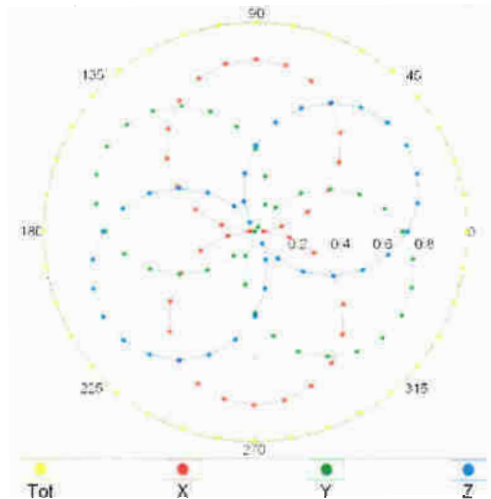
(TEM-Cell:ifi110 EXX, Waveguide: R22)



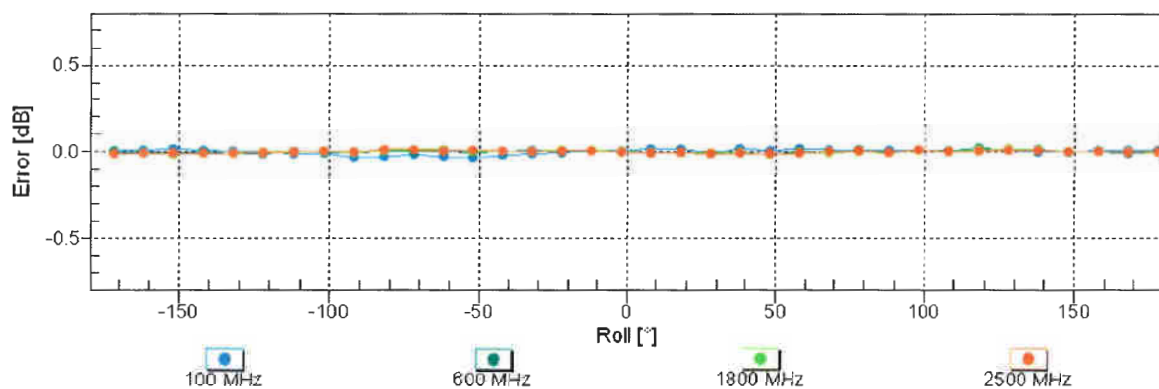
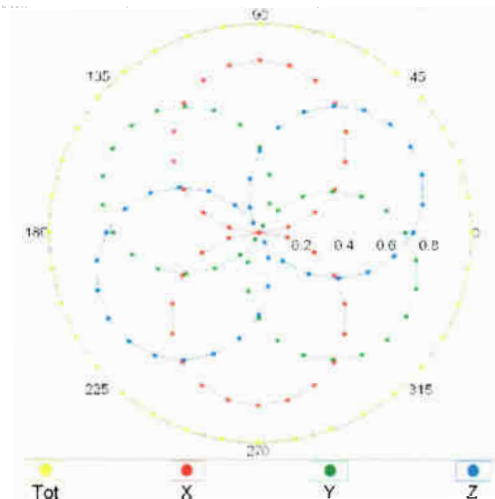
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

f=600 MHz,TEM

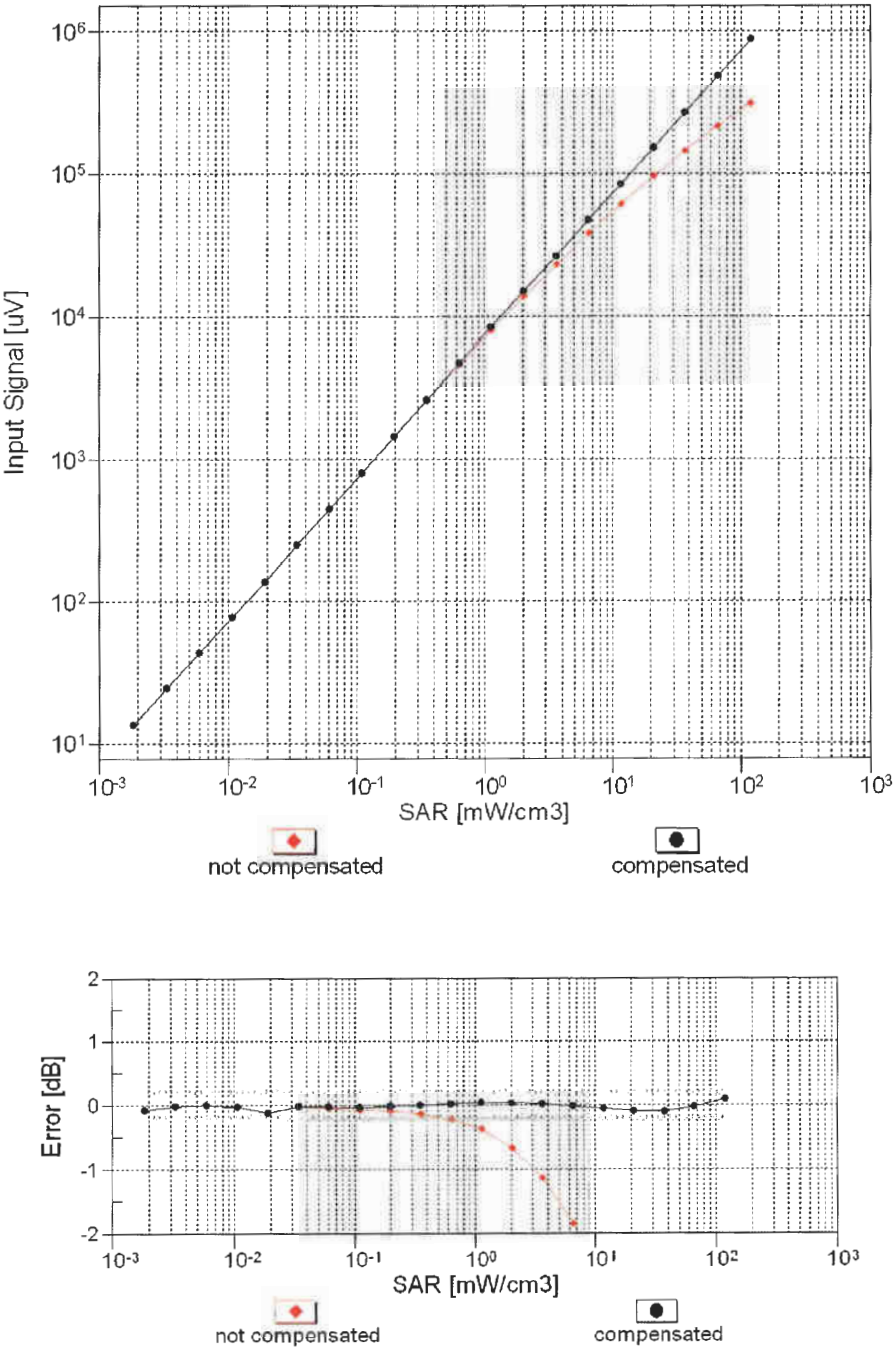


f=1800 MHz,R22



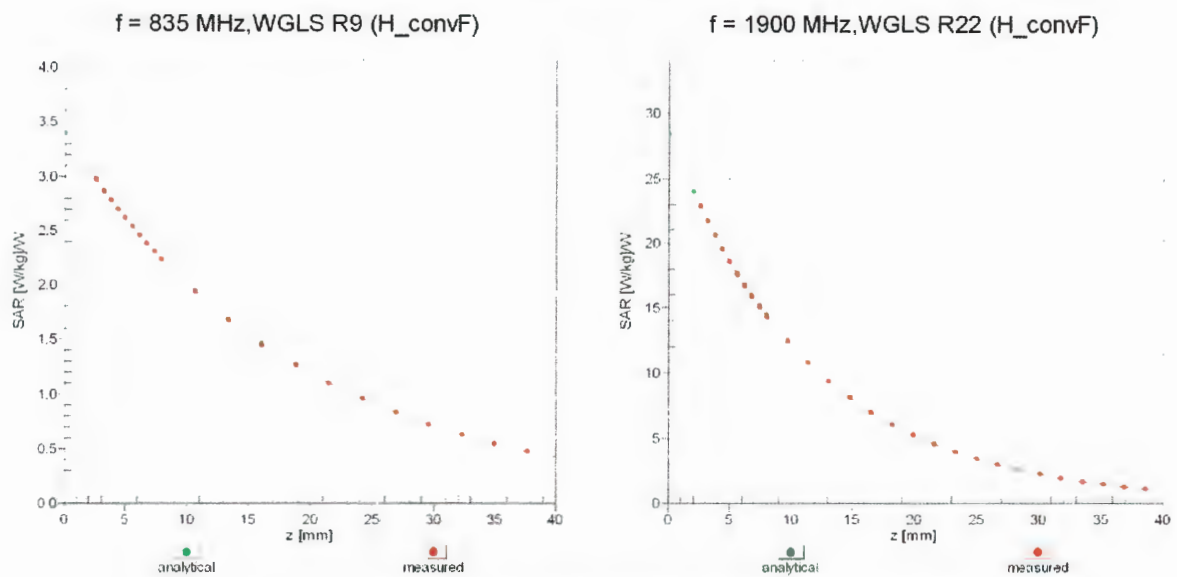
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ ($k=2$)

