## DC Voltage Measurement

A/D - Converter Resolution nominal

| | | | | |
|---|---|---|---|---|
| High Range: | 1LSB = | 6.1μV , | full range = | -100...+300 mV |
| Low Range: | 1LSB = | 61nV , | full range = | -1.....+3mV |

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| Calibration Factors | X | Y | Z |
|---|---|---|---|
| **High Range** | 404.160 ± 0.02% (k=2) | 404.976 ± 0.02% (k=2) | 405.094 ± 0.02% (k=2) |
| **Low Range** | 4.00057 ± 1.50% (k=2) | 3.98261 ± 1.50% (k=2) | 4.00043 ± 1.50% (k=2) |

## Connector Angle

| | |
|---|---|
| **Connector Angle** to be used in DASY system | 345.5 ° ± 1 ° |

## Appendix (Additional assessments outside the scope of SCS0108)

### 1. DC Voltage Linearity

| High Range | | Reading (μV) | Difference (μV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 199991.51 | -3.59 | -0.00 |
| Channel X | + Input | 20002.42 | 1.17 | 0.01 |
| Channel X | - Input | -19999.76 | 2.07 | -0.01 |
| Channel Y | + Input | 199990.24 | -4.87 | -0.00 |
| Channel Y | + Input | 20000.15 | -1.16 | -0.01 |
| Channel Y | - Input | -20001.02 | 0.85 | -0.00 |
| Channel Z | + Input | 199993.15 | -1.62 | -0.00 |
| Channel Z | + Input | 20000.24 | -1.01 | -0.01 |
| Channel Z | - Input | -20002.77 | -0.77 | 0.00 |

| Low Range | | Reading (μV) | Difference (μV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 2000.98 | 0.24 | 0.01 |
| Channel X | + Input | 201.15 | 0.18 | 0.09 |
| Channel X | - Input | -198.49 | 0.30 | -0.15 |
| Channel Y | + Input | 2000.93 | 0.15 | 0.01 |
| Channel Y | + Input | 201.11 | 0.10 | 0.05 |
| Channel Y | - Input | -199.20 | -0.34 | 0.17 |
| Channel Z | + Input | 2001.50 | 0.78 | 0.04 |
| Channel Z | + Input | 199.66 | -1.25 | -0.62 |
| Channel Z | - Input | -199.89 | -0.97 | 0.49 |

### 2. Common mode sensitivity

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| | Common mode Input Voltage (mV) | High Range Average Reading (μV) | Low Range Average Reading (μV) |
|---|---|---|---|
| Channel X | 200 | -6.73 | -8.02 |
| | - 200 | 8.24 | 6.60 |
| Channel Y | 200 | -8.48 | -8.76 |
| | - 200 | 8.37 | 8.32 |
| Channel Z | 200 | 11.47 | 11.82 |
| | - 200 | -14.71 | -14.52 |

### 3. Channel separation

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| | Input Voltage (mV) | Channel X (μV) | Channel Y (μV) | Channel Z (μV) |
|---|---|---|---|---|
| Channel X | 200 | - | 2.99 | -4.21 |
| Channel Y | 200 | 8.23 | - | 3.34 |
| Channel Z | 200 | 9.47 | 6.81 | - |

## 4. AD-Converter Values with inputs shorted

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| | High Range (LSB) | Low Range (LSB) |
|---|---|---|
| **Channel X** | 15963 | 16757 |
| **Channel Y** | 15963 | 16462 |
| **Channel Z** | 15874 | 16956 |

## 5. Input Offset Measurement

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec
Input 10MΩ

| | Average (μV) | min. Offset (μV) | max. Offset (μV) | Std. Deviation (μV) |
|---|---|---|---|---|
| **Channel X** | -1.06 | -2.29 | -0.14 | 0.43 |
| **Channel Y** | -0.26 | -1.46 | 1.12 | 0.48 |
| **Channel Z** | -0.17 | -1.06 | 1.57 | 0.45 |

## 6. Input Offset Current

Nominal Input circuitry offset current on all channels: <25fA

## 7. Input Resistance (Typical values for information)

| | Zeroing (kOhm) | Measuring (MOhm) |
|---|---|---|
| **Channel X** | 200 | 200 |
| **Channel Y** | 200 | 200 |
| **Channel Z** | 200 | 200 |

## 8. Low Battery Alarm Voltage (Typical values for information)

| Typical values | Alarm Level (VDC) |
|---|---|
| **Supply (+ Vcc)** | +7.9 |
| **Supply (- Vcc)** | -7.6 |

## 9. Power Consumption (Typical values for information)

| Typical values | Switched off (mA) | Stand by (mA) | Transmitting (mA) |
|---|---|---|---|
| **Supply (+ Vcc)** | +0.01 | +6 | +14 |
| **Supply (- Vcc)** | –0.01 | -8 | -9 |

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CNAS L0570

Client : **Sporton** **Certificate No: Z18-60487**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | DAE4 - SN: 1338 |
| Calibration Procedure(s) | FF-Z11-002-01<br>Calibration Procedure for the Data Acquisition Electronics (DAEx) |
| Calibration date: | December 03, 2018 |

This calibration Certificate documents the traceability to national standards, which realize the physical units of measurements(SI). The measurements and the uncertainties with confidence probability are given on the following pages and are part of the certificate.

All calibrations have been conducted in the closed laboratory facility: environment temperature(22±3)°C and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date(Calibrated by, Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Process Calibrator 753 | 1971018 | 20-Jun-18 (CTTL, No.J18X05034) | June-19 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Yu Zongying | SAR Test Engineer | |
| Reviewed by: | Lin Hao | SAR Test Engineer | |
| Approved by: | Qi Dianyuan | SAR Project Leader | |

Issued: December 05, 2018

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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**Glossary:**

| | |
|---|---|
| DAE | data acquisition electronics |
| Connector angle | information used in DASY system to align probe sensor X to the robot coordinate system. |

**Methods Applied and Interpretation of Parameters:**

- *DC Voltage Measurement*: Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.

