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Wireless test report – 403532-1TRFWL

Applicant: NCS Lab Srl

Product name: Muscle electrostimulator

Model: Shoulder pacemaker

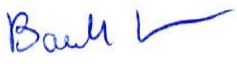
FCC ID: 2ATZJ-SPM

Specifications:

- FCC 47 CFR Part 15 Subpart C, §15.247

  Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz

Date of issue: 2020-09-25

Test engineer(s):	Sara Tessa, Wireless/EMC Specialist	Signature:	
Reviewed by:	Paolo Barbieri, Wireless/EMC Specialist	Signature:	

Test location(s)

Company name	Nemko Spa
Address	Via del Carroccio, 4
City	Biassono
Province	MB
Postal code	20853
Country	Italy
Telephone	+039 039 2201201
Facsimile	+39 039 220 1221
Toll free	--
Website	www.nemko.com
Site number	FCC Test Firm Registration Number: 682159

Limits of responsibility

Note that the results contained in this report relate only to the items tested and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.
This test report has been completed in accordance with the requirements of ISO/IEC 17025.

Copyright notification

Table of contents

Table of contents **3**

Section 1. Report summary **4**

1.1 Applicant and manufacturer 4

1.2 Test specifications 4

1.3 Test methods 4

1.4 Statement of compliance 4

1.5 Exclusions 4

1.6 Test report revision history 4

Section 2. Summary of test results **5**

2.1 FCC Part 15 Subpart C, general requirements test results 5

2.2 FCC Part 15 Subpart C, intentional radiators test results for digital transmission systems (DTS) 5

Section 3. Equipment under test (EUT) details **6**

3.1 Sample information 6

3.2 EUT information 6

3.3 Technical information 6

3.4 Product description and theory of operation 7

3.5 EUT exercise details 7

3.6 EUT setup diagram 8

3.7 EUT sub assemblies 8

Section 4. Engineering considerations **9**

4.1 Modifications incorporated in the EUT 9

4.2 Technical judgment 9

4.3 Deviations from laboratory tests procedures 9

Section 5. Test conditions **10**

5.1 Atmospheric conditions 10

5.2 Power supply range 10

Section 6. Measurement uncertainty **11**

6.1 Uncertainty of measurement 11

Section 7. Test equipment **13**

7.1 Test equipment list 13

Section 8. Testing data **14**

8.1 FCC 15.31(e) Variation of power source 14

8.2 FCC 15.31(m) Number of frequencies 15

8.3 FCC 15.203 Antenna requirement 16

8.4 FCC 15.207(a) AC power line conducted emissions limits 17

8.5 FCC 15.247(a)(2) Minimum 6 dB bandwidth for DTS systems 20

8.6 FCC 15.247(b) Transmitter output power and e.i.r.p. requirements for DTS in 2.4 GHz 24

8.7 FCC 15.247(d) Spurious (out-of-band) unwanted emissions 27

8.8 FCC 15.247(e) Power spectral density for digitally modulated devices 49

Section 9. Block diagrams of test set-ups **52**

9.1 Radiated emissions set-up for frequencies below 1 GHz 52

9.2 Radiated emissions set-up for frequencies above 1 GHz 53

9.3 Conducted emissions on AC line set-up 53

Section 10. Photos **54**

Section 1. Report summary

1.1 Applicant and manufacturer

Company name	NCS Lab Srl
Address	Via Pola Esterna 4/12
City	Carpi
Province/State	Modena
Postal/Zip code	41012
Country	Italy

1.2 Test specifications

FCC 47 CFR Part 15, Subpart C, Clause 15.247	Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–585 MHz

1.3 Test methods

558074 D01 15.247 Meas Guidance v05r02 (April 2, 2019)	Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247
ANSI C63.10 v2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard except as noted in section 1.5 below. Results obtained indicate that the product under test complies in full with the requirements tested. The test results relate only to the items tested.

See "Summary of test results" for full details.

1.5 Exclusions

None

1.6 Test report revision history

Revision #	Date of issue	Details of changes made to test report
TRF	September 25, 2020	Original report issued

Section 2. Summary of test results

2.1 FCC Part 15 Subpart C, general requirements test results

Table 2.1-1: FCC general requirements results

Part	Test description	Verdict
§15.207(a)	Conducted limits	Pass
§15.31(e)	Variation of power source	Pass
§15.31(m)	Number of tested frequencies	Pass
§15.203	Antenna requirement	Pass

2.2 FCC Part 15 Subpart C, intentional radiators test results for digital transmission systems (DTS)

Table 2.2-1: FCC 15.247 results for DTS

Part	Test description	Verdict
§15.247(a)(2)	Minimum 6 dB bandwidth	Pass
§15.247(b)(3)	Maximum peak output power in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands	Pass
§15.247(c)(1)	Fixed point-to-point operation with directional antenna gains greater than 6 dBi	Not applicable
§15.247(c)(2)	Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams	Not applicable
§15.247(d)	Spurious emissions	Pass
§15.247(e)	Power spectral density	Pass
§15.247(f)	Time of occupancy for hybrid systems	Not applicable

Section 3. Equipment under test (EUT) details

3.1 Sample information

Receipt date	2020-09-07
Nemko sample ID number	403532-1/2

3.2 EUT information

Product name	Muscle electrostimulator
Model	Shoulder pacemaker
Model variant	--
Serial number	000042

3.3 Technical information

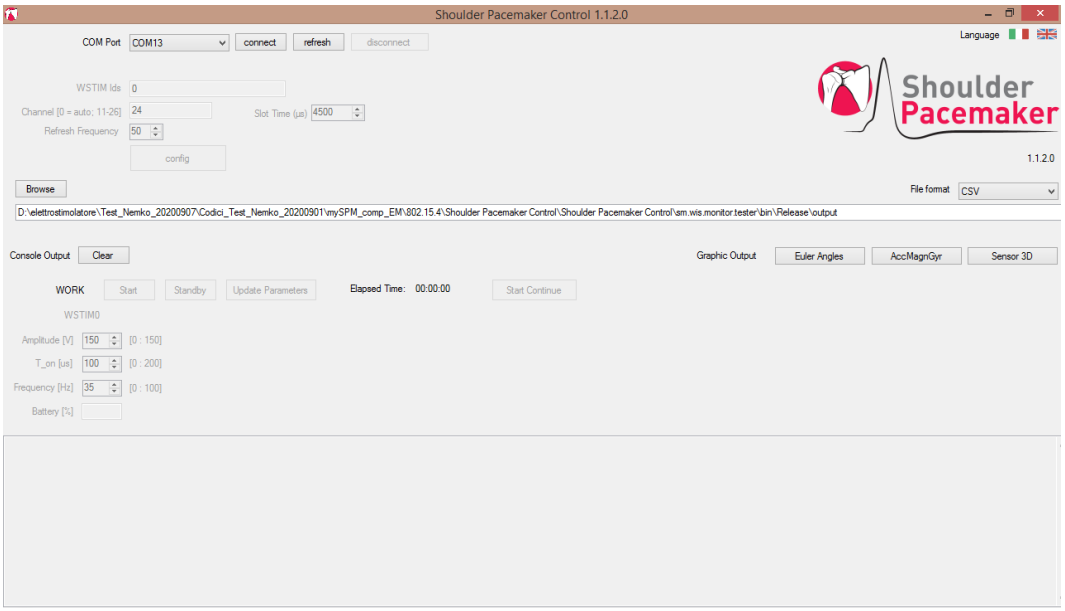
Frequency band	2400 to 2483.5 MHz
Frequency Min (MHz)	2405
Frequency Max (MHz)	2480
RF power Min (W), Conducted	-12.3 dBm
RF power Max (W), Conducted	-1.6 dBm
Field strength, Units @ distance	N/A
Measured BW (kHz) (6 dB)	1640
Measured BW (kHz) (99%)	2480
Calculated BW (kHz), as per TRC-43	N/A
Type of modulation	IEEE Std. 802.15.4 compliant
Emission classification (F1D, G1D, D1D)	2M48F7D
Transmitter spurious, Units @ distance	53.68 dBµV/m at 7214 MHz, @ 3 m
Power requirements	5 $V_{DC,}$ battery
Equipment Class	DTS
Antenna information	The EUT uses a unique antenna coupling. EUT has an integral antenna configuration. The max antenna peak gain, as declared by manufacturer, is 1.5 dBi at 2.4 GHz band

3.4 Product description and theory of operation

The E.U.T is an electrical muscle stimulator, internally powered and used for medical purposes. It incorporates accelerometers, gyroscopes and magnetometers.
The wireless protocol developed for the transmission allows 2 types of transmission:
Bluetooth Low Energy (BLE): 2402-2480 MHz
Compliant with the IEEE 802.15.4 standard: 2405-2480 MHz

3.5 EUT exercise details

EUT was set to continuously transmit mode during tests, by test software provided by client.
These tools/scripts configure the radio modules to enable continuous transmission with the ability to adjust modulation, frequency and output power as required.



3.6 EUT setup diagram

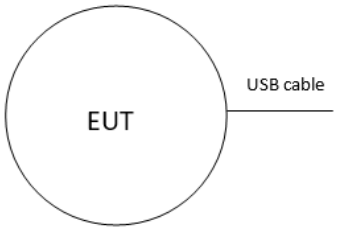


Figure 3.6-1: Setup diagram

3.7 EUT sub assemblies

Table 3.7-1: EUT sub assemblies

Description	Brand name	Model/Part number	Serial number
--	--	--	--

Section 4. Engineering considerations

4.1 Modifications incorporated in the EUT

There were no modifications performed to the EUT during this assessment.

4.2 Technical judgment

None

4.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

Section 5. Test conditions

5.1 Atmospheric conditions

Temperature	18÷33 °C
Relative humidity	30÷60 %
Air pressure	980÷1060 hPa

When it is impracticable to carry out tests under these conditions, a note to this effect stating the ambient temperature and relative humidity during the tests shall be recorded and stated.

5.2 Power supply range

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages ±5 %, for which the equipment was designed.

Section 6. Measurement uncertainty

6.1 Uncertainty of measurement

The assessment of conformity for each test performed on the equipment is performed not taking into account the measurement uncertainty. The two following possible verdicts are stated in the report:

P (Pass) - The measured values of the equipment respect the specification limit at the points tested. The specific risk of false accept is up to 50% when the measured result is close to the limit.

F (Fail) - One or more measured values of the equipment do not respect the specification limit at the points tested. The specific risk of false reject is up to 50% when the measured result is close to the limit.

Hereafter Nemko's measurement uncertainties are reported:

Table 6.1-1: Measurement uncertainty

EUT	Type	Test	Range	Measurement Uncertainty	Notes
Transmitter	Conducted	Frequency error	0.001 MHz ÷ 40 GHz	0.08 ppm	(1)
		Carrier power RF Output Power	0.009 MHz ÷ 30 MHz	1.1 dB	(1)
			30 MHz ÷ 18 GHz	1.5 dB	(1)
			18 MHz ÷ 40 GHz	3.0 dB	(1)
			40 MHz ÷ 140 GHz	5.0 dB	(1)
		Adjacent channel power	1 MHz ÷ 18 GHz	1.4 dB	(1)
		Conducted spurious emissions	0.009 MHz ÷ 18 GHz	3.0 dB	(1)
			18 GHz ÷ 40 GHz	4.2 dB	(1)
			40 GHz ÷ 220 GHz	6.0 dB	(1)
		Intermodulation attenuation	1 MHz ÷ 18 GHz	2.2 dB	(1)
		Attack time – frequency behaviour	1 MHz ÷ 18 GHz	2.0 ms	(1)
		Attack time – power behaviour	1 MHz ÷ 18 GHz	2.5 ms	(1)
		Release time – frequency behaviour	1 MHz ÷ 18 GHz	2.0 ms	(1)
		Release time – power behaviour	1 MHz ÷ 18 GHz	2.5 ms	(1)
		Transient behaviour of the transmitter– Transient frequency behaviour	1 MHz ÷ 18 GHz	0.2 kHz	(1)
		Transient behaviour of the transmitter – Power level slope	1 MHz ÷ 18 GHz	9%	(1)
		Frequency deviation - Maximum permissible frequency deviation	0.001 MHz ÷ 18 GHz	1.3%	(1)
		Frequency deviation - Response of the transmitter to modulation frequencies above 3 kHz	0.001 MHz ÷ 18 GHz	0.5 dB	(1)
		Dwell time	-	3%	(1)
		Hopping Frequency Separation	0.01 MHz ÷ 18 GHz	1%	(1)
		Occupied Channel Bandwidth	0.01 MHz ÷ 18 GHz	2%	(1)
		Modulation Bandwidth	0.01 MHz ÷ 18 GHz	2%	(1)
	Radiated	Radiated spurious emissions	0.009 MHz ÷ 26.5 GHz	6.0 dB	(1)
			26.5 GHz ÷ 66 GHz	8.0 dB	(1)
			66 GHz ÷ 220 GHz	10 dB	(1)
		Effective radiated power transmitter	10 kHz ÷ 26.5 GHz	6.0 dB	(1)
			26.5 GHz ÷ 66 GHz	8.0 dB	(1)
			66 GHz ÷ 220 GHz	10 dB	(1)
Receiver	Radiated	Radiated spurious emissions	0.009 MHz ÷ 26.5 GHz	6.0 dB	(1)
			26.5 GHz ÷ 66 GHz	8.0 dB	(1)
			66 GHz ÷ 220 GHz	10 dB	(1)
		Sensitivity measurement	1 MHz ÷ 18 GHz	6.0 dB	(1)
	Conducted	Conducted spurious emissions	0.009 MHz ÷ 18 GHz	3.0 dB	(1)
			18 GHz ÷ 40 GHz	4.2 dB	(1)
			40 GHz ÷ 220 GHz	6.0 dB	(1)

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

Section 7. Test equipment

7.1 Test equipment list

Table 7.1-1: Equipment list

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI receiver 2 Hz ÷ 43.5 GHz	R&S	FSW43	101767	2020/07	2021/07
Broadband preamplifier	Schwarzbeck	BBV 9718	9718-137	2020/07	2021/07
Trilog Broadband Antenna	Schwarzbeck	VULB 9162	9162-025	2018/07	2021/07
Semi-anechoic chamber	Nemko	10m semi-anechoic chamber	530	2018/09	2021/09
Antenna mast	Maturo	TAM4.0-E	10042	NCR	NCR
Controller	Maturo	FCU3.0	10041	NCR	NCR
EMI receiver 20 Hz ÷ 8 GHz	R&S	ESU8	100202	2020/04	2021/04
Turntable	Maturo	TT4.0-5T	2.527	NCR	NCR
LISN 9 kHz ÷ 30 MHz	R&S	ESH2-Z5	872 460/041	2020/08	2021/08
Bilog antenna 1 ÷18 GHz	Schwarzbeck	STLP 9148-123	123	2018/07	2021/07
Double Ridged Waveguide Horn	RF SPIN	DRH40	061106A40	2020/04	2023/04
Wide band Amplifier 18 GHz ÷ 40 GHz	MITEQ	AMF-5F-18004000-37-8P	128061	2020/07	2021/07
High pass filter	Wainwright Instruments	WHNX6-2555-3500-26500-60CC	01	2018/10	2020/10

Note: NCR - no calibration required, VOU - verify on use

Section 8. Testing data

8.1 FCC 15.31(e) Variation of power source

8.1.1 Definitions and limits

For intentional radiators, measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, shall be performed with the supply voltage varied between 85% and 115% of the nominal rated supply voltage. For battery operated equipment, the equipment tests shall be performed using a new battery.

8.1.2 Test date

Start date	September 7, 2020

8.1.3 Observations, settings and special notes

None

8.1.4 Test data

EUT Power requirements:	☐ AC	☐ DC	☒ Battery
If EUT is an AC or a DC powered, was the noticeable output power variation observed?	☐ YES	☐ NO	☒ N/A
If EUT is battery operated, was the testing performed using fresh batteries?	☐ YES	☐ NO	☒ N/A
If EUT is rechargeable battery operated, was the testing performed using fully charged batteries?	☒ YES	☐ NO	☐ N/A

8.2 FCC 15.31(m) Number of frequencies

8.2.1 Definitions and limits

FCC:
Measurements on intentional radiators or receivers shall be performed and, if required, reported for each band in which the device can be operated with the device operating at the number of frequencies in each band specified in the following table.

Table 8.2-1: Frequency Range of Operation

Frequency range over which the device operates (in each band)	Number of test frequencies required	Location of measurement frequency inside the operating frequency range
1 MHz or less	1	Center (middle of the band)
1–10 MHz	2	1 near high end, 1 near low end
Greater than 10 MHz	3	1 near high end, 1 near center and 1 near low end

Note: “near” means as close as possible to or at the centre / low end / high end of the frequency range over which the device operates.

8.2.2 Test date

Start date	September 7, 2020

8.2.3 Observations, settings and special notes

None

8.2.4 Test data

Table 8.2-2: Test channels selection

Modulation	Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
802.15.4	2400	2483.5	83.5	2405	2440	2480

8.3 FCC 15.203 Antenna requirement

8.3.1 Definitions and limits

FCC:
An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with §15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

8.3.2 Test date

Start date	September 7, 2020

8.3.3 Observations, settings and special notes

None

8.3.4 Test data

Must the EUT be professionally installed?	☐ YES	☒ NO	
Does the EUT have detachable antenna(s)?	☐ YES	☒ NO	
If detachable, is the antenna connector(s) non-standard?	☐ YES	☐ NO	☐ N/A

8.4 FCC 15.207(a) AC power line conducted emissions limits

8.4.1 Definitions and limits

FCC:
Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 µH/50 Ω line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

Table 8.4-1: Conducted emissions limit

Frequency of emission, MHz	Conducted limit, dBµV	
	Quasi-peak	Average**
0.15–0.5	66 to 56*	56 to 46*
0.5–5	56	46
5–30	60	50

Note: * - The level decreases linearly with the logarithm of the frequency.
** - A linear average detector is required.

