

TEST REPORT

Test report no.: 1-9737/19-01-02-D

BNetzA-CAB-02/21-102

Testing laboratory

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Accredited Testing Laboratory:

The testing laboratory (area of testing) is accredited according to DIN EN ISO/IEC 17025 (2005) by the Deutsche Akkreditierungsstelle GmbH (DAkkS)

The accreditation is valid for the scope of testing procedures as stated in the accreditation certificate starting with the registration number: D-PL-12076-01.

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Test standard/s

FCC - Title 47 CFR Part 15 FCC - Title 47 of the Code of Federal Regulations; Chapter I; Part 15 - Radio frequency devices

RSS - 247 Issue 2 Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSS) and Licence - Exempt Local Area Network (LE-LAN) Devices

For further applied test standards please refer to section 3 of this test report.

Test Item

Kind of test item: **Smiley Box V2 915 LoRa**
Model name: **8354B**
FCC ID: **U3Z-A8354**
IC: **7016A-A8354**
Frequency: ISM band 902 MHz – 928 MHz
Technology tested: Long Range Wide Area Network
Antenna: Integrated antenna
Power supply: 3.3 V DC by battery
Temperature range: -20°C to +55°C

This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

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2 General information

2.1 Notes and disclaimer

The test results of this test report relate exclusively to the test item specified in this test report. CTC advanced GmbH does not assume responsibility for any conclusions and generalizations drawn from the test results with regard to other specimens or samples of the type of the equipment represented by the test item.

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This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

This test report replaces the test report with the number 1-9737/19-01-02-C and dated 2020-03-27.

2.2 Application details

Date of receipt of order:	2020-01-15
Date of receipt of test item:	2020-01-15
Start of test:	2020-01-20
End of test:	2020-01-21
Person(s) present during the test:	-/-





2.3 Test laboratories sub-contracted

None

3 Test standard/s and references

Test standard	Date	Description
FCC - Title 47 CFR Part 15	-/-	FCC - Title 47 of the Code of Federal Regulations; Chapter I; Part 15 - Radio frequency devices
RSS - 247 Issue 2	February 2017	Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence - Exempt Local Area Network (LE-LAN) Devices
RSS - Gen Issue 5	April 2018	Spectrum Management and Telecommunications Radio Standards Specification - General Requirements for Compliance of Radio Apparatus

Guidance	Version	Description
DTS: KDB 558074 D01	v05r02	GUIDANCE FOR COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEM, FREQUENCY HOPPING SPREAD SPECTRUM SYSTEM, AND HYBRID SYSTEM DEVICES OPERATING UNDER SECTION 15.247 OF THE FCC RULES
ANSI C63.4-2014	-/-	American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
ANSI C63.10-2013	-/-	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

Accreditation	Description	
D-PL-12076-01-04	Telecommunication and EMC Canada https://www.dakks.de/as/ast/d/D-PL-12076-01-04.pdf	 
D-PL-12076-01-05	Telecommunication FCC requirements https://www.dakks.de/as/ast/d/D-PL-12076-01-05.pdf	 

4 Test environment

Temperature	:	T_{nom} +22 °C during room temperature tests T_{max} No tests under extreme conditions required. T_{min} No tests under extreme conditions required.
Relative humidity content	:	55 %
Barometric pressure	:	1021 hpa
Power supply	:	V_{nom} 3.3 V DC by battery V_{max} No tests under extreme conditions required. V_{min} No tests under extreme conditions required.

5 Test item

5.1 General description

Kind of test item	:	Smiley Box V2 915 LoRa
Model name	:	8354B
HMN	:	-/-
PMN	:	Smiley Box
HVIN	:	8354B
FVIN	:	-/-
S/N serial number	:	-/-
Hardware status	:	ARF8354/B
Software status	:	V02.00.00
Firmware status	:	-/-
Frequency band	:	ISM band 902 MHz – 928 MHz
Type of radio transmission	:	DTS and Hybrid mode
Use of frequency spectrum	:	
Number of channels	:	Hybrid mode: 64 DTS mode: 8
Antenna	:	Integrated antenna
Power supply	:	3.3 V DC by battery
Temperature range	:	-20°C to +55°C

5.2 Additional information

The content of the following annexes is defined in the QA. It may be that not all of the listed annexes are necessary for this report, thus some values in between may be missing.

Test setup and EUT photos are included in test report:

- 1-9737/19-01-01_AnnexA
- 1-9737/19-01-01_AnnexB
- 1-9737/19-01-01_AnnexD

6 Description of the test setup

Typically, the calibrations of the test apparatus are commissioned to and performed by an accredited calibration laboratory. The calibration intervals are determined in accordance with the DIN EN ISO/IEC 17025. In addition to the external calibrations, the laboratory executes comparison measurements with other calibrated test systems or effective verifications. Weekly chamber inspections and range calibrations are performed. Where possible, RF generating and signaling equipment as well as measuring receivers and analyzers are connected to an external high-precision 10 MHz reference (GPS-based or rubidium frequency standard).

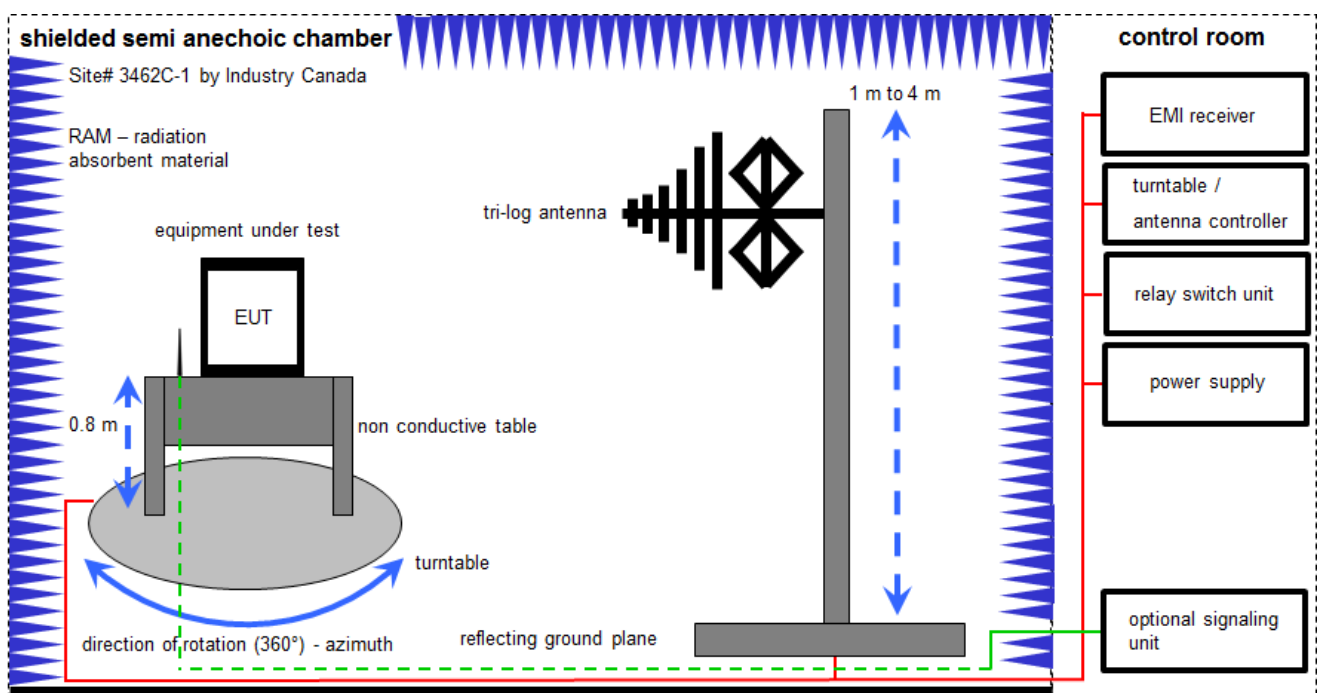
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

Agenda: Kind of Calibration

k	calibration / calibrated	EK	limited calibration
ne	not required (k, ev, izw, zw not required)	zw	cyclical maintenance (external cyclical maintenance)
ev	periodic self verification	izw	internal cyclical maintenance
Ve	long-term stability recognized	g	blocked for accredited testing
vlk!	Attention: extended calibration interval		
NK!	Attention: not calibrated	*)	next calibration ordered / currently in progress

6.1 Shielded semi anechoic chamber

The radiated measurements are performed in vertical and horizontal plane in the frequency range from 30 MHz to 1 GHz in semi-anechoic chambers. The EUT is positioned on a non-conductive support with a height of 0.80 m above a conductive ground plane that covers the whole chamber. The receiving antennas are conform to specifications ANSI C63. These antennas can be moved over the height range between 1.0 m and 4.0 m in order to search for maximum field strength emitted from EUT. The measurement distances between EUT and receiving antennas are indicated in the test setups for the various frequency ranges. For each measurement, the EUT is rotated in all three axes until the maximum field strength is received. The wanted and unwanted emissions are received by spectrum analyzers where the detector modes and resolution bandwidths over various frequency ranges are set according to requirement ANSI C63.



Measurement distance: tri-log antenna 10 meter

$$FS = UR + CL + AF$$

(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

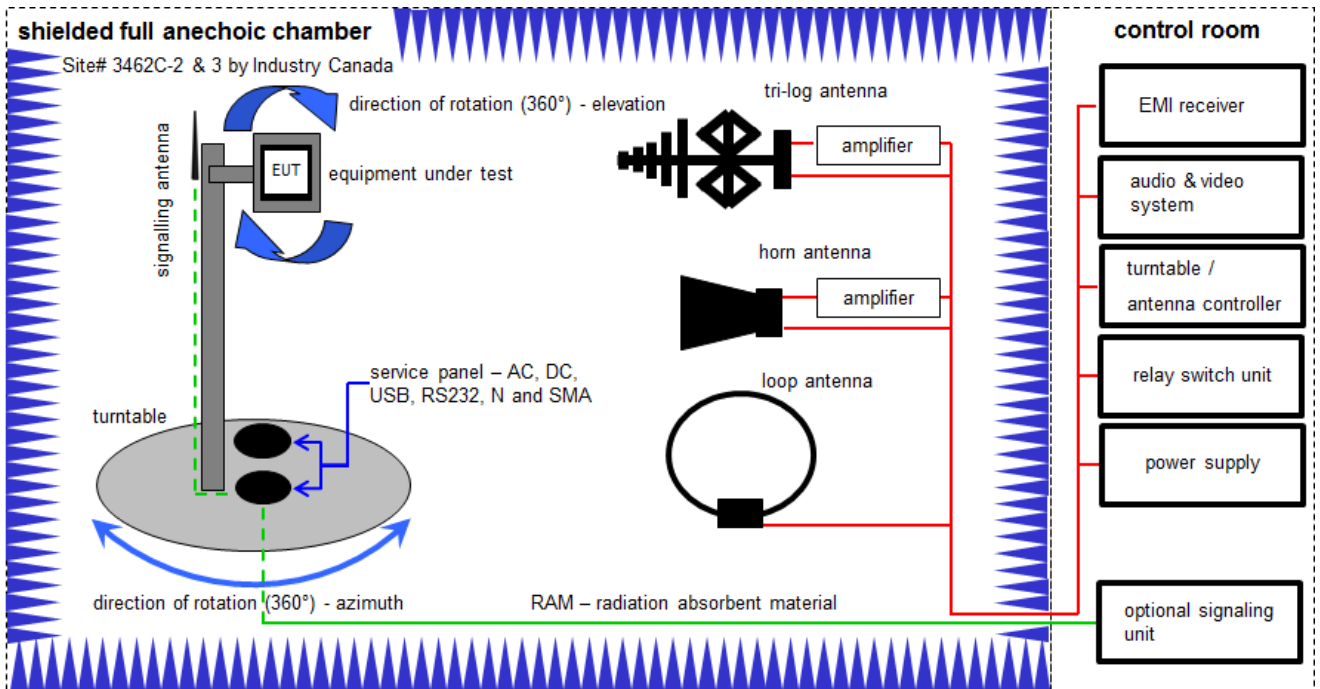
Example calculation:

$$FS [dB\mu V/m] = 12.35 [dB\mu V/m] + 1.90 [dB] + 16.80 [dB/m] = 31.05 [dB\mu V/m] (35.69 \mu V/m)$$

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	A	Switch-Unit	3488A	HP	2719A14505	30000368	ev	-/-	-/-
2	A	Meßkabine 1	HF-Absorberhalle	MWB AG 300023		30000551	ne	-/-	-/-
3	A	EMI Test Receiver	ESR3	Rohde & Schwarz	102587	300005771	k	21.05.2019	20.05.2020
4	A	Antenna Tower	Model 2175	ETS-Lindgren	64762	300003745	izw	-/-	-/-
5	A	Positioning Controller	Model 2090	ETS-Lindgren	64672	300003746	izw	-/-	-/-
6	A	Turntable Interface-Box	Model 105637	ETS-Lindgren	44583	300003747	izw	-/-	-/-
7	A	TRILOG Broadband Test-Antenna 30 MHz - 3 GHz	VULB9163	Schwarzbeck Mess-Elektronik	371	300003854	vKI!	24.11.2017	23.11.2020

6.2 Shielded fully anechoic chamber



Measurement distance: tri-log antenna and horn antenna 3 meter; loop antenna 3 meter / 1 meter

FS = UR + CA + AF

(FS-field strength; UR-voltage at the receiver; CA-loss of the signal path; AF-antenna factor)

Example calculation:

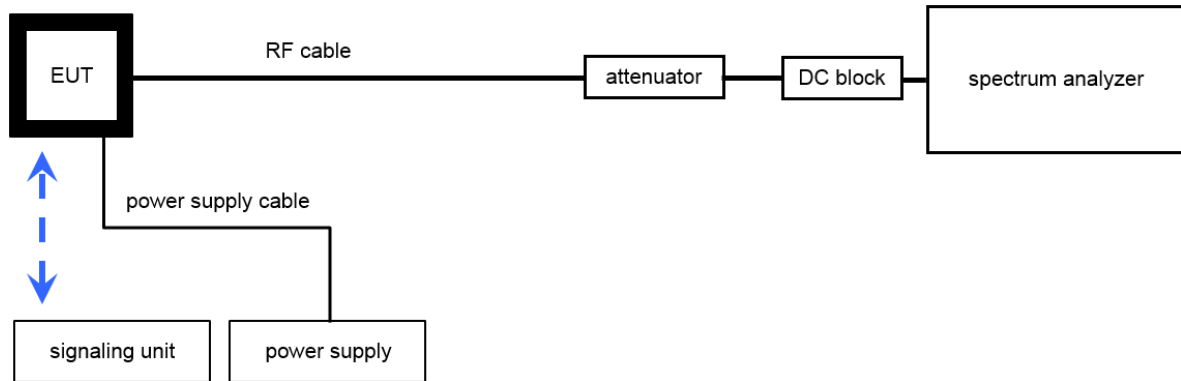
FS [dBµV/m] = 40.0 [dBµV/m] + (-35.8) [dB] + 32.9 [dB/m] = 37.1 [dBµV/m] (71.61 µV/m)

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	A	Active Loop Antenna 9 kHz to 30 MHz	6502	EMCO	2210	300001015	vKI!	13.06.2019	12.06.2021
2	A, B.	Anechoic chamber	FAC 3/5m	MWB / TDK	87400/02	300000996	ev	-/-	-/-
3	B	Double-Ridged Waveguide Horn Antenna 1-18.0GHz	3115	EMCO	9107-3697	300001605	vKI!	27.02.2019	26.02.2021
4	A, B.	Switch / Control Unit	3488A	HP	*	300000199	ne	-/-	-/-
5	A, B.	EMI Test Receiver 20Hz- 26,5GHz	ESU26	R&S	100037	300003555	k	11.12.2019	10.12.2020
6	B	Highpass Filter	WHKX7.0/18G-8SS	Wainwright	19	300003790	ne	-/-	-/-
7	B	High Pass Filter	VHF-3500+	Mini Circuits	-/-	400000193	ne	-/-	-/-
8	B	Broadband Amplifier 0.5-18 GHz	CBLU5184540	CERNEX	22049	300004481	ev	-/-	-/-
9	A, B.	4U RF Switch Platform	L4491A	Agilent Technologies	MY50000037	300004509	ne	-/-	-/-
10	A, B.	NEXIO EMV-Software	BAT EMC V3.19.1.19	EMCO		300004682	ne	-/-	-/-
11	A, B.	PC	ExOne	F+W		300004703	ne	-/-	-/-
12	B.	RF-Amplifier	AMF-6F06001800-30-10P-R	NARDA-MITEQ Inc	2011572	300005241	ev	-/-	-/-

6.3 Conducted measurements

Conducted measurements normal conditions



OP = AV + CA
(OP-output power; AV-analyzer value; CA-loss signal path)

Example calculation:

OP [dBm] = 6.0 [dBm] + 11.7 [dB] = 17.7 [dBm] (58.88 mW)

Equipment table:

No.	Lab / Item	Equipment	Type	Manufacturer	Serial No.	INV. No.	Kind of Calibration	Last Calibration	Next Calibration
1	A	Signal- and Spectrum Analyzer 2 Hz - 26 GHz	FSW26	R&S	101455	300004528	k	12.12.2019	11.12.2020
2	A	RF-Cable SRD021 No. 2	Enviroflex 316 D	Huber & Suhner		400001312	ev	-/-	-/-

7 Sequence of testing

7.1 Sequence of testing radiated spurious 9 kHz to 30 MHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, it is placed on a table with 0.8 m height.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement*

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna height is 1 m.
- At each turntable position the analyzer sweeps with positive-peak detector to find the maximum of all emissions.

Final measurement

- Identified emissions during the pre-measurement are maximized by the software by rotating the turntable from 0° to 360°.
- Loop antenna is rotated about its vertical axis for maximum response at each azimuth about the EUT. (For certain applications, the loop antenna plane may also need to be positioned horizontally at the specified distance from the EUT)
- The final measurement is done in the position (turntable and elevation) causing the highest emissions with quasi-peak (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, correction factor, margin to the limit and limit will be recorded. A plot with the graph of the premeasurement and the limit is stored.

*Note: The sequence will be repeated three times with different EUT orientations.

7.2 Sequence of testing radiated spurious 30 MHz to 1 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a table with 0.8 m height is used, which is placed on the ground plane.
- If the EUT is a floor standing device, it is placed on the ground plane with insulation between both.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 10 m or 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height changes from 1 m to 3 m.
- At each turntable position, antenna polarization and height the analyzer sweeps three times in peak to find the maximum of all emissions.

Final measurement

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximize the peaks by changing turntable position $\pm 45^\circ$ and antenna height between 1 and 4 m.
- The final measurement is done with quasi-peak detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, antenna height, antenna polarization, turntable angle, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

7.3 Sequence of testing radiated spurious 1 GHz to 12.75 GHz

Setup

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a 2-axis positioner with 1.5 m height is used.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

Premeasurement

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height is 1.5 m.
- At each turntable position and antenna polarization the analyzer sweeps with positive peak detector to find the maximum of all emissions.

Final measurement

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximizes the peaks by rotating the turntable from 0° to 360°. This measurement is repeated for different EUT-table positions (0° to 150° in 30°-steps) and for both antenna polarizations.
- The final measurement is done in the position (turntable, EUT-table and antenna polarization) causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, EUT-table position, antenna polarization, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

8 Measurement uncertainty

Measurement uncertainty	
Test case	Uncertainty
Antenna gain	± 3 dB
Carrier frequency separation	± 21.5 kHz
Number of hopping channels	-/-
Spectrum bandwidth	± 21.5 kHz absolute; ± 15.0 kHz relative
Maximum output power	± 1 dB
Detailed conducted spurious emissions @ the band edge	± 1 dB
Band edge compliance radiated	± 3 dB
Spurious emissions conducted	± 3 dB
Spurious emissions radiated below 30 MHz	± 3 dB
Spurious emissions radiated 30 MHz to 1 GHz	± 3 dB
Spurious emissions radiated 1 GHz to 12.75 GHz	± 3.7 dB
Spurious emissions radiated above 12.75 GHz	± 4.5 dB

9 Summary of measurement results

<input checked="" type="checkbox"/>	No deviations from the technical specifications were ascertained
<input type="checkbox"/>	There were deviations from the technical specifications ascertained
<input type="checkbox"/>	This test report is only a partial test report. The content and verdict of the performed test cases are listed below.

9.1 Part 1: DTS mode

Test specification clause	Test case	Temperature conditions	Power source voltages	Mode	C	NC	NA	NP	Remark
§15.247(b)(4) RSS 210 / A8.4(2)	Antenna gain	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(e) RSS - 247 / 5.2 (b)	Power spectral density	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(a)(2) RSS Gen clause 4.6.1	Spectrum bandwidth 6dB bandwidth	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(b)(3) RSS - 247 / 5.4 (d)	Maximum output power	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.205 RSS - 247 / 5.5 RSS - Gen	Band edge compliance conducted	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.205 RSS - 247 / 5.5 RSS - Gen	Band edge compliance radiated	Nominal	Nominal	-/-	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§§15.247(d) RSS - 247 / 5.5	TX spurious emissions conducted	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(d) RSS-210 / A8.5	TX spurious emissions radiated	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.109 RSS-Gen.	RX spurious emissions radiated	Nominal	Nominal	RX	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.209(a) RSS-Gen	TX spurious emissions radiated < 30 MHz	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-

Note: C = Compliant; NC = Not compliant; NA = Not applicable; NP = Not performed

9.2 Part 2: Hybrid mode

Test specification clause	Test case	Temperature conditions	Power source voltages	Mode	C	NC	NA	NP	Remark
§15.247(b)(4) RSS - 247 / 5.4 (d)	Antenna gain	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(a)(1) RSS - 247 / 5.1 (b)	Carrier frequency separation	Nominal	Nominal	TX hopping	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(a)(1) RSS - 247 / 5.1 (a)	Spectrum bandwidth	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(f) RSS - 247 / 5.2 (b)	Power spectral density	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(b)(3) RSS - 247 / 5.4 (b)	Maximum output power	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(d) RSS - 247 / 5.5	Detailed spurious emissions @ the band edge - conducted	Nominal	Nominal	TX hopping	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(d) RSS - 247 / 5.5	Spurious emissions conducted	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(f) RSS - 247 / 5.1 (d)	Time of occupancy (dwell time)	Nominal	Nominal	TX hopping	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.247(d) RSS-210 / A8.5	TX spurious emissions radiated	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-
§15.209(a) RSS-Gen	TX spurious emissions radiated < 30 MHz	Nominal	Nominal	TX single channel	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	-/-

Note: C = Compliant; NC = Not compliant; NA = Not applicable; NP = Not performed

10 RF measurements

10.1 Additional comments

Reference documents: None

Special test descriptions: The EUT uses a Long Range Wide Area Network (LoRaWAN) technology with a combination of a hybrid system and a DTS system. Both systems were tested.

