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Multilateral Agreement for the recognition of calibration certificates

Accreditation No.: **SCS 108**

Client **UL CCS USA**

Certificate No: **EX3-3772_Feb14**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3772**

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: **February 26, 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 (Certificate No.) | Scheduled Calibration |
|----------------------------|-----------------|-----------------------------------|------------------------|
| Power meter E4419B | GB41293874 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Power sensor E4412A | MY41498087 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 04-Apr-13 (No. 217-01737) | Apr-14 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-13 (No. 217-01735) | Apr-14 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 04-Apr-13 (No. 217-01738) | Apr-14 |
| Reference Probe ES3DV2 | SN: 3013 | 30-Dec-13 (No. ES3-3013_Dec13) | Dec-14 |
| DAE4 | SN: 660 | 13-Dec-13 (No. DAE4-660_Dec13) | Dec-14 |
| 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-13) | In house check: Oct-14 |

| | Name | Function | Signature |
|---|----------------|-----------------------|---------------------------|
| Calibrated by: | Israe El-Naouq | Laboratory Technician | |
| Approved by: | Katja Pokovic | Technical Manager | |
| | | | Issued: February 26, 2014 |
| This calibration certificate shall not be reproduced except in full without written approval of the laboratory. | | | |



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Accreditation No.: **SCS 108**

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:3772

Manufactured: January 10, 2011
Calibrated: February 26, 2014

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3772

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|---------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.49 | 0.55 | 0.55 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 100.8 | 98.9 | 99.8 | |

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 | 133.0 | $\pm 3.0 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 132.9 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 143.6 | |

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

^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:3772

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 | 9.20 | 9.20 | 9.20 | 0.32 | 1.01 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 8.98 | 8.98 | 8.98 | 0.27 | 1.12 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 8.84 | 8.84 | 8.84 | 0.26 | 1.08 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 7.55 | 7.55 | 7.55 | 0.53 | 0.71 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 7.45 | 7.45 | 7.45 | 0.80 | 0.57 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 7.28 | 7.28 | 7.28 | 0.57 | 0.68 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 7.04 | 7.04 | 7.04 | 0.54 | 0.70 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 7.23 | 7.23 | 7.23 | 0.80 | 0.59 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 6.96 | 6.96 | 6.96 | 0.41 | 0.79 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 6.65 | 6.65 | 6.65 | 0.29 | 1.00 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 6.42 | 6.42 | 6.42 | 0.44 | 0.80 | ± 12.0 % |
| 5200 | 36.0 | 4.66 | 4.63 | 4.63 | 4.63 | 0.45 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 4.64 | 4.64 | 4.64 | 0.35 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 4.37 | 4.37 | 4.37 | 0.40 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.18 | 4.18 | 4.18 | 0.40 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.23 | 4.23 | 4.23 | 0.45 | 1.80 | ± 13.1 % |

^C Frequency validity 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.

^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:3772

Calibration Parameter Determined in Body Tissue Simulating Media

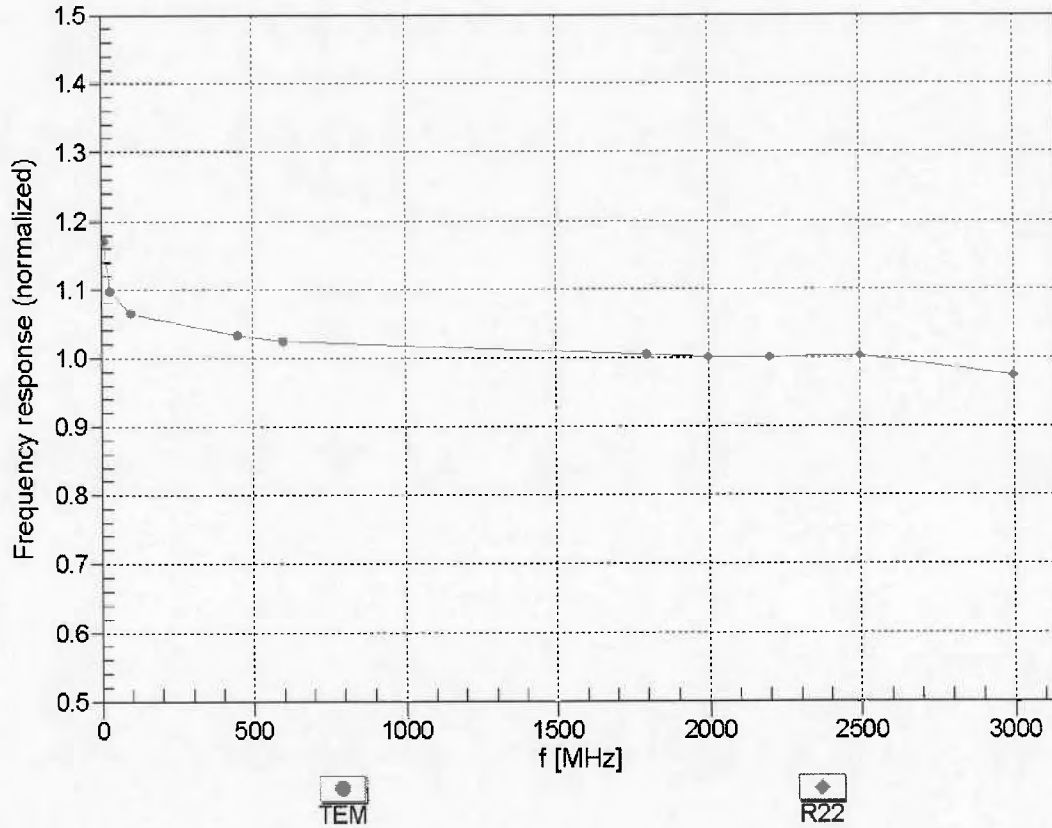
| f (MHz) ^C | Relative Permittivity ^F | Conductivity (S/m) ^F | ConvF X | ConvF Y | ConvF Z | Alpha ^G | Depth ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 750 | 55.5 | 0.96 | 8.68 | 8.68 | 8.68 | 0.51 | 0.79 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 8.59 | 8.59 | 8.59 | 0.24 | 1.24 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 8.41 | 8.41 | 8.41 | 0.50 | 0.78 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 7.74 | 7.74 | 7.74 | 0.62 | 0.76 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 7.21 | 7.21 | 7.21 | 0.71 | 0.69 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 6.96 | 6.96 | 6.96 | 0.70 | 0.67 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 7.06 | 7.06 | 7.06 | 0.49 | 0.80 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 6.92 | 6.92 | 6.92 | 0.80 | 0.62 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 6.64 | 6.64 | 6.64 | 0.70 | 0.64 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 6.43 | 6.43 | 6.43 | 0.80 | 0.50 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.15 | 6.15 | 6.15 | 0.80 | 0.50 | ± 12.0 % |
| 5200 | 49.0 | 5.30 | 4.05 | 4.05 | 4.05 | 0.55 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.03 | 4.03 | 4.03 | 0.46 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 3.70 | 3.70 | 3.70 | 0.50 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.54 | 3.54 | 3.54 | 0.50 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 3.85 | 3.85 | 3.85 | 0.50 | 1.90 | ± 13.1 % |

^C Frequency validity 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.

^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)

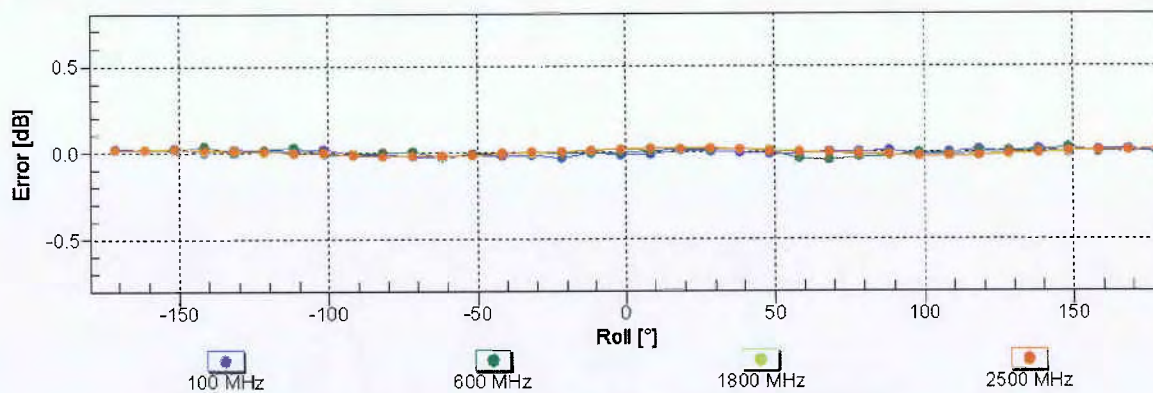
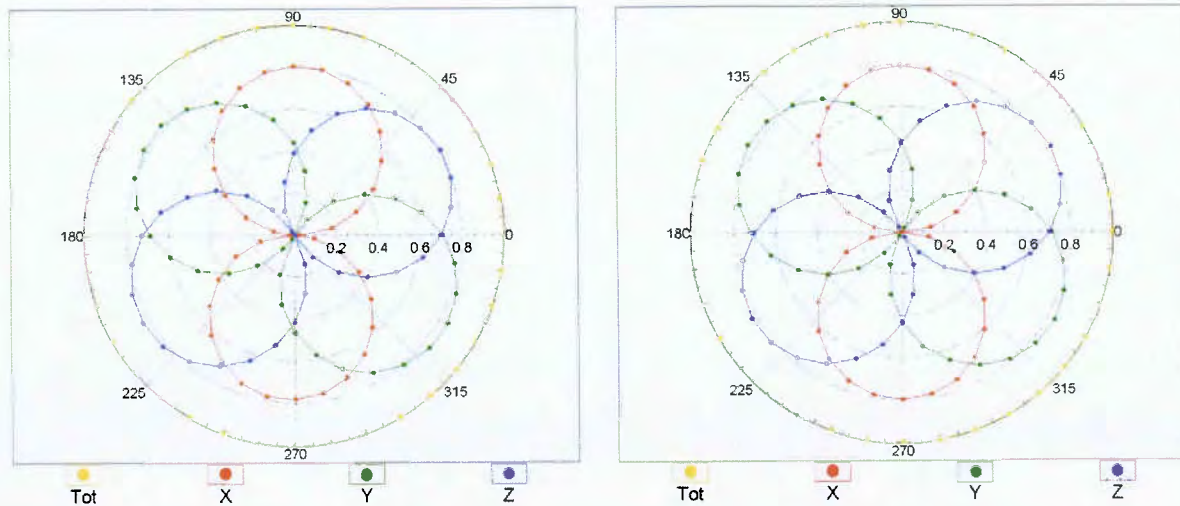


