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Tel: +86-10-62304633-2079 Fax: +86-10-62304633-2504  
E-mail: cttl@chinattl.com [Http://www.chinattl.cn](http://www.chinattl.cn)

Client

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Certificate No: Z16-97077

### CALIBRATION CERTIFICATE

Object D2450V2 - SN: 817

Calibration Procedure(s) FD-Z11-2-003-01  
Calibration Procedures for dipole validation kits

Calibration date: May 31, 2016

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	01-Jul-15 (CTTL, No.J15X04256)	Jun-16
Power sensor NRP-Z91	101547	01-Jul-15 (CTTL, No.J15X04256)	Jun-16
Reference Probe EX3DV4	SN 7307	19-Feb-16(SPEAG,No.EX3-7307_Feb16)	Feb-17
DAE4	SN 771	02-Feb-16(CTTL-SPEAG,No.Z16-97011)	Feb-17
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Signal Generator E4438C	MY49071430	01-Feb-16 (CTTL, No.J16X00893)	Jan-17
Network Analyzer E5071C	MY46110673	26-Jan-16 (CTTL, No.J16X00894)	Jan-17

	Name	Function	Signature
Calibrated by:	Zhao Jing	SAR Test Engineer	
Reviewed by:	Qi Dianyuan	SAR Project Leader	
Approved by:	Lu Bingsong	Deputy Director of the laboratory	

Issued: Jun 2, 2016

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**Glossary:**

TSL	tissue simulating liquid
ConvF	sensitivity in TSL / NORM <sub>x,y,z</sub>
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, "Procedure to measure the Specific Absorption Rate (SAR) For hand-held devices used in close proximity to the ear (frequency range of 300MHz to 3GHz)", February 2005
- 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	52.8.8.1258
Extrapolation	Advanced Extrapolation	
Phantom	Triple Flat Phantom 5.1C	
Distance Dipole Center - TSL	10 mm	with Spacer
Zoom Scan Resolution	dx, dy, dz = 5 mm	
Frequency	2450 MHz ± 1 MHz	

### Head TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	39.2	1.80 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	38.8 ± 6 %	1.81 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

### SAR result with Head TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	250 mW input power	13.0 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	51.7 mW /g ± 20.8 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	Condition	
SAR measured	250 mW input power	6.15 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	24.5 mW /g ± 20.4 % (k=2)

### Body TSL parameters

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	52.7	1.95 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	53.2 ± 6 %	1.94 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

### SAR result with Body TSL

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	250 mW input power	12.8 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	51.5 mW /g ± 20.8 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	250 mW input power	6.07 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	24.4 mW /g ± 20.4 % (k=2)



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**Appendix**

**Antenna Parameters with Head TSL**

Impedance, transformed to feed point	51.0Ω+ 4.41jΩ
Return Loss	- 27.0dB

**Antenna Parameters with Body TSL**

Impedance, transformed to feed point	47.7Ω+ 4.00jΩ
Return Loss	- 26.6dB

**General Antenna Parameters and Design**

Electrical Delay (one direction)	1.269 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**

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**DASY5 Validation Report for Head TSL**

Date: 05.31.2016

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 817**

Communication System: UID 0, CW; Frequency: 2450 MHz; Duty Cycle: 1:1

Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.814$  S/m;  $\epsilon_r = 38.78$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Center Section

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

**DASY5 Configuration:**

- Probe: EX3DV4 - SN7307; ConvF(7.36, 7.36, 7.36); Calibrated: 2/19/2016;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn771; Calibrated: 2/2/2016
- Phantom: Triple Flat Phantom 5.1C; Type: QD 000 P51 CA; Serial: 1161/1
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7372)

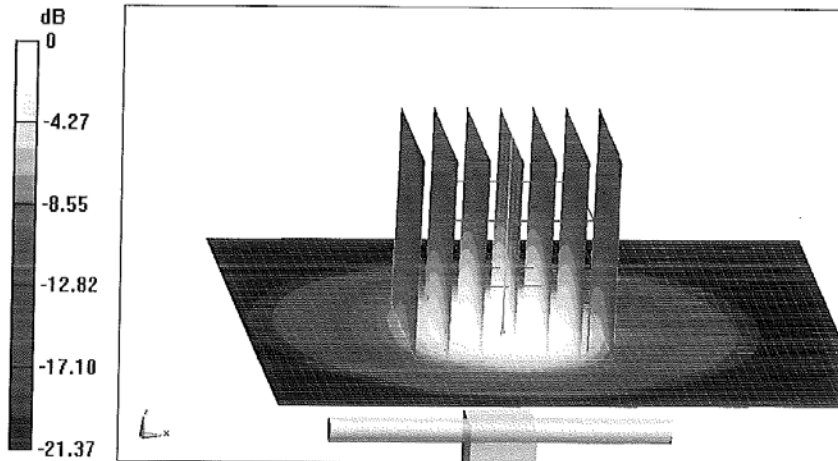
**Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 104.8 V/m; Power Drift = 0.01 dB

Peak SAR (extrapolated) = 26.2 W/kg

**SAR(1 g) = 13 W/kg; SAR(10 g) = 6.15 W/kg**

Maximum value of SAR (measured) = 19.8 W/kg



0 dB = 19.8 W/kg = 12.97 dBW/kg

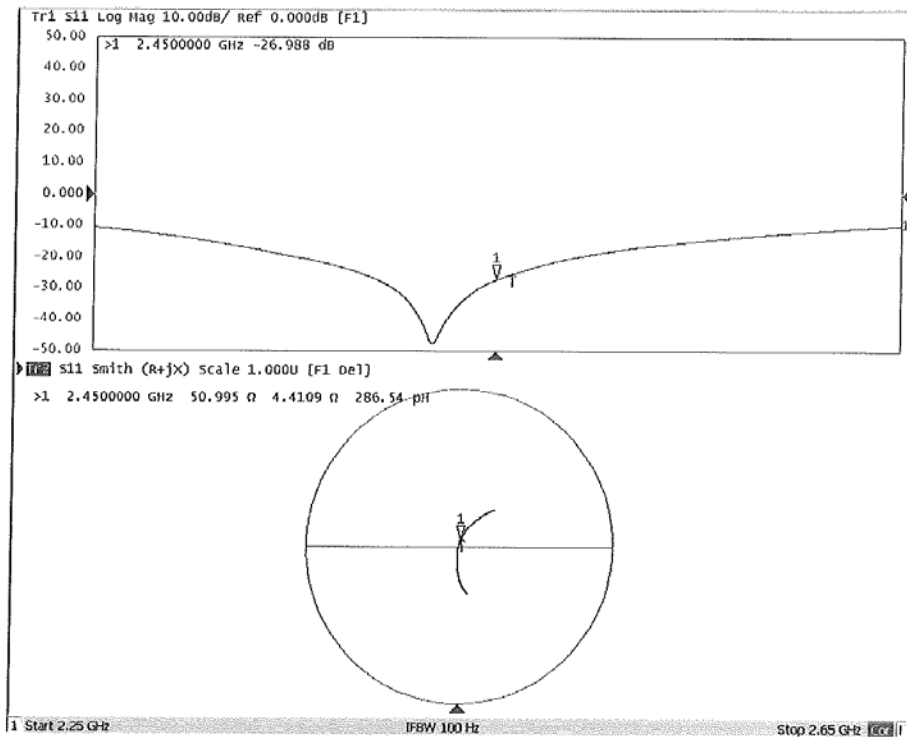




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Impedance Measurement Plot for Head TSL





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**DASY5 Validation Report for Body TSL**  
Test Laboratory: CTTL, Beijing, China

Date: 05.31.2016

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 817**

Communication System: UID 0, CW; Frequency: 2450 MHz; Duty Cycle: 1:1

Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.936$  S/m;  $\epsilon_r = 53.17$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Left Section

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

DASY5 Configuration:

- Probe: EX3DV4 - SN7307; ConvF(7.22, 7.22, 7.22); Calibrated: 2/19/2016;
- Sensor-Surface: 2mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn771; Calibrated: 2/2/2016
- Phantom: Triple Flat Phantom 5.1C; Type: QD 000 P51 CA; Serial: 1161/1
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7372)

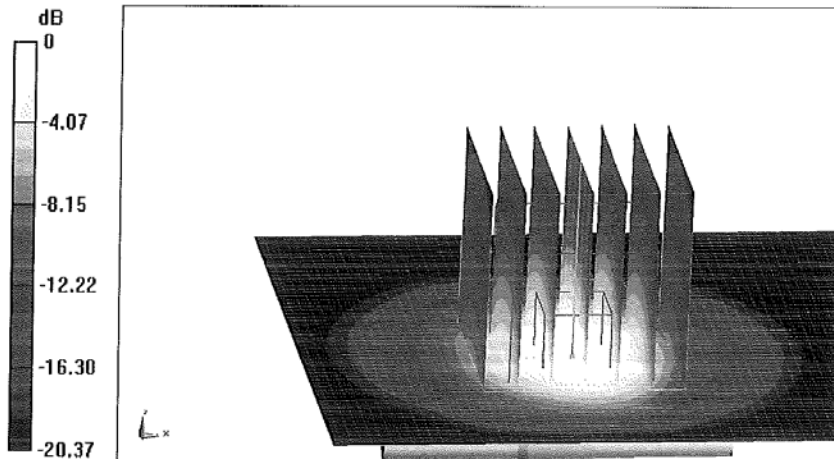
**Dipole Calibration/Zoom Scan (7x7x7) (7x7x7)/Cube 0:** Measurement grid: dx=5mm, dy=5mm, dz=5mm

Reference Value = 93.64 V/m; Power Drift = -0.04 dB

Peak SAR (extrapolated) = 25.1 W/kg

**SAR(1 g) = 12.8 W/kg; SAR(10 g) = 6.07 W/kg**

Maximum value of SAR (measured) = 19.2 W/kg



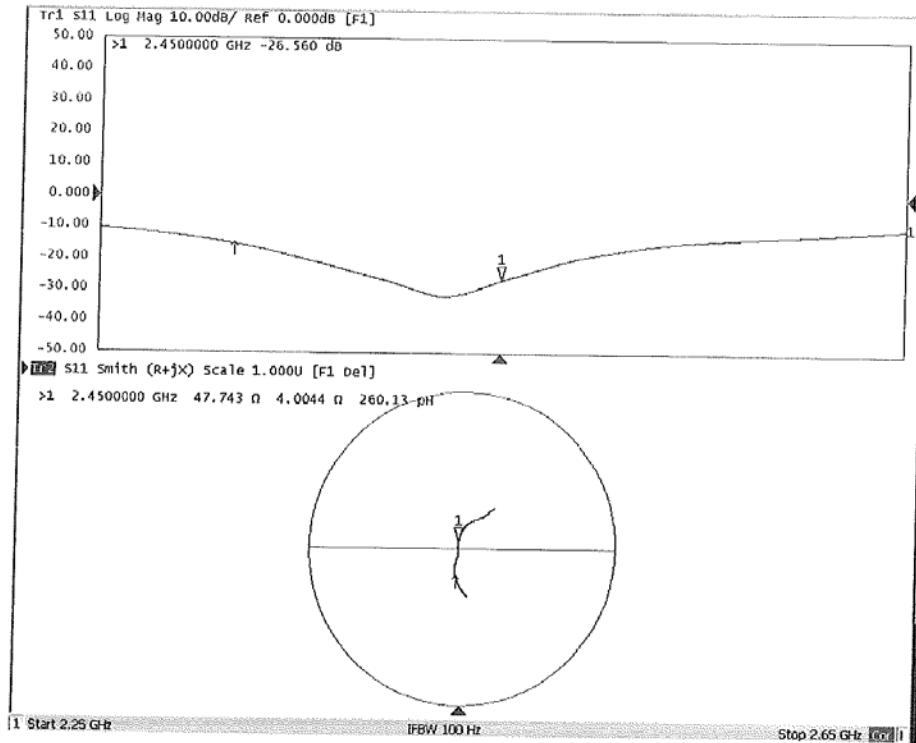
0 dB = 19.2 W/kg = 12.83 dBW/kg



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### Impedance Measurement Plot for Body TSL





Per IEEE Std 1528-2003, the dipole should have a return loss better than -20dB at the test frequency to reduce uncertainty in the power measurement.