Configuration descriptions: **DTS mode:** 8 channels with 500 kHz nominal bandwidth and 1600 kHz channel spacing:

lowest channel	903.0 MHz,
middle channel	907.8 MHz,
highest channel	914.2 MHz

These channels were tested in part 1 of this test report.

Hybrid mode: 64 channels with a nominal bandwidth of 125 kHz:

lowest channel	902.3 MHz,
middle channel	908.5 MHz,
highest channel	914.9 MHz.

These channels were tested in part 2 of this test report.

NOTE: In hybrid mode the minimum number of hopping channels is 8. In this mode the minimum channel separation and bandwidths stay the same as in the mode with 64 channels. Also the device also comply with the dwell time requirements while using 8 channels:

The time slot length: 164.81 ms
 Average time of occupancy: 329.62 ms
 Hops in 3.2 second: 2

Test mode: Special software is used.
 EUT is transmitting pseudo random data by itself

11 Measurement results Part 1 DTS mode

11.1 Maximum output power

Measurement:

Measurement parameter	
Detector:	RMS
Sweep time:	Auto
Resolution bandwidth:	10 kHz
Video bandwidth:	30 kHz
Span:	1.83 MHz
Trace mode:	Max hold
Measurement method	According to ANSI C63.10-2013 11.9.2.2.3 Method AVGSA-1A (alternative)
Used equipment:	See chapter 6.3 A
Measurement uncertainty:	See chapter 8

Limits:

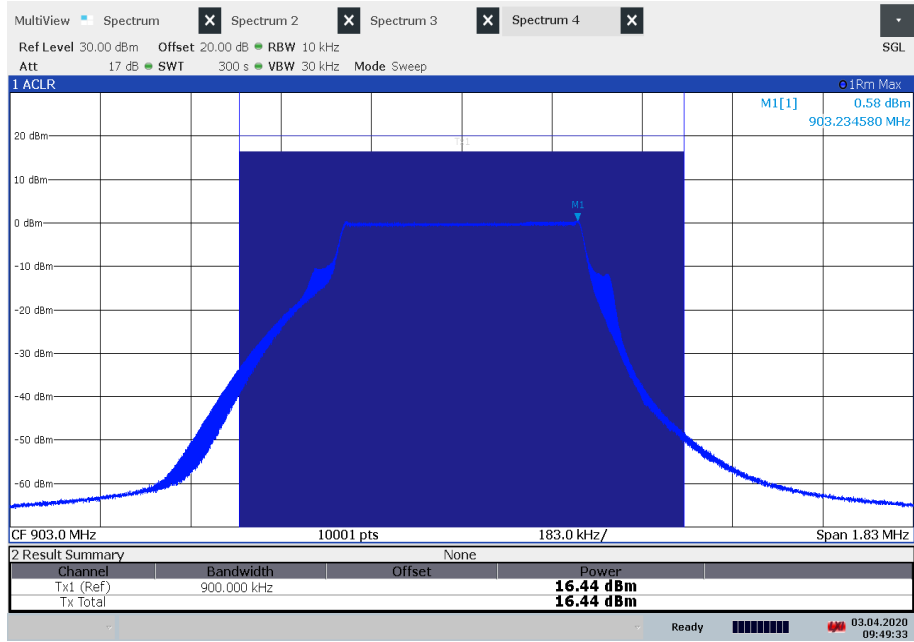
FCC	IC
1 watt (30 dBm) Maximum Output Power Conducted	

Result:

Test Conditions		Maximum Output Power Conducted		
		Lowest channel	Middle channel	Highest channel
T_{nom}	V_{nom}	16.4 dBm	16.5 dBm	16.5 dBm

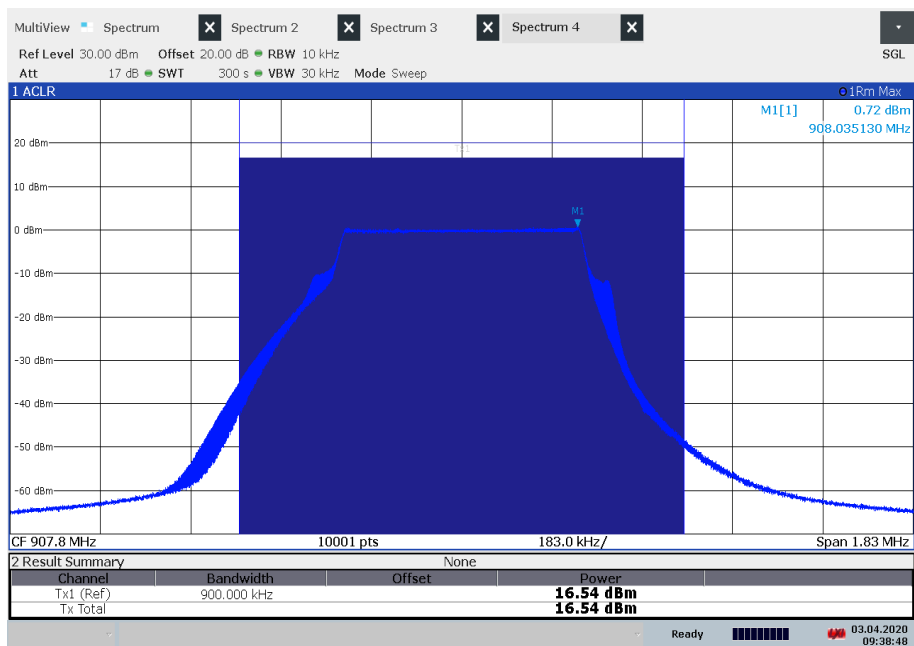
Plots:

Plot 1: Lowest Channel



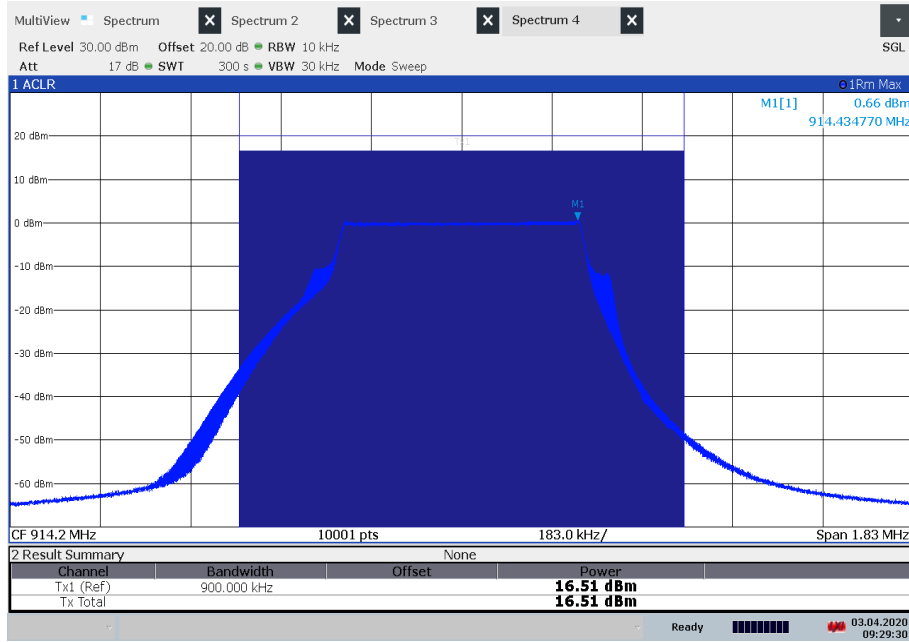
09:49:33 03.04.2020

Plot 2: Middle Channel



09:38:49 03.04.2020

Plot 3: Highest Channel



09:29:31 03.04.2020

11.2 Antenna gain

The antenna gain of the complete system is calculated by the difference of radiated power in EIRP and the conducted power of the module.

Measurement parameters	
Detector	Peak
Sweep time	Auto
Resolution bandwidth	1 MHz
Video bandwidth	3 MHz
Span	5 MHz
Trace mode	Max hold
Test setup	See sub clause 6.1 A (radiated) See sub clause 6.3 A (conducted)
Measurement uncertainty	See sub clause 8

Limits:

FCC	IC
Antenna gain	
<p>The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.</p>	

Results:

	Lowest channel	Middle channel	Highest channel
Conducted power	16.48 dBm	16.50 dBm	16.45 dBm
Radiated power	20.51 dBm	20.86 dBm	21.54 dBm
Gain Calculated	4.03 dBi	4.36 dBi	5.09 dBi

11.3 Power spectral density

Description:

Measurement of the power spectral density of a digital modulated system. The measurement is repeated at the lowest, middle and highest channel.

Measurement:

Measurement parameter	
Detector:	RMS
Sweep time:	10 s
Video bandwidth:	10 kHz
Resolution bandwidth:	3 kHz
Span:	2 MHz
Trace mode:	Max hold
Measurement method	According to ANSI C63.10-2013 11.10.4 Method AVGPS-1A (alternative)
Test setup	See sub clause 6.3 A
Measurement uncertainty	See sub clause 8

Limits:

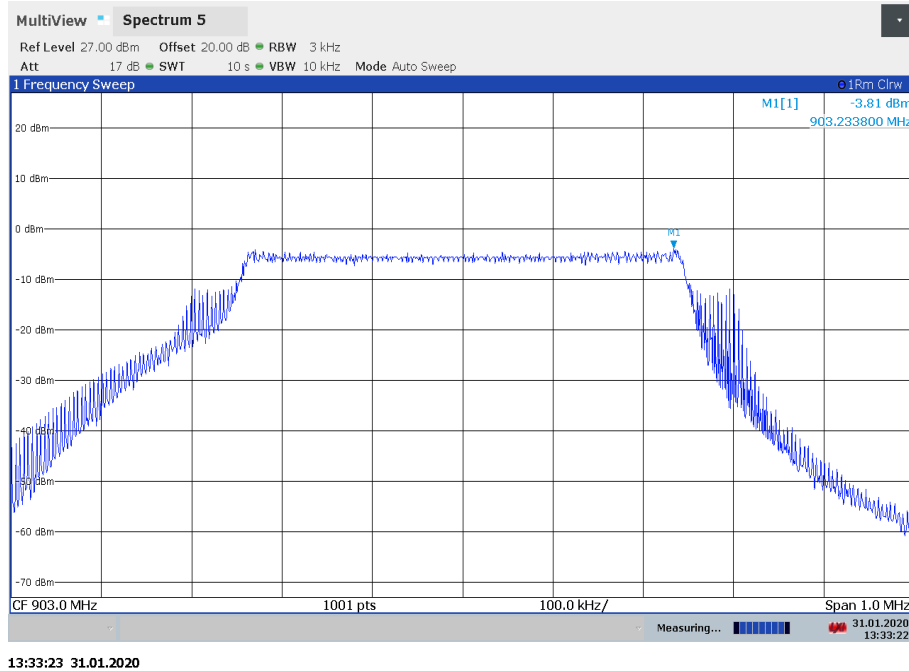
FCC	IC
Power Spectral Density	
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission or over 1.0 second if the transmission exceeds 1.0-second duration.	

Results:

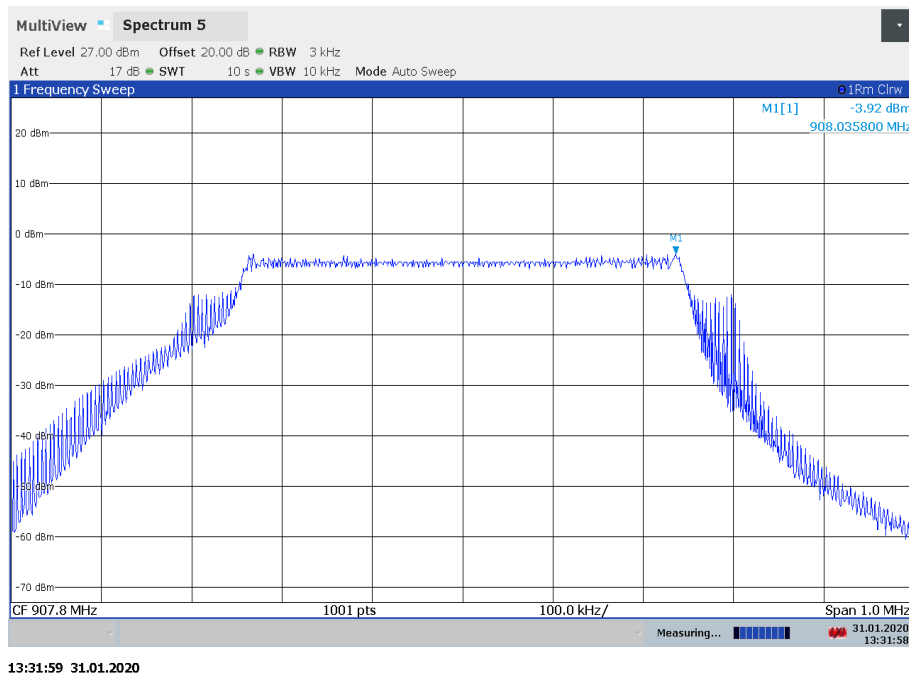
Power Spectral density [dBm/3kHz]			
Channel	Lowest	Middle	Highest
	-3.81	-3.92	-3.75

Plots:

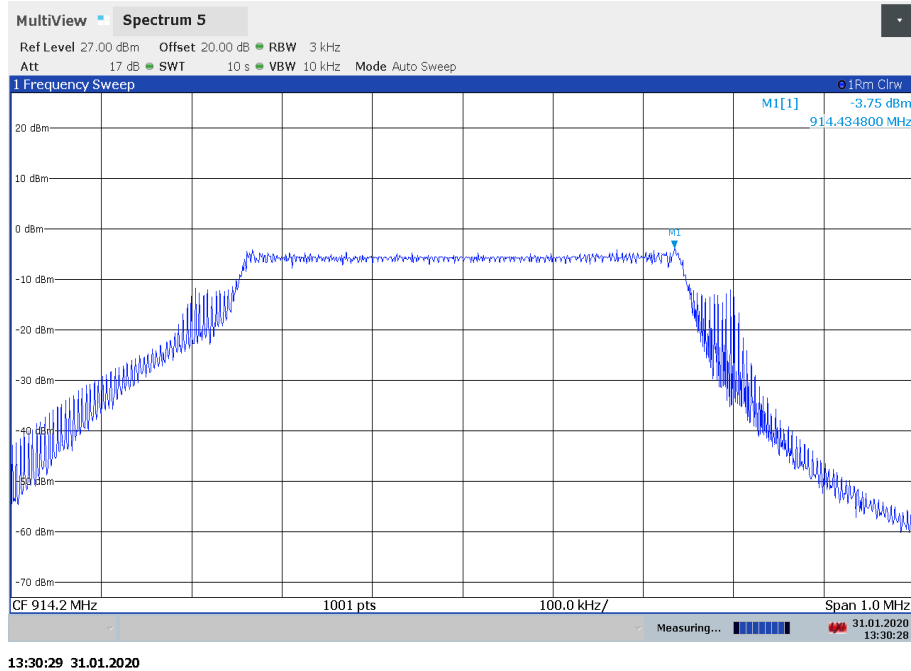
Plot 1: Lowest Channel



Plot 2: Middle Channel



Plot 3: Highest Channel



11.4 Spectrum bandwidth – 6 dB bandwidth and 99% bandwidth

Description:

Measurement of the 6 dB bandwidth of the modulated signal.

Measurement:

Measurement parameter	
Detector:	Peak
Sweep time:	Auto
Video bandwidth:	300 kHz
Resolution bandwidth:	100 kHz
Span:	2 MHz
Trace mode:	Max Hold
Test setup	See sub clause 6.3 A
Measurement uncertainty	See sub clause 8

Limits:

FCC	IC
Spectrum Bandwidth – 6 dB Bandwidth	
The minimum 6 dB bandwidth shall be at least 500 kHz.	

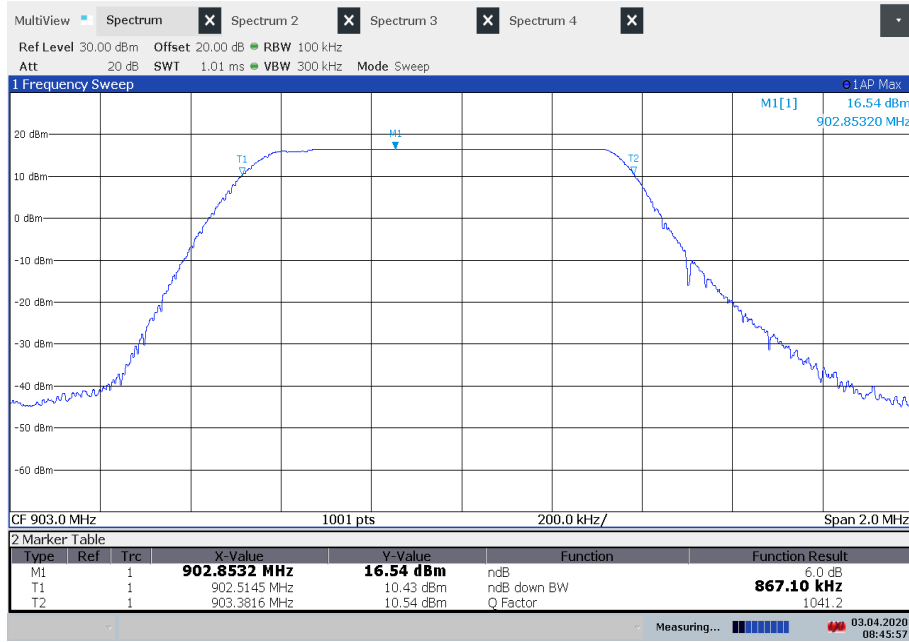
Results:

Test Conditions		6-dB BANDWIDTH [kHz]		
		Lowest channel	Middle channel	Highest channel
T_{nom}	V_{nom}	867.1	859.1	863.1

Test Conditions		99% BANDWIDTH [kHz]		
		Lowest channel	Middle channel	Highest channel
T_{nom}	V_{nom}	900.7	891.9	899.8

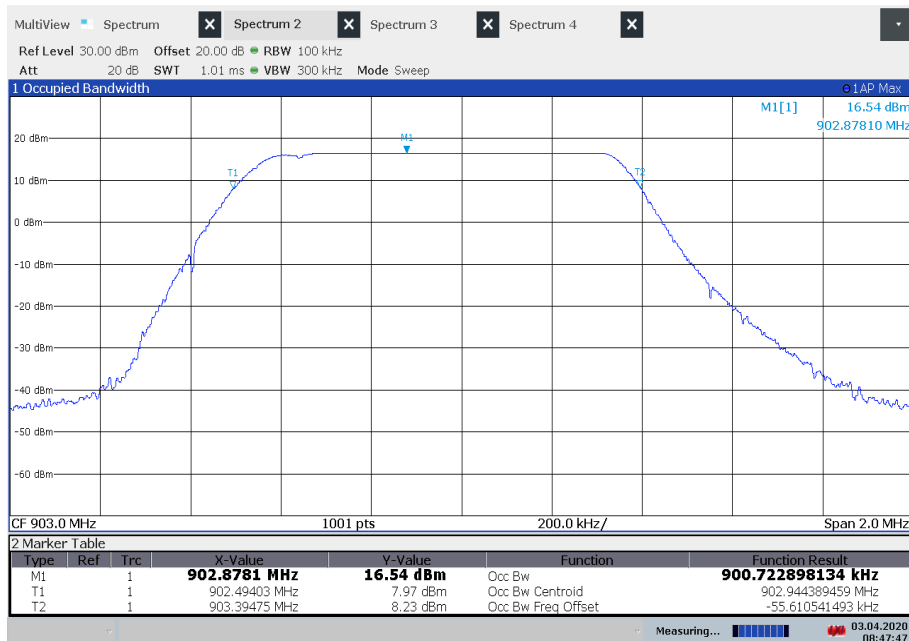
Plots:

