Using the BlueNRG-LP/LPS family transceivers under FCC title 47 part 15 in the 2400 – 2483.5 MHz band

Introduction

BlueNRG-LP and BlueNRG-LPS (together referred to as BlueNRG-LP/LPS in this document) are very low power Bluetooth® Low Energy (BLE) devices, compliant with Bluetooth specifications.

Bluetooth® Low Energy technology operates in the same spectrum range (2400 - 2483.5 MHz, ISM band) as classical Bluetooth® technology, but uses a different set of channels. Bluetooth® Low Energy technology has 40 channels (37 data channels + 3 advertising channels) of 2 MHz band. Within the channel, data are transmitted using GFSK (gaussian frequency shift modulation). The bit rate is 1 Msymb/s, 2 Msymb/s, 500 ksymb/s or 125 ksymb/s the maximum transmit power is 100 mW (20 dBm).

Further details are given in volume 6 part A of the Bluetooth® core specification V5.2.

This application note outlines the expected performance when using a device of the BlueNRG-LP/LPS family under FCC title 47 part 15 [2] in the 2400 to 2483.5 MHz band.

For details on the regulatory limits in the 2400 - 2483.5 MHz frequency band, refer to the FCC title 47 part 15 regulations [2]. These can be downloaded from [5].

The list of the appropriate documents containing the measurement procedures to demonstrate compliance with the FCC rules can be checked at [6].

1 An overview of FCC regulations

Low power, non-licensed devices operating in the 2400 - 2483.5 MHz band are found everywhere, such as: toys, wireless security systems, wireless telemetry, wireless automatic meter reading applications, and so on.

The FCC is the body responsible in the USA to implement rules limiting the potential for interference to licensed operations by low power, non-licensed transmitters. These rules are documented in part 15 of title 47 of the FCC.

For operation in the 2400 - 2483.5 MHz band, a low power, non-licensed device must meet one of the following sub-parts of the regulation:

- Part 15.247: devices that operate to this part are limited to frequency hopping and digitally modulated scheme
- Part 15.249: this sub-part does not enforce restrictions on either modulation scheme or the end application.

The FCC classifies Bluetooth BR/EDR as an FHSS system. However, Bluetooth LE does not fulfill these requirements. Instead, the FCC classifies Bluetooth LE as a system using digital modulation techniques.

1.1 Part 15.247

To be compliant with the FCC part 15.247 digital modulation scheme, the devices or systems must meet the following requirements:

1. The minimum 6 dB bandwidth of the signal is at least 500 kHz
2. The maximum permitted peak conducted output power is +30 dBm (1 W). However, the power spectral density conducted from the intentional radiator to the antenna is not greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.
3. In any 100 kHz bandwidth outside the frequency band of operation, the power is 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, the attenuation required under this paragraph is 30 dB instead of 20 dB.
4. Attenuation below the general limits specified in 15.209 is not required. In addition, radiated harmonic and spurious emissions which fall within the restricted bands, as defined in FCC part 15.205, must also comply with the radiated emission limits specified in FCC part 15.209.

A detailed guide document called “Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under Part 15.247” was written from FCC [3]. Here, this guidance is followed when performing the FCC part 15.247 compliance measurements.

1.2 Parts 15.205 and 15.209

As previously described, radiated harmonics and spurious emissions of those devices that comply with part 15.247, which fall within the restricted bands as defined in FCC part 15.205, must comply with the radiated emission limits specified in FCC part 15.209. For any 100 kHz bandwidth outside the frequency band of operation and outside the restricted bands, the power is at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power.

Part 15.205 shows the bands where only spurious emissions are permitted (see Table 1). The field strength of emissions appearing within these frequency bands do not exceed the limits shown in part 15.209. The tables below show the restricted bands as defined in part 15.205, and the radiated and conducted emission limits are defined in part 15.209. In Table 2, the maximum permissible electric field strength at a specific measurement distance is reported, along with the equivalent EIRP value. To determinate the equivalent EIRP value, the formula described in ANSI C63.10 chapter 9.5 is used. The same formula is reported in Section 1.4 Considerations on unwanted emissions.

Table 1. Restricted bands defined in part 15.205

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			

Table 2. Radiated and conducted emission limits defined in part 15.209

Frequency (MHz)	Field strength (µV/m)	Measurement distance(m)	Conducted (dBm)
0.009 – 0.490	2400/f [kHz]	300	12.4-20*log(f) [kHz]
0.490 – 1.705	24000/f [kHz]	30	12.4-20*log(f) [kHz]
1.705 – 30.0	30	30	-46
30 – 88	100	3	-56
88 – 216	150	3	-52
216 – 960	200	3	-49
960	500	3	-41

1.3 Relaxation factor

FCC regulations outlined in CFR title 47 part 15 subpart A section 15.35 (b) specify that unless otherwise noted, emission limits above 1 GHz are expressed employing a measurement instrument average detector. However, because of an average detector dependency on the characteristics of pulse train and the specifications of the measuring instrument, repeatability is nearly impossible from instrument to instrument. The FCC regulations provide an allowance to correct pulsed transmissions when the limits are expressed in terms of an average, and the average measurement may be derived from the peak pulse amplitude corrected for the duty cycle of the pulse modulation. This is the “relaxation factor”, henceforth referred to as a duty cycle correction, which is in fact a normalized duty cycle correction applied to a peak measurement to increase accuracy and repeatability when a pulsed average emission is represented.

The calculation of the duty cycle correction factor is done using a spectrum analyzer with the following settings:

- Span = zero span
- RBW = 1 MHz
- VBW = RBW
- Sweep = auto
- Detector function = peak

- Trace = max hold

The transmit pulse widths and period have to be measured.

If the pulse train is less than 100 ms, including blanking intervals, the duty cycle is calculated by averaging the sum of the pulse widths over one complete pulse train.

If the pulse train exceeds 100 ms the duty cycle is calculated by averaging the sum of the pulse widths over the 100 ms width with the highest average value.

The duty cycle is the value of the sum of the pulse widths in one period (or 100 ms), divided by the length of the period (or 100 ms). The duty cycle correction factor is then expressed in dB and the peak emissions adjusted accordingly to give an average value of the emission.

Correction factor [dB] = 20 x log10 (calculated duty cycle).