Per KDB 865664 D01, if dipoles are verified in return loss (< -20dB, 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.

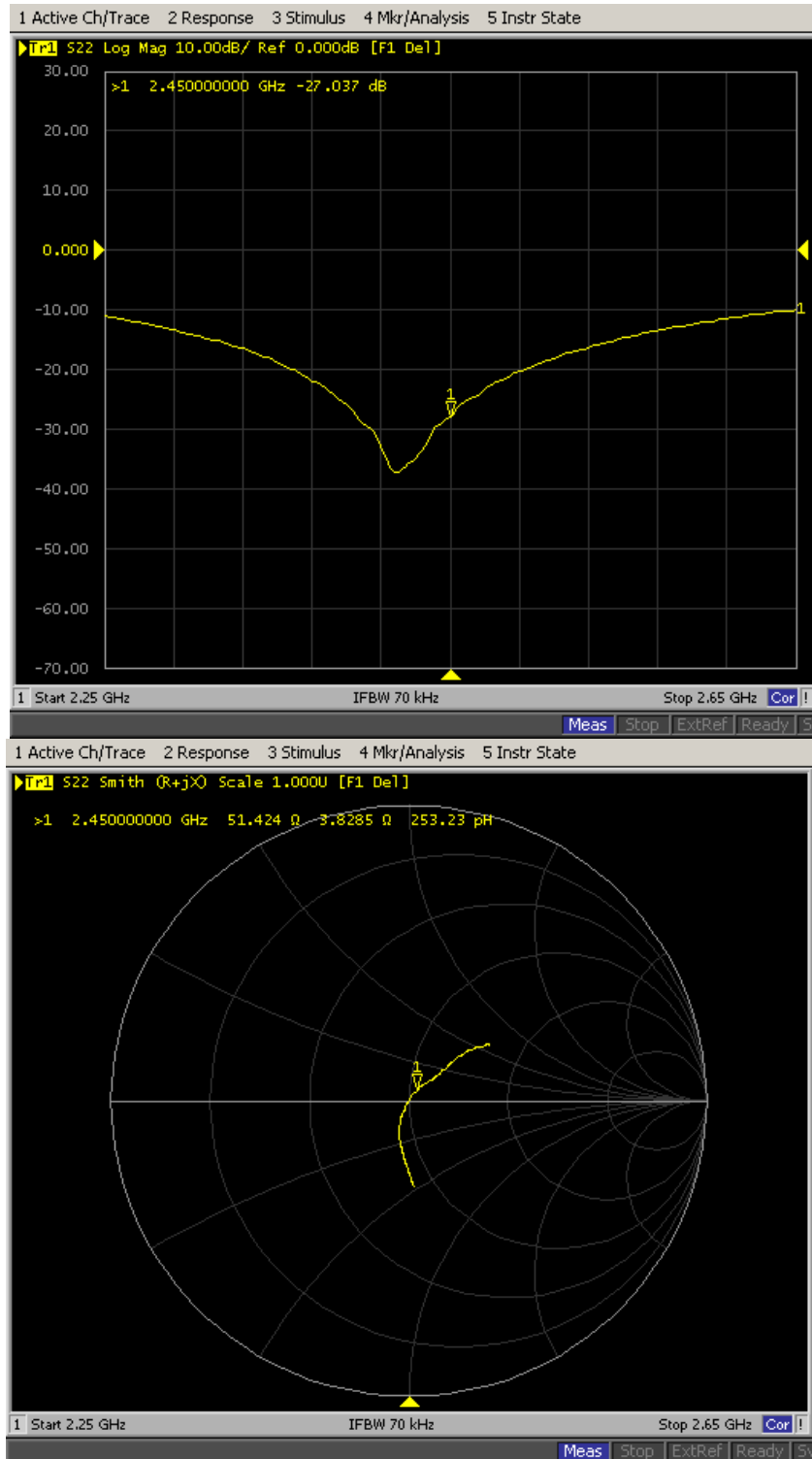
**Justification of the extended calibration**

D2450V2 Serial No.817						
2450 Head						
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
5.31.2016	-26.988	--	50.995	--	4.4109	--
5.30.2017	-27.037	0.18	51.424	0.469	3.8285	0.5824

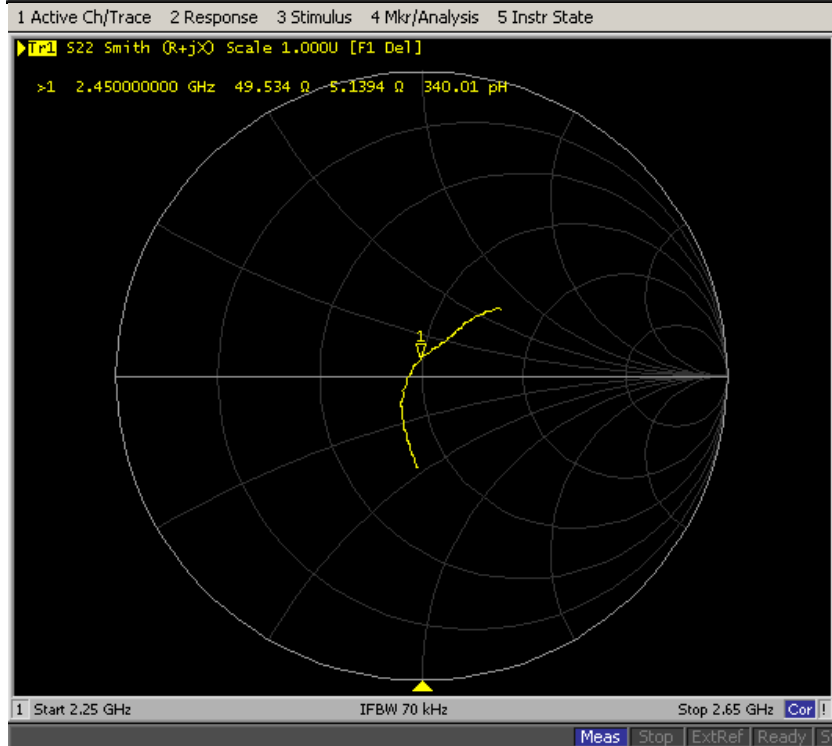
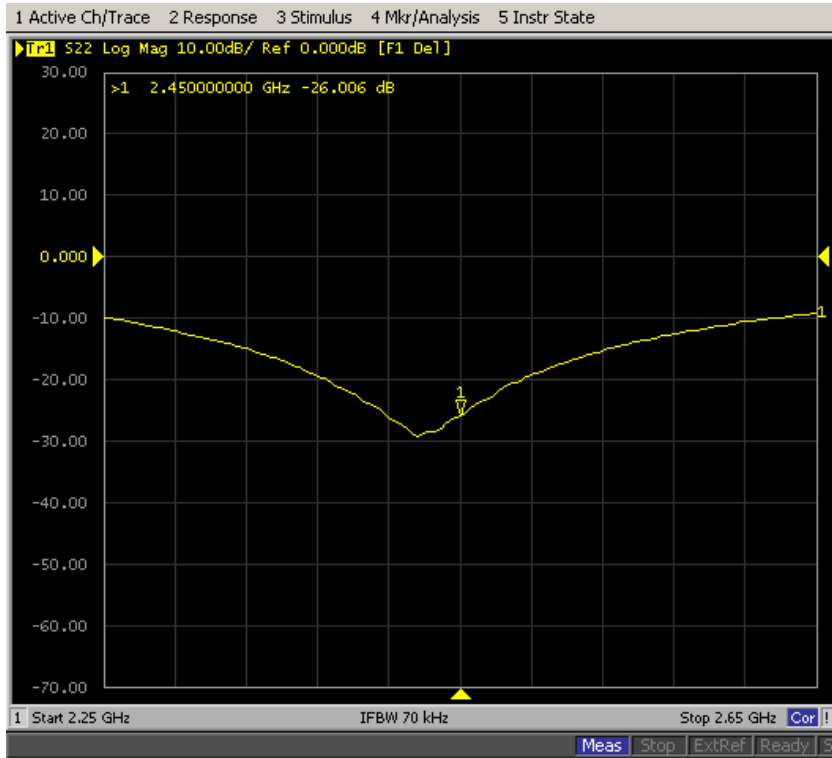
D2450V2 Serial No.817						
2450 Body						
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
5.31.2016	-26.560	--	47.743	--	4.0044	--
5.30.2017	-26.006	2.09	49.534	1.791	5.1394	1.135

The return loss is < -20dB, 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 D2450V2 Serial No.817 2450 MHz-Head



## 2450 MHz-Body



### D2450V2, Serial No.817 Extended Dipole Calibrations

Per IEEE Std 1528-2013, the dipole should have a return loss better than -20dB at the test frequency to reduce uncertainty in the power measurement.

Per KDB 865664 D01, if dipoles are verified in return loss (< -20dB, 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.

