Test Report 20-1-0014002T01a

Number of pages:	31	**Date of Report:**	2020-Apr-14
Testing company:	CETECOM GmbH Im Teelbruch 116 45219 Essen Germany Tel. + 49 (0) 20 54 / 95 19-0 Fax: + 49 (0) 20 54 / 95 19-150	**Applicant:**	Husqvarna AB
Test Object / Tested Device(s):	**Application Board Type 1, Bluetooth Low-Energy Module HQ-BLE-1**		
Listing FCC ID:	ZASHQ-BLE-1C	**ISED:**	23307-HQBLE1C
Testing has been carried out in accordance with:	**Title 47 CFR, Chapter I FCC Regulations, Subchapter A** Subpart C: §15.247 (DTS) , **RSS-247, Issue 2 (DTS) RSS-Gen., Issue 5** Deviations, modifications or clarifications (if any) to above mentioned documents are written in each section under "Test method and limit".section under "Test method and limit".		
Tested Technology:	Bluetooth Low Energy		
Test Results:	☒ **The EUT complies with the requirements in respect of all parameters subject to the test.** The test results relate only to devices specified in this document		

Signatures:

Digital signiert von: Christian Lorenz
Datum: 2020.04.14 16:27:53 + 02'00'

Dipl.-Ing. Christian Lorenz
Senior Test Manager
Authorization of test report

Digital signiert von: Muhammad Faiq Khan
Datum: 2020.04.14 16:22:24 + 02'00'

B.Sc. M. Faiq Khan
Test manager
Responsible of test report

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1 General information

1.1 Disclaimer and Notes

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Also we refer on special conditions which the applicant should fulfill according §2.927 to §2.948, special focus regarding modification of the equipment and availability of sample equipment for market surveillance tests.

1.1. Summary of Test Results

The EUT integrates a BTLE transmitter. Other implemented wireless technologies were not considered within this test report.

Test case	Reference Clause FCC ☒	Reference Clause ISED ☒	Page	Remark	Result
Duty-Cycle	§15.35(c)	RSS-Gen Issue 5, §8.2	10		PASSED
Minimum Emission Bandwidth 6 dB	§15.247 5.2(a)	RSS-247, §5.2(a) RSS-Gen Issue 5, §6.7	13		PASSED
Occupied Channel Bandwidth 99%	2.1049(h)	RSS-Gen Issue 5, §6.7	16		PASSED
Peak output power (Sweep)	§15.247(b)(3)	RSS-247, §5.4(d)	11		PASSED
Transmitter Peak output power radiated	§15.247(b)(4)(c)	RSS-247, §5.4(d)	--		NP
Emissions in non-restricted frequency bands	§15.247(d)	RSS-247, §5.5	14		PASSED
Radiated Band-Edge emissions	§15.205(b) §15.247(d)	RSS-Gen: Issue 5 §8.9, §8.10 RSS-247, §5.5	25		PASSED
Power spectral density	§15.247(e)	RSS-247, §5.2(b)	12		PASSED
Radiated field strength emissions below 30 MHz	§15.205(a) §15.209(a)	RSS-Gen: Issue 5 §8.9 Table 6	17		PASSED
Radiated field strength emissions 30 MHz – 1 GHz	§15.209 §15.247(d)	RSS-Gen: Issue 5 §8.9 Table 5 RSS-247, §5.5	21		PASSED
Radiated field strength emissions above 1 GHz	§15.209(a) §15.247(d)	RSS-Gen: Issue 5: §8.9 Table 5+6 RSS-247, §5.5	23		PASSED
AC-Power Lines Conducted Emissions	§15.207	RSS-Gen Issue 5, §8.8, Table 4	--		Not relevant

PASSED The EUT complies with the essential requirements in the standard.
FAILED The EUT does not comply with the essential requirements in the standard.
NP The test was not performed by the CETECOM Laboratory.

1.2. Summary of Test Methods

Test case	Test method
Duty-Cycle	ANSI C63.10-2013, §11.6(b)
Minimum Emission Bandwidth 6 dB	ANSI C63.10-2013, §6.9.2, §11.8
Occupied Channel Bandwidth 99%	ANSI C63.10-2013, §6.9.3
Peak output power (Sweep)	ANSI C63.10-2013, §11.9
Power spectral density	ANSI C63.10-2013, §11.10
Emissions in non-restricted frequency bands	ANSI C63.10-2013, §11.11, §6.10.5
Radiated Band-Edge emissions	ANSI C63.10-2013; "Marker-Delta method", §6.10.5, §11.13
Transmitter Peak output power radiated	Result calculated with measured conducted RF-power value and stated/measured antenna gain for band of interest
Radiated field strenght emissions below 30 MHz	ANSI C63.10-2013 §6.3, §6.4
Radiated field strenght emissions 30 MHz- 1 GHz	ANSI C63.4-2014 §8.2.3, ANSI C63.10-2013 §6.3, § 6.5
Radiated field strenght emissions above 1 GHz	ANSI C63.4-2014 §8.3, ANSI C63.10-2013 §6.3, § 6.6
AC-Power Lines Conducted Emissions	ANSI C63.4-2014 §7, ANSI C63.10-2013 §6.2

And reference also to Test methods in KDB558074

2 Administrative Data

2.1 Identification of the Testing Laboratory

Company name:	CETECOM GmbH
Address:	Im Teelbruch 116 45219 Essen - Kettwig Germany
Responsible for testing laboratory:	Volker Wittmann
Accreditation scope:	DAkkS Webpage
Test location:	CETECOM GmbH; Im Teelbruch 116 ;45219 Essen - Kettwig

2.2 General limits for environmental conditions

Temperature:	22±2° C
Relative. humidity:	45±15% rH
Barometric Pressure:	1001 hPa

2.3 Test Laboratories sub-contracted

Company name:

2.4 Organizational Items

Order No.:	20-1-00140
Responsible test manager:	B.Sc. M. Faiq Khan
Project Leader:	Dipl.-Ing. Ninovic Perez
Receipt of EUT:	17-Feb-20
Date(s) of test:	17-Mar-20 – 23-Mar-20
Version of template:	13.02

2.5 Applicant’s details

Applicant’s name:	Husqvarna AB
Address:	Drottninggatan 2 56182 Huskvarna Sweden
Contact Person:	Therese Berg
Contact Person’s Email:	therese.berg@husqvarnagroup.com

2.6 Manufacturer’s details

Manufacturer’s name:	see Applicant’s details
Address:	see Applicant’s details

2.7 EUT: Type, S/N etc. and short descriptions used in this test report

Short description*)	PMT Sample No.	EUT	Type	S/N	HW status	SW status
EUT A	Sample 02 (Radiated)	Application Board Type 1	Bluetooth Low-Energy Module HQ-BLE-1	19372547050030	591 10 05	596 24 44
EUT B	Sample 03 (Conducted)	Application Board Type 1	Bluetooth Low-Energy Module HQ-BLE-1	19372547050195	591 10 05	596 24 44

*) EUT short description is used to simplify the identification of the EUT in this test report.