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

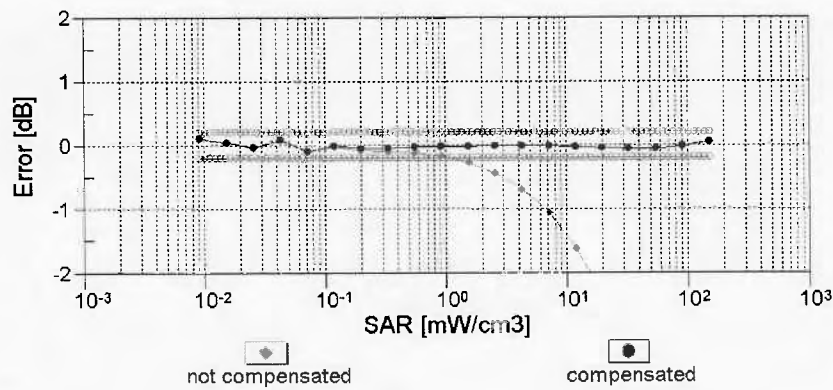
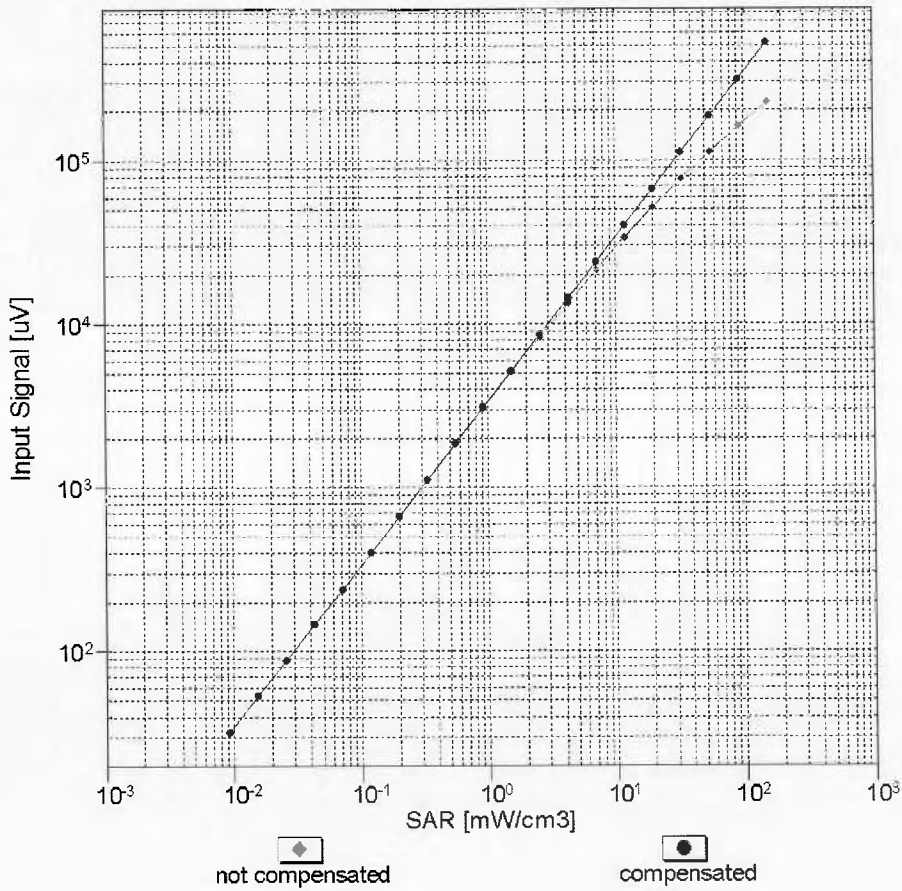
f=600 MHz,TEM

f=1800 MHz,R22



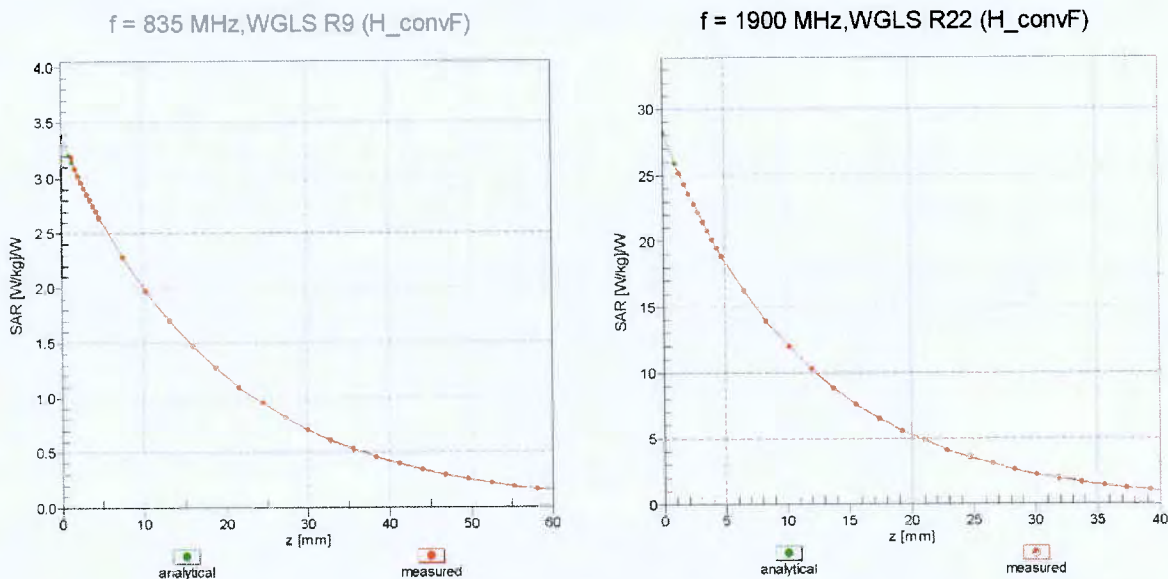
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

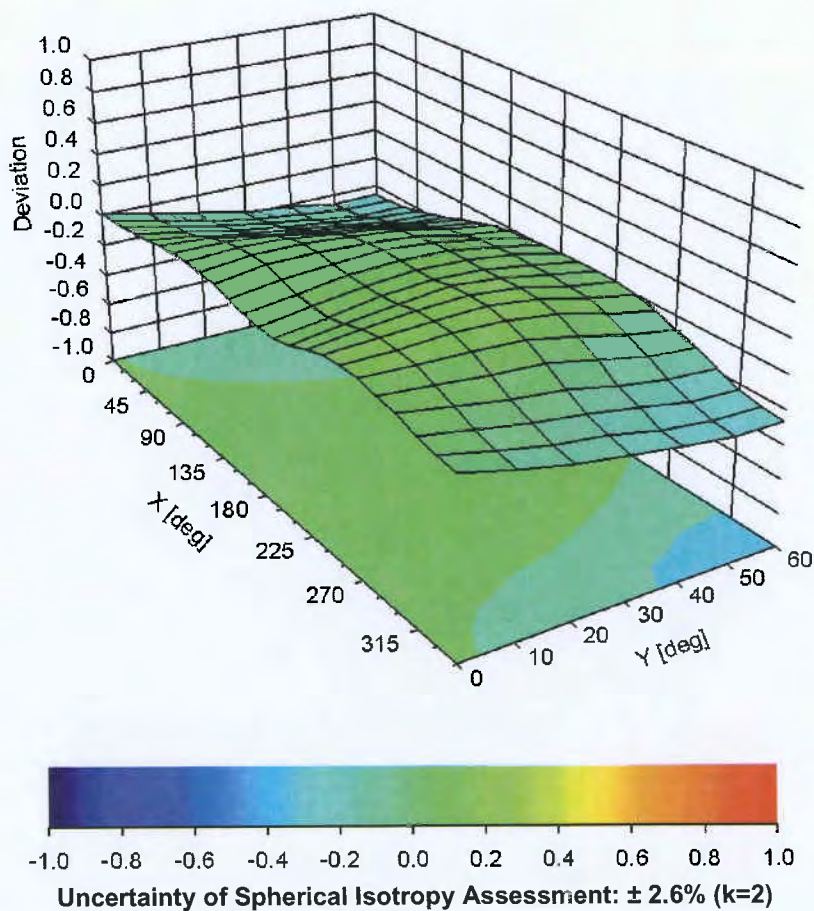


Uncertainty of Linearity Assessment: $\pm 0.6\%$ (k=2)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:3772

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -101.6 |
| 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 | 2 mm |



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Accreditation No.: **SCS 108**

Client **UL CCS USA**

Certificate No: **EX3-3686_Mar14**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3686**

