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# **Appendix B - DAE & Probe Calibration Certificate**

Calibration Laboratory of Schweizerischer Kalibrierdienst S Schmid & Partner Service suisse d'étalonnage C Engineering AG Servizio svizzero di taratura S Swiss Calibration Service Accreditation No.: SCS 0108 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 SGS - TW (Auden) Certificate No: DAE4-547\_Mar17 CALIBRATION CERTIFICATE DAE4 - SD 000 D04 BM - SN: 547 Object Calibration procedure(s) QA CAL-06.v29 Calibration procedure for the data acquisition electronics (DAE) March 22, 2017 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 at the certificate. All calibrations have been conducted in the closed laboratory tability: environment temperature (22 ± 3)°C and humidity < 70%. Calibration Equipment used (M&TE ortical for calibration) Primary Standards Cal Date (Certificate No.) Keithley Multimeter Type 2001 SN: 0810278 09-Sep-18 (No:19065) Secondary Standards Scheduled Check Auto DAE Calibration Unit SE L/WS 053 AA 1001 (05-Jan-17 (in house check) In house check: Jan-18 Calibrator Box V2.1 SE UMB 006 AA 1002 (05-Jan-17 (in house check) In house chuck: Jan-18. Function Eric Hairdeld Technician Ein Bemholt Deputy Technical Manager Issued March 22, 2017 This calibration certificate shall not be reproduced except in full without written approval of the liaboratory

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Calibration Laboratory of Schmid & Partner Engineering AG Zeughausstrasse 43, 9004 Zurich, Switzerland





5 Service suisse d'étalonnage C Servizio svizzoro di taratura Swiss Calibration Service

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Glossary

DAE data acquisition electronics

information used in DASY system to align probe sensor X to the robot Connector angle

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 lool 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

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## DC Voltage Measurement

A/D - Converter Resolution nominal High Range: 1LSB = 5.10V full range = -100, +300 mV DASY measurement parameters: Auto Zero Time: 3 sec; Measuring filme: 3 sec

| Calibration Factors | ×                     | ¥.                    | 2                     |
|---------------------|-----------------------|-----------------------|-----------------------|
| High Range          | 403.189 ± 0.02% (k=2) | 403 093 ± 0.02% (k=2) | 402,739 ± 0.02% (k-2) |
| Low Range           | 3.95348 1 1.50% (k=2) | 3.90456 ± 1.50% (k=2) | 3.96243 ± 1.50% (k=2) |

#### Connector Angle

| Connector Angle to be used in DASY system | 91.0 % ± 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 | 200031.23    | 0,59            | 0.00      |
| Channel X + Input | 20005.44     | 2.04            | 0.01      |
| Channel X - Input | -20000.97    | 4.91            | -0.02     |
| Channel Y + Input | 200029.80    | -1.03.          | -0.00     |
| Channel Y + Input | 2000030      | -3.03           | 0.02      |
| Channel Y - Input | +20007.73    | -1.72           | 0.01      |
| Channel Z + Input | 200030,21    | -0.96           | -0.00     |
| Channel Z + Input | 20003.13     | -0:21           | 0.00      |
| Channel Z - Input | -20005.14    | 0.81            | -0.00     |

| Low Range         | Reading (µV) | Difference (µV) | Error (%) |
|-------------------|--------------|-----------------|-----------|
| Channel X + Input | 2000.02      | -0.08           | -0.00     |
| Channel X + Input | 200,18       | 0.36            | 0.18      |
| Channel X - Input | 200.16       | 0.00            | -0.00     |
| Channel Y + Input | 2000.10      | 0.06            | 0.00      |
| Channel Y + Input | 199.43       | -0.40           | -0.20     |
| Channel Y - Input | -200.77      | -0.70           | 0.35      |
| Channel Z + Input | 2000.19      | 0.28            | 0.01      |
| Channel Z + Input | 198.82       | -1.00           | 0.50      |
| Channel Z - Input | /201,46      | -1,37           | 0.68      |
|                   |              |                 |           |

#### 2. Common mode sensitivity

|           | Common mode<br>Input Voltage (mV) | High Range<br>Average Reading (µV) | Low Range<br>Average Reading (μV) |
|-----------|-----------------------------------|------------------------------------|-----------------------------------|
| Channel X | 200                               | -2.09                              | -5,00                             |
|           | -200                              | 6.80                               | 4,50                              |
| Channel Y | 200                               | -D.67                              | -1.21                             |
|           | -200                              | 0.27                               | -0.41                             |
| Channel Z | 200                               | 5.07                               | 4.93                              |
|           | -200                              | -7.67                              | -8.12                             |

