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

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

Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

**Client** **Sporton**

**Certificate No: CD835V3-1045_Sep18**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | CD835V3 - SN: 1045 |
| Calibration procedure(s) | QA CAL-20.v6<br>Calibration procedure for dipoles in air |
| Calibration date: | September 19, 2018 |

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter NRP | SN: 104778 | 04-Apr-18 (No. 217-02672/02673) | Apr-19 |
| Power sensor NRP-Z91 | SN: 103244 | 04-Apr-18 (No. 217-02672) | Apr-19 |
| Power sensor NRP-Z91 | SN: 103245 | 04-Apr-18 (No. 217-02673) | Apr-19 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 04-Apr-18 (No. 217-02682) | Apr-19 |
| Type-N mismatch combination | SN: 5047.2 / 06327 | 04-Apr-18 (No. 217-02683) | Apr-19 |
| Probe EF3DV3 | SN: 4013 | 05-Mar-18 (No. EF3-4013_Mar18) | Mar-19 |
| DAE4 | SN: 781 | 17-Jan-18 (No. DAE4-781_Jan18) | Jan-19 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| Power meter Agilent 4419B | SN: GB42420191 | 09-Oct-09 (in house check Oct-17) | In house check: Oct-20 |
| Power sensor HP E4412A | SN: US38485102 | 05-Jan-10 (in house check Oct-17) | In house check: Oct-20 |
| Power sensor HP 8482A | SN: US37295597 | 09-Oct-09 (in house check Oct-17) | In house check: Oct-20 |
| RF generator R&S SMT-06 | SN: 832283/011 | 27-Aug-12 (in house check Oct-17) | In house check: Oct-20 |
| Network Analyzer Agilent E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-17) | In house check: Oct-18 |

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

Issued: September 24, 2018

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

## References

[1] ANSI-C63.19-2011
American National Standard, Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids.

## Methods Applied and Interpretation of Parameters:

- *Coordinate System:* y-axis is in the direction of the dipole arms. z-axis is from the basis of the antenna (mounted on the table) towards its feed point between the two dipole arms. x-axis is normal to the other axes. In coincidence with the standards [1], the measurement planes (probe sensor center) are selected to be at a distance of 15 mm above the top metal edge of the dipole arms.
- *Measurement Conditions:* Further details are available from the hardcopies at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated. The forward power to the dipole connector is set with a calibrated power meter connected and monitored with an auxiliary power meter connected to a directional coupler. While the dipole under test is connected, the forward power is adjusted to the same level.
- *Antenna Positioning:* The dipole is mounted on a HAC Test Arch phantom using the matching dipole positioner with the arms horizontal and the feeding cable coming from the floor. The measurements are performed in a shielded room with absorbers around the setup to reduce the reflections.
  It is verified before the mounting of the dipole under the Test Arch phantom, that its arms are perfectly in a line. It is installed on the HAC dipole positioner with its arms parallel below the dielectric reference wire and able to move elastically in vertical direction without changing its relative position to the top center of the Test Arch phantom. The vertical distance to the probe is adjusted after dipole mounting with a DASY5 Surface Check job. Before the measurement, the distance between phantom surface and probe tip is verified. The proper measurement distance is selected by choosing the matching section of the HAC Test Arch phantom with the proper device reference point (upper surface of the dipole) and the matching grid reference point (tip of the probe) considering the probe sensor offset. The vertical distance to the probe is essential for the accuracy.
- *Feed Point Impedance and Return Loss:* These parameters are measured using a HP 8753E Vector Network Analyzer. The impedance is specified at the SMA connector of the dipole. The influence of reflections was eliminating by applying the averaging function while moving the dipole in the air, at least 70cm away from any obstacles.
- *E-field distribution:* E field is measured in the x-y-plane with an isotropic ER3D-field probe with 100 mW forward power to the antenna feed point. In accordance with [1], the scan area is 20mm wide, its length exceeds the dipole arm length (180 or 90mm). The sensor center is 15 mm (in z) above the metal top of the dipole arms. Two 3D maxima are available near the end of the dipole arms. Assuming the dipole arms are perfectly in one line, the average of these two maxima (in subgrid 2 and subgrid 8) is determined to compensate for any non-parallelity to the measurement plane as well as the sensor displacement. The E-field value stated as calibration value represents the maximum of the interpolated 3D-E-field, in the plane above the dipole surface.

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

## Measurement Conditions

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

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.10.1 |
| **Phantom** | HAC Test Arch | |
| **Distance Dipole Top - Probe Center** | 15 mm | |
| **Scan resolution** | dx, dy = 5 mm | |
| **Frequency** | 835 MHz ± 1 MHz | |
| **Input power drift** | < 0.05 dB | |

## Maximum Field values at 835 MHz

| **E-field 15 mm above dipole surface** | condition | **Interpolated maximum** |
|---|---|---|
| Maximum measured above high end | 100 mW input power | 109.3 V/m = 40.77 dBV/m |
| Maximum measured above low end | 100 mW input power | 108.2 V/m = 40.68 dBV/m |
| Averaged maximum above arm | 100 mW input power | **108.8 V/m ± 12.8 % (k=2)** |

## Appendix (Additional assessments outside the scope of SCS 0108)

## Antenna Parameters

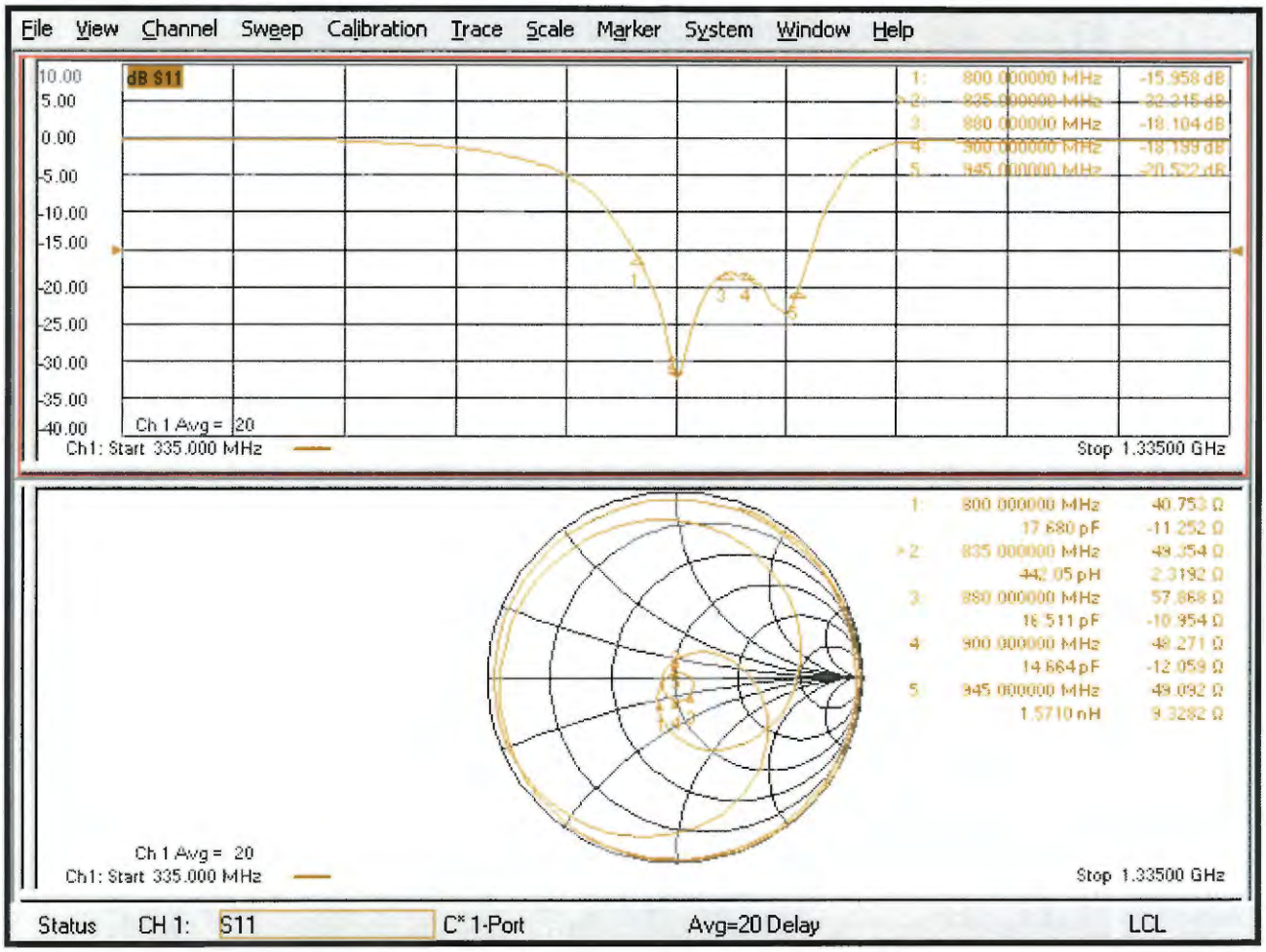
| **Frequency** | **Return Loss** | **Impedance** |
|---|---|---|
| 800 MHz | 16.0 dB | 40.8 Ω - 11.3 jΩ |
| 835 MHz | 32.3 dB | 49.4 Ω + 2.3 jΩ |
| 880 MHz | 18.1 dB | 57.9 Ω - 11.0 jΩ |
| 900 MHz | 18.2 dB | 48.3 Ω - 12.1 jΩ |
| 945 MHz | 20.5 dB | 49.1 Ω + 9.3 jΩ |

### 3.2 Antenna Design and Handling

The calibration dipole has a symmetric geometry with a built-in two stub matching network, which leads to the enhanced bandwidth.
The dipole is built of standard semirigid coaxial cable. The internal matching line is open ended. The antenna is therefore open for DC signals.
Do not apply force to dipole arms, as they are liable to bend. The soldered connections near the feedpoint may be damaged. After excessive mechanical stress or overheating, check the impedance characteristics to ensure that the internal matching network is not affected.