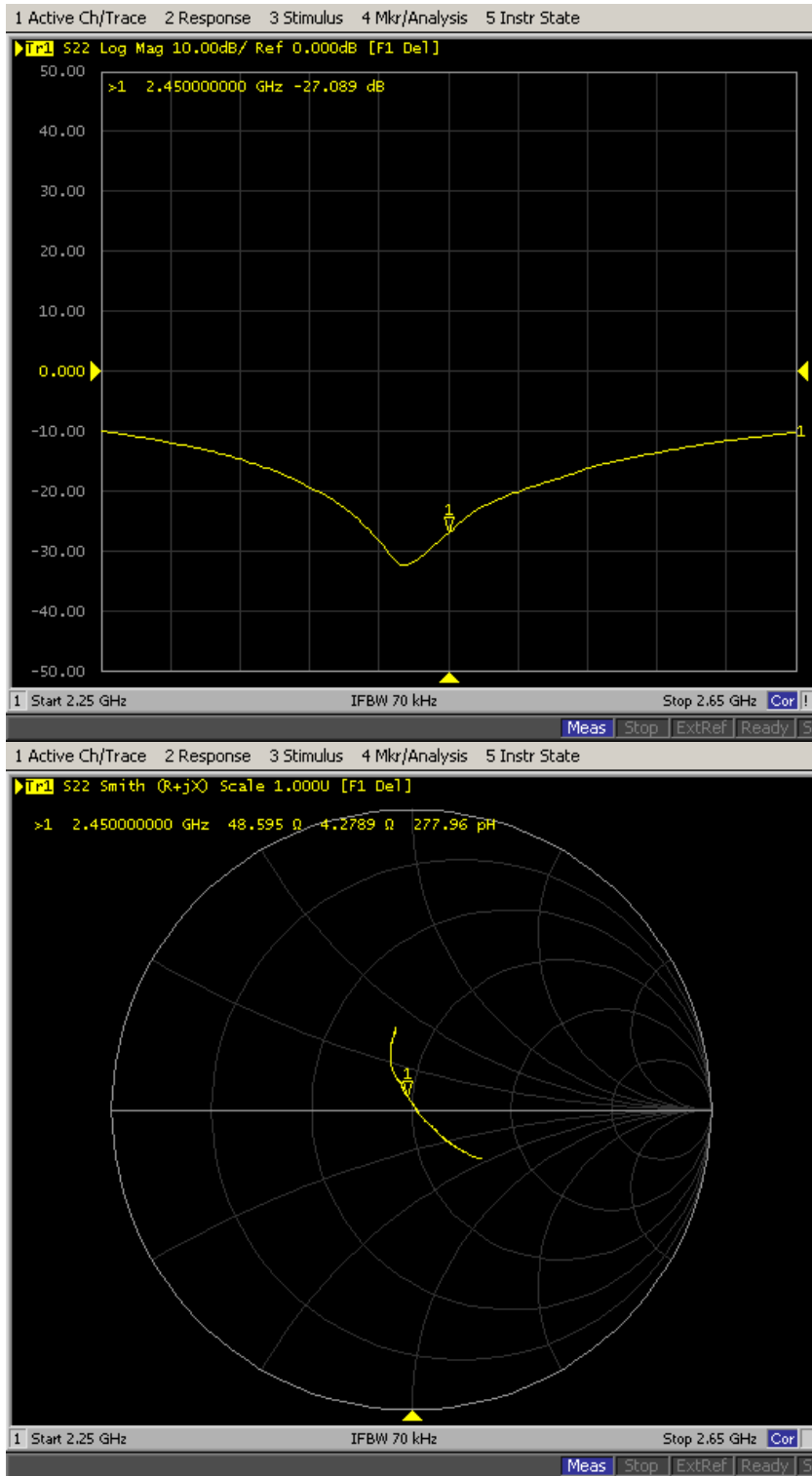
#### Justification of the extended calibration

D2450V2 Serial No.817						
2450 Head						
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
5.31.2016	-26.988	--	50.995	--	4.4109	--
5.30.2017	-27.037	0.18	51.424	0.469	3.8285	0.5824
5.29.2018	-27.089	0.23	48.595	2.829	4.2789	0.4504

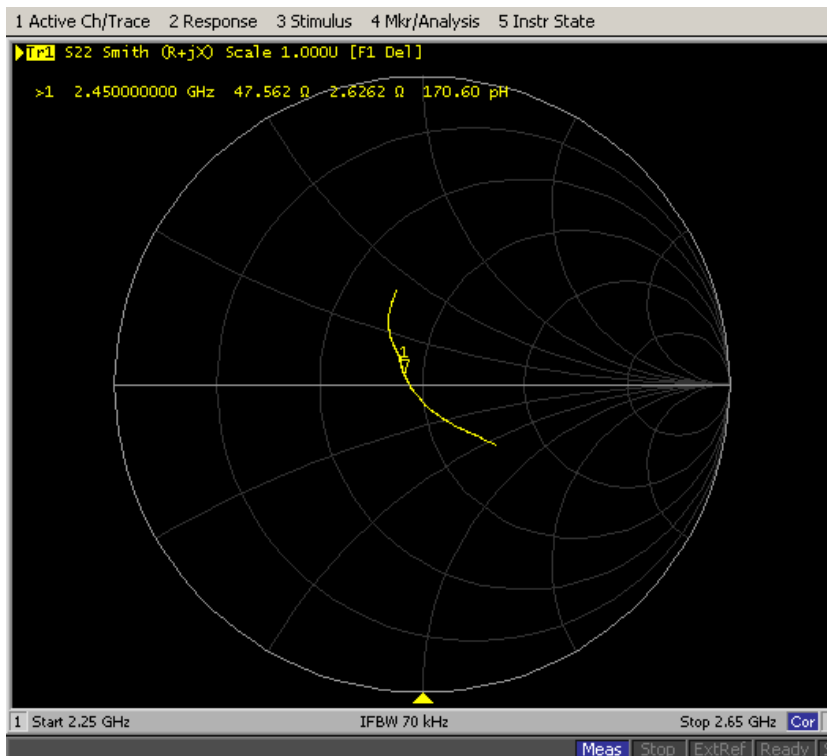
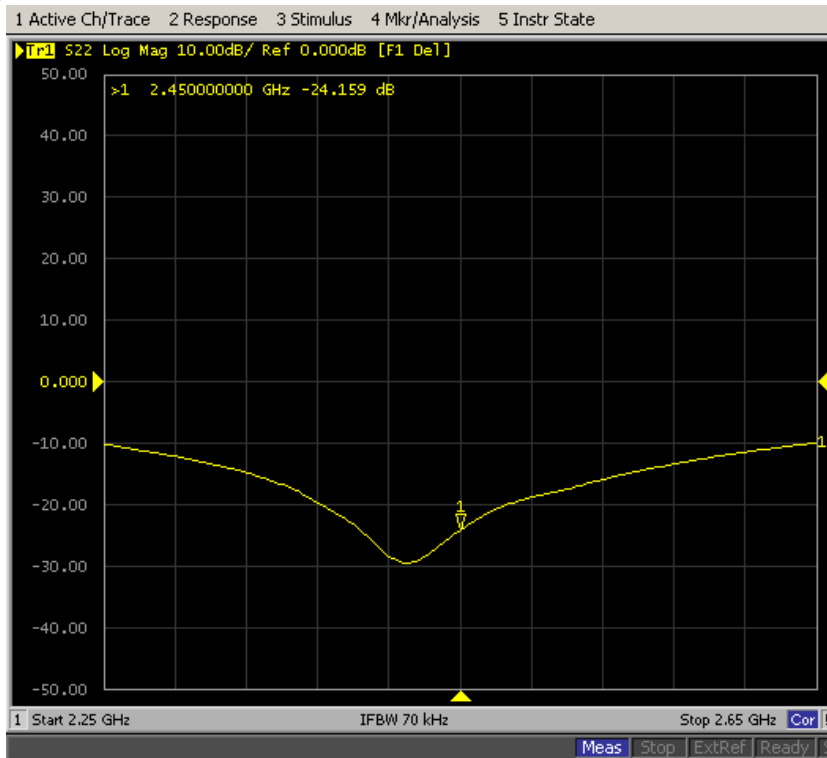
D2450V2 Serial No.817						
2450 Body						
Date of Measurement	Return-Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
5.31.2016	-26.560	--	47.743	--	4.0044	--
5.30.2017	-26.006	2.09	49.534	1.791	5.1394	1.135
5.29.2018	-24.159	7.10	47.562	1.972	2.6262	2.5132

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

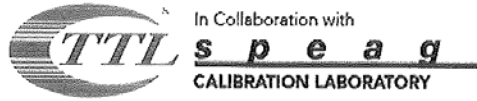
## Dipole Verification Data D2450V2 Serial No.817 2450 MHz-Head



## 2450 MHz-Body







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Client **CCS\_CN**

Certificate No: **Z16-97078**

## CALIBRATION CERTIFICATE

Object **D5GHzV2 - SN: 1095**

Calibration Procedure(s) **FD-Z11-2-003-01**  
**Calibration Procedures for dipole validation kits**

Calibration date: **May 25, 2016**

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

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

Calibration Equipment used (M&TE critical for calibration)

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DAE4	SN 771	02-Feb-16(CTTL-SPEAG,No.Z16-97011)	Feb-17
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Signal Generator E4438C	MY49071430	01-Feb-16 (CTTL, No.J16X00893)	Jan-17
NetworkAnalyzer E5071C	MY46110673	26-Jan-16 (CTTL, No.J16X00894)	Jan-17

	Name	Function	Signature
Calibrated by:	Zhao Jing	SAR Test Engineer	
Reviewed by:	Qi Dianyuan	SAR Project Leader	
Approved by:	Lu Bingsong	Deputy Director of the laboratory	

Issued: May 31, 2016

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TSL	tissue simulating liquid
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N/A	not applicable or not measured

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- IEC 62209-1, "Procedure to measure the Specific Absorption Rate (SAR) For hand-held devices used in close proximity to the ear (frequency range of 300MHz to 3GHz)", February 2005
- 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:**

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- 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	52.8.8.1258
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	5200 MHz ± 1 MHz 5300 MHz ± 1 MHz 5500 MHz ± 1 MHz 5600 MHz ± 1 MHz 5800 MHz ± 1 MHz	

**Head TSL parameters at 5200 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	36.0	4.66 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	36.8 ± 6 %	4.61 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

**SAR result with Head TSL at 5200 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.76 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	77.9 mW /g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.21 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	22.2 mW /g ± 22.2 % (k=2)



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**Head TSL parameters at 5300 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.9	4.76 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	36.7 ± 6 %	4.71 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

**SAR result with Head TSL at 5300 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.07 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	81.0 mW /g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.30 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	23.1 mW /g ± 22.2 % (k=2)

**Head TSL parameters at 5500 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.6	4.96 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	36.4 ± 6 %	4.91 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

**SAR result with Head TSL at 5500 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.22 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	82.5 mW /g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.33 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	23.4 mW /g ± 22.2 % (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	36.3 ± 6 %	5.01 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 <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	8.19 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	82.2 mW / g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Head TSL	Condition	
SAR measured	100 mW input power	2.33 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	23.4 mW / g ± 22.2 % (k=2)

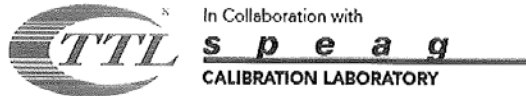
#### Head TSL parameters at 5800 MHz

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Head TSL parameters	22.0 °C	35.3	5.27 mho/m
Measured Head TSL parameters	(22.0 ± 0.2) °C	36.1 ± 6 %	5.17 mho/m ± 6 %
Head TSL temperature change during test	<1.0 °C	----	----

#### SAR result with Head TSL at 5800 MHz

SAR averaged over 1 cm <sup>3</sup> (1 g) of Head TSL	Condition	
SAR measured	100 mW input power	7.83 mW / g
SAR for nominal Head TSL parameters	normalized to 1W	78.6 mW / g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (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	22.1 mW / g ± 22.2 % (k=2)



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**Body TSL parameters at 5200 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	49.0	5.30 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.4 ± 6 %	5.39 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

**SAR result with Body TSL at 5200 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.47 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	74.5 mW /g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.14 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	21.4 mW /g ± 22.2 % (k=2)

**Body TSL parameters at 5300 MHz**

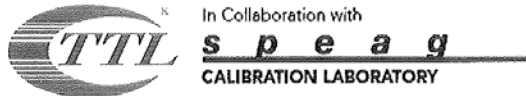
The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.9	5.42 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.3 ± 6 %	5.51 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

**SAR result with Body TSL at 5300 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.74 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	77.2 mW /g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.20 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	22.0 mW /g ± 22.2 % (k=2)





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**Body TSL parameters at 5500 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.6	5.65 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	49.1 ± 6 %	5.58 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

**SAR result with Body TSL at 5500 MHz**

SAR averaged over 1 cm <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	8.10 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	81.1 mW / g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.36 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	23.7 mW / g ± 22.2 % (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	49.0 ± 6 %	5.70 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 <sup>3</sup> (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.97 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	79.8 mW / g ± 23.0 % (k=2)
SAR averaged over 10 cm <sup>3</sup> (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.26 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	22.7 mW / g ± 22.2 % (k=2)



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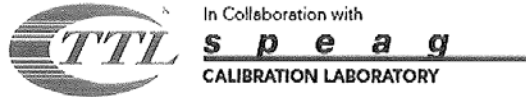
**Body TSL parameters at 5800 MHz**

The following parameters and calculations were applied.

