# APPENDIX C: PROBE CALIBRATION

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

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

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** **PC Test**

**Certificate No: D835V2-4d119_Apr14**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | D835V2 - SN: 4d119 |
| Calibration procedure(s) | QA CAL-05.v9<br>Calibration procedure for dipole validation kits above 700 MHz |
| Calibration date: | April 07, 2014 |

CC✓ 4/25/14

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 EPM-442A | GB37480704 | 09-Oct-13 (No. 217-01827) | Oct-14 |
| Power sensor HP 8481A | US37292783 | 09-Oct-13 (No. 217-01827) | Oct-14 |
| Power sensor HP 8481A | MY41092317 | 09-Oct-13 (No. 217-01828) | Oct-14 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 03-Apr-14 (No. 217-01918) | Apr-15 |
| Type-N mismatch combination | SN: 5047.2 / 06327 | 03-Apr-14 (No. 217-01921) | Apr-15 |
| Reference Probe ES3DV3 | SN: 3205 | 30-Dec-13 (No. ES3-3205_Dec13) | Dec-14 |
| DAE4 | SN: 601 | 25-Apr-13 (No. DAE4-601_Apr13) | Apr-14 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| RF generator R&S SMT-06 | 100005 | 04-Aug-99 (in house check Oct-13) | In house check: Oct-16 |
| Network Analyzer HP 8753E | US37390585 S4206 | 18-Oct-01 (in house check Oct-13) | In house check: Oct-14 |

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

Issued: April 9, 2014

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

## Glossary:

| | |
|---|---|
| TSL | tissue simulating liquid |
| ConvF | sensitivity in TSL / NORM x,y,z |
| N/A | not applicable or not measured |

## 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
c) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Additional Documentation:

d) DASY4/5 System Handbook

## Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

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%.

## Measurement Conditions

DASY system configuration, as far as not given on page 1.

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.8.7 |
| **Extrapolation** | Advanced Extrapolation | |
| **Phantom** | Modular Flat Phantom | |
| **Distance Dipole Center - TSL** | 15 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy, dz = 5 mm | |
| **Frequency** | 835 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 41.5 | 0.90 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 41.6 ± 6 % | 0.94 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 2.38 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **9.22 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 1.53 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **5.97 W/kg ± 16.5 % (k=2)** |

## Body TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 55.2 | 0.97 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 53.6 ± 6 % | 1.02 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 2.44 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **9.34 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 1.59 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **6.15 W/kg ± 16.5 % (k=2)** |

## Appendix

### Antenna Parameters with Head TSL

| | |
|---|---|
| Impedance, transformed to feed point | 51.2 Ω - 1.6 jΩ |
| Return Loss | - 34.0 dB |

### Antenna Parameters with Body TSL

| | |
|---|---|
| Impedance, transformed to feed point | 46.3 Ω - 4.5 jΩ |
| Return Loss | - 24.4 dB |

### General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.386 ns |

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

### Additional EUT Data

| | |
|---|---|
| Manufactured by | SPEAG |
| Manufactured on | June 29, 2010 |

## DASY5 Validation Report for Head TSL

Date: 07.04.2014

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 835 MHz; Type: D835V2; Serial: D835V2 - SN: 4d119**

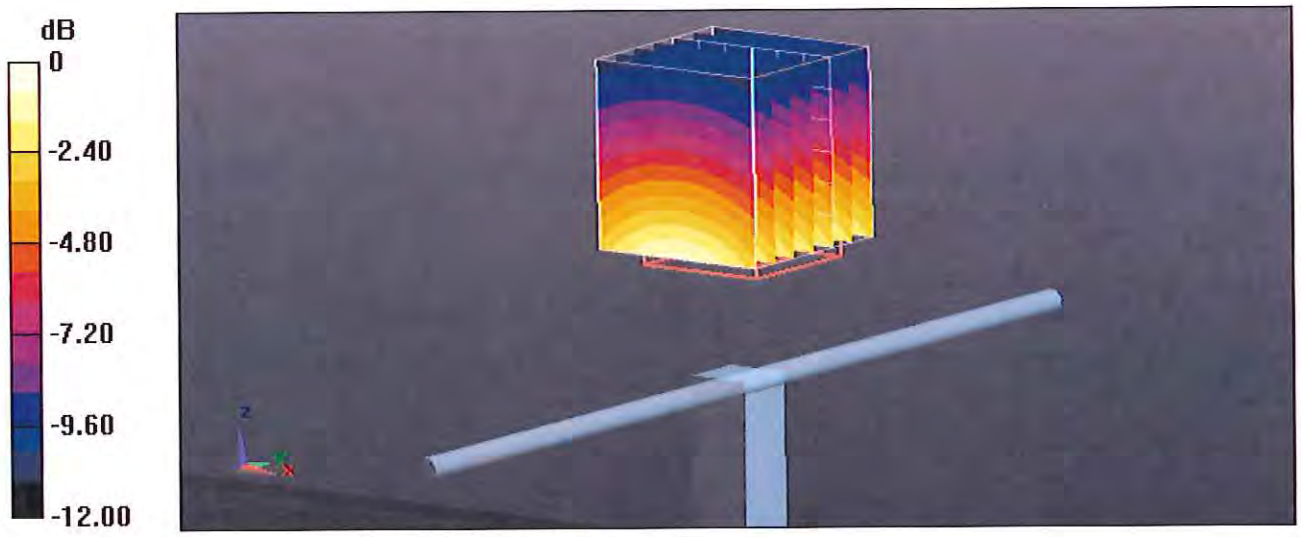
Communication System: UID 0 - CW; Frequency: 835 MHz
Medium parameters used: f = 835 MHz; $\sigma$ = 0.94 S/m; $\varepsilon_r$ = 41.6; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(6.22, 6.22, 6.22); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 4.9L; Type: QD000P49AA; Serial: 1001
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

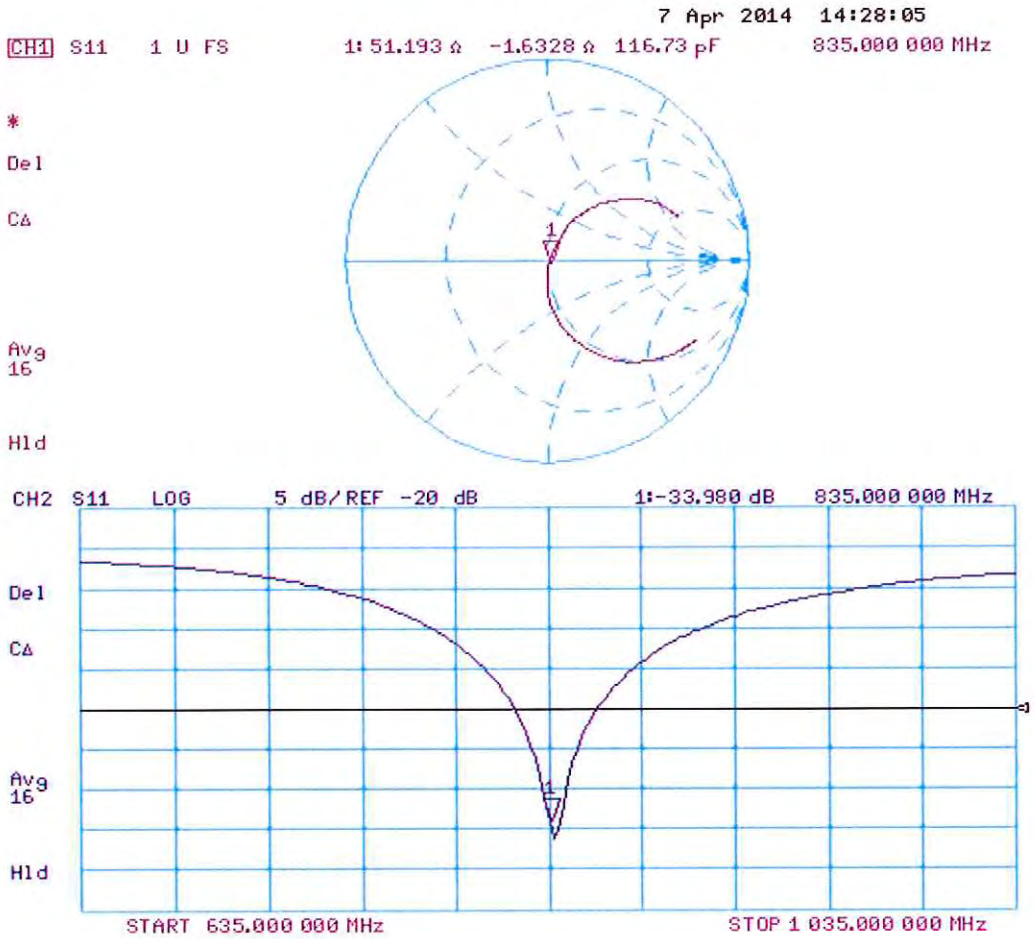
### Dipole Calibration for Head Tissue/Pin=250 mW, d=15mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 56.289 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 3.59 W/kg
**SAR(1 g) = 2.38 W/kg; SAR(10 g) = 1.53 W/kg**
Maximum value of SAR (measured) = 2.80 W/kg




0 dB = 2.80 W/kg = 4.47 dBW/kg

## Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Date: 07.04.2014

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 835 MHz; Type: D835V2; Serial: D835V2 - SN: 4d119**

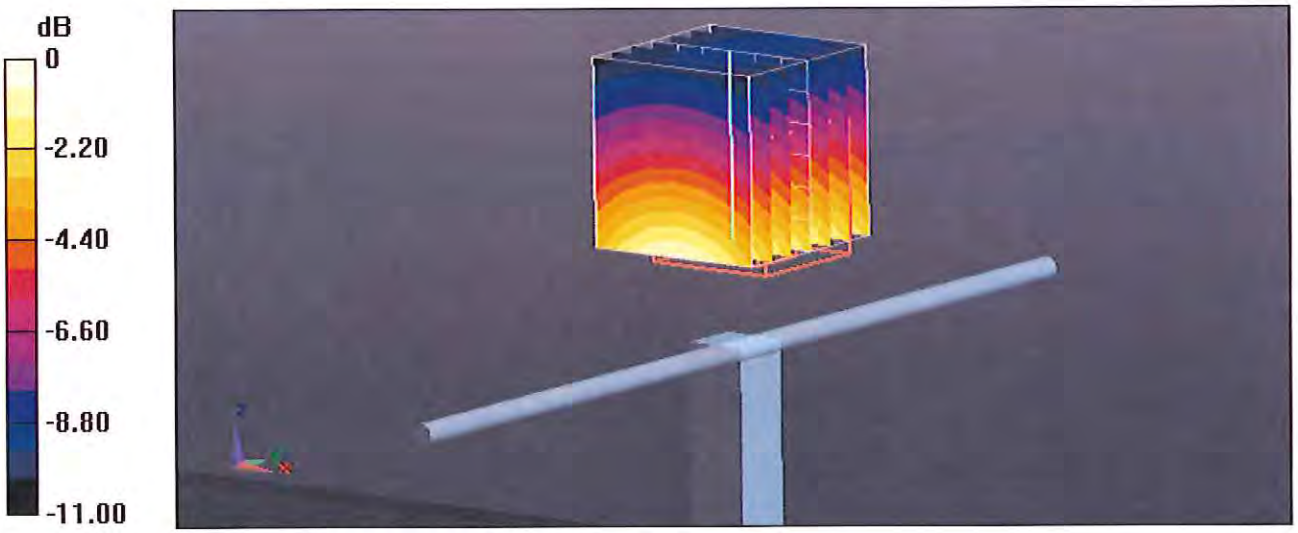
Communication System: UID 0 - CW; Frequency: 835 MHz
Medium parameters used: f = 835 MHz; $\sigma$ = 1.02 S/m; $\varepsilon_r$ = 53.6; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(6.09, 6.09, 6.09); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 4.9L; Type: QD000P49AA; Serial: 1001
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

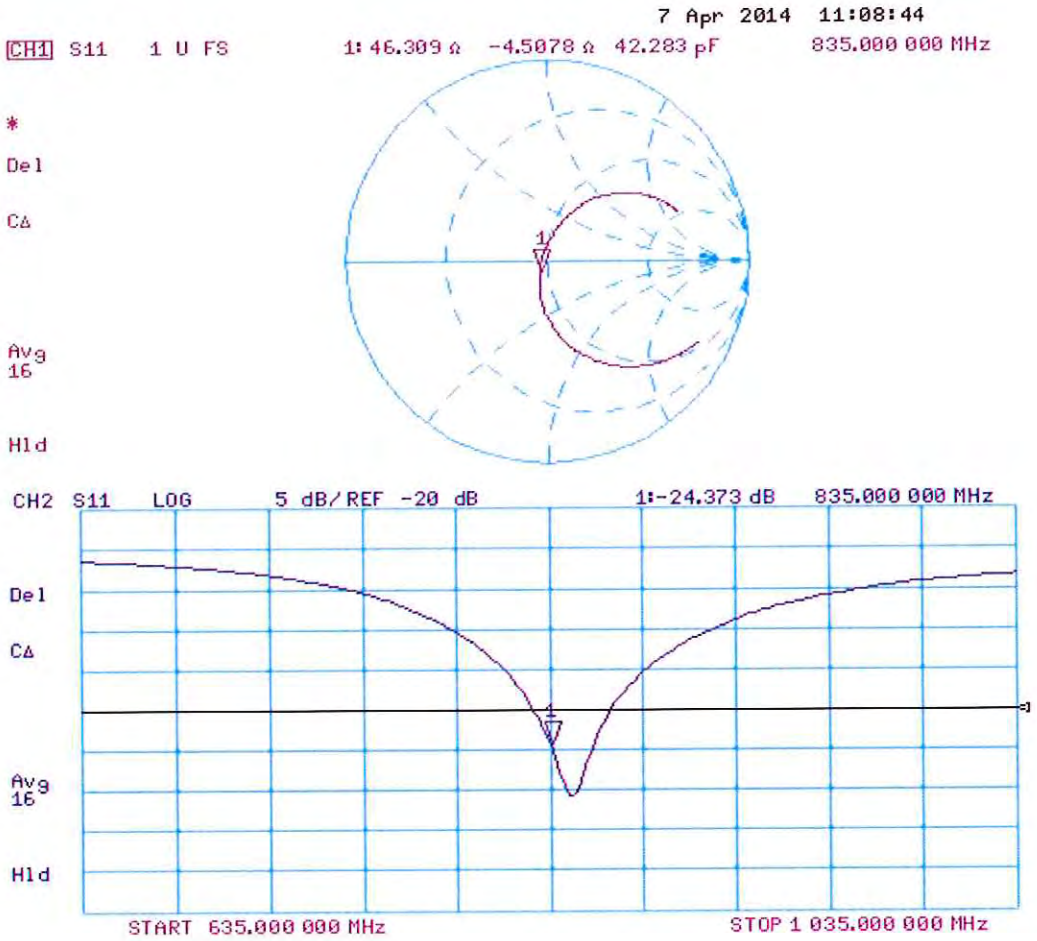
### Dipole Calibration for Body Tissue/Pin=250 mW, d=15mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 54.594 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 3.61 W/kg
**SAR(1 g) = 2.44 W/kg; SAR(10 g) = 1.59 W/kg**
Maximum value of SAR (measured) = 2.85 W/kg




0 dB = 2.85 W/kg = 4.55 dBW/kg

## Impedance Measurement Plot for Body TSL



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**Accreditation No.: SCS 108**

**Client** **PC Test**

**Certificate No: D1900V2-5d149_Jul13**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | D1900V2 - SN: 5d149 |
| Calibration procedure(s) | QA CAL-05.v9<br>Calibration procedure for dipole validation kits above 700 MHz |
| Calibration date: | July 22, 2013 |

✓ KOK 8/19/13

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 EPM-442A | GB37480704 | 01-Nov-12 (No. 217-01640) | Oct-13 |
| Power sensor HP 8481A | US37292783 | 01-Nov-12 (No. 217-01640) | Oct-13 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 04-Apr-13 (No. 217-01736) | Apr-14 |
| Type-N mismatch combination | SN: 5047.3 / 06327 | 04-Apr-13 (No. 217-01739) | Apr-14 |
| Reference Probe ES3DV3 | SN: 3205 | 28-Dec-12 (No. ES3-3205_Dec12) | Dec-13 |
| DAE4 | SN: 601 | 25-Apr-13 (No. DAE4-601_Apr13) | Apr-14 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| Power sensor HP 8481A | MY41092317 | 18-Oct-02 (in house check Oct-11) | In house check: Oct-13 |
| RF generator R&S SMT-06 | 100005 | 04-Aug-99 (in house check Oct-11) | In house check: Oct-13 |
| Network Analyzer HP 8753E | US37390585 S4206 | 18-Oct-01 (in house check Oct-12) | In house check: Oct-13 |

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

Issued: July 22, 2013

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

## Glossary:

| | |
|---|---|
| TSL | tissue simulating liquid |
| ConvF | sensitivity in TSL / NORM x,y,z |
| N/A | not applicable or not measured |

## Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003
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
c) Federal Communications Commission Office of Engineering & Technology (FCC OET), "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields; Additional Information for Evaluating Compliance of Mobile and Portable Devices with FCC Limits for Human Exposure to Radiofrequency Emissions", Supplement C (Edition 01-01) to Bulletin 65

## Additional Documentation:

d) DASY4/5 System Handbook

## Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

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%.

## Measurement Conditions

DASY system configuration, as far as not given on page 1.

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.8.7 |
| **Extrapolation** | Advanced Extrapolation | |
| **Phantom** | Modular Flat Phantom | |
| **Distance Dipole Center - TSL** | 10 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy, dz = 5 mm | |
| **Frequency** | 1900 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 40.0 | 1.40 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 38.9 ± 6 % | 1.36 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 9.99 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **40.4 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 5.28 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **21.3 W/kg ± 16.5 % (k=2)** |

## Body TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 53.3 | 1.52 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 53.4 ± 6 % | 1.49 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 10.0 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **40.5 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 5.36 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **21.6 W/kg ± 16.5 % (k=2)** |

## Appendix

## Antenna Parameters with Head TSL

| | |
|---|---|
| Impedance, transformed to feed point | 52.9 Ω + 6.0 jΩ |
| Return Loss | - 23.8 dB |

## Antenna Parameters with Body TSL

| | |
|---|---|
| Impedance, transformed to feed point | 48.5 Ω + 6.4 jΩ |
| Return Loss | - 23.5 dB |

## General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.196 ns |

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

## Additional EUT Data

| | |
|---|---|
| Manufactured by | SPEAG |
| Manufactured on | March 11, 2011 |

## DASY5 Validation Report for Head TSL

Date: 22.07.2013

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d149**

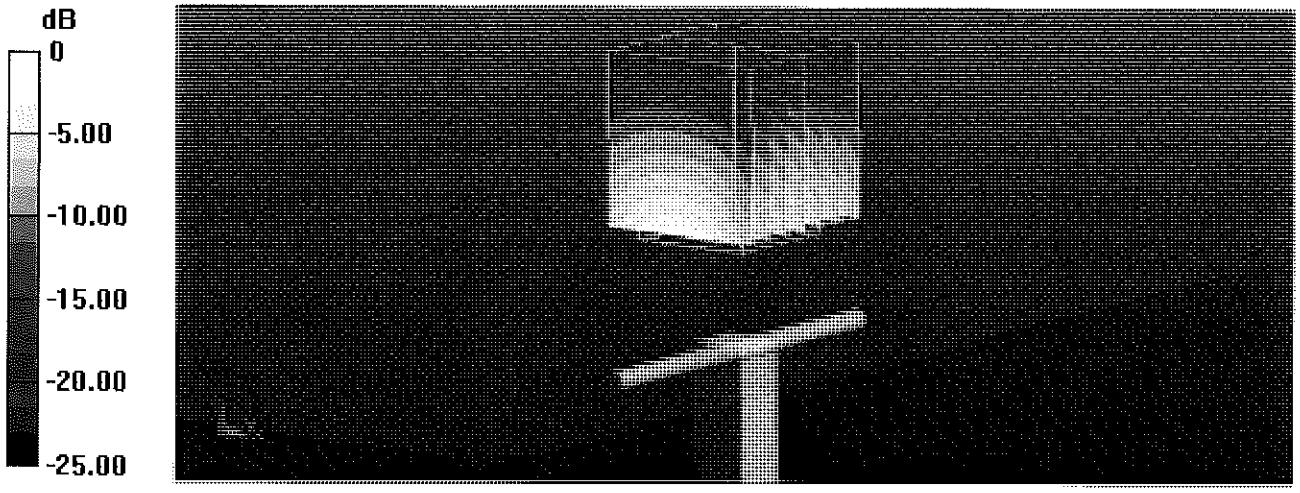
Communication System: UID 0 - CW ; Frequency: 1900 MHz
Medium parameters used: f = 1900 MHz; $\sigma$ = 1.36 S/m; $\varepsilon_r$ = 38.9; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(4.98, 4.98, 4.98); Calibrated: 28.12.2012;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

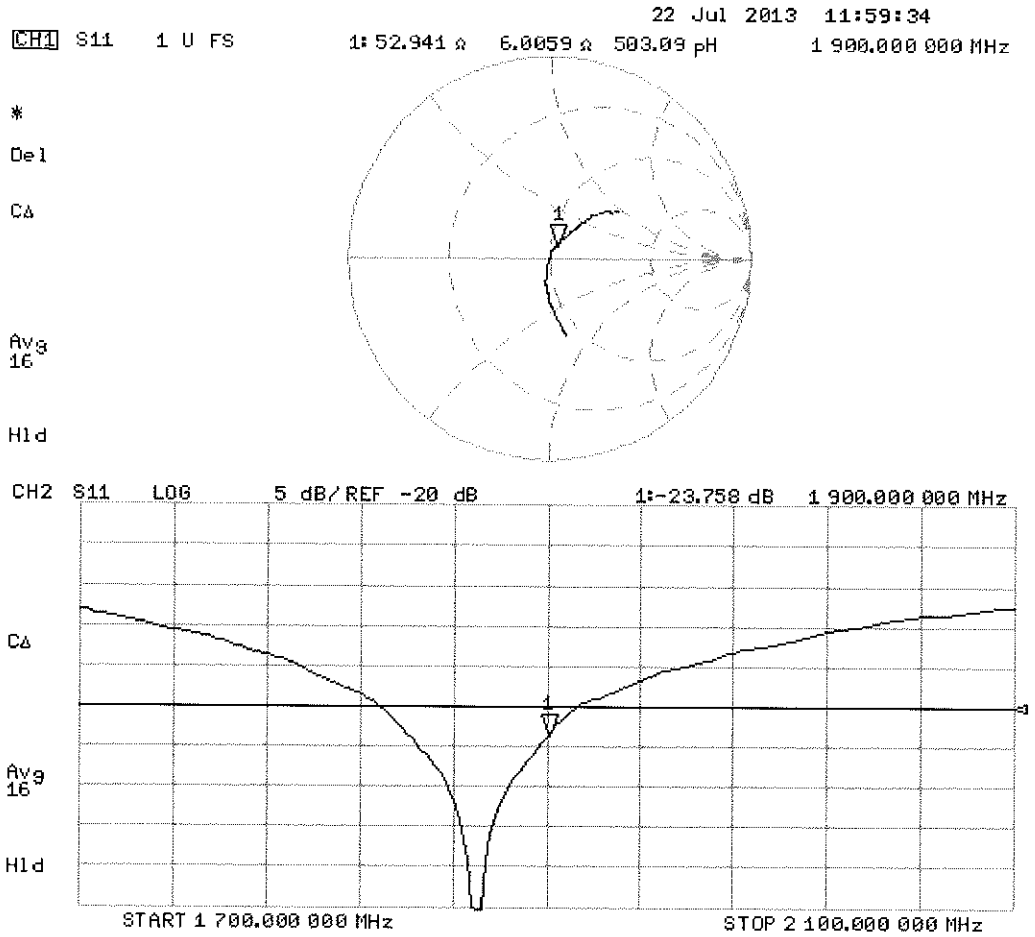
### Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 96.173 V/m; Power Drift = 0.04 dB
Peak SAR (extrapolated) = 18.0 W/kg
**SAR(1 g) = 9.99 W/kg; SAR(10 g) = 5.28 W/kg**
Maximum value of SAR (measured) = 12.4 W/kg




0 dB = 12.4 W/kg = 10.93 dBW/kg

## Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Date: 22.07.2013

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d149**

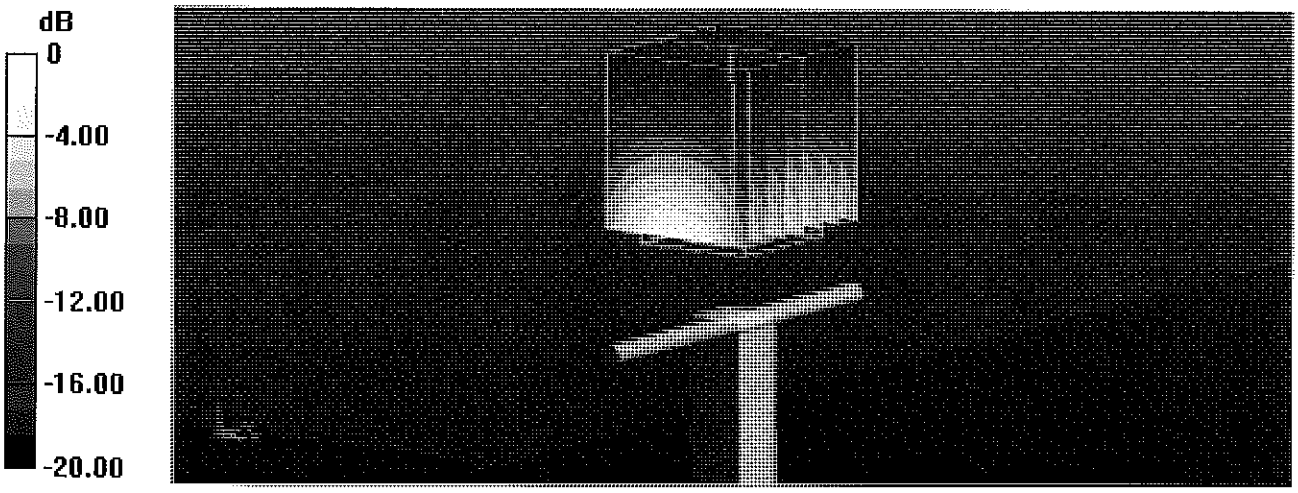
Communication System: UID 0 - CW ; Frequency: 1900 MHz
Medium parameters used: f = 1900 MHz; $\sigma$ = 1.49 S/m; $\varepsilon_r$ = 53.4; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(4.6, 4.6, 4.6); Calibrated: 28.12.2012;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

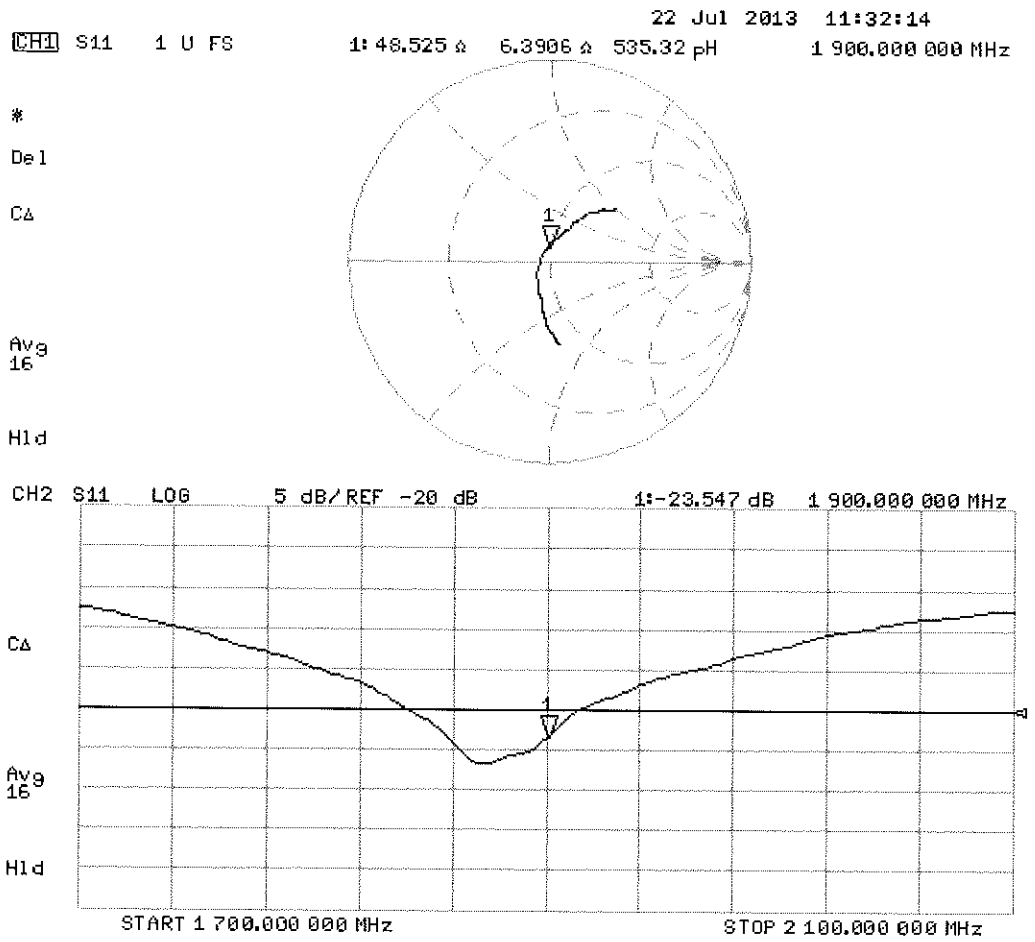
### Dipole Calibration for Body Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 96.173 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 17.0 W/kg
**SAR(1 g) = 10 W/kg; SAR(10 g) = 5.36 W/kg**
Maximum value of SAR (measured) = 12.6 W/kg




0 dB = 12.6 W/kg = 11.00 dBW/kg

## Impedance Measurement Plot for Body TSL



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

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

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** **PC Test**

**Certificate No: D1900V2-5d141_Apr14**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | D1900V2 - SN: 5d141 |
| Calibration procedure(s) | QA CAL-05.v9<br>Calibration procedure for dipole validation kits above 700 MHz |
| Calibration date: | April 09, 2014 |

✓ KOK 5/7/14

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 EPM-442A | GB37480704 | 09-Oct-13 (No. 217-01827) | Oct-14 |
| Power sensor HP 8481A | US37292783 | 09-Oct-13 (No. 217-01827) | Oct-14 |
| Power sensor HP 8481A | MY41092317 | 09-Oct-13 (No. 217-01828) | Oct-14 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 03-Apr-14 (No. 217-01918) | Apr-15 |
| Type-N mismatch combination | SN: 5047.2 / 06327 | 03-Apr-14 (No. 217-01921) | Apr-15 |
| Reference Probe ES3DV3 | SN: 3205 | 30-Dec-13 (No. ES3-3205_Dec13) | Dec-14 |
| DAE4 | SN: 601 | 25-Apr-13 (No. DAE4-601_Apr13) | Apr-14 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| RF generator R&S SMT-06 | 100005 | 04-Aug-99 (in house check Oct-13) | In house check: Oct-16 |
| Network Analyzer HP 8753E | US37390585 S4206 | 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: April 9, 2014

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

## Glossary:

| | |
|---|---|
| TSL | tissue simulating liquid |
| ConvF | sensitivity in TSL / NORM x,y,z |
| N/A | not applicable or not measured |

## 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
c) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Additional Documentation:

d) DASY4/5 System Handbook

## Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

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%.

## Measurement Conditions

DASY system configuration, as far as not given on page 1.

