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Accreditation No.: **SCS 108**

Client **UL CCS USA**

Certificate No: **EX3-3902_May14**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3902**

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: **May 19, 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: | Claudio Leubler | Laboratory Technician | |
| Approved by: | Katja Pokovic | Technical Manager | |
| | | | Issued: May 20, 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**

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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:3902

Manufactured: September 4, 2012
Calibrated: May 19, 2014

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3902

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|---------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.45 | 0.46 | 0.46 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 101.3 | 100.1 | 97.9 | |

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 | 132.5 | $\pm 2.5 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 142.7 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 139.7 | |

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:3902

Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) ^C | Relative Permittivity ^F | Conductivity (S/m) ^F | ConvF X | ConvF Y | ConvF Z | Alpha ^G | Depth ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 750 | 41.9 | 0.89 | 10.36 | 10.36 | 10.36 | 0.47 | 0.76 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 10.04 | 10.04 | 10.04 | 0.18 | 1.45 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 9.91 | 9.91 | 9.91 | 0.40 | 0.84 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 8.59 | 8.59 | 8.59 | 0.44 | 0.84 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.46 | 8.46 | 8.46 | 0.48 | 0.78 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.19 | 8.19 | 8.19 | 0.45 | 0.77 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 7.91 | 7.91 | 7.91 | 0.49 | 0.75 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 8.16 | 8.16 | 8.16 | 0.36 | 0.90 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 7.75 | 7.75 | 7.75 | 0.39 | 0.75 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.29 | 7.29 | 7.29 | 0.34 | 0.90 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.06 | 7.06 | 7.06 | 0.36 | 0.89 | ± 12.0 % |
| 5200 | 36.0 | 4.66 | 5.30 | 5.30 | 5.30 | 0.35 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 5.12 | 5.12 | 5.12 | 0.35 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 5.00 | 5.00 | 5.00 | 0.40 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.78 | 4.78 | 4.78 | 0.40 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.75 | 4.75 | 4.75 | 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. Above 5 GHz frequency validity can be extended to ± 110 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:3902

Calibration Parameter Determined in Body Tissue Simulating Media

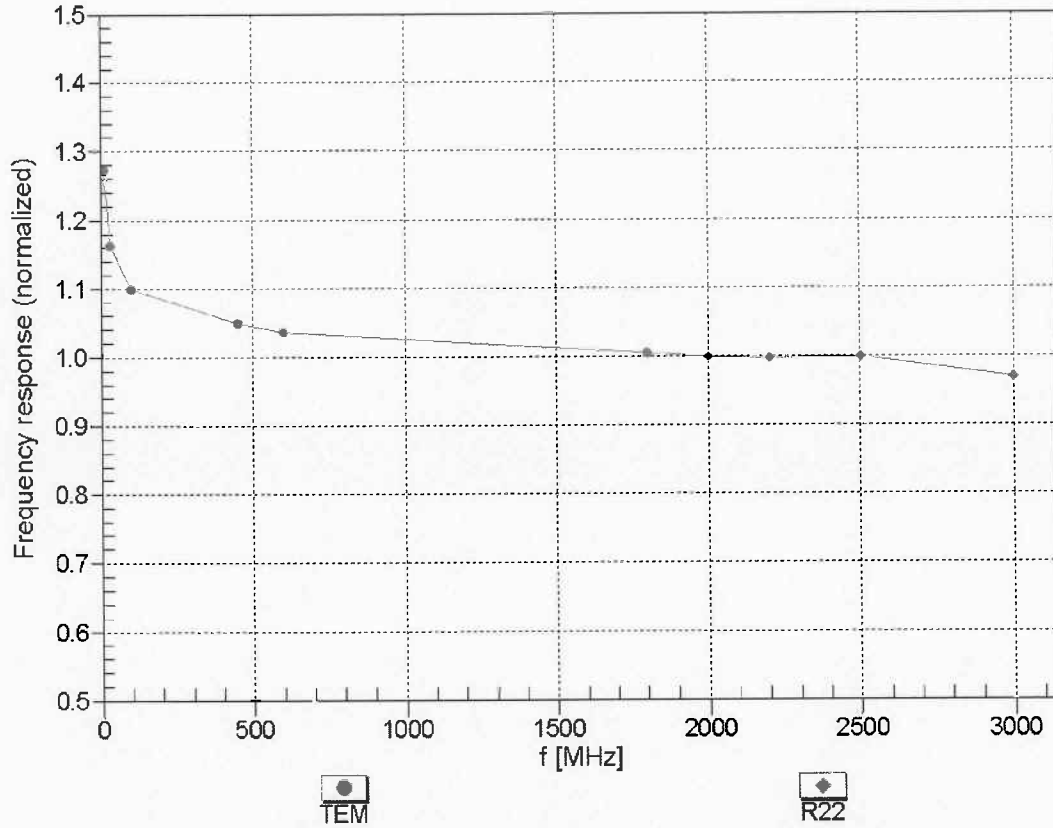
| f (MHz) ^C | Relative Permittivity ^F | Conductivity (S/m) ^F | ConvF X | ConvF Y | ConvF Z | Alpha ^G | Depth ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 750 | 55.5 | 0.96 | 9.90 | 9.90 | 9.90 | 0.46 | 0.79 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 9.86 | 9.86 | 9.86 | 0.39 | 0.86 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 9.65 | 9.65 | 9.65 | 0.40 | 0.86 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 8.67 | 8.67 | 8.67 | 0.59 | 0.69 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 8.06 | 8.06 | 8.06 | 0.73 | 0.62 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.80 | 7.80 | 7.80 | 0.33 | 0.93 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 8.05 | 8.05 | 8.05 | 0.27 | 1.05 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 7.94 | 7.94 | 7.94 | 0.38 | 0.87 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 7.55 | 7.55 | 7.55 | 0.72 | 0.59 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.35 | 7.35 | 7.35 | 0.80 | 0.58 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 7.18 | 7.18 | 7.18 | 0.80 | 0.50 | ± 12.0 % |
| 5200 | 49.0 | 5.30 | 4.49 | 4.49 | 4.49 | 0.45 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.33 | 4.33 | 4.33 | 0.45 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 3.93 | 3.93 | 3.93 | 0.50 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.73 | 3.73 | 3.73 | 0.50 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 4.11 | 4.11 | 4.11 | 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. Above 5 GHz frequency validity can be extended to ± 110 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)

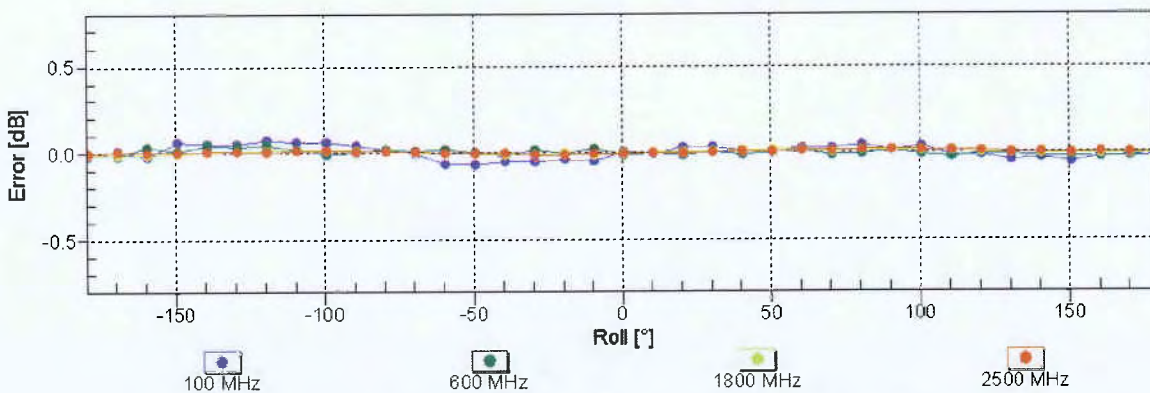
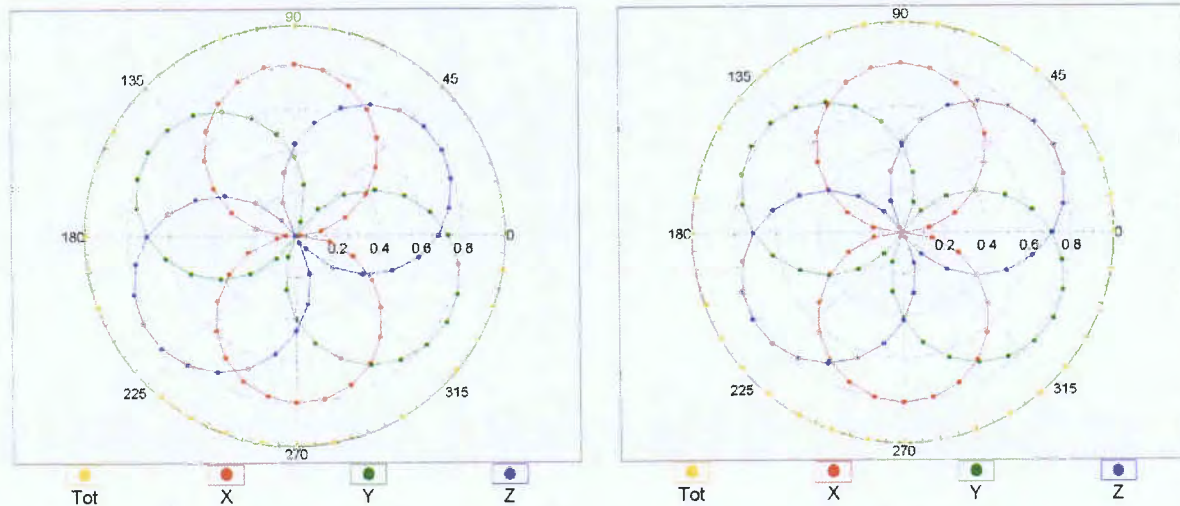


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

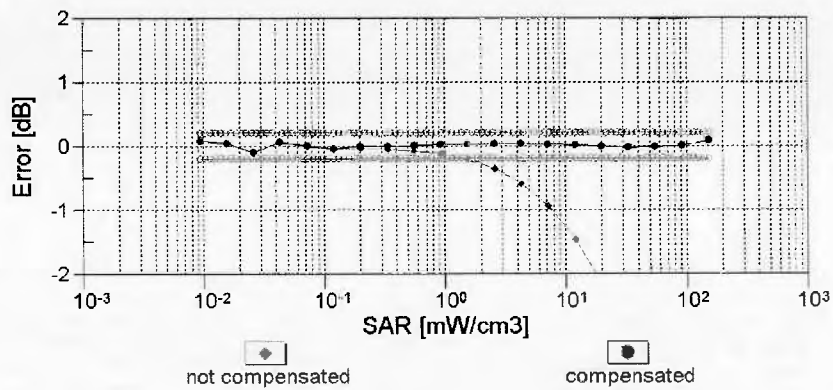
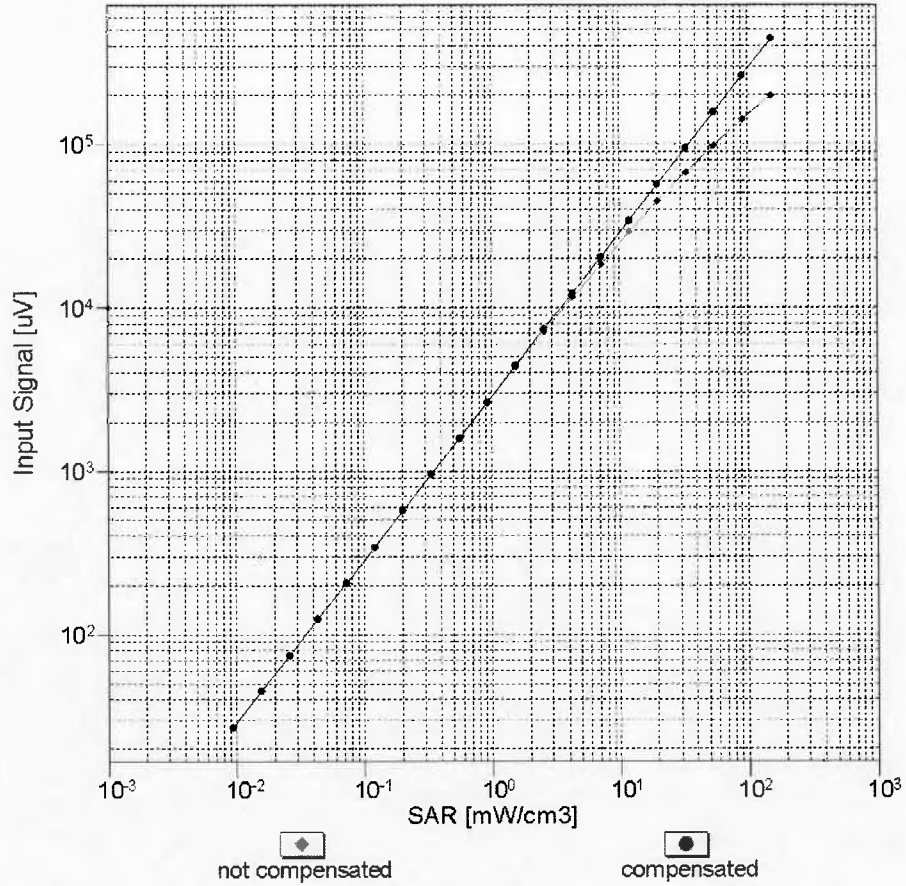
f=600 MHz,TEM