8.4.2 Test date

Start date	September 07, 2020

8.4.3 Observations, settings and special notes

The EUT was set up as tabletop configuration.

The spectral scan has been corrected with transducer factors (i.e. cable loss, LISN factors, and attenuators) for determination of compliance.

A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 6 dB or above limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement.

Receiver settings for preview measurements:

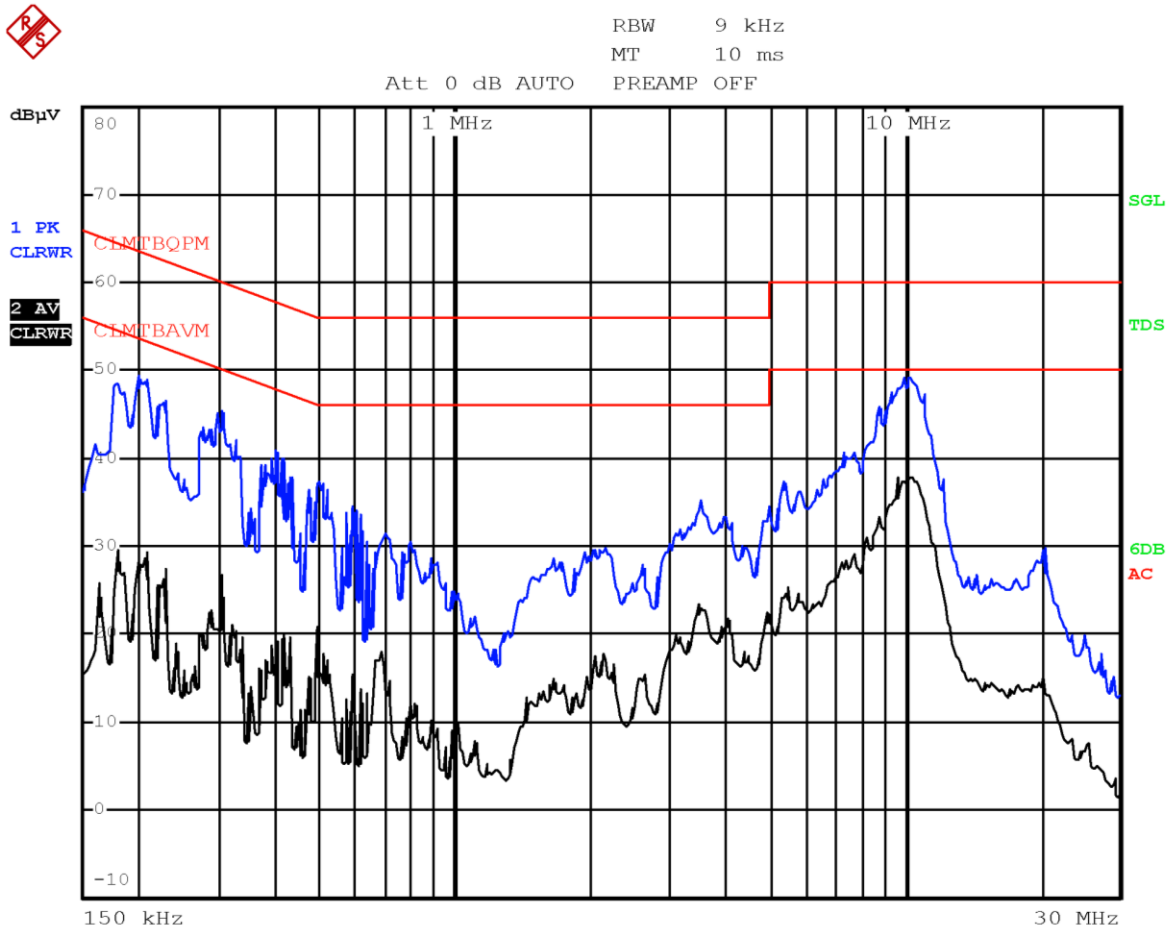
Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Peak and Average
Trace mode	Max Hold
Measurement time	100 ms

Receiver settings for final measurements:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Quasi-Peak and Average
Trace mode	Max Hold
Measurement time	100 ms

8.4.4 Test data

Plot 8.4-1: Conducted emissions on phase line

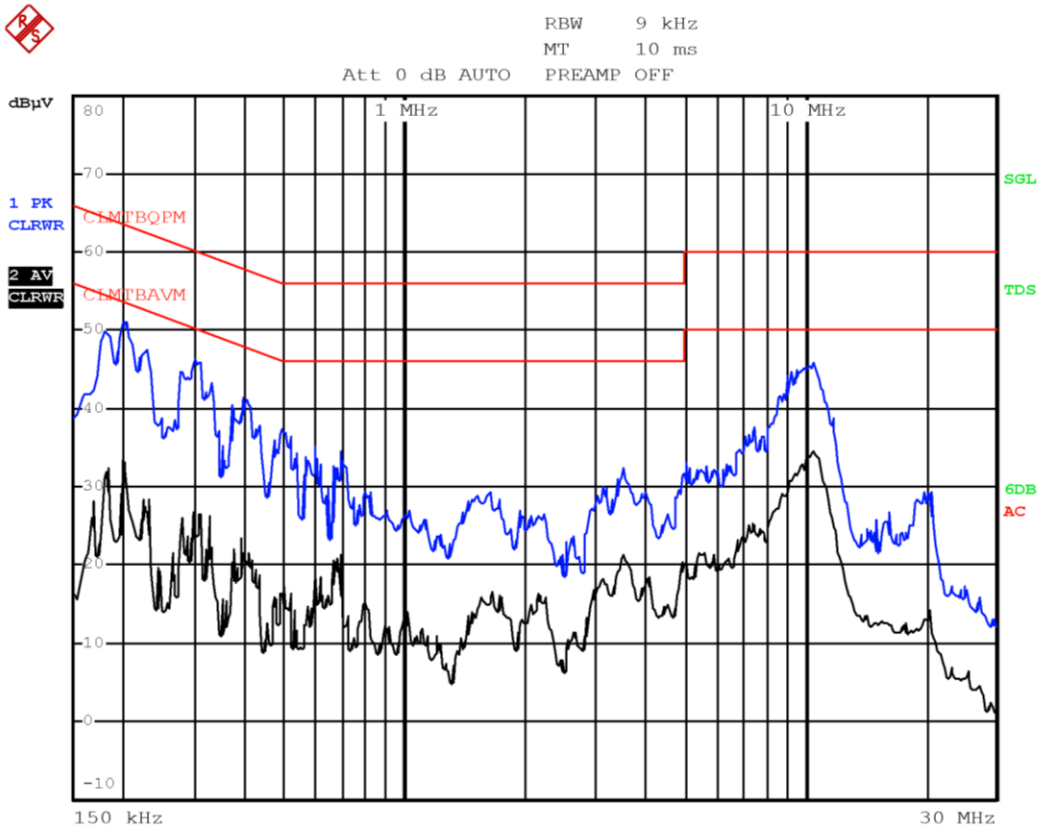


Notes:

[1] Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + attenuator (dB)
[3] Emissions that were continuously present for a minimum of 1 second and occurred more than once for every 15 seconds observation period were considered valid emissions. The maximum value of valid emissions have been recorded.

Sample calculation: 37.1 dBµV (result) = 26.6 dBµV (receiver reading) + 9.5 dB (Correction factor)

Plot 8.4-2: Conducted emissions on neutral line



Notes:

[1] Result (dBµV) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + attenuator (dB)
[3] Emissions that were continuously present for a minimum of 1 second and occurred more than once for every 15 seconds observation period were considered valid emissions. The maximum value of valid emissions have been recorded.

Sample calculation: 37.1 dBµV (result) = 26.6 dBµV (receiver reading) + 9.5 dB (Correction factor)

8.5 FCC 15.247(a)(2) Minimum 6 dB bandwidth for DTS systems

8.5.1 Definitions and limits

FCC:
Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

8.5.1 Test date

Start date	September 08, 2020

8.5.2 Observations, settings and special notes

Spectrum analyser settings:

Resolution bandwidth	100 kHz
Video bandwidth	≥3 × RBW
Frequency span	30 MHz for 20 MHz channel; 80 MHz for 40 MHz channel
Detector mode	Peak
Trace mode	Max Hold

8.5.3 Test data

Horizontal Polarization

Table 8.5-1: 6 dB bandwidth results

Modulation	Frequency, MHz	6 dB bandwidth, kHz	Limit, kHz	Margin, KHz
802.15.4	2405	1600	500	1100
	2440	1600	500	1100
	2480	1590	500	1090

Table 8.5-2: 99% occupied bandwidth results

Modulation	Frequency, MHz	99% occupied bandwidth, MHz
802.15.4	2405	2.48
	2440	2.48
	2480	2.43

Note: there is no 99% occupied bandwidth limit in the standard's requirements, the measurement results provided for information purposes only.

Vertical Polarization

Table 8.5-3: 6 dB bandwidth results

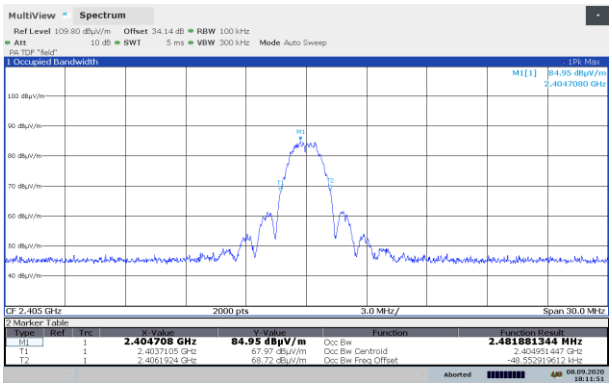
Modulation	Frequency, MHz	6 dB bandwidth, kHz	Limit, kHz	Margin, KHz
802.15.4	2405	1590	500	1090
	2440	1640	500	1140
	2480	1600	500	1100

Table 8.5-4: 99% occupied bandwidth results

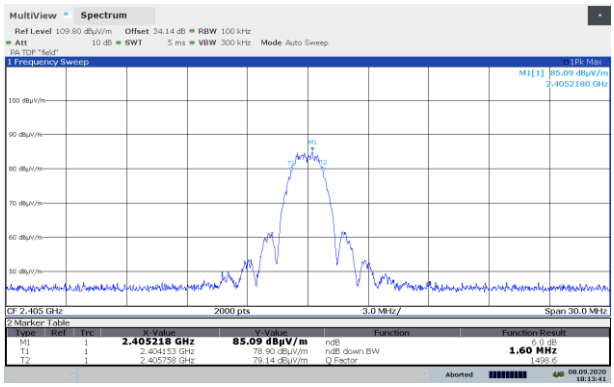
Modulation	Frequency, MHz	99% occupied bandwidth, MHz
802.15.4	2405	2.41
	2440	2.39
	2480	2.37

Note: there is no 99% occupied bandwidth limit in the standard's requirements, the measurement results provided for information purposes only.

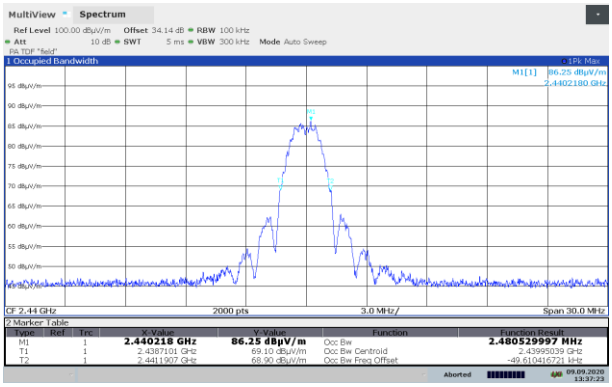
Horizontal polarization



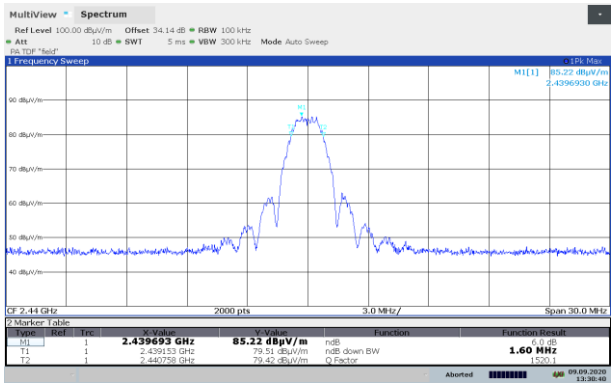
99% bandwidth on low channel



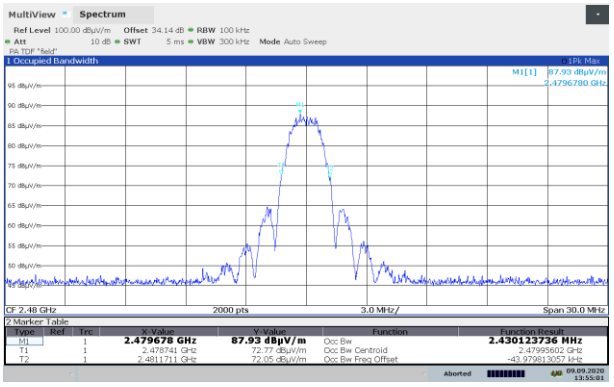
6 dB bandwidth on low channel



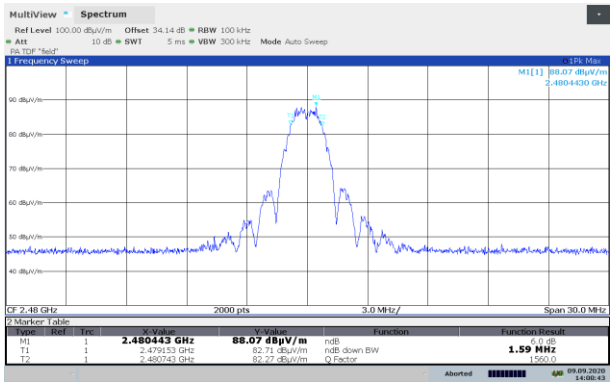
99% bandwidth on middle channel



6 dB bandwidth on middle channel

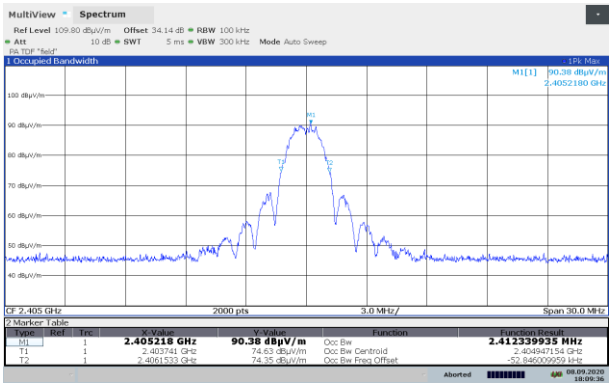


99% bandwidth on high channel

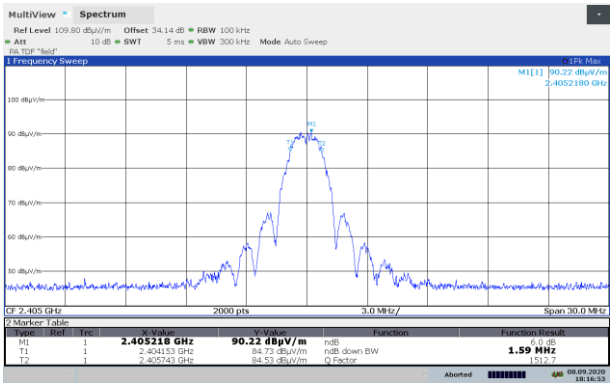


6 dB bandwidth on high channel

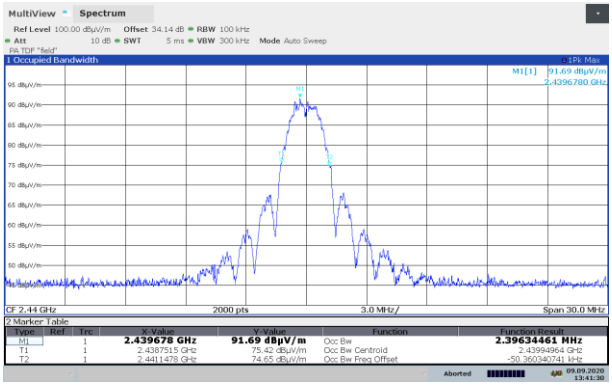
Vertical polarization



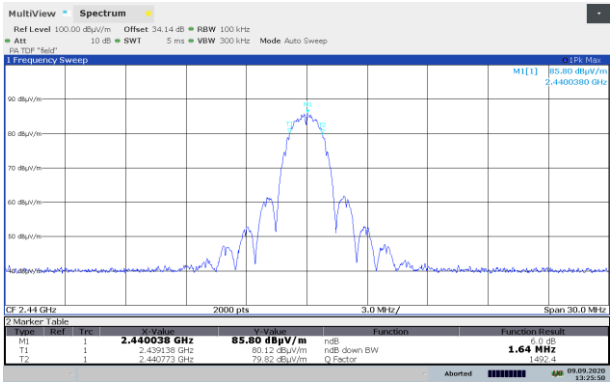
99% bandwidth on low channel



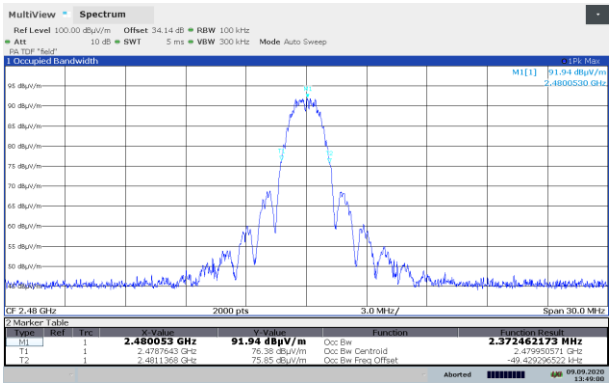
6 dB bandwidth on low channel



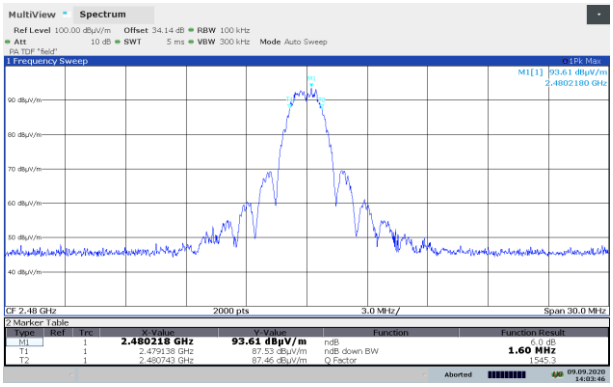
99% bandwidth on middle channel



6 dB bandwidth on middle channel



99% bandwidth on high channel



6 dB bandwidth on high channel

8.6 FCC 15.247(b) Transmitter output power and e.i.r.p. requirements for DTS in 2.4 GHz

8.6.1 Definitions and limits

FCC:

(b) The maximum peak conducted output power of the intentional radiator shall not exceed the following:

(3) For systems using digital modulation in the 2400–2483.5 MHz band: 1 W (30 dBm). As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

(4) 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.