2.8 Auxiliary Equipment (AE): Type, S/N etc. and short descriptions

Short description*)	PMT Sample No.	Auxiliary Equipment	Type	S/N	HW status	SW status
AE1	Sample 06	Cable	Cable Harness	--	--	--
AE2	--	DELL Laptop	Latitude E6420	DPN: VVF52 A01	Intel Core i5	Windows 7

*) AE short description is used to simplify the identification of the auxiliary equipment in this test report.

2.9 Connected cables

Cable short description *)	Cable type	Connectors	Length
CAB 1	Cable Harness	--	1 m
CAB 2			

*) AE short description is used to simplify the identification of the auxiliary equipment in this test report.

2.10 EUT set-ups

set-up no.*)	Combination of EUT and AE	Description
1	EUTA + AE1 + (AE2)	Used for Radiated measurements. AE2 was only used to set the EUT into respective operating mode and was removed during the measurement.
2	EUTB + AE1 + AE2	Used for Conducted measurements

*) EUT set-up no. is used to simplify the identification of the EUT set-up in this test report.

2.11 EUT operation modes

EUT operating mode no.*)	Operating modes	Additional information
op. 1	BTLE_TX-Mode	With help of special test firmware a continuous traffic mode could be established on certain channels. We refer to applicants information/papers for details about necessary commands. Tests on advertising channels have been performed.

*) EUT operating mode no. is used to simplify the test report.

2.12 Software

SW	Payload Model	Developer	Version	Stotrage
HCI Tester	HCI packets	Texas Instruments	3.0.0.37	AE2

3 Equipment under test (EUT)

3.1 General Data of Main EUT as Declared by Applicant

Product name	Application Board Type 1		
Kind of product	Bluetooth Low-Energy Module HQ-BLE-1		
Firmware	☒ for normal use	☒ Special version for test execution	
	☐ AC Mains	-	
	☒ DC Mains	**18** V DC	
	☐ Battery	-	
Operational conditions	T_{nom} = 22 °C	T_{min} = -5 °C	T_{max} = 70 °C
EUT sample type	**Pre-Production**		
Weight			
Size			
Interfaces/Ports	1 UART, 1 USB and 2 LAN interfaces		
For further details refer Applicants Declaration & following technical documents			
For further details regarding radio parameters, please refer to Bluetooth Core Specification			

3.2 Detailed Technical data of Main EUT as Declared by Applicant

Frequency Band	2.4 GHz ISM Band (2400 MHz - 2483.5 MHz)	
Number of Channels (USA/Canada -bands)	40 (37 Hopping + 3 Advertising)	
Nominal Channel Bandwidth	2 MHz	
Type of Modulation | Data Rate	☒ GFSK | 1 Mbit / s	☐ GFSK | 2 Mbit / s
	☐ GFSK | 500 kbit / s	☐ GFSK | 125 kbit / s
Other wireless options	☐ a/n/ac mode ☐ b/g/n mode ☐ Bluetooth EDR (not tested within this report) ☐ Cellular transceiver (2G/3G/4G/5G/GPS, not tested in this report)	
Max. Conducted Output Power (Measured RMS Power)	GFSK **5.1** dBm	
EIRP Power (Calculated EIRP)	GFSK **5.1** dBm + **3** dBi = **8.1** dBm	
Antenna Type(s)	PCB	
Antenna Gain(s)	3 dBi	
FCC label attached	☒	
Test firmware / software and storage location	AE2	

For further details refer Applicants Declaration & following technical documents		
Description of Reference Document (supplied by applicant)	**Version**	**Total Pages**
Operational description BT solution	**2020-01-23**	**7**

3.3 Modifications on Test sample

Additions/deviations or exclusions	

4 Measurements

4.1 Duty-Cycle

Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

The necessary duty-cycle correction factor is determined on nominal conditions on middle channel only. It is assumed that no noticeable changes occur when tested on other channels or climatic conditions.

EUT settings
The EUT was instructed to send with maximum power (if adjustable) according applicants instructions.
Different modulation characteristics have been checked, e.g. data rates which EUT can operate.

A special firmware program is used for test purposes. In opposite to normal operating mode a higher duty-cycle is set in order to facilitate the measurements. This is maximized at the extent possible.

The necessary duty-cycle correction factor is determined on nominal conditions on one channel in each operable frequency-band. It is assumed that no noticeable changes occur when tested on other channels or climatic conditions. The Duty-Cycle was constant, means without variations.

Formula to calculate Duty-Cycle:

Duty cycle calculations: $x = {TX_{ON}}/{(TX_{ON} + TX_{OFF})}$	Duty cycle factor: DC=	Regarding power: $10 * log({1}/{x})$ dB Regarding field strength: $20 * log({1}/{x})$ dB

4.1.1 Result

☐ The results were corrected in order to evaluate for worst-case result each time when average values are necessary for example average radiated emissions or similar
☒ No correction necessary: Duty-Cycle > 98%

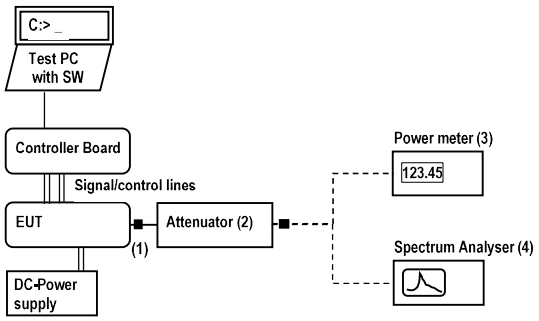
Duty-Cycle Correction [dB]
0

4.2 Peak output power (Sweep)

4.2.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is first attenuated (2) then connected to power meter (3) or spectrum-analyzer (4) for RF-conducted measurements. The specific attenuation loss is determined prior to the measurement within a set-up attenuation measurement. These are then taken into account by correcting the measurement readings.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

Measurement is made using Rohde & Schwarz TS8997 test system.

