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CALIBRATION LABORATORY



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Client

**Auden**

**Certificate No: Z14-97001**

## CALIBRATION CERTIFICATE

Object

EX3DV4 - SN:3898

Calibration Procedure(s)

TMC-OS-E-02-195

Calibration Procedures for Dosimetric E-field Probes

Calibration date:

March 10, 2014

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-13 (TMC, No.JW13-044)             | Jun-14                |
| Power sensor NRP-Z91    | 101547     | 01-Jul-13 (TMC, No.JW13-044)             | Jun-14                |
| Power sensor NRP-Z91    | 101548     | 01-Jul-13 (TMC, No.JW13-044)             | Jun-14                |
| Reference10dBAttenuator | BT0520     | 12-Dec-12(TMC,No.JZ12-867)               | Dec-14                |
| Reference20dBAttenuator | BT0267     | 12-Dec-12(TMC,No.JZ12-866)               | Dec-14                |
| Reference Probe EX3DV4  | SN 3846    | 03-Sep-13(SPEAG,No.EX3-3846_Sep13)       | Sep-14                |
| DAE4                    | SN 777     | 22-Feb-13 (SPEAG, DAE4-777_Feb13)        | Feb -14               |
| DAE4                    | SN 905     | 11-Jun-13 (SPEAG, DAE4-905_Jun13)        | Jun -14               |
| Secondary Standards     | ID #       | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
| SignalGeneratorMG3700A  | 6201052605 | 01-Jul-13 (TMC, No.JW13-045)             | Jun-14                |
| Network Analyzer E5071C | MY46110673 | 15-Feb-14 (TMC, No.JZ14-781)             | Feb-15                |

|                | Name        | Function                          | Signature |
|----------------|-------------|-----------------------------------|-----------|
| Calibrated by: | Yu Zongying | SAR Test Engineer                 |           |
| Reviewed by:   | Qi Dianyuan | SAR Project Leader                |           |
| Approved by:   | Lu Bingsong | Deputy Director of the laboratory |           |

Issued: March 12, 2014

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 $\Phi$   | $\Phi$ rotation around probe axis                                                                                                           |
| Polarization $\theta$ | $\theta$ rotation around an axis that is in the plane normal to probe axis (at measurement center), i<br>$\theta=0$ 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, "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

## 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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# Probe EX3DV4

## SN: 3898

Calibrated: March 10, 2014

Calibrated for DASY/EASY Systems

(Note: non-compatible with DASY2 system!)



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## DASY – Parameters of Probe: EX3DV4 - SN: 3898

### Basic Calibration Parameters

|                                                          | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|----------------------------------------------------------|----------|----------|----------|-----------|
| Norm( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup> | 0.50     | 0.54     | 0.48     | ±10.8%    |
| DCP(mV) <sup>B</sup>                                     | 106.5    | 104.9    | 101.2    |           |

### Modulation Calibration Parameters

| UID | Communication System Name |   | A<br>dB | B<br>dB $\sqrt{\mu\text{V}}$ | C   | D<br>dB | VR<br>mV | Unc <sup>E</sup><br>(k=2) |
|-----|---------------------------|---|---------|------------------------------|-----|---------|----------|---------------------------|
| 0   | CW                        | X | 0.0     | 0.0                          | 1.0 | 0.00    | 203.2    | ±2.1%                     |
|     |                           | Y | 0.0     | 0.0                          | 1.0 |         | 211.8    |                           |
|     |                           | Z | 0.0     | 0.0                          | 1.0 |         | 194.9    |                           |

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 5 and Page 6).

<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 – Parameters of Probe: EX3DV4 - SN: 3898

