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Wireless test report – 406683TRFWL

Applicant:

SECO S.p.A.

Product name:

Enhanced sensor to cloud for IOT

Model:

SYS-D47-IOT-0131-1121-C0

FCC ID:

2ALZB-D47IOT

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: February 9, 2021

Tested by (name, function and signature)	S. Tessa	(project handler)	Signature:	Sara Tessa
Reviewed by (name, function and signature)	P. Barbieri	(verifier)	Signature:	Barbieri

Test location(s)

Company name	Nemko Spa
Address	Via del Carroccio, 4
City	Biassono
Province	MB
Postal code	20853
Country	Italy
Telephone	+39 039 220 12 01
Facsimile	+39 039 220 12 21
Website	www.nemko.com
Site number	FCC: 682159 (10 m semi anechoic chamber)

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. All results contain in this report are within Nemko Spa ISO/IEC 17025 accreditation.

Copyright notification

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Section 1. Report summary

1.1 Applicant and manufacturer

Company name	SECO S.p.A.
Address	Via A. Grandi – 52100 Arezzo, 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	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 C63.10 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
406683TRFWL	February 9, 2021	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	Not tested
§15.31(e)	Variation of power source	Pass
§15.31(m)	Number of tested frequencies	Pass
§15.203	Antenna requirement	Pass

Notes: [1]. EUT is a DC powered device.

2.2 FCC Part 15 Subpart C, intentional radiators test results for frequency hopping spread spectrum systems

Table 2.2-1: *FCC 15.247 results for FHSS*

Part	Test description	Verdict
§15.247(a)(1)(i)	Requirements for operation in the 902–928 MHz band	Not applicable
§15.247(a)(1)(ii)	Requirements for operation in the 5725–5850 MHz band	Not applicable
§15.247(a)(1)(iii)	Requirements for operation in the 2400–2483.5 MHz band	Not applicable
§15.247(b)(1)	Maximum peak output power in the 2400–2483.5 MHz band and 5725–5850 MHz band	Not applicable
§15.247(b)(2)	Maximum peak output power in the 902–928 MHz band	Not applicable
§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	Not applicable
§15.247(f)	Time of occupancy for hybrid systems	Not applicable

Notes: Not applicable because the EUT has been tested only in BLE mode that it's chosen to be the representative worst case due to higher output power.

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

Table 2.3-1: *FCC 15.247 results for DTS*

Part	Test description	Verdict
§15.247(a)(2)	Minimum 6 dB bandwidth	Not tested
§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	Not tested
§15.247(f)	Time of occupancy for hybrid systems	Not applicable

Section 3. Equipment under test (EUT) details

3.1 Sample information

Receipt date	December 9, 2020
Nemko sample ID number	4066830004

3.2 EUT information

Product name	Enhanced sensor to cloud for IOT
Model	SYS-D47-IOT-0131-1121-C0
Serial number	-

3.3 Technical information

Frequency band	2400 to 2483.5 MHz
Frequency Min (MHz) BT/BLE	2402
Frequency Max (MHz) BT/BLE	2480
Frequency Min (MHz) WiFi	2412
Frequency Max (MHz) WiFi	2462
RF power Min (W), Conducted	N/A
RF power Max (W), Conducted BT/BLE	3.7 mW (5.7 dBm)
RF power Max (W), Conducted WiFi	309 mW (24.9 dBm)
Field strength, Units @ distance	N/A
Measured BW (kHz) (6 dB)	N/A
Calculated BW (kHz), as per TRC-43	N/A
Type of modulation BT/BLE	GFSK, π/4-DQPSK, 8-DPSK and BLE
Type of modulation WiFi	802.11b/g/n
Emission classification (F1D, G1D, D1D) BT/BLE	F1D
Emission classification (F1D, G1D, D1D) WiFi	W7D
Transmitter spurious, Units @ distance BT/BLE	53.09 dBµV/m @ 3 m
Transmitter spurious, Units @ distance WiFi	57.94 dBµV/m @ 3 m
Power requirements	9 - 24 V_{DC}, 1.3-3.5 A
Antenna information	External antenna

3.4 EUT setup diagram

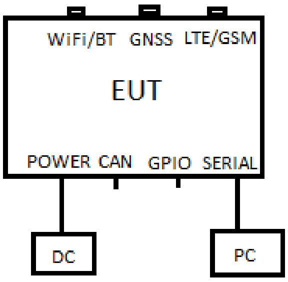

Figure 3.4-1: *Setup diagram*

3.5 Product description and theory of operation

SENSE D47 is a boxed module with a form factor of just 110 x 91 x 31 mm based on a module of Espressif ESP32-WROVER and SIMCOM. This module is suitable both for IoT applications, due to its rich connectivity, and for industrial applications. The EUT features a wide range of connectivity capabilities: it integrates Wi-Fi, Bluetooth, GSM/GPRS and GPS.

3.6 EUT sub assemblies

Table 3.6-1: *EUT sub assemblies*

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

3.7 EUT exercise details

EUT was set to continuously transmit mode during tests, by test software ESP32 tool 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. Communication with the EUT is via a serial.

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

No Technical judgment

4.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

Section 5. Test conditions

5.1 Atmospheric conditions

In the laboratory, the following ambient conditions are respected for each test reported below:

Temperature	18 – 33 °C
Relative humidity	25 – 70 %
Air pressure	860 – 1060 mbar

The following instruments are used to monitor the environmental conditions:

Equipment	Manufacturer	Model no.	Asset no.	Cal date	Next cal.
Thermo-hygrometer data loggers	Testo	175-H2	20012380/305	2020-12	2022-12
Thermo-hygrometer data loggers	Testo	175-H2	38203337/703	2020-12	2022-12
Barometer	Castle	GPB 3300	072015	2020-03	2021-03

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 measurement uncertainty was calculated for each test and quantity listed in this test report, according to CISPR 16-4-2 and other specific test standard and is documented in Nemko Spa working manual WML1002.

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:

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)

<table>
<tr><th>EUT</th><th>Type</th><th>Test</th><th>Range</th><th>Measurement Uncertainty</th><th>Notes</th></tr>
<tr><td rowspan="7">Receiver</td><td rowspan="4">Radiated</td><td rowspan="3">Radiated spurious emissions</td><td>0.009 MHz ÷ 26.5 GHz</td><td>6.0 dB</td><td>(1)</td></tr>
<tr><td>26.5 GHz ÷ 66 GHz</td><td>8.0 dB</td><td>(1)</td></tr>
<tr><td>66 GHz ÷ 220 GHz</td><td>10 dB</td><td>(1)</td></tr>
<tr><td>Sensitivity measurement</td><td>1 MHz ÷ 18 GHz</td><td>6.0 dB</td><td>(1)</td></tr>
<tr><td rowspan="3">Conducted</td><td rowspan="3">Conducted spurious emissions</td><td>0.009 MHz ÷ 18 GHz</td><td>3.0 dB</td><td>(1)</td></tr>
<tr><td>18 GHz ÷ 40 GHz</td><td>4.2 dB</td><td>(1)</td></tr>
<tr><td>40 GHz ÷ 220 GHz</td><td>6.0 dB</td><td>(1)</td></tr>
<tr><td colspan="6">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 %</td></tr>
</table>

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 (20 Hz ÷ 8 GHz)	Rohde & Schwarz	ESU8	100202	2020-08	2021-08
EMI receiver (20 Hz ÷ 8 GHz)	Rohde & Schwarz	ESW44	101620	2020-08	2021-08
Trilog Antenna (30 MHz ÷ 7 GHz)	Schwarzbeck	VULB 9162	9162-025	2018-07	2021-07
Bilog antenna (1 ÷ 18 GHz)	Schwarzbeck	STLP 9148	9148-123	2018-07	2021-07
Preamplifier (1 ÷ 18 GHz)	Schwarzbeck	BBV 9718	9718-137	2020-09	2021-09
Horn antenna (18 ÷ 40 GHz)	A.H. System	SAS-574	558	2020-01	2023-01
Preamplifier (18 ÷ 40 GHz)	SAGE	STB-1834034030-KFKF-L1	18490-01	2020-03	2021-03
Controller	Maturo	FCU3.0	10041	NCR	NCR
Tilt antenna mast	Maturo	TAM4.0-E	10042	NCR	NCR
Turntable	Maturo	TT4.0-5T	2.527	NCR	NCR
Semi-anechoic chamber	Nemko	10m semi-anechoic chamber	530	2019-09	2021-09
Shielded room	Siemens	10m control room	1947	NCR	NCR
Shielded room	Siemens	Conducted emission test room	1862	NCR	NCR

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	January 4, 2021

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	December 14, 2020

8.2.3 Observations, settings and special notes

None

8.2.4 Test data

Table 8.2-2: *Test channels selection BT/BLE*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
2400	2483.5	83.5	2402	2440	2480
Note:					

Table 8.2-3: *Test channels selection WiFi*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
2400	2483.5	83.5	2412	2437	2462
Note:					

8.3 FCC 15.203, section 6.8 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	December 14, 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 15.247(b) Transmitter output power requirements for DTS in 2 GHz

8.4.1 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.

8.4.1 Test equipment list

Table 8.4-1: *Equipment list*

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI receiver (20 Hz ÷ 8 GHz)	Rohde & Schwarz	ESU8	100202	2020-08	2021-08
Shielded room	Siemens	Conducted emission test room	1862	NCR	NCR

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

8.4.1 Test date

Start date	December 14, 2020

8.4.2 Observations, settings and special notes

The test was performed according to DTS guidelines section 9.1 Maximum peak conducted output power.
The power level for BT and BLE has been set at level 5 on the tool provided by manufacturer.

8.4.3 Test data

Table 8.4-2: *Output power measurements results, BT Modulation GFSK*

Frequency, MHz	Conducted output power, dBm		Margin, dB
	Measured	Limit	
2402	4.0	30	-26.0
2441	3.6	30	-26.4
2480	3.5	30	-26.5

Table 8.4-3: *Output power measurements results, BT Modulation π/4-DQPSK*

Frequency, MHz	Conducted output power, dBm		Margin, dB
	Measured	Limit	
2402	5.6	20.97	-15.4
2441	5.2	20.97	-15.8
2480	5.1	20.97	-15.9

Table 8.4-4: *Output power measurements results, BT Modulation 8DPSK*

Frequency, MHz	Conducted output power, dBm		Margin, dB
	Measured	Limit	
2402	5.7	20.97	-15.3
2441	5.5	20.97	-15.5
2480	5.4	20.97	-15.6

Table 8.4-4: *Output power measurements results, BLE Modulation GFSK*

Frequency, MHz	Conducted output power, dBm		Margin, dB
	Measured	Limit	
2402	3.9	30	-26.9
2441	3.5	30	-26.5
2480	3.4	30	-26.6

Table 8.4-5: *Output power measurements results, WiFi modulation 802.11 b*

Frequency, MHz	Conducted output power, dBm		Margin, dB
	Measured	Limit	
2412	24.9	30	-5.1
2437	23.8	30	-6.2
2462	23.0	30	-7.0

Table 8.4-6: *Output power measurements results, WiFi modulation 802.11 g*

Frequency, MHz	Conducted output power, dBm		Margin, dB
	Measured	Limit	
2412	23.6	30	-6.4
2437	23.6	30	-6.4
2462	23.5	30	-6.5

Table 8.4-7: *Output power measurements results, WiFi modulation 802.11 n (HT20)*

Frequency, MHz	Conducted output power, dBm		Margin, dB
	Measured	Limit	
2412	23.8	30	-6.2
2437	23.8	30	-6.2
2462	23.5	30	-6.5

Table 8.4-8: *Output power measurements results, WiFi modulation 802.11 n (HT40)*

Frequency, MHz	Conducted output power, dBm		Margin, dB
	Measured	Limit	
2422	23.8	30	-6.2
2437	23.9	30	-6.1
2452	23.8	30	-6.2