Test method	Maximum peak conducted output power(RBW = DTS-bandwidth of the signal)
Remarks	In Compliance

The measurement was performed in non-hopping transmission mode with the carrier set to lowest/middle and highest channel.

EUT settings
The EUT was instructed to send with maximum power (if adjustable) according applicants instructions.
Different modulation characteristics have been checked, e.g. data rates which EUT can operate

4.2.2 Limit

Frequency Range [MHz]	Limit [W]	Limit [dBm]	Detector	RBW / VBW [MHz]
2400 - 2483.5	**1**	**30**	**MaxPeak**	**2 / 10**

4.2.3 Result

Mode	Channel	Frequency [MHz]	Max Peak Power [dBm]	Result
GFSK | 1 Mbit / s	0	**2402**	**5.1**	**Pass**
GFSK | 1 Mbit / s	20	**2442**	**4.7**	**Pass**
GFSK | 1 Mbit / s	39	**2480**	**4.7**	**Pass**

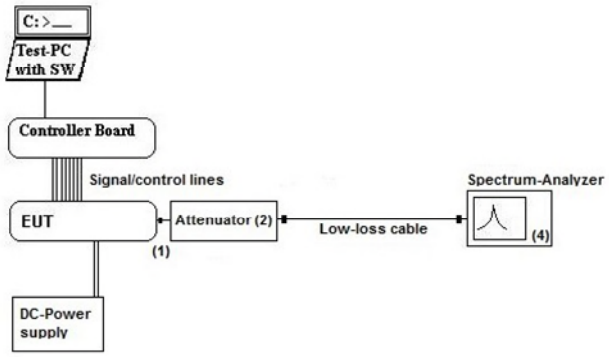
Remark: for more information and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1** .

4.3 Power spectral density

4.3.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is first attenuated (2) then connected to spectrum-analyzer (4) for RF-conducted measurements. The specific attenuation loss is determined prior to the measurement within a set-up attenuation measurement. These are then taken into account by correcting the measurement readings of the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

Measurement is made using Rohde & Schwarz TS8997 test system.

Test method	PKPSD-Method
Remarks	In Compliance

EUT settings
The EUT was instructed to send with maximum power (if adjustable) according applicants instructions.

4.3.2 Limit

Limit [dBm] at 3 kHz	Detector [MaxHold]	RBW / VBW [kHz]
≤ 8	Peak	3 / 10

4.3.3 Result

Mode	Channel	Frequency [MHz]	PSD [dBm]	Result
GFSK | 1 Mbit / s	0	2402	0.681	Pass
GFSK | 1 Mbit / s	20	2442	-0.136	Pass
GFSK | 1 Mbit / s	39	2480	-0.085	Pass

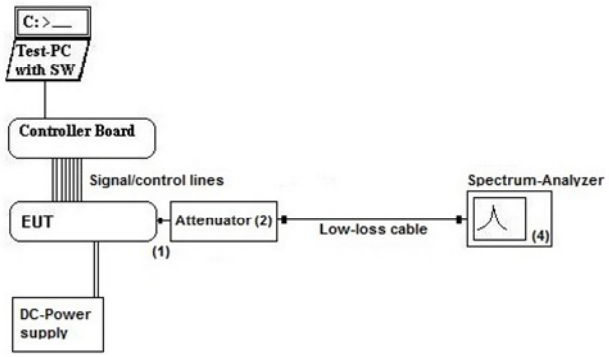
Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

4.4 Minimum Emission Bandwidth 6 dB

4.4.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is first attenuated (2) then connected to spectrum-analyzer (4) for RF-conducted measurements. The specific attenuation loss is determined prior to the measurement within a set-up attenuation measurement. These are then taken into account by correcting the measurement readings of the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

Measurement is made using Rohde & Schwarz TS8997 test system.

4.4.2 Limit

Limit [kHz]	Detector [MaxHold]	RBW / VBW [kHz]
≥ 500	**MaxPeak**	**100 / 300**

4.4.3 Result

Mode	Channel	Frequency [MHz]	6 dB bandwidth [MHz]	Result
GFSK | 1 Mbit / s	0	2402	0.732674	Pass
GFSK | 1 Mbit / s	20	2442	0.752476	Pass
GFSK | 1 Mbit / s	39	2480	0.772278	Pass

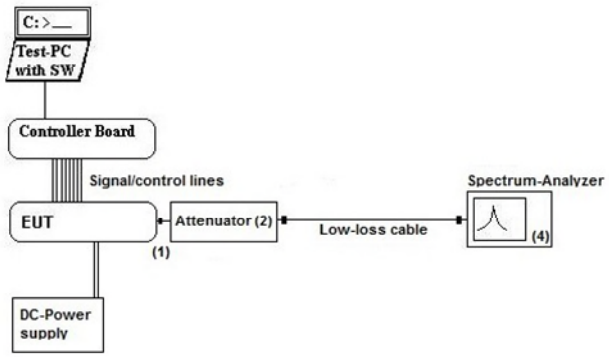
Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

4.5 Emissions in non-restricted frequency bands

4.5.1 Description of the general conducted test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is first attenuated (2) then connected to spectrum-analyzer (4) for RF-conducted measurements. The specific attenuation loss is determined prior to the measurement within a set-up attenuation measurement. These are then taken into account by correcting the measurement readings of the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

Measurement is made using Rohde & Schwarz TS8997 test system.

The measurements were performed with the RBW set to 100 kHz & maximum carrier level was indicated with MAX-Hold positive peak detector using markers.

Then using RBW 100 kHz & spectrum analyzer span from 30 MHz to 26 GHz in three steps spurious emissions were measured with MAX-Hold positive peak detector.

The sweep time set as long as necessary to capture the full signal burst per hopping channel. The burst on-period is captured by setting appropriate markers in the rising and falling edges.

EUT settings
The EUT was instructed to send with maximum power (if adjustable) according applicants instructions.
Different modulation characteristics have been checked e.g. data rates which EUT can operate.