### 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                            | 10.32   | 10.32   | 10.32   | 2.94               | 0.48                    | ± 12%       |
| 850                  | 41.5                               | 0.92                            | 9.85    | 9.85    | 9.85    | 0.09               | 1.71                    | ± 12%       |
| 900                  | 41.5                               | 0.97                            | 9.83    | 9.83    | 9.83    | 0.29               | 0.92                    | ± 12%       |
| 1750                 | 40.1                               | 1.37                            | 8.38    | 8.38    | 8.38    | 0.19               | 1.35                    | ± 12%       |
| 1900                 | 40.0                               | 1.40                            | 8.20    | 8.20    | 8.20    | 0.19               | 1.43                    | ± 12%       |
| 2000                 | 40.0                               | 1.40                            | 8.19    | 8.19    | 8.19    | 0.18               | 1.54                    | ± 12%       |
| 2450                 | 39.2                               | 1.80                            | 7.55    | 7.55    | 7.55    | 0.50               | 0.76                    | ± 12%       |
| 2600                 | 39.0                               | 1.96                            | 7.34    | 7.34    | 7.34    | 0.80               | 0.59                    | ± 12%       |
| 5200                 | 36.0                               | 4.66                            | 5.52    | 5.52    | 5.52    | 0.39               | 1.24                    | ± 13%       |
| 5300                 | 35.9                               | 4.76                            | 5.23    | 5.23    | 5.23    | 0.39               | 1.01                    | ± 13%       |
| 5500                 | 35.6                               | 4.96                            | 4.95    | 4.95    | 4.95    | 0.41               | 1.10                    | ± 13%       |
| 5600                 | 35.5                               | 5.07                            | 4.74    | 4.74    | 4.74    | 0.42               | 1.16                    | ± 13%       |
| 5800                 | 35.3                               | 5.27                            | 4.84    | 4.84    | 4.84    | 0.44               | 1.07                    | ± 13%       |

<sup>C</sup> Frequency validity 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.

<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 – Parameters of Probe: EX3DV4 - SN: 3898

### 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                            | 10.18   | 10.18   | 10.18   | 0.95               | 0.64                    | ± 12%       |
| 850                  | 55.2                               | 0.99                            | 9.63    | 9.63    | 9.63    | 0.19               | 1.33                    | ± 12%       |
| 900                  | 55.0                               | 1.05                            | 9.63    | 9.63    | 9.63    | 0.23               | 1.14                    | ± 12%       |
| 1750                 | 53.4                               | 1.49                            | 8.16    | 8.16    | 8.16    | 0.19               | 1.57                    | ± 12%       |
| 1900                 | 53.3                               | 1.52                            | 7.83    | 7.83    | 7.83    | 0.19               | 1.63                    | ± 12%       |
| 2000                 | 53.3                               | 1.52                            | 8.10    | 8.10    | 8.10    | 0.15               | 3.04                    | ± 12%       |
| 2450                 | 52.7                               | 1.95                            | 7.49    | 7.49    | 7.49    | 0.61               | 0.75                    | ± 12%       |
| 2600                 | 52.5                               | 2.16                            | 7.06    | 7.06    | 7.06    | 0.58               | 0.77                    | ± 12%       |
| 5200                 | 49.0                               | 5.30                            | 4.80    | 4.80    | 4.80    | 0.47               | 1.05                    | ± 13%       |
| 5300                 | 48.9                               | 5.42                            | 4.60    | 4.60    | 4.60    | 0.42               | 1.43                    | ± 13%       |
| 5500                 | 48.6                               | 5.65                            | 4.25    | 4.25    | 4.25    | 0.45               | 1.56                    | ± 13%       |
| 5600                 | 48.5                               | 5.77                            | 4.22    | 4.22    | 4.22    | 0.46               | 1.41                    | ± 13%       |
| 5800                 | 48.2                               | 6.00                            | 4.34    | 4.34    | 4.34    | 0.50               | 1.27                    | ± 13%       |

<sup>C</sup> Frequency validity 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.