#### 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 | 500                | -              | 2.65           | +2.08          |
| Channel Y | 200                | 10.56          |                | 3.60           |
| Channel Z | 200                | 4.55           | 7.85           | ~              |

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4. AD-Converter Values with inputs shorted

|           | High Range (LSB) | Low Range (LSB) |
|-----------|------------------|-----------------|
| Channel X | 16364            | 15364           |
| Channel Y | 16476            | 16801           |
| Channel Z | 16077            | 16468           |

## 5. Input Offset Measurement

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

innul 10MO

|           | Average (μV) | min. Offset (μV) | max. Offset (μV) | Std. Deviation (µV) |
|-----------|--------------|------------------|------------------|---------------------|
| Channel X | -0.53        | -1.714           | 0.26             | 0.31                |
| Channel Y | -1.03        | -2.43            | -0.21            | 0.32                |
| Channel Z | -1.56        | -2.31            | -0.62            | 0.35                |

## 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 info

| 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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SGS-TW (Auden)

Accreditation No.: SCS 0108

Certificate No: DAE4-547\_Mar20 **CALIBRATION CERTIFICATE** DAE4 - SD 000 D04 BM - SN: 547 Object Calibration procedure(s) QA CAL-06.v30 Calibration procedure for the data acquisition electronics (DAE) March 17, 2020 Calibration date: 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) Cal Date (Certificate No.) Scheduled Calibration ID# Primary Standards 03-Sep-19 (No:25949) Sep-20 SN: 0810278 Keithley Multimeter Type 2001 Scheduled Check ID# Secondary Standards Check Date (in house) In house check: Jan-21 SF UWS 053 AA 1001 09-Jan-20 (in house check) Auto DAE Calibration Unit SE UMS 006 AA 1002 09-Jan-20 (in house check) In house check: Jan-21 Calibrator Box V2.1 Name Laboratory Technician Adrian Gehring Calibrated by: Deputy Manager Approved by: Sven Kühn This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

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Connector angle information used in DASY system to align probe sensor X to the robot

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  - 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

full range = -100...+300 mV full range = -1......+3mV High Range: 1LSB = 6.1µV, Low Range: 1LSB = 61nV , DASY measurement parameters: Auto Zero Time: 3 sec; Measuring time: 3 sec

| Calibration Factors | X                     | Υ                     | Z                     |
|---------------------|-----------------------|-----------------------|-----------------------|
| High Range          | 403.278 ± 0.02% (k=2) | 403.179 ± 0.02% (k=2) | 402.830 ± 0.02% (k=2) |
| Low Range           | 3.95688 ± 1.50% (k=2) | 3.90777 ± 1.50% (k=2) | 3.96411 ± 1.50% (k=2) |

### Connector Angle

| Connector Angle to be used in DASV system | 91.5 ° ± 1 ° |
|---|--------------|
| Connector Angle to be used in DASY system | 91.5 11      |

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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 | 199995.01    | 0.39            | 0.00      |
| Channel X + Input | 20004.46     | 2.22            | 0.01      |
| Channel X - Input | -19996.11    | 4.80            | -0.02     |
| Channel Y + Input | 199994.74    | -0.27           | -0.00     |
| Channel Y + Input | 20000.81     | -1.32           | -0.01     |
| Channel Y - Input | -20002,22    | -1.19           | 0.01      |
| Channel Z + Input | 199996.62    | 2.14            | 0.00      |
| Channel Z + Input | 20003.74     | 1.72            | 0.01      |
| Channel Z - Input | -19998.94    | 2.27            | -0.01     |

| Low Range         | Reading (μV) | Difference (μV) | Error (%) |
|-------------------|--------------|-----------------|-----------|
| Channel X + Input | 2003.02      | 1.37            | 0.07      |
| Channel X + Input | 202.40       | 0.52            | 0.26      |
| Channel X - Input | -197.81      | 0.27            | -0.14     |
| Channel Y + Input | 2002.86      | 1.28            | 0.06      |
| Channel Y + Input | 201.87       | 0.04            | 0.02      |
| Channel Y - Input | -198.64      | -0.54           | 0.27      |
| Channel Z + Input | 2002.13      | 0.62            | 0.03      |
| Channel Z + Input | 200.85       | -0.82           | -0.41     |
| Channel Z - Input | -199.40      | -1.23           | 0.62      |

#### 2. Common mode sensitivity

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

|           | Common mode<br>Input Voltage (mV) | High Range<br>Average Reading (μV) | Low Range<br>Average Reading (μV) |
|-----------|-----------------------------------|------------------------------------|-----------------------------------|
| Channel X | 200                               | -3.58                              | -4.73                             |
|           | - 200                             | 5.85                               | 4.21                              |
| Channel Y | 200                               | -0.25                              | -0.89                             |
|           | - 200                             | 0.38                               | -0.39                             |
| Channel Z | 200                               | 5.47                               | 5.10                              |
|           | - 200                             | -8.07                              | -8.21                             |