Plot 1: Lowest Channel, 6 dB-BW



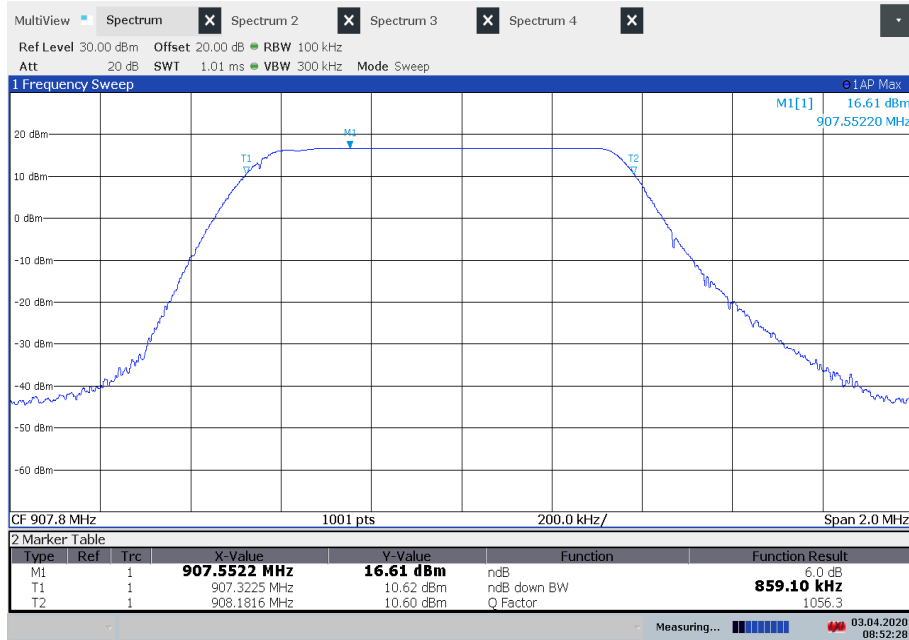
08:45:57 03.04.2020

Plot 2: Lowest Channel, 99%OBW



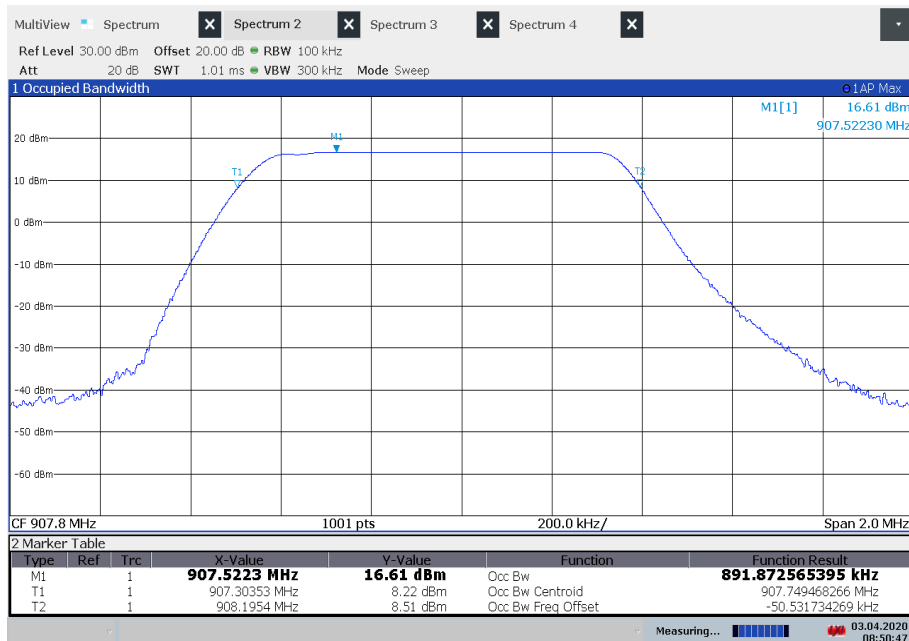
08:47:48 03.04.2020

Plot 3: Middle Channel, 6 dB-BW



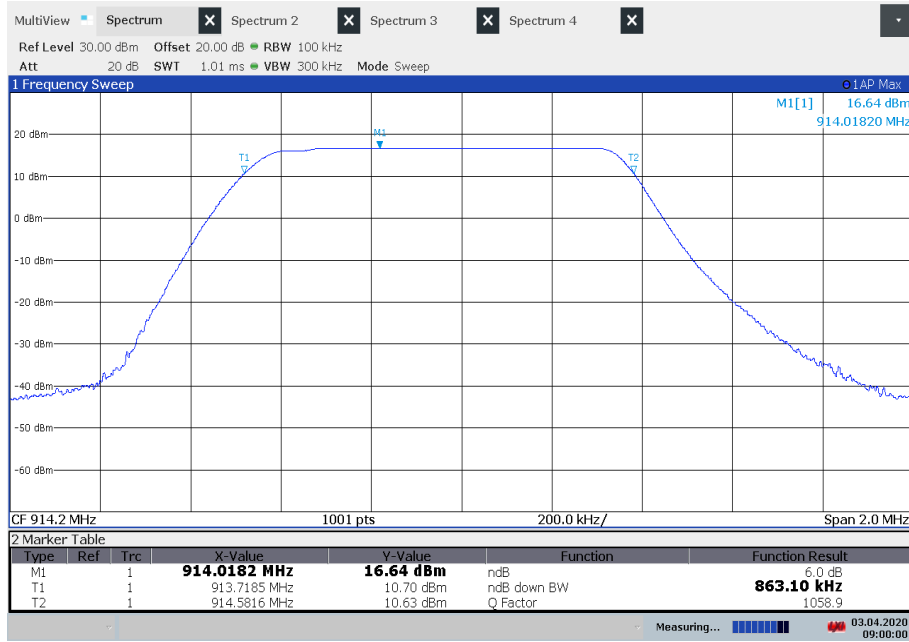
08:52:28 03.04.2020

Plot 4: Middle Channel, 99%OBW



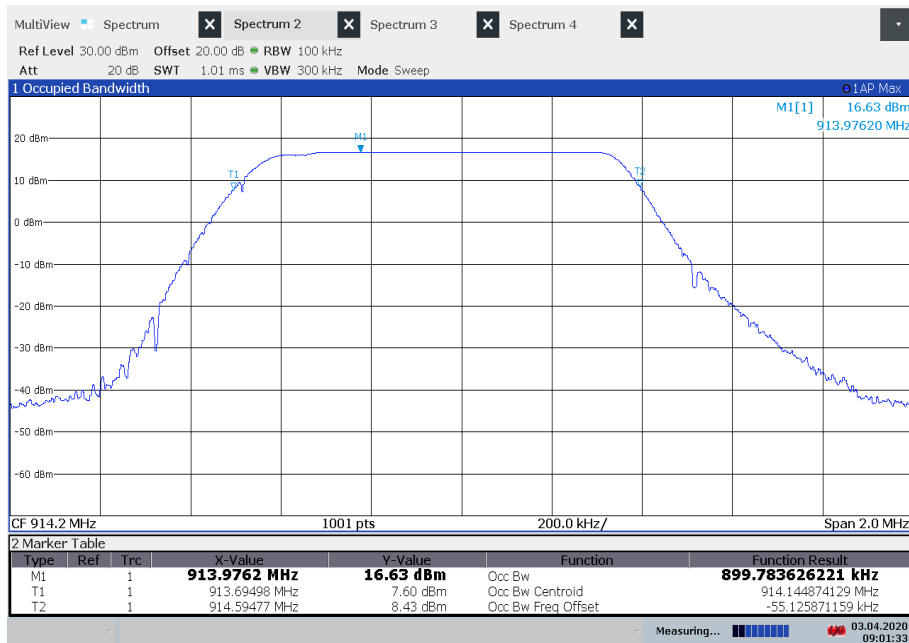
08:50:48 03.04.2020

Plot 5: Highest Channel, 6 dB-BW



09:00:01 03.04.2020

Plot 6: Highest Channel, 99%OBW



09:01:34 03.04.2020

11.5 Detailed spurious emissions @ the band edge – conducted and radiated

Description:

Measurement of the conducted band edge compliance. EUT is measured at the lower and upper band edge in single channel mode.

Measurement:

Measurement parameters	
Detector	Peak
Sweep time	Auto
Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Span	Lower Band Edge: 902 MHz Upper Band Edge: 928 MHz
Trace mode	Max hold
Test setup	See sub clause 6.3 A
Measurement uncertainty	See sub clause 8

Limits:

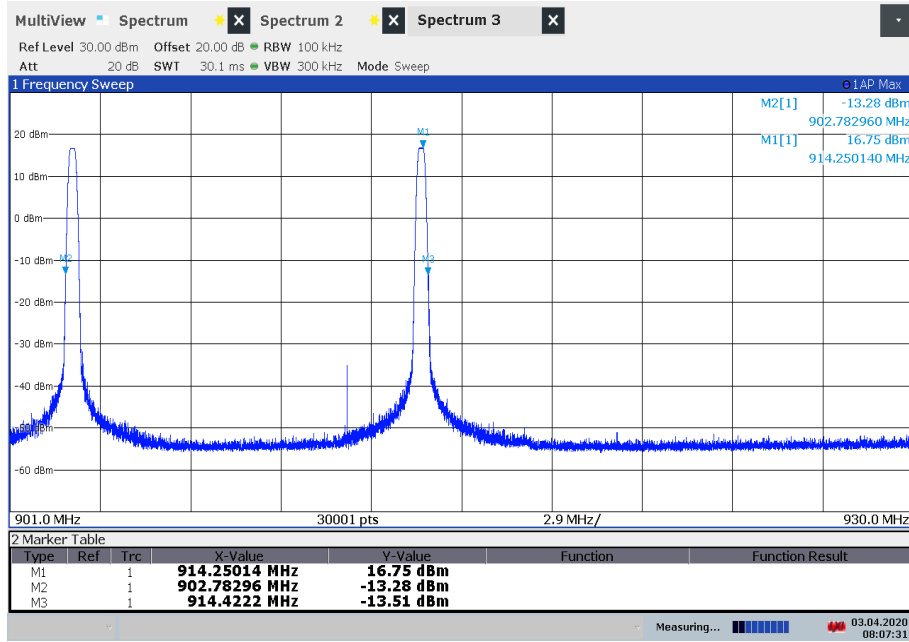
FCC	IC
<p>In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in Section 15.209(a) is not required.</p>	
<p>RSS-247, Issue 2: 5.5 Unwanted emissions: In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.</p>	

Results conducted:

Scenario Modulation	Spurious band edge conducted	
	lowest channel	highest channel
Lower band edge – single channel mode	> 30 dB	> 30 dB
Upper band edge – single channel mode	> 30 dB	> 30 dB

Plots:

Plot 1: lowest and highest channel



08:07:32 03.04.2020

Results radiated:

No restricted band in the range ± 2 channel bandwidths of the Band-edges of the specified emission band! (608 MHz – 614 MHz and 960 MHz – 1240 MHz).

Section 15.205 Restricted bands of operation.

(a) Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090 - 0.110	16.42 - 16.423	399.9 - 410	4.5 - 5.15
¹ 0.495 - 0.505	16.69475 - 16.69525	608 - 614	5.35 - 5.46
2.1735 - 2.1905	16.80425 - 16.80475	960 - 1240	7.25 - 7.75
4.125 - 4.128	25.5 - 25.67	1300 - 1427	8.025 - 8.5
4.17725 - 4.17775	37.5 - 38.25	1435 - 1626.5	9.0 - 9.2
4.20725 - 4.20775	73 - 74.6	1645.5 - 1646.5	9.3 - 9.5
6.215 - 6.218	74.8 - 75.2	1660 - 1710	10.6 - 12.7
6.26775 - 6.26825	108 - 121.94	1718.8 - 1722.2	13.25 - 13.4
6.31175 - 6.31225	123 - 138	2200 - 2300	14.47 - 14.5
8.291 - 8.294	149.9 - 150.05	2310 - 2390	15.35 - 16.2
8.362 - 8.366	156.52475 - 156.52525	2483.5 - 2500	17.7 - 21.4
8.37625 - 8.38675	156.7 - 156.9	2690 - 2900	22.01 - 23.12
8.41425 - 8.41475	162.0125 - 167.17	3260 - 3267	23.6 - 24.0
12.29 - 12.293	167.72 - 173.2	3332 - 3339	31.2 - 31.8
12.51975 - 12.52025	240 - 285	3345.8 - 3358	36.43 - 36.5
12.57675 - 12.57725	322 - 335.4	3600 - 4400	(²)
13.36 - 13.41			

11.6 Spurious Emissions Conducted

Description:

Measurement of the conducted spurious emissions in transmit mode. The EUT is set to single channel mode. The measurement is repeated for low, mid and high channel.

Measurement:

Measurement parameter	
Detector:	Peak
Sweep time:	Auto
Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Span:	9 kHz to 12.75 GHz
Trace mode:	Max Hold
Used equipment:	See chapter 6.3A
Measurement uncertainty:	See chapter 8

Limits:

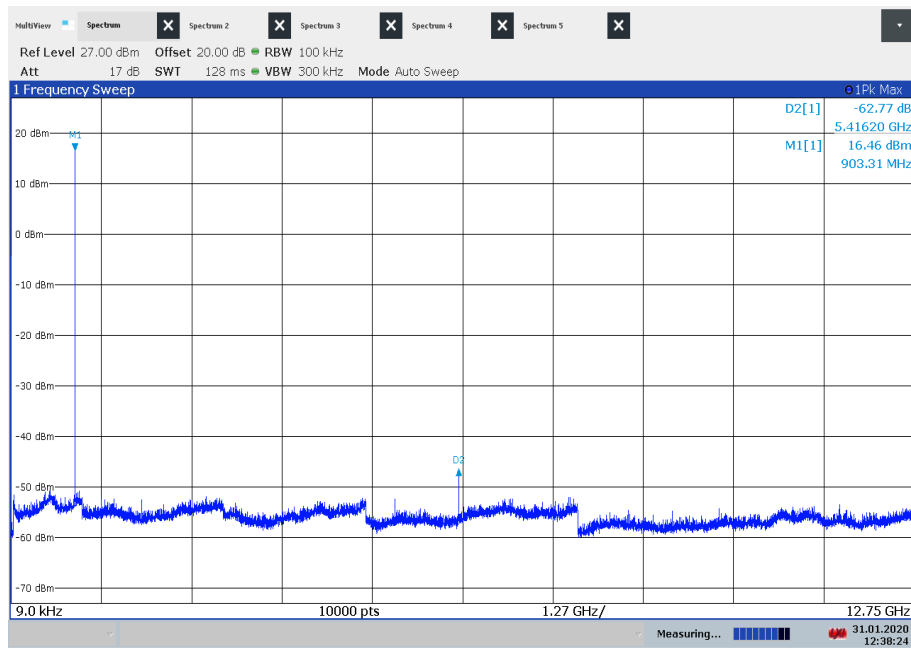
FCC	IC
TX spurious emissions conducted	
<p>In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in Section 15.209(a) is not required.</p>	
<p>RSS-247, Issue 2: 5.5 Unwanted emissions: In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.</p>	

Result:

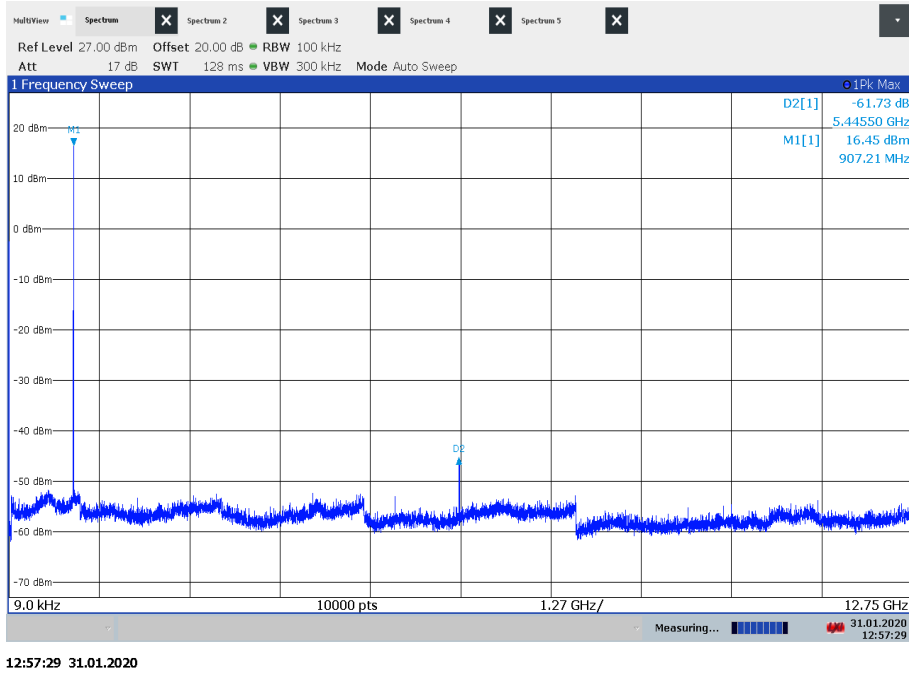
Emission Limitation					
Frequency [MHz]		Amplitude of emission [dBm]	Limit max. allowed emission power	actual attenuation below frequency of operation [dB]	Results
903.0		16.46	24 dBm		Operating frequency
See plots			-30 dBc	No emissions detected!	
907.8		16.45	24 dBm		Operating frequency
See plots			-30 dBc	No emissions detected!	
914.2		16.40	24 dBm		Operating frequency
See plots			-30 dBc	No emissions detected!	

Plots:

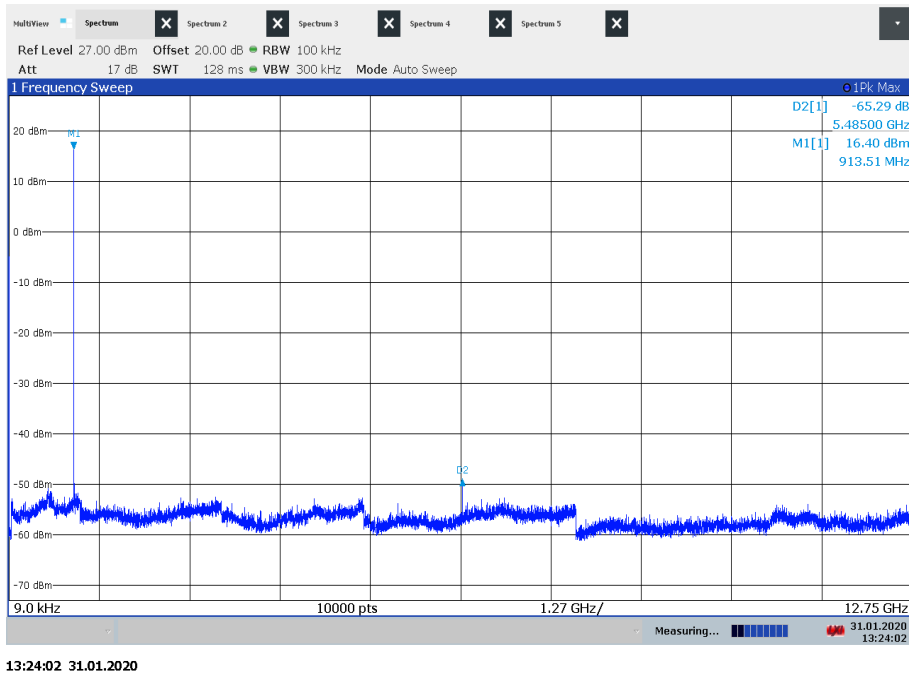
Plot 1: Lowest channel, 9 kHz – 12.75 GHz



Plot 2: Middle channel, 9 kHz – 12.75 GHz



Plot 3: Highest channel, 9 kHz – 12.75 GHz



11.7 Spurious Emissions Radiated < 30 MHz

Description:

The measurement is performed in the mode with the highest output power. The limits are recalculated to a measurement distance of 3 m according the ANSI C63.10.

Measurement:

Measurement parameter	
Detector:	Peak / Quasi Peak
Sweep time:	Auto
Video bandwidth:	F < 150 kHz: 200 Hz F > 150 kHz: 9 kHz
Resolution bandwidth:	F < 150 kHz: 1 kHz F > 150 kHz: 100 kHz
Span:	9 kHz to 30 MHz
Trace mode:	Max Hold
Used equipment:	See chapter 6.2 A
Measurement uncertainty:	See chapter 8

Limits:

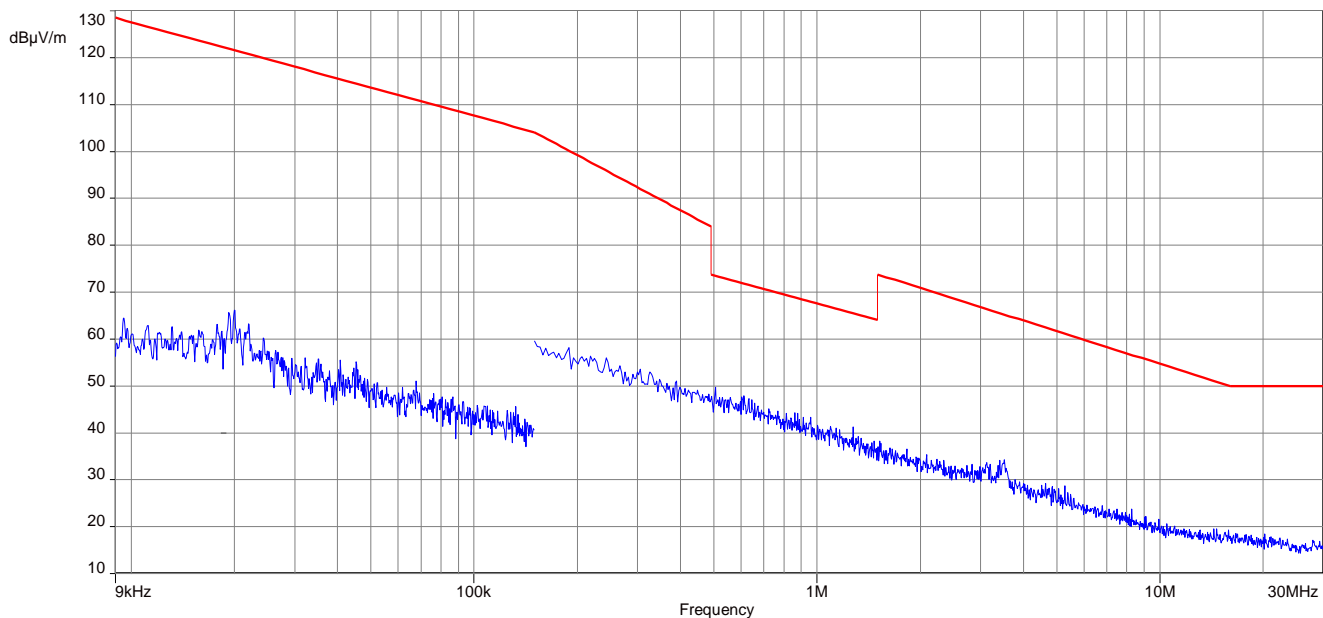
FCC		IC	
TX spurious emissions radiated < 30 MHz			
Frequency (MHz)	Field strength (dBµV/m)	Measurement distance	
0.009 – 0.490	2400/F(kHz)	300	
0.490 – 1.705	24000/F(kHz)	30	
1.705 – 30.0	30	30	

Result:

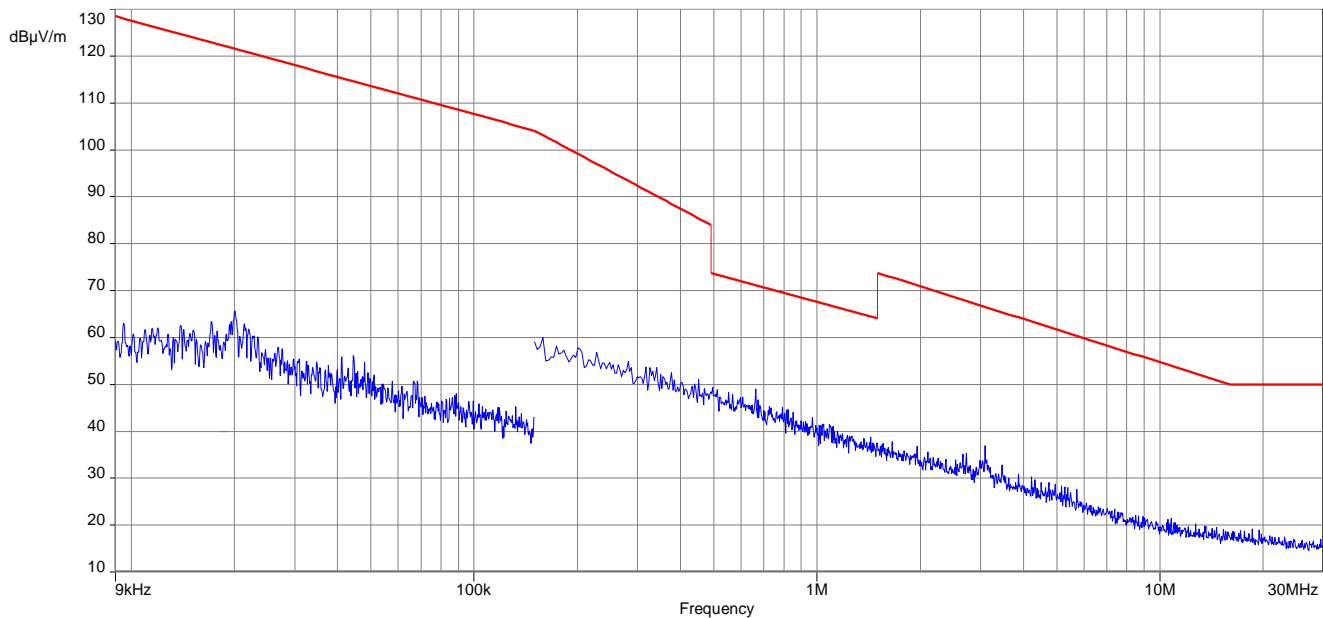
SPURIOUS EMISSIONS LEVEL								
Lowest channel			Middle channel			Highest channel		
Frequency [MHz]	Detector	Level [dBµV/m]	Frequency [MHz]	Detector	Level [dBµV/m]	Frequency [MHz]	Detector	Level [dBµV/m]
All emissions were more than 10 dB below the limit.								

