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Swiss Calibration Service

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Accreditation No.: SCS 0108

Client

Sporton

Certificate No: 5G-Veri30-1007_Nov19

CALIBRATION (CERTIFICA	TE .	
Object	5G Verification	Source 30 GHz - SN: 1007	
Calibration procedure(s)	QA CAL-45.v2 Calibration pro	cedure for sources in air above 6 GHz	Z
Calibration date:	November 19,	2019	
The measurements and the unce	ertainties with confidence	national standards, which realize the physical units of e probability are given on the following pages and an atory facility: environment temperature $(22 \pm 3)^{\circ}$ C an	re part of the certificate.
Calibration Equipment used (M&	TE critical for calibration	1)	
Primary Standards	ID#	Cal Date (Certificate No.)	Scheduled Calibration
Reference Probe EUmmWV3 DAE4ip	SN: 9374 SN: 1602	31-Dec-18 (No. EUmmWV3-9374_Dec18) 01-Oct-19 (No. DAE4ip-1602_Oct19)	Dec-19 Oct-20
Secondary Standards	ID#	Check Date (in house)	Scheduled Check
	Name	Function	Signature
Calibrated by:	Leif Klysner	Laboratory Technician	Sel Hy
Approved by:	Katja Pokovic	Technical Manager	alles
			Issued: November 20, 2019

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Accreditation No.: SCS 0108

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", January 2018

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 connected to the cable and the antenna ohmic and mismatch losses are determined by far-field measurements. (2) 30, 45, 60 and 90 GHz: The verification sources are switched on for at least 30 minutes. Absorbers are used around the probe cub and at the ceiling 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. Probe distance is verified using mechanical gauges positioned on the flare of the horn.
- E- field distribution: E field is measured in two x-y-plane (10mm, 10mm + λ/4) with a vectorial E-field probe. The E-field value stated as calibration value represents the E-fieldmaxima and the averaged (1cm² and 4cm²) power density values at 10mm in front of the horn.
- Field polarization: Above the open horn, linear polarization of the field is expected. This is verified graphically in the field representation.

Calibrated Quantity

 Local peak E-field (V/m) and peak values of the total and normal component of the poynting vector |Re{S}| and n.Re{S} averaged over the surface area of 1 cm² (pStotavg1cm² and pSnavg1cm²) and 4cm² (pStotavg4cm² and pSnavg4cm²) at the nominal operational frequency of the verification source.

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

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Measurement Conditions

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

DASY Version	cDASY6 Module mmWave	V2.0
Phantom	5G Phantom	
Distance Horn Aperture - plane	10 mm	
XY Scan Resolution	dx, dy = 2.5 mm	
Number of measured planes	2 (10mm, 10mm + λ/4)	
Frequency	30 GHz ± 10 MHz	

Calibration Parameters, 30 GHz

Distance Horn Aperture	Prad¹	Max E-field	Uncertainty	Avg Power Density		Uncertainty
to Measured Plane	(mW)	(V/m)	(k = 2)	n.Re{S}, Re{S}		(k = 2)
				(W/	m2)	
				1 cm ²	4 cm ²	
10 mm	30.3	131	1.27 dB	39.0, 39.4	33.7, 34.1	1.28 dB

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¹ derived from far-field data

DASY Report

Measurement Report for 5G Verification Source 30 GHz, UID 0 -, Channel 30000 (30000.0MHz)

Device under Test Properties

 Name, Manufacturer
 Dimensions [mm]
 IMEI
 DUT Type

 5G Verification Source 30 GHz
 100.0 x 100.0 x 100.0
 SN: 1007

Exposure Conditions

Phantom Section Position, Test Distance [mm] Frequency [MHz], Conversion Factor Channel Number

5G - 5.55 mm Validation band CW 30000.0, 30000

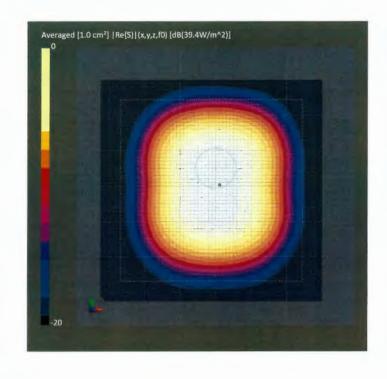
Hardware Setup

PhantomMediumProbe, Calibration DateDAE, Calibration DatemmWave Phantom - 1002AirEUmmWV3 - SN9374, 2018-12-31DAE4ip Sn1602, 2019-10-01

