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CALIBRATION LABORATORY



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Appendix (Additional assessments outside the scope of CNAS L0570)

Antenna Parameters with Head TSL

| | |
|--------------------------------------|---------------|
| Impedance, transformed to feed point | 48.6Ω- 6.32jΩ |
| Return Loss | - 23.7dB |

General Antenna Parameters and Design

| | |
|----------------------------------|----------|
| Electrical Delay (one direction) | 1.058 ns |
|----------------------------------|----------|

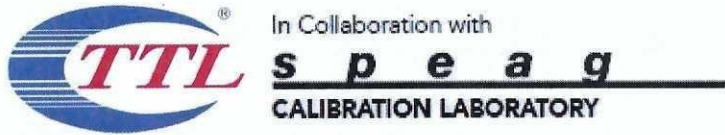
After long term use with 100W radiated power, only a slight warming of the dipole near the feed-point can be measured.

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 feed-point may be damaged.

Additional EUT Data

| | |
|-----------------|-------|
| Manufactured by | SPEAG |
|-----------------|-------|



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DASY5 Validation Report for Head TSL

Date: 2023-06-20

Test Laboratory: CTTL, Beijing, China

DUT: Dipole 2600 MHz; Type: D2600V2; Serial: D2600V2 - SN: 1071

Communication System: UID 0, CW; Frequency: 2600 MHz

Medium parameters used: $f = 2600$ MHz; $\sigma = 1.98$ S/m; $\epsilon_r = 39.75$; $\rho = 1000$ kg/m³

Phantom section: Right Section

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

DASY5 Configuration:

- Probe: EX3DV4 - SN7464; ConvF(7.5, 7.5, 7.5) @ 2600 MHz; Calibrated: 2023-01-19
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn1556; Calibrated: 2023-01-11
- Phantom: MFP_V5.1C (20deg probe tilt); Type: QD 000 P51 Cx; Serial: 1062
- DASY52 52.10.4(1535); SEMCAD X 14.6.14(7501)