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



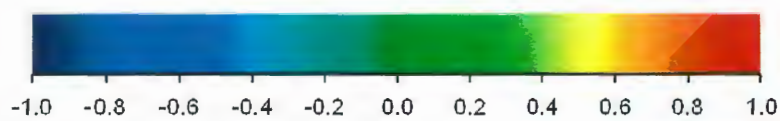
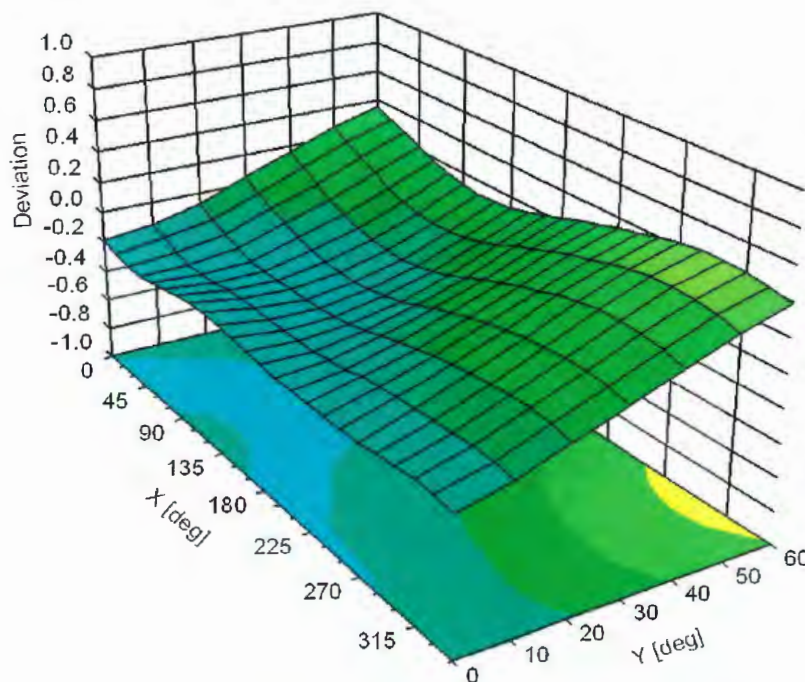
Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment



Deviation from Isotropy in Liquid

Error (ϕ, θ), $f = 900 \text{ MHz}$



Uncertainty of Spherical Isotropy Assessment: $\pm 2.6\%$ ($k=2$)



Accredited by the Swiss Accreditation Service (SAS)

Accreditation No.: **SCS 0108**

The Swiss Accreditation Service is one of the signatories to the EA
Multilateral Agreement for the recognition of calibration certificates

Client **Sporton**

Certificate No: **EX3-3642_Apr19/2**

CALIBRATION CERTIFICATE (Replacement of No: EX3-3642_Apr19)

Object **EX3DV4 - SN:3642**

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

Calibration date: **April 29, 2019**

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	03-Apr-19 (No. 217-02892/02893)	Apr-20
Power sensor NRP-Z91	SN: 103244	03-Apr-19 (No. 217-02892)	Apr-20
Power sensor NRP-Z91	SN: 103245	03-Apr-19 (No. 217-02893)	Apr-20
Reference 20 dB Attenuator	SN: S5277 (20x)	04-Apr-19 (No. 217-02894)	Apr-20
DAE4	SN: 660	19-Dec-18 (No. DAE4-660_Dec18)	Dec-19
Reference Probe ES3DV2	SN: 3013	31-Dec-18 (No. ES3-3013_Dec18)	Dec-19
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-18)	In house check: Jun-20
Network Analyzer E8358A	SN: US41080477	31-Mar-14 (in house check Oct-18)	In house check: Oct-19

Calibrated by:	Name Claudio Leubler	Function Laboratory Technician	Signature
Approved by:	Katja Pokovic	Technical Manager	
Issued: May 21, 2019			
This calibration certificate shall not be reproduced except in full without written approval of the laboratory.			



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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., $\vartheta = 0$ 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
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- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

Methods Applied and Interpretation of Parameters:

- NORM_{x,y,z}**: Assessed for E-field polarization $\vartheta = 0$ ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not affect the E²-field uncertainty inside TSL (see below ConvF).
- NORM(f)_{x,y,z}** = NORM_{x,y,z} * frequency_response (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of ConvF.
- DCP_{x,y,z}**: DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (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_{x,y,z}; B_{x,y,z}; C_{x,y,z}; D_{x,y,z}; VR_{x,y,z}**: A, B, C, D are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. VR is the maximum calibration range expressed in RMS voltage across the diode.
- ConvF and Boundary Effect Parameters**: Assessed in flat phantom using E-field (or Temperature Transfer Standard for $f \leq 800$ MHz) and inside waveguide using analytical field distributions based on power measurements for $f > 800$ MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to NORM_{x,y,z} * ConvF whereby the uncertainty corresponds to that given for ConvF. A frequency dependent ConvF is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- Spherical isotropy (3D deviation from isotropy)**: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the NORM_x (no uncertainty required).

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3642

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.30	0.31	0.38	± 10.1 %
DCP (mV) ^B	100.4	96.8	100.9	

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Max dev.	Max Unc ^E (k=2)
0	CW	X	0.00	0.00	1.00	0.00	120.8	± 2.7 %	± 4.7 %
		Y	0.00	0.00	1.00		132.3		
		Z	0.00	0.00	1.00		136.8		
10352-AAA	Pulse Waveform (200Hz, 10%)	X	4.53	71.70	13.81	10.00	60.0	± 2.7 %	± 9.6 %
		Y	1.96	62.61	10.00		60.0		
		Z	12.83	83.67	17.75		60.0		
10353-AAA	Pulse Waveform (200Hz, 20%)	X	12.05	83.21	16.28	6.99	80.0	± 1.9 %	± 9.6 %
		Y	1.88	64.97	9.53		80.0		
		Z	15.00	86.77	17.56		80.0		
10354-AAA	Pulse Waveform (200Hz, 40%)	X	15.00	86.47	15.76	3.98	95.0	± 1.3 %	± 9.6 %
		Y	0.58	60.03	5.58		95.0		
		Z	15.00	89.80	17.49		95.0		
10355-AAA	Pulse Waveform (200Hz, 60%)	X	15.00	89.56	15.81	2.22	120.0	± 1.2 %	± 9.6 %
		Y	0.35	60.00	3.83		120.0		
		Z	15.00	94.26	18.24		120.0		
10387-AAA	QPSK Waveform, 1 MHz	X	0.42	60.00	5.47	0.00	150.0	± 3.7 %	± 9.6 %
		Y	0.45	60.00	5.51		150.0		
		Z	0.63	61.76	8.40		150.0		
10388-AAA	QPSK Waveform, 10 MHz	X	2.42	71.50	17.89	0.00	150.0	± 1.3 %	± 9.6 %
		Y	1.99	67.60	15.30		150.0		
		Z	2.36	69.94	16.78		150.0		
10396-AAA	64-QAM Waveform, 100 kHz	X	2.27	67.55	17.70	3.01	150.0	± 1.1 %	± 9.6 %
		Y	2.72	69.18	18.04		150.0		
		Z	3.04	72.26	19.62		150.0		
10399-AAA	64-QAM Waveform, 40 MHz	X	3.52	68.12	16.61	0.00	150.0	± 2.9 %	± 9.6 %
		Y	3.34	66.87	15.63		150.0		
		Z	3.45	67.40	15.99		150.0		
10414-AAA	WLAN CCDF, 64-QAM, 40MHz	X	4.67	66.12	16.03	0.00	150.0	± 5.1 %	± 9.6 %
		Y	4.67	65.55	15.56		150.0		
		Z	4.70	65.67	15.57		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 E²-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:3642

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	29.8	223.97	36.29	6.69	0.69	5.00	0.00	0.33	1.00
Y	37.1	288.37	38.20	7.07	0.93	5.03	0.00	0.55	1.01
Z	38.6	281.69	34.29	7.94	0.36	5.03	1.26	0.18	1.01

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	109.5
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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3642