Plots:

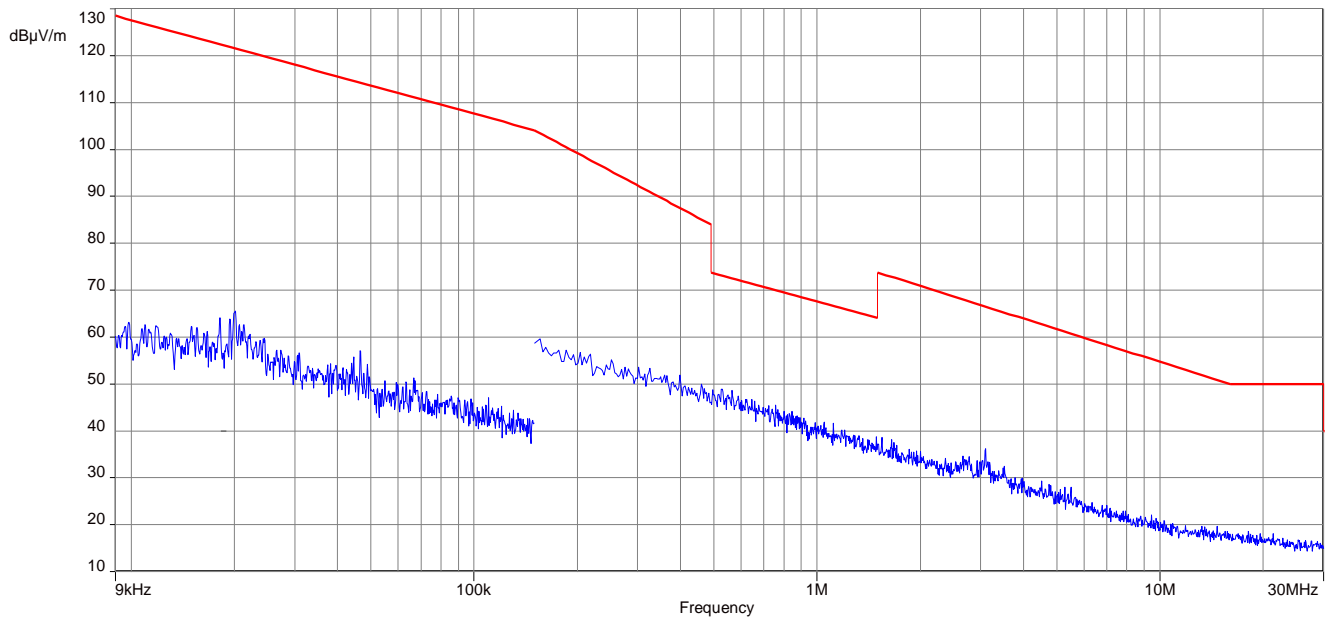
Plot 1: TX-Mode lowest channel



Plot 2: TX-Mode middle channel



Plot 3: TX-Mode highest channel



11.8 Spurious Emissions Radiated > 30 MHz

11.8.1 Spurious emissions radiated 30 MHz to 1 GHz

Description:

Measurement of the radiated spurious emissions in transmit mode. The measurement is performed at channel low, mid and high.

Measurement:

Measurement parameters	
Detector	Peak / Quasi Peak
Sweep time	Auto
Resolution bandwidth	3 x VBW
Video bandwidth	120 kHz
Span	30 MHz to 1 GHz
Trace mode	Max hold
Measured modulation	DSSS
Test setup	See sub clause 6.1 A
Measurement uncertainty	See sub clause 8

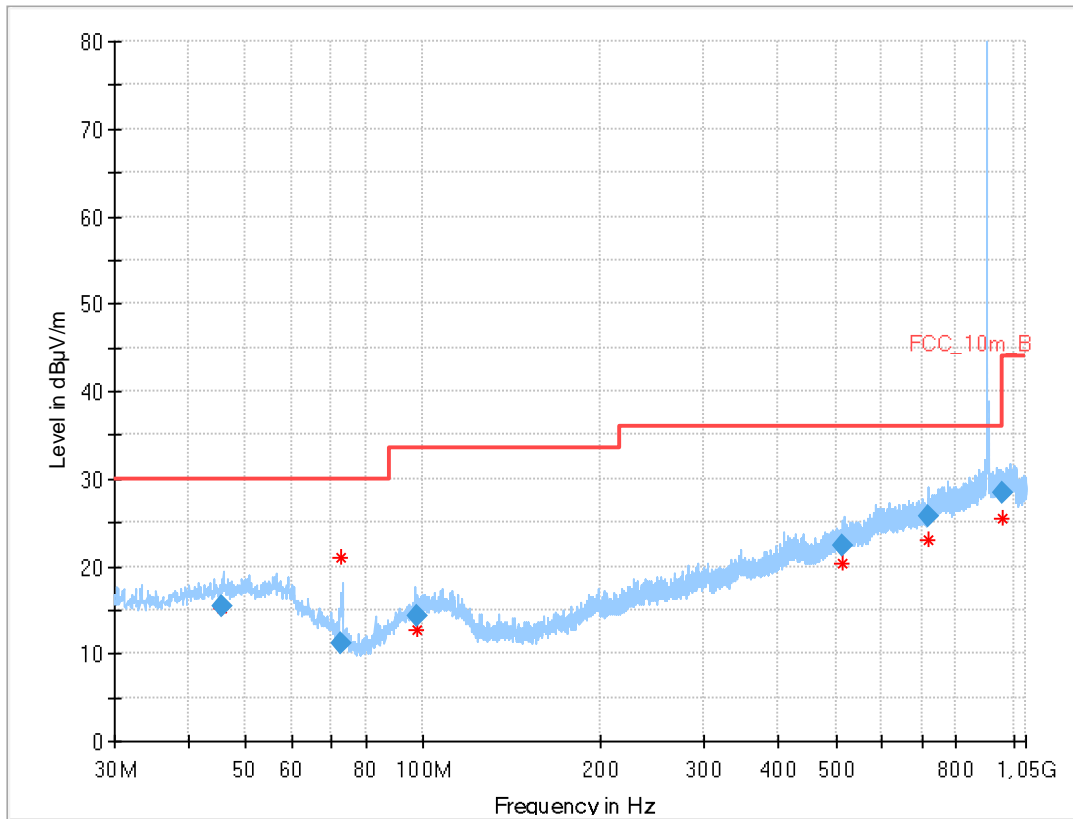
Limits:

FCC	IC	
Band-edge Compliance of conducted and radiated emissions		
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).		
Frequency (MHz)	Field Strength (dBµV/m)	Measurement distance
30 - 88	30.0	10
88 – 216	33.5	10
216 – 960	36.0	10
Above 960	54.0	3

Result: See result table below the plots.

Plots:

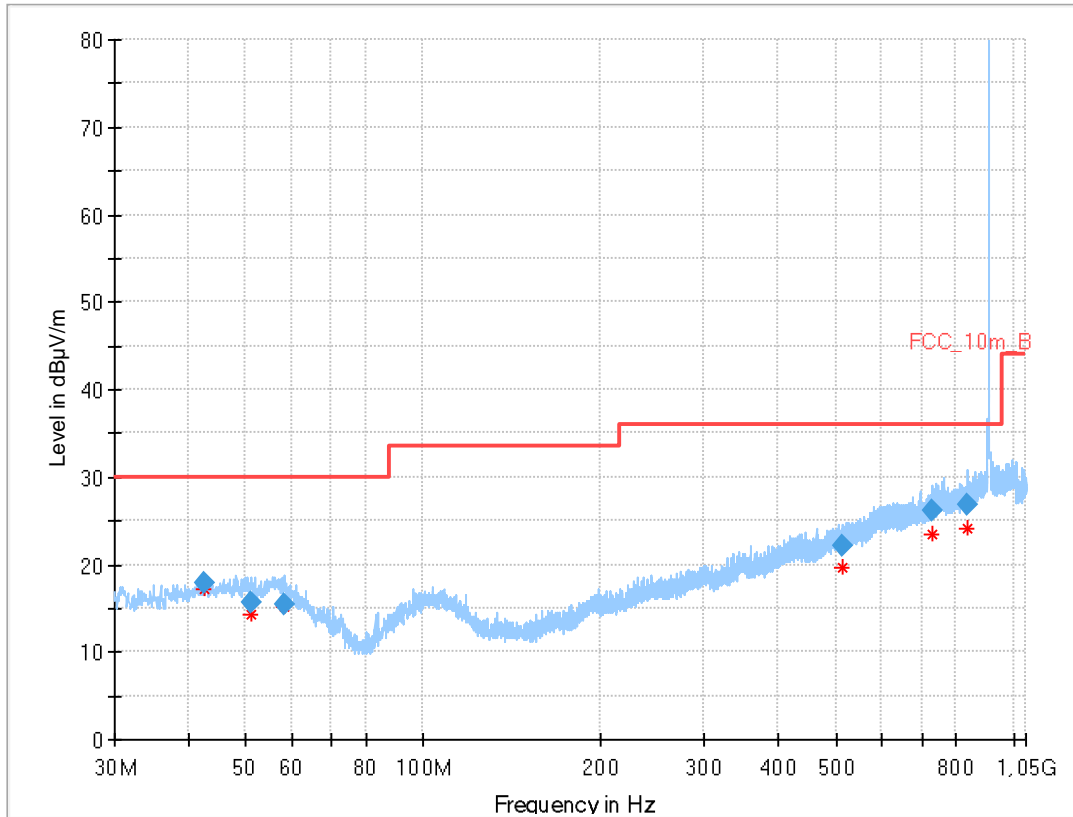
Plot 1: 30 MHz – 1 GHz, horizontal & vertical polarisation (lowest channel)



Final_Result

Frequency (MHz)	QuasiPeak (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
45.669	15.45	30.0	14.6	1000	120	170.0	H	112	14
72.706	11.23	30.0	18.8	1000	120	170.0	V	202	9
97.607	14.32	33.5	19.2	1000	120	170.0	H	-22	12
515.211	22.30	36.0	13.7	1000	120	123.0	H	157	19
719.786	25.69	36.0	10.3	1000	120	170.0	V	-22	21
960.385	28.29	44.0	15.7	1000	120	170.0	V	-22	24

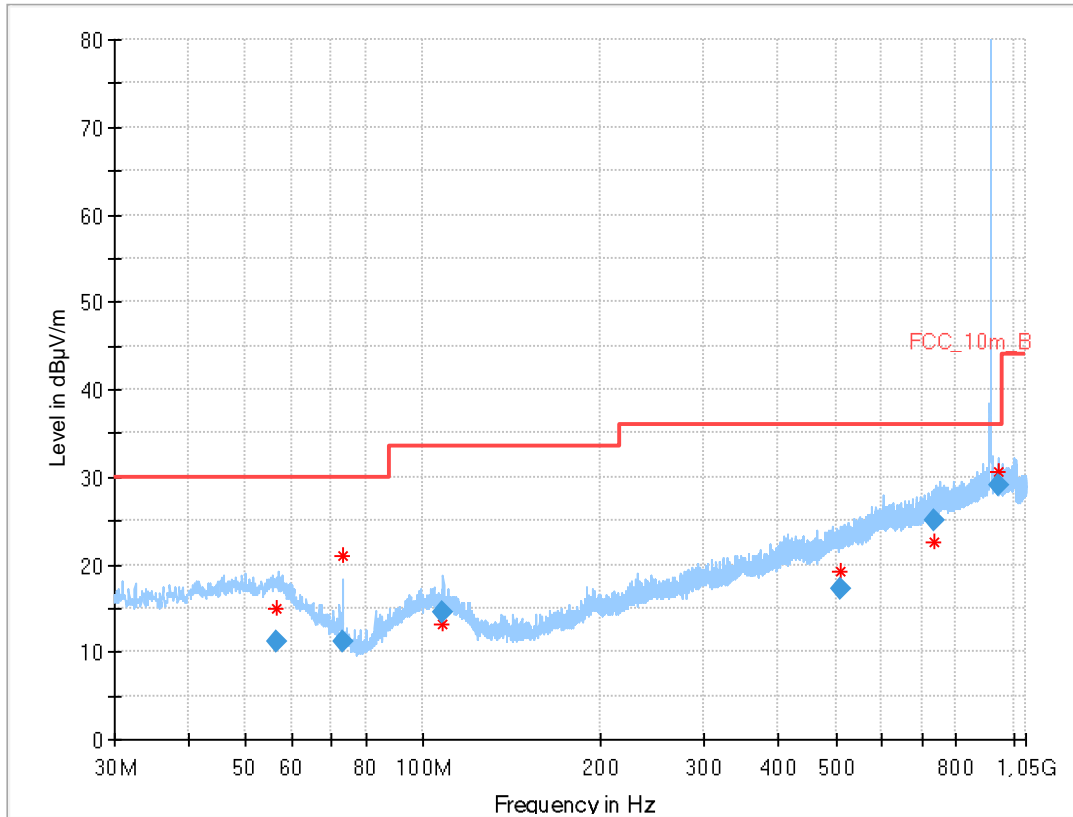
Plot 2: 30 MHz – 1 GHz, horizontal & vertical polarisation (middle channel)



Final_Result

Frequency (MHz)	QuasiPeak (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
42.681	17.84	30.0	12.2	1000	120	121.0	H	158	14
50.972	15.65	30.0	14.4	1000	120	170.0	H	67	14
58.353	15.49	30.0	14.5	1000	120	106.0	V	247	14
511.700	22.14	36.0	13.9	1000	120	147.0	H	247	19
728.044	26.14	36.0	9.9	1000	120	170.0	H	247	21
833.156	26.76	36.0	9.2	1000	120	105.0	V	157	23

Plot 3: 30 MHz – 1 GHz, horizontal & vertical polarisation (highest channel)



Final_Result

Frequency (MHz)	QuasiPeak (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
56.400	11.25	30.0	18.8	1000	120	170.0	H	292	15
73.034	11.21	30.0	18.8	1000	120	170.0	V	89	9
108.007	14.63	33.5	18.9	1000	120	170.0	H	-22	12
510.582	17.20	36.0	18.8	1000	120	170.0	H	247	19
734.509	25.04	36.0	11.0	1000	120	106.0	V	67	22
946.351	29.16	36.0	6.8	1000	120	118.0	H	189	24

11.8.2 Spurious emissions radiated above 1 GHz

Description:

Measurement of the radiated spurious emissions in transmit mode. The measurement is performed in the mode with the highest output power.

Measurement parameters	
Detector	Peak / RMS
Sweep time	Auto
Resolution bandwidth	1 MHz
Video bandwidth	3 x RBW
Span	1 GHz to 12.75 GHz
Trace mode	Max hold
Test setup	See sub clause 6.2 B (1 GHz – 12.75 GHz)
Measurement uncertainty	See sub clause 8

The modulation with the highest output power was used to perform the transmitter spurious emissions. If spurious were detected a re-measurement was performed on the detected frequency with each modulation.

Limits:

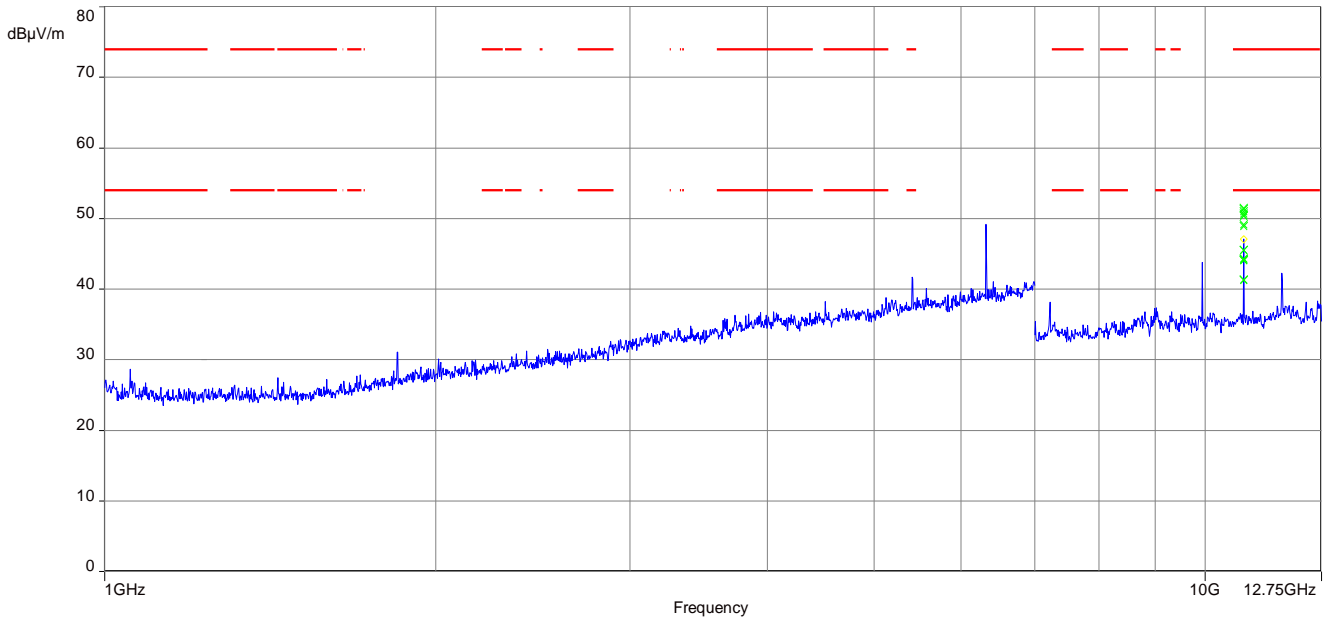
FCC		IC	
TX spurious emissions radiated			
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).			
§15.209			
Frequency (MHz)	Field strength (dBµV/m)	Measurement distance	
Above 960	54.0	3	

Results:

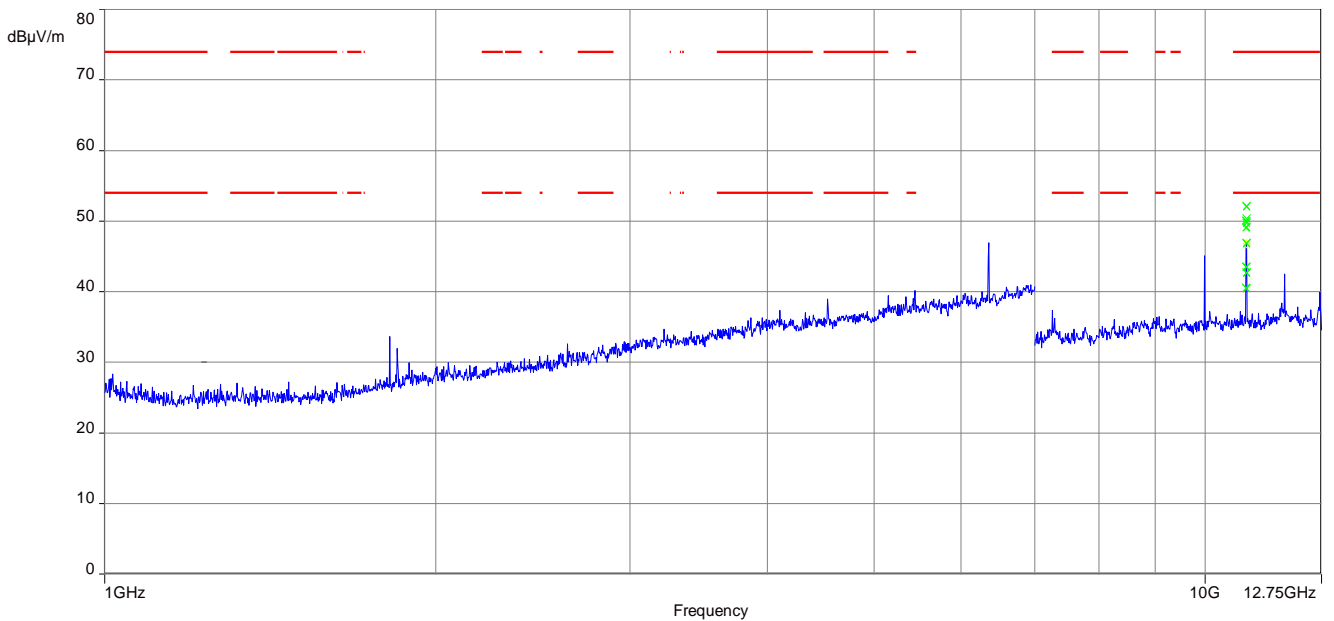
TX spurious emissions radiated								
Lowest channel			Middle channel			Highest channel		
F [MHz]	Detector	Level [dBµV/m]	F [MHz]	Detector	Level [dBµV/m]	F [MHz]	Detector	Level [dBµV/m]
10837	Peak	51.54	10893	Peak	52.18	10968	Peak	51.39
	RMS	45.60		RMS	46.87		RMS	44.99

