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 CALIBRATION LABORATORY

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**DASY5 Validation Report for Body TSL**

Date: 06.15.2020

Test Laboratory: CTTL, Beijing, China

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 862**

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

Medium parameters used:  $f = 2450$  MHz;  $\sigma = 1.937$  S/m;  $\epsilon_r = 52.32$ ;  $\rho = 1000$  kg/m<sup>3</sup>

Phantom section: Center Section

DASY5 Configuration:

- Probe: EX3DV4 - SN7514; ConvF(7.32, 7.32, 7.32) @ 2450 MHz; Calibrated: 2019-09-27
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1555; Calibrated: 2019-08-22
- Phantom: MFP\_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx; Serial: 1062
- Measurement SW: DASY52, Version 52.10 (4); SEMCAD X Version 14.6.14 (7483)

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

Reference Value = 98.50 V/m; Power Drift = 0.08 dB

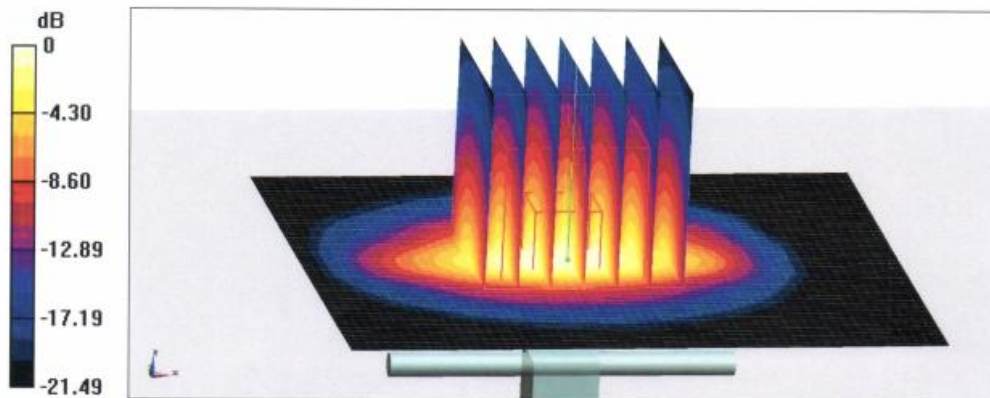
Peak SAR (extrapolated) = 26.2 W/kg

**SAR(1 g) = 12.8 W/kg; SAR(10 g) = 5.94 W/kg**

Smallest distance from peaks to all points 3 dB below = 8.5 mm

Ratio of SAR at M2 to SAR at M1 = 50.3%

Maximum value of SAR (measured) = 21.1 W/kg



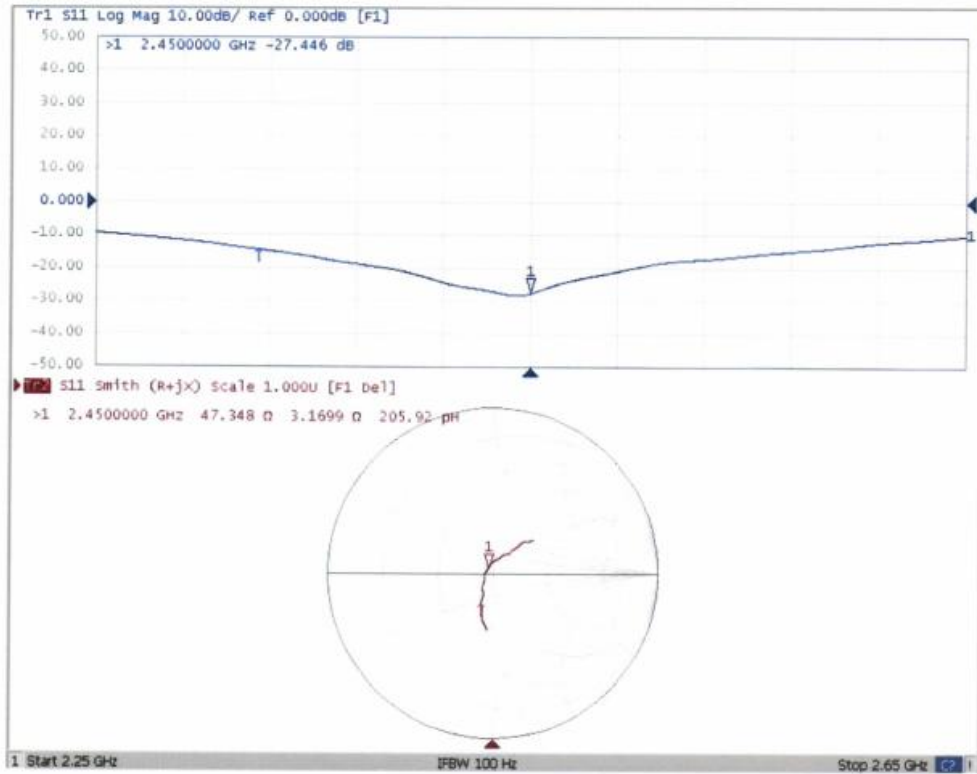
0 dB = 21.1 W/kg = 13.24 dBW/kg



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**Impedance Measurement Plot for Body TSL**





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Client : **Audix**

Certificate No: **Z20-60111**

### CALIBRATION CERTIFICATE

Object: **DAE4 - SN: 899**

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




Calibration date: **March 18, 2020**

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	24-Jun-19 (CTTL, No.J19X05126)	Jun-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: March 20, 2020

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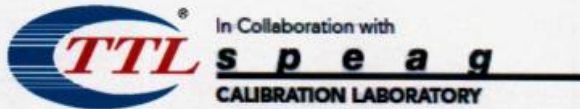
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**Glossary:**