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	9.16	9.16	9.16	0.43	0.95	± 12.0 %
835	41.5	0.90	9.05	9.05	9.05	0.47	0.80	± 12.0 %
900	41.5	0.97	8.93	8.93	8.93	0.36	0.96	± 12.0 %
1450	40.5	1.20	8.52	8.52	8.52	0.45	0.80	± 12.0 %
1750	40.1	1.37	8.18	8.18	8.18	0.52	0.85	± 12.0 %
1900	40.0	1.40	7.91	7.91	7.91	0.43	0.83	± 12.0 %
2000	40.0	1.40	7.90	7.90	7.90	0.41	0.85	± 12.0 %
2300	39.5	1.67	7.57	7.57	7.57	0.34	0.85	± 12.0 %
2450	39.2	1.80	7.32	7.32	7.32	0.36	0.85	± 12.0 %
2600	39.0	1.96	7.14	7.14	7.14	0.45	0.85	± 12.0 %
3300	38.2	2.71	6.85	6.85	6.85	0.30	1.20	± 14.0 %
3500	37.9	2.91	6.75	6.75	6.75	0.35	1.20	± 14.0 %
3700	37.7	3.12	6.46	6.46	6.46	0.35	1.25	± 14.0 %
3900	37.5	3.32	6.40	6.40	6.40	0.30	1.40	± 14.0 %
4100	37.2	3.53	6.00	6.00	6.00	0.40	1.50	± 14.0 %
4400	36.9	3.84	5.89	5.89	5.89	0.50	1.55	± 14.0 %
4600	36.7	4.04	5.60	5.60	5.60	0.40	1.50	± 14.0 %
4800	36.4	4.25	5.33	5.33	5.33	0.40	1.50	± 14.0 %
4950	36.3	4.40	5.11	5.11	5.11	0.40	1.80	± 14.0 %
5250	35.9	4.71	4.54	4.54	4.54	0.40	1.80	± 14.0 %
5600	35.5	5.07	4.28	4.28	4.28	0.40	1.80	± 14.0 %
5750	35.4	5.22	4.36	4.36	4.36	0.40	1.80	± 14.0 %

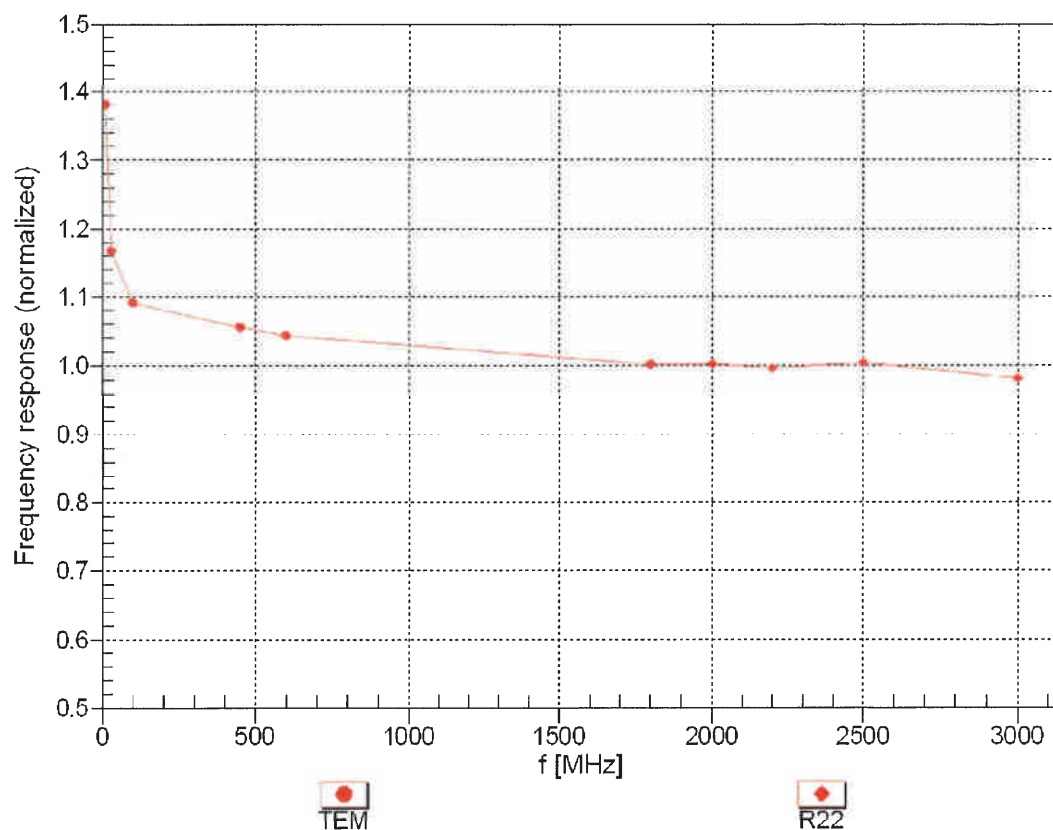
^C Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is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

^F At frequencies up to 6 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.

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Frequency Response of E-Field

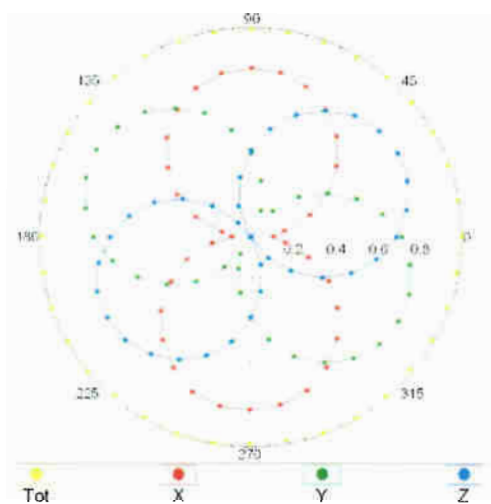
(TEM-Cell:ifi110 EXX, Waveguide: R22)



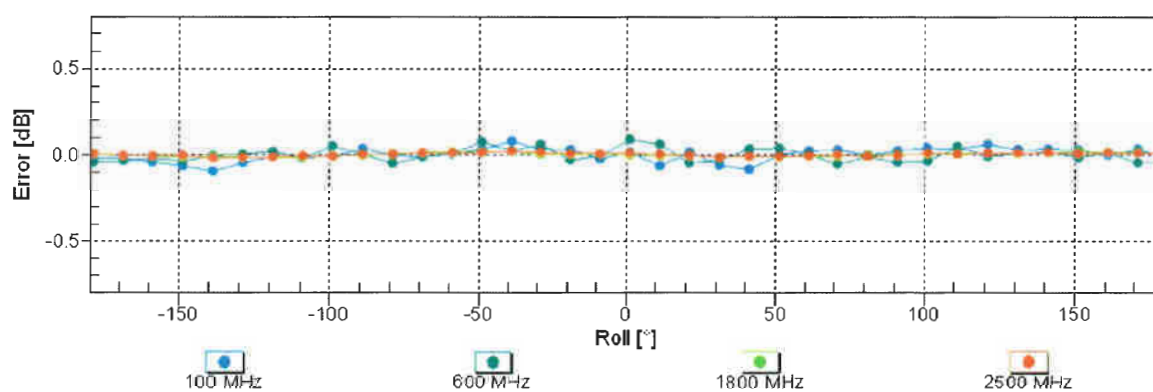
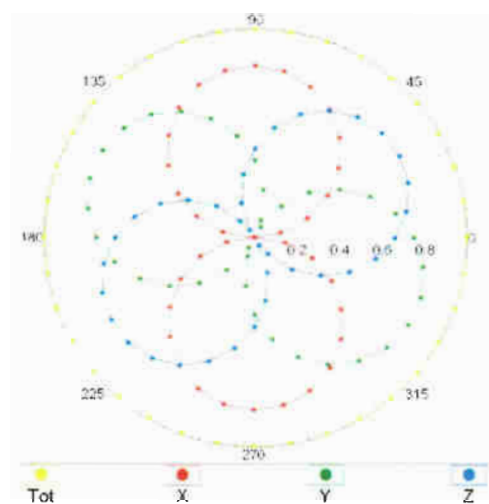
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ ($k=2$)

