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 Multilateral Agreement for the recognition of calibration certificates**

Accreditation No.: **SCS 0108**

Client **UL CCS USA**

Certificate No: **EX3-7356_Apr15**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:7356**

Calibration procedure(s) **QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v4, QA CAL-23.v5,
 QA CAL-25.v6
 Calibration procedure for dosimetric E-field probes**

Calibration date: **April 22, 2015**

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 E4419B | GB41293874 | 01-Apr-15 (No. 217-02128) | Mar-16 |
| Power sensor E4412A | MY41498087 | 01-Apr-15 (No. 217-02128) | Mar-16 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 01-Apr-15 (No. 217-02129) | Mar-16 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 01-Apr-15 (No. 217-02132) | Mar-16 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 01-Apr-15 (No. 217-02133) | Mar-16 |
| Reference Probe ES3DV2 | SN: 3013 | 30-Dec-14 (No. ES3-3013_Dec14) | Dec-15 |
| DAE4 | SN: 660 | 14-Jan-15 (No. DAE4-660_Jan15) | Jan-16 |
| Secondary Standards | ID | Check Date (in house) | Scheduled Check |
| RF generator HP 8648C | US3642U01700 | 4-Aug-99 (in house check Apr-13) | In house check: Apr-16 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-14) | In house check: Oct-15 |

| | | | |
|----------------|---------------|-----------------------|------------------|
| | Name | Function | Signature |
| Calibrated by: | Israe Elnaouq | Laboratory Technician | |
| Approved by: | Katja Pokovic | Technical Manager | |

Issued: April 23, 2015

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Glossary:

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

Calibration is Performed According to the Following Standards:

- IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
- IEC 62209-1, "Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)", February 2005

Methods Applied and Interpretation of Parameters:

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

Probe EX3DV4

SN:7356

Manufactured: February 5, 2015
Calibrated: April 22, 2015

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|--------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.37 | 0.55 | 0.58 | $\pm 10.1\%$ |
| DCP (mV) ^B | 98.7 | 98.6 | 97.8 | |

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 | 138.6 | $\pm 3.0\%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 142.4 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 154.0 | |

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

^A The uncertainties of NormX,Y,Z do not affect the E²-field uncertainty inside TSL (see Pages 5 and 6).

^B Numerical linearization parameter: uncertainty not required.

^E Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

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 (mm) ^G | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 43.5 | 0.87 | 11.11 | 11.11 | 11.11 | 0.15 | 1.20 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 10.78 | 10.78 | 10.78 | 0.24 | 1.34 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 9.96 | 9.96 | 9.96 | 0.21 | 1.60 | ± 12.0 % |
| 1450 | 40.5 | 1.20 | 9.30 | 9.30 | 9.30 | 0.22 | 1.27 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.87 | 8.87 | 8.87 | 0.38 | 0.80 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.61 | 8.61 | 8.61 | 0.27 | 0.80 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 8.23 | 8.23 | 8.23 | 0.34 | 0.80 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.89 | 7.89 | 7.89 | 0.25 | 0.89 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.67 | 7.67 | 7.67 | 0.27 | 0.88 | ± 12.0 % |
| 3500 | 37.9 | 2.91 | 7.36 | 7.36 | 7.36 | 0.38 | 1.05 | ± 13.1 % |
| 3700 | 37.7 | 3.12 | 7.19 | 7.19 | 7.19 | 0.39 | 1.01 | ± 13.1 % |
| 4950 | 36.3 | 4.40 | 6.32 | 6.32 | 6.32 | 0.30 | 1.80 | ± 13.1 % |
| 5250 | 35.9 | 4.71 | 5.55 | 5.55 | 5.55 | 0.30 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 5.15 | 5.15 | 5.15 | 0.35 | 1.80 | ± 13.1 % |
| 5750 | 35.4 | 5.22 | 5.26 | 5.26 | 5.26 | 0.40 | 1.80 | ± 13.1 % |

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

^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

Calibration Parameter Determined in Body Tissue Simulating Media

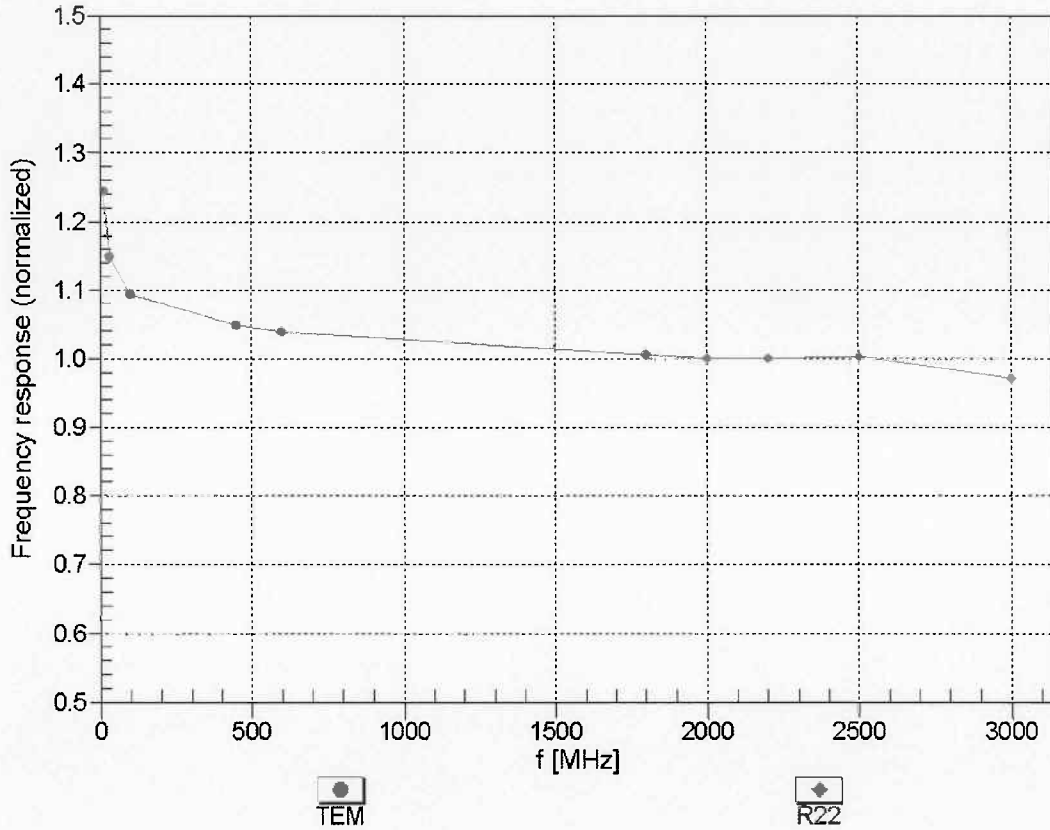
| f (MHz) ^C | Relative Permittivity ^F | Conductivity (S/m) ^F | ConvF X | ConvF Y | ConvF Z | Alpha ^G | Depth ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 56.7 | 0.94 | 11.41 | 11.41 | 11.41 | 0.10 | 1.15 | ± 13.3 % |
| 750 | 55.5 | 0.96 | 10.31 | 10.31 | 10.31 | 0.19 | 1.51 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 9.97 | 9.97 | 9.97 | 0.42 | 0.86 | ± 12.0 % |
| 1450 | 54.0 | 1.30 | 8.78 | 8.78 | 8.78 | 0.22 | 1.54 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 8.47 | 8.47 | 8.47 | 0.42 | 0.81 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.94 | 7.94 | 7.94 | 0.24 | 1.06 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 7.83 | 7.83 | 7.83 | 0.31 | 0.80 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.54 | 7.54 | 7.54 | 0.29 | 0.94 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 7.27 | 7.27 | 7.27 | 0.30 | 0.99 | ± 12.0 % |
| 3500 | 51.3 | 3.31 | 6.79 | 6.79 | 6.79 | 0.30 | 1.30 | ± 13.1 % |
| 3700 | 51.0 | 3.55 | 6.81 | 6.81 | 6.81 | 0.32 | 1.37 | ± 13.1 % |
| 4950 | 49.4 | 5.01 | 5.19 | 5.19 | 5.19 | 0.50 | 1.90 | ± 13.1 % |
| 5250 | 48.9 | 5.36 | 4.89 | 4.89 | 4.89 | 0.50 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 4.17 | 4.17 | 4.17 | 0.55 | 1.90 | ± 13.1 % |
| 5750 | 48.3 | 5.94 | 4.52 | 4.52 | 4.52 | 0.55 | 1.90 | ± 13.1 % |