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: **March 18, 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 (Certificate No.) | Scheduled Calibration |
|----------------------------|-----------------|-----------------------------------|------------------------|
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| Reference 30 dB Attenuator | SN: S5129 (30b) | 04-Apr-13 (No. 217-01738) | Apr-14 |
| Reference Probe ES3DV2 | SN: 3013 | 30-Dec-13 (No. ES3-3013_Dec13) | Dec-14 |
| DAE4 | SN: 660 | 13-Dec-13 (No. DAE4-660_Dec13) | Dec-14 |
| 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-13) | In house check: Oct-14 |

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

Issued: March 20, 2014

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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:

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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:3686

Manufactured: March 10, 2009
Calibrated: March 18, 2014

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3686

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|---------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.49 | 0.49 | 0.51 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 101.6 | 99.4 | 98.5 | |

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 | 163.2 | $\pm 2.5 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 155.0 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 156.5 | |

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:3686

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 | 9.18 | 9.18 | 9.18 | 0.44 | 0.83 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 8.88 | 8.88 | 8.88 | 0.21 | 1.30 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 8.74 | 8.74 | 8.74 | 0.18 | 1.66 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 7.78 | 7.78 | 7.78 | 0.80 | 0.63 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 7.69 | 7.69 | 7.69 | 0.41 | 0.84 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 7.52 | 7.52 | 7.52 | 0.45 | 0.77 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 7.29 | 7.29 | 7.29 | 0.52 | 0.69 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 7.48 | 7.48 | 7.48 | 0.40 | 0.80 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 7.18 | 7.18 | 7.18 | 0.47 | 0.75 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 6.87 | 6.87 | 6.87 | 0.31 | 0.92 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 6.72 | 6.72 | 6.72 | 0.44 | 0.82 | ± 12.0 % |
| 5200 | 36.0 | 4.66 | 4.65 | 4.65 | 4.65 | 0.40 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 4.45 | 4.45 | 4.45 | 0.40 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 4.29 | 4.29 | 4.29 | 0.40 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.16 | 4.16 | 4.16 | 0.35 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.22 | 4.22 | 4.22 | 0.40 | 1.80 | ± 13.1 % |

^C Frequency validity 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.

^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:3686

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 | 8.90 | 8.90 | 8.90 | 0.49 | 0.84 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 8.83 | 8.83 | 8.83 | 0.37 | 1.01 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 8.60 | 8.60 | 8.60 | 0.66 | 0.70 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 7.69 | 7.69 | 7.69 | 0.55 | 0.74 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 7.37 | 7.37 | 7.37 | 0.44 | 0.86 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.09 | 7.09 | 7.09 | 0.38 | 0.90 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 7.28 | 7.28 | 7.28 | 0.45 | 0.80 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 7.20 | 7.20 | 7.20 | 0.37 | 0.86 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 6.97 | 6.97 | 6.97 | 0.38 | 0.87 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 6.79 | 6.79 | 6.79 | 0.75 | 0.57 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.53 | 6.53 | 6.53 | 0.80 | 0.58 | ± 12.0 % |
| 5200 | 49.0 | 5.30 | 4.25 | 4.25 | 4.25 | 0.40 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.07 | 4.07 | 4.07 | 0.40 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 3.74 | 3.74 | 3.74 | 0.45 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.47 | 3.47 | 3.47 | 0.50 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 3.81 | 3.81 | 3.81 | 0.50 | 1.90 | ± 13.1 % |

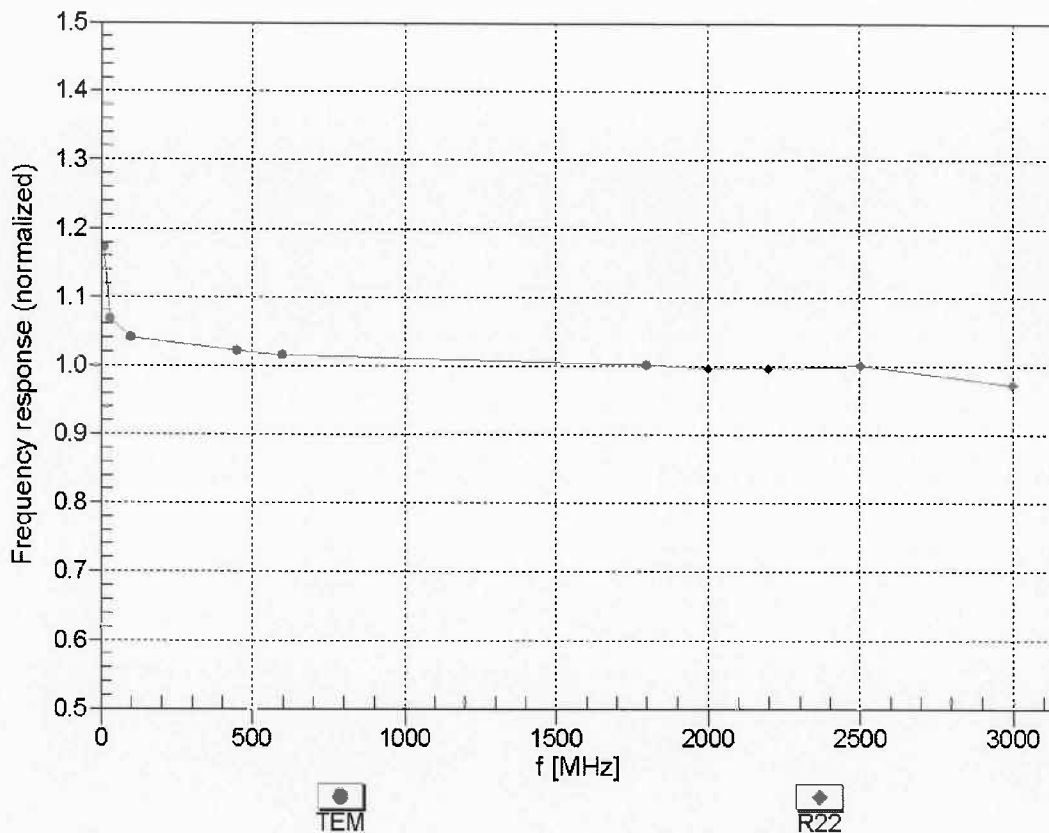
^C Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

^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

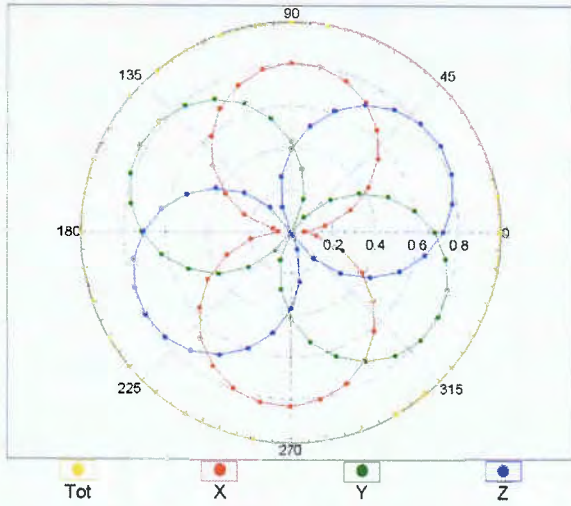
(TEM-Cell:ifi110 EXX, Waveguide: R22)



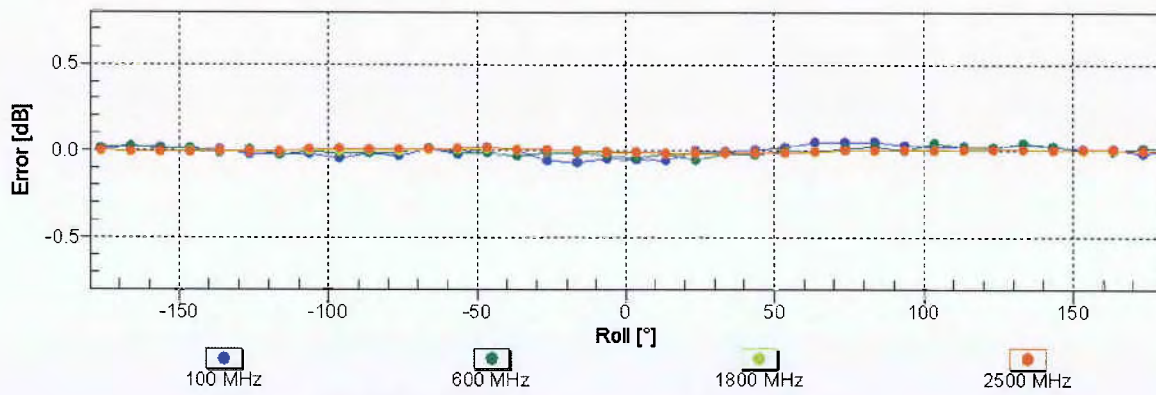
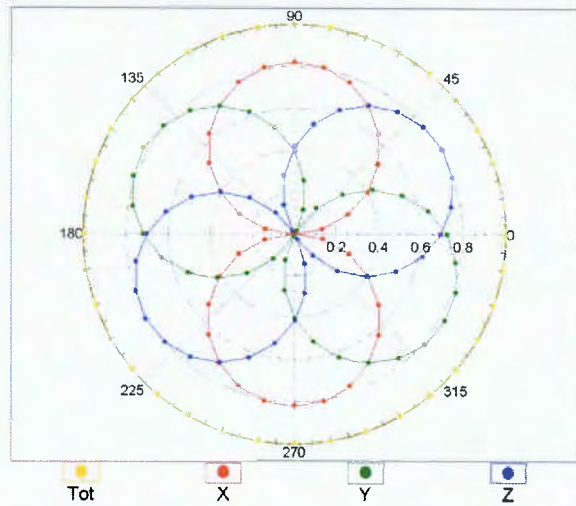
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