f=1800 MHz,R22



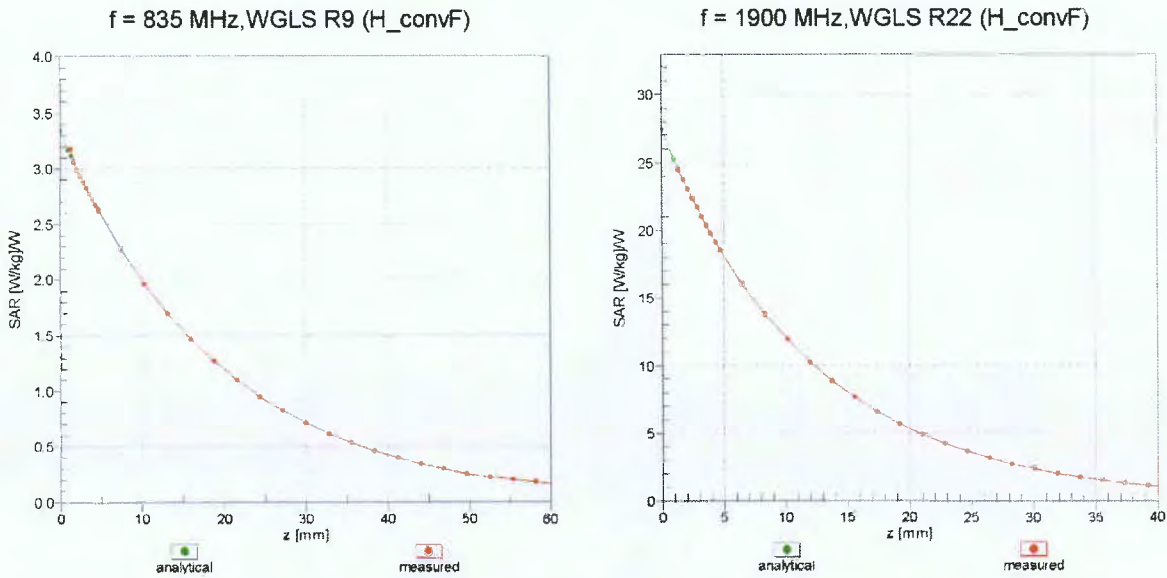
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ ($k=2$)

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

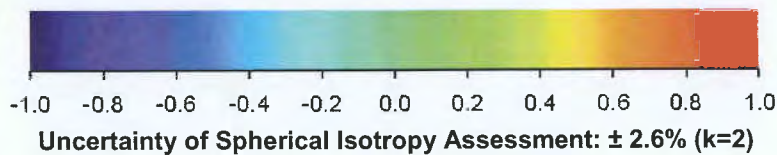
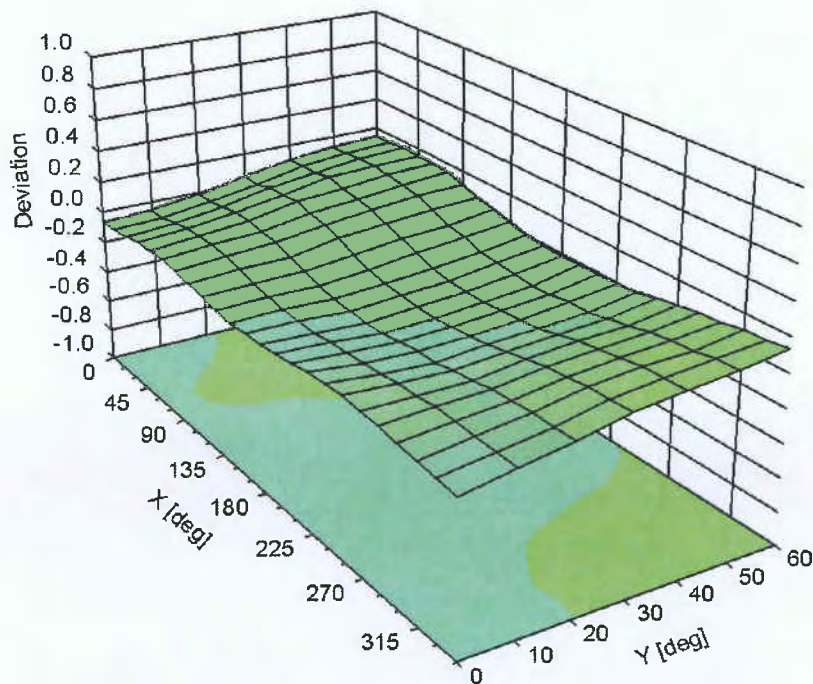


Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:3902**Other Probe Parameters**

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | 0.6 |
| 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: **EX3-3871_Aug14**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3871**

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: **August 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 | 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 |

| | | | |
|----------------|--------------------------------|-----------------------------------|---------------|
| Calibrated by: | Name Claudio Leubler | Function Laboratory Technician | Signature |
| Approved by: | Katja Pokovic | Technical Manager | |

Issued: August 26, 2014

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Accreditation No.: **SCS 108**

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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:

- 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 $\vartheta = 0$ ($f \leq 900$ 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 E^2 -field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)_{x,y,z}* = *NORM_{x,y,z}* * *frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of *ConvF*.
- *DCP_{x,y,z}*: DCP are numerical linearization parameters assessed based on the data of power sweep 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:3871

Manufactured: February 2, 2012
Calibrated: August 26, 2014

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3871

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|--------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.42 | 0.30 | 0.51 | $\pm 10.1\%$ |
| DCP (mV) ^B | 102.7 | 113.1 | 101.8 | |

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 | 143.3 | $\pm 3.5\%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 147.0 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 138.2 | |

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:3871

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 | 10.27 | 10.27 | 10.27 | 0.13 | 1.35 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 10.17 | 10.17 | 10.17 | 0.79 | 0.60 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 9.79 | 9.79 | 9.79 | 0.75 | 0.61 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 9.63 | 9.63 | 9.63 | 0.74 | 0.61 | ± 12.0 % |
| 1450 | 40.5 | 1.20 | 8.88 | 8.88 | 8.88 | 0.53 | 0.72 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 8.48 | 8.48 | 8.48 | 0.74 | 0.56 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.42 | 8.42 | 8.42 | 0.80 | 0.60 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.20 | 8.20 | 8.20 | 0.60 | 0.70 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 7.95 | 7.95 | 7.95 | 0.62 | 0.63 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 8.15 | 8.15 | 8.15 | 0.65 | 0.62 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 7.94 | 7.94 | 7.94 | 0.69 | 0.60 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.44 | 7.44 | 7.44 | 0.52 | 0.68 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.38 | 7.38 | 7.38 | 0.35 | 0.86 | ± 12.0 % |
| 3500 | 37.9 | 2.91 | 7.22 | 7.22 | 7.22 | 0.43 | 0.89 | ± 13.1 % |
| 3700 | 37.7 | 3.12 | 6.87 | 6.87 | 6.87 | 0.77 | 0.67 | ± 13.1 % |
| 4950 | 36.3 | 4.40 | 5.55 | 5.55 | 5.55 | 0.35 | 1.80 | ± 13.1 % |
| 5200 | 36.0 | 4.66 | 5.23 | 5.23 | 5.23 | 0.35 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 5.02 | 5.02 | 5.02 | 0.35 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 4.93 | 4.93 | 4.93 | 0.35 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.86 | 4.86 | 4.86 | 0.35 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.62 | 4.62 | 4.62 | 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:3871

Calibration Parameter Determined in Body Tissue Simulating Media

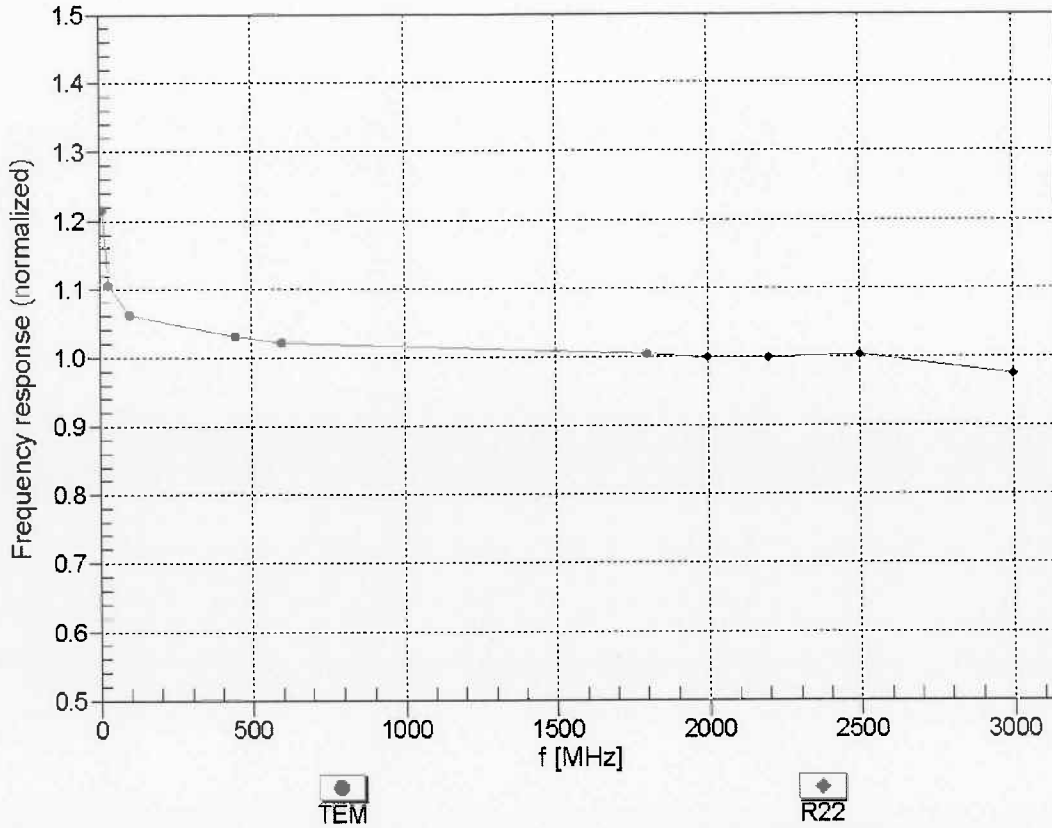
| f (MHz) ^C | Relative Permittivity ^F | Conductivity (S/m) ^F | ConvF X | ConvF Y | ConvF Z | Alpha ^G | Depth ^G (mm) | Unct. (k=2) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 56.7 | 0.94 | 11.23 | 11.23 | 11.23 | 0.06 | 1.20 | ± 13.3 % |
| 750 | 55.5 | 0.96 | 9.73 | 9.73 | 9.73 | 0.30 | 0.99 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 9.59 | 9.59 | 9.59 | 0.36 | 1.03 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 9.53 | 9.53 | 9.53 | 0.58 | 0.74 | ± 12.0 % |
| 1450 | 54.0 | 1.30 | 8.52 | 8.52 | 8.52 | 0.25 | 1.15 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 8.54 | 8.54 | 8.54 | 0.72 | 0.65 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 8.05 | 8.05 | 8.05 | 0.56 | 0.74 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.77 | 7.77 | 7.77 | 0.38 | 0.85 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 8.07 | 8.07 | 8.07 | 0.31 | 1.04 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 7.94 | 7.94 | 7.94 | 0.48 | 0.75 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 7.68 | 7.68 | 7.68 | 0.76 | 0.59 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.47 | 7.47 | 7.47 | 0.76 | 0.55 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 7.41 | 7.41 | 7.41 | 0.80 | 0.50 | ± 12.0 % |
| 3500 | 51.3 | 3.31 | 6.68 | 6.68 | 6.68 | 0.37 | 1.15 | ± 13.1 % |
| 3700 | 51.0 | 3.55 | 6.67 | 6.67 | 6.67 | 0.44 | 0.95 | ± 13.1 % |
| 4950 | 49.4 | 5.01 | 4.91 | 4.91 | 4.91 | 0.40 | 1.90 | ± 13.1 % |
| 5200 | 49.0 | 5.30 | 4.69 | 4.69 | 4.69 | 0.40 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.50 | 4.50 | 4.50 | 0.40 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 4.24 | 4.24 | 4.24 | 0.45 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 4.06 | 4.06 | 4.06 | 0.45 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 4.24 | 4.24 | 4.24 | 0.45 | 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)