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

^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

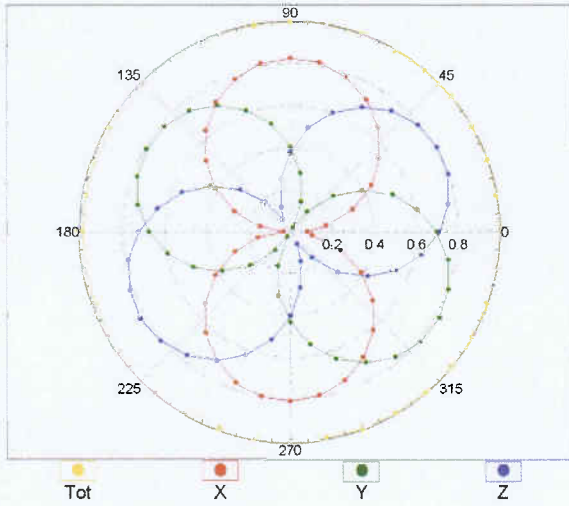
Frequency Response of E-Field (TEM-Cell:ifi110 EXX, Waveguide: R22)



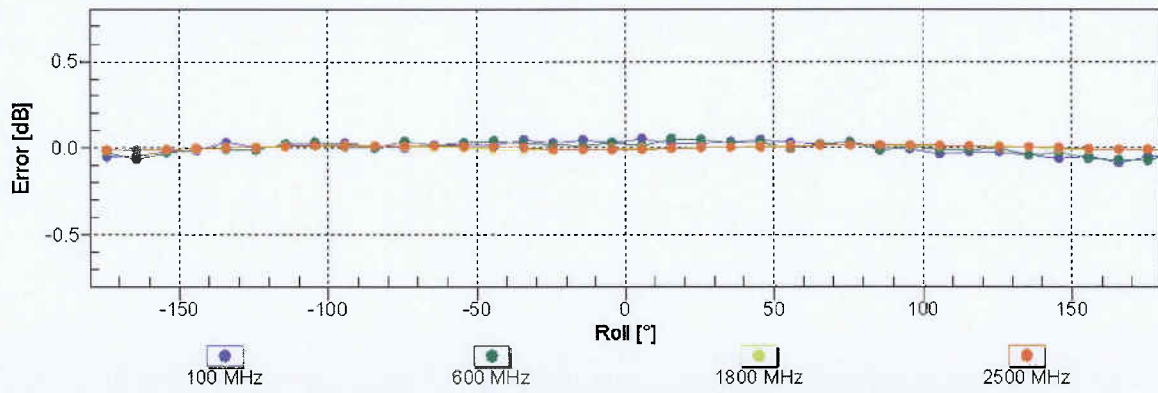
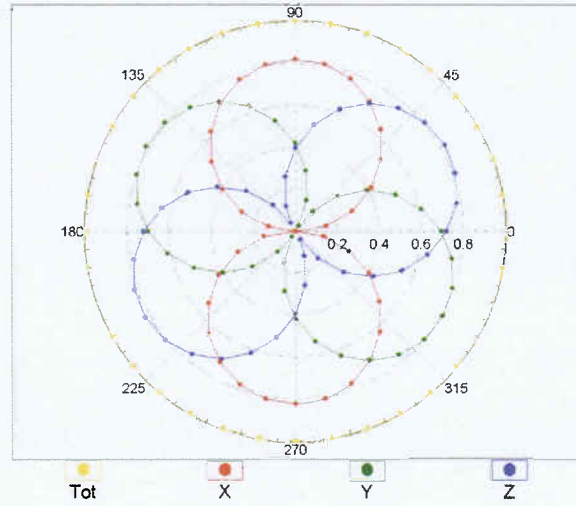
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

f=600 MHz,TEM

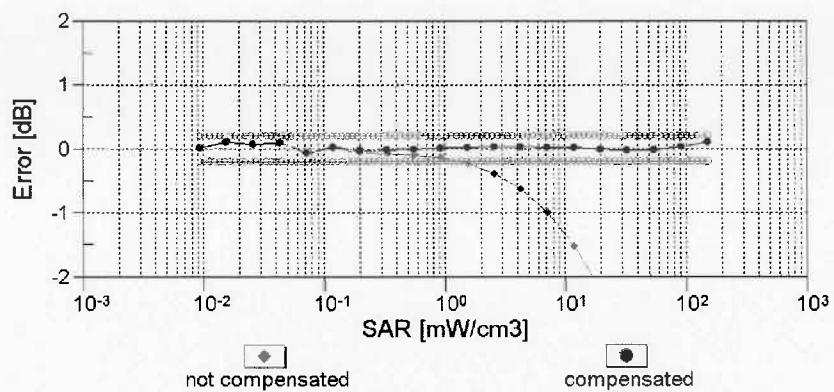
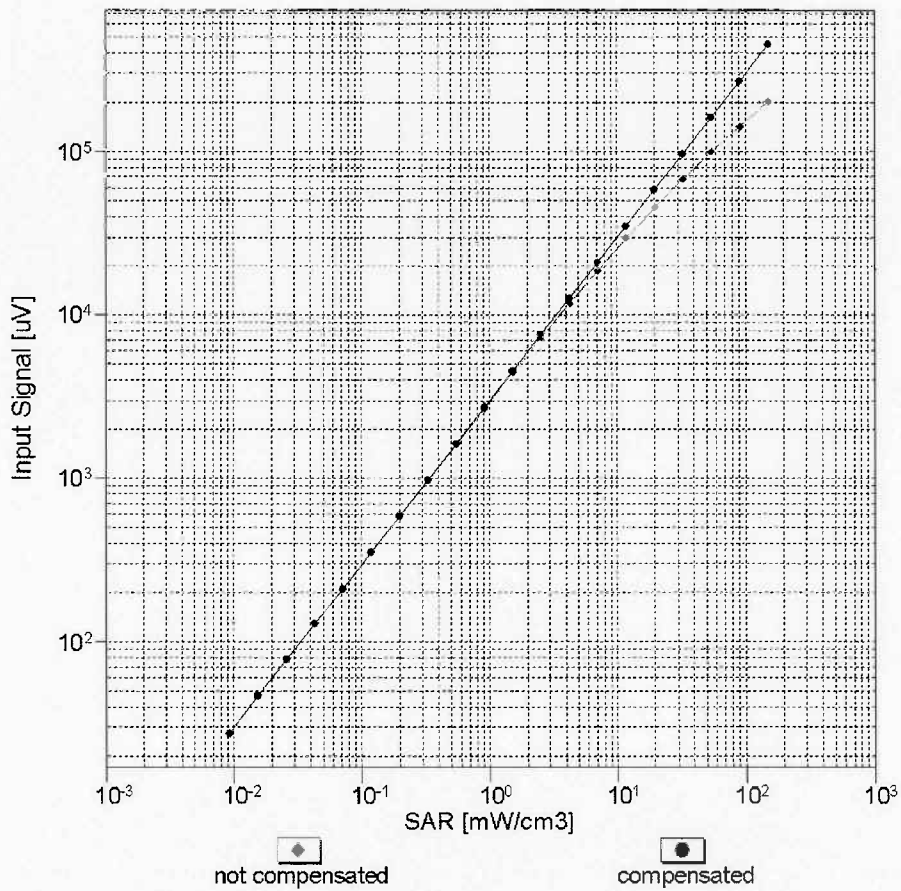