(c) Operation with directional antenna gains greater than 6 dBi.

(1) Fixed point-to-point operation:

(i) Systems operating in the 2400–2483.5 MHz band that are used exclusively for fixed, point-to-point operations may employ transmitting antennas with directional gain greater than 6 dBi provided the maximum conducted output power of the intentional radiator is reduced by 1 dB for every 3 dB that the directional gain of the antenna exceeds 6 dBi.

(iii) Fixed, point-to-point operation, as used in paragraphs (c)(1)(i) and (c)(1)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.

(2) In addition to the provisions in paragraphs (b)(1), (b)(3), (b)(4) and (c)(1)(i) of this section, transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams, simultaneously or sequentially, for the purpose of directing signals to individual receivers or to groups of receivers provided the emissions comply with the following:

(i) Different information must be transmitted to each receiver.

(ii) If the transmitter employs an antenna system that emits multiple directional beams but does not do emit multiple directional beams simultaneously, the total output power conducted to the array or arrays that comprise the device, i.e., the sum of the power supplied to all antennas, antenna elements, staves, etc. and summed across all carriers or frequency channels, shall not exceed the limit specified in paragraph (b)(1) or (b)(3) of this section, as applicable. However, the total conducted output power shall be reduced by 1 dB below the specified limits for each 3 dB that the directional gain of the antenna/antenna array exceeds 6 dBi. The directional antenna gain shall be computed as follows:

(A) The directional gain shall be calculated as the sum of 10 log (number of array elements or staves) plus the directional gain of the element or stave having the highest gain.

(B) A lower value for the directional gain than that calculated in paragraph (c)(2)(ii)(A) of this section will be accepted if sufficient evidence is presented, e.g., due to shading of the array or coherence loss in the beamforming.

(iii) If a transmitter employs an antenna that operates simultaneously on multiple directional beams using the same or different frequency channels, the power supplied to each emission beam is subject to the power limit specified in paragraph (c)(2)(ii) of this section. If transmitted beams overlap, the power shall be reduced to ensure that their aggregate power does not exceed the limit specified in paragraph (c)(2)(ii) of this section. In addition, the aggregate power transmitted simultaneously on all beams shall not exceed the limit specified in paragraph (c)(2)(ii) of this section by more than 8 dB.

(iv) Transmitters that emit a single directional beam shall operate under the provisions of paragraph (c)(1) of this section.

8.6.1 Test date

Start date	2019-07-10

8.6.2 Observations, settings and special notes

The test was performed using RBW > DTS bandwidth power method. Tests were performed with highest data rates.

8.6.3 Test data

$$\text{EIRP} = EMeas + 20 * \log(dMeas) - 104.7$$

Where:
EIRP is the equivalent isotropically radiated power, in dBm
*E*Meas is the field strength of the emission at the measurement distance, in dBµV/m
*d*Meas is the measurement distance, in m (d = 3 m)

Vertical polarization

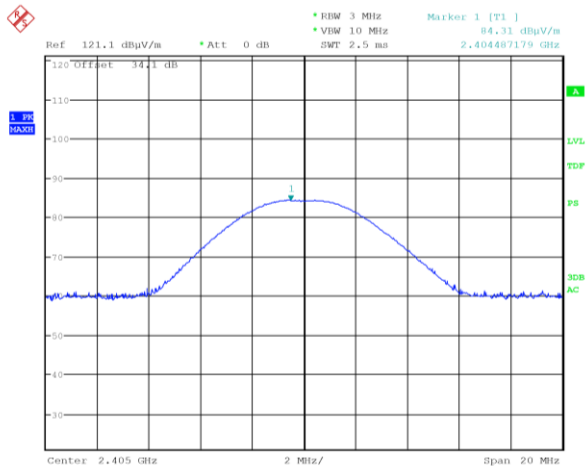
Modulation	Frequency, MHz	E field, dBuV/m	EIRP dBm	Antenna gain, dBi	Conducted output power dBm	Limit	Margin dB
802.15.4	2405	93.7	-1.4	1.5	-2.9	30	-32.9
	2440	95.0	-0.1	1.5	-1.6	30	-31.6
	2480	94.9	-0.3	1.5	-1.8	30	-31.8

Horizontal polarization

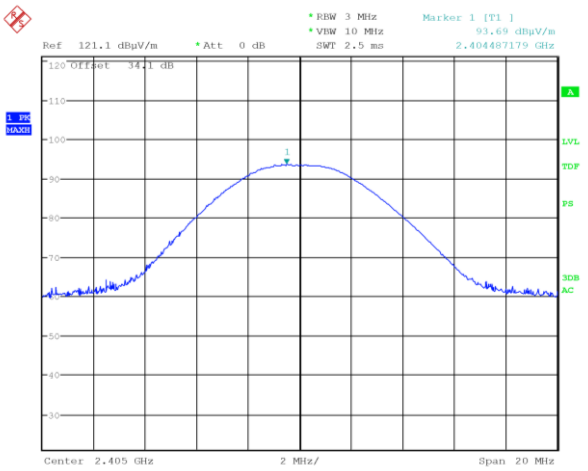
Modulation	Frequency, MHz	E field, dBuV/m	EIRP dBm	Antenna gain, dBi	Conducted output power dBm	Limit	Margin dB
802.15.4	2405	84.3	-10.8	1.5	-12.3	30	-42.3
	2440	86.1	-9.0	1.5	-10.5	30	-40.5
	2480	85.3	-9.8	1.5	-11.3	30	-41.3

Section (8) Results, continued BT

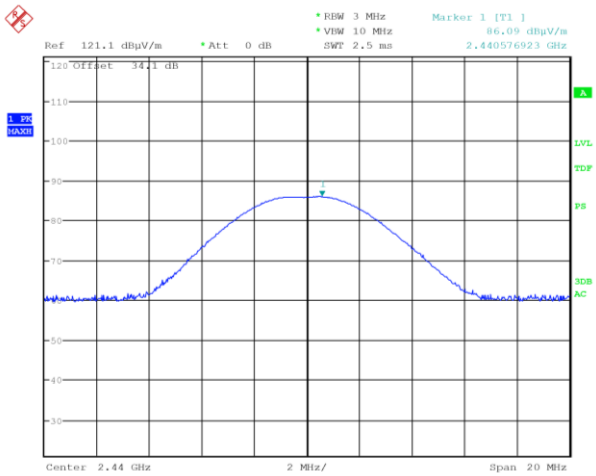
Low channel, horizontal polarization



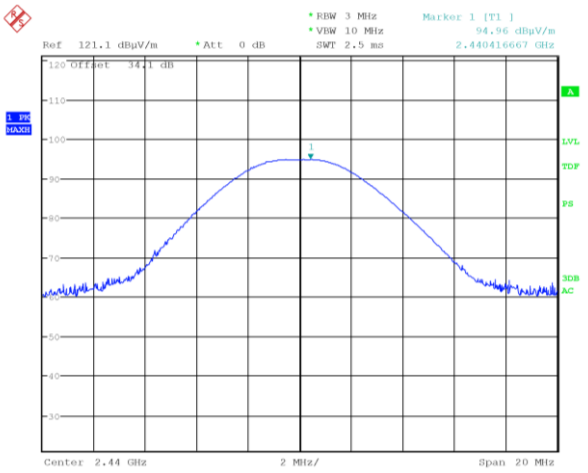
Low channel, vertical polarization



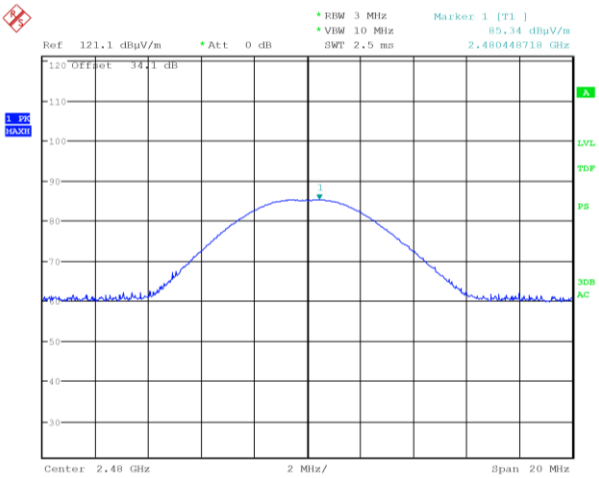
Middle channel, horizontal polarization



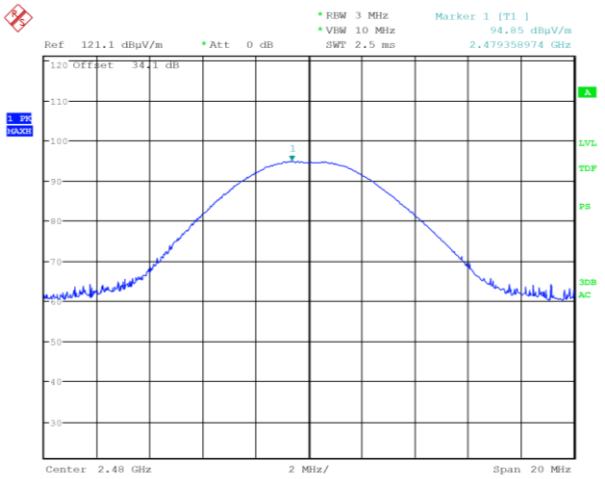
Middle channel, vertical polarization



High channel horizontal polarization



High channel vertical polarization



8.7 FCC 15.247(d) Spurious (out-of-band) unwanted emissions

8.7.1 Definitions and limits

FCC:
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)).

Table 8.7-1: FCC §15.209 – Radiated emission limits

Frequency, MHz	Field strength of emissions		Measurement distance, m
	µV/m	dBµV/m	
0.009–0.490	2400/F	$67.6 - 20 \times \log_{10}(F)$	300
0.490–1.705	24000/F	$87.6 - 20 \times \log_{10}(F)$	30
1.705–30.0	30	29.5	30
30–88	100	40.0	3
88–216	150	43.5	3
216–960	200	46.0	3
above 960	500	54.0	3

Notes: In the emission table above, the tighter limit applies at the band edges.
For frequencies above 1 GHz the limit on peak RF emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test

Table 8.7-2: FCC restricted frequency bands

MHz	MHz	MHz	GHz
0.090–0.110	16.42–16.423	399.9–410	4.5–5.15
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	Above 38.6
13.36–13.41			

8.7.1 Test date

Start date	September 10, 2020

8.7.2 Observations, settings and special notes

The spectrum was searched from 30 MHz to the 10th harmonic.
EUT was set to transmit continuously. Tests were performed with EUT set to highest and lowest data rate, different antenna configurations and modulation schemes were investigated, only the worst case are presented.
Radiated measurements were performed at a distance of 3 m. Cabinet radiated emissions were performed with antenna port terminated with 50 Ω load.
.

Spectrum analyzer settings for conducted spurious emissions measurements:

Resolution bandwidth:	100 kHz
Video bandwidth:	300 kHz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyzer settings for radiated measurements within restricted bands below 1 GHz:

Resolution bandwidth:	100 kHz
Video bandwidth:	300 kHz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyzer settings for peak radiated measurements within restricted bands above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyzer settings for average conducted measurements within restricted bands above 1 GHz:

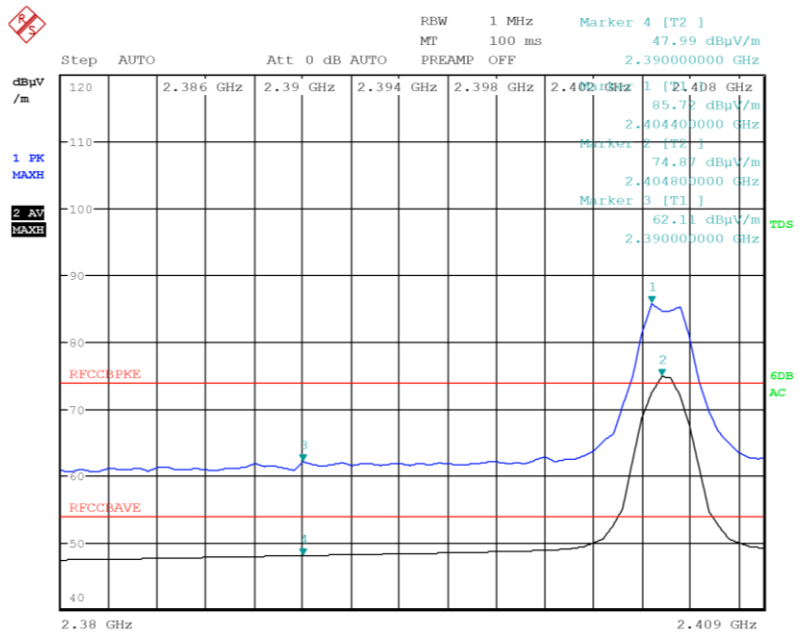
Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	power averaging (RMS)
Trace mode:	averaging (RMS)

Spectrum analyzer settings for average radiated measurements within restricted bands above 1 GHz:

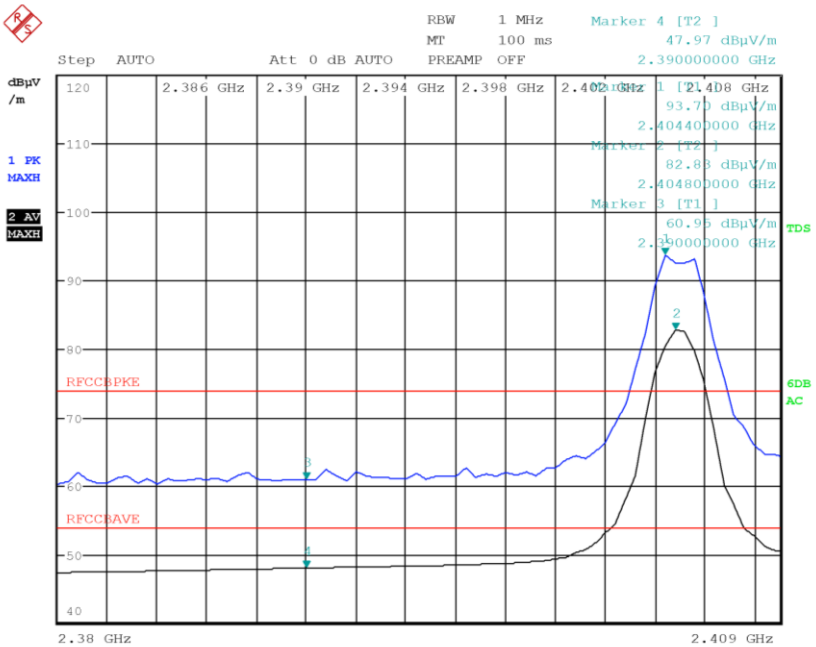
Resolution bandwidth:	1 MHz
Video bandwidth:	10 Hz
Detector mode:	Peak
Trace mode:	Max Hold

8.7.4 Test data

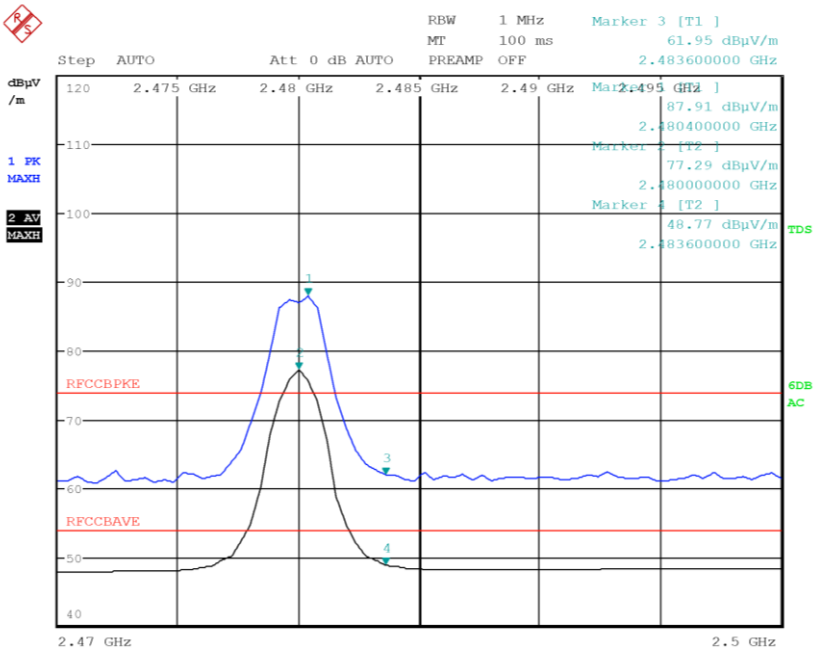
Restricted-band band-edge measurements protocol BT, horizontal polarization, channel 11