	Temperature	Permittivity	Conductivity
Nominal Body TSL parameters	22.0 °C	48.2	6.00 mho/m
Measured Body TSL parameters	(22.0 ± 0.2) °C	48.7 ± 6 %	5.93 mho/m ± 6 %
Body TSL temperature change during test	<1.0 °C	----	----

**SAR result with Body TSL at 5800 MHz**

SAR averaged over 1 $cm^3$ (1 g) of Body TSL	Condition	
SAR measured	100 mW input power	7.71 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	77.2 mW /g ± 23.0 % (k=2)
SAR averaged over 10 $cm^3$ (10 g) of Body TSL	Condition	
SAR measured	100 mW input power	2.17 mW / g
SAR for nominal Body TSL parameters	normalized to 1W	21.8 mW /g ± 22.2 % (k=2)



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### Appendix

#### Antenna Parameters with Head TSL at 5200 MHz

Impedance, transformed to feed point	49.2Ω - 5.46jΩ
Return Loss	- 25.1dB

#### Antenna Parameters with Head TSL at 5300 MHz

Impedance, transformed to feed point	47.2Ω - 3.86jΩ
Return Loss	- 26.2dB

#### Antenna Parameters with Head TSL at 5500 MHz

Impedance, transformed to feed point	53.4Ω - 5.61jΩ
Return Loss	- 23.9dB

#### Antenna Parameters with Head TSL at 5600 MHz

Impedance, transformed to feed point	56.6Ω - 1.04jΩ
Return Loss	- 24.0dB

#### Antenna Parameters with Head TSL at 5800 MHz

Impedance, transformed to feed point	53.0Ω - 6.28jΩ
Return Loss	- 23.4dB

#### Antenna Parameters with Body TSL at 5200 MHz

Impedance, transformed to feed point	49.5Ω - 3.51jΩ
Return Loss	- 29.0dB

#### Antenna Parameters with Body TSL at 5300 MHz

Impedance, transformed to feed point	47.7Ω - 1.89jΩ
Return Loss	- 30.4dB



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**Antenna Parameters with Body TSL at 5500 MHz**

Impedance, transformed to feed point	54.0Ω - 3.83jΩ
Return Loss	- 25.5dB

**Antenna Parameters with Body TSL at 5600 MHz**

Impedance, transformed to feed point	59.3Ω + 0.88jΩ
Return Loss	- 21.4dB

**Antenna Parameters with Body TSL at 5800 MHz**

Impedance, transformed to feed point	55.1Ω - 6.15jΩ
Return Loss	- 22.4dB

**General Antenna Parameters and Design**

Electrical Delay (one direction)	1.308 ns
----------------------------------	----------

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**

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**DASY5 Validation Report for Head TSL**

Date: 05.23.2016

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1095**

Communication System: CW; Frequency: 5200 MHz, Frequency: 5300 MHz,  
Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz,  
Medium parameters used: f = 5200 MHz;  $\sigma = 4.614$  mho/m;  $\epsilon_r = 36.82$ ;  $\rho = 1000$   
kg/m<sup>3</sup>, Medium parameters used: f = 5300 MHz;  $\sigma = 4.713$  mho/m;  $\epsilon_r = 36.71$ ;  $\rho =$   
1000 kg/m<sup>3</sup>, Medium parameters used: f = 5500 MHz;  $\sigma = 4.911$  mho/m;  $\epsilon_r = 36.41$ ;  
 $\rho = 1000$  kg/m<sup>3</sup>, Medium parameters used: f = 5600 MHz;  $\sigma = 5.006$  mho/m;  $\epsilon_r =$   
36.27;  $\rho = 1000$  kg/m<sup>3</sup>, Medium parameters used: f = 5800 MHz;  $\sigma = 5.171$  mho/m;  
 $\epsilon_r = 36.05$ ;  $\rho = 1000$  kg/m<sup>3</sup>,

Phantom section: Center Section

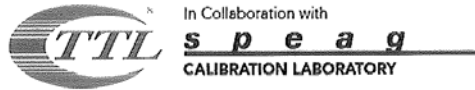
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

**DASY5 Configuration:**

- Probe: EX3DV4 - SN7307; ConvF(5.32,5.32,5.32); Calibrated: 2016/2/19,  
ConvF(5.02,5.02,5.02); Calibrated: 2016/2/19, ConvF(4.85,4.85,4.85);  
Calibrated: 2016/2/19, ConvF(4.52,4.52,4.52); Calibrated: 2016/2/19,  
ConvF(4.45,4.45,4.45); Calibrated: 2016/2/19,
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn771; Calibrated: 2016/2/02
- Phantom: Triple Flat Phantom 5.1C; Type: QD 000 P51 CA; Serial: 1161/3
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10  
(7372)

**Dipole Calibration /Pin=100mW, d=10mm, f=5200 MHz/Zoom Scan,**  
**dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 71.75 V/m; Power Drift = 0.00 dB  
Peak SAR (extrapolated) = 31.7 W/kg  
**SAR(1 g) = 7.76 W/kg; SAR(10 g) = 2.21 W/kg**  
Maximum value of SAR (measured) = 18.7 W/kg

**Dipole Calibration /Pin=100mW, d=10mm, f=5300 MHz/Zoom Scan,**  
**dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 73.42 V/m; Power Drift = 0.01 dB  
Peak SAR (extrapolated) = 33.6 W/kg  
**SAR(1 g) = 8.07 W/kg; SAR(10 g) = 2.3 W/kg**  
Maximum value of SAR (measured) = 19.5 W/kg

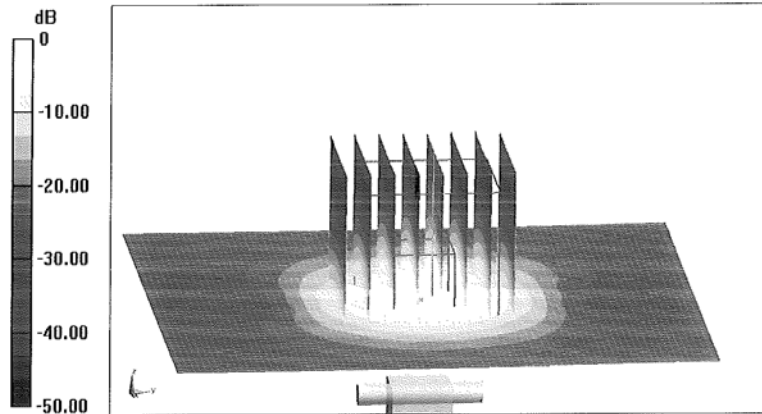


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Dipole Calibration /Pin=100mW, d=10mm, f=5500 MHz/Zoom Scan,  
dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 72.44 V/m; Power Drift = 0.00 dB  
Peak SAR (extrapolated) = 36.1 W/kg  
**SAR(1 g) = 8.22 W/kg; SAR(10 g) = 2.33 W/kg**  
Maximum value of SAR (measured) = 19.9 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 = 72.62 V/m; Power Drift = -0.05 dB  
Peak SAR (extrapolated) = 34.9 W/kg  
**SAR(1 g) = 8.19 W/kg; SAR(10 g) = 2.33 W/kg**  
Maximum value of SAR (measured) = 19.7 W/kg

Dipole Calibration /Pin=100mW, d=10mm, f=5800 MHz/Zoom Scan,  
dist=1.4mm (8x8x7)/Cube 0: Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 72.13 V/m; Power Drift = 0.00 dB  
Peak SAR (extrapolated) = 34.6 W/kg  
**SAR(1 g) = 7.83 W/kg; SAR(10 g) = 2.2 W/kg**  
Maximum value of SAR (measured) = 19.3 W/kg



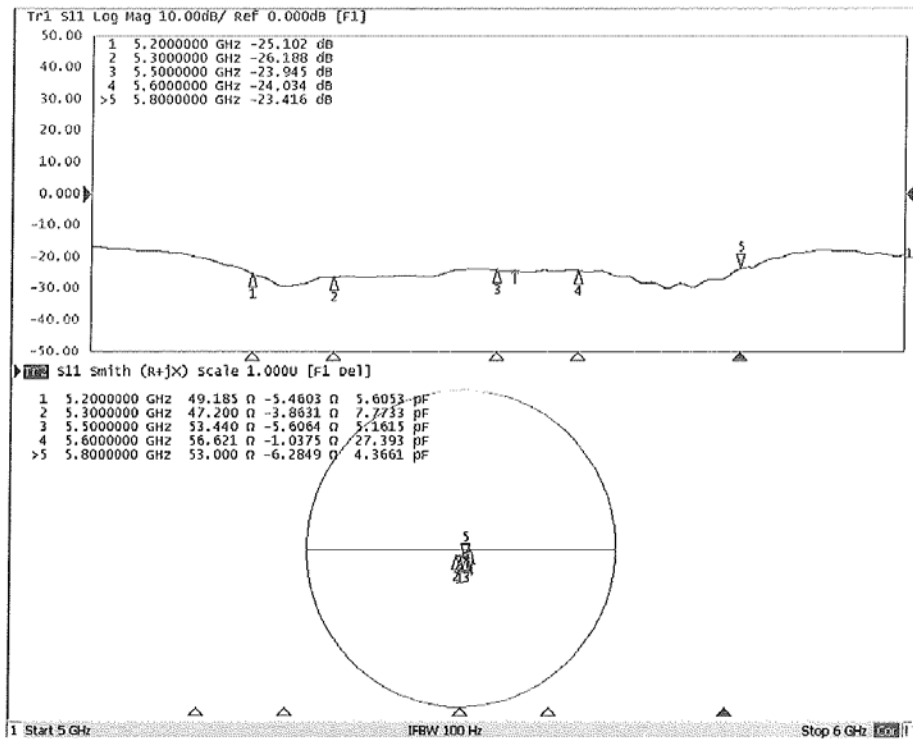
0 dB = 19.3 W/kg = 12.86 dBW/kg





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### Impedance Measurement Plot for Head TSL





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#### DASY5 Validation Report for Body TSL

Date: 05.25.2016

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1095

Communication System: CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz, Medium parameters used: f = 5200 MHz;  $\sigma = 5.391$  mho/m;  $\epsilon_r = 48.36$ ;  $\rho = 1000$  kg/m<sup>3</sup>, Medium parameters used: f = 5300 MHz;  $\sigma = 5.513$  mho/m;  $\epsilon_r = 48.26$ ;  $\rho = 1000$  kg/m<sup>3</sup>, Medium parameters used: f = 5500 MHz;  $\sigma = 5.582$  mho/m;  $\epsilon_r = 49.14$ ;  $\rho = 1000$  kg/m<sup>3</sup>, Medium parameters used: f = 5600 MHz;  $\sigma = 5.703$  mho/m;  $\epsilon_r = 49.04$ ;  $\rho = 1000$  kg/m<sup>3</sup>, Medium parameters used: f = 5800 MHz;  $\sigma = 5.932$  mho/m;  $\epsilon_r = 48.71$ ;  $\rho = 1000$  kg/m<sup>3</sup>,

