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

Client **Sporton** **Certificate No: 5G-Veri30-1007_Apr18**

CALIBRATION CERTIFICATE

Object	5G Verification Source 30 GHz – SN: 1007
Calibration procedure(s)	QA CAL-45.v1 Calibration procedure for 5G Verification and Validation Sources
Calibration date:	April 06, 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
Reference Probe EUmmWV2	SN: 9374	23-Mar-18 (No. EUmmWV2-9374_Mar18)	Mar-19
DAE4	SN: 1215	26-Feb-18 (No. DAE4-1215_Feb18)	Feb-19
Secondary Standards	**ID #**	**Check Date (in house)**	**Scheduled Check**

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

Issued: April 28, 2018

Calibration Laboratory of
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Zeughausstrasse 43, 8004 Zurich, Switzerland

Glossary

CW Continuous wave

Calibration is Performed According to the Following Standards

- Internal procedure QA CAL-45-5Gsources
- IEC TR-63170 ED1, "Measurement procedure for the evaluation of power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 100 GHz", November 2017
- DASY6 Handbook

Methods Applied and Interpretation of Parameters

- *Coordinate System:* z-axis in the waveguide horn boresight, x-axis is in the direction of the E-field, y-axis normal to the others in the field scanning plane parallel to the horn flare and horn flange.
- *Measurement Conditions: (1) 10 GHz:* The forward power to the horn antenna is measured prior and after the measurement with a power sensor. During the measurements, the horn is directly mounted to the waveguide source and the reflected power is monitored and adjusted. (2) 30, 60 and 90 GHz: The verification sources are switched on for at least 30 minutes. Absorbers are used around the probe cup to minimize reflections.
- *Horn Positioning:* The waveguide horn is mounted vertically on the flange of the waveguide source to allow vertical positioning of the EUmmW probe during the scan. The plane is parallel to the phantom surface (plane height defined by teaching the point at the surface of the flare of the horn).
- *E- field distribution:* E field is measured in four x-y-planes (10mm, 10mm + λ/4, 150mm; 150mm+ λ/4) with a vectorial E-field probe. The results at 150 mm are used to derive radiated power P_{rad} using numerically determined values. The E-field value stated as calibration value represents the E-field-maxima and the averaged ($1cm^2$ and $4cm^2$) power density values at 10mm in front of the horn.
- *E-field polarization:* Above the open horn, linear polarization of the field is expected.

Calibrated Quantity

- Local peak E-field and spatial-averaged power density S ($1\ cm^2$ and $4cm^2$) at 10, 30, 60 or 90 GHz.

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	cDASY6 5G module	V1.0.0.12565
Phantom	5G Phantom	
Distance Horn Aperture - plane	10 mm and 150 mm	
XY Scan Resolution	dx, dy = λ/4	
Number of measured planes	4 (10mm, 10mm + λ/4, 150mm; 150mm+ λ/4)	
Frequency	30 GHz ± 10 MHz	

Calibration Parameters, 30 GHz

Distance Horn Aperture to Measured Plane	P_{rad}[1] ***(dBm)***	**Max E-field (V/m)**	Uncertainty E (k = 2)	Avg Power Density (W/m^2)		Uncertainty S (k = 2)
				1 cm^2	**4** cm^2	
10 mm	15.4	**133.0**	1.2 dB	**39.8**	**33.6**	1.4 dB
150 mm	15.4	**51.9**	1.2 dB	**6.88**	**6.59**	1.4 dB

[1] derived from far-field E-field data

Measurement Report for 30 GHz Verification Source, FRONT (SCREEN), Validation, UID 0 -, Channel 30000 (30000.0MHz)

Device under Test Properties

Name, Manufacturer	Dimensions [mm]	IMEI	DUT Type
, 30 GHz Verification Source	100.0 x 100.0 x 100.0		Bar/Brick

Exposure Conditions

Phantom Section	Position, Test Distance [mm]	Band	Group, UID	Frequency [MHz], Channel Number	Conversion Factor
5G -	FRONT (SCREEN), 5.55 mm	Validation	CW, 0--	30000.0, 30000	1.0

Hardware Setup

Phantom	Medium	Probe, Calibration Date	DAE, Calibration Date
5G Phantom V0.1- xxxx	Air ---	EUmmWV2 - SN9374, 2018-03-23	DAE4 Sn1215, 2018-02-26