4.5.2 Limit

Frequency Range [MHz]	Limit [dBc]
0.15 – 25000	**-20**

4.5.3 Result

Maximum Level Peak [dBc]

Mode	Channel	Frequency [MHz]	Result
GFSK | 1 Mbit / s	0	2402	Pass
GFSK | 1 Mbit / s	20	2442	Pass
GFSK | 1 Mbit / s	39	2480	Pass

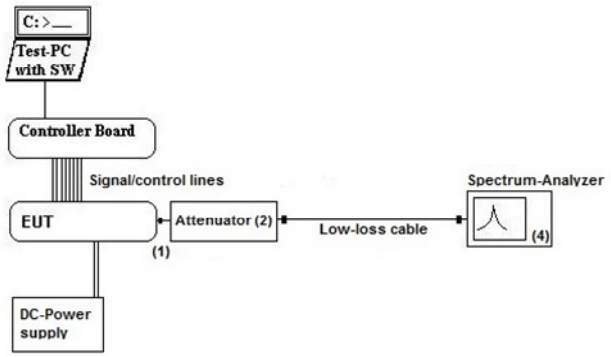
Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

4.6 Occupied Channel Bandwidth 99%

4.6.1 Description of the general test setup and methodology, see below example:

The EUT's RF-signal is coupled out by a suitable antenna coupling connector (1). The signal is first attenuated (2) then connected to spectrum-analyzer (4) for RF-conducted measurements. The specific attenuation loss is determined prior to the measurement within a set-up attenuation measurement. These are then taken into account by correcting the measurement readings of the spectrum-analyzer.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

Measurement is made using Rohde & Schwarz TS8997 test system.

4.6.2 Limit

When the occupied bandwidth limit is not stated in the applicable reference measurement method, the transmitted signal bandwidth shall be reported as the 99% emission bandwidth, as calculated or measured.

4.6.3 Result

Mode	Channel	Frequency [MHz]	99% Occupied bandwidth [MHz]
GFSK | 1 Mbit / s	0	2402	1.0600
GFSK | 1 Mbit / s	20	2442	1.0650
GFSK | 1 Mbit / s	39	2480	1.0500

Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

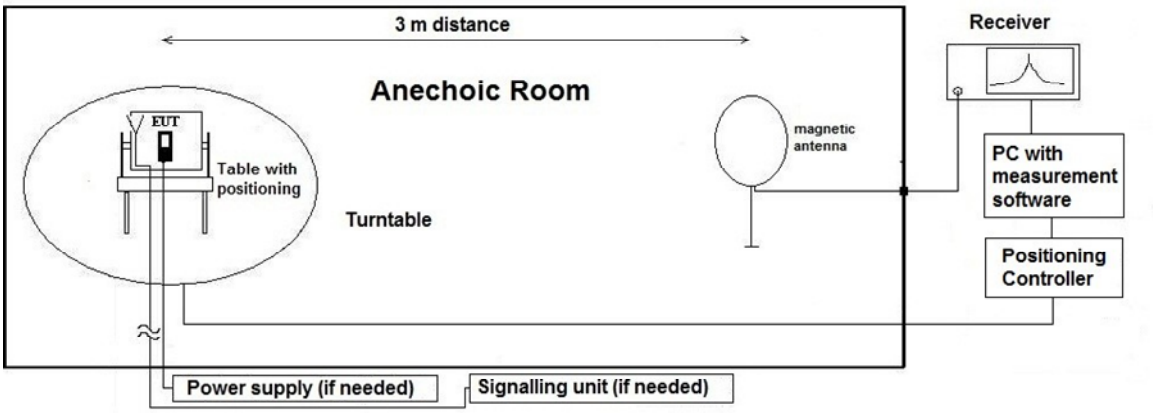
4.7 Radiated field strength emissions below 30 MHz

4.7.1 Description of the general test setup and methodology, see below example:

Evaluating the radiated field emissions are done first by an exploratory emission measurement and a final measurement for most critical frequencies determined.

The loop antenna was placed at 1 m height above ground plane and 3 m measurement distance from set-up for investigations. Because of reduced measurement distance, correction data were applied, as stated in chapter "General Limit - Radiated field strength emissions below 30 MHz". The tests are performed in the semi anechoic room recognized by the regulatory commission.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

Exploratory, preliminary measurements
The EUT and its associated accessories are placed on a non-conductive position manipulator (tipping device) of 0.8 m height which is placed on the turntable. By rotating the turntable (step 90°, range 0°to 360°) and the EUT itself either on 3-orthogonal axis (portable equipment) or 2-orthogonal axis (defined operational position of EUT), the emission spectrum was recorded.

The loop antenna was moved at least to 2-perpendicular axes (antenna vector in direction of EUT and parallel to EUT) in order to maximize the emissions. The results are documented in a diagram. Critical frequencies (low margin to limit) are saved within a data reduction table for further investigations. If various operating modes are supported, further investigations are made to find the worst-case. Also the interconnection cables and equipment position were varied in order to maximize the emissions.

Final measurement on critical frequencies
Based on the exploratory measurements, the most critical frequencies are re-measured by maintaining the EUT's worst-case operation mode, cable position, etc.

First a frequency zoom around the critical frequency is done to locate the frequency more precisely. After this step, for all identified critical frequencies, the maximum peak was determined.

Following parameters were varied: the turntable angle continuously in the range 0 to 360 degree, the EUT itself either over 3-orthogonal axis (not defined usage position) or 2-orthogonal axis (defined usage position).

On the determined worst-case position, a final measurement with necessary bandwidth and detector according standard has been carried out.

Formula:

$E_C = E_R + AF + C_L + D_F - G_A$

$M = L_T - E_C$

AF = Antenna factor
C_L = Cable loss
D_F = Distance correction factor (if used)
E_C = Electrical field – corrected value
E_R = Receiver reading
G_A = Gain of pre-amplifier (if used)
L_T = Limit
M = Margin

All units are dB-units, positive margin means value is below limit.