Plots:

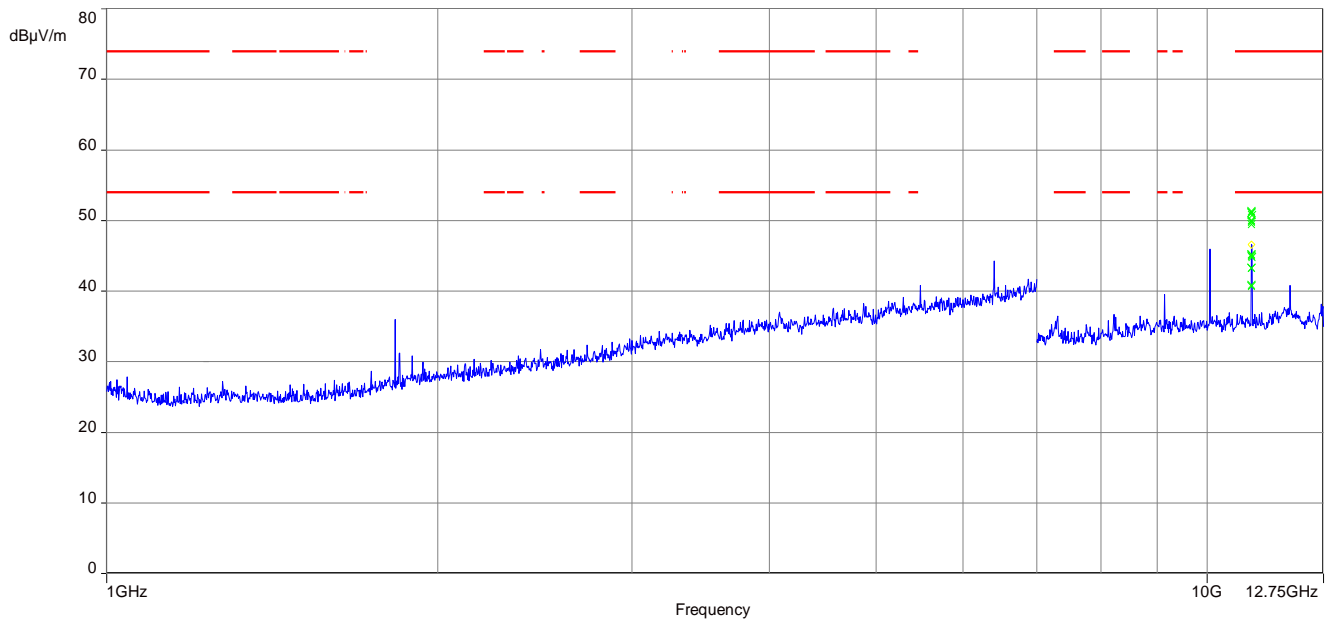
Plot 1: 1 GHz – 12.75 GHz, horizontal & vertical polarisation (lowest channel)



Plot 2: 1 GHz – 12.75 GHz, horizontal & vertical polarisation (middle channel)



Plot 3: 1 GHz – 12.75 GHz, horizontal & vertical polarisation (highest channel)



12 Measurement results Part 2 Hybrid Mode

12.1 Antenna gain

Description:

The antenna gain of the complete system is calculated by the difference of radiated power in EIRP and the conducted power of the module.

Measurement:

Measurement parameters	
Detector	Peak
Sweep time	Auto
Resolution bandwidth	1 MHz
Video bandwidth	3 MHz
Span	5 MHz
Trace mode	Max hold
Test setup	See sub clause 6.2 B (radiated) See sub clause 6.3 A (conducted)
Measurement uncertainty	See sub clause 8

Limits:

FCC	IC
Antenna gain	
<p>The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.</p>	

Results:

	Low channel	Middle channel	High channel
Conducted power	16.43 dBm	16.49 dBm	16.46 dBm
Radiated power	20.46 dBm	20.90 dBm	21.54 dBm
Gain Calculated	4.03 dBi	4.41 dBi	5.08 dBi

12.2 Carrier Frequency Separation

Description:

Measurement of the carrier frequency separation of a hybrid system. EUT in hopping mode.

Measurement:

Measurement parameters	
Detector	Peak
Sweep time	Auto
Resolution bandwidth	See plots
Video bandwidth	See plots
Span	See plots
Trace mode	Max hold
Test setup	See sub clause 6.3 A
Measurement uncertainty	See sub clause 8

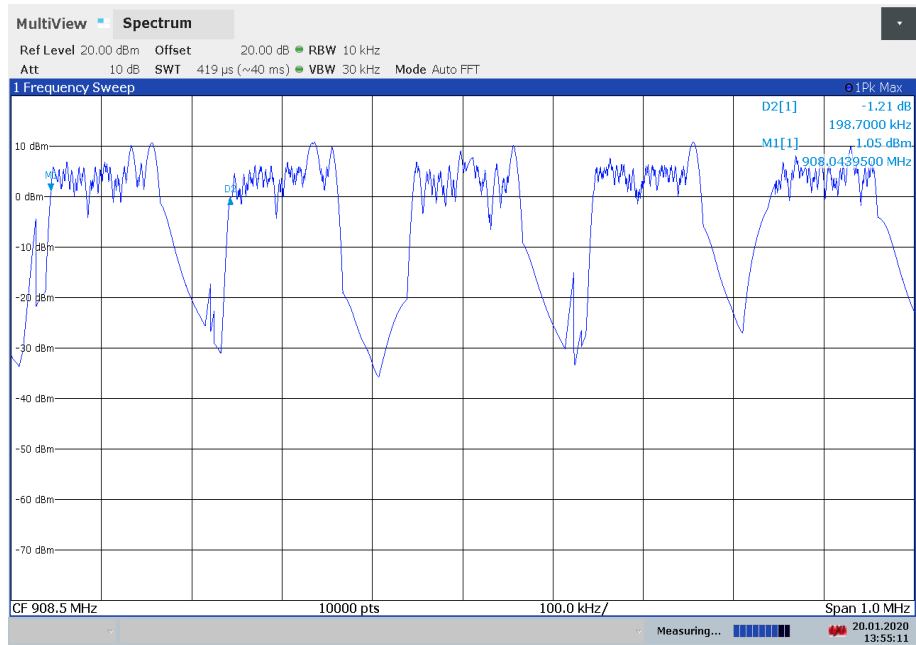
Limits:

FCC	IC
Carrier frequency separation	
Minimum 25 kHz or two-thirds of the 20 dB bandwidth of the hybrid system whichever is greater.	

Result: The channel separation is 198.70 kHz

Plots:

Plot 1: Frequency separation



13:55:11 20.01.2020

12.3 Spectrum bandwidth

Description:

Measurement of the 20dB bandwidth and 99% bandwidth of the modulated signal. The measurement is performed according to the "Measurement Guidelines" (DA 00-705, March 30, 2000). EUT in single channel mode.

Measurement:

Measurement parameters	
Detector	Peak
Sweep time	Auto
Resolution bandwidth	5 kHz
Video bandwidth	100 kHz
Span	See plots
Trace mode	Max hold
Test setup	See sub clause 6.3 A
Measurement uncertainty	See sub clause 8

Limits:

FCC	IC
None	

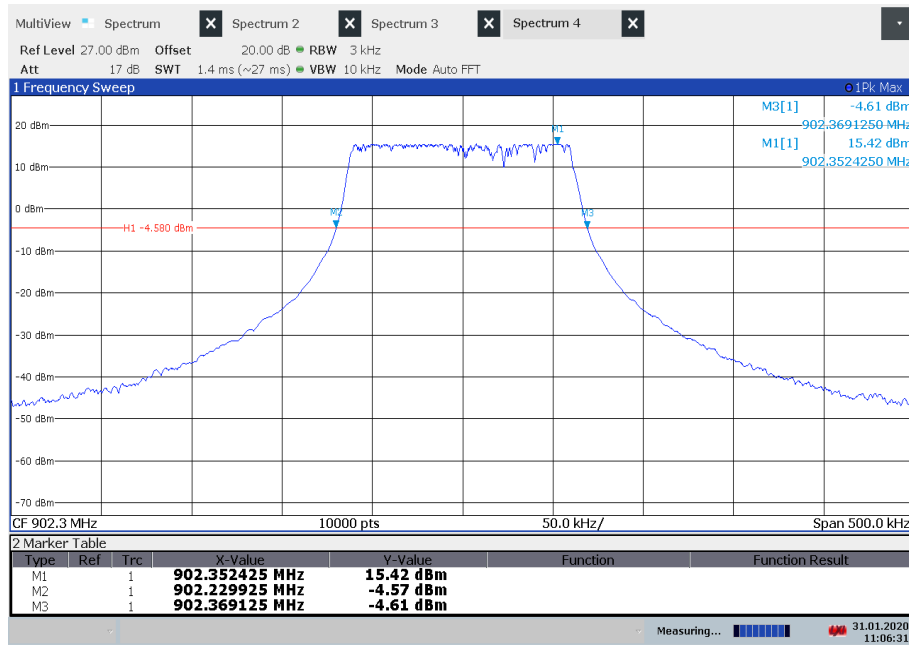
Result:

Test Conditions		20dB BANDWIDTH [kHz]		
		Low channel	Middle channel	High channel
T_{nom}	V_{nom}	139.2	138.9	139.10

Test Conditions		99% BANDWIDTH [kHz]		
		Low channel	Middle channel	High channel
T_{nom}	V_{nom}	125.95	126.02	126.17

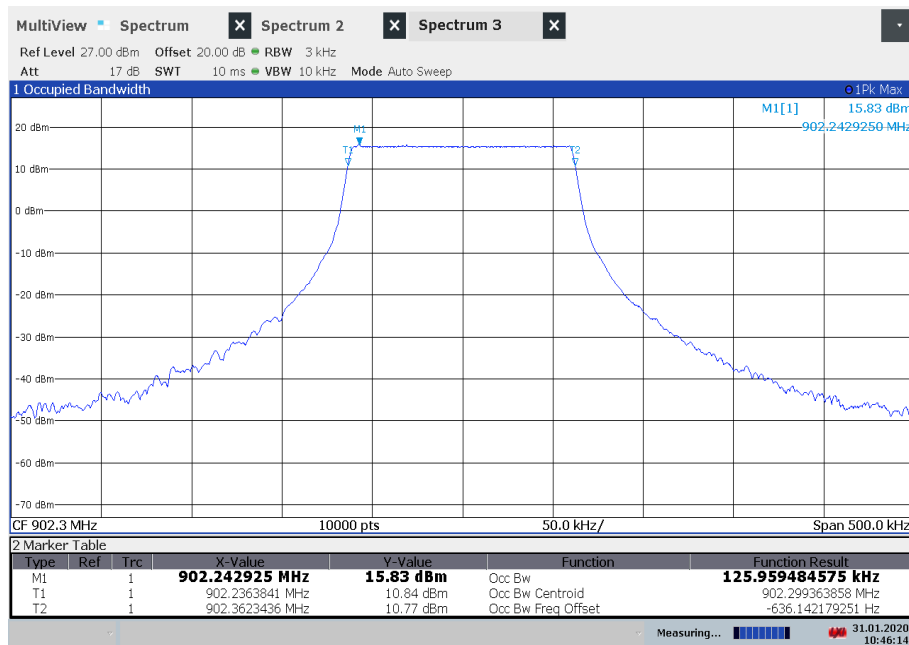
Plots:

Plot 1: Lowest Channel, 20 dB-BW



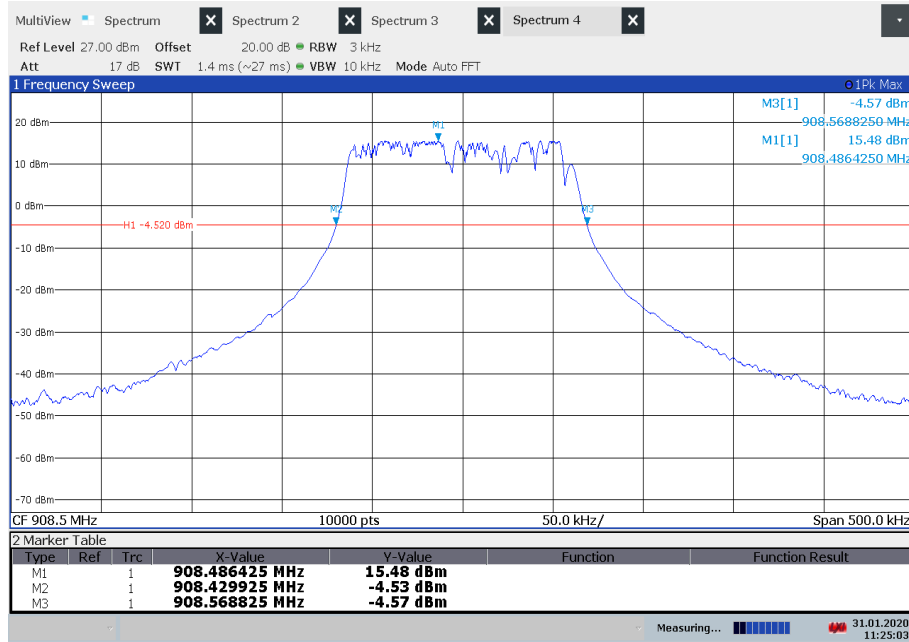
11:06:31 31.01.2020

Plot 2: Lowest Channel, 99%OBW



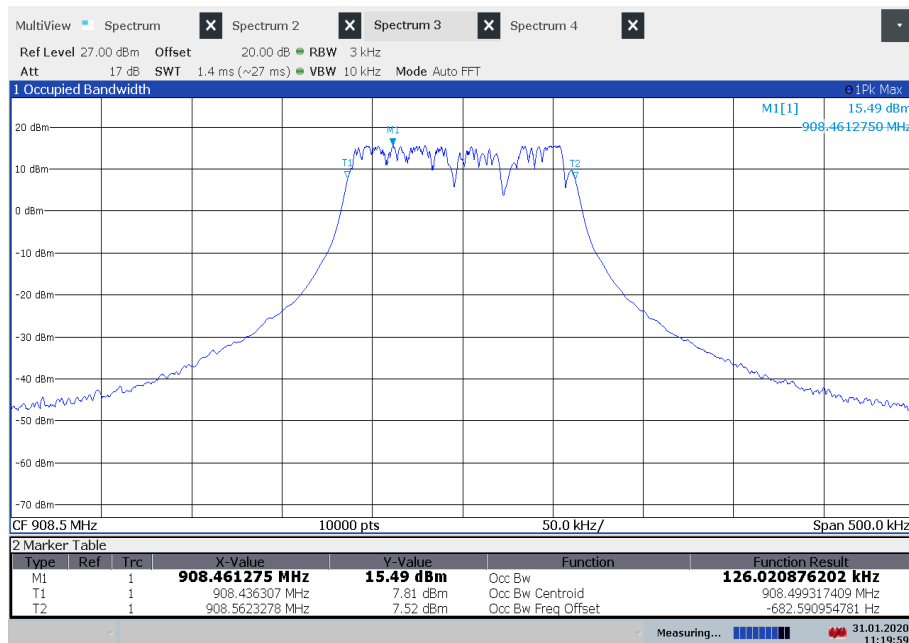
10:46:14 31.01.2020

Plot 3: Middle Channel, 20 dB-BW



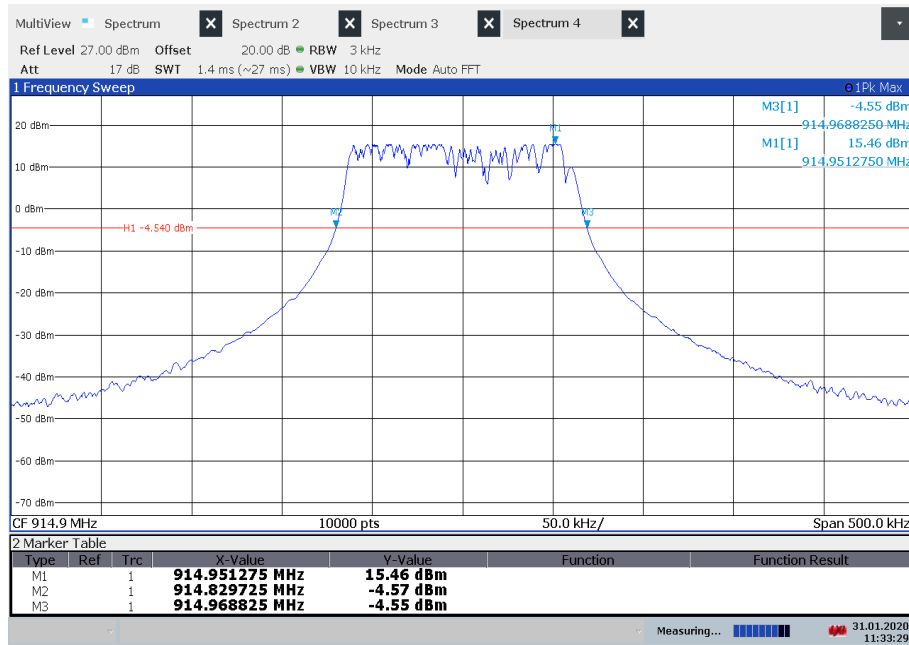
11:25:04 31.01.2020

Plot 4: Middle Channel, 99%OBW



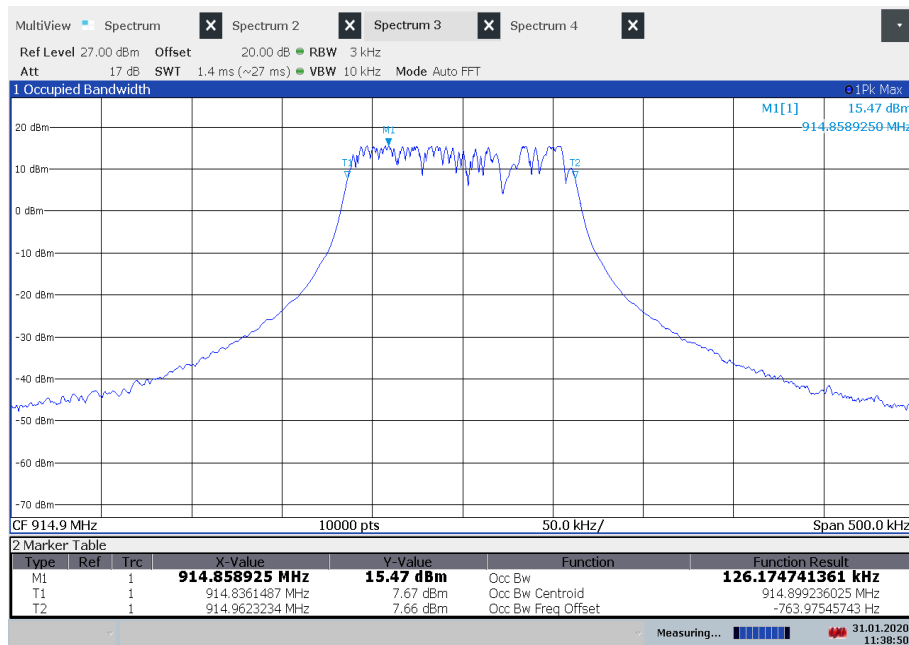
11:20:00 31.01.2020

Plot 3: Highest Channel, 20 dB-BW



11:33:30 31.01.2020

Plot 2: Highest Channel, 99%OBW



11:38:50 31.01.2020

12.4 Average Time of Occupancy (dwell time)

Measurement:

The measurement is performed in zero span mode to show that none of the 64 used channels is allocated more than 0.4 seconds within a 25.6 seconds interval (64 channels times 0.4s).

Limits:

FCC
Average time of occupancy
For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4

Result: The time slot length is = 164.81 ms
Number of hops / channel @ 25.6s = 2

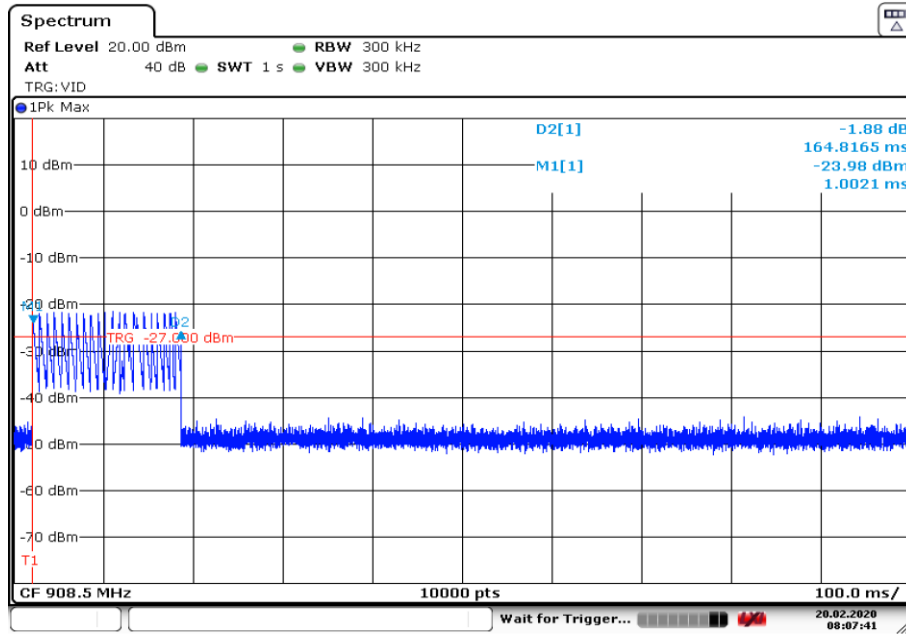
Within 25.6 s period, the average time of occupancy in 25.6 s: $2 * 164.81$ ms

→ The average time of occupancy = 330.62 ms

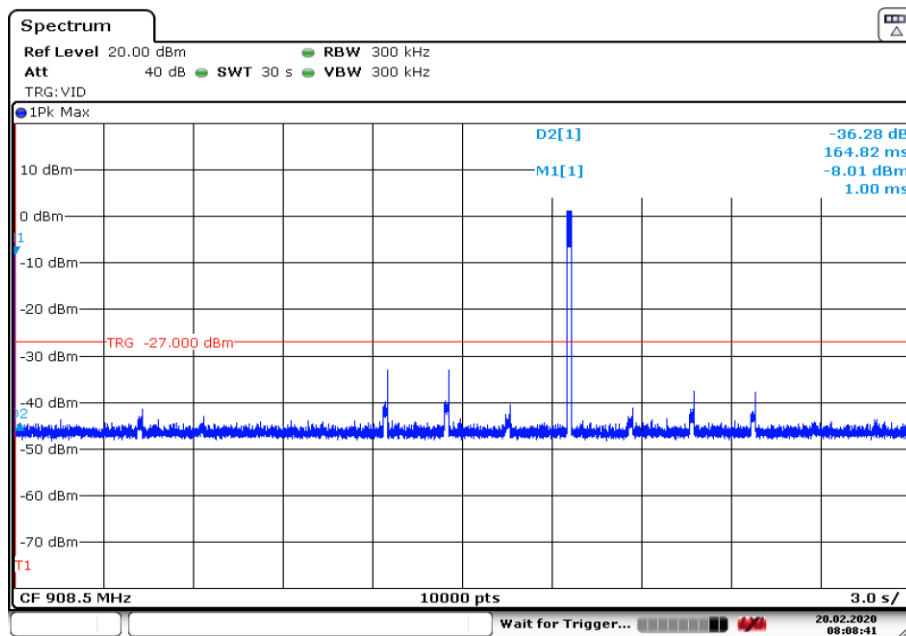
NOTE: In hybrid mode the minimum number of hopping channels is 8. In this mode the minimum channel separation and bandwidths stay the same as in the mode with 64 channels. Also the device also comply with the dwell time requirements while using 8 channels:
The time slot length: 164.81 ms
Average time of occupancy: 329.62 ms
Hops in 3.2 second: 2

Plots:

Plot 1: Time slot length = 164.81ms



Plot 2: hops / channel @ 30s = 2



12.5 Power spectral density

Description:

Measurement of the power spectral density of a digital modulated system. The measurement is repeated at the lowest, middle and highest channel.