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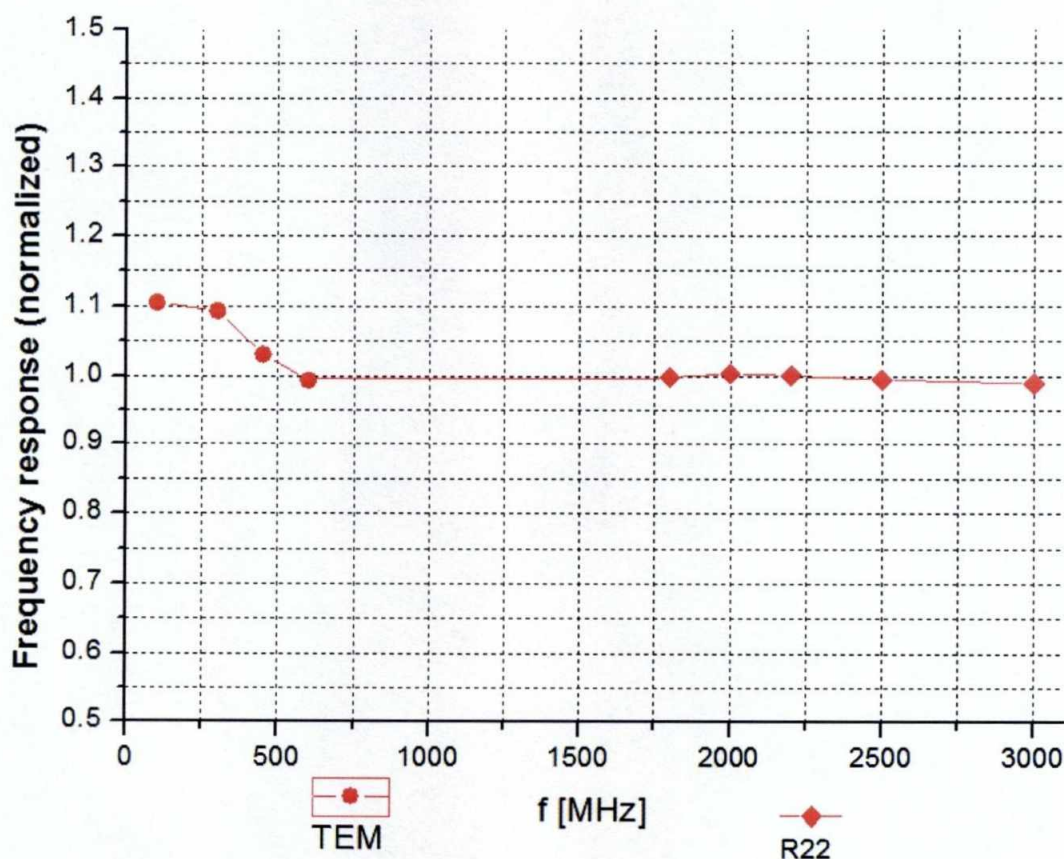
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## Frequency Response of E-Field (TEM-Cell: ifi110 EXX, Waveguide: R22)



Uncertainty of Frequency Response of E-field:  $\pm 7.5\%$  ( $k=2$ )