Correction factors due to reduced meas. distance (f< 30 MHz):

The used correction factors when the measurement distance is reduced compared to regulatory measurement distance, are calculated according Extrapolation formulas valid for EUT's with maximum dimension of 0.625xLambda. Formula 2+3+4 as presented in ANSI C63.10, Chapter 6.4.4 are used for the calculations of proper extrapolation factors

Frequency -Range	f [kHz/MHz]	Lambda [m]	Far-Field Point [m]	Distance Limit accord. 15.209 [m]		1st Condition (dmeas< Dnear-field)	2'te Condition (Limit distance bigger dnear-field)	Distance Correction accord. Formula
kHz	9.00E+03	33333.33	5305.17	300		fullfilled	not fullfilled	-80.00
	1.00E+04	30000.00	4774.65			fullfilled	not fullfilled	-80.00
	2.00E+04	15000.00	2387.33			fullfilled	not fullfilled	-80.00
	3.00E+04	10000.00	1591.55			fullfilled	not fullfilled	-80.00
	4.00E+04	7500.00	1193.66			fullfilled	not fullfilled	-80.00
	5.00E+04	6000.00	954.93			fullfilled	not fullfilled	-80.00
	6.00E+04	5000.00	795.78			fullfilled	not fullfilled	-80.00
	7.00E+04	4285.71	682.09			fullfilled	not fullfilled	-80.00
	8.00E+04	3750.00	596.83			fullfilled	not fullfilled	-80.00
	9.00E+04	3333.33	530.52			fullfilled	not fullfilled	-80.00
	1.00E+05	3000.00	477.47			fullfilled	not fullfilled	-80.00
	1.25E+05	2400.00	381.97			fullfilled	not fullfilled	-80.00
	2.00E+05	1500.00	238.73			fullfilled	fullfilled	-78.02
	3.00E+05	1000.00	159.16			fullfilled	fullfilled	-74.49
	4.00E+05	750.00	119.37			fullfilled	fullfilled	-72.00
	4.90E+05	612.24	97.44			fullfilled	fullfilled	-70.23
	5.00E+05	600.00	95.49	30		fullfilled	not fullfilled	-40.00
	6.00E+05	500.00	79.58			fullfilled	not fullfilled	-40.00
	7.00E+05	428.57	68.21			fullfilled	not fullfilled	-40.00
	8.00E+05	375.00	59.68			fullfilled	not fullfilled	-40.00
	9.00E+05	333.33	53.05			fullfilled	not fullfilled	-40.00
MHz	1.00	300.00	47.75			fullfilled	not fullfilled	-40.00
	1.59	188.50	**30.00**			fullfilled	not fullfilled	-40.00
	2.00	150.00	23.87			fullfilled	fullfilled	-38.02
	3.00	100.00	15.92			fullfilled	fullfilled	-34.49
	4.00	75.00	11.94			fullfilled	fullfilled	-32.00
	5.00	60.00	9.55			fullfilled	fullfilled	-30.06
	6.00	50.00	7.96			fullfilled	fullfilled	-28.47
	7.00	42.86	6.82			fullfilled	fullfilled	-27.13
	8.00	37.50	5.97			fullfilled	fullfilled	-25.97
	9.00	33.33	5.31			fullfilled	fullfilled	-24.95
	10.00	30.00	4.77			fullfilled	fullfilled	-24.04
	10.60	28.30	4.50			fullfilled	fullfilled	-23.53
	11.00	27.27	4.34			fullfilled	fullfilled	-23.21
	12.00	25.00	3.98			fullfilled	fullfilled	-22.45
	13.56	22.12	3.52			fullfilled	fullfilled	-21.39
	15.00	20.00	3.18			fullfilled	fullfilled	-20.51
	15.92	18.85	**3.00**			fullfilled	fullfilled	-20.00
	17.00	17.65	2.81			not fullfilled	fullfilled	-20.00
	18.00	16.67	2.65			not fullfilled	fullfilled	-20.00
	20.00	15.00	2.39			not fullfilled	fullfilled	-20.00
	21.00	14.29	2.27			not fullfilled	fullfilled	-20.00
	23.00	13.04	2.08			not fullfilled	fullfilled	-20.00
	25.00	12.00	1.91			not fullfilled	fullfilled	-20.00
	27.00	11.11	1.77			not fullfilled	fullfilled	-20.00
	29.00	10.34	1.65			not fullfilled	fullfilled	-20.00
	30.00	10.00	1.59			not fullfilled	fullfilled	-20.00

4.7.2 Limit

Radiated emissions limits, (3 meters)					
Frequency Range [MHz]	Limit [µV/m]	Limit [dBµV/m] *	Distance [m]	Detector	RBW [kHz]
0.009 – 0.09	2400 / f [kHz]	67.6 – 20Log(f) (kHz)	300	Pk & Avg	0.2
0.09 – 0.11	2400 / f [kHz]	67.6 – 20Log(f) (kHz)	300	Quasi peak	0.2
0.11 – 0.15	2400 / f [kHz]	67.6 – 20Log(f) (kHz)	300	Pk & Avg	0.2
0.15 – 0.49	2400 / f [kHz]	67.6 – 20Log(f) (kHz)	300	Pk & Avg	9
0.49 – 1.705	24000 / f [kHz]	87.6 – 20Log(f) (kHz)	30	Quasi peak	9
1.705 - 30	30	29.5	30	Quasi peak	9

*Remark: In Canada same limits apply, just unit reference is different

4.7.3 Result

Diagram	Channel	Mode	Maximum Level [dBµV/m] Frequency Range 0.009 – 30MHz	Result
2.01a	0	TX mode - GFSK | 1 Mbit/s - Standing	20.09	Pass
2.01b	0	TX mode - GFSK | 1 Mbit/s - Laying	22.01	Pass
2.02a	20	TX mode - GFSK | 1 Mbit/s - Standing	21.46	Pass
2.02b	20	TX mode - GFSK | 1 Mbit/s - Laying	21.17	Pass
2.03a	39	TX mode - GFSK | 1 Mbit/s - Standing	22.79	Pass
2.03b	39	TX mode - GFSK | 1 Mbit/s - Laying	22.15	Pass