- *Connector angle*: The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.

- The report provide only calibration results for DAE, it does not contain other performance test results.

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## DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1μV , full range = -100...+300 mV
Low Range: 1LSB = 61nV , full range = -1.....+3mV

DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| Calibration Factors | X | Y | Z |
|---|---|---|---|
| High Range | 403.662 ± 0.15% (k=2) | 404.235 ± 0.15% (k=2) | 404.194 ± 0.15% (k=2) |
| Low Range | 3.97131 ± 0.7% (k=2) | 3.97736 ± 0.7% (k=2) | 3.97366 ± 0.7% (k=2) |

## Connector Angle

| | |
|---|---|
| **Connector Angle** to be used in DASY system | 63.5° ± 1 ° |

**Calibration Laboratory of**
Schmid & Partner
Engineering AG
**Zeughausstrasse 43, 8004 Zurich, Switzerland**

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**Accreditation No.: SCS 0108**

**Client** **Sporton**

**Certificate No: ES3-3293_Oct18**

# CALIBRATION CERTIFICATE

Object: ES3DV3 - SN:3293

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

Calibration date: October 25, 2018

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 NRP | SN: 104778 | 04-Apr-18 (No. 217-02672/02673) | Apr-19 |
| Power sensor NRP-Z91 | SN: 103244 | 04-Apr-18 (No. 217-02672) | Apr-19 |
| Power sensor NRP-Z91 | SN: 103245 | 04-Apr-18 (No. 217-02673) | Apr-19 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-18 (No. 217-02682) | Apr-19 |
| Reference Probe ES3DV2 | SN: 3013 | 30-Dec-17 (No. ES3-3013_Dec17) | Dec-18 |
| DAE4 | SN: 660 | 21-Dec-17 (No. DAE4-660_Dec17) | Dec-18 |
| | | | |
| Secondary Standards | ID | Check Date (in house) | Scheduled Check |
| Power meter E4419B | SN: GB41293874 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: MY41498087 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: 000110210 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| RF generator HP 8648C | SN: US3642U01700 | 04-Aug-99 (in house check Jun-18) | In house check: Jun-20 |
| Network Analyzer E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-18) | In house check: Oct-19 |

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

Issued: October 25, 2018

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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**C** Service suisse d'étalonnage
**S** Servizio svizzero di taratura
Swiss Calibration Service

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

**Accreditation No.: SCS 0108**

## Glossary:

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

## Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
b) IEC 62209-1, ", "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
c) IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Methods Applied and Interpretation of Parameters:

- *NORMx,y,z*: Assessed for E-field polarization ϑ = 0 (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the $E^2$-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,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*.
- *DCPx,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
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z*: *A, B, C, D* are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. *VR* is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters:* Assessed in flat phantom using E-field (or Temperature Transfer Standard for f ≤ 800 MHz) and inside waveguide using analytical field distributions based on power measurements for f > 800 MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to *NORMx,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 *NORMx* (no uncertainty required).

# Probe ES3DV3

## SN:3293

| | |
|---|---|
| Manufactured: | July 6, 2010 |
| Repaired: | October 19,2018 |
| Calibrated: | October 25, 2018 |

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

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3293

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 1.09 | 0.90 | 0.73 | ± 10.1 % |
| DCP (mV)[B] | 104.3 | 103.5 | 107.8 | |

## Modulation Calibration Parameters

| UID | Communication System Name | | A dB | B dB√μV | C | D dB | VR mV | Unc[E] (k=2) |
|---|---|---|---|---|---|---|---|---|
| 0 | CW | X | 0.0 | 0.0 | 1.0 | 0.00 | 175.8 | ±3.0 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 175.7 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 187.4 | |

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: ES3DV3 - SN:3293

## 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) | Unc (k=2) |
|---|---|---|---|---|---|---|---|---|
| 750 | 41.9 | 0.89 | 6.78 | 6.78 | 6.78 | 0.80 | 1.20 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 6.47 | 6.47 | 6.47 | 0.44 | 1.60 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 6.34 | 6.34 | 6.34 | 0.80 | 1.20 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 5.40 | 5.40 | 5.40 | 0.76 | 1.20 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 5.19 | 5.19 | 5.19 | 0.59 | 1.36 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 5.17 | 5.17 | 5.17 | 0.60 | 1.41 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 4.83 | 4.83 | 4.83 | 0.72 | 1.31 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 4.53 | 4.53 | 4.53 | 0.80 | 1.23 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 4.44 | 4.44 | 4.44 | 0.80 | 1.31 | ± 12.0 % |

[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: ES3DV3 - SN:3293

## 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) | Unc (k=2) |
|---|---|---|---|---|---|---|---|---|
| 750 | 55.5 | 0.96 | 6.34 | 6.34 | 6.34 | 0.80 | 1.12 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 6.24 | 6.24 | 6.24 | 0.80 | 1.18 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 5.01 | 5.01 | 5.01 | 0.55 | 1.54 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 4.74 | 4.74 | 4.74 | 0.60 | 1.44 | ± 12.0 % |
| 2300 | 52.9 | 1.81 | 4.51 | 4.51 | 4.51 | 0.80 | 1.28 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 4.39 | 4.39 | 4.39 | 0.80 | 1.22 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 4.28 | 4.28 | 4.28 | 0.80 | 1.20 | ± 12.0 % |

[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.