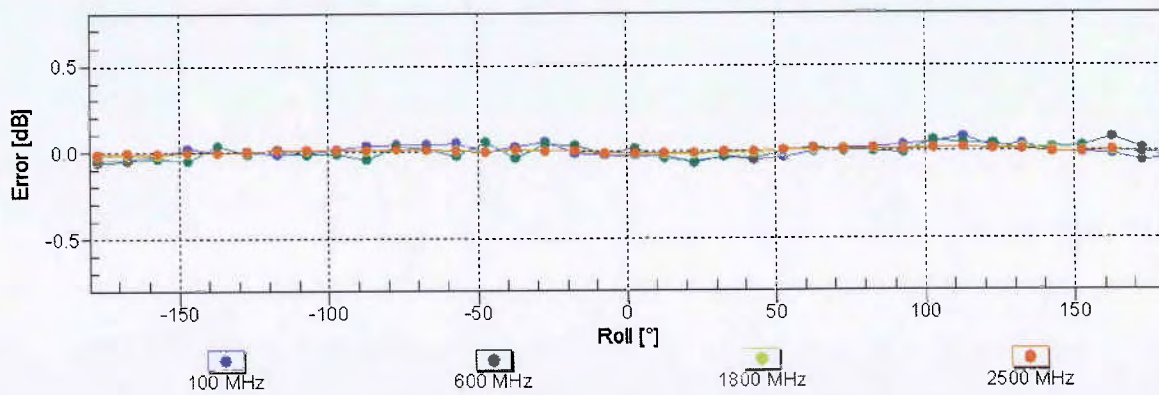
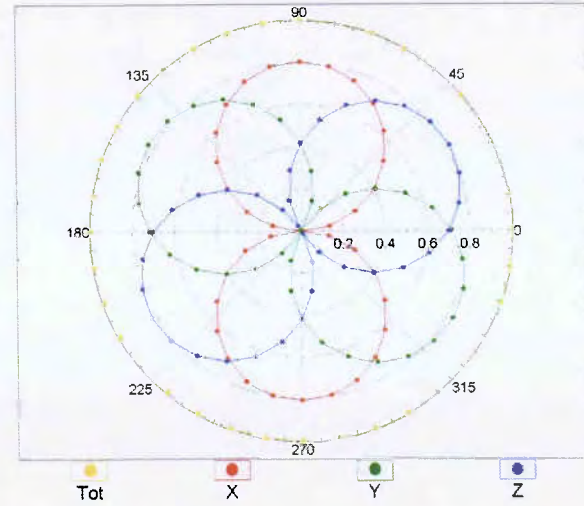
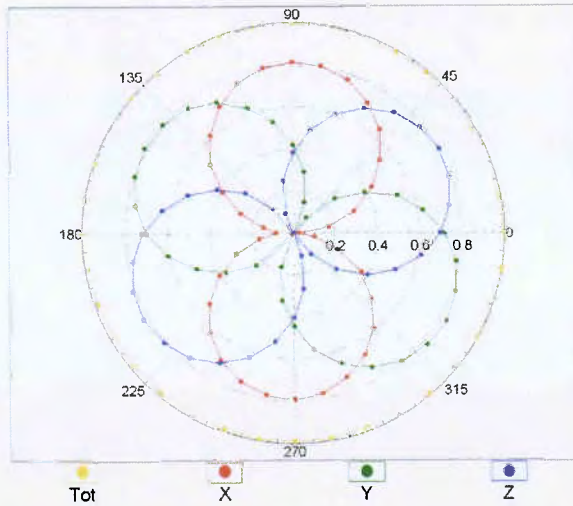


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

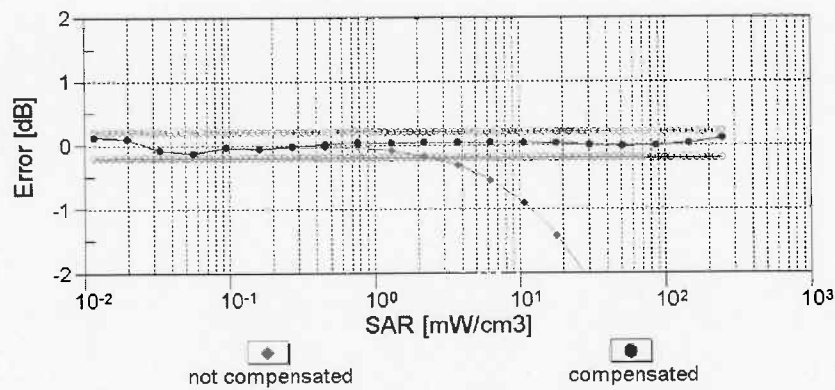
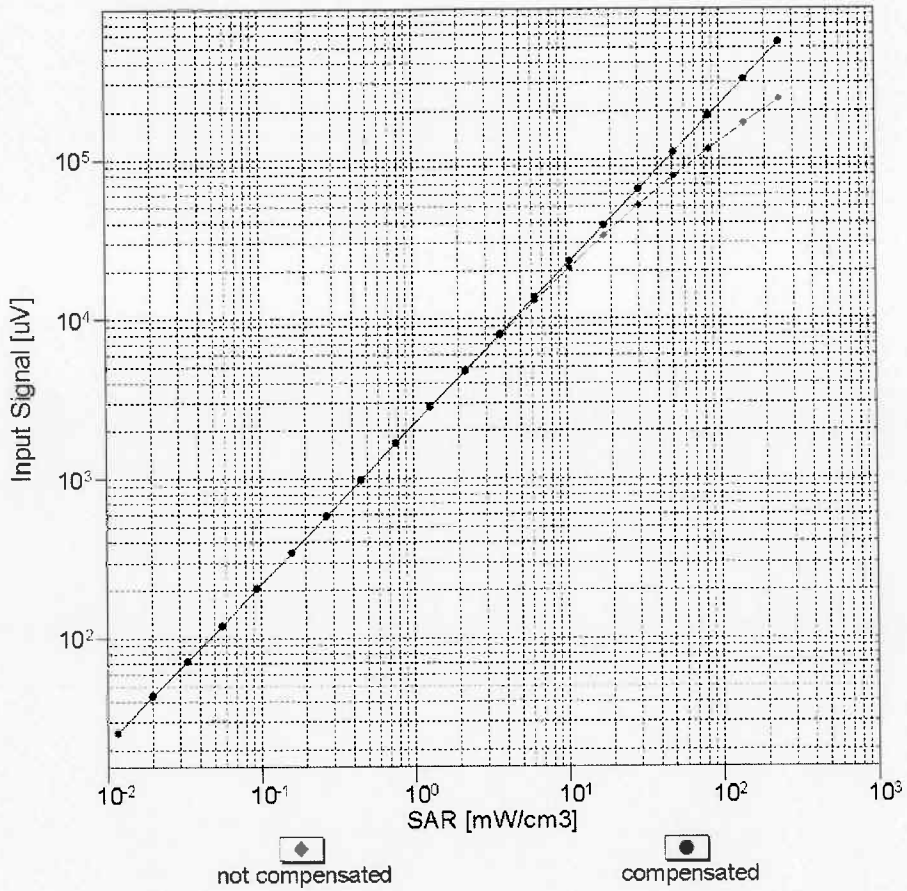
f=600 MHz, TEM

f=1800 MHz, R22



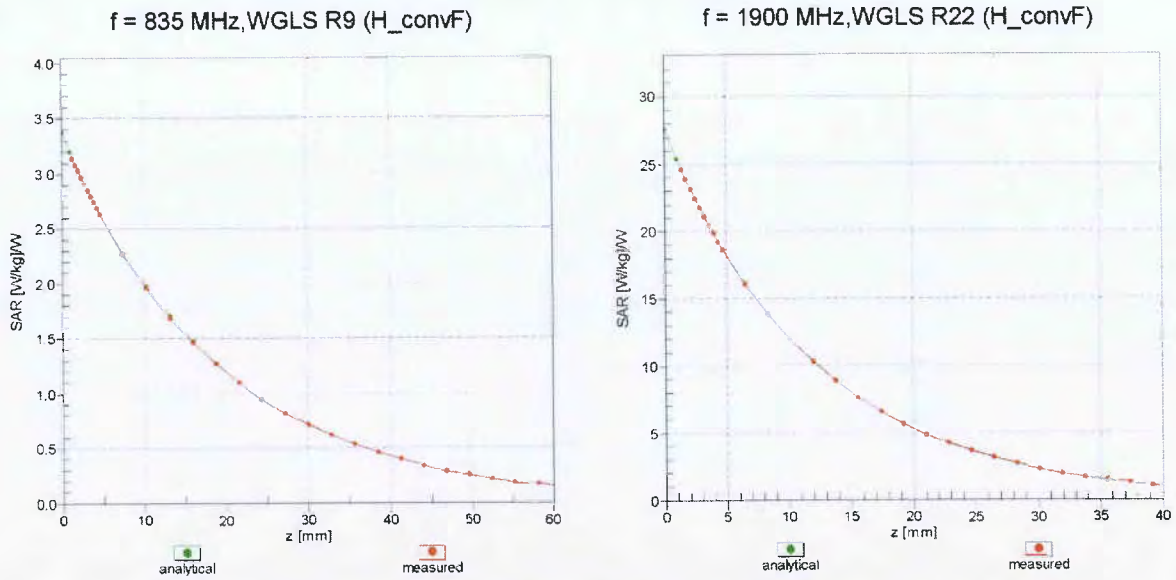
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

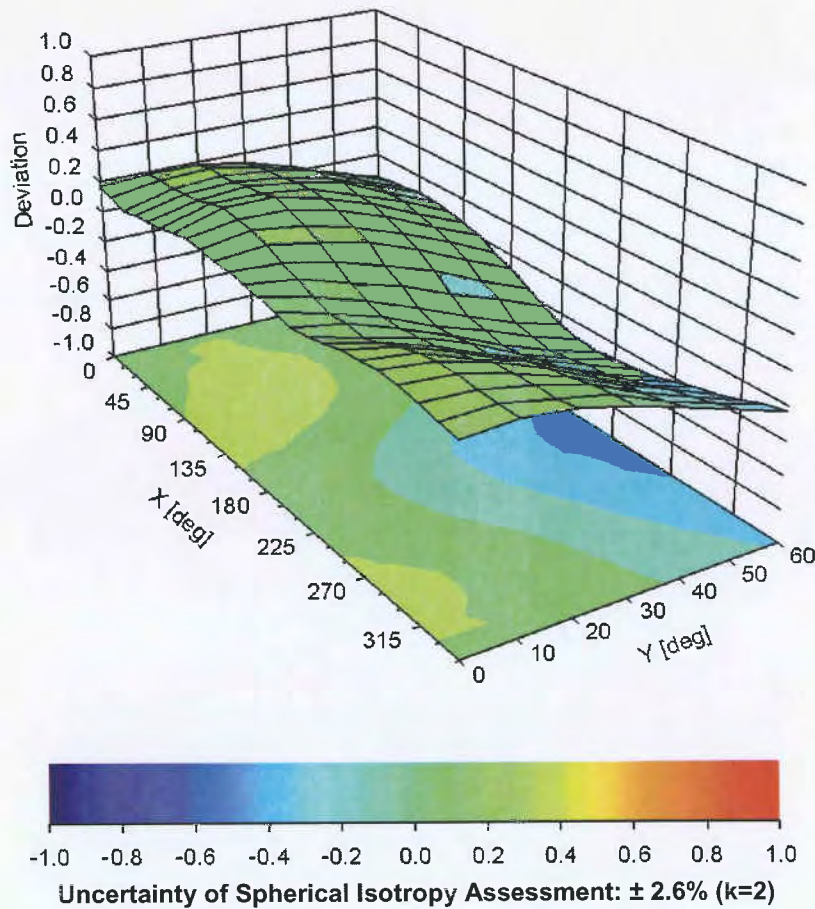


Uncertainty of Linearity Assessment: $\pm 0.6\%$ (k=2)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:3871**Other Probe Parameters**