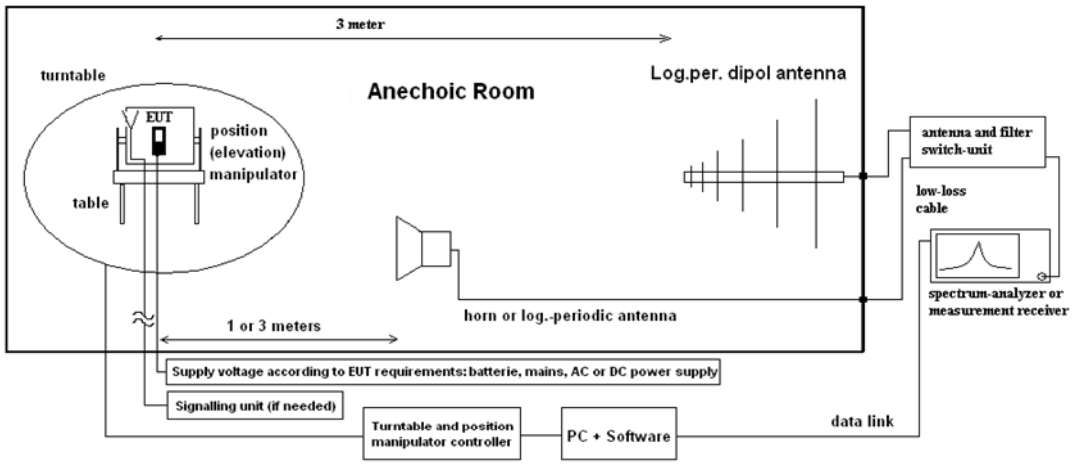
Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

4.8 Radiated field strength emissions 30 MHz – 1 GHz

4.8.1 Description of the general test setup and methodology, see below example:

Evaluating the emissions have to be done first by an exploratory emissions measurement and a final measurement for most critical frequencies. The tests are performed in a CISPR 16-1-4:2010 compliant fully anechoic room (FAR) recognized by the regulatory commission. The measurement distance was set to 3 meter for frequencies up to 18 GHz and 2 meter above 18 GHz. A logarithmic periodic antenna is used for the frequency range 30 MHz to 1 GHz. Horn antennas are used for frequency range 1 GHz to 40 GHz. The EUT is aligned within 3 dB beam width of the measurement antenna with three orthogonal axis measurements on the EUT.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

Exploratory, preliminary measurements
The EUT and its associated accessories are placed on a non-conductive position manipulator (tipping device) of 0.8 m height which is placed on the turntable. By rotating the turntable (range 0° to 360°, step 90°) and the EUT itself either on 3-orthogonal axis (portable equipment) or 2-orthogonal axis (defined operational position of EUT) the emission spectrum and it's characteristics was recorded with an EMI-receiver, broadband antenna and software.

Measurement antenna: horizontal and vertical, heights: 1,0 m and 1,82 m as worst-case determined by an exploratory emission measurements. The results are documented in a diagram. Critical frequencies (low margin to limit) are saved within a table for further investigations. If various operating modes are supported, further investigations are made to find the worst-case of them. Also the interconnection cables and equipment position were varied in order to maximize the emissions.

Final measurement on critical frequencies
Based on the exploratory measurements, the most critical frequencies are re-measured by main-taining the EUT's worst-case operation mode, cable position, etc. either on 10m OATS or 3m semi-anechoic room.
First a frequency zoom around the critical frequency is done to locate the frequency more precisely. After this step, for all identified critical frequencies, the maximum peak was determined.

Following parameters were varied: the turntable angle continuously in the range 0 to 360 degree, the EUT itself either over 3-orthogonal axis (not defined usage position) or 2-orthogonal axis (defined usage position). The measurement antenna height between 1 m and 4 m.
On the determined worst-case position, a final measurement with necessary bandwidth and detector according standard has been carried out

Formula:

$E_C = E_R + AF + C_L + D_F - G_A$ (1)

$M = L_T - E_C$ (2)

AF = Antenna factor
C_L = Cable loss
D_F = Distance correction factor (if used)
E_C = Electrical field – corrected value
E_R = Receiver reading
G_A = Gain of pre-amplifier (if used)
L_T = Limit
M = Margin

All units are dB-units, positive margin means value is below limit.

4.8.2 Limit

Radiated emissions limits, (3 meters)				
Frequency Range [MHz]	**Limit [µV/m]**	**Limit [dBµV/m]**	**Detector**	**RBW / VBW [kHz]**
30 - 88	100	40.0	Quasi peak	100 / 300
88 - 216	150	43.5	Quasi peak	100 / 300
216 - 960	200	46.0	Quasi peak	100 / 300
960 - 1000	500	54.0	Quasi peak	100 / 300

4.8.3 Result

Diagram	Channel	Mode	Maximum Level [dBµV/m] Frequency Range 30 – 1000MHz	Result
3.01a	0	TX mode - GFSK | 1 Mbit/s - Standing	36.359	Pass
3.01b	0	TX mode - GFSK | 1 Mbit/s - Laying	32.579	Pass
3.02a	20	TX mode - GFSK | 1 Mbit/s - Standing	36.486	Pass
3.02b	20	TX mode - GFSK | 1 Mbit/s - Laying	35.455	Pass
3.03a	39	TX mode - GFSK | 1 Mbit/s - Standing	34.947	Pass
3.03b	39	TX mode - GFSK | 1 Mbit/s - Laying	33.794	Pass

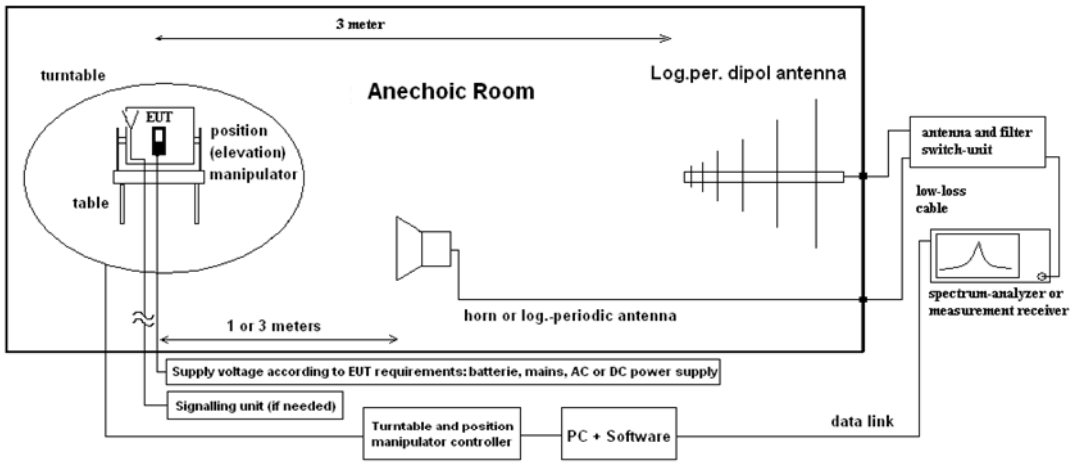
Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

4.9 Radiated field strength emissions above 1 GHz

4.9.1 Description of the general test setup and methodology, see below example:

Evaluating the emissions have to be done first by an exploratory emissions measurement and a final measurement for most critical frequencies. The tests are performed in a CISPR 18-1-4:2010 compliant fully anechoic room (FAR) recognized by the regulatory commission. The measurement distance was set to 3 meter for frequencies up to 18 GHz and 2 meter above 18 GHz. A logarithmic periodic antenna is used for the frequency range 30 MHz to 1 GHz. Horn antennas are used for frequency range 1 GHz to 40 GHz. The EUT is aligned within 3 dB beam width of the measurement antenna with three orthogonal axis measurements on the EUT.