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.8.7 |
| **Extrapolation** | Advanced Extrapolation | |
| **Phantom** | Modular Flat Phantom | |
| **Distance Dipole Center - TSL** | 10 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy, dz = 5 mm | |
| **Frequency** | 1900 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 40.0 | 1.40 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 39.1 ± 6 % | 1.36 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 9.91 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **40.1 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 5.17 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **20.8 W/kg ± 16.5 % (k=2)** |

## Body TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 53.3 | 1.52 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 52.4 ± 6 % | 1.52 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 10.2 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **40.6 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 5.41 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **21.6 W/kg ± 16.5 % (k=2)** |

## Appendix

## Antenna Parameters with Head TSL

| | |
|---|---|
| Impedance, transformed to feed point | 52.8 Ω + 5.5 jΩ |
| Return Loss | - 24.5 dB |

## Antenna Parameters with Body TSL

| | |
|---|---|
| Impedance, transformed to feed point | 48.8 Ω + 6.3 jΩ |
| Return Loss | - 23.7 dB |

## General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.199 ns |

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

## Additional EUT Data

| | |
|---|---|
| Manufactured by | SPEAG |
| Manufactured on | March 11, 2011 |

## DASY5 Validation Report for Head TSL

Date: 09.04.2014

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d141**

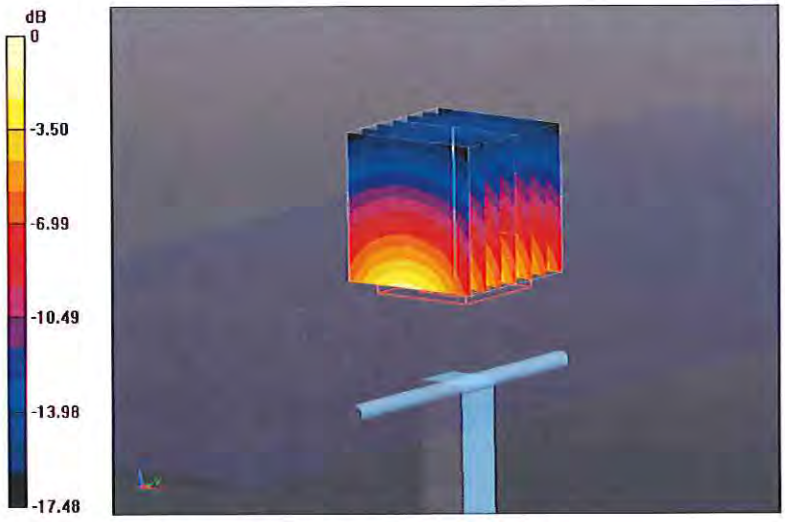
Communication System: UID 0 - CW; Frequency: 1900 MHz
Medium parameters used: f = 1900 MHz; $\sigma$ = 1.36 S/m; $\varepsilon_r$ = 39.1; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(5.06, 5.06, 5.06); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

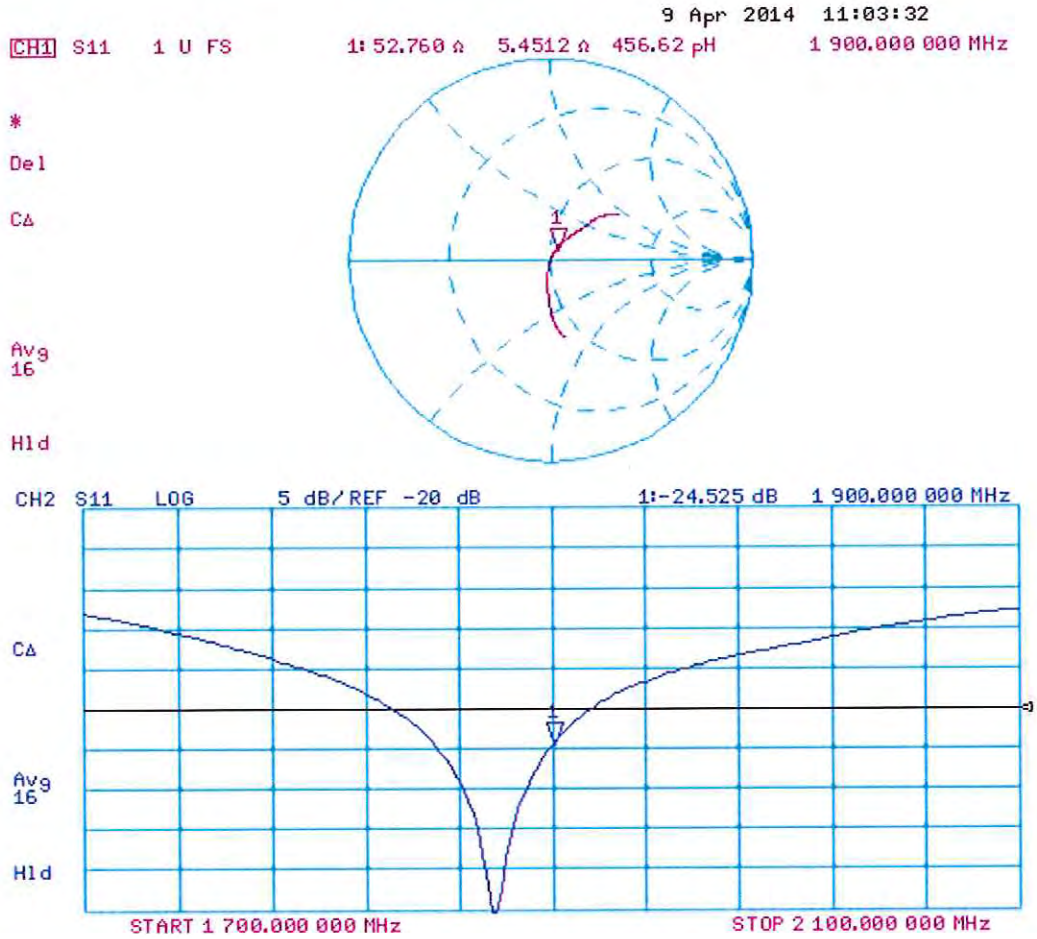
### Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 99.080 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 18.2 W/kg
**SAR(1 g) = 9.91 W/kg; SAR(10 g) = 5.17 W/kg**
Maximum value of SAR (measured) = 12.5 W/kg




0 dB = 12.5 W/kg = 10.97 dBW/kg

## Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Date: 09.04.2014

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 1900 MHz; Type: D1900V2; Serial: D1900V2 - SN: 5d141**

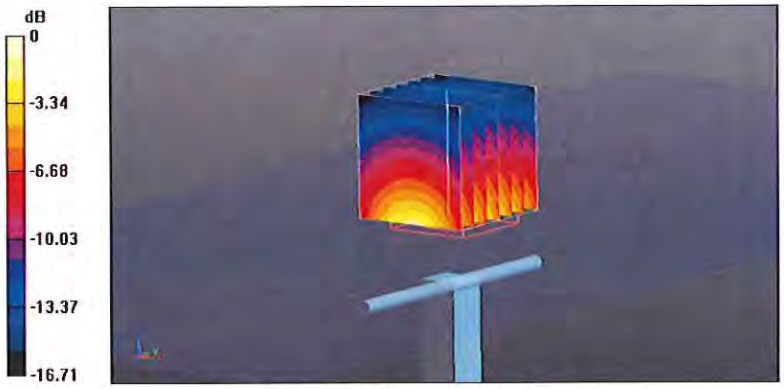
Communication System: UID 0 - CW; Frequency: 1900 MHz
Medium parameters used: f = 1900 MHz; $\sigma$ = 1.52 S/m; $\varepsilon_r$ = 52.4; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(4.76, 4.76, 4.76); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

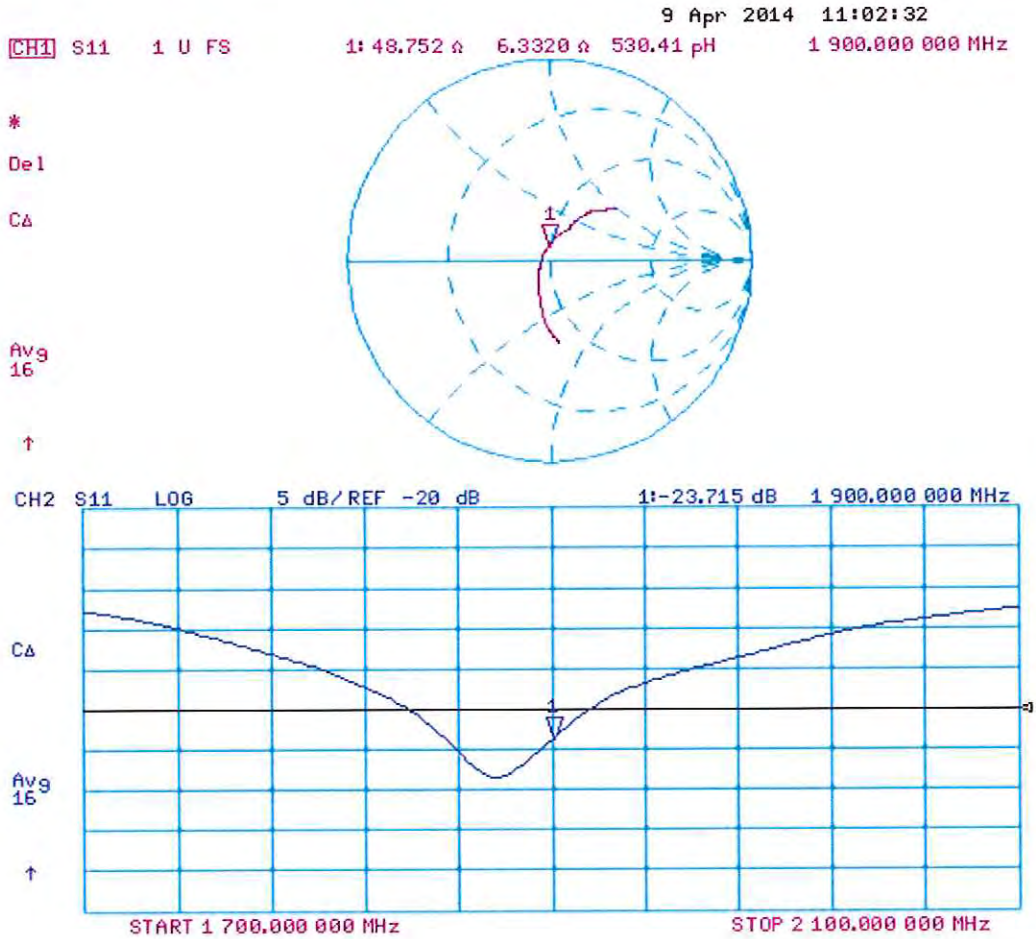
### Dipole Calibration for Body Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 95.820 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 17.9 W/kg
**SAR(1 g) = 10.2 W/kg; SAR(10 g) = 5.41 W/kg**
Maximum value of SAR (measured) = 12.9 W/kg




0 dB = 12.9 W/kg = 11.11 dBW/kg

## Impedance Measurement Plot for Body TSL



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**S** Schweizerischer Kalibrierdienst
**C** Service suisse d'étalonnage
Servizio svizzero di taratura
**S** 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 108**

**Client** **PC Test**

**Certificate No: D2450V2-797_Jan14**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | D2450V2 - SN: 797 |
| Calibration procedure(s) | QA CAL-05.v9<br>Calibration procedure for dipole validation kits above 700 MHz |
| Calibration date: | January 21, 2014 |

CC ✓
2/5/14

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 EPM-442A | GB37480704 | 09-Oct-13 (No. 217-01827) | Oct-14 |
| Power sensor HP 8481A | US37292783 | 09-Oct-13 (No. 217-01827) | Oct-14 |
| Power sensor HP 8481A | MY41092317 | 09-Oct-13 (No. 217-01828) | Oct-14 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 04-Apr-13 (No. 217-01736) | Apr-14 |
| Type-N mismatch combination | SN: 5047.3 / 06327 | 04-Apr-13 (No. 217-01739) | Apr-14 |
| Reference Probe ES3DV3 | SN: 3205 | 30-Dec-13 (No. ES3-3205_Dec13) | Dec-14 |
| DAE4 | SN: 601 | 25-Apr-13 (No. DAE4-601_Apr13) | Apr-14 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| RF generator R&S SMT-06 | 100005 | 04-Aug-99 (in house check Oct-13) | In house check: Oct-16 |
| Network Analyzer HP 8753E | US37390585 S4206 | 18-Oct-01 (in house check Oct-13) | In house check: Oct-14 |

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

Issued: January 21, 2014

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



PCT# 751

## Glossary:

| | |
|---|---|
| TSL | tissue simulating liquid |
| ConvF | sensitivity in TSL / NORM x,y,z |
| N/A | not applicable or not measured |

## 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
c) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Additional Documentation:

d) DASY4/5 System Handbook

## Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

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%.

## Measurement Conditions

DASY system configuration, as far as not given on page 1.

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.8.7 |
| **Extrapolation** | Advanced Extrapolation | |
| **Phantom** | Modular Flat Phantom | |
| **Distance Dipole Center - TSL** | 10 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy, dz = 5 mm | |
| **Frequency** | 2450 MHz ± 1 MHz | |

## Head TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 39.2 | 1.80 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 38.7 ± 6 % | 1.86 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 13.2 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **51.8 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 6.13 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **24.3 W/kg ± 16.5 % (k=2)** |

## Body TSL parameters

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 52.7 | 1.95 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 51.3 ± 6 % | 2.04 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 250 mW input power | 12.7 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **49.4 W/kg ± 17.0 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 250 mW input power | 5.86 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **23.1 W/kg ± 16.5 % (k=2)** |

## Appendix

### Antenna Parameters with Head TSL

| | |
|---|---|
| Impedance, transformed to feed point | 53.5 Ω + 3.2 jΩ |
| Return Loss | - 26.7 dB |

### Antenna Parameters with Body TSL

| | |
|---|---|
| Impedance, transformed to feed point | 50.0 Ω + 4.9 jΩ |
| Return Loss | - 26.2 dB |

### General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.151 ns |

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

### Additional EUT Data

| | |
|---|---|
| Manufactured by | SPEAG |
| Manufactured on | January 24, 2006 |

## DASY5 Validation Report for Head TSL

Date: 21.01.2014

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 797**

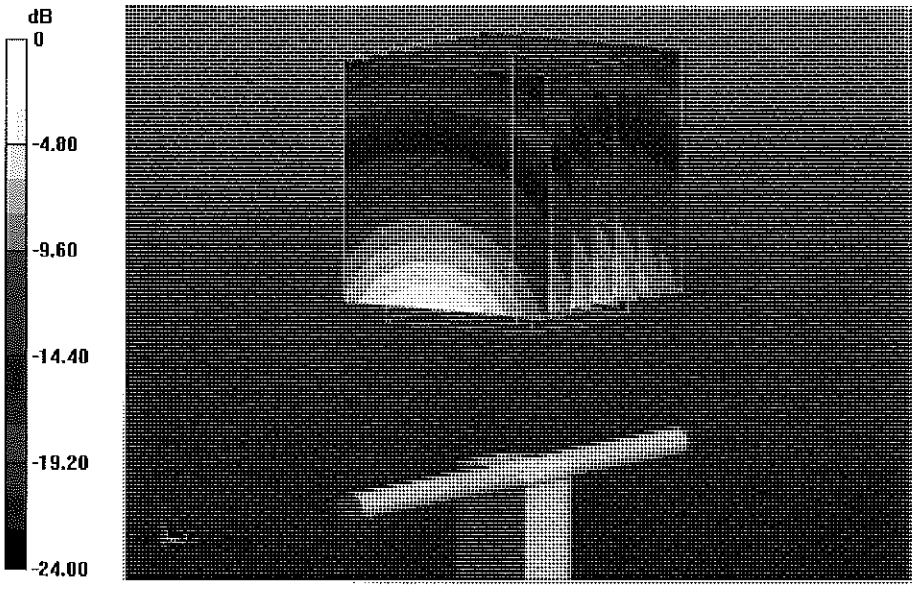
Communication System: UID 0 - CW; Frequency: 2450 MHz
Medium parameters used: f = 2450 MHz; $\sigma$ = 1.86 S/m; $\varepsilon_r$ = 38.7; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(4.53, 4.53, 4.53); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

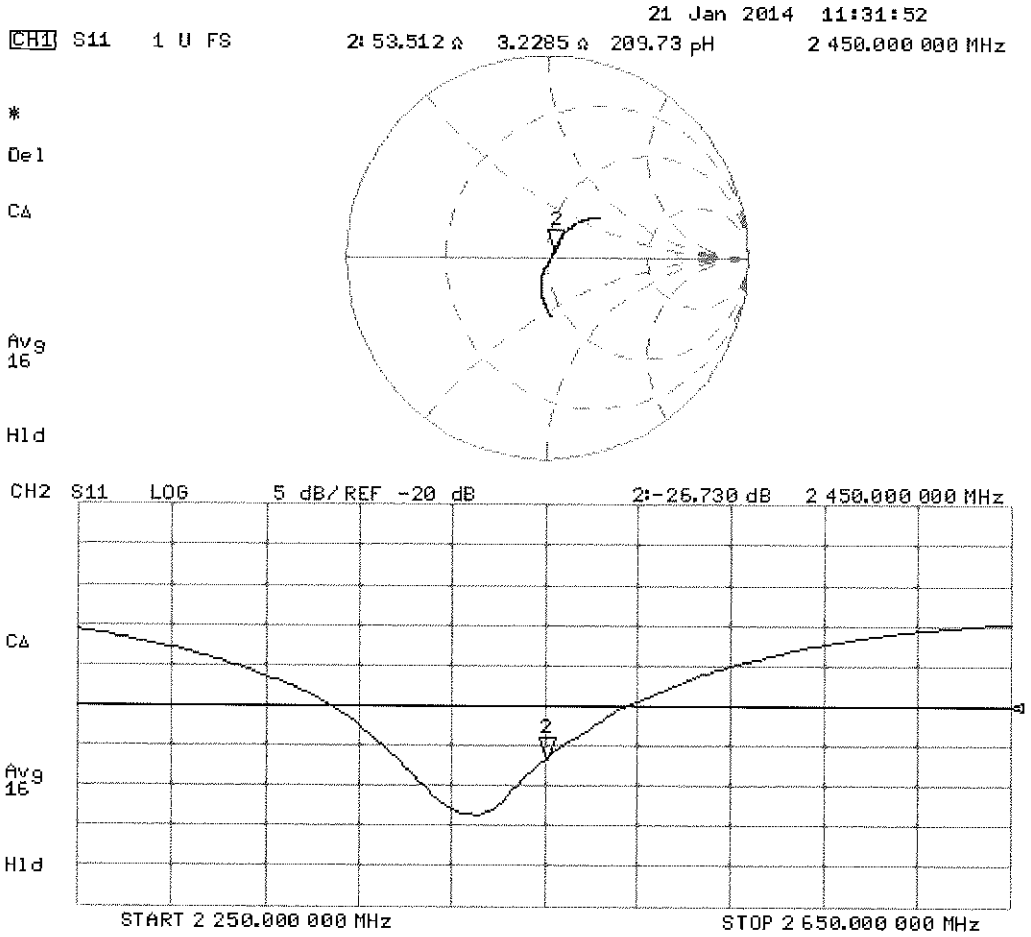
### Dipole Calibration for Head Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 99.151 V/m; Power Drift = 0.05 dB
Peak SAR (extrapolated) = 27.5 W/kg
**SAR(1 g) = 13.2 W/kg; SAR(10 g) = 6.13 W/kg**
Maximum value of SAR (measured) = 16.9 W/kg




0 dB = 16.9 W/kg = 12.28 dBW/kg

## Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Date: 21.01.2014

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 2450 MHz; Type: D2450V2; Serial: D2450V2 - SN: 797**

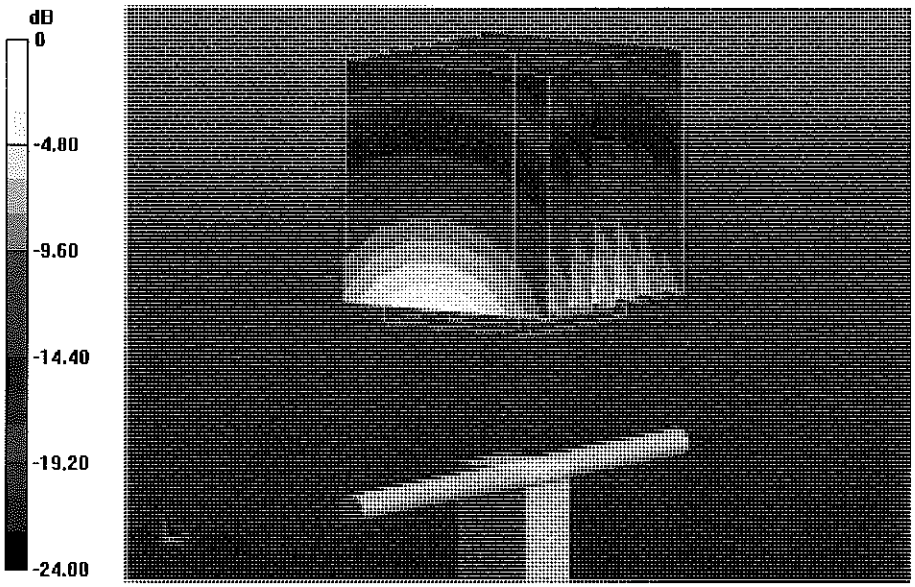
Communication System: UID 0 - CW; Frequency: 2450 MHz
Medium parameters used: f = 2450 MHz; $\sigma$ = 2.04 S/m; $\varepsilon_r$ = 51.3; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: ES3DV3 - SN3205; ConvF(4.35, 4.35, 4.35); Calibrated: 30.12.2013;
- Sensor-Surface: 3mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

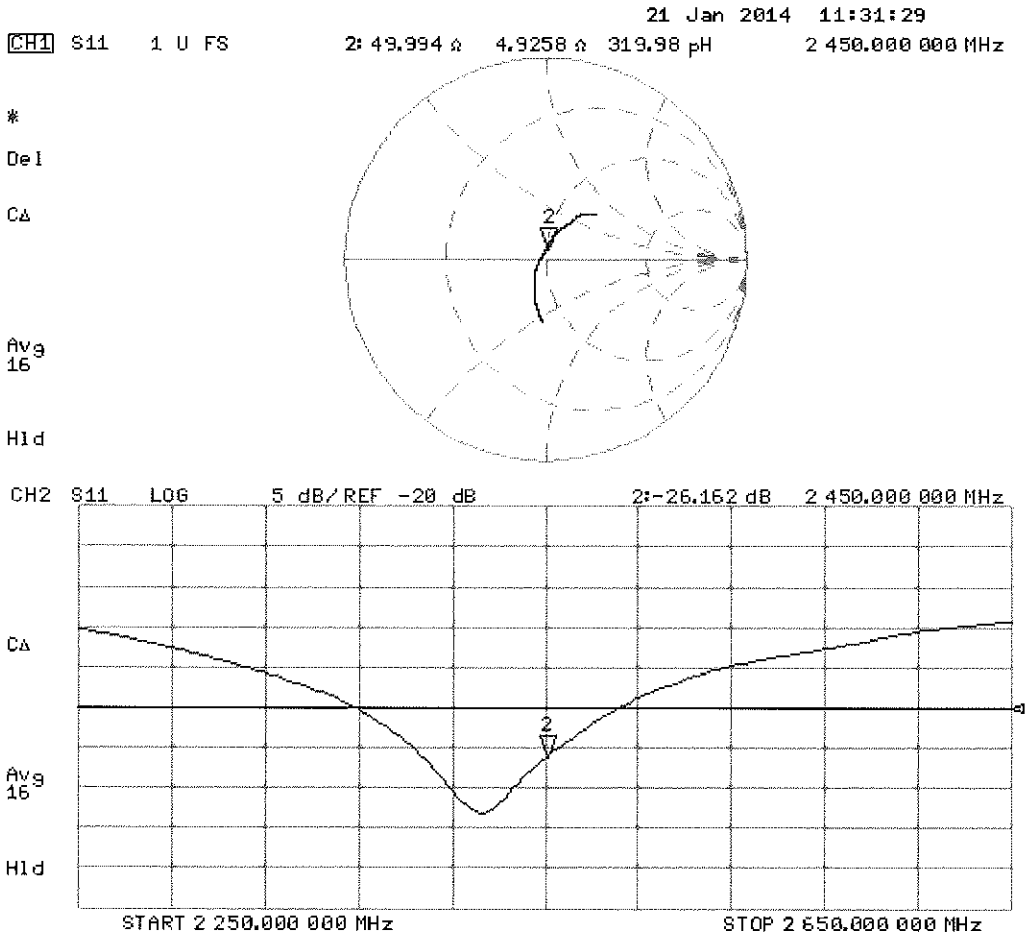
### Dipole Calibration for Body Tissue/Pin=250 mW, d=10mm/Zoom Scan (7x7x7)/Cube 0:

Measurement grid: dx=5mm, dy=5mm, dz=5mm
Reference Value = 93.709 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 26.4 W/kg
**SAR(1 g) = 12.7 W/kg; SAR(10 g) = 5.86 W/kg**
Maximum value of SAR (measured) = 16.8 W/kg




0 dB = 16.8 W/kg = 12.25 dBW/kg

## Impedance Measurement Plot for Body TSL



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

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

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** **PC Test**

**Certificate No: D5GHzV2-1057_Jan14**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | D5GHzV2 - SN: 1057 |
| Calibration procedure(s) | QA CAL-22.v2<br>Calibration procedure for dipole validation kits between 3-6 GHz |
| Calibration date: | January 27, 2014 |

CC 2/5/14 ✓

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 EPM-442A | GB37480704 | 09-Oct-13 (No. 217-01827) | Oct-14 |
| Power sensor HP 8481A | US37292783 | 09-Oct-13 (No. 217-01827) | Oct-14 |
| Power sensor HP 8481A | MY41092317 | 09-Oct-13 (No. 217-01828) | Oct-14 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 04-Apr-13 (No. 217-01736) | Apr-14 |
| Type-N mismatch combination | SN: 5047.3 / 06327 | 04-Apr-13 (No. 217-01739) | Apr-14 |
| Reference Probe EX3DV4 | SN: 3503 | 30-Dec-13 (No. EX3-3503_Dec13) | Dec-14 |
| DAE4 | SN: 601 | 25-Apr-13 (No. DAE4-601_Apr13) | Apr-14 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| RF generator R&S SMT-06 | 100005 | 04-Aug-99 (in house check Oct-13) | In house check: Oct-16 |
| Network Analyzer HP 8753E | US37390585 S4206 | 18-Oct-01 (in house check Oct-13) | In house check: Oct-14 |

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

Issued: January 27, 2014

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



PCT# 753

## Glossary:

| | |
|---|---|
| TSL | tissue simulating liquid |
| ConvF | sensitivity in TSL / NORM x,y,z |
| N/A | not applicable or not measured |

## Calibration is Performed According to the Following Standards:

a) IEC 62209-2, "Evaluation of Human Exposure to Radio Frequency Fields from Handheld and Body-Mounted Wireless Communication Devices in the Frequency Range of 30 MHz to 6 GHz: Human models, Instrumentation, and Procedures"; Part 2: "Procedure to determine the Specific Absorption Rate (SAR) for including accessories and multiple transmitters", March 2010
b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"
c) 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

## Additional Documentation:

d) DASY4/5 System Handbook

## Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

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%.

## Measurement Conditions

DASY system configuration, as far as not given on page 1.

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.8.7 |
| **Extrapolation** | Advanced Extrapolation | |
| **Phantom** | Modular Flat Phantom V5.0 | |
| **Distance Dipole Center - TSL** | 10 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy = 4.0 mm, dz = 1.4 mm | Graded Ratio = 1.4 (Z direction) |
| **Frequency** | 5200 MHz ± 1 MHz<br>5300 MHz ± 1 MHz<br>5500 MHz ± 1 MHz<br>5600 MHz ± 1 MHz<br>5800 MHz ± 1 MHz | |

## Head TSL parameters at 5200 MHz

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 36.0 | 4.66 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 35.0 ± 6 % | 4.45 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5200 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.85 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **78.0 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.25 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **22.3 W/kg ± 19.5 % (k=2)** |

## Head TSL parameters at 5300 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 35.9 | 4.76 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 34.9 ± 6 % | 4.54 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5300 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.36 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **83.0 W / kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.40 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **23.8 W/kg ± 19.5 % (k=2)** |

## Head TSL parameters at 5500 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 35.6 | 4.96 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 34.6 ± 6 % | 4.74 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5500 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.50 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **84.3 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.42 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **24.0 W/kg ± 19.5 % (k=2)** |

## Head TSL parameters at 5600 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 35.5 | 5.07 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 34.5 ± 6 % | 4.86 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5600 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.42 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **83.5 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.40 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **23.8 W/kg ± 19.5 % (k=2)** |

## Head TSL parameters at 5800 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 35.3 | 5.27 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 34.2 ± 6 % | 5.07 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5800 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.00 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **79.3 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.28 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **22.6 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5200 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 49.0 | 5.30 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 47.3 ± 6 % | 5.44 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5200 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.58 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **75.3 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.12 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **21.0 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5300 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 48.9 | 5.42 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 47.2 ± 6 % | 5.57 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5300 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.79 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **77.4 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.17 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **21.5 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5500 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 48.6 | 5.65 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 46.8 ± 6 % | 5.84 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5500 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.96 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **79.1 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.22 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **22.0 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5600 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 48.5 | 5.77 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 46.6 ± 6 % | 5.98 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5600 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.07 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **80.2 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.24 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **22.2 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5800 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 48.2 | 6.00 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 46.3 ± 6 % | 6.23 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5800 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.48 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **74.3 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.06 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **20.4 W/kg ± 19.5 % (k=2)** |

## Appendix

### Antenna Parameters with Head TSL at 5200 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 43.1 Ω - 4.6 jΩ |
| Return Loss | - 21.0 dB |

### Antenna Parameters with Head TSL at 5300 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 46.5 Ω - 1.3 jΩ |
| Return Loss | - 28.1 dB |

### Antenna Parameters with Head TSL at 5500 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 46.2 Ω - 2.5 jΩ |
| Return Loss | - 26.4 dB |

### Antenna Parameters with Head TSL at 5600 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 48.9 Ω - 5.7 jΩ |
| Return Loss | - 24.6 dB |

### Antenna Parameters with Head TSL at 5800 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 48.7 Ω - 3.1 jΩ |
| Return Loss | - 29.5 dB |

### Antenna Parameters with Body TSL at 5200 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 49.4 Ω - 7.7 jΩ |
| Return Loss | - 22.2 dB |

### Antenna Parameters with Body TSL at 5300 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 49.6 Ω - 3.0 jΩ |
| Return Loss | - 30.3 dB |

### Antenna Parameters with Body TSL at 5500 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 50.8 Ω - 3.9 jΩ |
| Return Loss | - 28.0 dB |

## Antenna Parameters with Body TSL at 5600 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 55.4 Ω - 2.5 jΩ |
| Return Loss | - 25.0 dB |

## Antenna Parameters with Body TSL at 5800 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 52.3 Ω - 0.7 jΩ |
| Return Loss | - 32.5 dB |

## General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.186 ns |

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

## Additional EUT Data

| | |
|---|---|
| Manufactured by | SPEAG |
| Manufactured on | November 27, 2006 |

## DASY5 Validation Report for Head TSL

Date: 27.01.2014

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1057**

Communication System: UID 0 - CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz
Medium parameters used: f = 5200 MHz; $\sigma$ = 4.45 S/m; $\varepsilon_r$ = 35; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5300 MHz; $\sigma$ = 4.54 S/m; $\varepsilon_r$ = 34.9; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5500 MHz; $\sigma$ = 4.74 S/m; $\varepsilon_r$ = 34.6; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5600 MHz; $\sigma$ = 4.86 S/m; $\varepsilon_r$ = 34.5; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5800 MHz; $\sigma$ = 5.07 S/m; $\varepsilon_r$ = 34.2; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.52, 5.52, 5.52); Calibrated: 30.12.2013, ConvF(5.2, 5.2, 5.2); Calibrated: 30.12.2013, ConvF(5.01, 5.01, 5.01); Calibrated: 30.12.2013, ConvF(4.86, 4.86, 4.86); Calibrated: 30.12.2013, ConvF(4.91, 4.91, 4.91); Calibrated: 30.12.2013;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

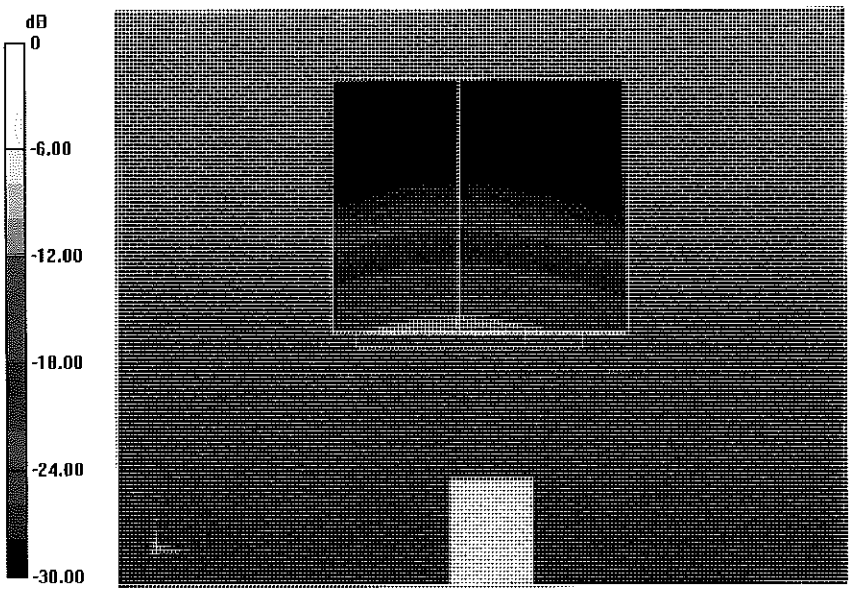
**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.497 V/m; Power Drift = 0.04 dB
Peak SAR (extrapolated) = 28.2 W/kg
**SAR(1 g) = 7.85 W/kg; SAR(10 g) = 2.25 W/kg**
Maximum value of SAR (measured) = 18.6 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 64.444 V/m; Power Drift = 0.07 dB
Peak SAR (extrapolated) = 31.2 W/kg
**SAR(1 g) = 8.36 W/kg; SAR(10 g) = 2.4 W/kg**
Maximum value of SAR (measured) = 20.1 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5500 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.807 V/m; Power Drift = 0.07 dB
Peak SAR (extrapolated) = 33.0 W/kg
**SAR(1 g) = 8.5 W/kg; SAR(10 g) = 2.42 W/kg**
Maximum value of SAR (measured) = 20.8 W/kg

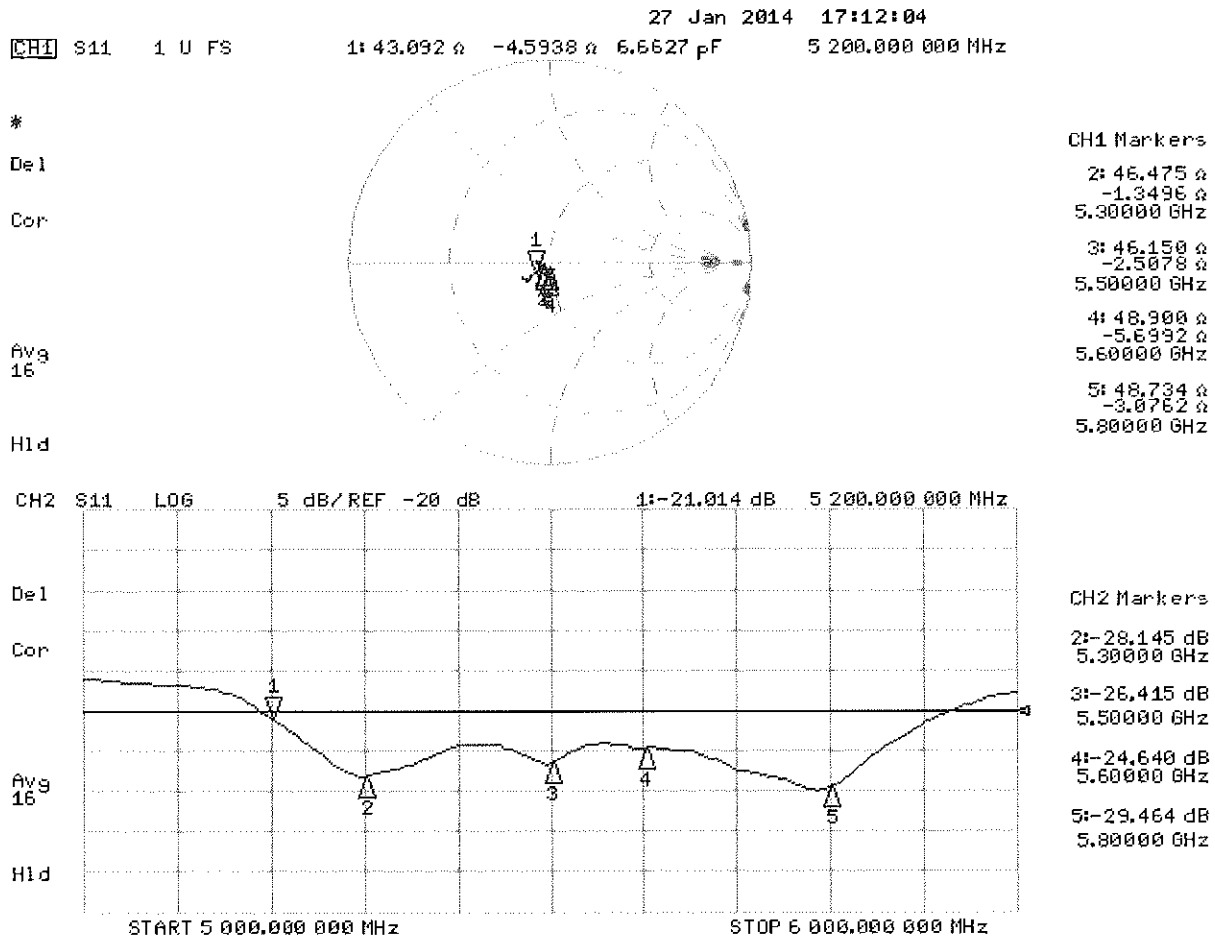
**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.194 V/m; Power Drift = 0.06 dB
Peak SAR (extrapolated) = 33.2 W/kg
**SAR(1 g) = 8.42 W/kg; SAR(10 g) = 2.4 W/kg**

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 60.646 V/m; Power Drift = 0.08 dB
Peak SAR (extrapolated) = 32.9 W/kg
**SAR(1 g) = 8 W/kg; SAR(10 g) = 2.28 W/kg**
Maximum value of SAR (measured) = 19.9 W/kg



0 dB = 19.9 W/kg = 12.99 dBW/kg

## Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Date: 24.01.2014

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1057**

Communication System: UID 0 - CW; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz
Medium parameters used: f = 5200 MHz; $\sigma$ = 5.44 S/m; $\varepsilon_r$ = 47.3; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5300 MHz; $\sigma$ = 5.57 S/m; $\varepsilon_r$ = 47.2; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5500 MHz; $\sigma$ = 5.84 S/m; $\varepsilon_r$ = 46.8; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5600 MHz; $\sigma$ = 5.98 S/m; $\varepsilon_r$ = 46.6; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5800 MHz; $\sigma$ = 6.23 S/m; $\varepsilon_r$ = 46.3; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.01, 5.01, 5.01); Calibrated: 30.12.2013, ConvF(4.76, 4.76, 4.76); Calibrated: 30.12.2013, ConvF(4.52, 4.52, 4.52); Calibrated: 30.12.2013, ConvF(4.3, 4.3, 4.3); Calibrated: 30.12.2013, ConvF(4.47, 4.47, 4.47); Calibrated: 30.12.2013;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