Measurement:

Measurement parameter*	
Detector:	RMS
Sweep time:	10 s
Video bandwidth:	10 kHz
Resolution bandwidth:	3 kHz
Span:	200 kHz
Trace mode:	Single sweep
Measurement method	According to ANSI C63.10-2013 11.10.4 Method AVGPS-1A (alternative)
Test setup	See sub clause 6.3 A
Measurement uncertainty	See sub clause 8

*) according ANSI C63.10-2013; 11.11.4

Limits:

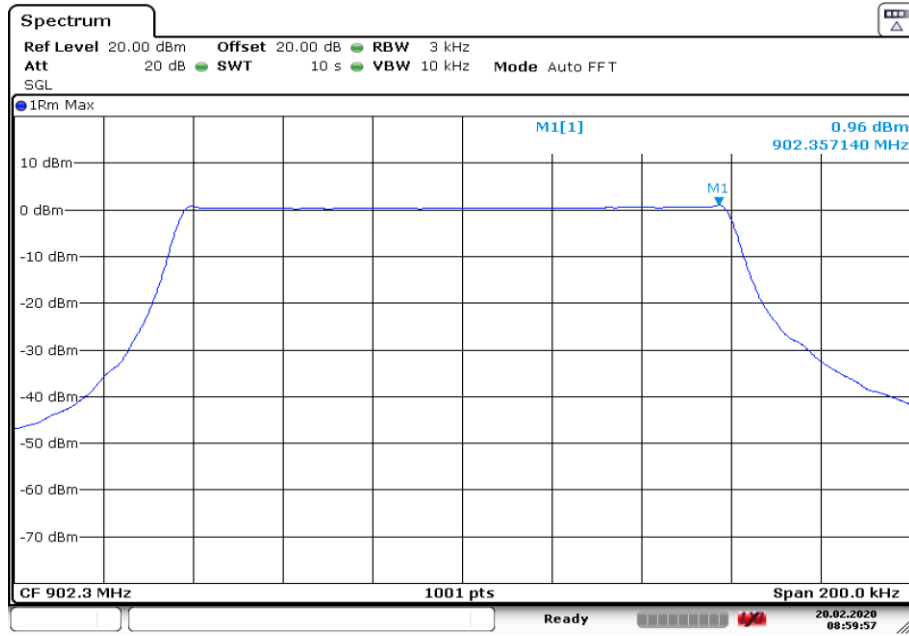
FCC	IC
Power Spectral Density	
A hybrid system must comply with the power density standard of 8 dBm in any 3 kHz band when the frequency hopping function is turned off.	

Results:

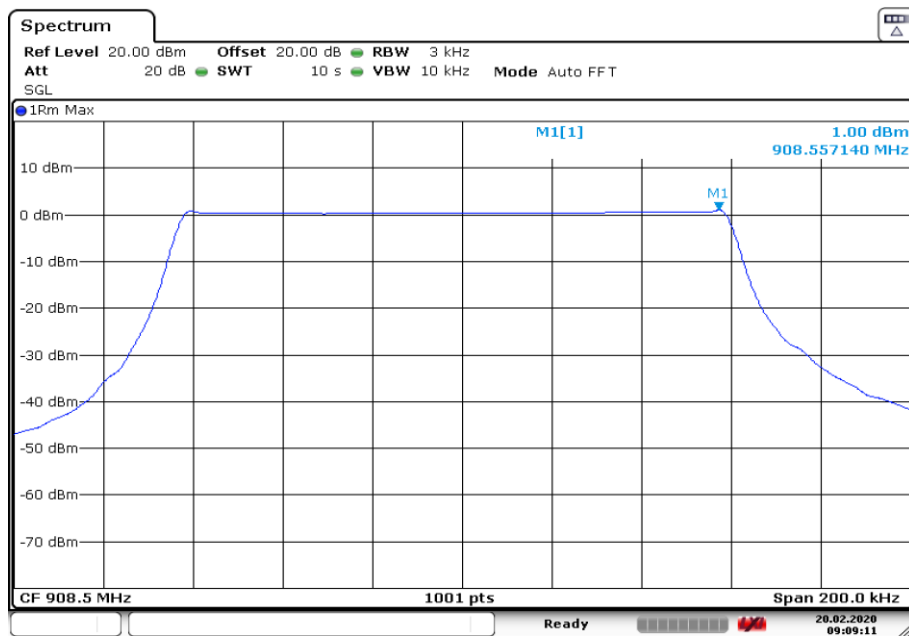
Channel	Power Spectral density*/ 3 kHz		
	902.3 MHz	908.5 MHz	914.9 MHz
	0.96 dBm	1.0 dBm	0.97 dBm

Plots:

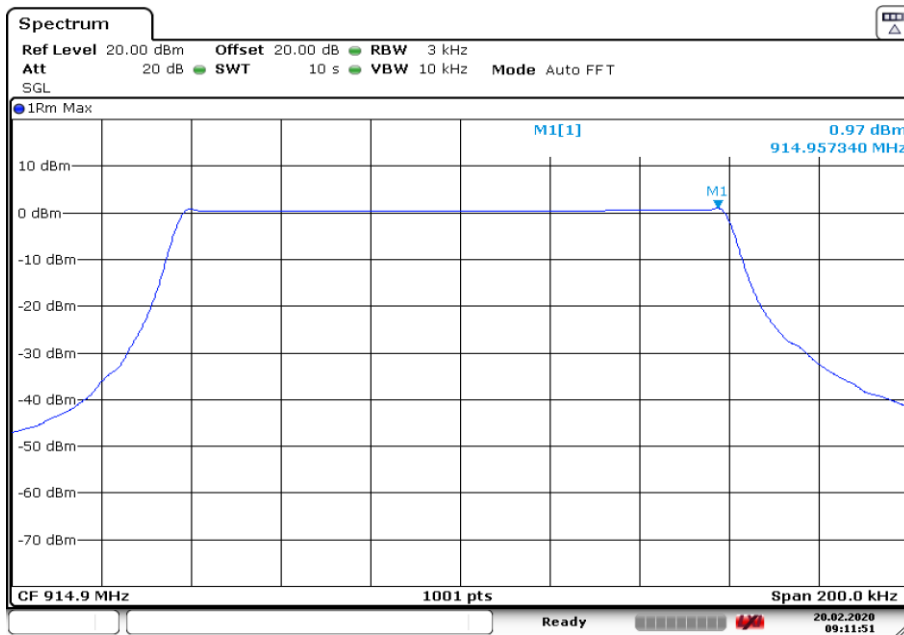
Plot 1: 902.3 MHz



Plot 2: 908.5 MHz



Plot 3: 914.9 MHz



Date: 20.FEB.2020 09:11:51

12.6 Maximum Output Power

Measurement:

Measurement parameter	
Detector:	RMS
Sweep time:	Auto
Resolution bandwidth:	10 kHz
Video bandwidth:	30 kHz
Span:	256 kHz
Trace mode:	Max hold
Measurement method	According to ANSI C63.10-2013 11.9.2.2.3 Method AVGSA-1A (alternative)
Used equipment:	See chapter 6.3 A
Measurement uncertainty:	See chapter 8

Limits:

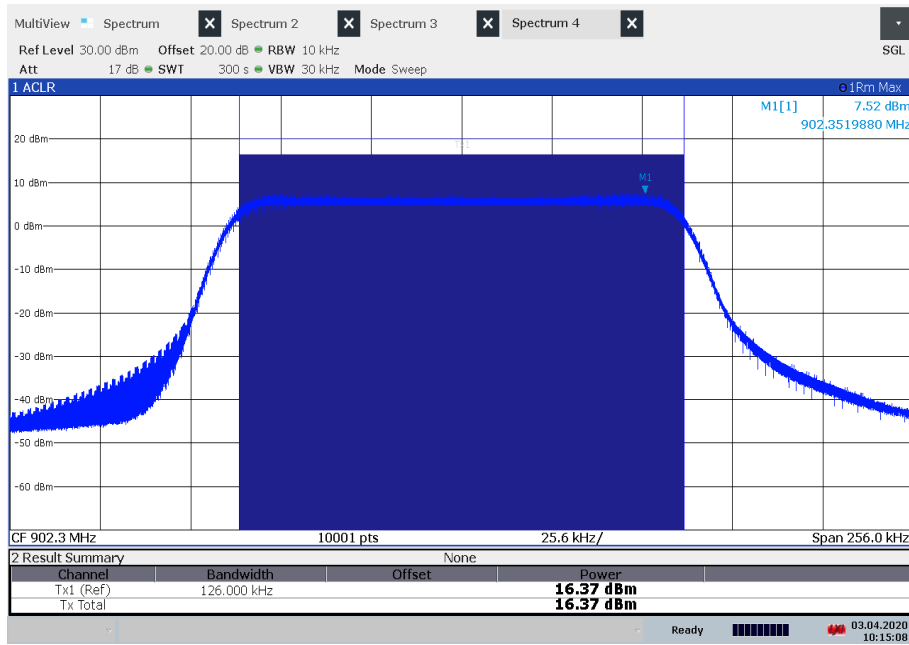
FCC	IC
Maximum Output Power Conducted	
Shall not exceed 30 dBm if number of hopping channels is above 50. Shall not exceed 24 dBm if number of hopping channels is below 50.	

Result:

Test Conditions		Maximum Output Power Conducted [dBm]		
		Lowest channel	Middle channel	Highest channel
T_{nom}	V_{nom}	16.4	16.4	16.4

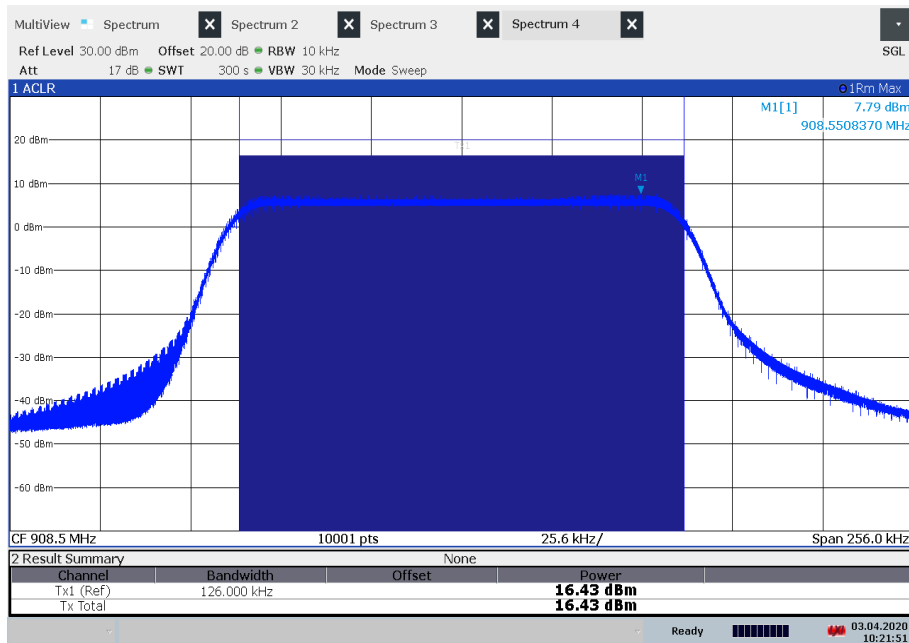
Plots:

Plot 1: Lowest Channel



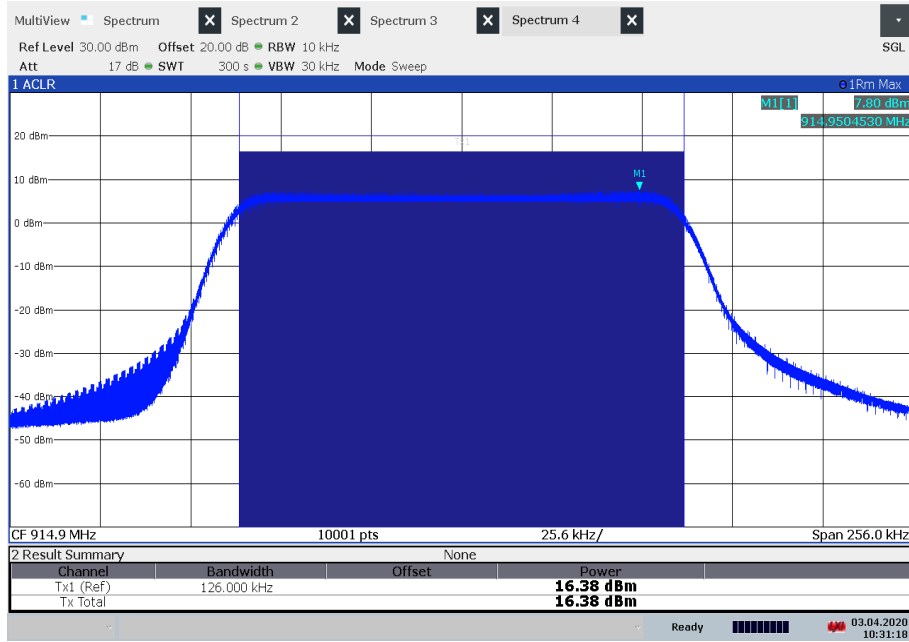
10:15:08 03.04.2020

Plot 2: Middle Channel



10:21:51 03.04.2020

Plot 3: Highest Channel



10:31:18 03.04.2020

12.7 Detailed spurious emissions @ the band edge – conducted and radiated

Description:

Measurement of the conducted band edge compliance. EUT is measured at the lower and upper band in hopping mode.

Measurement parameters	
Detector	Peak
Sweep time	Auto
Resolution bandwidth	100 kHz
Video bandwidth	300 kHz / 500 kHz
Span	Lower Band Edge: 902 MHz Upper Band Edge: 928 MHz
Trace mode	Max hold
Test setup	See sub clause 6.3 A
Measurement uncertainty	See sub clause 8

Limits:

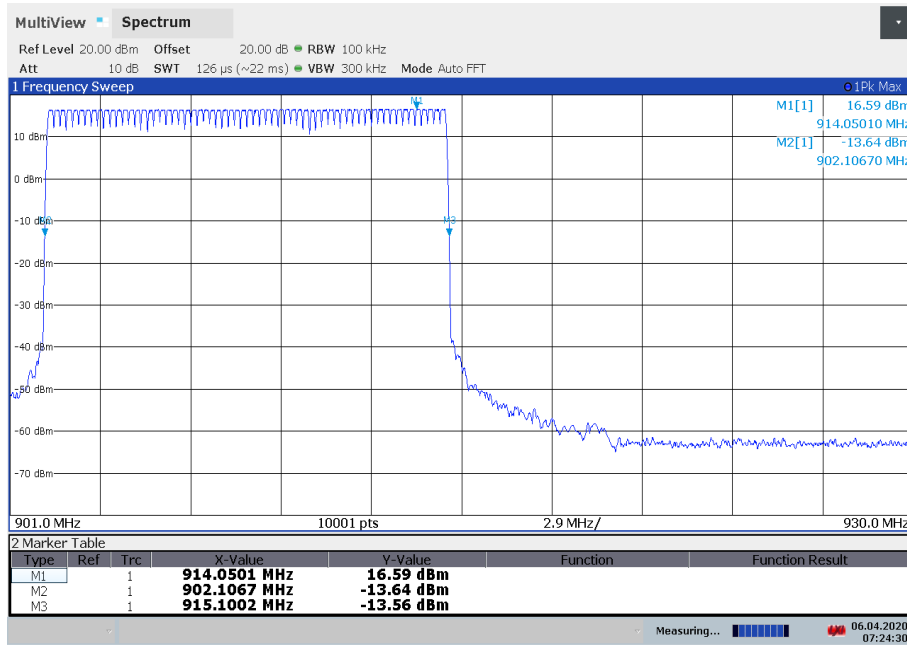
FCC	IC
<p>In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in Section 15.209(a) is not required.</p> <p>RSS-247, Issue 2: 5.5 Unwanted emissions: In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.</p>	

Results conducted:

Scenario Modulation	Spurious band edge conducted	
	lowest channel	highest channel
Lower band edge – hopping on	> 30 dB	> 30 dB
Upper band edge – hopping off	> 30 dB	> 30 dB

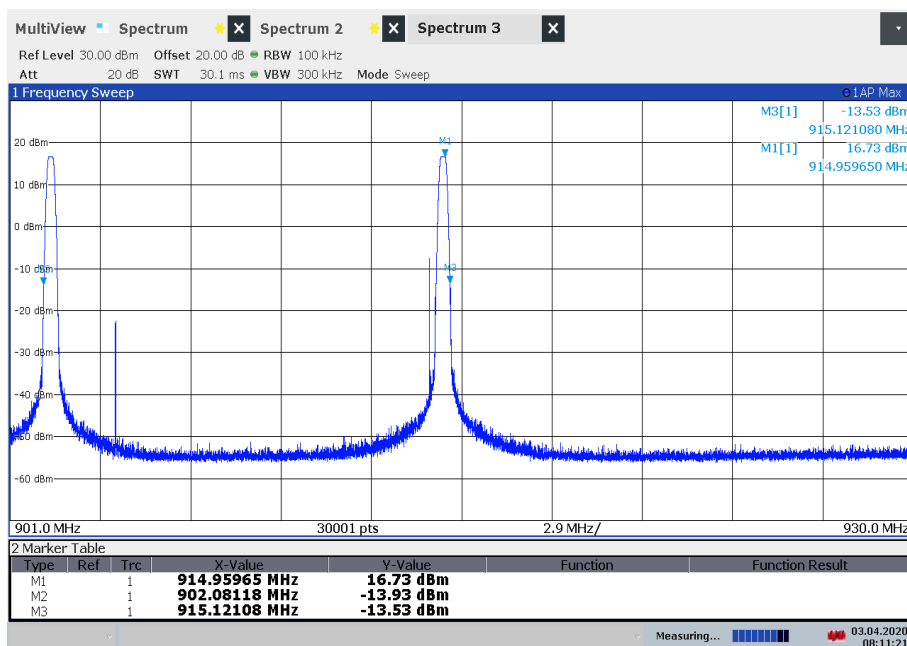
Plots:

Plot 1: 30 dB – hopping on



07:24:31 06.04.2020

Plot 2: 30 dB – hopping off



08:11:21 03.04.2020

Results radiated:

No restricted band in the range ± 2 channel bandwidths of the Band-edges of the specified emission band! (608 MHz – 614 MHz and 960 MHz – 1240 MHz).

Section 15.205 Restricted bands of operation.

(a) Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090 - 0.110	16.42 - 16.423	399.9 - 410	4.5 - 5.15
¹ 0.495 - 0.505	16.69475 - 16.69525	608 - 614	5.35 - 5.46
2.1735 - 2.1905	16.80425 - 16.80475	960 - 1240	7.25 - 7.75
4.125 - 4.128	25.5 - 25.67	1300 - 1427	8.025 - 8.5
4.17725 - 4.17775	37.5 - 38.25	1435 - 1626.5	9.0 - 9.2
4.20725 - 4.20775	73 - 74.6	1645.5 - 1646.5	9.3 - 9.5
6.215 - 6.218	74.8 - 75.2	1660 - 1710	10.6 - 12.7
6.26775 - 6.26825	108 - 121.94	1718.8 - 1722.2	13.25 - 13.4
6.31175 - 6.31225	123 - 138	2200 - 2300	14.47 - 14.5
8.291 - 8.294	149.9 - 150.05	2310 - 2390	15.35 - 16.2
8.362 - 8.366	156.52475 - 156.52525	2483.5 - 2500	17.7 - 21.4
8.37625 - 8.38675	156.7 - 156.9	2690 - 2900	22.01 - 23.12
8.41425 - 8.41475	162.0125 - 167.17	3260 - 3267	23.6 - 24.0
12.29 - 12.293	167.72 - 173.2	3332 - 3339	31.2 - 31.8
12.51975 - 12.52025	240 - 285	3345.8 - 3358	36.43 - 36.5
12.57675 - 12.57725	322 - 335.4	3600 - 4400	(²)
13.36 - 13.41			

12.8 Spurious Emissions Conducted

Description:

Measurement of the conducted spurious emissions in transmit mode. The EUT is set to single channel mode. The measurement is repeated for low, mid and high channel.