f=600 MHz,TEM

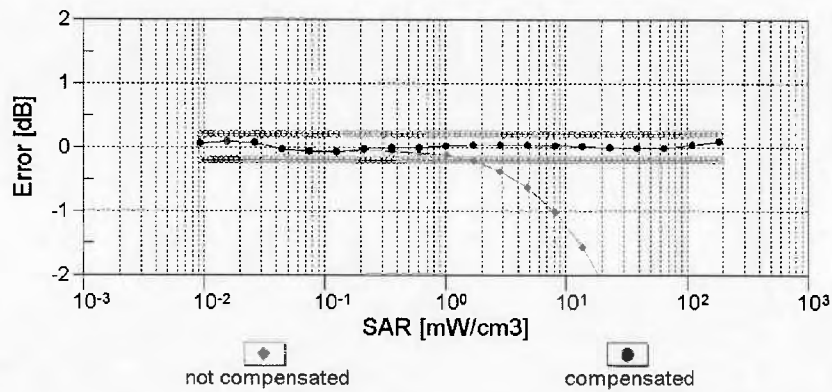
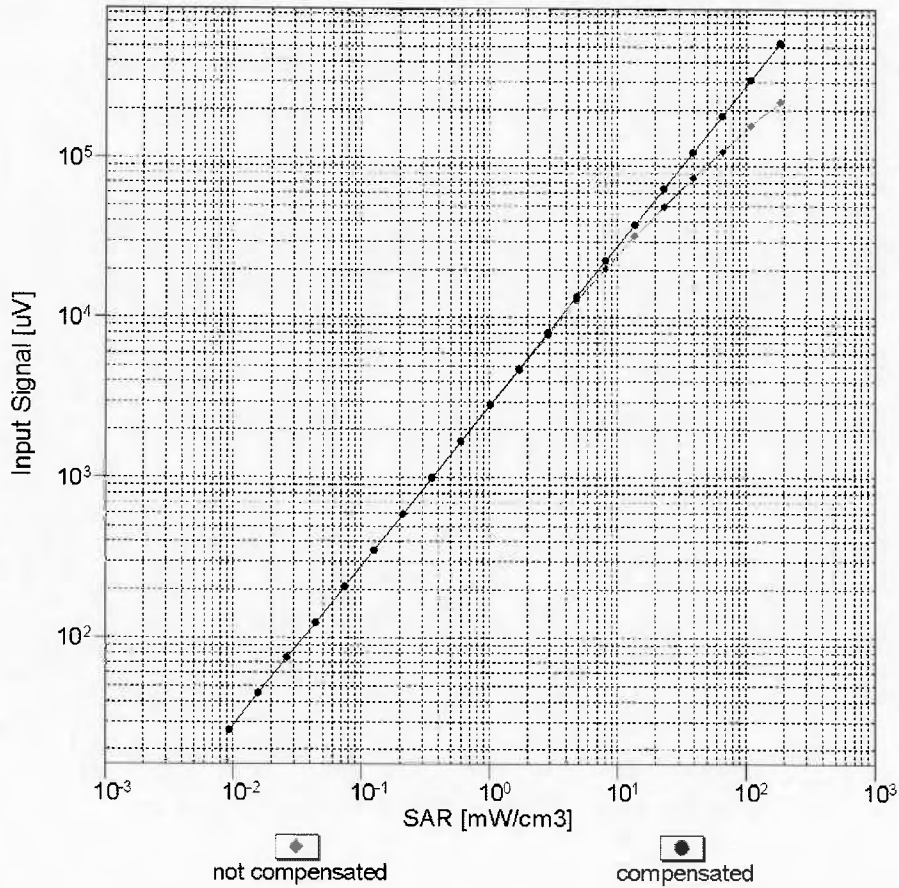


f=1800 MHz,R22



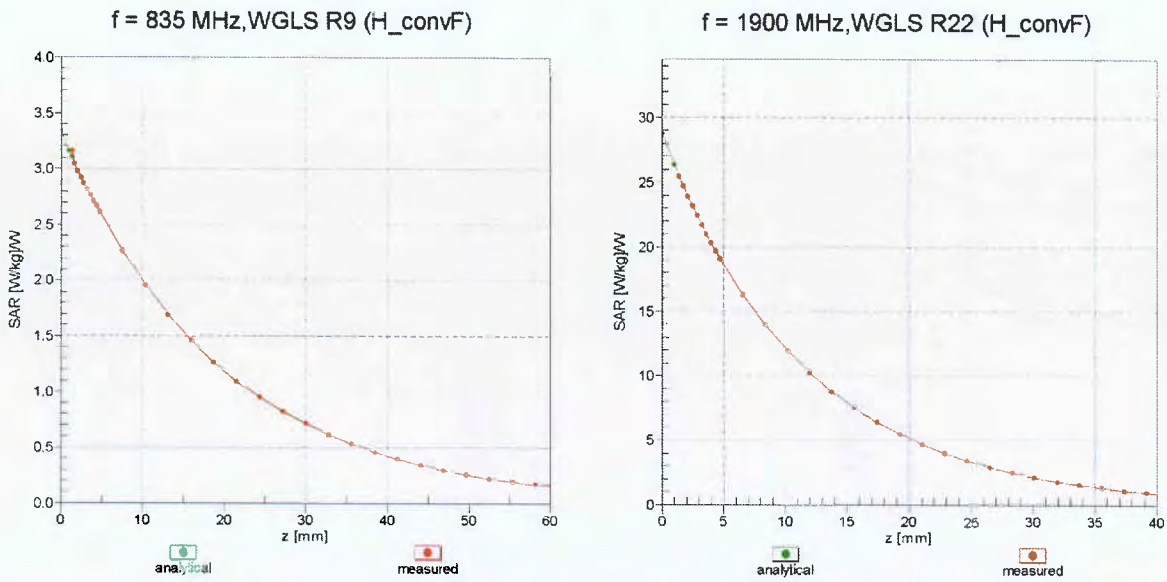
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

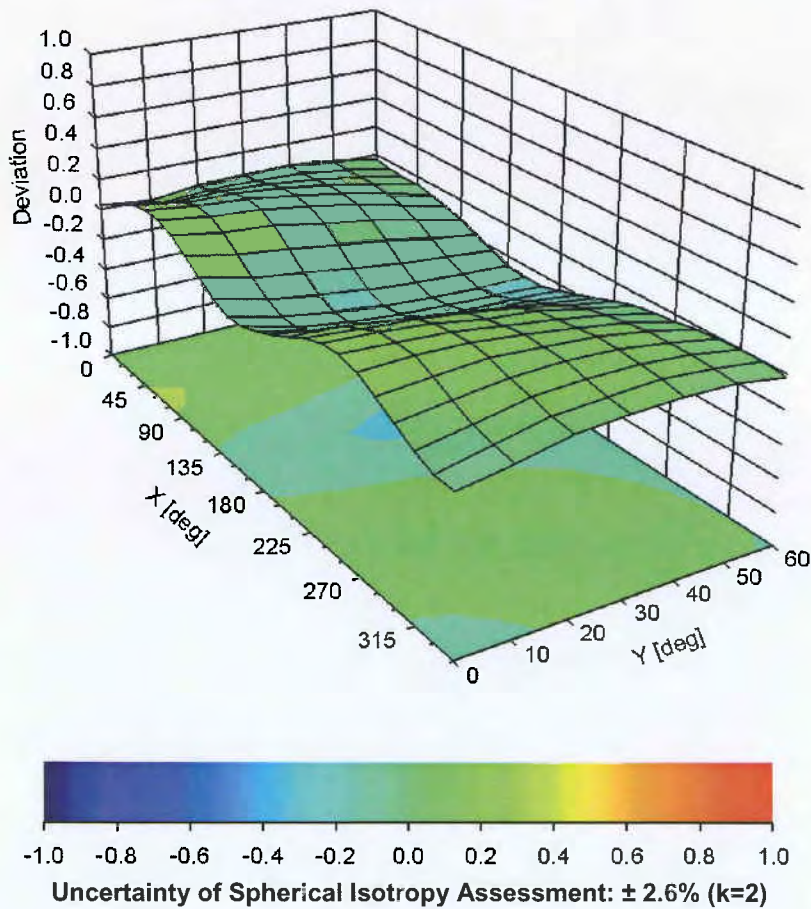


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:3686

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -106.4 |
| 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 | 2 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 108**

Client **UL CCS USA**

Certificate No: **EX3-3989_Apr14**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3989**

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 15, 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 (Certificate No.) | Scheduled Calibration |
|----------------------------|-----------------|-----------------------------------|------------------------|
| Power meter E4419B | GB41293874 | 03-Apr-14 (No. 217-01911) | Apr-15 |
| Power sensor E4412A | MY41498087 | 03-Apr-14 (No. 217-01911) | Apr-15 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 03-Apr-14 (No. 217-01915) | Apr-15 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 03-Apr-14 (No. 217-01919) | Apr-15 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 03-Apr-14 (No. 217-01920) | Apr-15 |
| Reference Probe ES3DV2 | SN: 3013 | 30-Dec-13 (No. ES3-3013_Dec13) | Dec-14 |
| DAE4 | SN: 660 | 13-Dec-13 (No. DAE4-660_Dec13) | Dec-14 |
| 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-13) | In house check: Oct-14 |

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

Issued: April 15, 2014

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 108**

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., $\vartheta = 0$ 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:3989

Manufactured: November 11, 2013
Calibrated: April 15, 2014

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3989

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|---------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.56 | 0.53 | 0.49 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 100.1 | 96.4 | 101.0 | |

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 | 148.3 | $\pm 3.3 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 145.3 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 128.5 | |