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

$f=600$ MHz, TEM

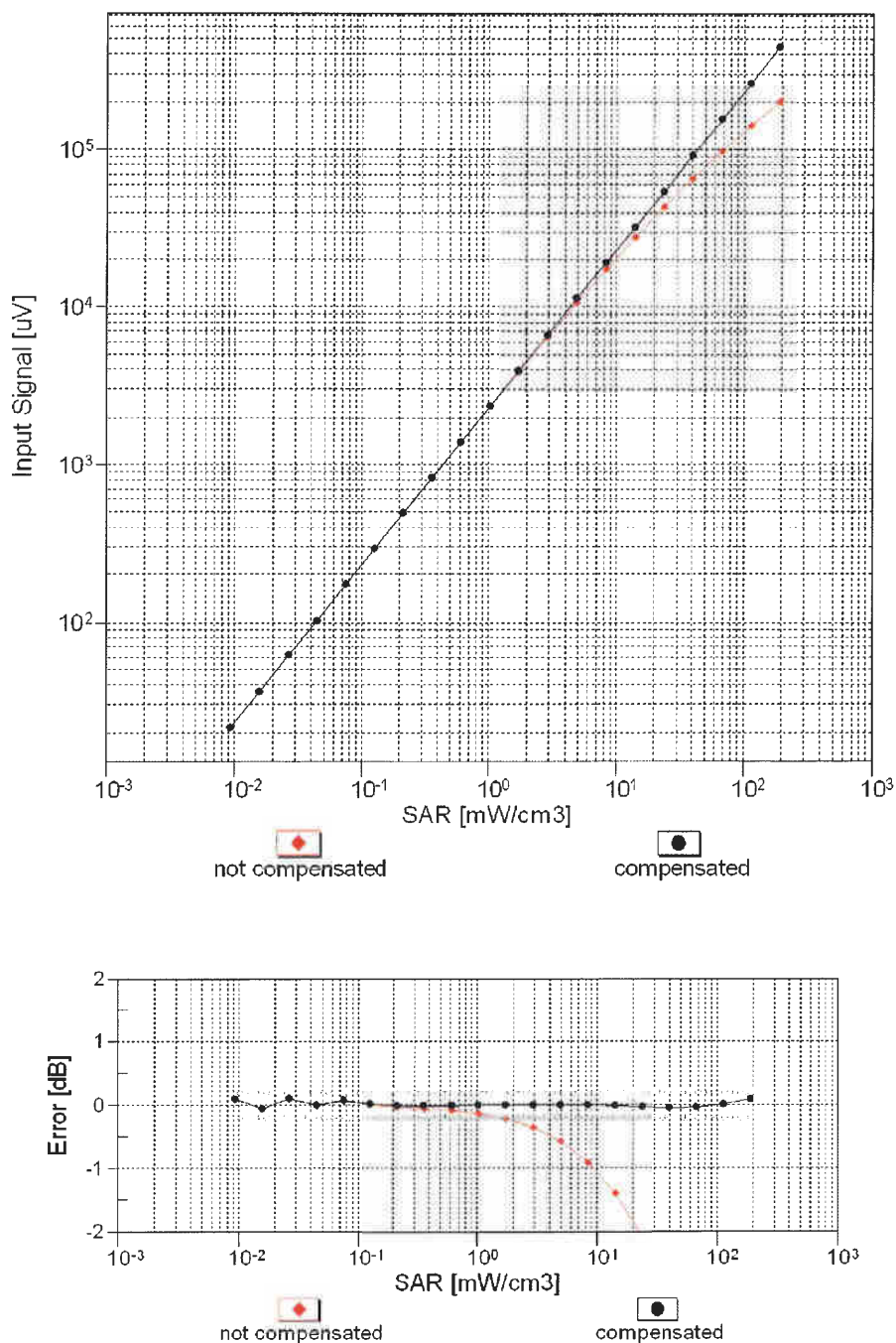


$f=1800$ MHz, R22



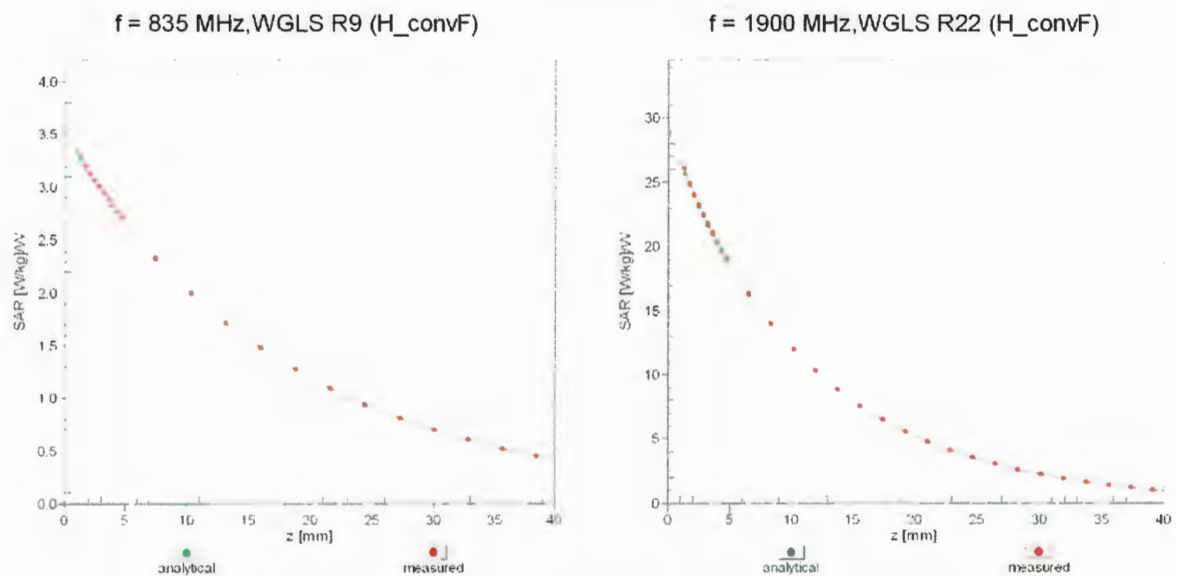
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ ($k=2$)

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



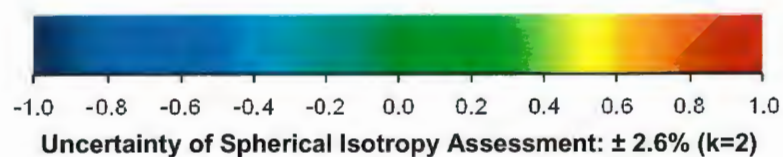
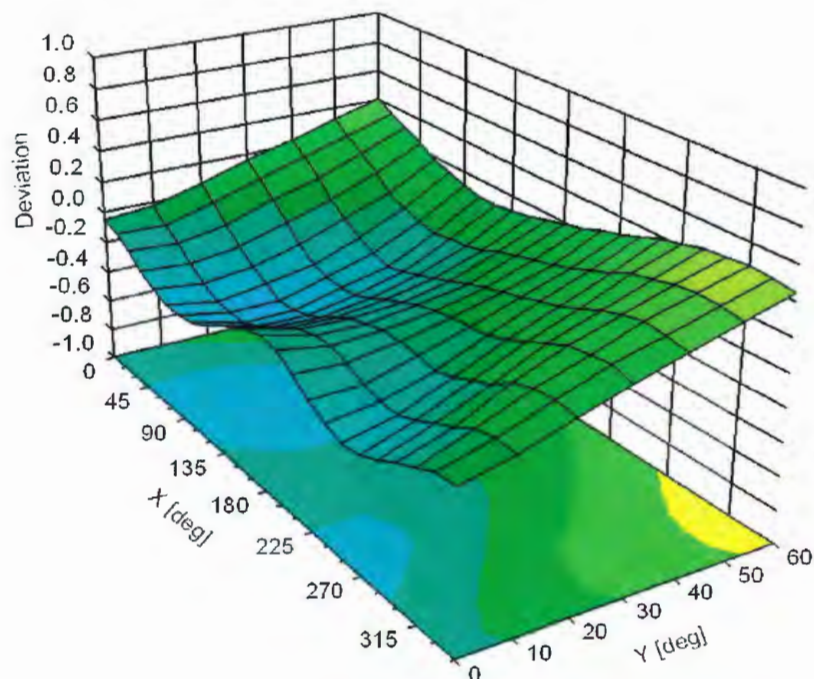
Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

Conversion Factor Assessment



Deviation from Isotropy in Liquid

Error (ϕ, θ), $f = 900 \text{ MHz}$





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Client

Auden

Certificate No: **Z19-60105**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:7346**

Calibration Procedure(s) **FF-Z11-004-01**
Calibration Procedures for Dosimetric E-field Probes

Calibration date: **April 25, 2019**

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

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

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	101919	20-Jun-18 (CTTL, No.J18X05032)	Jun-19
Power sensor NRP-Z91	101547	20-Jun-18 (CTTL, No.J18X05032)	Jun-19
Power sensor NRP-Z91	101548	20-Jun-18 (CTTL, No.J18X05032)	Jun-19
Reference10dBAttenuator	18N50W-10dB	09-Feb-18(CTTL, No.J18X01133)	Feb-20
Reference20dBAttenuator	18N50W-20dB	09-Feb-18(CTTL, No.J18X01132)	Feb-20
Reference Probe EX3DV4	SN 7514	27-Aug-18(SPEAG,No.EX3-7514_Aug18/2)	Aug-19
DAE4	SN 1555	20-Aug-18(SPEAG, No.DAE4-1555_Aug18)	Aug -19
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
SignalGeneratorMG3700A	6201052605	21-Jun-18 (CTTL, No.J18X05033)	Jun-19
Network Analyzer E5071C	MY46110673	24-Jan-19 (CTTL, No.J19X00547)	Jan -20

	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 27, 2019

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



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Glossary:

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- DCP_{x,y,z}:** DCP are numerical linearization parameters assessed based on the data of power sweep (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_{x,y,z}; B_{x,y,z}; C_{x,y,z}; VR_{x,y,z}:** A,B,C 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 $f \leq 800\text{MHz}$) and inside waveguide using analytical field distributions based on power measurements for $f > 800\text{MHz}$. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty valued 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 $\pm 50\text{MHz}$ to $\pm 100\text{MHz}$.
- Spherical isotropy (3D deviation from isotropy):** in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset:** The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle:** The angle is assessed using the information gained by determining the NORM_x (no uncertainty required).