1.4 Considerations on unwanted emissions

The DTS rules specify that any emission outside the authorized frequency band has to be attenuated and it is defined in point 4. of this document. The described procedure can be used either in an antenna port conducted or radiated test setup.

Besides, the DTS rules specify that emissions, which fall into restricted frequency bands, comply with the general radiated emission limits. Since the emission limits are specified in terms of radiated field strength levels, measurements performed to demonstrate compliance have traditionally relied on a radiated test configuration. Radiated measurements remain the principal method to demonstrate compliance to the specified limits; however antenna port conducted measurements are also now acceptable to demonstrate compliance [3].

The general procedure for conducted measurement in restricted band is:

- Measure the conducted output power, in dBm, using the detector specified.
- Add the maximum transmit antenna gain, in dBi, to the measured output power level to determine the EIRP level.
- Add the appropriate maximum ground reflection factor to the EIRP level (6 dB for frequencies ≤ 30 MHz, 4.7 dB for frequencies between 30 MHz and 1000 MHz and 0 dB for frequencies > 1000 MHz).
- For a device with multiple antenna ports measure the power of each individual chain and sum the EIRP of all chains in linear terms.
- Convert the applicable limit level to an equivalent dBm level using the following relationship:
  EIRP = E + 20log D - 104.8
  Where:
  E = electric field strength in dBuV/m,
  EIRP = equivalent isotropic radiated power in dBm,
  D = specified measurement distance in meters.
- Compare the resultant applicable limit level in dBm with the measured EIRP.

2 Application circuit

Figure 1 and Figure 2 show the BlueNRG-LP evaluation platform STEVAL-IDB011V2 and the BlueNRG-LPS evaluation platform STEVAL-IDB012V1.

They provide a set of hardware resources to implement a wide range of application scenarios: sensor data (accelerometer, pressure and temperature sensor), remote control (buttons and LEDs) and manage debug messages though USB virtual COM. Three power options are available (USB only, battery only, external power supply + USB) for high application development and testing flexibility.

The application board is equipped with a 32 MHz XTAL to provide the correct oscillator to the BlueNRG-LP/LPS. A 32.768 kHz low speed crystal oscillator is also mounted on the board and used by the BlueNRG-LP/LPS.

An internal SMPS is present on the BlueNRG-LP/LPS to reduce drastically the power consumption. The SMPS is fed from the battery and provides a programmable voltage to the device (1.4 V typically).

A RF connector (SMA or U.FL) is present to connect the board to an antenna or to an instrument to verify correct functioning and to verify standard compliance.

The evaluation kit includes an STM32F103 microcontroller to program and debug the transceiver.

A graphical user interface (GUI) can be used to control the BlueNRG-LP/LPS.

Figure 1. The BlueNRG-LP evaluation board

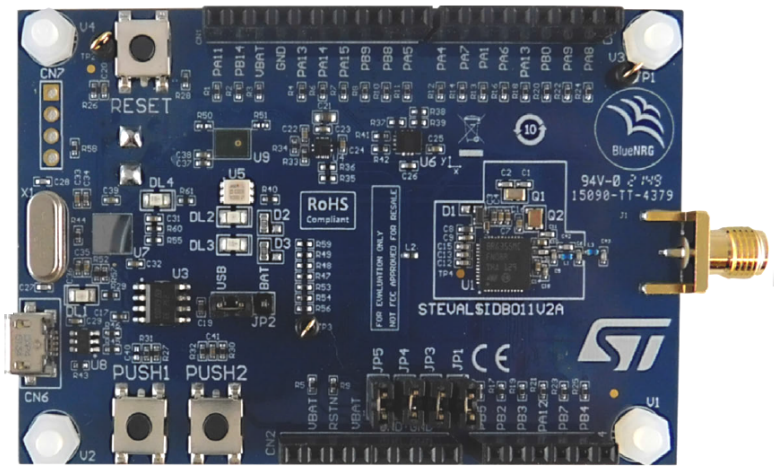

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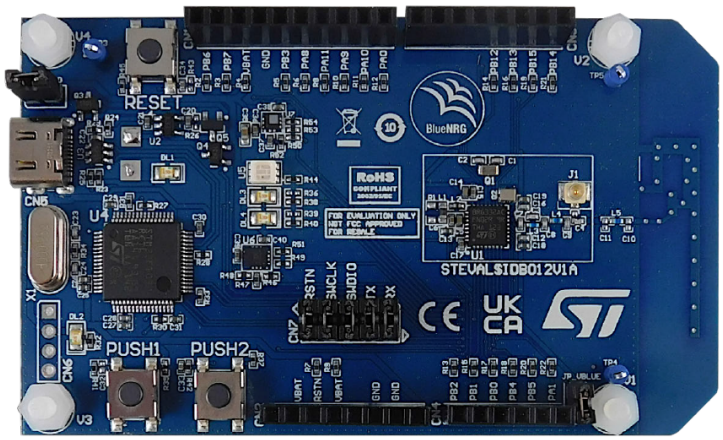
Figure 2. BlueNRG-LPS application board



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3 Transmitter parameter

All the measurements reported here come from the following parameters:

T_c = 25 °C, V_{dd} = 3.3 V, f = 2402 MHz, 2440 MHz and 2480 MHz (lower, middle and high frequency of the useful bandwidth), unless otherwise specified.

Frequencies inside the band that exceed the limits are ignored.

The aforementioned BlueNRG-LP and BlueNRG-LPS application circuits are used as DUTs.

3.1 6 dB channel bandwidth

The 6 dB channel bandwidth is defined as the difference between the upper and lower frequencies that are -6 dB relative to the peak. The measurement is performed in conducted mode connecting the BlueNRG-LP/LPS application board to a spectrum analyzer.

The spectrum analyzer settings are as defined in [3]:

- Span = no requirement, set to approximately 2 to 3 times the 6 dB bandwidth
- RBW ≥ 100 kHz
- VBW ≥ 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

The measured 6 dB bandwidth is shown in figures below. The measured bandwidth meets the FCC requirement with margin.