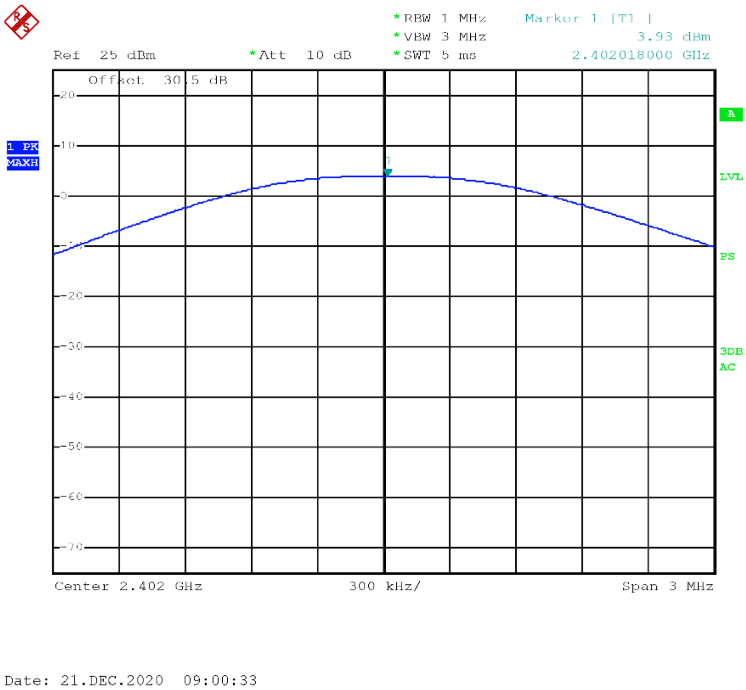

Figure 8.4-1: *Output power of BT Modulation GFSK, channel LOW*

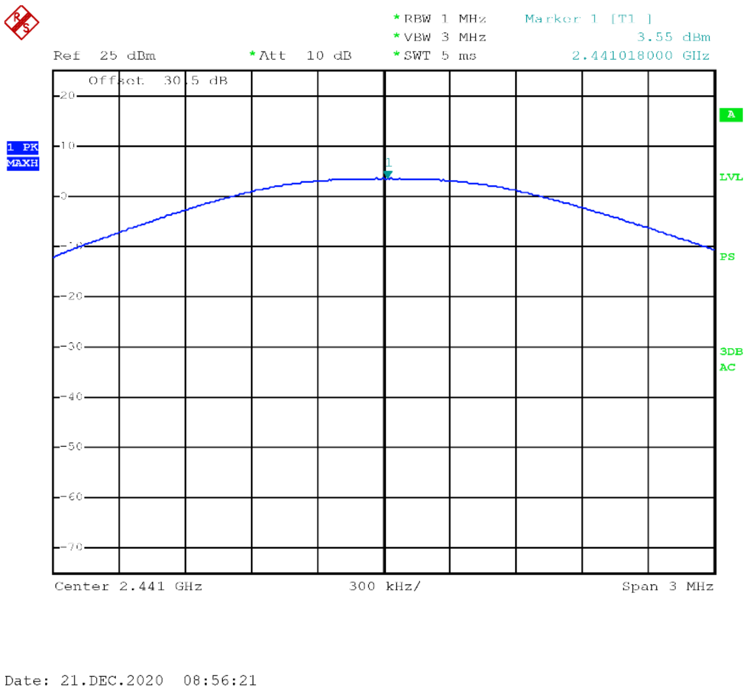

Figure 8.4-2: *Output power of BT Modulation GFSK, channel MID*

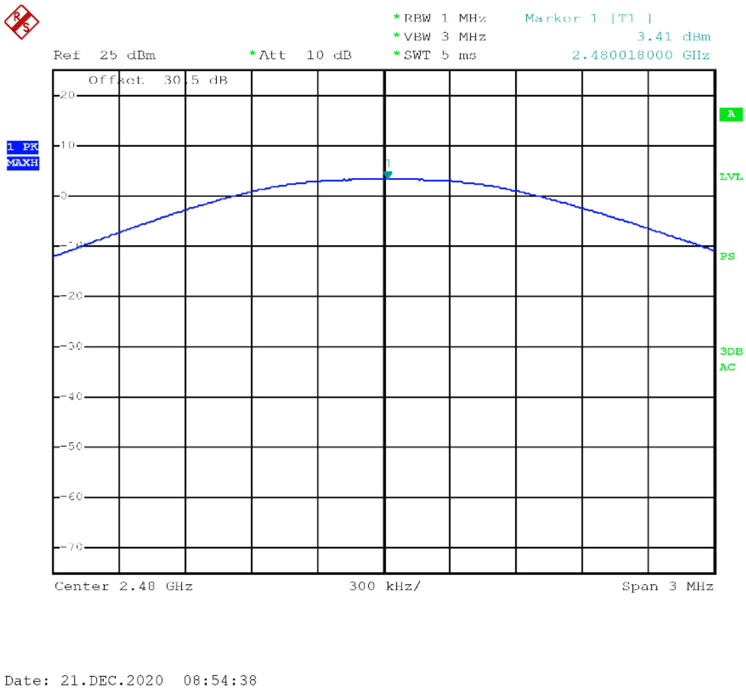

Figure 8.4-3: *Output power of BT Modulation GFSK, channel HIGH*

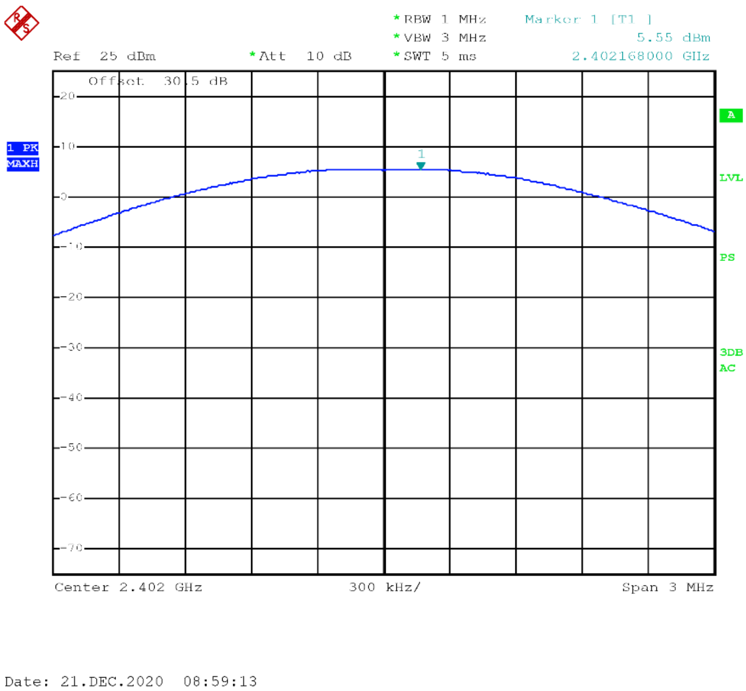

Figure 8.4-4: *Output power of BT Modulation π/4-DQPSK, channel LOW*

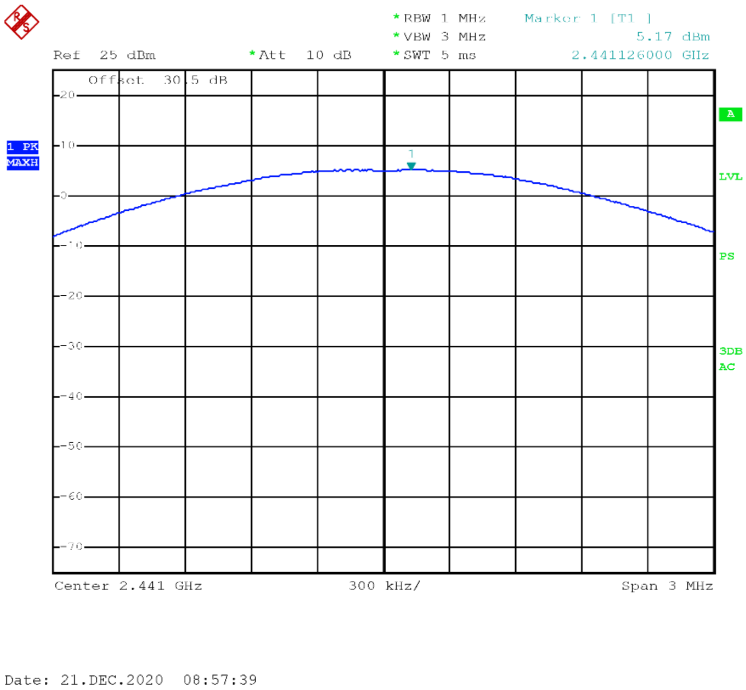

Figure 8.4-5: *Output power of BT Modulation π/4-DQPSK, channel MID*

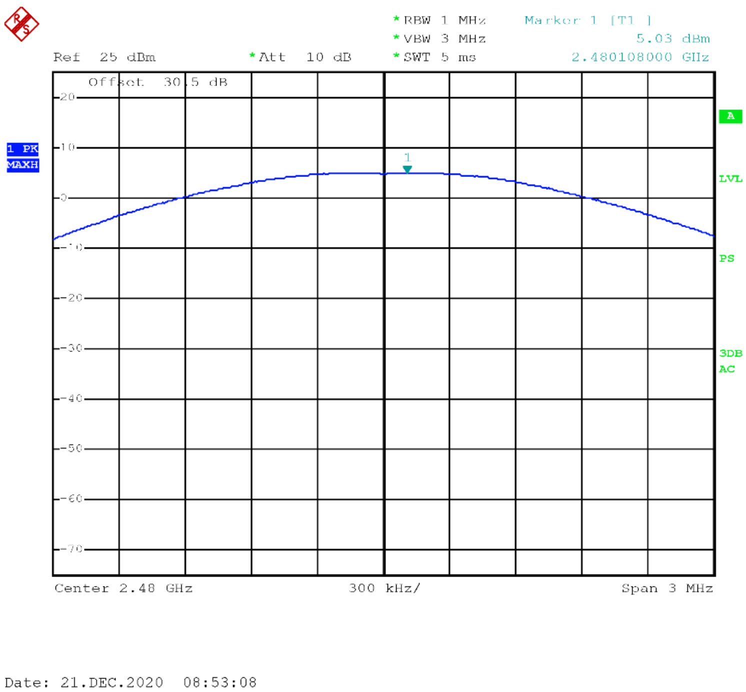

Figure 8.4-6: *Output power of BT Modulation π/4-DQPSK, channel HIGH*

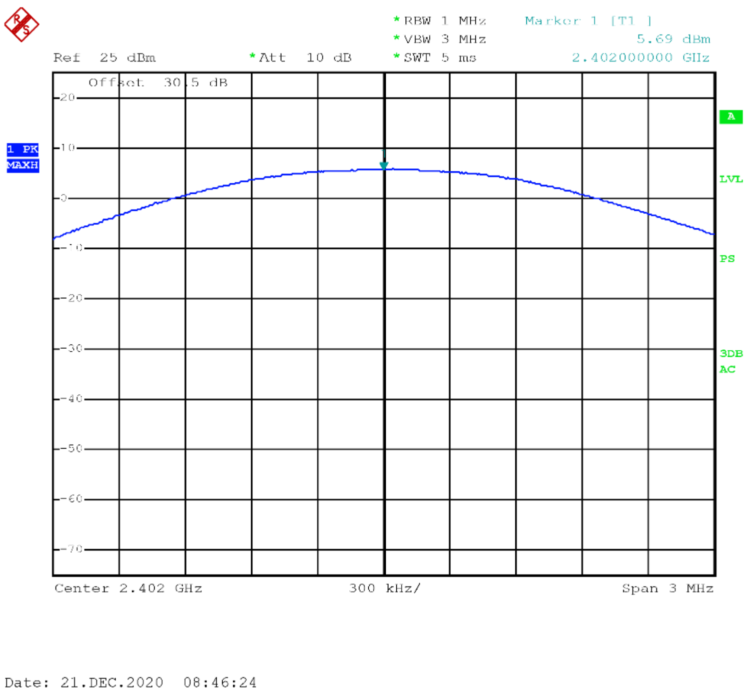

Figure 8.4-7: *Output power of BT Modulation 8DPSK, channel LOW*

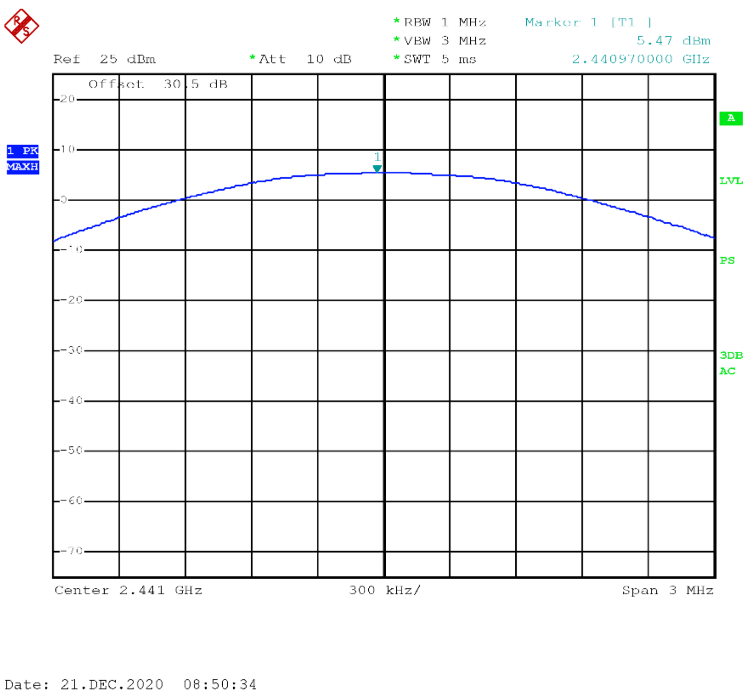

Figure 8.4-8: *Output power of BT Modulation 8DPSK, channel MID*

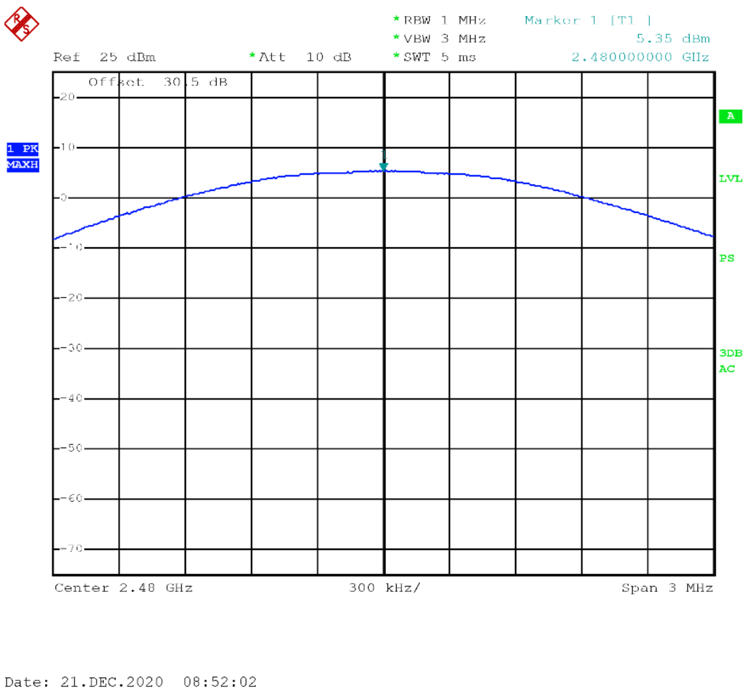

Figure 8.4-9: *Output power of BT Modulation 8DPSK, channel HIGH*

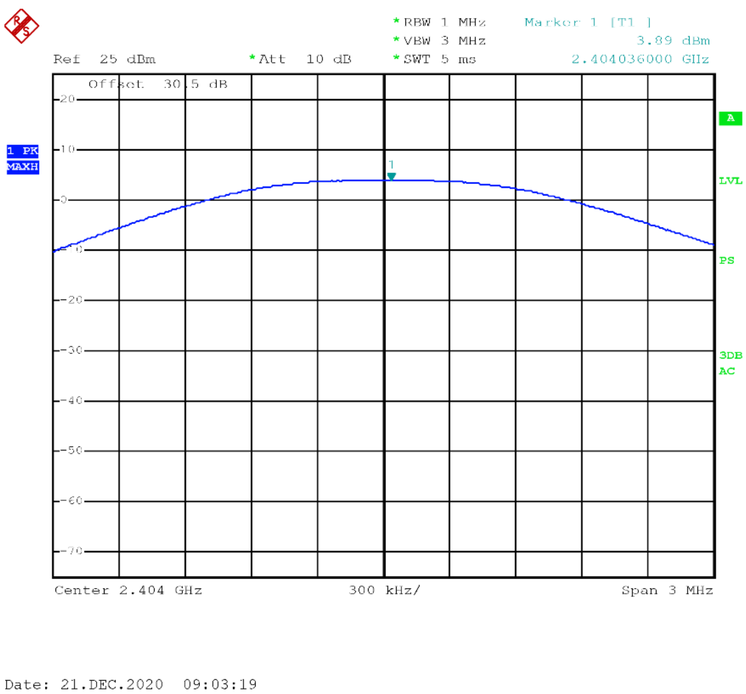

Figure 8.4-10: *Output power of BLE Modulation GFSK, channel LOW*

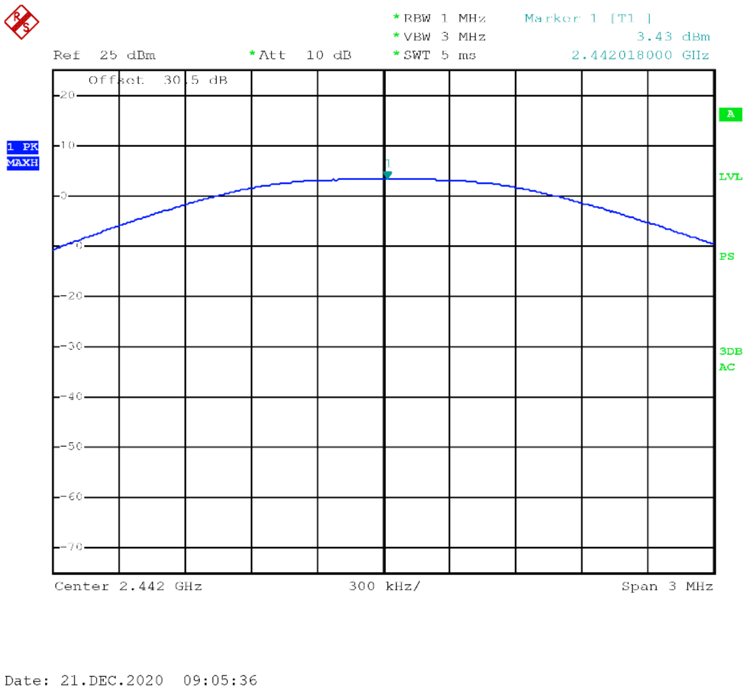

Figure 8.4-11: *Output power of BLE Modulation GFSK, channel MID*

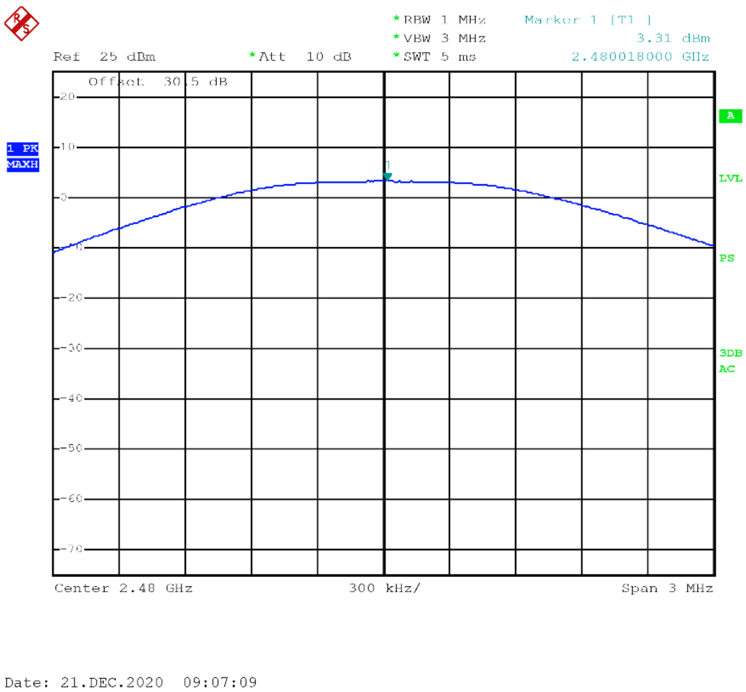

Figure 8.4-12: *Output power of BLE Modulation GFSK, channel HIGH*

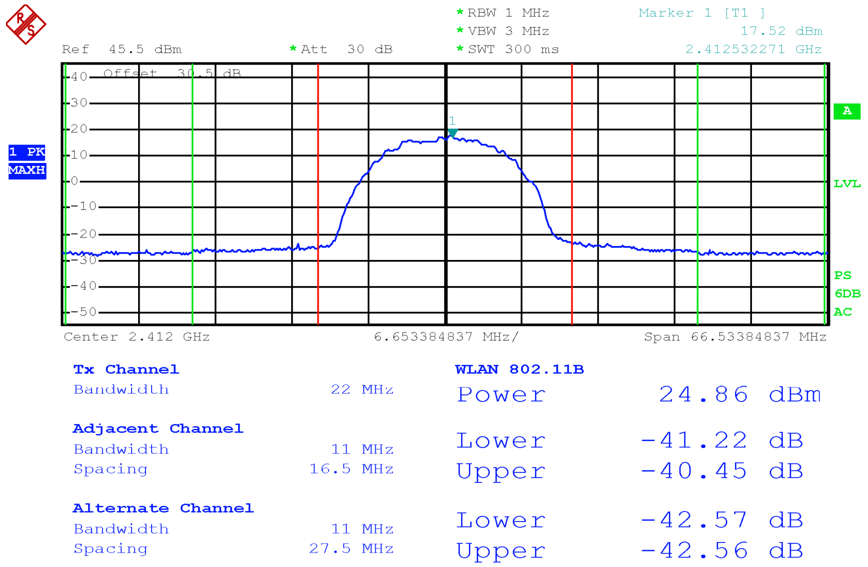

Figure 8.4-13: Output power of WiFi Modulation 802.11b, channel LOW

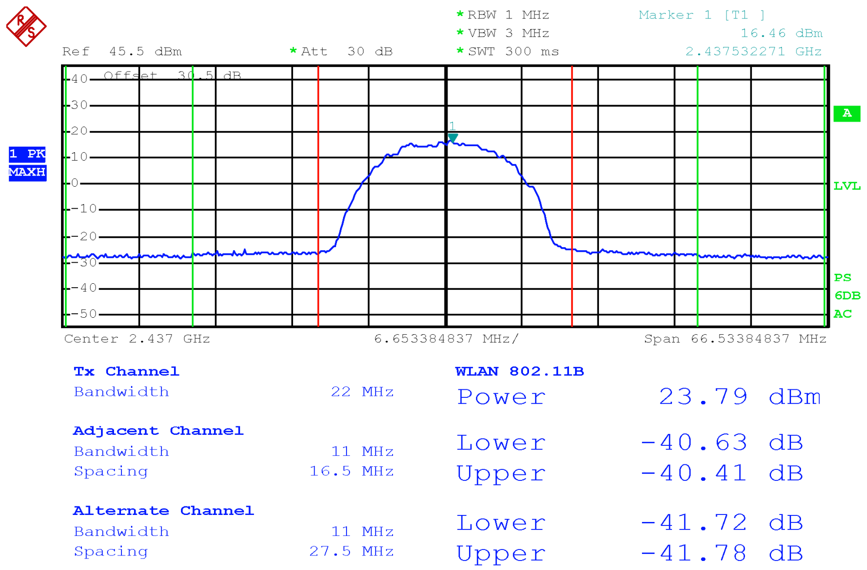

Figure 8.4-14: Output power of WiFi Modulation 802.11b, channel MID

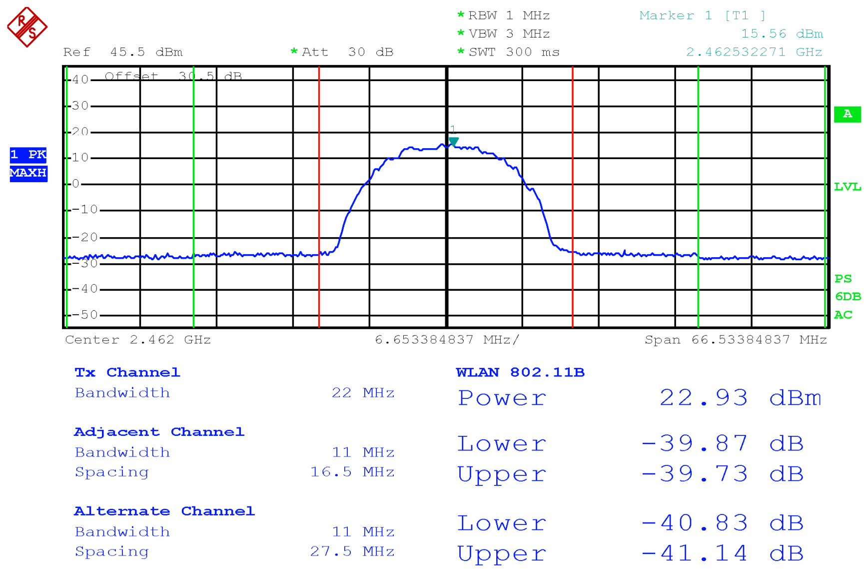

Figure 8.4-15: Output power of WiFi Modulation 802.11b, channel HIGH

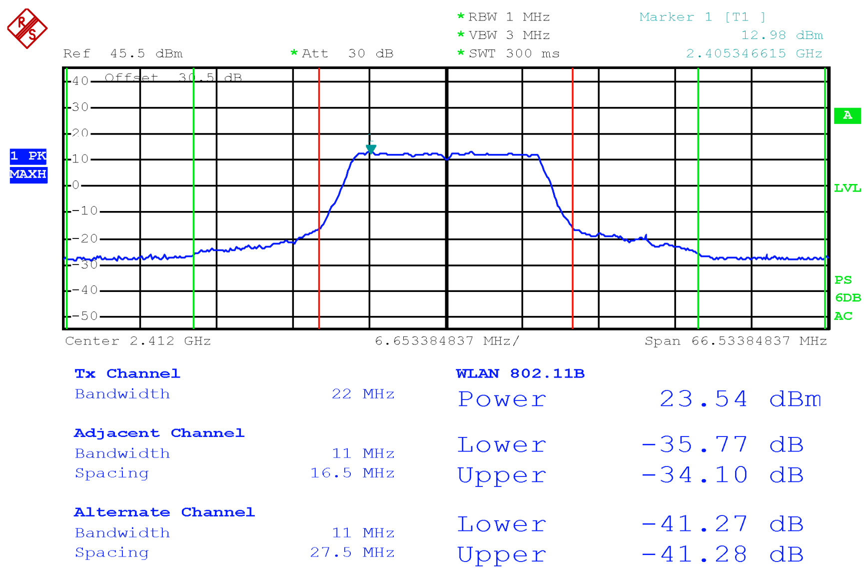

Figure 8.4-16: Output power of WiFi Modulation 802.11g, channel LOW

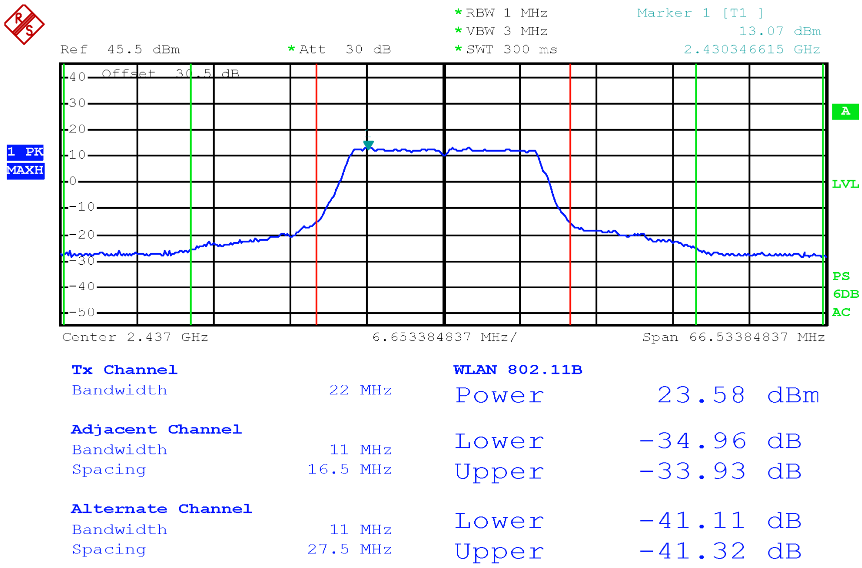

Figure 8.4-17: Output power of WiFi Modulation 802.11g, channel MID

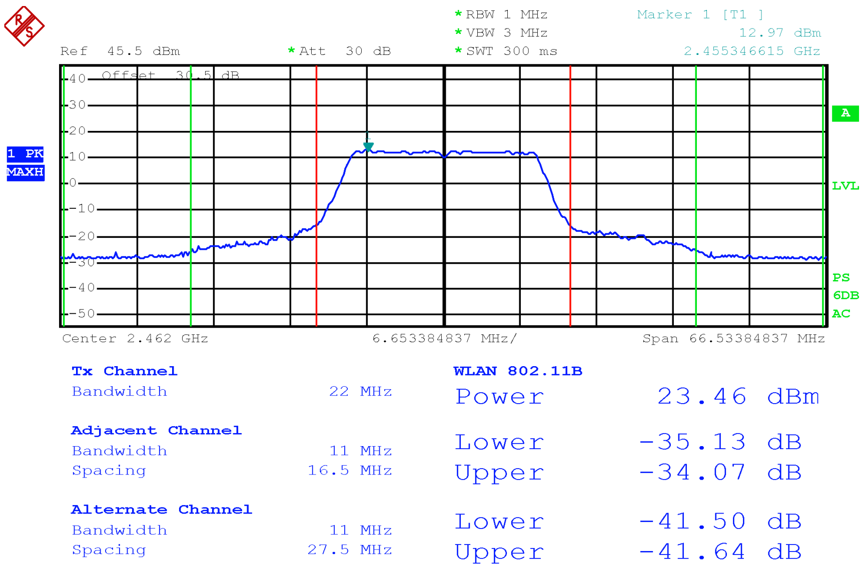

Figure 8.4-18: Output power of WiFi Modulation 802.11g, channel HIGH

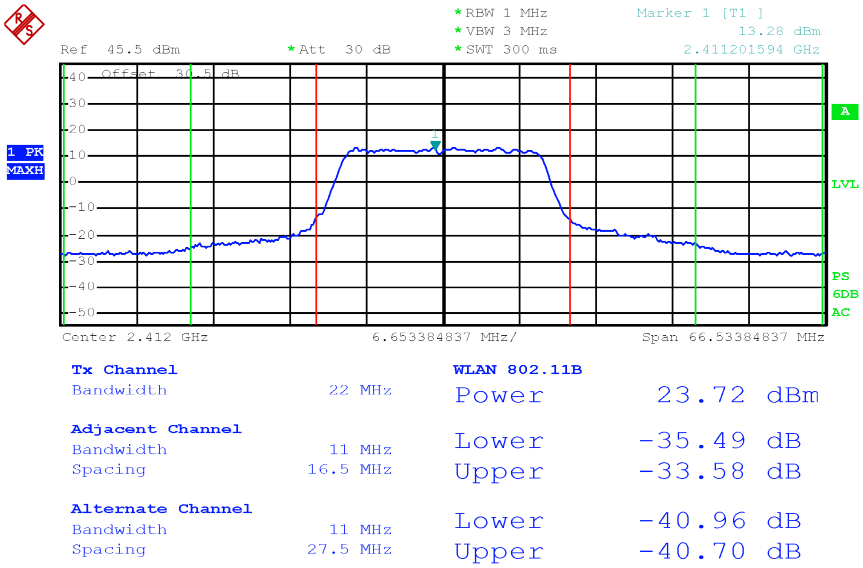

Figure 8.4-19: Output power of WiFi Modulation 802.11n (HT20), channel LOW

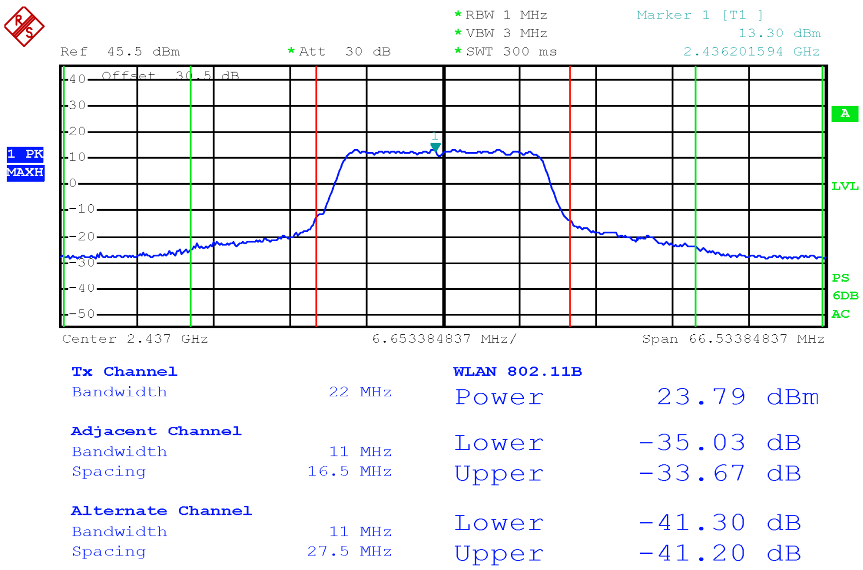

Figure 8.4-20: Output power of WiFi Modulation 802.11n (HT20), channel MID

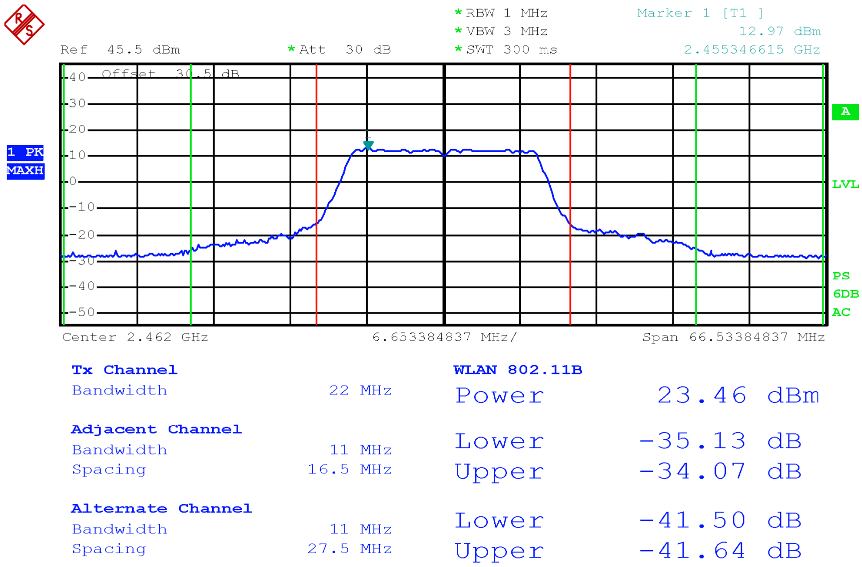

Figure 8.4-21: Output power of WiFi Modulation 802.11n (HT20), channel HIGH

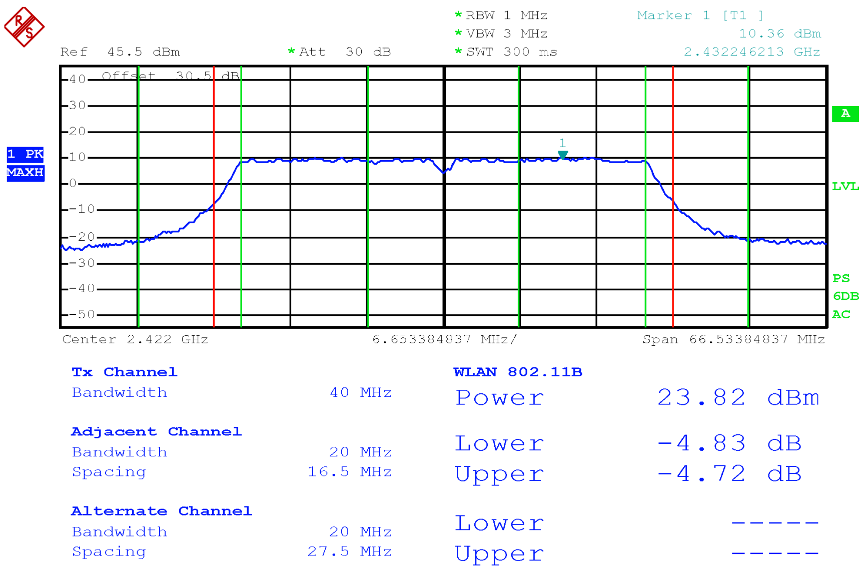

Figure 8.4-22: Output power of WiFi Modulation 802.11n (HT40), channel LOW

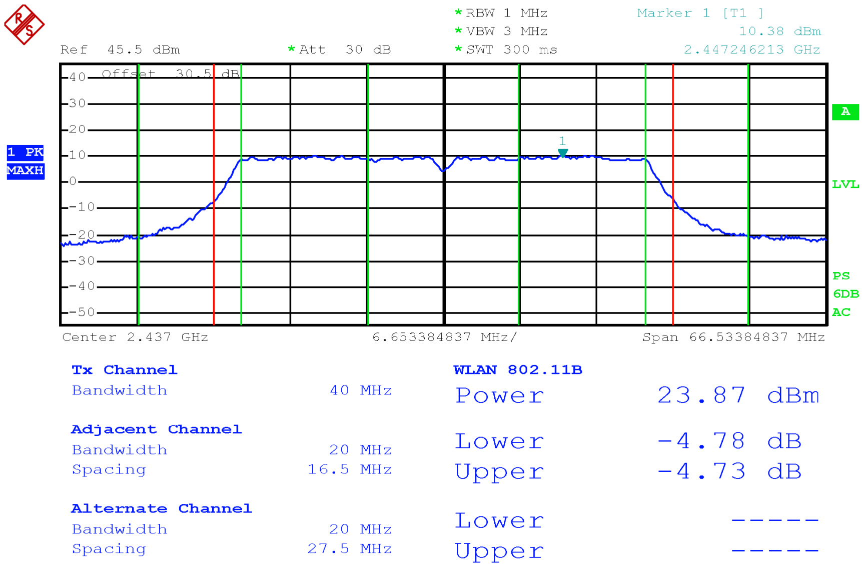

Figure 8.4-23: Output power of WiFi Modulation 802.11n (HT40), channel MID

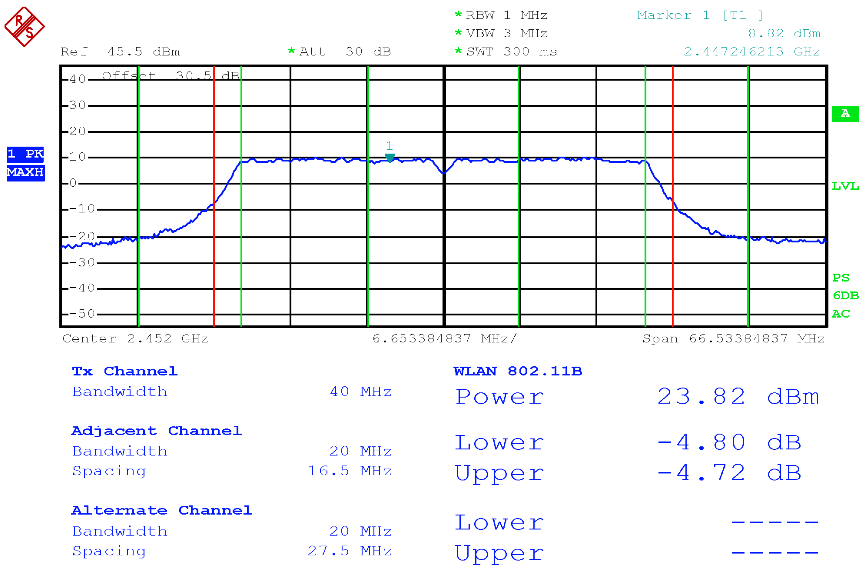

Figure 8.4-24: Output power of WiFi Modulation 802.11n (HT40), channel HIGH

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

8.5.1 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 8.5-1: *FCC §15.209– Radiated emission limits*

Frequency, MHz	Field strength of emissions µV/m	dBµV/m	Measurement distance, 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 8.5-2: *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			

8.5.1 Test date