After long term use with 40W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

## Impedance Measurement Plot



## DASY5 E-field Result

Date: 19.09.2018

Test Laboratory: SPEAG Lab2

**DUT: HAC-Dipole 835 MHz; Type: CD835V3; Serial: CD835V3 - SN: 1045**

Communication System: UID 0 - CW ; Frequency: 835 MHz
Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Phantom section: RF Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

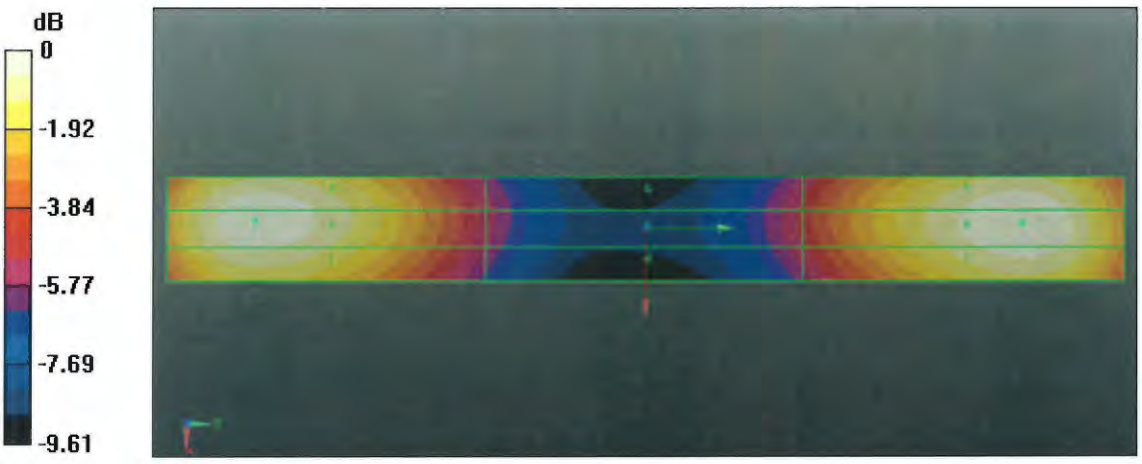
DASY52 Configuration:

- Probe: EF3DV3 - SN4013; ConvF(1, 1, 1) @ 835 MHz; Calibrated: 05.03.2018
- Sensor-Surface: (Fix Surface)
- Electronics: DAE4 Sn781; Calibrated: 17.01.2018
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA; Serial: 1070
- DASY52 52.10.1(1476); SEMCAD X 14.6.11(7439)

**Dipole E-Field measurement @ 835MHz/E-Scan - 835MHz d=15mm/Hearing Aid Compatibility Test (41x361x1):**
Interpolated grid: dx=0.5000 mm, dy=0.5000 mm
Device Reference Point: 0, 0, -6.3 mm
Reference Value = 132.0 V/m; Power Drift = 0.00 dB
Applied MIF = 0.00 dB
RF audio interference level = 40.77 dBV/m
**Emission category: M3**

MIF scaled E-field

| | | |
|---|---|---|
| Grid 1 **M3**<br>**40.25 dBV/m** | Grid 2 **M3**<br>**40.68 dBV/m** | Grid 3 **M3**<br>**40.63 dBV/m** |
| Grid 4 **M4**<br>**35.68 dBV/m** | Grid 5 **M4**<br>**35.97 dBV/m** | Grid 6 **M4**<br>**35.93 dBV/m** |
| Grid 7 **M3**<br>**40.47 dBV/m** | Grid 8 **M3**<br>**40.77 dBV/m** | Grid 9 **M3**<br>**40.67 dBV/m** |




0 dB = 109.3 V/m = 40.77 dBV/m

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**Accreditation No.: SCS 0108**

**Client** **Sporton**

**Certificate No: CD1880V3-1038_Sep18**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | CD1880V3 - SN: 1038 |
| Calibration procedure(s) | QA CAL-20.v6<br>Calibration procedure for dipoles in air |
| Calibration date: | September 19, 2018 |

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
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| Power sensor NRP-Z91 | SN: 103244 | 04-Apr-18 (No. 217-02672) | Apr-19 |
| Power sensor NRP-Z91 | SN: 103245 | 04-Apr-18 (No. 217-02673) | Apr-19 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 04-Apr-18 (No. 217-02682) | Apr-19 |
| Type-N mismatch combination | SN: 5047.2 / 06327 | 04-Apr-18 (No. 217-02683) | Apr-19 |
| Probe EF3DV3 | SN: 4013 | 05-Mar-18 (No. EF3-4013_Mar18) | Mar-19 |
| DAE4 | SN: 781 | 17-Jan-18 (No. DAE4-781_Jan18) | Jan-19 |

| Secondary Standards | ID # | Check Date (in house) | Scheduled Check |
|---|---|---|---|
| Power meter Agilent 4419B | SN: GB42420191 | 09-Oct-09 (in house check Oct-17) | In house check: Oct-20 |
| Power sensor HP E4412A | SN: US38485102 | 05-Jan-10 (in house check Oct-17) | In house check: Oct-20 |
| Power sensor HP 8482A | SN: US37295597 | 09-Oct-09 (in house check Oct-17) | In house check: Oct-20 |
| RF generator R&S SMT-06 | SN: 832283/011 | 27-Aug-12 (in house check Oct-17) | In house check: Oct-20 |
| Network Analyzer HP 8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-17) | In house check: Oct-18 |

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

Issued: September 24, 2018

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## References

[1] ANSI-C63.19-2011
American National Standard, Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids.

## Methods Applied and Interpretation of Parameters:

- *Coordinate System:* y-axis is in the direction of the dipole arms. z-axis is from the basis of the antenna (mounted on the table) towards its feed point between the two dipole arms. x-axis is normal to the other axes. In coincidence with the standards [1], the measurement planes (probe sensor center) are selected to be at a distance of 15 mm above the top metal edge of the dipole arms.
- *Measurement Conditions:* Further details are available from the hardcopies at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated. The forward power to the dipole connector is set with a calibrated power meter connected and monitored with an auxiliary power meter connected to a directional coupler. While the dipole under test is connected, the forward power is adjusted to the same level.
- *Antenna Positioning:* The dipole is mounted on a HAC Test Arch phantom using the matching dipole positioner with the arms horizontal and the feeding cable coming from the floor. The measurements are performed in a shielded room with absorbers around the setup to reduce the reflections.
  It is verified before the mounting of the dipole under the Test Arch phantom, that its arms are perfectly in a line. It is installed on the HAC dipole positioner with its arms parallel below the dielectric reference wire and able to move elastically in vertical direction without changing its relative position to the top center of the Test Arch phantom. The vertical distance to the probe is adjusted after dipole mounting with a DASY5 Surface Check job. Before the measurement, the distance between phantom surface and probe tip is verified. The proper measurement distance is selected by choosing the matching section of the HAC Test Arch phantom with the proper device reference point (upper surface of the dipole) and the matching grid reference point (tip of the probe) considering the probe sensor offset. The vertical distance to the probe is essential for the accuracy.
- *Feed Point Impedance and Return Loss:* These parameters are measured using a HP 8753E Vector Network Analyzer. The impedance is specified at the SMA connector of the dipole. The influence of reflections was eliminating by applying the averaging function while moving the dipole in the air, at least 70cm away from any obstacles.
- *E-field distribution:* E field is measured in the x-y-plane with an isotropic ER3D-field probe with 100 mW forward power to the antenna feed point. In accordance with [1], the scan area is 20mm wide, its length exceeds the dipole arm length (180 or 90mm). The sensor center is 15 mm (in z) above the metal top of the dipole arms. Two 3D maxima are available near the end of the dipole arms. Assuming the dipole arms are perfectly in one line, the average of these two maxima (in subgrid 2 and subgrid 8) is determined to compensate for any non-parallelity to the measurement plane as well as the sensor displacement. The E-field value stated as calibration value represents the maximum of the interpolated 3D-E-field, in the plane above the dipole surface.