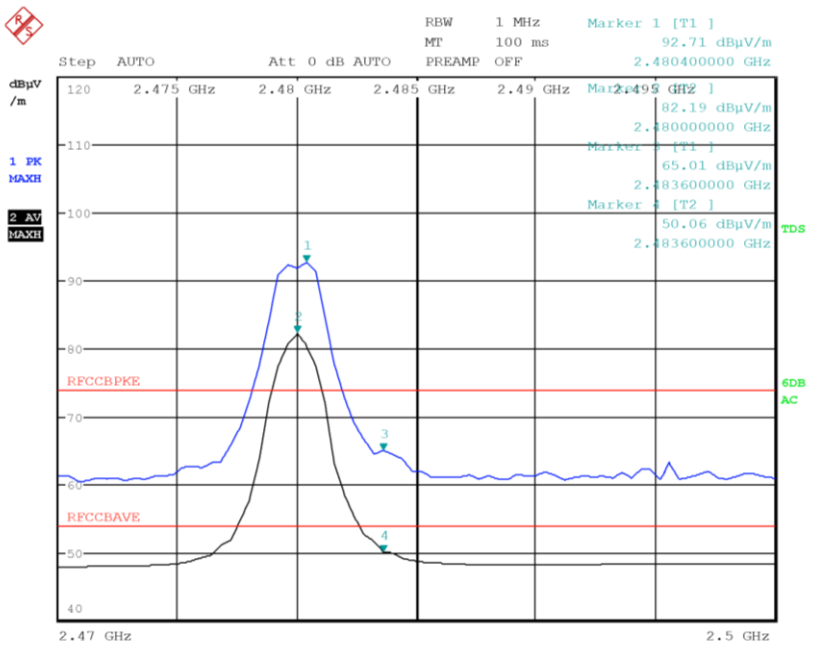
Restricted-band band-edge measurements protocol BT, vertical polarization, channel 11



Restricted-band band-edge measurements protocol BT, horizontal polarization channel 26

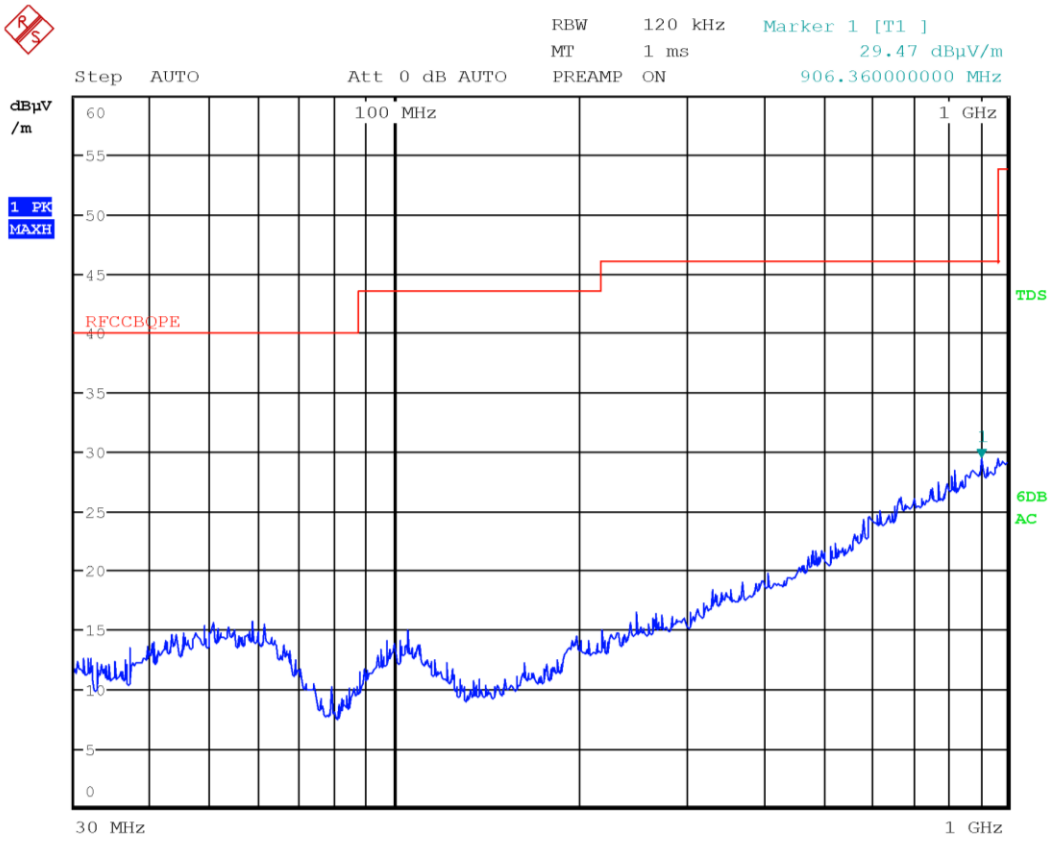


Restricted-band band-edge measurements protocol BT, vertical polarization channel 26



8.7.1 Test data, continued

Radiated measurement BT horizontal polarization, low channel



Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
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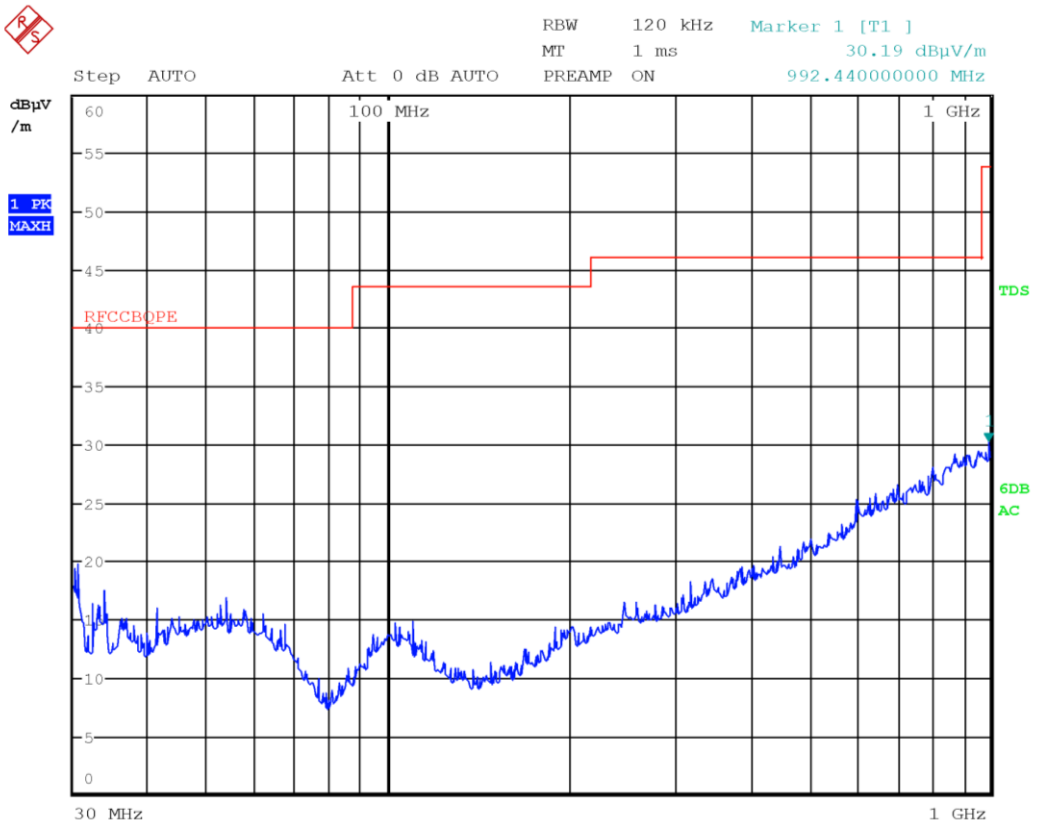
Radiated measurement BT vertical polarization, low channel



Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
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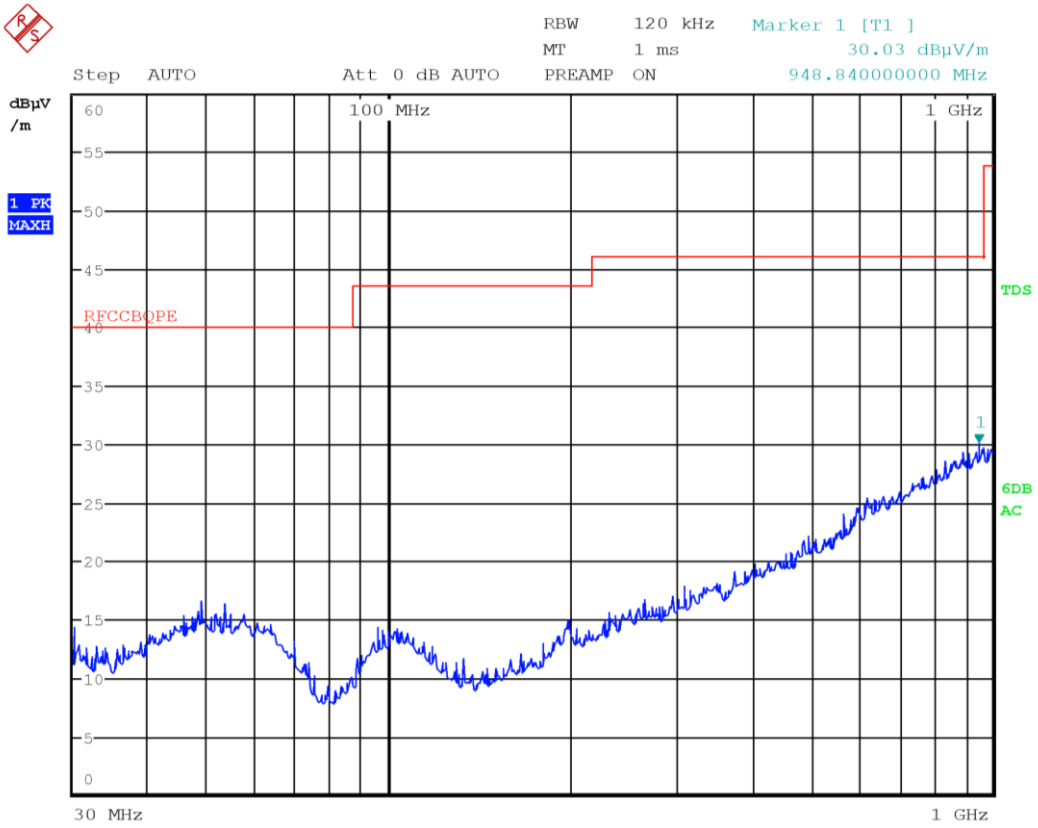
Radiated measurement BT horizontal polarization, middle channel



Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
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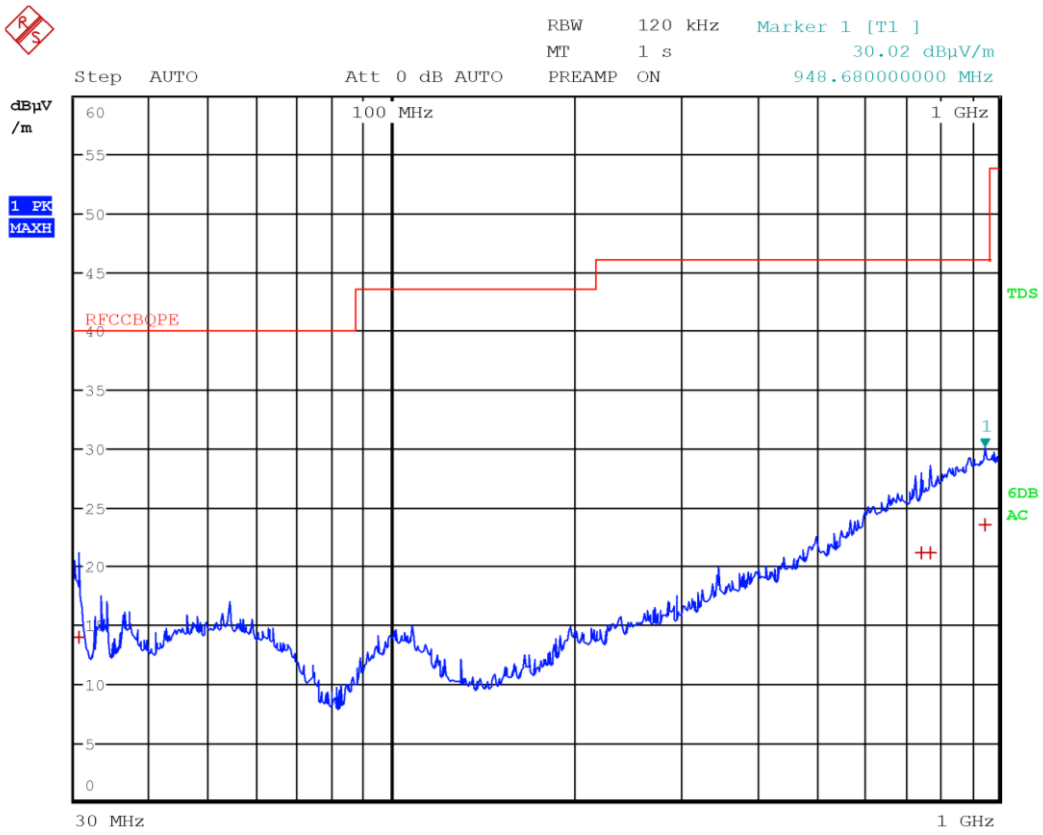
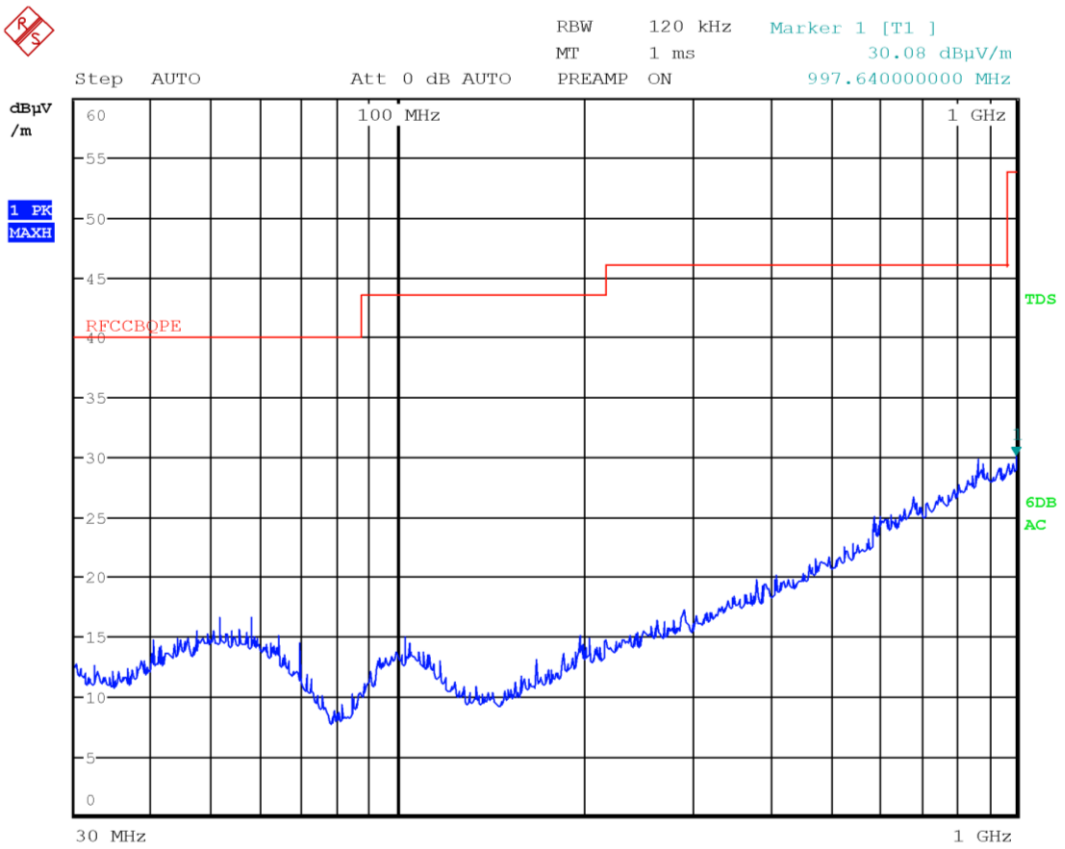
Radiated measurement BT vertical polarization, middle channel