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

Reference Value = 98.06 V/m; Power Drift = -0.04 dB

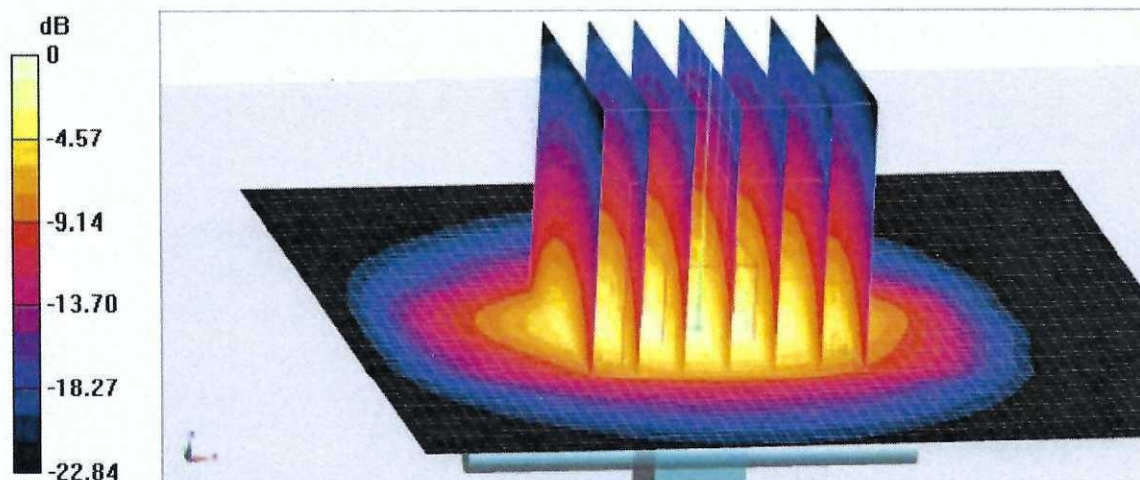
Peak SAR (extrapolated) = 30.6 W/kg

SAR(1 g) = 14.2 W/kg; SAR(10 g) = 6.36 W/kg

Smallest distance from peaks to all points 3 dB below = 8.9 mm

Ratio of SAR at M2 to SAR at M1 = 47.1%

Maximum value of SAR (measured) = 24.5 W/kg

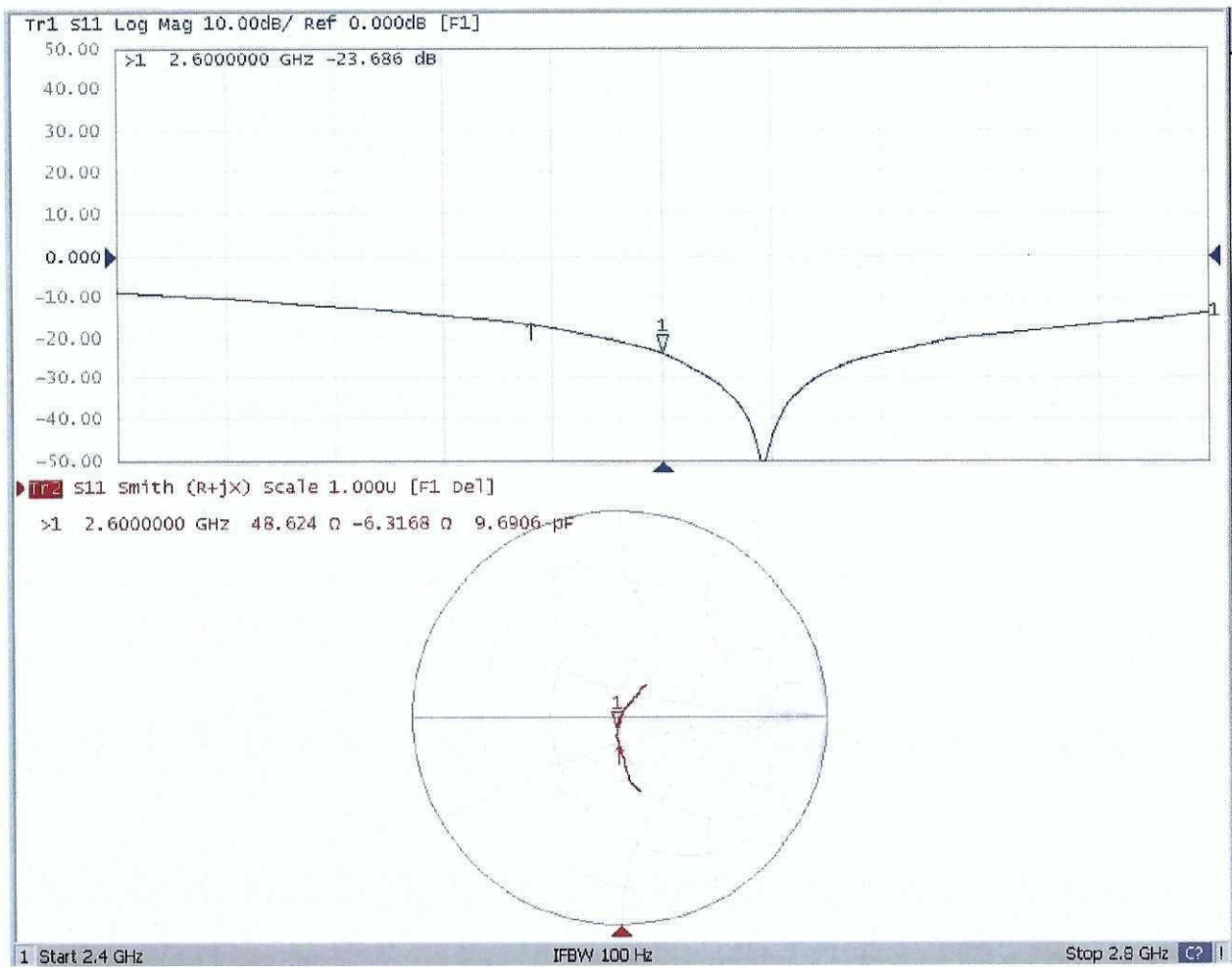


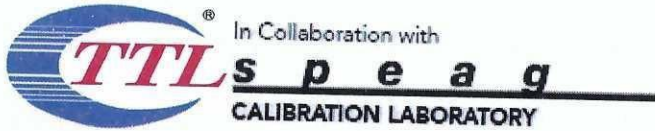
0 dB = 24.5 W/kg = 13.89 dBW/kg



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Impedance Measurement Plot for Head TSL