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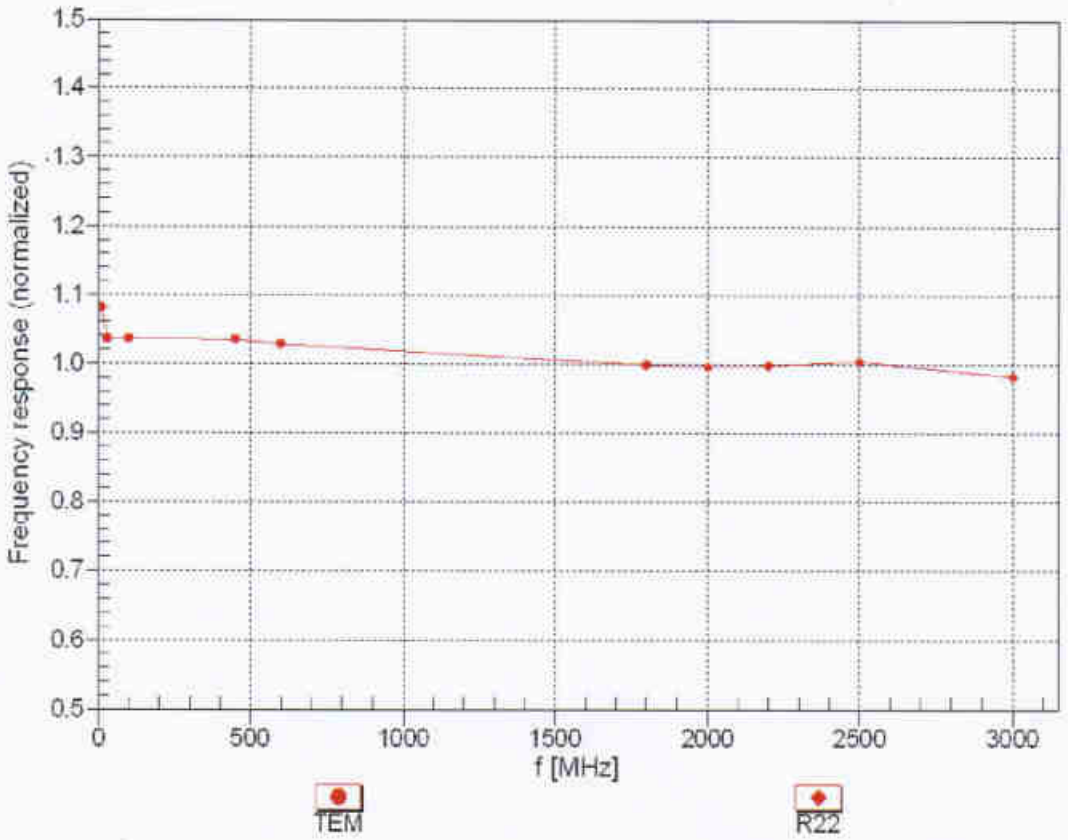
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from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

# Frequency Response of E-Field

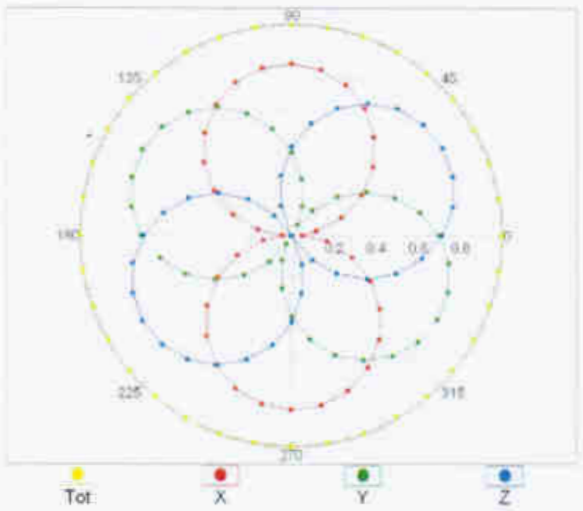
**(TEM-Cell:ifi110 EXX, Waveguide: R22)**



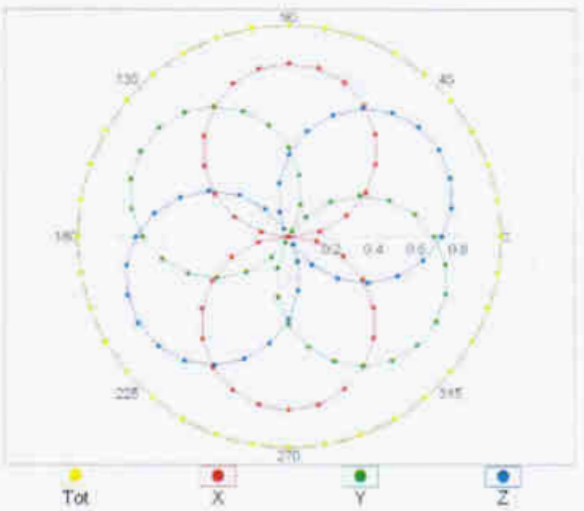

**Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)**

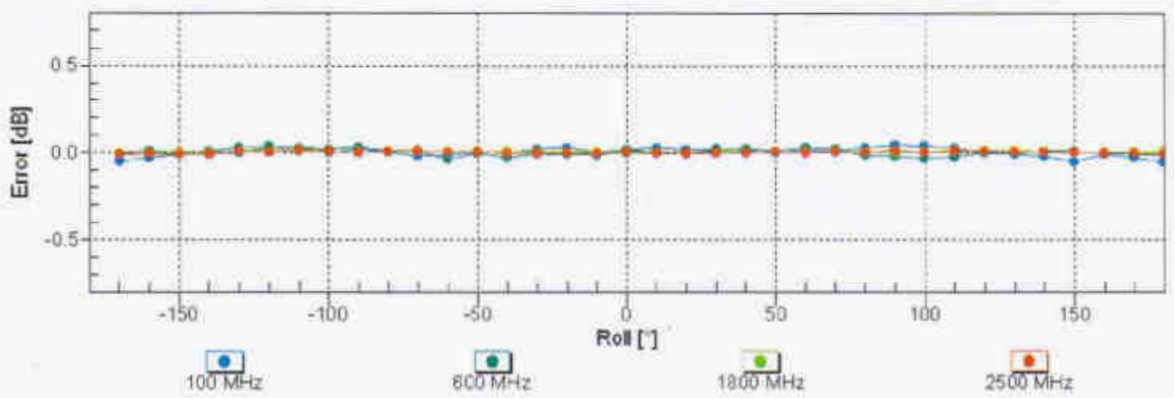
# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