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 = 6.1μV , full range = -100...+300 mV

Low Range: 1LSB = 61nV , full range = -1.....+3mV

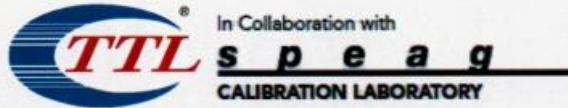
DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

Calibration Factors	X	Y	Z
High Range	402.285 ± 0.15% (k=2)	403.043 ± 0.15% (k=2)	403.034 ± 0.15% (k=2)
Low Range	3.97978 ± 0.7% (k=2)	3.97684 ± 0.7% (k=2)	3.98312 ± 0.7% (k=2)

**Connector Angle**

Connector Angle to be used in DASY system	350° ± 1 °
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 CALIBRATION  
 CNAS L0570

Client

**Audix**

Certificate No: **Z20-60110**

**CALIBRATION CERTIFICAT**

Object **EX3DV4 - SN : 3767**

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

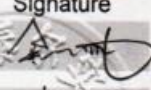
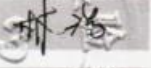

Calibration date: **April 01, 2020**

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)

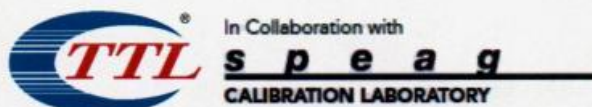
Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Power Meter NRP2	101919	18-Jun-19(CTTL, No.J19X05125)	Jun-20
Power sensor NRP-Z91	101547	18-Jun-19(CTTL, No.J19X05125)	Jun-20
Power sensor NRP-Z91	101548	18-Jun-19(CTTL, No.J19X05125)	Jun-20
Reference 10dBAttenuator	18N50W-10dB	10-Feb-20(CTTL, No.J20X00525)	Feb-22
Reference 20dBAttenuator	18N50W-20dB	10-Feb-20(CTTL, No.J20X00526)	Feb-22
Reference Probe EX3DV4	SN 7307	24-May-19(SPEAG, No.EX3-7307_May19/2)	May-20
DAE4	SN 1525	26-Aug-19(SPEAG, No.DAE4-1525_Aug19)	Aug-20
Secondary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
SignalGenerator MG3700A	6201052605	18-Jun-19(CTTL, No.J19X05127)	Jun-20
Network Analyzer E5071C	MY46110673	10-Feb-20(CTTL, No.J20X00515)	Feb-21

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

Issued: April 03, 2020

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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  $\Phi$   $\Phi$  rotation around probe axis
- Polarization  $\theta$   $\theta$  rotation around an axis that is in the plane normal to probe axis (at measurement center),  $\theta=0$  is normal to probe axis