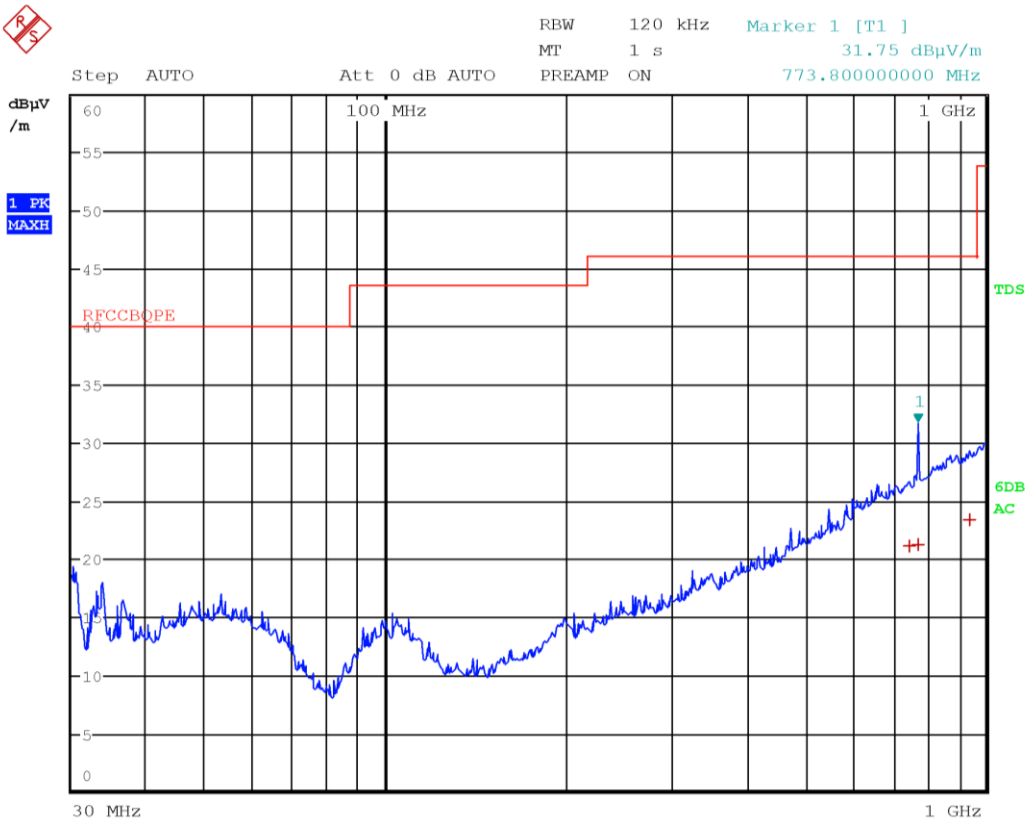
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
30.4800	13.9	40.0	-26.1	QP
744.6400	21.1	46.0	-24.9	QP
771.0800	21.1	46.0	-24.9	QP
948.6800	23.5	46.0	-22.5	QP

Radiated measurement BT horizontal polarization, high channel



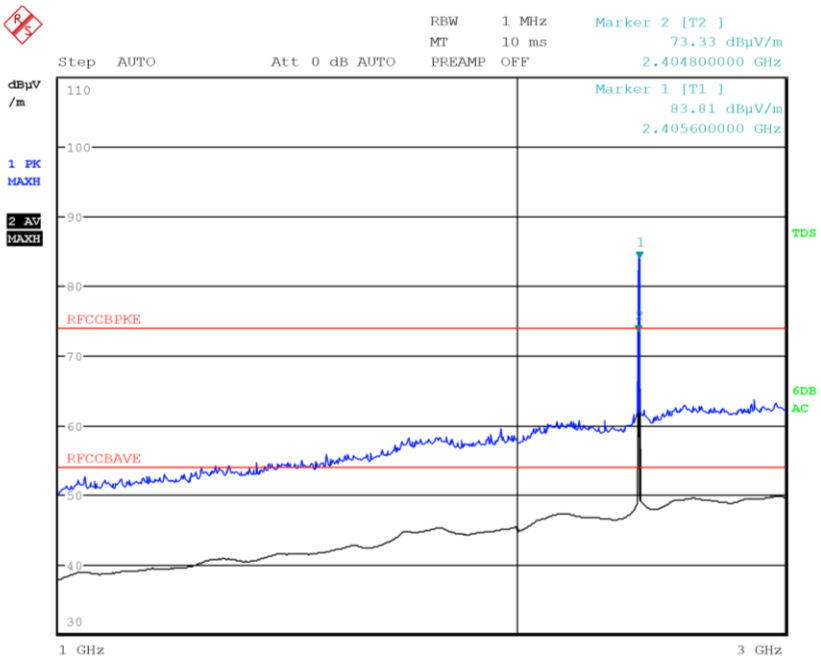
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
--	--	--	--	--

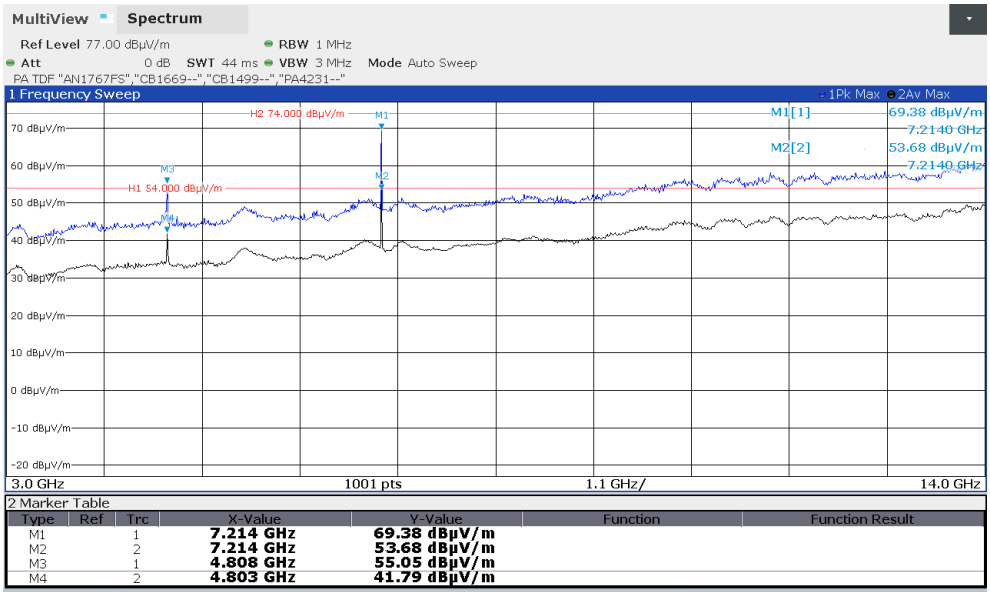
Radiated measurement BT vertical polarization, high channel



Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
746.2400	21.2	46.0	-24.8	QP
773.8000	21.3	46.0	-24.7	QP
941.1200	23.5	46.0	-22.5	QP

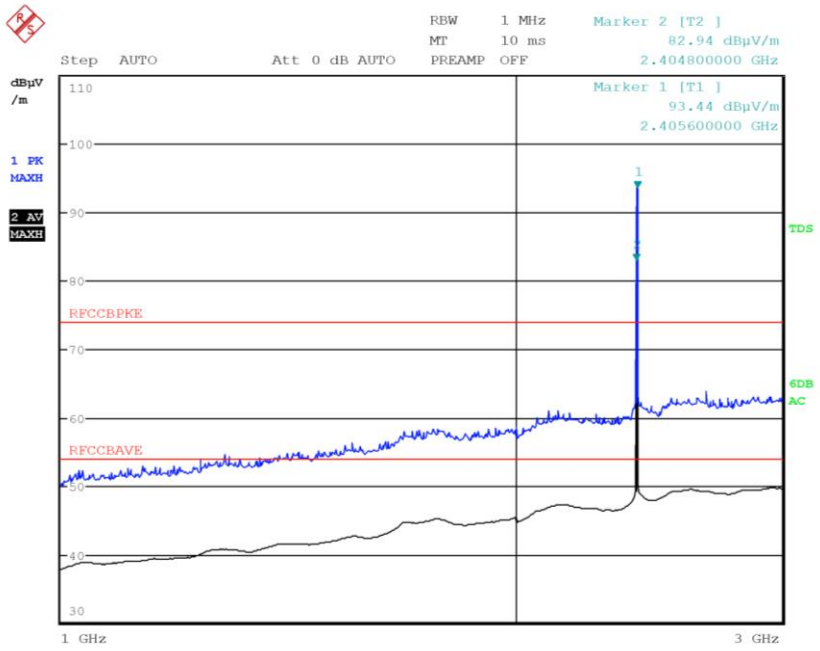
Radiated measurement horizontal polarization, low channel

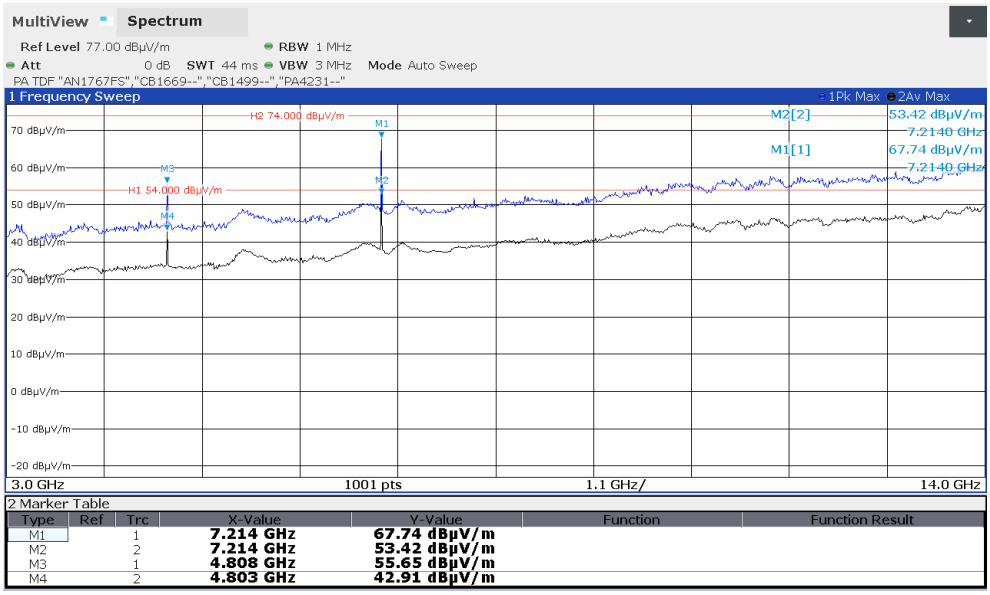




Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
2405.8000	83.8	--	--	Pk
2405.6000	73.3	--	--	Av
4808.0000	55.1	74	-18.9	Pk
4803.0000	41.8	54	-12.2	Av
7214.0000	69.4	74	-4.6	Pk
7214.0000	53.7	54	-0.3	Av

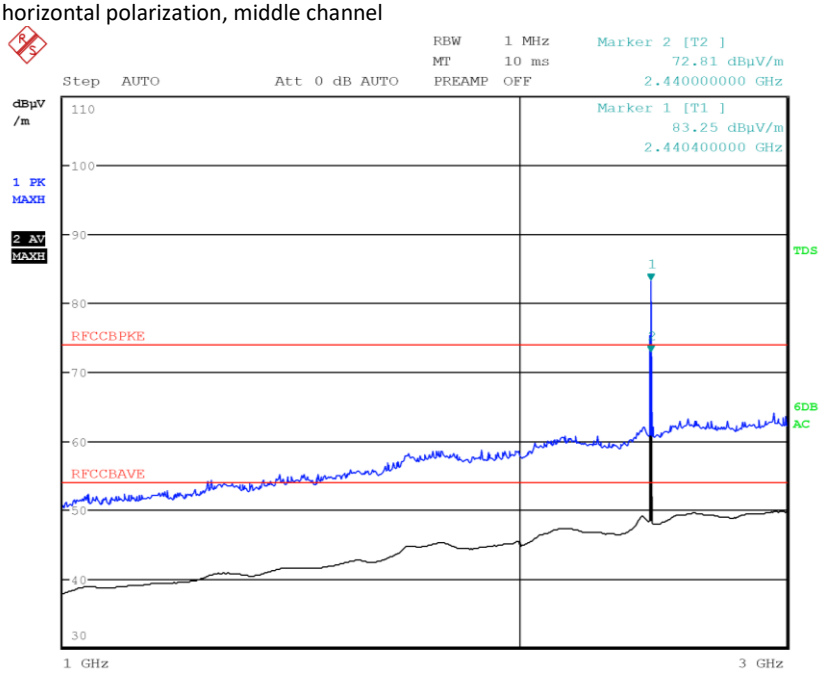
Radiated measurement vertical polarization, low channel

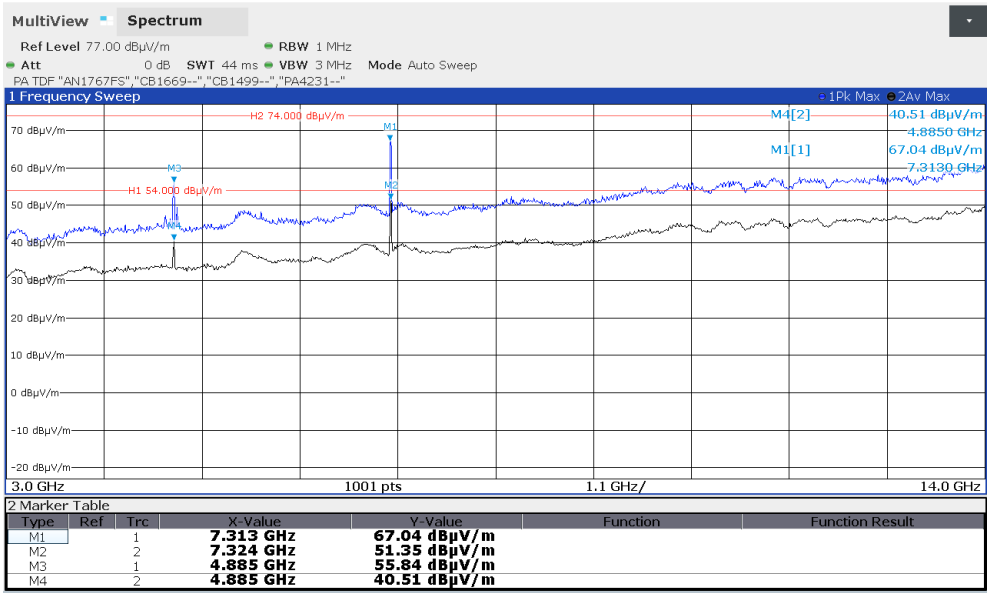




Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
2405.6	93.44	--	--	Pk
2404.8	82.94	--	--	Av
4808.0	55.65	74	-18.35	Pk
4803.0	42.91	54	-11.09	Av
7214.0	67.74	74	-6.26	Pk
7214.0	53.42	54	-0.58	Av

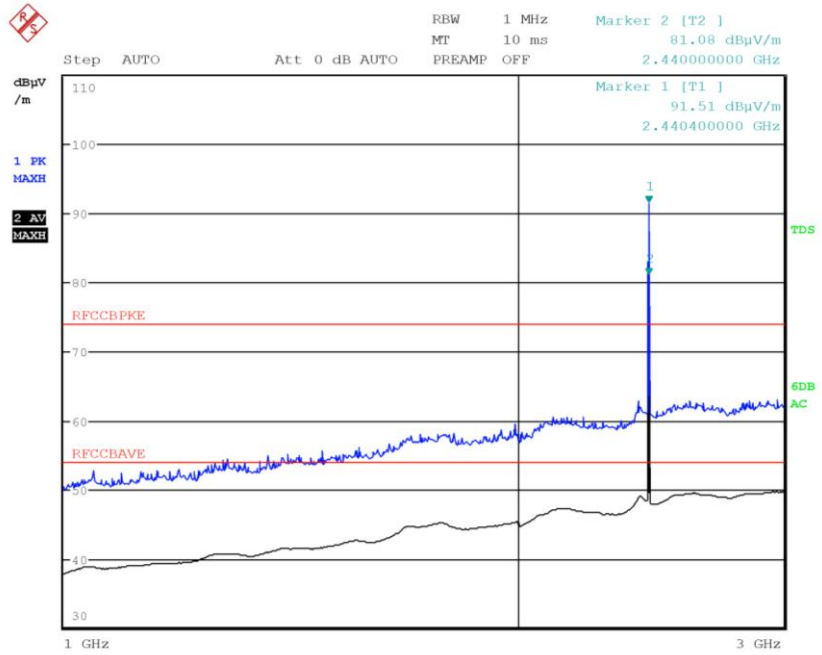
Radiated measurement BT horizontal polarization, middle channel

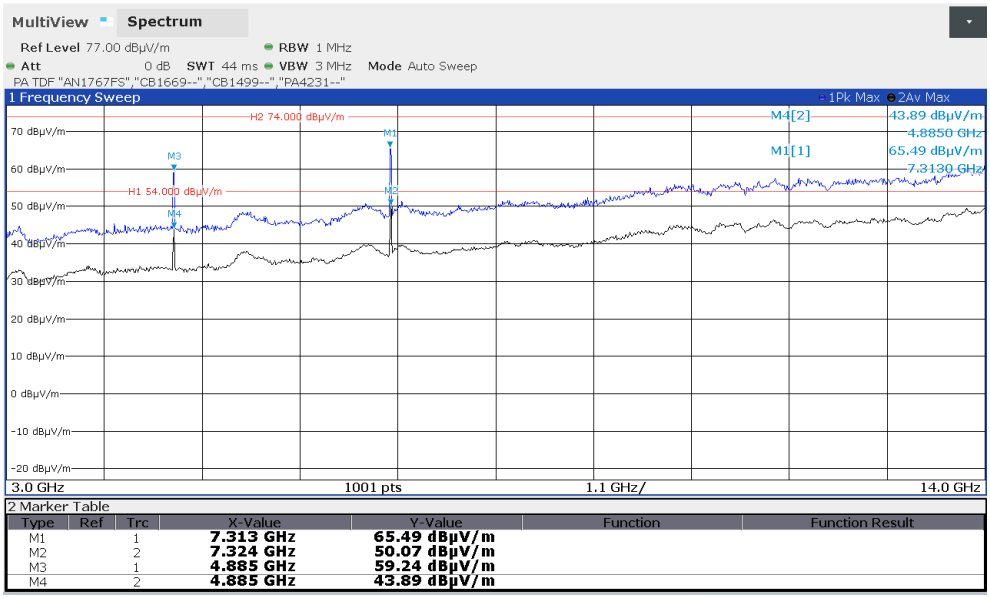




Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
2440.4000	83.3	--	--	Pk
2440.0000	72.8	--	--	Av
4885.0000	55.8	74	-18.2	Pk
4885.0000	40.5	54	-13.5	Av
7313.0000	67.1	74	-6.9	Pk
7324.0000	51.4	54	-2.6	Av