Figure 3. IDB011V2 - 6 dB bandwidth 2402 MHz

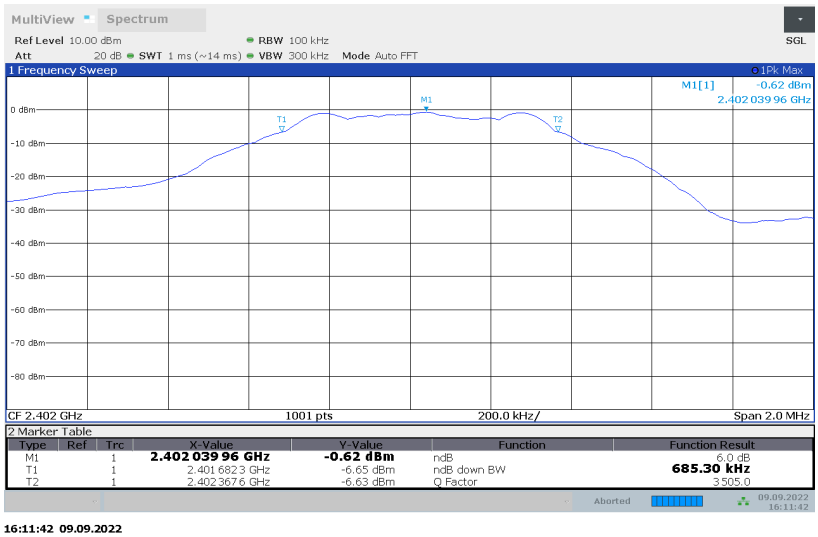

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Figure 4. **IDB011V2 - 6 dB bandwidth 2440 MHz**

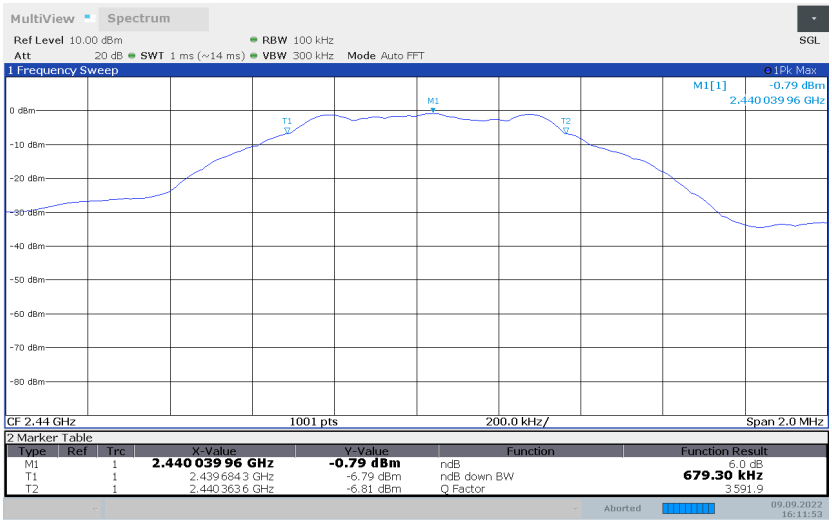

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Figure 5. **IDB011V2 - 6 dB bandwidth 2480 MHz**

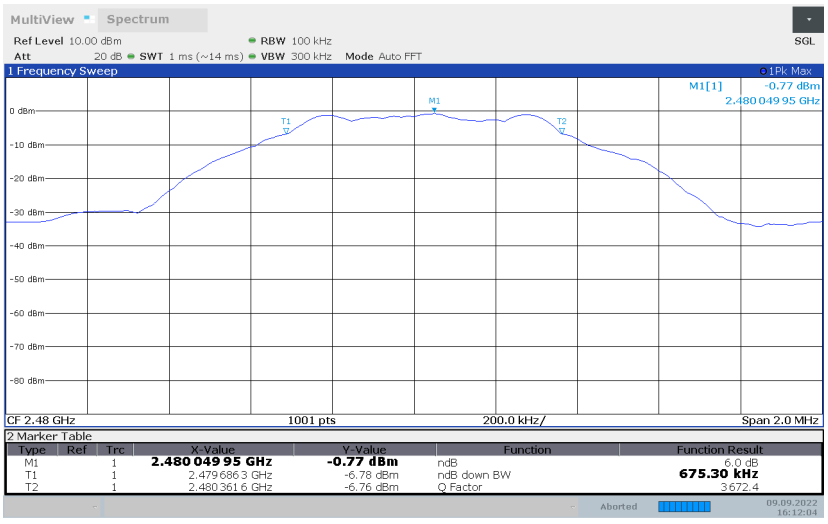

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Figure 6. **IDB012V1 - 6 dB bandwidth 2402 MHz**

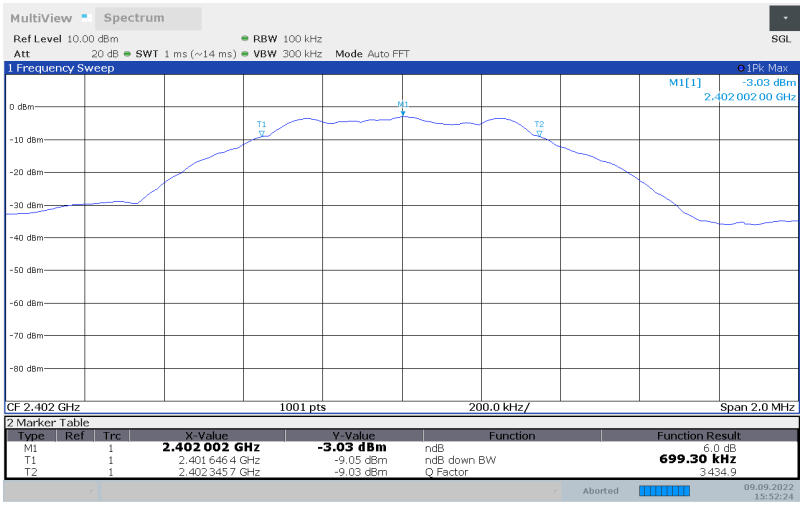

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Figure 7. **IDB012V1 - 6 dB bandwidth 2440 MHz**