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -17.2 |
| 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 108

Client **UL CCS USA**

Certificate No: **EX3-3773_Apr14**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3773**

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, 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 23, 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:3773

Manufactured: January 10, 2011
Calibrated: April 22, 2014

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 | 0.57 | 0.56 | 0.52 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 98.9 | 98.0 | 100.8 | |

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 | 149.1 | $\pm 3.5 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 145.4 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 147.5 | |

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: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) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 43.5 | 0.87 | 10.03 | 10.03 | 10.03 | 0.18 | 1.20 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 9.34 | 9.34 | 9.34 | 0.23 | 1.26 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 8.91 | 8.91 | 8.91 | 0.34 | 0.92 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 8.75 | 8.75 | 8.75 | 0.22 | 1.23 | ± 12.0 % |
| 1450 | 40.5 | 1.20 | 7.76 | 7.76 | 7.76 | 0.80 | 0.61 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 7.52 | 7.52 | 7.52 | 0.76 | 0.61 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 7.44 | 7.44 | 7.44 | 0.68 | 0.70 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 7.26 | 7.26 | 7.26 | 0.47 | 0.82 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 7.01 | 7.01 | 7.01 | 0.72 | 0.66 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 7.21 | 7.21 | 7.21 | 0.44 | 0.86 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 6.90 | 6.90 | 6.90 | 0.34 | 1.02 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 6.52 | 6.52 | 6.52 | 0.35 | 1.08 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 6.37 | 6.37 | 6.37 | 0.29 | 1.36 | ± 12.0 % |
| 3500 | 37.9 | 2.91 | 6.55 | 6.55 | 6.55 | 0.46 | 0.89 | ± 13.1 % |
| 3700 | 37.7 | 3.12 | 6.20 | 6.20 | 6.20 | 0.44 | 0.93 | ± 13.1 % |
| 4950 | 36.3 | 4.40 | 4.99 | 4.99 | 4.99 | 0.25 | 1.80 | ± 13.1 % |
| 5200 | 36.0 | 4.66 | 4.88 | 4.88 | 4.88 | 0.30 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 4.69 | 4.69 | 4.69 | 0.30 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 4.60 | 4.60 | 4.60 | 0.30 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.33 | 4.33 | 4.33 | 0.35 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.36 | 4.36 | 4.36 | 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: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) |
|----------------------|------------------------------------|---------------------------------|---------|---------|---------|--------------------|-------------------------|-------------|
| 450 | 56.7 | 0.94 | 10.02 | 10.02 | 10.02 | 0.10 | 1.20 | ± 13.3 % |
| 750 | 55.5 | 0.96 | 8.79 | 8.79 | 8.79 | 0.30 | 1.07 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 8.77 | 8.77 | 8.77 | 0.52 | 0.80 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 8.58 | 8.58 | 8.58 | 0.40 | 0.86 | ± 12.0 % |
| 1450 | 54.0 | 1.30 | 7.38 | 7.38 | 7.38 | 0.23 | 1.20 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 7.59 | 7.59 | 7.59 | 0.63 | 0.66 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 7.13 | 7.13 | 7.13 | 0.34 | 0.96 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 6.90 | 6.90 | 6.90 | 0.39 | 0.89 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 7.18 | 7.18 | 7.18 | 0.44 | 0.81 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 7.03 | 7.03 | 7.03 | 0.39 | 0.87 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 6.78 | 6.78 | 6.78 | 0.63 | 0.66 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 6.67 | 6.67 | 6.67 | 0.78 | 0.61 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.44 | 6.44 | 6.44 | 0.80 | 0.50 | ± 12.0 % |
| 3500 | 51.3 | 3.31 | 5.95 | 5.95 | 5.95 | 0.44 | 1.06 | ± 13.1 % |
| 3700 | 51.0 | 3.55 | 5.97 | 5.97 | 5.97 | 0.41 | 1.09 | ± 13.1 % |
| 4950 | 49.4 | 5.01 | 4.40 | 4.40 | 4.40 | 0.30 | 1.90 | ± 13.1 % |
| 5200 | 49.0 | 5.30 | 4.39 | 4.39 | 4.39 | 0.35 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.19 | 4.19 | 4.19 | 0.35 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 3.92 | 3.92 | 3.92 | 0.40 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.75 | 3.75 | 3.75 | 0.40 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 4.12 | 4.12 | 4.12 | 0.40 | 1.90 | ± 13.1 % |

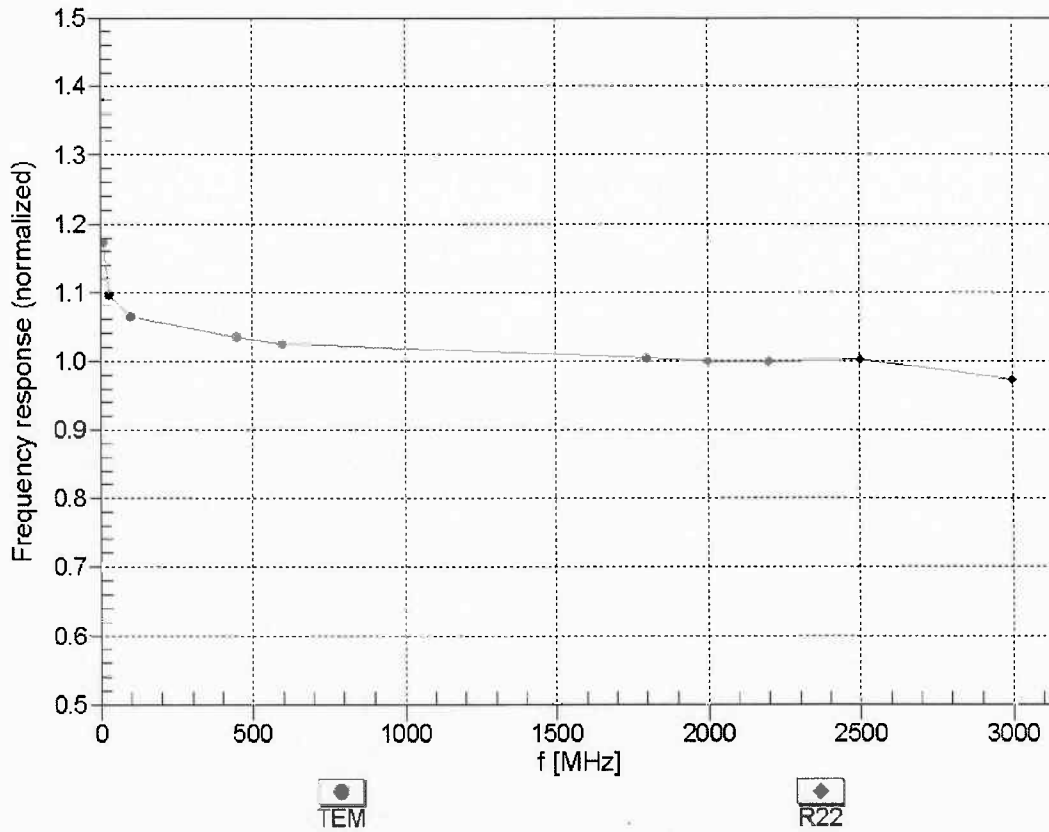
^C Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.

^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 diameter from the boundary.

Frequency Response of E-Field

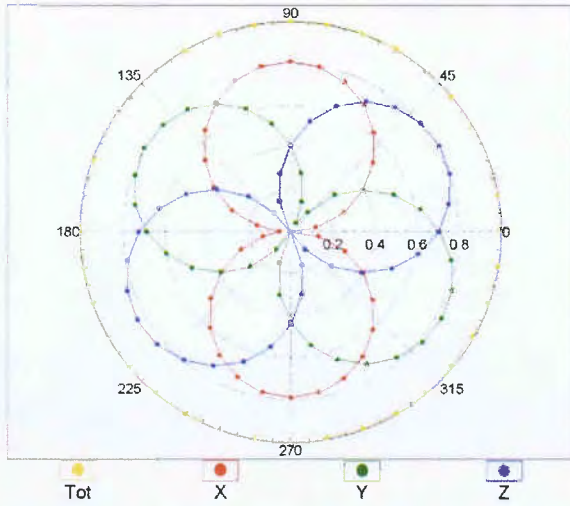
(TEM-Cell:ifi110 EXX, Waveguide: R22)



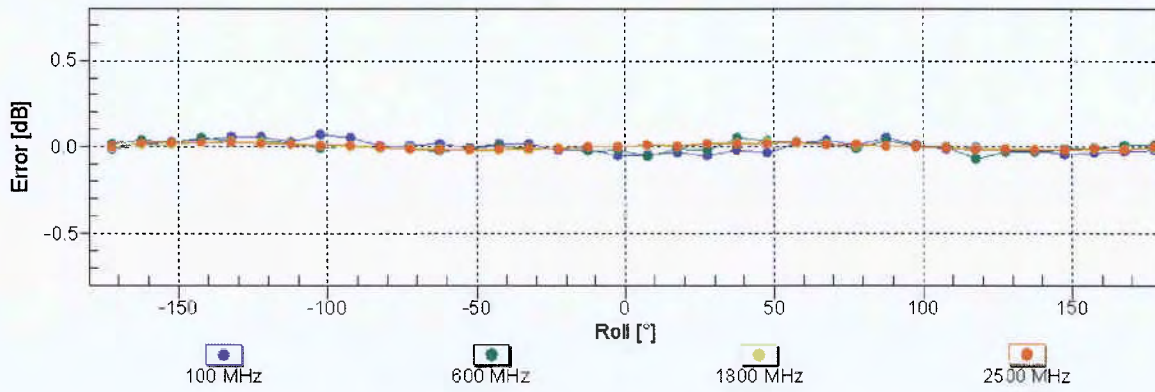
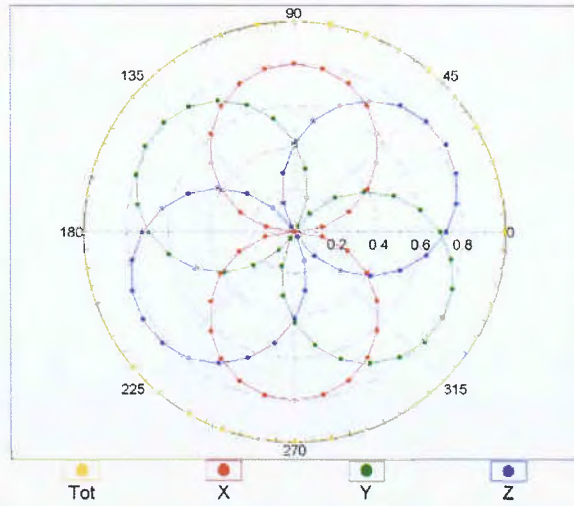
Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ ($k=2$)