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

## Measurement Conditions

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

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.10.1 |
| **Phantom** | HAC Test Arch | |
| **Distance Dipole Top - Probe Center** | 15 mm | |
| **Scan resolution** | dx, dy = 5 mm | |
| **Frequency** | 1730 MHz ± 1 MHz<br>1880 MHz ± 1 MHz | |
| **Input power drift** | < 0.05 dB | |

## Maximum Field values at 1730 MHz

| **E-field 15 mm above dipole surface** | condition | **Interpolated maximum** |
|---|---|---|
| Maximum measured above high end | 100 mW input power | 97.0 V/m = 39.74 dBV/m |
| Maximum measured above low end | 100 mW input power | 96.0 V/m = 39.65 dBV/m |
| Averaged maximum above arm | 100 mW input power | **96.5 V/m ± 12.8 % (k=2)** |

## Maximum Field values at 1880 MHz

| **E-field 15 mm above dipole surface** | condition | **Interpolated maximum** |
|---|---|---|
| Maximum measured above high end | 100 mW input power | 90.3 V/m = 39.11 dBV/m |
| Maximum measured above low end | 100 mW input power | 88.8 V/m = 38.97 dBV/m |
| Averaged maximum above arm | 100 mW input power | **89.5 V/m ± 12.8 % (k=2)** |

## Appendix (Additional assessments outside the scope of SCS 0108)

## Antenna Parameters

### Nominal Frequencies

| Frequency | Return Loss | Impedance |
|---|---|---|
| 1730 MHz | 22.9 dB | 55.7 Ω + 5.1 jΩ |
| 1880 MHz | 21.2 dB | 59.3 Ω + 2.0 jΩ |
| 1900 MHz | 21.6 dB | 59.1 Ω - 1.1 jΩ |
| 1950 MHz | 25.9 dB | 50.7 Ω - 5.0 jΩ |
| 2000 MHz | 20.7 dB | 43.8 Ω + 6.1 jΩ |

### Additional Frequencies

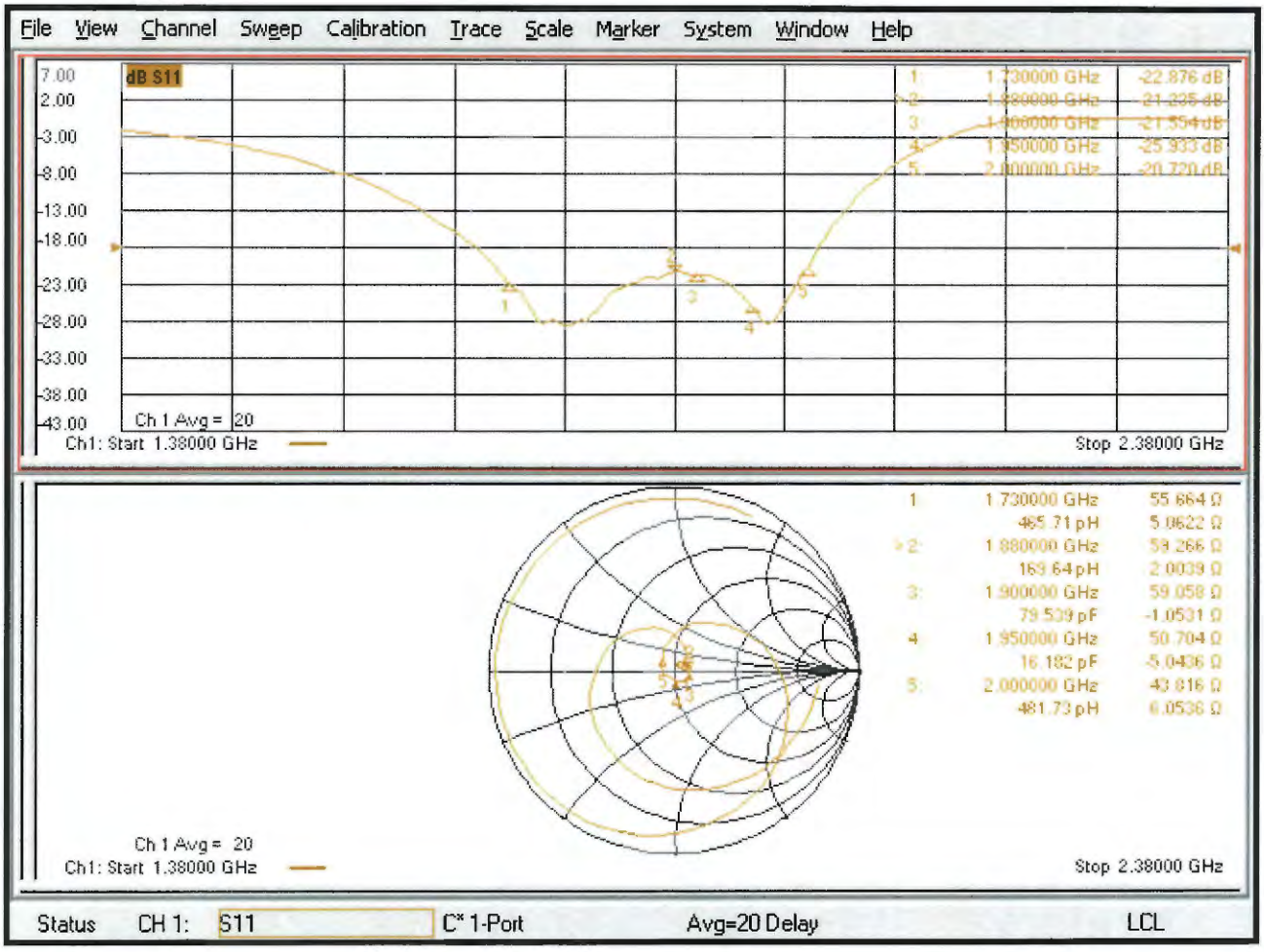
| Frequency | Return Loss | Impedance |
|---|---|---|
| 1730 MHz | 22.9 dB | 55.7 Ω + 5.1 jΩ |

### 3.2 Antenna Design and Handling

The calibration dipole has a symmetric geometry with a built-in two stub matching network, which leads to the enhanced bandwidth.
The dipole is built of standard semirigid coaxial cable. The internal matching line is open ended. The antenna is therefore open for DC signals.
Do not apply force to dipole arms, as they are liable to bend. The soldered connections near the feedpoint may be damaged. After excessive mechanical stress or overheating, check the impedance characteristics to ensure that the internal matching network is not affected.

After long term use with 40W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

## Impedance Measurement Plot



## DASY5 E-field Result

Date: 19.09.2018

Test Laboratory: SPEAG Lab2

**DUT: HAC Dipole 1880 MHz; Type: CD1880V3; Serial: CD1880V3 - SN: 1038**

Communication System: UID 0 - CW ; Frequency: 1880 MHz, Frequency: 1730 MHz
Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Phantom section: RF Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

DASY52 Configuration:

- Probe: EF3DV3 - SN4013; ConvF(1, 1, 1) @ 1880 MHz, ConvF(1, 1, 1) @ 1730 MHz; Calibrated: 05.03.2018
- Sensor-Surface: (Fix Surface)
- Electronics: DAE4 Sn781; Calibrated: 17.01.2018
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA; Serial: 1070
- DASY52 52.10.1(1476); SEMCAD X 14.6.11(7439)

**Dipole E-Field measurement @ 1880MHz/E-Scan - 1880MHz d=15mm/Hearing Aid Compatibility Test (41x181x1):**
Interpolated grid: dx=0.5000 mm, dy=0.5000 mm
Device Reference Point: 0, 0, -6.3 mm
Reference Value = 155.2 V/m; Power Drift = -0.03 dB
Applied MIF = 0.00 dB
RF audio interference level = 39.11 dBV/m
**Emission category: M2**

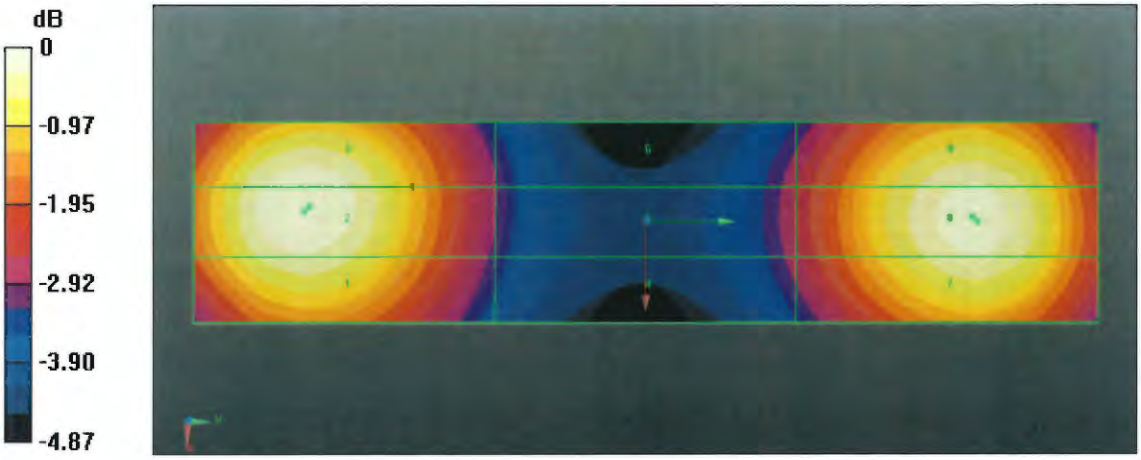
MIF scaled E-field

| | | |
|---|---|---|
| Grid 1 **M2**<br>**38.75 dBV/m** | Grid 2 **M2**<br>**39.11 dBV/m** | Grid 3 **M2**<br>**39.05 dBV/m** |
| Grid 4 **M2**<br>**36.11 dBV/m** | Grid 5 **M2**<br>**36.24 dBV/m** | Grid 6 **M2**<br>**36.17 dBV/m** |
| Grid 7 **M2**<br>**38.77 dBV/m** | Grid 8 **M2**<br>**38.97 dBV/m** | Grid 9 **M2**<br>**38.81 dBV/m** |