f=1800 MHz,R22



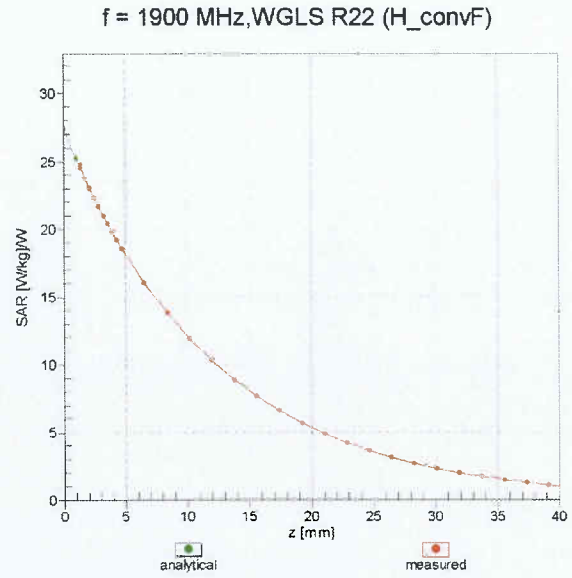
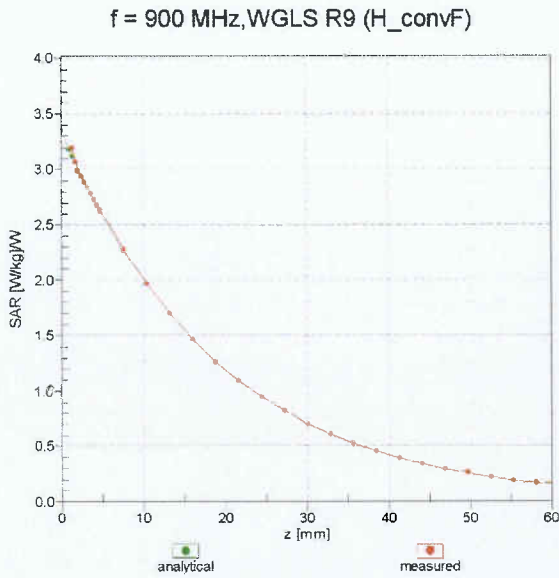
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

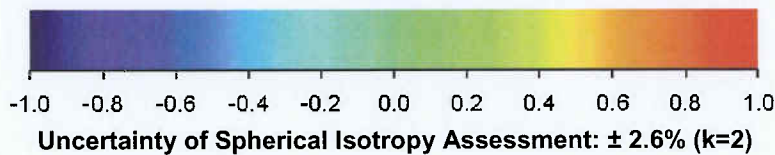
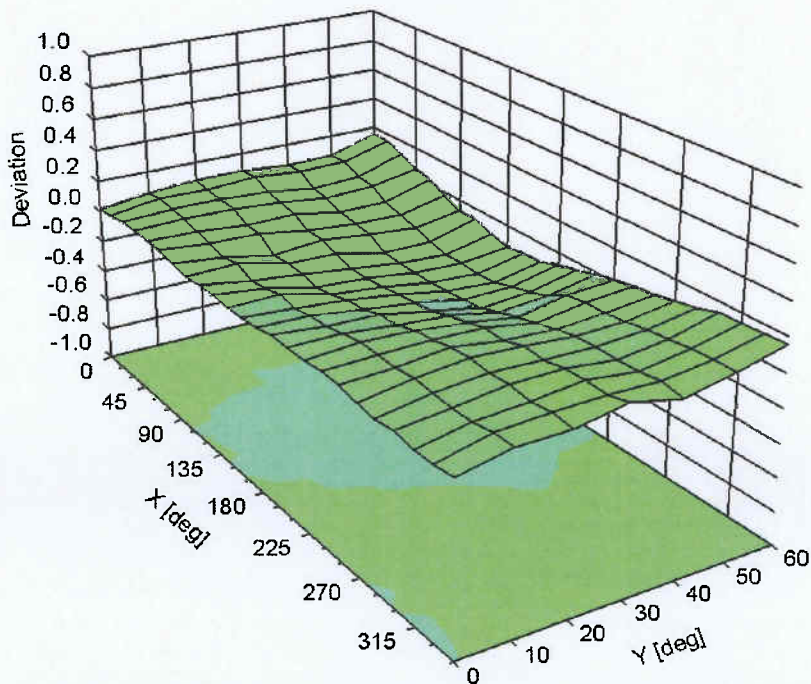


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:7356

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -4.3 |
| 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 |

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 info@speag.com, http://www.speag.com

PHANTOM MATERIAL COMPATIBILITY WITH SPEAG LIQUIDS

INTRODUCTION

SPEAG offers a wide range of tissue simulating liquids. These liquids are based on various ingredients depending on their frequency range. The below table shows compatibility of these tissue simulating liquids and various phantom materials.

COMPATIBILITY TABLE

- Y= fully compatible** with the tissue simulating liquid. Long time exposure is not critical.
P= partially compatible. It is essential to keep the exposure time to a minimum and to rinse and clean the item after exposure to the respective tissue simulating liquid. Liquids can have a softening effect on the material. Fiber reinforced material may reduce this effect. Continuous exposure will reduce the item life-time considerably.
R= restricted compatibility with the respective tissue simulating liquid. Liquids can enter and damage the material structure. Short time exposure (e.g. few hours) is possible given that the item is thoroughly rinsed and dried after each exposure.
N= not compatible with the respective tissue simulating liquid. Short time exposure can cause irreparable damage to the item exposed.

| Phantom Material \ Liquid Type | 772-SLAAx0yy | | | 772-SLAAx1yy | | 772-SLAAx4yy | | 772-SLAAx6yy | | 772-SLAAx6yy | |
|-------------------------------------|--------------|----------------------|----------------------|------------------------|------------------------|-----------------|-----------------|------------------------------------|------------------------------------|--------------|---------------|
| | B 900 | HSL175V2 to HSL900V2 | MSL300V2 to MSL900V2 | HSL1450V2 to HSL2450V2 | MSL1450V2 to MSL2450V2 | HBBL3500-5800V5 | MBBL3500-5800V5 | HBBL1350-1850V3 to HBBL1900-3800V3 | MBBL1350-1850V3 to MBBL1900-3800V3 | HBBL30-250V3 | MBBL125-250V3 |
| PEEK | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| POM | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| PTFE | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Glass | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Phenol resin plates | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Silicone * | Y | Y | Y | Y* | Y* | Y | Y | Y | Y | Y | Y |
| Acrylic resin * | Y | Y | Y | Y* | Y* | Y | Y | Y | Y | Y | Y |
| Polyethylene | Y | Y | Y | P | P | Y | Y | Y | Y | Y | Y |
| Vinylester, glass fiber (VE-GF) | Y | Y | Y | P | P | Y | Y | Y | Y | Y | Y |
| Polypropylene, glass fiber (PP-GF) | Y | Y | Y | P | P | Y | Y | Y | Y | Y | Y |
| Epoxy resin, glass fiber reinforced | Y | Y | Y | R | R | Y | Y | Y | Y | Y | Y |
| PMMA (Acrylic glass, Plexiglass) ** | Y | Y | Y | N | N | Y | Y | Y | Y | Y | Y |

NOTES:

* Liquids may cause damage by entering adhesive joints or bonding surfaces.