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CNAS L0570



Client : SHENZHEN LCS

Certificate No: Z23-60556

CALIBRATION CERTIFICATE

Object DAE3 - SN: 419

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

Calibration date: June 20, 2023

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 | 14-Jun-23 (CTTL, No.J22X04184) | Jun-24 |

| | 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: June 26, 2023

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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 | 402.650 \pm 0.15% (k=2) | 403.236 \pm 0.15% (k=2) | 402.697 \pm 0.15% (k=2) |
| Low Range | 3.92055 \pm 0.7% (k=2) | 3.97661 \pm 0.7% (k=2) | 3.93420 \pm 0.7% (k=2) |

Connector Angle

| | |
|---|-----------------------------------|
| Connector Angle to be used in DASY system | 293 $^{\circ}$ \pm 1 $^{\circ}$ |
|---|-----------------------------------|



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<http://www.caict.ac.cn>**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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Client SHENZHEN LCS

Certificate No: J23Z60272

CALIBRATION CERTIFICATE

Object EX3DV4 - SN : 3805

Calibration Procedure(s) FF-Z11-004-02
Calibration Procedures for Dosimetric E-field Probes

Calibration date: June 21, 2023

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 | 12-Jun-23(CTTL, No.J23X05435) | Jun-24 |
| Power sensor NRP-Z91 | 101547 | 12-Jun-23(CTTL, No.J23X05435) | Jun-24 |
| Power sensor NRP-Z91 | 101548 | 12-Jun-23(CTTL, No.J23X05435) | Jun-24 |
| Reference 10dBAttenuator | 18N50W-10dB | 19-Jan-23(CTTL, No.J23X00212) | Jan-25 |
| Reference 20dBAttenuator | 18N50W-20dB | 19-Jan-23(CTTL, No.J23X00211) | Jan-25 |
| Reference Probe EX3DV4 | SN 7517 | 27-Jan-23(SPEAG, No.EX-7517_Jan23) | Jan-24 |
| DAE4 | SN 1555 | 25-Aug-22(SPEAG, No.DAE4-1555_Aug22) | Aug-23 |
| Secondary Standards | ID # | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
| SignalGenerator MG3700A | 6201052605 | 12-Jun-23(CTTL, No.J23X05434) | Jun-24 |
| Network Analyzer E5071C | MY46110673 | 10-Jan-23(CTTL, No.J23X00104) | Jan-24 |
| Reference 10dBAttenuator | BT0520 | 11-May-23(CTTL, No.J23X04061) | May-25 |
| Reference 20dBAttenuator | BT0267 | 11-May-23(CTTL, No.J23X04062) | May-25 |
| OCP DAK-3.5 | SN 1040 | 18-Jan-23(SPEAG, No.OCP-DAK3.5-1040_Jan23) | Jan-24 |

| | 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: June 27, 2023

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Glossary:

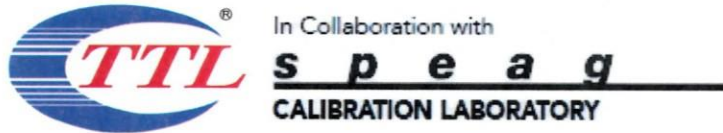
| | |
|-----------------------|--|
| TSL | tissue simulating liquid |
| NORM _{x,y,z} | sensitivity in free space |
| ConvF | sensitivity in TSL / NORM _{x,y,z} |
| DCP | diode compression point |
| CF | crest factor (1/duty_cycle) of the RF signal |
| A,B,C,D | modulation dependent linearization parameters |
| 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), $\theta=0$ 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:

- 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 $\theta=0$ ($f \leq 900\text{MHz}$ in TEM-cell; $f > 1800\text{MHz}$: waveguide). NORM_{x,y,z} are only intermediate values, i.e., the uncertainties of NORM_{x,y,z} does not effect 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 (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).