## 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                |                | 3.40           | -1.88          |
| Channel Y | 200                | 9.97           |                | 4.19           |
| Channel Z | 200                | 5.21           | 8.10           |                |

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### 4. AD-Converter Values with inputs shorted

nt parameters: Auto Zero Time: 3 sec: Measuring time: 3 sec

|           | High Range (LSB) | Low Range (LSB) |
|-----------|------------------|-----------------|
| Channel X | 16359            | 14869           |
| Channel Y | 16462            | 15382           |
| Channel Z | 16084            | 17197           |

#### 5. Input Offset Measurement

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

| nput TOMIS2 | Average (μV) | min. Offset (μV) | max. Offset (μV) | Std. Deviation (µV) |
|-------------|--------------|------------------|------------------|---------------------|
| Channel X   | -0.39        | -1.31            | 0.90             | 0.34                |
| Channel Y   | 0.25         | -0.76            | 1.38             | 0.41                |
| Channel Z   | 0.73         | -0.73            | 3.00             | 0.74                |

## 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              |

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

Certificate No: DAE4-547\_Mar20

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Calibration Laboratory of Schmid & Partner Engineering AG sughausstrasse 43, 8004 Zunch, Switzerla



Schweizerischer Kalibrighdienst Service suisse d'étalonnage Servizio svizzero di taratura Swiss Calibration Service

Accreditation No.: SCS 0108

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

Auden Client

Certificate No: EX3-7351\_Dec17

## CALIBRATION CERTIFICATE

Otjent

EX3DV4 - SN:7351

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

December 21, 2017

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

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

Calibration Equipment used (M&TE critical to calibration)

| Primary Standards          | fipi             | Cal Date (Certificate No.)        | Scheduled Calibration      |
|----------------------------|------------------|-----------------------------------|----------------------------|
| Power mater NRP            | SN: 104778       | 04-Apr-17 (No. 217-02521/02522)   | Apri 18                    |
| Power sensor NRP-Z91       | SN: 1032/14      | 85-Apr-17 (No. 217-02521)         | Apr-18                     |
| Power sensor NRP-Z91       | SN: 103245       | 04-Apr-17 (No. 217-02525)         | Apr-18                     |
| Reference 20 dB Attenuator | SN: 55277 (20x)  | 07-Apr-17 (No. 217-02528)         | Apr-16                     |
| Reference Probe ES30V2     | SN: 3013         | 31-Dec-16 (No. EE3-3013_Dec18)    | Dec-17                     |
| DAEK                       | SN: 654          | 24-Jul-17 (No. DAE4-654_Jul-17)   | Jul-18                     |
| Secondary Standards        | 10               | Chack Date (in figure)            | Scheduled Check            |
| Power motor E44198         | SN_GB41293874    | 06-Apr-15 (in house check Jun-15) | linhouse check: Jun-18     |
| Power sensor E4412A        | SN: MY41498087   | 08-Apr-18 (in house check Jun-18) | In house check: Jun-18     |
| Power sensor E4412A        | SN: 900110210    | D5-Apr-16 (in house check Jun-18) | In house check, Jun-18.    |
| RF generator NP 8048C      | SN: U53642U01700 | 04-Aug-99 (in house check Jun-16) | In house check: Jun-18     |
| Millson's Augston HP 8770F | an usaranoses    | 18-Oct-01 Un house check Cits-12) | Or figures others: Cirp-18 |

Function Castreted by Jeton Kastrati Laboratory Technic Approved by Kittja Pokovic Testwical Manager ssied December 21, 2017 This calibration conficate shell not be reproduced except in full without written approval of the laborator

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Calibration Laboratory of Schmid & Partner Engineering AG ighausstrasse 43, 5004 Zurich, Switzerland





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Accrecipation No., SCS 0108

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#### Glossary:

lissue simulating liquid NORMAYZ sensitivity in free space sensitivity in TSL / NORMx,y z. ConvP diode compression point

CF crest factor (1/duty\_cycle) of the RF agnal modulation dependent linearization parameters A.B.C.D

Palarization o

Polarization 4 A rotation around an axis that is in the plane normal to probe axis (at measurement center)

e., a = 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 Spetial-Averaged Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement
- Techniques", June 2013
  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
  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 b)
- 6
- 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 3 = 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<sup>2</sup>-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 CarryF
- DCPx,y,z: DCP and 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 signs. 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  $\pm 50$  MHz to  $\pm 100$ MHo
- Spherical isotropy (3D deviation from isotropy): In a field of low gradients realized using a flat phontom exposed by a patch antenna.
- Sensor Offset. The sensor offset corresponds to the offset of virtual measurement center from the probe lip (on probe axis). No tolerance required.
- Connector Angle: The angle is assessed using the information gained by determining the WORMx (no uncertainty required).

