

## IMPORTANT NOTICE

### USAGE OF THE DAE4

The DAE unit is a delicate, high precision instrument and requires careful treatment by the user. There are no serviceable parts inside the DAE. Special attention shall be given to the following points:

**Battery Exchange:** The battery cover of the DAE4 unit is fixed using a screw, over tightening the screw may cause the threads inside the DAE to wear out.

**Shipping of the DAE:** Before shipping the DAE to SPEAG for calibration, remove the batteries and pack the DAE in an antistatic bag. This antistatic bag shall then be packed into a larger box or container which protects the DAE from impacts during transportation. The package shall be marked to indicate that a fragile instrument is inside.

**E-Stop Failures:** Touch detection may be malfunctioning due to broken magnets in the E-stop. Rough handling of the E-stop may lead to damage of these magnets. Touch and collision errors are often caused by dust and dirt accumulated in the E-stop. To prevent E-stop failure, the customer shall always mount the probe to the DAE carefully and keep the DAE unit in a non-dusty environment if not used for measurements.

**Repair:** Minor repairs are performed at no extra cost during the annual calibration. However, SPEAG reserves the right to charge for any repair especially if rough unprofessional handling caused the defect.

**DASY Configuration Files:** Since the exact values of the DAE input resistances, as measured during the calibration procedure of a DAE unit, are not used by the DASY software, a nominal value of 200 MOhm is given in the corresponding configuration file.

**Important Note:**

**Warranty and calibration is void if the DAE unit is disassembled partly or fully by the Customer.**

**Important Note:**

**Never attempt to grease or oil the E-stop assembly. Cleaning and readjusting of the E-stop assembly is allowed by certified SPEAG personnel only and is part of the annual calibration procedure.**

**Important Note:**

**To prevent damage of the DAE probe connector pins, use great care when installing the probe to the DAE. Carefully connect the probe with the connector notch oriented in the mating position. Avoid any rotational movement of the probe body versus the DAE while turning the locking nut of the connector. The same care shall be used when disconnecting the probe from the DAE.**



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Multilateral Agreement for the recognition of calibration certificates

Client **BTL**

Certificate No: **DAE4-1486\_May22**

## CALIBRATION CERTIFICATE

Object **DAE4 - SD 000 D04 BO - SN: 1486**

Calibration procedure(s) **QA CAL-06.v30**  
**Calibration procedure for the data acquisition electronics (DAE)**

Calibration date: **May 31, 2022**

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  $(22 \pm 3)^{\circ}\text{C}$  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        | 31-Aug-21 (No:31368)       | Aug-22                 |
| Secondary Standards           | ID #               | Check Date (in house)      | Scheduled Check        |
| Auto DAE Calibration Unit     | SE UWS 053 AA 1001 | 24-Jan-22 (in house check) | In house check: Jan-23 |
| Calibrator Box V2.1           | SE UMS 006 AA 1002 | 24-Jan-22 (in house check) | In house check: Jan-23 |

Calibrated by: 

|                   |                       |           |
|-------------------|-----------------------|-----------|
| Name              | Function              | Signature |
| Dominique Steffen | Laboratory Technician |           |

Approved by: 

|           |                   |
|-----------|-------------------|
| Sven Kühn | Technical Manager |
|-----------|-------------------|

Issued: June 3, 2022

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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.

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          | 403.920 ± 0.02% (k=2) | 403.992 ± 0.02% (k=2) | 403.716 ± 0.02% (k=2) |
| Low Range           | 3.97930 ± 1.50% (k=2) | 3.98883 ± 1.50% (k=2) | 3.96086 ± 1.50% (k=2) |

Connector Angle

|                                           |              |
|-------------------------------------------|--------------|
| Connector Angle to be used in DASY system | 32.0 ° ± 1 ° |
|-------------------------------------------|--------------|