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

Exploratory, preliminary measurements

The EUT and its associated accessories are placed on a non-conductive position manipulator (tipping device) of 1.55 m height which is placed on the turntable. By rotating the turntable (range 0° to 360°, step 15°) and the EUT itself either on 3-orthogonal axis (portable equipment) or 2-orthogonal axis (defined operational position of EUT) the emission spectrum and its characteristics was recorded with an EMI-receiver, broadband antenna and software.
The measurements are performed in horizontal and vertical polarization of the measurement antennas. The results are documented in a diagram. Critical frequencies (low margin to limit) are saved within a table for further investigations. If various operating modes are supported, further investigations are made to find the worst-case of them. Also the interconnection cables and equipment position were varied in order to maximize the emissions.

Final measurement on critical frequencies

Based on the exploratory measurements, the most critical frequencies are re-measured by maintaining the EUT's worst-case operation mode, cable position, etc.

First a frequency zoom around the critical frequency is done to locate the frequency more precisely. After this step, for all identified critical frequencies, the maximum peak was determined.

Following parameters were varied: the turntable angle continuously in the range 0 to 360 degree, the EUT itself over 3-orthogonal axis and the height for EUT with large dimensions or three axis scan for portable/small equipment.

On the determined worst-case position, a final measurement with necessary bandwidth and detector according standard has been carried out.

Formula:

$E_C = E_R + A_F + C_L + D_F - G_A$ (1)

$M = L_T - E_C$ (2)

E_C = Electrical field – corrected value
E_R = Receiver reading
M = Margin
L_T = Limit
A_F = Antenna factor
C_L = Cable loss
D_F = Distance correction factor (if used)
G_A = Gain of pre-amplifier (if used)

All units are dB-units, positive margin means value is below limit.

4.9.2 Limit

Radiated emissions limits, (3 meters)				
Frequency Range [MHz]	**Limit [µV/m]**	**Limit [dBµV/m]**	**Detector**	**RBW / VBW [kHz]**
Above 1000	500	54	Average	1000 / 3000
Above 1000	5000	74	Peak	1000 / 3000

4.9.3 Result

Diagram	Channel	Mode	Maximum Level [dBµV/m] Frequency Range 1 – 18GHz	Result
4.01a	0	TX mode - GFSK | 1 Mbit/s |1 – 2.8 GHz	60.15	Pass
4.01b	0	TX mode - GFSK | 1 Mbit/s |2.8 – 18 GHz	63.26	Pass
4.02a	20	TX mode - GFSK | 1 Mbit/s |1 – 15 GHz	59.160	Pass
4.03a	39	TX mode - GFSK | 1 Mbit/s |1 – 18 GHz	64.09	Pass

Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

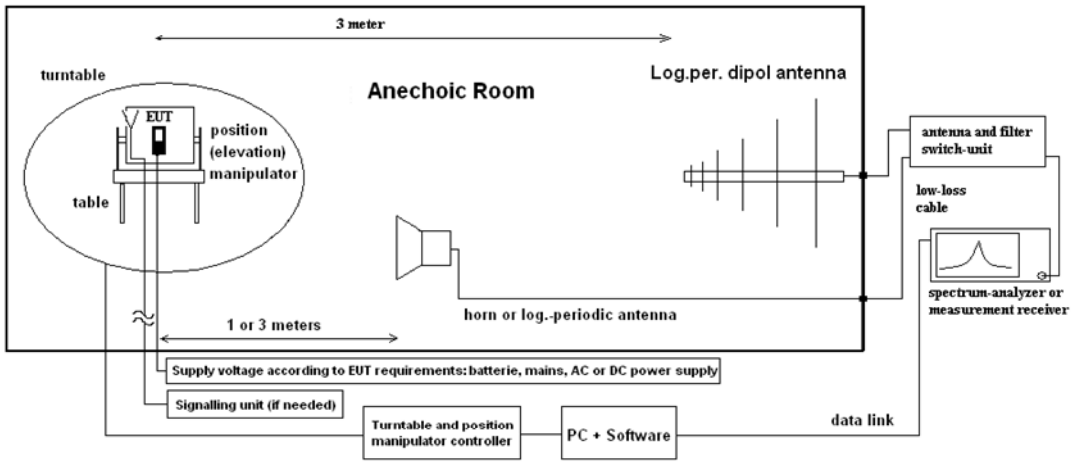
Diagram	Channel	Mode	Maximum Level [dBµV/m] Frequency Range 15 – 26.5GHz	Result
4.01c	0	TX mode - GFSK | 1 Mbit/s	57.65	Pass
4.02b	20	TX mode - GFSK | 1 Mbit/s	57.29	Pass
4.03b	39	TX mode - GFSK | 1 Mbit/s	57.00	Pass

Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

4.10 Radiated Band-Edge emissions

4.10.1 Description of the general test setup and methodology, see below example:

Schematic:



Testing method:

The measurement is made according to relevant reference clauses:
(See Tables *Summary of Test Results* and *Summary of Test Methods* on page 5)

For uncritical results where a measurement resolution bandwidth of 1MHz can clearly show the compliance without influencing the results, a field strength measurement was performed to show compliance.

For critical results a Marker-Delta marker method was used for showing compliance to restricted bands.
The method consists of three independent steps:

1. Step: Prior to the measurement the fundamental radiated In-Band field strength was performed. The determined value is used as reference value.