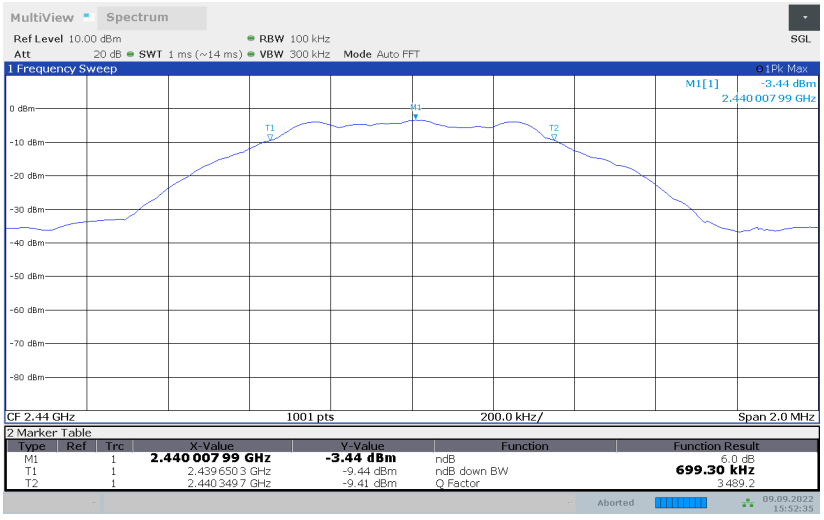

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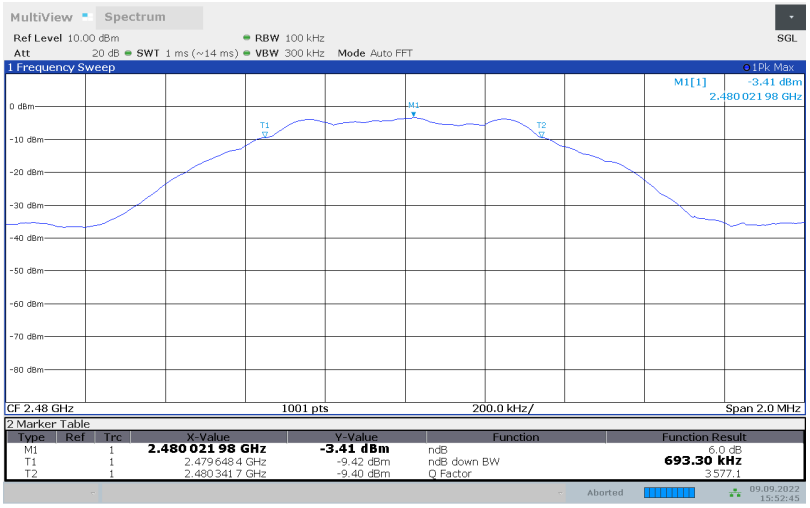
Figure 8. **IDB012V1 - 6 dB bandwidth 2480 MHz**



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3.2 Maximum peak conducted output power

To measure the peak output power, center the spectrum analyzer on the wanted channel and put the BlueNRG-LP in carrier mode.

The spectrum analyzer settings are as defined in [3]:

- Span ≥ 3 x RBW
- RBW ≥ DTS bandwidth (that is the 6 dB bandwidth)
- VBW ≥ 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

The maximum permitted peak conducted output power is 30 dBm (1 W). The measured output power is below +8 dBm. This output power is lower than the maximum permitted output power. The measurement result is reported in Table 3. IDB011V2 - Maximum peak output power.

Table 3. **IDB011V2 - Maximum peak output power**

Frequency [MHz]	Output power [dBm]	FCC spec [dBm]
2402	+7.9	+30
2440	+7.9	+30
2480	+7.9	+30

Table 4. **IDB012V2 - Maximum peak output power**

Frequency [MHz]	Output power [dBm]	FCC spec [dBm]
2402	+7.5	+30
2440	+7.3	+30
2480	+7.3	+30

3.3 Maximum power spectral density level in the fundamental emission

The power spectral density conducted from the intentional radiator to the antenna should not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. The method to measure the power spectral density is similar to that used for the conducted output power.

The spectrum analyzer settings are as defined in [3], method PKPSD (peak PSD):

Span ≥ 1.5 times the DTS bandwidth (that is the 6 dB bandwidth)

3 kHz ≥ RBW ≥ 100 kHz

VBW ≥ 3 x RBW

Sweep = auto

Detector function = peak

Trace = max hold

The measurement result is shown below. The BlueNRG-LP/LPS devices meet the power spectral density requirement with large margin.

Figure 9. IDB011V2 - PSD 2402 MHz

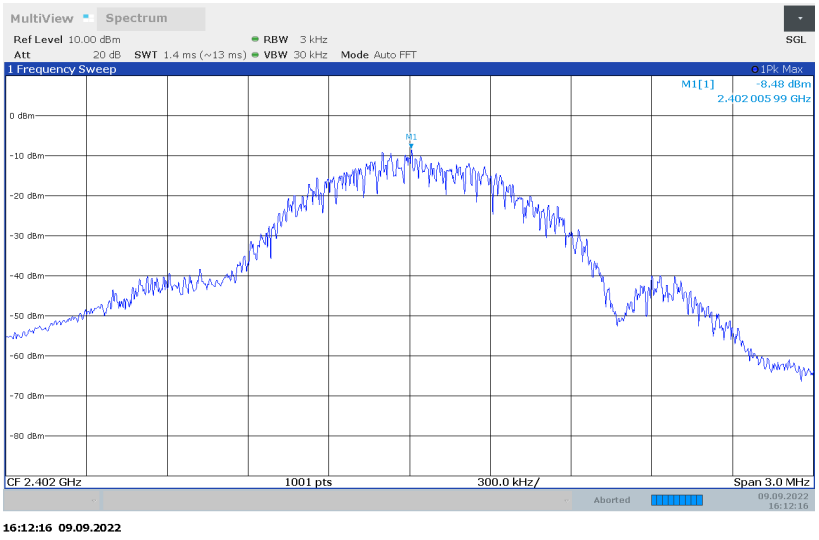

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Figure 10. IDB011V2 - PSD 2440 MHz