Scan Setup

5G Scan 5G Scan Grid Extents [mm] 60.0 x 60.0 Date 2019-11-19, 08:47 Grid Steps [lambda] 0.25 x 0.25 Avg. Area [cm²] 1.00 Sensor Surface [mm] 5.55 pStot avg [W/m²] 39.4 MAIA pS_n avg [W/m²] 39.0 MAIA not used $E_{peak} [V/m]$ 131 Power Drift [dB] -0.00

Measurement Results







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Client

Sporton

Certificate No: EUmmWV4-9461_Nov19

CALIBRATION CERTIFICATE

Object

EUmmWV4 - SN:9461

Calibration procedure(s)

QA CAL-02.v9, QA CAL-25.v7, QA CAL-42.v2

Calibration procedure for E-field probes optimized for close near field

evaluations in air

Calibration date:

November 5, 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	03-Apr-19 (No. 217-02892/02893)	Apr-20
Power sensor NRP-Z91	SN: 103244	03-Apr-19 (No. 217-02892)	Apr-20
Power sensor NRP-Z91	SN: 103245	03-Apr-19 (No. 217-02893)	Apr-20
Reference 20 dB Attenuator	SN: S5277 (20x)	04-Apr-19 (No. 217-02894)	Apr-20
Reference Probe ER3DV6	SN: 2328	05-Oct-19 (No. ER3-2328_Oct19)	Oct-20
DAE4	SN: 789	14-Jan-19 (No. DAE4-789_Jan19)	Jan-20
Secondary Standards	ID	Check Date (in house)	Scheduled Check
Power meter E4419B	SN: GB41293874	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: MY41498087	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
Power sensor E4412A	SN: 000110210	06-Apr-16 (in house check Jun-18)	In house check: Jun-20
RF generator HP 8648C	SN: US3642U01700	04-Aug-99 (in house check Jun-18)	In house check: Jun-20
Network Analyzer HP 8753E	SN: US37390585	18-Oct-01 (in house check Oct-19)	In house check: Oct-20

Calibrated by:

Name
Function
Signature
Laboratory Technician

Approved by:

Katja Pokovic
Technical Manager

Issued: November 5, 2019

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

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

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:

 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.

EUmmWV4 - SN: 9461 November 5, 2019

DASY - Parameters of Probe: EUmmWV4 - SN:9461

Basic Calibration Parameters

	Sensor X	Sensor Y	Unc (k=2)
Norm $(\mu V/(V/m)^2)$	0.02153	0.02252	± 10.1 %
DCP (mV) ^B	100.0	112.0	
Equivalent Sensor Angle	-60.6	35.0	

Frequency	Target E-Field	Deviation Sensor X	Deviation Sensor Y	Unc (k=2)
GHz	V/m	dB	dB	dB
0.75	77.2	-0.16	0.17	± 0.43 dB
1.8	140.4	0.10	0.13	± 0.43 dB
2	133.0	0.03	0.07	± 0.43 dB
2.2	124.8	0.03	0.04	± 0.43 dB
2.5	123.0	-0.05	-0.09	± 0.43 dB
3.5	256.2	0.07	-0.12	± 0.43 dB
3.7	249.8	0.13	-0.10	± 0.43 dB
6.6	41.8	0.13	0.52	± 0.98 dB
8	48.4	-0.21	-0.20	± 0.98 dB
10	54.4	-0.03	0.00	± 0.98 dB
15	71.5	0.36	-0.25	± 0.98 dB
18	85.3	-0.34	-0.02	± 0.98 dB
26.6	96.9	0.02	0.02	± 0.98 dB
30	92.6	0.19	0.10	± 0.98 dB
35	93.7	-0.29	-0.16	± 0.98 dB
40	91.5	-0.77	-0.57	± 0.98 dB
50	19.6	-0.05	0.12	± 0.98 dB
55	22.4	0.44	0.40	± 0.98 dB
60	23.0	-0.04	-0.04	± 0.98 dB
65	27.4	-0.22	-0.01	± 0.98 dB
70	23.9	0.21	-0.10	± 0.98 dB
75	20.0	0.04	-0.04	± 0.98 dB
75	14.8	0.20	0.35	± 0.98 dB
80	22.5	0.14	0.28	± 0.98 dB
85	22.8	0.01	0.05	± 0.98 dB
90	23.8	0.03	0.03	± 0.98 dB
92	23.9	-0.11	-0.15	± 0.98 dB
95	20.5	-0.19	-0.15	± 0.98 dB
97	24.4	-0.08	-0.10	± 0.98 dB
100	22.6	0.09	-0.01	± 0.98 dB
105	22.7	0.03	0.03	± 0.98 dB
110	19.7	0.06	0.17	± 0.98 dB

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.