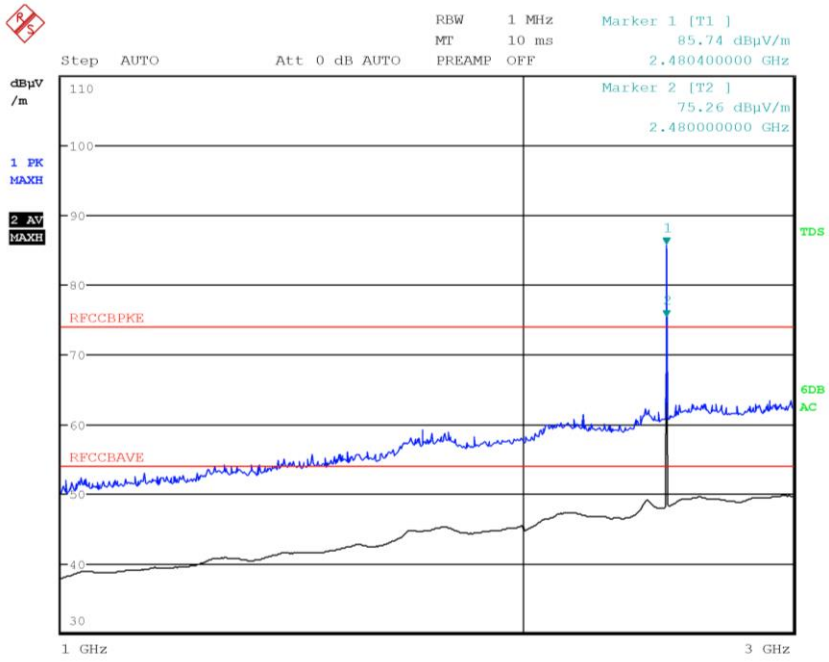
Radiated measurement BT vertical polarization, middle channel

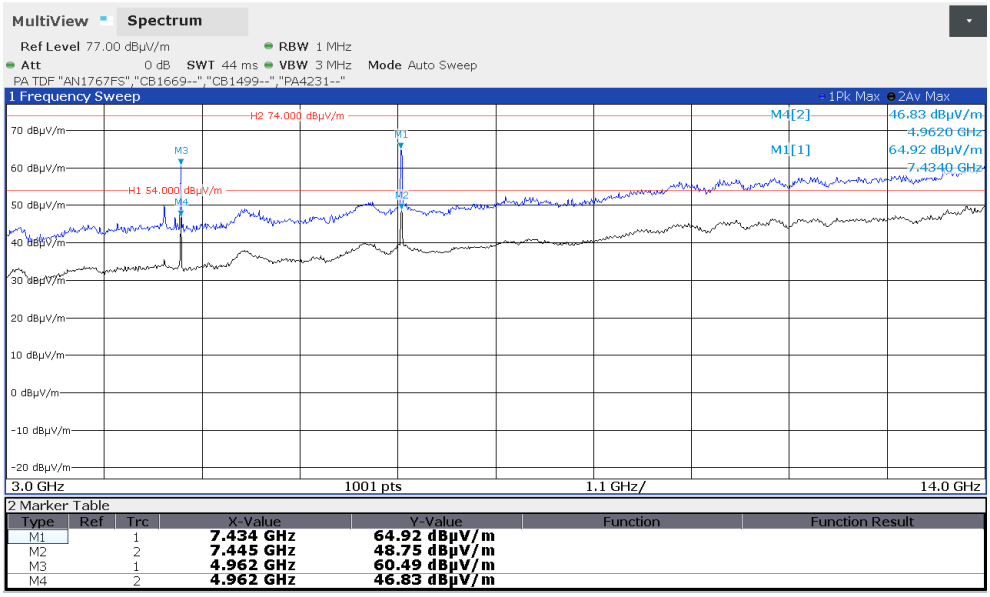




Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
2440.4000	91.5	--	--	Pk
2440.0000	81.1	--	--	Av
4885.0000	59.3	74	-14.7	Pk
4885.0000	43.9	54	-10.1	Av
7313.0000	65.5	74	-8.5	Pk
7324.0000	50.1	54	-3.9	Av

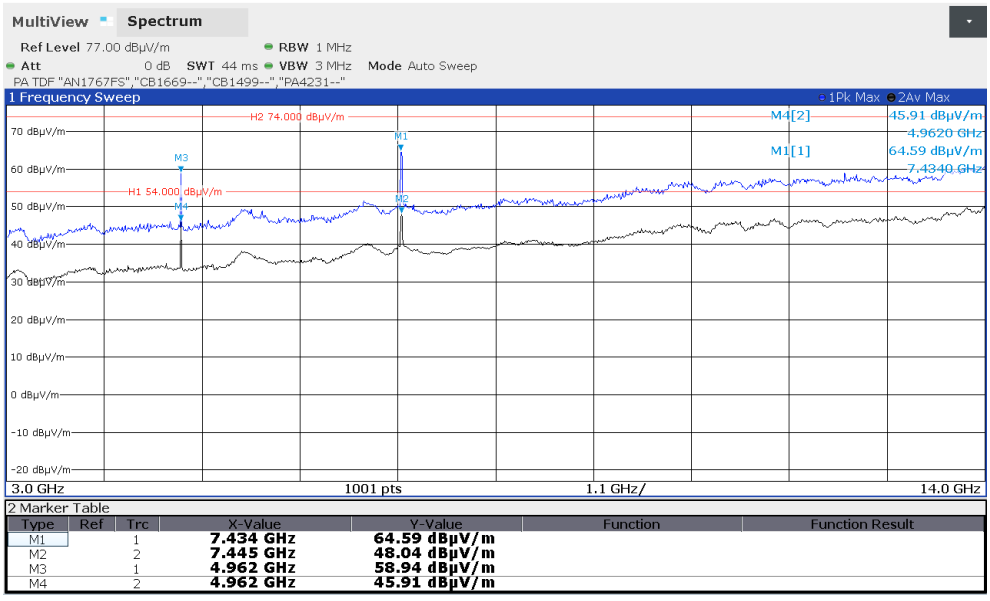
Radiated measurement BT horizontal polarization, high channel





Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
2480.4000	85.7	--	--	Pk
2480.0000	75.3	--	--	Av
4962.0000	60.5	74	-13.5	Pk
4962.0000	46.8	54	-7.2	Av
7434.0000	64.9	74	-9.1	Pk
7445.0000	48.8	54	-5.2	Av

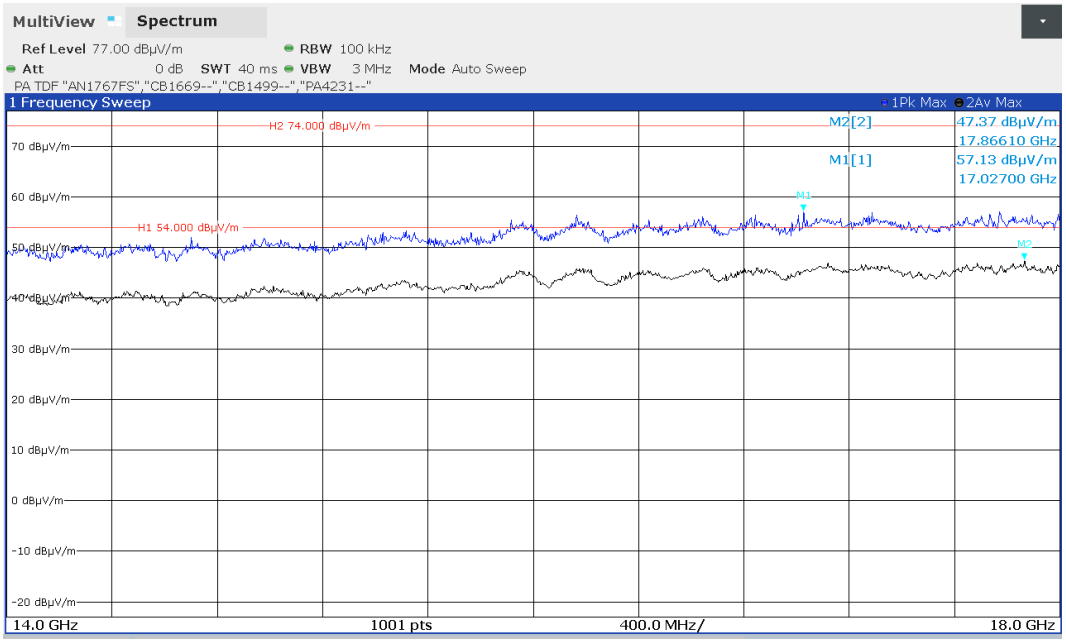
Radiated measurement BT vertical polarization, high channel



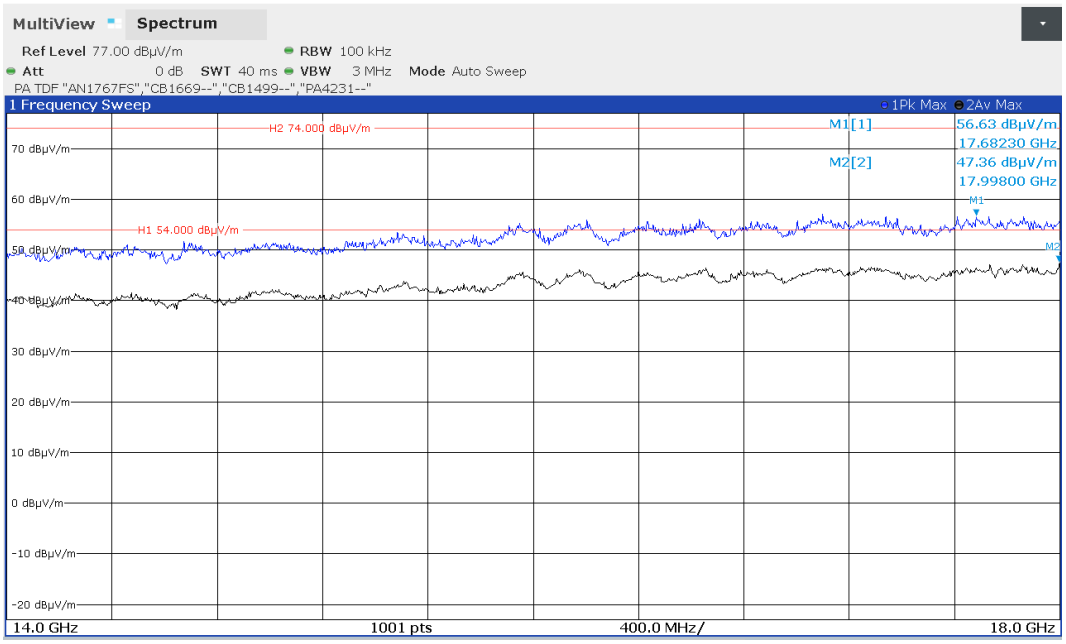
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
2480.4000	93.5	--	--	Pk
2480.0000	83.1	--	--	Av
4962.0000	58.9	74	-15.1	Pk
4962.0000	45.9	54	-8.1	Av
7434.0000	64.6	74	-9.4	Pk
7445.0000	48.1	54	-5.9	Av

Radiated measurement low channel

Horizontal



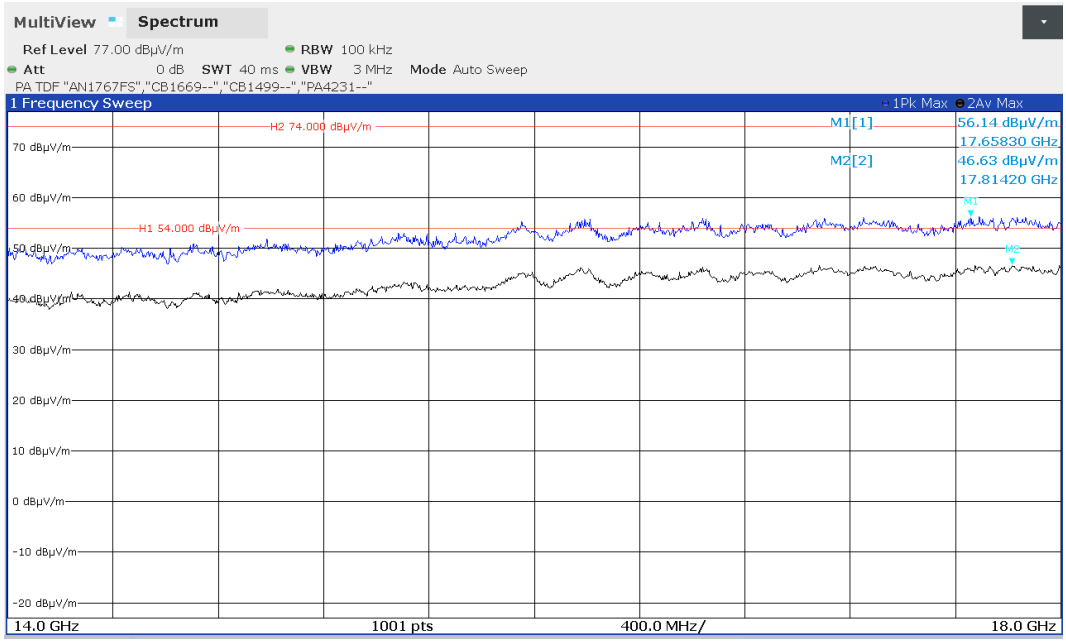
Vertical



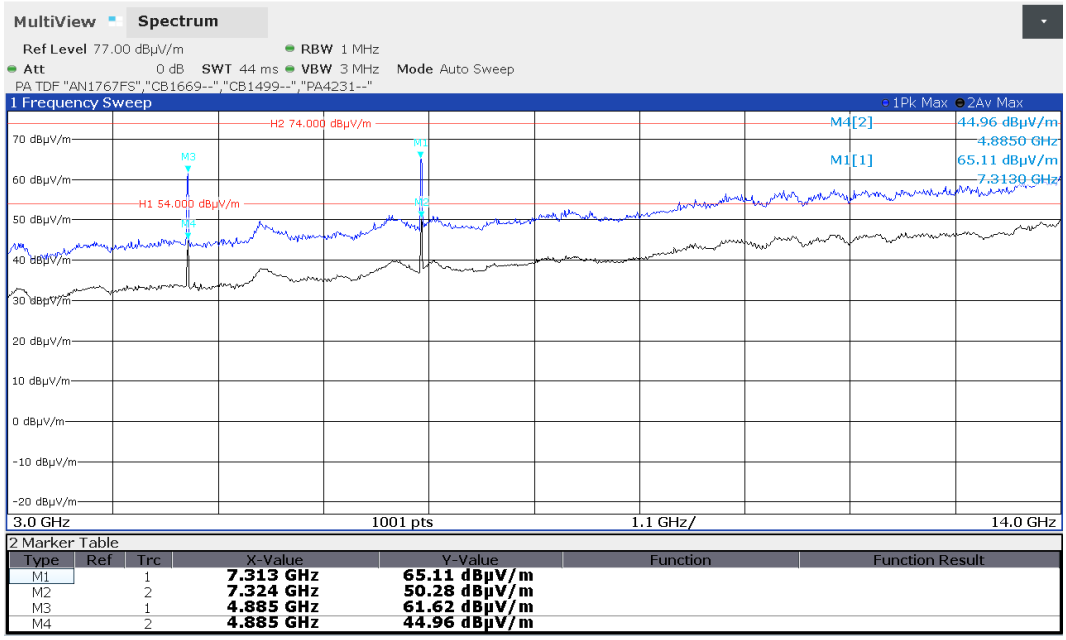
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
--	--	--	--	--

Radiated measurement BT middle channel

Horizontal



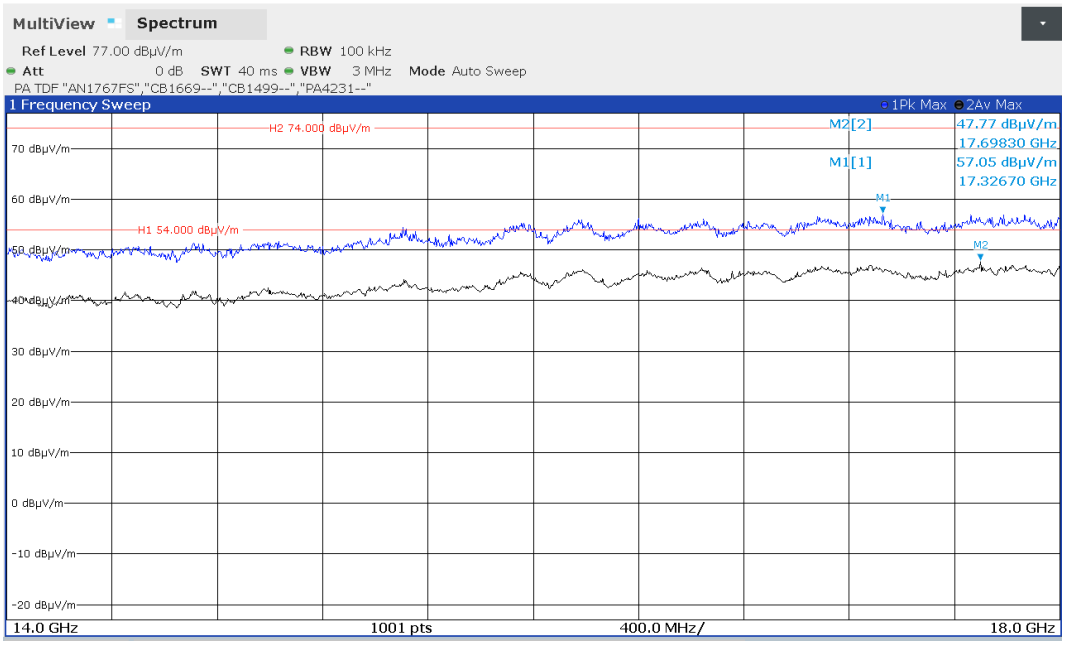
Vertical



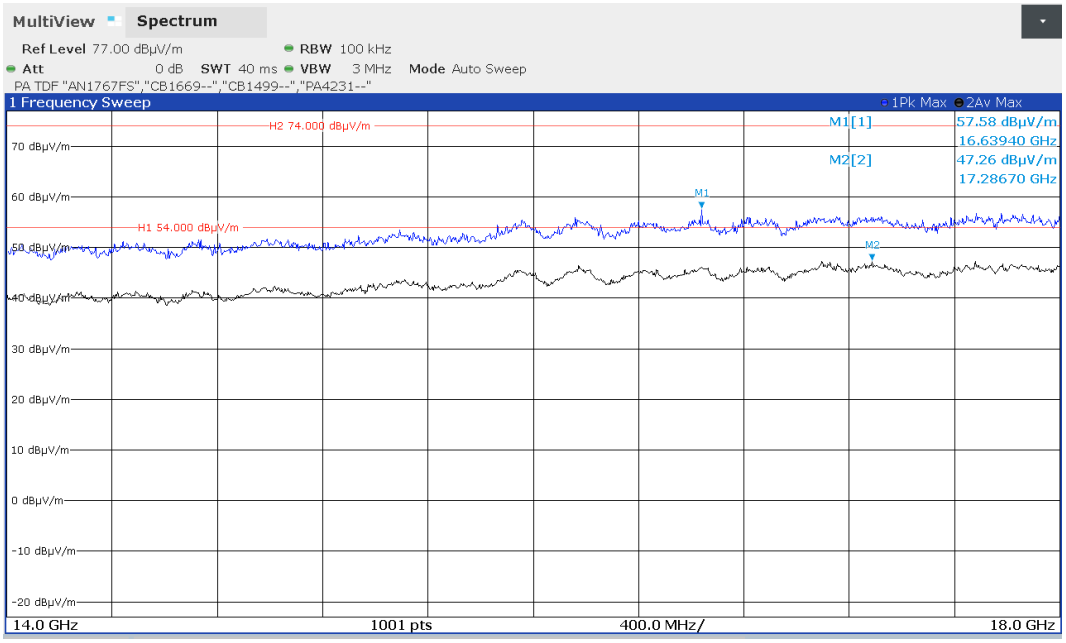
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
--	--	--	--	--