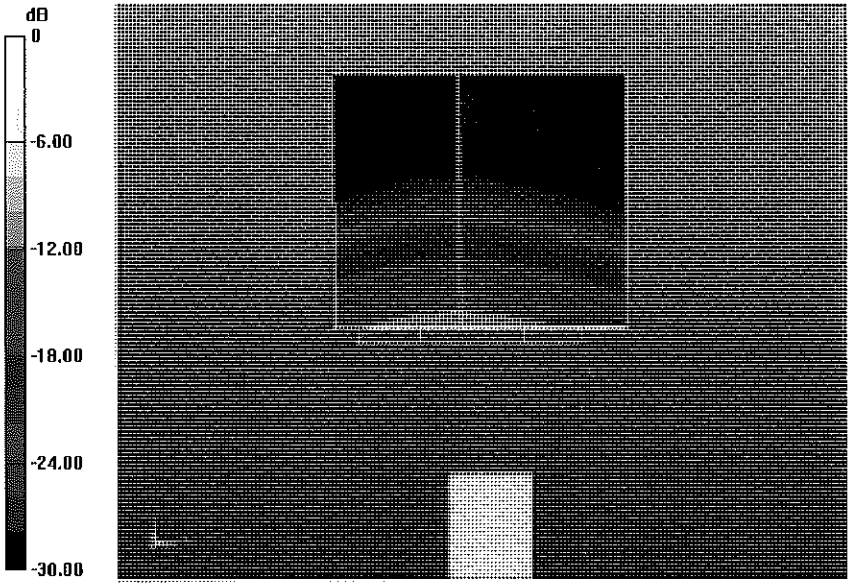
**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.809 V/m; Power Drift = -0.05 dB
Peak SAR (extrapolated) = 30.1 W/kg
**SAR(1 g) = 7.58 W/kg; SAR(10 g) = 2.12 W/kg**
Maximum value of SAR (measured) = 18.2 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.585 V/m; Power Drift = -0.00 dB
Peak SAR (extrapolated) = 32.2 W/kg
**SAR(1 g) = 7.79 W/kg; SAR(10 g) = 2.17 W/kg**
Maximum value of SAR (measured) = 19.1 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5500 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.364 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 34.4 W/kg
**SAR(1 g) = 7.96 W/kg; SAR(10 g) = 2.22 W/kg**
Maximum value of SAR (measured) = 19.4 W/kg

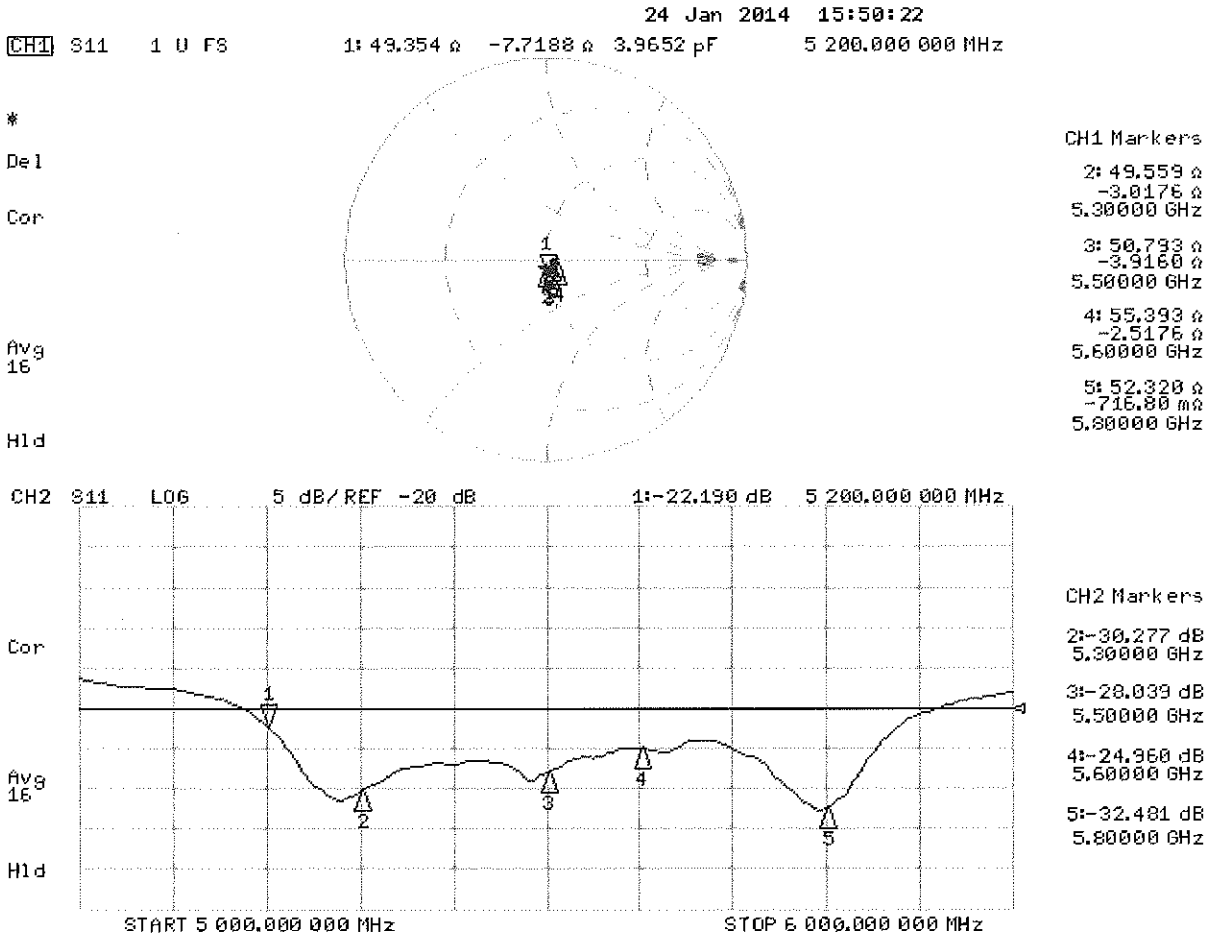
**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 57.864 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 35.8 W/kg
**SAR(1 g) = 8.07 W/kg; SAR(10 g) = 2.24 W/kg**
Maximum value of SAR (measured) = 19.8 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 54.817 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 35.1 W/kg
**SAR(1 g) = 7.48 W/kg; SAR(10 g) = 2.06 W/kg**
Maximum value of SAR (measured) = 18.8 W/kg



0 dB = 18.8 W/kg = 12.74 dBW/kg

## Impedance Measurement Plot for Body TSL



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

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

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** **PC Test**

**Certificate No: D5GHzV2-1007_Sep13/2**

# CALIBRATION CERTIFICATE (Replacement of No: D5GHzV2-1007_Sep13)

Object: D5GHzV2 - SN: 1007

CC✓ 10/5/13

Calibration procedure(s): QA CAL-22.v2
Calibration procedure for dipole validation kits between 3-6 GHz

Calibration date: September 23, 2013

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 EPM-442A | GB37480704 | 01-Nov-12 (No. 217-01640) | Oct-13 |
| Power sensor HP 8481A | US37292783 | 01-Nov-12 (No. 217-01640) | Oct-13 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 04-Apr-13 (No. 217-01736) | Apr-14 |
| Type-N mismatch combination | SN: 5047.3 / 06327 | 04-Apr-13 (No. 217-01739) | Apr-14 |
| Reference Probe EX3DV4 | SN: 3503 | 28-Dec-12 (No. EX3-3503_Dec12) | Dec-13 |
| DAE4 | SN: 601 | 25-Apr-13 (No. DAE4-601_Apr13) | Apr-14 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| Power sensor HP 8481A | MY41092317 | 18-Oct-02 (in house check Oct-11) | In house check: Oct-13 |
| RF generator R&S SMT-06 | 100005 | 04-Aug-99 (in house check Oct-11) | In house check: Oct-13 |
| Network Analyzer HP 8753E | US37390585 S4206 | 18-Oct-01 (in house check Oct-12) | In house check: Oct-13 |

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

Issued: October 4, 2013

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



PCT# 685

## Glossary:

| | |
|---|---|
| TSL | tissue simulating liquid |
| ConvF | sensitivity in TSL / NORM x,y,z |
| N/A | not applicable or not measured |

## Calibration is Performed According to the Following Standards:

a) IEC 62209-2, "Evaluation of Human Exposure to Radio Frequency Fields from Handheld and Body-Mounted Wireless Communication Devices in the Frequency Range of 30 MHz to 6 GHz: Human models, Instrumentation, and Procedures"; Part 2: "Procedure to determine the Specific Absorption Rate (SAR) for including accessories and multiple transmitters", March 2010
b) KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"
c) 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

## Additional Documentation:

d) DASY4/5 System Handbook

## Methods Applied and Interpretation of Parameters:

- *Measurement Conditions:* Further details are available from the Validation Report at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated.
- *Antenna Parameters with TSL:* The dipole is mounted with the spacer to position its feed point exactly below the center marking of the flat phantom section, with the arms oriented parallel to the body axis.
- *Feed Point Impedance and Return Loss:* These parameters are measured with the dipole positioned under the liquid filled phantom. The impedance stated is transformed from the measurement at the SMA connector to the feed point. The Return Loss ensures low reflected power. No uncertainty required.
- *Electrical Delay:* One-way delay between the SMA connector and the antenna feed point. No uncertainty required.
- *SAR measured:* SAR measured at the stated antenna input power.
- *SAR normalized:* SAR as measured, normalized to an input power of 1 W at the antenna connector.
- *SAR for nominal TSL parameters:* The measured TSL parameters are used to calculate the nominal SAR result.

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%.

## Measurement Conditions

DASY system configuration, as far as not given on page 1.

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.8.7 |
| **Extrapolation** | Advanced Extrapolation | |
| **Phantom** | Modular Flat Phantom V5.0 | |
| **Distance Dipole Center - TSL** | 10 mm | with Spacer |
| **Zoom Scan Resolution** | dx, dy = 4.0 mm, dz = 1.4 mm | Graded Ratio = 1.4 (Z direction) |
| **Frequency** | 5200 MHz ± 1 MHz<br>5300 MHz ± 1 MHz<br>5500 MHz ± 1 MHz<br>5600 MHz ± 1 MHz<br>5800 MHz ± 1 MHz | |

## Head TSL parameters at 5200 MHz

The following parameters and calculations were applied.

| | **Temperature** | **Permittivity** | **Conductivity** |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 36.0 | 4.66 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 35.8 ± 6 % | 4.48 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5200 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.77 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **77.5 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.23 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **22.2 W/kg ± 19.5 % (k=2)** |

## Head TSL parameters at 5300 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 35.9 | 4.76 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 35.6 ± 6 % | 4.62 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5300 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.04 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **80.2 W / kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.30 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **22.9 W/kg ± 19.5 % (k=2)** |

## Head TSL parameters at 5500 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 35.6 | 4.96 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 35.4 ± 6 % | 4.76 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5500 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.17 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **81.4 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.32 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **23.1 W/kg ± 19.5 % (k=2)** |

## Head TSL parameters at 5600 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 35.5 | 5.07 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 35.2 ± 6 % | 4.86 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5600 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 8.03 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **80.0 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.28 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **22.7 W/kg ± 19.5 % (k=2)** |

## Head TSL parameters at 5800 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Head TSL parameters** | 22.0 °C | 35.3 | 5.27 mho/m |
| **Measured Head TSL parameters** | (22.0 ± 0.2) °C | 35.0 ± 6 % | 5.07 mho/m ± 6 % |
| **Head TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Head TSL at 5800 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Head TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.78 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **77.5 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Head TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.20 W/kg |
| SAR for nominal Head TSL parameters | normalized to 1W | **21.9 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5200 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 49.0 | 5.30 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 48.3 ± 6 % | 5.36 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5200 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.28 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **72.6 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.03 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **20.2 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5300 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 48.9 | 5.42 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 48.1 ± 6 % | 5.56 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5300 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.49 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **74.7 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.09 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **20.8 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5500 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 48.6 | 5.65 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 47.8 ± 6 % | 5.75 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5500 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.61 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **75.9 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.11 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **21.0 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5600 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 48.5 | 5.77 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 47.6 ± 6 % | 5.88 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5600 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.75 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **77.3 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.16 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **21.5 W/kg ± 19.5 % (k=2)** |

## Body TSL parameters at 5800 MHz

The following parameters and calculations were applied.

| | Temperature | Permittivity | Conductivity |
|---|---|---|---|
| **Nominal Body TSL parameters** | 22.0 °C | 48.2 | 6.00 mho/m |
| **Measured Body TSL parameters** | (22.0 ± 0.2) °C | 47.3 ± 6 % | 6.17 mho/m ± 6 % |
| **Body TSL temperature change during test** | < 0.5 °C | ---- | ---- |

## SAR result with Body TSL at 5800 MHz

| **SAR averaged over 1 $cm^3$ (1 g) of Body TSL** | Condition | |
|---|---|---|
| SAR measured | 100 mW input power | 7.31 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **72.9 W/kg ± 19.9 % (k=2)** |

| **SAR averaged over 10 $cm^3$ (10 g) of Body TSL** | condition | |
|---|---|---|
| SAR measured | 100 mW input power | 2.02 W/kg |
| SAR for nominal Body TSL parameters | normalized to 1W | **20.1 W/kg ± 19.5 % (k=2)** |

## Appendix

### Antenna Parameters with Head TSL at 5200 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 52.4 Ω - 11.0 jΩ |
| Return Loss | - 19.2 dB |

### Antenna Parameters with Head TSL at 5300 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 56.8 Ω - 4.4 jΩ |
| Return Loss | - 22.3 dB |

### Antenna Parameters with Head TSL at 5500 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 48.8 Ω - 5.4 jΩ |
| Return Loss | - 25.1 dB |

### Antenna Parameters with Head TSL at 5600 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 57.3 Ω - 8.7 jΩ |
| Return Loss | - 19.5 dB |

### Antenna Parameters with Head TSL at 5800 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 56.9 Ω + 1.6 jΩ |
| Return Loss | - 23.5 dB |

### Antenna Parameters with Body TSL at 5200 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 53.1 Ω - 10.3 jΩ |
| Return Loss | - 19.7 dB |

### Antenna Parameters with Body TSL at 5300 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 54.3 Ω - 1.5 jΩ |
| Return Loss | - 27.2 dB |

### Antenna Parameters with Body TSL at 5500 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 49.7 Ω - 3.6 jΩ |
| Return Loss | - 28.7 dB |

## Antenna Parameters with Body TSL at 5600 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 58.2 Ω - 5.2 jΩ |
| Return Loss | - 20.9 dB |

## Antenna Parameters with Body TSL at 5800 MHz

| | |
|---|---|
| Impedance, transformed to feed point | 58.7 Ω + 3.9 jΩ |
| Return Loss | - 21.1 dB |

## General Antenna Parameters and Design

| | |
|---|---|
| Electrical Delay (one direction) | 1.201 ns |

After long term use with 100W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

The dipole is made of standard semirigid coaxial cable. The center conductor of the feeding line is directly connected to the second arm of the dipole. The antenna is therefore short-circuited for DC-signals. On some of the dipoles, small end caps are added to the dipole arms in order to improve matching when loaded according to the position as explained in the "Measurement Conditions" paragraph. The SAR data are not affected by this change. The overall dipole length is still according to the Standard.
No excessive force must be applied to the dipole arms, because they might bend or the soldered connections near the feedpoint may be damaged.

## Additional EUT Data

| | |
|---|---|
| Manufactured by | SPEAG |
| Manufactured on | August 28, 2003 |

## DASY5 Validation Report for Head TSL

Date: 23.09.2013

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1007**

Communication System: UID 0 - CW ; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz
Medium parameters used: f = 5200 MHz; $\sigma$ = 4.48 S/m; $\varepsilon_r$ = 35.8; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5300 MHz; $\sigma$ = 4.62 S/m; $\varepsilon_r$ = 35.6; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5500 MHz; $\sigma$ = 4.76 S/m; $\varepsilon_r$ = 35.4; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5600 MHz; $\sigma$ = 4.86 S/m; $\varepsilon_r$ = 35.2; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5800 MHz; $\sigma$ = 5.07 S/m; $\varepsilon_r$ = 35; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(5.41, 5.41, 5.41); Calibrated: 28.12.2012, ConvF(5.1, 5.1, 5.1); Calibrated: 28.12.2012, ConvF(4.91, 4.91, 4.91); Calibrated: 28.12.2012, ConvF(4.76, 4.76, 4.76); Calibrated: 28.12.2012, ConvF(4.81, 4.81, 4.81); Calibrated: 28.12.2012;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (front); Type: QD000P50AA; Serial: 1001
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

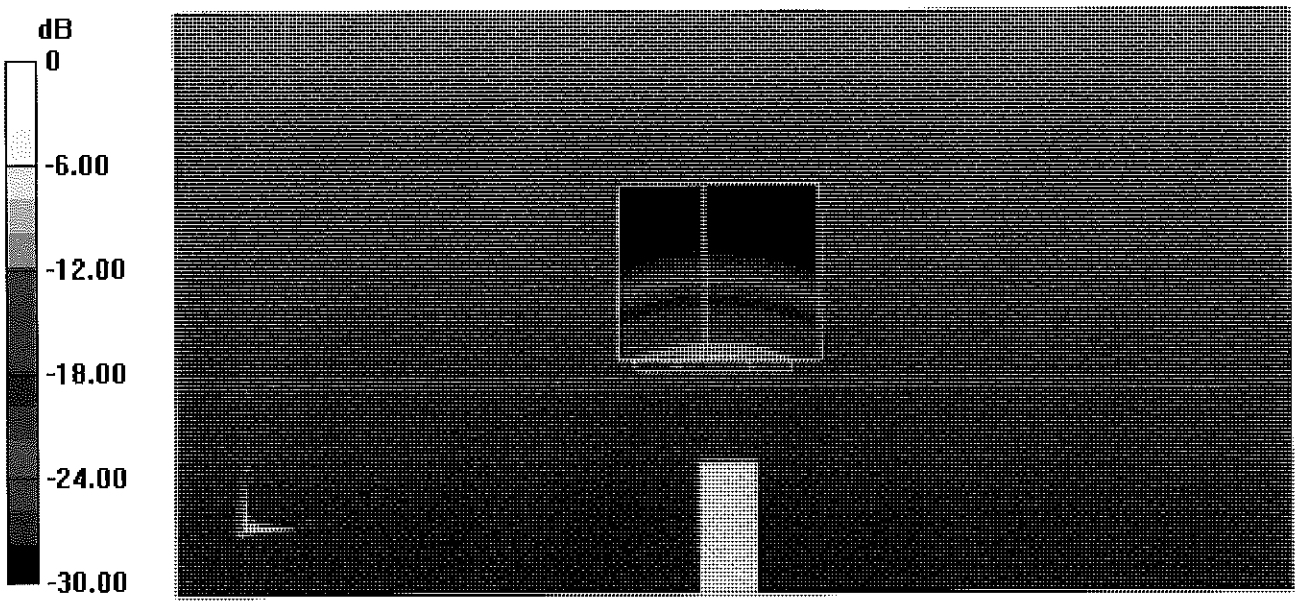
**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.505 V/m; Power Drift = 0.07 dB
Peak SAR (extrapolated) = 28.1 W/kg
**SAR(1 g) = 7.77 W/kg; SAR(10 g) = 2.23 W/kg**
Maximum value of SAR (measured) = 18.1 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.817 V/m; Power Drift = 0.07 dB
Peak SAR (extrapolated) = 29.7 W/kg
**SAR(1 g) = 8.04 W/kg; SAR(10 g) = 2.3 W/kg**
Maximum value of SAR (measured) = 18.7 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5500 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 64.029 V/m; Power Drift = 0.07 dB
Peak SAR (extrapolated) = 32.0 W/kg
**SAR(1 g) = 8.17 W/kg; SAR(10 g) = 2.32 W/kg**
Maximum value of SAR (measured) = 19.7 W/kg

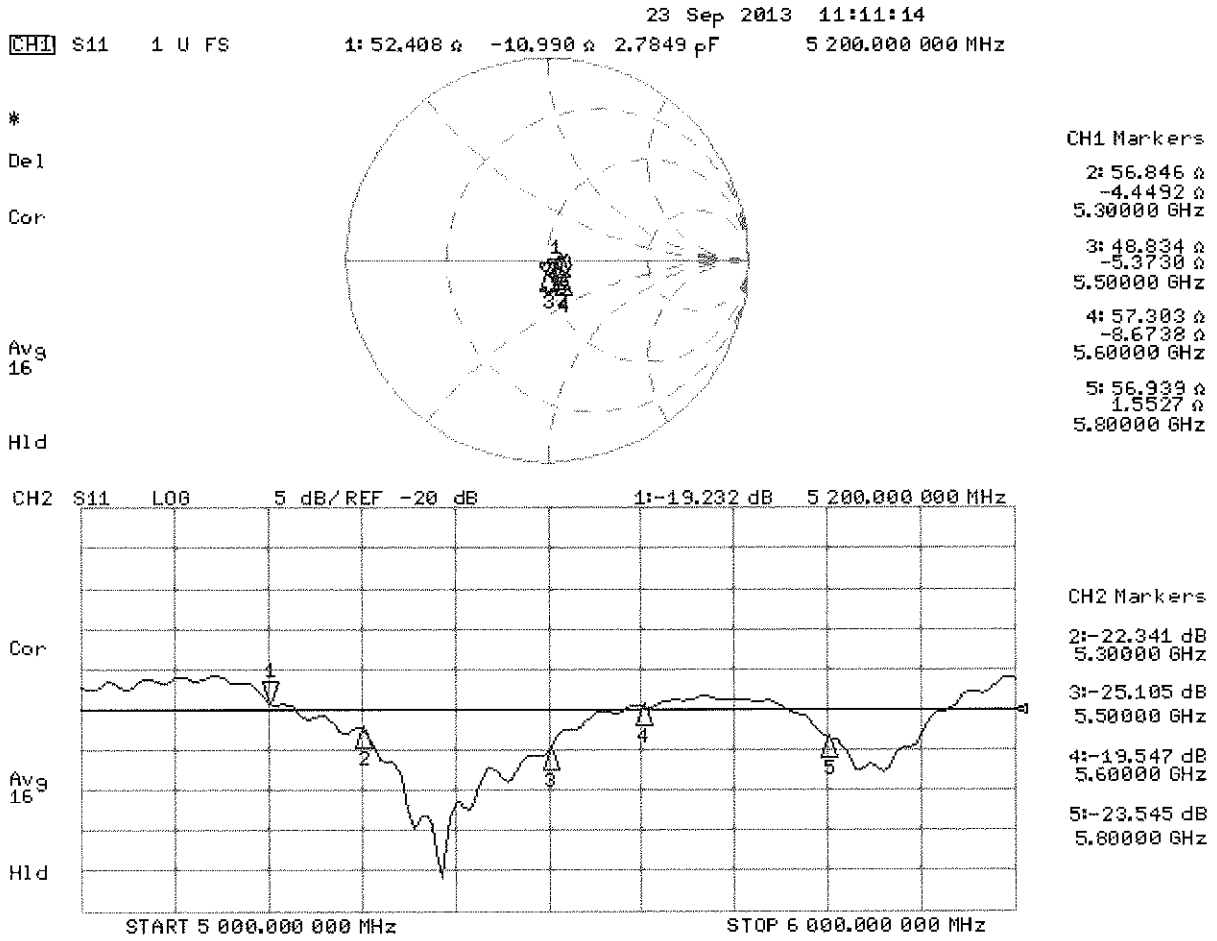
**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 63.403 V/m; Power Drift = 0.05 dB
Peak SAR (extrapolated) = 31.3 W/kg
**SAR(1 g) = 8.03 W/kg; SAR(10 g) = 2.28 W/kg**
Maximum value of SAR (measured) = 19.3 W/kg

**Dipole Calibration for Head Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 60.987 V/m; Power Drift = 0.06 dB
Peak SAR (extrapolated) = 31.9 W/kg
**SAR(1 g) = 7.78 W/kg; SAR(10 g) = 2.2 W/kg**
Maximum value of SAR (measured) = 19.0 W/kg



0 dB = 19.0 W/kg = 12.79 dBW/kg

## Impedance Measurement Plot for Head TSL



## DASY5 Validation Report for Body TSL

Date: 20.09.2013

Test Laboratory: SPEAG, Zurich, Switzerland

**DUT: Dipole 5GHz; Type: D5GHzV2; Serial: D5GHzV2 - SN: 1007**

Communication System: UID 0 - CW ; Frequency: 5200 MHz, Frequency: 5300 MHz, Frequency: 5500 MHz, Frequency: 5600 MHz, Frequency: 5800 MHz
Medium parameters used: f = 5200 MHz; $\sigma$ = 5.36 S/m; $\varepsilon_r$ = 48.3; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5300 MHz; $\sigma$ = 5.56 S/m; $\varepsilon_r$ = 48.1; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5500 MHz; $\sigma$ = 5.75 S/m; $\varepsilon_r$ = 47.8; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5600 MHz; $\sigma$ = 5.88 S/m; $\varepsilon_r$ = 47.6; $\rho$ = 1000 kg/m$^3$ , Medium parameters used: f = 5800 MHz; $\sigma$ = 6.17 S/m; $\varepsilon_r$ = 47.3; $\rho$ = 1000 kg/m$^3$
Phantom section: Flat Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2007)

DASY52 Configuration:

- Probe: EX3DV4 - SN3503; ConvF(4.91, 4.91, 4.91); Calibrated: 28.12.2012, ConvF(4.67, 4.67, 4.67); Calibrated: 28.12.2012, ConvF(4.43, 4.43, 4.43); Calibrated: 28.12.2012, ConvF(4.22, 4.22, 4.22); Calibrated: 28.12.2012, ConvF(4.38, 4.38, 4.38); Calibrated: 28.12.2012;
- Sensor-Surface: 1.4mm (Mechanical Surface Detection)
- Electronics: DAE4 Sn601; Calibrated: 25.04.2013
- Phantom: Flat Phantom 5.0 (back); Type: QD000P50AA; Serial: 1002
- DASY52 52.8.7(1137); SEMCAD X 14.6.10(7164)

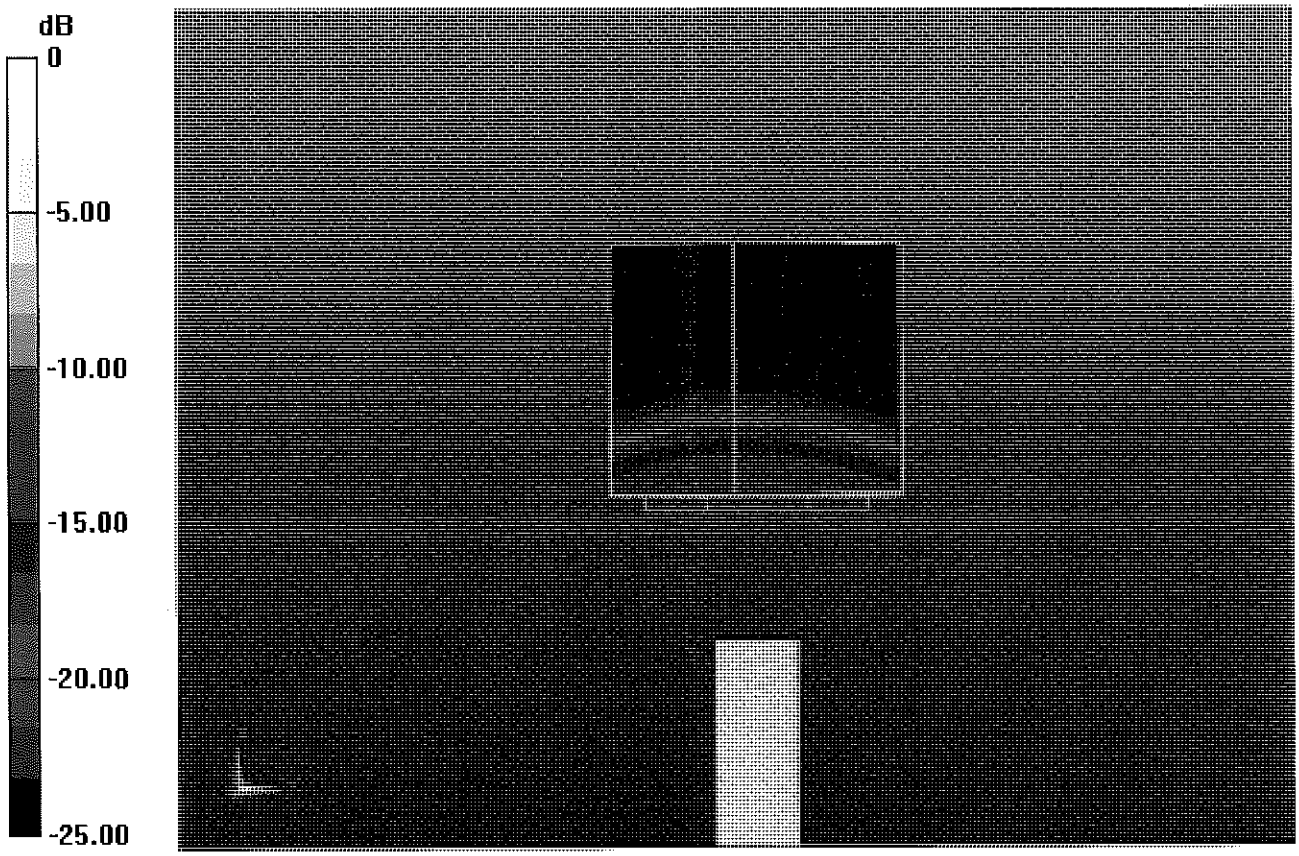
**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5200 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.606 V/m; Power Drift = -0.02 dB
Peak SAR (extrapolated) = 28.6 W/kg
**SAR(1 g) = 7.28 W/kg; SAR(10 g) = 2.03 W/kg**
Maximum value of SAR (measured) = 17.2 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5300 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.305 V/m; Power Drift = 0.01 dB
Peak SAR (extrapolated) = 30.3 W/kg
**SAR(1 g) = 7.49 W/kg; SAR(10 g) = 2.09 W/kg**
Maximum value of SAR (measured) = 17.8 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5500 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.471 V/m; Power Drift = -0.00 dB
Peak SAR (extrapolated) = 32.4 W/kg
**SAR(1 g) = 7.61 W/kg; SAR(10 g) = 2.11 W/kg**
Maximum value of SAR (measured) = 18.5 W/kg

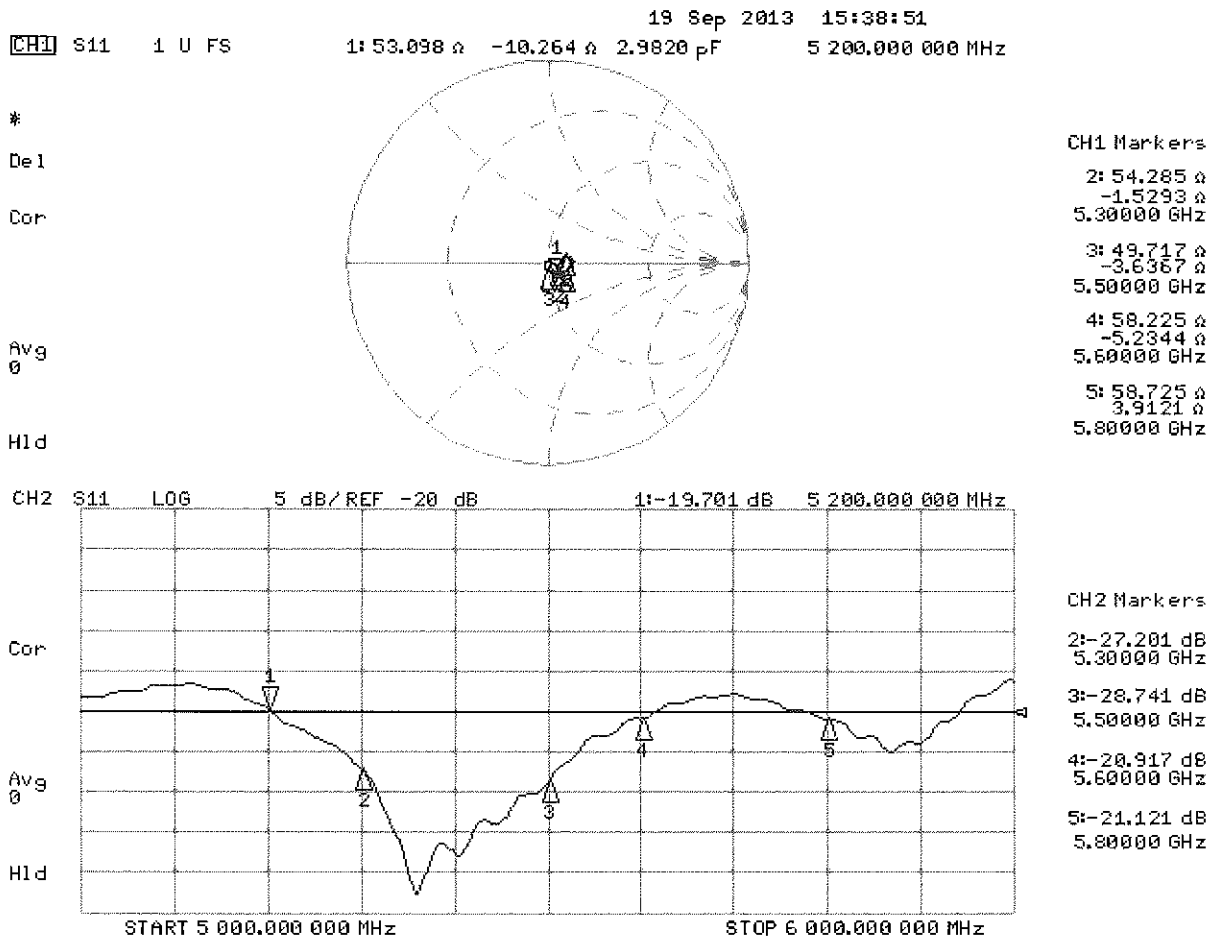
**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5600 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 58.333 V/m; Power Drift = -0.01 dB
Peak SAR (extrapolated) = 33.8 W/kg
**SAR(1 g) = 7.75 W/kg; SAR(10 g) = 2.16 W/kg**
Maximum value of SAR (measured) = 19.1 W/kg

**Dipole Calibration for Body Tissue/Pin=100mW, dist=10mm, f=5800 MHz/Zoom Scan, dist=1.4mm (8x8x7)/Cube 0:** Measurement grid: dx=4mm, dy=4mm, dz=1.4mm
Reference Value = 55.389 V/m; Power Drift = 0.00 dB
Peak SAR (extrapolated) = 34.1 W/kg
**SAR(1 g) = 7.31 W/kg; SAR(10 g) = 2.02 W/kg**
Maximum value of SAR (measured) = 18.3 W/kg



0 dB = 18.3 W/kg = 12.62 dBW/kg

## Impedance Measurement Plot for Body TSL



**Calibration Laboratory of**
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**Accreditation No.: SCS 108**

**Client** PC Test

**Certificate No: ES3-3287_Nov13**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | ES3DV3 - SN:3287 |
| Calibration procedure(s) | QA CAL-01.v9, QA CAL-23.v5, QA CAL-25.v6<br>Calibration procedure for dosimetric E-field probes |
| Calibration date: | November 20, 2013 ✓ CC 11/26/2013 |

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter E4419B | GB41293874 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Power sensor E4412A | MY41498087 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 04-Apr-13 (No. 217-01737) | Apr-14 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-13 (No. 217-01735) | Apr-14 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 04-Apr-13 (No. 217-01738) | Apr-14 |
| Reference Probe ES3DV2 | SN: 3013 | 28-Dec-12 (No. ES3-3013_Dec12) | Dec-13 |
| DAE4 | SN: 660 | 4-Sep-13 (No. DAE4-660_Sep13) | Sep-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-15 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-13) | In house check: Oct-14 |

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

Issued: November 20, 2013

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

## 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, "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:

- *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:3287

Manufactured: June 7, 2010
Calibrated: November 20, 2013

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

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3287

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 1.31 | 1.25 | 1.25 | ± 10.1 % |
| DCP (mV)[B] | 102.6 | 102.5 | 100.4 | |