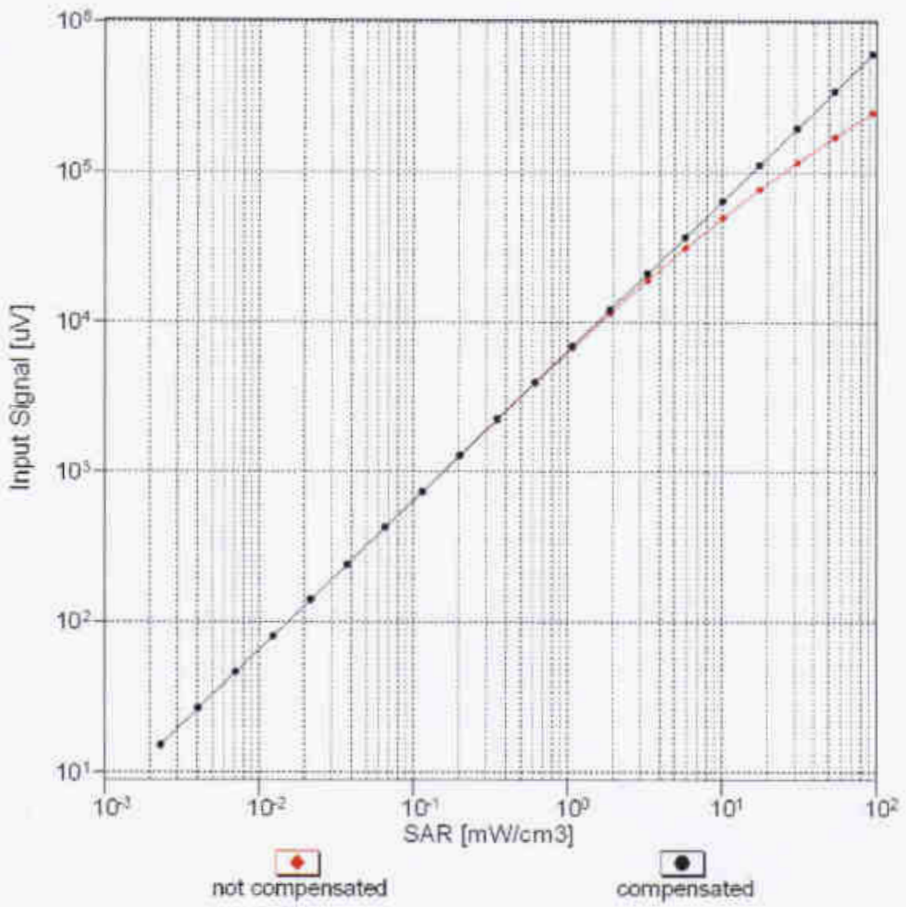

f=1800 MHz,R22

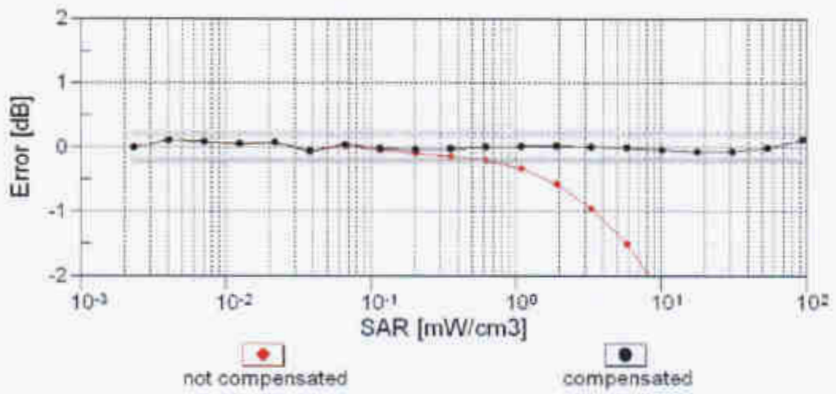



**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

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

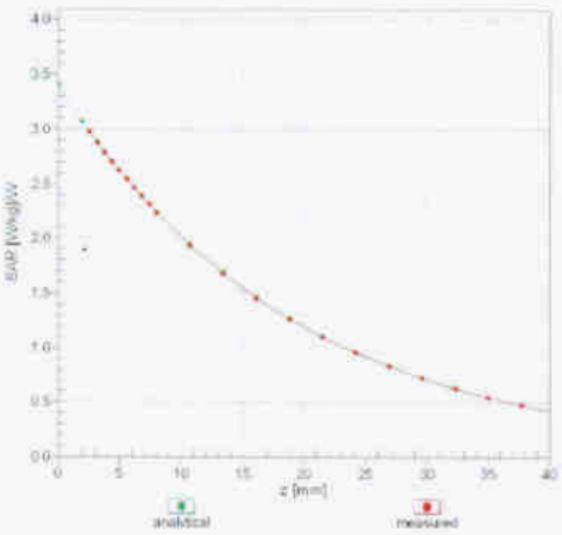


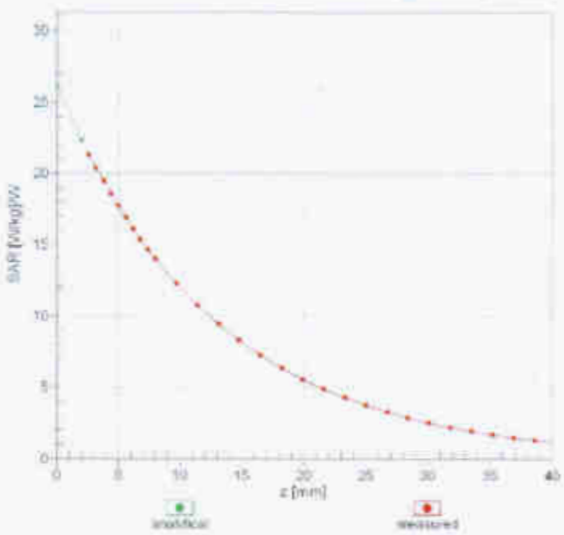

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Conversion Factor Assessment

f = 900 MHz,WGLS R9 (H_convF)