Start date	December 14, 2020

8.5.2 Observations, settings and special notes

The spectrum was searched from 30 MHz to the 10th harmonic.
EUT was set to transmit with 100 % duty cycle. Radiated measurements were performed at distance of 3 m.
Since fundamental power was tested using peak method, the spurious emissions limit is −20 dBc/100 kHz.
Different antenna configurations and modulation schemes were investigated, only the worst case are presented

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 radiated measurements within restricted bands above 1 GHz:

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

1. Test equipment list

Table 8.5-3: *Equipment list*

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
EMI receiver (20 Hz ÷ 8 GHz)	Rohde & Schwarz	ESU8	100202	2020-08	2021-08
EMI receiver (20 Hz ÷ 8 GHz)	Rohde & Schwarz	ESW44	101620	2020-08	2021-08
Trilog Antenna (30 MHz ÷ 7 GHz)	Schwarzbeck	VULB 9162	9162-025	2018-07	2021-07
Bilog antenna (1 ÷ 18 GHz)	Schwarzbeck	STLP 9148	9148-123	2018-07	2021-07
Preamplifier (1 ÷ 18 GHz)	Schwarzbeck	BBV 9718	9718-137	2020-09	2021-09
Horn antenna (18 ÷ 40 GHz)	A.H. System	SAS-574	558	2020-01	2023-01
Preamplifier (18 ÷ 40 GHz)	SAGE	STB-1834034030-KFKF-L1	18490-01	2020-03	2021-03
Controller	Maturo	FCU3.0	10041	NCR	NCR
Tilt antenna mast	Maturo	TAM4.0-E	10042	NCR	NCR
Turntable	Maturo	TT4.0-5T	2.527	NCR	NCR
Semi-anechoic chamber	Nemko	10m semi-anechoic chamber	530	2019-09	2021-09
Shielded room	Siemens	10m control room	1947	NCR	NCR
Shielded room	Siemens	Conducted emission test room	1862	NCR	NCR

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

8.5.4 Test data

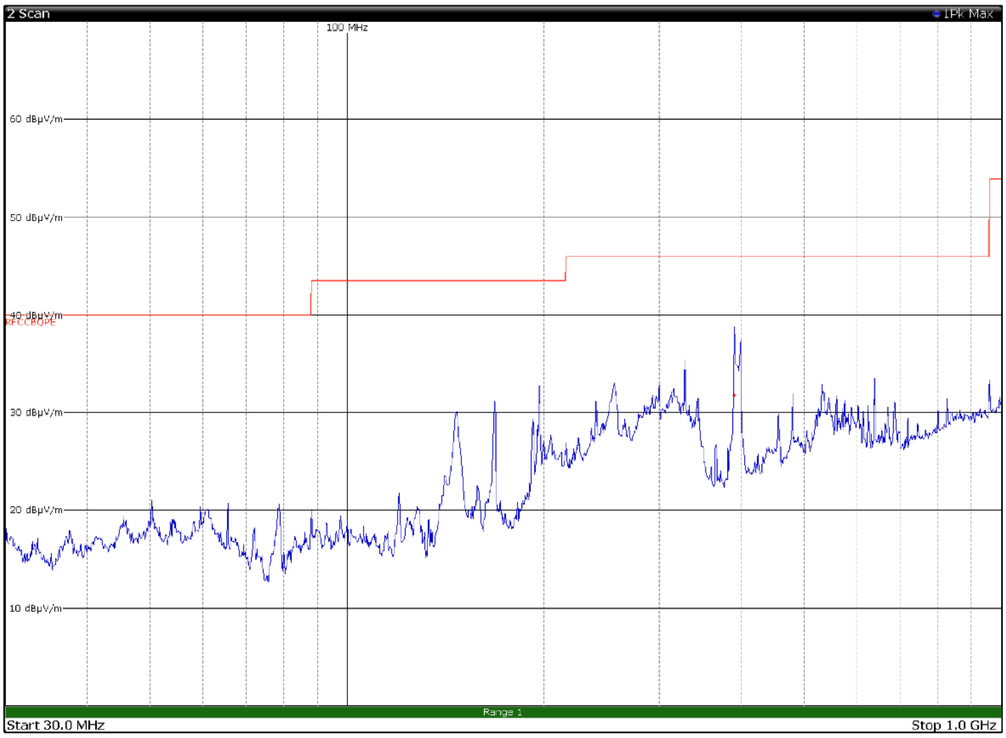

Figure 8.5-1: *Radiated spurious emissions 30 to 1000 MHz, Worst case BLE middle channel with antenna in horizontal polarization*

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
309.6300	32.1	46.0	-13.9	QP

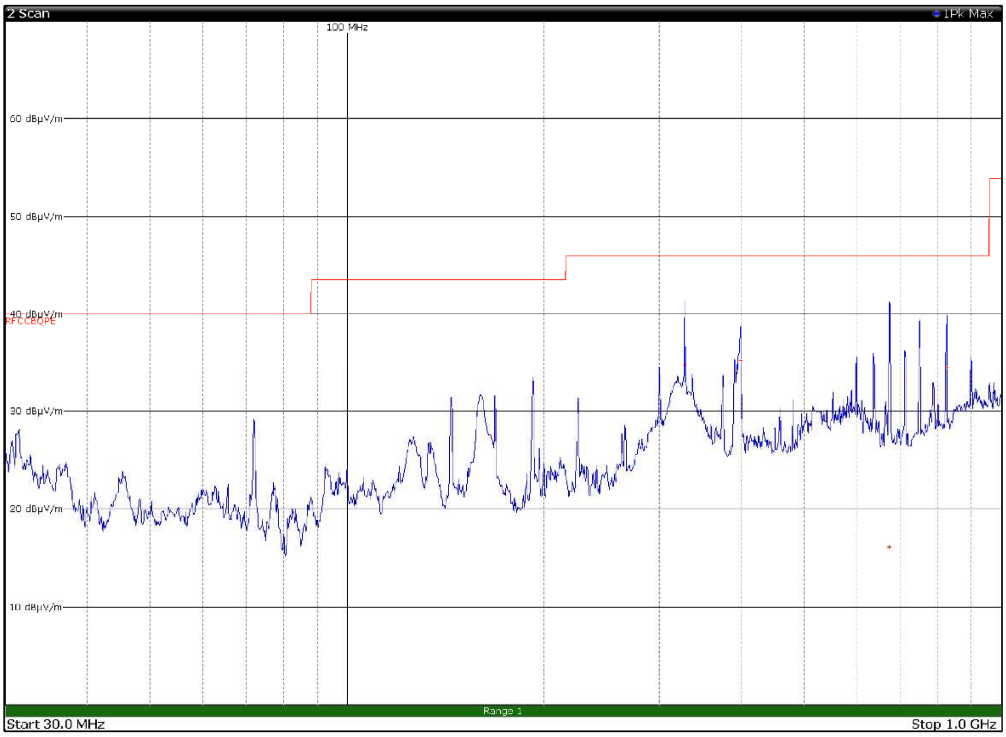

Figure 8.5-2: *Radiated spurious emissions 30 to 1000 MHz, Worst case BLE middle channel with antenna in vertical polarization*

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
328.0800	34.8	46.0	-11.2	QP
399.5400	35.2	46.0	-10.8	QP
674.2200	16.1	46.0	-29.9	QP
826.6800	34.5	46.0	-11.5	QP

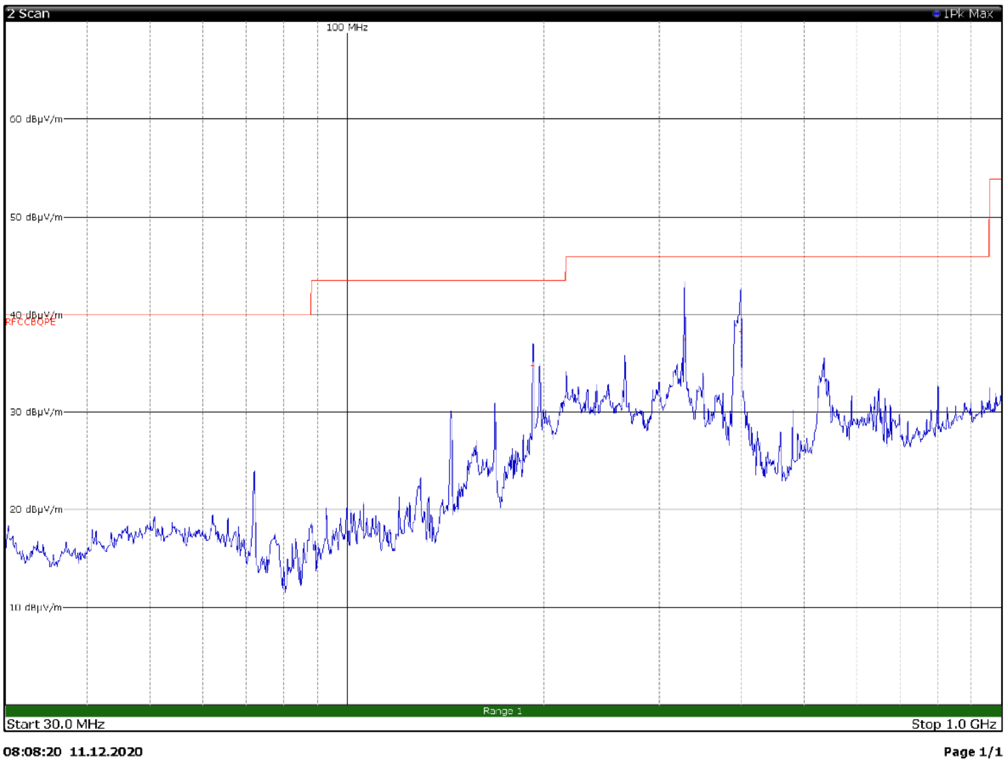

Figure 8.5-3: *Radiated spurious emissions 30 to 1000 MHz, Worst case BT high channel of 8DPSK Mode with antenna in horizontal polarization*

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
192.1800	34.8	43.5	-8.7	QP
328.2300	37.5	46.0	-8.5	QP
399.6000	38.3	46.0	-7.7	QP

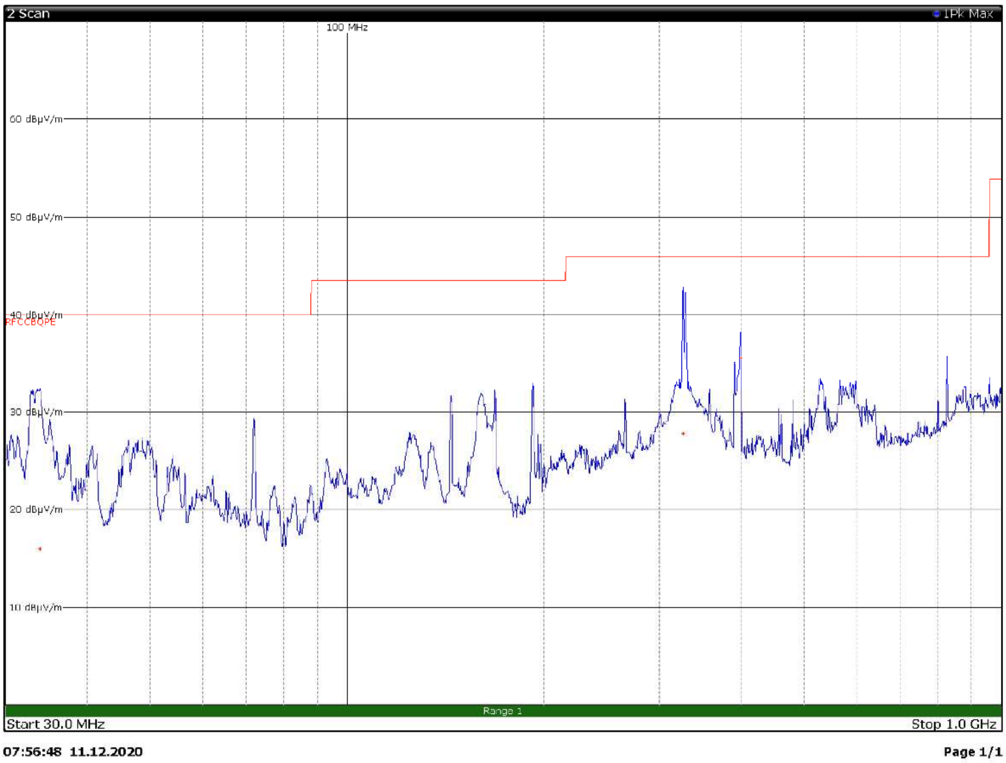

Figure 8.5-4: *Radiated spurious emissions 30 to 1000 MHz, Worst case BT high channel of 8DPSK Mode with antenna in vertical polarization*

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
33.8700	16.0	40.0	-24.0	QP
326.0400	27.8	46.0	-18.2	QP
399.5700	35.7	46.0	-10.3	QP

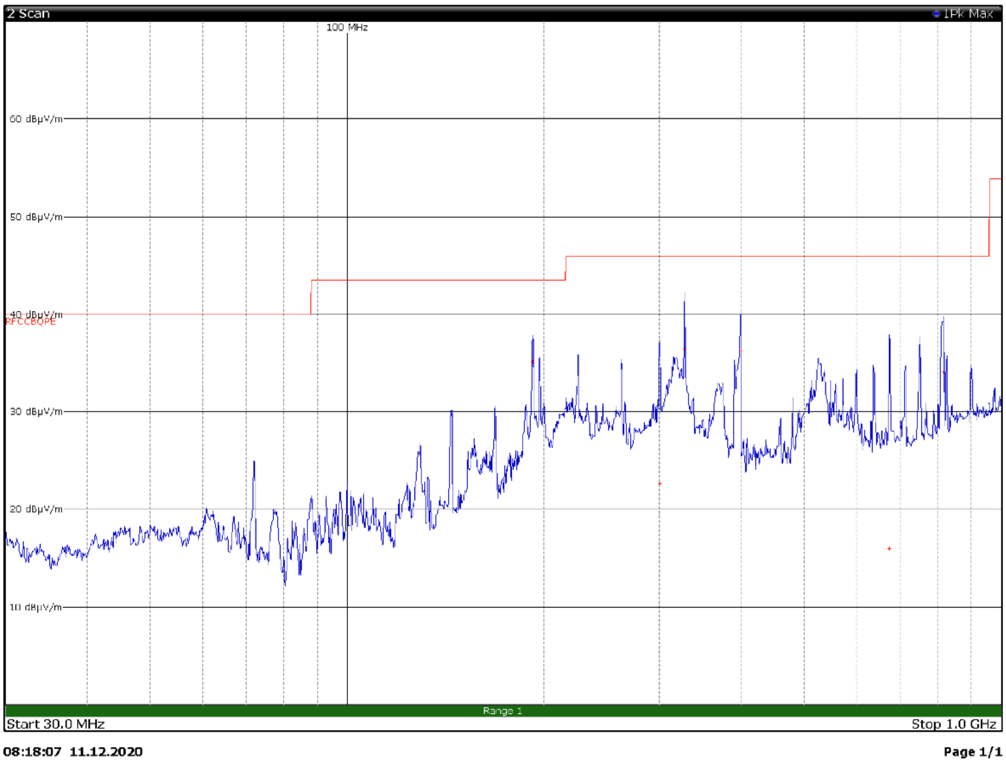

Figure 8.5-5: *Radiated spurious emissions 30 to 1000 MHz, Worst case WiFi middle channel of 802.11b mode with antenna in horizontal polarization*