## 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 | 157.3 | ±2.7 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 159.9 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 152.5 | |
| 10010-CAA | SAR Validation (Square, 100ms, 10ms) | X | 2.23 | 57.9 | 9.9 | 10.00 | 45.7 | ±1.4 % |
| | | Y | 2.13 | 57.6 | 9.8 | | 46.6 | |
| | | Z | 3.31 | 61.1 | 11.8 | | 47.6 | |
| 10011-CAA | UMTS-FDD (WCDMA) | X | 3.25 | 66.3 | 17.9 | 2.91 | 124.8 | ±0.5 % |
| | | Y | 3.16 | 65.7 | 17.4 | | 127.4 | |
| | | Z | 3.15 | 65.5 | 17.4 | | 122.8 | |
| 10012-CAA | IEEE 802.11b WiFi 2.4 GHz (DSSS, 1 Mbps) | X | 3.08 | 68.7 | 18.3 | 1.87 | 127.2 | ±0.7 % |
| | | Y | 3.03 | 68.2 | 17.9 | | 129.4 | |
| | | Z | 2.87 | 67.0 | 17.3 | | 126.5 | |
| 10021-DAA | GSM-FDD (TDMA, GMSK) | X | 15.99 | 90.6 | 25.0 | 9.39 | 99.9 | ±1.2 % |
| | | Y | 12.41 | 86.6 | 23.6 | | 101.5 | |
| | | Z | 29.18 | 99.9 | 28.5 | | 109.2 | |
| 10023-DAA | GPRS-FDD (TDMA, GMSK, TN 0) | X | 25.67 | 98.9 | 27.8 | 9.57 | 97.9 | ±1.7 % |
| | | Y | 14.20 | 88.5 | 24.3 | | 100.6 | |
| | | Z | 27.68 | 99.8 | 28.8 | | 107.7 | |
| 10024-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1) | X | 42.95 | 99.6 | 24.9 | 6.56 | 124.4 | ±1.4 % |
| | | Y | 45.27 | 99.9 | 24.8 | | 128.8 | |
| | | Z | 42.64 | 99.6 | 25.5 | | 135.7 | |
| 10027-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1-2) | X | 27.78 | 91.3 | 21.1 | 4.80 | 136.0 | ±1.4 % |
| | | Y | 32.74 | 93.9 | 21.9 | | 146.6 | |
| | | Z | 23.93 | 89.5 | 21.1 | | 144.8 | |
| 10028-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1-2-3) | X | 59.17 | 99.6 | 22.4 | 3.55 | 142.5 | ±1.2 % |
| | | Y | 78.76 | 99.7 | 21.7 | | 104.9 | |
| | | Z | 38.06 | 94.2 | 21.4 | | 148.8 | |
| 10032-CAA | IEEE 802.15.1 Bluetooth (GFSK, DH5) | X | 93.35 | 99.7 | 19.5 | 1.16 | 108.1 | ±0.9 % |
| | | Y | 96.67 | 94.0 | 16.9 | | 114.7 | |
| | | Z | 98.17 | 96.2 | 18.2 | | 108.9 | |
| 10039-CAA | CDMA2000 (1xRTT, RC1) | X | 4.84 | 66.7 | 18.8 | 4.57 | 126.5 | ±0.9 % |
| | | Y | 4.83 | 66.6 | 18.6 | | 134.4 | |
| | | Z | 4.76 | 66.0 | 18.3 | | 125.9 | |
| 10081-CAA | CDMA2000 (1xRTT, RC3) | X | 4.00 | 66.2 | 18.5 | 3.97 | 121.9 | ±0.7 % |
| | | Y | 3.91 | 65.5 | 17.9 | | 128.9 | |
| | | Z | 3.88 | 65.2 | 17.8 | | 120.7 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10098-CAA | UMTS-FDD (HSUPA, Subtest 2) | X | 4.66 | 66.6 | 18.4 | 3.98 | 132.5 | ±0.7 % |
| | | Y | 4.66 | 66.5 | 18.2 | | 141.3 | |
| | | Z | 4.54 | 65.9 | 17.9 | | 130.7 | |
| 10100-CAB | LTE-FDD (SC-FDMA, 100% RB, 20 MHz, QPSK) | X | 6.65 | 68.3 | 20.1 | 5.67 | 139.5 | ±1.4 % |
| | | Y | 6.69 | 68.3 | 19.9 | | 148.9 | |
| | | Z | 6.60 | 67.9 | 19.8 | | 137.5 | |
| 10108-CAB | LTE-FDD (SC-FDMA, 100% RB, 10 MHz, QPSK) | X | 6.52 | 67.8 | 20.0 | 5.80 | 137.3 | ±1.4 % |
| | | Y | 6.53 | 67.6 | 19.7 | | 147.5 | |
| | | Z | 6.51 | 67.6 | 19.8 | | 135.3 | |
| 10110-CAB | LTE-FDD (SC-FDMA, 100% RB, 5 MHz, QPSK) | X | 6.19 | 67.2 | 19.7 | 5.75 | 134.3 | ±1.2 % |
| | | Y | 6.24 | 67.3 | 19.6 | | 142.9 | |
| | | Z | 6.23 | 67.1 | 19.6 | | 132.3 | |
| 10151-CAB | LTE-TDD (SC-FDMA, 50% RB, 20 MHz, QPSK) | X | 11.56 | 79.1 | 27.9 | 9.28 | 130.1 | ±3.0 % |
| | | Y | 11.01 | 76.8 | 26.2 | | 141.9 | |
| | | Z | 12.98 | 81.2 | 28.7 | | 135.7 | |
| 10154-CAB | LTE-FDD (SC-FDMA, 50% RB, 10 MHz, QPSK) | X | 6.25 | 67.4 | 19.8 | 5.75 | 135.1 | ±1.2 % |
| | | Y | 6.17 | 66.9 | 19.3 | | 143.6 | |
| | | Z | 6.16 | 66.8 | 19.4 | | 132.8 | |
| 10160-CAB | LTE-FDD (SC-FDMA, 50% RB, 15 MHz, QPSK) | X | 6.66 | 67.8 | 20.0 | 5.82 | 140.3 | ±1.4 % |
| | | Y | 6.72 | 67.9 | 19.9 | | 148.8 | |
| | | Z | 6.66 | 67.6 | 19.8 | | 137.4 | |
| 10169-CAB | LTE-FDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 5.05 | 66.7 | 19.5 | 5.73 | 117.8 | ±0.9 % |
| | | Y | 4.93 | 66.0 | 18.9 | | 125.0 | |
| | | Z | 5.08 | 66.3 | 19.3 | | 116.3 | |
| 10172-CAB | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 8.47 | 76.8 | 26.9 | 9.21 | 100.3 | ±2.2 % |
| | | Y | 8.06 | 74.6 | 25.3 | | 107.5 | |
| | | Z | 9.43 | 78.2 | 27.4 | | 102.5 | |
| 10175-CAB | LTE-FDD (SC-FDMA, 1 RB, 10 MHz, QPSK) | X | 4.98 | 66.3 | 19.3 | 5.72 | 118.2 | ±0.9 % |
| | | Y | 4.96 | 66.1 | 19.0 | | 119.9 | |
| | | Z | 5.03 | 66.1 | 19.1 | | 116.1 | |
| 10181-CAB | LTE-FDD (SC-FDMA, 1 RB, 15 MHz, QPSK) | X | 5.06 | 66.7 | 19.6 | 5.72 | 118.7 | ±0.9 % |
| | | Y | 4.97 | 66.2 | 19.1 | | 120.0 | |
| | | Z | 5.03 | 66.1 | 19.1 | | 116.3 | |
| 10225-CAA | UMTS-FDD (HSPA+) | X | 6.78 | 66.1 | 18.9 | 5.97 | 105.3 | ±1.2 % |
| | | Y | 6.68 | 65.7 | 18.6 | | 106.8 | |
| | | Z | 7.32 | 67.6 | 19.7 | | 148.0 | |
| 10237-CAB | LTE-TDD (SC-FDMA, 1 RB, 10 MHz, QPSK) | X | 8.56 | 77.1 | 27.1 | 9.21 | 100.8 | ±1.9 % |
| | | Y | 8.33 | 75.8 | 26.1 | | 103.8 | |
| | | Z | 9.39 | 78.0 | 27.3 | | 101.9 | |
| 10252-CAB | LTE-TDD (SC-FDMA, 50% RB, 10 MHz, QPSK) | X | 10.58 | 77.8 | 27.4 | 9.24 | 123.3 | ±2.5 % |
| | | Y | 10.48 | 76.9 | 26.5 | | 128.1 | |
| | | Z | 11.79 | 79.6 | 28.0 | | 127.0 | |
| 10267-CAB | LTE-TDD (SC-FDMA, 100% RB, 10 MHz, QPSK) | X | 11.52 | 79.1 | 27.9 | 9.30 | 130.1 | ±2.7 % |
| | | Y | 11.24 | 77.7 | 26.9 | | 136.0 | |
| | | Z | 12.96 | 81.2 | 28.8 | | 134.8 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10274-CAA | UMTS-FDD (HSUPA, Subtest 5, 3GPP Rel8.10) | X | 6.14 | 67.4 | 19.0 | 4.87 | 145.5 | ±1.2 % |
| | | Y | 6.19 | 67.4 | 19.0 | | 149.2 | |
| | | Z | 6.10 | 66.9 | 18.8 | | 142.3 | |
| 10275-CAA | UMTS-FDD (HSUPA, Subtest 5, 3GPP Rel8.4) | X | 4.41 | 66.4 | 18.3 | 3.96 | 126.4 | ±0.7 % |
| | | Y | 4.43 | 66.3 | 18.2 | | 130.4 | |
| | | Z | 4.36 | 65.9 | 18.0 | | 123.8 | |
| 10291-AAA | CDMA2000, RC3, SO55, Full Rate | X | 3.57 | 65.9 | 17.9 | 3.46 | 120.0 | ±0.5 % |
| | | Y | 3.55 | 65.6 | 17.6 | | 121.7 | |
| | | Z | 3.50 | 65.1 | 17.5 | | 117.2 | |
| 10292-AAA | CDMA2000, RC3, SO32, Full Rate | X | 3.55 | 66.1 | 18.0 | 3.39 | 121.3 | ±0.5 % |
| | | Y | 3.54 | 66.0 | 17.8 | | 123.6 | |
| | | Z | 3.45 | 65.2 | 17.4 | | 118.9 | |
| 10297-AAA | LTE-FDD (SC-FDMA, 50% RB, 20 MHz, QPSK) | X | 6.53 | 67.8 | 20.0 | 5.81 | 136.2 | ±1.2 % |
| | | Y | 6.48 | 67.5 | 19.6 | | 139.3 | |
| | | Z | 6.52 | 67.6 | 19.8 | | 134.1 | |
| 10311-AAA | LTE-FDD (SC-FDMA, 100% RB, 15 MHz, QPSK) | X | 7.12 | 68.4 | 20.4 | 6.06 | 141.7 | ±1.4 % |
| | | Y | 7.11 | 68.3 | 20.1 | | 145.3 | |
| | | Z | 7.14 | 68.4 | 20.3 | | 139.8 | |
| 10315-AAA | IEEE 802.11b WiFi 2.4 GHz (DSSS, 1 Mbps, 96pc duty cycle) | X | 2.79 | 67.6 | 18.0 | 1.71 | 125.5 | ±0.5 % |
| | | Y | 2.71 | 66.9 | 17.3 | | 128.2 | |
| | | Z | 2.64 | 66.2 | 17.0 | | 123.5 | |
| 10403-AAA | CDMA2000 (1xEV-DO, Rev. 0) | X | 4.78 | 67.5 | 18.3 | 3.76 | 130.6 | ±0.5 % |
| | | Y | 4.77 | 67.5 | 18.2 | | 133.8 | |
| | | Z | 4.65 | 66.5 | 17.8 | | 130.0 | |
| 10404-AAA | CDMA2000 (1xEV-DO, Rev. A) | X | 4.83 | 68.2 | 18.6 | 3.77 | 129.2 | ±0.7 % |
| | | Y | 4.68 | 67.4 | 18.0 | | 131.9 | |
| | | Z | 4.52 | 66.3 | 17.7 | | 128.7 | |

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 7 and 8).
[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:3287

## 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 | 6.52 | 6.52 | 6.52 | 0.47 | 1.46 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 6.30 | 6.30 | 6.30 | 0.40 | 1.59 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 5.27 | 5.27 | 5.27 | 0.63 | 1.34 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 5.08 | 5.08 | 5.08 | 0.62 | 1.37 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 4.43 | 4.43 | 4.43 | 0.79 | 1.28 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 4.29 | 4.29 | 4.29 | 0.77 | 1.38 | ± 12.0 % |

[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: ES3DV3 - SN:3287

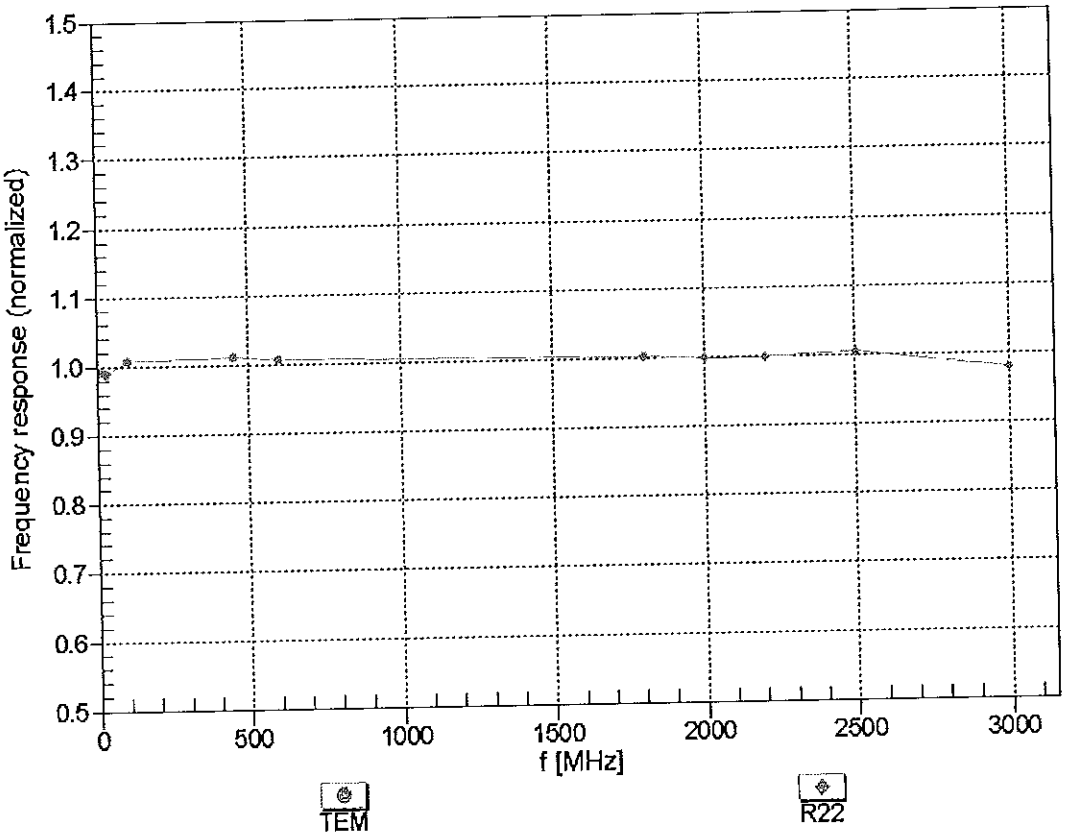
## Calibration Parameter Determined in Body Tissue Simulating Media

| 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 | 6.09 | 6.09 | 6.09 | 0.55 | 1.37 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 6.04 | 6.04 | 6.04 | 0.55 | 1.39 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 4.93 | 4.93 | 4.93 | 0.39 | 1.73 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 4.67 | 4.67 | 4.67 | 0.38 | 1.75 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 4.17 | 4.17 | 4.17 | 0.60 | 1.20 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 4.00 | 4.00 | 4.00 | 0.60 | 1.10 | ± 12.0 % |

[C] Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

# Frequency Response of E-Field

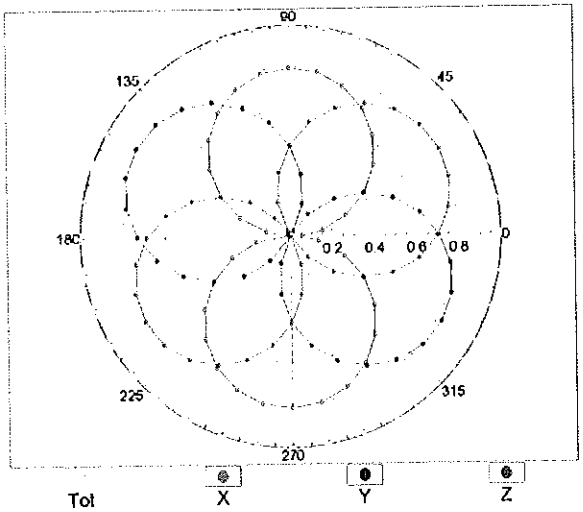
## (TEM-Cell:ifi110 EXX, Waveguide: R22)



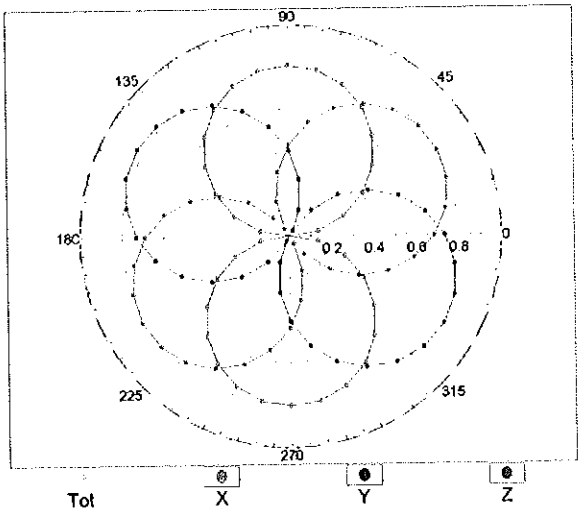

**Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)**

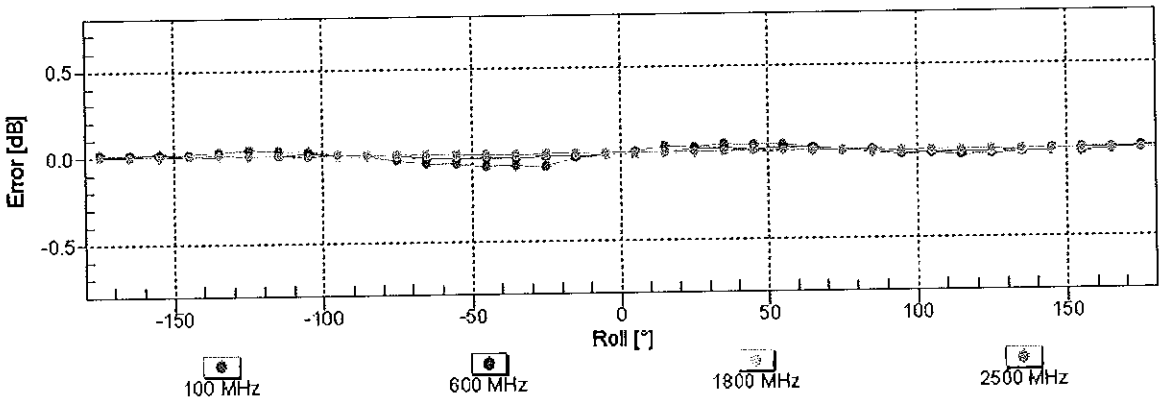
# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



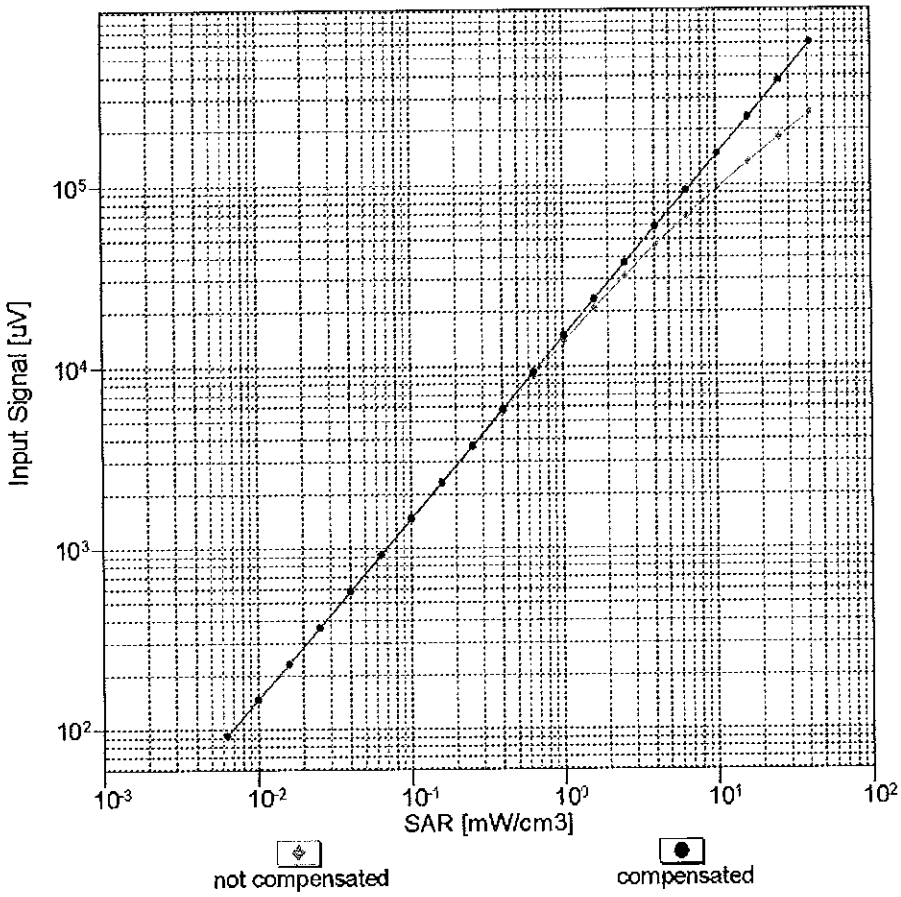

f=1800 MHz,R22

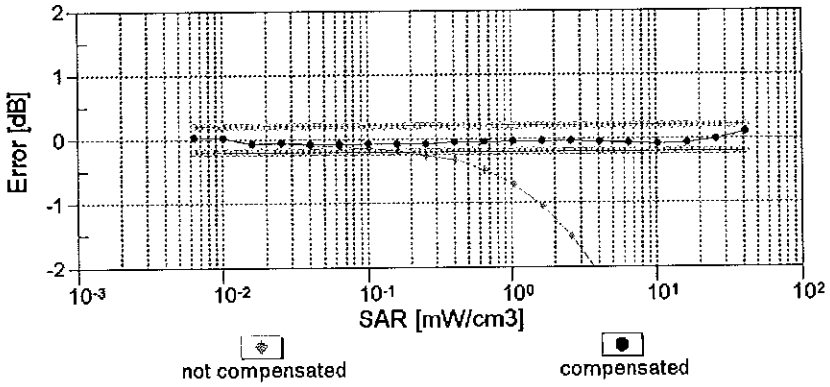



**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

# Dynamic Range f($SAR_{head}$)
**(TEM cell , f = 900 MHz)**

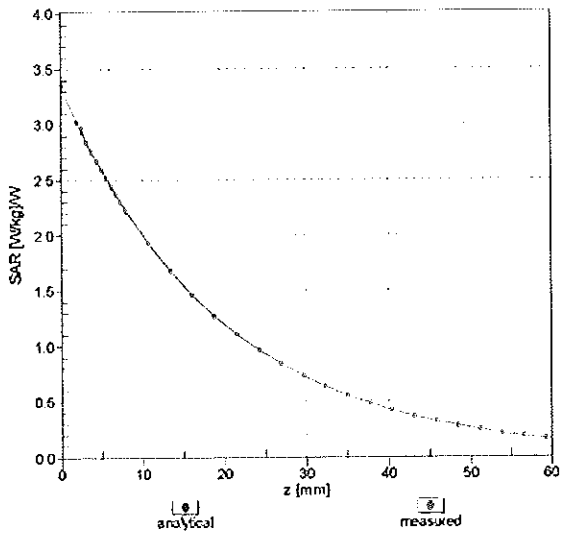


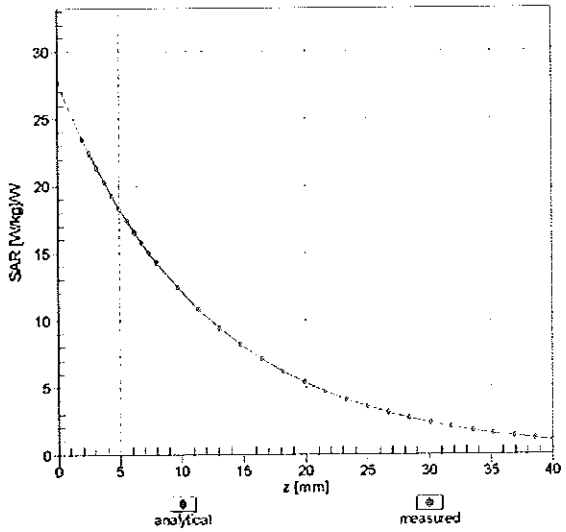

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

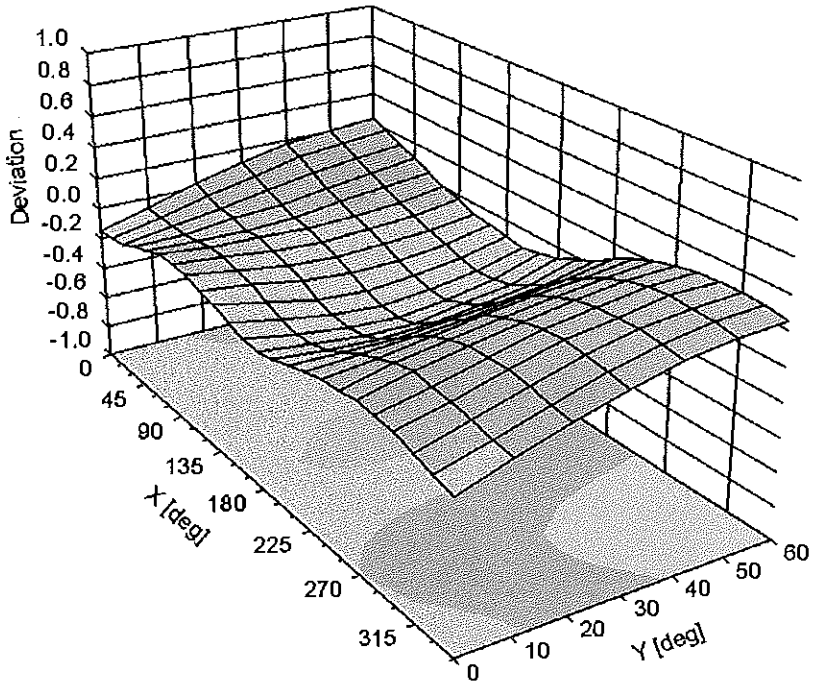


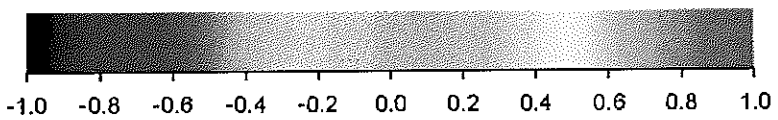

f = 1900 MHz,WGLS R22 (H_convF)




# Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**




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

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3287

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -15 |
| 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
Servizio svizzero di taratura
**S** Swiss Calibration Service

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** **PC Test**

**Certificate No: ES3-3022_Aug13**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | ES3DV2 - SN:3022 |
| Calibration procedure(s) | QA CAL-01.v9, QA CAL-23.v5, QA CAL-25.v6<br>Calibration procedure for dosimetric E-field probes |
| Calibration date: | August 22, 2013 |

UCC 9/13/13

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter E4419B | GB41293874 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Power sensor E4412A | MY41498087 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 04-Apr-13 (No. 217-01737) | Apr-14 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-13 (No. 217-01735) | Apr-14 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 04-Apr-13 (No. 217-01738) | Apr-14 |
| Reference Probe ES3DV2 | SN: 3013 | 28-Dec-12 (No. ES3-3013_Dec12) | Dec-13 |
| DAE4 | SN: 660 | 31-Jan-13 (No. DAE4-660_Jan13) | Jan-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-15 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-12) | In house check: Oct-13 |

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

Issued: August 23, 2013

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

## 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 |

## Calibration is Performed According to the Following Standards:

a) IEEE Std 1528-2003, "IEEE Recommended Practice for Determining the Peak Spatial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques", December 2003
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:

- *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.

# Probe ES3DV2

## SN:3022

Manufactured: April 15, 2003
Calibrated: August 22, 2013

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

# DASY/EASY - Parameters of Probe: ES3DV2 - SN:3022

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 1.00 | 1.04 | 0.99 | ± 10.1 % |
| DCP (mV)[B] | 100.7 | 97.4 | 99.7 | |

## Modulation Calibration Parameters

| UID | Communication System Name | | A dB | B dB$\sqrt{\mu V}$ | C | D dB | VR mV | Unc[E] (k=2) |
|---|---|---|---|---|---|---|---|---|
| 0 | CW | X | 0.0 | 0.0 | 1.0 | 0.00 | 178.6 | ±3.0 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 141.9 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 134.7 | |

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: ES3DV2 - SN:3022

## 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 | Depth (mm) | Unct. (k=2) |
|---|---|---|---|---|---|---|---|---|
| 750 | 41.9 | 0.89 | 6.21 | 6.21 | 6.21 | 0.19 | 2.37 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 6.09 | 6.09 | 6.09 | 0.30 | 1.70 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 5.19 | 5.19 | 5.19 | 0.65 | 1.23 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 5.03 | 5.03 | 5.03 | 0.51 | 1.43 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 4.36 | 4.36 | 4.36 | 0.51 | 1.51 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 4.16 | 4.16 | 4.16 | 0.74 | 1.29 | ± 12.0 % |

[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.

# DASY/EASY - Parameters of Probe: ES3DV2 - SN:3022

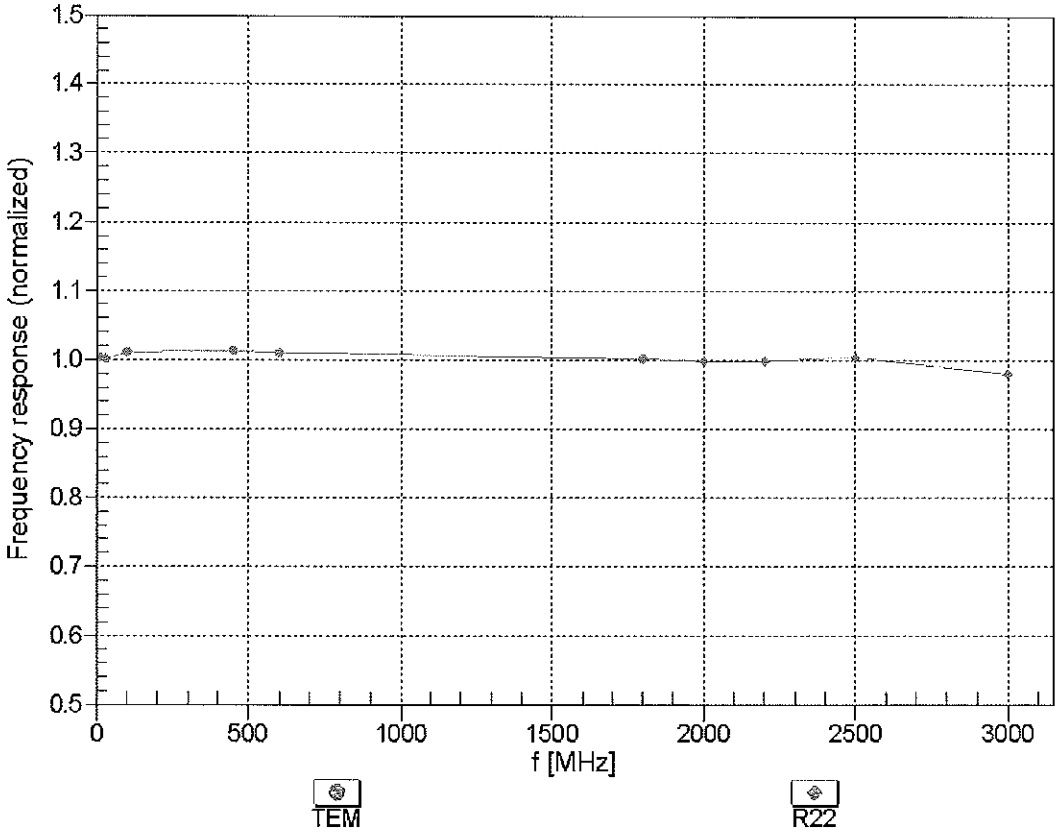
## Calibration Parameter Determined in Body Tissue Simulating Media

| f (MHz) [C] | Relative Permittivity [F] | Conductivity (S/m) [F] | ConvF X | ConvF Y | ConvF Z | Alpha | Depth (mm) | Unct. (k=2) |
|---|---|---|---|---|---|---|---|---|
| 750 | 55.5 | 0.96 | 5.92 | 5.92 | 5.92 | 0.24 | 1.99 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 5.91 | 5.91 | 5.91 | 0.29 | 1.85 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 4.75 | 4.75 | 4.75 | 0.52 | 1.52 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 4.49 | 4.49 | 4.49 | 0.49 | 1.56 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 4.01 | 4.01 | 4.01 | 0.70 | 1.02 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 3.85 | 3.85 | 3.85 | 0.58 | 0.90 | ± 12.0 % |

[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.