Probe EX3DV4

SN: 7346

Calibrated: April 25, 2019

Calibrated for DASY/EASY Systems

(Note: non-compatible with DASY2 system!)



DASY/EASY – Parameters of Probe: EX3DV4 – SN: 7346

Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm($\mu\text{V}/(\text{V}/\text{m})^2$) ^A	0.43	0.50	0.51	±10.0%
DCP(mV) ^B	100.5	104.9	102.0	

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	156.3	±2.7%
		Y	0.0	0.0	1.0		172.9	
		Z	0.0	0.0	1.0		171.6	

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%.

^A The uncertainties of Norm X, Y, Z do not affect the E²-field uncertainty inside TSL (see Page 5 and Page 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: 7346

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)	Unct. (k=2)
750	41.9	0.89	10.19	10.19	10.19	0.09	1.78	± 12.1%
835	41.5	0.90	9.81	9.81	9.81	0.10	1.63	± 12.1%
900	41.5	0.97	9.79	9.79	9.79	0.16	1.35	± 12.1%
1450	40.5	1.20	8.71	8.71	8.71	0.11	1.49	± 12.1%
1750	40.1	1.37	8.50	8.50	8.50	0.28	0.97	± 12.1%
1900	40.0	1.40	8.07	8.07	8.07	0.27	0.99	± 12.1%
2000	40.0	1.40	8.06	8.06	8.06	0.27	0.97	± 12.1%
2300	39.5	1.67	7.81	7.81	7.81	0.63	0.70	± 12.1%
2450	39.2	1.80	7.50	7.50	7.50	0.66	0.70	± 12.1%
2600	39.0	1.96	7.31	7.31	7.31	0.69	0.69	± 12.1%
3500	37.9	2.91	6.91	6.91	6.91	0.55	0.92	± 13.3%
5250	35.9	4.71	5.36	5.36	5.36	0.40	1.40	± 13.3%
5600	35.5	5.07	4.75	4.75	4.75	0.45	1.35	± 13.3%
5750	35.4	5.22	4.78	4.78	4.78	0.50	1.45	± 13.3%

^C Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of 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 frequency 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 the 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: 7346

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)	Unct. (k=2)
750	55.5	0.96	10.35	10.35	10.35	0.40	0.80	± 12.1%
835	55.2	0.97	9.88	9.88	9.88	0.18	1.40	± 12.1%
900	55.0	1.05	9.91	9.91	9.91	0.20	1.29	± 12.1%
1450	54.0	1.30	8.45	8.45	8.45	0.11	1.51	± 12.1%
1750	53.4	1.49	8.20	8.20	8.20	0.24	1.07	± 12.1%
1900	53.3	1.52	7.92	7.92	7.92	0.23	1.16	± 12.1%
2000	53.3	1.52	7.90	7.90	7.90	0.20	1.27	± 12.1%
2300	52.9	1.81	7.69	7.69	7.69	0.58	0.81	± 12.1%
2450	52.7	1.95	7.64	7.64	7.64	0.69	0.72	± 12.1%
2600	52.5	2.16	7.36	7.36	7.36	0.70	0.71	± 12.1%
3500	51.3	3.31	6.74	6.74	6.74	0.55	1.02	± 13.3%
5250	48.9	5.36	4.86	4.86	4.86	0.45	1.62	± 13.3%
5600	48.5	5.77	4.27	4.27	4.27	0.50	1.65	± 13.3%
5750	48.3	5.94	4.26	4.26	4.26	0.55	1.55	± 13.3%

^C Frequency validity above 300 MHz of ±100MHz only applies for DASY v4.4 and higher (Page 2), else it is restricted to ±50MHz. The uncertainty is the RSS of 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 frequency 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.

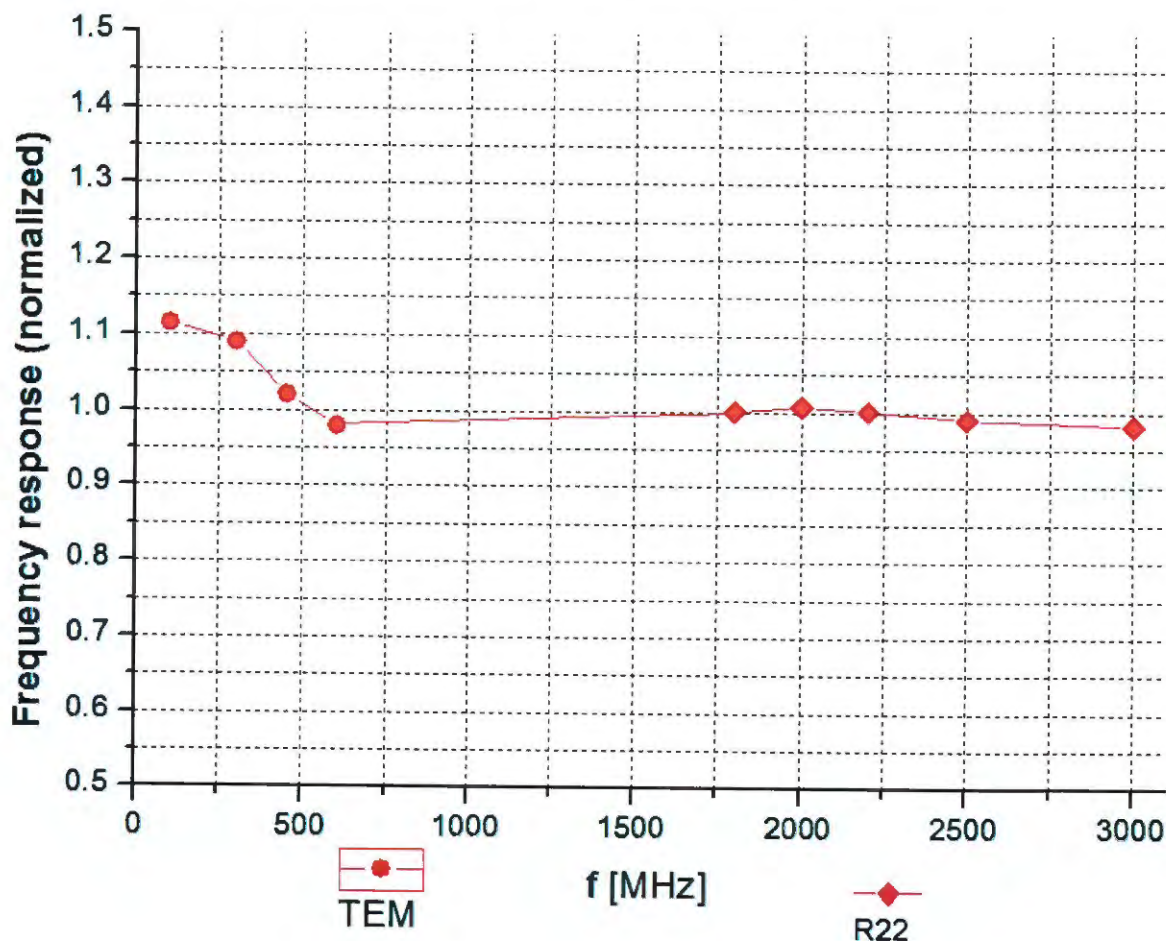
^G Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for the frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from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



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



Uncertainty of Frequency Response of E-field: $\pm 7.4\%$ ($k=2$)