Scan Setup

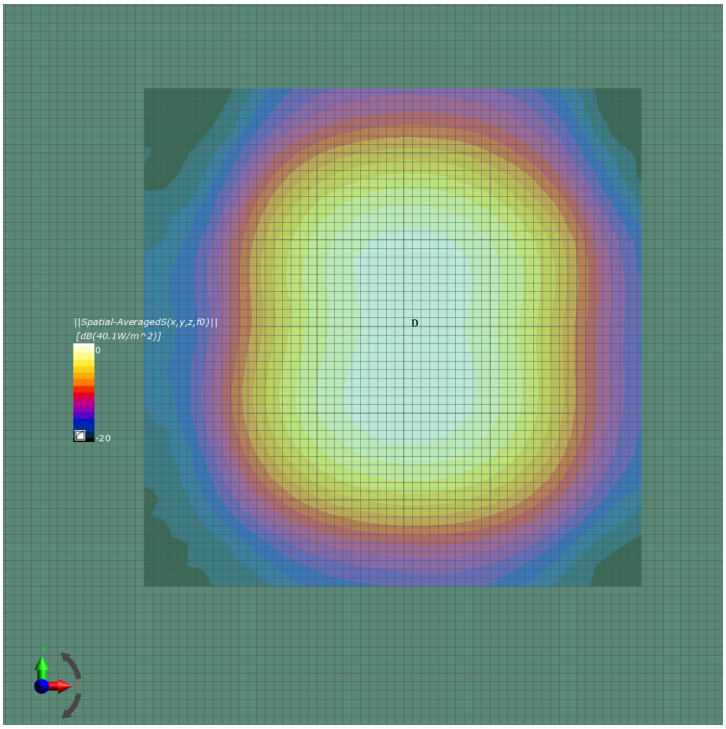
	5G Scan
Grid Extents [mm]	60.0 x 60.0 x 2.5
Grid Steps [mm]	2.5 x 2.5
Sensor Surface [mm]	5.55
MAIA	MAIA not used

Measurement Results

	5G Scan
Date	2018-04-06, 16:36
Avg. Area [cm^2]	1.00
S_{avg} [W/m^2]	39.8
S_{peak} [W/m^2]	54.8
E_{peak} [V/m]	133
H_{peak} [A/m]	0.413
Power Drift [dB]	-0.09

Warning(s) / Error(s)

Details	Area Scan
Warning(s)	
Error(s)	



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Client **Sporton**

Certificate No: 5G-Veri30-1009_Jun18

CALIBRATION CERTIFICATE

Object	5G Verification Source 30 GHz – SN: 1009
Calibration procedure(s)	QA CAL-45.v1 Calibration procedure for 5G Verification and Validation Sources
Calibration date:	June 29, 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
Reference Probe EUmmWV2	SN: 9374	23-Mar-18 (No. EUmmWV2-9374_Mar18)	Mar-19
DAE4	SN: 1215	26-Feb-18 (No. DAE4-1215_Feb18)	Feb-19
Secondary Standards	**ID #**	**Check Date (in house)**	**Scheduled Check**

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

Issued: July 2, 2018

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

Glossary

CW Continuous wave

Calibration is Performed According to the Following Standards

- Internal procedure QA CAL-45-5Gsources
- IEC TR-63170 ED1, "Measurement procedure for the evaluation of power density related to human exposure to radio frequency fields from wireless communication devices operating between 6 GHz and 100 GHz", November 2017
- DASY6 Handbook

Methods Applied and Interpretation of Parameters

- *Coordinate System:* z-axis in the waveguide horn boresight, x-axis is in the direction of the E-field, y-axis normal to the others in the field scanning plane parallel to the horn flare and horn flange.
- *Measurement Conditions: (1) 10 GHz:* The forward power to the horn antenna is measured prior and after the measurement with a power sensor. During the measurements, the horn is directly mounted to the waveguide source and the reflected power is monitored and adjusted. (2) 30, 60 and 90 GHz: The verification sources are switched on for at least 30 minutes. Absorbers are used around the probe cup to minimize reflections.
- *Horn Positioning:* The waveguide horn is mounted vertically on the flange of the waveguide source to allow vertical positioning of the EUmmW probe during the scan. The plane is parallel to the phantom surface (plane height defined by teaching the point at the surface of the flare of the horn).
- *E- field distribution:* E field is measured in four x-y-planes (10mm, 10mm + $\lambda/4$, 150mm; 150mm+ $\lambda/4$) with a vectorial E-field probe. The results at 150 mm are used to derive radiated power P_{rad} using numerically determined values. The E-field value stated as calibration value represents the E-field-maxima and the averaged ($1cm^2$ and $4cm^2$) power density values at 10mm in front of the horn.
- *E-field polarization:* Above the open horn, linear polarization of the field is expected.

Calibrated Quantity

- Local peak E-field and spatial-averaged power density S ($1\ cm^2$ and $4cm^2$) at 10, 30, 60 or 90 GHz.