# Frequency Response of E-Field

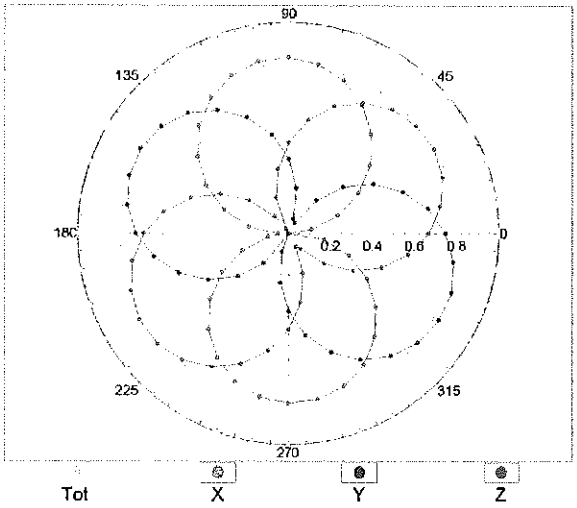
**(TEM-Cell:ifi110 EXX, Waveguide: R22)**



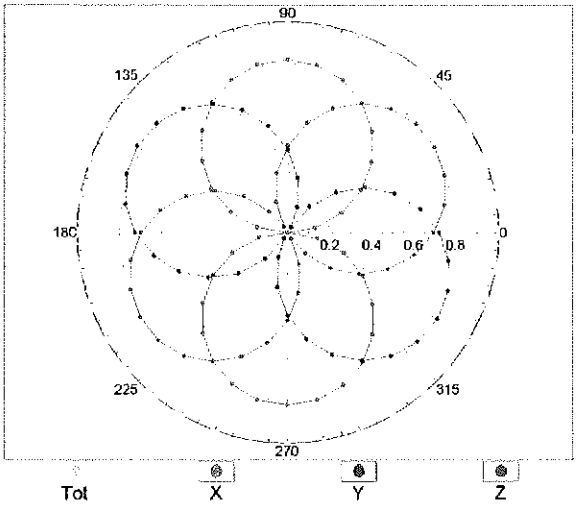

**Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)**

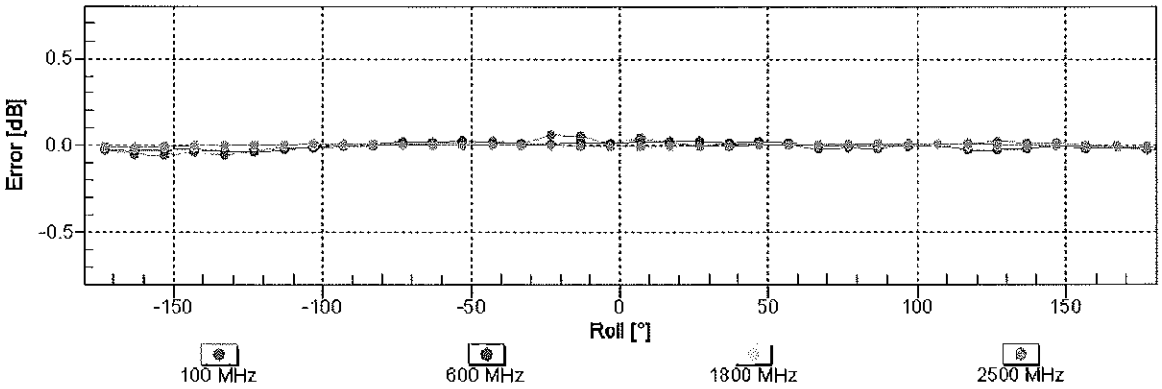
# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



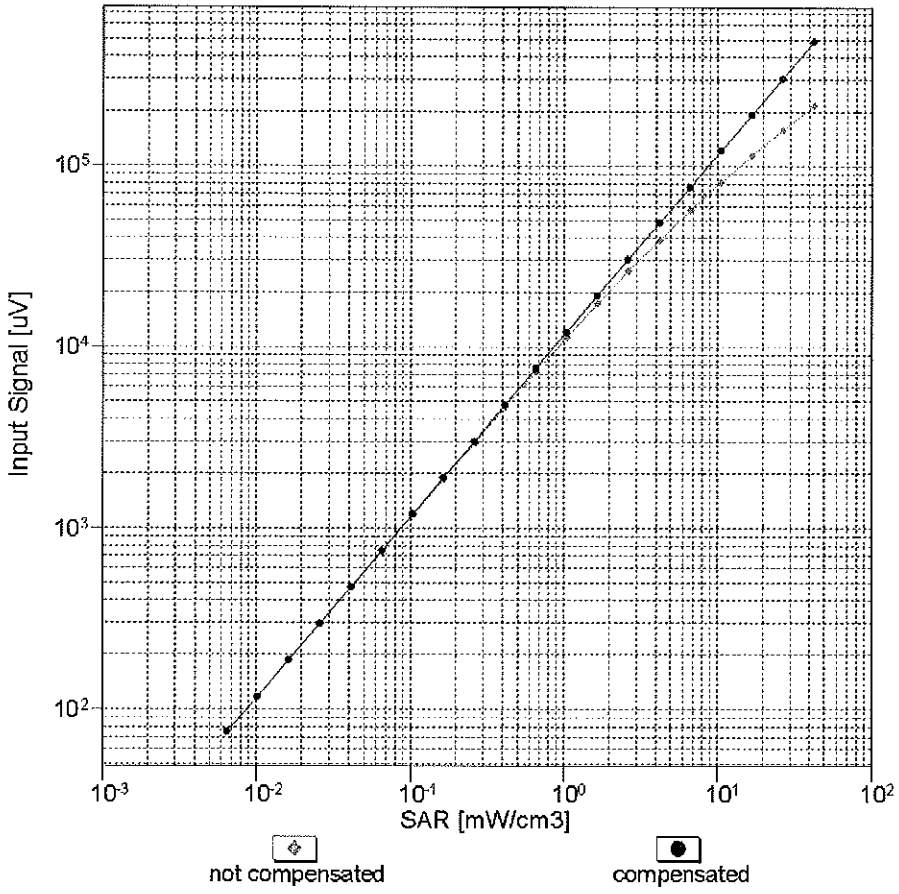

f=1800 MHz,R22

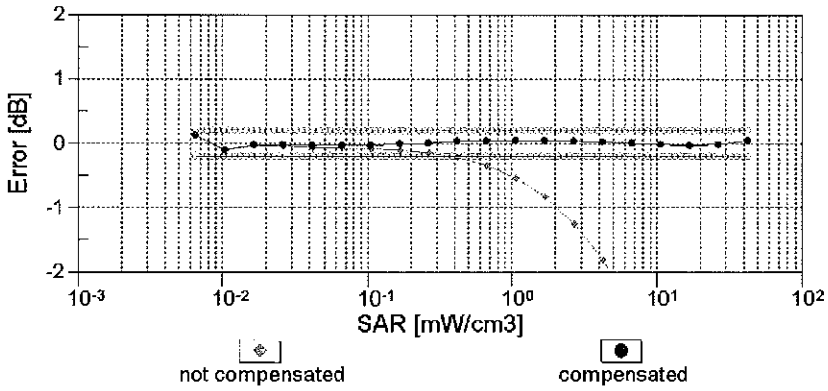



**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

# Dynamic Range f($SAR_{head}$)
**(TEM cell , f = 900 MHz)**

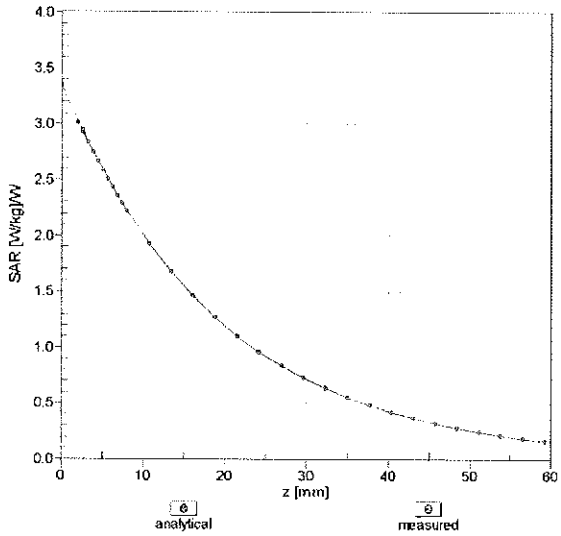


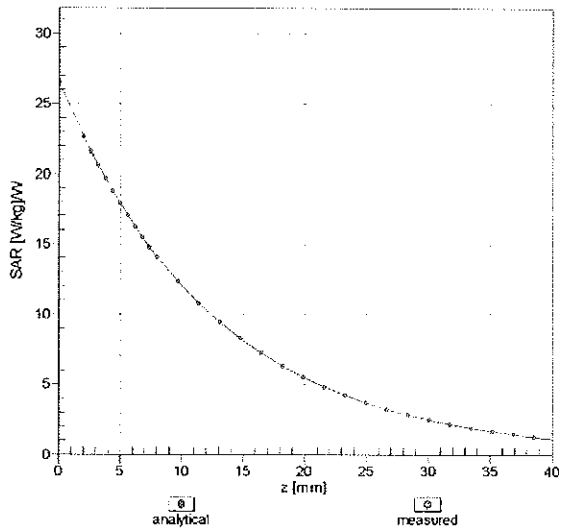

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

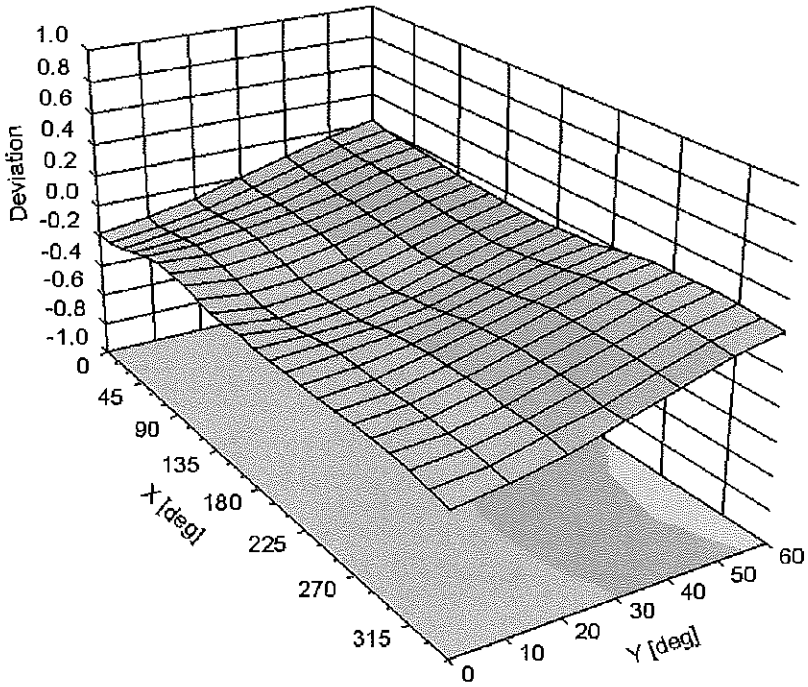


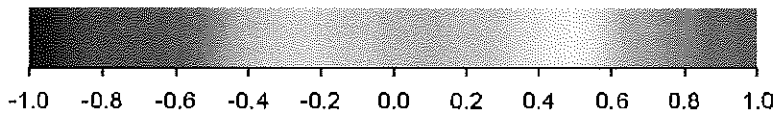

f = 1750 MHz,WGLS R22 (H_convF)




# 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: ES3DV2 - SN:3022

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -83.1 |
| 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
Servizio svizzero di taratura
**S** Swiss Calibration Service

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** **PC Test**

**Certificate No: ES3-3319_Apr14**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | ES3DV3 - SN:3319 |
| Calibration procedure(s) | QA CAL-01.v9, QA CAL-23.v5, QA CAL-25.v6<br>Calibration procedure for dosimetric E-field probes |
| Calibration date: | April 17, 2014 |

OCV 5/7/14

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: April 21, 2014

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

## 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, "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:

- *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:3319

| | |
|---|---|
| Manufactured: | January 10, 2012 |
| Repaired: | April 11, 2014 |
| Calibrated: | April 17, 2014 |

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

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3319

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 1.11 | 1.08 | 1.15 | ± 10.1 % |
| DCP (mV)[B] | 102.6 | 104.2 | 103.7 | |

## 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 | 199.6 | ±3.5 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 188.8 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 178.5 | |
| 10010-CAA | SAR Validation (Square, 100ms, 10ms) | X | 3.31 | 63.3 | 12.9 | 10.00 | 42.6 | ±2.2 % |
| | | Y | 5.10 | 68.0 | 14.1 | | 38.8 | |
| | | Z | 2.84 | 61.7 | 12.1 | | 44.3 | |
| 10011-CAB | UMTS-FDD (WCDMA) | X | 3.30 | 66.9 | 18.4 | 2.91 | 136.7 | ±0.5 % |
| | | Y | 3.32 | 67.1 | 18.4 | | 127.0 | |
| | | Z | 3.45 | 68.0 | 19.1 | | 145.1 | |
| 10012-CAA | IEEE 802.11b WiFi 2.4 GHz (DSSS, 1 Mbps) | X | 3.12 | 69.3 | 19.0 | 1.87 | 138.7 | ±0.7 % |
| | | Y | 3.22 | 70.2 | 19.3 | | 127.0 | |
| | | Z | 3.40 | 71.3 | 19.9 | | 146.4 | |
| 10021-DAB | GSM-FDD (TDMA, GMSK) | X | 25.66 | 99.7 | 28.3 | 9.39 | 139.0 | ±1.4 % |
| | | Y | 16.30 | 92.5 | 25.7 | | 141.7 | |
| | | Z | 25.20 | 99.5 | 28.1 | | 144.9 | |
| 10023-DAB | GPRS-FDD (TDMA, GMSK, TN 0) | X | 25.81 | 100.0 | 28.5 | 9.57 | 128.3 | ±2.2 % |
| | | Y | 13.99 | 89.5 | 24.6 | | 129.0 | |
| | | Z | 25.39 | 99.7 | 28.3 | | 141.2 | |
| 10024-DAB | GPRS-FDD (TDMA, GMSK, TN 0-1) | X | 37.04 | 99.8 | 25.7 | 6.56 | 131.4 | ±2.2 % |
| | | Y | 37.62 | 99.7 | 25.0 | | 139.6 | |
| | | Z | 38.36 | 99.8 | 25.3 | | 145.5 | |
| 10027-DAB | GPRS-FDD (TDMA, GMSK, TN 0-1-2) | X | 48.04 | 99.6 | 23.8 | 4.80 | 144.6 | ±1.9 % |
| | | Y | 29.62 | 94.2 | 22.1 | | 129.3 | |
| | | Z | 43.87 | 99.7 | 24.0 | | 129.9 | |
| 10028-DAB | GPRS-FDD (TDMA, GMSK, TN 0-1-2-3) | X | 54.95 | 99.9 | 22.9 | 3.55 | 149.6 | ±1.7 % |
| | | Y | 57.76 | 99.6 | 22.2 | | 138.2 | |
| | | Z | 54.27 | 99.8 | 22.7 | | 137.3 | |
| 10032-CAA | IEEE 802.15.1 Bluetooth (GFSK, DH5) | X | 44.58 | 99.9 | 21.1 | 1.16 | 134.6 | ±1.7 % |
| | | Y | 96.74 | 98.9 | 18.8 | | 149.0 | |
| | | Z | 59.46 | 99.9 | 20.4 | | 149.1 | |
| 10039-CAB | CDMA2000 (1xRTT, RC1) | X | 4.70 | 66.3 | 18.7 | 4.57 | 130.9 | ±0.9 % |
| | | Y | 4.85 | 67.1 | 19.0 | | 147.5 | |
| | | Z | 4.88 | 67.3 | 19.3 | | 147.2 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10081-CAB | CDMA2000 (1xRTT, RC3) | X | 3.90 | 65.8 | 18.4 | 3.97 | 130.0 | ±0.7 % |
| | | Y | 4.00 | 66.5 | 18.6 | | 140.8 | |
| | | Z | 3.99 | 66.5 | 18.7 | | 142.5 | |
| 10098-CAB | UMTS-FDD (HSUPA, Subtest 2) | X | 4.64 | 66.7 | 18.6 | 3.98 | 143.1 | ±0.9 % |
| | | Y | 4.58 | 66.5 | 18.4 | | 132.8 | |
| | | Z | 4.60 | 66.7 | 18.6 | | 131.9 | |
| 10100-CAB | LTE-FDD (SC-FDMA, 100% RB, 20 MHz, QPSK) | X | 6.32 | 67.1 | 19.5 | 5.67 | 125.8 | ±1.4 % |
| | | Y | 6.41 | 67.4 | 19.5 | | 138.4 | |
| | | Z | 6.51 | 67.9 | 19.9 | | 143.6 | |
| 10108-CAB | LTE-FDD (SC-FDMA, 100% RB, 10 MHz, QPSK) | X | 6.48 | 67.7 | 20.0 | 5.80 | 148.0 | ±1.4 % |
| | | Y | 6.28 | 66.9 | 19.4 | | 135.8 | |
| | | Z | 6.39 | 67.4 | 19.8 | | 141.0 | |
| 10110-CAB | LTE-FDD (SC-FDMA, 100% RB, 5 MHz, QPSK) | X | 6.17 | 67.2 | 19.8 | 5.75 | 141.0 | ±1.4 % |
| | | Y | 5.94 | 66.3 | 19.1 | | 132.2 | |
| | | Z | 6.08 | 67.0 | 19.6 | | 137.9 | |
| 10114-CAA | IEEE 802.11n (HT Greenfield, 13.5 Mbps, BPSK) | X | 10.35 | 69.2 | 21.5 | 8.10 | 133.6 | ±2.2 % |
| | | Y | 9.93 | 68.1 | 20.7 | | 124.5 | |
| | | Z | 10.29 | 69.2 | 21.5 | | 131.9 | |
| 10117-CAA | IEEE 802.11n (HT Mixed, 13.5 Mbps, BPSK) | X | 10.42 | 69.4 | 21.6 | 8.07 | 140.6 | ±2.2 % |
| | | Y | 9.93 | 68.1 | 20.7 | | 125.5 | |
| | | Z | 10.28 | 69.1 | 21.5 | | 132.6 | |
| 10151-CAB | LTE-TDD (SC-FDMA, 50% RB, 20 MHz, QPSK) | X | 11.18 | 78.2 | 27.5 | 9.28 | 143.6 | ±3.3 % |
| | | Y | 9.33 | 73.0 | 24.5 | | 124.3 | |
| | | Z | 10.45 | 76.4 | 26.6 | | 132.7 | |
| 10154-CAB | LTE-FDD (SC-FDMA, 50% RB, 10 MHz, QPSK) | X | 6.16 | 67.2 | 19.8 | 5.75 | 145.7 | ±1.4 % |
| | | Y | 5.96 | 66.4 | 19.1 | | 133.0 | |
| | | Z | 6.08 | 66.9 | 19.6 | | 138.6 | |
| 10160-CAB | LTE-FDD (SC-FDMA, 50% RB, 15 MHz, QPSK) | X | 6.32 | 66.6 | 19.4 | 5.82 | 126.2 | ±1.4 % |
| | | Y | 6.40 | 66.9 | 19.4 | | 137.3 | |
| | | Z | 6.51 | 67.4 | 19.8 | | 143.8 | |
| 10169-CAB | LTE-FDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 5.12 | 67.3 | 20.0 | 5.73 | 147.9 | ±1.2 % |
| | | Y | 4.90 | 66.4 | 19.4 | | 134.4 | |
| | | Z | 5.07 | 67.2 | 20.0 | | 141.5 | |
| 10172-CAB | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 9.44 | 80.0 | 28.6 | 9.21 | 128.7 | ±3.3 % |
| | | Y | 8.63 | 77.8 | 27.1 | | 143.9 | |
| | | Z | 10.62 | 83.7 | 30.3 | | 148.2 | |
| 10175-CAB | LTE-FDD (SC-FDMA, 1 RB, 10 MHz, QPSK) | X | 5.04 | 66.9 | 19.8 | 5.72 | 140.4 | ±1.4 % |
| | | Y | 4.92 | 66.6 | 19.5 | | 133.7 | |
| | | Z | 5.01 | 66.9 | 19.8 | | 134.9 | |
| 10181-CAB | LTE-FDD (SC-FDMA, 1 RB, 15 MHz, QPSK) | X | 5.05 | 67.0 | 19.9 | 5.72 | 140.6 | ±1.4 % |
| | | Y | 4.90 | 66.5 | 19.4 | | 132.4 | |
| | | Z | 4.97 | 66.7 | 19.7 | | 134.1 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10193-CAA | IEEE 802.11n (HT Greenfield, 6.5 Mbps, BPSK) | X | 9.98 | 68.8 | 21.4 | 8.09 | 131.1 | ±2.5 % |
| | | Y | 10.00 | 68.8 | 21.2 | | 145.5 | |
| | | Z | 10.14 | 69.4 | 21.7 | | 144.7 | |
| 10196-CAA | IEEE 802.11n (HT Mixed, 6.5 Mbps, BPSK) | X | 9.99 | 68.9 | 21.5 | 8.10 | 132.0 | ±2.7 % |
| | | Y | 10.05 | 69.0 | 21.3 | | 148.1 | |
| | | Z | 10.16 | 69.5 | 21.8 | | 145.8 | |
| 10219-CAA | IEEE 802.11n (HT Mixed, 7.2 Mbps, BPSK) | X | 9.88 | 68.8 | 21.4 | 8.03 | 131.3 | ±2.5 % |
| | | Y | 9.96 | 69.0 | 21.3 | | 147.8 | |
| | | Z | 10.03 | 69.3 | 21.6 | | 144.7 | |
| 10222-CAA | IEEE 802.11n (HT Mixed, 15 Mbps, BPSK) | X | 10.34 | 69.3 | 21.6 | 8.06 | 137.1 | ±2.2 % |
| | | Y | 9.93 | 68.2 | 20.8 | | 127.8 | |
| | | Z | 10.07 | 68.6 | 21.2 | | 125.1 | |
| 10225-CAB | UMTS-FDD (HSPA+) | X | 6.97 | 66.8 | 19.4 | 5.97 | 133.6 | ±1.4 % |
| | | Y | 6.90 | 66.7 | 19.2 | | 129.7 | |
| | | Z | 7.14 | 67.5 | 19.8 | | 147.4 | |
| 10237-CAB | LTE-TDD (SC-FDMA, 1 RB, 10 MHz, QPSK) | X | 9.18 | 79.3 | 28.2 | 9.21 | 128.1 | ±3.5 % |
| | | Y | 8.54 | 77.6 | 27.0 | | 144.1 | |
| | | Z | 9.99 | 81.9 | 29.4 | | 141.7 | |
| 10252-CAB | LTE-TDD (SC-FDMA, 50% RB, 10 MHz, QPSK) | X | 9.65 | 75.1 | 26.1 | 9.24 | 126.1 | ±3.5 % |
| | | Y | 9.34 | 74.2 | 25.3 | | 141.3 | |
| | | Z | 10.46 | 77.6 | 27.3 | | 144.1 | |
| 10267-CAB | LTE-TDD (SC-FDMA, 100% RB, 10 MHz, QPSK) | X | 10.46 | 76.2 | 26.5 | 9.30 | 133.6 | ±3.5 % |
| | | Y | 9.23 | 72.7 | 24.4 | | 122.8 | |
| | | Z | 9.90 | 74.8 | 25.7 | | 123.8 | |
| 10274-CAB | UMTS-FDD (HSUPA, Subtest 5, 3GPP Rel8.10) | X | 6.04 | 67.1 | 19.0 | 4.87 | 149.9 | ±1.2 % |
| | | Y | 6.02 | 67.1 | 18.9 | | 142.8 | |
| | | Z | 6.00 | 67.1 | 19.0 | | 141.0 | |
| 10275-CAB | UMTS-FDD (HSUPA, Subtest 5, 3GPP Rel8.4) | X | 4.22 | 65.6 | 18.1 | 3.96 | 131.0 | ±0.9 % |
| | | Y | 4.49 | 66.9 | 18.6 | | 144.3 | |
| | | Z | 4.55 | 67.3 | 19.1 | | 147.0 | |
| 10291-AAB | CDMA2000, RC3, SO55, Full Rate | X | 3.74 | 67.2 | 18.9 | 3.46 | 145.6 | ±0.5 % |
| | | Y | 3.66 | 66.8 | 18.5 | | 136.7 | |
| | | Z | 3.71 | 67.2 | 18.9 | | 136.5 | |
| 10292-AAB | CDMA2000, RC3, SO32, Full Rate | X | 3.65 | 67.0 | 18.7 | 3.39 | 147.2 | ±0.7 % |
| | | Y | 3.61 | 66.8 | 18.4 | | 139.6 | |
| | | Z | 3.64 | 67.1 | 18.8 | | 139.6 | |
| 10297-AAA | LTE-FDD (SC-FDMA, 50% RB, 20 MHz, QPSK) | X | 6.37 | 67.3 | 19.8 | 5.81 | 140.5 | ±1.4 % |
| | | Y | 6.24 | 66.8 | 19.3 | | 134.0 | |
| | | Z | 6.33 | 67.2 | 19.8 | | 134.8 | |
| 10311-AAA | LTE-FDD (SC-FDMA, 100% RB, 15 MHz, QPSK) | X | 7.00 | 68.0 | 20.2 | 6.06 | 146.8 | ±1.7 % |
| | | Y | 6.82 | 67.4 | 19.7 | | 140.3 | |
| | | Z | 6.90 | 67.8 | 20.1 | | 141.4 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10315-AAA | IEEE 802.11b WiFi 2.4 GHz (DSSS, 1 Mbps, 96pc duty cycle) | X | 2.85 | 68.5 | 18.8 | 1.71 | 129.5 | ±0.5 % |
| | | Y | 3.09 | 70.0 | 19.2 | | 146.1 | |
| | | Z | 3.15 | 70.6 | 19.8 | | 146.8 | |
| 10403-AAB | CDMA2000 (1xEV-DO, Rev. 0) | X | 4.73 | 67.9 | 18.7 | 3.76 | 137.5 | ±0.5 % |
| | | Y | 4.77 | 68.3 | 18.7 | | 126.5 | |
| | | Z | 4.77 | 68.1 | 18.8 | | 128.1 | |
| 10404-AAB | CDMA2000 (1xEV-DO, Rev. A) | X | 4.55 | 67.6 | 18.6 | 3.77 | 132.0 | ±0.7 % |
| | | Y | 4.89 | 69.1 | 19.1 | | 148.8 | |
| | | Z | 4.90 | 69.1 | 19.3 | | 148.0 | |

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

[A] The uncertainties of NormX,Y,Z do not affect the $E^2$-field uncertainty inside TSL (see Pages 8 and 9).
[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:3319

## 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 | 6.48 | 6.48 | 6.48 | 0.28 | 2.09 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 6.27 | 6.27 | 6.27 | 0.34 | 1.72 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 5.24 | 5.24 | 5.24 | 0.80 | 1.14 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 5.05 | 5.05 | 5.05 | 0.72 | 1.24 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 4.45 | 4.45 | 4.45 | 0.77 | 1.23 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 4.29 | 4.29 | 4.29 | 0.80 | 1.27 | ± 12.0 % |

[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: ES3DV3 - SN:3319

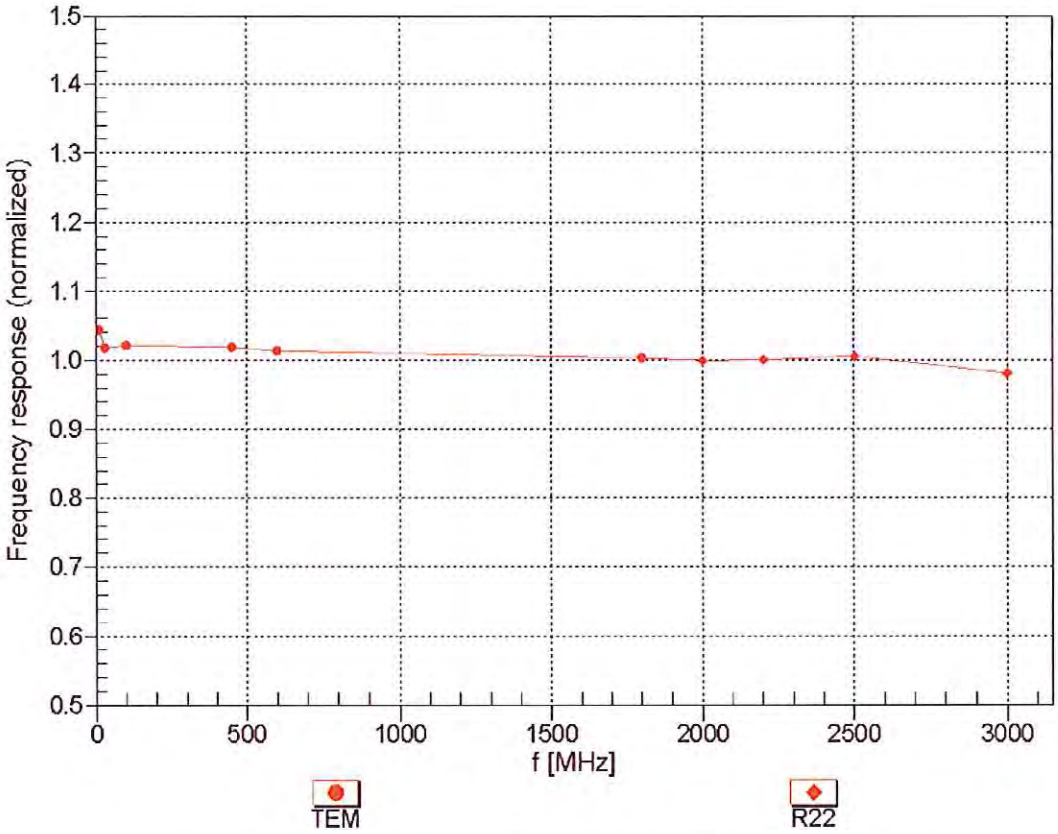
## Calibration Parameter Determined in Body Tissue Simulating Media

| 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 | 6.25 | 6.25 | 6.25 | 0.39 | 1.65 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 6.18 | 6.18 | 6.18 | 0.56 | 1.37 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 4.85 | 4.85 | 4.85 | 0.57 | 1.46 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 4.67 | 4.67 | 4.67 | 0.53 | 1.58 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 4.24 | 4.24 | 4.24 | 0.74 | 1.10 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 4.05 | 4.05 | 4.05 | 0.80 | 1.02 | ± 12.0 % |

[C] Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

# Frequency Response of E-Field

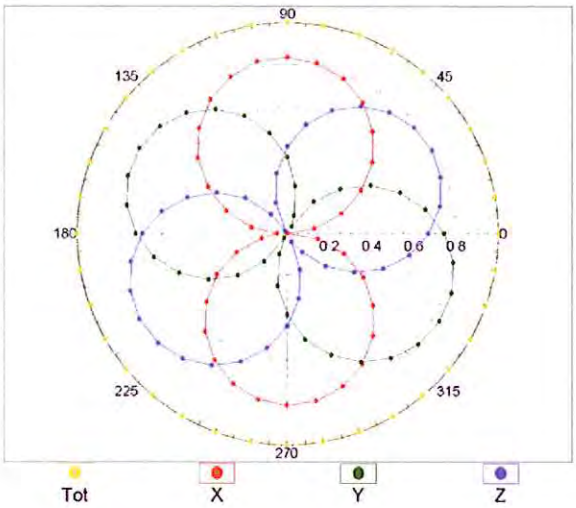
**(TEM-Cell:ifi110 EXX, Waveguide: R22)**



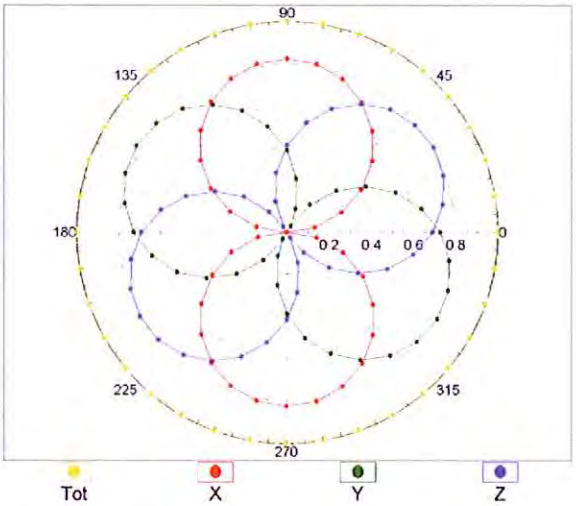

**Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)**

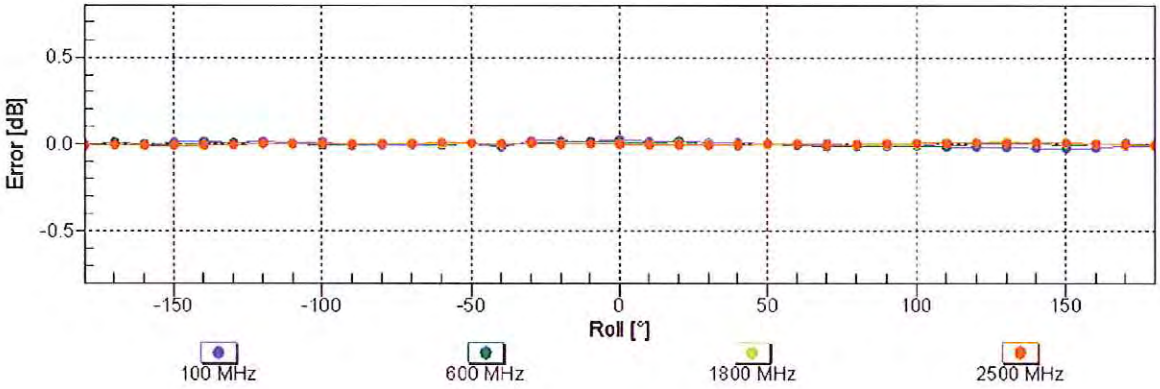
# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM




f=1800 MHz,R22

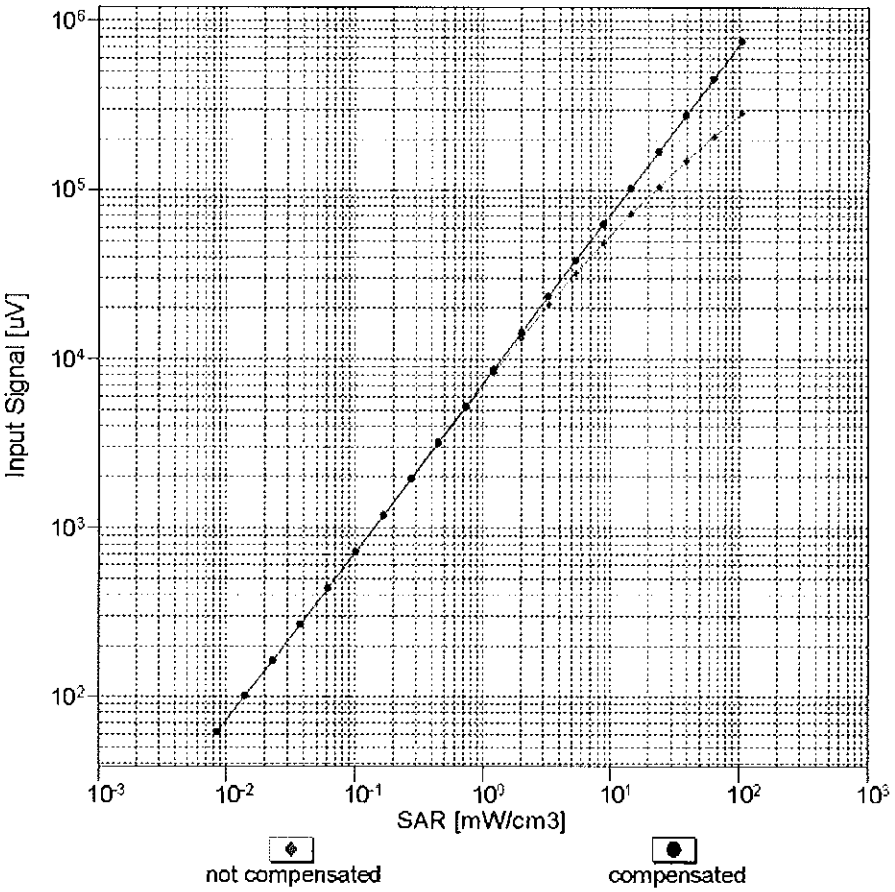


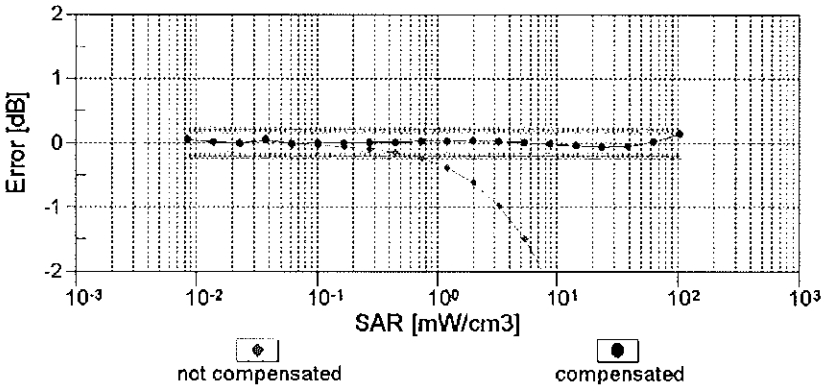




**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

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

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

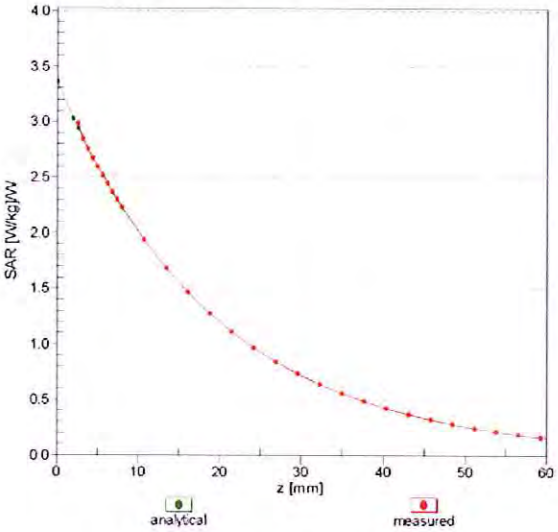


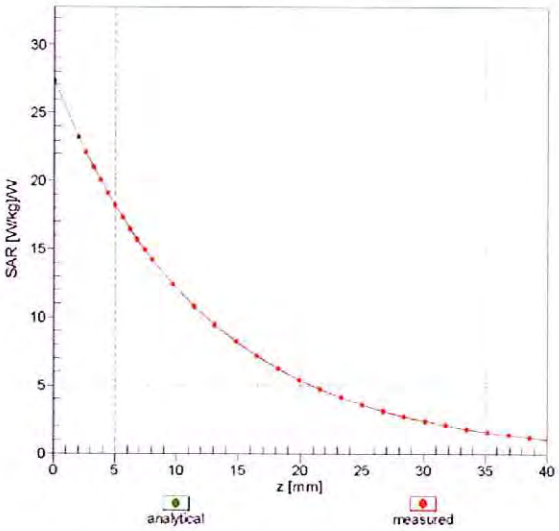

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

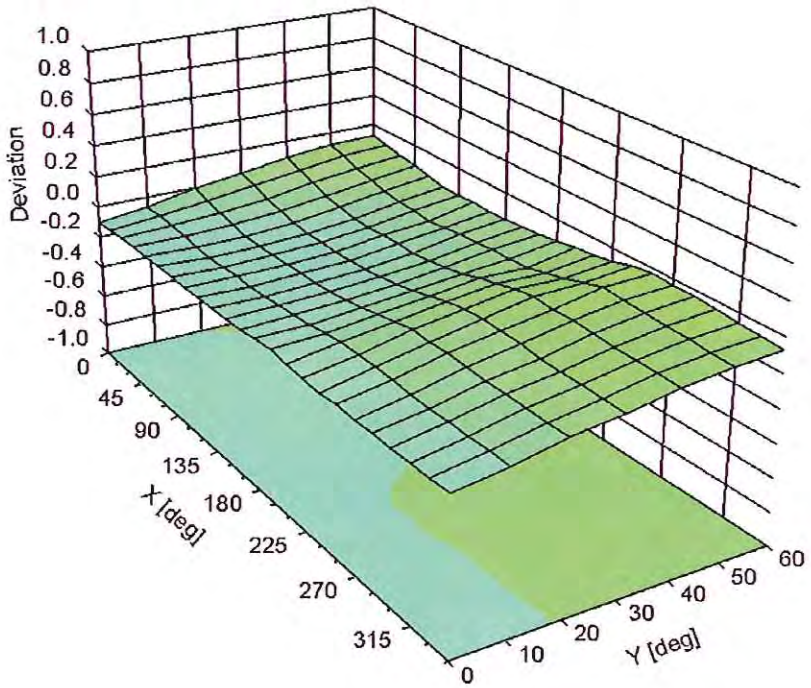


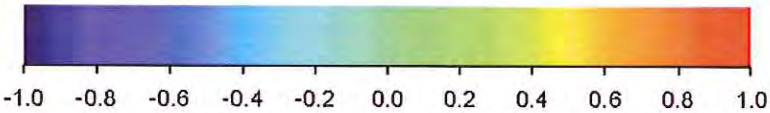

f = 1900 MHz,WGLS R22 (H_convF)




# Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**




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

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3319

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -119.8 |
| 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

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** PC Test

**Certificate No: EX3-3914_Oct13**

# CALIBRATION CERTIFICATE

Object: EX3DV4 - SN:3914

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: October 23, 2013

VCC
11/26/2013

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter E4419B | GB41293874 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Power sensor E4412A | MY41498087 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 04-Apr-13 (No. 217-01737) | Apr-14 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-13 (No. 217-01735) | Apr-14 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 04-Apr-13 (No. 217-01738) | Apr-14 |
| Reference Probe ES3DV2 | SN: 3013 | 28-Dec-12 (No. ES3-3013_Dec12) | Dec-13 |
| DAE4 | SN: 660 | 4-Sep-13 (No. DAE4-660_Sep13) | Sep-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-15 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-13) | In house check: Oct-14 |

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

Issued: October 25, 2013

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

PCT # 81072

## 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, "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:

- *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 EX3DV4

# SN:3914

Manufactured: December 18, 2012
Calibrated: October 23, 2013

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

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3914

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 0.47 | 0.49 | 0.51 | ± 10.1 % |
| DCP (mV)[B] | 99.2 | 98.9 | 98.2 | |

## 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 | 158.3 | ±3.0 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 154.6 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 170.8 | |
| 10010-CAA | SAR Validation (Square, 100ms, 10ms) | X | 0.71 | 53.3 | 6.1 | 10.00 | 48.4 | ±2.5 % |
| | | Y | 2.43 | 67.0 | 13.8 | | 39.9 | |
| | | Z | 4.18 | 68.7 | 13.8 | | 45.7 | |
| 10011-CAA | UMTS-FDD (WCDMA) | X | 3.05 | 64.4 | 16.5 | 2.91 | 122.4 | ±0.5 % |
| | | Y | 3.31 | 66.5 | 18.2 | | 123.5 | |
| | | Z | 3.34 | 66.3 | 17.8 | | 136.6 | |
| 10012-CAA | IEEE 802.11b WiFi 2.4 GHz (DSSS, 1 Mbps) | X | 2.49 | 64.8 | 16.1 | 1.87 | 120.6 | ±0.5 % |
| | | Y | 2.94 | 68.6 | 18.7 | | 123.6 | |
| | | Z | 2.63 | 65.9 | 17.0 | | 135.4 | |
| 10021-DAA | GSM-FDD (TDMA, GMSK) | X | 1.52 | 61.5 | 10.9 | 9.39 | 83.6 | ±1.2 % |
| | | Y | 2.22 | 67.4 | 15.0 | | 116.0 | |
| | | Z | 2.47 | 66.8 | 14.7 | | 95.9 | |
| 10023-DAA | GPRS-FDD (TDMA, GMSK, TN 0) | X | 1.73 | 63.3 | 11.9 | 9.57 | 81.5 | ±1.7 % |
| | | Y | 2.11 | 66.2 | 14.2 | | 111.8 | |
| | | Z | 2.76 | 69.0 | 16.0 | | 93.6 | |
| 10024-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1) | X | 1.34 | 62.1 | 9.4 | 6.56 | 121.0 | ±1.2 % |
| | | Y | 4.24 | 78.6 | 17.9 | | 130.0 | |
| | | Z | 2.91 | 70.7 | 14.9 | | 141.4 | |
| 10027-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1-2) | X | 1.25 | 63.5 | 9.7 | 4.80 | 143.5 | ±1.4 % |
| | | Y | 1.59 | 66.9 | 12.2 | | 149.7 | |
| | | Z | 2.98 | 71.5 | 14.0 | | 123.3 | |
| 10028-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1-2-3) | X | 0.51 | 58.3 | 7.4 | 3.55 | 113.4 | ±1.2 % |
| | | Y | 25.43 | 100.0 | 22.6 | | 121.3 | |
| | | Z | 38.67 | 97.5 | 20.6 | | 133.3 | |
| 10032-CAA | IEEE 802.15.1 Bluetooth (GFSK, DH5) | X | 0.28 | 58.6 | 5.3 | 1.16 | 134.7 | ±0.9 % |
| | | Y | 65.75 | 99.6 | 18.6 | | 141.3 | |
| | | Z | 0.20 | 55.6 | 4.1 | | 112.1 | |
| 10039-CAA | CDMA2000 (1xRTT, RC1) | X | 4.33 | 64.6 | 17.4 | 4.57 | 113.8 | ±0.7 % |
| | | Y | 4.55 | 66.0 | 18.6 | | 120.8 | |
| | | Z | 4.85 | 66.2 | 18.4 | | 135.9 | |
| 10062-CAA | IEEE 802.11a/h WiFi 5 GHz (OFDM, 6 Mbps) | X | 9.83 | 67.6 | 20.7 | 8.68 | 109.0 | ±2.5 % |
| | | Y | 10.06 | 68.4 | 21.5 | | 118.2 | |
| | | Z | 10.66 | 69.2 | 21.7 | | 134.0 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10081-CAA | CDMA2000 (1xRTT, RC3) | X | 3.59 | 63.9 | 16.9 | 3.97 | 113.6 | ±0.7 % |
| | | Y | 3.84 | 65.6 | 18.2 | | 119.6 | |
| | | Z | 3.95 | 65.4 | 17.8 | | 134.5 | |
| 10098-CAA | UMTS-FDD (HSUPA, Subtest 2) | X | 4.41 | 65.2 | 17.3 | 3.98 | 126.0 | ±0.7 % |
| | | Y | 4.73 | 66.9 | 18.6 | | 132.5 | |
| | | Z | 4.51 | 65.5 | 17.7 | | 105.6 | |
| 10100-CAB | LTE-FDD (SC-FDMA, 100% RB, 20 MHz, QPSK) | X | 6.26 | 66.2 | 18.6 | 5.67 | 130.5 | ±1.2 % |
| | | Y | 6.61 | 67.7 | 19.8 | | 139.3 | |
| | | Z | 6.21 | 66.0 | 18.7 | | 107.7 | |
| 10108-CAB | LTE-FDD (SC-FDMA, 100% RB, 10 MHz, QPSK) | X | 6.13 | 65.8 | 18.6 | 5.80 | 126.3 | ±1.2 % |
| | | Y | 6.40 | 67.1 | 19.6 | | 135.6 | |
| | | Z | 6.10 | 65.5 | 18.5 | | 107.4 | |
| 10110-CAB | LTE-FDD (SC-FDMA, 100% RB, 5 MHz, QPSK) | X | 5.78 | 65.3 | 18.3 | 5.75 | 123.1 | ±1.2 % |
| | | Y | 5.97 | 66.3 | 19.2 | | 131.5 | |
| | | Z | 5.86 | 65.3 | 18.4 | | 104.9 | |
| 10114-CAA | IEEE 802.11n (HT Greenfield, 13.5 Mbps, BPSK) | X | 9.92 | 67.7 | 20.3 | 8.10 | 115.7 | ±2.5 % |
| | | Y | 10.25 | 68.7 | 21.2 | | 126.8 | |
| | | Z | 10.71 | 69.4 | 21.3 | | 146.0 | |
| 10117-CAA | IEEE 802.11n (HT Mixed, 13.5 Mbps, BPSK) | X | 9.95 | 67.8 | 20.3 | 8.07 | 116.6 | ±2.5 % |
| | | Y | 10.26 | 68.7 | 21.1 | | 128.3 | |
| | | Z | 10.70 | 69.4 | 21.3 | | 146.9 | |
| 10151-CAB | LTE-TDD (SC-FDMA, 50% RB, 20 MHz, QPSK) | X | 7.19 | 67.3 | 21.5 | 9.28 | 145.0 | ±2.2 % |
| | | Y | 7.40 | 68.3 | 22.4 | | 110.8 | |
| | | Z | 7.79 | 68.4 | 22.0 | | 128.0 | |
| 10154-CAB | LTE-FDD (SC-FDMA, 50% RB, 10 MHz, QPSK) | X | 5.79 | 65.3 | 18.3 | 5.75 | 124.2 | ±1.2 % |
| | | Y | 6.03 | 66.5 | 19.4 | | 131.9 | |
| | | Z | 6.29 | 66.9 | 19.3 | | 149.7 | |
| 10160-CAB | LTE-FDD (SC-FDMA, 50% RB, 15 MHz, QPSK) | X | 6.23 | 65.9 | 18.6 | 5.82 | 128.3 | ±1.2 % |
| | | Y | 6.51 | 67.2 | 19.7 | | 136.9 | |
| | | Z | 6.24 | 65.7 | 18.6 | | 107.3 | |
| 10169-CAB | LTE-FDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 4.83 | 66.0 | 18.9 | 5.73 | 147.5 | ±1.2 % |
| | | Y | 4.72 | 65.8 | 19.2 | | 113.8 | |
| | | Z | 5.03 | 66.1 | 19.1 | | 129.7 | |
| 10172-CAB | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 5.83 | 69.2 | 22.8 | 9.21 | 149.9 | ±1.9 % |
| | | Y | 5.81 | 69.4 | 23.4 | | 120.3 | |
| | | Z | 6.38 | 70.0 | 23.2 | | 137.2 | |
| 10175-CAB | LTE-FDD (SC-FDMA, 1 RB, 10 MHz, QPSK) | X | 4.86 | 66.1 | 18.9 | 5.72 | 149.8 | ±1.2 % |
| | | Y | 4.72 | 65.8 | 19.2 | | 113.3 | |
| | | Z | 5.09 | 66.4 | 19.1 | | 126.0 | |
| 10181-CAB | LTE-FDD (SC-FDMA, 1 RB, 15 MHz, QPSK) | X | 4.83 | 66.0 | 18.9 | 5.72 | 146.3 | ±1.2 % |
| | | Y | 4.69 | 65.6 | 19.1 | | 112.2 | |
| | | Z | 5.02 | 66.1 | 19.0 | | 125.1 | |
| 10193-CAA | IEEE 802.11n (HT Greenfield, 6.5 Mbps, BPSK) | X | 9.51 | 67.4 | 20.2 | 8.09 | 108.6 | ±2.5 % |
| | | Y | 9.72 | 68.1 | 20.9 | | 118.2 | |
| | | Z | 10.30 | 68.9 | 21.1 | | 135.0 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10196-CAA | IEEE 802.11n (HT Mixed, 6.5 Mbps, BPSK) | X | 9.52 | 67.4 | 20.2 | 8.10 | 111.6 | ±2.5 % |
| | | Y | 9.79 | 68.3 | 21.1 | | 121.3 | |
| | | Z | 10.30 | 68.9 | 21.2 | | 139.2 | |
| 10219-CAA | IEEE 802.11n (HT Mixed, 7.2 Mbps, BPSK) | X | 9.47 | 67.4 | 20.2 | 8.03 | 111.8 | ±2.2 % |
| | | Y | 9.67 | 68.3 | 21.0 | | 120.0 | |
| | | Z | 10.20 | 68.9 | 21.1 | | 138.0 | |
| 10222-CAA | IEEE 802.11n (HT Mixed, 15 Mbps, BPSK) | X | 9.96 | 67.9 | 20.4 | 8.06 | 118.4 | ±2.5 % |
| | | Y | 10.25 | 68.8 | 21.2 | | 128.2 | |
| | | Z | 10.65 | 69.3 | 21.3 | | 144.5 | |
| 10225-CAA | UMTS-FDD (HSPA+) | X | 6.96 | 66.7 | 18.9 | 5.97 | 140.0 | ±1.4 % |
| | | Y | 7.23 | 67.9 | 20.0 | | 148.9 | |
| | | Z | 7.03 | 66.4 | 18.9 | | 115.6 | |
| 10237-CAB | LTE-TDD (SC-FDMA, 1 RB, 10 MHz, QPSK) | X | 5.51 | 67.5 | 21.8 | 9.21 | 114.2 | ±1.9 % |
| | | Y | 5.82 | 69.4 | 23.4 | | 123.0 | |
| | | Z | 6.49 | 70.6 | 23.6 | | 140.2 | |
| 10252-CAB | LTE-TDD (SC-FDMA, 50% RB, 10 MHz, QPSK) | X | 6.83 | 67.1 | 21.4 | 9.24 | 136.6 | ±1.9 % |
| | | Y | 7.30 | 69.4 | 23.2 | | 147.3 | |
| | | Z | 7.36 | 68.1 | 22.0 | | 117.5 | |
| 10267-CAB | LTE-TDD (SC-FDMA, 100% RB, 10 MHz, QPSK) | X | 7.26 | 67.5 | 21.6 | 9.30 | 142.7 | ±1.9 % |
| | | Y | 7.44 | 68.4 | 22.4 | | 110.5 | |
| | | Z | 7.84 | 68.7 | 22.2 | | 122.6 | |
| 10274-CAA | UMTS-FDD (HSUPA, Subtest 5, 3GPP Rel8.10) | X | 5.86 | 66.2 | 18.2 | 4.87 | 135.4 | ±0.9 % |
| | | Y | 6.12 | 67.5 | 19.2 | | 142.3 | |
| | | Z | 5.91 | 65.9 | 18.2 | | 107.6 | |
| 10275-CAA | UMTS-FDD (HSUPA, Subtest 5, 3GPP Rel8.4) | X | 4.17 | 64.8 | 17.3 | 3.96 | 115.6 | ±0.7 % |
| | | Y | 4.42 | 66.4 | 18.5 | | 124.6 | |
| | | Z | 4.47 | 66.0 | 18.0 | | 132.6 | |
| 10291-AAA | CDMA2000, RC3, SO55, Full Rate | X | 3.36 | 64.7 | 17.1 | 3.46 | 109.4 | ±0.5 % |
| | | Y | 3.55 | 66.2 | 18.3 | | 118.2 | |
| | | Z | 3.60 | 65.6 | 17.7 | | 120.9 | |
| 10292-AAA | CDMA2000, RC3, SO32, Full Rate | X | 3.34 | 64.9 | 17.2 | 3.39 | 110.1 | ±0.5 % |
| | | Y | 3.57 | 66.7 | 18.5 | | 121.0 | |
| | | Z | 3.54 | 65.6 | 17.7 | | 123.9 | |
| 10297-AAA | LTE-FDD (SC-FDMA, 50% RB, 20 MHz, QPSK) | X | 6.14 | 65.8 | 18.6 | 5.81 | 125.1 | ±1.2 % |
| | | Y | 6.44 | 67.2 | 19.7 | | 135.7 | |
| | | Z | 6.52 | 67.0 | 19.3 | | 142.2 | |
| 10311-AAA | LTE-FDD (SC-FDMA, 100% RB, 15 MHz, QPSK) | X | 6.76 | 66.6 | 19.1 | 6.06 | 131.8 | ±1.4 % |
| | | Y | 7.03 | 67.8 | 20.0 | | 142.5 | |
| | | Z | 7.15 | 67.7 | 19.7 | | 148.6 | |
| 10315-AAA | IEEE 802.11b WiFi 2.4 GHz (DSSS, 1 Mbps, 96pc duty cycle) | X | 2.42 | 64.6 | 16.1 | 1.71 | 116.8 | ±0.5 % |
| | | Y | 3.00 | 69.3 | 19.0 | | 126.9 | |
| | | Z | 2.61 | 66.3 | 17.2 | | 128.2 | |
| 10317-AAA | IEEE 802.11a WiFi 5 GHz (OFDM, 6 Mbps, 96pc duty cycle) | X | 9.71 | 67.6 | 20.5 | 8.36 | 111.7 | ±2.5 % |
| | | Y | 9.99 | 68.6 | 21.4 | | 122.2 | |
| | | Z | 10.38 | 68.9 | 21.3 | | 129.5 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10400-AAA | IEEE 802.11ac WiFi (20MHz, 64-QAM, 99pc duty cycle) | X | 9.83 | 67.8 | 20.6 | 8.37 | 112.9 | ±2.5 % |
| | | Y | 10.09 | 68.7 | 21.4 | | 123.9 | |
| | | Z | 10.48 | 68.9 | 21.3 | | 130.5 | |
| 10402-AAA | IEEE 802.11ac WiFi (80MHz, 64-QAM, 99pc duty cycle) | X | 10.61 | 68.3 | 20.7 | 8.53 | 121.1 | ±2.5 % |
| | | Y | 11.25 | 70.0 | 21.9 | | 135.4 | |
| | | Z | 11.15 | 69.4 | 21.4 | | 137.4 | |
| 10403-AAA | CDMA2000 (1xEV-DO, Rev. 0) | X | 4.51 | 67.4 | 17.8 | 3.76 | 119.2 | ±0.5 % |
| | | Y | 4.91 | 69.5 | 19.3 | | 128.3 | |
| | | Z | 4.84 | 67.5 | 18.1 | | 135.4 | |
| 10404-AAA | CDMA2000 (1xEV-DO, Rev. A) | X | 4.51 | 67.7 | 18.0 | 3.77 | 117.4 | ±0.5 % |
| | | Y | 4.92 | 69.8 | 19.5 | | 125.4 | |
| | | Z | 4.71 | 67.3 | 18.0 | | 131.9 | |

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

[A] The uncertainties of NormX,Y,Z do not affect the $E^2$-field uncertainty inside TSL (see Pages 8 and 9).
[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:3914

## 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 | 9.70 | 9.70 | 9.70 | 0.34 | 1.01 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 9.34 | 9.34 | 9.34 | 0.67 | 0.67 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 7.99 | 7.99 | 7.99 | 0.79 | 0.56 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 7.69 | 7.69 | 7.69 | 0.80 | 0.58 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 6.95 | 6.95 | 6.95 | 0.41 | 0.77 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 6.79 | 6.79 | 6.79 | 0.40 | 0.82 | ± 12.0 % |
| 5200 | 36.0 | 4.66 | 4.99 | 4.99 | 4.99 | 0.30 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 4.82 | 4.82 | 4.82 | 0.30 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 4.55 | 4.55 | 4.55 | 0.35 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.37 | 4.37 | 4.37 | 0.35 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.52 | 4.52 | 4.52 | 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:3914

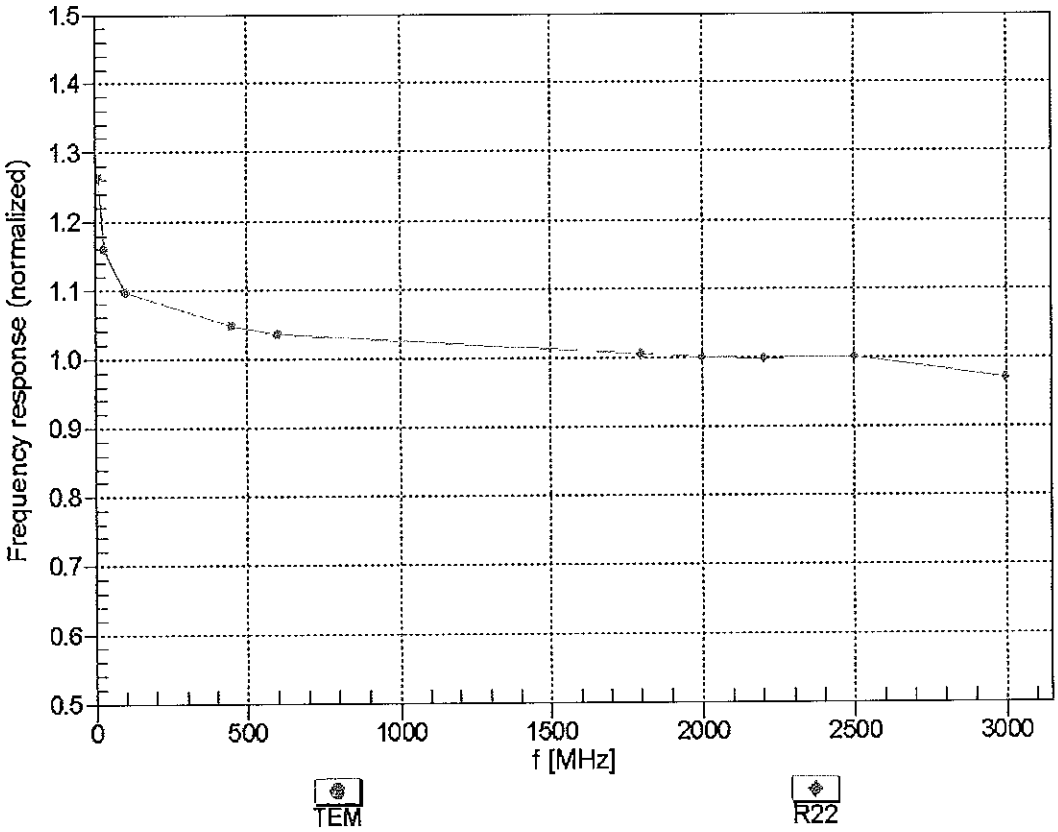
## Calibration Parameter Determined in Body Tissue Simulating Media

| 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 | 9.39 | 9.39 | 9.39 | 0.63 | 0.74 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 9.31 | 9.31 | 9.31 | 0.56 | 0.76 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 7.89 | 7.89 | 7.89 | 0.32 | 1.03 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.51 | 7.51 | 7.51 | 0.51 | 0.76 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.02 | 7.02 | 7.02 | 0.80 | 0.50 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.81 | 6.81 | 6.81 | 0.80 | 0.50 | ± 12.0 % |
| 5200 | 49.0 | 5.30 | 4.52 | 4.52 | 4.52 | 0.35 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.32 | 4.32 | 4.32 | 0.35 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 4.07 | 4.07 | 4.07 | 0.35 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.97 | 3.97 | 3.97 | 0.35 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 4.14 | 4.14 | 4.14 | 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 tip diameter from the boundary.

# Frequency Response of E-Field

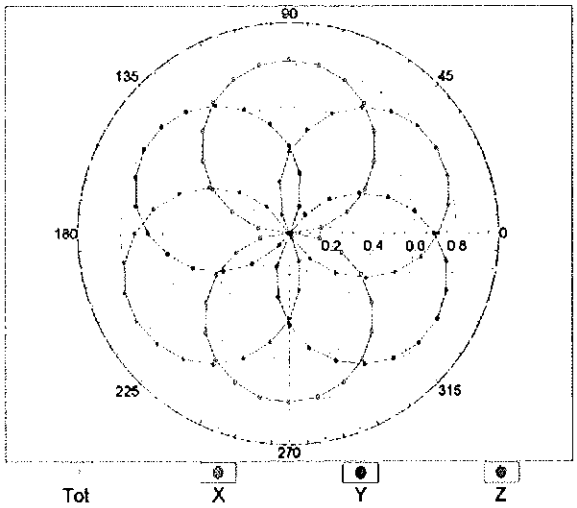
**(TEM-Cell:ifi110 EXX, Waveguide: R22)**



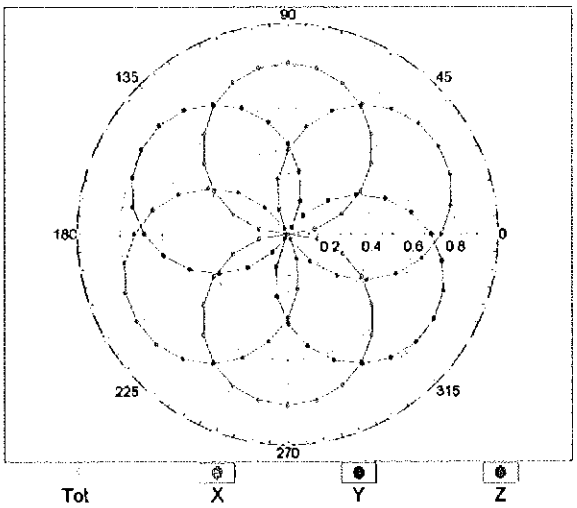

**Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)**

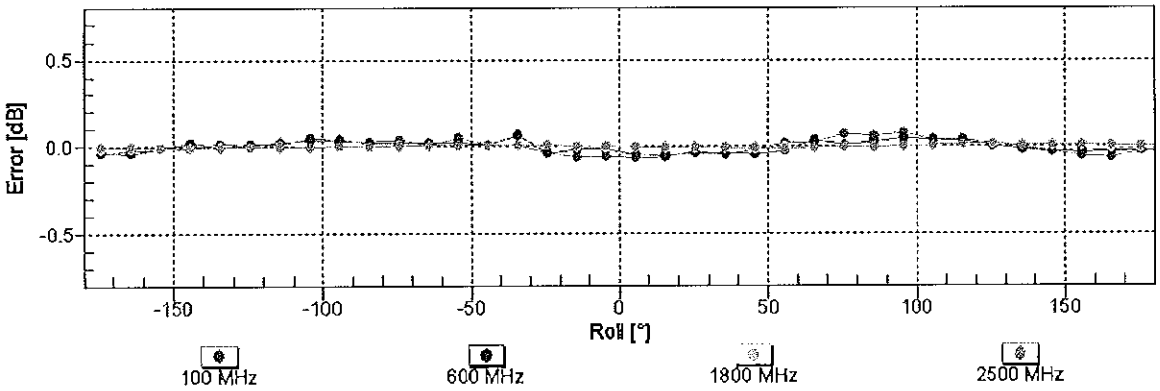
# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



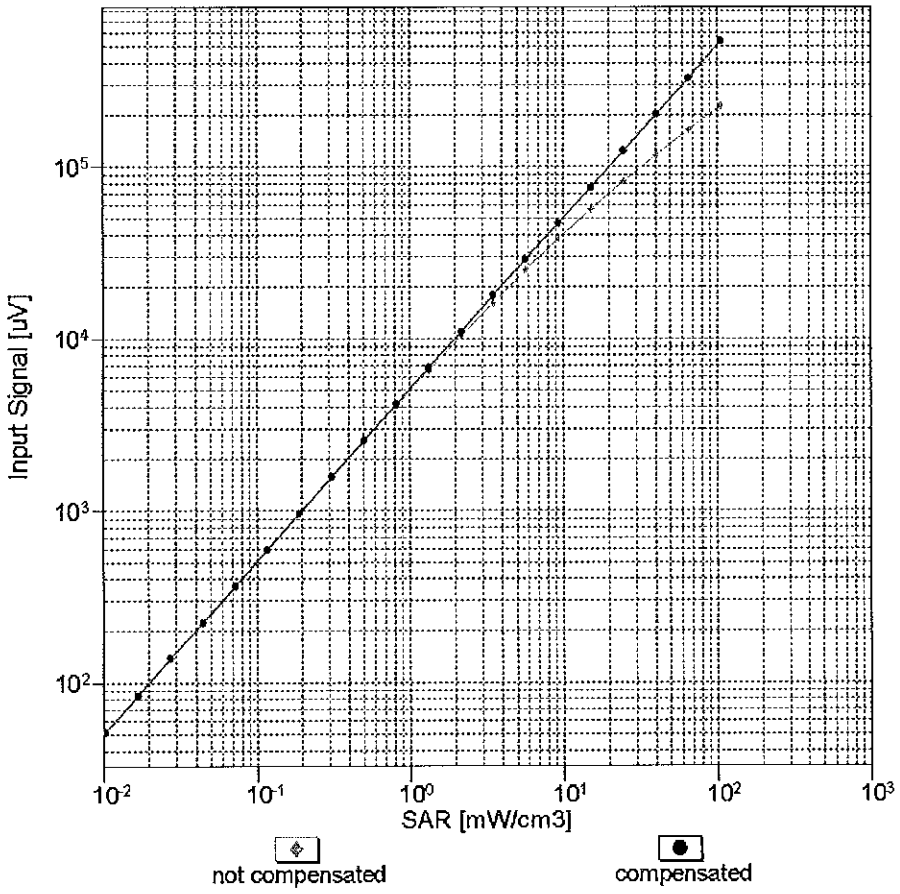

f=1800 MHz,R22

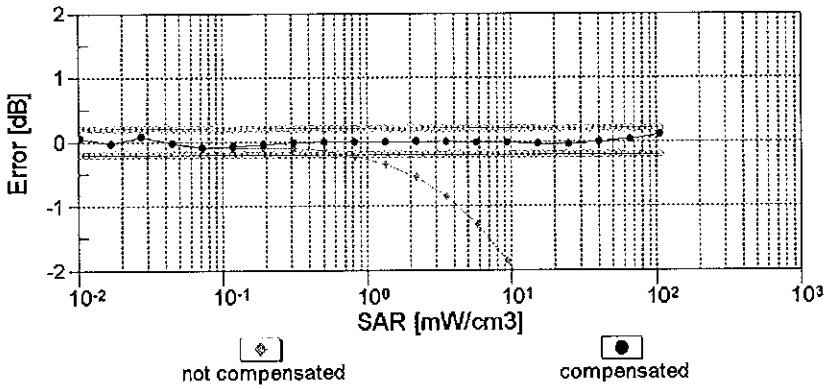



**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

# Dynamic Range f($SAR_{head}$)
**(TEM cell , f = 900 MHz)**

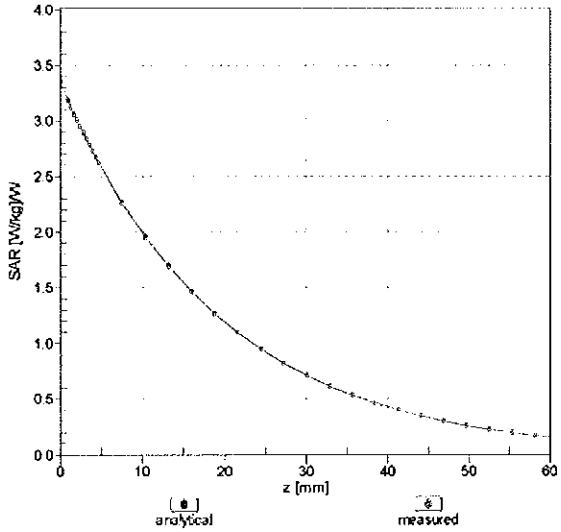


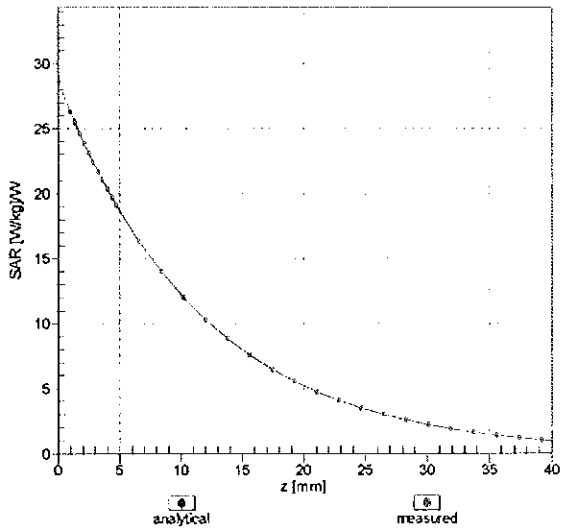

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

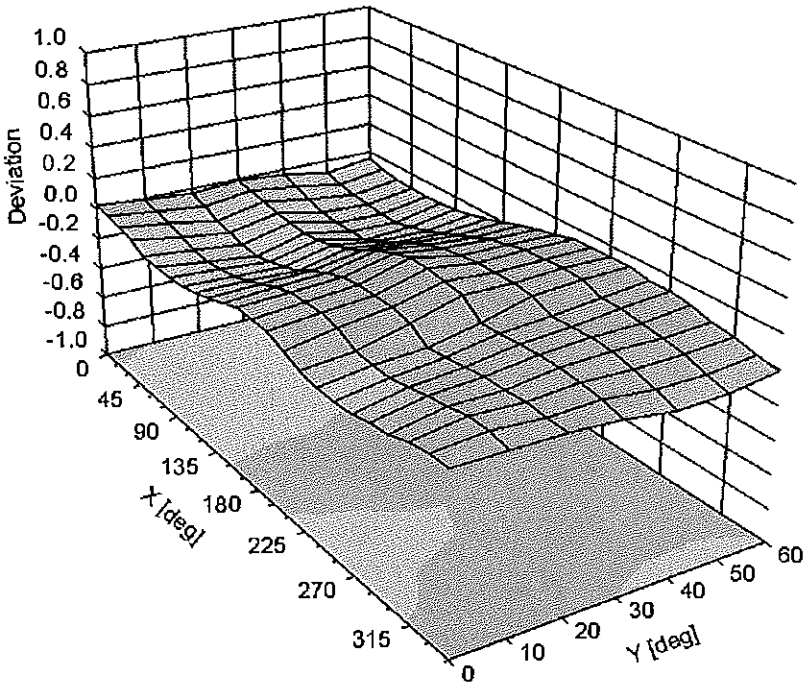


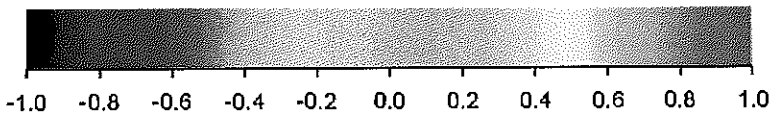

f = 1900 MHz,WGLS R22 (H_convF)




# Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**




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

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3914

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -24.3 |
| 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 |

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

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

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** **PC Test**

**Certificate No: ES3-3332_Nov13**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | ES3DV3 - SN:3332 |
| Calibration procedure(s) | QA CAL-01.v9, QA CAL-23.v5, QA CAL-25.v6<br>Calibration procedure for dosimetric E-field probes |
| Calibration date: | November 25, 2013 |

JCC 1/12/14

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter E4419B | GB41293874 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Power sensor E4412A | MY41498087 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 04-Apr-13 (No. 217-01737) | Apr-14 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-13 (No. 217-01735) | Apr-14 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 04-Apr-13 (No. 217-01738) | Apr-14 |
| Reference Probe ES3DV2 | SN: 3013 | 28-Dec-12 (No. ES3-3013_Dec12) | Dec-13 |
| DAE4 | SN: 660 | 4-Sep-13 (No. DAE4-660_Sep13) | Sep-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-15 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-13) | In house check: Oct-14 |

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

Issued: November 25, 2013

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

## 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, "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:

- *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:3332

Manufactured: January 24, 2012
Calibrated: November 25, 2013

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

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3332

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 0.94 | 1.16 | 0.97 | ± 10.1 % |
| DCP (mV)[B] | 103.5 | 101.0 | 111.0 | |

## 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 | 179.7 | ±2.5 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 147.3 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 188.8 | |

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

[A] The uncertainties of NormX,Y,Z do not affect the $E^2$-field uncertainty inside TSL (see Pages 5 and 6).
[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3332

## 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 | 6.46 | 6.46 | 6.46 | 0.52 | 1.42 | ± 12.0 % |
| 850 | 41.5 | 0.92 | 6.29 | 6.29 | 6.29 | 0.78 | 1.17 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 5.27 | 5.27 | 5.27 | 0.80 | 1.10 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 5.06 | 5.06 | 5.06 | 0.80 | 1.18 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 4.50 | 4.50 | 4.50 | 0.80 | 1.19 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 4.38 | 4.38 | 4.38 | 0.76 | 1.31 | ± 12.0 % |

[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.