Phantom section: Right Section

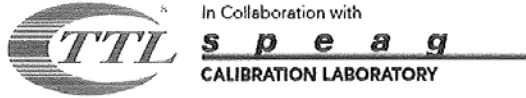
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

#### DASY5 Configuration:

- Probe: EX3DV4 - SN7307; ConvF(4.48,4.48,4.48); Calibrated: 2016/2/19, ConvF(4.29,4.29,4.29); Calibrated: 2016/2/19, ConvF(3.97,3.97,3.97); Calibrated: 2016/2/19, ConvF(3.72,3.72,3.72); Calibrated: 2016/2/19, ConvF(3.91,3.91,3.91); Calibrated: 2016/2/19,
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn771; Calibrated: 2016/2/02
- Phantom: Triple Flat Phantom 5.1C; Type: QD 000 P51 CA; Serial: 1161/3
- Measurement SW: DASY52, Version 52.8 (8); SEMCAD X Version 14.6.10 (7372)

**Dipole Calibration /Pin=100mW, d=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 66.16 V/m; Power Drift = 0.03 dB  
Peak SAR (extrapolated) = 27.8 W/kg  
**SAR(1 g) = 7.47 W/kg; SAR(10 g) = 2.14 W/kg**  
Maximum value of SAR (measured) = 17.0 W/kg

**Dipole Calibration /Pin=100mW, d=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 65.52 V/m; Power Drift = -0.02 dB  
Peak SAR (extrapolated) = 29.9 W/kg  
**SAR(1 g) = 7.74 W/kg; SAR(10 g) = 2.2 W/kg**  
Maximum value of SAR (measured) = 17.8 W/kg

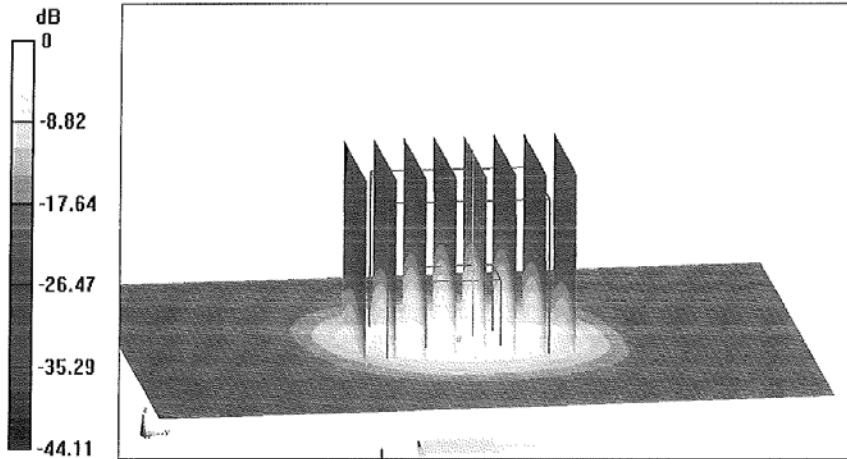


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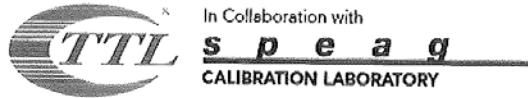
**Dipole Calibration /Pin=100mW, d=10mm, f=5500 MHz/Zoom Scan,**  
**dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 66.84 V/m; Power Drift = -0.00 dB  
Peak SAR (extrapolated) = 30.8 W/kg  
**SAR(1 g) = 8.1 W/kg; SAR(10 g) = 2.36 W/kg**  
Maximum value of SAR (measured) = 18.5 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 = 69.68 V/m; Power Drift = 0.01 dB  
Peak SAR (extrapolated) = 30.8 W/kg  
**SAR(1 g) = 7.97 W/kg; SAR(10 g) = 2.26 W/kg**  
Maximum value of SAR (measured) = 18.5 W/kg

**Dipole Calibration /Pin=100mW, d=10mm, f=5800 MHz/Zoom Scan,**  
**dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm  
Reference Value = 68.24 V/m; Power Drift = 0.04 dB  
Peak SAR (extrapolated) = 31.6 W/kg  
**SAR(1 g) = 7.71 W/kg; SAR(10 g) = 2.17 W/kg**  
Maximum value of SAR (measured) = 18.2 W/kg

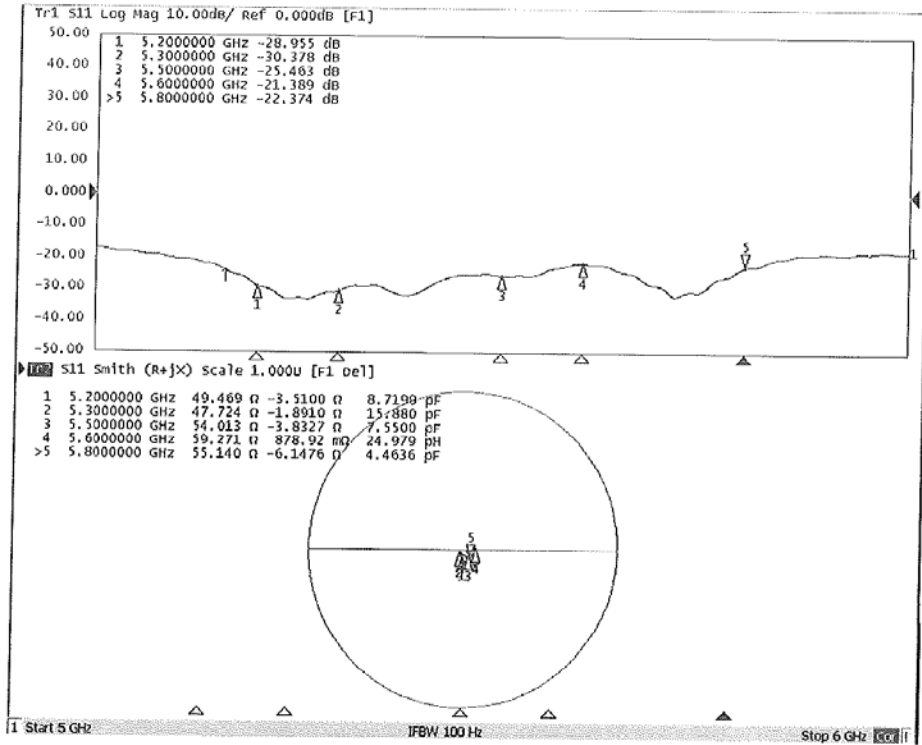


0 dB = 18.2 W/kg = 12.60 dBW/kg



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### Impedance Measurement Plot for Body TSL



## D5GHzV2, Serial No.1095 Extended Dipole Calibrations

Per IEEE Std 1528-2013, the dipole should have a return loss better than -20dB at the test frequency to

reduce uncertainty in the power measurement

Per KDB 865664 D01, if dipoles are verified in return loss (<-20dB, 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.

**Justification of the extended calibration**

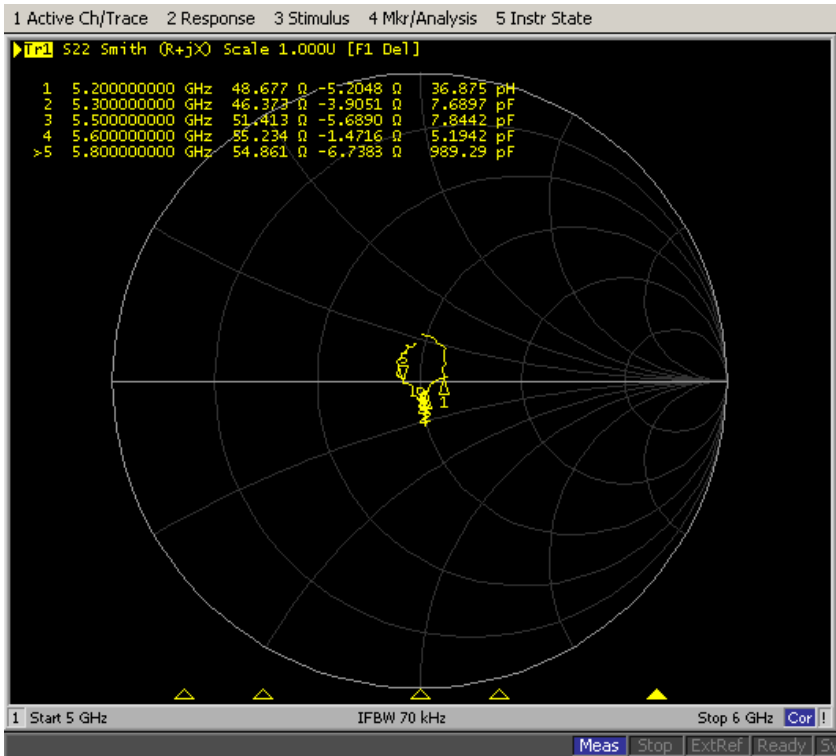
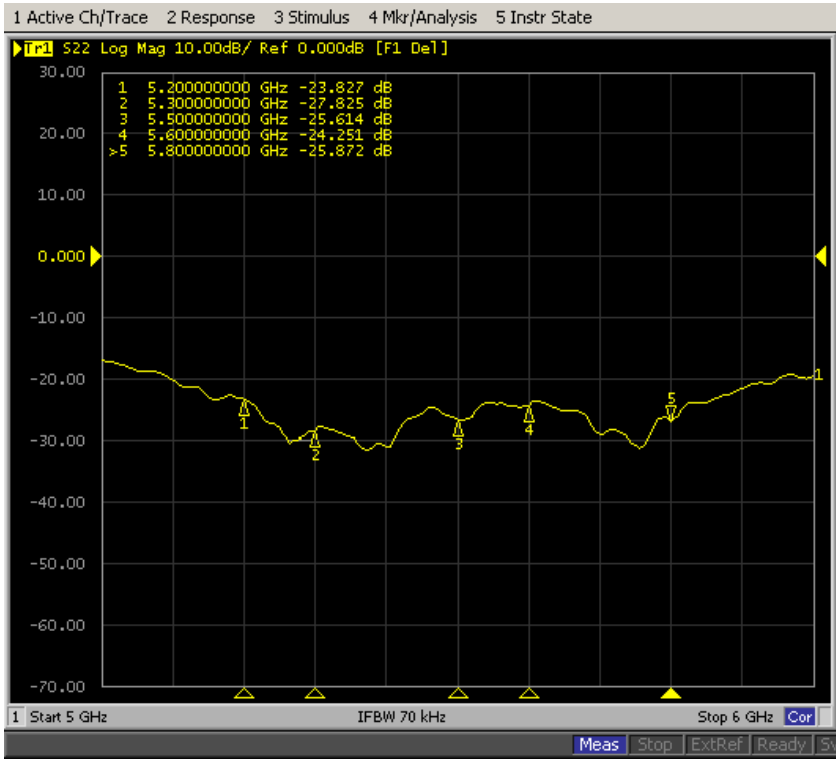
D5GHzV2 Serial No.1095							
Head							
Date of Measurement		Return Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
5200MHz	5.25.2016	-25.102	--	49.185	--	-5.4603	--
	5.23.2017	-23.827	5.08	48.677	0.508	-5.2048	0.2555
5300MHz	5.25.2016	-26.188	--	47.200	--	-3.8631	--
	5.23.2017	-27.825	6.25	46.373	0.827	-3.9051	0.042
5500MHz	5.25.2016	-23.945	--	53.440	--	-5.6064	--
	5.23.2017	-25.614	6.97	51.413	2.027	-5.6890	0.0826
5600MHz	5.25.2016	-24.034	--	56.621	--	-1.0375	--
	5.23.2017	-24.251	0.90	55.234	1.387	-1.4716	0.4341
5800MHz	5.25.2016	-23.416	--	53.000	--	-6.2849	--
	5.23.2017	-25.872	10.5	54.861	1.861	-6.7383	0.4534