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

f=600 MHz,TEM

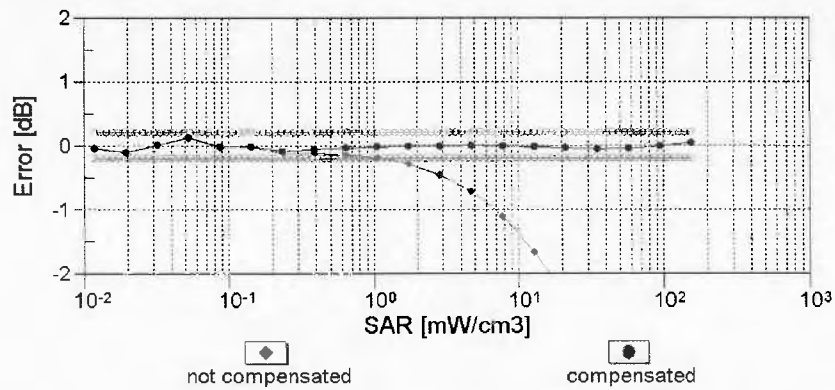
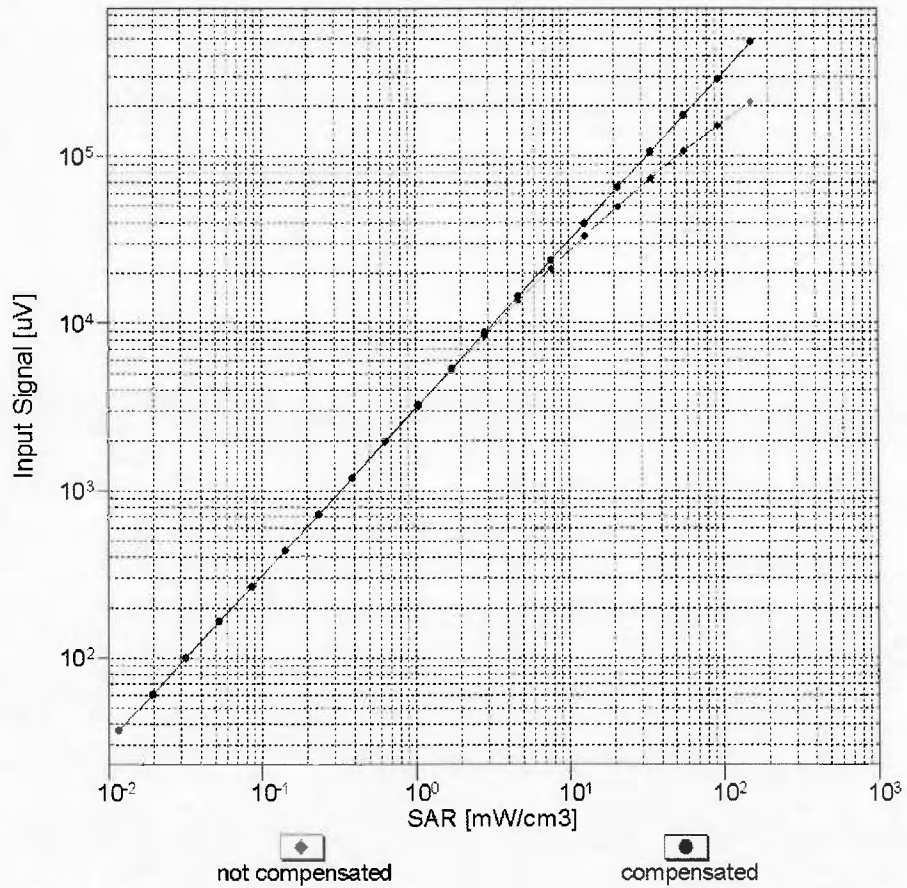


f=1800 MHz,R22



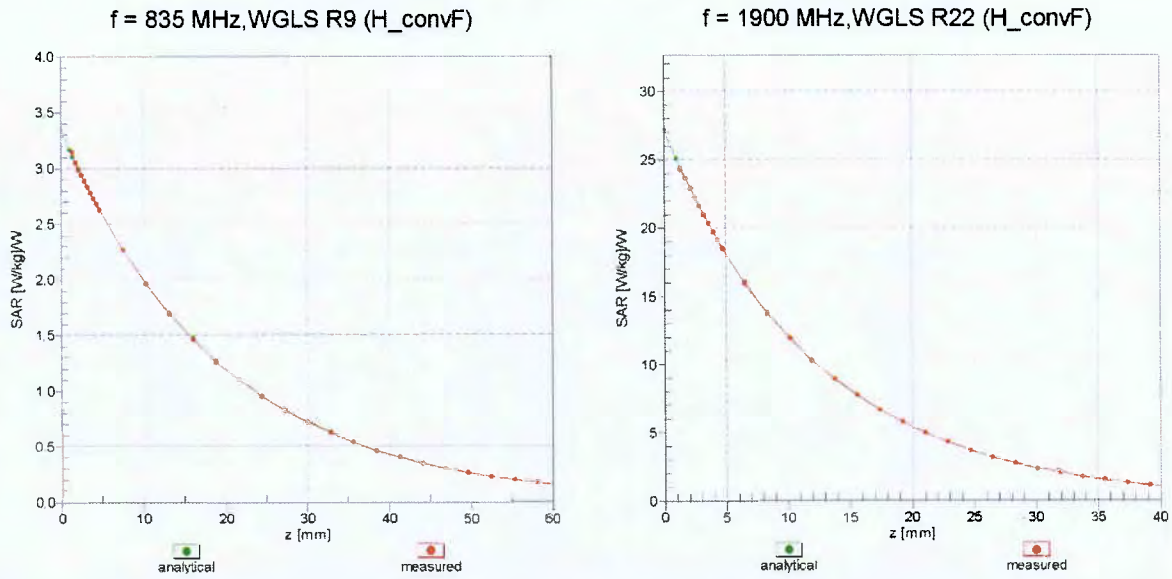
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

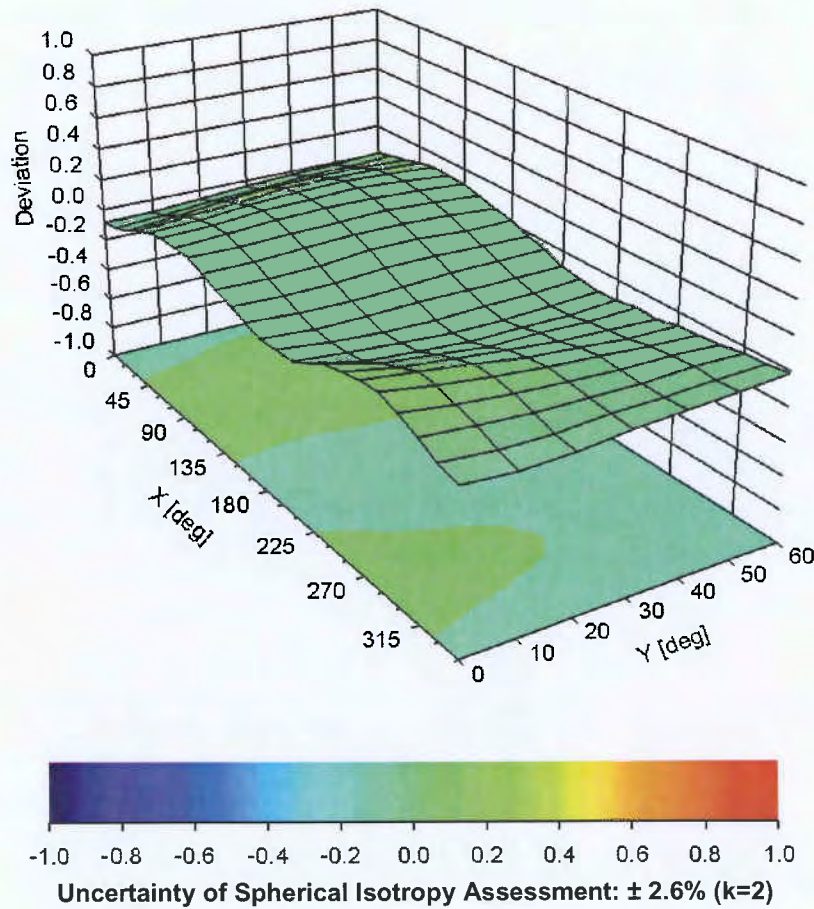


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment



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



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

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -22.3 |
| 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 | 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: **EX3-3929_May14**

CALIBRATION CERTIFICATE

Object: **EX3DV4 - SN:3929**

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: **May 9, 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: May 10, 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**

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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:3929

Manufactured: March 8, 2013
Calibrated: May 9, 2014

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3929

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|---------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.55 | 0.50 | 0.40 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 95.6 | 95.0 | 94.4 | |

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 | 125.4 | $\pm 2.7 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 138.3 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 138.9 | |

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 Norm X,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:3929

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 | 9.41 | 9.41 | 9.41 | 0.46 | 0.84 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 9.01 | 9.01 | 9.01 | 0.54 | 0.76 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 8.89 | 8.89 | 8.89 | 0.64 | 0.70 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 7.84 | 7.84 | 7.84 | 0.56 | 0.80 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 7.56 | 7.56 | 7.56 | 0.46 | 0.92 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 7.23 | 7.23 | 7.23 | 0.37 | 1.04 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 6.95 | 6.95 | 6.95 | 0.49 | 0.88 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 7.11 | 7.11 | 7.11 | 0.30 | 1.24 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 6.75 | 6.75 | 6.75 | 0.25 | 1.34 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 6.56 | 6.56 | 6.56 | 0.28 | 1.25 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 6.37 | 6.37 | 6.37 | 0.25 | 1.38 | ± 12.0 % |
| 5200 | 36.0 | 4.66 | 4.80 | 4.80 | 4.80 | 0.35 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 4.60 | 4.60 | 4.60 | 0.40 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 4.56 | 4.56 | 4.56 | 0.40 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.36 | 4.36 | 4.36 | 0.40 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.30 | 4.30 | 4.30 | 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. Above 5 GHz frequency validity can be extended to ± 110 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:3929

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 | 9.20 | 9.20 | 9.20 | 0.26 | 1.25 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 9.21 | 9.21 | 9.21 | 0.80 | 0.65 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 8.98 | 8.98 | 8.98 | 0.44 | 0.85 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 7.90 | 7.90 | 7.90 | 0.30 | 1.00 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 7.47 | 7.47 | 7.47 | 0.51 | 0.77 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.25 | 7.25 | 7.25 | 0.30 | 1.00 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 7.45 | 7.45 | 7.45 | 0.57 | 0.73 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 7.41 | 7.41 | 7.41 | 0.38 | 0.90 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 7.11 | 7.11 | 7.11 | 0.51 | 0.74 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 6.91 | 6.91 | 6.91 | 0.68 | 0.61 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.64 | 6.64 | 6.64 | 0.80 | 0.50 | ± 12.0 % |
| 5200 | 49.0 | 5.30 | 4.19 | 4.19 | 4.19 | 0.50 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.04 | 4.04 | 4.04 | 0.50 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 3.82 | 3.82 | 3.82 | 0.50 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.66 | 3.66 | 3.66 | 0.50 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 3.90 | 3.90 | 3.90 | 0.50 | 1.90 | ± 13.1 % |

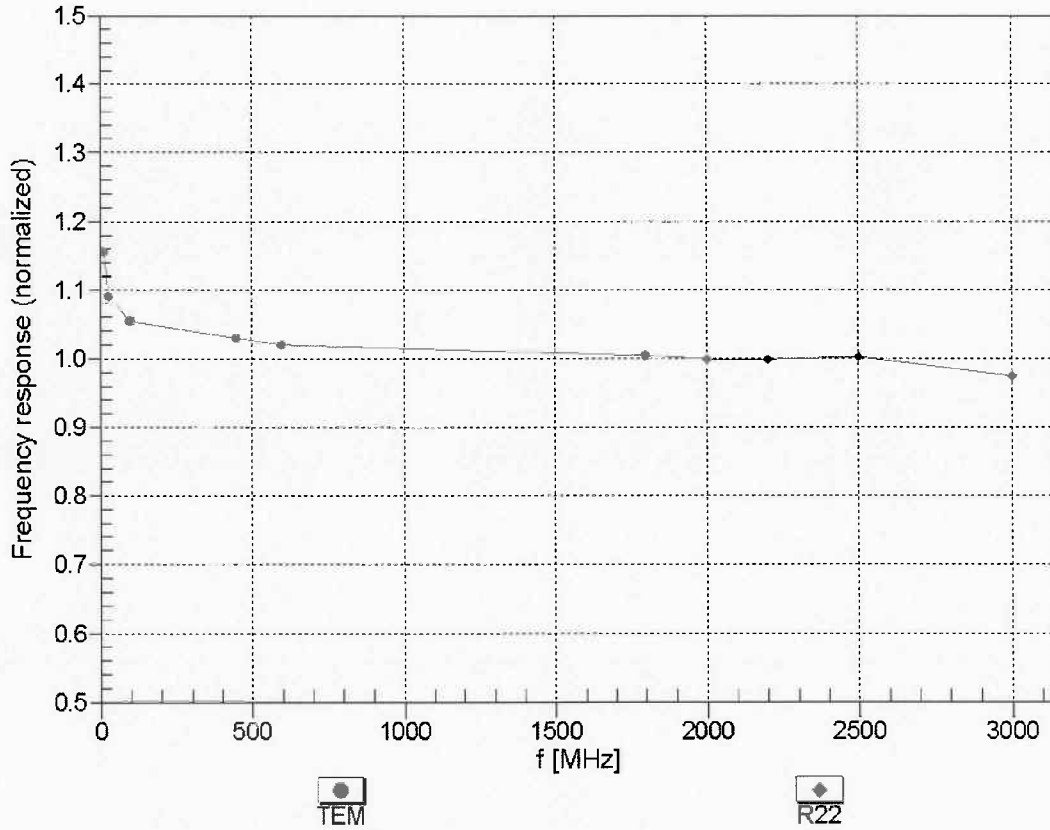
^C Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency 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)