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	cDASY6 5G module	V1.2.0
Phantom	5G Phantom	
Distance Horn Aperture - plane	10 mm and 150 mm	
XY Scan Resolution	dx, dy = λ/4	
Number of measured planes	4 (10mm, 10mm + λ/4, 150mm; 150mm+ λ/4)	
Frequency	30 GHz ± 10 MHz	

Calibration Parameters, 30 GHz

Distance Horn Aperture to Measured Plane	P_{rad}[1] (dBm)	Max E-field (V/m)	Uncertainty E ($k = 2$)	Avg Power Density (W/m^2)		Uncertainty S ($k = 2$)
				1 cm^2	**4** cm^2	
10 mm	15.8	**141**	1.2 dB	**45.7**	**41.3**	1.4 dB
150 mm	15.8	**55.4**	1.2 dB	**7.83**	**7.26**	1.4 dB

[1] derived from far-field E-field data

Measurement Report for Device, FRONT, Validation band, UID 0 -, Channel 30000 (30000.0MHz)

Device under Test Properties

Name, Manufacturer	Dimensions [mm]	IMEI	DUT Type
, Device	100.0 x 100.0 x 100.0		Phone

Exposure Conditions

Phantom Section	Position, Test Distance [mm]	Band	Group, UID	Frequency [MHz], Channel Number	Conversion Factor
5G -	FRONT, 5.55	Validation band	CW, 0--	30000.0, 30000	1.0

Hardware Setup

Phantom	Medium	Probe, Calibration Date	DAE, Calibration Date
5G Cover- xxxx	--Air-	EUmmWV2 - SN9374, 2018-03-23	DAE4 Sn1215, 2018-02-26

Scan Setup

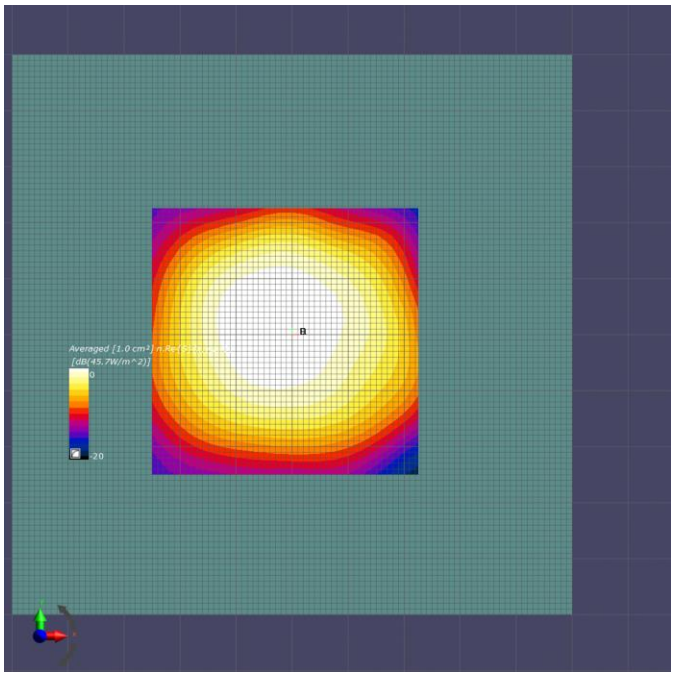
	5G Scan
Grid Extents [mm]	60.0 x 60.0
Grid Steps [lambda]	0.25 x 0.25
Sensor Surface [mm]	5.55
MAIA	MAIA not used

Measurement Results

	5G Scan
Date	2018-06-26, 14:38
Avg. Area [cm^2]	1.00
pS_{tot} avg [W/m^2]	46.1
pS_n avg [W/m^2]	45.7
E_{peak} [V/m]	141
Power Drift [dB]	-0.01

Warning(s) / Error(s)

Details	5G Scan
Warning(s)	
Error(s)	



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Accreditation No.: SCS 0108

Client **Sporton**

Certificate No: EUmmWV2-9388_Apr18

CALIBRATION CERTIFICATE

Object	EUmmWV2 - SN:9388
Calibration procedure(s)	QA CAL-02.v8, QA CAL-25.v6, QA CAL-42.v2 Calibration procedure for E-field probes optimized for close near field evaluations in air
Calibration date:	April 10, 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: S5277 (20x)	04-Apr-18 (No. 217-02682)	Apr-19
Reference Probe ER3DV6	SN: 2328	10-Oct-17 (No. ER3-2328_Oct17)	Oct-18
DAE4	SN: 789	2-Aug-17 (No. DAE4-789_Aug17)	Aug-18
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-16)	In house check: Jun-18
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-16)	In house check: Jun-18
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-17)	In house check: Oct-18

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

Issued: April 28, 2018

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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

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
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., $\vartheta = 0$ is normal to probe axis
Connector Angle	information used in DASY system to align probe sensor X to the robot coordinate system
Sensor Angles	sensor deviation from the probe axis, used to calculate the field orientation and polarization
k	is the wave propagation direction

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

Methods Applied and Interpretation of Parameters:

- *NORMx,y,z:* Assessed for E-field polarization $\vartheta = 0$ for XY sensors and $\vartheta = 90$ for Z sensor ($f \leq 900$ MHz in TEM-cell; $f > 1800$ MHz: R22 waveguide). For frequencies > 6 GHz, the far field in front of waveguide horn antennas is measured for a set of frequencies in various waveguide bands up to 110 GHz.
- *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
- The frequency sensor model parameters are determined prior to calibration based on a frequency sweep (sensor model involving resistors R, R_p, inductance L and capacitors C, C_p).
- *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.
- *Sensor Offset*: The sensor offset corresponds to the mechanical 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).
- *Equivalent Sensor Angle*: The two probe sensors are mounted in the same plane at different angles. The angles are assessed using the information gained by determining the *NORMx* (no uncertainty required).
- *Spherical isotropy (3D deviation from isotropy)*: in a locally homogeneous field realized using an open waveguide / horn setup.

Probe EUmmWV2

SN:9388

Manufactured: June 14, 2017
Calibrated: April 10, 2018

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

DASY - Parameters of Probe: EUmmWV2 - SN:9388

Basic Calibration Parameters (750 MHz – 3 GHz)

	Sensor X	Sensor Y	Unc (k=2)
Norm ($\mu V/(V/m)^2$)	0.01971	0.02321	± 10.1 %
DCP (mV)[B]	105.0	105.0	
Equivalent Sensor Angle	-59.2	32.2	

Calibration results for Frequency Response (6 – 110 GHz)

Frequency GHz	Target E-Field V/m	Deviation Sensor X dB	Deviation Sensor Y dB	Unc (k=2) dB
6.6	40.04	-0.09	0.03	± 0.98 dB
8	48.41	-0.39	-0.36	± 0.98 dB
10	54.41	-0.11	-0.06	± 0.98 dB
15	75.04	-0.02	0.14	± 0.98 dB
18	85.30	0.29	0.17	± 0.98 dB
26.6	96.89	0.38	0.36	± 0.98 dB
30	92.55	0.32	0.29	± 0.98 dB
35	93.71	0.08	0.09	± 0.98 dB
40	91.46	-0.13	-0.21	± 0.98 dB
50	19.62	0.28	0.19	± 0.98 dB
55	22.38	0.30	0.24	± 0.98 dB
60	23.03	0.18	0.04	± 0.98 dB
65	27.40	-0.17	-0.16	± 0.98 dB
70	23.95	-0.23	-0.27	± 0.98 dB
75	19.61	-0.24	-0.29	± 0.98 dB
75	14.11	-0.15	-0.12	± 0.98 dB
80	21.51	-0.30	-0.07	± 0.98 dB
85	22.75	-0.07	0.06	± 0.98 dB
90	23.84	0.23	0.30	± 0.98 dB
92	23.93	0.06	0.00	± 0.98 dB
95	20.55	0.04	0.00	± 0.98 dB
97	24.41	0.15	0.03	± 0.98 dB
100	22.61	0.13	0.06	± 0.98 dB
105	22.75	0.00	0.02	± 0.98 dB
110	18.85	-0.38	-0.26	± 0.98 dB

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Unc[E] (k=2)
0	CW	X	0.0	0.0	1.0	0.00	50.4	+ 2.5 %	± 4.7 %
		Y	0.0	0.0	1.0		22.6		

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%.

[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 - Parameters of Probe: EUmmWV2 - SN:9388

Sensor Frequency Model Parameters

	Sensor X	Sensor Y
R (Ω)	38.90	41.13
R_p (Ω)	95.86	92.34
L (nH)	0.03220	0.03158
C (pF)	0.2221	0.2600
C_p (pF)	0.1255	0.1212