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:3989

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) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 43.5 | 0.87 | 13.02 | 13.02 | 13.02 | 0.22 | 1.30 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 10.78 | 10.78 | 10.78 | 0.39 | 0.90 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 10.29 | 10.29 | 10.29 | 0.28 | 1.12 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 10.10 | 10.10 | 10.10 | 0.39 | 0.86 | ± 12.0 % |
| 1450 | 40.5 | 1.20 | 9.16 | 9.16 | 9.16 | 0.36 | 1.06 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 8.63 | 8.63 | 8.63 | 0.40 | 0.80 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.49 | 8.49 | 8.49 | 0.51 | 0.71 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.29 | 8.29 | 8.29 | 0.52 | 0.73 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 8.02 | 8.02 | 8.02 | 0.74 | 0.61 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 8.28 | 8.28 | 8.28 | 0.56 | 0.68 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 7.87 | 7.87 | 7.87 | 0.47 | 0.74 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.56 | 7.56 | 7.56 | 0.53 | 0.71 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.39 | 7.39 | 7.39 | 0.35 | 0.90 | ± 12.0 % |
| 3500 | 37.9 | 2.91 | 7.15 | 7.15 | 7.15 | 1.00 | 0.53 | ± 13.1 % |
| 3700 | 37.7 | 3.12 | 7.05 | 7.05 | 7.05 | 0.38 | 1.03 | ± 13.1 % |
| 4950 | 36.3 | 4.40 | 5.50 | 5.50 | 5.50 | 0.35 | 1.80 | ± 13.1 % |
| 5200 | 36.0 | 4.66 | 5.28 | 5.28 | 5.28 | 0.35 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 5.18 | 5.18 | 5.18 | 0.30 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 5.08 | 5.08 | 5.08 | 0.35 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 5.01 | 5.01 | 5.01 | 0.30 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.81 | 4.81 | 4.81 | 0.40 | 1.80 | ± 13.1 % |

^C Frequency validity 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.

^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:3989

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 (mm) ^G | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 56.7 | 0.94 | 11.21 | 11.21 | 11.21 | 0.10 | 1.15 | ± 13.3 % |
| 750 | 55.5 | 0.96 | 10.12 | 10.12 | 10.12 | 0.29 | 1.12 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 9.96 | 9.96 | 9.96 | 0.59 | 0.74 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 9.77 | 9.77 | 9.77 | 0.50 | 0.83 | ± 12.0 % |
| 1450 | 54.0 | 1.30 | 8.54 | 8.54 | 8.54 | 0.35 | 1.01 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 8.51 | 8.51 | 8.51 | 0.63 | 0.67 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 8.39 | 8.39 | 8.39 | 0.32 | 1.01 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.95 | 7.95 | 7.95 | 0.42 | 0.84 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 8.07 | 8.07 | 8.07 | 0.42 | 0.80 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 7.99 | 7.99 | 7.99 | 0.35 | 0.93 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 7.69 | 7.69 | 7.69 | 0.65 | 0.67 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.43 | 7.43 | 7.43 | 0.80 | 0.50 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 7.20 | 7.20 | 7.20 | 0.80 | 0.57 | ± 12.0 % |
| 3500 | 51.3 | 3.31 | 6.88 | 6.88 | 6.88 | 0.33 | 1.22 | ± 13.1 % |
| 3700 | 51.0 | 3.55 | 6.84 | 6.84 | 6.84 | 0.40 | 1.13 | ± 13.1 % |
| 4950 | 49.4 | 5.01 | 4.81 | 4.81 | 4.81 | 0.40 | 1.90 | ± 13.1 % |
| 5200 | 49.0 | 5.30 | 4.77 | 4.77 | 4.77 | 0.45 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.58 | 4.58 | 4.58 | 0.45 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 4.34 | 4.34 | 4.34 | 0.45 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 4.60 | 4.60 | 4.60 | 0.30 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 4.23 | 4.23 | 4.23 | 0.55 | 1.90 | ± 13.1 % |

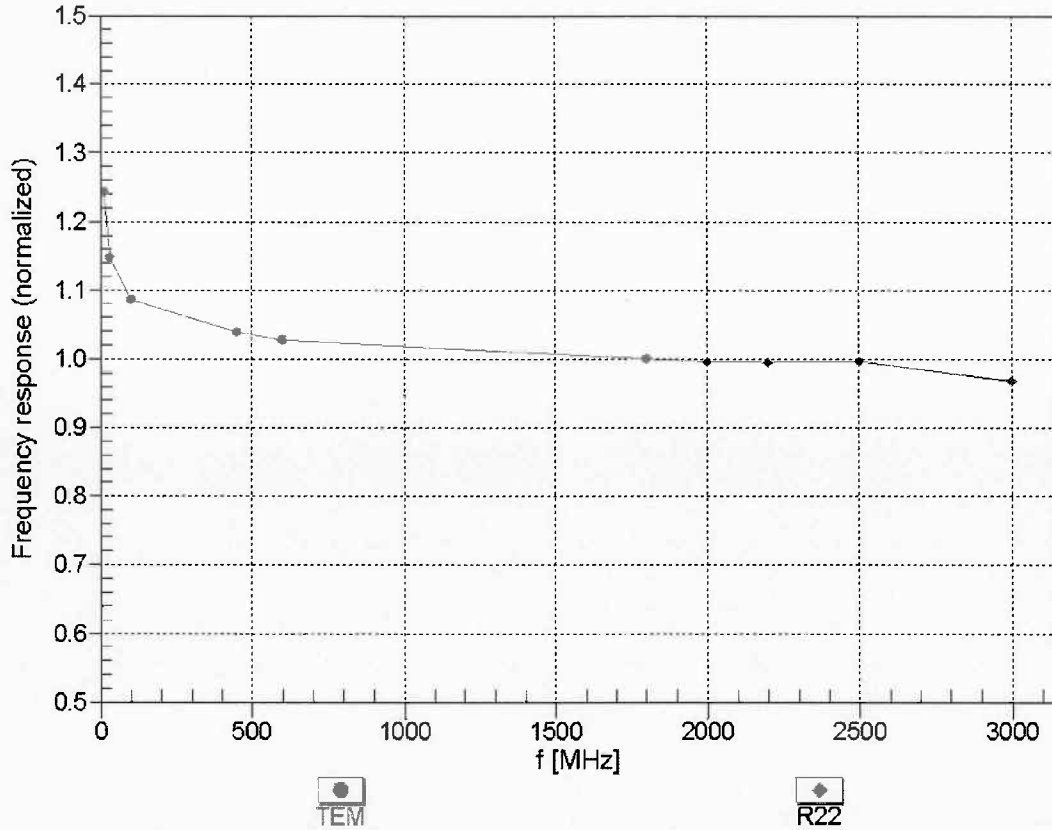
^C Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

^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)

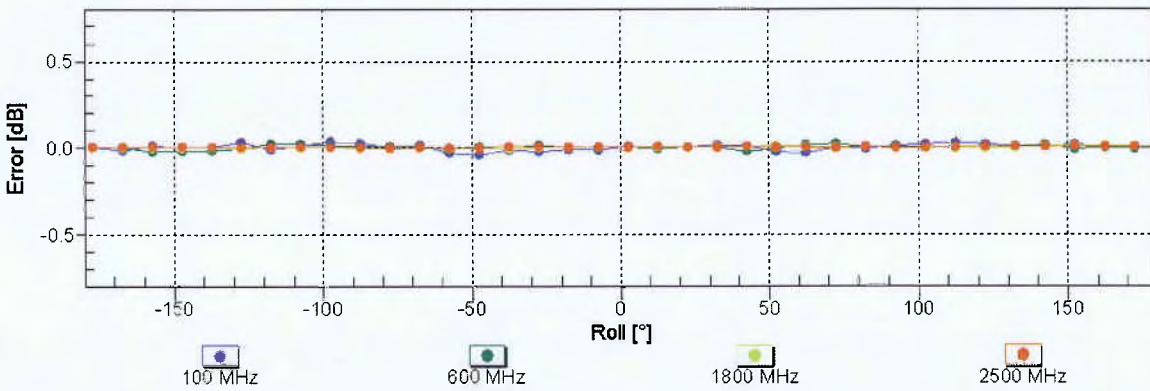
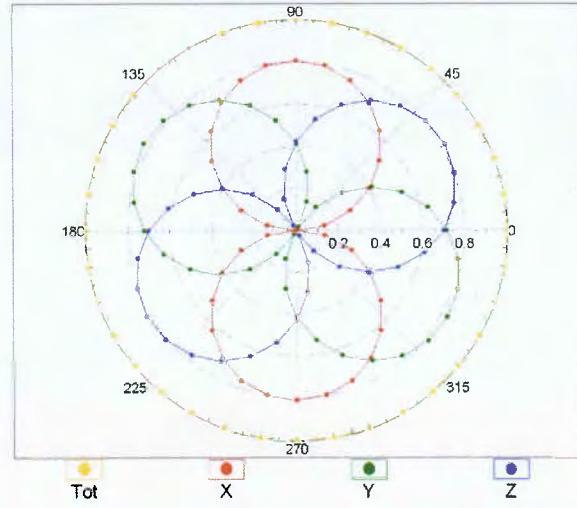
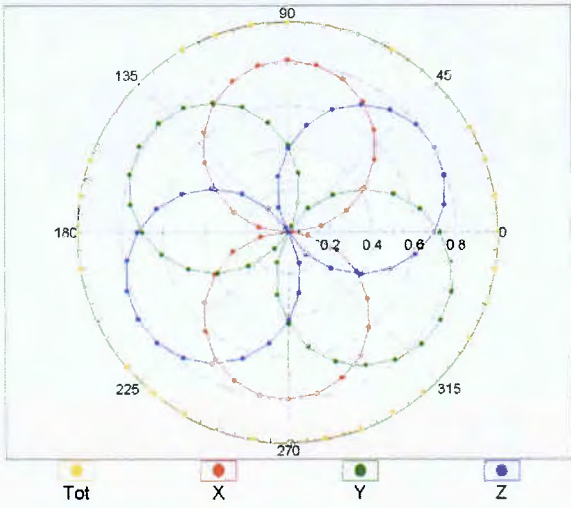