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DASY/EASY – Parameters of Probe: EX3DV4 – SN:3805

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|--|----------|----------|----------|-----------|
| Norm($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.44 | 0.35 | 0.41 | ±10.0% |
| DCP(mV) ^B | 100.5 | 101.6 | 100.6 | |

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 | 161.9 | ±2.2% |
| | | Y | 0.0 | 0.0 | 1.0 | | 139.0 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 149.3 | |

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 E^2 -field uncertainty inside TSL (see Page 4).

^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.



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DASY/EASY – Parameters of Probe: EX3DV4 – SN:3805

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 | 10.02 | 10.02 | 10.02 | 0.17 | 1.27 | ± 12.7% |
| 835 | 41.5 | 0.90 | 9.62 | 9.62 | 9.62 | 0.18 | 1.30 | ± 12.7% |
| 1750 | 40.1 | 1.37 | 8.35 | 8.35 | 8.35 | 0.28 | 1.02 | ± 12.7% |
| 1900 | 40.0 | 1.40 | 8.05 | 8.05 | 8.05 | 0.24 | 1.11 | ± 12.7% |
| 2100 | 39.8 | 1.49 | 8.00 | 8.00 | 8.00 | 0.24 | 1.11 | ± 12.7% |
| 2300 | 39.5 | 1.67 | 7.75 | 7.75 | 7.75 | 0.65 | 0.67 | ± 12.7% |
| 2450 | 39.2 | 1.80 | 7.50 | 7.50 | 7.50 | 0.65 | 0.69 | ± 12.7% |
| 2600 | 39.0 | 1.96 | 7.35 | 7.35 | 7.35 | 0.47 | 0.85 | ± 12.7% |
| 3500 | 37.9 | 2.91 | 6.85 | 6.85 | 6.85 | 0.41 | 1.03 | ± 13.9% |
| 3700 | 37.7 | 3.12 | 6.69 | 6.69 | 6.69 | 0.43 | 1.03 | ± 13.9% |
| 3900 | 37.5 | 3.32 | 6.58 | 6.58 | 6.58 | 0.30 | 1.50 | ± 13.9% |
| 4100 | 37.2 | 3.53 | 6.62 | 6.62 | 6.62 | 0.35 | 1.25 | ± 13.9% |
| 4200 | 37.1 | 3.63 | 6.52 | 6.52 | 6.52 | 0.30 | 1.45 | ± 13.9% |
| 4400 | 36.9 | 3.84 | 6.44 | 6.44 | 6.44 | 0.30 | 1.50 | ± 13.9% |
| 4600 | 36.7 | 4.04 | 6.41 | 6.41 | 6.41 | 0.35 | 1.48 | ± 13.9% |
| 4800 | 36.4 | 4.25 | 6.36 | 6.36 | 6.36 | 0.35 | 1.50 | ± 13.9% |
| 4950 | 36.3 | 4.40 | 5.95 | 5.95 | 5.95 | 0.35 | 1.55 | ± 13.9% |
| 5250 | 35.9 | 4.71 | 5.45 | 5.45 | 5.45 | 0.40 | 1.55 | ± 13.9% |
| 5600 | 35.5 | 5.07 | 4.86 | 4.86 | 4.86 | 0.45 | 1.40 | ± 13.9% |
| 5750 | 35.4 | 5.22 | 4.96 | 4.96 | 4.96 | 0.45 | 1.40 | ± 13.9% |

^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.