2. Step: Second step consist of finding the relative attenuation between the fundamental emission and the maximum local out-of-band emission (within 2 MHz range around the band edge either on the band-edge directly or some modulation product if the level is greater than that on the band-edge) when measured with lower resolution bandwidth.

3. .Step: The delta value recorded in step 2 will be subtracted from value recorded in step 1, thus giving the required field strength at the band-edge. This value must fulfil the requirements for radiated spurious emissions in restricted bands in FCC §15.205 with the general limits of FCC §15.209

The EUT was instructed to send with maximum power (if adjustable) according to applicants instructions.

4.10.2 Limit

Frequency Range [MHz]	Pk Limit [dBc]	Avg Limit [dBc]	Avg Limit [dBµV/m]	Pk Limit [dBµV/m]	Detector	RBW / VBW [kHz]
Below 2390	-	-	54	74	Average / Peak	100 / 300
Above 2483.5	-	-	54	74	Average / Peak	1000 / 3000
2390 - 2400	-20	-	-	-	Peak	100 / 300
2390 - 2400	-	-30	-	-	Average	100 / 300

4.10.3 Result

No Duty Cycle correction necessary

Non-restricted bands near-by

Diagram	Channel	Mode	Peak [dBc]	Average [dBc]	Result
9.01	0	TX mode - GFSK | 1 Mbit/s	46.06	47.14	Pass

Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

Restricted bands near-by

Diagram	Channel	Mode	Peak [dBµV/m]	Average [dBµV/m]	Result
9.02	39	TX mode - GFSK | 1 Mbit/s	58.43	47.27	Pass

Remark: for more informations and graphical plot see annex A1 **CETECOM_TR20_1_0014002T01a_A1**

4.11 Results from external laboratory

None	-

4.12 Opinions and interpretations

None	-

5 Equipment lists

ID	Description	Manufacturer	SerNo	Cal Date
120904	FAC1 - Radiated Emissions			
20720	EMC32 [FAC]	Rohde & Schwarz Messgerätebau GmbH	V10.50	
20020	Horn Antenna 3115 (Subst 1)	EMCO Elektronik GmbH	9107-3699	19.07.2021
20549	Log.Per-Antenna HL025	Rohde & Schwarz Messgerätebau GmbH	1000060	31.07.2021
20700	PC ctc662012 [FAC]	Dell Inc.		
20262	Power Meter NRV-S	Rohde & Schwarz Messgerätebau GmbH	825770/0010	15.05.2020
20357	power sensor NRV-Z1	Rohde & Schwarz Messgerätebau GmbH	861761/002	21.05.2021
20338	Pre-Amplifier 100 MHz - 26 GHz JS4-00102600-38-5P	Miteq Inc.	838697	
20484	Pre-Amplifier 2,5 GHz - 18 GHz AMF-5D-02501800-25-10P	Miteq Inc.	1244554	
20287	Pre-Amplifier 25 MHz - 4 GHz AMF-2D-100 M4 G-35-10P	Miteq Inc.	379418	
20690	Spectrum Analyzer FSU	Rohde & Schwarz Messgerätebau GmbH	100302/026	23.05.2021
120901	SAC - Radiated Emission <1 GHz			
25038	Loop Antenna (H-Field) HFH2-Z2	Rohde & Schwarz	879824/13	31.03.2020
20574	Biconilog Hybrid Antenna BTA-L	Frankonia	980026L	03.05.2022
20620	ESU 26	Rohde & Schwarz	100362	30.05.2020

ID	Description	Manufacturer	SerNo	Cal Date
120910	CTC-Radio Laboratory 1			
20866	FSV3030 Signal Analyzer 30 GHz	Rohde & Schwarz Messgerätebau GmbH	101247	02.10.2020
20805	Open Switch and control Platform OSP B157WX 40 GHz 8Port Switch	Rohde & Schwarz Messgerätebau GmbH	101264	03.05.2020
20693	TS8997	Rohde & Schwarz Messgerätebau GmbH	--	--

6 Measurement Uncertainty valid for conducted/radiated measurements

The reported uncertainties are calculated based on the standard uncertainty multiplied with the appropriate coverage factor **k**, such that a confidence level of approximately 95% is achieved. For uncertainty determination, each component used in the concrete measurement set-up was taken in account and it contribution to the overall uncertainty according its statistical distribution calculated.

RF-Measurement	Reference	Frequency range	Calculated uncertainty based on a confidence level of 95%						Remarks
Conducted emissions (U_{CISPR})	CISPR 16-2-1	9 kHz - 150 kHz 150 kHz - 30 MHz	4.0 dB 3.6 dB						-
Radiated emissions Enclosure	CISPR 16-2-3	30 MHz - 1 GHz 1 GHz - 18 GHz	4.2 dB 5.1 dB						E-Field
Disturbance power	CISPR 16-2-2	30 MHz - 300 MHz	-						-
Power Output radiated	-	30 MHz - 4 GHz	3.17 dB						Substitution method
Power Output conducted	-	Set-up No.	Cel-C1	Cel-C2	BT1	W1	W2	--	
		9 kHz - 12.75 GHz	N/A	0.60	0.7	0.25	N/A	--	-
		12.75 - 26.5GHz	N/A	0.82	--	N/A	N/A	--	
Conducted emissions on RF-port	-	9 kHz - 2.8 GHz	0.70	N/A	0.70	N/A	0.69	--	N/A - not applicable
		2.8 GHz - 12.75GHz	1.48	N/A	1.51	N/A	1.43	--	
		12.75 GHz - 18GHz	1.81	N/A	1.83	N/A	1.77	--	
		18 GHz - 26.5GHz	1.83	N/A	1.85	N/A	1.79	--	
Occupied bandwidth	-	9 kHz - 4 GHz	0.1272 ppm (Delta Marker)						Frequency error
			1.0 dB						Power
Emission bandwidth	-	9 kHz - 4 GHz	0.1272 ppm (Delta Marker)						Frequency error
	-		See above: 0.70 dB						Power
Frequency stability	-	9 kHz - 20 GHz	0.0636 ppm						-
Radiated emissions Enclosure	-	150 kHz - 30 MHz 30 MHz - 1 GHz 1 GHz - 20 GHz	5.0 dB 4.2 dB 3.17 dB						Magnetic field E-field Substitution

7 Versions of test reports (change history)

Version	Applied changes	Date of release
--	Initial release	2020-Apr-14
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End Of Test Report