# Appendix B - DAE & Probe Calibration Certificate

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

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Accreditation No.: SCS 0108

Client SGS-TW (Auden)

Certificate No: DAE4-856_Apr20

## CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | DAE4 - SD 000 D04 BM - SN: 856 |
| Calibration procedure(s) | QA CAL-06.v30<br>Calibration procedure for the data acquisition electronics (DAE) |
| Calibration date: | April 23, 2020 |

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 |
|---|---|---|---|
| Keithley Multimeter Type 2001 | SN: 0810278 | 03-Sep-19 (No:25949) | Sep-20 |
| **Secondary Standards** | **ID #** | **Check Date (in house)** | **Scheduled Check** |
| Auto DAE Calibration Unit | SE UWS 053 AA 1001 | 09-Jan-20 (in house check) | In house check: Jan-21 |
| Calibrator Box V2.1 | SE UMS 006 AA 1002 | 09-Jan-20 (in house check) | In house check: Jan-21 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Eric Hainfeld | Laboratory Technician | |
| Approved by: | Sven Kühn | Deputy Manager | i.V. |

Issued: April 23, 2020

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Certificate No: DAE4-856_Apr20 Page 1 of 5

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**Zeughausstrasse 43, 8004 Zurich, Switzerland**

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## Glossary

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

## Methods Applied and Interpretation of Parameters

- *DC Voltage Measurement:* Calibration Factor assessed for use in DASY system by comparison with a calibrated instrument traceable to national standards. The figure given corresponds to the full scale range of the voltmeter in the respective range.
- *Connector angle*: The angle of the connector is assessed measuring the angle mechanically by a tool inserted. Uncertainty is not required.
- The following parameters as documented in the Appendix contain technical information as a result from the performance test and require no uncertainty.
  - *DC Voltage Measurement Linearity:* Verification of the Linearity at +10% and -10% of the nominal calibration voltage. Influence of offset voltage is included in this measurement.
  - *Common mode sensitivity:* Influence of a positive or negative common mode voltage on the differential measurement.
  - *Channel separation:* Influence of a voltage on the neighbor channels not subject to an input voltage.
  - *AD Converter Values with inputs shorted:* Values on the internal AD converter corresponding to zero input voltage
  - *Input Offset Measurement*: Output voltage and statistical results over a large number of zero voltage measurements.
  - *Input Offset Current:* Typical value for information; Maximum channel input offset current, not considering the input resistance.
  - *Input resistance:* Typical value for information: DAE input resistance at the connector, during internal auto-zeroing and during measurement.
  - *Low Battery Alarm Voltage:* Typical value for information. Below this voltage, a battery alarm signal is generated.
  - *Power consumption:* Typical value for information. Supply currents in various operating modes.





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## DC Voltage Measurement

A/D - Converter Resolution nominal

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

Low Range: 1LSB = 61nV , full range = -1.......+3mV

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

| Calibration Factors | X | Y | Z |
|---|---|---|---|
| **High Range** | 403.380 ± 0.02% (k=2) | 404.495 ± 0.02% (k=2) | 403.816 ± 0.02% (k=2) |
| **Low Range** | 3.97758 ± 1.50% (k=2) | 3.98914 ± 1.50% (k=2) | 3.94307 ± 1.50% (k=2) |

## Connector Angle

| | |
|---|---|
| **Connector Angle** to be used in DASY system | 263.5 ° ± 1 ° |




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

### 1. DC Voltage Linearity

| High Range | | Reading (μV) | Difference (μV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 199992.31 | -2.11 | -0.00 |
| Channel X | + Input | 20000.67 | -1.62 | -0.01 |
| Channel X | - Input | -20000.13 | 0.85 | -0.00 |
| Channel Y | + Input | 199991.79 | -2.27 | -0.00 |
| Channel Y | + Input | 19998.81 | -3.48 | -0.02 |
| Channel Y | - Input | -20001.25 | -0.35 | 0.00 |
| Channel Z | + Input | 199991.81 | -2.40 | -0.00 |
| Channel Z | + Input | 19999.55 | -2.68 | -0.01 |
| Channel Z | - Input | -20002.25 | -1.05 | 0.01 |