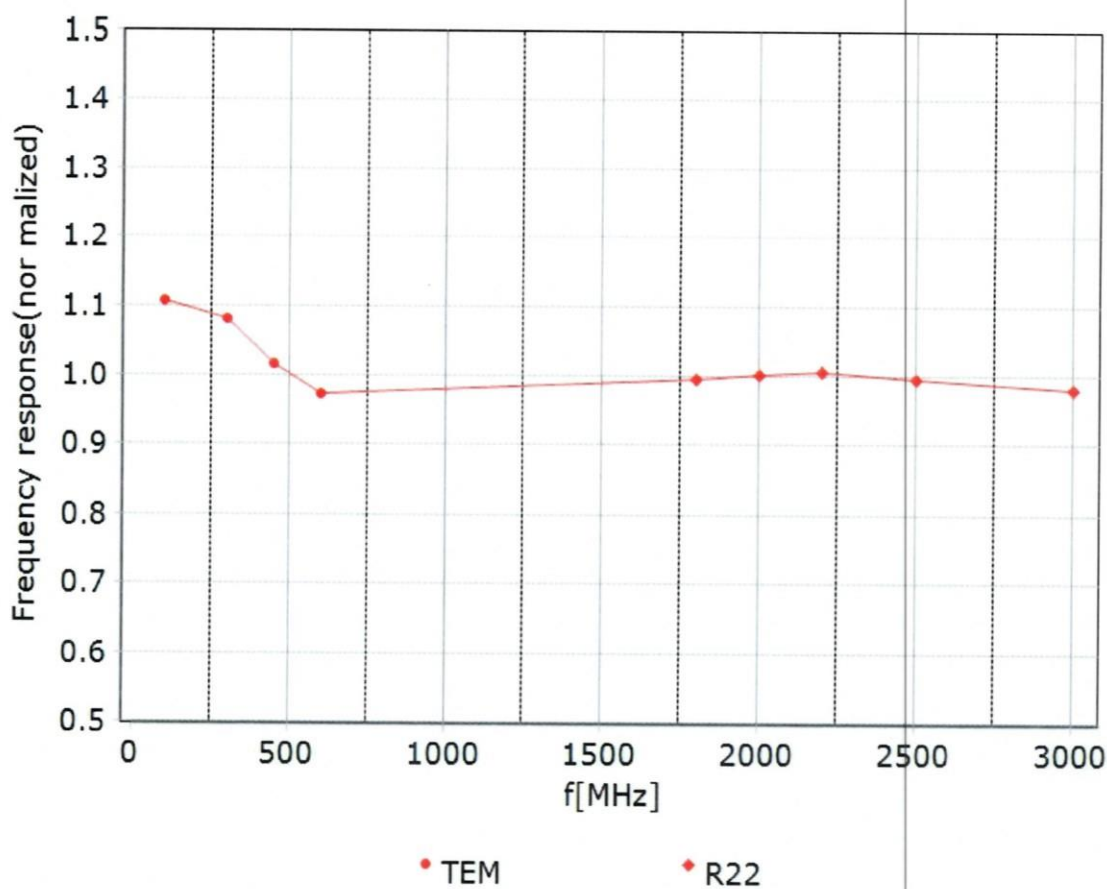
^F At frequency up to 6 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ±10% if liquid compensation formula is applied to measured SAR values. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

^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: $\pm 7.4\%$ ($k=2$)