D5GHzV2 Serial No.1095							
Body							
Date of Measurement		Return Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
5200MHz	5.25.2016	-28.955	--	49.469	--	-3.5100	--
	5.23.2017	-28.384	1.97	50.314	0.845	-3.5312	0.0212
5300MHz	5.25.2016	-30.378	--	47.724	--	-1.8910	--
	5.23.2017	-31.358	3.22	46.806	0.918	-1.5284	0.3626
5500MHz	5.25.2016	-25.463	--	54.013	--	-3.8327	--
	5.23.2017	24.064	5.49	52.539	1.474	-3.5216	0.3111
5600MHz	5.25.2016	-21.389	--	59.271	--	0.8789	--
	5.23.2017	-22.755	6.39	58.225	1.046	0.8415	0.0374
5800MHz	5.25.2016	-22.374	--	55.140	--	-6.1476	--
	5.23.2017	-23.183	3.62	55.119	0.021	-6.6894	0.5418

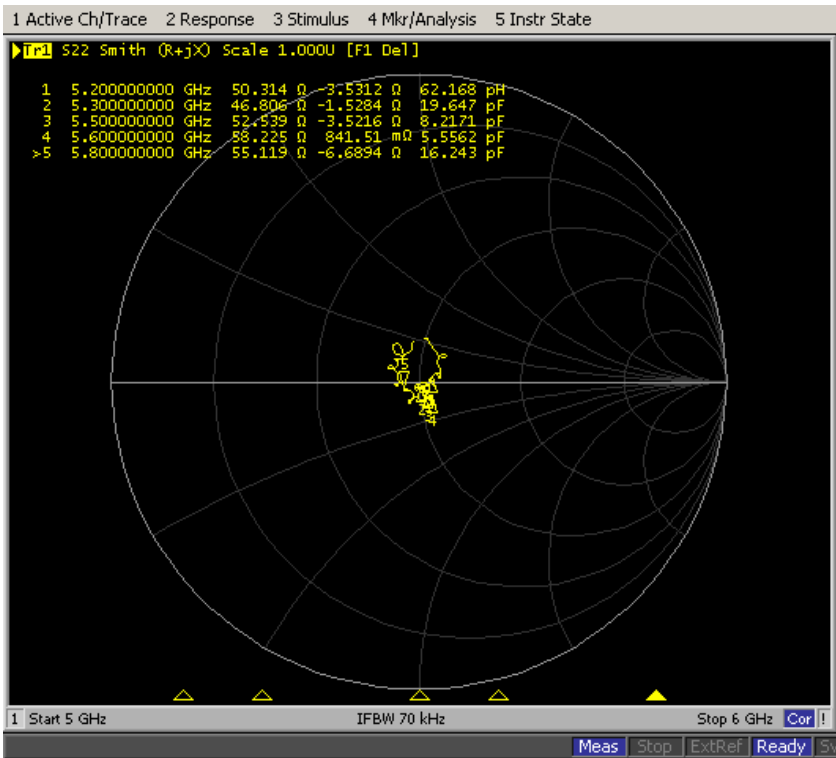
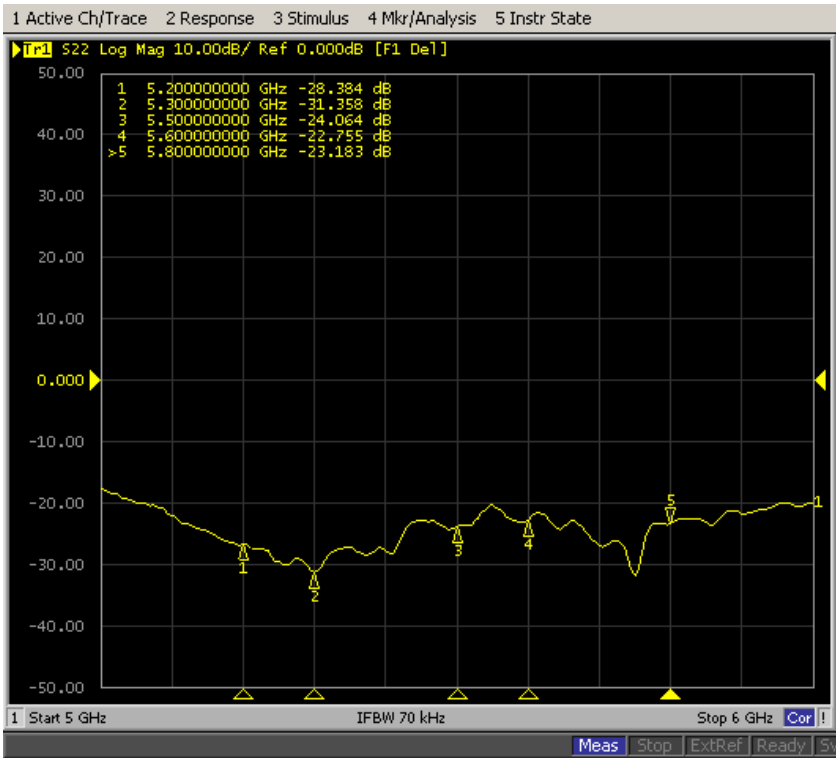
The return loss is < -20dB, within 20% of prior calibration; the impedance is within 5 ohm of prior calibration. Therefore the verification result should support extended calibration.



## Dipole Verification Data D5GHzV2 Serial No.1095 D5GHzV2-Head



## Dipole Verification Data D5GHzV2 Serial No.1095 D5GHzV2-Body



### D5GHzV2, Serial No.1095 Extended Dipole Calibrations

Per IEEE Std 1528-2013, the dipole should have a return loss better than -20dB at the test frequency to reduce uncertainty in the power measurement

Per KDB 865664 D01, if dipoles are verified in return loss (<-20dB, 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.

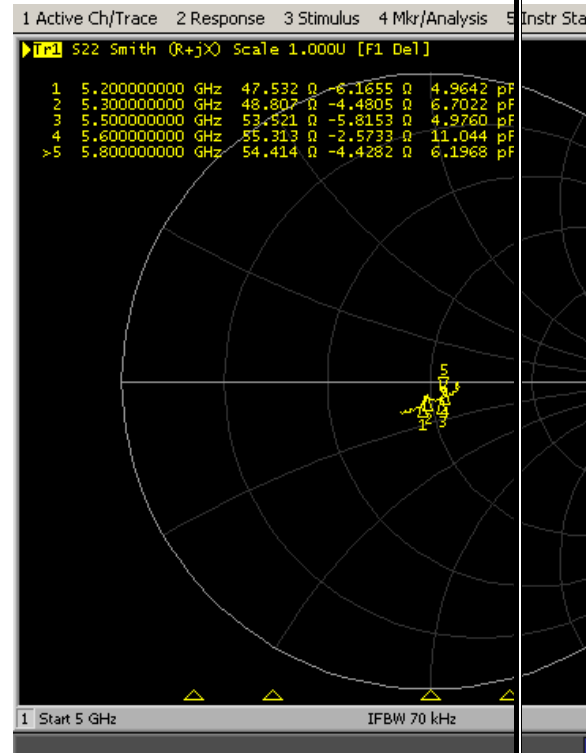
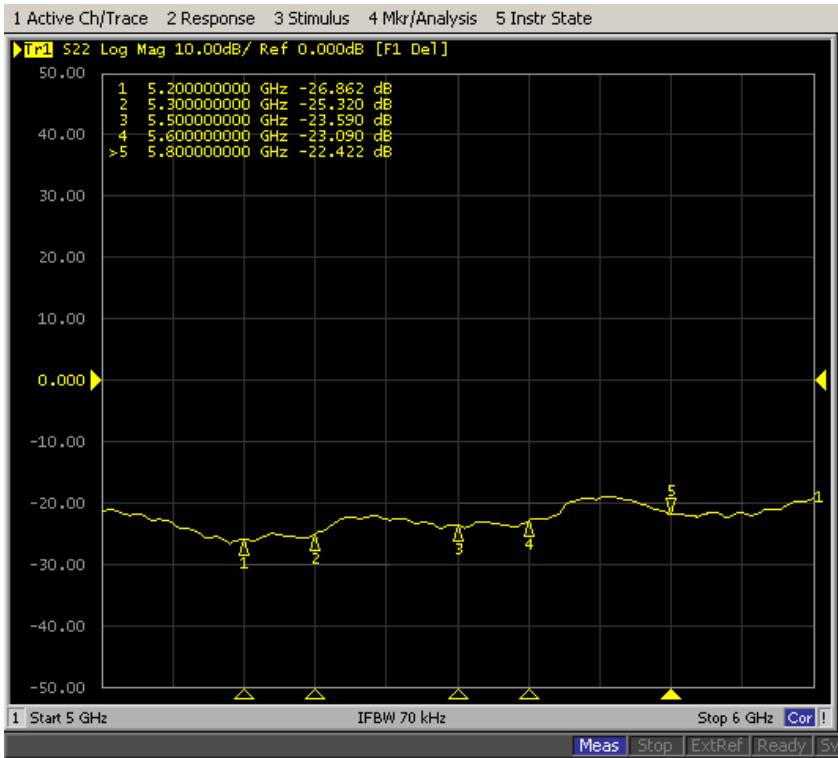
#### Justification of the extended calibration

D5GHzV2 Serial No.1095							
Head							
Date of Measurement		Return Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
5200MHz	5.25.2016	-25.102	--	49.185	--	-5.4603	--
	5.23.2017	-23.827	5.08	48.677	0.508	-5.2048	0.2555
	5.22.2018	-26.862	12.7	47.532	1.145	-6.1655	0.9607
5300MHz	5.25.2016	-26.188	--	47.200	--	-3.8631	--
	5.23.2017	-27.825	6.25	46.373	0.827	-3.9051	0.042
	5.22.2018	-25.320	9.00	48.807	2.434	-4.4805	0.5754
5500MHz	5.25.2016	-23.945	--	53.440	--	-5.6064	--
	5.23.2017	-25.614	6.97	51.413	2.027	-5.6890	0.0826
	5.22.2018	-23.590	7.90	53.521	2.108	-5.8153	0.1263
5600MHz	5.25.2016	-24.034	--	56.621	--	-1.0375	--
	5.23.2017	-24.251	0.90	55.234	1.387	-1.4716	0.4341
	5.22.2018	-23.090	4.79	55.313	0.079	-2.5733	1.1017
5800MHz	5.25.2016	-23.416	--	53.000	--	-6.2849	--
	5.23.2017	-25.872	10.5	54.861	1.861	-6.7383	0.4534
	5.22.2018	-22.422	13.3	54.414	0.427	-4.4282	2.3101