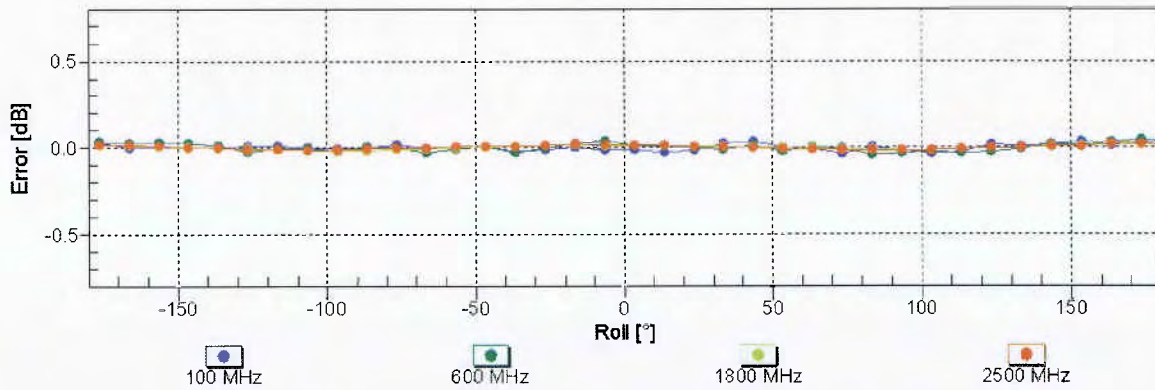
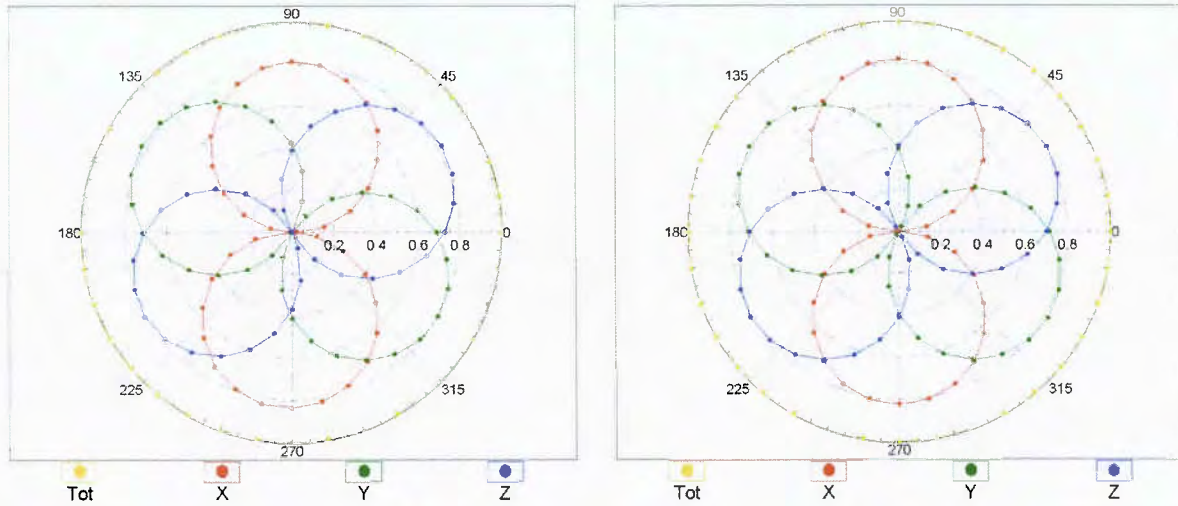


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

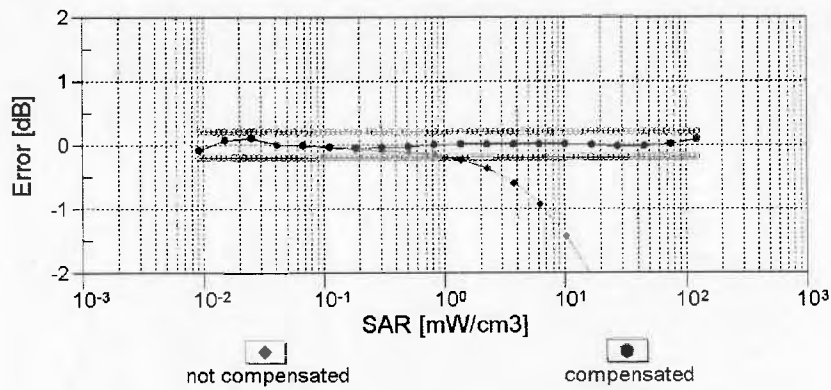
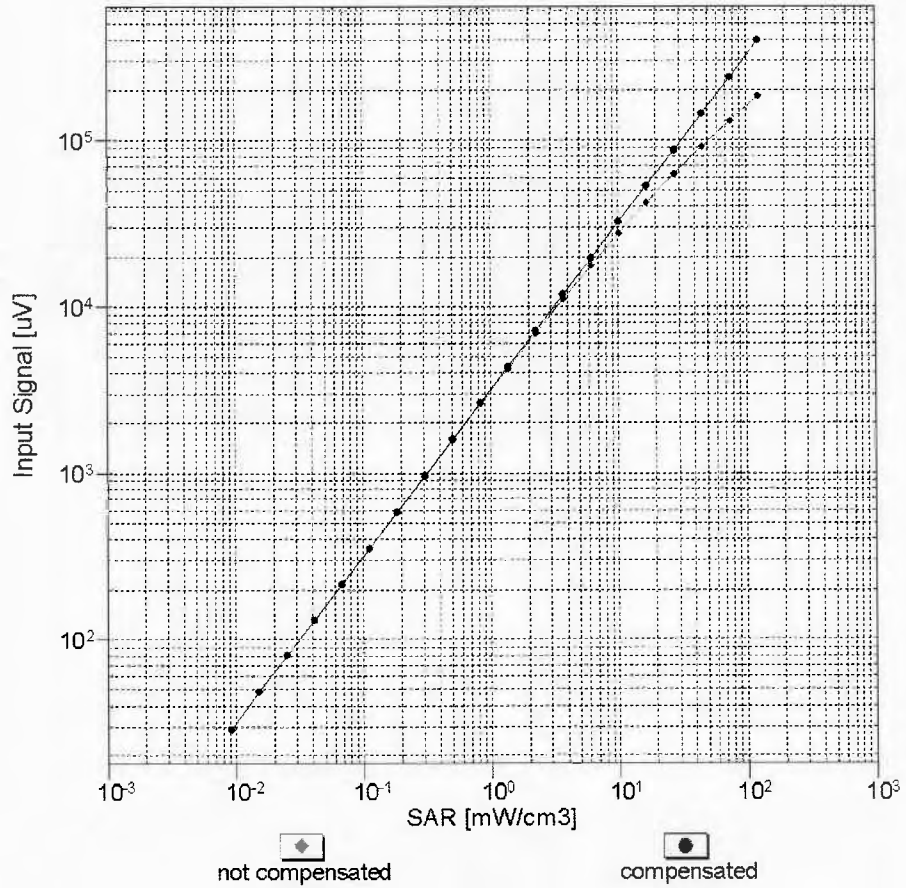
f=600 MHz,TEM

f=1800 MHz,R22



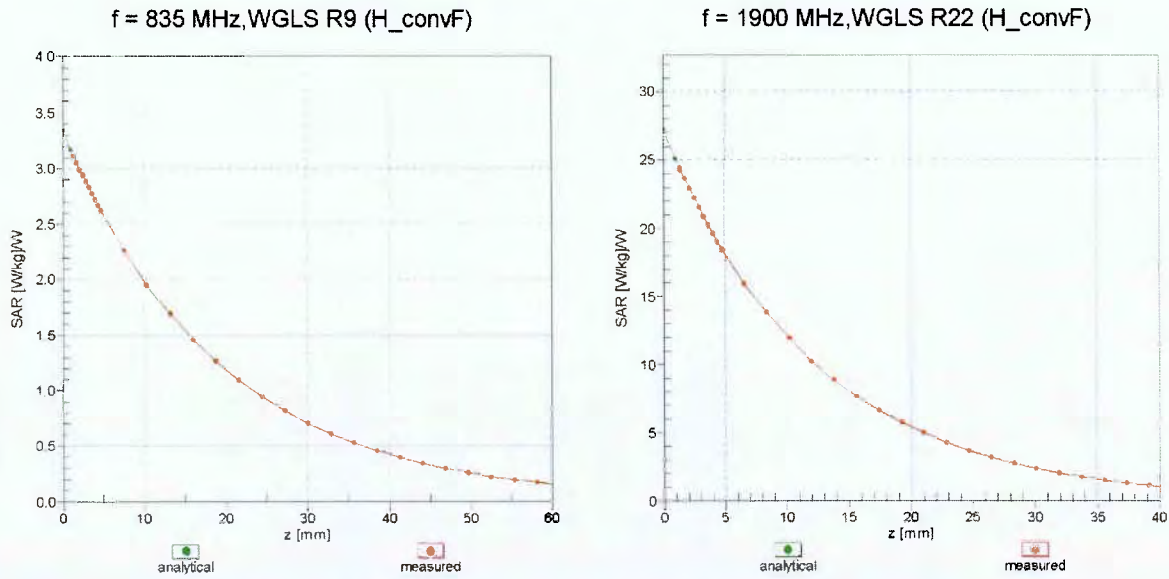
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

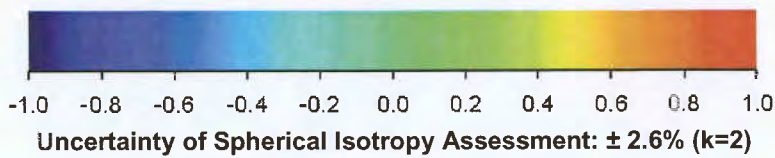
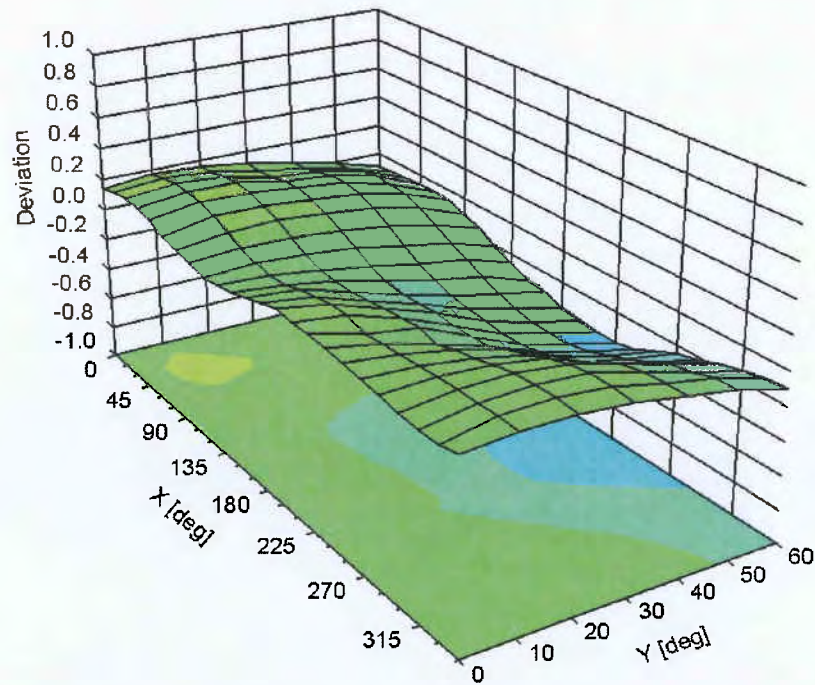


Uncertainty of Linearity Assessment: $\pm 0.6\%$ ($k=2$)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:3929

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -16.5 |
| 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 |

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USAGE OF ORGANIC SOLVENTS WITH SPEAG PRODUCTS

INTRODUCTION

SPEAG offers a wide range of simulating liquids. These liquids are based on various ingredients depending on their frequency range. The below compatibility table shows compatibility of SPEAG products used in conjunction with tissue simulating liquids. Proper treatment and maintenance of all SPEAG products is essential regardless of its compliance status.