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

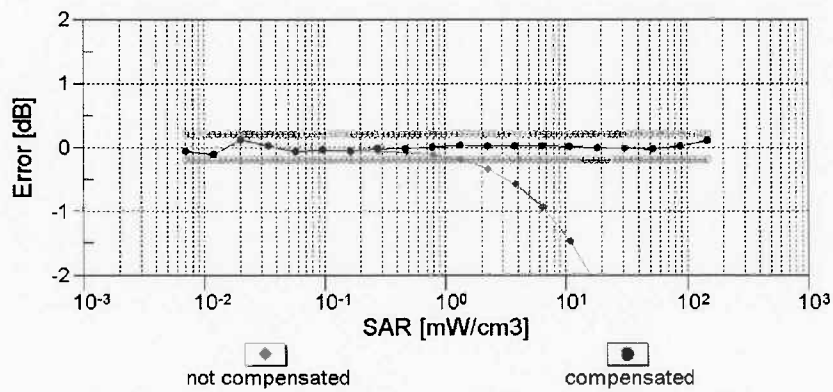
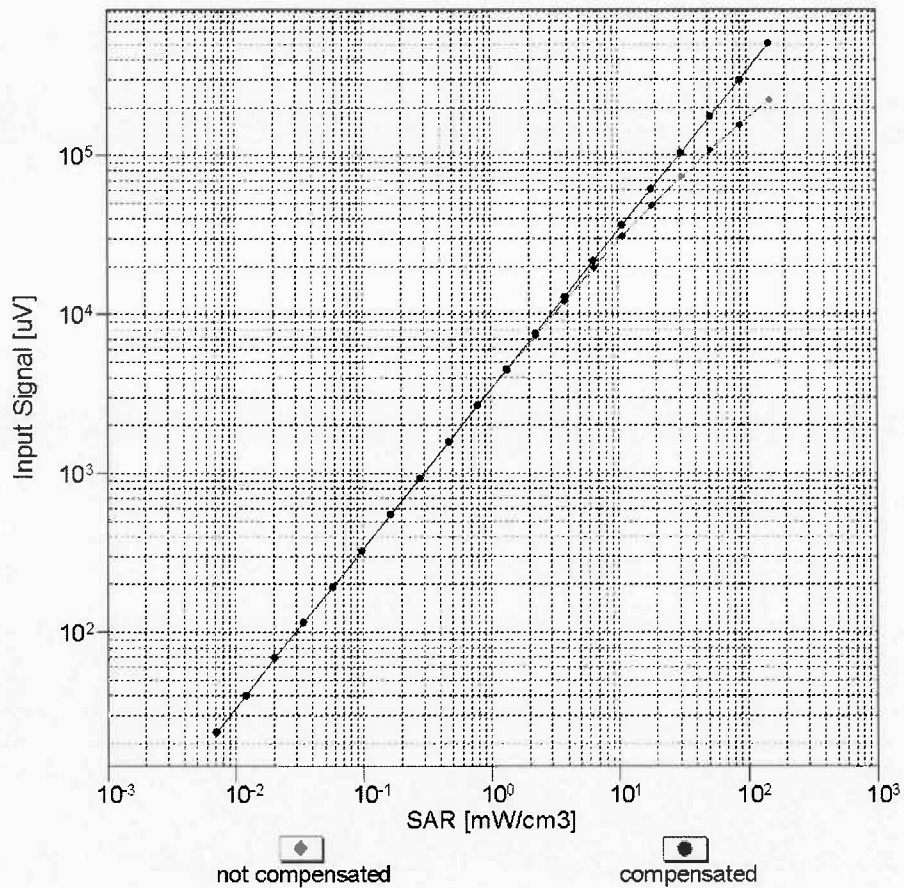
f=600 MHz,TEM

f=1800 MHz,R22



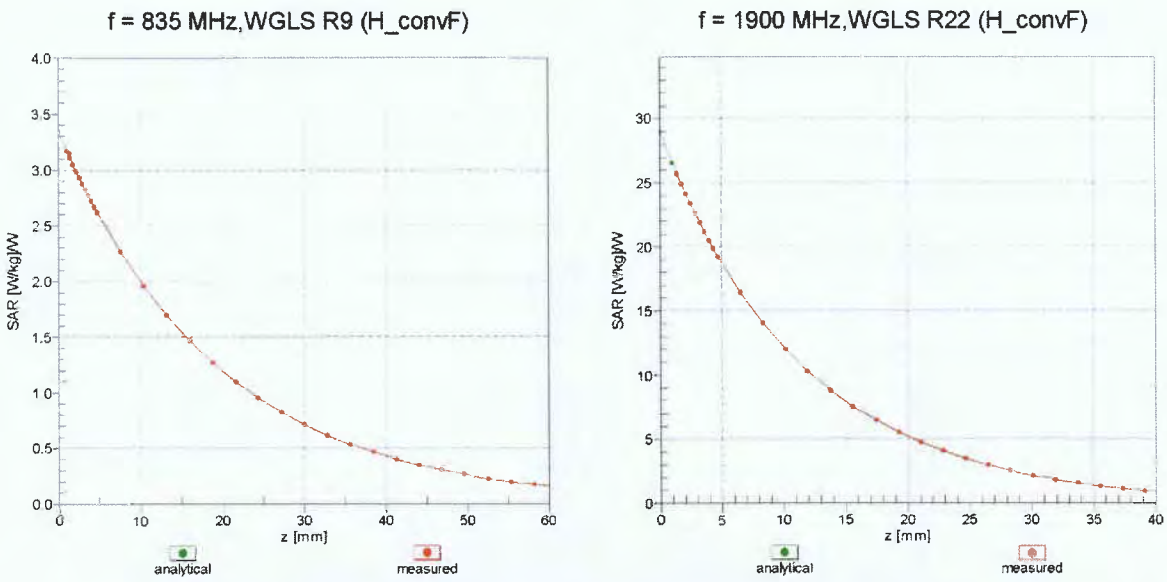
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

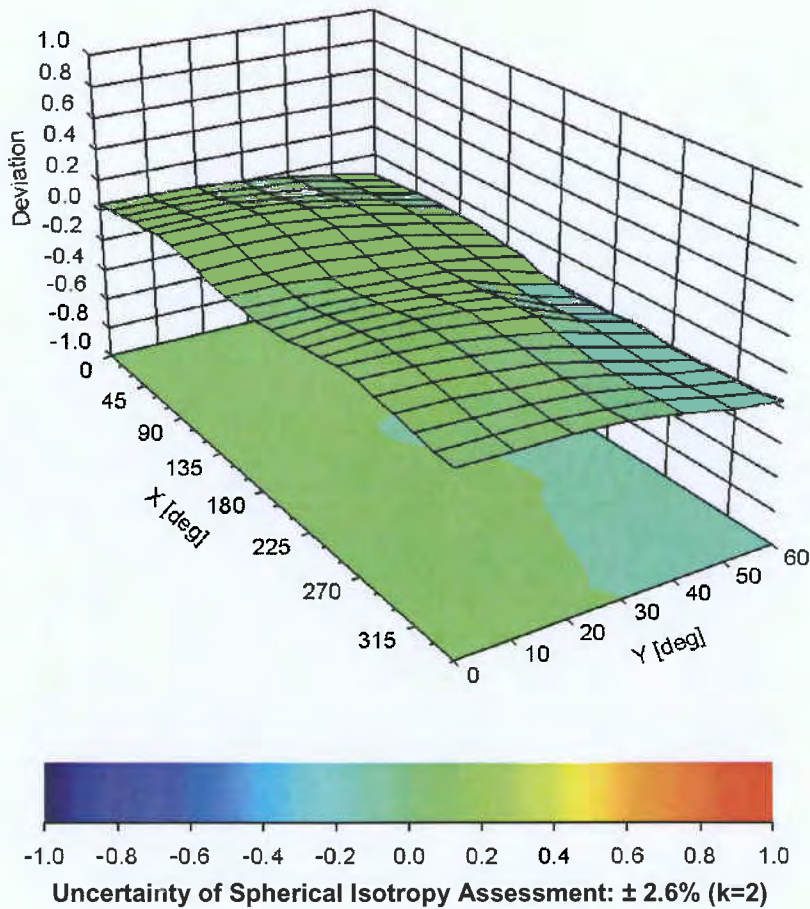


Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:3989

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -97.5 |
| Mechanical Surface Detection Mode | enabled |
| Optical Surface Detection Mode | disabled |
| Probe Overall Length | 337 mm |
| Probe Body Diameter | 10 mm |
| Tip Length | 9 mm |
| Tip Diameter | 2.5 mm |
| Probe Tip to Sensor X Calibration Point | 1 mm |
| Probe Tip to Sensor Y Calibration Point | 1 mm |
| Probe Tip to Sensor Z Calibration Point | 1 mm |
| Recommended Measurement Distance from Surface | 2 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 108

Client **UL CCS USA**

Certificate No: **EX3-3990_Apr14**

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**

Calibration date: **April 15, 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 (Certificate No.) | Scheduled Calibration |
|----------------------------|-----------------|-----------------------------------|------------------------|
| Power meter E4419B | GB41293874 | 03-Apr-14 (No. 217-01911) | Apr-15 |
| Power sensor E4412A | MY41498087 | 03-Apr-14 (No. 217-01911) | Apr-15 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 03-Apr-14 (No. 217-01915) | Apr-15 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 03-Apr-14 (No. 217-01919) | Apr-15 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 03-Apr-14 (No. 217-01920) | Apr-15 |
| Reference Probe ES3DV2 | SN: 3013 | 30-Dec-13 (No. ES3-3013_Dec13) | Dec-14 |
| DAE4 | SN: 660 | 13-Dec-13 (No. DAE4-660_Dec13) | Dec-14 |
| 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-13) | In house check: Oct-14 |