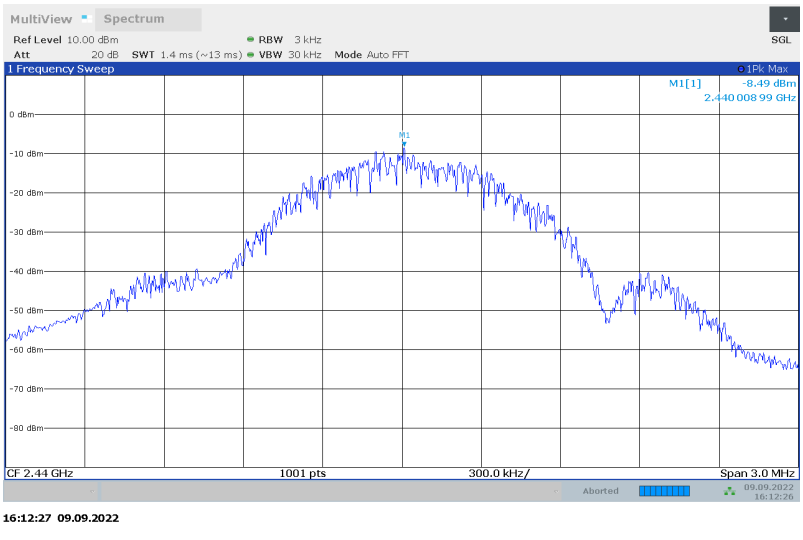

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Figure 11. **IDB011V2 - PSD 2480 MHz**

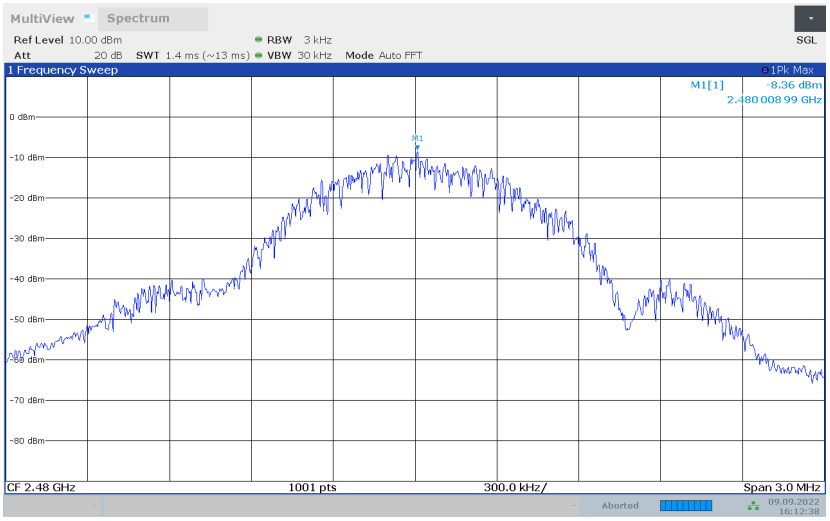

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Figure 12. **IDB012V1 - PSD 2402 MHz**

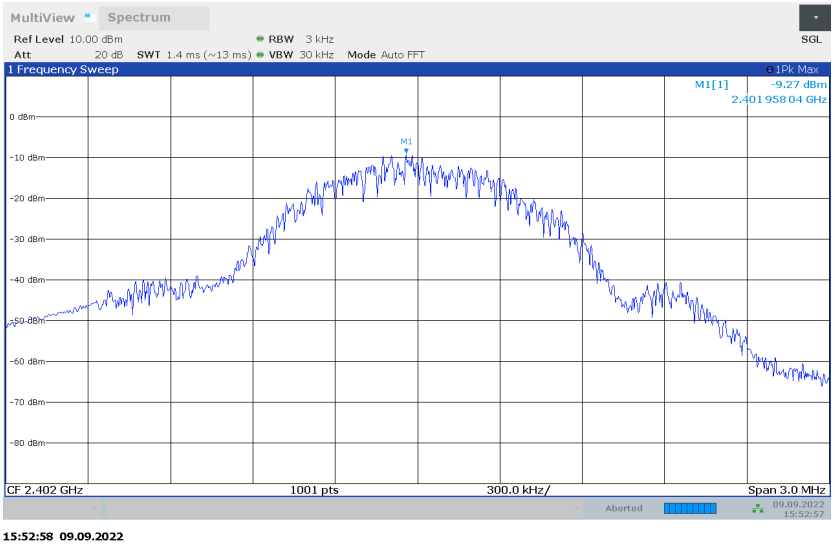

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Figure 13. **IDB012V1 - PSD 2440 MHz**

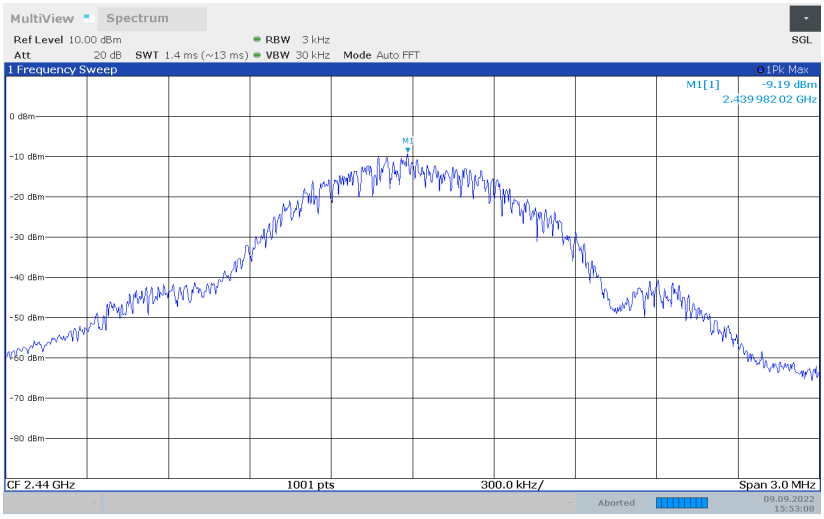

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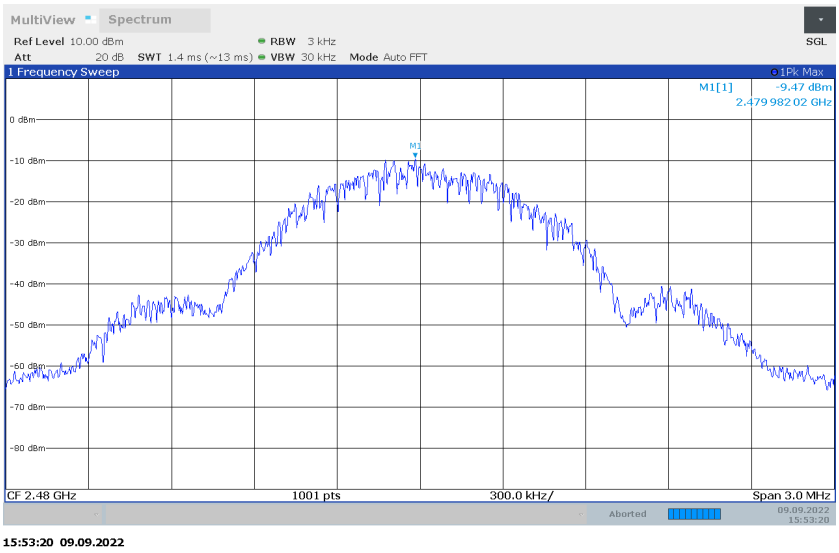
Figure 14. **IDB012V1 - PSD 2480 MHz**