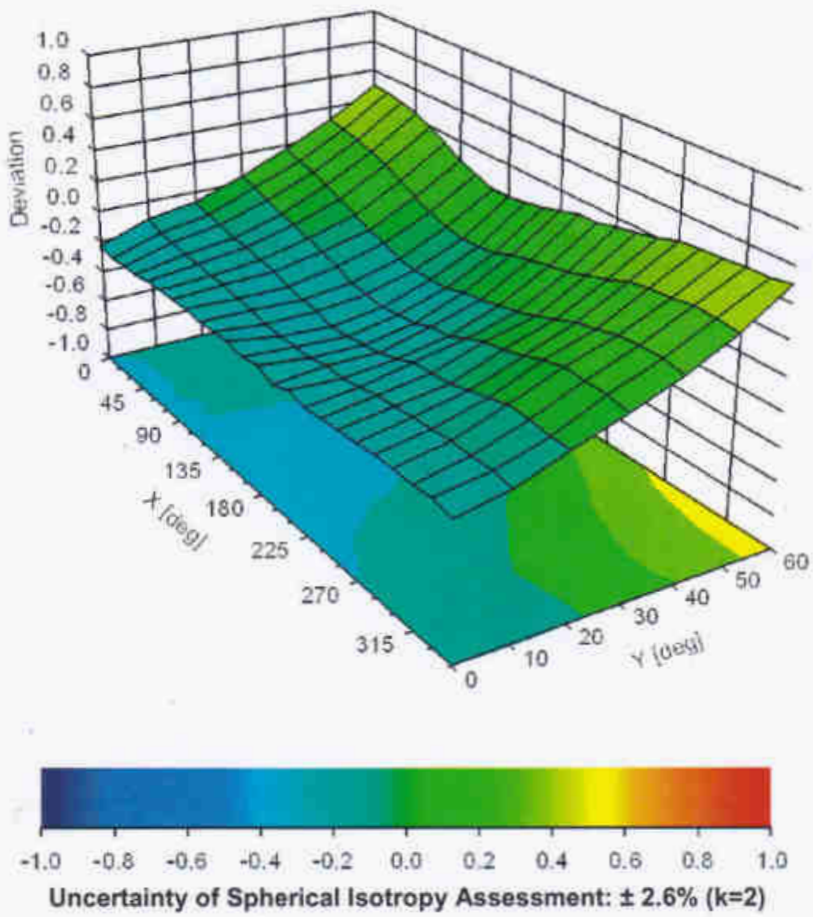



f = 1750 MHz,WGLS R22 (H_convF)




# Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**







**Uncertainty of Spherical Isotropy Assessment: ± 2.6% (k=2)**

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3293

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -0.1 |
| Mechanical Surface Detection Mode | enabled |
| Optical Surface Detection Mode | disabled |
| Probe Overall Length | 337 mm |
| Probe Body Diameter | 10 mm |
| Tip Length | 10 mm |
| Tip Diameter | 4 mm |
| Probe Tip to Sensor X Calibration Point | 2 mm |
| Probe Tip to Sensor Y Calibration Point | 2 mm |
| Probe Tip to Sensor Z Calibration Point | 2 mm |
| Recommended Measurement Distance from Surface | 3 mm |

**Calibration Laboratory of**
Schmid & Partner
Engineering AG
**Zeughausstrasse 43, 8004 Zurich, Switzerland**

**S** Schweizerischer Kalibrierdienst
**C** Service suisse d'étalonnage
**S** Servizio svizzero di taratura
Swiss Calibration Service

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**Accreditation No.: SCS 0108**

**Client** **Sporton**

**Certificate No: EX3-3954_Apr19**

# CALIBRATION CERTIFICATE

Object: EX3DV4 - SN:3954

Calibration procedure(s): QA CAL-01.v9, QA CAL-14.v5, QA CAL-23.v5, QA CAL-25.v7
Calibration procedure for dosimetric E-field probes

Calibration date: April 25, 2019

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 NRP | SN: 104778 | 03-Apr-19 (No. 217-02892/02893) | Apr-20 |
| Power sensor NRP-Z91 | SN: 103244 | 03-Apr-19 (No. 217-02892) | Apr-20 |
| Power sensor NRP-Z91 | SN: 103245 | 03-Apr-19 (No. 217-02893) | Apr-20 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-19 (No. 217-02894) | Apr-20 |
| DAE4 | SN: 660 | 19-Dec-18 (No. DAE4-660_Dec18) | Dec-19 |
| Reference Probe ES3DV2 | SN: 3013 | 31-Dec-18 (No. ES3-3013_Dec18) | Dec-19 |
| | | | |
| Secondary Standards | ID | Check Date (in house) | Scheduled Check |
| Power meter E4419B | SN: GB41293874 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: MY41498087 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: 000110210 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| RF generator HP 8648C | SN: US3642U01700 | 04-Aug-99 (in house check Jun-18) | In house check: Jun-20 |
| Network Analyzer E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-18) | In house check: Oct-19 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Leif Klysner | Laboratory Technician | |
| Approved by: | Katja Pokovic | Technical Manager | |

Issued: April 25, 2019

This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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**Accreditation No.: SCS 0108**

## Glossary:

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

## Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2013, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", June 2013
b) IEC 62209-1, ", "Measurement procedure for the assessment of Specific Absorption Rate (SAR) from hand-held and body-mounted devices used next to the ear (frequency range of 300 MHz to 6 GHz)", July 2016
c) IEC 62209-2, "Procedure to determine the Specific Absorption Rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)", March 2010
d) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization ϑ = 0 (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the $E^2$-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,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*.
- *DCPx,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
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: A, B, C, D* are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. *VR* is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters:* Assessed in flat phantom using E-field (or Temperature Transfer Standard for f ≤ 800 MHz) and inside waveguide using analytical field distributions based on power measurements for f > 800 MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to *NORMx,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 *NORMx* (no uncertainty required).