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
192.1500	35.2	43.5	-8.3	QP
300.8100	22.7	46.0	-23.3	QP
328.1700	36.5	46.0	-9.5	QP
399.5400	36.4	46.0	-9.6	QP
674.1900	16.0	46.0	-30.0	QP
815.3400	34.1	46.0	-11.9	QP

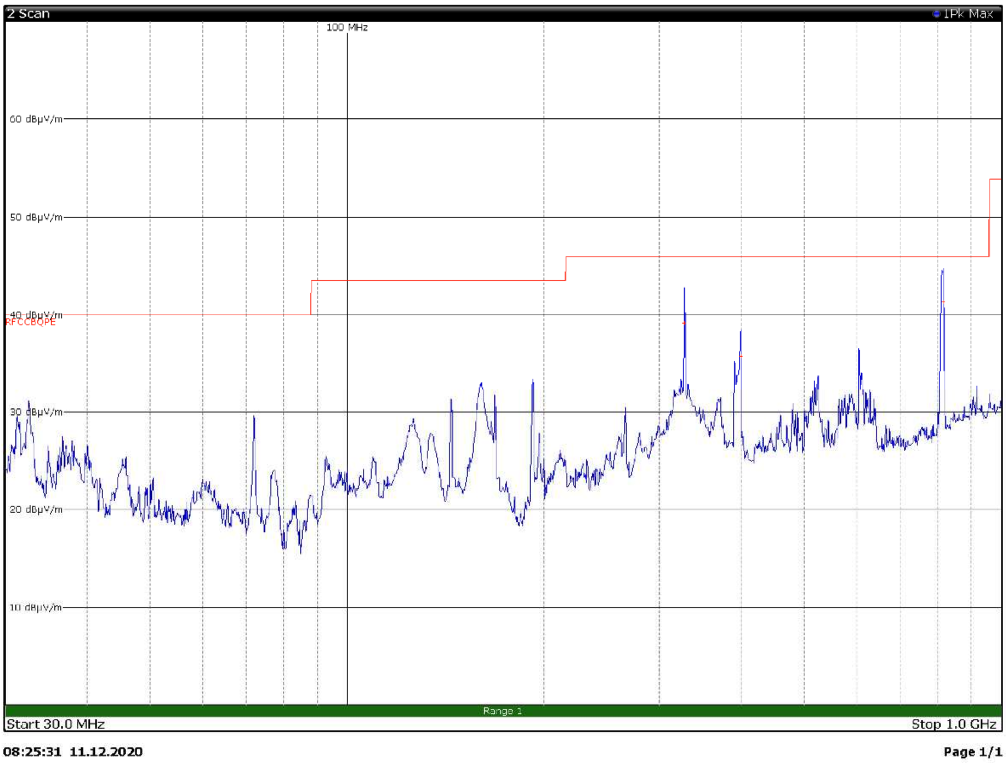

Figure 8.5-6: *Radiated spurious emissions 30 to 1000 MHz, Worst case WiFi middle channel of 802.11b mode with antenna in vertical polarization*

Frequency (MHz)	Level (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Detector
327.6300	39.2	46.0	-6.8	QP
399.5400	35.8	46.0	-10.2	QP
815.3400	41.3	46.0	-4.7	QP

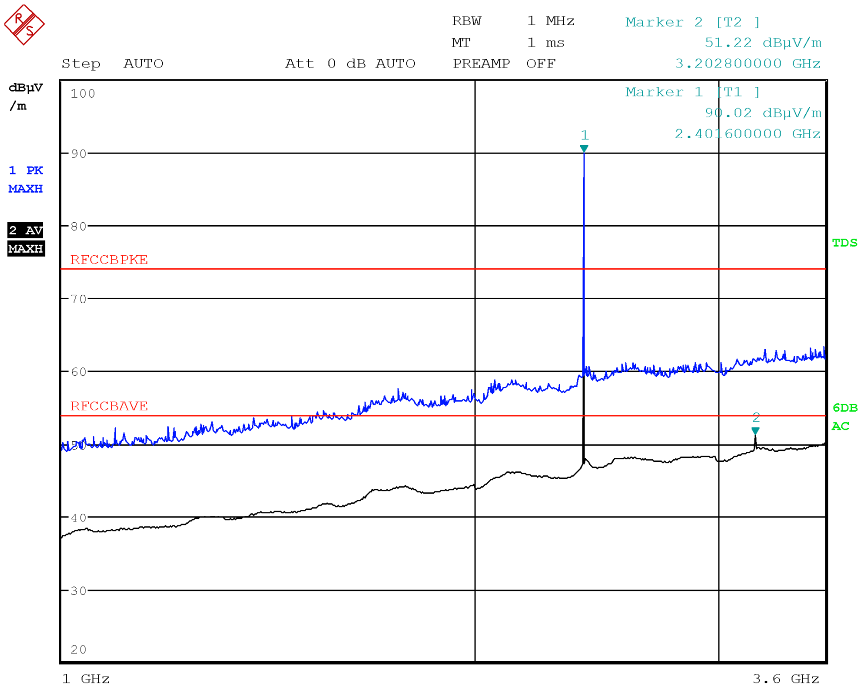

Figure 8.5-7: *Radiated spurious emissions 1 to 3.6 GHz, Worst case BT modulation 8DPSK low channel with antenna in horizontal polarization*

Limit exceeded by the carrier

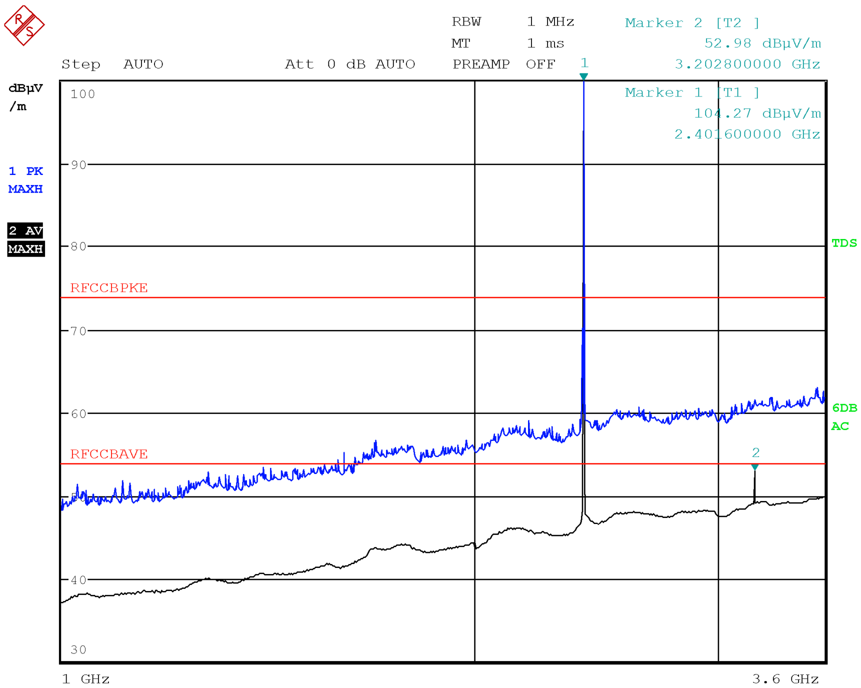

Figure 8.5-8: *Radiated spurious emissions 1 to 3.6 GHz, Worst case BT modulation 8DPSK low channel with antenna in vertical polarization*

Limit exceeded by the carrier

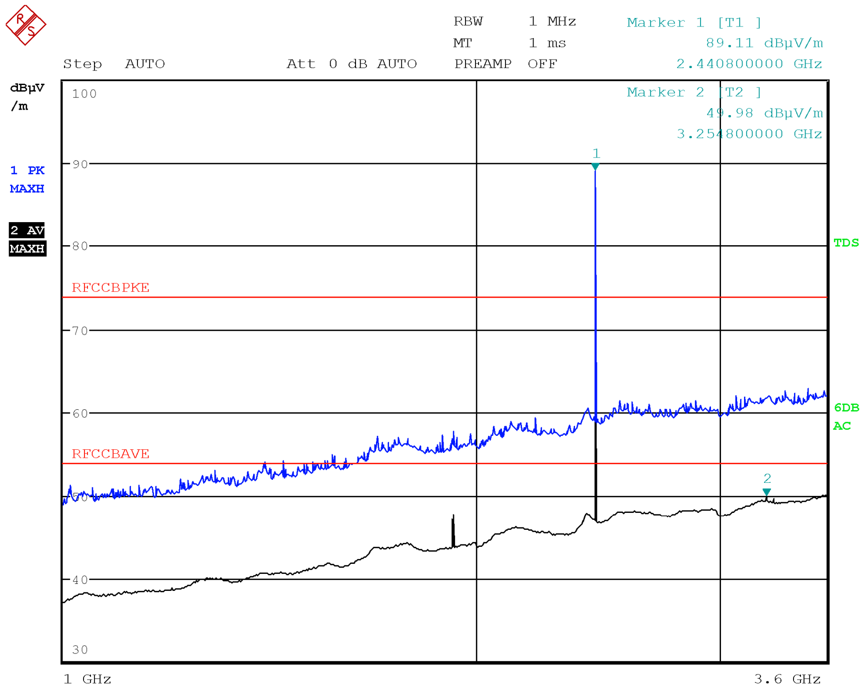

Figure 8.5-9: *Radiated spurious emissions 1 to 3.6 GHz, Worst case BT modulation 8DPSK mid channel with antenna in horizontal polarization*

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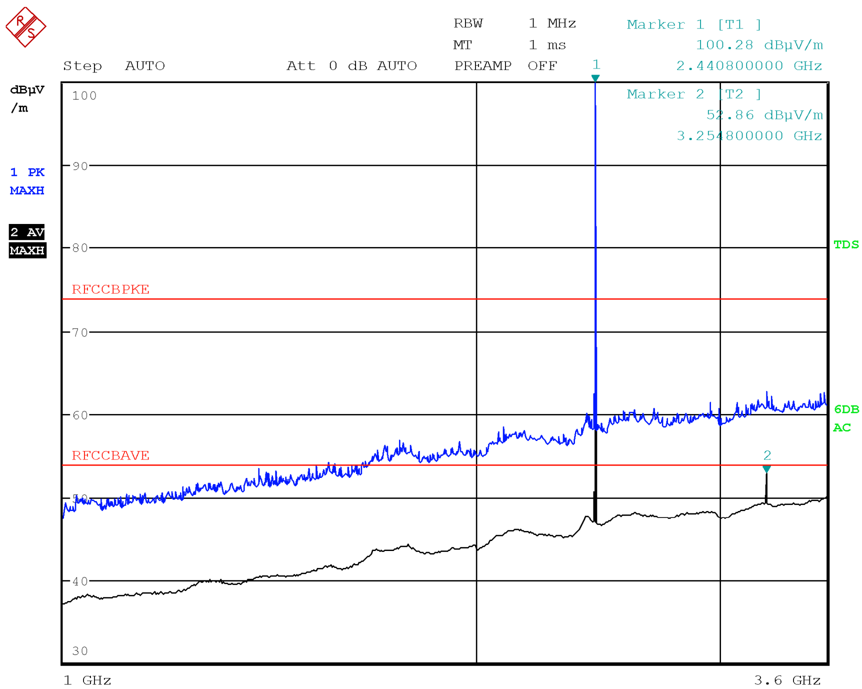

Figure 8.5-10: *Radiated spurious emissions 1 to 3.6 GHz, Worst case BT modulation 8DPSK mid channel with antenna in vertical polarization*

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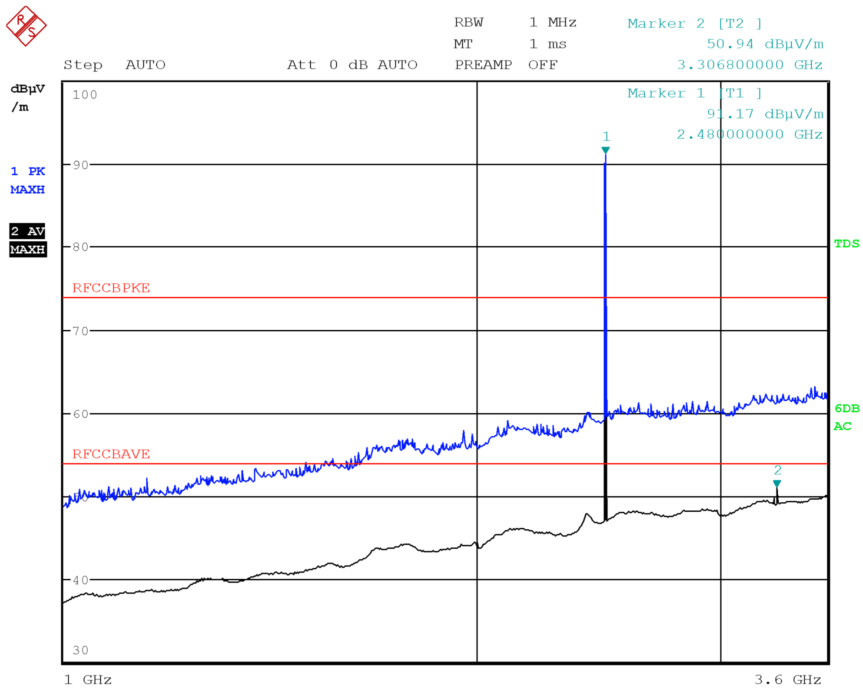

Figure 8.5-11: *Radiated spurious emissions 1 to 3.6 GHz, Worst case BT modulation 8DPSK high channel with antenna in horizontal polarization*

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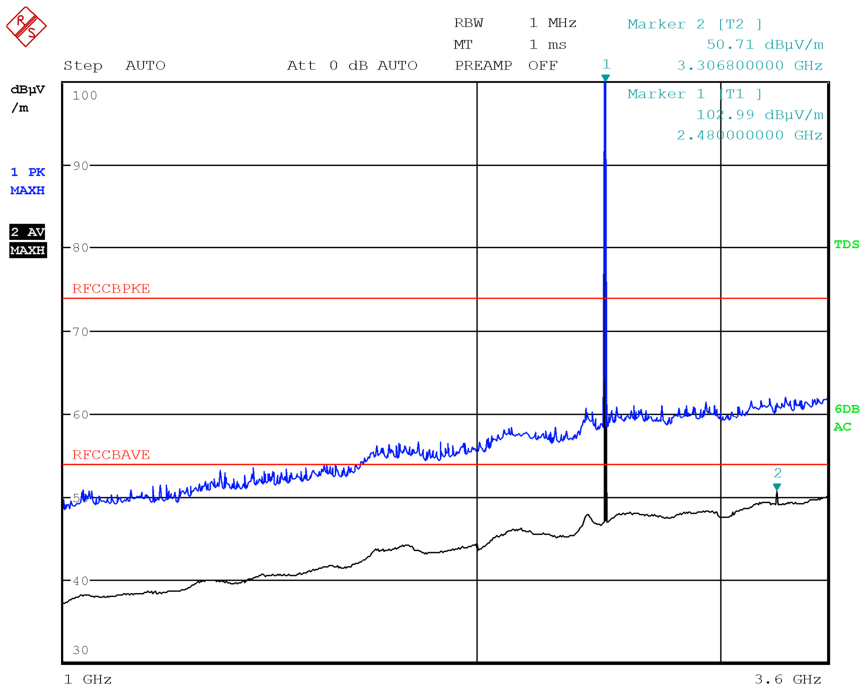

Figure 8.5-12: *Radiated spurious emissions 1 to 3.6 GHz, Worst case BT modulation 8DPSK high channel with antenna in vertical polarization*

Limit exceeded by the carrier

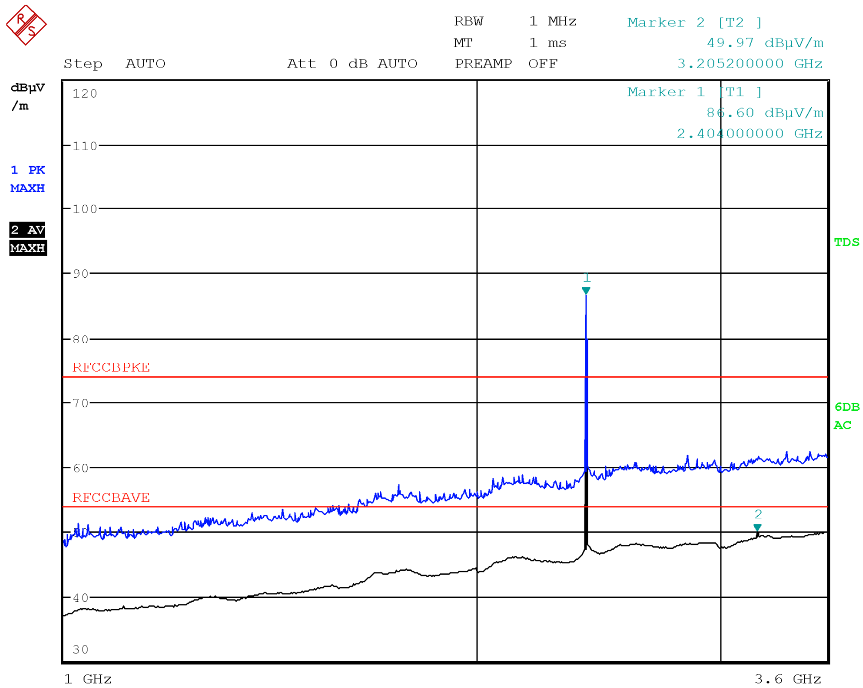

Figure 8.5-13: *Radiated spurious emissions 1 to 3.6 GHz, Low channel BLE with antenna in horizontal polarization*

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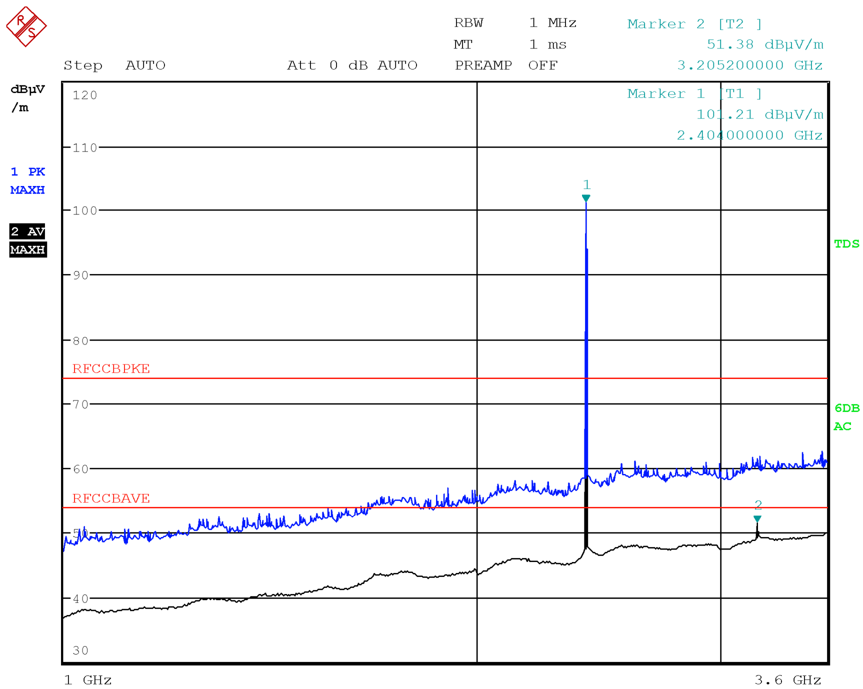

Figure 8.5-14: *Radiated spurious emissions 1 to 3.6 GHz, Low channel BLE with antenna in vertical polarization*

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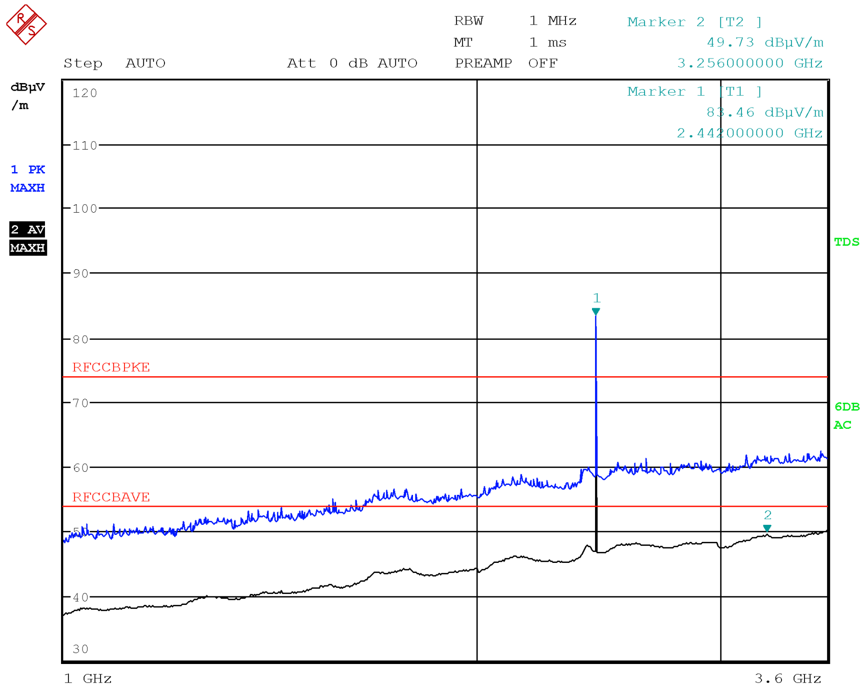