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

### 1. DC Voltage Linearity

| High Range        | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 199990.64                 | -2.71                        | -0.00     |
| Channel X + Input | 20002.71                  | 0.85                         | 0.00      |
| Channel X - Input | -19998.53                 | 3.34                         | -0.02     |
| Channel Y + Input | 199993.39                 | 0.36                         | 0.00      |
| Channel Y + Input | 20000.92                  | -0.95                        | -0.00     |
| Channel Y - Input | -19999.12                 | 2.67                         | -0.01     |
| Channel Z + Input | 199994.87                 | 1.76                         | 0.00      |
| Channel Z + Input | 20000.09                  | -1.69                        | -0.01     |
| Channel Z - Input | -20001.59                 | 0.15                         | -0.00     |

| Low Range         | Reading ( $\mu\text{V}$ ) | Difference ( $\mu\text{V}$ ) | Error (%) |
|-------------------|---------------------------|------------------------------|-----------|
| Channel X + Input | 2001.40                   | 0.28                         | 0.01      |
| Channel X + Input | 201.53                    | 0.03                         | 0.02      |
| Channel X - Input | -198.05                   | 0.41                         | -0.21     |
| Channel Y + Input | 2001.06                   | -0.01                        | -0.00     |
| Channel Y + Input | 200.99                    | -0.39                        | -0.19     |
| Channel Y - Input | -198.65                   | -0.01                        | 0.01      |
| Channel Z + Input | 2001.03                   | 0.11                         | 0.01      |
| Channel Z + Input | 199.98                    | -1.30                        | -0.64     |
| Channel Z - Input | -199.59                   | -0.91                        | 0.46      |

### 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 ( $\mu\text{V}$ ) | Low Range Average Reading ( $\mu\text{V}$ ) |
|-----------|--------------------------------|----------------------------------------------|---------------------------------------------|
| Channel X | 200                            | -0.61                                        | -2.55                                       |
|           | - 200                          | 3.93                                         | 1.67                                        |
| Channel Y | 200                            | -20.15                                       | -20.64                                      |
|           | - 200                          | 20.35                                        | 20.14                                       |
| Channel Z | 200                            | -4.19                                        | -4.47                                       |
|           | - 200                          | 2.03                                         | 2.26                                        |

### 3. Channel separation

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

|           | Input Voltage (mV) | Channel X ( $\mu\text{V}$ ) | Channel Y ( $\mu\text{V}$ ) | Channel Z ( $\mu\text{V}$ ) |
|-----------|--------------------|-----------------------------|-----------------------------|-----------------------------|
| Channel X | 200                | -                           | -0.86                       | -3.89                       |
| Channel Y | 200                | 6.28                        | -                           | 0.80                        |
| Channel Z | 200                | 10.73                       | 4.31                        | -                           |

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Client

**BTL**

Certificate No

**EX-7369\_May22****CALIBRATION CERTIFICATE**

Object

**EX3DV4 - SN:7369**

Calibration procedure(s)

**QA CAL-01.v9, QA CAL-12.v9, QA CAL-14.v6, QA CAL-23.v5,  
QA CAL-25.v7****Calibration procedure for dosimetric E-field probes**

Calibration date

**May 28, 2022**

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  $(22 \pm 3)^\circ\text{C}$  and humidity  $< 70\%$ .

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards          | ID               | Cal Date (Certificate No.)        | Scheduled Calibration |
|----------------------------|------------------|-----------------------------------|-----------------------|
| Power meter NRP            | SN: 104778       | 04-Apr-22 (No. 217-03525/03524)   | Apr-23                |
| Power sensor NRP-Z91       | SN: 103244       | 04-Apr-22 (No. 217-03524)         | Apr-23                |
| OCP DAK-3.5 (weighted)     | SN: 1249         | 20-Oct-21 (OCP-DAK3.5-1249_Oct21) | Oct-22                |
| OCP DAK-12                 | SN: 1016         | 20-Oct-21 (OCP-DAK12-1016_Oct21)  | Oct-22                |
| Reference 20 dB Attenuator | SN: CC2552 (20x) | 04-Apr-22 (No. 217-03527)         | Apr-23                |
| DAE4                       | SN: 660          | 13-Oct-21 (No. DAE4-660_Oct21)    | Oct-22                |
| Reference Probe ES3DV2     | SN: 3013         | 27-Dec-21 (No. ES3-3013_Dec21)    | Dec-22                |