EUmmWV4 - SN: 9461 November 5, 2019

DASY - Parameters of Probe: EUmmWV4 - SN:9461

Calibration Results for Modulation Response

UID	Communication System Name		A dB	B dBõV	С	dB D	VR mV	Max dev.	Max Unc ^E
0	CW	X	0.00	0.00	1.00	0.00	111.3	± 3.8 %	(k=2) ± 4.7 %
•		Y	0.00	0.00	1.00	1	88.6		
10352-	Pulse Waveform (200Hz, 10%)	X	1.51	60.00	12.61	10.00	6.0	± 1.5 %	± 9.6 %
AAA	, , ,	Υ	2.31	60.00	12.97	1	6.0	1	
10353-	Pulse Waveform (200Hz, 20%)	X	0.92	60.00	11.74	6.99	12.0	± 0.9 %	± 9.6 %
AAA	, , , ,	Y	14.00	78.00	17.00	1	12.0		
10354-	Pulse Waveform (200Hz, 40%)	X	0.51	60.00	10.67	3.98	23.0	± 1.1 %	± 9.6 %
AAA		Y	0.73	60.00	11.46]	23.0		
10355-	Pulse Waveform (200Hz, 60%)	X	0.33	60.00	9.70	2.22	27.0	± 0.7 %	± 9.6 %
AAA		Y	0.48	60.00	10.79		27.0		
10387-	QPSK Waveform, 1 MHz	X	0.11	101.24	0.22	0.00	22.0	± 1.2 %	± 9.6 %
AAA		Y	2.53	81.91	0.54		22.0		
10388-	QPSK Waveform, 10 MHz	X	1.26	60.00	11.42	0.00	22.0	± 0.7 %	± 9.6 %
AAA		Y	1.20	60.00	11.92		22.0		
10396-	64-QAM Waveform, 100 kHz	Х	1.88	60.00	13.67	3.01	17.0	± 0.6 %	± 9.6 %
AAA		Y	1.94	60.52	13.93		17.0		
10399-	64-QAM Waveform, 40 MHz	Х	2.14	60.00	12.11	0.00	19.0	± 0.7 %	± 9.6 %
AAA		Υ	1.97	60.00	12.44		19.0		
10414-	WLAN CCDF, 64-QAM, 40MHz	Х	3.17	60.00	12.58	0.00	12.0	± 0.8 %	± 9.6 %
AAA		Y	2.90	60.00	12.86		12.0		

Note: For details on all calibrated UID parameters see Appendix

Calibration Results for Linearity Response

Frequency GHz	Target E-Field V/m	Deviation Sensor X dB	Deviation Sensor Y dB	Unc (k=2) dB
0.9	50.0	0.09	-0.09	± 0.2 dB
0.9	100.0	0.04	0.09	± 0.2 dB
0.9	500.0	-0.01	-0.02	± 0.2 dB
0.9	1000.0	0.01	0.01	± 0.2 dB
0.9	1500.0	0.00	0.01	± 0.2 dB
0.9	2000.0	-0.04	0.01	± 0.2 dB

Sensor Frequency Model Parameters (750 MHz - 78 GHz)

	Sensor X	Sensor Y
R (Ω)	42.91	43.78
$R_{0}(\Omega)$	94.99	91.70
L (nH)	0.04383	0.04084
C (pF)	0.2089	0.2543
C _p (pF)	0.1087	0.1140

Sensor Frequency Model Parameters (55 GHz - 110 GHz)

	Sensor X	Sensor Y
R (Ω)	28.99	29.33
$R_{p}(\Omega)$	99.67	97.13
L (nH)	0.03854	0.03920
C (pF)	0.1439	0.1488
C _p (pF)	0.1219	0.1187

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EUmmWV4 - SN: 9461 November 5, 2019

DASY - Parameters of Probe: EUmmWV4 - SN:9461

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	Т6
X	24.1	182.58	36.01	0.00	1.73	5.00	0.00	0.98	1.01
Υ	28.1	195.63	31.32	0.92	3.12	4.97	0.00	1.15	1.01