Figure 8.5-15: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel BLE with antenna in horizontal polarization*

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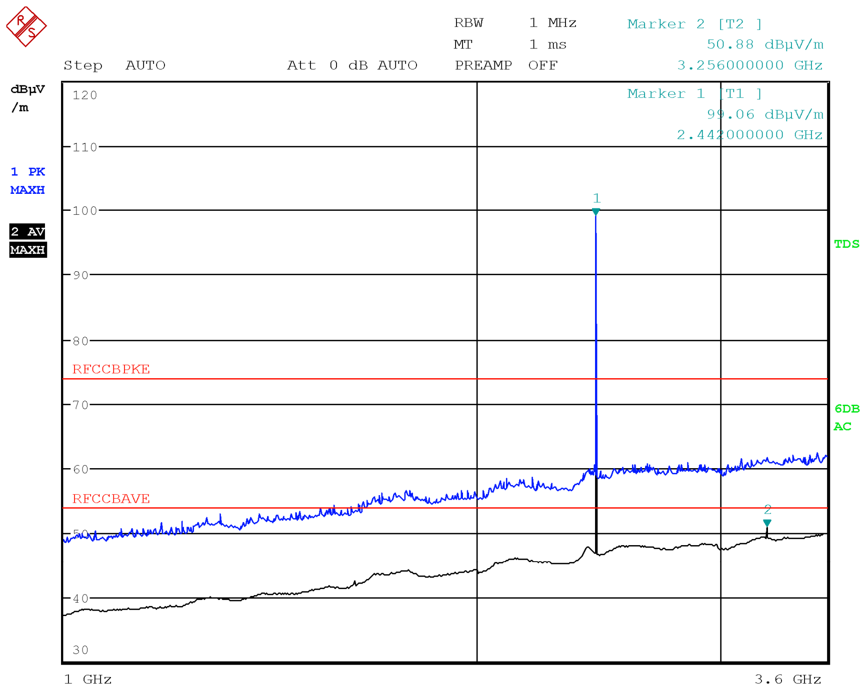

Figure 8.5-16: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel BLE with antenna in vertical polarization*

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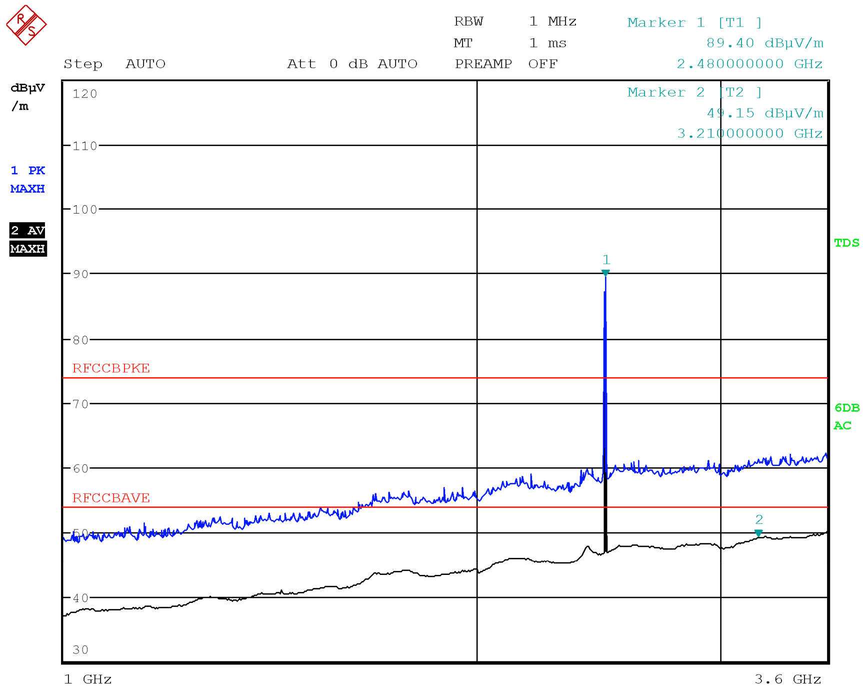

Figure 8.5-17: *Radiated spurious emissions 1 to 3.6 GHz, High channel BLE with antenna in horizontal polarization*

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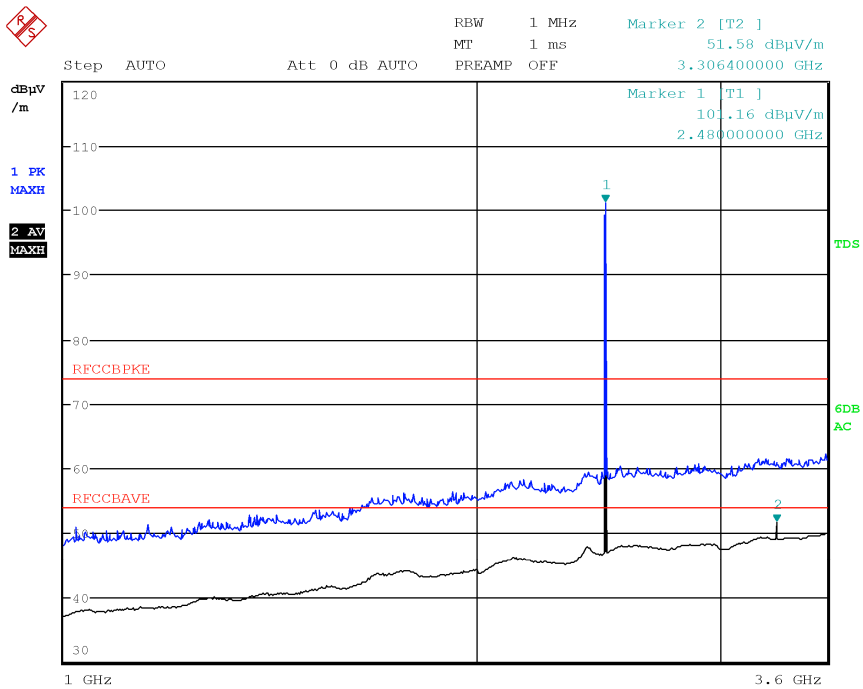

Figure 8.5-18: *Radiated spurious emissions 1 to 3.6 GHz, High channel BLE with antenna in vertical polarization*

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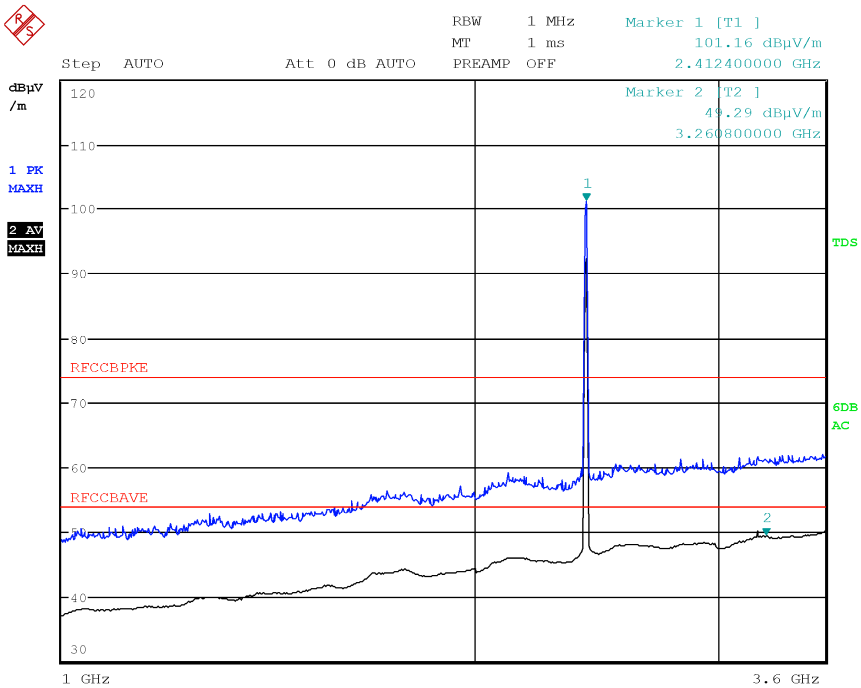

Figure 8.5-19: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11b with antenna in horizontal polarization*

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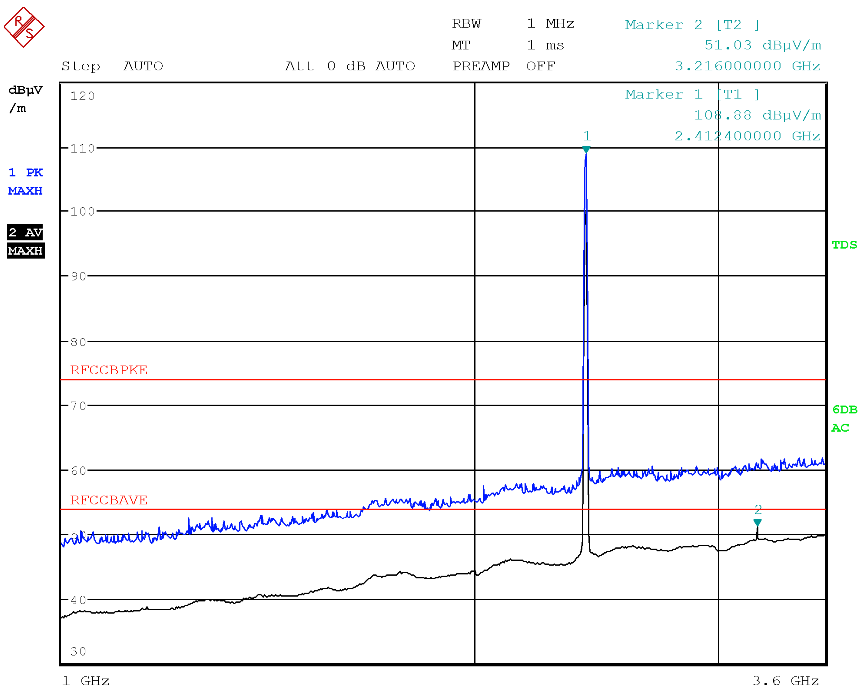

Figure 8.5-20: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11b with antenna in vertical polarization*

Limit exceeded by the carrier

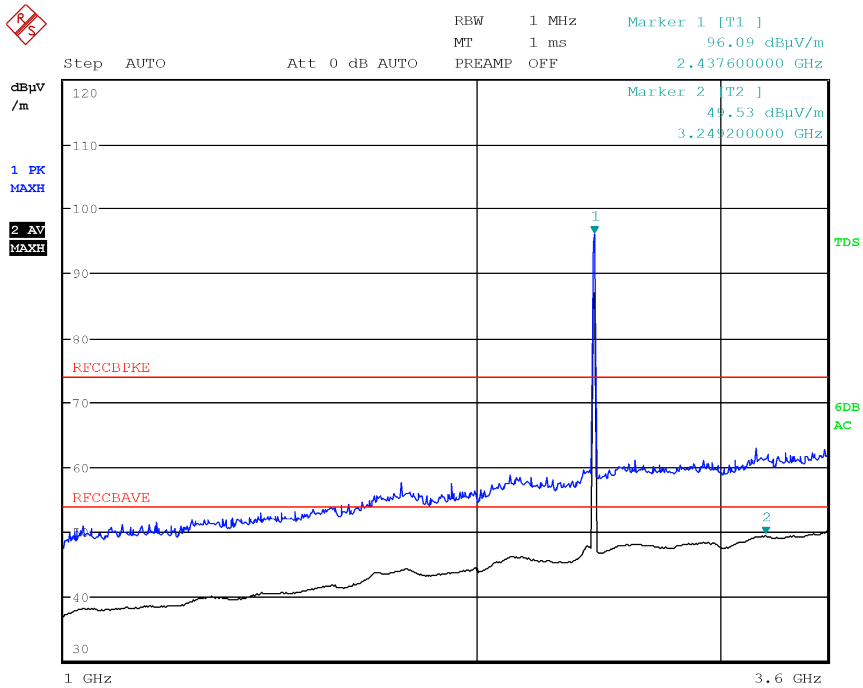

Figure 8.5-21: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11b with antenna in horizontal polarization*

Limit exceeded by the carrier

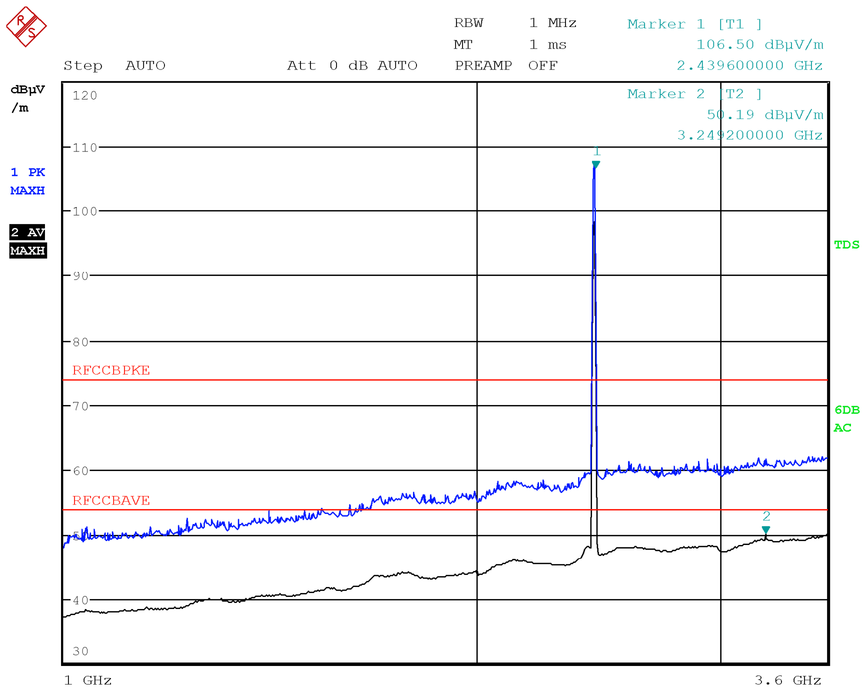

Figure 8.5-22: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11b with antenna in vertical polarization*

Limit exceeded by the carrier

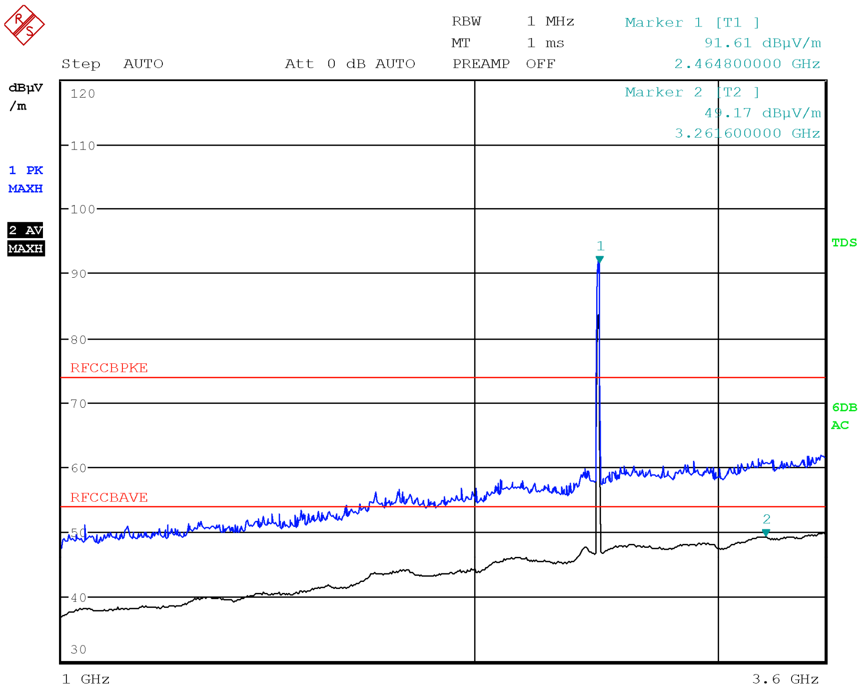

Figure 8.5-23: *Radiated spurious emissions 1 to 3.6 GHz, High channel WIFi modulation 802.11b with antenna in horizontal polarization*

Limit exceeded by the carrier

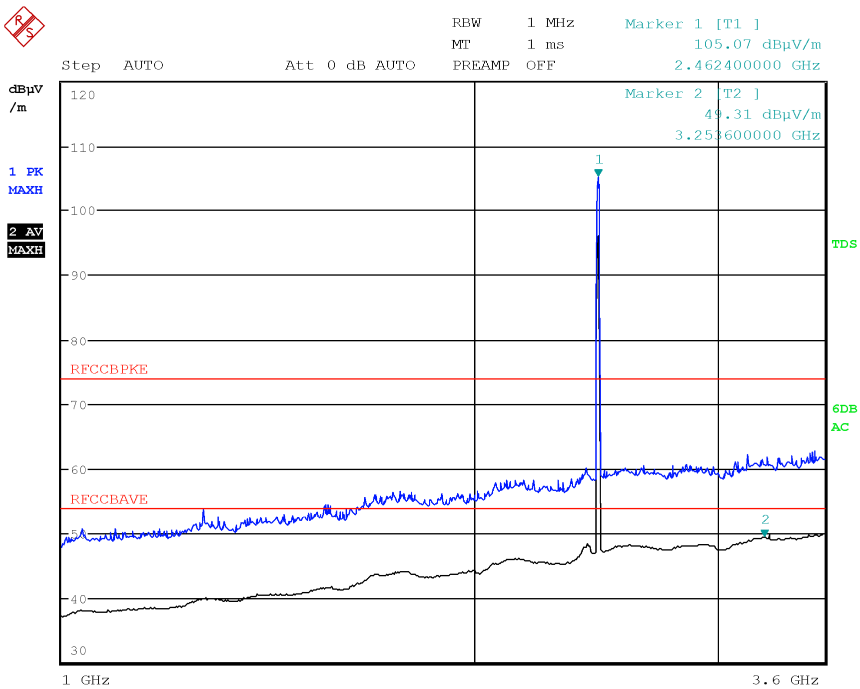

Figure 8.5-24: *Radiated spurious emissions 1 to 3.6 GHz, High channel WIFi modulation 802.11b with antenna in vertical polarization*

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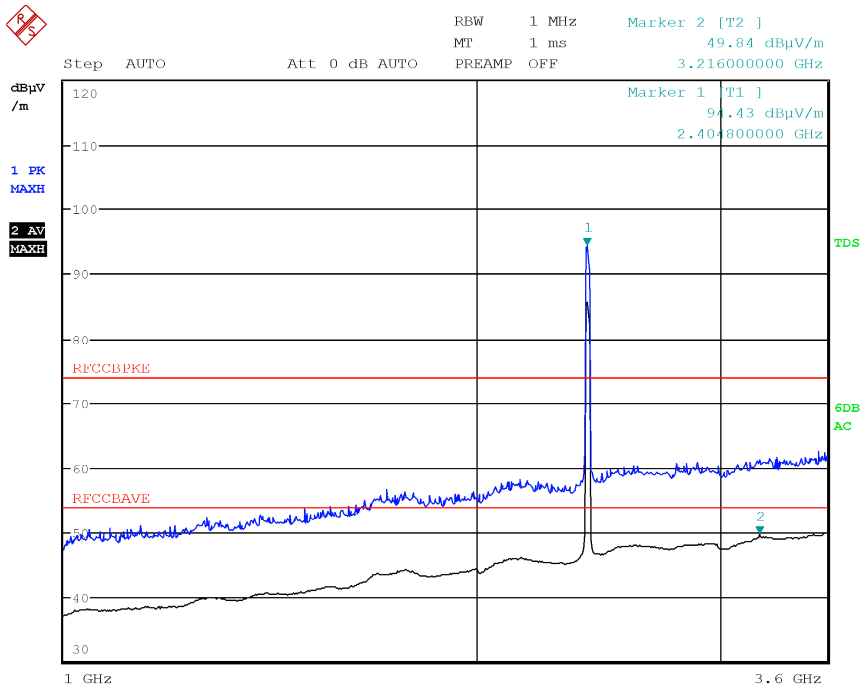

Figure 8.5-25: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11g with antenna in horizontal polarization*

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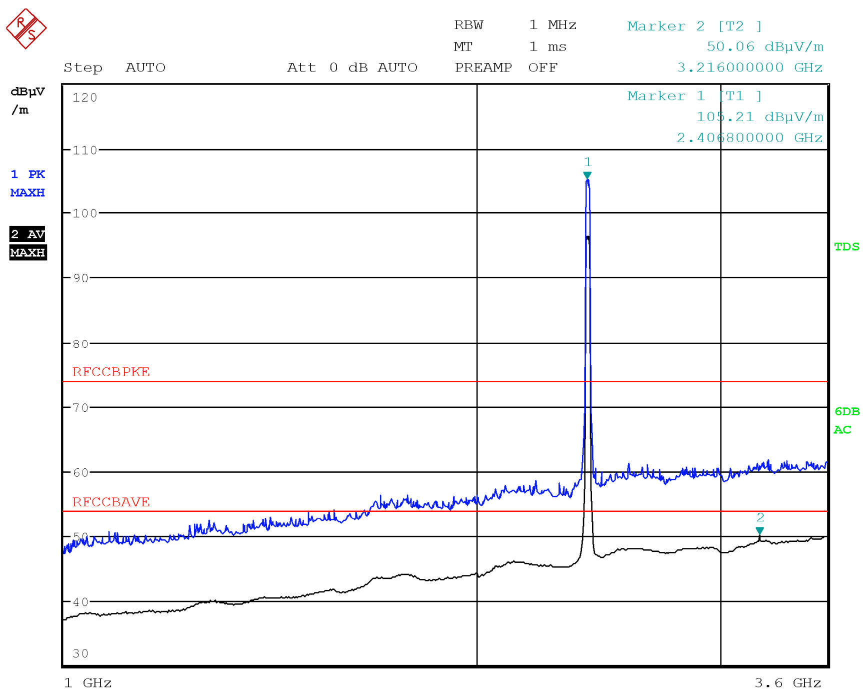

Figure 8.5-26: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11g with antenna in vertical polarization*