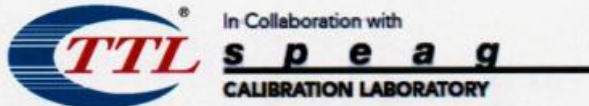
Connector Angle information used in DASY system to align probe sensor X to the robot coordinate system

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

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

**Methods Applied and Interpretation of Parameters:**

- NORM<sub>x,y,z</sub>: Assessed for E-field polarization  $\theta=0$  ( $f \leq 900\text{MHz}$  in TEM-cell;  $f > 1800\text{MHz}$ : waveguide). NORM<sub>x,y,z</sub> are only intermediate values, i.e., the uncertainties of NORM<sub>x,y,z</sub> does not effect the  $E^2$ -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 (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>; VR<sub>x,y,z</sub>: 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<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  $\pm 50\text{MHz}$  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<sub>x</sub> (no uncertainty required).



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## DASY/EASY – Parameters of Probe: EX3DV4 – SN:3767

### Basic Calibration Parameters

	Sensor X	Sensor Y	Sensor Z	Unc (k=2)
Norm( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup>	0.55	0.57	0.48	±10.0%
DCP(mV) <sup>B</sup>	101.3	100.7	103.7	

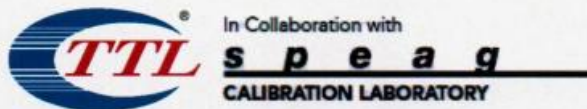
### Modulation Calibration Parameters

UID	Communication System Name		A dB	B dB $\sqrt{\mu\text{V}}$	C	D dB	VR mV	Unc <sup>E</sup> (k=2)
0	CW	X	0.0	0.0	1.0	0.00	173.8	±2.3%
		Y	0.0	0.0	1.0		175.2	
		Z	0.0	0.0	1.0		160.6	

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

- <sup>A</sup> The uncertainties of Norm X, Y, Z do not affect the E<sup>2</sup>-field uncertainty inside TSL (see Page 4 and Page 5).  
<sup>B</sup> Numerical linearization parameter: uncertainty not required.  
<sup>E</sup> Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.





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## DASY/EASY – Parameters of Probe : EX3DV4 – SN:3767

### Calibration Parameter Determined in Head Tissue Simulating Media

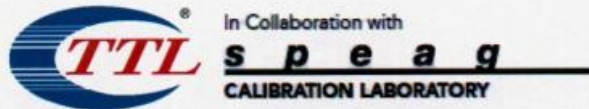
f [MHz] <sup>C</sup>	Relative Permittivity <sup>F</sup>	Conductivity (S/m) <sup>F</sup>	ConvF X	ConvF Y	ConvF Z	Alpha <sup>G</sup>	Depth <sup>G</sup> (mm)	Unct. (k=2)
750	41.9	0.89	9.81	9.81	9.81	0.40	0.80	±12.1%
835	41.5	0.90	9.53	9.53	9.53	0.14	1.49	±12.1%
900	41.5	0.97	9.55	9.55	9.55	0.16	1.30	±12.1%
1640	40.3	1.29	8.41	8.41	8.41	0.20	1.04	±12.1%
1750	40.1	1.37	8.26	8.26	8.26	0.20	1.14	±12.1%
1900	40.0	1.40	8.02	8.02	8.02	0.25	1.05	±12.1%
2000	40.0	1.40	8.00	8.00	8.00	0.19	1.19	±12.1%
2300	39.5	1.67	7.79	7.79	7.79	0.47	0.77	±12.1%
2450	39.2	1.80	7.46	7.46	7.46	0.53	0.74	±12.1%
2600	39.0	1.96	7.31	7.31	7.31	0.64	0.68	±12.1%
3300	38.2	2.71	7.40	7.40	7.40	0.66	0.68	±13.3%
3500	37.9	2.91	6.98	6.98	6.98	0.52	0.80	±13.3%
3700	37.7	3.12	6.60	6.60	6.60	0.47	0.88	±13.3%
3900	37.5	3.32	6.50	6.50	6.50	0.40	1.15	±13.3%
4100	37.2	3.53	6.43	6.43	6.43	0.40	1.20	±13.3%
4400	36.9	3.84	6.32	6.32	6.32	0.35	1.33	±13.3%
4600	36.7	4.04	6.15	6.15	6.15	0.45	1.40	±13.3%
4800	36.4	4.25	5.98	5.98	5.98	0.40	1.65	±13.3%
4950	36.3	4.40	5.80	5.80	5.80	0.40	1.60	±13.3%
5200	36.0	4.66	5.55	5.55	5.55	0.40	1.45	±13.3%
5300	35.9	4.76	5.14	5.14	5.14	0.40	1.70	±13.3%
5500	35.6	4.96	4.82	4.82	4.82	0.45	1.65	±13.3%
5600	35.5	5.07	4.75	4.75	4.75	0.45	1.55	±13.3%
5800	35.3	5.27	4.70	4.70	4.70	0.50	1.40	±13.3%

<sup>C</sup> 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.

