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

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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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

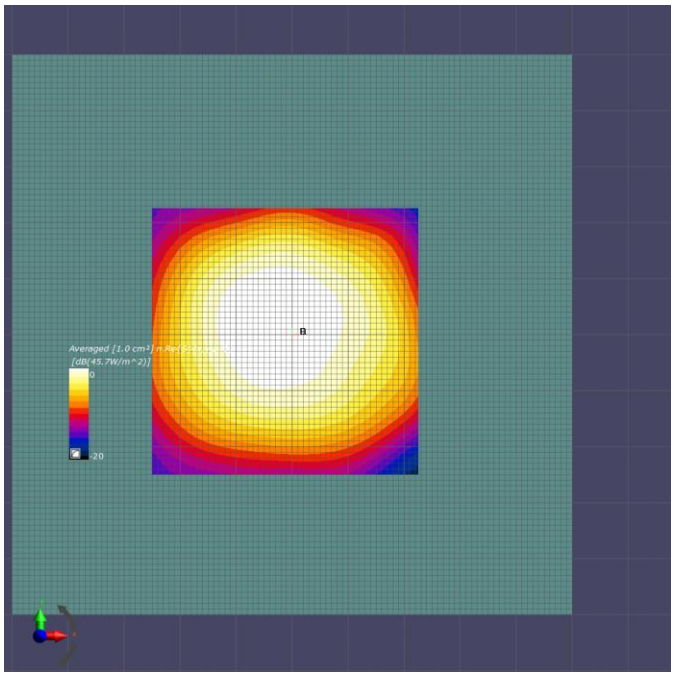
	5G Scan
Grid Extents [mm]	60.0 x 60.0
Grid Steps [lambda]	0.25 x 0.25
Sensor Surface [mm]	5.55
MAIA	MAIA not used

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: 5G-Veri30-1009_May19

CALIBRATION CERTIFICATE

Object	5G Verification Source 30 GHz - SN: 1009
Calibration procedure(s)	QA CAL-45.v2 Calibration procedure for sources in air above 6 GHz
Calibration date:	May 03, 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
Reference Probe EUmmWV3	SN: 9374	31-Dec-18 (No. EUmmWV3-9374_Dec18)	Dec-19
DAE4	SN: 1215	22-Feb-19 (No. DAE4-1215_Feb19)	Feb-20

Secondary Standards	ID #	Check Date (in house)	Scheduled Check

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

Issued: May 6, 2019

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 taking into account the 0.2dB horn loss. (2) 30, 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 + $\lambda/4$) with a vectorial E-field probe. 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.
- *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 cm^2 ($pS_{tot}avg1cm^2$ and $pS_navg1cm^2$) and $4cm^2$ ($pS_{tot}avg4cm^2$ and $pS_navg4cm^2$) 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%.

Measurement Conditions

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

DASY Version	cDASY6 Module mmWave	V1.6
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 to Measured Plane	***Prad1 (mW)***	**Max E-field (V/m)**	Uncertainty (k = 2)	Avg Power Density n.Re{S}, |Re{S}| (W/m2)		Uncertainty (k = 2)
				1 cm^2	4 cm^2	
10 mm	44.9	**154**	1.27 dB	**54.4, 54.9**	**48.0, 48.5**	1.28 dB