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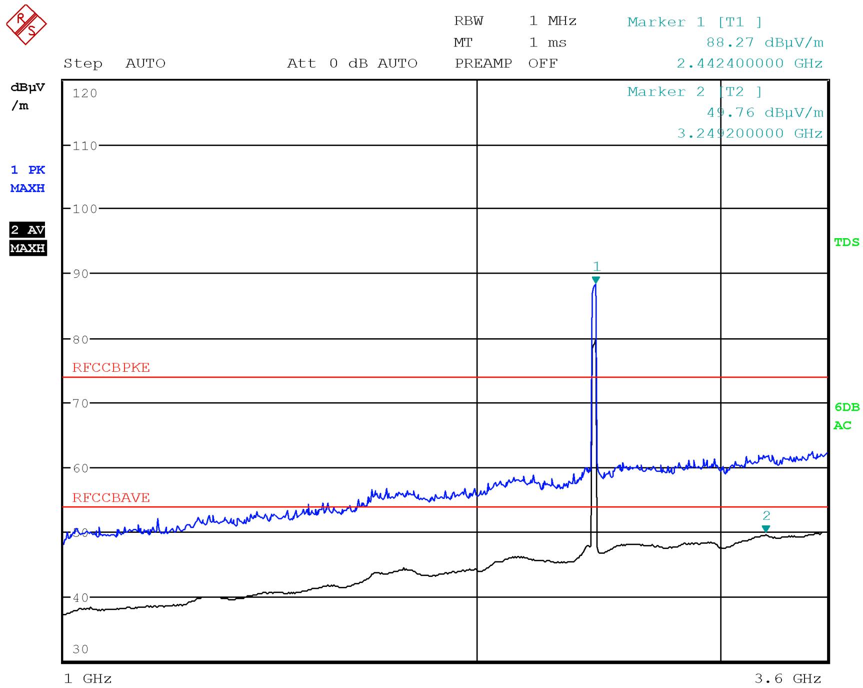

Figure 8.5-27: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11g with antenna in horizontal polarization*

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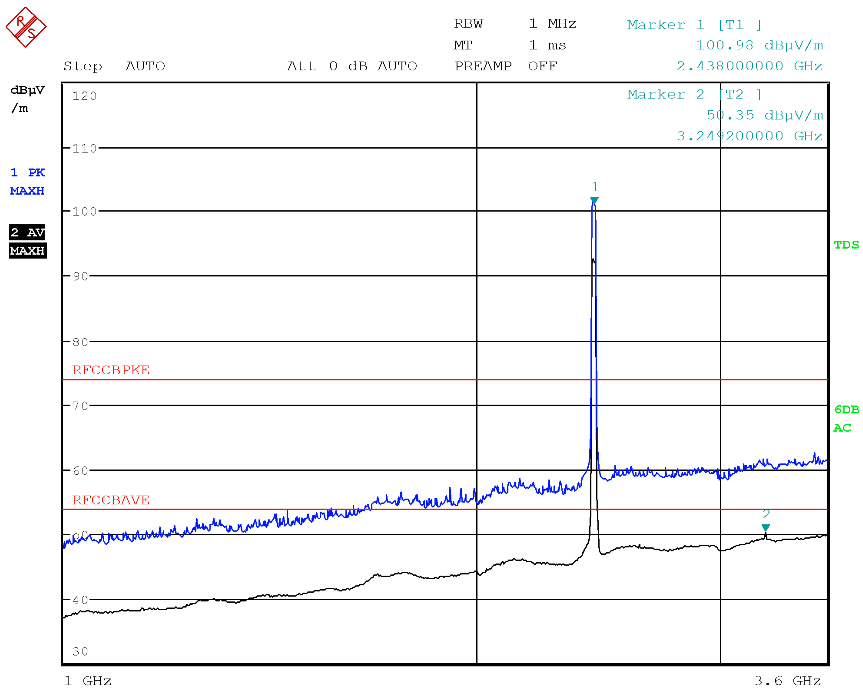

Figure 8.5-28: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11g with antenna in vertical polarization*

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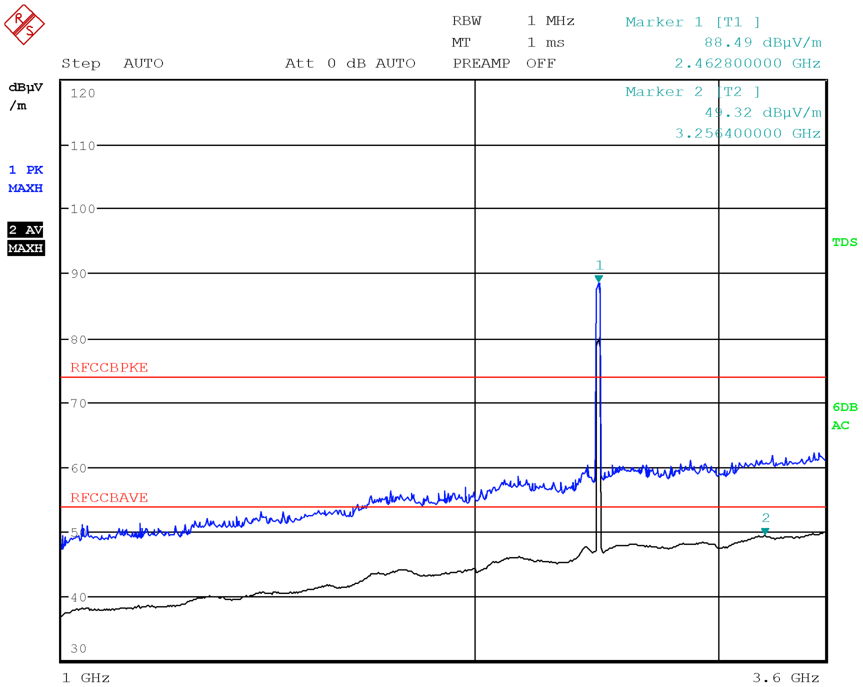

Figure 8.5-29: *Radiated spurious emissions 1 to 3.6 GHz, High channel WIFi modulation 802.11g with antenna in horizontal polarization*

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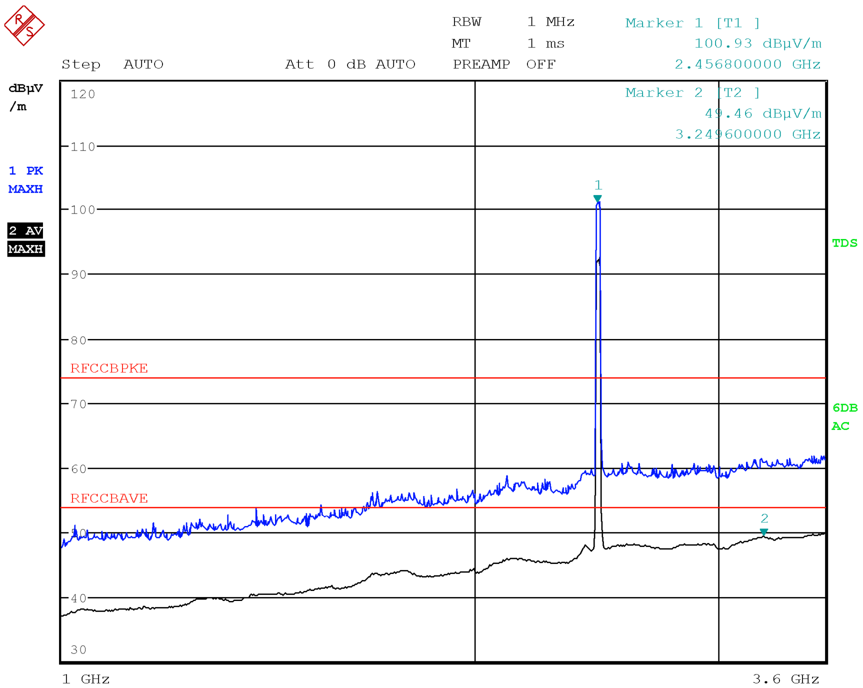

Figure 8.5-30: *Radiated spurious emissions 1 to 3.6 GHz, High channel WIFi modulation 802.11g with antenna in vertical polarization*

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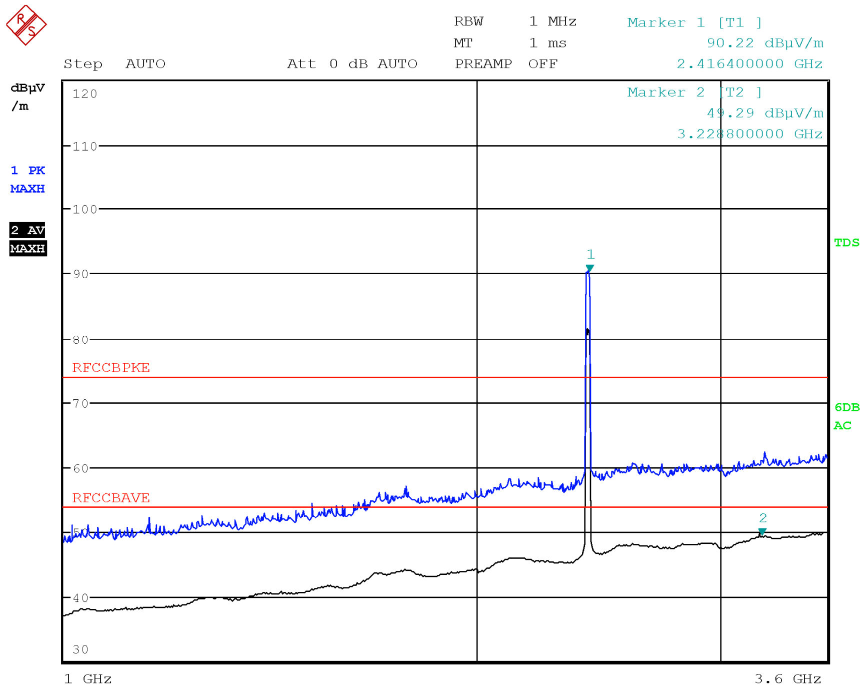

Figure 8.5-31: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11n(HT20) with antenna in horizontal polarization*

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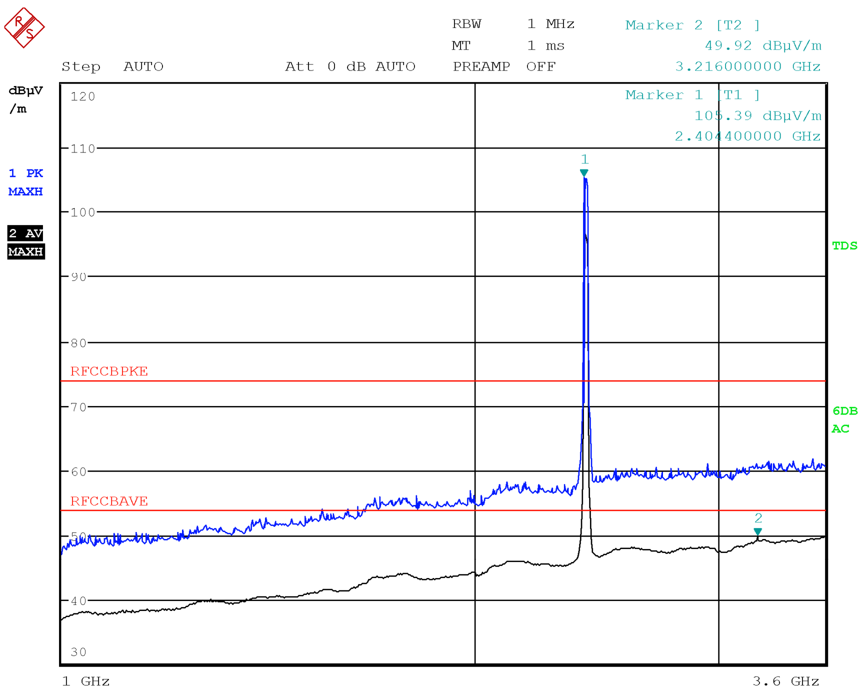

Figure 8.5-32: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11 n(HT20) with antenna in vertical polarization*

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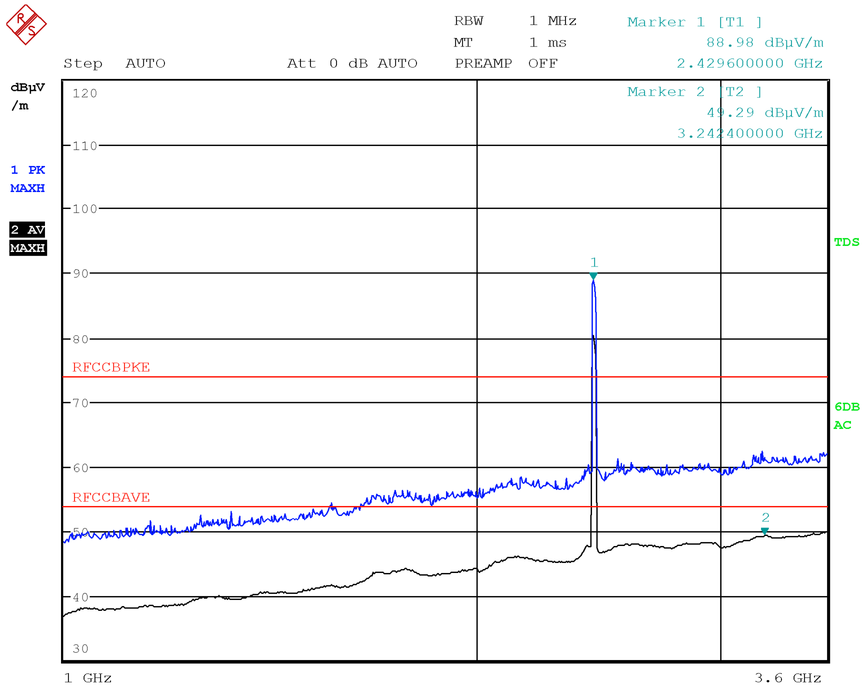

Figure 8.5-33: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11 n(HT20) with antenna in horizontal polarization*

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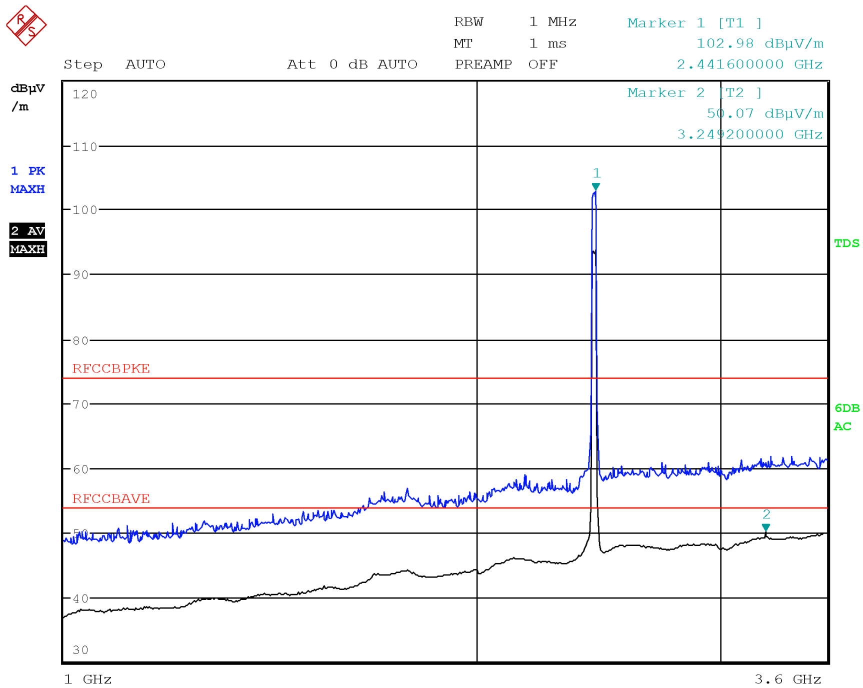

Figure 8.5-34: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11 n(HT20) with antenna in vertical polarization*

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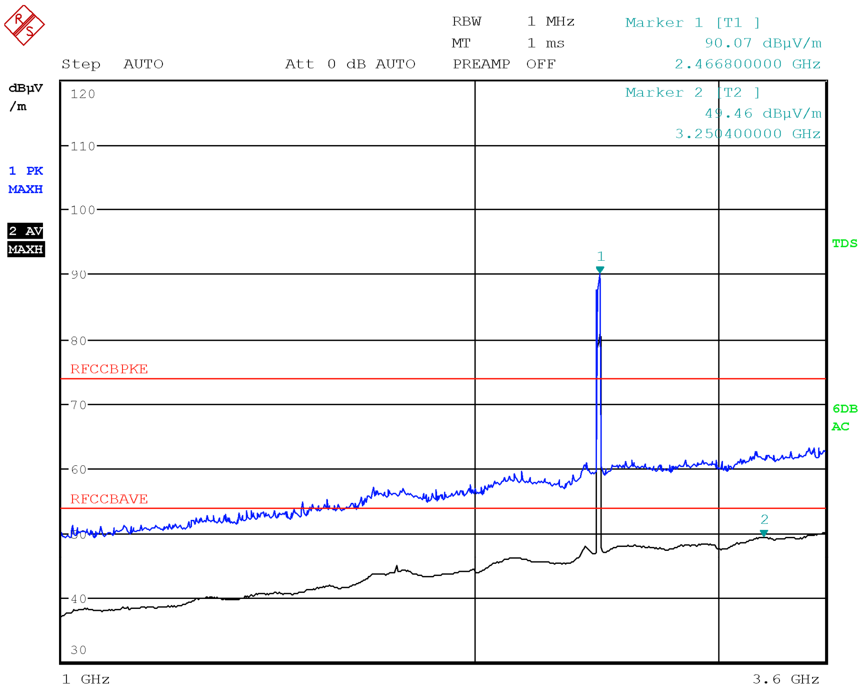

Figure 8.5-35: *Radiated spurious emissions 1 to 3.6 GHz, High channel WIFi modulation 802.11 n(HT20) with antenna in horizontal polarization*

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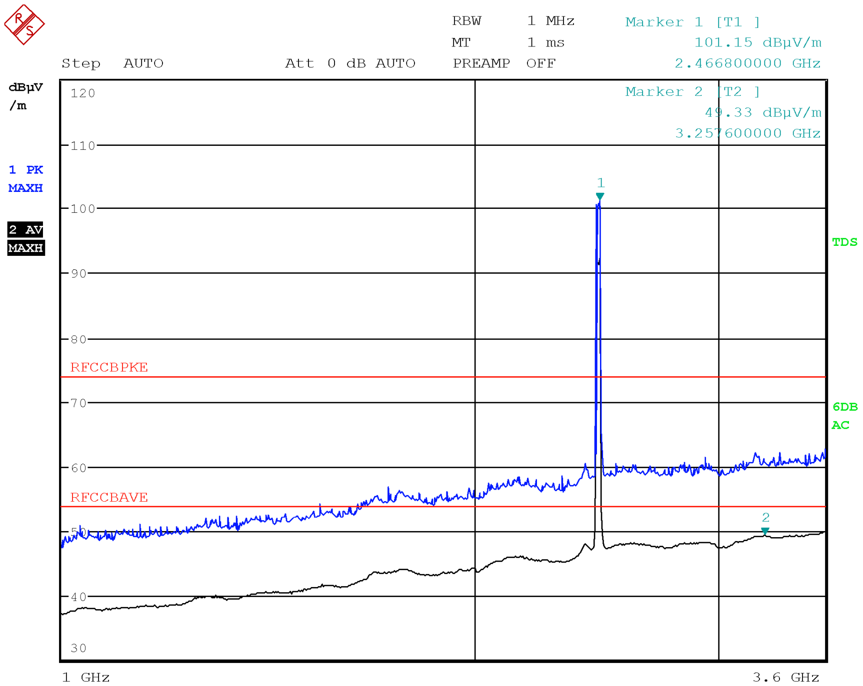

Figure 8.5-36: *Radiated spurious emissions 1 to 3.6 GHz, High channel WIFi modulation 802.11 n(HT20) with antenna in vertical polarization*

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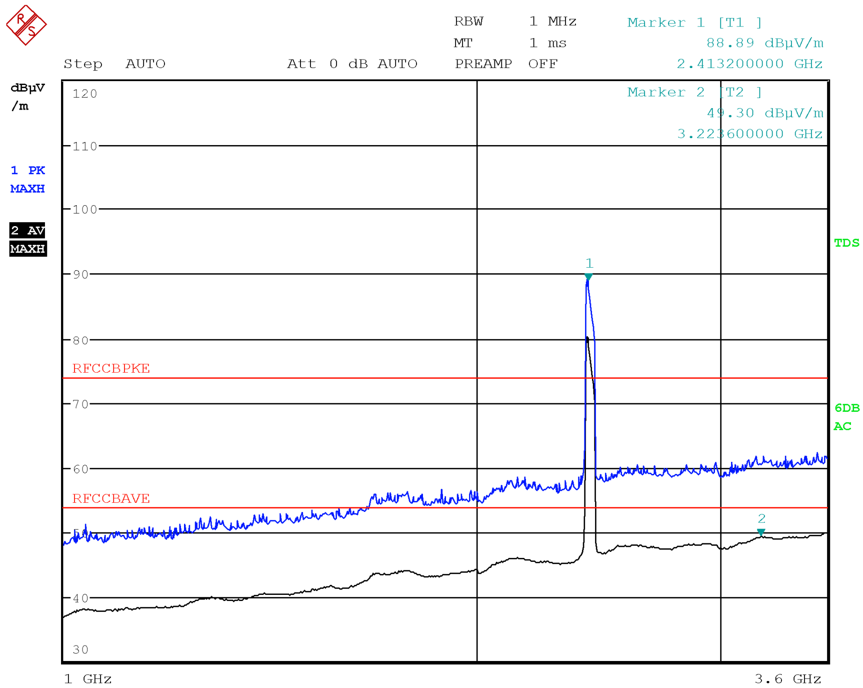

Figure 8.5-37: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11 n(HT40) with antenna in horizontal polarization*