| Secondary Standards     | ID               | Check Date (in house)             | Scheduled Check        |
|-------------------------|------------------|-----------------------------------|------------------------|
| Power meter E4419B      | SN: GB41293874   | 06-Apr-16 (in house check Jun-20) | In house check: Jun-22 |
| Power sensor E4412A     | SN: MY41498087   | 06-Apr-16 (in house check Jun-20) | In house check: Jun-22 |
| Power sensor E4412A     | SN: 000110210    | 06-Apr-16 (in house check Jun-20) | In house check: Jun-22 |
| RF generator HP 8648C   | SN: US3642U01700 | 04-Aug-99 (in house check Jun-20) | In house check: Jun-22 |
| Network Analyzer E8358A | SN: US41080477   | 31-Mar-14 (in house check Oct-20) | In house check: Oct-22 |

|               | Name           | Function              | Signature |
|---------------|----------------|-----------------------|-----------|
| Calibrated by | Jeton Kastrati | Laboratory Technician |           |
| Approved by   | Sven Kühn      | Technical Manager     |           |

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## Glossary

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

## Calibration is Performed According to the Following Standards:

- IEC/IEEE 62209-1528, "Measurement Procedure for the Assessment of Specific Absorption Rate of Human Exposure to Radio Frequency Fields from Hand-Held and Body-Worn Wireless Communication Devices – Part 1528: Human Models, Instrumentation and Procedures (Frequency Range of 4 MHz to 10 GHz)", October 2020.
- KDB 865664, "SAR Measurement Requirements for 100 MHz to 6 GHz"

## Methods Applied and Interpretation of Parameters:

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

## Parameters of Probe: EX3DV4 - SN:7369

### Basic Calibration Parameters

|                                                           | Sensor X | Sensor Y | Sensor Z | Unc ( $k = 2$ ) |
|-----------------------------------------------------------|----------|----------|----------|-----------------|
| Norm ( $\mu\text{V}/(\text{V}/\text{m})^2$ ) <sup>A</sup> | 0.39     | 0.48     | 0.39     | $\pm 10.1\%$    |
| DCP (mV) <sup>B</sup>                                     | 102.0    | 96.0     | 108.0    | $\pm 4.7\%$     |