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

Issued: April 15, 2014

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Accreditation No.: **SCS 108**

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 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., $\vartheta = 0$ 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:3990

Manufactured: January 21, 2014
Calibrated: April 15, 2014

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 | 0.44 | 0.57 | 0.35 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 99.9 | 101.6 | 104.1 | |

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 | 133.8 | $\pm 2.7 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 128.2 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 132.9 | |

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 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: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 ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 43.5 | 0.87 | 11.14 | 11.14 | 11.14 | 0.18 | 1.25 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 10.76 | 10.76 | 10.76 | 0.52 | 0.75 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 10.26 | 10.26 | 10.26 | 0.40 | 0.83 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 10.13 | 10.13 | 10.13 | 0.70 | 0.61 | ± 12.0 % |
| 1450 | 40.5 | 1.20 | 9.23 | 9.23 | 9.23 | 0.80 | 0.59 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 8.49 | 8.49 | 8.49 | 0.58 | 0.66 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.58 | 8.58 | 8.58 | 0.34 | 0.85 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.37 | 8.37 | 8.37 | 0.48 | 0.73 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 8.16 | 8.16 | 8.16 | 0.41 | 0.80 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 8.28 | 8.28 | 8.28 | 0.33 | 0.88 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 8.01 | 8.01 | 8.01 | 0.52 | 0.68 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.65 | 7.65 | 7.65 | 0.54 | 0.69 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.42 | 7.42 | 7.42 | 0.43 | 0.79 | ± 12.0 % |
| 3500 | 37.9 | 2.91 | 7.16 | 7.16 | 7.16 | 0.57 | 0.81 | ± 13.1 % |
| 3700 | 37.7 | 3.12 | 7.07 | 7.07 | 7.07 | 0.82 | 0.63 | ± 13.1 % |
| 4950 | 36.3 | 4.40 | 5.74 | 5.74 | 5.74 | 0.25 | 1.80 | ± 13.1 % |
| 5200 | 36.0 | 4.66 | 5.48 | 5.48 | 5.48 | 0.25 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 5.32 | 5.32 | 5.32 | 0.25 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 5.27 | 5.27 | 5.27 | 0.25 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.95 | 4.95 | 4.95 | 0.30 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.92 | 4.92 | 4.92 | 0.35 | 1.80 | ± 13.1 % |

^C Frequency validity 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.

^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

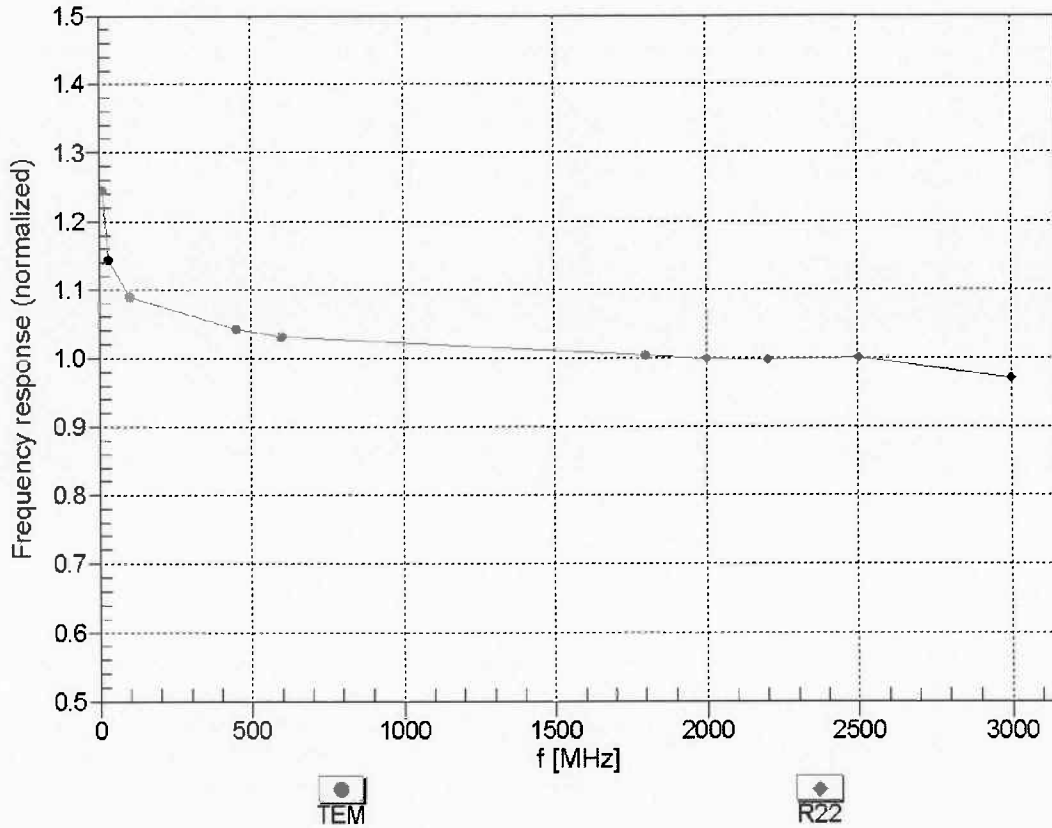
| f (MHz) ^C | Relative Permittivity ^F | Conductivity (S/m) ^F | ConvF X | ConvF Y | ConvF Z | Alpha ^G | Depth ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 56.7 | 0.94 | 11.48 | 11.48 | 11.48 | 0.10 | 1.10 | ± 13.3 % |
| 750 | 55.5 | 0.96 | 10.21 | 10.21 | 10.21 | 0.26 | 1.19 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 10.05 | 10.05 | 10.05 | 0.38 | 0.94 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 9.82 | 9.82 | 9.82 | 0.68 | 0.67 | ± 12.0 % |
| 1450 | 54.0 | 1.30 | 8.51 | 8.51 | 8.51 | 0.80 | 0.58 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 8.51 | 8.51 | 8.51 | 0.52 | 0.71 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 8.26 | 8.26 | 8.26 | 0.45 | 0.82 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.88 | 7.88 | 7.88 | 0.42 | 0.82 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 8.17 | 8.17 | 8.17 | 0.41 | 0.84 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 8.08 | 8.08 | 8.08 | 0.62 | 0.68 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 7.69 | 7.69 | 7.69 | 0.62 | 0.66 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.46 | 7.46 | 7.46 | 0.80 | 0.56 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 7.31 | 7.31 | 7.31 | 0.80 | 0.50 | ± 12.0 % |
| 3500 | 51.3 | 3.31 | 7.05 | 7.05 | 7.05 | 0.52 | 0.86 | ± 13.1 % |
| 3700 | 51.0 | 3.55 | 6.82 | 6.82 | 6.82 | 0.46 | 0.97 | ± 13.1 % |
| 4950 | 49.4 | 5.01 | 5.01 | 5.01 | 5.01 | 0.30 | 1.90 | ± 13.1 % |
| 5200 | 49.0 | 5.30 | 4.94 | 4.94 | 4.94 | 0.35 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.76 | 4.76 | 4.76 | 0.35 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 4.47 | 4.47 | 4.47 | 0.40 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 4.12 | 4.12 | 4.12 | 0.45 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 4.69 | 4.69 | 4.69 | 0.35 | 1.90 | ± 13.1 % |

^C Frequency validity 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.

^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)

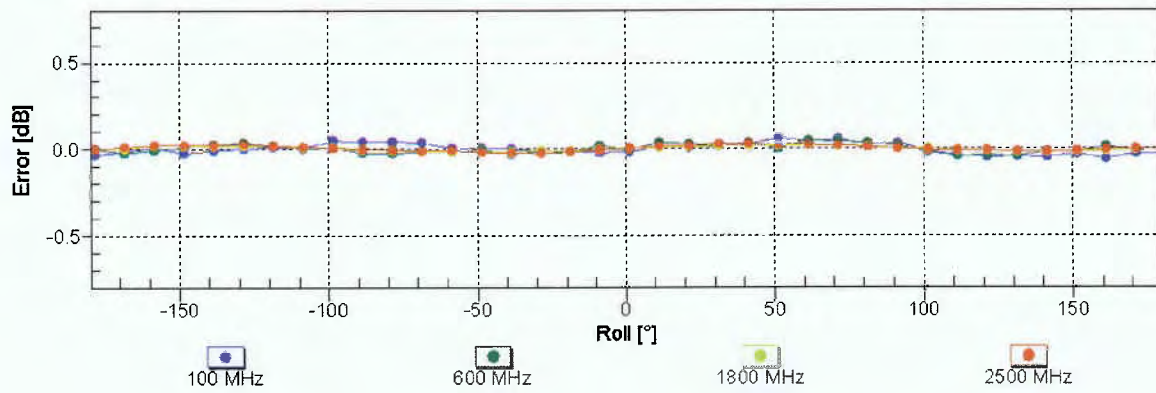
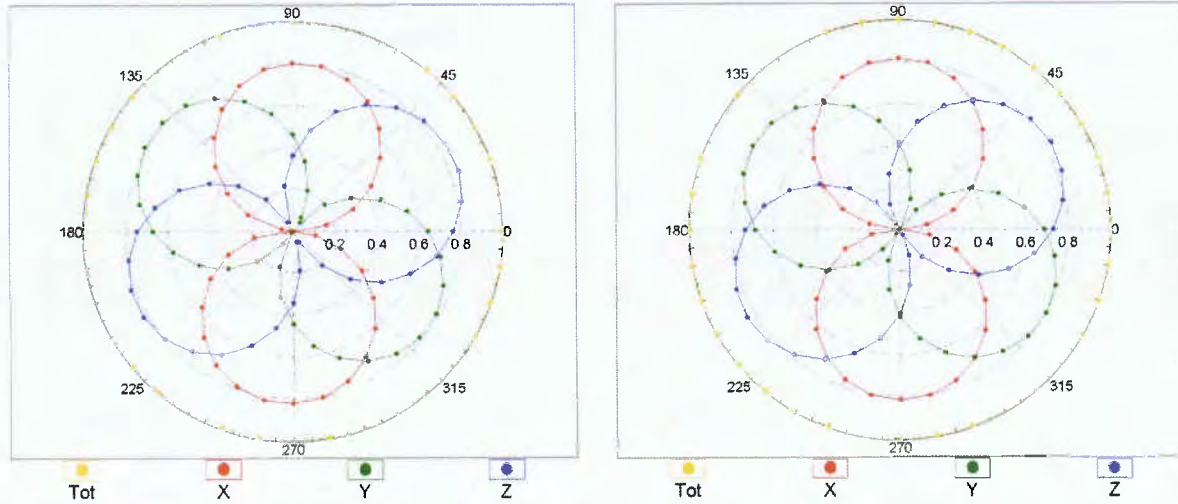