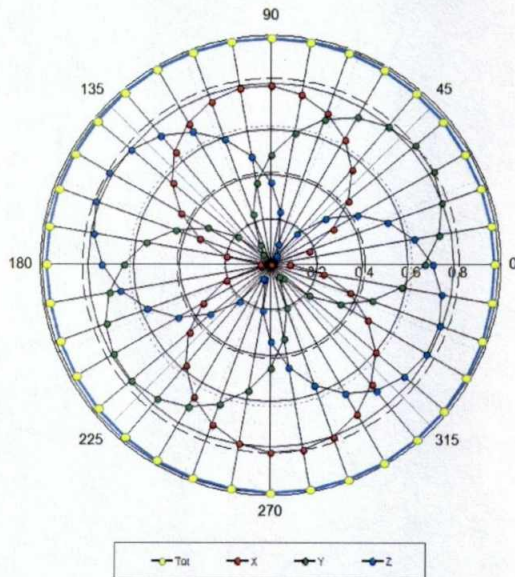


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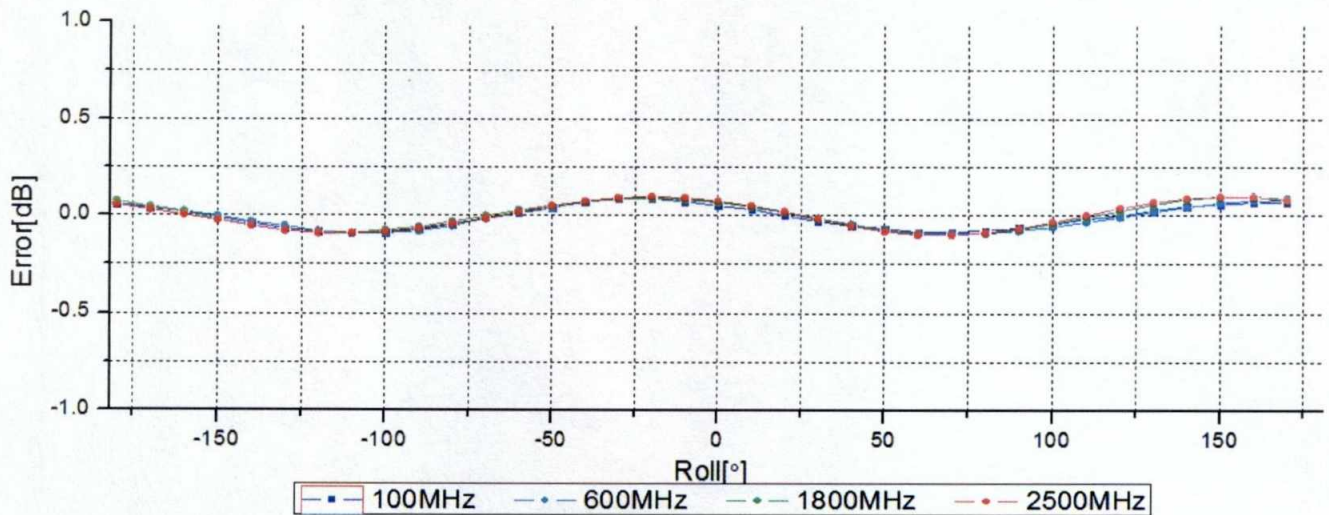
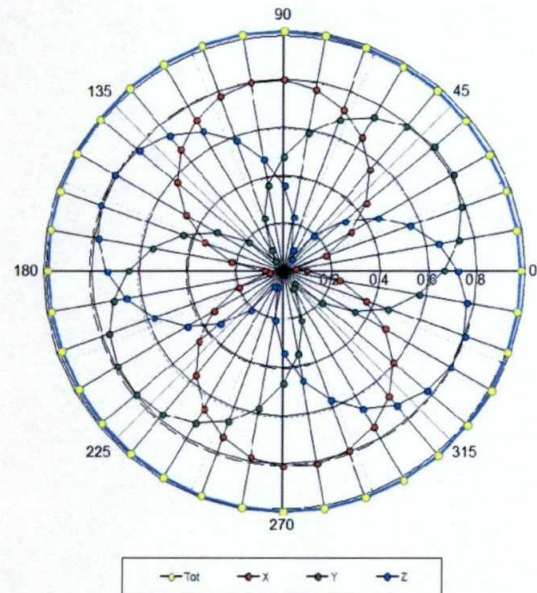
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## Receiving Pattern ( $\Phi$ ), $\theta=0^\circ$