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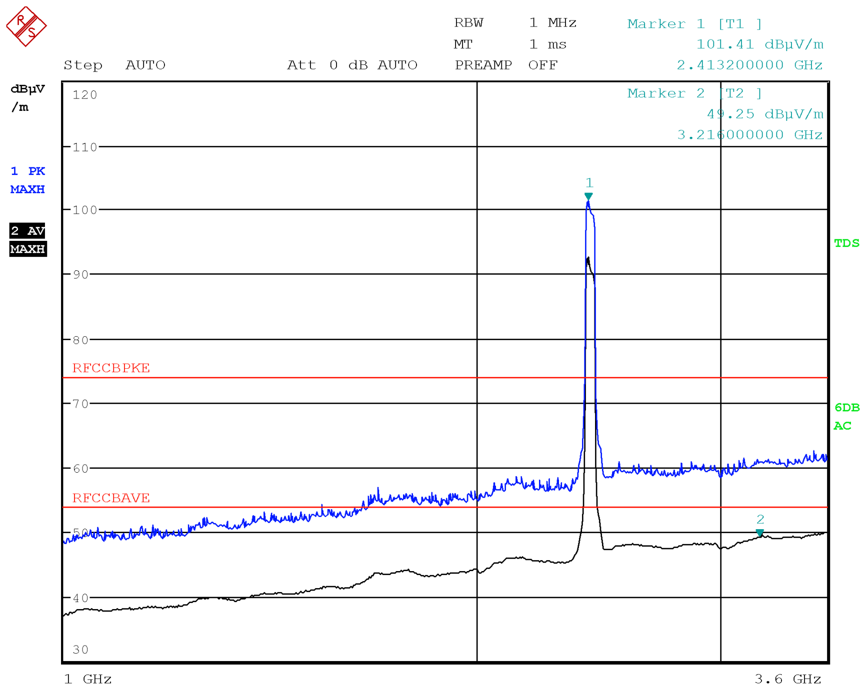

Figure 8.5-38: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11 n(HT40) with antenna in vertical polarization*

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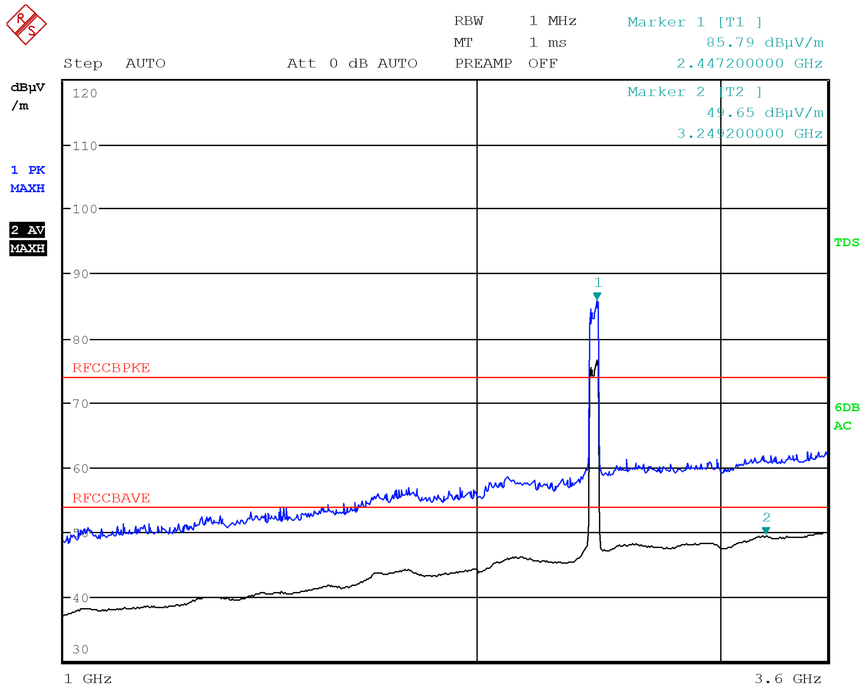

Figure 8.5-39: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11 n(HT40) with antenna in horizontal polarization*

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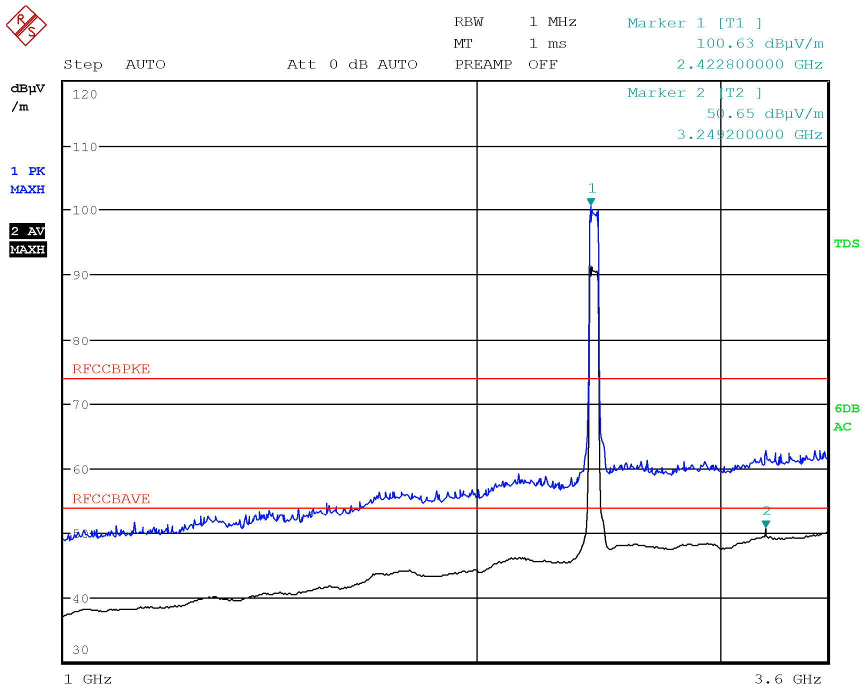

Figure 8.5-40: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11 n(HT40) with antenna in vertical polarization*

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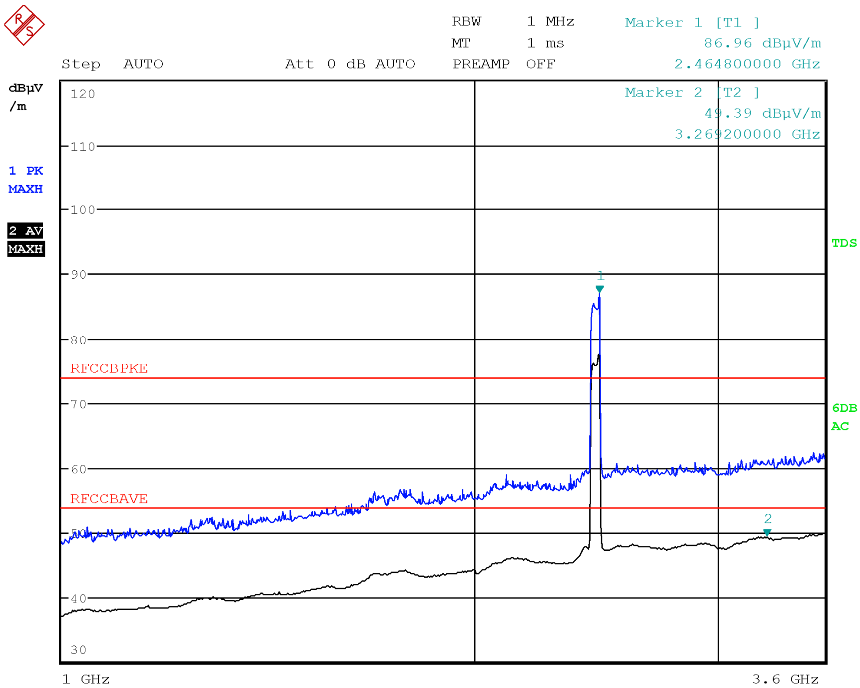

Figure 8.5-41: *Radiated spurious emissions 1 to 3.6 GHz, High channel WIFi modulation 802.11 n(HT40) with antenna in horizontal polarization*

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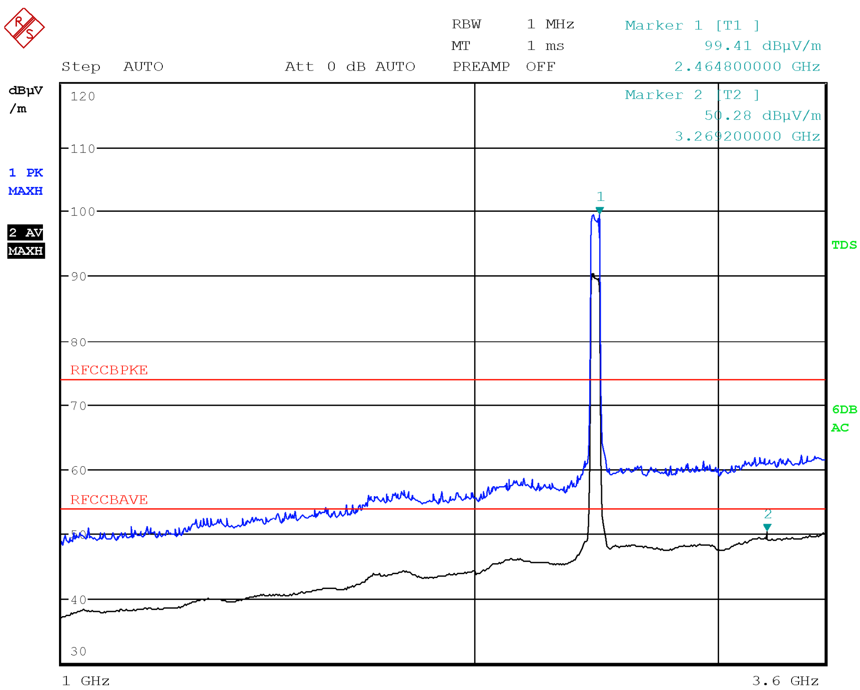

Figure 8.5-42: *Radiated spurious emissions 1 to 3.6 GHz, High channel WIFi modulation 802.11 n(HT40) with antenna in vertical polarization*

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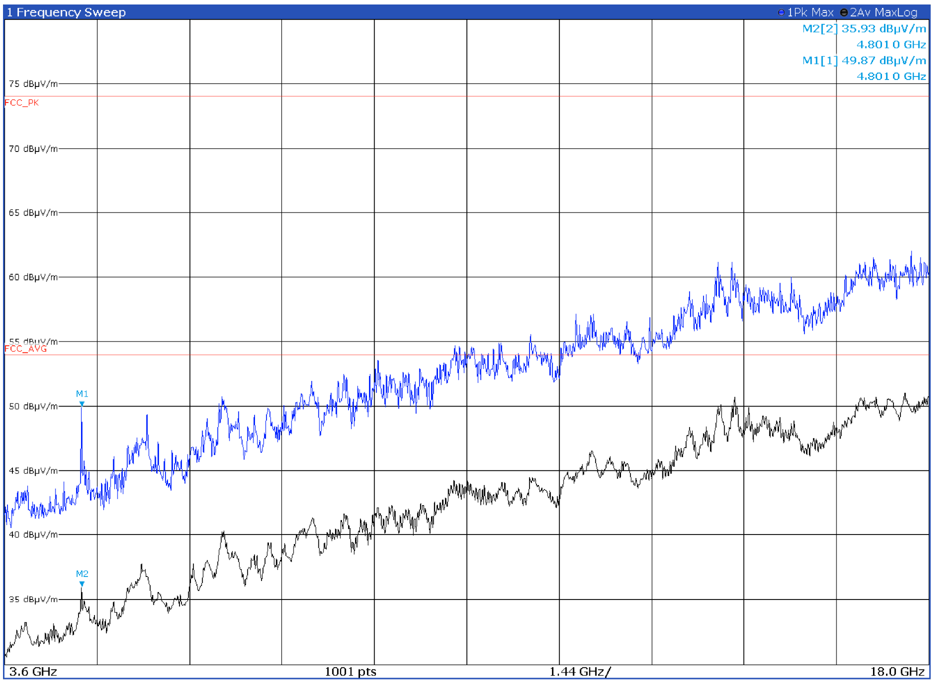

Figure 8.5-43: *Radiated spurious emissions 3.61 to 18 GHz, Worst case BT modulation 8DPSK low channel with antenna in horizontal polarization*

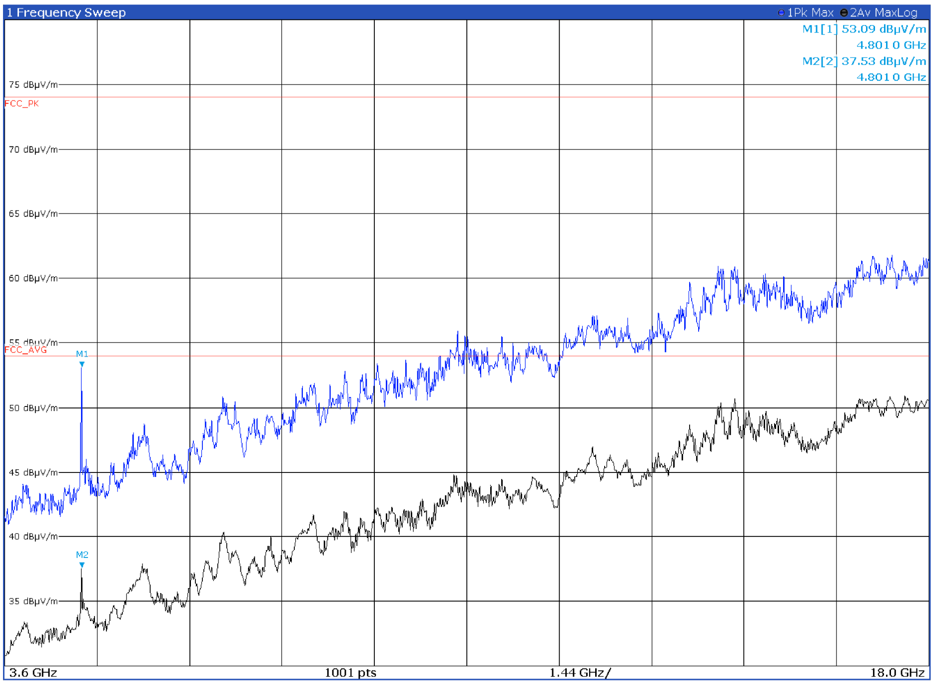

Figure 8.5-44: *Radiated spurious emissions 3.61 to 18 GHz, Worst case BT modulation 8DPSK low channel with antenna in vertical polarization*

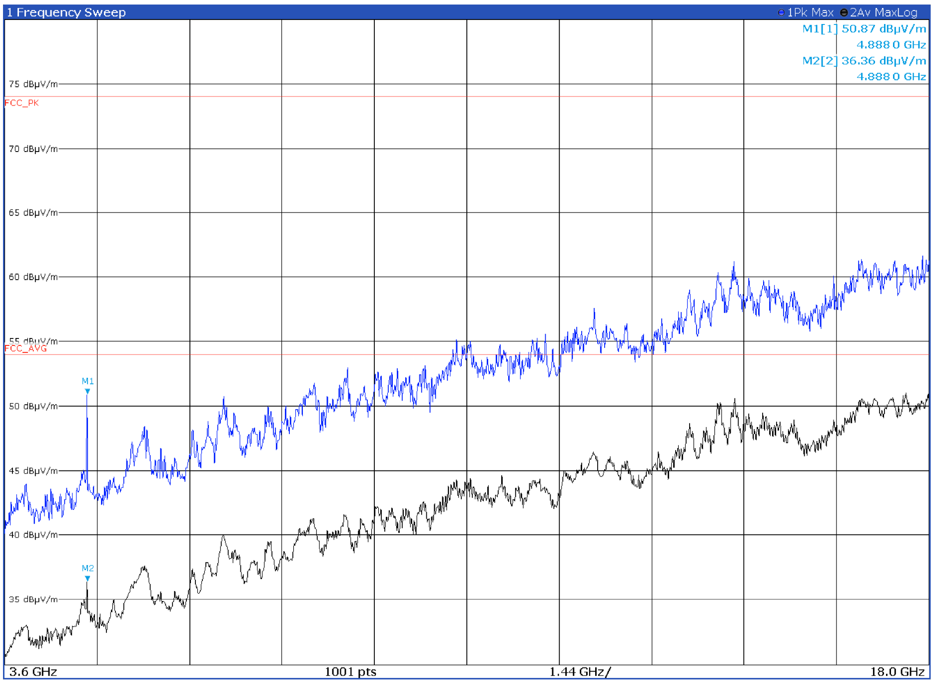

Figure 8.5-45: *Radiated spurious emissions 3.61 to 18 GHz, Worst case BT modulation 8DPSK mid channel with antenna in horizontal polarization*

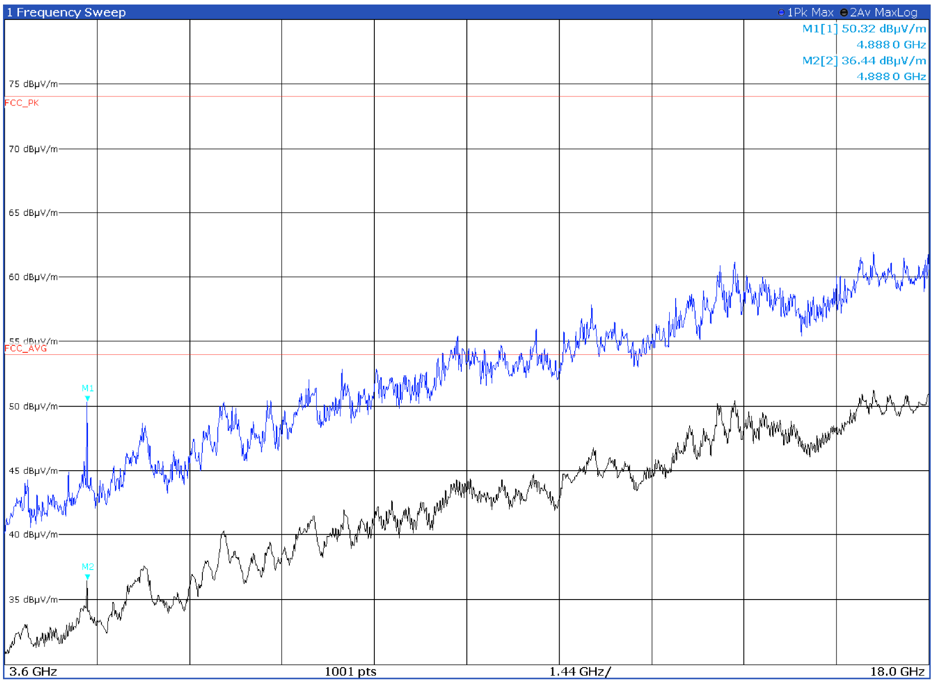

Figure 8.5-46: *Radiated spurious emissions 3.61 to 18 GHz, Worst case BT modulation 8DPSK mid channel with antenna in vertical polarization*

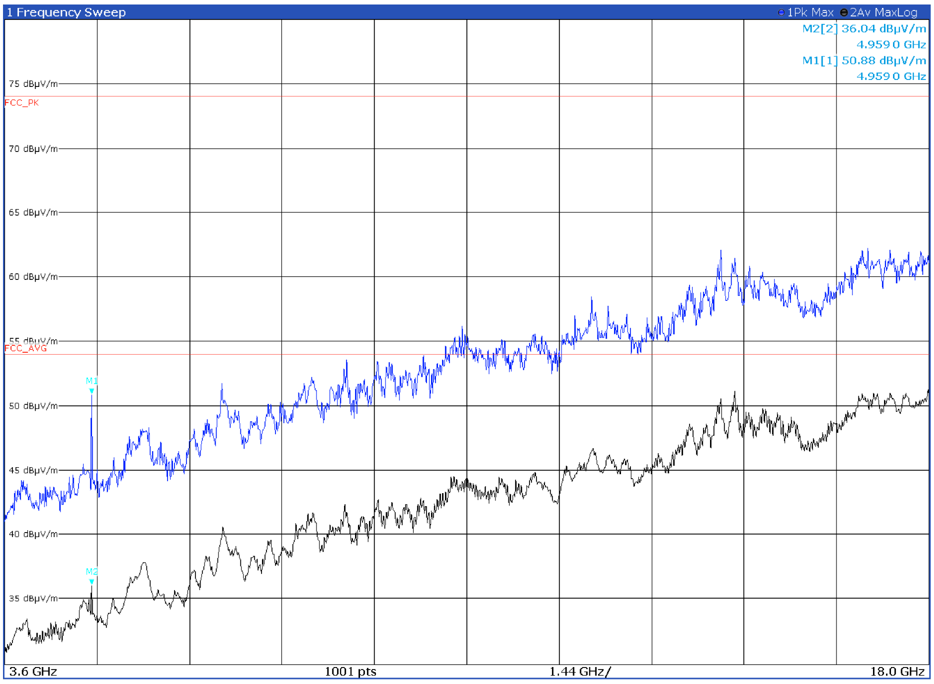

Figure 8.5-47: *Radiated spurious emissions 1 to 3.6 GHz, Worst case BT modulation 8DPSK high channel with antenna in horizontal polarization*

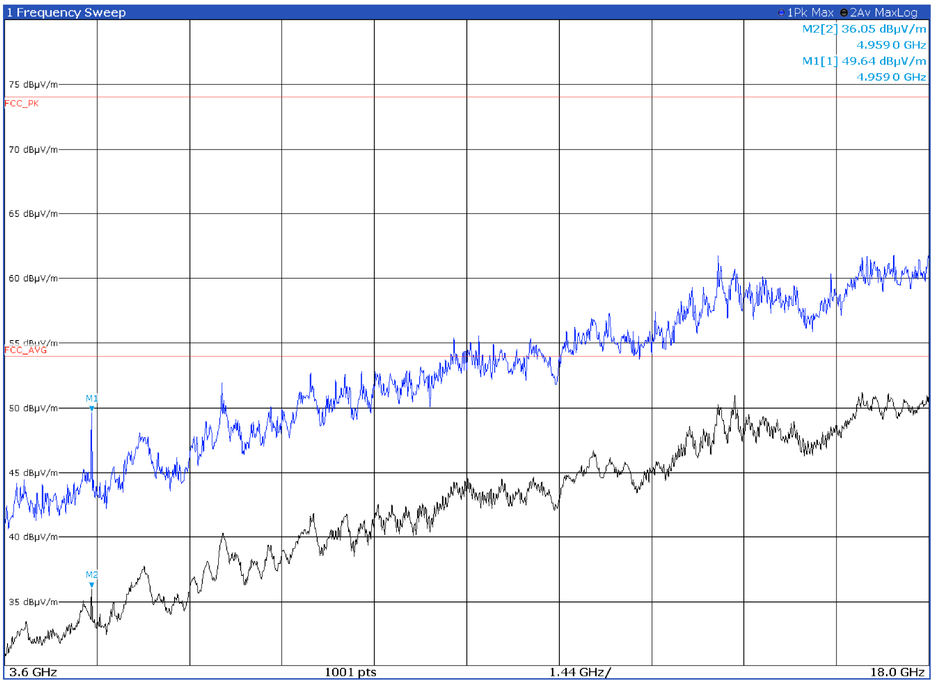

Figure 8.5-48: *Radiated spurious emissions 1 to 3.6 GHz, Worst case BT modulation 8DPSK high channel with antenna in vertical polarization*