Radiated measurement BT high channel

Horizontal



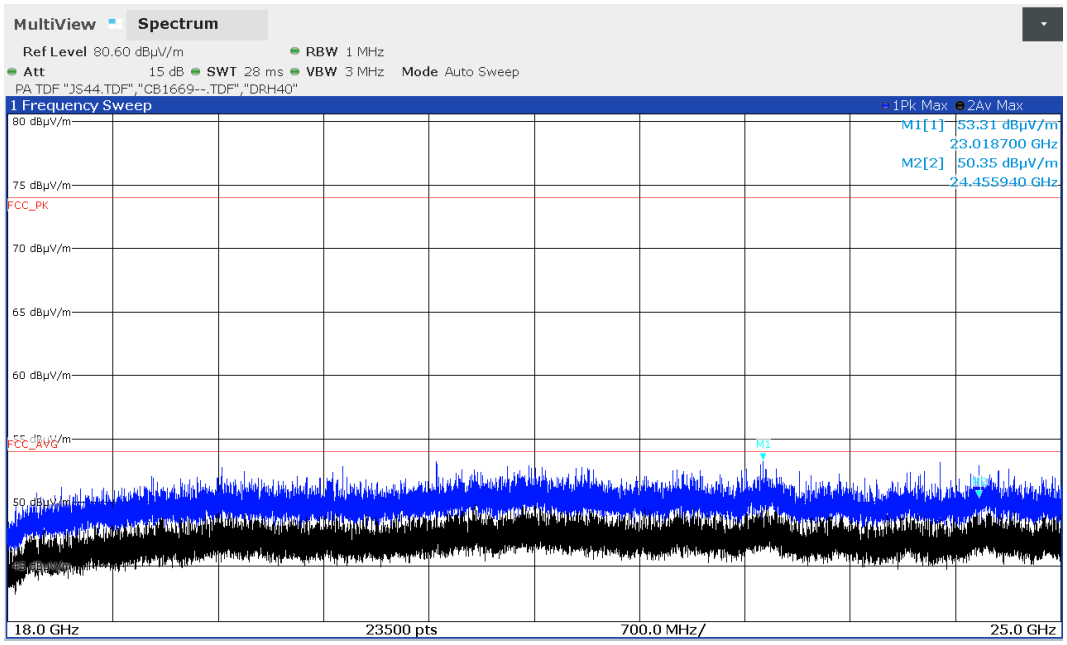
Vertical



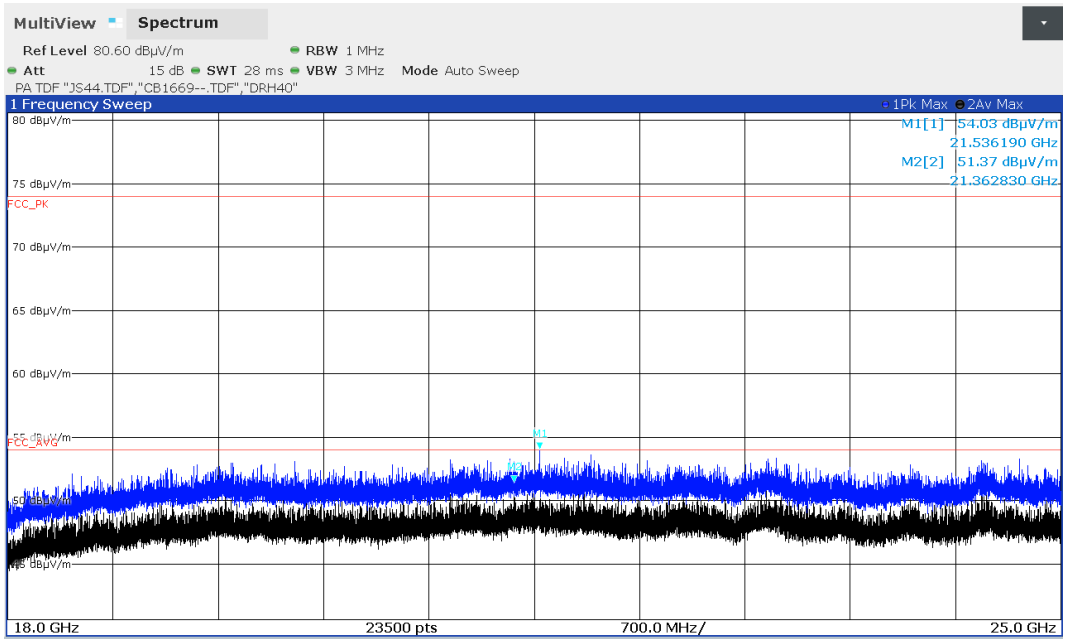
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
--	--	--	--	--

Radiated measurement low channel

Horizontal



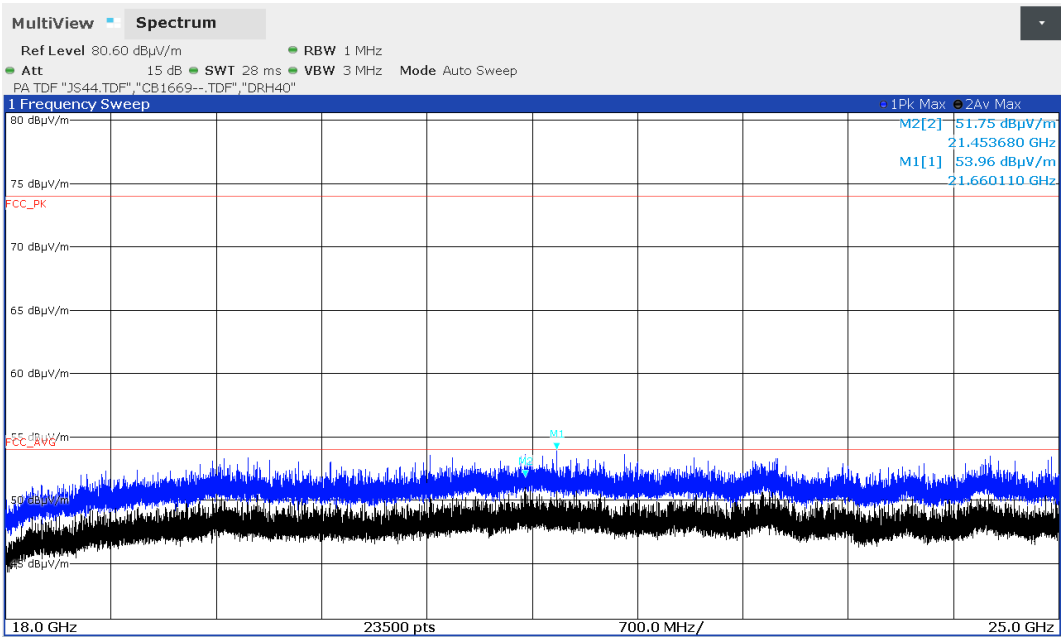
Vertical



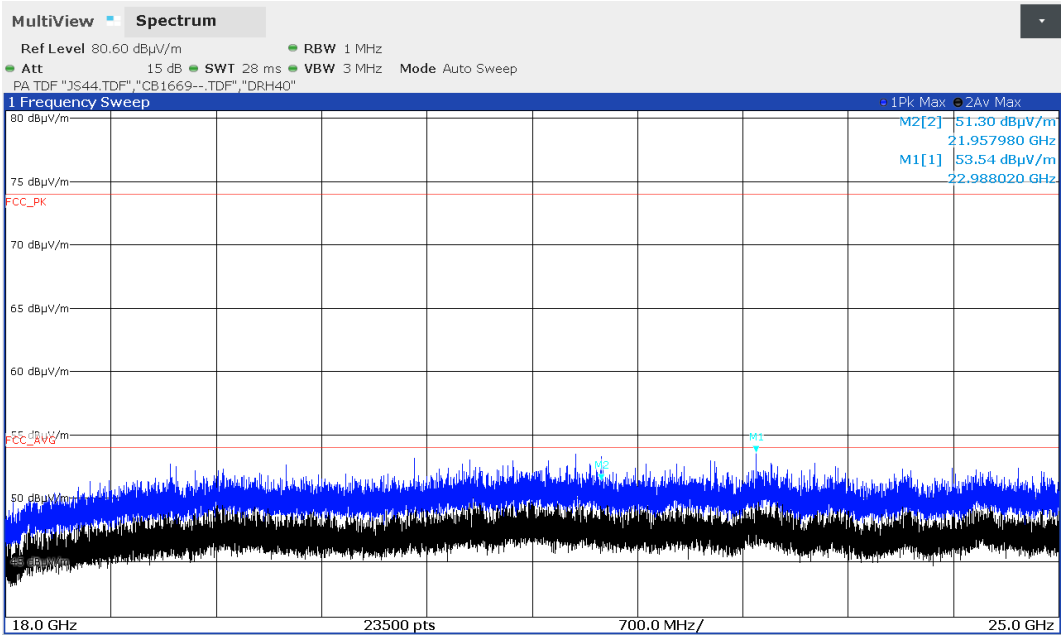
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
--	--	--	--	--

Radiated measurement BT middle channel

Horizontal



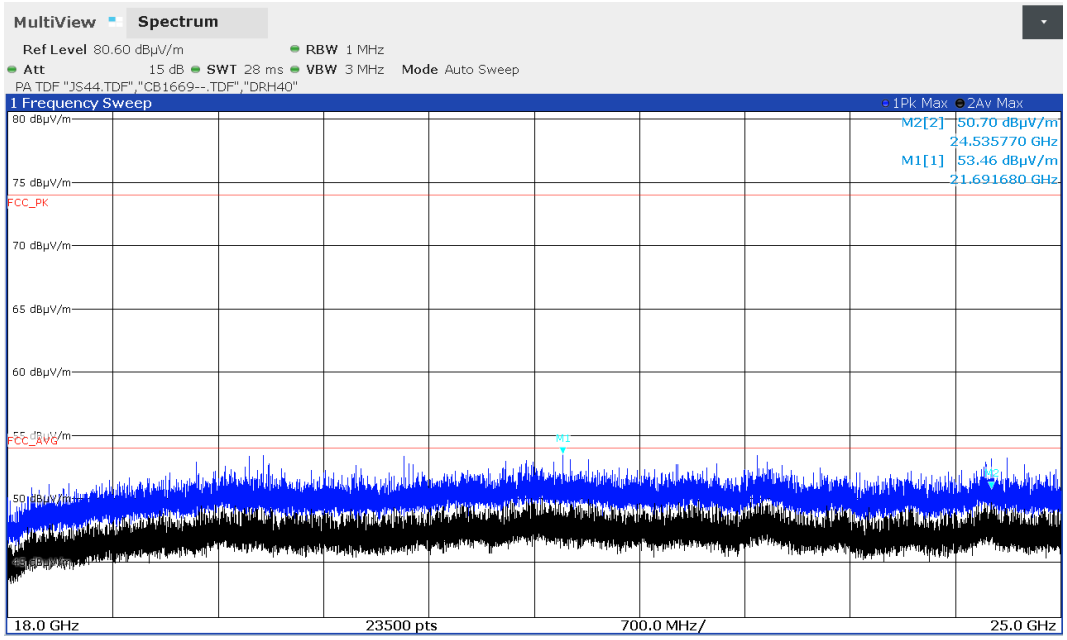
Vertical



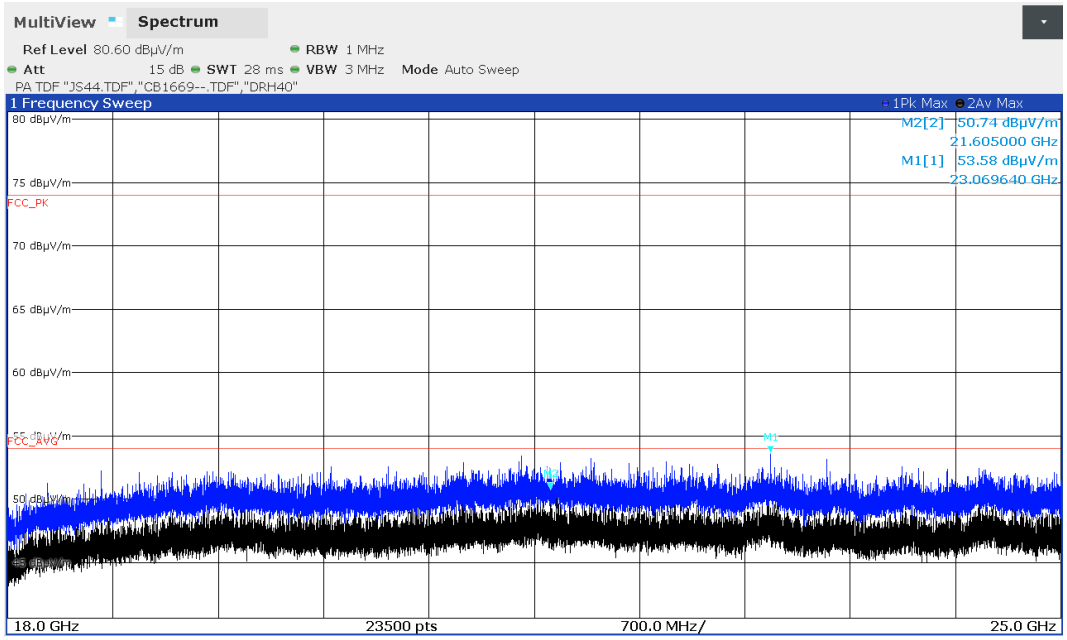
Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
--	--	--	--	--

Radiated measurement BT high channel

Horizontal



Vertical



Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
--	--	--	--	--

8.8 FCC 15.247(e) Power spectral density for digitally modulated devices

8.8.1 Definitions and limits

FCC:
For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

8.8.1 Test date

Start date	September 11, 2020

8.8.2 Observations, settings and special notes

The test was performed using method PKPSD (peak PSD).
Spectrum analyser settings:

Resolution bandwidth:	3 kHz ≤ RBW ≤ 100 kHz
Video bandwidth:	≥3 × RBW
Frequency span:	1.5 times the OBW
Detector mode:	Peak
Trace mode:	Max hold

8.8.3 Test data

$$EIRP\ (dBm/3kHz) = EMeas\ (dBuV/m/3kHz) + 20*\log(dMeas) - 104.7$$

where
EIRP is the equivalent isotropically radiated power
*E*Meas is the field strength of the emission at the measurement distance
*d*Meas is the measurement distance, in m (d=3 m)

Horizontal polarization

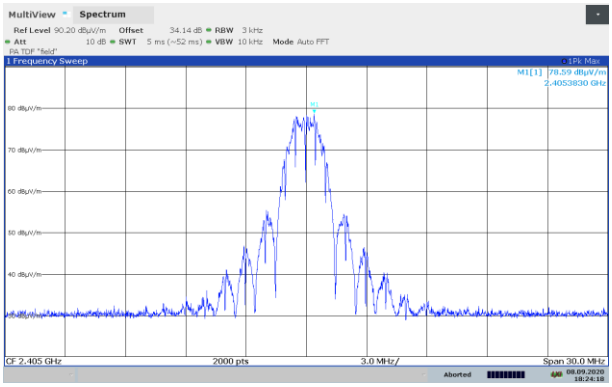
Modulation	Frequency, MHz	E field, dBuV/m/3kHz	EIRP dBm/3 kHz	Antenna gain	PSD, dBm/3 kHz	PSD limit, dBm/3 kHz	Margin, dB
802.15.4	2405	78.6	-16.5	1.5	-18.0	8	-26.0
	2440	73.6	-21.5	1.5	-23.0	8	-31.0
	2480	74.8	-20.3	1.5	-21.8	8	-29.8