**Dipole E-Field measurement @ 1730MHz/E-Scan - 1730MHz d=15mm/Hearing Aid Compatibility Test (41x181x1):**
Interpolated grid: dx=0.5000 mm, dy=0.5000 mm
Device Reference Point: 0, 0, -6.3 mm
Reference Value = 168.4 V/m; Power Drift = 0.00 dB
Applied MIF = 0.00 dB
RF audio interference level = 39.74 dBV/m
**Emission category: M2**

MIF scaled E-field

| | | |
|---|---|---|
| Grid 1 **M2**<br>**39.27 dBV/m** | Grid 2 **M2**<br>**39.65 dBV/m** | Grid 3 **M2**<br>**39.59 dBV/m** |
| Grid 4 **M2**<br>**36.98 dBV/m** | Grid 5 **M2**<br>**37.17 dBV/m** | Grid 6 **M2**<br>**37.12 dBV/m** |
| Grid 7 **M2**<br>**39.5 dBV/m** | Grid 8 **M2**<br>**39.74 dBV/m** | Grid 9 **M2**<br>**39.61 dBV/m** |




0 dB = 90.29 V/m = 39.11 dBV/m

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**Accreditation No.: SCS 0108**

**Client** **Sporton**

**Certificate No: CD2600V3-1018_Aug18**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | CD2600V3 - SN: 1018 |
| Calibration procedure(s) | QA CAL-20.v6<br>Calibration procedure for dipoles in air |
| Calibration date: | August 22, 2018 |

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| Power sensor NRP-Z91 | SN: 103245 | 04-Apr-18 (No. 217-02673) | Apr-19 |
| Reference 20 dB Attenuator | SN: 5058 (20k) | 04-Apr-18 (No. 217-02682) | Apr-19 |
| Type-N mismatch combination | SN: 5047.2 / 06327 | 04-Apr-18 (No. 217-02683) | Apr-19 |
| Probe EF3DV3 | SN: 4013 | 05-Mar-18 (No. EF3-4013_Mar18) | Mar-19 |
| DAE4 | SN: 781 | 17-Jan-18 (No. DAE4-781_Jan18) | Jan-19 |

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|---|---|---|---|
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| Power sensor HP 8482A | SN: US37295597 | 09-Oct-09 (in house check Oct-17) | In house check: Oct-20 |
| RF generator R&S SMT-06 | SN: 832283/011 | 27-Aug-12 (in house check Oct-17) | In house check: Oct-20 |
| Network Analyzer HP 8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-17) | In house check: Oct-18 |

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

Issued: August 23, 2018

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## References

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American National Standard, Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids.

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- *Coordinate System:* y-axis is in the direction of the dipole arms. z-axis is from the basis of the antenna (mounted on the table) towards its feed point between the two dipole arms. x-axis is normal to the other axes. In coincidence with the standards [1], the measurement planes (probe sensor center) are selected to be at a distance of 15 mm above the top metal edge of the dipole arms.
- *Measurement Conditions:* Further details are available from the hardcopies at the end of the certificate. All figures stated in the certificate are valid at the frequency indicated. The forward power to the dipole connector is set with a calibrated power meter connected and monitored with an auxiliary power meter connected to a directional coupler. While the dipole under test is connected, the forward power is adjusted to the same level.
- *Antenna Positioning:* The dipole is mounted on a HAC Test Arch phantom using the matching dipole positioner with the arms horizontal and the feeding cable coming from the floor. The measurements are performed in a shielded room with absorbers around the setup to reduce the reflections.
  It is verified before the mounting of the dipole under the Test Arch phantom, that its arms are perfectly in a line. It is installed on the HAC dipole positioner with its arms parallel below the dielectric reference wire and able to move elastically in vertical direction without changing its relative position to the top center of the Test Arch phantom. The vertical distance to the probe is adjusted after dipole mounting with a DASY5 Surface Check job. Before the measurement, the distance between phantom surface and probe tip is verified. The proper measurement distance is selected by choosing the matching section of the HAC Test Arch phantom with the proper device reference point (upper surface of the dipole) and the matching grid reference point (tip of the probe) considering the probe sensor offset. The vertical distance to the probe is essential for the accuracy.
- *Feed Point Impedance and Return Loss:* These parameters are measured using a HP 8753E Vector Network Analyzer. The impedance is specified at the SMA connector of the dipole. The influence of reflections was eliminating by applying the averaging function while moving the dipole in the air, at least 70cm away from any obstacles.
- *E-field distribution:* E field is measured in the x-y-plane with an isotropic ER3D-field probe with 100 mW forward power to the antenna feed point. In accordance with [1], the scan area is 20mm wide, its length exceeds the dipole arm length (180 or 90mm). The sensor center is 15 mm (in z) above the metal top of the dipole arms. Two 3D maxima are available near the end of the dipole arms. Assuming the dipole arms are perfectly in one line, the average of these two maxima (in subgrid 2 and subgrid 8) is determined to compensate for any non-parallelity to the measurement plane as well as the sensor displacement. The E-field value stated as calibration value represents the maximum of the interpolated 3D-E-field, in the plane above the dipole surface.

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

## Measurement Conditions

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

| | | |
|---|---|---|
| **DASY Version** | DASY5 | V52.10.1 |
| **Phantom** | HAC Test Arch | |
| **Distance Dipole Top - Probe Center** | 15 mm | |
| **Scan resolution** | dx, dy = 5 mm | |
| **Frequency** | 2600 MHz ± 1 MHz | |
| **Input power drift** | < 0.05 dB | |

## Maximum Field values at 2600 MHz

| **E-field 15 mm above dipole surface** | condition | **Interpolated maximum** |
|---|---|---|
| Maximum measured above high end | 100 mW input power | 86.0 V/m = 38.69 dBV/m |
| Maximum measured above low end | 100 mW input power | 85.7 V/m = 38.66 dBV/m |
| Averaged maximum above arm | 100 mW input power | **85.8 V/m ± 12.8 % (k=2)** |

## Appendix (Additional assessments outside the scope of SCS 0108)

## Antenna Parameters

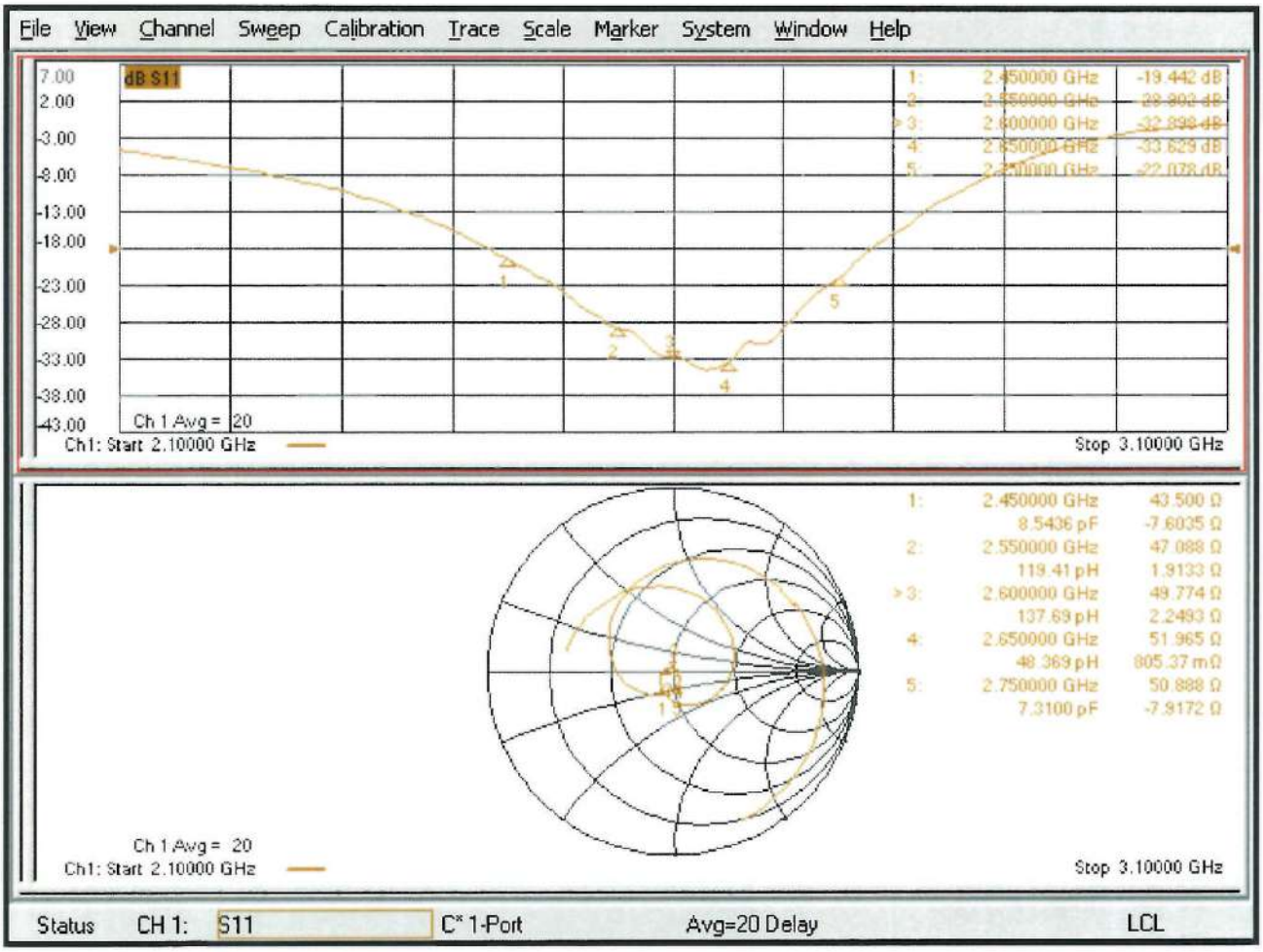
| **Frequency** | **Return Loss** | **Impedance** |
|---|---|---|
| 2450 MHz | 19.4 dB | 43.5 Ω - 7.6 jΩ |
| 2550 MHz | 28.9 dB | 47.1 Ω + 1.9 jΩ |
| 2600 MHz | 32.9 dB | 49.8 Ω + 2.2 jΩ |
| 2650 MHz | 33.6 dB | 52.0 Ω + 0.8 jΩ |
| 2750 MHz | 22.1 dB | 50.9 Ω - 7.9 jΩ |

### 3.2 Antenna Design and Handling

The calibration dipole has a symmetric geometry with a built-in two stub matching network, which leads to the enhanced bandwidth.
The dipole is built of standard semirigid coaxial cable. The internal matching line is open ended. The antenna is therefore open for DC signals.
Do not apply force to dipole arms, as they are liable to bend. The soldered connections near the feedpoint may be damaged. After excessive mechanical stress or overheating, check the impedance characteristics to ensure that the internal matching network is not affected.