**f=600 MHz, TEM**

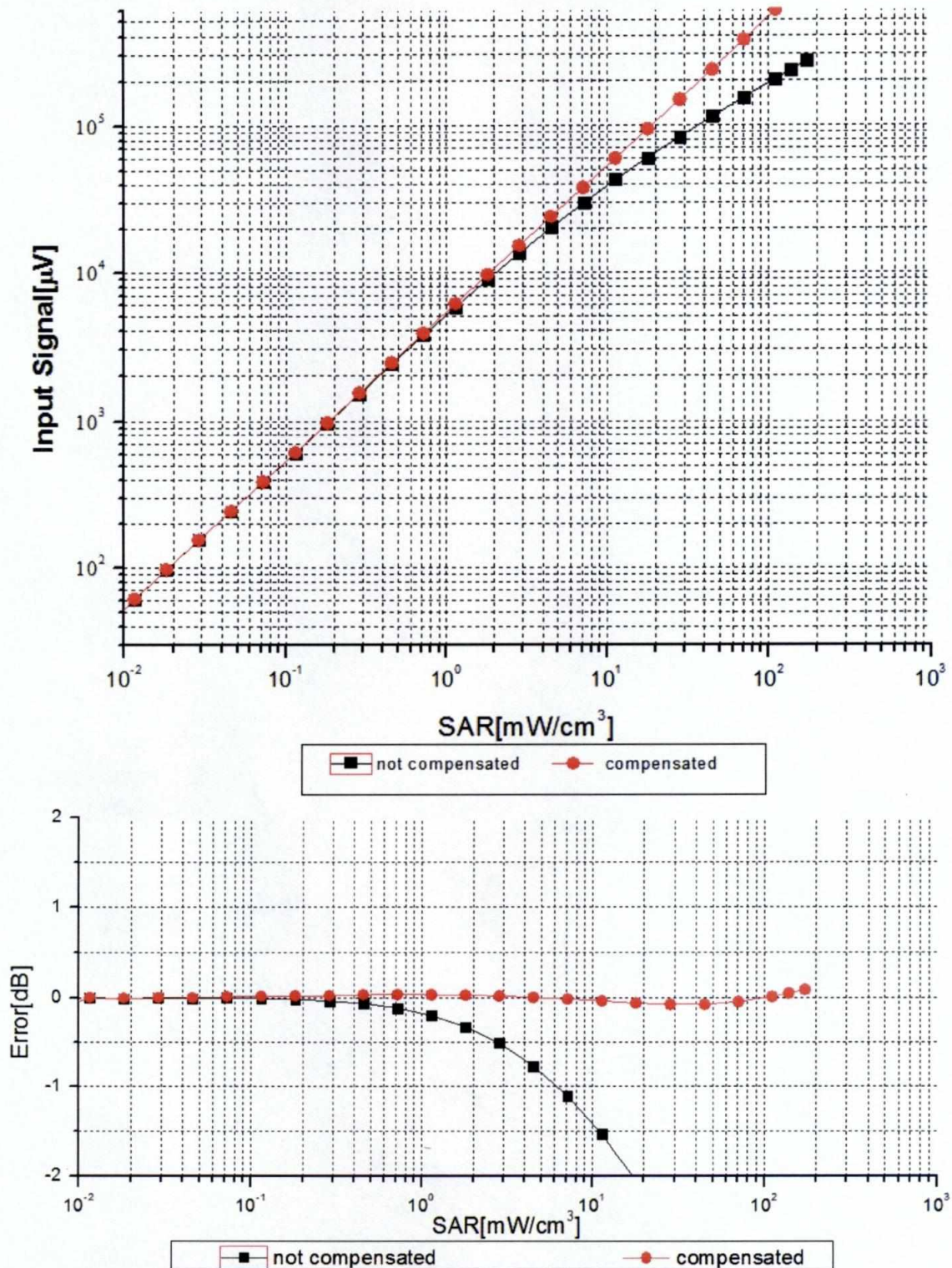


**f=1800 MHz, R22**



**Uncertainty of Axial Isotropy Assessment:  $\pm 0.9\%$  ( $k=2$ )**

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

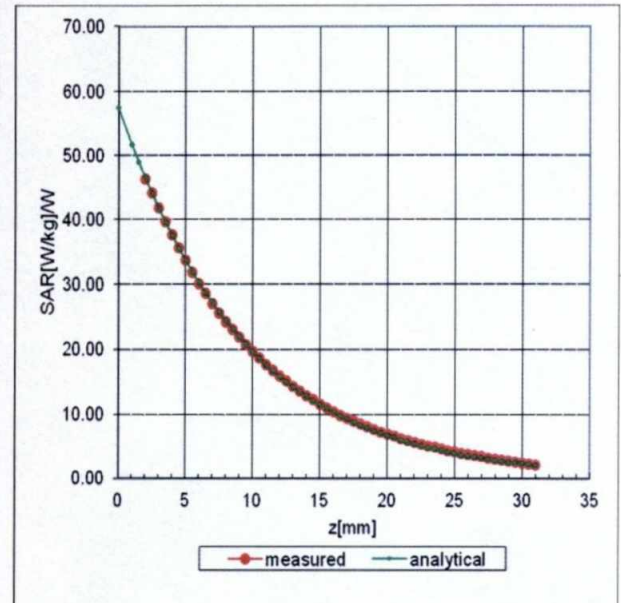
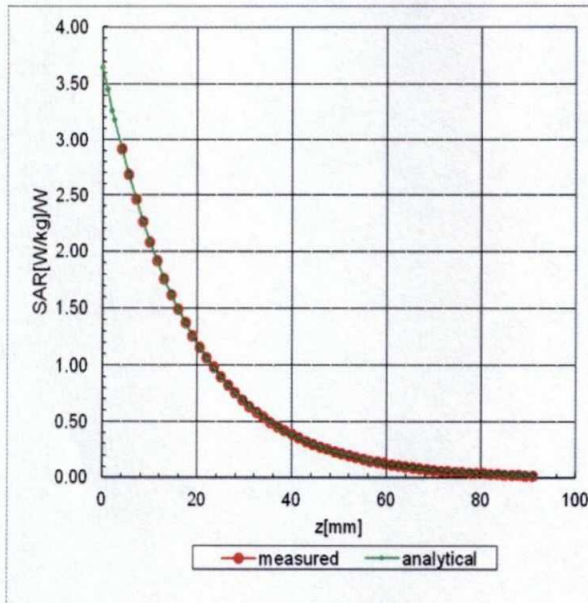