| Low Range | | Reading (μV) | Difference (μV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 2002.54 | 0.95 | 0.05 |
| Channel X | + Input | 202.22 | 0.24 | 0.12 |
| Channel X | - Input | -197.73 | 0.20 | -0.10 |
| Channel Y | + Input | 2003.16 | 1.65 | 0.08 |
| Channel Y | + Input | 201.59 | -0.37 | -0.18 |
| Channel Y | - Input | -198.84 | -0.80 | 0.40 |
| Channel Z | + Input | 2002.02 | 0.51 | 0.03 |
| Channel Z | + Input | 200.67 | -1.21 | -0.60 |
| Channel Z | - Input | -199.34 | -1.36 | 0.69 |

### 2. Common mode sensitivity

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

| | Common mode Input Voltage (mV) | High Range Average Reading (μV) | Low Range Average Reading (μV) |
|---|---|---|---|
| Channel X | 200 | -14.42 | -15.77 |
| | - 200 | 17.98 | 16.30 |
| Channel Y | 200 | -2.18 | -2.42 |
| | - 200 | 0.61 | 0.73 |
| Channel Z | 200 | 11.03 | 10.60 |
| | - 200 | -13.19 | -13.39 |

### 3. Channel separation

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

| | Input Voltage (mV) | Channel X (μV) | Channel Y (μV) | Channel Z (μV) |
|---|---|---|---|---|
| Channel X | 200 | - | 2.68 | -3.13 |
| Channel Y | 200 | 7.35 | - | 3.16 |
| Channel Z | 200 | 8.96 | 5.12 | - |





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## 4. AD-Converter Values with inputs shorted

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

| | High Range (LSB) | Low Range (LSB) |
|---|---|---|
| Channel X | 16228 | 16904 |
| Channel Y | 15956 | 16202 |
| Channel Z | 15884 | 16758 |

## 5. Input Offset Measurement

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

| | Average (μV) | min. Offset (μV) | max. Offset (μV) | Std. Deviation (μV) |
|---|---|---|---|---|
| Channel X | 0.87 | -0.58 | 2.15 | 0.46 |
| Channel Y | 0.80 | -0.45 | 3.76 | 0.65 |
| Channel Z | 0.61 | -0.84 | 3.29 | 0.77 |

## 6. Input Offset Current

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

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

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

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

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

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

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





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Accreditation No.: **SCS 0108**

Client **SGS-TW (Auden)**

Certificate No: **EX3-3770_May20**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | EX3DV4 - SN:3770 |
| Calibration procedure(s) | QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v5, QA CAL-23.v5, QA CAL-25.v7<br>Calibration procedure for dosimetric E-field probes |
| Calibration date: | May 27, 2020 |

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter NRP | SN: 104778 | 01-Apr-20 (No. 217-03100/03101) | Apr-21 |
| Power sensor NRP-Z91 | SN: 103244 | 01-Apr-20 (No. 217-03100) | Apr-21 |
| Power sensor NRP-Z91 | SN: 103245 | 01-Apr-20 (No. 217-03101) | Apr-21 |
| Reference 20 dB Attenuator | SN: CC2552 (20x) | 31-Mar-20 (No. 217-03106) | Apr-21 |
| DAE4 | SN: 660 | 27-Dec-19 (No. DAE4-660_Dec19) | Dec-20 |
| Reference Probe ES3DV2 | SN: 3013 | 31-Dec-19 (No. ES3-3013_Dec19) | Dec-20 |
| | | | |
| Secondary Standards | ID | Check Date (in house) | Scheduled Check |
| Power meter E4419B | SN: GB41293874 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: MY41498087 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: 000110210 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| RF generator HP 8648C | SN: US3642U01700 | 04-Aug-99 (in house check Jun-18) | In house check: Jun-20 |
| Network Analyzer E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-19) | In house check: Oct-20 |

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

Issued: June 2, 2020

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Certificate No: EX3-3770_May20 Page 1 of 10

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## Glossary:

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

## Calibration is Performed According to the Following Standards:

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

## Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization ϑ = 0 (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide). NORMx,y,z are only intermediate values, i.e., the uncertainties of NORMx,y,z does not affect the $E^2$-field uncertainty inside TSL (see below *ConvF*).
- *NORM(f)x,y,z = NORMx,y,z * frequency_response* (see Frequency Response Chart). This linearization is implemented in DASY4 software versions later than 4.2. The uncertainty of the frequency response is included in the stated uncertainty of *ConvF*.
- *DCPx,y,z:* DCP are numerical linearization parameters assessed based on the data of power sweep with CW signal (no uncertainty required). DCP does not depend on frequency nor media.
- *PAR:* PAR is the Peak to Average Ratio that is not calibrated but determined based on the signal characteristics
- *Ax,y,z; Bx,y,z; Cx,y,z; Dx,y,z; VRx,y,z: A, B, C, D* are numerical linearization parameters assessed based on the data of power sweep for specific modulation signal. The parameters do not depend on frequency nor media. *VR* is the maximum calibration range expressed in RMS voltage across the diode.
- *ConvF and Boundary Effect Parameters:* Assessed in flat phantom using E-field (or Temperature Transfer Standard for f ≤ 800 MHz) and inside waveguide using analytical field distributions based on power measurements for f > 800 MHz. The same setups are used for assessment of the parameters applied for boundary compensation (alpha, depth) of which typical uncertainty values are given. These parameters are used in DASY4 software to improve probe accuracy close to the boundary. The sensitivity in TSL corresponds to *NORMx,y,z * ConvF* whereby the uncertainty corresponds to that given for *ConvF*. A frequency dependent *ConvF* is used in DASY version 4.4 and higher which allows extending the validity from ± 50 MHz to ± 100 MHz.
- *Spherical isotropy (3D deviation from isotropy)*: in a field of low gradients realized using a flat phantom exposed by a patch antenna.
- *Sensor Offset*: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle*: The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).





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# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3770

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$)[A] | 0.29 | 0.31 | 0.36 | ± 10.1 % |
| DCP (mV)[B] | 101.0 | 102.1 | 107.8 | |

## Calibration Results for Modulation Response

| UID | Communication System Name | | A dB | B dB√μV | C | D dB | VR mV | Max dev. | Unc[E] (k=2) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | CW | X | 0.0 | 0.0 | 1.0 | 0.00 | 134.3 | ± 2.7 % | ± 4.7 % |
| | | Y | 0.0 | 0.0 | 1.0 | | 144.6 | | |
| | | Z | 0.0 | 0.0 | 1.0 | | 131.2 | | |

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

[A] The uncertainties of Norm X,Y,Z do not affect the $E^2$-field uncertainty inside TSL (see Pages 5 and 10).
[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.





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# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3770

## Other Probe Parameters

| | |
|---|---|
| Sensor Arrangement | Triangular |
| Connector Angle (°) | -17.9 |
| Mechanical Surface Detection Mode | enabled |
| Optical Surface Detection Mode | disabled |
| Probe Overall Length | 337 mm |
| Probe Body Diameter | 10 mm |
| Tip Length | 9 mm |
| Tip Diameter | 2.5 mm |
| Probe Tip to Sensor X Calibration Point | 1 mm |
| Probe Tip to Sensor Y Calibration Point | 1 mm |
| Probe Tip to Sensor Z Calibration Point | 1 mm |
| Recommended Measurement Distance from Surface | 1.4 mm |





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# DASY/EASY - Parameters of Probe: EX3DV4 - SN:3770

## Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) [C] | Relative Permittivity [F] | Conductivity (S/m) [F] | ConvF X | ConvF Y | ConvF Z | Alpha [G] | Depth [G] (mm) | Unc (k=2) |
|---|---|---|---|---|---|---|---|---|
| 450 | 43.5 | 0.87 | 10.65 | 10.65 | 10.65 | 0.13 | 1.25 | ± 13.3 % |
| 750 | 41.9 | 0.89 | 9.84 | 9.84 | 9.84 | 0.51 | 0.80 | ± 12.0 % |
| 835 | 41.5 | 0.90 | 9.50 | 9.50 | 9.50 | 0.28 | 1.12 | ± 12.0 % |
| 900 | 41.5 | 0.97 | 9.28 | 9.28 | 9.28 | 0.42 | 0.85 | ± 12.0 % |
| 1450 | 40.5 | 1.20 | 8.47 | 8.47 | 8.47 | 0.32 | 0.80 | ± 12.0 % |
| 1750 | 40.1 | 1.37 | 8.36 | 8.36 | 8.36 | 0.31 | 0.86 | ± 12.0 % |
| 1900 | 40.0 | 1.40 | 8.03 | 8.03 | 8.03 | 0.21 | 0.86 | ± 12.0 % |
| 2000 | 40.0 | 1.40 | 7.93 | 7.93 | 7.93 | 0.27 | 0.94 | ± 12.0 % |
| 2300 | 39.5 | 1.67 | 7.67 | 7.67 | 7.67 | 0.31 | 0.90 | ± 12.0 % |
| 2450 | 39.2 | 1.80 | 7.40 | 7.40 | 7.40 | 0.37 | 0.90 | ± 12.0 % |
| 2600 | 39.0 | 1.96 | 7.21 | 7.21 | 7.21 | 0.40 | 0.90 | ± 12.0 % |
| 3300 | 38.2 | 2.71 | 7.00 | 7.00 | 7.00 | 0.35 | 1.30 | ± 13.1 % |
| 3500 | 37.9 | 2.91 | 6.70 | 6.70 | 6.70 | 0.35 | 1.30 | ± 13.1 % |
| 3700 | 37.7 | 3.12 | 6.60 | 6.60 | 6.60 | 0.35 | 1.30 | ± 13.1 % |
| 3900 | 37.5 | 3.32 | 6.39 | 6.39 | 6.39 | 0.40 | 1.60 | ± 13.1 % |
| 4100 | 37.2 | 3.53 | 6.34 | 6.34 | 6.34 | 0.40 | 1.60 | ± 13.1 % |
| 4200 | 37.1 | 3.63 | 6.18 | 6.18 | 6.18 | 0.40 | 1.60 | ± 13.1 % |
| 4400 | 36.9 | 3.84 | 6.08 | 6.08 | 6.08 | 0.40 | 1.60 | ± 13.1 % |
| 4600 | 36.7 | 4.04 | 5.97 | 5.97 | 5.97 | 0.40 | 1.80 | ± 13.1 % |
| 4800 | 36.4 | 4.25 | 5.93 | 5.93 | 5.93 | 0.40 | 1.80 | ± 13.1 % |
| 4950 | 36.3 | 4.40 | 5.77 | 5.77 | 5.77 | 0.40 | 1.80 | ± 13.1 % |
| 5250 | 35.9 | 4.71 | 5.40 | 5.40 | 5.40 | 0.40 | 1.80 | ± 13.1 % |
| 5600 | 35.5 | 5.07 | 4.79 | 4.79 | 4.79 | 0.40 | 1.80 | ± 13.1 % |
| 5750 | 35.4 | 5.22 | 4.90 | 4.90 | 4.90 | 0.40 | 1.80 | ± 13.1 % |

[C] Frequency validity above 300 MHz of ± 100 MHz only applies for DASY v4.4 and higher (see Page 2), else it is restricted to ± 50 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Validity of ConvF assessed at 6 MHz is 4-9 MHz, and ConvF assessed at 13 MHz is 9-19 MHz. Above 5 GHz frequency validity can be extended to ± 110 MHz.
[F] At frequencies 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.





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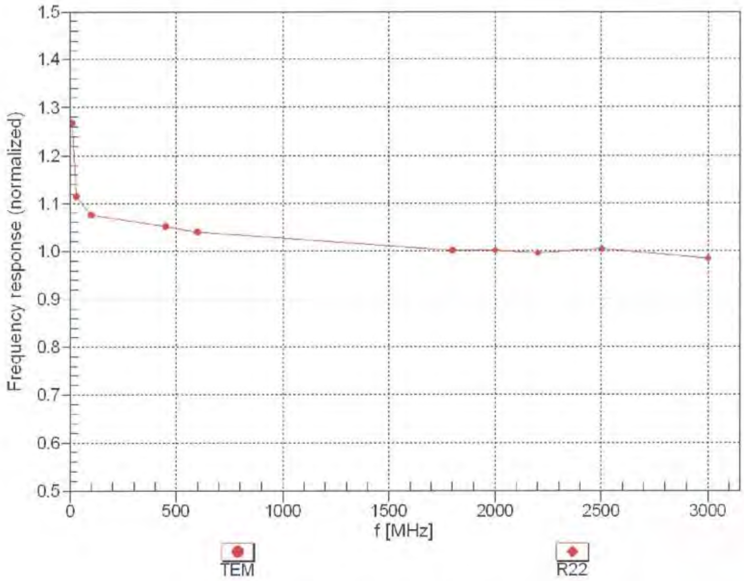
# Frequency Response of E-Field