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. Continuous exposure will reduce the item life-time drastically and will therefore void any warranty. 100 hours per 7 days maximum exposure.
R= **restricted** compatibility with the respective tissue simulating liquid. Short time exposure of less than 4 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 will cause irreparable damage to the item exposed.

| SPEAG MSDS Liquid Type Probes & Phantoms | 772-SLAAx0yy | | | 772-SLAAx1yy | | | 772-SLAAx4yy | | 772-SLAAx6yy | | 772-SLAAx6yy | | | 3rd Party Liquids | | |
|--|--------------|----------------------|----------------------|------------------------|------------------------|----------------------------|---------------------------|--------------------------------------|------------------------------------|---------------|--------------|--|---|----------------------|-------|----------|
| | B 900 | HSL175V2 to HSL900V2 | MSL300V2 to MSL900V2 | HSL1450V2 to HSL2450V2 | MSL1450V2 to MSL2450V2 | HIBBL3500-5800V5 Broadband | MBBL3500-5800V5 Broadband | HIBBL1350-1850V3 to HIBBL1900-3800V3 | MBBL1350-1850V3 to MBBL1900-3800V3 | HIBBL30-250V3 | | | | Triton Based Liquids | Acids | Solvents |
| Twin SAM Phantom V4.0 | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| ELI Oval Phantom V4.0 | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| Flat Phantom V4.x / V5.x | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| Whole Body Mannequin | Y | Y | Y | R | R | Y | Y | Y | Y | Y | | | N | N | N | |
| SAM HEAD V4.5 | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| SAM HEAD V4.5 CTIA | Y | Y | Y | N | N | Y | Y | Y | Y | Y | | | N | N | N | |
| SAM HEAD V4.5 BS | | | | | | | | | | | | | | | | |
| SAM HEAD V6.0 / 6.1 | Y | Y | Y | R | R | Y | Y | Y | Y | Y | | | N | N | N | |
| Probe ER3DV6 / ET3DV6R | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| Probe ES3DVx / EX3DVx | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| Probe H3DV6 and higher | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| Probe EU2DVx / HU2DVx | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| Probe ET1DVx | Y | Y | Y | R | R | Y | Y | Y | Y | Y | | | N | N | N | |
| Probe T1V3 / T1V3 Lab | Y | Y | Y | R | R | Y | Y | Y | Y | Y | | | N | N | N | |
| PEX 150 / 300 Probe Extension | Y | Y | Y | P | P | Y | Y | Y | Y | Y | | | N | N | N | |
| Probes in PMMA enclosures | Y | Y | Y | N | N | Y | Y | Y | Y | Y | | | N | N | N | |
| ASTM Phantom | Y | Y | Y | N | N | Y | Y | Y | Y | Y | | | N | N | N | |
| ELIT 1.5 / 3.0T Phantom | Y | Y | Y | N | N | Y | Y | Y | Y | Y | | | N | N | N | |

IMPORTANT NOTE FOR PROBES: The probe shall not be exposed to solvents longer than necessary for the measurements and shall be cleaned daily after use with warm water and stored dry.

IMPORTANT NOTE FOR PHANTOMS: Phantoms shall not be exposed to solvents longer than necessary for the measurement. After use, they shall be washed in the inside with clean water and stored dry. Any damaging of the inner surface must be avoided. Once a week, also the outside of the phantom shell shall be washed with clean water and dried.



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: **EX3-3991_Ma14**

CALIBRATION CERTIFICATE

Object **EX3DV4 - SN:3991**

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: **May 16, 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: May 17, 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:

- 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 $\vartheta = 0$ ($f \leq 900$ 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 E^2 -field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)_{x,y,z} = NORM_{x,y,z} * frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of *ConvF*.
- *DCP_{x,y,z}*: DCP are numerical linearization parameters assessed based on the data of power sweep 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:3991

Manufactured: January 21, 2014
Calibrated: May 16, 2014

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

DASY/EASY - Parameters of Probe: EX3DV4 - SN:3991

Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|----------|----------|----------|---------------|
| Norm ($\mu\text{V}/(\text{V}/\text{m})^2$) ^A | 0.48 | 0.51 | 0.60 | $\pm 10.1 \%$ |
| DCP (mV) ^B | 99.9 | 101.6 | 99.2 | |

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 | 140.3 | $\pm 2.7 \%$ |
| | | Y | 0.0 | 0.0 | 1.0 | | 138.9 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 131.6 | |

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:3991

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 | 11.75 | 11.75 | 11.75 | 0.18 | 1.20 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 10.46 | 10.46 | 10.46 | 0.50 | 0.69 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 9.94 | 9.94 | 9.94 | 0.20 | 1.20 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 9.78 | 9.78 | 9.78 | 0.52 | 0.68 | ± 12.0 % |
| 1450 | 40.5 | 1.20 | 8.80 | 8.80 | 8.80 | 0.37 | 1.00 | ± 12.0 % |
| 1640 | 40.3 | 1.29 | 8.22 | 8.22 | 8.22 | 0.57 | 0.68 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.83 | 8.83 | 8.83 | 0.43 | 0.85 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.55 | 8.55 | 8.55 | 0.66 | 0.67 | ± 12.0 % |
| 1950 | 40.0 | 1.40 | 8.11 | 8.11 | 8.11 | 0.30 | 1.00 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 8.29 | 8.29 | 8.29 | 0.50 | 0.77 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 7.88 | 7.88 | 7.88 | 0.32 | 0.98 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.45 | 7.45 | 7.45 | 0.32 | 0.97 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.21 | 7.21 | 7.21 | 0.36 | 0.93 | ± 12.0 % |
| 3500 | 37.9 | 2.91 | 6.97 | 6.97 | 6.97 | 0.39 | 1.04 | ± 13.1 % |
| 3700 | 37.7 | 3.12 | 6.90 | 6.90 | 6.90 | 0.53 | 0.88 | ± 13.1 % |
| 4950 | 36.3 | 4.40 | 5.42 | 5.42 | 5.42 | 0.30 | 1.80 | ± 13.1 % |
| 5200 | 36.0 | 4.66 | 5.23 | 5.23 | 5.23 | 0.35 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 4.96 | 4.96 | 4.96 | 0.35 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 4.93 | 4.93 | 4.93 | 0.35 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.73 | 4.73 | 4.73 | 0.40 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.66 | 4.66 | 4.66 | 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. Above 5 GHz frequency validity can be extended to ± 110 MHz. 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.

^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:3991

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 | 11.38 | 11.38 | 11.38 | 0.10 | 1.20 | ± 13.3 % |
| 750 | 55.5 | 0.96 | 9.85 | 9.85 | 9.85 | 0.20 | 1.38 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 9.70 | 9.70 | 9.70 | 0.28 | 1.10 | ± 12.0 % |
| 900 | 55.0 | 1.05 | 9.49 | 9.49 | 9.49 | 0.65 | 0.73 | ± 12.0 % |
| 1450 | 54.0 | 1.30 | 8.33 | 8.33 | 8.33 | 0.31 | 1.02 | ± 12.0 % |
| 1640 | 53.8 | 1.40 | 8.28 | 8.28 | 8.28 | 0.52 | 0.76 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 8.08 | 8.08 | 8.08 | 0.51 | 0.86 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.65 | 7.65 | 7.65 | 0.35 | 0.97 | ± 12.0 % |
| 1950 | 53.3 | 1.52 | 7.88 | 7.88 | 7.88 | 0.34 | 0.87 | ± 12.0 % |
| 2000 | 53.3 | 1.52 | 7.76 | 7.76 | 7.76 | 0.44 | 0.75 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 7.45 | 7.45 | 7.45 | 0.61 | 0.68 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.23 | 7.23 | 7.23 | 0.71 | 0.59 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.98 | 6.98 | 6.98 | 0.80 | 0.50 | ± 12.0 % |
| 3500 | 51.3 | 3.31 | 6.83 | 6.83 | 6.83 | 0.39 | 1.10 | ± 13.1 % |
| 3700 | 51.0 | 3.55 | 6.77 | 6.77 | 6.77 | 0.32 | 1.20 | ± 13.1 % |
| 4950 | 49.4 | 5.01 | 4.79 | 4.79 | 4.79 | 0.35 | 1.90 | ± 13.1 % |
| 5200 | 49.0 | 5.30 | 4.66 | 4.66 | 4.66 | 0.40 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.47 | 4.47 | 4.47 | 0.40 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 4.13 | 4.13 | 4.13 | 0.45 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 4.41 | 4.41 | 4.41 | 0.25 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 4.32 | 4.32 | 4.32 | 0.45 | 1.90 | ± 13.1 % |

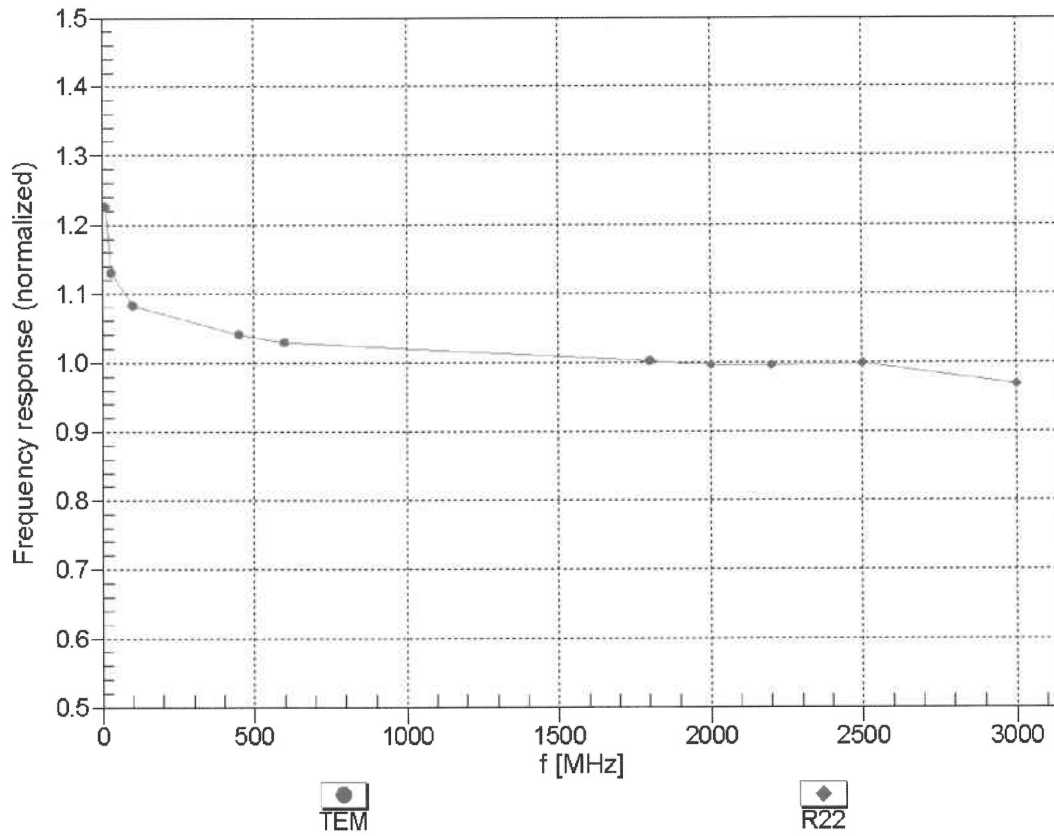
^C Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Above 5 GHz frequency validity can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