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3954

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 0.55 | 0.43 | 0.53 | ± 10.1 % |
| DCP (mV)[B] | 94.1 | 106.6 | 95.7 | |

## Calibration Results for Modulation Response

| UID | Communication System Name | | A dB | B dB√μV | C | D dB | VR mV | Max dev. | Unc[E] (k=2) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | CW | X | 0.0 | 0.0 | 1.0 | 0.00 | 198.1 | ±2.2 % | ± 4.7 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 173.3 | | |
| | | Y | 0.0 | 0.0 | 1.0 | | 190.4 | | |

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

[A] The uncertainties of Norm X,Y,Z do not affect the $E^2$-field uncertainty inside TSL (see Page 5).
[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:3954

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | 68.4 |
| 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 | 1.4 mm |

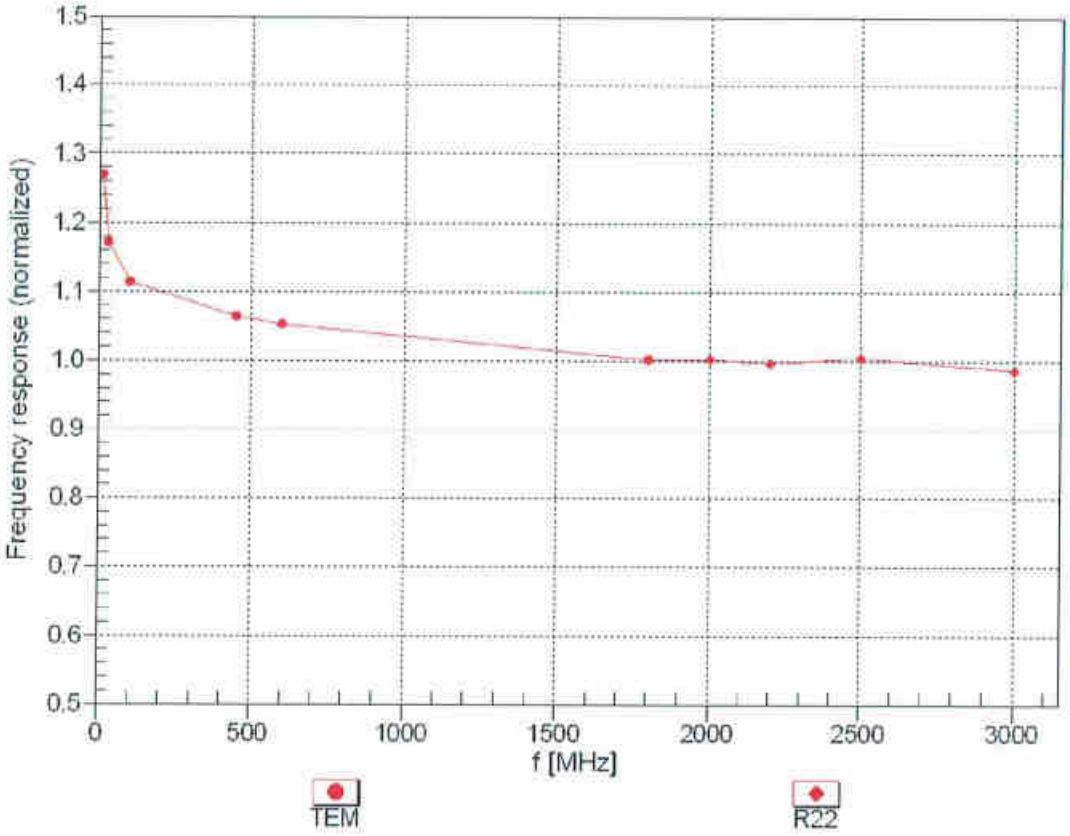
# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3954

## 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) | Unc (k=2) |
|---|---|---|---|---|---|---|---|---|
| 750 | 41.9 | 0.89 | 10.57 | 10.57 | 10.57 | 0.57 | 0.80 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 10.36 | 10.36 | 10.36 | 0.51 | 0.80 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 10.15 | 10.15 | 10.15 | 0.34 | 1.09 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.61 | 8.61 | 8.61 | 0.39 | 0.85 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.27 | 8.27 | 8.27 | 0.39 | 0.84 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 8.25 | 8.25 | 8.25 | 0.38 | 0.85 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 7.91 | 7.91 | 7.91 | 0.38 | 0.85 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.62 | 7.62 | 7.62 | 0.35 | 0.93 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.30 | 7.30 | 7.30 | 0.43 | 0.89 | ± 12.0 % |
| 5250 | 35.9 | 4.71 | 4.98 | 4.98 | 4.98 | 0.40 | 1.80 | ± 14.0 % |
| 5600 | 35.5 | 5.07 | 4.51 | 4.51 | 4.51 | 0.40 | 1.80 | ± 14.0 % |
| 5750 | 35.4 | 5.22 | 4.65 | 4.65 | 4.65 | 0.40 | 1.80 | ± 14.0 % |

[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. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies up to 6 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