After long term use with 40W radiated power, only a slight warming of the dipole near the feedpoint can be measured.

## Impedance Measurement Plot



## DASY5 E-field Result

Date: 22.08.2018

Test Laboratory: SPEAG Lab2

**DUT: HAC Dipole 2600 MHz; Type: CD2600V3; Serial: CD2600V3 - SN: 1018**

Communication System: UID 0 - CW ; Frequency: 2600 MHz
Medium parameters used: $\sigma = 0$ S/m, $\varepsilon_r = 1$; $\rho = 0$ kg/m$^3$
Phantom section: RF Section
Measurement Standard: DASY5 (IEEE/IEC/ANSI C63.19-2011)

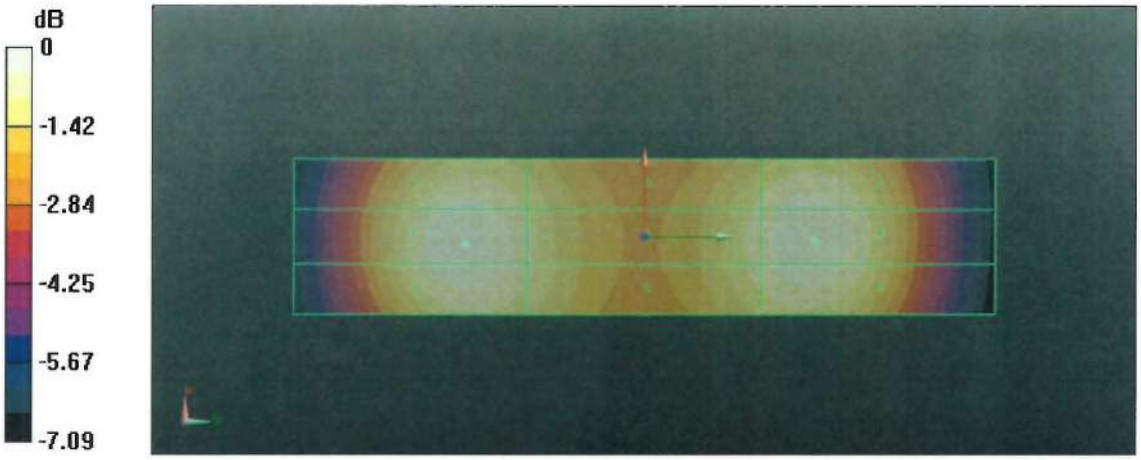
DASY52 Configuration:

- Probe: EF3DV3 - SN4013; ConvF(1, 1, 1) @ 2600 MHz; Calibrated: 05.03.2018
- Sensor-Surface: (Fix Surface)
- Electronics: DAE4 Sn781; Calibrated: 17.01.2018
- Phantom: HAC Test Arch with AMCC; Type: SD HAC P01 BA; Serial: 1070
- DASY52 52.10.1(1476); SEMCAD X 14.6.11(7439)

**Dipole E-Field measurement @ 2600MHz/E-Scan - 2600MHz d=15mm/Hearing Aid Compatibility Test (41x181x1):**
Interpolated grid: dx=0.5000 mm, dy=0.5000 mm
Device Reference Point: 0, 0, -6.3 mm
Reference Value = 64.13 V/m; Power Drift = 0.00 dB
Applied MIF = 0.00 dB
RF audio interference level = 38.69 dBV/m
**Emission category: M2**

MIF scaled E-field

| | | |
|---|---|---|
| Grid 1 **M2**<br>**38.4 dBV/m** | Grid 2 **M2**<br>**38.69 dBV/m** | Grid 3 **M2**<br>**38.62 dBV/m** |
| Grid 4 **M2**<br>**37.92 dBV/m** | Grid 5 **M2**<br>**38.1 dBV/m** | Grid 6 **M2**<br>**38.04 dBV/m** |
| Grid 7 **M2**<br>**38.47 dBV/m** | Grid 8 **M2**<br>**38.66 dBV/m** | Grid 9 **M2**<br>**38.53 dBV/m** |




0 dB = 86.00 V/m = 38.69 dBV/m

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

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

Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

**Client** Sporton

**Certificate No: EF3-4047_Jan19**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | EF3DV3- SN:4047 |
| Calibration procedure(s) | QA CAL-02.v9, QA CAL-25.v7<br>Calibration procedure for E-field probes optimized for close near field evaluations in air |
| Calibration date: | January 30, 2019 |

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Power meter NRP | SN: 104778 | 04-Apr-18 (No. 217-02672/02673) | Apr-19 |
| Power sensor NRP-Z91 | SN: 103244 | 04-Apr-18 (No. 217-02672) | Apr-19 |
| Power sensor NRP-Z91 | SN: 103245 | 04-Apr-18 (No. 217-02673) | Apr-19 |
| Reference 20 dB Attenuator | SN: S5277 (20x) | 04-Apr-18 (No. 217-02682) | Apr-19 |
| DAE4 | SN: 789 | 14-Jan-19 (No. DAE4-789_Jan19) | Jan-20 |
| Reference Probe ER3DV6 | SN: 2328 | 09-Oct-18 (No. ER3-2328_Oct18) | Oct-19 |
| | | | |
| Secondary Standards | ID | Check Date (in house) | Scheduled Check |
| Power meter E4419B | SN: GB41293874 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: MY41498087 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| Power sensor E4412A | SN: 000110210 | 06-Apr-16 (in house check Jun-18) | In house check: Jun-20 |
| RF generator HP 8648C | SN: US3642U01700 | 04-Aug-99 (in house check Jun-18) | In house check: Jun-20 |
| Network Analyzer E8358A | SN: US41080477 | 31-Mar-14 (in house check Oct-18) | In house check: Oct-19 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Manu Seitz | Laboratory Technician | |
| Approved by: | Katja Pokovic | Technical Manager | |

Issued: January 31, 2019

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

## Glossary:

| | |
|---|---|
| NORMx,y,z | sensitivity in free space |
| DCP | diode compression point |
| CF | crest factor (1/duty_cycle) of the RF signal |
| A, B, C, D | modulation dependent linearization parameters |
| En | incident E-field orientation normal to probe axis |
| Ep | incident E-field orientation parallel to probe axis |
| 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 1309-2005, " IEEE Standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz", December 2005
b) CTIA Test Plan for Hearing Aid Compatibility, Rev 3.1.1, May 2017

## Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization ϑ = 0 for XY sensors and ϑ = 90 for Z sensor (f ≤ 900 MHz in TEM-cell; f > 1800 MHz: R22 waveguide).
- *NORM(f)x,y,z = NORMx,y,z * frequency_response* (see Frequency Response Chart).
- *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.
- *Spherical isotropy (3D deviation from isotropy)*: in a locally homogeneous field realized using an open waveguide setup.
- *Sensor Offset*: The sensor offset corresponds to the offset of virtual measurement center from the probe tip (on probe axis). No tolerance required.
- *Connector Angle*: The angle is assessed using the information gained by determining the *NORMx* (no uncertainty required).