Measurement:

Measurement parameter	
Detector:	Peak
Sweep time:	Auto
Resolution bandwidth	100 kHz
Video bandwidth	300 kHz
Span:	9 kHz to 12.75 GHz
Trace-Mode:	Max Hold
Used equipment:	See chapter 6.3A
Measurement uncertainty:	See chapter 8

Limits:

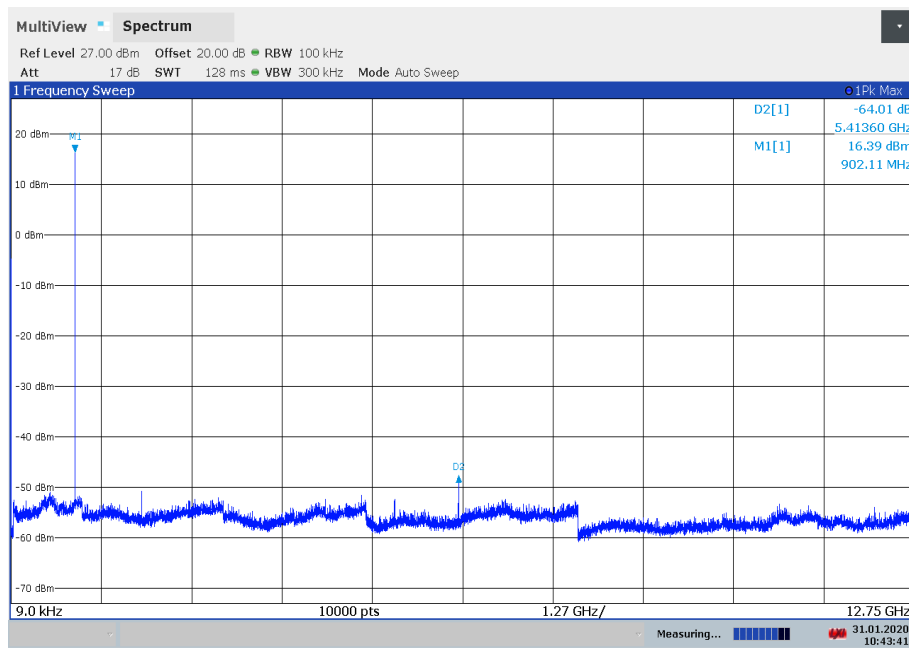
FCC	IC
TX spurious emissions conducted	
<p>In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in Section 15.209(a) is not required.</p>	
<p>RSS-247, Issue 2: 5.5 Unwanted emissions: In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.</p>	

Result:

Emission Limitation					
Frequency [MHz]		Amplitude of emission [dBm]	Limit max. allowed emission power	actual attenuation below frequency of operation [dB]	Results
902.3		16.39	24 dBm		Operating frequency
See Plots			30 dBc		
908.5		16.46	24 dBm		Operating frequency
See Plots			-30 dBc		
914.9		16.42	24 dBm		Operating frequency
See Plots			-30 dBc		

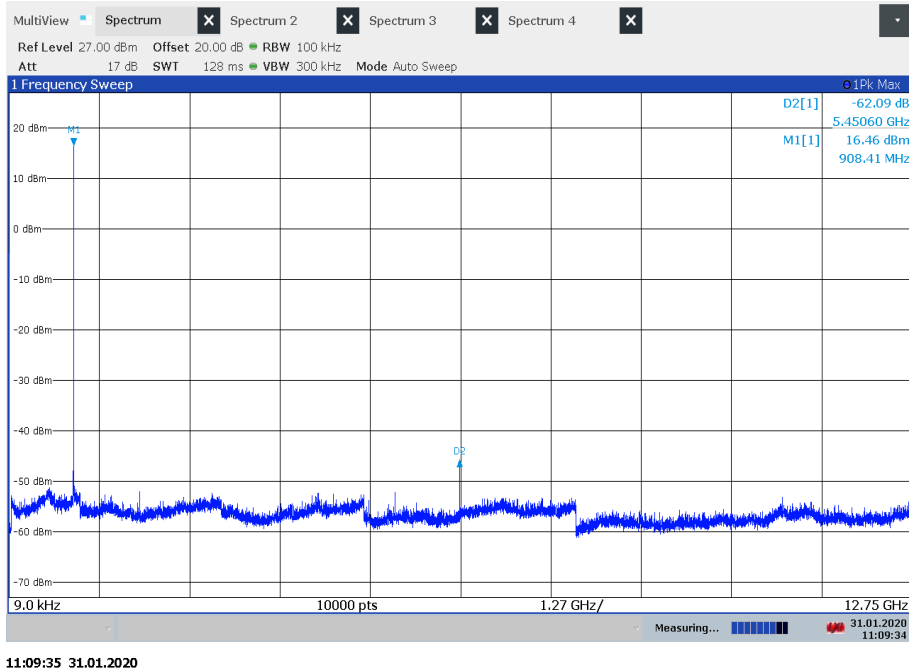
Plots:

Plot 1: Lowest channel, 9 kHz – 12.75 GHz

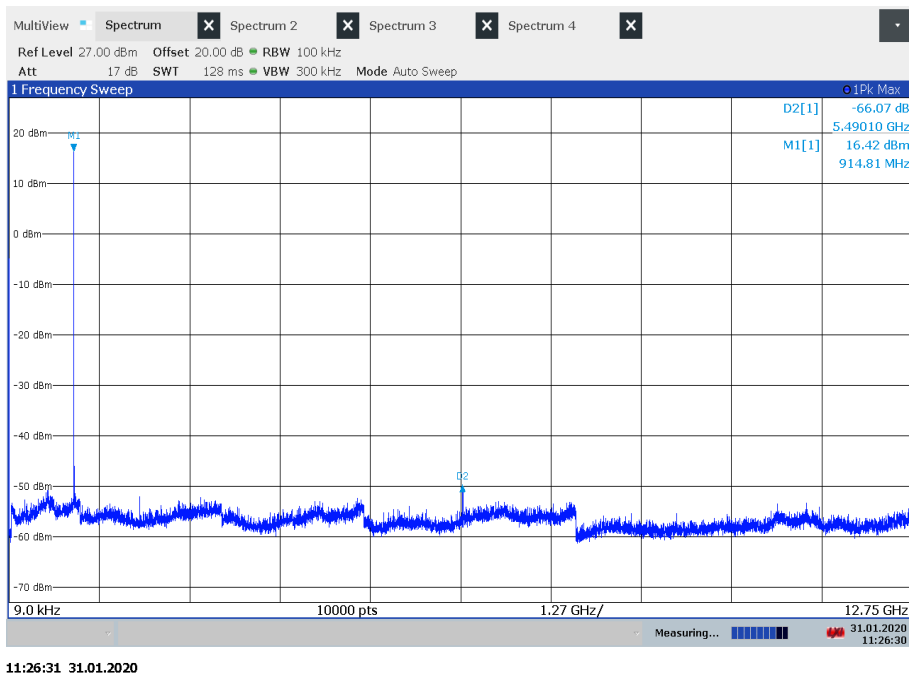


10:43:42 31.01.2020

Plot 2: Middle channel, 9 kHz – 12.75 GHz



Plot 3: Highest channel, 9 kHz – 12.75 GHz



12.9 Spurious Emissions Radiated < 30 MHz

Description:

The limits are recalculated to a measurement distance of 3 m according the ANSI C63.10.

Measurement:

Measurement parameter	
Detector:	Peak / Quasi Peak
Sweep time:	Auto
Video bandwidth:	F < 150 kHz: 200 Hz F > 150 kHz: 9 kHz
Resolution bandwidth:	F < 150 kHz: 1 kHz F > 150 kHz: 100 kHz
Span:	9 kHz to 30 MHz
Trace mode:	Max Hold
Used equipment:	See chapter 6.2 A
Measurement uncertainty:	See chapter 8

Limits:

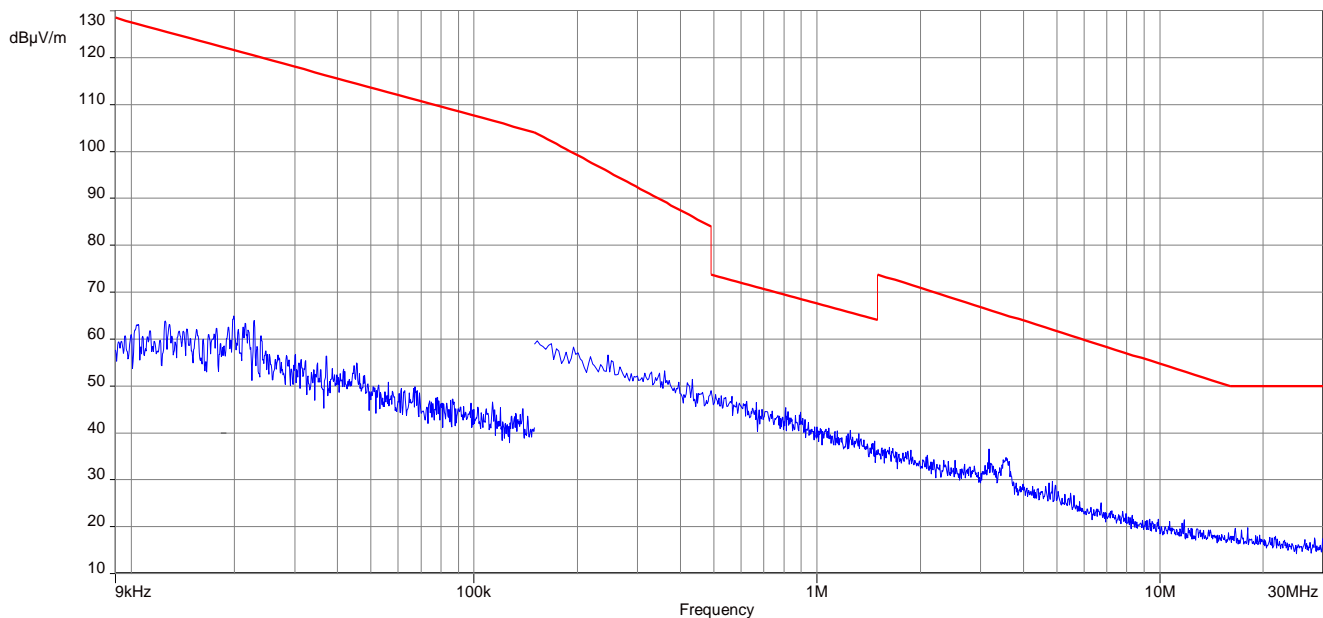
FCC		
TX spurious emissions radiated < 30 MHz		
Frequency (MHz)	Field strength (dB μ V/m)	Measurement distance
0.009 – 0.490	2400/F(kHz)	300
0.490 – 1.705	24000/F(kHz)	30
1.705 – 30.0	30	30

Result:

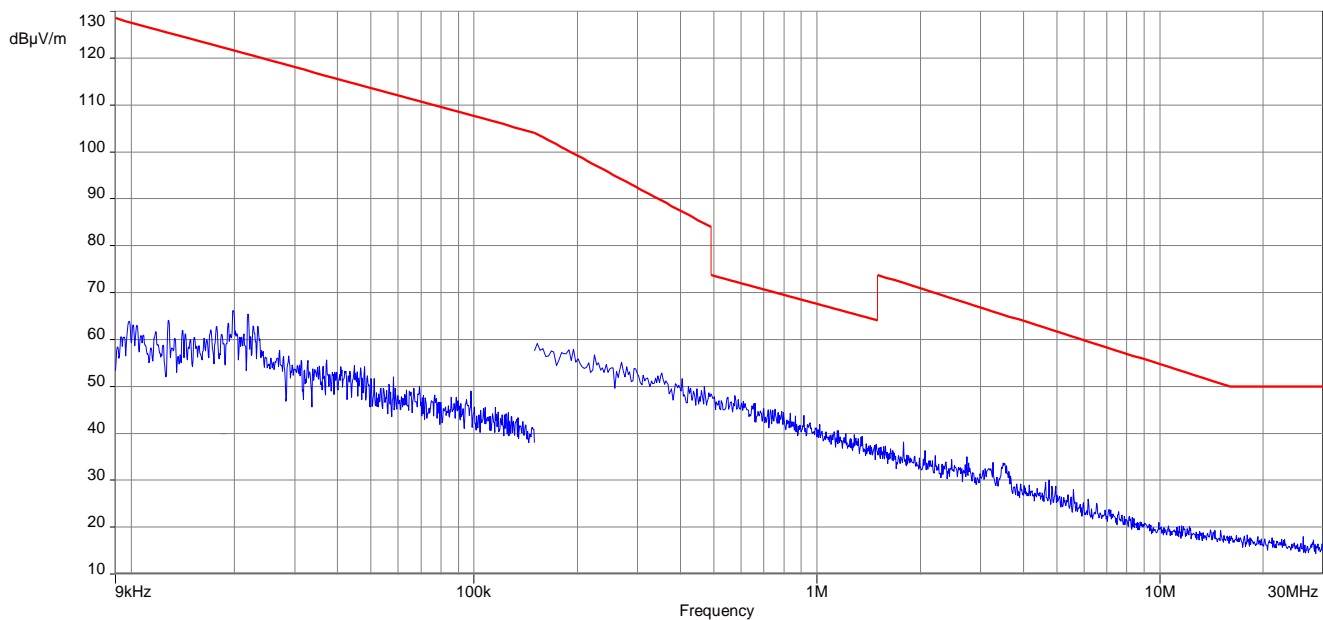
SPURIOUS EMISSIONS LEVEL [dB μ V/m]								
Lowest channel			Middle channel			Highest channel		
Frequency [MHz]	Detector	Level [dB μ V/m]	Frequency [MHz]	Detector	Level [dB μ V/m]	Frequency [MHz]	Detector	Level [dB μ V/m]
All emissions were more than 10 dB below the limit.								

Plots:

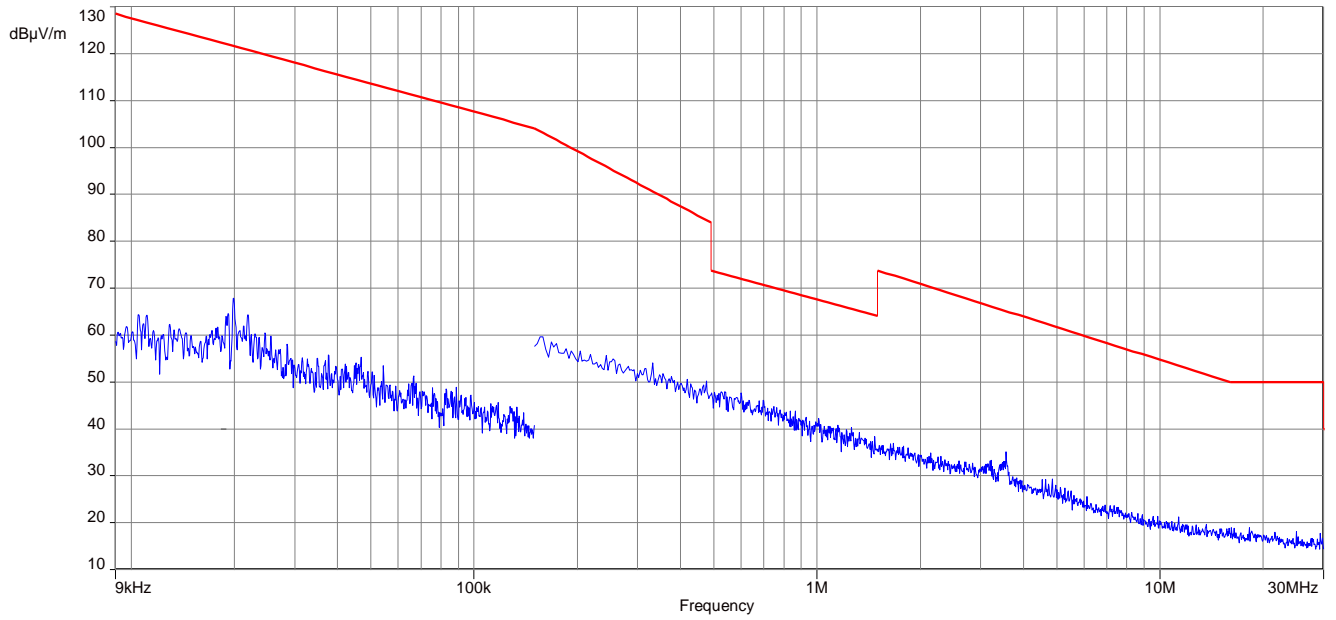
Plot 1: TX-Mode lowest channel



Plot 2: TX-Mode middle channel



Plot 3: TX-Mode highest channel



12.10 Spurious Emissions Radiated > 30 MHz

12.10.1 Spurious emissions radiated 30 MHz to 1 GHz

Description:

Measurement of the radiated spurious emissions in transmit mode. The measurement is performed at channel low, mid and high.

Measurement:

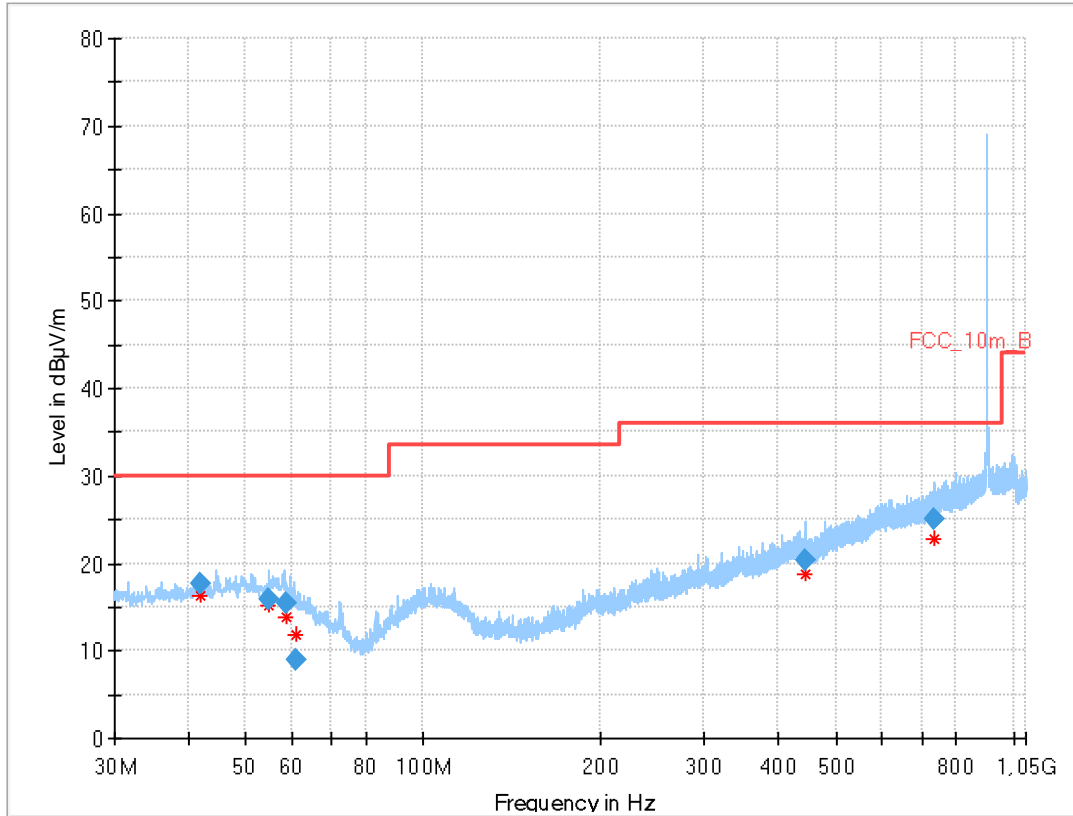
Measurement parameters	
Detector	Peak / Quasi Peak
Sweep time	Auto
Resolution bandwidth	120 kHz
Video bandwidth	3 x RBW
Span	30 MHz to 1 GHz
Trace mode	Max hold
Test setup	See sub clause 6.1 A
Measurement uncertainty	See sub clause 8

Limits:

FCC	IC	
Band-edge Compliance of conducted and radiated emissions		
<p>In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).</p>		
Frequency (MHz)	Field Strength (dBµV/m)	Measurement distance
30 - 88	30.0	10
88 – 216	33.5	10
216 – 960	36.0	10
Above 960	54.0	3

Plots:

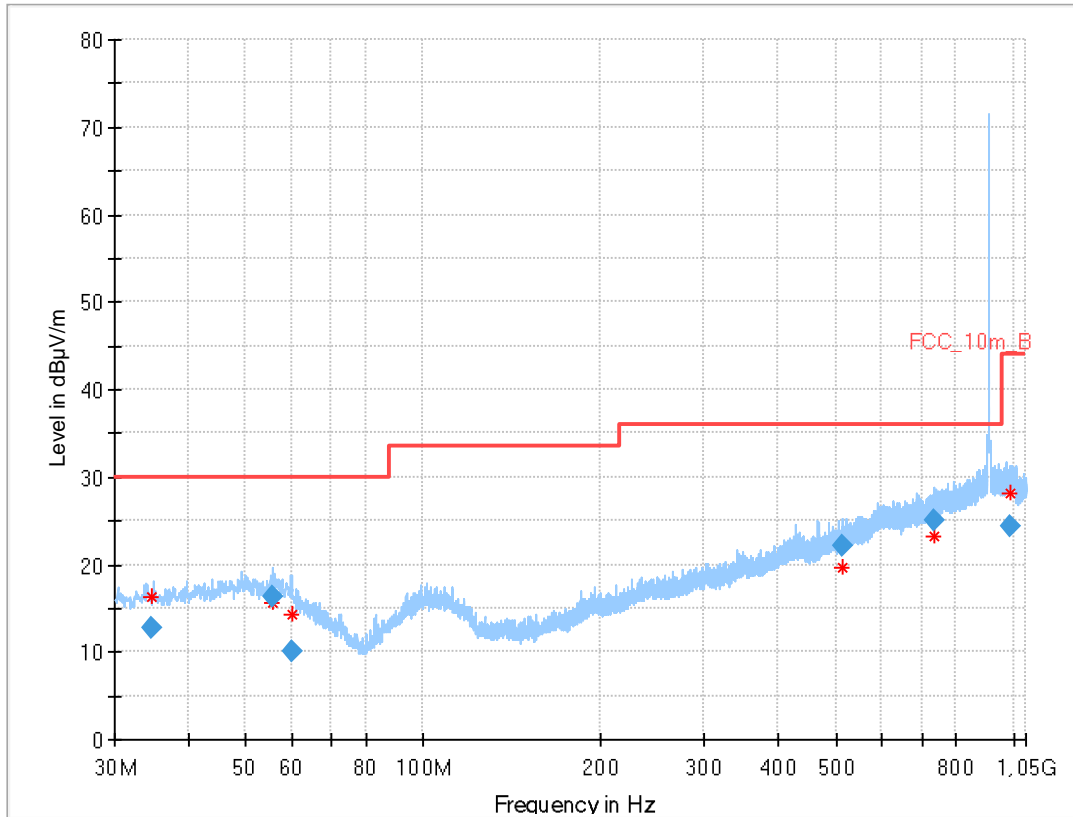
Plot 1: 30 MHz – 1 GHz, horizontal & vertical polarisation (lowest channel)