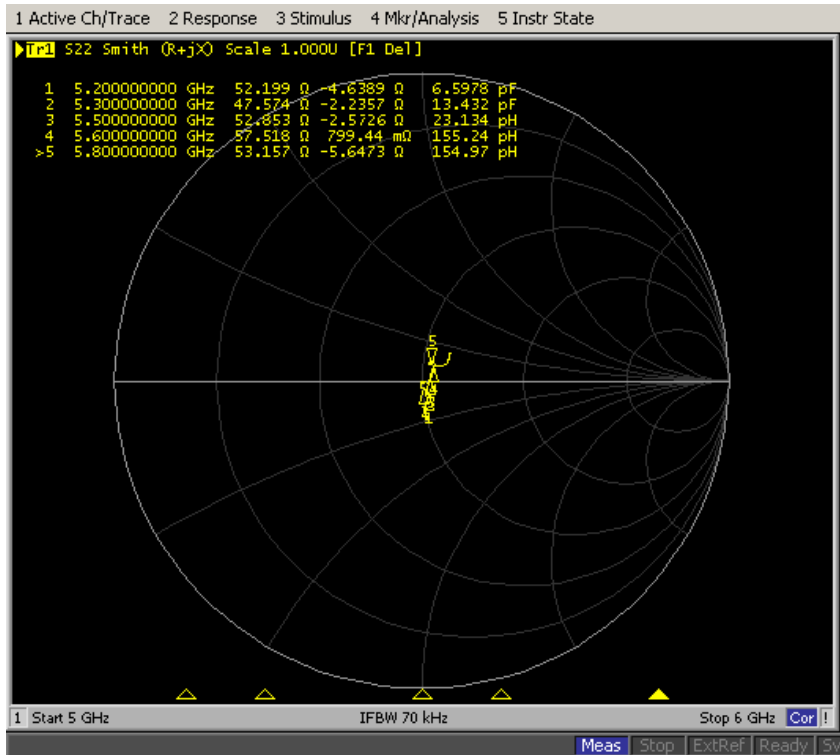
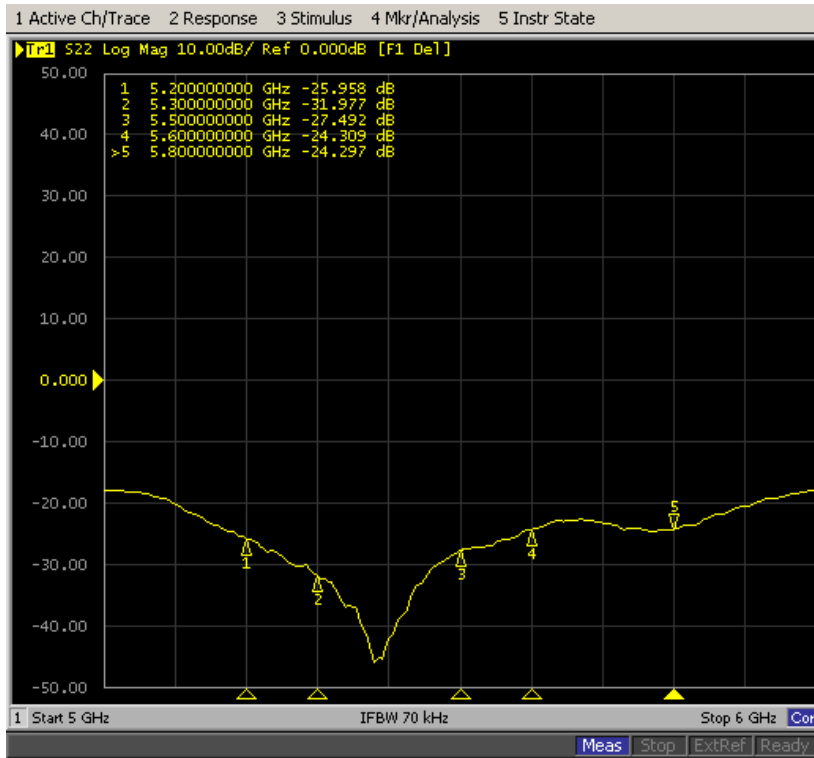
D5GHzV2 Serial No.1095							
Body							
Date of Measurement		Return Loss (dB)	Delta (%)	Real Impedance (ohm)	Delta (ohm)	Imaginary Impedance (ohm)	Delta (ohm)
5200MHz	5.25.2016	-28.955	--	49.469	--	-3.5100	--
	5.23.2017	-28.384	1.97	50.314	0.845	-3.5312	0.0212
	5.22.2018	-25.958	8.55	52.199	1.885	-4.6389	1.1077
5300MHz	5.25.2016	-30.378	--	47.724	--	-1.8910	--
	5.23.2017	-31.358	3.22	46.806	0.918	-1.5284	0.3626
	5.22.2018	-31.977	1.97	47.574	0.768	-2.2357	0.7073
5500MHz	5.25.2016	-25.463	--	54.013	--	-3.8327	--
	5.23.2017	-24.064	5.49	52.539	1.474	-3.5216	0.3111
	5.22.2018	-27.492	14.2	52.853	0.314	-2.5726	0.949
5600MHz	5.25.2016	-21.389	--	59.271	--	0.8789	--
	5.23.2017	-22.755	6.39	58.225	1.046	0.8415	0.0374
	5.22.2018	-24.309	6.83	57.518	0.707	0.7994	0.0421
5800MHz	5.25.2016	-22.374	--	55.140	--	-6.1476	--
	5.23.2017	-23.183	3.62	55.119	0.021	-6.6894	0.5418
	5.22.2018	-24.297	4.81	53.157	1.962	-5.6473	1.0421

The return loss is < -20dB, 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 D5GHzV2 Serial No.1095 D5GHzV2-Head



## Dipole Verification Data D5GHzV2 Serial No.1095 D5GHzV2-Body



Schmid & Partner Engineering AG

s p e a g

Zougheustrasse 43, 8004 Zurich, Switzerland  
Phone +41 44 245 9700, Fax +41 44 245 9779  
info@speag.com, <http://www.speag.com>

## IMPORTANT NOTICE

### USAGE OF THE DAE 4

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 closed 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.**

Schmid & Partner Engineering

TN\_BR040315AD DAE4.doc

11.12.2009



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



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

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

Calibration Factors	X	Y	Z
High Range	405.976 $\pm$ 0.02% (k=2)	404.686 $\pm$ 0.02% (k=2)	405.823 $\pm$ 0.02% (k=2)
Low Range	4.00366 $\pm$ 1.50% (k=2)	3.98422 $\pm$ 1.50% (k=2)	4.02584 $\pm$ 1.50% (k=2)

### Connector Angle

Connector Angle to be used in DASY system	29.5 " $\pm$ 1 "
---	------------------

**Appendix (Additional assessments outside the scope of SCS0108)**

**1. DC Voltage Linearity**

High Range	Reading ( $\mu\text{V}$ )	Difference ( $\mu\text{V}$ )	Error (%)
Channel X + Input	199993.34	-3.72	-0.00
Channel X + Input	20003.85	2.28	0.01
Channel X - Input	-19999.42	1.70	-0.01
Channel Y + Input	199991.78	-5.46	-0.00
Channel Y + Input	20002.02	0.30	0.00
Channel Y - Input	-20000.26	0.73	-0.00
Channel Z + Input	199994.14	-3.09	-0.00
Channel Z + Input	20000.91	-0.57	-0.00
Channel Z - Input	-20000.60	0.62	-0.00

Low Range	Reading ( $\mu\text{V}$ )	Difference ( $\mu\text{V}$ )	Error (%)
Channel X + Input	2001.47	0.29	0.01
Channel X + Input	202.09	0.42	0.21
Channel X - Input	-197.15	1.05	-0.53
Channel Y + Input	2001.46	0.25	0.01
Channel Y + Input	201.47	-0.31	-0.16
Channel Y - Input	-198.81	-0.64	0.32
Channel Z + Input	2001.57	0.41	0.02
Channel Z + Input	201.30	-0.28	-0.14
Channel Z - Input	-200.23	-1.77	0.89

**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 ( $\mu\text{V}$ )	Low Range Average Reading ( $\mu\text{V}$ )
Channel X	200	-7.70	-8.90
	-200	9.15	8.20
Channel Y	200	-7.22	-7.45
	-200	6.67	6.20
Channel Z	200	-5.90	-6.14
	-200	3.91	4.23

**3. Channel separation**

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

	Input Voltage (mV)	Channel X ( $\mu\text{V}$ )	Channel Y ( $\mu\text{V}$ )	Channel Z ( $\mu\text{V}$ )
Channel X	200	-	3.52	-3.41
Channel Y	200	9.08	-	4.30
Channel Z	200	9.44	7.03	-

**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	15881	17340
Channel Y	16455	16613
Channel Z	15938	16783

**5. Input Offset Measurement**

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

Input 10MΩ

	Average (μV)	min. Offset (μV)	max. Offset (μV)	Std. Deviation (μV)
Channel X	0.84	-0.23	1.93	0.43
Channel Y	-0.31	-1.54	0.85	0.43
Channel Z	-0.47	-1.92	-0.51	0.47

**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

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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: SCS 0108

Client **CCS-CN (Auden)**

Certificate No: EX3-3798\_Jul17

### CALIBRATION CERTIFICATE

Object	EX3DV4 - SN:3798
Calibration procedure(s)	QA CAL-01.v9, QA CAL-14.v4, QA CAL-23.v5, QA CAL-25.v6 Calibration procedure for dosimetric E-field probes
Calibration date:	July 26, 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 ± 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-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. 217-02525)	Apr-18
Reference 20 dB Attenuator	SN: S5277 (20x)	07-Apr-17 (No. 217-02528)	Apr-18
Reference Probe ES3DV2	SN: 3013	31-Dec-16 (No. ES3-3013 Dec16)	Dec-17
DAE4	SN: 660	7-Dec-16 (No. DAE4-660 Dec16)	Dec-17
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293674	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-16)	In house check: Jun-18
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-16)	In house check: Oct-17

Calibrated by:	Name Michael Weber	Function Laboratory Technician	Signature 
Approved by:	Name Katja Pokovic	Technical Manager	

Issued: July 26, 2017

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 <sub>x,y,z</sub>	sensitivity in free space
ConvF	sensitivity in TSL / NORM <sub>x,y,z</sub>
DCP	diode compression point
CF	crest factor (1/duty_cycle) of the RF signal
A, B, C, D	modulation dependent linearization parameters
Polarization $\varphi$	$\varphi$ rotation around probe axis
Polarization $\beta$	$\beta$ rotation around an axis that is in the plane normal to probe axis (at measurement center). i.e., $\beta = 0$ is normal to probe axis
Connector Angle	information used in DASY system to align probe sensor X to the robot coordinate system

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

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

### Methods Applied and Interpretation of Parameters:

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

EX3DV4 – SN:3798

July 26, 2017

# Probe EX3DV4

## SN:3798

Manufactured: April 5, 2011  
Calibrated: July 26, 2017

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

EX3DV4 - SN.3798

July 26, 2017

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

### Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup>	0.53	0.49	0.57	$\pm 10.1\%$
DCP (mV) <sup>B</sup>	100.5	98.4	99.6	

### Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB/ $\mu\text{V}$	C	D dB	VR mV	Unc <sup>F</sup> (k=2)
0	CW	X	0.0	0.0	1.0	0.00	150.9	$\pm 2.7\%$
		Y	0.0	0.0	1.0		149.9	
		Z	0.0	0.0	1.0		140.8	

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

<sup>A</sup> The uncertainties of Norm X, Y, Z do not affect the  $E^2$ -field uncertainty inside TSL (see Pages 5 and 6).