# DASY/EASY - Parameters of Probe: EF3DV3 - SN:4047

## Basic Calibration Parameters

| | Sensor X | Sensor Y | Sensor Z | Unc (k=2) |
|---|---|---|---|---|
| Norm ($\mu V/(V/m)^2$) | 0.84 | 0.68 | 1.20 | ± 10.1 % |
| DCP (mV)[B] | 96.3 | 98.2 | 94.1 | |

## Calibration results for Frequency Response (30 MHz – 6 GHz)

| Frequency MHz | Target E-Field V/m | Measured E-field (En) V/m | Deviation E-normal in % | Measured E-field (Ep) V/m | Deviation E-normal in % | Unc (k=2) % |
|---|---|---|---|---|---|---|
| 30 | 77.2 | 77.3 | 0.2% | 77.3 | 0.1% | ± 5.1 % |
| 100 | 77.4 | 78.0 | 0.8% | 77.9 | 0.6% | ± 5.1 % |
| 450 | 77.1 | 77.8 | 1.0% | 77.9 | 1.1% | ± 5.1 % |
| 600 | 77.1 | 77.4 | 0.5% | 77.7 | 0.9% | ± 5.1 % |
| 750 | 77.2 | 77.4 | 0.2% | 77.4 | 0.2% | ± 5.1 % |
| | | | | | | |
| 1800 | 140.4 | 136.9 | -2.5% | 137.3 | -2.2% | ± 5.1 % |
| 2000 | 133.0 | 129.2 | -2.8% | 129.4 | -2.7% | ± 5.1 % |
| 2200 | 124.7 | 121.4 | -2.7% | 122.7 | -1.6% | ± 5.1 % |
| 2500 | 123.6 | 120.6 | -2.4% | 121.8 | -1.4% | ± 5.1 % |
| 3000 | 78.9 | 75.4 | -4.4% | 75.9 | -3.7% | ± 5.1 % |
| | | | | | | |
| 3500 | 256.3 | 248.2 | -3.1% | 246.0 | -4.0% | ± 5.1 % |
| 3700 | 251.0 | 240.6 | -4.1% | 240.2 | -4.3% | ± 5.1 % |
| | | | | | | |
| 5200 | 50.9 | 50.9 | 0.1% | 51.1 | 0.6% | ± 5.1 % |
| 5500 | 49.6 | 49.0 | -1.3% | 48.7 | -2.0% | ± 5.1 % |
| 5800 | 48.9 | 49.2 | 0.6% | 49.3 | 0.8% | ± 5.1 % |

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%.

[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

# DASY/EASY - Parameters of Probe: EF3DV3 - SN:4047

## Calibration Results for Modulation Response

| UID | Communication System Name | | A dB | B dB√μV | C | D dB | VR mV | Max dev. | Max Unc[E] (k=2) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | CW | X | 0.00 | 0.00 | 1.00 | 0.00 | 134.9 | ±3.3 % | ± 4.7 % |
| | | Y | 0.00 | 0.00 | 1.00 | | 134.5 | | |
| | | Z | 0.00 | 0.00 | 1.00 | | 145.8 | | |
| 10021-DAC | GSM-FDD (TDMA, GMSK) | X | 2.86 | 71.7 | 16.2 | 9.39 | 148.8 | ±2.2 % | ± 4.7 % |
| | | Y | 2.74 | 67.4 | 14.0 | | 134.9 | | |
| | | Z | 2.46 | 70.8 | 16.0 | | 134.1 | | |
| 10061-CAB | IEEE 802.11b WiFi 2.4 GHz (DSSS, 11 Mbps) | X | 3.86 | 74.5 | 22.3 | 3.60 | 147.9 | ±0.9 % | ± 4.7 % |
| | | Y | 4.32 | 75.1 | 21.9 | | 149.2 | | |
| | | Z | 3.08 | 69.7 | 19.8 | | 135.9 | | |
| 10069-CAC | IEEE 802.11a/h WiFi 5 GHz (OFDM, 54 Mbps) | X | 11.16 | 70.1 | 24.2 | 10.56 | 133.8 | ±3.0 % | ± 4.7 % |
| | | Y | 11.16 | 69.9 | 23.8 | | 133.4 | | |
| | | Z | 10.90 | 69.7 | 24.0 | | 140.7 | | |
| 10077-CAB | IEEE 802.11g WiFi 2.4 GHz (DSSS/OFDM, 54 Mbps) | X | 10.27 | 70.0 | 24.8 | 11.00 | 132.3 | ±3.0 % | ± 4.7 % |
| | | Y | 10.50 | 70.4 | 24.7 | | 133.1 | | |
| | | Z | 10.09 | 69.8 | 24.7 | | 138.1 | | |
| 10172-CAG | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, QPSK) | X | 6.24 | 71.6 | 25.1 | 9.21 | 136.7 | ±3.0 % | ± 4.7 % |
| | | Y | 6.55 | 72.1 | 24.8 | | 139.6 | | |
| | | Z | 5.89 | 70.4 | 24.4 | | 143.0 | | |
| 10173-CAG | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, 16-QAM) | X | 6.60 | 72.6 | 25.6 | 9.48 | 135.6 | ±2.7 % | ± 4.7 % |
| | | Y | 6.95 | 73.0 | 25.2 | | 138.7 | | |
| | | Z | 6.20 | 71.4 | 24.9 | | 140.9 | | |
| 10174-CAG | LTE-TDD (SC-FDMA, 1 RB, 20 MHz, 64-QAM) | X | 7.30 | 72.9 | 26.4 | 10.25 | 135.9 | ±2.2 % | ± 4.7 % |
| | | Y | 7.63 | 73.3 | 26.1 | | 139.1 | | |
| | | Z | 6.88 | 71.6 | 25.7 | | 141.1 | | |
| 10295-AAB | CDMA2000, RC1, SO3, 1/8th Rate 25 fr. | X | 6.03 | 71.0 | 27.2 | 12.49 | 128.1 | ±1.4 % | ± 4.7 % |
| | | Y | 6.36 | 71.0 | 26.3 | | 115.8 | | |
| | | Z | 5.50 | 68.7 | 25.8 | | 114.5 | | |

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%.

[B] Numerical linearization parameter: uncertainty not required.
[E] Uncertainty is determined using the max. deviation from linear response applying rectangular distribution and is expressed for the square of the field value.

# DASY/EASY - Parameters of Probe: EF3DV3 - SN:4047

## Sensor Frequency Model Parameters

| | Sensor X | Sensor Y | Sensor Z |
|---|---|---|---|
| Frequency Corr. (LF) | -0.33 | -0.24 | 5.86 |
| Frequency Corr. (HF) | 2.82 | 2.82 | 2.82 |

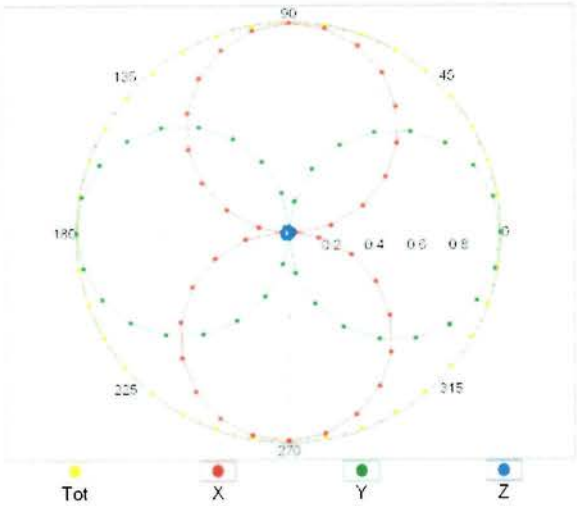
## Sensor Model Parameters

## Other Probe Parameters

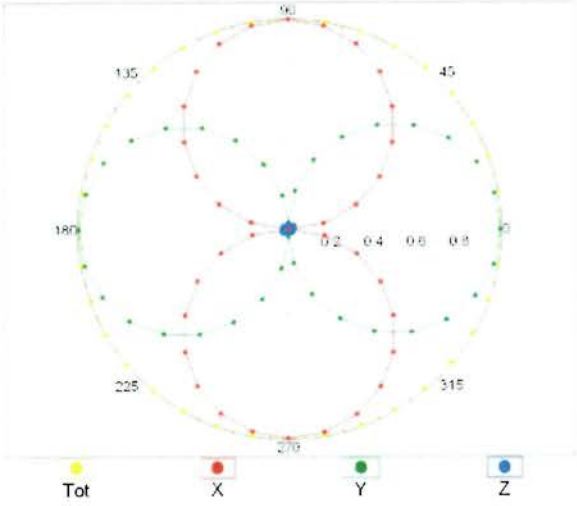
| | |
|---|---|
| Sensor Arrangement | Rectangular |
| Connector Angle (°) | -32.7 |
| Mechanical Surface Detection Mode | enabled |
| Optical Surface Detection Mode | disabled |
| Probe Overall Length | 335 mm |
| Probe Body Diameter | 12 mm |
| Tip Length | 25 mm |
| Tip Diameter | 4 mm |
| Probe Tip to Sensor X Calibration Point | 1.5 mm |
| Probe Tip to Sensor Y Calibration Point | 1.5 mm |
| Probe Tip to Sensor Z Calibration Point | 1.5 mm |