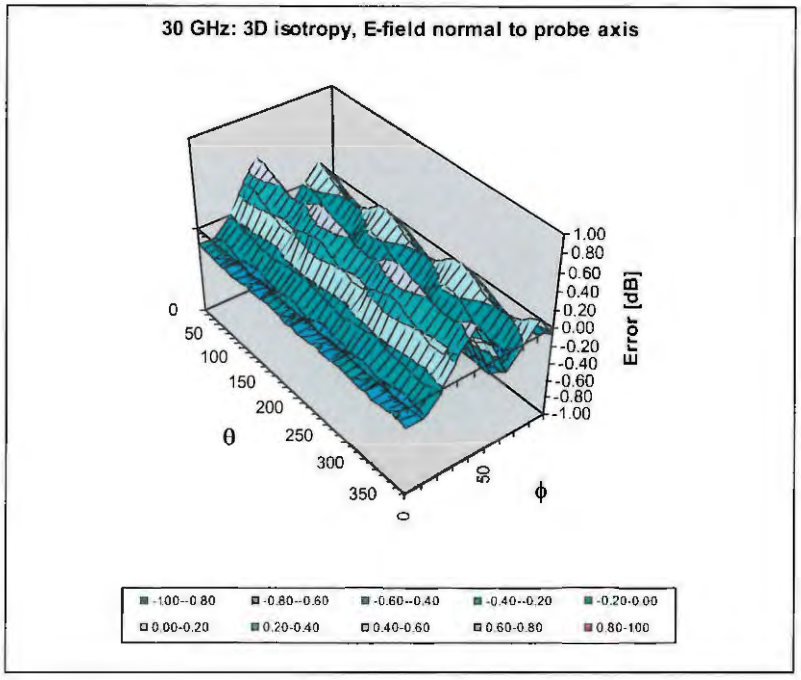
Sensor Model Parameters

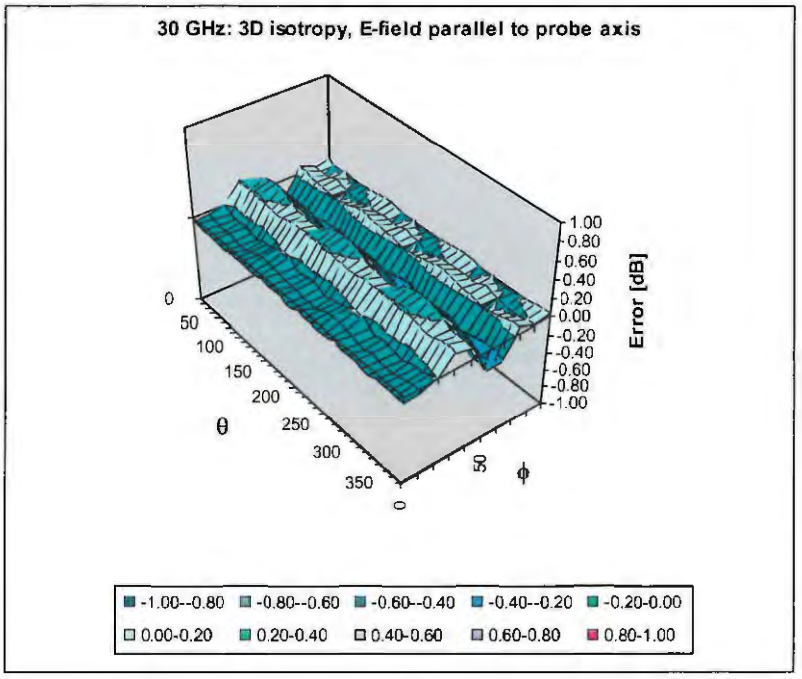
	C1 fF	C2 fF	α V^{-1}	T1 $ms.V^{-2}$	T2 $ms.V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
X	7.692	52.62	30.48	0.916	2.245	4.905	0	0.502	0.997
Y	5.836	42.35	33.63	0.916	2.257	4.941	0	0.824	0.999

Other Probe Parameters

Sensor Arrangement	Rectangular
Connector Angle (°)	44.0
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	320 mm
Probe Body Diameter	8 mm
Tip Length	23 mm
Tip Diameter	8.0 mm
Probe Tip to Sensor X Calibration Point	1.5 mm
Probe Tip to Sensor Y Calibration Point	1.5 mm

Deviation from Isotropy in Air
f = 30 GHz





Probe isotropy for E_{tot}: probe rotated φ = 0° to 360°, tilted from field propagation direction $\vec{k}$
Parallel to the field propagation (ψ =0° - 90°): deviation within ± 0.29 dB
Normal to field orientation (ϑ =0° - 90°): deviation within ± 0.44 dB

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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: EUmmWV3-9390_Jun18

CALIBRATION CERTIFICATE

Object: EUmmWV3 - SN:9390

Calibration procedure(s): QA CAL-02.v8, QA CAL-25.v6, QA CAL-42.v2
Calibration procedure for E-field probes optimized for close near field evaluations in air

Calibration date: June 28, 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: S5277 (20x)	04-Apr-18 (No. 217-02682)	Apr-19
Reference Probe ER3DV6	SN: 2328	10-Oct-17 (No. ER3-2328_Oct17)	Oct-18
DAE4	SN: 789	2-Aug-17 (No. DAE4-789_Aug17)	Aug-18
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 HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-17)	In house check: Oct-18

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

Issued: July 2, 2018

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
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
Sensor Angles	sensor deviation from the probe axis, used to calculate the field orientation and polarization
k	is the wave propagation direction

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

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). For frequencies > 6 GHz, the far field in front of waveguide horn antennas is measured for a set of frequencies in various waveguide bands up to 110 GHz.
- *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
- The frequency sensor model parameters are determined prior to calibration based on a frequency sweep (sensor model involving resistors R, R_p, inductance L and capacitors C, C_p).
- *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.
- *Sensor Offset*: The sensor offset corresponds to the mechanical 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).
- *Equivalent Sensor Angle*: The two probe sensors are mounted in the same plane at different angles. The angles are assessed using the information gained by determining the *NORMx* (no uncertainty required).
- *Spherical isotropy (3D deviation from isotropy)*: in a locally homogeneous field realized using an open waveguide / horn setup.