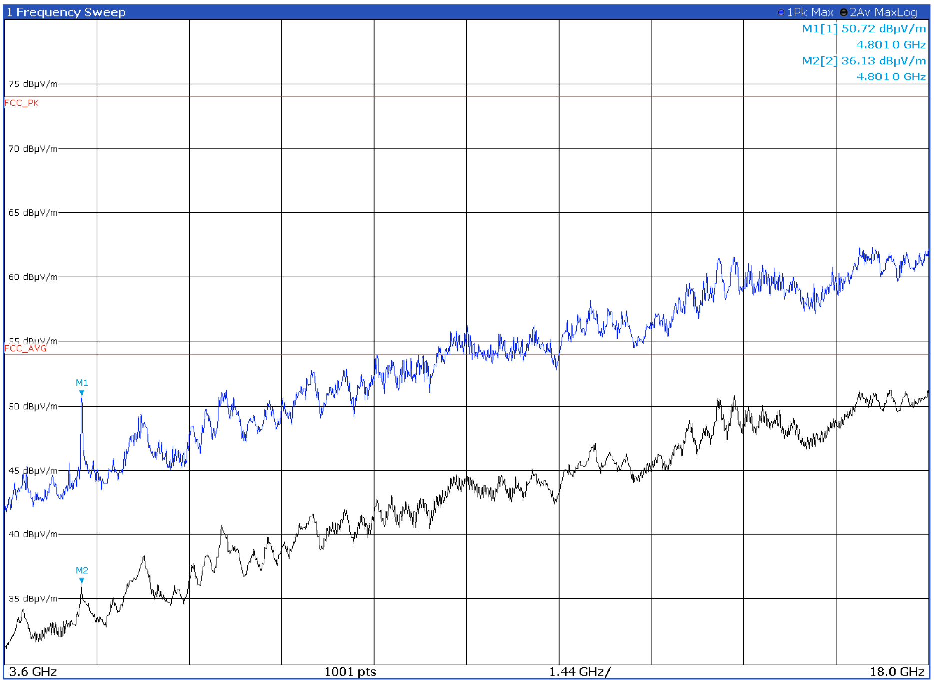

Figure 8.5-49: *Radiated spurious emissions 1 to 3.6 GHz, Low channel BLE with antenna in horizontal polarization*

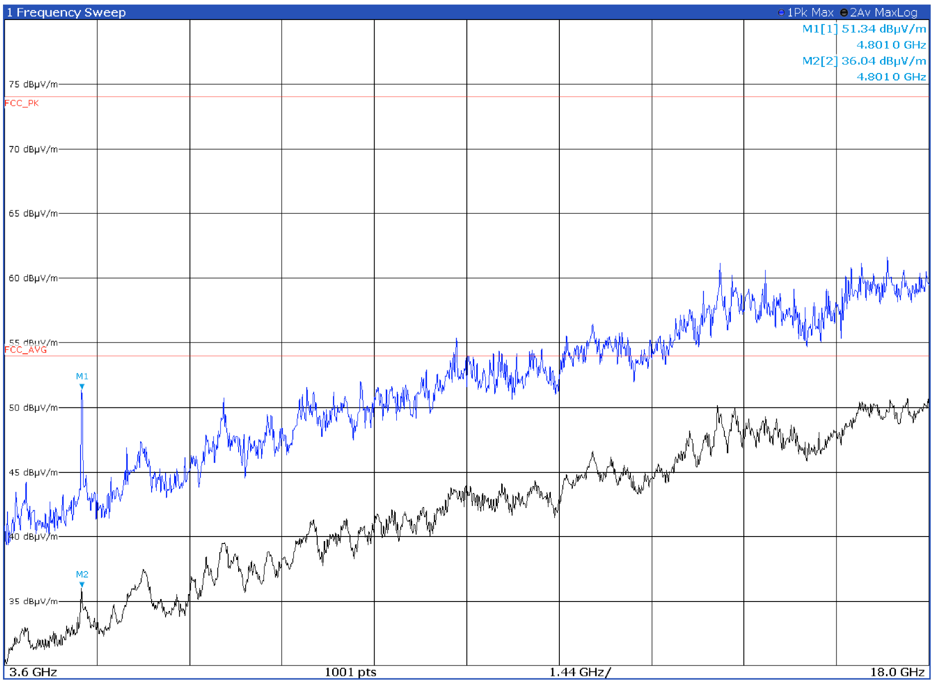

Figure 8.5-50: *Radiated spurious emissions 1 to 3.6 GHz, Low channel BLE with antenna in vertical polarization*

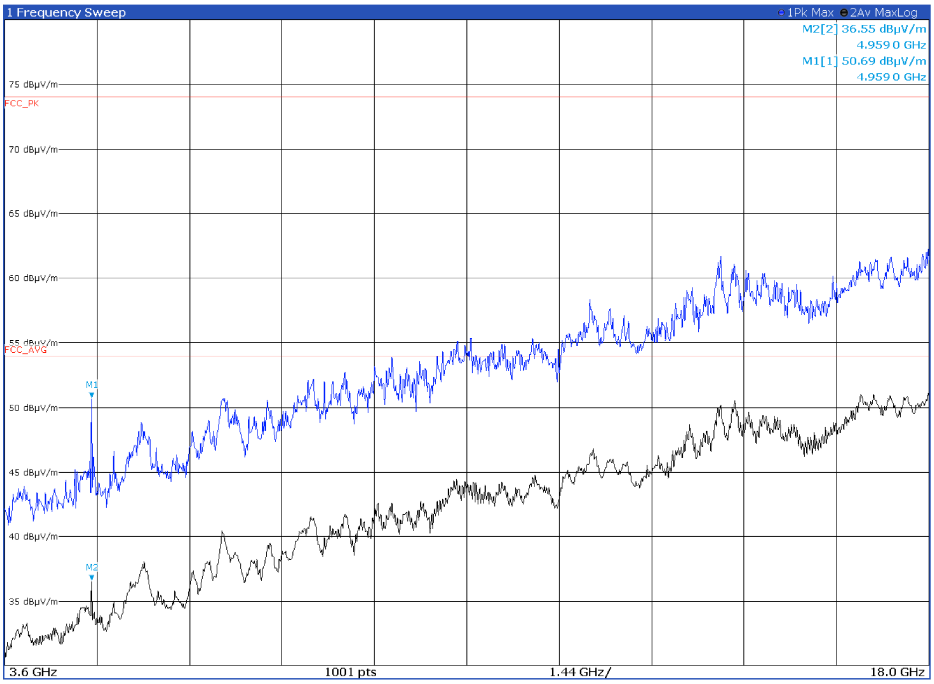

Figure 8.5-51: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel BLE with antenna in horizontal polarization*

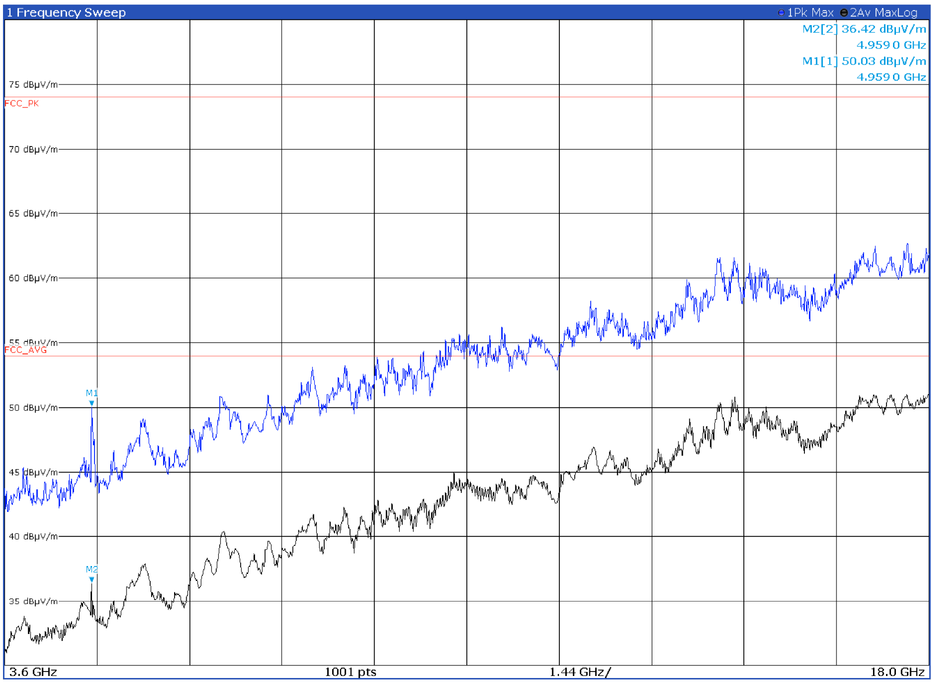

Figure 8.5-52: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel BLE with antenna in vertical polarization*

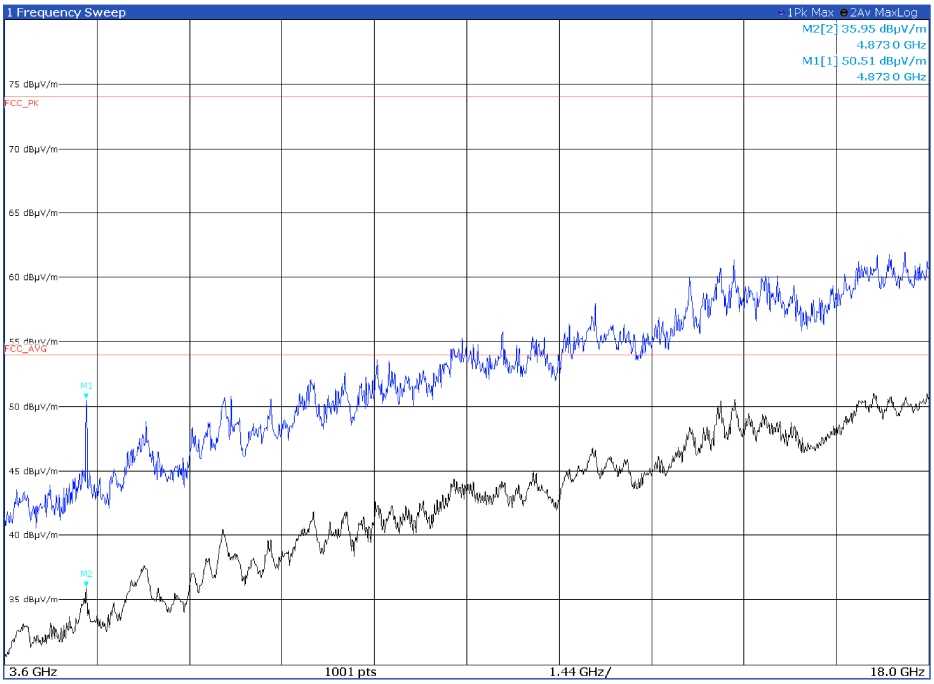

Figure 8.5-53: *Radiated spurious emissions 1 to 3.6 GHz, High channel BLE with antenna in horizontal polarization*

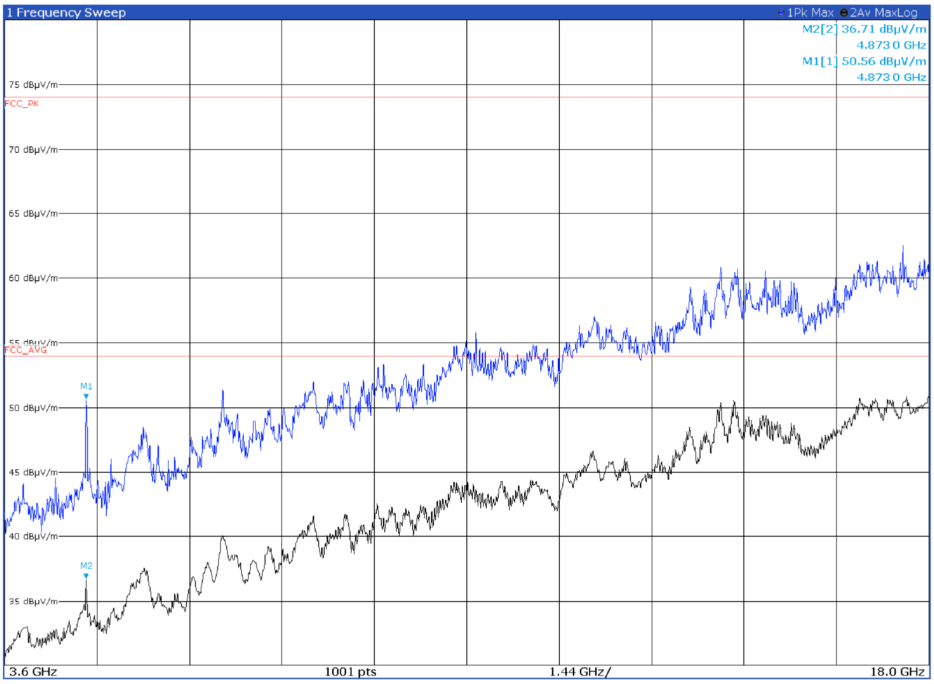

Figure 8.5-54: *Radiated spurious emissions 1 to 3.6 GHz, High channel BLE with antenna in vertical polarization*

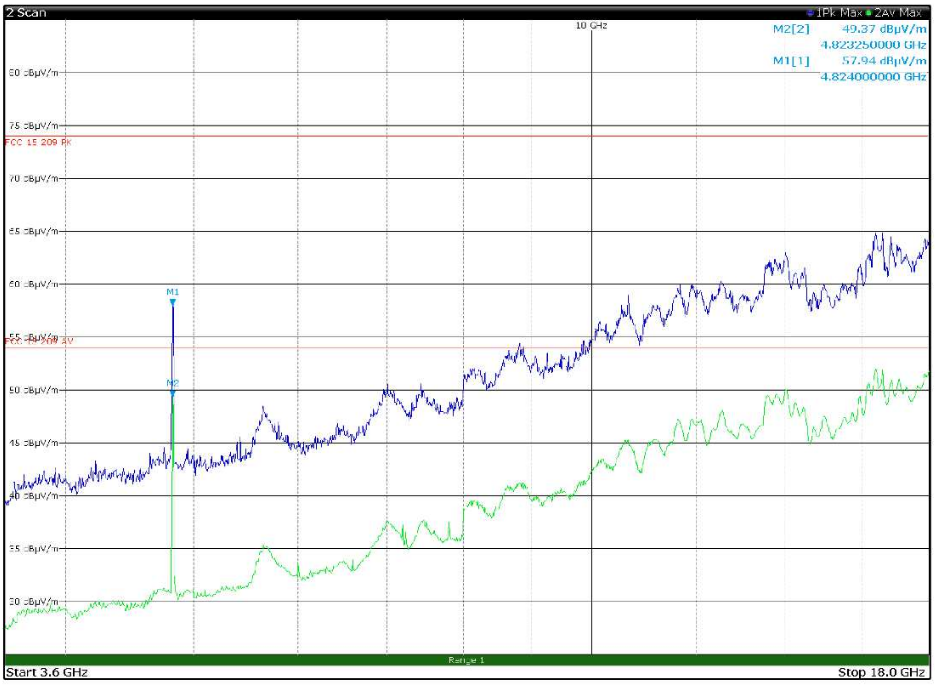

Figure 8.5-55: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11b with antenna in horizontal polarization*

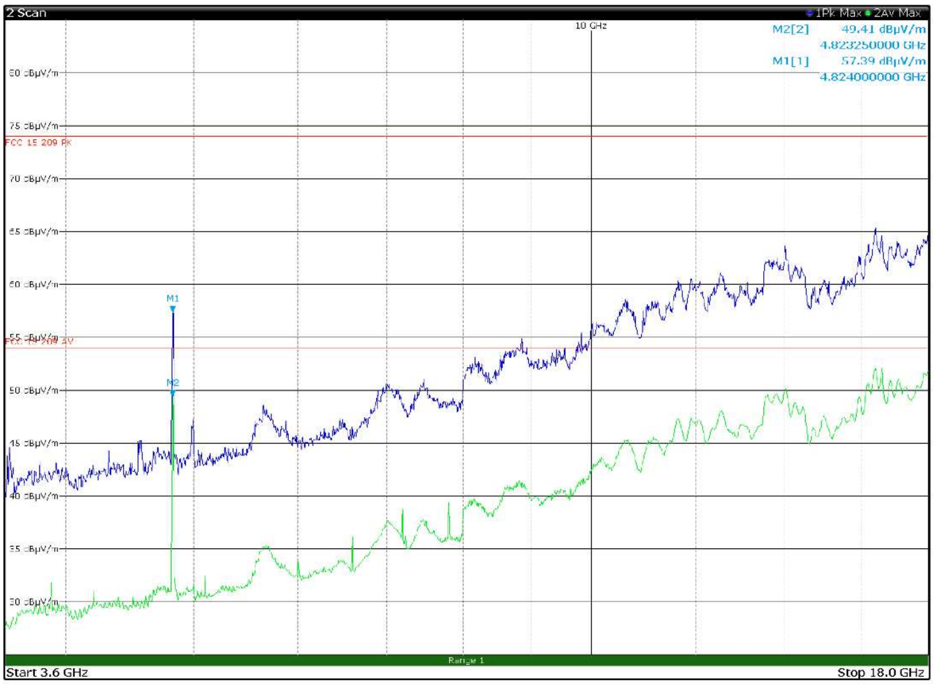

Figure 8.5-56: *Radiated spurious emissions 1 to 3.6 GHz, Low channel WIFi modulation 802.11b with antenna in vertical polarization*

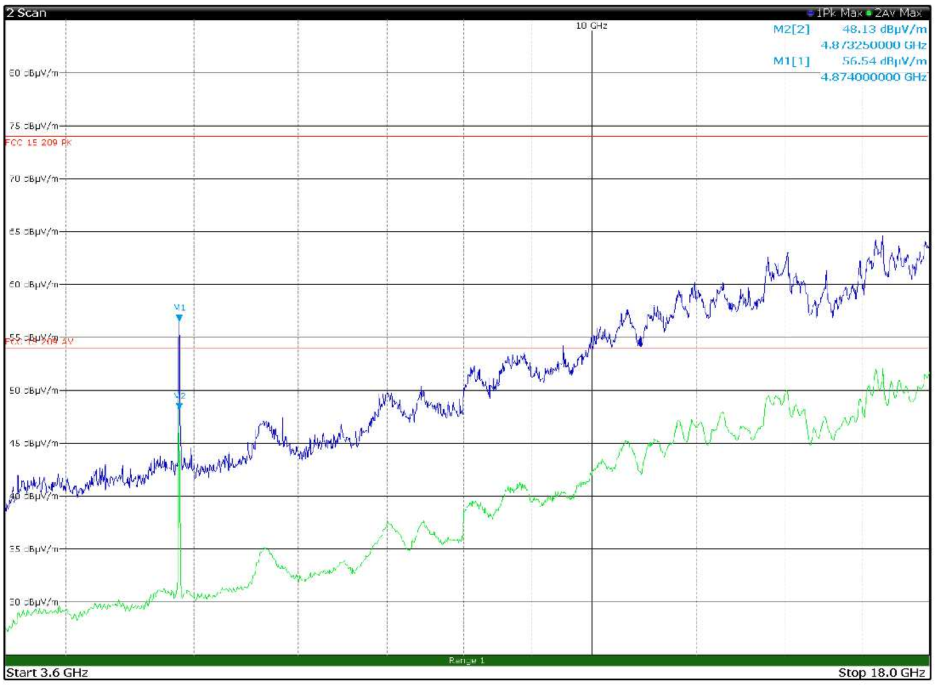

Figure 8.5-57: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11b with antenna in horizontal polarization*

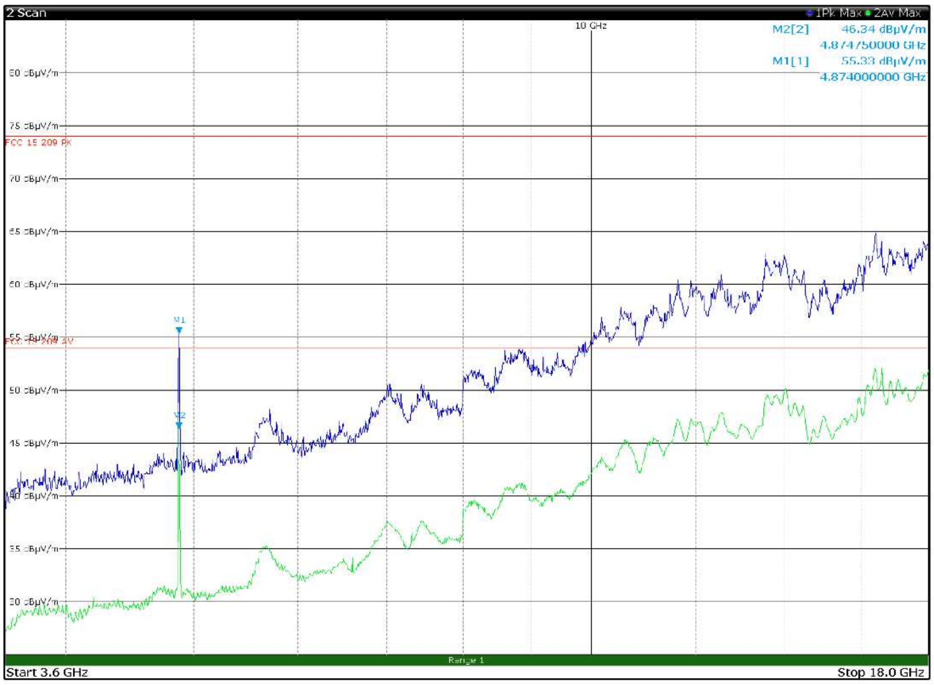

Figure 8.5-58: *Radiated spurious emissions 1 to 3.6 GHz, Mid channel WIFi modulation 802.11b with antenna in vertical polarization*