Final_Result

Frequency (MHz)	QuasiPeak (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
42.059	17.74	30.0	12.3	1000	120	104.0	H	202	14
54.885	15.77	30.0	14.2	1000	120	114.0	V	159	14
58.513	15.50	30.0	14.5	1000	120	170.0	V	247	14
61.074	9.05	30.0	21.0	1000	120	160.0	H	157	13
443.453	20.43	36.0	15.6	1000	120	98.0	H	-22	17
732.268	25.02	36.0	11.0	1000	120	170.0	H	-7	22

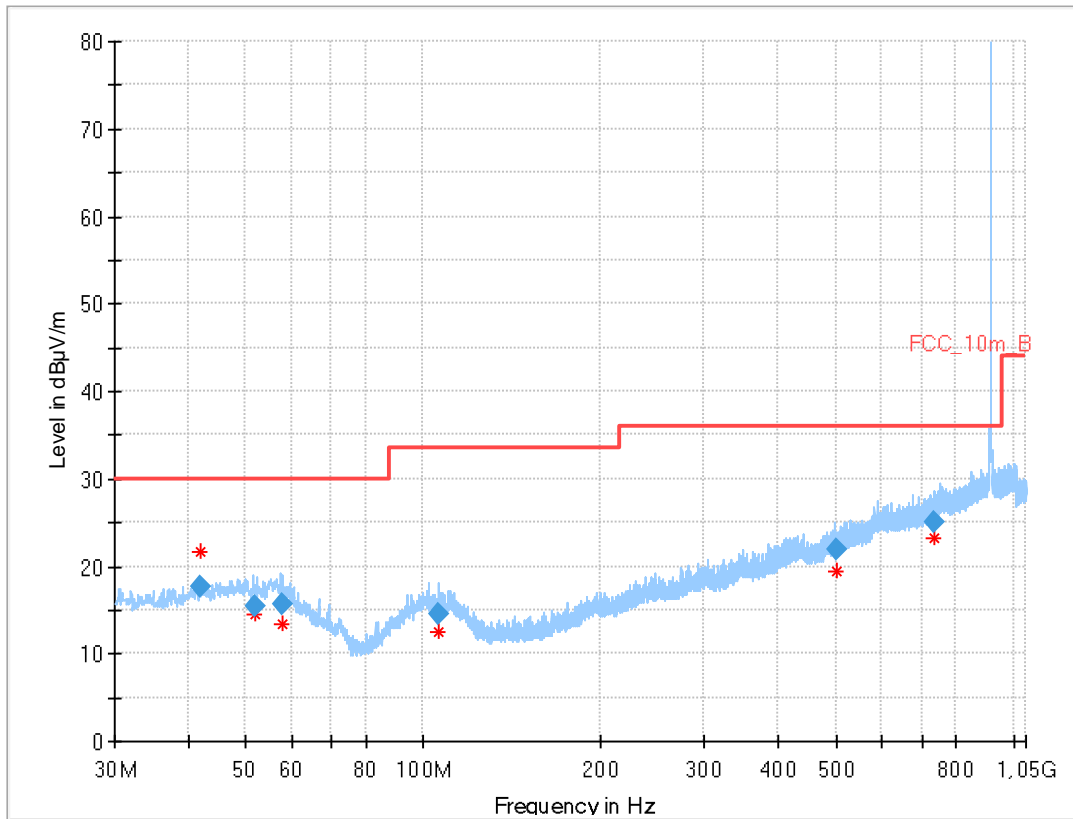
Plot 2: 30 MHz – 1 GHz, horizontal & vertical polarisation (middle channel)



Final_Result

Frequency (MHz)	QuasiPeak (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
34.540	12.67	30.0	17.3	1000	120	150.0	H	202	12
55.693	16.25	30.0	13.8	1000	120	104.0	H	157	15
60.068	10.08	30.0	19.9	1000	120	109.0	V	-6	13
512.201	22.17	36.0	13.8	1000	120	170.0	V	82	19
734.657	25.07	36.0	10.9	1000	120	170.0	H	11	22
984.844	24.25	44.0	19.8	1000	120	98.0	H	-17	24

Plot 3: 30 MHz – 1 GHz, horizontal & vertical polarisation (highest channel)



Final_Result

Frequency (MHz)	QuasiPeak (dBuV/m)	Limit (dBuV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
42.053	17.70	30.0	12.3	1000	120	102.0	V	281	14
51.943	15.46	30.0	14.5	1000	120	170.0	V	157	14
57.683	15.71	30.0	14.3	1000	120	170.0	H	-22	14
105.980	14.58	33.5	18.9	1000	120	170.0	V	-22	12
499.853	21.88	36.0	14.1	1000	120	170.0	H	157	18
734.628	25.04	36.0	11.0	1000	120	170.0	V	165	22

12.10.2 Spurious emissions radiated above 1 GHz

Description:

Measurement of the radiated spurious emissions in transmit mode. The measurement is performed in the mode with the highest output power.

Measurement parameters	
Detector	Peak / RMS
Sweep time	Auto
Resolution bandwidth	1 MHz
Video bandwidth	3 x RBW
Span	1 GHz to 12.75 GHz
Trace mode	Max hold
Test setup	See sub clause 6.2 B (1 GHz – 12.75 GHz)
Measurement uncertainty	See sub clause 8

The modulation with the highest output power was used to perform the transmitter spurious emissions. If spurious were detected a re-measurement was performed on the detected frequency with each modulation.

Limits:

ANSI C63.10
The average emission shall be determined by using Video averaging (VBW = 10 Hz). If the dwell time of the hopping signal is less than 100 ms (per channel), the VBW=10 Hz reading may be adjusted by a factor: $F = 20\log(\text{dwell time}/100 \text{ ms})$

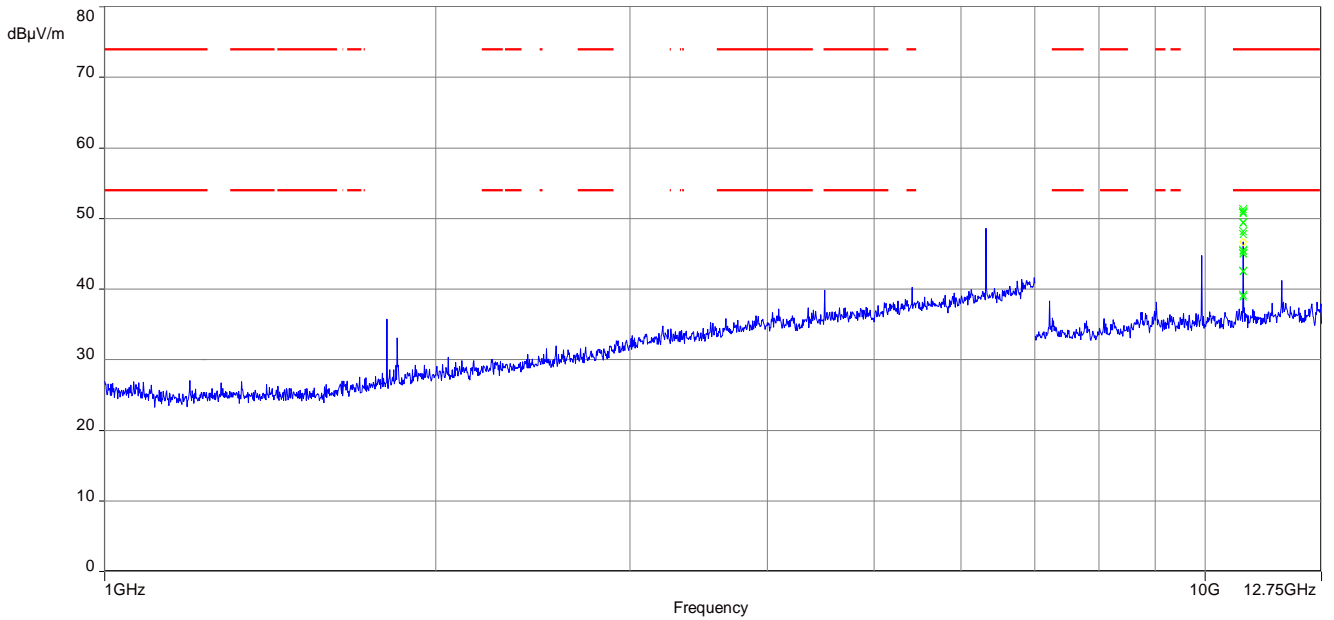
FCC		
TX spurious emissions radiated		
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. Attenuation below the general limits specified in Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).		
§15.209		
Frequency (MHz)	Field strength (dBµV/m)	Measurement distance
Above 960	54.0	3

Results:

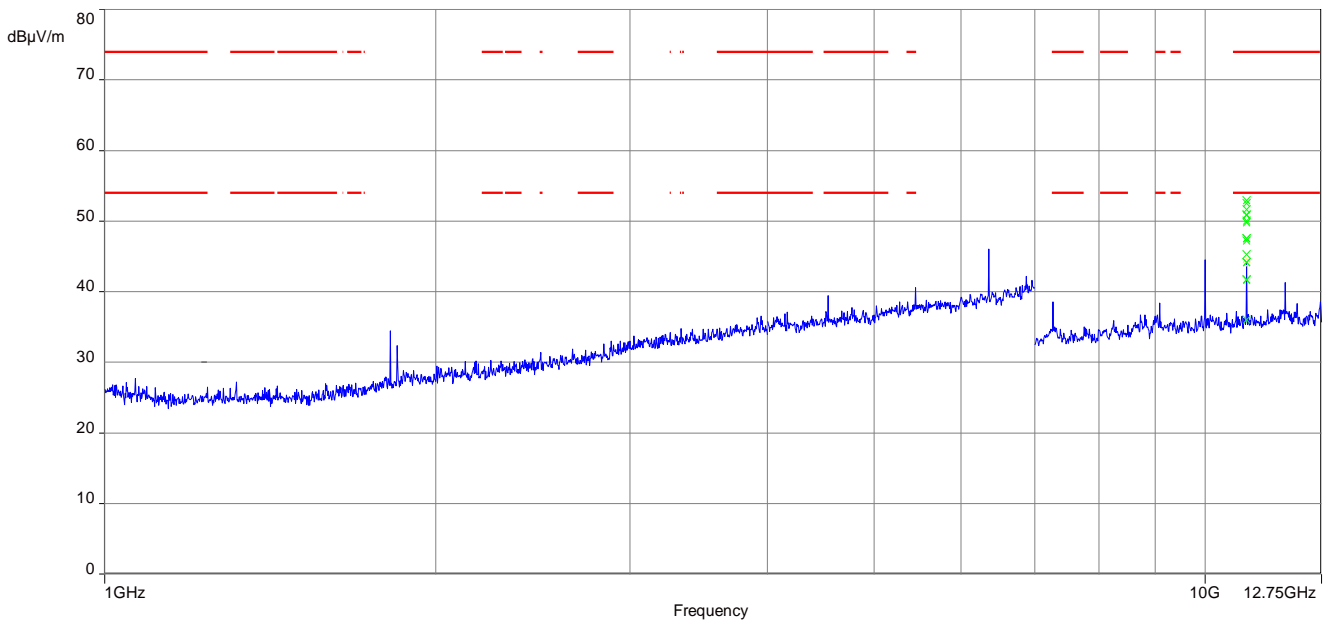
TX spurious emissions radiated								
Lowest channel			Middle channel			Highest channel		
F [MHz]	Detector	Level [dBµV/m]	F [MHz]	Detector	Level [dBµV/m]	F [MHz]	Detector	Level [dBµV/m]
10827	Peak	51.37	10901	Peak	52.95	10978	Peak	51.34
	RMS	45.57		RMS	47.56		RMS	44.97

Plots:

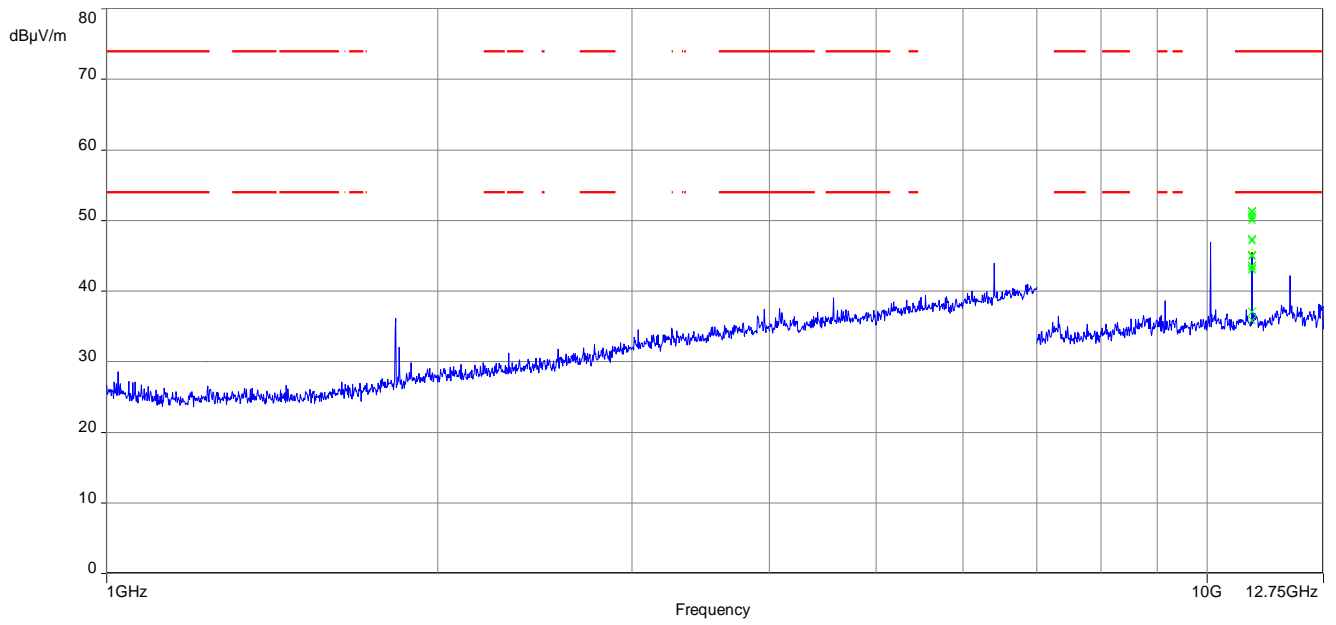
Plot 1: 1 GHz – 12.75 GHz, horizontal & vertical polarisation (lowest channel)



Plot 2: 1 GHz – 12.75 GHz, horizontal & vertical polarisation (middle channel)



Plot 3: 1 GHz – 12.75 GHz, horizontal & vertical polarisation (highest channel)



13 Observations

No observations except those reported with the single test cases have been made.

Annex A Glossary

EUT	Equipment under test
DUT	Device under test
UUT	Unit under test
GUE	GNSS User Equipment
ETSI	European Telecommunications Standards Institute
EN	European Standard
FCC	Federal Communications Commission
FCC ID	Company Identifier at FCC
IC	Industry Canada
PMN	Product marketing name
HMN	Host marketing name
HVIN	Hardware version identification number
FVIN	Firmware version identification number
EMC	Electromagnetic Compatibility
HW	Hardware
SW	Software
Inv. No.	Inventory number
S/N or SN	Serial number
C	Compliant
NC	Not compliant
NA	Not applicable
NP	Not performed
PP	Positive peak
QP	Quasi peak
AVG	Average
OC	Operating channel
OCW	Operating channel bandwidth
OBW	Occupied bandwidth
OOB	Out of band
DFS	Dynamic frequency selection
CAC	Channel availability check
OP	Occupancy period
NOP	Non occupancy period
DC	Duty cycle
PER	Packet error rate
CW	Clean wave
MC	Modulated carrier
WLAN	Wireless local area network
RLAN	Radio local area network
DSSS	Dynamic sequence spread spectrum
OFDM	Orthogonal frequency division multiplexing
FHSS	Frequency hopping spread spectrum
GNSS	Global Navigation Satellite System
C/N₀	Carrier to noise-density ratio, expressed in dB-Hz

Annex B Document history

Version	Applied changes	Date of release
-/-	Initial release	2020-02-14
A	Updated HW / SW information	2020-02-18
B	Hybrid Mode added, FHSS mode removed, editorial changes	2020-03-26
C	Changes in Chapters 10.1 and 12.4.	2020-03-27
D	Several plots and measurement results replaced	2020-04-06

Annex C Accreditation Certificate – D-PL-12076-01-04

first page	last page
 <p>Deutsche Akkreditierungsstelle GmbH</p> <p>Entrusted according to Section 8 subsection 1 AkkStelleG in connection with Section 1 subsection 1 AkkStelleGBV Signatory to the Multilateral Agreements of EA, ILAC and IAF for Mutual Recognition</p> <p>Accreditation </p> <p>The Deutsche Akkreditierungsstelle GmbH attests that the testing laboratory</p> <p>CTC advanced GmbH Untertürkheimer Straße 6-10, 66117 Saarbrücken</p> <p>is competent under the terms of DIN EN ISO/IEC 17025:2005 to carry out tests in the following fields:</p> <p>Telecommunication (TC) and Electromagnetic Compatibility (EMC) for Canadian Standards</p> <p>The accreditation certificate shall only apply in connection with the notice of accreditation of 11.01.2019 with the accreditation number D-PL-12076-01 and is valid until 21.04.2021. It comprises the cover sheet, the reverse side of the cover sheet and the following annex with a total of 7 pages.</p> <p>Registration number of the certificate: D-PL-12076-01-04</p> <p>Frankfurt am Main, 11.01.2019</p>  Dipl.-Ing. Uwe Zimmermann Head of Division	<p>Deutsche Akkreditierungsstelle GmbH</p> <p>Office Berlin Spittelmarkt 10 10117 Berlin</p> <p>Office Frankfurt am Main Europa-Allee 52 60327 Frankfurt am Main</p> <p>Office Braunschweig Bundesallee 100 38116 Braunschweig</p> <p>The publication of extracts of the accreditation certificate is subject to the prior written approval by Deutsche Akkreditierungsstelle GmbH (DAkkS). Exempted is the unchanged form of separate disseminations of the cover sheet by the conformity assessment body mentioned overleaf.</p> <p>No impression shall be made that the accreditation also extends to fields beyond the scope of accreditation attested by DAkkS.</p> <p>The accreditation was granted pursuant to the Act on the Accreditation Body (AkkStelleG) of 31 July 2009 (Federal Law Gazette I p. 2625) and the Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products (Official Journal of the European Union L 218 of 9 July 2008, p. 30). DAkkS is a signatory to the Multilateral Agreements for Mutual Recognition of the European co-operation for Accreditation (EA), International Accreditation Forum (IAF) and International Laboratory Accreditation Cooperation (ILAC). The signatories to these agreements recognise each other's accreditations.</p> <p>The up-to-date state of membership can be retrieved from the following websites: EA: www.european-accreditation.org ILAC: www.ilac.org IAF: www.iaf.nu</p>

Note: The current certificate annex is published on the website (link see below) of the Accreditation Body DAkKS or may be received by CTC advanced GmbH on request

https://www.dakks.de/as/ast/d/D-PL-12076-01-04.pdf

Annex D Accreditation Certificate – D-PL-12076-01-05

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 <p>Deutsche Akkreditierungsstelle GmbH</p> <p>Entrusted according to Section 8 subsection 1 AkkStelleG in connection with Section 1 subsection 1 AkkStelleGBV Signatory to the Multilateral Agreements of EA, ILAC and IAF for Mutual Recognition</p> <p>Accreditation </p> <p>The Deutsche Akkreditierungsstelle GmbH attests that the testing laboratory CTC advanced GmbH Untertürkheimer Straße 6-10, 66117 Saarbrücken is competent under the terms of DIN EN ISO/IEC 17025:2005 to carry out tests in the following fields: Telecommunication (FCC Requirements)</p> <p>The accreditation certificate shall only apply in connection with the notice of accreditation of 11.01.2019 with the accreditation number D-PL-12076-01 and is valid until 21.04.2021. It comprises the cover sheet, the reverse side of the cover sheet and the following annex with a total of 5 pages.</p> <p>Registration number of the certificate: D-PL-12076-01-05</p> <p>Frankfurt am Main, 11.01.2019  Head of Division</p> <p><small>See notes on back</small></p>	<p>Deutsche Akkreditierungsstelle GmbH</p> <table border="0"> <tr> <td>Office Berlin Spittelmarkt 10 10117 Berlin</td> <td>Office Frankfurt am Main Europa-Allee 52 60327 Frankfurt am Main</td> <td>Office Braunschweig Bundesallee 100 38116 Braunschweig</td> </tr> </table> <p>The publication of extracts of the accreditation certificate is subject to the prior written approval by Deutsche Akkreditierungsstelle GmbH (DAkKS). Exempted is the unchanged form of separate disseminations of the cover sheet by the conformity assessment body mentioned overleaf.</p> <p>No impression shall be made that the accreditation also extends to fields beyond the scope of accreditation attested by DAkKS.</p> <p>The accreditation was granted pursuant to the Act on the Accreditation Body (AkkStelleG) of 31 July 2009 (Federal Law Gazette I p. 2625) and the Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products (Official Journal of the European Union L 218 of 9 July 2008, p. 30). DAkKS is a signatory to the Multilateral Agreements for Mutual Recognition of the European co-operation for Accreditation (EA), International Accreditation Forum (IAF) and International Laboratory Accreditation Cooperation (ILAC). The signatories to these agreements recognise each other's accreditations.</p> <p>The up-to-date state of membership can be retrieved from the following websites: EA: www.european-accreditation.org ILAC: www.ilac.org IAF: www.iaf.nu</p>	Office Berlin Spittelmarkt 10 10117 Berlin	Office Frankfurt am Main Europa-Allee 52 60327 Frankfurt am Main	Office Braunschweig Bundesallee 100 38116 Braunschweig
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END OF TEST REPORT