DASY - Parameters of Probe: EUmmWV3 - SN:9390

Basic Calibration Parameters (750 MHz – 3 GHz)

	Sensor X	Sensor Y	Unc (k=2)
Norm ($\mu V/(V/m)^2$)	0.01947	0.02257	± 10.1 %
DCP (mV)[B]	105.0	105.0	
Equivalent Sensor Angle	-59.7	31.8	

Calibration results for Frequency Response (6 – 110 GHz)

Frequency GHz	Target E-Field V/m	Deviation Sensor X dB	Deviation Sensor Y dB	Unc (k=2) dB
6.6	40.04	-0.14	-0.09	± 0.98 dB
8	48.41	-0.44	-0.41	± 0.98 dB
10	54.41	-0.16	-0.06	± 0.98 dB
15	75.04	0.10	0.20	± 0.98 dB
18	85.30	0.37	0.28	± 0.98 dB
26.6	96.89	0.43	0.42	± 0.98 dB
30	92.55	0.27	0.38	± 0.98 dB
35	93.71	0.00	0.11	± 0.98 dB
40	91.46	-0.12	-0.15	± 0.98 dB
50	19.62	0.17	0.07	± 0.98 dB
55	22.38	0.53	0.32	± 0.98 dB
60	23.03	0.14	-0.02	± 0.98 dB
65	27.40	-0.19	-0.15	± 0.98 dB
70	23.95	-0.03	-0.25	± 0.98 dB
75	19.61	-0.37	-0.34	± 0.98 dB
75	14.11	-0.25	-0.19	± 0.98 dB
80	21.51	-0.20	-0.09	± 0.98 dB
85	22.75	-0.10	0.08	± 0.98 dB
90	23.84	0.18	0.27	± 0.98 dB
92	23.93	0.00	0.02	± 0.98 dB
95	20.55	0.12	0.07	± 0.98 dB
97	24.41	0.16	0.05	± 0.98 dB
100	22.61	0.17	0.04	± 0.98 dB
105	22.75	-0.01	0.02	± 0.98 dB
110	18.85	-0.41	-0.33	± 0.98 dB

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dB√μV	C	D dB	VR mV	Max dev.	Unc[E] (k=2)
0	CW	X	0.0	0.0	1.0	0.00	43.9	+ 3.7 %	± 4.7 %
		Y	0.0	0.0	1.0		31.1		

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%.

[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.

June 28, 2018

DASY - Parameters of Probe: EUmmWV3 - SN:9390

Sensor Frequency Model Parameters

	Sensor X	Sensor Y
R (Ω)	38.81	40.25
R_p (Ω)	95.91	92.72
L (nH)	0.03209	0.03114
C (pF)	0.2210	0.2615
C_p (pF)	0.1259	0.1242