Detects No. EX3.7351-Dec17.

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EX3DV4 - SN:7351

December 21, 2017

# Probe EX3DV4

SN:7351

Manufactured: Calibrated:

October 13, 2014 December 21, 2017

Calibrated for DASY/EASY Systems

(Note: non-compatible with DASY2 system!)

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EX3DV4-SN:7351

December 21, 2017

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:7351

#### Basic Calibration Parameters

|                          | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|--------------------------|----------|----------|----------|-----------|
| Norm $(\mu V/(V/m)^2)^A$ | 0.47     | 0.44     | 0.45     | ± 10.1 %  |
| DCP (mV) <sup>8</sup>    | 97.9     | 104.3    | 97.1     |           |

#### Modulation Calibration Parameters

| UID | Communication System Name |   | A<br>dB | B<br>dB√μV | С   | D<br>dB | VR<br>mV | Unc <sup>E</sup><br>(k=2) |
|-----|---------------------------|---|---------|------------|-----|---------|----------|---------------------------|
| 0   | CW                        | X | 0.0     | 0.0        | 1.0 | 0.00    | 136.5    | ±3.8 %                    |
|     |                           | Y | 0.0     | 0.0        | 1.0 |         | 136.4    |                           |
|     |                           | Z | 0.0     | 0.0        | 1.0 |         | 147.3    |                           |

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%.

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The uncertainties of Norm X,Y,Z do not affect the E2-field uncertainty inside TSL (see Pages 5 and 6).

Numerical Insertization parameter: uncertainty not required.

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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December 21, 2017

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:7351

## Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) <sup>c</sup> | Relative<br>Permittivity <sup>F</sup> | Conductivity<br>(S/m) <sup>F</sup> | ConvF X | ConvF Y | ConvF Z | Alpha <sup>6</sup> | Depth <sup>C</sup><br>(mm) | Unc<br>(k=2) |
|----------------------|---------------------------------------|------------------------------------|---------|---------|---------|--------------------|----------------------------|--------------|
| 750                  | 41.9                                  | 0.89                               | 10.92   | 10.92   | 10.92   | 0.55               | 0.80                       | ± 12.0 %     |
| 835                  | 41.5                                  | 0.90                               | 10.60   | 10.60   | 10.60   | 0.55               | 0.80                       | ± 12.0 %     |
| 900                  | 41.5                                  | 0.97                               | 10.31   | 10.31   | 10.31   | 0.40               | 0.95                       | ± 12.0 %     |
| 1750                 | 40.1                                  | 1.37                               | 8.78    | 8.78    | 8.78    | 0.28               | 0.80                       | ± 12.0 %     |
| 1900                 | 40.0                                  | 1.40                               | 8.50    | 8.50    | 8.50    | 0.29               | 0.80                       | ± 12.0 9     |
| 2000                 | 40.0                                  | 1.40                               | 8.41    | 8.41    | 8.41    | 0.30               | 0.80                       | ± 12.0 9     |
| 2300                 | 39.5                                  | 1.67                               | 8.03    | 8.03    | 8.03    | 0.31               | 0.84                       | ± 12.0 9     |
| 2450                 | 39.2                                  | 1.80                               | 7.74    | 7.74    | 7.74    | 0.34               | 0.85                       | ± 12.0 9     |
| 2600                 | 39.0                                  | 1.96                               | 7.51    | 7.51    | 7.51    | 0.36               | 0.81                       | ± 12.0 9     |
| 5200                 | 36.0                                  | 4.66                               | 5.49    | 5.49    | 5.49    | 0.35               | 1.80                       | ± 13.1 9     |
| 5300                 | 35.9                                  | 4.76                               | 5.15    | 5.15    | 5.15    | 0.40               | 1.80                       | ± 13.1 9     |
| 5500                 | 35.6                                  | 4.96                               | 5.04    | 5.04    | 5.04    | 0.40               | 1.80                       | ± 13.1 9     |
| 5600                 | 35.5                                  | 5.07                               | 4.81    | 4.81    | 4.81    | 0.40               | 1.80                       | ± 13.1 9     |
| 5800                 | 35.3                                  | 5.27                               | 4.90    | 4.90    | 4.90    | 0.40               | 1.80                       | ± 13.19      |

<sup>&</sup>lt;sup>C</sup> 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 Corolf-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 Corolf-assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

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variety can be extended to ± 110 MHz.