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3.4 Unwanted emissions

FCC part 15.247 defines two different cases for the emission outside the 2402 MHz – 2480.5 MHz band:

- Emission that falls in a not-restricted band
- Emission that falls in a restricted band as defined in 15.205

For the emission in the not-restricted band the DTS [3] rules specify that in any 100 kHz bandwidth the power is attenuated according to the following conditions:

- If the maximum peak conducted output power procedure was used to demonstrate compliance of the fundamental emission output power, then the peak output power measured in any 100 kHz bandwidth outside of the authorized frequency band is attenuated by at least 20 dB relative to the maximum in-band peak PSD level in 100 kHz (i.e., 20 dBc)
- If maximum conducted (average) output power was used to demonstrate compliance of the fundamental emission output power, then the peak power in any 100 kHz bandwidth outside of the authorized frequency band is attenuated by at least 30 dB relative to the maximum in-band peak PSD level in 100 kHz (i.e., 30 dBc)

- In either case, attenuation to levels below the 15.209 general radiated emissions is not required.

The compliance of the fundamental emission output power of the BlueNRG-LP/LPS family devices has been demonstrated using the maximum peak conducted output power procedure, so the 20 dBc limit has to be considered.

The measurement has to be performed using the following settings [3]:

- Set the center frequency and span to encompass frequency range to be measured
- RBW = 100 kHz
- VBW ≥ 3 x RBW
- Sweep time = auto
- Detector function = peak
- Trace = max hold

Use the peak marker function to determine the maximum amplitude level and ensure that the amplitude of all unwanted emissions are attenuated by at least the minimum requirements.

For the emissions in restricted frequency bands the DTS rules specify that emissions which fall into restricted frequency bands comply with the general radiated emission limits. Since the emission limits are specified in terms of radiated field strength levels, measurements performed to demonstrate compliance have traditionally relied on a radiated test configuration. Radiated measurements remain the principal method for demonstrating compliance to the specified limits; however antenna-port conducted measurements are also now acceptable to demonstrate the compliance.

As per Section 1.4 Considerations on unwanted emissions for a correct comparison between the measured values, in conducted mode, and the specified limits, in radiated mode, the following values are considered in the calculation:

- Antenna gain = 0 dBi
- Ground reflection factor = 0 dB (for frequencies > 1 GHz)

The compliance of the emission in restricted bands of the BlueNRG-LP/LPS devices is shown using the conducted measurement. The peak power measurement procedure (paragraph 11.12.2.4 of [4]) is used with the following settings:

- RBW = as specified in Table 5
- VBW ≥ 3 x RBW
- Sweep time = auto
- Detector function = peak
- Trace = max hold

Table 5. RBW as a function of frequency

Frequency	RBW
9-150 kHz	200–300 Hz
0.15-30 MHz	9–10 kHz
30-1000 MHz	100–120 kHz
>1000 MHz	1 MHz

If the peak-detected amplitude can be shown to comply with average limit, then it is not necessary to perform a separate average measurement.

Three conditional procedures are provided for performing conducted average power measurements. The three cases are:

- EUT can be configured to transmit continuously (paragraph 11.12.2.5.1 of [4])
- EUT cannot be configured to transmit continuously but the duty cycle is constant (paragraph 11.12.2.5.2 of [4])
- EUT cannot be configured to transmit continuously and the duty cycle is not constant (paragraph 11.12.2.5.3 of [4])

The BlueNRG-LP/LPS has been configured to transmit a continuous wave and the compliance is demonstrated using the peak detected amplitude method. Therefore, it is not necessary to perform the average amplitude measurement.

Finally, the limits for radiated measurements in part 15.209 have been taken into account.
The spurious conducted emissions are show below.
First, the full span is presented.Then, the different frequency segments are showed.
For each segment, only relevant frequencies close to the applicable limit are marked.
The same approach is used to demonstrate the compliance when BlueNRG-LP/LPS is receiving.
The results are presented after the unwanted emissions in Tx.
Both in tx and rx the FCC unwanted emission requirements are met.

Figure 15. IDB011V2 - Tx (2402 MHz) unwanted emissions full span

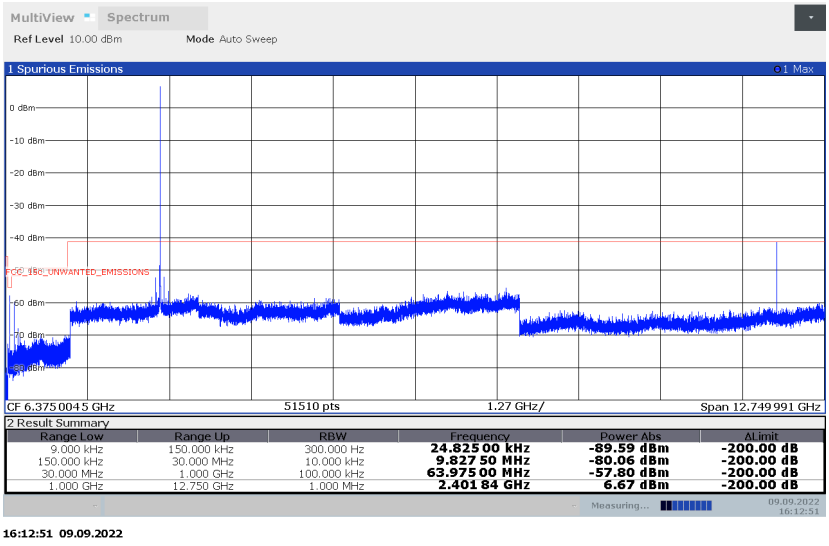

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Figure 16. IDB011V2 - Tx (2402 MHz) unwanted emissions in the 150 kHz - 30 MHz band