### Calibration Results for Modulation Response

| UID   | Communication System Name   |   | A<br>dB | B<br>$\text{dB}\sqrt{\mu\text{V}}$ | C     | D<br>dB | VR<br>mV | Max<br>dev. | Max<br>Unc <sup>E</sup><br>$k = 2$ |
|-------|-----------------------------|---|---------|------------------------------------|-------|---------|----------|-------------|------------------------------------|
| 0     | CW                          | X | 0.00    | 0.00                               | 1.00  | 0.00    | 162.2    | $\pm 2.2\%$ | $\pm 4.7\%$                        |
|       |                             | Y | 0.00    | 0.00                               | 1.00  |         | 158.0    |             |                                    |
|       |                             | Z | 0.00    | 0.00                               | 1.00  |         | 167.3    |             |                                    |
| 10352 | Pulse Waveform (200Hz, 10%) | X | 3.21    | 67.91                              | 11.73 | 10.00   | 60.0     | $\pm 3.3\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 2.84    | 66.87                              | 10.67 |         | 60.0     |             |                                    |
|       |                             | Z | 3.46    | 68.82                              | 11.42 |         | 60.0     |             |                                    |
| 10353 | Pulse Waveform (200Hz, 20%) | X | 2.70    | 69.08                              | 11.09 | 6.99    | 80.0     | $\pm 2.2\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 2.41    | 67.75                              | 10.18 |         | 80.0     |             |                                    |
|       |                             | Z | 20.00   | 84.54                              | 14.99 |         | 80.0     |             |                                    |
| 10354 | Pulse Waveform (200Hz, 40%) | X | 20.00   | 84.88                              | 14.21 | 3.98    | 95.0     | $\pm 1.4\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 20.00   | 84.33                              | 14.06 |         | 95.0     |             |                                    |
|       |                             | Z | 20.00   | 84.33                              | 13.40 |         | 95.0     |             |                                    |
| 10355 | Pulse Waveform (200Hz, 60%) | X | 20.00   | 83.94                              | 12.67 | 2.22    | 120.0    | $\pm 1.4\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 20.00   | 86.16                              | 13.97 |         | 120.0    |             |                                    |
|       |                             | Z | 20.00   | 78.95                              | 9.95  |         | 120.0    |             |                                    |
| 10387 | QPSK Waveform, 1 MHz        | X | 1.74    | 68.06                              | 16.00 | 1.00    | 150.0    | $\pm 3.4\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 1.71    | 66.69                              | 15.42 |         | 150.0    |             |                                    |
|       |                             | Z | 1.42    | 68.75                              | 15.13 |         | 150.0    |             |                                    |
| 10388 | QPSK Waveform, 10 MHz       | X | 2.44    | 70.22                              | 16.95 | 0.00    | 150.0    | $\pm 1.0\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 2.27    | 68.46                              | 16.12 |         | 150.0    |             |                                    |
|       |                             | Z | 1.84    | 67.52                              | 15.50 |         | 150.0    |             |                                    |
| 10396 | 64-QAM Waveform, 100 kHz    | X | 2.56    | 69.31                              | 18.41 | 3.01    | 150.0    | $\pm 1.4\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 2.32    | 67.06                              | 17.51 |         | 150.0    |             |                                    |
|       |                             | Z | 1.98    | 66.07                              | 16.59 |         | 150.0    |             |                                    |
| 10399 | 64-QAM Waveform, 40 MHz     | X | 3.63    | 68.13                              | 16.39 | 0.00    | 150.0    | $\pm 1.8\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 3.52    | 67.18                              | 15.94 |         | 150.0    |             |                                    |
|       |                             | Z | 3.31    | 67.42                              | 15.85 |         | 150.0    |             |                                    |
| 10414 | WLAN CCDF, 64-QAM, 40 MHz   | X | 4.78    | 65.72                              | 15.67 | 0.00    | 150.0    | $\pm 3.6\%$ | $\pm 9.6\%$                        |
|       |                             | Y | 4.85    | 65.56                              | 15.61 |         | 150.0    |             |                                    |
|       |                             | Z | 4.52    | 66.17                              | 15.69 |         | 150.0    |             |                                    |

Note: For details on UID parameters see Appendix

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%.

<sup>A</sup> The uncertainties of Norm X,Y,Z do not affect the  $E^2$ -field uncertainty inside TSL (see Pages 5 and 6).

<sup>B</sup> Linearization parameter uncertainty for maximum specified field strength.

<sup>E</sup> Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

## Parameters of Probe: EX3DV4 - SN:7369

### Sensor Model Parameters

|   | C1<br>fF | C2<br>fF | $\alpha$<br>$V^{-1}$ | T1<br>$ms V^{-2}$ | T2<br>$ms V^{-1}$ | T3<br>ms | T4<br>$V^{-2}$ | T5<br>$V^{-1}$ | T6   |
|---|----------|----------|----------------------|-------------------|-------------------|----------|----------------|----------------|------|
| x | 41.8     | 309.70   | 35.25                | 6.73              | 0.44              | 4.99     | 0.75           | 0.24           | 1.01 |
| y | 45.4     | 344.26   | 36.61                | 11.33             | 0.00              | 5.00     | 0.00           | 0.33           | 1.01 |
| z | 24.2     | 174.33   | 33.40                | 4.50              | 0.00              | 5.04     | 0.40           | 0.16           | 1.00 |

### Other Probe Parameters

|                                               |            |
|-----------------------------------------------|------------|
| Sensor Arrangement                            | Triangular |
| Connector Angle                               | -115.5°    |
| Mechanical Surface Detection Mode             | enabled    |
| Optical Surface Detection Mode                | disabled   |
| Probe Overall Length                          | 337 mm     |
| Probe Body Diameter                           | 10 mm      |
| Tip Length                                    | 9 mm       |
| Tip Diameter                                  | 2.5 mm     |
| Probe Tip to Sensor X Calibration Point       | 1 mm       |
| Probe Tip to Sensor Y Calibration Point       | 1 mm       |
| Probe Tip to Sensor Z Calibration Point       | 1 mm       |
| Recommended Measurement Distance from Surface | 1.4 mm     |

**Note:** Measurement distance from surface can be increased to 3–4 mm for an *Area Scan* job.