At frequencies below 3 GHz, the validity of tissue parameters (x and e) can be released to ± 10% if liquid compensation formula is applied to measured SAR values. At frequencies above 3 GHz, the validity of tissue parameters (x and e) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

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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EX3DV4-SN:7351

December 21, 2017

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:7351

#### Calibration Parameter Determined in Body Tissue Simulating Media

| f (MHz) <sup>c</sup> | Relative<br>Permittivity | Conductivity<br>(S/m) F | ConvF X | ConvF Y | ConvF Z | Alpha <sup>6</sup> | Depth <sup>G</sup><br>(mm) | Unc<br>(k=2) |
|----------------------|--------------------------|-------------------------|---------|---------|---------|--------------------|----------------------------|--------------|
| 750                  | 55.5                     | 0.96                    | 10.81   | 10.81   | 10.81   | 0.40               | 0.91                       | ± 12.0 %     |
| 835                  | 55.2                     | 0.97                    | 10.39   | 10.39   | 10.39   | 0.47               | 0.87                       | ± 12.0 %     |
| 900                  | 55.0                     | 1.05                    | 10.18   | 10.18   | 10.18   | 0.48               | 0.85                       | ± 12.0 %     |
| 1750                 | 53.4                     | 1.49                    | 8.58    | 8.58    | 8.58    | 0.37               | 0.85                       | ± 12.0 %     |
| 1900                 | 53.3                     | 1.52                    | 8.22    | 8.22    | 8.22    | 0.43               | 0.80                       | ± 12.0 %     |
| 2000                 | 53.3                     | 1.52                    | 8.40    | 8.40    | 8.40    | 0.31               | 0.99                       | ± 12.0 %     |
| 2300                 | 52.9                     | 1.81                    | 7.98    | 7.98    | 7.98    | 0.40               | 0.87                       | ± 12.0 %     |
| 2450                 | 52.7                     | 1.95                    | 7.82    | 7.82    | 7.82    | 0.37               | 0.88                       | ± 12.0 %     |
| 2600                 | 52.5                     | 2.16                    | 7.56    | 7.56    | 7.56    | 0.32               | 0.93                       | ± 12.0 %     |
| 5200                 | 49.0                     | 5.30                    | 4.60    | 4.60    | 4.60    | 0.40               | 1.90                       | ± 13.1 %     |
| 5300                 | 48.9                     | 5.42                    | 4.56    | 4.56    | 4.56    | 0.40               | 1.90                       | ± 13.1 %     |
| 5500                 | 48.6                     | 5.65                    | 4.09    | 4.09    | 4.09    | 0.45               | 1.90                       | ± 13.1 %     |
| 5600                 | 48.5                     | 5.77                    | 3.98    | 3.98    | 3.98    | 0.45               | 1.90                       | ± 13.1 %     |
| 5800                 | 48.2                     | 6.00                    | 4.21    | 4.21    | 4.21    | 0.45               | 1.90                       | ± 13.1 %     |

<sup>&</sup>lt;sup>6</sup> 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 ComF uncertainty at calibration frequency and the uncertainty for the indicated frequency band. Frequency validity below 300 MHz is ± 10, 25, 40, 50 and 70 MHz for ConvF assessments at 30, 64, 128, 150 and 220 MHz respectively. Above 5 GHz frequency validity can be extended to ± 110 MHz.

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validity can be extended to ± 110 MHz.

At frequencies below 3 GHz, the validity of tissue parameters (c and d) 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 (c and d) is restricted to ± 5%. The uncertainty is the RSS of the Const uncertainty for indicated target tissue parameters.

AphalDepth are determined during calibration. SPEAG instructs 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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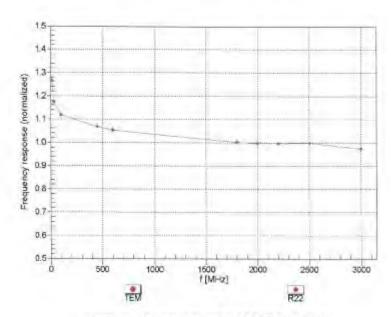
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EX3DV4- SN:7351

December 21, 2017

## 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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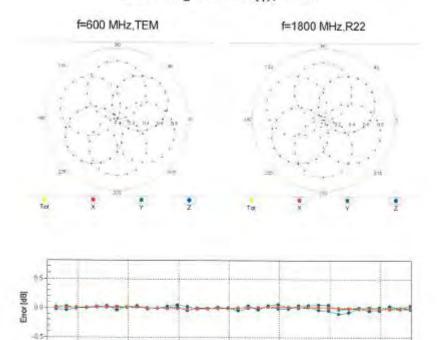


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EX3DV4-SN:7351 December 21, 2017