# Receiving Pattern (ϕ), ϑ = 0°

f=600 MHz,TEM,0°

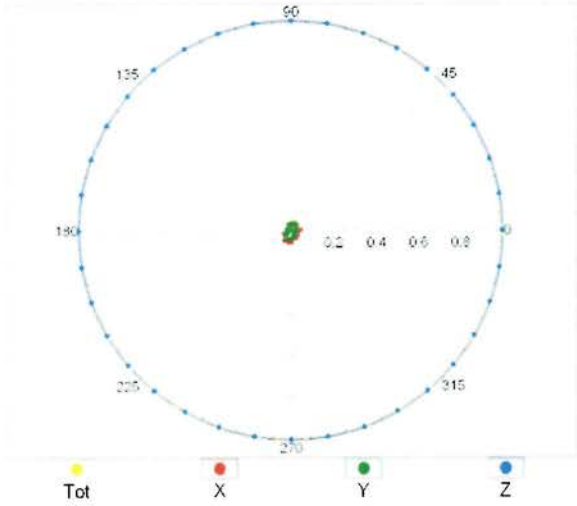



f=1800 MHz,R22,0°

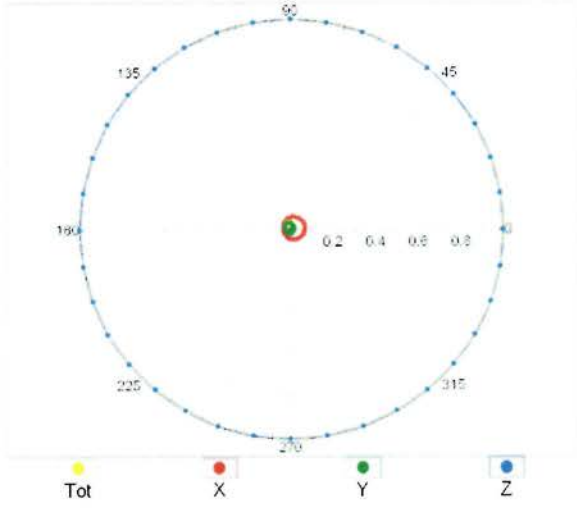



# Receiving Pattern (ϕ), ϑ = 90°

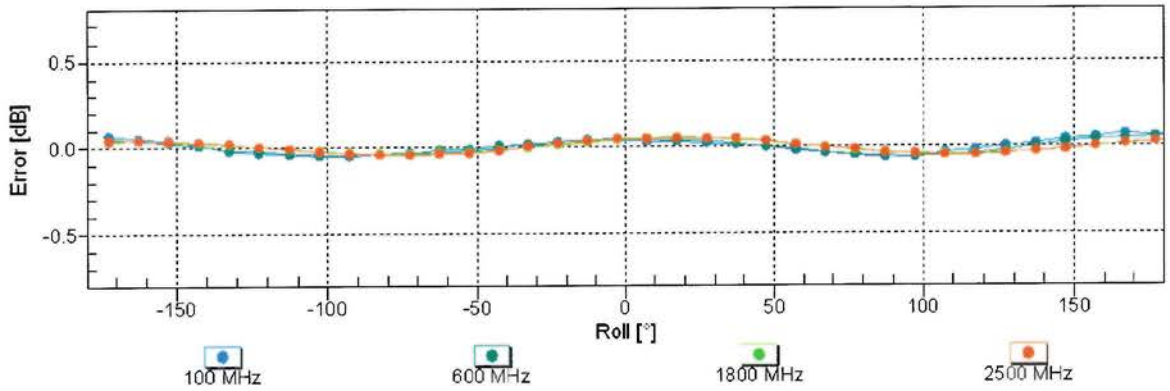
f=600 MHz,TEM,90°




f=1800 MHz,R22,90°

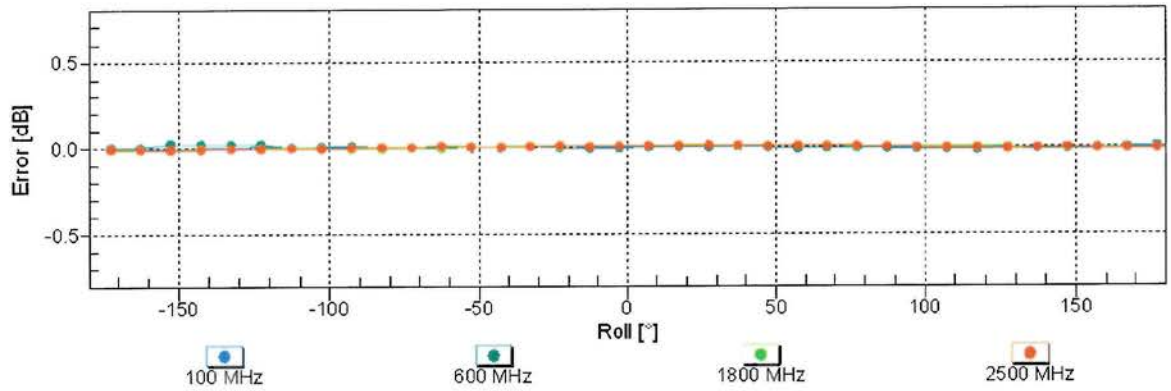


# Receiving Pattern (ϕ), ϑ = 0°



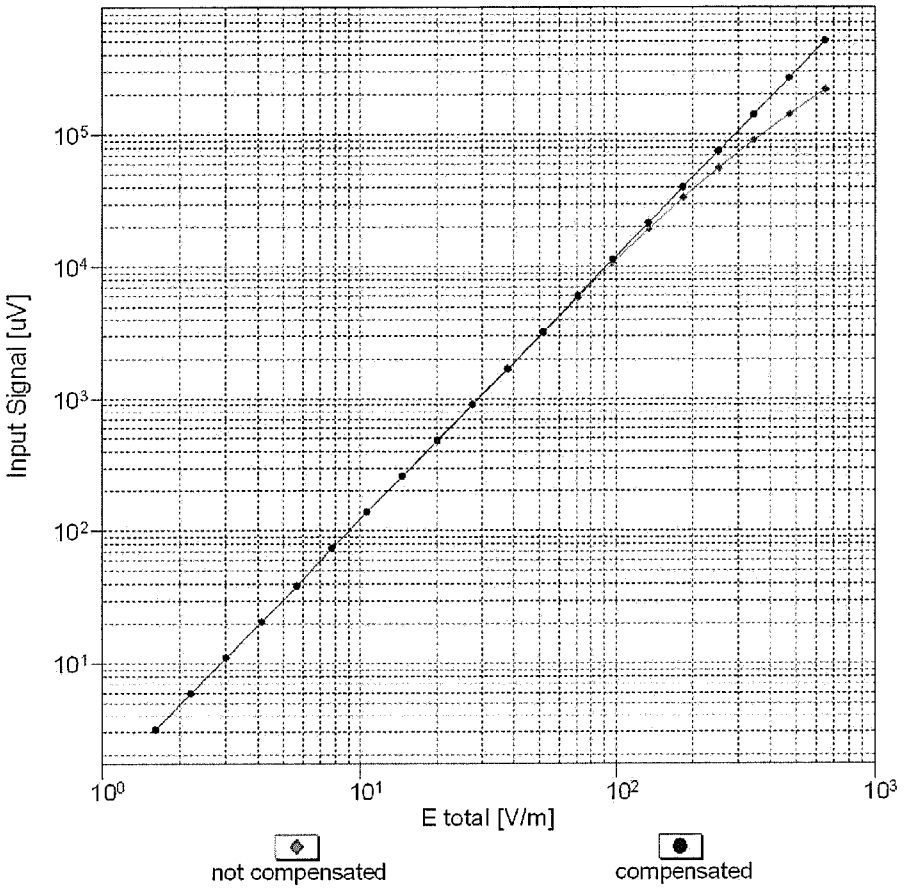

**Uncertainty of Axial Isotropy Assessment: ± 0.5% (k=2)**

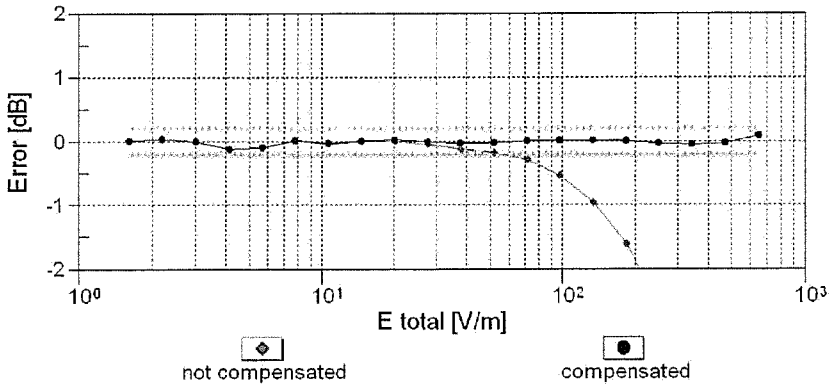
# Receiving Pattern (ϕ), ϑ = 90°




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

# Dynamic Range f(E-field)
**(TEM cell, f = 900 MHz)**

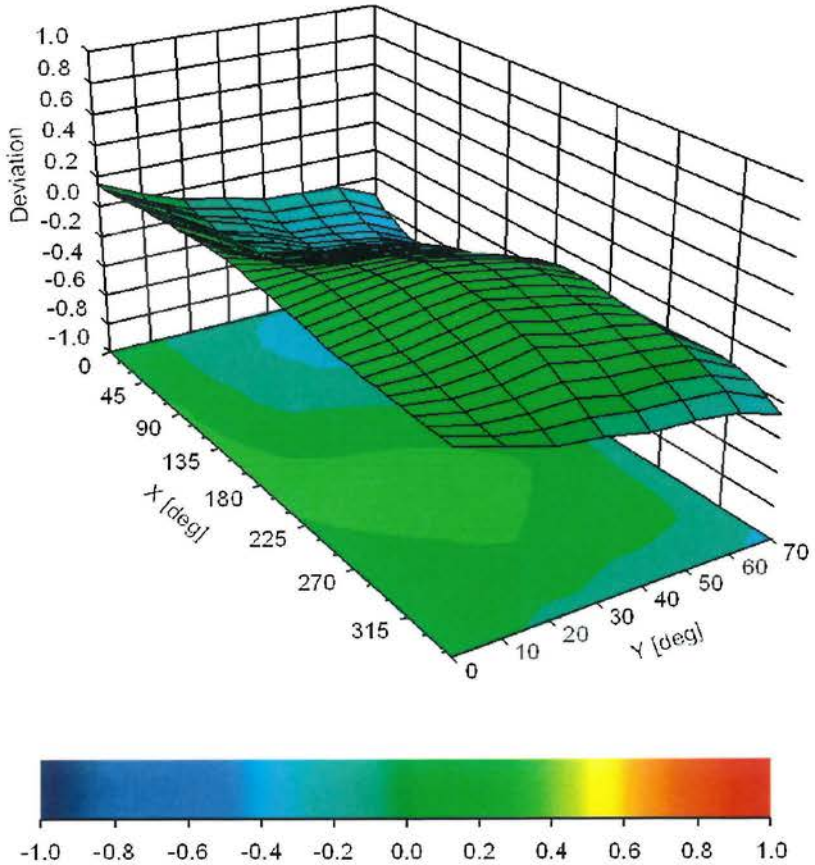



**Uncertainty of Linearity Assessment: ± 0.6% (k=2)**

# Deviation from Isotropy in Air

**Error (ϕ, ϑ), f = 900 MHz**




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

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**Zeughausstrasse 43, 8004 Zurich, Switzerland**