** Damage of material macro structure possible.



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Client **UL CCS USA**

Certificate No: **EX3-3990_Mar15**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3990**

Calibration procedure(s) **QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v4, QA CAL-23.v5,
QA CAL-25.v6
Calibration procedure for dosimetric E-field probes**

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| | Name | Function | Signature |
|----------------|----------------|-----------------------|-----------|
| Calibrated by: | Jeton Kastrati | Laboratory Technician | |
| Approved by: | Katja Pokovic | Technical Manager | |

Issued: March 18, 2015

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

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- Spherical isotropy (3D deviation from isotropy)**: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- Sensor Offset**: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- Connector Angle**: The angle is assessed using the information gained by determining the NORM_x (no uncertainty required).

Probe EX3DV4

SN:3990

Manufactured: January 21, 2014
Calibrated: March 18, 2015

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3990

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|---------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.43 | 0.57 | 0.35 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 102.6 | 96.6 | 100.1 | |

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 | 128.5 | $\pm 3.3 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 130.2 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 130.9 | |

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%.

^A The uncertainties of NormX,Y,Z do not affect the E²-field uncertainty inside TSL (see Pages 5 and 6).

^B Numerical linearization parameter: uncertainty not required.

^E Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3990

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 (mm) ^G | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 43.5 | 0.87 | 11.50 | 11.50 | 11.50 | 0.17 | 1.25 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 10.45 | 10.45 | 10.45 | 0.35 | 0.98 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 9.70 | 9.70 | 9.70 | 0.31 | 1.03 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.70 | 8.70 | 8.70 | 0.40 | 0.80 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.38 | 8.38 | 8.38 | 0.38 | 0.80 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.68 | 7.68 | 7.68 | 0.40 | 0.80 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.36 | 7.36 | 7.36 | 0.42 | 0.80 | ± 12.0 % |
| 3500 | 37.9 | 2.91 | 7.31 | 7.31 | 7.31 | 0.41 | 1.05 | ± 13.1 % |
| 3700 | 37.7 | 3.12 | 6.87 | 6.87 | 6.87 | 0.35 | 1.18 | ± 13.1 % |
| 4950 | 36.3 | 4.40 | 5.60 | 5.60 | 5.60 | 0.40 | 1.80 | ± 13.1 % |
| 5250 | 35.9 | 4.71 | 5.28 | 5.28 | 5.28 | 0.40 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.75 | 4.75 | 4.75 | 0.45 | 1.80 | ± 13.1 % |
| 5750 | 35.4 | 5.22 | 4.92 | 4.92 | 4.92 | 0.45 | 1.80 | ± 13.1 % |

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

^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3990

Calibration Parameter Determined in Body Tissue Simulating Media

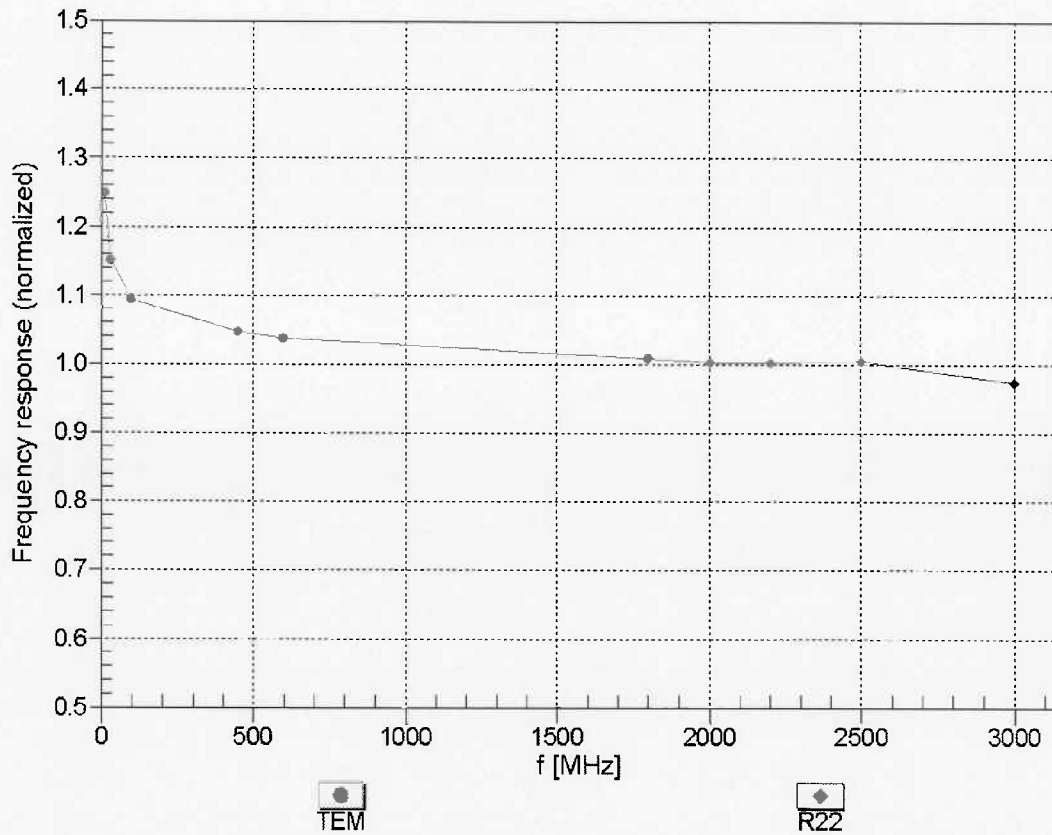
| f (MHz) ^C | Relative Permittivity ^F | Conductivity (S/m) ^F | ConvF X | ConvF Y | ConvF Z | Alpha ^G | Depth ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 56.7 | 0.94 | 11.87 | 11.87 | 11.87 | 0.10 | 1.20 | ± 13.3 % |
| 750 | 55.5 | 0.96 | 10.09 | 10.09 | 10.09 | 0.20 | 1.46 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 9.97 | 9.97 | 9.97 | 0.42 | 0.80 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 8.08 | 8.08 | 8.08 | 0.29 | 1.05 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.67 | 7.67 | 7.67 | 0.40 | 0.86 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.36 | 7.36 | 7.36 | 0.27 | 0.80 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 7.08 | 7.08 | 7.08 | 0.21 | 0.80 | ± 12.0 % |
| 3500 | 51.3 | 3.31 | 6.81 | 6.81 | 6.81 | 0.30 | 1.45 | ± 13.1 % |
| 3700 | 51.0 | 3.55 | 6.65 | 6.65 | 6.65 | 0.30 | 1.51 | ± 13.1 % |
| 4950 | 49.4 | 5.01 | 4.83 | 4.83 | 4.83 | 0.50 | 1.90 | ± 13.1 % |
| 5250 | 48.9 | 5.36 | 4.50 | 4.50 | 4.50 | 0.50 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 4.10 | 4.10 | 4.10 | 0.55 | 1.90 | ± 13.1 % |
| 5750 | 48.3 | 5.94 | 4.36 | 4.36 | 4.36 | 0.55 | 1.90 | ± 13.1 % |

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

^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

Frequency Response of E-Field (TEM-Cell:ifi1110 EXX, Waveguide: R22)