## Receiving Pattern (6), 9 = 0°



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

1800 MHz

2500 MHz

ect MHz

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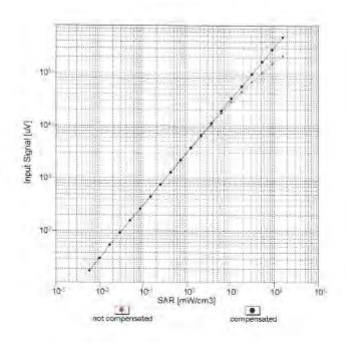
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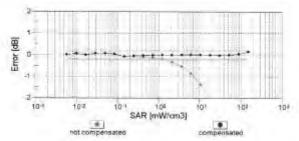
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EX3DV4-SN 7351

December 21, 2017

# Dynamic Range f(SAR<sub>head</sub>) (TEM cell , f<sub>eral</sub>= 1900 MHz)





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

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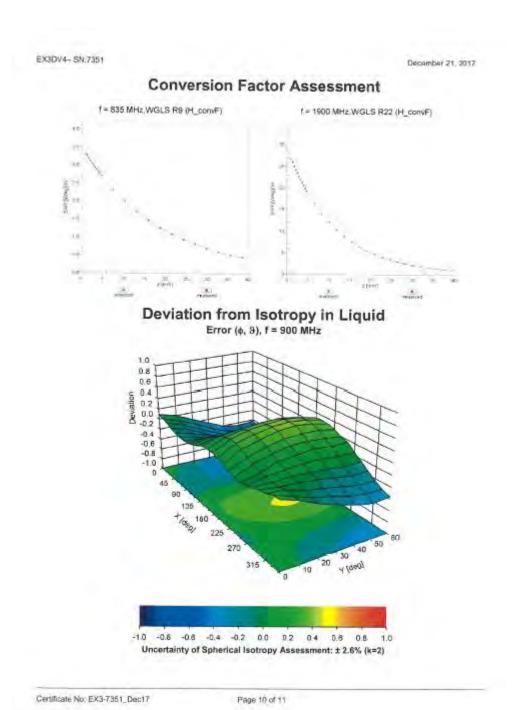
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EX3DV4-SN:7351

December 21, 2017

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:7351

#### Other Probe Parameters

| Sensor Arrangement                            | Triangular |
|---|------------|
| Connector Angle (°)                           | 88.8       |
| 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     |

Certificate No: EX3-7351\_Dec17 Page 11 of 11

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SGS Taiwan Ltd.



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





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Accreditation No.: SCS 0108

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

SGS-TW (Auden)

Certificate No: EX3-3938\_Feb20

## **CALIBRATION CERTIFICATE**

Object

EX3DV4 - SN:3938

Calibration procedure(s)

QA CAL-01.v9, QA CAL-14.v5, QA CAL-23.v5, QA CAL-25.v7

Calibration procedure for dosimetric E-field probes

Calibration date:

February 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       | 03-Apr-19 (No. 217-02892/02893)   | Apr-20                 |
| Power sensor NRP-Z91       | SN: 103244       | 03-Apr-19 (No. 217-02892)         | Apr-20                 |
| Power sensor NRP-Z91       | SN: 103245       | 03-Apr-19 (No. 217-02893)         | Apr-20                 |
| Reference 20 dB Attenuator | SN: S5277 (20x)  | 04-Apr-19 (No. 217-02894)         | Apr-20                 |
| DAE4                       | SN: 660          | 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 |

Function Calibrated by: Laboratory Technician Leif Klysner Approved by: Katja Pokovic Technical Manager Issued: February 27, 2020 This calibration certificate shall not be reproduced except in full without written approval of the laboratory.

Certificate No: EX3-3938\_Feb20

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Calibration Laboratory of

Schmid & Partner Engineering AG 43, 8004 Zurich, Switzerland





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Accreditation No.: SCS 0108

Accredited by the Swiss Accreditation Service (SAS)

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Glossary:

tissue simulating liquid NORMx,y,z sensitivity in free space sensitivity in TSL / NORMx,y,z ConvF DCP diode compression point

crest factor (1/duty\_cycle) of the RF signal modulation dependent linearization parameters CF A, B, C, D

Polarization o o rotation around probe axis

Polarization 9 9 rotation around an axis that is in the plane normal to probe axis (at measurement center),

i.e., 9 = 0 is normal to probe axis

information used in DASY system to align probe sensor X to the robot coordinate system Connector Angle

## 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
- Absorption Rate (SAR) in the Human Head from Yilliams Scientification Rate (SAR) from hand-rechniques", June 2013
  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
  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 9 = 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 E2-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
- 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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EX3DV4 - SN:3938 February 27, 2020