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




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





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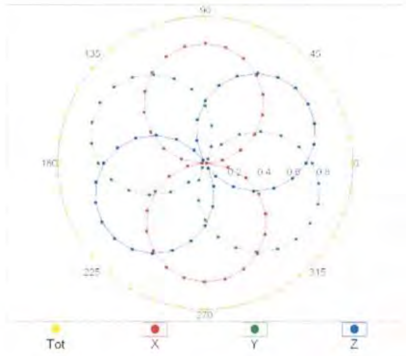
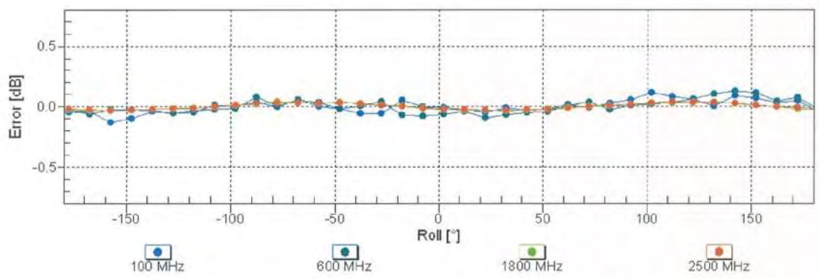
## Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM


f=1800 MHz,R22




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





SGS Taiwan Ltd. | No.134,Wu Kung Road, New Taipei Industrial Park, Wuku District, New Taipei City, Taiwan/新北市五股區新北產業園區五工路 134 號
台灣檢驗科技股份有限公司 | t (886-2) 2299-3279 f (886-2) 2298-0488 www.sgs.com.tw
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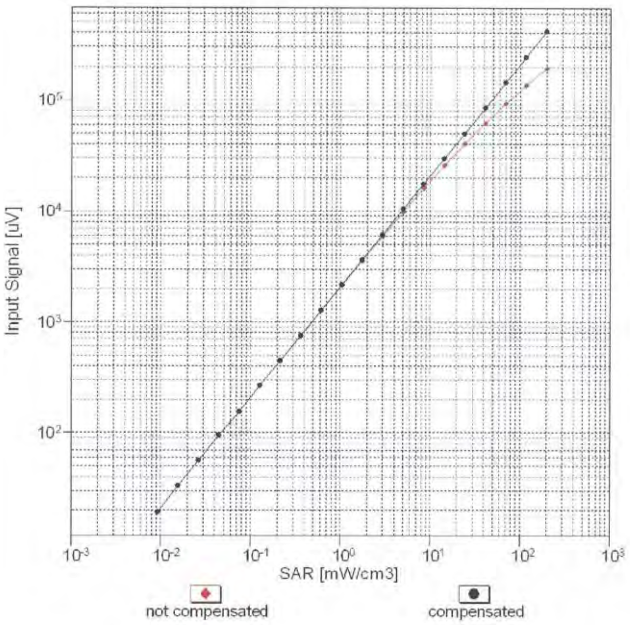
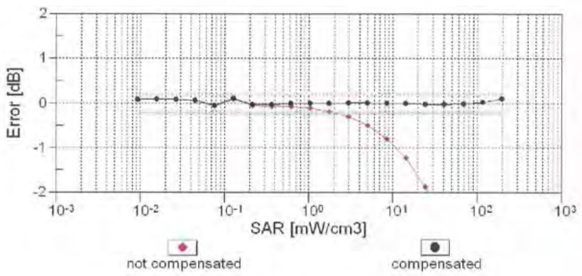
EX3DV4– SN:3770 May 27, 2020