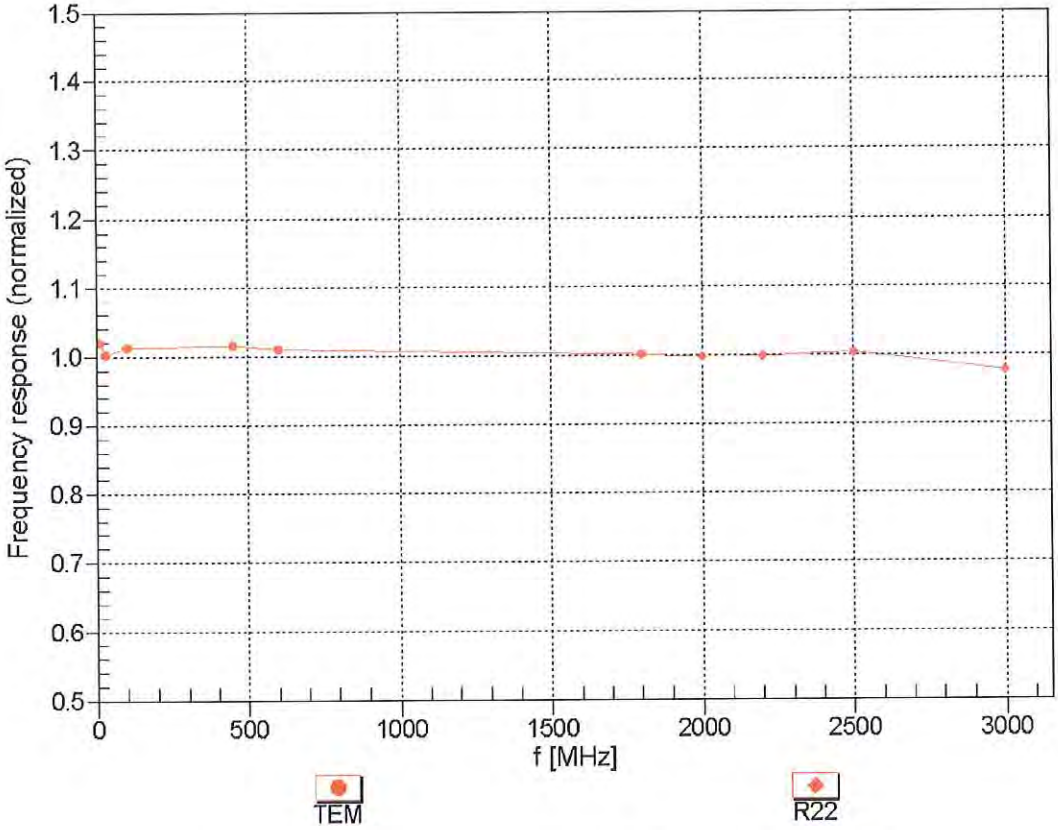
# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3332

## 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 | 6.21 | 6.21 | 6.21 | 0.80 | 1.19 | ± 12.0 % |
| 850 | 55.2 | 0.99 | 6.08 | 6.08 | 6.08 | 0.51 | 1.48 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 4.93 | 4.93 | 4.93 | 0.42 | 1.72 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 4.70 | 4.70 | 4.70 | 0.48 | 1.59 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 4.24 | 4.24 | 4.24 | 0.80 | 1.01 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 4.07 | 4.07 | 4.07 | 0.80 | 0.50 | ± 12.0 % |

[C] Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

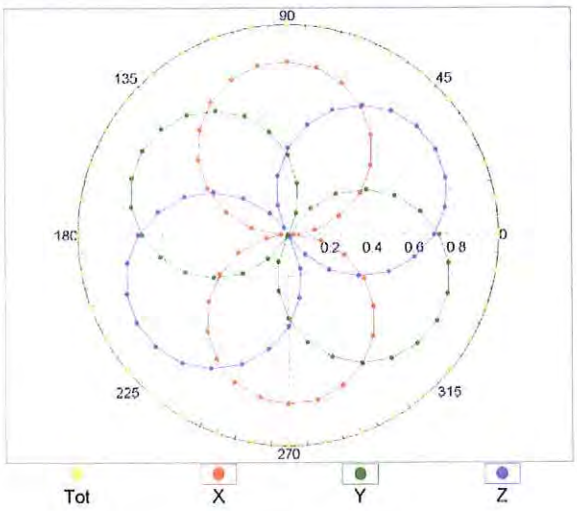
# Frequency Response of E-Field
## (TEM-Cell:ifi110 EXX, Waveguide: R22)



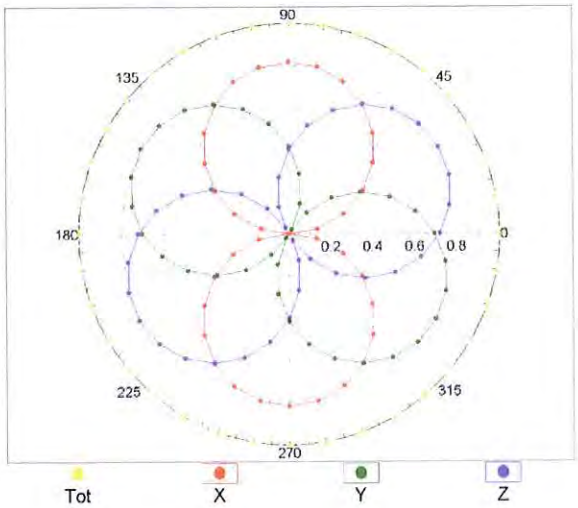

**Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)**

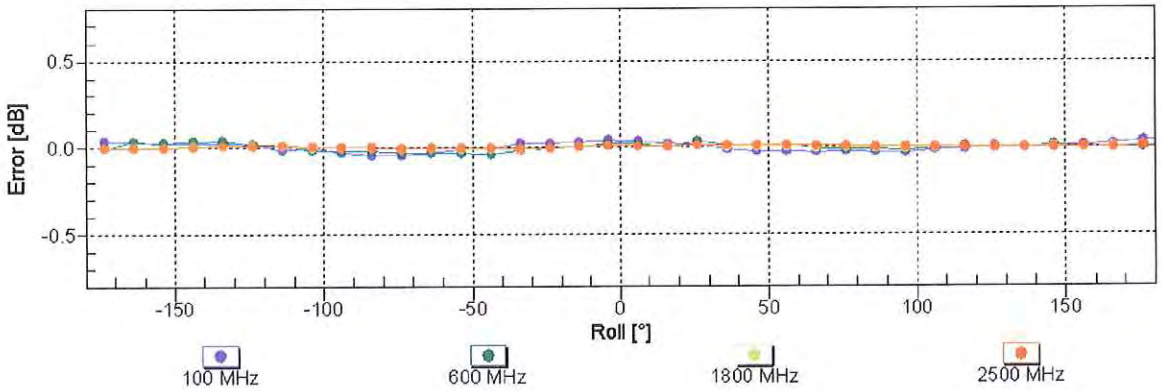
# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



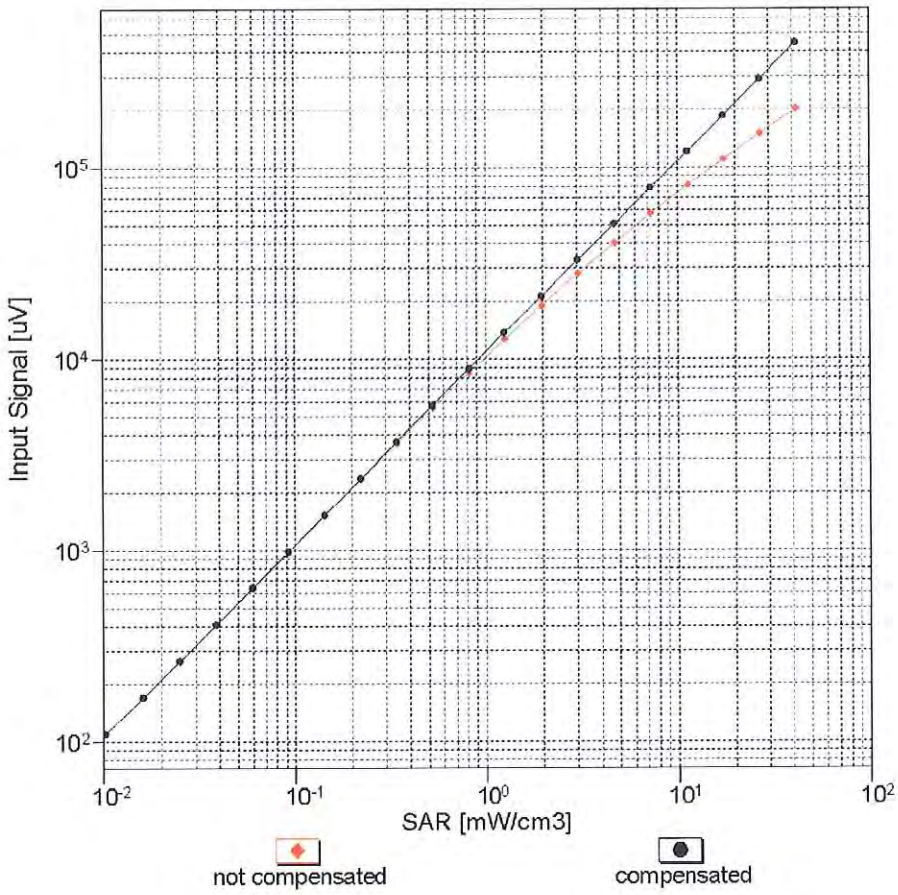

f=1800 MHz,R22

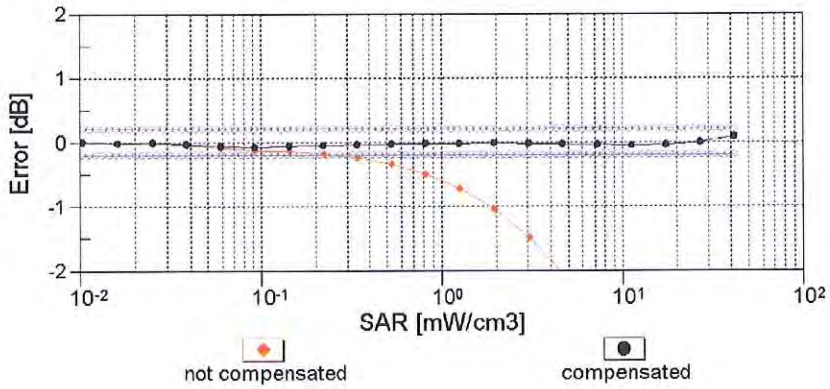



**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

# Dynamic Range f($SAR_{head}$)
**(TEM cell , f = 900 MHz)**

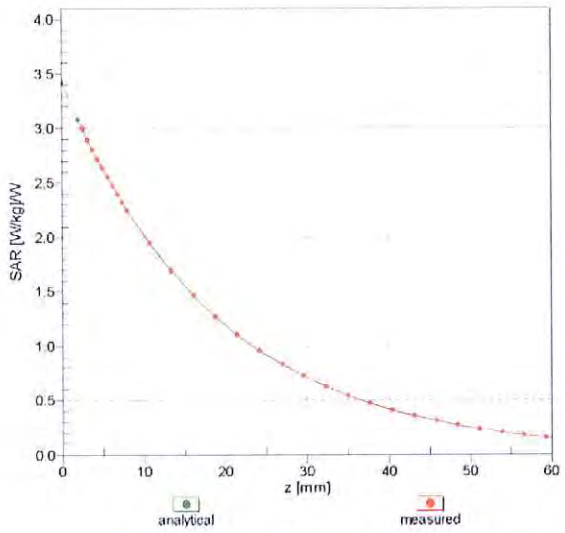


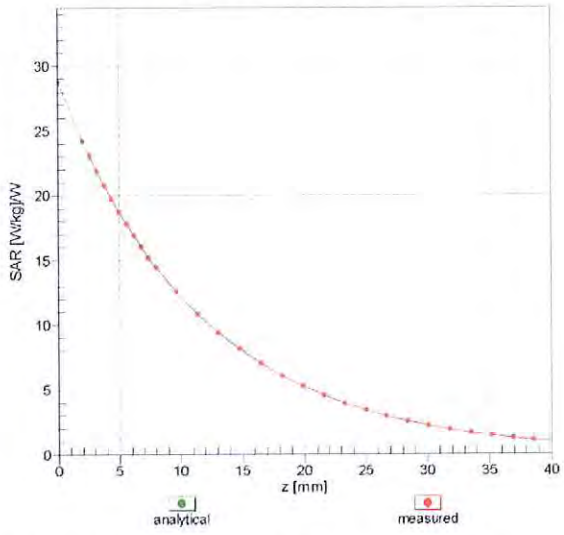

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Conversion Factor Assessment

f = 850 MHz,WGLS R9 (H_convF)

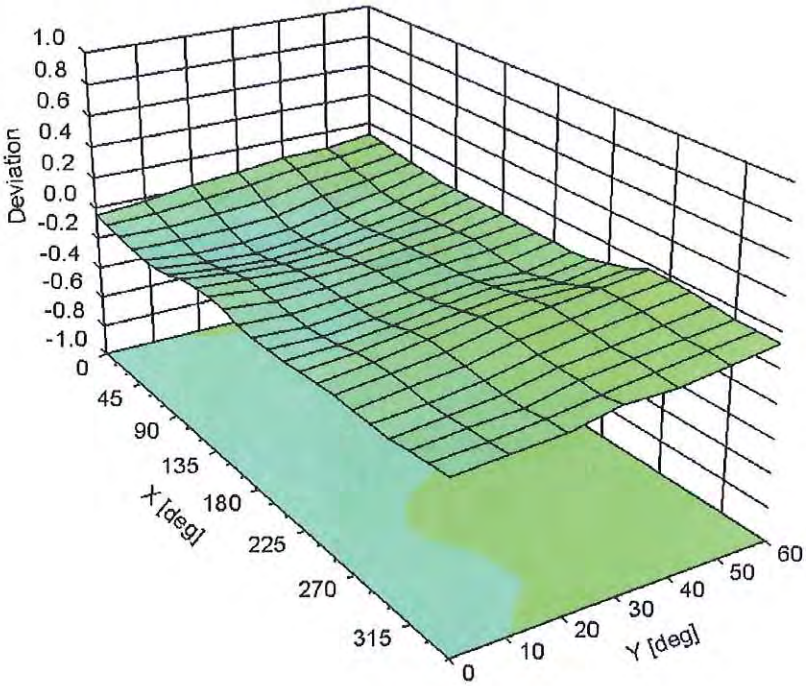


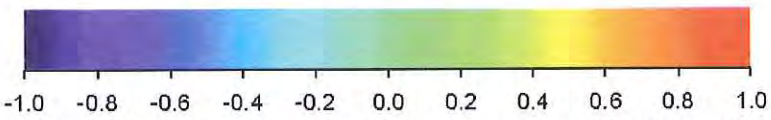

f = 1900 MHz,WGLS R22 (H_convF)




# Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**




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

# DASY/EASY - Parameters of Probe: ES3DV3 - SN:3332

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -3.9 |
| 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
Servizio svizzero di taratura
**S** Swiss Calibration Service

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** **PC Test**

**Certificate No: EX3-3920_Dec13**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | EX3DV4 - SN:3920 |
| Calibration procedure(s) | QA CAL-01.v9, QA CAL-14.v4, QA CAL-23.v5, QA CAL-25.v6<br>Calibration procedure for dosimetric E-field probes |
| Calibration date: | December 18, 2013 |

JCC 1/12/14

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter E4419B | GB41293874 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Power sensor E4412A | MY41498087 | 04-Apr-13 (No. 217-01733) | Apr-14 |
| Reference 3 dB Attenuator | SN: S5054 (3c) | 04-Apr-13 (No. 217-01737) | Apr-14 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-13 (No. 217-01735) | Apr-14 |
| Reference 30 dB Attenuator | SN: S5129 (30b) | 04-Apr-13 (No. 217-01738) | Apr-14 |
| Reference Probe ES3DV2 | SN: 3013 | 28-Dec-12 (No. ES3-3013_Dec12) | Dec-13 |
| 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-15 |
| Network Analyzer HP 8753E | US37390585 | 18-Oct-01 (in house check Oct-13) | In house check: Oct-14 |

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

Issued: December 19, 2013

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

## 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, "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:

- *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 EX3DV4

## SN:3920

Manufactured: December 18, 2012
Calibrated: December 18, 2013

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

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3920

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 0.34 | 0.50 | 0.49 | ± 10.1 % |
| DCP (mV)[B] | 102.9 | 99.5 | 98.3 | |

## 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 | 182.5 | ±2.7 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 164.9 | |
| | | Z | 0.0 | 0.0 | 1.0 | | 153.0 | |
| 10010-CAA | SAR Validation (Square, 100ms, 10ms) | X | 0.76 | 53.8 | 6.5 | 10.00 | 44.1 | ±2.2 % |
| | | Y | 2.33 | 62.8 | 11.4 | | 43.7 | |
| | | Z | 1.15 | 55.6 | 7.5 | | 53.0 | |
| 10011-CAA | UMTS-FDD (WCDMA) | X | 3.36 | 66.5 | 17.5 | 2.91 | 142.4 | ±0.5 % |
| | | Y | 3.15 | 65.0 | 16.7 | | 131.4 | |
| | | Z | 3.26 | 66.0 | 17.7 | | 121.6 | |
| 10012-CAA | IEEE 802.11b WiFi 2.4 GHz (DSSS, 1 Mbps) | X | 2.69 | 66.4 | 16.9 | 1.87 | 138.1 | ±0.5 % |
| | | Y | 2.56 | 65.1 | 16.2 | | 130.7 | |
| | | Z | 2.72 | 66.6 | 17.2 | | 121.4 | |
| 10021-DAA | GSM-FDD (TDMA, GMSK) | X | 2.06 | 63.4 | 11.7 | 9.39 | 99.7 | ±1.9 % |
| | | Y | 2.43 | 66.1 | 14.1 | | 94.7 | |
| | | Z | 2.90 | 69.9 | 16.1 | | 121.8 | |
| 10023-DAA | GPRS-FDD (TDMA, GMSK, TN 0) | X | 1.94 | 62.4 | 11.3 | 9.57 | 95.1 | ±1.9 % |
| | | Y | 2.31 | 64.8 | 13.1 | | 90.1 | |
| | | Z | 2.98 | 70.4 | 16.4 | | 117.0 | |
| 10024-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1) | X | 2.19 | 67.1 | 12.2 | 6.56 | 140.1 | ±1.4 % |
| | | Y | 2.35 | 67.0 | 12.9 | | 134.0 | |
| | | Z | 3.45 | 73.5 | 16.1 | | 131.4 | |
| 10027-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1-2) | X | 1.18 | 61.7 | 8.5 | 4.80 | 121.6 | ±1.2 % |
| | | Y | 1.57 | 63.4 | 10.0 | | 116.0 | |
| | | Z | 1.57 | 65.5 | 11.9 | | 109.2 | |
| 10028-DAA | GPRS-FDD (TDMA, GMSK, TN 0-1-2-3) | X | 3.80 | 74.5 | 13.3 | 3.55 | 130.3 | ±0.9 % |
| | | Y | 1.00 | 60.5 | 8.0 | | 123.9 | |
| | | Z | 1.58 | 66.1 | 11.1 | | 119.0 | |
| 10032-CAA | IEEE 802.15.1 Bluetooth (GFSK, DH5) | X | 0.18 | 55.2 | 3.4 | 1.16 | 111.6 | ±0.7 % |
| | | Y | 0.34 | 57.4 | 4.4 | | 143.6 | |
| | | Z | 0.40 | 59.2 | 5.7 | | 136.6 | |
| 10039-CAA | CDMA2000 (1xRTT, RC1) | X | 4.49 | 65.9 | 18.1 | 4.57 | 131.8 | ±0.9 % |
| | | Y | 4.57 | 65.1 | 17.5 | | 123.0 | |
| | | Z | 4.66 | 65.9 | 18.3 | | 118.6 | |
| 10062-CAA | IEEE 802.11a/h WiFi 5 GHz (OFDM, 6 Mbps) | X | 10.09 | 68.6 | 21.3 | 8.68 | 126.5 | ±2.5 % |
| | | Y | 10.31 | 68.5 | 21.1 | | 121.9 | |
| | | Z | 10.12 | 68.3 | 21.3 | | 115.8 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10098-CAA | UMTS-FDD (HSUPA, Subtest 2) | X | 4.64 | 66.6 | 18.1 | 3.98 | 144.6 | ±0.7 % |
| | | Y | 4.54 | 65.4 | 17.4 | | 133.9 | |
| | | Z | 4.60 | 66.1 | 18.0 | | 128.0 | |
| 10100-CAB | LTE-FDD (SC-FDMA, 100% RB, 20 MHz, QPSK) | X | 6.00 | 65.5 | 18.3 | 5.67 | 104.2 | ±1.4 % |
| | | Y | 6.44 | 66.7 | 18.8 | | 138.2 | |
| | | Z | 6.54 | 67.4 | 19.4 | | 134.7 | |
| 10108-CAB | LTE-FDD (SC-FDMA, 100% RB, 10 MHz, QPSK) | X | 6.37 | 67.0 | 19.2 | 5.80 | 149.0 | ±1.4 % |
| | | Y | 6.40 | 66.6 | 18.9 | | 141.2 | |
| | | Z | 6.40 | 66.9 | 19.4 | | 132.1 | |
| 10110-CAB | LTE-FDD (SC-FDMA, 100% RB, 5 MHz, QPSK) | X | 5.96 | 66.3 | 18.9 | 5.75 | 142.3 | ±1.4 % |
| | | Y | 6.05 | 66.1 | 18.7 | | 136.6 | |
| | | Z | 6.03 | 66.3 | 19.1 | | 128.2 | |
| 10114-CAA | IEEE 802.11n (HT Greenfield, 13.5 Mbps, BPSK) | X | 10.28 | 68.7 | 20.9 | 8.10 | 137.3 | ±2.5 % |
| | | Y | 10.32 | 68.5 | 20.7 | | 131.3 | |
| | | Z | 10.24 | 68.5 | 20.9 | | 124.5 | |
| 10117-CAA | IEEE 802.11n (HT Mixed, 13.5 Mbps, BPSK) | X | 10.29 | 68.8 | 20.9 | 8.07 | 138.5 | ±2.5 % |
| | | Y | 10.34 | 68.6 | 20.8 | | 131.9 | |
| | | Z | 10.26 | 68.5 | 20.9 | | 125.5 | |
| 10151-CAB | LTE-TDD (SC-FDMA, 50% RB, 20 MHz, QPSK) | X | 7.20 | 67.5 | 21.6 | 9.28 | 118.6 | ±2.2 % |
| | | Y | 7.59 | 67.9 | 21.6 | | 116.7 | |
| | | Z | 7.78 | 69.2 | 22.7 | | 110.7 | |
| 10154-CAB | LTE-FDD (SC-FDMA, 50% RB, 10 MHz, QPSK) | X | 5.98 | 66.4 | 18.9 | 5.75 | 142.7 | ±1.2 % |
| | | Y | 5.97 | 65.7 | 18.4 | | 132.7 | |
| | | Z | 6.06 | 66.4 | 19.1 | | 128.6 | |
| 10160-CAB | LTE-FDD (SC-FDMA, 50% RB, 15 MHz, QPSK) | X | 6.41 | 66.8 | 19.1 | 5.82 | 147.7 | ±1.4 % |
| | | Y | 6.48 | 66.5 | 18.8 | | 137.3 | |
| | | Z | 6.53 | 67.0 | 19.4 | | 134.9 | |
| 10169-CAB | LTE-FDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 4.59 | 65.5 | 18.6 | 5.73 | 120.3 | ±1.2 % |
| | | Y | 4.76 | 65.0 | 18.2 | | 113.9 | |
| | | Z | 4.82 | 65.6 | 18.9 | | 112.0 | |
| 10172-CAB | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 5.77 | 69.3 | 22.7 | 9.21 | 128.1 | ±1.9 % |
| | | Y | 6.15 | 69.3 | 22.6 | | 123.8 | |
| | | Z | 6.22 | 70.3 | 23.6 | | 120.8 | |
| 10175-CAB | LTE-FDD (SC-FDMA, 1 RB, 10 MHz, QPSK) | X | 4.62 | 65.6 | 18.7 | 5.72 | 120.2 | ±0.9 % |
| | | Y | 4.75 | 65.0 | 18.2 | | 113.5 | |
| | | Z | 4.80 | 65.6 | 18.8 | | 110.7 | |
| 10181-CAB | LTE-FDD (SC-FDMA, 1 RB, 15 MHz, QPSK) | X | 4.57 | 65.4 | 18.6 | 5.72 | 118.9 | ±0.9 % |
| | | Y | 4.72 | 64.8 | 18.1 | | 113.1 | |
| | | Z | 4.81 | 65.6 | 18.8 | | 110.4 | |
| 10193-CAA | IEEE 802.11n (HT Greenfield, 6.5 Mbps, BPSK) | X | 9.77 | 68.3 | 20.8 | 8.09 | 128.1 | ±2.5 % |
| | | Y | 9.84 | 67.9 | 20.5 | | 117.1 | |
| | | Z | 9.80 | 68.1 | 20.8 | | 116.6 | |
| 10196-CAA | IEEE 802.11n (HT Mixed, 6.5 Mbps, BPSK) | X | 9.78 | 68.4 | 20.8 | 8.10 | 128.4 | ±2.5 % |
| | | Y | 9.86 | 68.0 | 20.5 | | 120.3 | |
| | | Z | 9.82 | 68.1 | 20.9 | | 119.1 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10219-CAA | IEEE 802.11n (HT Mixed, 7.2 Mbps, BPSK) | X | 9.70 | 68.4 | 20.8 | 8.03 | 128.0 | ±2.5 % |
| | | Y | 9.79 | 68.0 | 20.5 | | 119.6 | |
| | | Z | 9.72 | 68.1 | 20.8 | | 118.7 | |
| 10222-CAA | IEEE 802.11n (HT Mixed, 15 Mbps, BPSK) | X | 10.27 | 68.8 | 20.9 | 8.06 | 137.0 | ±2.5 % |
| | | Y | 10.18 | 68.3 | 20.6 | | 125.2 | |
| | | Z | 10.20 | 68.5 | 20.9 | | 124.8 | |
| 10225-CAA | UMTS-FDD (HSPA+) | X | 6.64 | 66.1 | 18.7 | 5.97 | 108.8 | ±1.4 % |
| | | Y | 7.23 | 67.1 | 19.1 | | 148.9 | |
| | | Z | 7.31 | 67.7 | 19.7 | | 146.5 | |
| 10237-CAB | LTE-TDD (SC-FDMA, 1 RB, 10 MHz, QPSK) | X | 5.82 | 69.6 | 23.0 | 9.21 | 130.2 | ±1.9 % |
| | | Y | 6.14 | 69.2 | 22.6 | | 123.9 | |
| | | Z | 6.25 | 70.4 | 23.7 | | 122.2 | |
| 10252-CAB | LTE-TDD (SC-FDMA, 50% RB, 10 MHz, QPSK) | X | 6.85 | 67.5 | 21.7 | 9.24 | 112.9 | ±2.2 % |
| | | Y | 7.54 | 69.0 | 22.4 | | 149.2 | |
| | | Z | 7.80 | 70.6 | 23.7 | | 147.3 | |
| 10267-CAB | LTE-TDD (SC-FDMA, 100% RB, 10 MHz, QPSK) | X | 7.23 | 67.6 | 21.6 | 9.30 | 118.3 | ±2.2 % |
| | | Y | 7.55 | 67.7 | 21.5 | | 111.5 | |
| | | Z | 7.79 | 69.2 | 22.7 | | 109.6 | |
| 10274-CAA | UMTS-FDD (HSUPA, Subtest 5, 3GPP Rel8.10) | X | 5.64 | 65.9 | 18.1 | 4.87 | 105.5 | ±1.2 % |
| | | Y | 6.04 | 66.4 | 18.2 | | 142.6 | |
| | | Z | 6.09 | 66.9 | 18.7 | | 138.4 | |
| 10275-CAA | UMTS-FDD (HSUPA, Subtest 5, 3GPP Rel8.4) | X | 4.42 | 66.3 | 18.1 | 3.96 | 135.8 | ±0.7 % |
| | | Y | 4.26 | 65.0 | 17.3 | | 119.3 | |
| | | Z | 4.40 | 65.9 | 18.0 | | 120.4 | |
| 10291-AAA | CDMA2000, RC3, SO55, Full Rate | X | 3.62 | 66.7 | 18.1 | 3.46 | 123.6 | ±0.7 % |
| | | Y | 3.38 | 64.3 | 16.7 | | 112.5 | |
| | | Z | 3.59 | 66.0 | 17.9 | | 114.3 | |
| 10292-AAA | CDMA2000, RC3, SO32, Full Rate | X | 3.46 | 66.0 | 17.7 | 3.39 | 127.3 | ±0.5 % |
| | | Y | 3.35 | 64.5 | 16.8 | | 113.7 | |
| | | Z | 3.50 | 65.7 | 17.7 | | 115.4 | |
| 10297-AAA | LTE-FDD (SC-FDMA, 50% RB, 20 MHz, QPSK) | X | 6.35 | 66.9 | 19.2 | 5.81 | 145.7 | ±1.2 % |
| | | Y | 6.26 | 66.1 | 18.7 | | 129.2 | |
| | | Z | 6.42 | 67.0 | 19.4 | | 131.3 | |
| 10311-AAA | LTE-FDD (SC-FDMA, 100% RB, 15 MHz, QPSK) | X | 6.45 | 65.9 | 18.7 | 6.06 | 103.7 | ±1.7 % |
| | | Y | 6.90 | 66.9 | 19.1 | | 137.2 | |
| | | Z | 7.04 | 67.7 | 19.8 | | 137.5 | |
| 10315-AAA | IEEE 802.11b WiFi 2.4 GHz (DSSS, 1 Mbps, 96pc duty cycle) | X | 2.85 | 67.8 | 17.7 | 1.71 | 135.6 | ±0.5 % |
| | | Y | 2.45 | 64.7 | 16.0 | | 121.4 | |
| | | Z | 2.75 | 67.3 | 17.6 | | 122.1 | |
| 10317-AAA | IEEE 802.11a WiFi 5 GHz (OFDM, 6 Mbps, 96pc duty cycle) | X | 9.93 | 68.5 | 21.0 | 8.36 | 128.1 | ±2.7 % |
| | | Y | 10.02 | 68.1 | 20.7 | | 117.9 | |
| | | Z | 10.01 | 68.3 | 21.1 | | 119.4 | |
| 10400-AAA | IEEE 802.11ac WiFi (20MHz, 64-QAM, 99pc duty cycle) | X | 10.09 | 68.8 | 21.2 | 8.37 | 134.9 | ±2.5 % |
| | | Y | 10.16 | 68.3 | 20.8 | | 119.8 | |
| | | Z | 10.14 | 68.5 | 21.2 | | 121.0 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 10402-AAA | IEEE 802.11ac WiFi (80MHz, 64-QAM, 99pc duty cycle) | X | 11.18 | 69.8 | 21.5 | 8.53 | 147.1 | ±2.7 % |
| | | Y | 10.79 | 68.6 | 20.8 | | 126.5 | |
| | | Z | 11.17 | 69.6 | 21.6 | | 131.4 | |
| 10403-AAA | CDMA2000 (1xEV-DO, Rev. 0) | X | 4.83 | 69.6 | 18.9 | 3.76 | 139.6 | ±0.5 % |
| | | Y | 4.70 | 67.1 | 17.6 | | 128.1 | |
| | | Z | 4.90 | 68.4 | 18.6 | | 127.8 | |
| 10404-AAA | CDMA2000 (1xEV-DO, Rev. A) | X | 4.73 | 69.5 | 18.9 | 3.77 | 134.8 | ±0.5 % |
| | | Y | 4.62 | 67.1 | 17.7 | | 124.9 | |
| | | Z | 4.67 | 67.7 | 18.1 | | 125.9 | |

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

[A] The uncertainties of NormX,Y,Z do not affect the $E^2$-field uncertainty inside TSL (see Pages 8 and 9).
[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:3920

## 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 | 10.05 | 10.05 | 10.05 | 0.27 | 1.13 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 9.69 | 9.69 | 9.69 | 0.50 | 0.76 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 7.91 | 7.91 | 7.91 | 0.72 | 0.62 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 7.70 | 7.70 | 7.70 | 0.77 | 0.61 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 6.98 | 6.98 | 6.98 | 0.37 | 0.86 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 6.74 | 6.74 | 6.74 | 0.34 | 0.97 | ± 12.0 % |
| 5200 | 36.0 | 4.66 | 4.87 | 4.87 | 4.87 | 0.40 | 1.80 | ± 13.1 % |
| 5300 | 35.9 | 4.76 | 4.66 | 4.66 | 4.66 | 0.40 | 1.80 | ± 13.1 % |
| 5500 | 35.6 | 4.96 | 4.54 | 4.54 | 4.54 | 0.40 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.37 | 4.37 | 4.37 | 0.40 | 1.80 | ± 13.1 % |
| 5800 | 35.3 | 5.27 | 4.11 | 4.11 | 4.11 | 0.50 | 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:3920

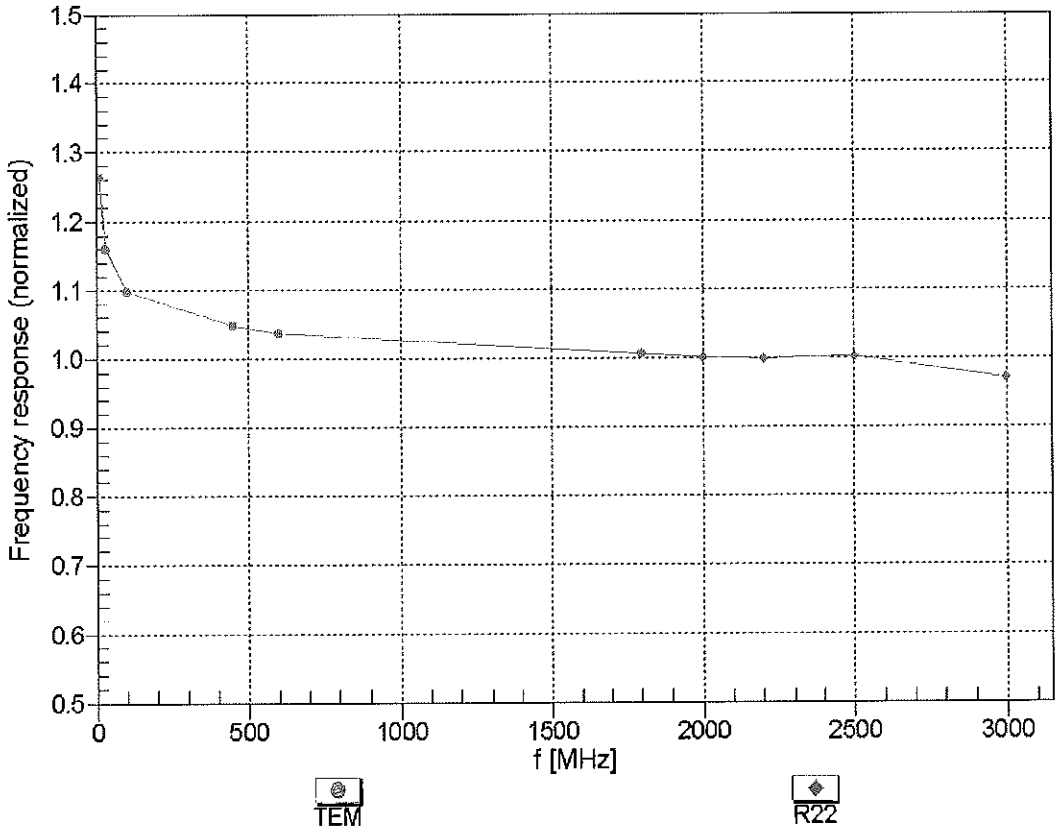
## Calibration Parameter Determined in Body Tissue Simulating Media

| 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 | 9.54 | 9.54 | 9.54 | 0.32 | 1.07 | ± 12.0 % |
| 835 | 55.2 | 0.97 | 9.47 | 9.47 | 9.47 | 0.45 | 0.85 | ± 12.0 % |
| 1750 | 53.4 | 1.49 | 7.77 | 7.77 | 7.77 | 0.59 | 0.74 | ± 12.0 % |
| 1900 | 53.3 | 1.52 | 7.50 | 7.50 | 7.50 | 0.37 | 0.91 | ± 12.0 % |
| 2450 | 52.7 | 1.95 | 7.18 | 7.18 | 7.18 | 0.80 | 0.56 | ± 12.0 % |
| 2600 | 52.5 | 2.16 | 6.91 | 6.91 | 6.91 | 0.80 | 0.57 | ± 12.0 % |
| 5200 | 49.0 | 5.30 | 4.23 | 4.23 | 4.23 | 0.50 | 1.90 | ± 13.1 % |
| 5300 | 48.9 | 5.42 | 4.11 | 4.11 | 4.11 | 0.50 | 1.90 | ± 13.1 % |
| 5500 | 48.6 | 5.65 | 3.80 | 3.80 | 3.80 | 0.50 | 1.90 | ± 13.1 % |
| 5600 | 48.5 | 5.77 | 3.62 | 3.62 | 3.62 | 0.50 | 1.90 | ± 13.1 % |
| 5800 | 48.2 | 6.00 | 4.00 | 4.00 | 4.00 | 0.50 | 1.90 | ± 13.1 % |

[C] Frequency validity of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] At frequencies below 3 GHz, the validity of tissue parameters (ε and σ) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (ε and σ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz and below ± 2% for frequencies between 3-6 GHz at any distance larger than half the probe tip diameter from the boundary.