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3938

#### **Basic Calibration Parameters**

|                          | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|--------------------------|----------|----------|----------|-----------|
| Norm $(\mu V/(V/m)^2)^A$ | 0.51     | 0.57     | 0.33     | ± 10.1 %  |
| DCP (mV) <sup>B</sup>    | 103.2    | 100.0    | 108.2    |           |

Calibration Results for Modulation Response

| UID | Communication System Name |   | A<br>dB | B<br>dB√μV | С   | D<br>dB | VR<br>mV | Max<br>dev. | Unc <sup>b</sup><br>(k=2) |
|-----|---------------------------|---|---------|------------|-----|---------|----------|-------------|---------------------------|
| 0   | CW                        | X | 0.0     | 0.0        | 1.0 | 0.00    | 165.0    | ±2.5 %      | ±4.7 %                    |
|     |                           | Y | 0.0     | 0.0        | 1.0 |         | 179.2    |             |                           |
|     |                           | Z | 0.0     | 0.0        | 1.0 |         | 176.1    |             |                           |

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%.

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The uncertainties of Norm X,Y,Z do not affect the E<sup>2</sup>-field uncertainty inside TSL (see Page 5).

Numerical linearization parameter: uncertainty not required.
 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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FX3DV4- SN:3938 February 27, 2020

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3938

## Other Probe Parameters

| Sensor Arrangement                            | Triangular |
|---|------------|
| Connector Angle (°)                           | -28.2      |
| Mechanical Surface Detection Mode             | enabled    |
| Optical Surface Detection Mode                | disabled   |
| Probe Overall Length                          | 337 mm     |
| Probe Body Diameter                           | 10 mm      |
| Tip Length                                    | 9 mm       |
| Tip Diameter                                  | 2.5 mm     |
| Probe Tip to Sensor X Calibration Point       | 1 mm       |
| Probe Tip to Sensor Y Calibration Point       | 1 mm       |
| Probe Tip to Sensor Z Calibration Point       | 1 mm       |
| Recommended Measurement Distance from Surface | 1.4 mm     |

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EX3DV4- SN:3938 February 27, 2020

## DASY/EASY - Parameters of Probe: EX3DV4 - SN:3938

#### Calibration Parameter Determined in Head Tissue Simulating Media

| f (MHz) <sup>C</sup> | Relative<br>Permittivity <sup>F</sup> | Conductivity<br>(S/m) F | ConvF X | ConvF Y | ConvF Z | Alpha <sup>G</sup> | Depth <sup>G</sup> (mm) | Unc<br>(k=2) |
|----------------------|---------------------------------------|-------------------------|---------|---------|---------|--------------------|-------------------------|--------------|
| 750                  | 41.9                                  | 0.89                    | 9.72    | 9.72    | 9.72    | 0.59               | 0.80                    | ± 12.0 %     |
| 835                  | 41.5                                  | 0.90                    | 9.48    | 9.48    | 9.48    | 0.57               | 0.80                    | ± 12.0 %     |
| 900                  | 41.5                                  | 0.97                    | 9.17    | 9.17    | 9.17    | 0.42               | 0.95                    | ± 12.0 %     |
| 1450                 | 40.5                                  | 1.20                    | 8.72    | 8.72    | 8.72    | 0.45               | 0.80                    | ± 12.0 %     |
| 1750                 | 40.1                                  | 1.37                    | 8.31    | 8.31    | 8.31    | 0.41               | 0.86                    | ± 12.0 %     |
| 1900                 | 40.0                                  | 1.40                    | 8.07    | 8.07    | 8.07    | 0.36               | 0.86                    | ± 12.0 %     |
| 2000                 | 40.0                                  | 1.40                    | 7.89    | 7.89    | 7.89    | 0.42               | 0.86                    | ± 12.0 %     |
| 2300                 | 39.5                                  | 1.67                    | 7.81    | 7.81    | 7.81    | 0.41               | 0.86                    | ± 12.0 %     |
| 2450                 | 39.2                                  | 1.80                    | 7.59    | 7.59    | 7.59    | 0.44               | 0.86                    | ± 12.0 %     |
| 2600                 | 39.0                                  | 1.96                    | 7.44    | 7.44    | 7.44    | 0.42               | 0.86                    | ± 12.0 %     |
| 3300                 | 38.2                                  | 2.71                    | 7.12    | 7.12    | 7.12    | 0.30               | 1.30                    | ± 13.1 %     |
| 3500                 | 37.9                                  | 2.91                    | 7.00    | 7.00    | 7.00    | 0.30               | 1.30                    | ± 13.1 %     |
| 3700                 | 37.7                                  | 3.12                    | 6.83    | 6.83    | 6.83    | 0.30               | 1.30                    | ± 13.1 %     |
| 3900                 | 37.5                                  | 3.32                    | 6.55    | 6.55    | 6.55    | 0.35               | 1.60                    | ± 13.1 %     |
| 4100                 | 37.2                                  | 3.53                    | 6.42    | 6.42    | 6.42    | 0.35               | 1.60                    | ± 13.1 %     |
| 4200                 | 37.1                                  | 3.63                    | 6.28    | 6.28    | 6.28    | 0.35               | 1.60                    | ± 13.1 %     |
| 4400                 | 36.9                                  | 3.84                    | 6.14    | 6.14    | 6.14    | 0.35               | 1.60                    | ± 13.1 %     |
| 4600                 | 36.7                                  | 4.04                    | 6.10    | 6.10    | 6.10    | 0.40               | 1.60                    | ± 13.1 %     |
| 4800                 | 36.4                                  | 4.25                    | 6.02    | 6.02    | 6.02    | 0.40               | 1.80                    | ± 13.1 %     |
| 4950                 | 36.3                                  | 4.40                    | 5,86    | 5.86    | 5.86    | 0.40               | 1.80                    | ± 13.1 %     |
| 5250                 | 35.9                                  | 4.71                    | 5.00    | 5.00    | 5.00    | 0.40               | 1.80                    | ± 13.1 %     |
| 5600                 | 35.5                                  | 5.07                    | 4.70    | 4.70    | 4.70    | 0.40               | 1.80                    | ± 13.1 %     |
| 5750                 | 35.4                                  | 5.22                    | 4.75    | 4.75    | 4.75    | 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 4-4 Above 5 GHz frequency validity can be extended to ± 110 MHz.