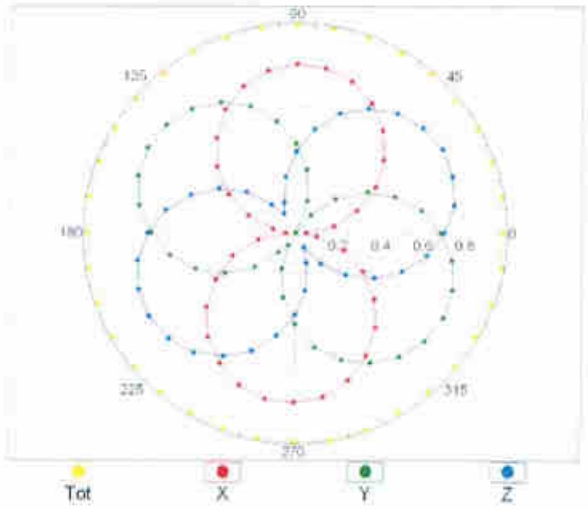
# Frequency Response of E-Field
## (TEM-Cell:ifi110 EXX, Waveguide: R22)



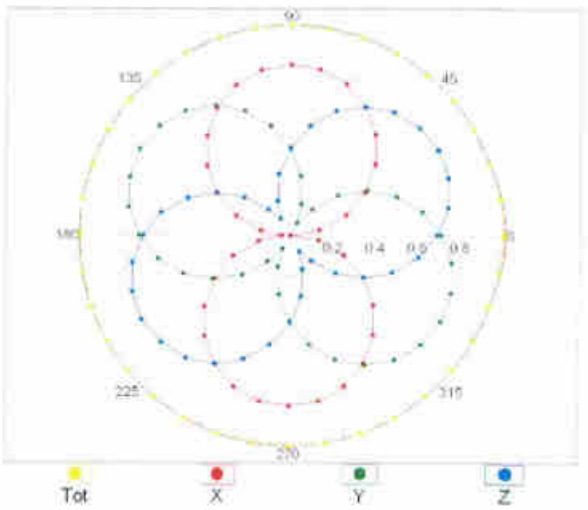

**Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)**

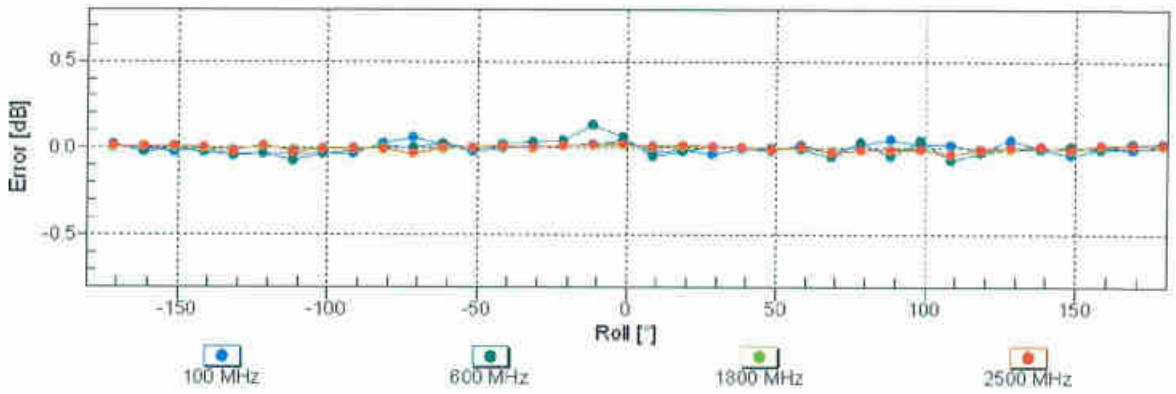
# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM




f=1800 MHz,R22

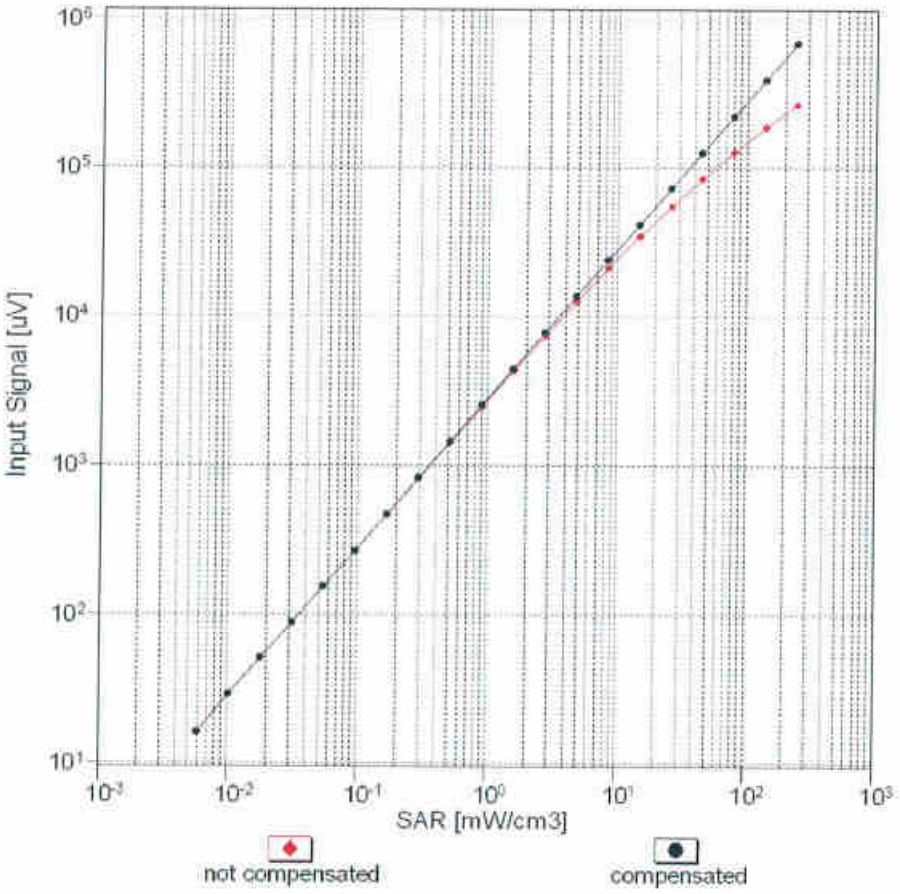


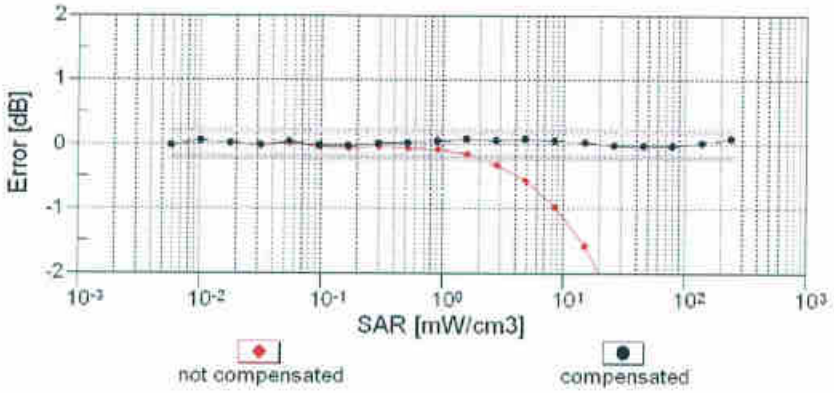




**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

# Dynamic Range f($SAR_{head}$)

**(TEM cell , $f_{eval}$= 1900 MHz)**

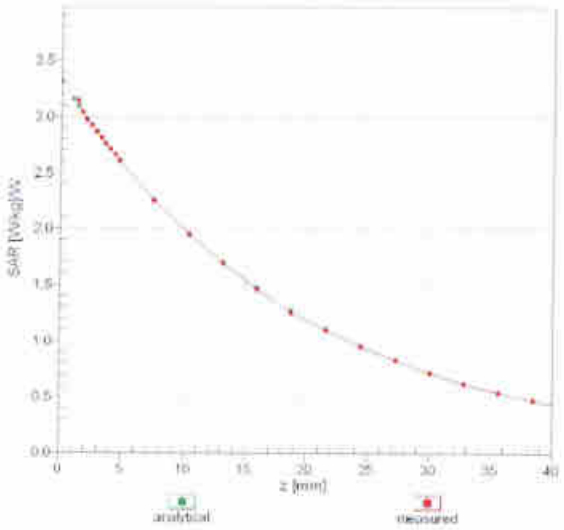


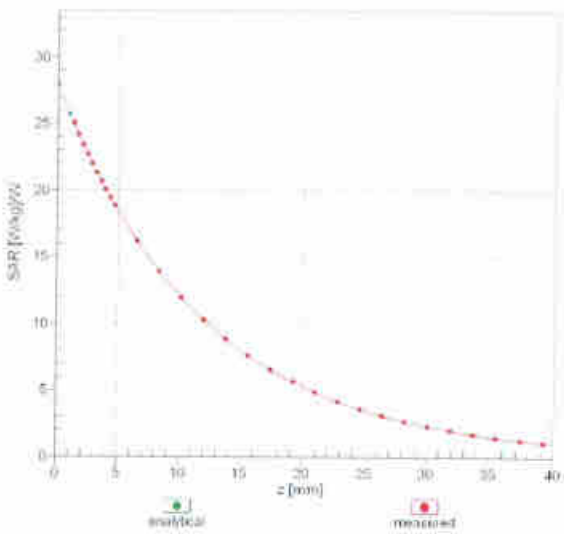

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

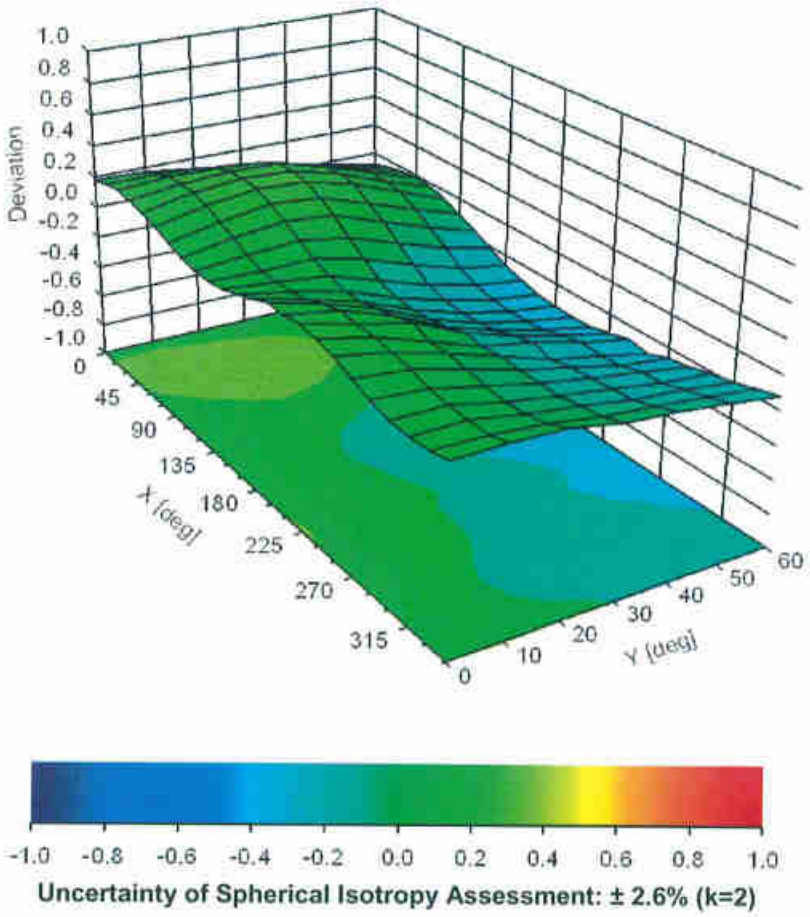



f = 1900 MHz,WGLS R22 (H_convF)




# Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**







**Uncertainty of Spherical Isotropy Assessment: ± 2.6% (k=2)**