<sup>F</sup> At frequency 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 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:3767

### Calibration Parameter Determined in Body Tissue Simulating Media

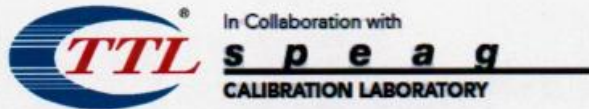
f [MHz] <sup>C</sup>	Relative Permittivity <sup>F</sup>	Conductivity (S/m) <sup>F</sup>	ConvF X	ConvF Y	ConvF Z	Alpha <sup>G</sup>	Depth <sup>G</sup> (mm)	Unct. (k=2)
750	55.5	0.96	9.91	9.91	9.91	0.40	0.80	±12.1%
835	55.2	0.97	9.60	9.60	9.60	0.15	1.51	±12.1%
900	55.0	1.05	9.53	9.53	9.53	0.22	1.16	±12.1%
1640	53.8	1.40	8.15	8.15	8.15	0.23	1.18	±12.1%
1750	53.4	1.49	7.87	7.87	7.87	0.18	1.25	±12.1%
1900	53.3	1.52	7.77	7.77	7.77	0.17	1.33	±12.1%
2000	53.3	1.52	7.70	7.70	7.70	0.20	1.38	±12.1%
2300	52.9	1.81	7.77	7.77	7.77	0.51	0.83	±12.1%
2450	52.7	1.95	7.59	7.59	7.59	0.57	0.78	±12.1%
2600	52.5	2.16	7.37	7.37	7.37	0.68	0.69	±12.1%
3300	51.6	3.08	6.82	6.82	6.82	0.43	1.00	±13.3%
3500	52.3	3.31	6.35	6.35	6.35	0.40	1.25	±13.3%
3700	52.1	3.55	6.19	6.19	6.19	0.40	1.25	±13.3%
3900	50.8	3.78	6.18	6.18	6.18	0.40	1.40	±13.3%
4100	50.5	4.01	6.18	6.18	6.18	0.35	1.40	±13.3%
4400	50.1	4.37	5.97	5.97	5.97	0.35	1.70	±13.3%
4600	49.8	4.60	5.63	5.63	5.63	0.40	1.55	±13.3%
4800	49.6	4.83	5.48	5.48	5.48	0.40	1.65	±13.3%
4950	49.4	5.01	5.24	5.24	5.24	0.45	1.65	±13.3%
5200	49.0	5.30	5.07	5.07	5.07	0.45	1.50	±13.3%
5300	48.9	5.42	4.80	4.80	4.80	0.45	1.50	±13.3%
5500	48.6	5.65	4.36	4.36	4.36	0.45	1.60	±13.3%
5600	48.5	5.77	4.32	4.32	4.32	0.50	1.50	±13.3%
5800	48.2	6.00	4.34	4.34	4.34	0.50	1.44	±13.3%

<sup>C</sup> 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.

<sup>F</sup> At frequency 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.