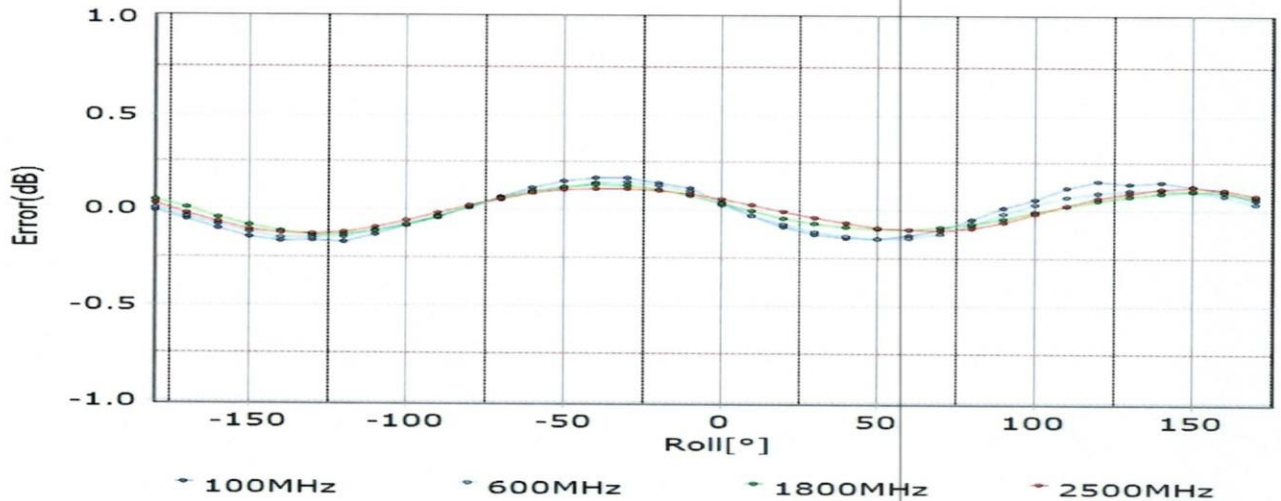
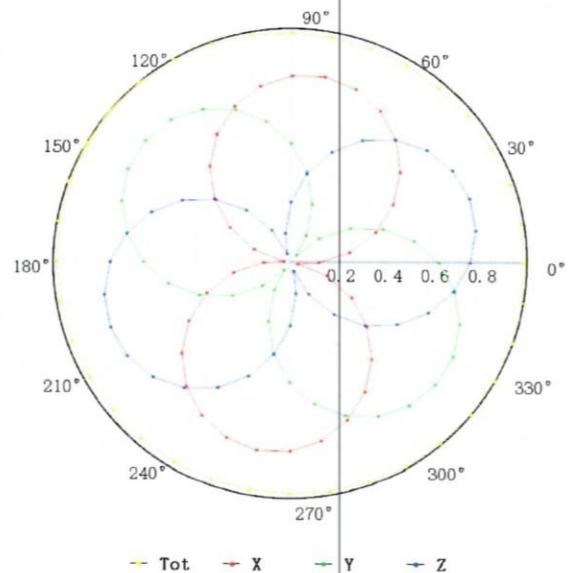
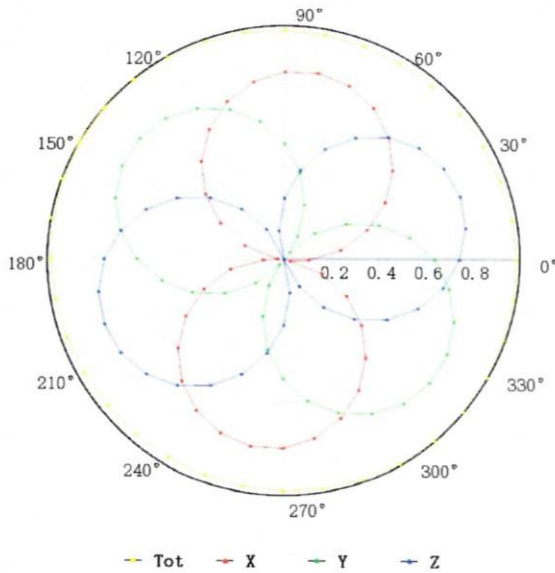


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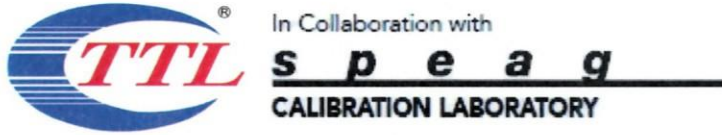
Receiving Pattern (Φ), $\theta=0^\circ$