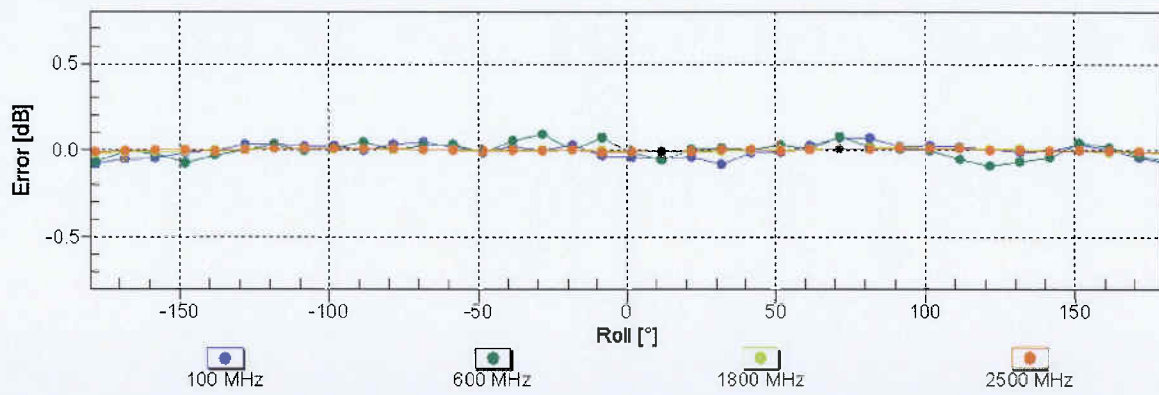
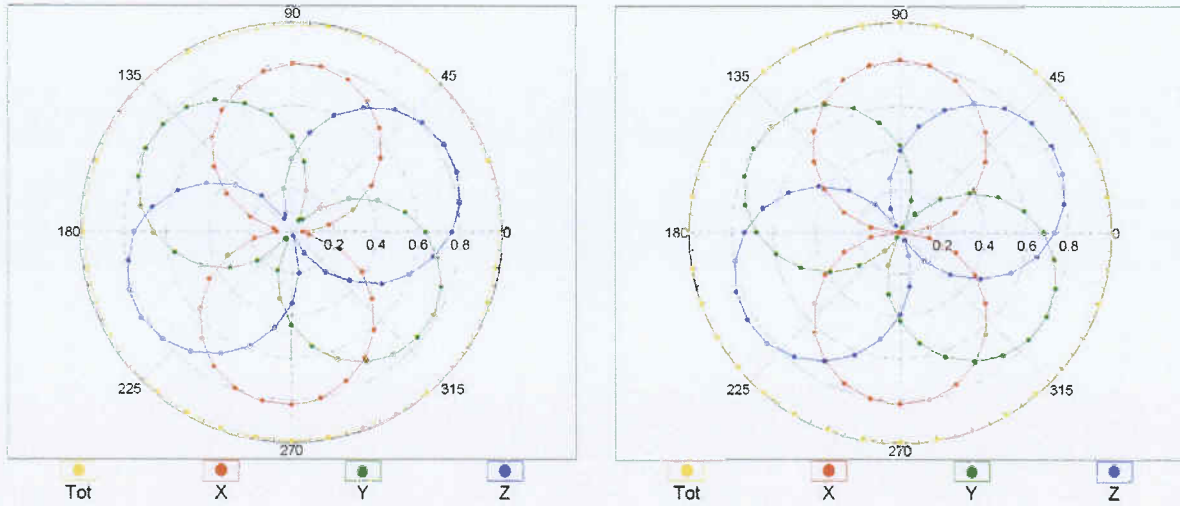


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

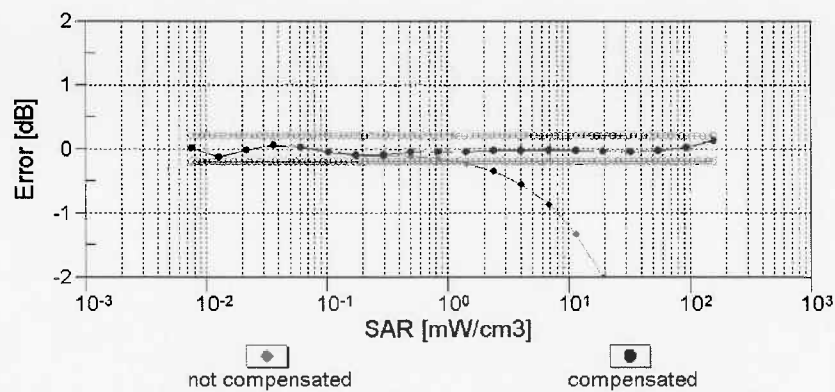
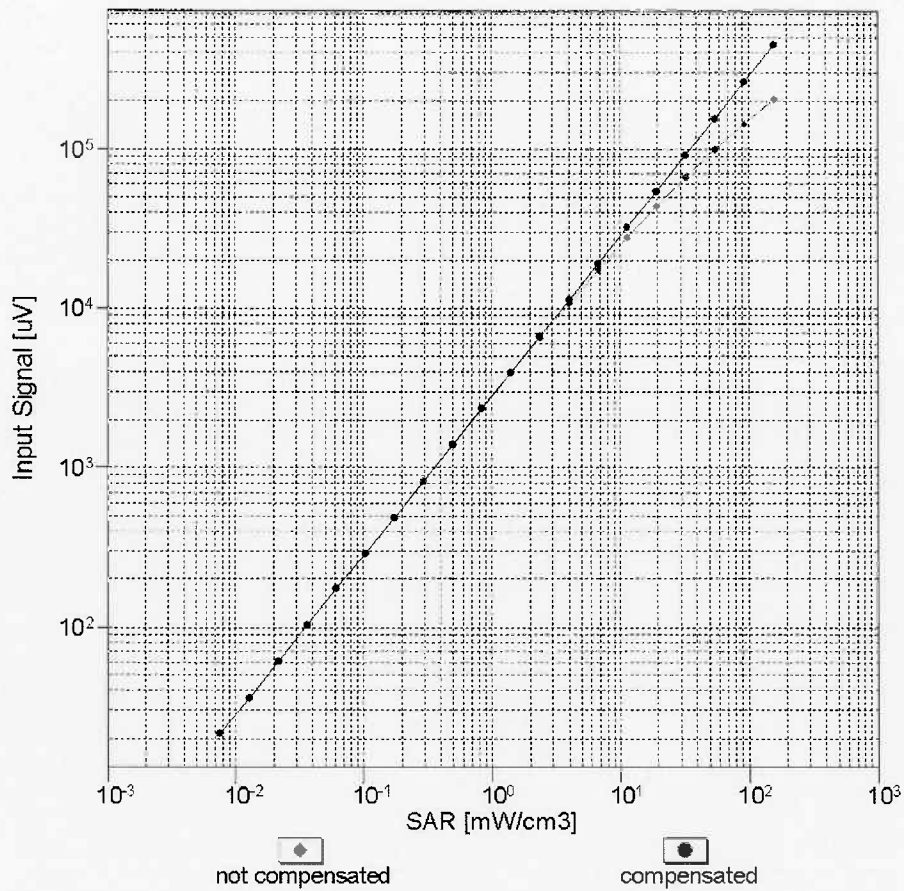
f=600 MHz,TEM