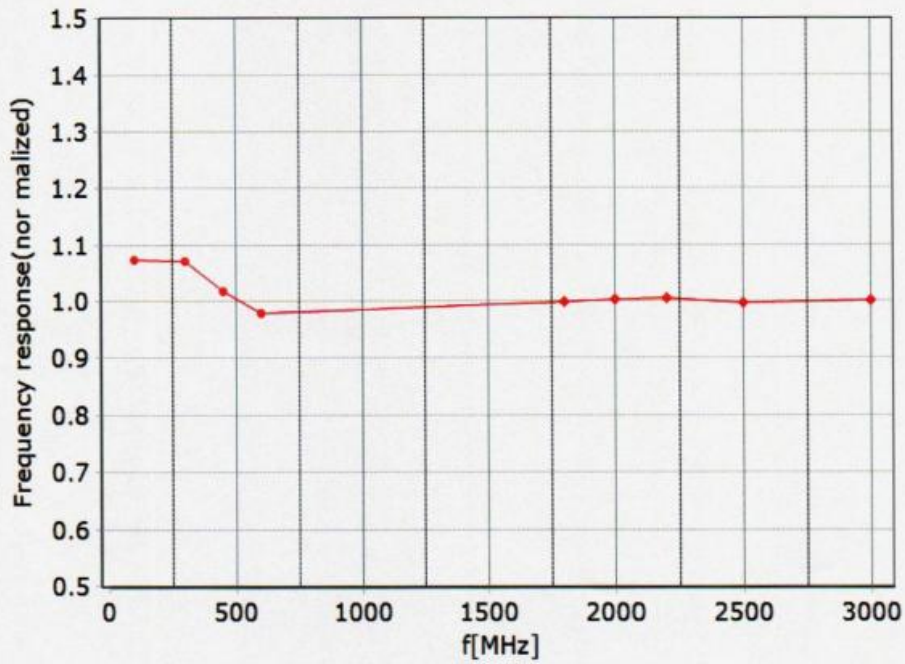
<sup>G</sup> Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for the frequencies between 3-6 GHz at any distance larger than half the probe tip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





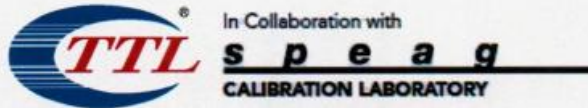
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### Frequency Response of E-Field (TEM-Cell: ifi110 EXX, Waveguide: R22)



• TEM      • R22

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

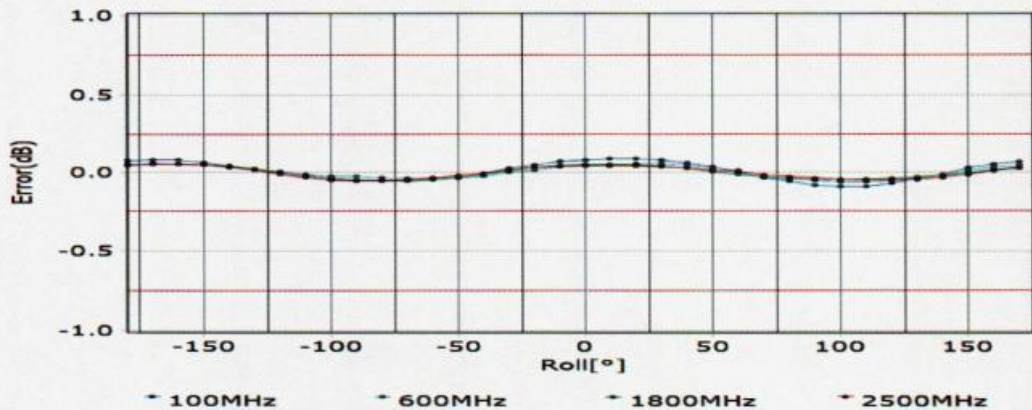
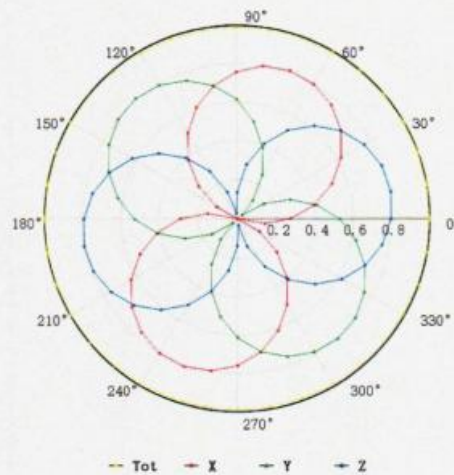
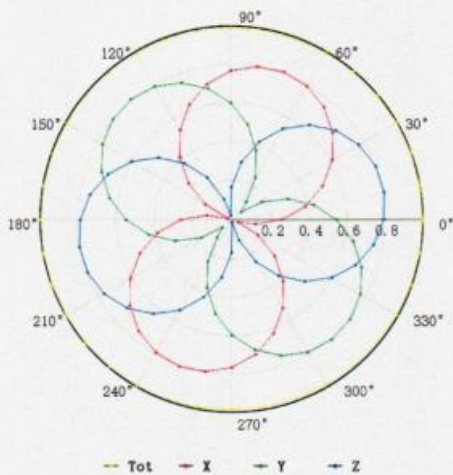