# Frequency Response of E-Field

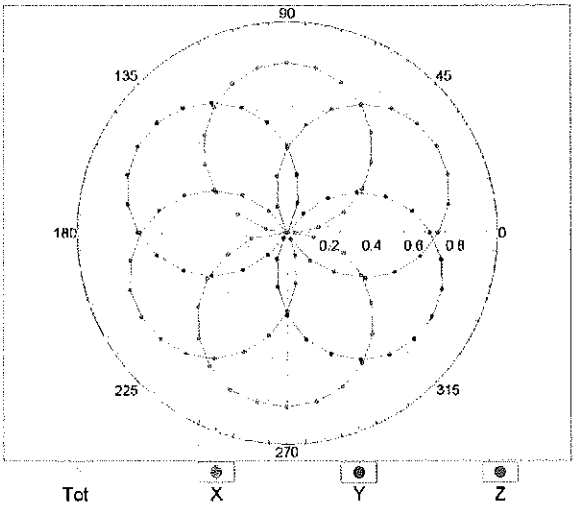
**(TEM-Cell:ifi110 EXX, Waveguide: R22)**



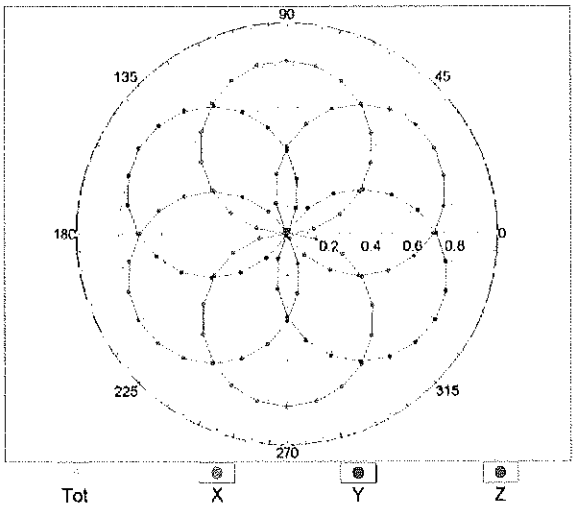

**Uncertainty of Frequency Response of E-field: ± 6.3% (k=2)**

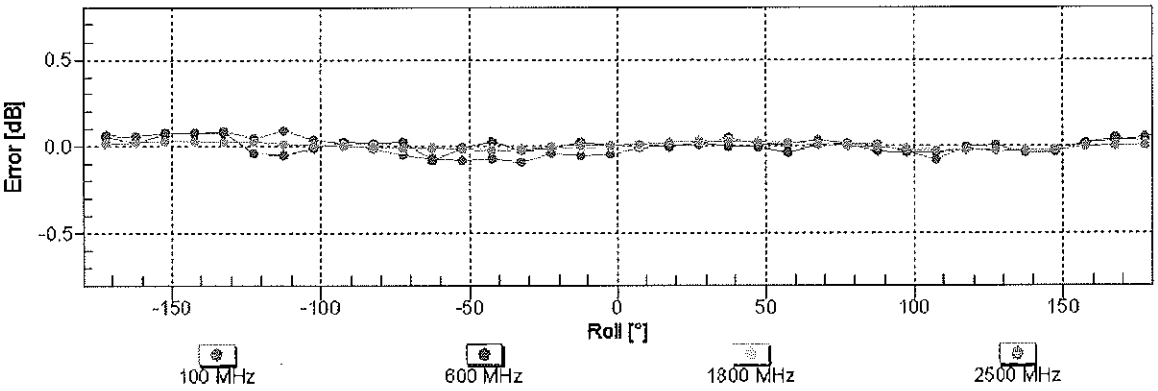
# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM



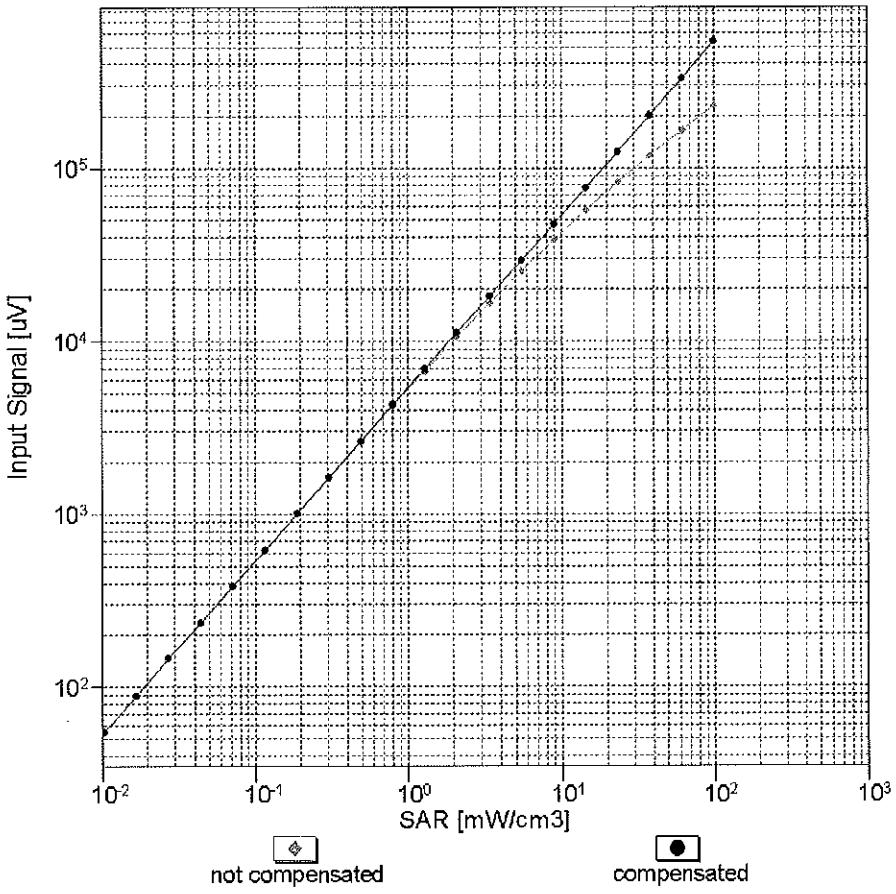

f=1800 MHz,R22

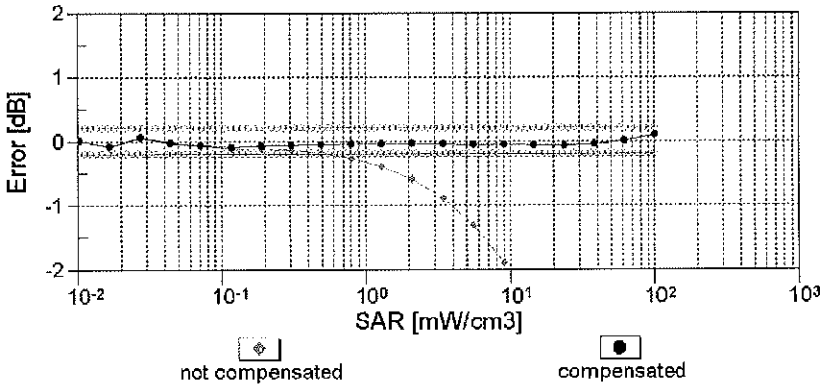



**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

# Dynamic Range f($SAR_{head}$)
**(TEM cell , f = 900 MHz)**

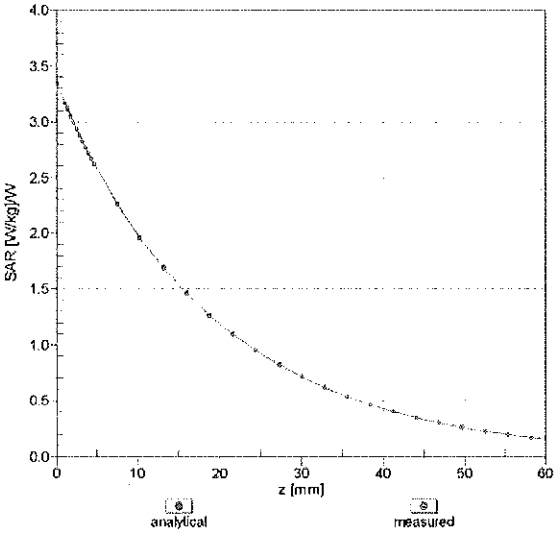


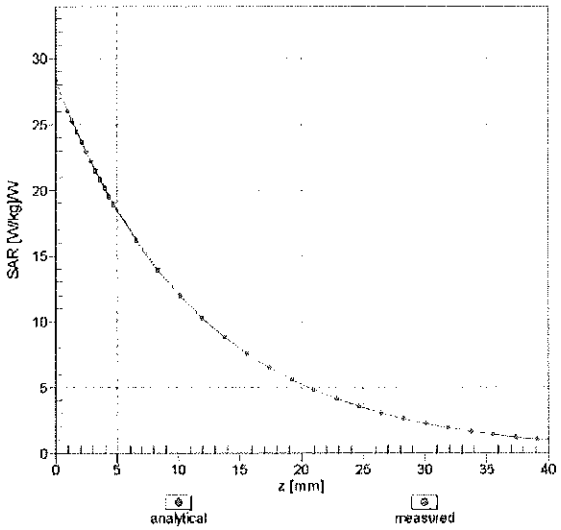

**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Conversion Factor Assessment

f = 835 MHz,WGLS R9 (H_convF)

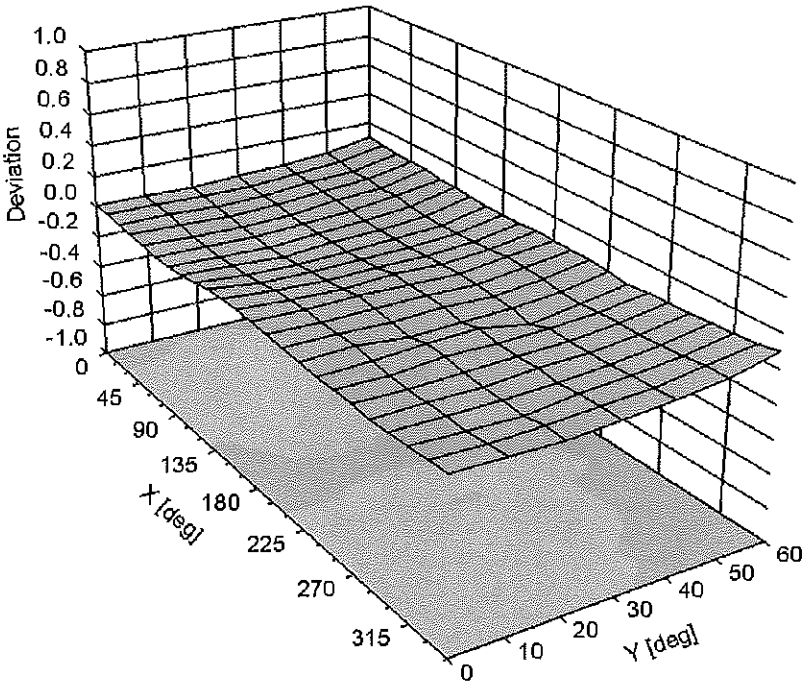


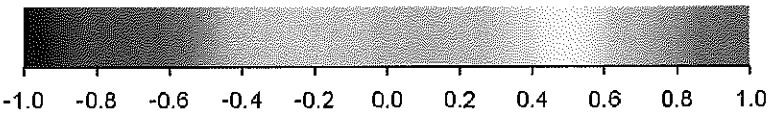

f = 1900 MHz,WGLS R22 (H_convF)




# Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**




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

# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3920

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -22.4 |
| Mechanical Surface Detection Mode | enabled |
| Optical Surface Detection Mode | disabled |
| Probe Overall Length | 337 mm |
| Probe Body Diameter | 10 mm |
| Tip Length | 9 mm |
| Tip Diameter | 2.5 mm |
| Probe Tip to Sensor X Calibration Point | 1 mm |
| Probe Tip to Sensor Y Calibration Point | 1 mm |
| Probe Tip to Sensor Z Calibration Point | 1 mm |
| Recommended Measurement Distance from Surface | 2 mm |

# APPENDIX D: SAR TISSUE SPECIFICATIONS

Measurement Procedure for Tissue verification:

1) The network analyzer and probe system was configured and calibrated.
2) The probe was immersed in the tissue. The tissue was placed in a nonmetallic container. Trapped air bubbles beneath the flange were minimized by placing the probe at a slight angle.
3) The complex admittance with respect to the probe aperture was measured
4) The complex relative permittivity $\varepsilon_r^{'}$ can be calculated from the below equation (Pournaropoulos and Misra):

$$Y = \frac{j2\omega\varepsilon_r\varepsilon_0}{[\ln(b/a)]^2}\int_a^b\int_a^b\int_0^\pi \cos\phi' \frac{\exp\left[-j\omega r(\mu_0\varepsilon_r^{'}\varepsilon_0)^{1/2}\right]}{r} d\phi' d\rho' d\rho$$

where *Y* is the admittance of the probe in contact with the sample, the primed and unprimed coordinates refer to source and observation points, respectively, $r^2 = \rho^2 + \rho'^2 - 2\rho\rho'\cos\phi'$ , $\omega$ is the angular frequency, and $j = \sqrt{-1}$ .

**Table D-I**
**Composition of the Tissue Equivalent Matter**

| Frequency (MHz) | 835 | 835 | 1900 | 1900 | 2450 | 2450 | 5200-5800 | 5200-5800 |
|---|---|---|---|---|---|---|---|---|
| Tissue | Head | Body | Head | Body | Head | Body | Head | Body |
| Ingredients (% by weight) | | | | | | | | |
| Bactericide | 0.1 | 0.1 | | | See p. 2 | | See p. 3 | |
| DGBE | | | 44.92 | 29.44 | | 26.7 | | |
| HEC | 1 | 1 | | | | | | |
| NaCl | 1.45 | 0.94 | 0.18 | 0.39 | | 0.1 | | |
| Sucrose | 57 | 44.9 | | | | | | |
| Polysorbate (Tween) 80 | | | | | | | | 20 |
| Water | 40.45 | 53.06 | 54.9 | 70.17 | | 73.2 | | 80 |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## 2 Composition / Information on ingredients

The Item is composed of the following ingredients:

| | |
|---|---|
| H2O | Water, 52 – 75% |
| C8H18O3 | Diethylene glycol monobutyl ether (DGBE), 25 – 48%<br>(CAS-No. 112-34-5, EC-No. 203-961-6, EC-index-No. 603-096-00-8)<br>Relevant for safety; Refer to the respective Safety Data Sheet*. |
| NaCl | Sodium Chloride, <1.0% |

**Figure D-1**
**Composition of 2.4 GHz Head Tissue Equivalent Matter**

**Note:** 2.4 GHz head liquid recipes are proprietary SPEAG. Since the composition is approximate to the actual liquids utilized, the manufacturer tissue-equivalent liquid data sheets are provided below.

**Measurement Certificate / Material Test**

| | |
|---|---|
| Item Name | **Head Tissue Simulating Liquid (HSL2450V2)** |
| Product No. | SL AAH 245 BA (Charge: 130212-2) |
| Manufacturer | SPEAG |

**Measurement Method**

TSL dielectric parameters measured using calibrated OCP probe.

**Setup Validation**

Validation results were within ± 2.5% towards the target values of Methanol.

**Target Parameters**

Target parameters as defined in the IEEE 1528 and IEC 62209 compliance standards.

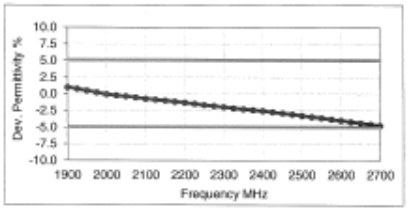
**Test Condition**

| | |
|---|---|
| Ambient | Environment temperatur (22 ± 3)°C and humidity < 70%. |
| TSL Temperature | 23°C |
| Test Date | 13-Feb-13 |
| Operator | DI |

**Additional Information**

| | |
|---|---|
| TSL Density | 0.988 g/cm$^3$ |
| TSL Heat-capacity | 3.680 kJ/(kg*K) |

| | Measured | | | Target | | Diff.to Target [%] | |
|---|---|---|---|---|---|---|---|
| f [MHz] | HP-ε' | HP-ε" | sigma | eps | sigma | Δ-eps | Δ-sigma |
| 1900 | 40.4 | 11.94 | 1.26 | 40.0 | 1.40 | 1.0 | -9.9 |
| 1925 | 40.3 | 12.02 | 1.29 | 40.0 | 1.40 | 0.7 | -8.0 |
| 1950 | 40.2 | 12.11 | 1.31 | 40.0 | 1.40 | 0.5 | -6.2 |
| 1975 | 40.1 | 12.20 | 1.34 | 40.0 | 1.40 | 0.2 | -4.2 |
| 2000 | 40.0 | 12.29 | 1.37 | 40.0 | 1.40 | -0.1 | -2.3 |
| 2025 | 39.9 | 12.39 | 1.40 | 40.0 | 1.42 | -0.2 | -1.9 |
| 2050 | 39.8 | 12.49 | 1.42 | 39.9 | 1.44 | -0.4 | -1.4 |
| 2075 | 39.6 | 12.57 | 1.45 | 39.9 | 1.47 | -0.6 | -1.1 |
| 2100 | 39.5 | 12.65 | 1.48 | 39.8 | 1.49 | -0.7 | -0.7 |
| 2125 | 39.4 | 12.74 | 1.51 | 39.8 | 1.51 | -0.9 | -0.4 |
| 2150 | 39.3 | 12.82 | 1.53 | 39.7 | 1.53 | -1.0 | 0.0 |
| 2175 | 39.2 | 12.89 | 1.56 | 39.7 | 1.56 | -1.2 | 0.3 |
| 2200 | 39.1 | 12.97 | 1.59 | 39.6 | 1.58 | -1.3 | 0.6 |
| 2225 | 39.0 | 13.04 | 1.61 | 39.6 | 1.60 | -1.5 | 0.9 |
| 2250 | 38.9 | 13.11 | 1.64 | 39.6 | 1.62 | -1.7 | 1.2 |
| 2275 | 38.8 | 13.20 | 1.67 | 39.5 | 1.64 | -1.8 | 1.6 |
| **2300** | **38.7** | **13.28** | **1.70** | **39.5** | **1.67** | **-2.0** | **2.0** |
| 2325 | 38.6 | 13.35 | 1.73 | 39.4 | 1.69 | -2.1 | 2.3 |
| 2350 | 38.5 | 13.42 | 1.75 | 39.4 | 1.71 | -2.3 | 2.6 |
| 2375 | 38.4 | 13.50 | 1.78 | 39.3 | 1.73 | -2.4 | 2.9 |
| 2400 | 38.3 | 13.58 | 1.81 | 39.3 | 1.76 | -2.6 | 3.3 |
| 2425 | 38.2 | 13.65 | 1.84 | 39.2 | 1.78 | -2.7 | 3.6 |
| **2450** | **38.1** | **13.73** | **1.87** | **39.2** | **1.80** | **-2.9** | **4.0** |
| 2475 | 38.0 | 13.79 | 1.90 | 39.2 | 1.83 | -3.1 | 3.9 |
| 2500 | 37.9 | 13.85 | 1.93 | 39.1 | 1.85 | -3.3 | 3.9 |
| 2525 | 37.8 | 13.94 | 1.96 | 39.1 | 1.88 | -3.4 | 4.0 |
| 2550 | 37.7 | 14.02 | 1.99 | 39.1 | 1.91 | -3.6 | 4.2 |
| 2575 | 37.6 | 14.09 | 2.02 | 39.0 | 1.94 | -3.8 | 4.3 |
| **2600** | **37.5** | **14.17** | **2.05** | **39.0** | **1.96** | **-4.0** | **4.4** |
| 2625 | 37.4 | 14.23 | 2.08 | 39.0 | 1.99 | -4.2 | 4.4 |
| 2650 | 37.3 | 14.29 | 2.11 | 38.9 | 2.02 | -4.3 | 4.4 |
| 2675 | 37.1 | 14.36 | 2.14 | 38.9 | 2.05 | -4.5 | 4.5 |
| 2700 | 37.0 | 14.43 | 2.17 | 38.9 | 2.07 | -4.8 | 4.6 |



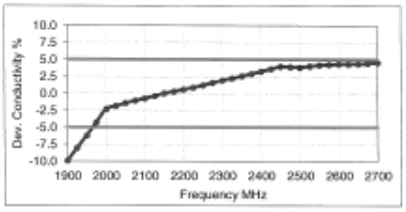




**Figure D-2**
**2.4 GHz Head Tissue Equivalent Matter**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## 2 Composition / Information on ingredients

The Item is composed of the following ingredients:

| | |
|---|---|
| Water | 50 – 65% |
| Mineral oil | 10 – 30% |
| Emulsifiers | 8 – 25% |
| Sodium salt | 0 – 1.5% |

**Figure D-3**
**Composition of 5 GHz Head Tissue Equivalent Matter**

**Note:** 5GHz head liquid recipes are proprietary SPEAG. Since the composition is approximate to the actual liquids utilized, the manufacturer tissue-equivalent liquid data sheets are provided below.

**Measurement Certificate / Material Test**

| | |
|---|---|
| Item Name | **Head Tissue Simulating Liquid (HBBL3500-5800V5)** |
| Product No. | SL AAH 502 AC (Charge: 130903-1) |
| Manufacturer | SPEAG |

**Measurement Method**

TSL dielectric parameters measured using calibrated OCP probe.

**Setup Validation**

Validation results were within ± 2.5% towards the target values of Methanol.

**Target Parameters**

Target parameters as defined in the IEEE 1528 and IEC 62209 compliance standards.

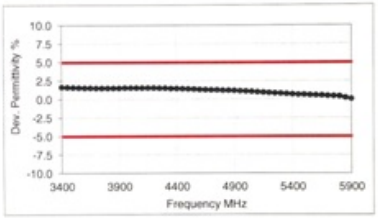
**Test Condition**

| | |
|---|---|
| Ambient | Environment temperatur (22 ± 3)°C and humidity < 70%. |
| TSL Temperature | 22°C |
| Test Date | 4-Sep-13 |
| Operator | IEN |

**Additional Information**

| | |
|---|---|
| TSL Density | 0.985 g/cm³ |
| TSL Heat-capacity | 3.383 kJ/(kg*K) |

| | Measured | | | Target | | Diff.to Target [%] | |
|---|---|---|---|---|---|---|---|
| f [MHz] | HP-e' | HP-e'' | sigma | eps | sigma | Δ-eps | Δ-sigma |
| 3400 | 38.7 | 15.01 | 2.84 | 38.0 | 2.81 | 1.7 | 1.1 |
| **3500** | **38.5** | **14.98** | **2.92** | **37.9** | **2.91** | **1.5** | **0.3** |
| 3600 | 38.4 | 14.98 | 3.00 | 37.8 | 3.02 | 1.5 | -0.5 |
| **3700** | **38.3** | **14.97** | **3.08** | **37.7** | **3.12** | **1.6** | **-1.2** |
| 3800 | 38.2 | 14.95 | 3.16 | 37.6 | 3.22 | 1.6 | -1.9 |
| 3900 | 38.1 | 14.96 | 3.25 | 37.5 | 3.32 | 1.7 | -2.2 |
| 4000 | 37.9 | 14.98 | 3.33 | 37.4 | 3.43 | 1.5 | -2.8 |
| 4100 | 37.8 | 15.00 | 3.42 | 37.2 | 3.53 | 1.5 | -3.0 |
| 4200 | 37.7 | 15.04 | 3.51 | 37.1 | 3.63 | 1.5 | -3.3 |
| 4300 | 37.6 | 15.10 | 3.61 | 37.0 | 3.73 | 1.6 | -3.3 |
| 4400 | 37.4 | 15.16 | 3.71 | 36.9 | 3.84 | 1.4 | -3.3 |
| 4500 | 37.3 | 15.22 | 3.81 | 36.8 | 3.94 | 1.4 | -3.2 |
| 4600 | 37.2 | 15.29 | 3.91 | 36.7 | 4.04 | 1.4 | -3.2 |
| 4700 | 37.0 | 15.34 | 4.01 | 36.6 | 4.14 | 1.2 | -3.2 |
| 4800 | 36.9 | 15.41 | 4.11 | 36.4 | 4.25 | 1.3 | -3.2 |
| 4850 | 36.8 | 15.43 | 4.16 | 36.4 | 4.30 | 1.1 | -3.2 |
| 4900 | 36.8 | 15.47 | 4.22 | 36.3 | 4.35 | 1.3 | -2.9 |
| 4950 | 36.7 | 15.49 | 4.26 | 36.3 | 4.40 | 1.2 | -3.2 |
| 5000 | 36.6 | 15.52 | 4.32 | 36.2 | 4.45 | 1.1 | -2.9 |
| 5050 | 36.5 | 15.55 | 4.37 | 36.2 | 4.50 | 0.9 | -2.9 |
| 5100 | 36.5 | 15.59 | 4.42 | 36.1 | 4.55 | 1.1 | -2.9 |
| 5150 | 36.4 | 15.62 | 4.47 | 36.0 | 4.60 | 1.0 | -2.9 |
| **5200** | **36.3** | **15.65** | **4.53** | **36.0** | **4.66** | **0.9** | **-2.7** |
| 5250 | 36.2 | 15.67 | 4.58 | 35.9 | 4.71 | 0.8 | -2.7 |
| 5300 | 36.2 | 15.71 | 4.63 | 35.9 | 4.76 | 0.9 | -2.7 |
| 5350 | 36.1 | 15.73 | 4.68 | 35.8 | 4.81 | 0.8 | -2.7 |
| 5400 | 36.0 | 15.75 | 4.73 | 35.8 | 4.86 | 0.7 | -2.7 |
| 5450 | 35.9 | 15.78 | 4.78 | 35.7 | 4.91 | 0.6 | -2.7 |
| **5500** | **35.9** | **15.79** | **4.83** | **35.6** | **4.96** | **0.7** | **-2.7** |
| 5550 | 35.8 | 15.83 | 4.89 | 35.6 | 5.01 | 0.6 | -2.5 |
| 5600 | 35.7 | 15.86 | 4.94 | 35.5 | 5.07 | 0.5 | -2.5 |
| 5650 | 35.7 | 15.89 | 5.00 | 35.5 | 5.12 | 0.6 | -2.3 |
| 5700 | 35.6 | 15.92 | 5.05 | 35.4 | 5.17 | 0.5 | -2.3 |
| 5750 | 35.5 | 15.96 | 5.11 | 35.4 | 5.22 | 0.4 | -2.1 |
| **5800** | **35.5** | **15.97** | **5.15** | **35.3** | **5.27** | **0.6** | **-2.3** |
| 5850 | 35.4 | 16.02 | 5.21 | 35.3 | 5.34 | 0.3 | -2.3 |
| 5900 | 35.3 | 16.03 | 5.26 | 35.3 | 5.40 | 0.0 | -2.6 |



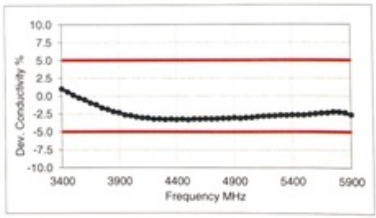




**Figure D-4**
**5GHz Head Tissue Equivalent Matter**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# APPENDIX E: SAR SYSTEM VALIDATION

Per FCC KDB 865664 D02v01, SAR system validation status should be documented to confirm measurement accuracy. The SAR systems (including SAR probes, system components and software versions) used for this device were validated against its performance specifications prior to the SAR measurements. Reference dipoles were used with the required tissue- equivalent media for system validation, according to the procedures outlined in FCC KDB 865664 D01 v01 and IEEE 1528-2013. Since SAR probe calibrations are frequency dependent, each probe calibration point was validated at a frequency within the valid frequency range of the probe calibration point, using the system that normally operates with the probe for routine SAR measurements and according to the required tissue-equivalent media.

A tabulated summary of the system validation status including the validation date(s), measurement frequencies, SAR probes and tissue dielectric parameters has been included.

**Table E-I**
**SAR System Validation Summary**

| SAR SYSTEM # | FREQ. [MHz] | DATE | PROBE SN | PROBE TYPE | PROBE CAL. POINT | | COND. | PERM. | CW VALIDATION | | | MOD. VALIDATION | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | (σ) | ($\varepsilon_r$) | SENSI-TIVITY | PROBE LINEARITY | PROBE ISOTROPY | MOD. TYPE | DUTY FACTOR | PAR |
| H | 835 | 7/23/2014 | 3319 | ES3DV3 | 835 | Head | 0.934 | 42.63 | PASS | PASS | PASS | GMSK | PASS | N/A |
| K | 835 | 6/23/2014 | 3287 | ES3DV3 | 835 | Head | 0.906 | 40.24 | PASS | PASS | PASS | GMSK | PASS | N/A |
| D | 1900 | 6/25/2014 | 3022 | ES3DV2 | 1900 | Head | 1.400 | 39.22 | PASS | PASS | PASS | GMSK | PASS | N/A |
| K | 1900 | 6/17/2014 | 3287 | ES3DV3 | 1900 | Head | 1.407 | 39.80 | PASS | PASS | PASS | GMSK | PASS | N/A |
| H | 2450 | 6/19/2014 | 3319 | ES3DV3 | 2450 | Head | 1.788 | 39.78 | PASS | PASS | PASS | OFDM | N/A | PASS |
| E | 5200 | 12/3/2013 | 3914 | EX3DV4 | 5200 | Head | 4.482 | 34.70 | PASS | PASS | PASS | OFDM | N/A | PASS |
| E | 5300 | 12/3/2013 | 3914 | EX3DV4 | 5300 | Head | 4.604 | 34.60 | PASS | PASS | PASS | OFDM | N/A | PASS |
| E | 5500 | 12/3/2013 | 3914 | EX3DV4 | 5500 | Head | 4.821 | 34.28 | PASS | PASS | PASS | OFDM | N/A | PASS |
| E | 5600 | 12/3/2013 | 3914 | EX3DV4 | 5600 | Head | 4.907 | 34.13 | PASS | PASS | PASS | OFDM | N/A | PASS |
| E | 5800 | 12/3/2013 | 3914 | EX3DV4 | 5800 | Head | 5.133 | 33.89 | PASS | PASS | PASS | OFDM | N/A | PASS |
| D | 835 | 6/23/2014 | 3022 | ES3DV3 | 835 | Body | 1.013 | 54.46 | PASS | PASS | PASS | GMSK | PASS | N/A |
| J | 1900 | 6/10/2014 | 3332 | ES3DV3 | 1900 | Body | 1.561 | 51.51 | PASS | PASS | PASS | GMSK | PASS | N/A |
| K | 1900 | 6/25/2014 | 3287 | ES3DV3 | 1900 | Body | 1.523 | 51.28 | PASS | PASS | PASS | GMSK | PASS | N/A |
| E | 2450 | 7/7/2014 | 3914 | EX3DV4 | 2450 | Body | 1.997 | 51.67 | PASS | PASS | PASS | OFDM/TDD | N/A | PASS |
| A | 5200 | 1/13/2014 | 3920 | EX3DV4 | 5200 | Body | 5.344 | 47.27 | PASS | PASS | PASS | OFDM | N/A | PASS |
| A | 5300 | 1/13/2014 | 3920 | EX3DV4 | 5300 | Body | 5.500 | 46.91 | PASS | PASS | PASS | OFDM | N/A | PASS |
| A | 5500 | 1/13/2014 | 3920 | EX3DV4 | 5500 | Body | 5.826 | 46.38 | PASS | PASS | PASS | OFDM | N/A | PASS |
| A | 5600 | 1/13/2014 | 3920 | EX3DV4 | 5600 | Body | 5.991 | 46.16 | PASS | PASS | PASS | OFDM | N/A | PASS |
| A | 5800 | 1/13/2014 | 3920 | EX3DV4 | 5800 | Body | 6.282 | 46.05 | PASS | PASS | PASS | OFDM | N/A | PASS |

NOTE: While the probes have been calibrated for both CW and modulated signals, all measurement were performed using communication systems calibrated for CW signals only. Modulations in the table above represent test configurations for which the measurement system has been validated per FCC KDB Publication 865664 D01v01 for scenarios when CW probe calibrations are used with other signal types. SAR systems were validated for modulated signals with a periodic duty cycle, such as GMSK, or with a high peak to average ratio (>5 dB), such as OFDM according to KDB 865664.


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