f=1800 MHz,R22



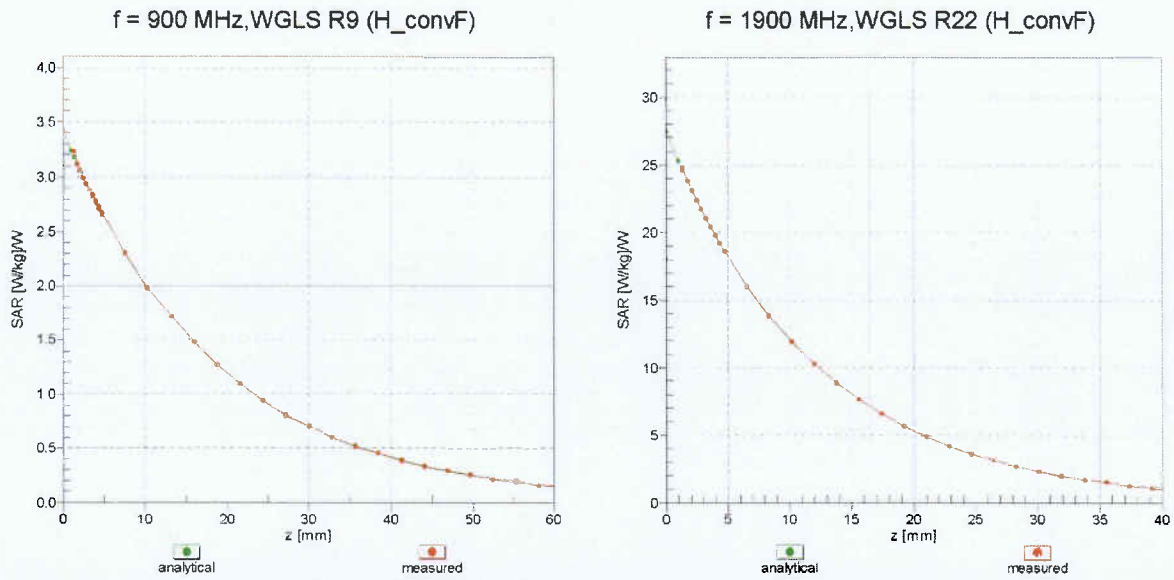
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

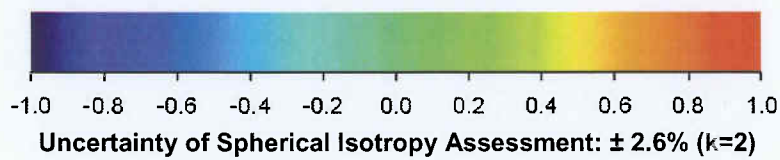
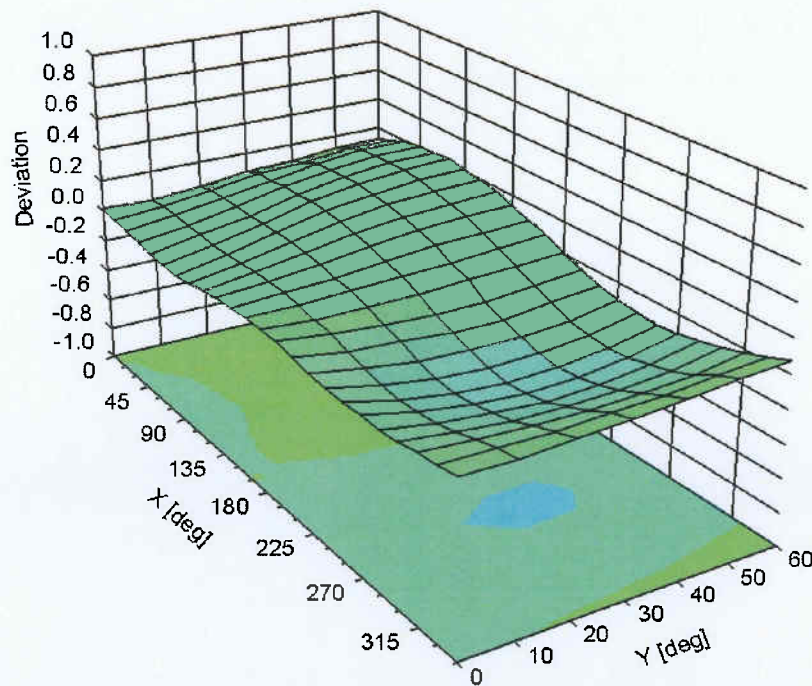


Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:3990

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | 21.7 |
| 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 |



Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA
Multilateral Agreement for the recognition of calibration certificates**

Accreditation No.: **SCS 0108**

Client **UL CCS USA**

Certificate No: **EX3-3773_Apr15**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3773**

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: **April 22, 2015**

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 E4419B | GB41293874 | 01-Apr-15 (No. 217-02128) | Mar-16 |
| Power sensor E4412A | MY41498087 | 01-Apr-15 (No. 217-02128) | Mar-16 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 01-Apr-15 (No. 217-02129) | Mar-16 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 01-Apr-15 (No. 217-02132) | Mar-16 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 01-Apr-15 (No. 217-02133) | Mar-16 |
| Reference Probe ES3DV2 | SN: 3013 | 30-Dec-14 (No. ES3-3013_Dec14) | Dec-15 |
| DAE4 | SN: 660 | 14-Jan-15 (No. DAE4-660_Jan15) | Jan-16 |
| Secondary Standards | ID | Check Date (in house) | Scheduled Check |
| RF generator HP 8648C | US3642U01700 | 4-Aug-99 (in house check Apr-13) | In house check: Apr-16 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-14) | In house check: Oct-15 |

| | Name | Function | Signature |
|---|---------------|-----------------------|------------------------|
| Calibrated by: | Israe Elnaouq | Laboratory Technician | |
| Approved by: | Katja Pokovic | Technical Manager | |
| | | | Issued: April 23, 2015 |
| This calibration certificate shall not be reproduced except in full without written approval of the laboratory. | | | |



Accredited by the Swiss Accreditation Service (SAS)

Accreditation No.: **SCS 0108**

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

Glossary:

| | |
|-----------------------|--|
| TSL | tissue simulating liquid |
| NORM _{x,y,z} | sensitivity in free space |
| ConvF | sensitivity in TSL / NORM _{x,y,z} |
| DCP | diode compression point |
| CF | crest factor (1/duty_cycle) of the RF signal |
| A, B, C, D | modulation dependent linearization parameters |
| Polarization φ | φ rotation around probe axis |
| Polarization ϑ | ϑ rotation around an axis that is in the plane normal to probe axis (at measurement center), i.e., ϑ = 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, "Procedure to measure the Specific Absorption Rate (SAR) for hand-held devices used in close proximity to the ear (frequency range of 300 MHz to 3 GHz)", February 2005

Methods Applied and Interpretation of Parameters:

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

Probe EX3DV4

SN:3773

Manufactured: January 10, 2011
Calibrated: April 22, 2015

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3773

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|---------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.58 | 0.56 | 0.52 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 101.7 | 98.2 | 98.6 | |

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 | 167.7 | $\pm 3.5 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 151.4 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 163.8 | |

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%.

^A The uncertainties of NormX,Y,Z do not affect the E^2 -field uncertainty inside TSL (see Pages 5 and 6).

^B Numerical linearization parameter: uncertainty not required.

^E Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3773

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 | 9.08 | 9.08 | 9.08 | 0.23 | 1.26 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 8.48 | 8.48 | 8.48 | 0.25 | 1.15 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 7.40 | 7.40 | 7.40 | 0.37 | 0.85 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 7.31 | 7.31 | 7.31 | 0.35 | 0.98 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 6.68 | 6.68 | 6.68 | 0.32 | 0.88 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 6.49 | 6.49 | 6.49 | 0.40 | 0.80 | ± 12.0 % |
| 5250 | 35.9 | 4.71 | 4.76 | 4.76 | 4.76 | 0.30 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.46 | 4.46 | 4.46 | 0.35 | 1.80 | ± 13.1 % |
| 5750 | 35.4 | 5.22 | 4.63 | 4.63 | 4.63 | 0.35 | 1.80 | ± 13.1 % |