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**Receiving Pattern ( $\Phi$ ),  $\theta=0^\circ$**

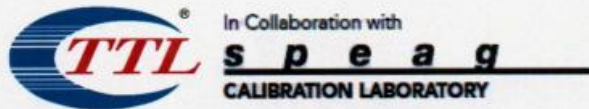
**f=600 MHz, TEM**

**f=1800 MHz, R22**



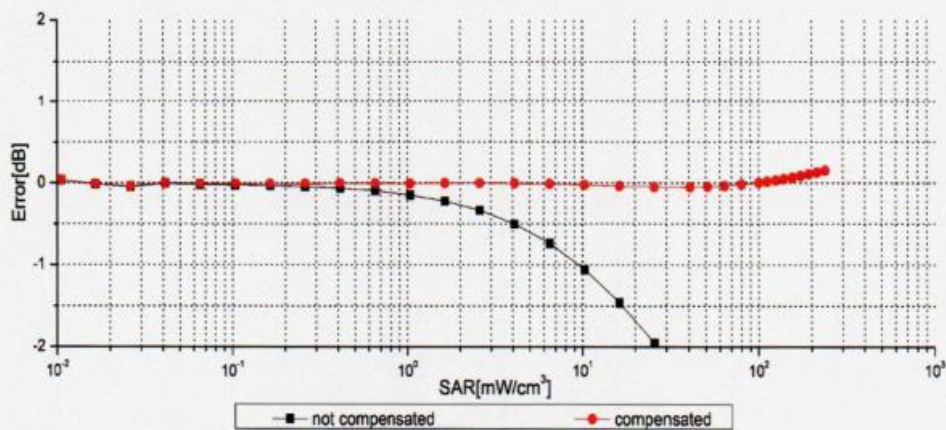
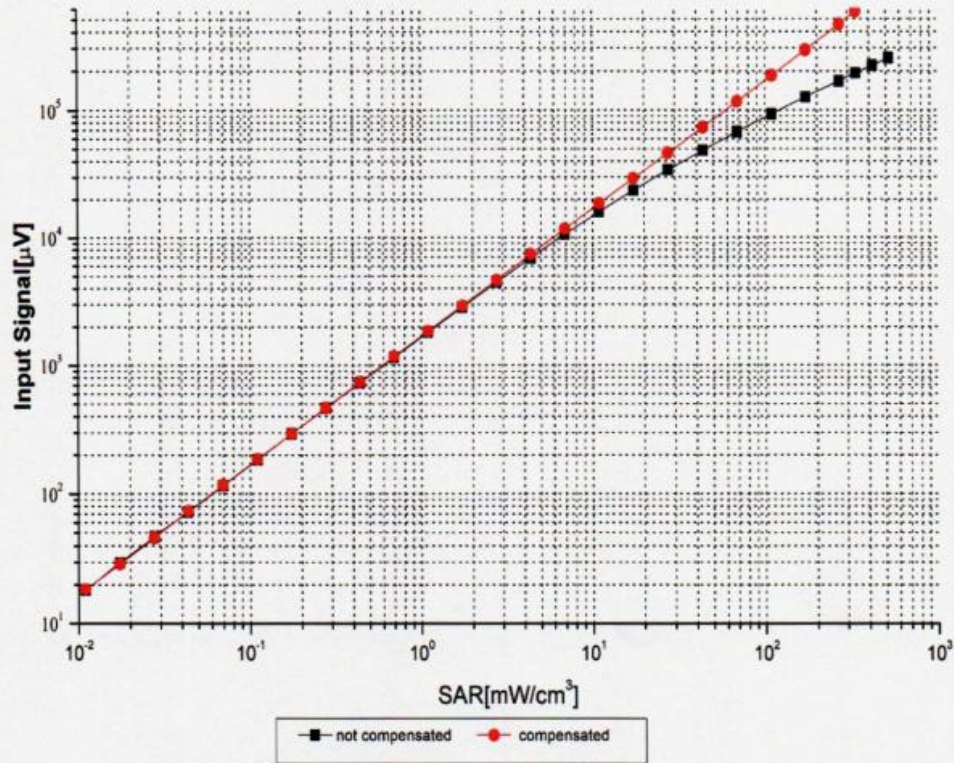
Uncertainty of Axial Isotropy Assessment:  $\pm 1.2\%$  ( $k=2$ )