f=600 MHz, TEM

f=1800 MHz, R22

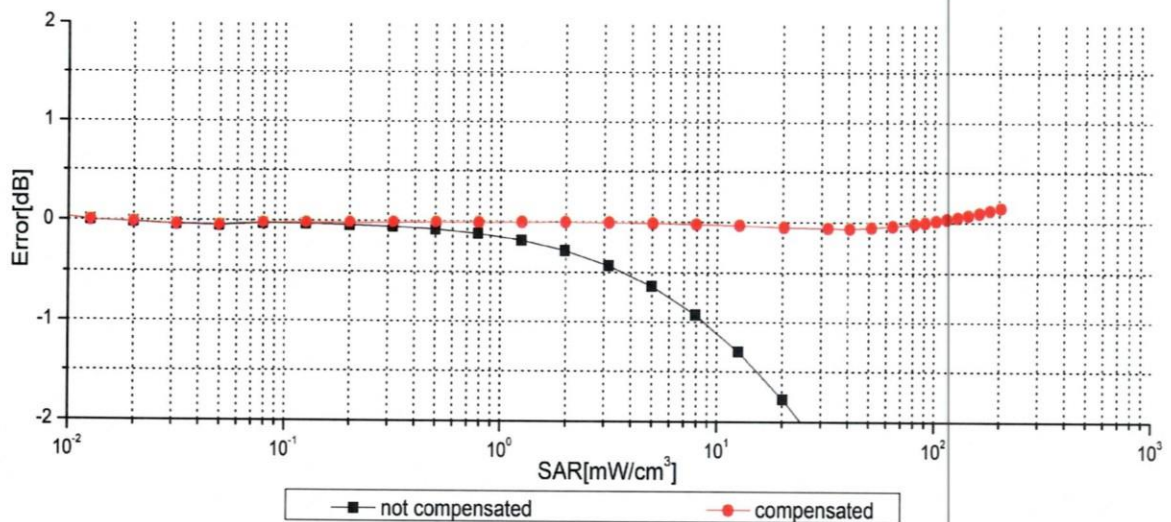
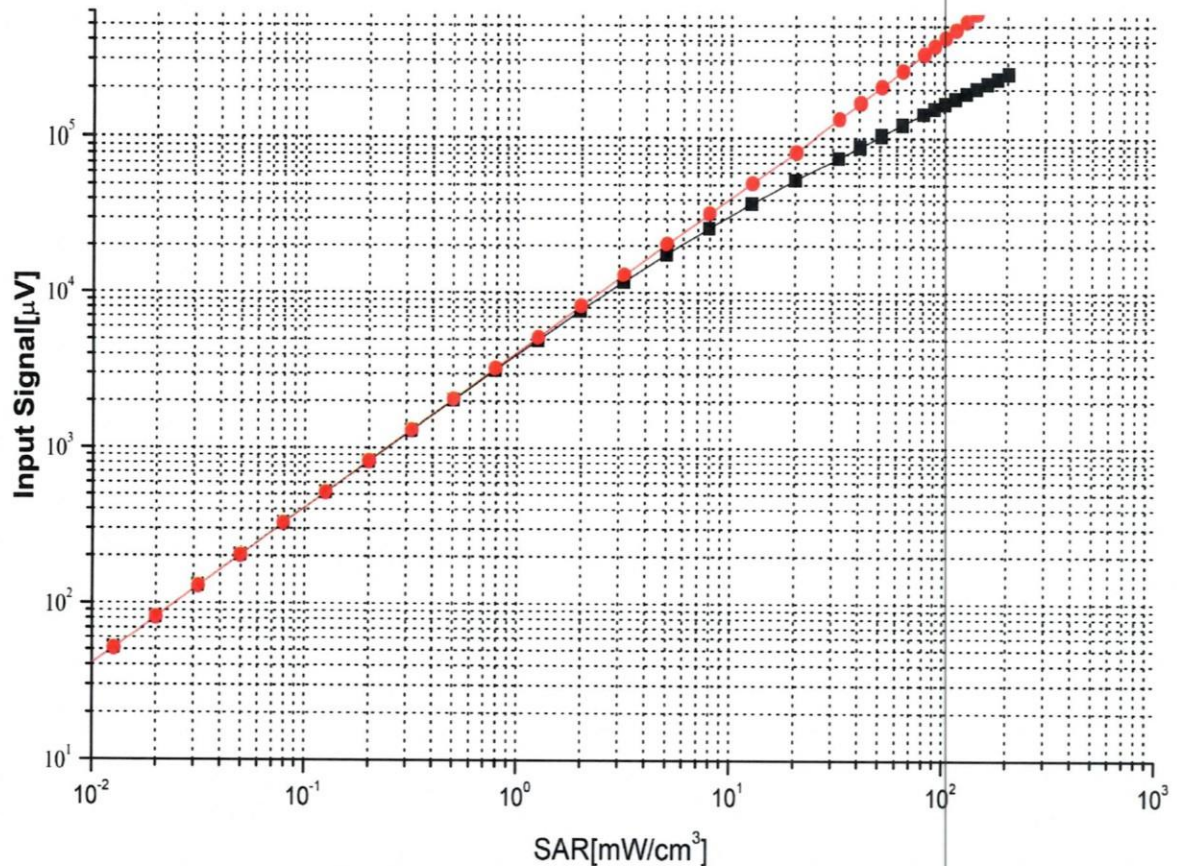