Vertical polarization

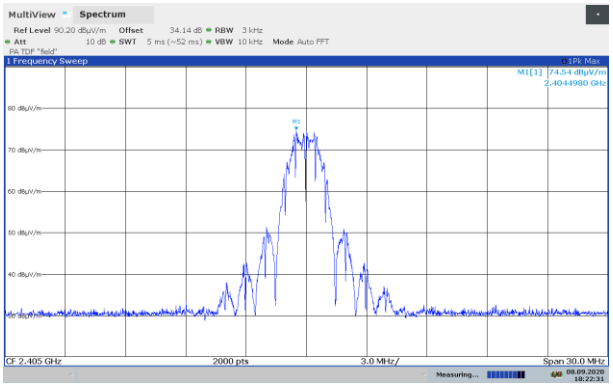
Modulation	Frequency, MHz	E field, dBuV/m/3kHz	EIRP dBm/3 kHz	Antenna gain	PSD, dBm/3 kHz	PSD limit, dBm/3 kHz	Margin, dB
802.15.4	2405	74.5	-20.6	1.5	-22.1	8	-30.1
	2440	78.8	-16.3	1.5	-17.8	8	-25.8
	2480	81.9	-13.2	1.5	-14.7	8	-22.7

Section (8) Results, BT

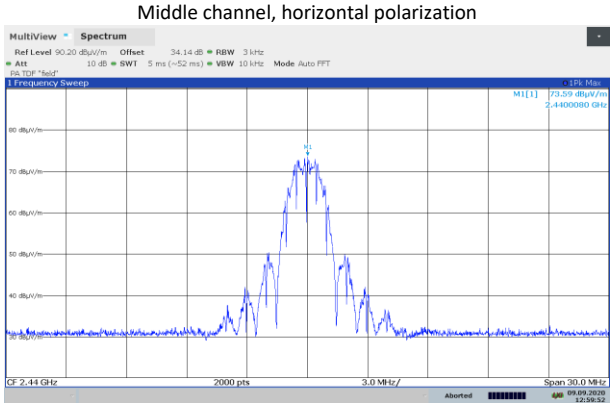
Low channel, horizontal polarization



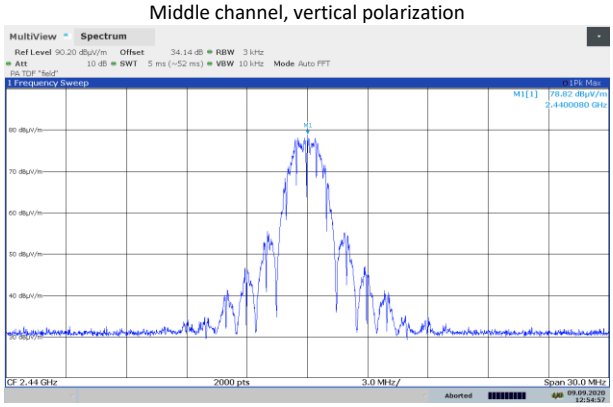
Low channel, vertical polarization



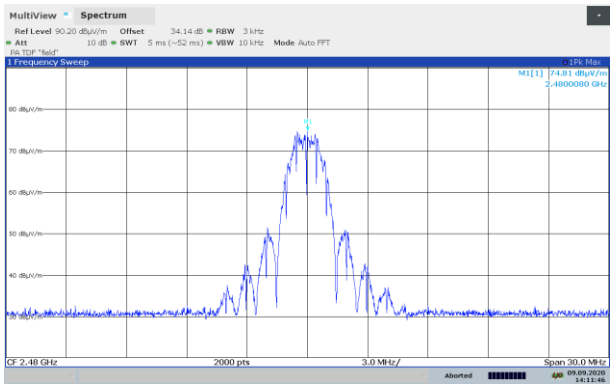
Middle channel, horizontal polarization



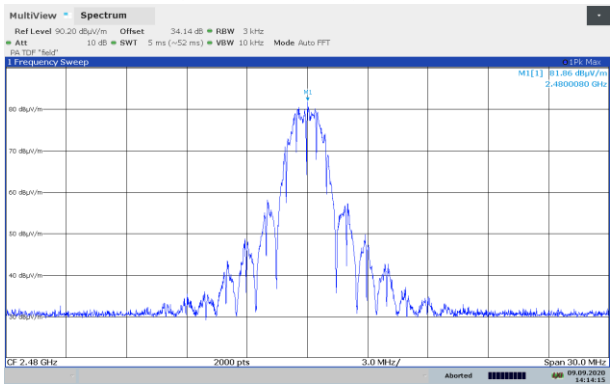
Middle channel, vertical polarization



High channel, horizontal polarization

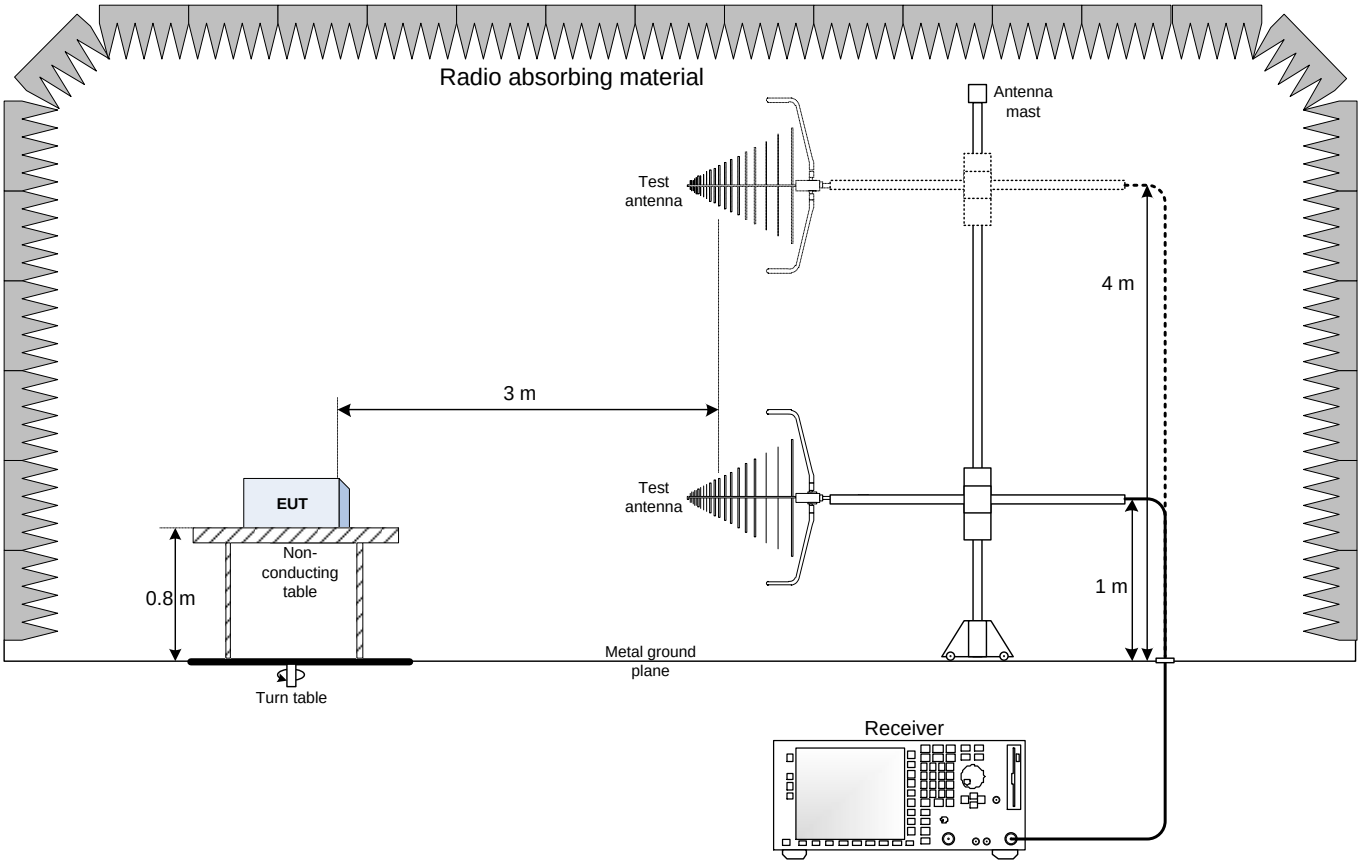


High channel, vertical polarization

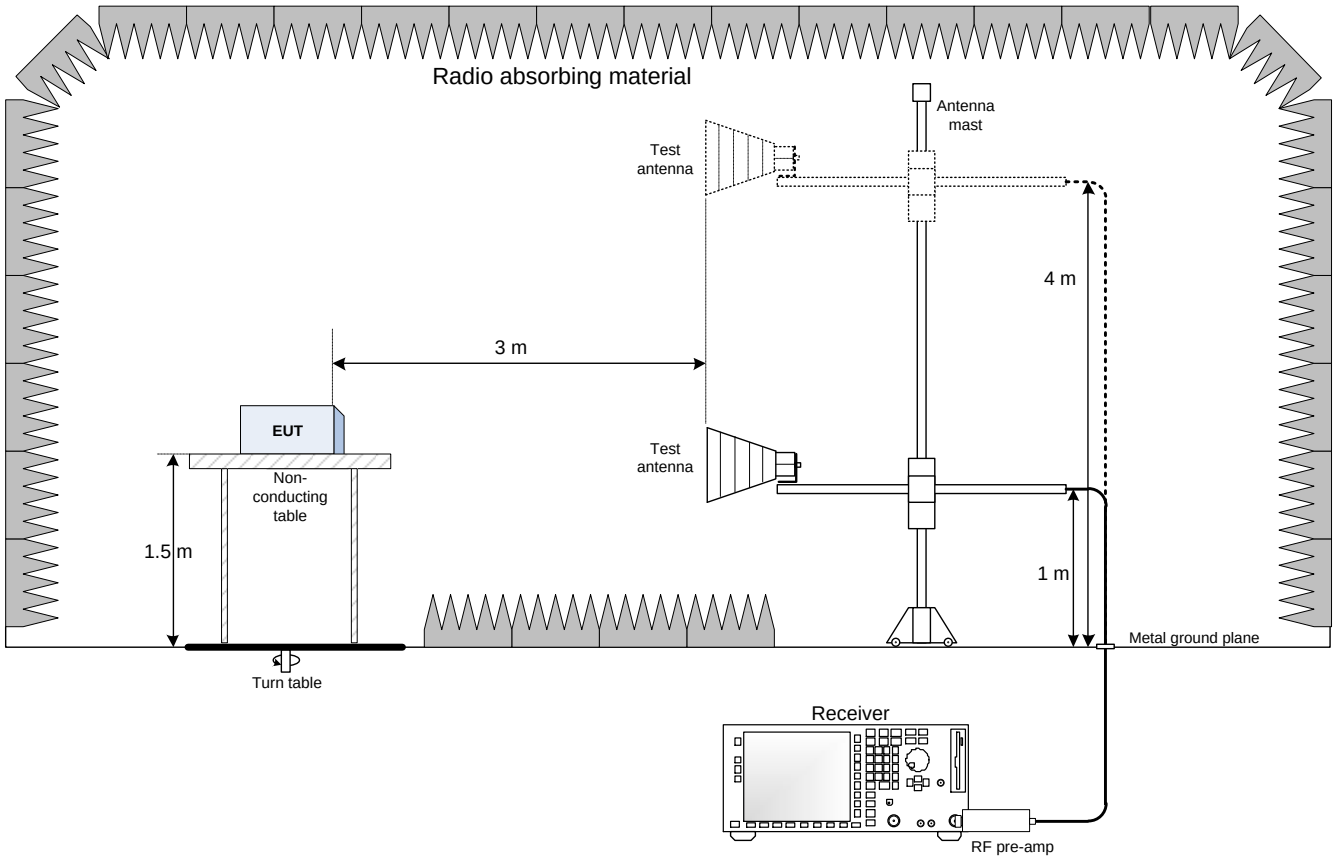


Section 9. Block diagrams of test set-ups

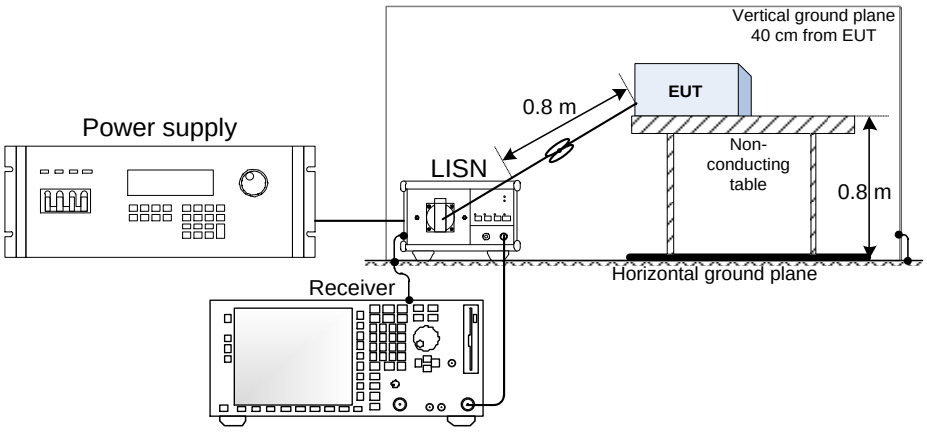
9.1 Radiated emissions set-up for frequencies below 1 GHz



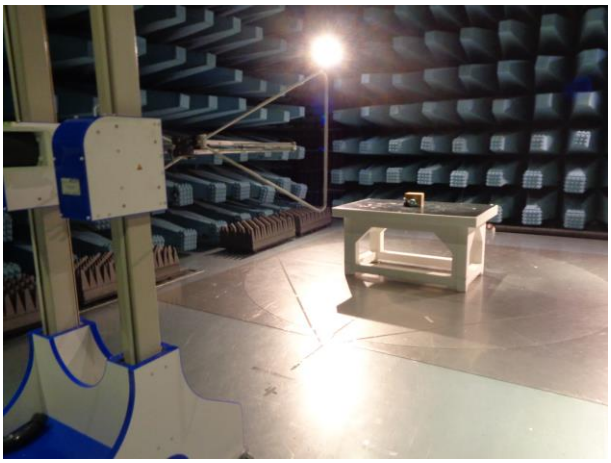
9.2 Radiated emissions set-up for frequencies above 1 GHz

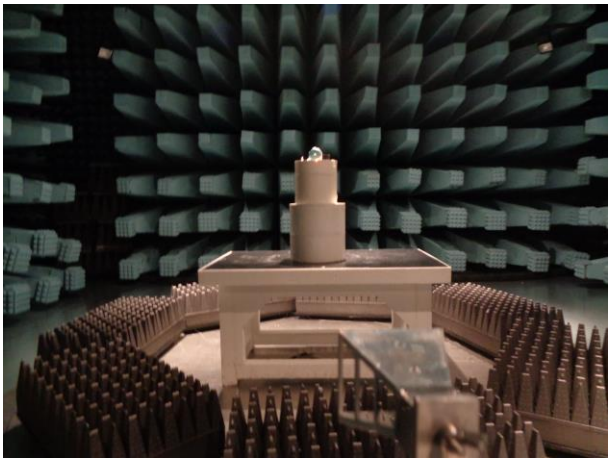


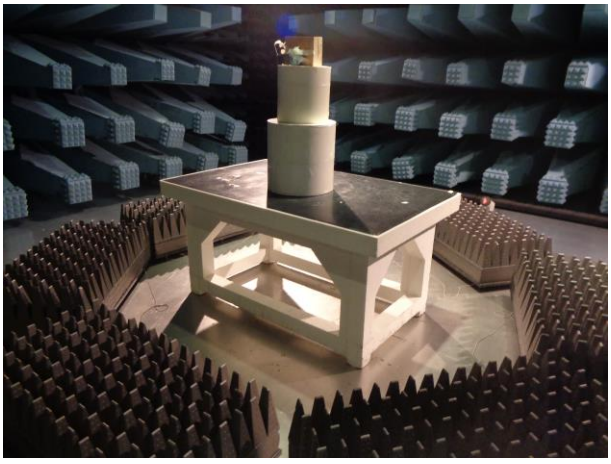
9.3 Conducted emissions on AC line set-up

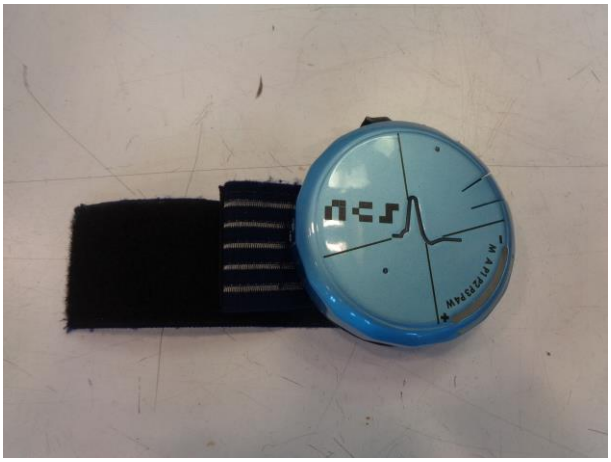


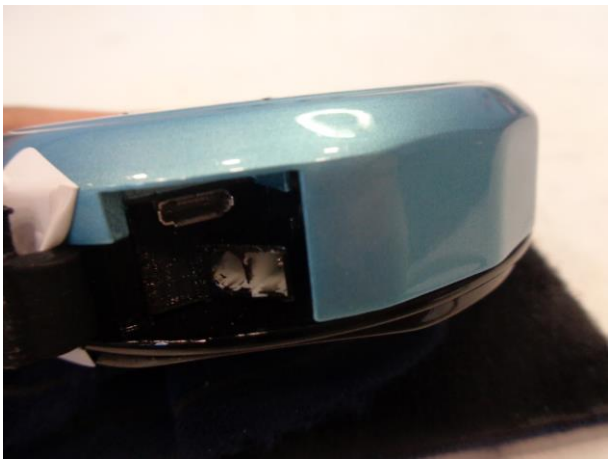
Section 10. Photos











End of report