Uncertainty of Linearity Assessment:  $\pm 0.9\%$  (k=2)

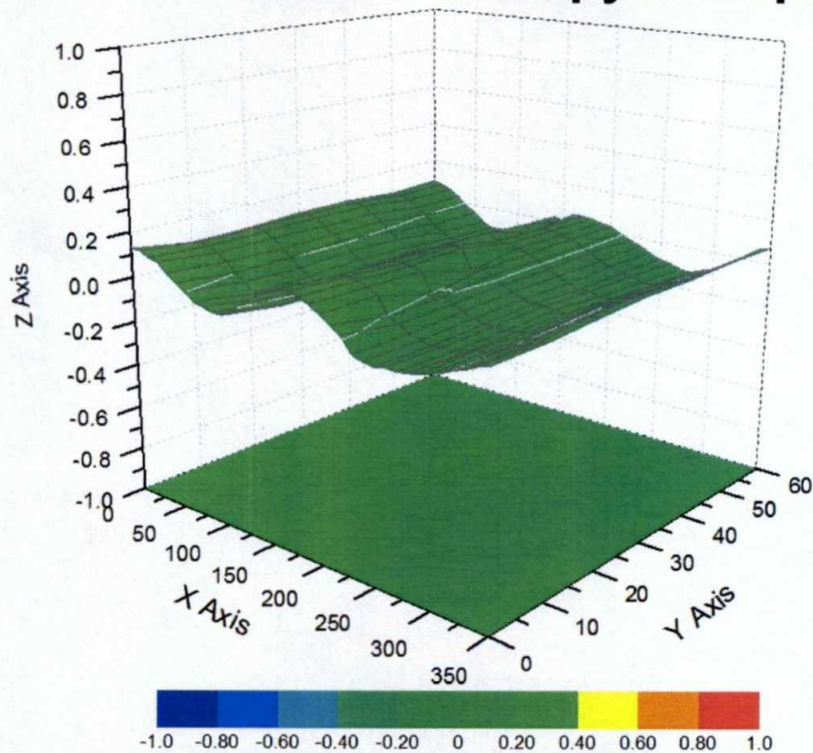
## Conversion Factor Assessment

**f=900 MHz, WGLS R9(H\_convF)**

**f=2450 MHz, WGLS R26(H\_convF)**



## Deviation from Isotropy in Liquid



Uncertainty of Spherical Isotropy Assessment:  $\pm 2.8\%$  (K=2)



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## **DASY - Parameters of Probe: EX3DV4 - SN: 3898**

### **Other Probe Parameters**

|                                                      |                   |
|------------------------------------------------------|-------------------|
| <b>Sensor Arrangement</b>                            | <b>Triangular</b> |
| <b>Connector Angle (°)</b>                           | <b>71</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>9mm</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>2mm</b>        |

**Acceptable Conditions for SAR Measurements Using Probes and Dipoles  
Calibrated under the SPEAG-TMC Dual-Logo Calibration Program to  
Support FCC Equipment Certification**

The acceptable conditions for SAR measurements using probes, dipoles and DAEs calibrated by TMC (*Telecommunication Metrology Center of MITT in Beijing, China*), under the Dual-Logo Calibration Certificate program and quality assurance (QA) protocols established between SPEAG (*Schmid & Partner Engineering AG, Switzerland*) and TMC, to support FCC (*U.S. Federal Communications Commission*) equipment certification are defined and described in the following.