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

^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3773

Calibration Parameter Determined in Body Tissue Simulating Media

| f (MHz) ^C | Relative Permittivity ^F | Conductivity (S/m) ^F | ConvF X | ConvF Y | ConvF Z | Alpha ^G | Depth ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 750 | 55.5 | 0.96 | 8.60 | 8.60 | 8.60 | 0.30 | 1.20 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 8.26 | 8.26 | 8.26 | 0.26 | 1.33 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 7.13 | 7.13 | 7.13 | 0.41 | 0.80 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 6.96 | 6.96 | 6.96 | 0.43 | 0.80 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 6.66 | 6.66 | 6.66 | 0.30 | 0.90 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.44 | 6.44 | 6.44 | 0.25 | 0.95 | ± 12.0 % |
| 5250 | 48.9 | 5.36 | 4.22 | 4.22 | 4.22 | 0.40 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.71 | 3.71 | 3.71 | 0.45 | 1.90 | ± 13.1 % |
| 5750 | 48.3 | 5.94 | 3.92 | 3.92 | 3.92 | 0.50 | 1.90 | ± 13.1 % |

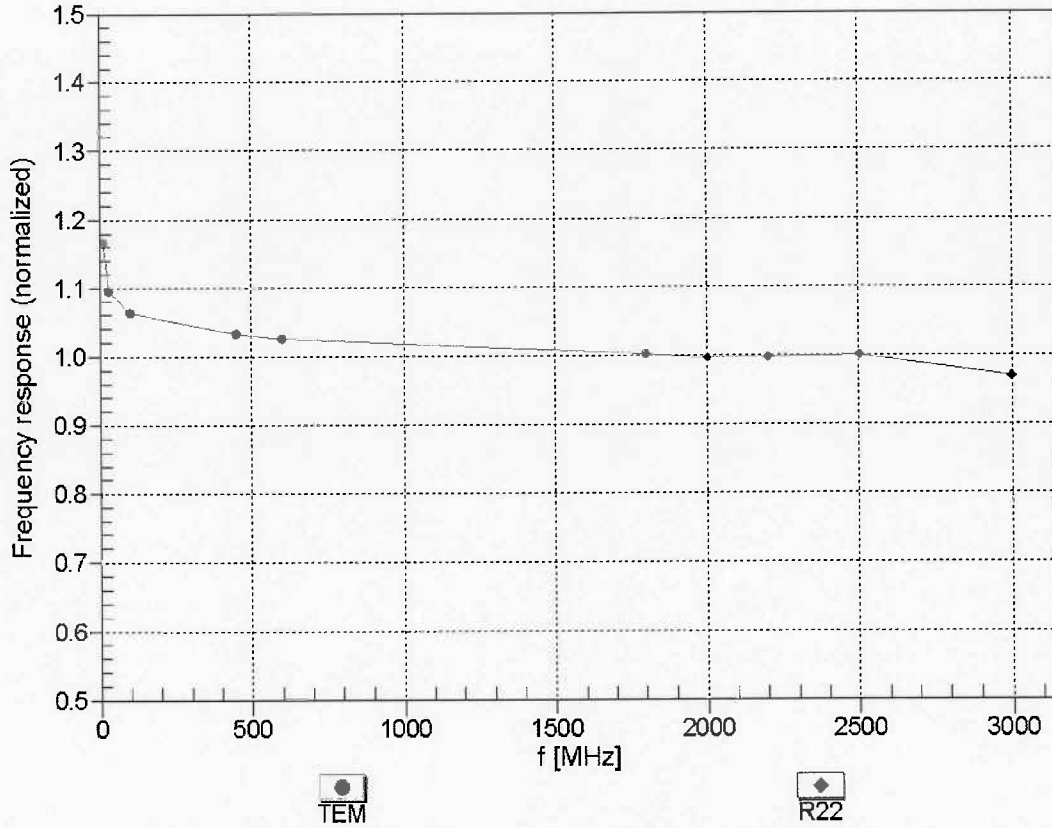
^C Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is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

^F At frequencies below 3 GHz, the validity of tissue parameters (ϵ and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ϵ and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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

Frequency Response of E-Field

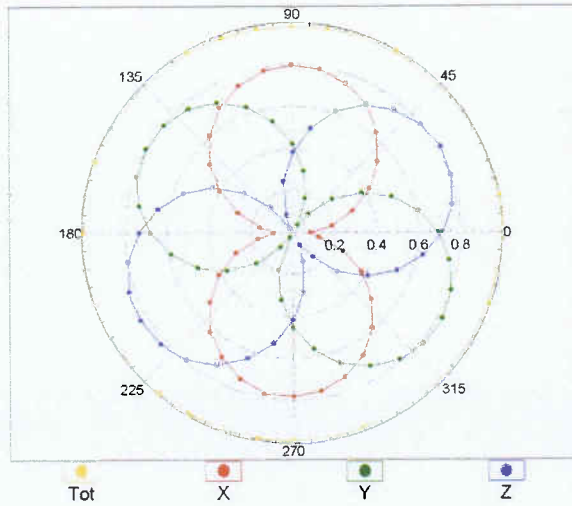
(TEM-Cell:ifi110 EXX, Waveguide: R22)



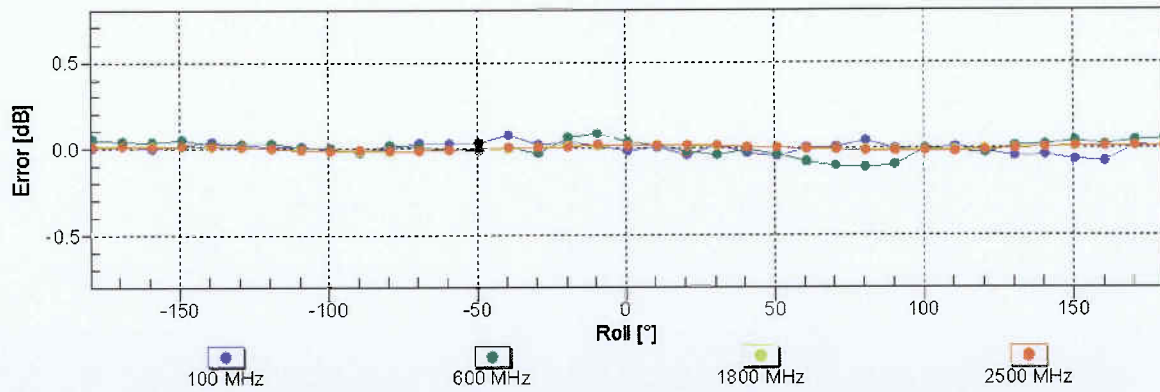
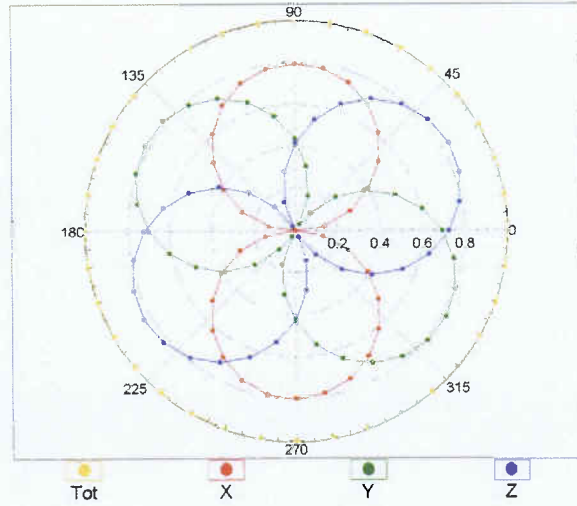
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