^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)

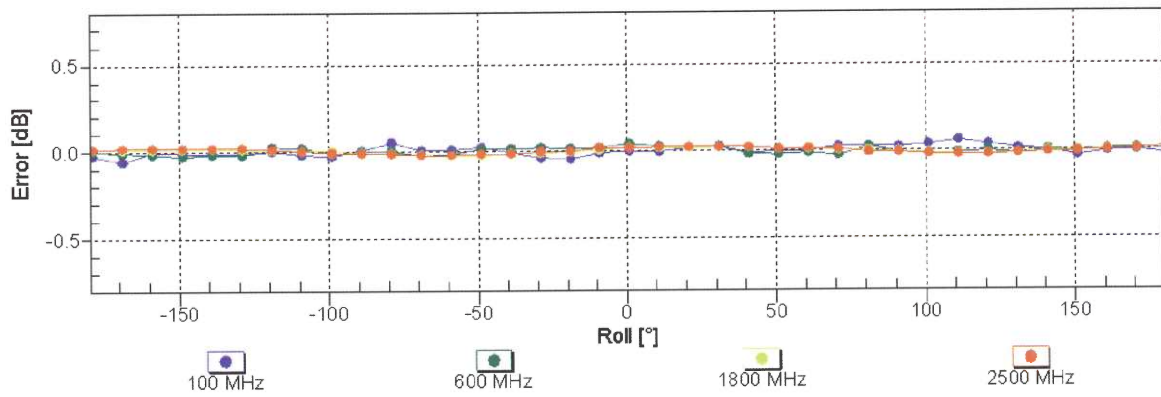
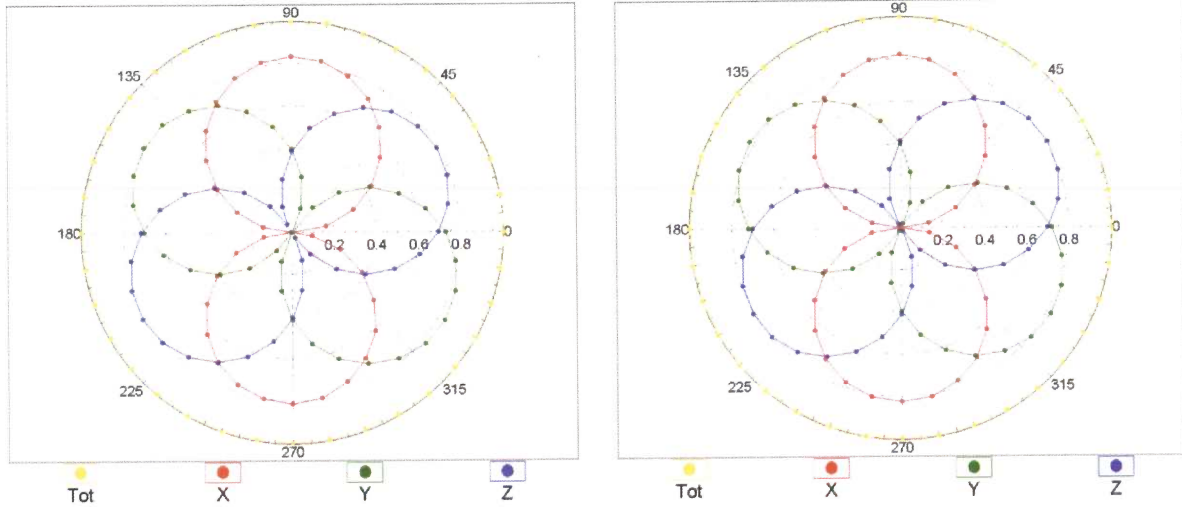


Uncertainty of Frequency Response of E-field: $\pm 6.3\%$ (k=2)

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

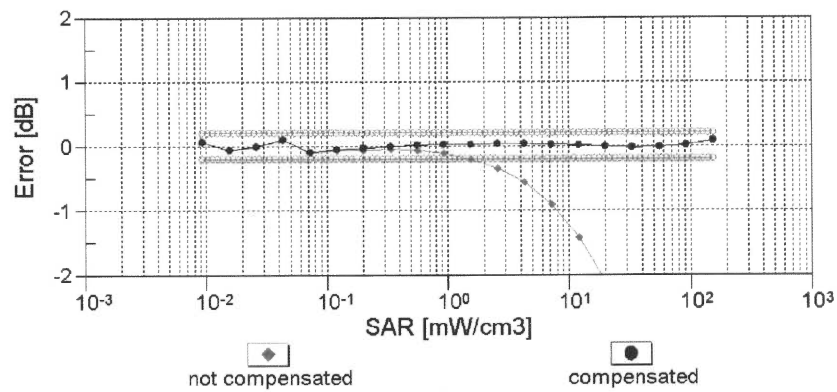
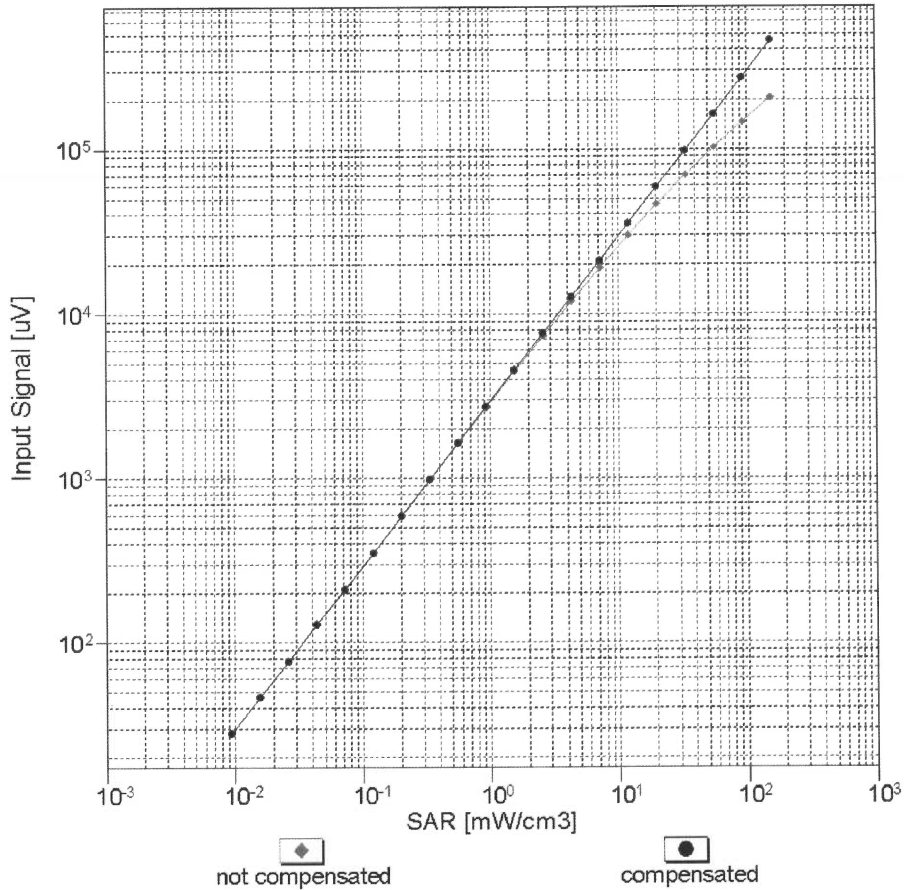
f=600 MHz,TEM

f=1800 MHz,R22



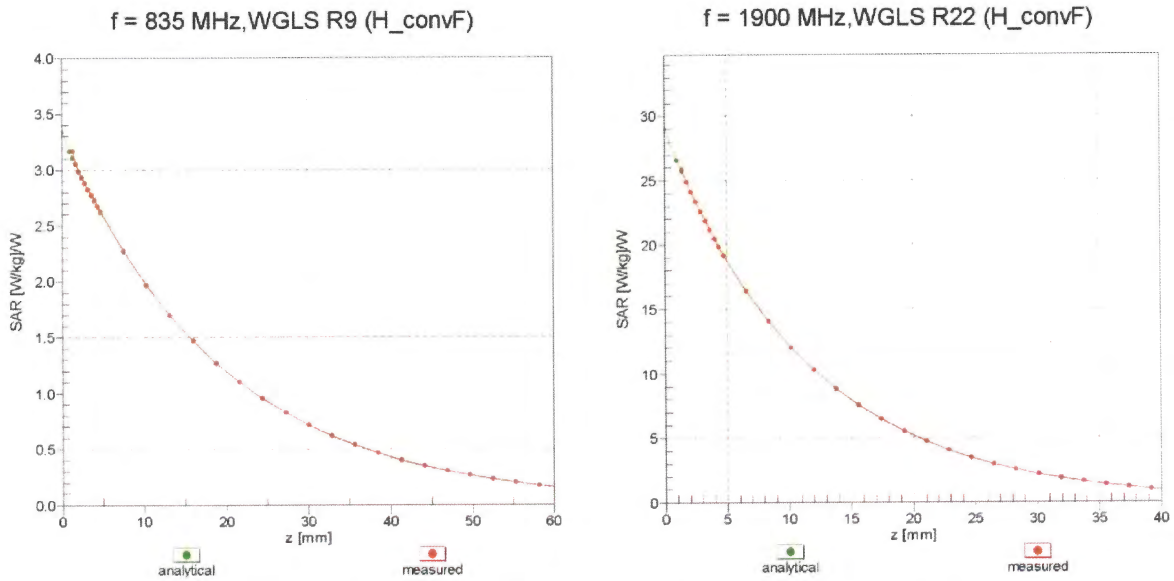
Uncertainty of Axial Isotropy Assessment: $\pm 0.5\%$ (k=2)

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

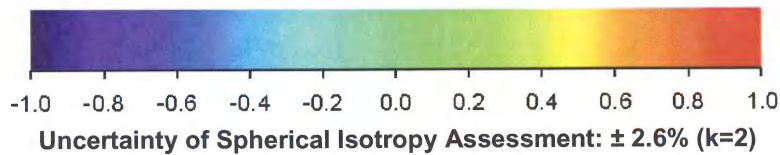
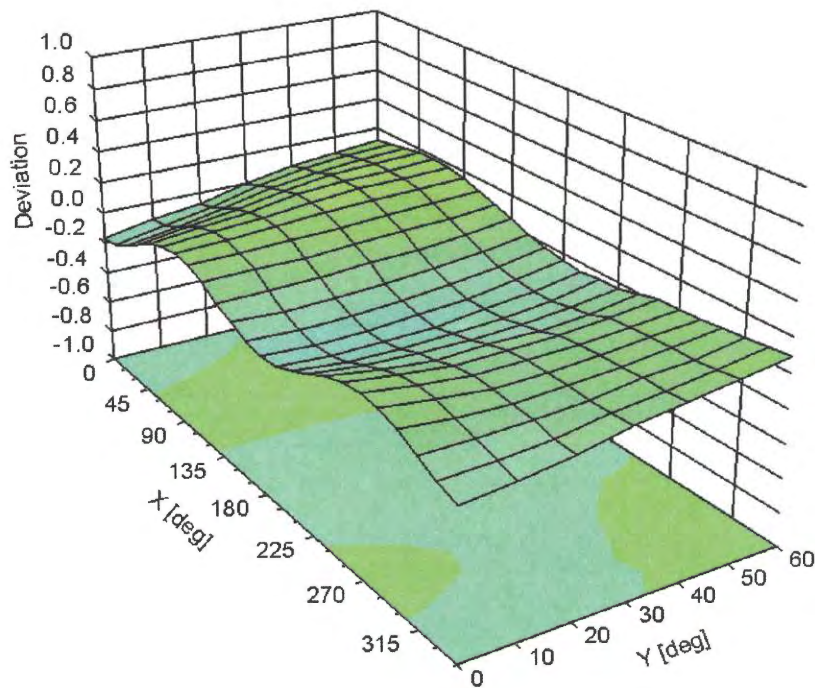


Uncertainty of Linearity Assessment: ± 0.6% (k=2)

Conversion Factor Assessment



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



DASY/EASY - Parameters of Probe: EX3DV4 - SN:3991

Other Probe Parameters

| | |
|---|------------|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | 1 |
| 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 |