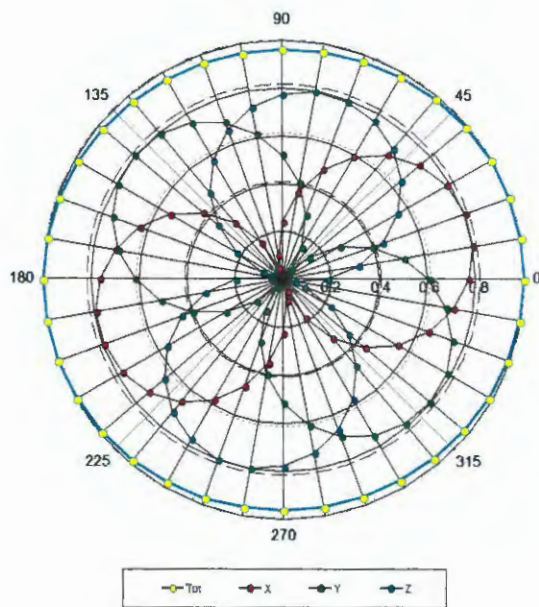


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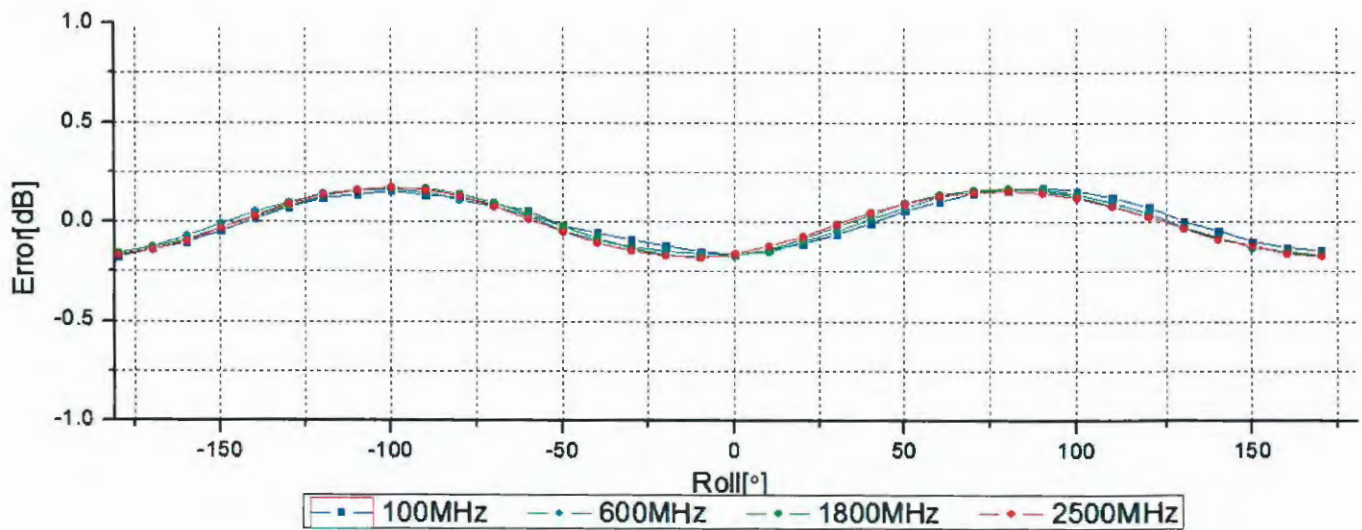
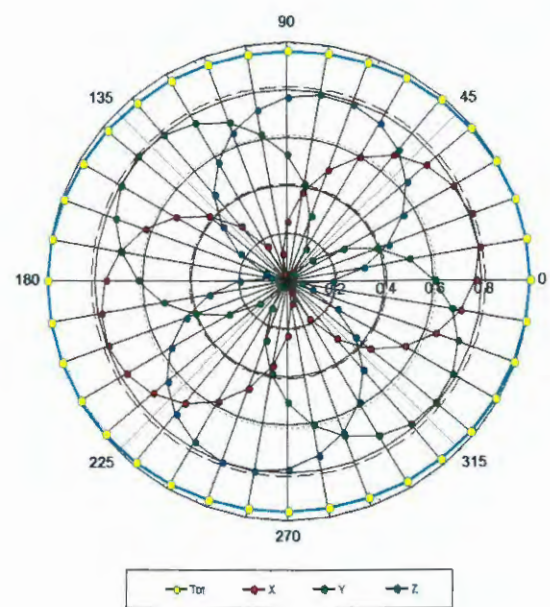
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Receiving Pattern (Φ), $\theta=0^\circ$

f=600 MHz, TEM



f=1800 MHz, R22



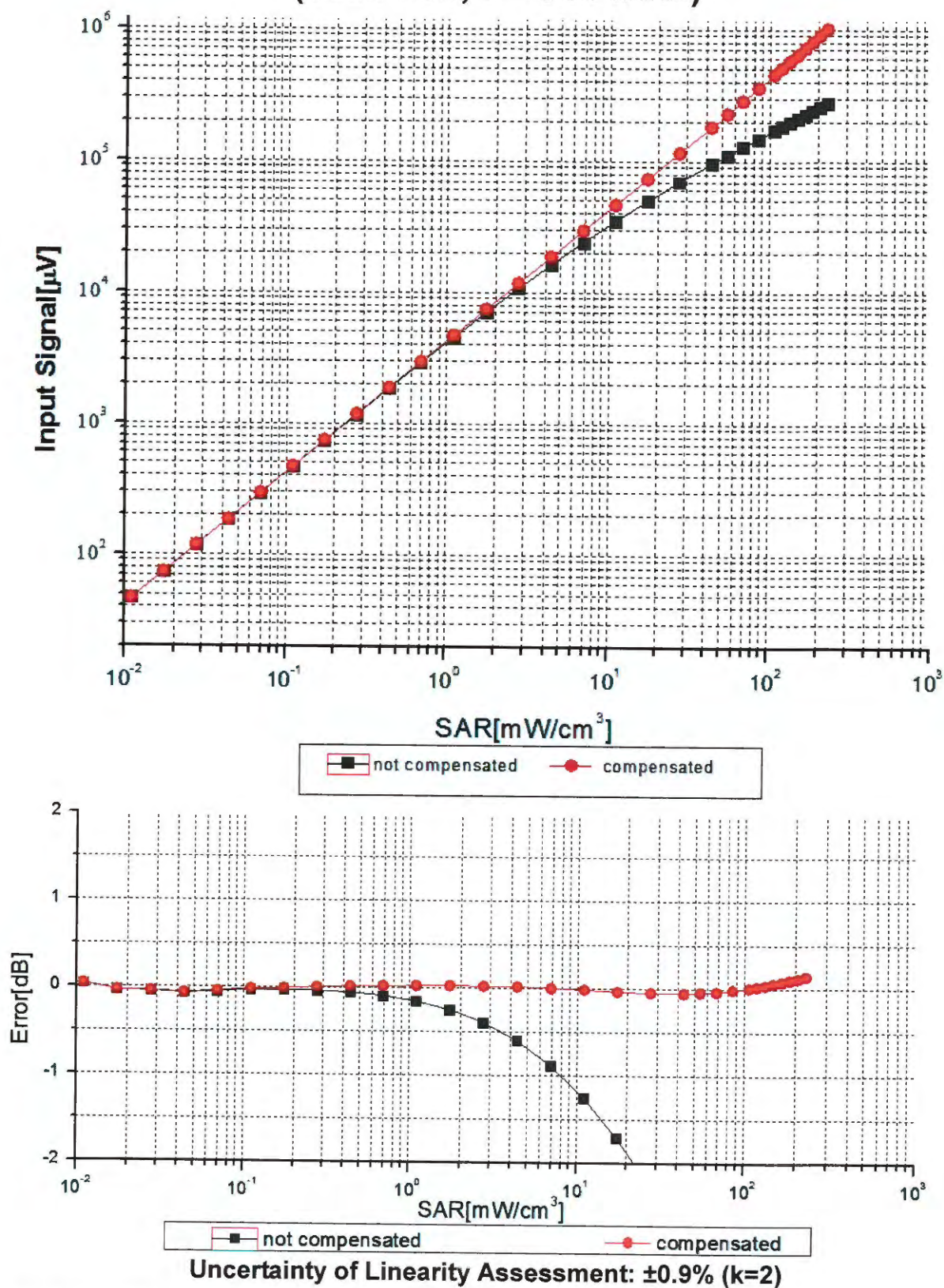
Uncertainty of Axial Isotropy Assessment: $\pm 1.2\%$ ($k=2$)