f=600 MHz,TEM

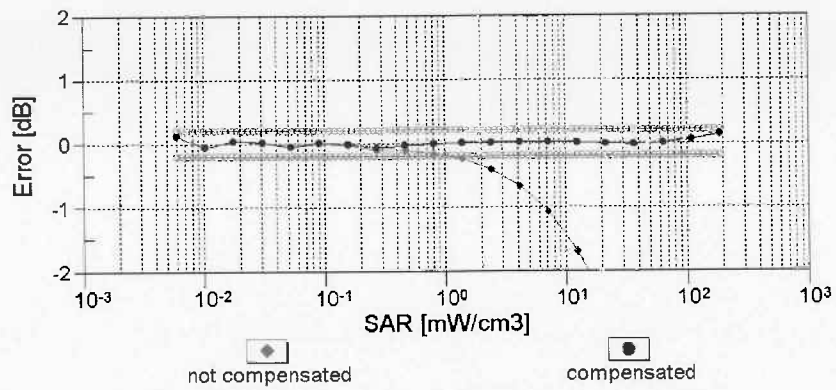
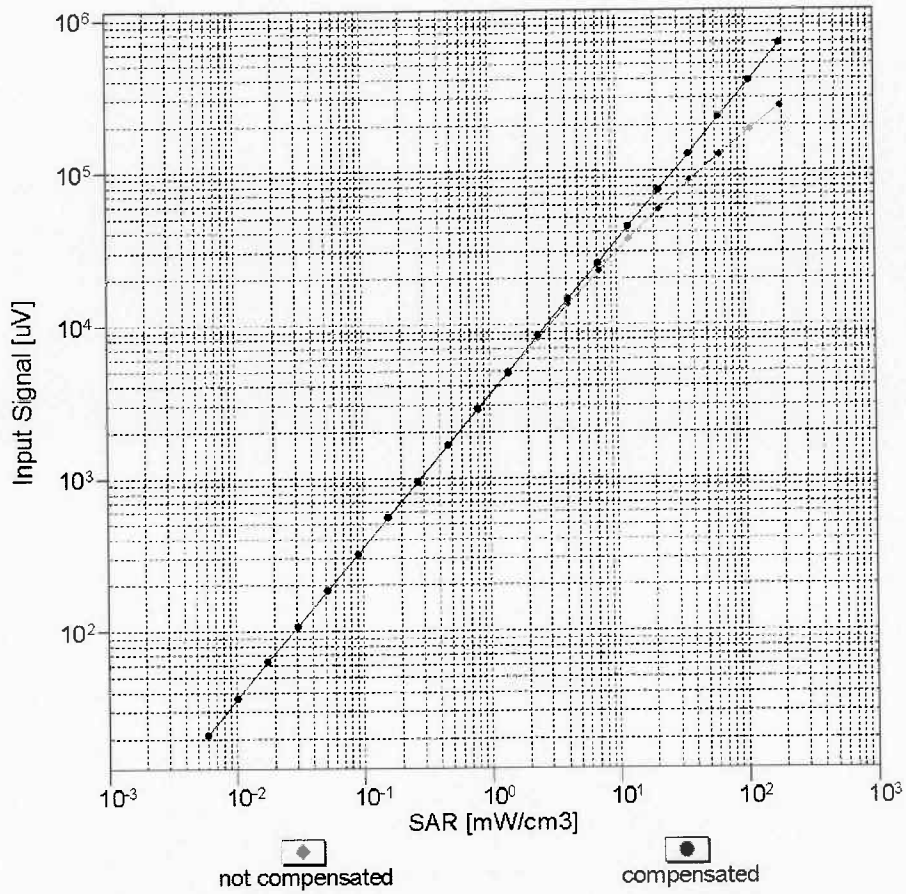


f=1800 MHz,R22



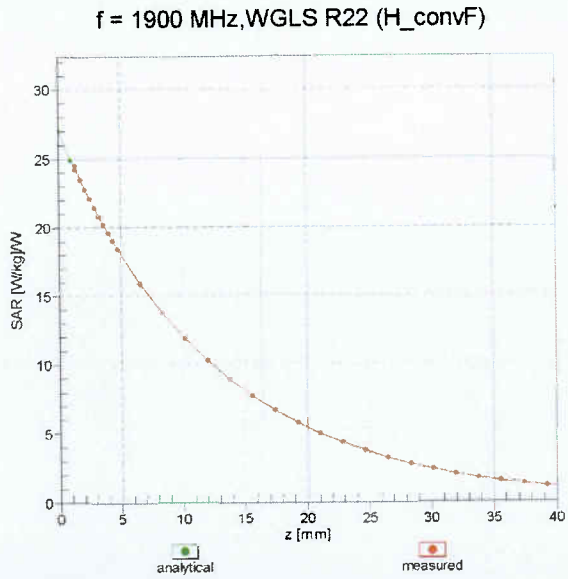
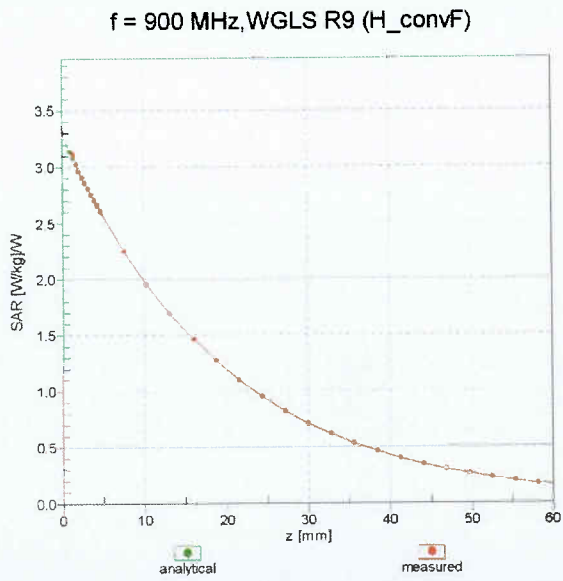
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

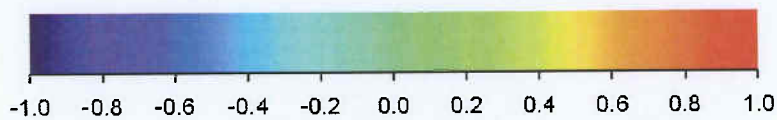
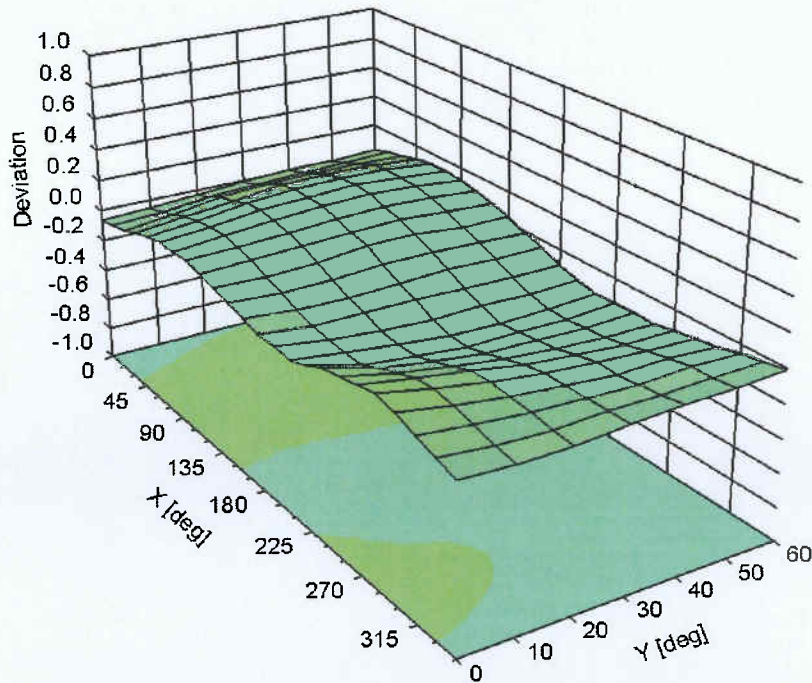


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment



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



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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3773

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -19.3 |
| 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 |