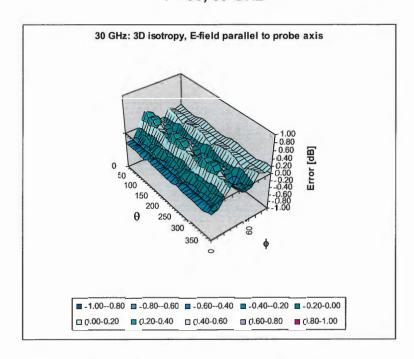
Other Probe Parameters

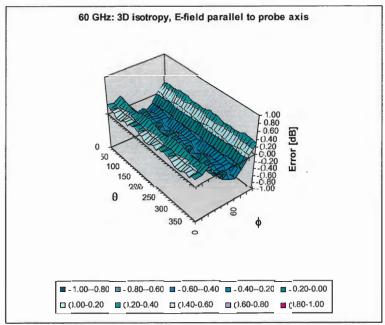
Sensor Arrangement	Rectangular
Connector Angle (°)	68.8
Mechanical Surface Detection Mode	enabled
Optical Surface Detection Mode	disabled
Probe Overall Length	320 mm
Probe Body Diameter	8 mm
Tip Length	23 mm
Tip Diameter	8.0 mm
Probe Tip to Sensor X Calibration Point	1.5 mm
Probe Tip to Sensor Y Calibration Point	1.5 mm

Certificate No: EUmmWV4-9461_Nov19

EUmmWV4 - SN: 9461 November 5, 2019

Deviation from Isotropy in Air f = 30, 60 GHz





Probe isotropy for E_{tot}: probe rotated ϕ = 0° to 360°, tilted from field propagation direction \overline{k} Parallel to the field propagation (ψ =0° - 90°) at 30 GHz: deviation within ± 0.40 dB Parallel to the field propagation (ψ =0° - 90°) at 60 GHz: deviation within ± 0.40 dB





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QA CAL-06.v29

Client

Sporton

Calibration procedure(s)

Accreditation No.: SCS 0108

Certificate No: DAE4-1424_Jan20

	ION CERTIFICATE
Object	DAE4 - SD 000 D04 BM - SN: 1424

Calibration procedure for the data acquisition electronics (DAE)

Calibration date: January 24, 2020

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

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

Calibration Equipment used (M&TE critical for calibration)

Primary Standards	ID#	Cal Date (Certificate No.)	Scheduled Calibration
Keithley Multimeter Type 2001	SN: 0810278	03-Sep-19 (No:25949)	Sep-20
Secondary Standards	ID#	Check Date (in house)	Scheduled Check
Auto DAE Calibration Unit	SE UWS 053 AA 1001	09-Jan-20 (in house check)	In house check: Jan-21
	TOTAL CONTROL OF THE	09-Jan-20 (in house check)	In house check: Jan-21

Name Function Calibrated by: Adrian Gehring Laboratory Technician

Approved by: Sven Kühn Deputy Manager

Issued: January 24, 2020

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Accreditation No.: SCS 0108

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	Υ	Z
High Range	403.154 ± 0.02% (k=2)	403.632 ± 0.02% (k=2)	403.207 ± 0.02% (k=2)
Low Range	3.96939 ± 1.50% (k=2)	3.99672 ± 1.50% (k=2)	3.98379 ± 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	358.0 ° ± 1 °
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Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	199991.78	-2.60	-0.00
Channel X	+ Input	20002.26	0.43	0.00
Channel X	- Input	-19999.39	2.05	-0.01
Channel Y	+ Input	199992.50	-2.06	-0.00
Channel Y	+ Input	20001.82	0.00	0.00
Channel Y	- Input	-20002.88	-1.46	0.01
Channel Z	+ Input	199994.03	-0.25	-0.00
Channel Z	+ Input	20000.92	-0.79	-0.00
Channel Z	- Input	-20003.25	-1.72	0.01

Low Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	2001.27	0.14	0.01
Channel X	+ Input	201.50	-0.01	-0.00
Channel X	- Input	-197.98	0.37	-0.18
Channel Y	+ Input	2001.11	-0.09	-0.00
Channel Y	+ Input	200.95	-0.69	-0.34
Channel Y	- Input	-198.79	-0.52	0.26
Channel Z	+ Input	2001.32	0.19	0.01
Channel Z	+ Input	200.32	-1.11	-0.55
Channel Z	- Input	-199.90	-1.46	0.74

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	-1.25	-2.37
	- 200	2.47	1.18
Channel Y	200	-13.29	-13.42
	- 200	12.27	12.19
Channel Z	200	-9.08	-9.03
	- 200	7.21	6.68

3. Channel separation

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

	Input Voltage (mV)	Channel X (μV)	Channel Y (μV)	Channel Z (μV)
Channel X	200	3	3.50	-3.56
Channel Y	200	8.47	-	3.59
Channel Z	200	9.31	6.86	-

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	15957	15898
Channel Y	15884	16568
Channel Z	15879	14410

5. Input Offset Measurement

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

Input $10M\Omega$

	Average (μV)	min. Offset (μV)	max. Offset (μV)	Std. Deviation (μV)
Channel X	0.91	-0.44	1.60	0.34
Channel Y	0.05	-0.80	0.98	0.40
Channel Z	-0.65	-1.82	0.20	0.32

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