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

<sup>F</sup> 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:3798

July 26, 2017

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

### Calibration Parameter Determined in Head Tissue Simulating Media

f (MHz) <sup>C</sup>	Relative Permittivity <sup>F</sup>	Conductivity (Sim) <sup>F</sup>	ConvF X	ConvF Y	ConvF Z	Alpha <sup>D</sup>	Depth <sup>U</sup> (mm)	Unc (k=2)
835	41.5	0.90	9.65	9.65	9.65	0.46	0.86	± 12.0 %
900	41.5	0.97	9.39	9.39	9.39	0.48	0.83	± 12.0 %
1810	40.0	1.40	8.15	8.15	8.15	0.36	0.80	± 12.0 %
1900	40.0	1.40	8.07	8.07	8.07	0.32	0.85	± 12.0 %
2450	39.2	1.80	7.40	7.40	7.40	0.32	0.90	± 12.0 %
5200	36.0	4.66	5.20	5.20	5.20	0.35	1.80	± 13.1 %
5300	35.9	4.76	4.94	4.94	4.94	0.35	1.80	± 13.1 %
5500	35.6	4.96	4.78	4.78	4.78	0.40	1.80	± 13.1 %
5600	35.5	5.07	4.72	4.72	4.72	0.40	1.80	± 13.1 %
5800	35.3	5.27	4.79	4.79	4.79	0.40	1.80	± 13.1 %

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

<sup>F</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

<sup>D</sup> Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-8 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:3798

### Calibration Parameter Determined in Body Tissue Simulating Media

f (MHz) <sup>c</sup>	Relative Permittivity <sup>e</sup>	Conductivity (S/m) <sup>f</sup>	ConvF X	ConvF Y	ConvF Z	Alpha <sup>g</sup>	Depth <sup>g</sup> (mm)	Unc (k=2)
835	55.2	0.97	9.35	9.35	9.35	0.55	0.80	± 12.0 %
900	55.0	1.05	9.17	9.17	9.17	0.42	0.86	± 12.0 %
1810	53.3	1.52	7.81	7.81	7.81	0.44	0.80 <sup>h</sup>	± 12.0 %
1900	53.3	1.52	7.75	7.75	7.75	0.45	0.80	± 12.0 %
2450	52.7	1.95	7.32	7.32	7.32	0.43	0.92	± 12.0 %
5200	49.0	5.30	4.81	4.81	4.81	0.35	1.90	± 13.1 %
5300	48.9	5.42	4.67	4.67	4.67	0.35	1.90	± 13.1 %
5500	48.6	5.65	4.26	4.26	4.26	0.40	1.90	± 13.1 %
5600	48.5	5.77	4.18	4.18	4.18	0.40	1.90	± 13.1 %
5800	48.2	6.00	4.45	4.45	4.45	0.40	1.90	± 13.1 %

<sup>c</sup> Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the Indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

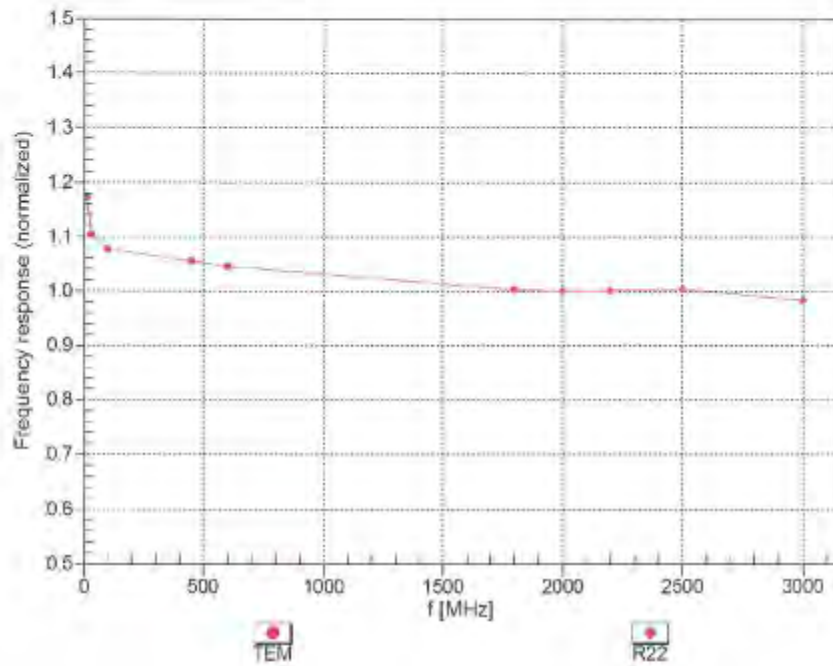
<sup>e</sup> At frequencies below 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters ( $\epsilon$  and  $\sigma$ ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

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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)

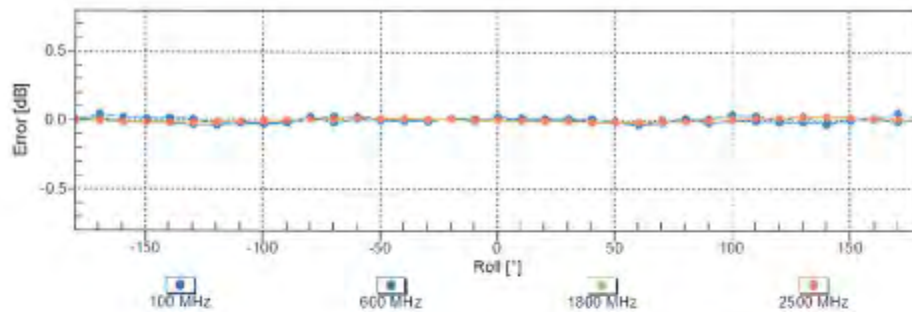
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## Receiving Pattern ( $\phi$ ), $\theta = 0^\circ$

f=600 MHz, TEM

f=1800 MHz, R22

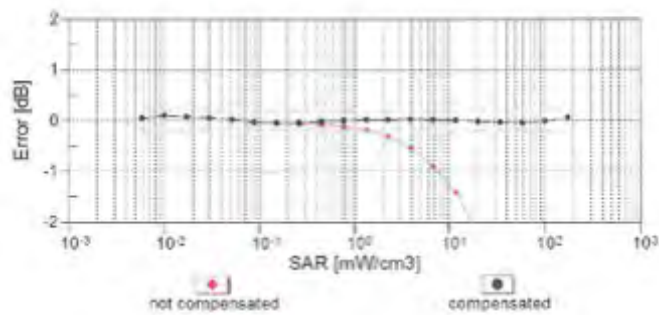
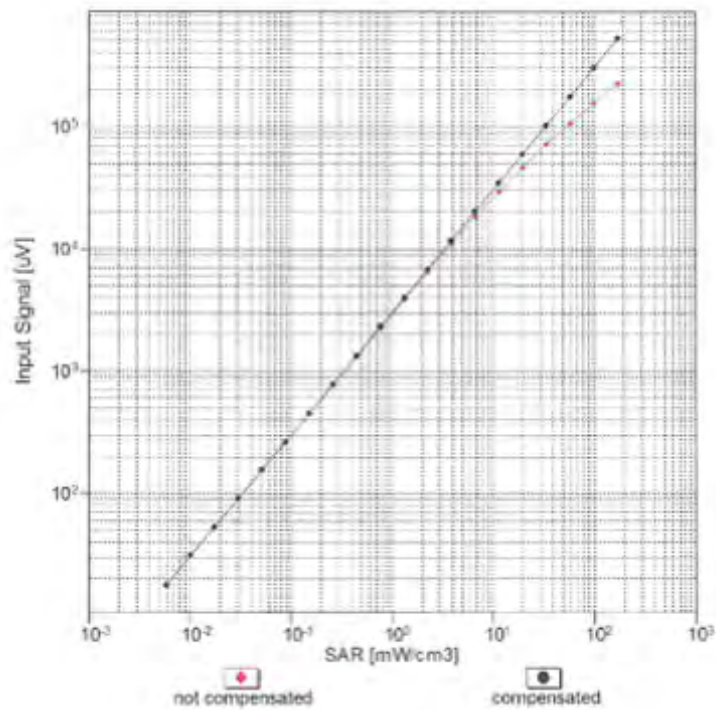


Uncertainty of Axial Isotropy Assessment:  $\pm 0.5\%$  (k=2)

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### Dynamic Range f(SAR<sub>head</sub>) (TEM cell, f<sub>eval</sub>= 1900 MHz)

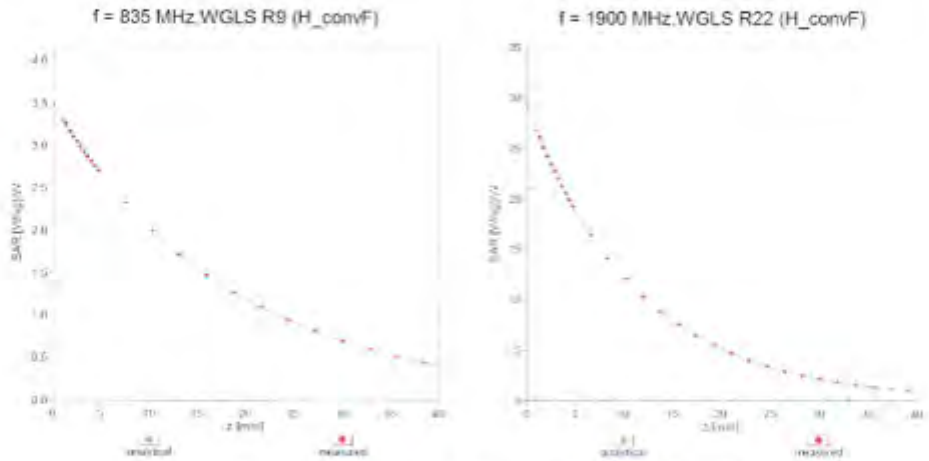


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

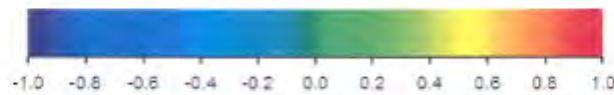
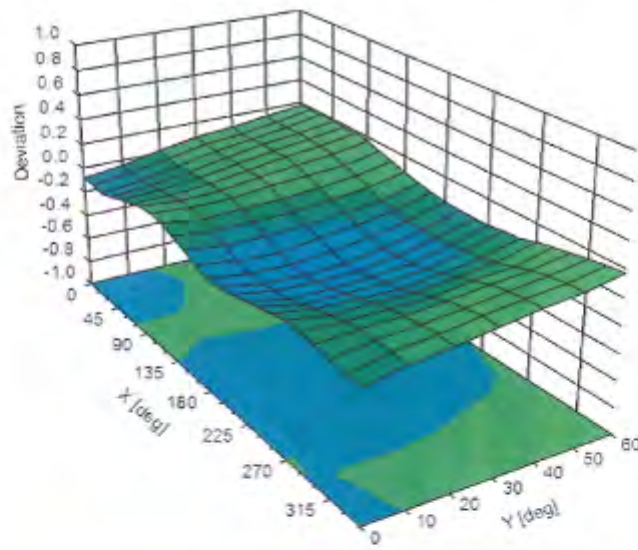
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### Conversion Factor Assessment



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



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



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

#### Other Probe Parameters

Sensor Arrangement	Triangular
Connector Angle (°)	-39.5
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