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

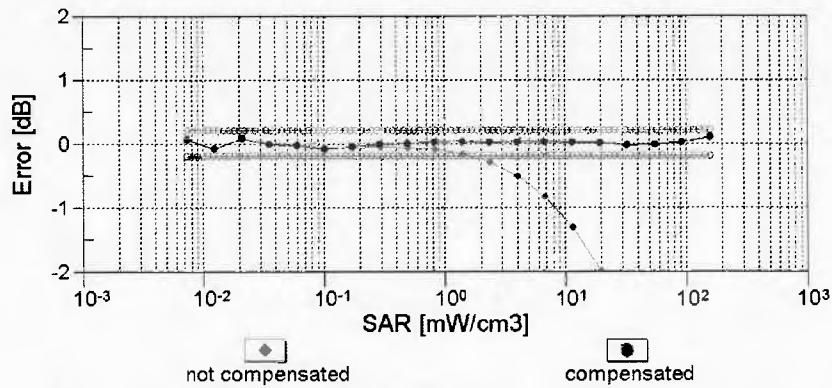
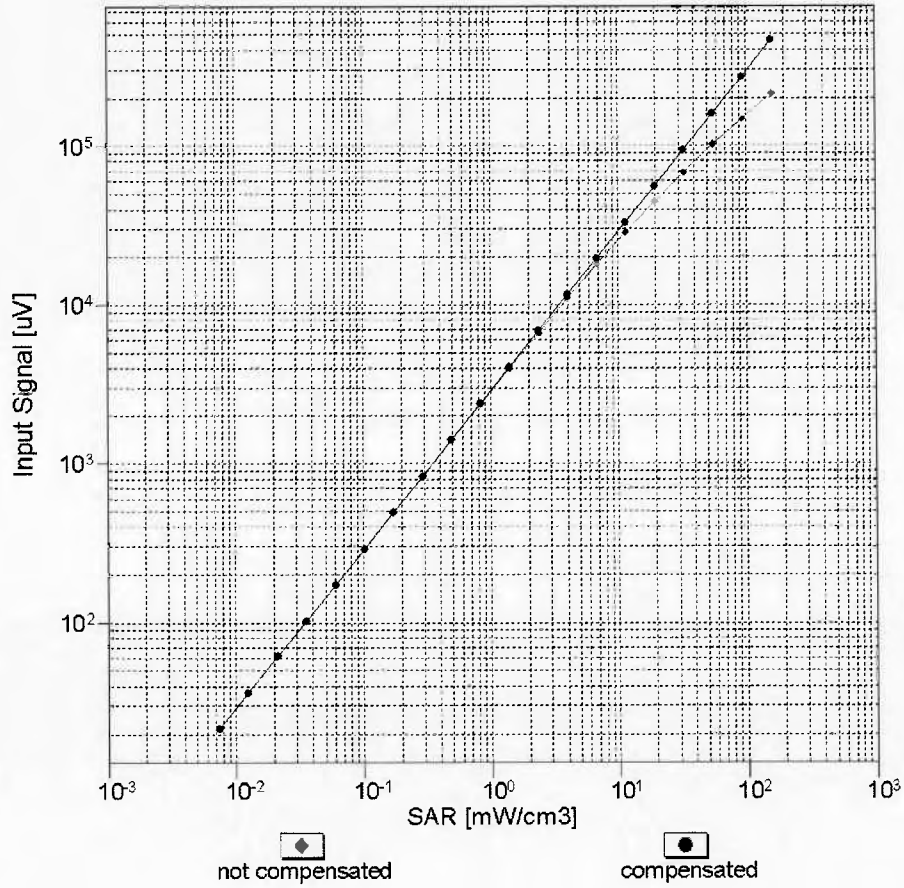
f=600 MHz,TEM

f=1800 MHz,R22



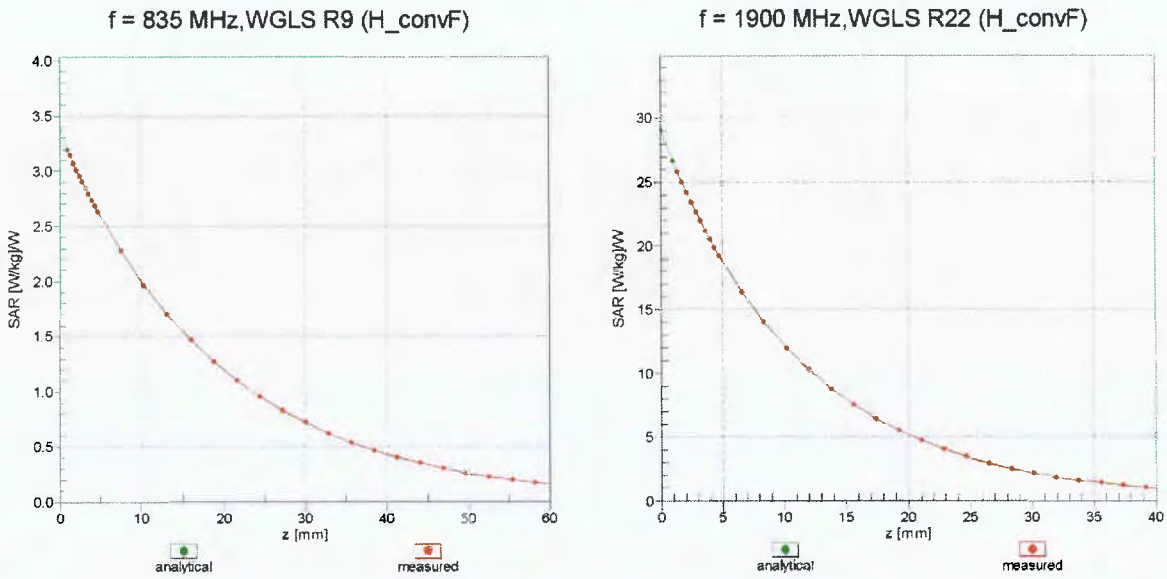
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

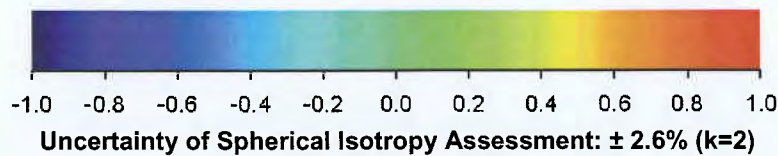
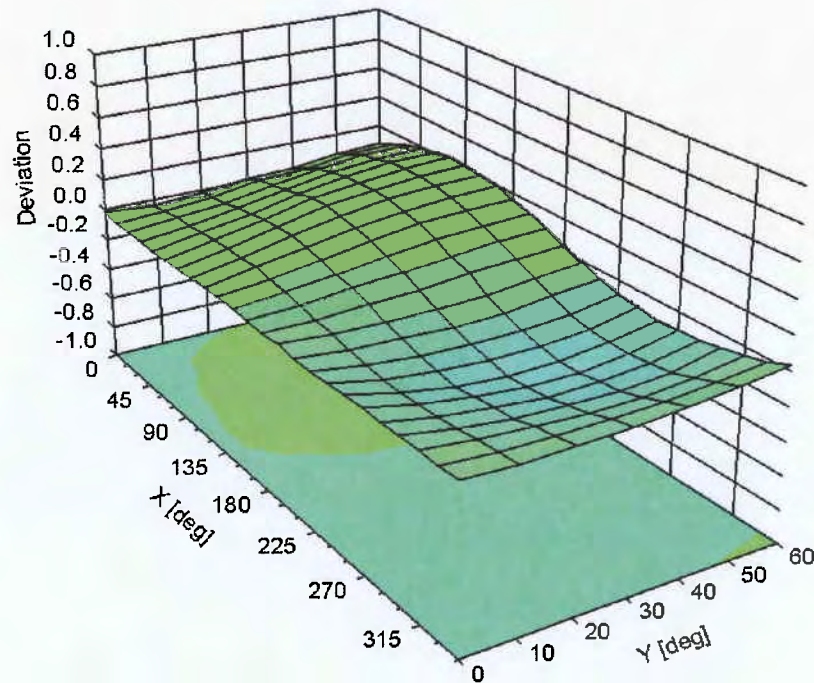


Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

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 (°) | 21.4 |
| 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 | 2 mm |