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



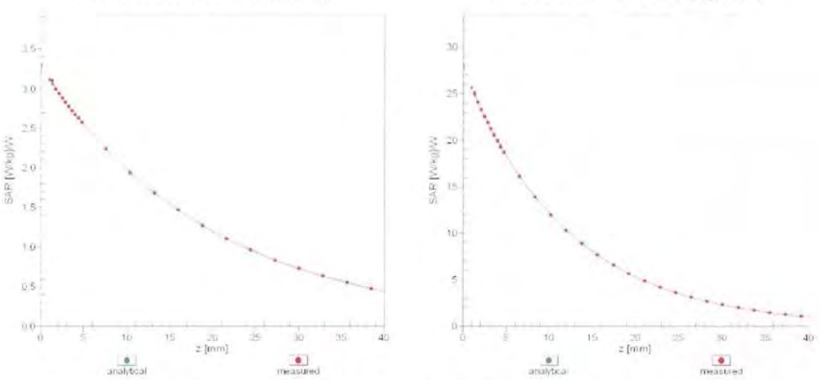




**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

Certificate No: EX3-3770_May20 Page 8 of 10

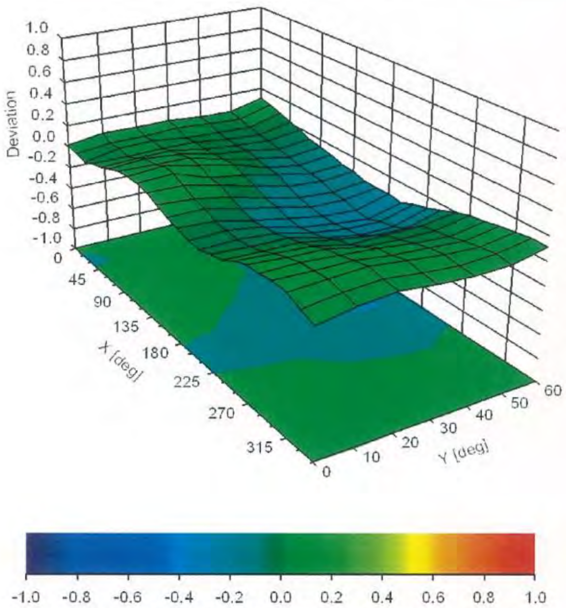
EX3DV4– SN:3770 May 27, 2020

## Conversion Factor Assessment




## Deviation from Isotropy in Liquid

**Error (ϕ, ϑ), f = 900 MHz**




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

Certificate No: EX3-3770_May20 Page 9 of 10

EX3DV4– SN:3770 May 27, 2020

## Appendix: Calibration Parameters above 6GHz

### Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) [C] | Relative Permittivity [F] | Conductivity (S/m) [F] | ConvF X | ConvF Y | ConvF Z | Alpha [G] | Depth [G] (mm) | Unc (k=2) |
|---|---|---|---|---|---|---|---|---|
| 6500 | 34.5 | 6.07 | 5.60 | 5.60 | 5.60 | 0.20 | 2.00 | ± 18.6 % |
| 7000 | 33.9 | 6.65 | 5.40 | 5.40 | 5.40 | 0.20 | 1.50 | ± 18.6 % |

[C] Calibration procedure for frequencies above 6 GHz is pending accreditation. Frequency validity above 6GHz is ± 700 MHz. The uncertainty is the RSS of the ConvF uncertainty at calibration frequency and the uncertainty for the indicated frequency band.
[F] At frequencies 6-10 GHz, the validity of tissue parameters ($\varepsilon$ and $\sigma$) can be relaxed to ± 10% if liquid compensation formula is applied to measured SAR values. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.
[G] Alpha/Depth are determined during calibration. SPEAG warrants that the remaining deviation due to the boundary effect after compensation is always less than ± 1% for frequencies below 3 GHz; below ± 2% for frequencies between 3-6 GHz; and below ± 4% for frequencies between 6-10 GHz at any distance larger than half the probe tip diameter from the boundary.



**- End of report -**



SGS Taiwan Ltd. No.134,Wu Kung Road, New Taipei Industrial Park, Wuku District, New Taipei City, Taiwan/新北市五股區新北產業園區五工路134號
台灣檢驗科技股份有限公司 t (886-2) 2299-3279 f (886-2) 2298-0488 www.sgs.com.tw
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