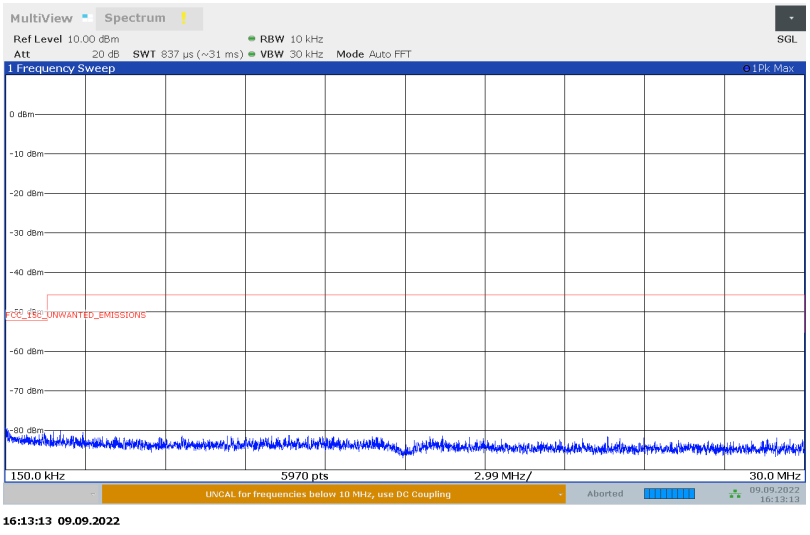

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Figure 17. **IDB011V2 - Tx (2402 MHz) unwanted emissions in the 30 MHz - 1000 MHz band**

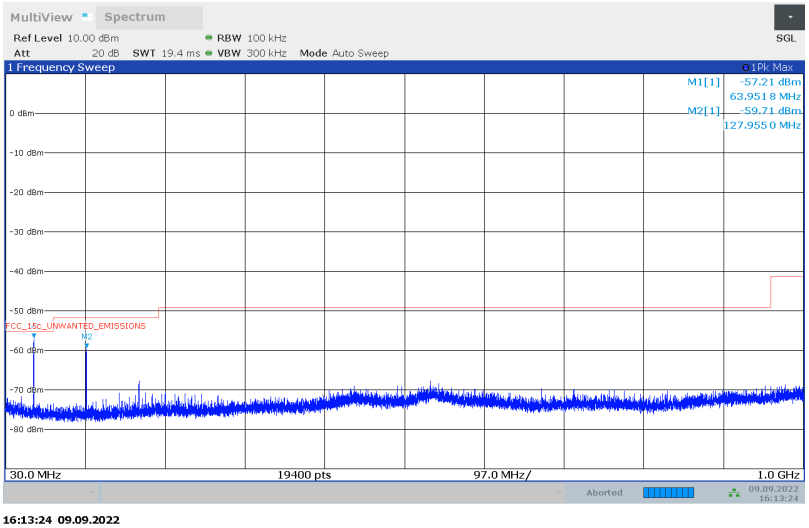

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Figure 18. **IDB011V2 - Tx (2402 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band**

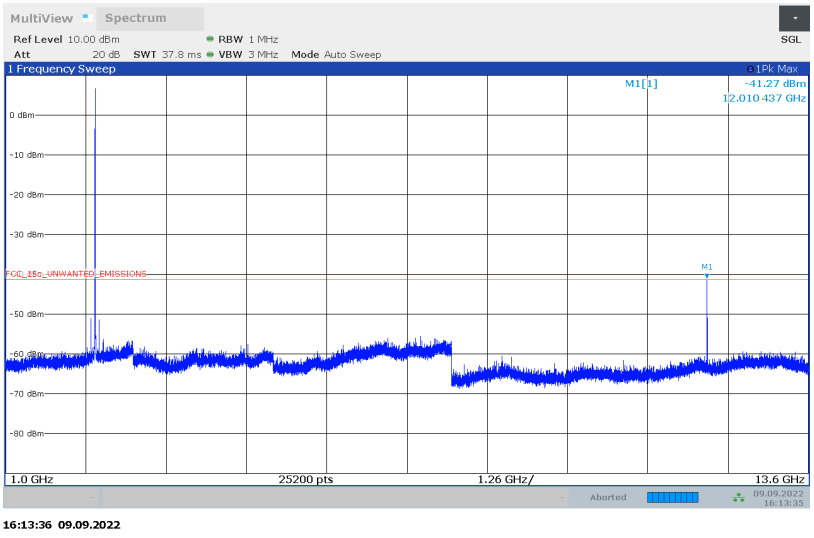

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Figure 19. IDB011V2 - Tx (2440 MHz) unwanted emissions full span

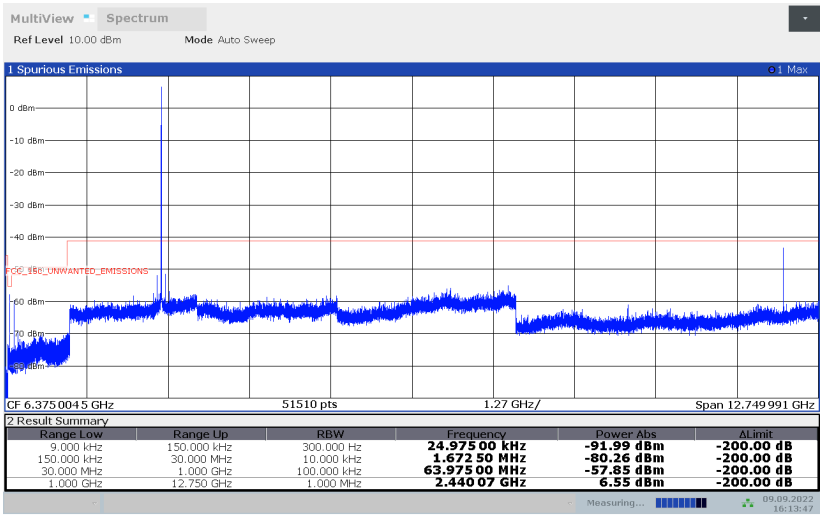

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Figure 20. IDB011V2 - Tx (2440 MHz) unwanted emissions in the 150 kHz - 30 MHz band