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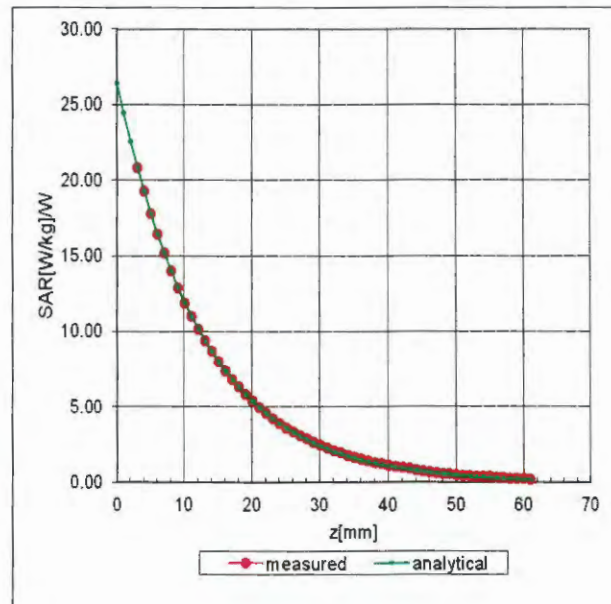
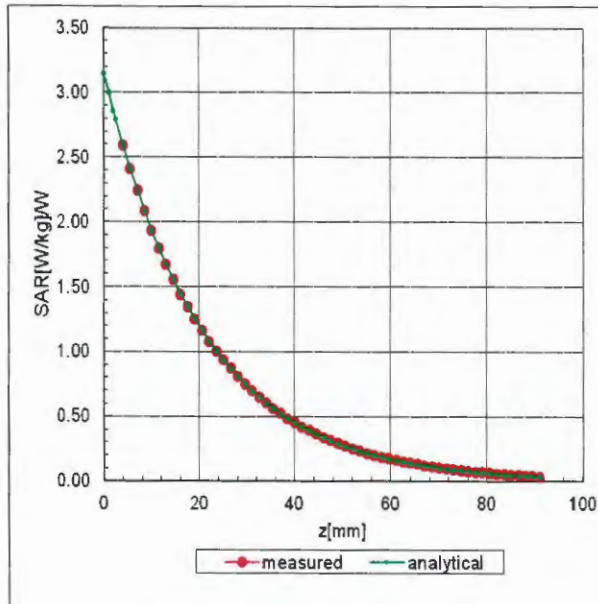
Dynamic Range f(SAR_{head}) (TEM cell, f = 900 MHz)



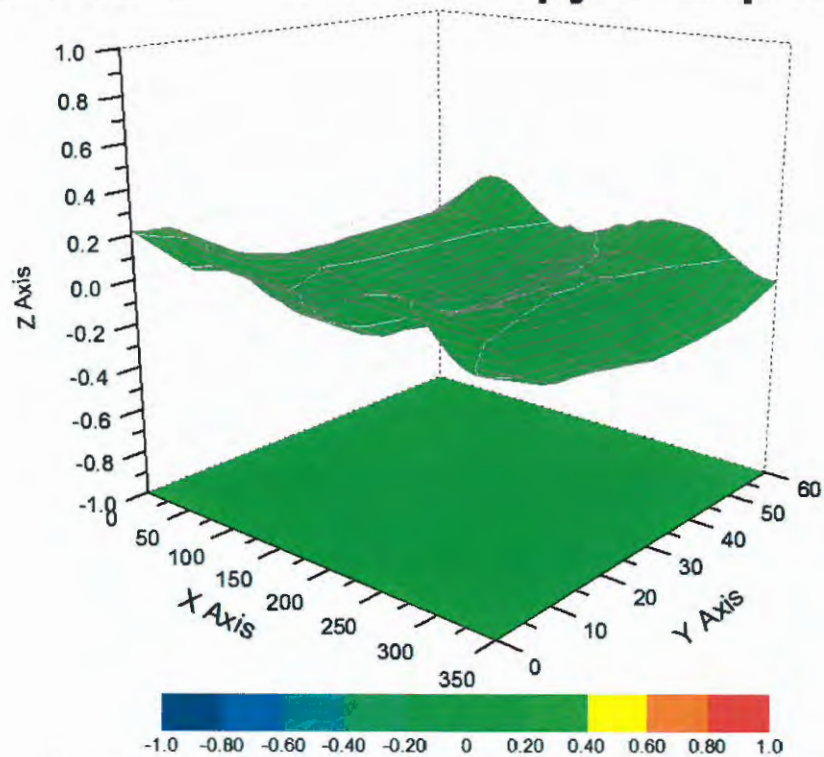
Conversion Factor Assessment

f=750 MHz, WGLS R9(H_convF)

f=1750 MHz, WGLS R22(H_convF)



Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment: $\pm 3.2\%$ (K=2)



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DASY/EASY – Parameters of Probe: EX3DV4 – SN: 7346

Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	93.3
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disable
Probe Overall Length	337mm
Probe Body Diameter	10mm
Tip Length	9mm
Tip Diameter	2.5mm
Probe Tip to Sensor X Calibration Point	1mm
Probe Tip to Sensor Y Calibration Point	1mm
Probe Tip to Sensor Z Calibration Point	1mm
Recommended Measurement Distance from Surface	1.4mm



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Client : **Sporton**

Certificate No: **Z19-60029**

CALIBRATION CERTIFICATE

Object **DAE4 - SN: 715**

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

Calibration date: **January 23, 2019**

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	20-Jun-18 (CTTL, No.J18X05034)	June-19

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

Signature

Issued: January 24, 2019

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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 μ 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	405.101 $\pm$ 0.15% (k=2)	404.654 $\pm$ 0.15% (k=2)	404.478 $\pm$ 0.15% (k=2)
Low Range	3.99019 $\pm$ 0.7% (k=2)	3.97763 $\pm$ 0.7% (k=2)	3.97614 $\pm$ 0.7% (k=2)

Connector Angle

Connector Angle to be used in DASY system	330.5° $\pm$ 1 °
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Client : **Sporton**

Certificate No: **Z19-60307**

CALIBRATION CERTIFICATE

Object **DAE4 - SN: 1386**

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

Calibration date: **September 09, 2019**

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) $^{\circ}\text{C}$ 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	24-Jun-19 (CTTL, No.J19X05126)	Jun-20

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

Signature

Issued: September 10, 2019

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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 μ 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	404.550 $\pm$ 0.15% (k=2)	404.640 $\pm$ 0.15% (k=2)	404.159 $\pm$ 0.15% (k=2)
Low Range	4.02000 $\pm$ 0.7% (k=2)	4.01341 $\pm$ 0.7% (k=2)	4.01171 $\pm$ 0.7% (k=2)

Connector Angle

Connector Angle to be used in DASY system	203.5° $\pm$ 1 °
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Client : **Auden**

Certificate No: **Z19-60142**

CALIBRATION CERTIFICATE

Object **DAE4 - SN: 1305**

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

Calibration date: **April 30, 2019**

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	20-Jun-18 (CTTL, No.J18X05034)	June-19

	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: May 01, 2019

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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 μ 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	403.824 $\pm$ 0.15% (k=2)	403.988 $\pm$ 0.15% (k=2)	404.309 $\pm$ 0.15% (k=2)
Low Range	3.98318 $\pm$ 0.7% (k=2)	3.99237 $\pm$ 0.7% (k=2)	3.99781 $\pm$ 0.7% (k=2)

Connector Angle

Connector Angle to be used in DASY system	96.5° $\pm$ 1 °
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Accredited by the Swiss Accreditation Service (SAS)

Accreditation No.: **SCS 0108**

The Swiss Accreditation Service is one of the signatories to the EA
 Multilateral Agreement for the recognition of calibration certificates

Client **Sporton**

Certificate No: **DAE4-853_Jul19**

CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 853**

Calibration procedure(s) **QA CAL-06.v29**
Calibration procedure for the data acquisition electronics (DAE)

Calibration date: **July 18, 2019**

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
Keithley Multimeter Type 2001	SN: 0810278	03-Sep-18 (No:23488)	Sep-19
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	07-Jan-19 (in house check)	In house check: Jan-20
Calibrator Box V2.1	SE UMS 006 AA 1002	07-Jan-19 (in house check)	In house check: Jan-20

	Name	Function	Signature
Calibrated by:	Adrian Gehring	Laboratory Technician	
Approved by:	Sven Kühn	Deputy Manager	

Issued: July 18, 2019

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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**

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 following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
 - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
 - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
 - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
 - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
 - *Input Offset Measurement:* Output voltage and statistical results over a large number of zero voltage measurements.
 - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
 - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
 - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
 - *Power consumption:* Typical value for information. Supply currents in various operating modes.

DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1 μ 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	402.636 $\pm$ 0.02% (k=2)	403.297 $\pm$ 0.02% (k=2)	403.459 $\pm$ 0.02% (k=2)
Low Range	3.95584 $\pm$ 1.50% (k=2)	3.96622 $\pm$ 1.50% (k=2)	3.96807 $\pm$ 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	134.0 ° $\pm$ 1 °
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Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	200042.65	4.84	0.00
Channel X	+ Input	20006.48	0.46	0.00
Channel X	- Input	-20004.66	1.31	-0.01
Channel Y	+ Input	200039.01	1.51	0.00
Channel Y	+ Input	20006.29	0.53	0.00
Channel Y	- Input	-20007.74	-1.68	0.01
Channel Z	+ Input	200041.36	3.13	0.00
Channel Z	+ Input	20004.58	-1.11	-0.01
Channel Z	- Input	-20007.54	-1.47	0.01

Low Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	2001.38	-0.13	-0.01
Channel X	+ Input	201.93	0.66	0.33
Channel X	- Input	-197.86	0.69	-0.35
Channel Y	+ Input	2001.20	-0.19	-0.01
Channel Y	+ Input	199.34	-1.82	-0.91
Channel Y	- Input	-199.56	-0.94	0.47
Channel Z	+ Input	2001.44	0.12	0.01
Channel Z	+ Input	200.21	-0.93	-0.46
Channel Z	- Input	-200.23	-1.56	0.79

2. Common mode sensitivity

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

	Common mode Input Voltage (mV)	High Range Average Reading (μV)	Low Range Average Reading (μV)
Channel X	200	-5.99	-7.95
	- 200	10.58	8.82
Channel Y	200	4.92	4.61
	- 200	-6.14	-6.13
Channel Z	200	0.74	0.71
	- 200	-3.12	-3.28

3. Channel separation

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

	Input Voltage (mV)	Channel X (μV)	Channel Y (μV)	Channel Z (μV)
Channel X	200	-	5.13	0.42
Channel Y	200	10.58	-	6.17
Channel Z	200	14.06	7.88	-

4. AD-Converter Values with inputs shorted

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

	High Range (LSB)	Low Range (LSB)
Channel X	16249	17230
Channel Y	16089	16493
Channel Z	16236	15987

5. Input Offset Measurement

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

Input 10M Ω

	Average (μ V)	min. Offset (μ V)	max. Offset (μ V)	Std. Deviation (μ V)
Channel X	0.46	-0.33	1.57	0.37
Channel Y	1.39	0.30	2.84	0.47
Channel Z	0.85	-0.17	2.74	0.67

6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

7. Input Resistance (Typical values for information)

	Zeroing (kOhm)	Measuring (MOhm)
Channel X	200	200
Channel Y	200	200
Channel Z	200	200

8. Low Battery Alarm Voltage (Typical values for information)

Typical values	Alarm Level (VDC)
Supply (+ Vcc)	+7.9
Supply (- Vcc)	-7.6

9. Power Consumption (Typical values for information)

Typical values	Switched off (mA)	Stand by (mA)	Transmitting (mA)
Supply (+ Vcc)	+0.01	+6	+14
Supply (- Vcc)	-0.01	-8	-9

IMPORTANT NOTICE

USAGE OF THE DAE4

The DAE unit is a delicate, high precision instrument and requires careful treatment by the user. There are no serviceable parts inside the DAE. Special attention shall be given to the following points:

Battery Exchange: The battery cover of the DAE4 unit is fixed using a screw, over tightening the screw may cause the threads inside the DAE to wear out.

Shipping of the DAE: Before shipping the DAE to SPEAG for calibration, remove the batteries and pack the DAE in an antistatic bag. This antistatic bag shall then be packed into a larger box or container which protects the DAE from impacts during transportation. The package shall be marked to indicate that a fragile instrument is inside.

E-Stop Failures: Touch detection may be malfunctioning due to broken magnets in the E-stop. Rough handling of the E-stop may lead to damage of these magnets. Touch and collision errors are often caused by dust and dirt accumulated in the E-stop. To prevent E-stop failure, the customer shall always mount the probe to the DAE carefully and keep the DAE unit in a non-dusty environment if not used for measurements.

Repair: Minor repairs are performed at no extra cost during the annual calibration. However, SPEAG reserves the right to charge for any repair especially if rough unprofessional handling caused the defect.

DASY Configuration Files: Since the exact values of the DAE input resistances, as measured during the calibration procedure of a DAE unit, are not used by the DASY software, a nominal value of 200 MOhm is given in the corresponding configuration file.

Important Note:

Warranty and calibration is void if the DAE unit is disassembled partly or fully by the Customer.

Important Note:

Never attempt to grease or oil the E-stop assembly. Cleaning and readjusting of the E-stop assembly is allowed by certified SPEAG personnel only and is part of the annual calibration procedure.

Important Note:

To prevent damage of the DAE probe connector pins, use great care when installing the probe to the DAE. Carefully connect the probe with the connector notch oriented in the mating position. Avoid any rotational movement of the probe body versus the DAE while turning the locking nut of the connector. The same care shall be used when disconnecting the probe from the DAE.



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 **Sporton**

Certificate No: **DAE4-854_May19**

CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BM - SN: 854**

Calibration procedure(s) **QA CAL-06.v29**
Calibration procedure for the data acquisition electronics (DAE)

Calibration date: **May 21, 2019**

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
Keithley Multimeter Type 2001	SN: 0810278	03-Sep-18 (No:23488)	Sep-19
Secondary Standards	ID #	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	07-Jan-19 (in house check)	In house check: Jan-20
Calibrator Box V2.1	SE UMS 006 AA 1002	07-Jan-19 (in house check)	In house check: Jan-20

Calibrated by:	Name	Function	Signature
	Adrian Gehring	Laboratory Technician	

Approved by:	Sven Kühn	Deputy Manager
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Issued: May 21, 2019

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



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**

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 following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
 - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
 - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
 - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
 - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
 - *Input Offset Measurement:* Output voltage and statistical results over a large number of zero voltage measurements.
 - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
 - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
 - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
 - *Power consumption:* Typical value for information. Supply currents in various operating modes.

DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1 μ 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	404.909 $\pm$ 0.02% (k=2)	404.692 $\pm$ 0.02% (k=2)	405.783 $\pm$ 0.02% (k=2)
Low Range	3.97164 $\pm$ 1.50% (k=2)	3.94913 $\pm$ 1.50% (k=2)	3.99482 $\pm$ 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	325.0 ° $\pm$ 1 °
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Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	199994.47	0.40	0.00
Channel X + Input	20000.57	-0.74	-0.00
Channel X - Input	-19999.89	1.86	-0.01
Channel Y + Input	199996.63	2.65	0.00
Channel Y + Input	19998.60	-2.61	-0.01
Channel Y - Input	-20002.11	-0.26	0.00
Channel Z + Input	199993.70	-0.37	-0.00
Channel Z + Input	19998.50	-2.78	-0.01
Channel Z - Input	-20002.17	-0.31	0.00

Low Range	Reading (μV)	Difference (μV)	Error (%)
Channel X + Input	2000.92	0.14	0.01
Channel X + Input	201.80	0.54	0.27
Channel X - Input	-198.07	0.52	-0.26
Channel Y + Input	2000.75	-0.14	-0.01
Channel Y + Input	200.51	-0.64	-0.32
Channel Y - Input	-199.85	-1.04	0.52
Channel Z + Input	2000.81	0.06	0.00
Channel Z + Input	200.50	-0.57	-0.28
Channel Z - Input	-199.70	-0.76	0.38

2. Common mode sensitivity

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

	Common mode Input Voltage (mV)	High Range Average Reading (μV)	Low Range Average Reading (μV)
Channel X	200	-11.53	-13.11
	- 200	15.52	13.66
Channel Y	200	-8.40	-8.84
	- 200	7.27	6.80
Channel Z	200	16.75	16.91
	- 200	-18.58	-18.86

3. Channel separation

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

	Input Voltage (mV)	Channel X (μV)	Channel Y (μV)	Channel Z (μV)
Channel X	200	-	1.02	-3.37
Channel Y	200	7.97	-	3.67
Channel Z	200	9.63	4.81	-

4. AD-Converter Values with inputs shorted

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

	High Range (LSB)	Low Range (LSB)
Channel X	16127	15569
Channel Y	15969	16516
Channel Z	15864	16505

5. Input Offset Measurement

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

Input 10M Ω

	Average (μ V)	min. Offset (μ V)	max. Offset (μ V)	Std. Deviation (μ V)
Channel X	0.80	0.09	2.25	0.35
Channel Y	-0.13	-1.04	0.67	0.35
Channel Z	-0.21	-1.03	0.51	0.33

6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

7. Input Resistance (Typical values for information)

	Zeroing (kOhm)	Measuring (MOhm)
Channel X	200	200
Channel Y	200	200
Channel Z	200	200

8. Low Battery Alarm Voltage (Typical values for information)

Typical values	Alarm Level (VDC)
Supply (+ Vcc)	+7.9
Supply (- Vcc)	-7.6

9. Power Consumption (Typical values for information)

Typical values	Switched off (mA)	Stand by (mA)	Transmitting (mA)
Supply (+ Vcc)	+0.01	+6	+14
Supply (- Vcc)	-0.01	-8	-9