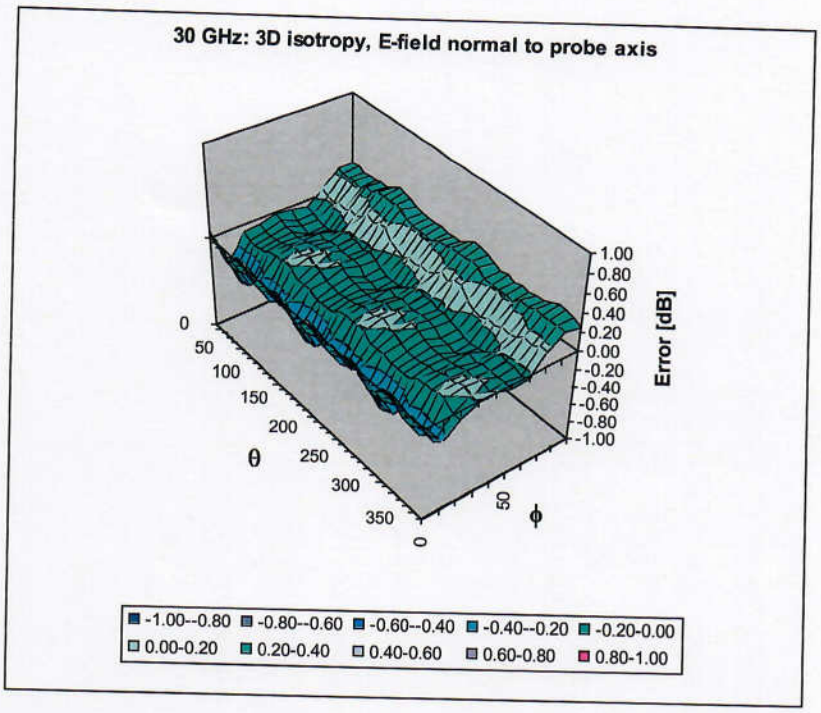
Sensor Model Parameters

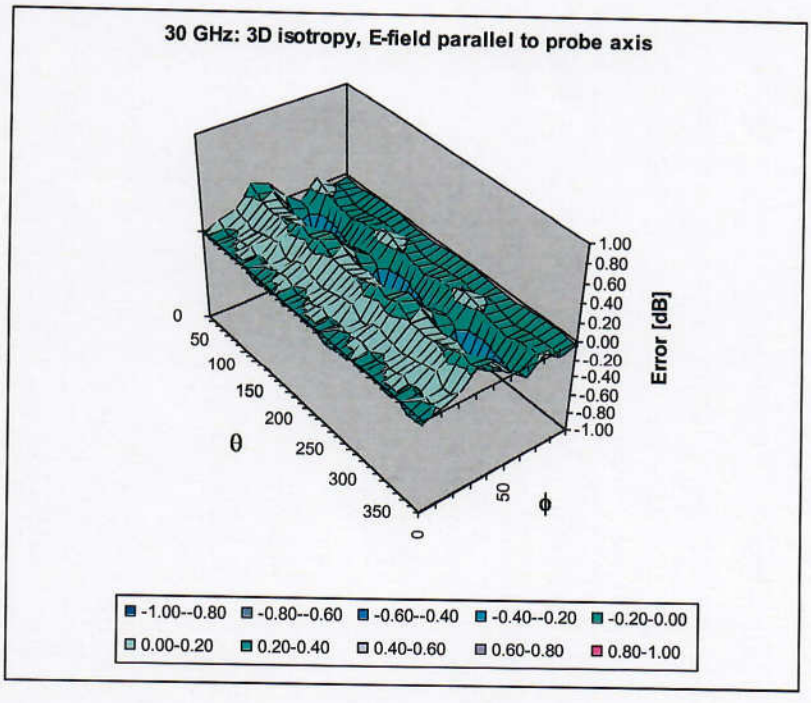
	C1 fF	C2 fF	α V^{-1}	T1 $ms.V^{-2}$	T2 $ms.V^{-1}$	T3 ms	T4 V^{-2}	T5 V^{-1}	T6
X	5.466	39.36	33.16	0.916	1.745	4.914	0	0.501	0.997
Y	7.841	53.77	30.61	0.916	0.868	4.977	0	0.593	0.999

Other Probe Parameters

Sensor Arrangement	Rectangular
Connector Angle (°)	-156.4
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	320 mm
Probe Body Diameter	8 mm
Tip Length	23 mm
Tip Diameter	8.0 mm
Probe Tip to Sensor X Calibration Point	1.5 mm
Probe Tip to Sensor Y Calibration Point	1.5 mm

Deviation from Isotropy in Air
f = 30 GHz





Probe isotropy for E_{tot}: probe rotated φ = 0° to 360°, tilted from field propagation direction $\vec{k}$
Parallel to the field propagation (ψ =0° - 90°): deviation within ± 0.38 dB
Normal to field orientation (ϑ =0° - 90°): deviation within ± 0.45 dB

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S Schweizerischer Kalibrierdienst
C Service suisse d'étalonnage
S 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 **Auden**

Certificate No: DAE4-918_Jun18

CALIBRATION CERTIFICATE

Object	DAE4 - SD 000 D04 BK - SN: 918
Calibration procedure(s)	QA CAL-06.v29 Calibration procedure for the data acquisition electronics (DAE)
Calibration date:	June 20, 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	31-Aug-17 (No:21092)	Aug-18
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:	Eric Hainfeld	Laboratory Technician	
Approved by:	Sven Kühn	Deputy Manager	i.V.

Issued: June 20, 2018

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	404.292 ± 0.02% (k=2)	404.471 ± 0.02% (k=2)	404.000 ± 0.02% (k=2)
Low Range	4.01048 ± 1.50% (k=2)	3.99008 ± 1.50% (k=2)	4.00845 ± 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	320.5 ° ± 1 °

Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	199995.21	-2.10	-0.00
Channel X	+ Input	20001.90	-0.02	-0.00
Channel X	- Input	-19998.43	2.67	-0.01
Channel Y	+ Input	199997.45	0.04	0.00
Channel Y	+ Input	20000.13	-1.84	-0.01
Channel Y	- Input	-20002.53	-1.31	0.01
Channel Z	+ Input	199998.07	0.90	0.00
Channel Z	+ Input	20000.07	-1.82	-0.01
Channel Z	- Input	-20002.88	-1.51	0.01

Low Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	2002.15	0.71	0.04
Channel X	+ Input	201.89	0.17	0.09
Channel X	- Input	-198.28	-0.11	0.06
Channel Y	+ Input	2000.77	-0.64	-0.03
Channel Y	+ Input	201.50	-0.14	-0.07
Channel Y	- Input	-198.61	-0.36	0.18
Channel Z	+ Input	2001.31	-0.10	-0.01
Channel Z	+ Input	200.36	-1.18	-0.59
Channel Z	- Input	-199.37	-1.01	0.51