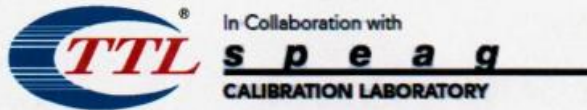


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### Dynamic Range f(SAR<sub>head</sub>) (TEM cell, f = 900 MHz)



Uncertainty of Linearity Assessment: ±0.9% (k=2)

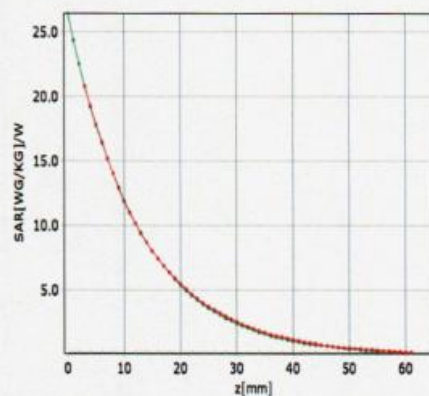
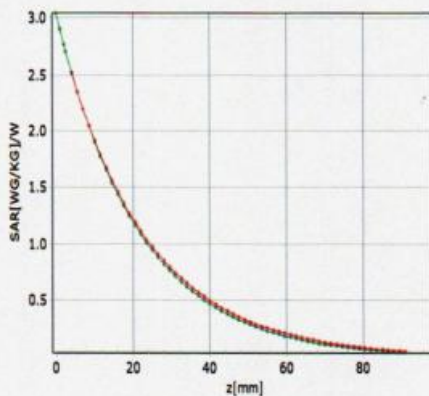


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## Conversion Factor Assessment

f=750 MHz,WGLS R9(H\_convF)

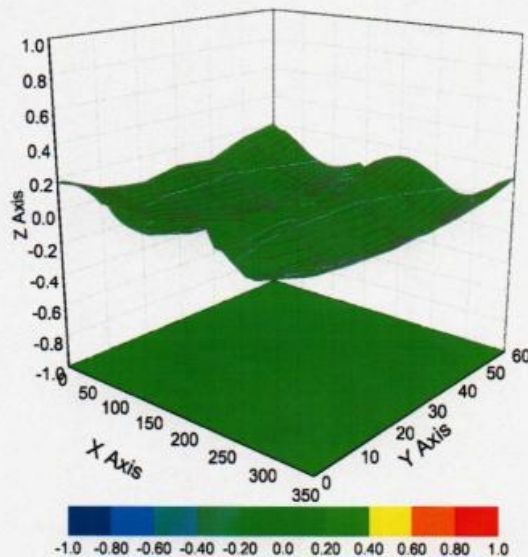
f=1750 MHz,WGLS R22(H\_convF)



\* analytical \* measured

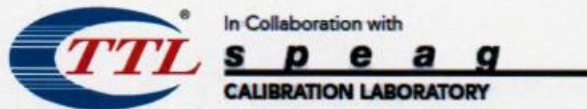
\* analytical \* measured

## 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:3767****Other Probe Parameters**

<b>Sensor Arrangement</b>	<b>Triangular</b>
<b>Connector Angle (°)</b>	<b>146.6</b>
<b>Mechanical Surface Detection Mode</b>	<b>enabled</b>
<b>Optical Surface Detection Mode</b>	<b>disable</b>
<b>Probe Overall Length</b>	<b>337mm</b>
<b>Probe Body Diameter</b>	<b>10mm</b>
<b>Tip Length</b>	<b>10mm</b>
<b>Tip Diameter</b>	<b>2.5mm</b>
<b>Probe Tip to Sensor X Calibration Point</b>	<b>1mm</b>
<b>Probe Tip to Sensor Y Calibration Point</b>	<b>1mm</b>
<b>Probe Tip to Sensor Z Calibration Point</b>	<b>1mm</b>
<b>Recommended Measurement Distance from Surface</b>	<b>1.4mm</b>