FAI frequencies below 3 GHz, the validity of tissue parameters (ɛ and ɑ) 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 (ɛ and ɑ) is restricted to ± 5%. The uncertainty is the RSS of the ConvF uncertainty for indicated target tissue parameters.

GAIPHATOPHY and the 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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diameter from the boundary



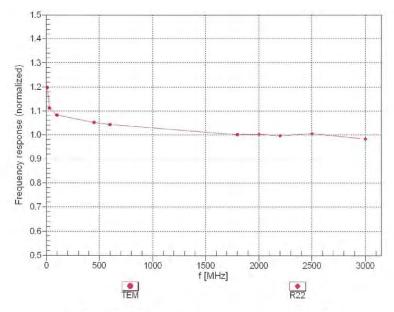
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## Frequency Response of E-Field

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



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

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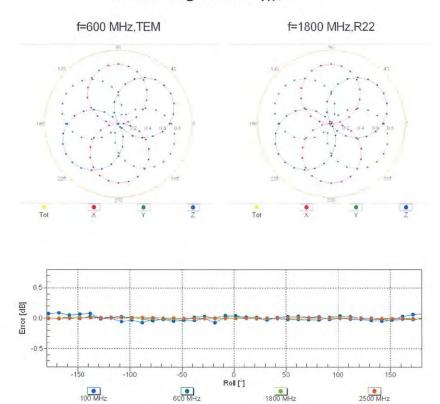


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## Receiving Pattern ( $\phi$ ), $\vartheta = 0^{\circ}$



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

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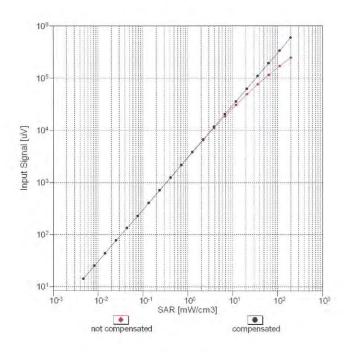


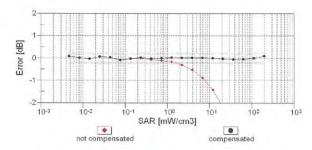
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## Dynamic Range f(SAR<sub>head</sub>) (TEM cell , feval= 1900 MHz)





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

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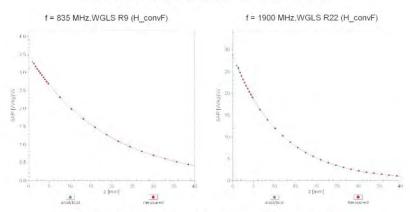


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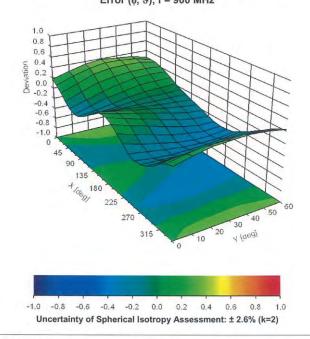
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## **Conversion Factor Assessment**



## Deviation from Isotropy in Liquid Error (6, 9), f = 900 MHz



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# - End of report -

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