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	4.32	2.70
	- 200	-2.19	-4.37
Channel Y	200	11.36	11.41
	- 200	-12.35	-12.96
Channel Z	200	-13.98	-14.32
	- 200	13.11	12.07

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	-	-0.68	-5.41
Channel Y	200	7.71	-	0.61
Channel Z	200	10.01	5.69	-

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	15930	14966
Channel Y	16009	15983
Channel Z	16005	17407

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	-0.01	-2.00	1.96	0.70
Channel Y	1.43	0.40	2.68	0.39
Channel Z	-0.70	-1.89	0.85	0.46

6. Input Offset Current

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

7. Input Resistance (Typical values for information)

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

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

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

9. Power Consumption (Typical values for information)

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

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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: DAE4-778_May18

CALIBRATION CERTIFICATE

Object	DAE4 - SD 000 D04 BM - SN: 778
Calibration procedure(s)	QA CAL-06.v29 Calibration procedure for the data acquisition electronics (DAE)
Calibration date:	May 25, 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	31-Aug-17 (No:21092)	Aug-18
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:	Dominique Steffen	Laboratory Technician	
Approved by:	Sven Kühn	Deputy Manager	

Issued: May 25, 2018

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	404.721 ± 0.02% (k=2)	403.519 ± 0.02% (k=2)	405.076 ± 0.02% (k=2)
Low Range	3.98715 ± 1.50% (k=2)	3.96471 ± 1.50% (k=2)	4.00070 ± 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	269.0 ° ± 1 °

Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	199995.64	0.22	0.00
Channel X	+ Input	20002.64	0.86	0.00
Channel X	- Input	-19997.90	3.08	-0.02
Channel Y	+ Input	199995.52	0.45	0.00
Channel Y	+ Input	20001.45	-0.24	-0.00
Channel Y	- Input	-19999.33	1.69	-0.01
Channel Z	+ Input	199995.39	0.09	0.00
Channel Z	+ Input	19999.28	-2.37	-0.01
Channel Z	- Input	-20004.97	-3.83	0.02

Low Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	2001.37	0.09	0.00
Channel X	+ Input	201.71	0.03	0.02
Channel X	- Input	-198.71	-0.55	0.28
Channel Y	+ Input	2002.06	0.78	0.04
Channel Y	+ Input	201.56	-0.13	-0.07
Channel Y	- Input	-198.85	-0.61	0.31
Channel Z	+ Input	2001.83	0.60	0.03
Channel Z	+ Input	200.63	-1.14	-0.57
Channel Z	- Input	-199.30	-0.95	0.48

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	-4.34	-5.51
	- 200	6.01	4.80
Channel Y	200	0.02	-1.10
	- 200	0.55	0.11
Channel Z	200	-13.81	-14.40
	- 200	12.18	11.59

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	-	-0.84	-2.53
Channel Y	200	8.46	-	0.02
Channel Z	200	4.29	6.73	-

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	16056	16906
Channel Y	16191	17602
Channel Z	16433	15344

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	-0.05	-1.10	1.05	0.43
Channel Y	0.23	-1.15	1.67	0.53
Channel Z	-0.76	-1.76	0.94	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

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CNAS L0570

Client : **Sporton** **Certificate No: Z18-60383**

CALIBRATION CERTIFICATE

Object	DAE4 - SN: 1326
Calibration Procedure(s)	FF-Z11-002-01 Calibration Procedure for the Data Acquisition Electronics (DAEx)
Calibration date:	September 18, 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)℃ and humidity<70%.

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID #	Cal Date(Calibrated by, Certificate No.)	Scheduled Calibration
Process Calibrator 753	1971018	20-Jun-18 (CTTL, No.J18X05034)	June-19

	Name	Function	Signature
Calibrated by:	Yu Zongying	SAR Test Engineer	
Reviewed by:	Lin Hao	SAR Test Engineer	
Approved by:	Qi Dianyuan	SAR Project Leader	

Issued: September 20, 2018

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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 report provide only calibration results for DAE, it does not contain other performance test results.

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DC Voltage Measurement

A/D - Converter Resolution nominal

High Range: 1LSB = 6.1μV , full range = -100...+300 mV
Low Range: 1LSB = 61nV , full range = -1.....+3mV

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

Calibration Factors	X	Y	Z
High Range	404.892 ± 0.15% (k=2)	405.233 ± 0.15% (k=2)	404.616 ± 0.15% (k=2)
Low Range	3.98868 ± 0.7% (k=2)	3.99146 ± 0.7% (k=2)	3.99194 ± 0.7% (k=2)

Connector Angle

Connector Angle to be used in DASY system	68° ± 1 °