Uncertainty of Axial Isotropy Assessment: $\pm 1.2\%$ ($k=2$)



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



Uncertainty of Linearity Assessment: $\pm 0.9\%$ ($k=2$)

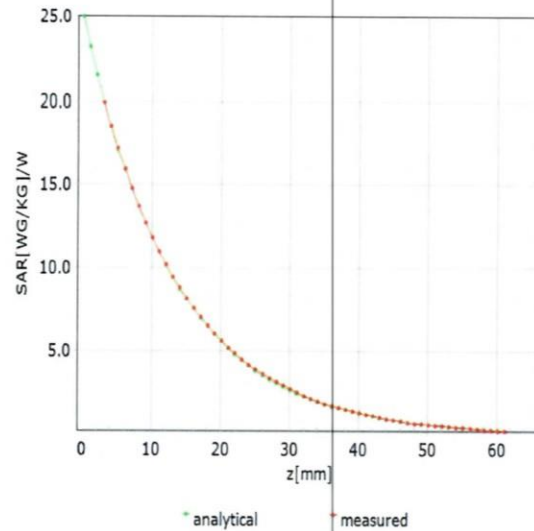
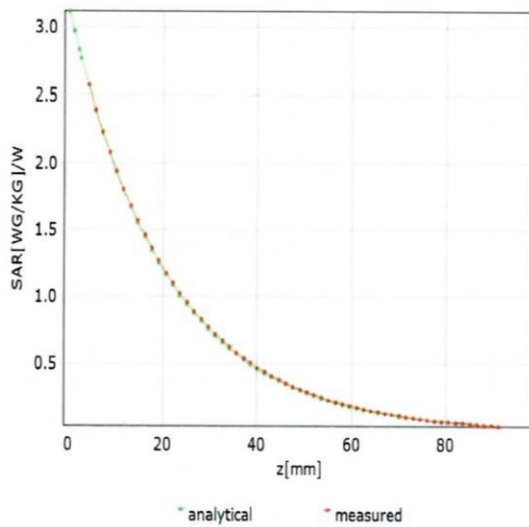


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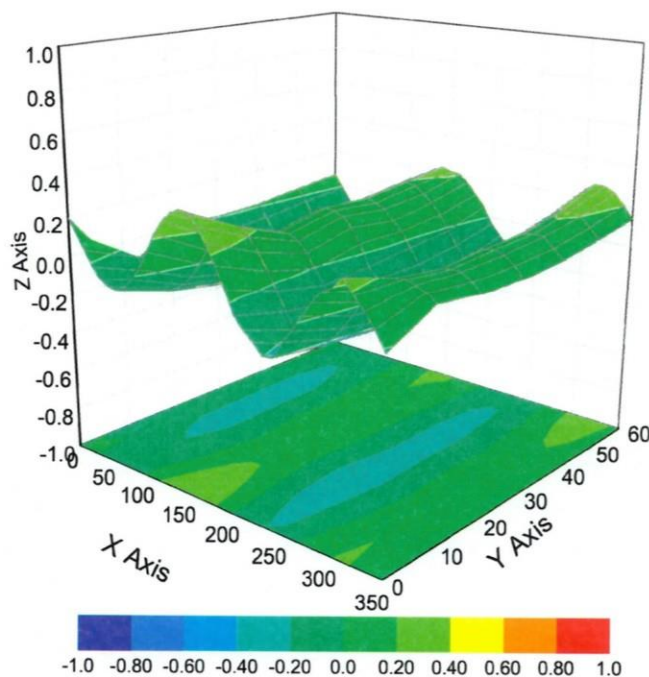
Conversion Factor Assessment

f=750 MHz,WGLS R9(H_convF)

f=1750 MHz,WGLS R22(H_convF)



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:3805

Other Probe Parameters

| | |
|--|-------------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | 83.7 |
| 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 |