[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: 1009	-

Exposure Conditions

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

Hardware Setup

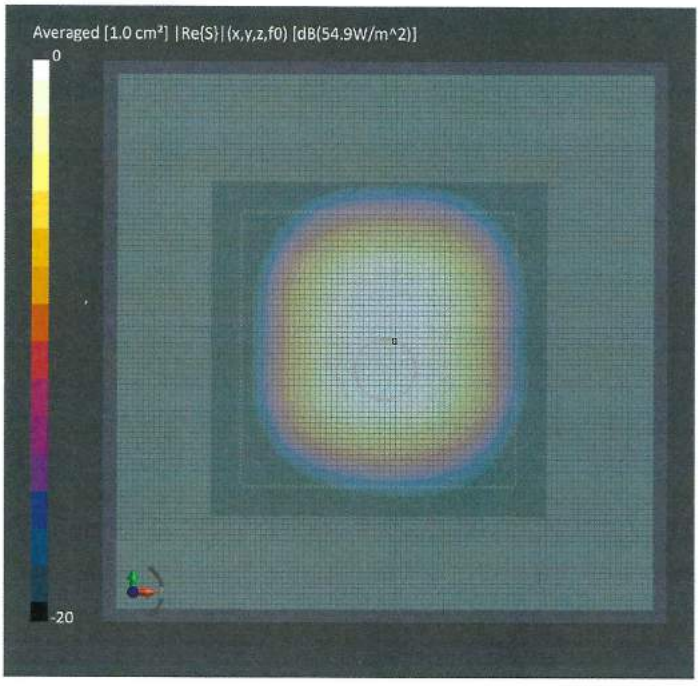
Phantom	Medium	Probe, Calibration Date	DAE, Calibration Date
5G Phantom	Air	EUmmWV3 - SN9374, 2018-12-31	DAE4 Sn1215, 2019-02-22

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	2019-05-03, 18:49
Avg. Area [cm^2]	1.00
pS_{tot} avg [W/m^2]	54.9
pS_n avg [W/m^2]	54.4
E_{peak} [V/m]	154
Power Drift [dB]	-0.02



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Accreditation No.: SCS 0108

Client **Sporton**

Certificate No: DAE4-1424_Jan19

CALIBRATION CERTIFICATE

Object	DAE4 - SD 000 D04 BM - SN: 1424
Calibration procedure(s)	QA CAL-06.v29 Calibration procedure for the data acquisition electronics (DAE)
Calibration date:	January 24, 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: January 24, 2019

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	403.169 ± 0.02% (k=2)	403.646 ± 0.02% (k=2)	403.220 ± 0.02% (k=2)
Low Range	3.96914 ± 1.50% (k=2)	3.99823 ± 1.50% (k=2)	3.98397 ± 1.50% (k=2)

Connector Angle

Connector Angle to be used in DASY system	358.5 ° ± 1 °

Appendix (Additional assessments outside the scope of SCS0108)

1. DC Voltage Linearity

High Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	199996.59	1.31	0.00
Channel X	+ Input	20002.78	1.36	0.01
Channel X	- Input	-20000.18	1.59	-0.01
Channel Y	+ Input	199995.17	-0.36	-0.00
Channel Y	+ Input	20001.06	-0.38	-0.00
Channel Y	- Input	-20003.62	-1.81	0.01
Channel Z	+ Input	199995.00	-0.39	-0.00
Channel Z	+ Input	20001.56	0.15	0.00
Channel Z	- Input	-20003.00	-1.20	0.01

Low Range		Reading (μV)	Difference (μV)	Error (%)
Channel X	+ Input	2001.17	0.29	0.01
Channel X	+ Input	201.79	0.63	0.31
Channel X	- Input	-198.19	0.59	-0.30
Channel Y	+ Input	2000.66	-0.14	-0.01
Channel Y	+ Input	200.33	-0.76	-0.38
Channel Y	- Input	-199.71	-0.96	0.48
Channel Z	+ Input	2001.09	0.32	0.02
Channel Z	+ Input	200.43	-0.62	-0.31
Channel Z	- Input	-199.65	-0.84	0.42

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	-0.54	-1.68
	- 200	3.49	1.62
Channel Y	200	-13.30	-13.81
	- 200	11.70	11.45
Channel Z	200	-8.34	-8.30
	- 200	6.94	6.84

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	-	3.10	-3.67
Channel Y	200	8.78	-	3.49
Channel Z	200	10.12	6.21	-

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	15959	16030
Channel Y	15879	16111
Channel Z	15879	14387

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	1.30	0.29	2.26	0.40
Channel Y	-0.51	-2.99	0.68	0.51
Channel Z	-0.39	-1.46	0.68	0.42

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