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Servizio svizzero di taratura
**S** Swiss Calibration Service

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

**Accreditation No.: SCS 0108**

**Client** Sporton

**Certificate No: DAE4-854_May19**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | DAE4 - SD 000 D04 BM - SN: 854 |
| Calibration procedure(s) | QA CAL-06.v29<br>Calibration procedure for the data acquisition electronics (DAE) |
| Calibration date: | May 21, 2019 |

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Keithley Multimeter Type 2001 | SN: 0810278 | 03-Sep-18 (No:23488) | Sep-19 |
| **Secondary Standards** | **ID #** | **Check Date (in house)** | **Scheduled Check** |
| Auto DAE Calibration Unit | SE UWS 053 AA 1001 | 07-Jan-19 (in house check) | In house check: Jan-20 |
| Calibrator Box V2.1 | SE UMS 006 AA 1002 | 07-Jan-19 (in house check) | In house check: Jan-20 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Adrian Gehring | Laboratory Technician | |
| Approved by: | Sven Kühn | Deputy Manager | |

Issued: May 21, 2019

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

## 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** | 404.909 ± 0.02% (k=2) | 404.692 ± 0.02% (k=2) | 405.783 ± 0.02% (k=2) |
| **Low Range** | 3.97164 ± 1.50% (k=2) | 3.94913 ± 1.50% (k=2) | 3.99482 ± 1.50% (k=2) |

## Connector Angle

| | |
|---|---|
| **Connector Angle** to be used in DASY system | 325.0 ° ± 1 ° |

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

### 1. DC Voltage Linearity

| High Range | | Reading (μV) | Difference (μV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 199994.47 | 0.40 | 0.00 |
| Channel X | + Input | 20000.57 | -0.74 | -0.00 |
| Channel X | - Input | -19999.89 | 1.86 | -0.01 |
| Channel Y | + Input | 199996.63 | 2.65 | 0.00 |
| Channel Y | + Input | 19998.60 | -2.61 | -0.01 |
| Channel Y | - Input | -20002.11 | -0.26 | 0.00 |
| Channel Z | + Input | 199993.70 | -0.37 | -0.00 |
| Channel Z | + Input | 19998.50 | -2.78 | -0.01 |
| Channel Z | - Input | -20002.17 | -0.31 | 0.00 |

| Low Range | | Reading (μV) | Difference (μV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 2000.92 | 0.14 | 0.01 |
| Channel X | + Input | 201.80 | 0.54 | 0.27 |
| Channel X | - Input | -198.07 | 0.52 | -0.26 |
| Channel Y | + Input | 2000.75 | -0.14 | -0.01 |
| Channel Y | + Input | 200.51 | -0.64 | -0.32 |
| Channel Y | - Input | -199.85 | -1.04 | 0.52 |
| Channel Z | + Input | 2000.81 | 0.06 | 0.00 |
| Channel Z | + Input | 200.50 | -0.57 | -0.28 |
| Channel Z | - Input | -199.70 | -0.76 | 0.38 |

### 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 | -11.53 | -13.11 |
| | - 200 | 15.52 | 13.66 |
| Channel Y | 200 | -8.40 | -8.84 |
| | - 200 | 7.27 | 6.80 |
| Channel Z | 200 | 16.75 | 16.91 |
| | - 200 | -18.58 | -18.86 |

### 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 | - | 1.02 | -3.37 |
| Channel Y | 200 | 7.97 | - | 3.67 |
| Channel Z | 200 | 9.63 | 4.81 | - |

## 4. AD-Converter Values with inputs shorted

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

| | High Range (LSB) | Low Range (LSB) |
|---|---|---|
| **Channel X** | 16127 | 15569 |
| **Channel Y** | 15969 | 16516 |
| **Channel Z** | 15864 | 16505 |

## 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** | 0.80 | 0.09 | 2.25 | 0.35 |
| **Channel Y** | -0.13 | -1.04 | 0.67 | 0.35 |
| **Channel Z** | -0.21 | -1.03 | 0.51 | 0.33 |

## 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 |

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

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

Accredited by the Swiss Accreditation Service (SAS)
**The Swiss Accreditation Service is one of the signatories to the EA Multilateral Agreement for the recognition of calibration certificates**

**Accreditation No.: SCS 0108**

**Client** **Sporton**

**Certificate No: DAE4-1399_Nov18**

# CALIBRATION CERTIFICATE

| | |
|---|---|
| Object | DAE4 - SD 000 D04 BM - SN: 1399 |
| Calibration procedure(s) | QA CAL-06.v29<br>Calibration procedure for the data acquisition electronics (DAE) |
| Calibration date: | November 16, 2018 |

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

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

Calibration Equipment used (M&TE critical for calibration)

| Primary Standards | ID # | Cal Date (Certificate No.) | Scheduled Calibration |
|---|---|---|---|
| Keithley Multimeter Type 2001 | SN: 0810278 | 03-Sep-18 (No:23488) | Sep-19 |
| **Secondary Standards** | **ID #** | **Check Date (in house)** | **Scheduled Check** |
| Auto DAE Calibration Unit | SE UWS 053 AA 1001 | 04-Jan-18 (in house check) | In house check: Jan-19 |
| Calibrator Box V2.1 | SE UMS 006 AA 1002 | 04-Jan-18 (in house check) | In house check: Jan-19 |

| | Name | Function | Signature |
|---|---|---|---|
| Calibrated by: | Adrian Gehring | Laboratory Technician | |
| Approved by: | Sven Kühn | Deputy Manager | |

Issued: November 16, 2018

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

## 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** | 403.615 ± 0.02% (k=2) | 403.876 ± 0.02% (k=2) | 403.729 ± 0.02% (k=2) |
| **Low Range** | 3.98279 ± 1.50% (k=2) | 3.99313 ± 1.50% (k=2) | 3.98038 ± 1.50% (k=2) |

## Connector Angle

| | |
|---|---|
| **Connector Angle** to be used in DASY system | 302.5 ° ± 1 ° |

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

### 1. DC Voltage Linearity

| High Range | | Reading (µV) | Difference (µV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 199995.97 | -0.84 | -0.00 |
| Channel X | + Input | 20003.53 | 1.96 | 0.01 |
| Channel X | - Input | -20000.06 | 1.70 | -0.01 |
| Channel Y | + Input | 199996.26 | -0.65 | -0.00 |
| Channel Y | + Input | 20000.25 | -1.15 | -0.01 |
| Channel Y | - Input | -20001.89 | 0.03 | -0.00 |
| Channel Z | + Input | 199995.39 | -1.51 | -0.00 |
| Channel Z | + Input | 19999.77 | -1.56 | -0.01 |
| Channel Z | - Input | -20003.54 | -1.57 | 0.01 |

| Low Range | | Reading (µV) | Difference (µV) | Error (%) |
|---|---|---|---|---|
| Channel X | + Input | 2001.10 | 0.21 | 0.01 |
| Channel X | + Input | 201.44 | 0.27 | 0.13 |
| Channel X | - Input | -198.21 | 0.48 | -0.24 |
| Channel Y | + Input | 2001.07 | 0.28 | 0.01 |
| Channel Y | + Input | 200.13 | -0.82 | -0.41 |
| Channel Y | - Input | -199.82 | -0.96 | 0.49 |
| Channel Z | + Input | 2000.99 | 0.25 | 0.01 |
| Channel Z | + Input | 200.17 | -0.73 | -0.36 |
| Channel Z | - Input | -199.39 | -0.48 | 0.24 |

### 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 | -5.15 | -6.61 |
| | - 200 | 7.82 | 6.45 |
| Channel Y | 200 | -5.89 | -6.47 |
| | - 200 | 4.11 | 4.20 |
| Channel Z | 200 | -7.04 | -6.67 |
| | - 200 | 5.06 | 5.01 |

### 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 | - | 4.43 | -1.37 |
| Channel Y | 200 | 10.10 | - | 6.50 |
| Channel Z | 200 | 8.99 | 6.87 | - |

## 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** | 15819 | 15315 |
| **Channel Y** | 16117 | 16356 |
| **Channel Z** | 15883 | 15504 |

## 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** | 0.62 | -0.33 | 1.64 | 0.36 |
| **Channel Y** | 0.11 | -1.02 | 1.57 | 0.46 |
| **Channel Z** | -0.26 | -1.48 | 1.84 | 0.52 |

## 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 |