- 1) The agreement established between SPEAG and TMC is only applicable to calibration services performed by TMC where its clients (companies and divisions of such companies) are headquartered in the Greater China Region, including Taiwan and Hong Kong. This agreement is subject to renewal at the end of each calendar year between SPEAG and TMC. TMC shall inform the FCC of any changes or early termination to the agreement.
- 2) Only a subset of the calibration services specified in the SPEAG-TMC agreement, while it remains valid, are applicable to SAR measurements performed using such equipment for supporting FCC equipment certification. These are identified in the following.
  - a) Calibration of dosimetric (SAR) probes EX3DVx, ET3DVx and ES3DVx.
    - i) Free-space E-field and H-field probes, including those used for HAC (hearing aid compatibility) evaluation, temperature probes, other probes or equipment not identified in this document, when calibrated by TMC, are excluded and cannot be used for measurements to support FCC equipment certification.
    - ii) Signal specific and bundled probe calibrations based on PMR (probe modulation response) characteristics or other test signal based probe linearization methods not fully described in SAR standards are handled according to the requirements of KDB 865664; that is, "Until standardized procedures are available to make such determination, the applicability of a signal specific probe calibration for testing specific wireless modes and technologies is determined on a case-by-case basis through KDB inquiries, including SAR system verification requirements."
  - b) Calibration of SAR system validation dipoles, excluding HAC dipoles.
  - c) Calibration of data acquisition electronics DAE3Vx, DAE4Vx and DAEasyVx.
  - d) For FCC equipment certification purposes, the frequency range of SAR probe and dipole calibrations is limited to 700 MHz - 6 GHz and provided it is supported by the equipment identified in the TMC QA protocol (a separate attachment to this document).
  - e) The identical system and equipment setup, measurement configurations, hardware, evaluation algorithms, calibration and QA protocols, including the format of calibration certificates and reports used by SPEAG shall be applied by TMC. Equivalent test equipment and measurement configurations may be considered only when agreed by both SPEAG and the FCC.

- f) The calibrated items are only applicable to SPEAG DASY 4 and DASY 5 systems or higher version systems that satisfy the requirements of this KDB.
- 3) The SPEAG-TMC agreement includes specific protocols identified in the following to ensure the quality of calibration services provided by TMC under this SPEAG-TMC Dual-Logo calibration agreement are equivalent to the calibration services provided by SPEAG. TMC shall apply the required protocols without modification and, upon request, provide copies of documentation to the FCC to substantiate program implementation.
  - a) The Inter-laboratory Calibration Evaluation (ILCE) stated in the TMC QA protocol shall be performed between SPEAG and TMC at least once every 12 months. The ILCE acceptance criteria defined in the TMC QA protocol shall be satisfied for the TMC, SPEAG and FCC agreements to remain valid.
  - b) Check of Calibration Certificate (CCC) shall be performed by SPEAG for all calibrations performed by TMC. Written confirmation from SPEAG is required for TMC to issue calibration certificates under the SPEAG-TMC Dual-Logo calibration program. Quarterly reports for all calibrations performed by TMC under the program are also issued by SPEAG.
  - c) The calibration equipment and measurement system used by TMC shall be verified before each calibration service according to the specific reference SAR probes, dipoles, and DAE calibrated by SPEAG. The results shall be reproducible and within the defined acceptance criteria specified in the TMC QA protocol before each actual calibration can commence. TMC shall maintain records of the measurement and calibration system verification results for all calibrations.
  - d) Quality Check of Calibration (QCC) certificates shall be performed by SPEAG at least once every 12 months. SPEAG shall visit TMC facilities to verify the laboratory, equipment, applied procedures and plausibility of randomly selected certificates.
- 4) A copy of this document, to be updated annually, shall be provided to TMC clients that accept calibration services according to the SPEAG-TMC Dual-Logo calibration program, which should be presented to a TCB (*Telecommunication Certification Body*), to facilitate FCC equipment approval.
- 5) TMC shall address any questions raised by its clients or TCBs relating to the SPEAG-TMC Dual-Logo calibration program and inform the FCC and SPEAG of any critical issues.

Note: It is expected that TMC (*Telecommunication Metrology Center*) may change its name in 2014. For this KDB to remain valid, it must be updated by TMC before the name change occurs. The SPEAG-TMC Dual-Logo calibration certificate shall also be updated accordingly to reflect the change.