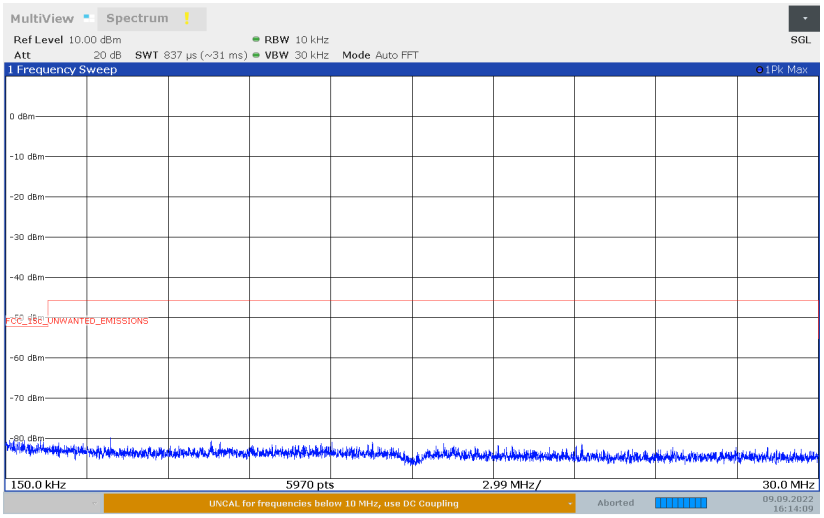

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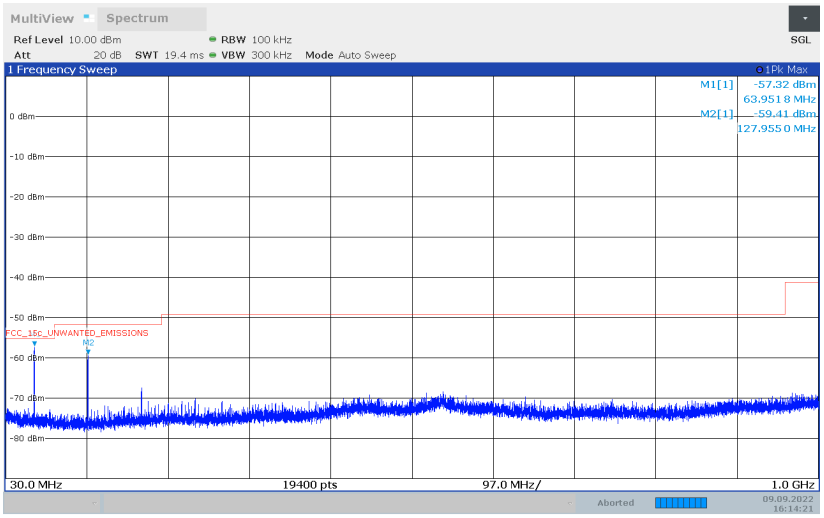
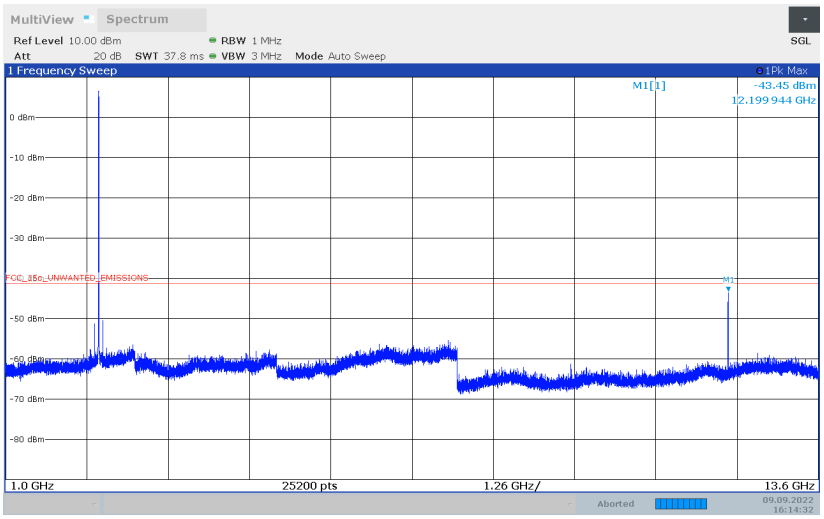
Figure 21. IDB011V2 - Tx (2440 MHz) unwanted emissions in the 30 MHz - 1000 MHz band



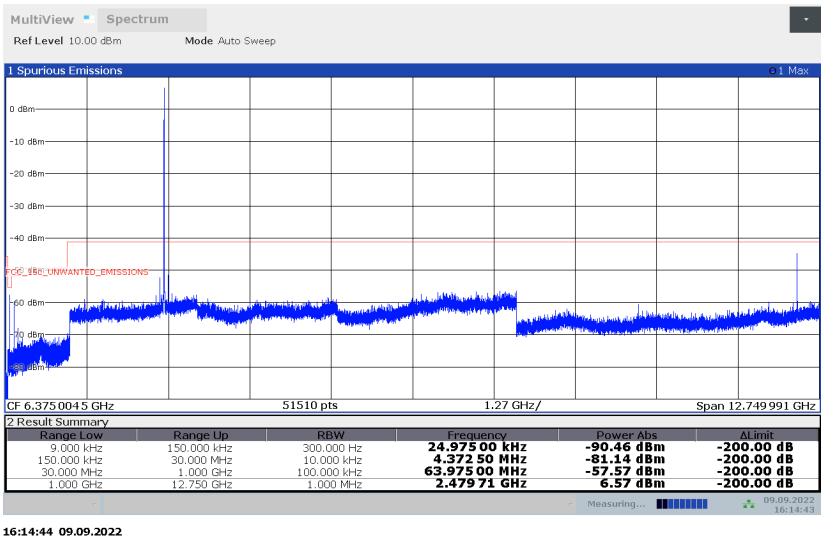
DT57121V1

Figure 22. IDB011V2 - Tx (2440 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band



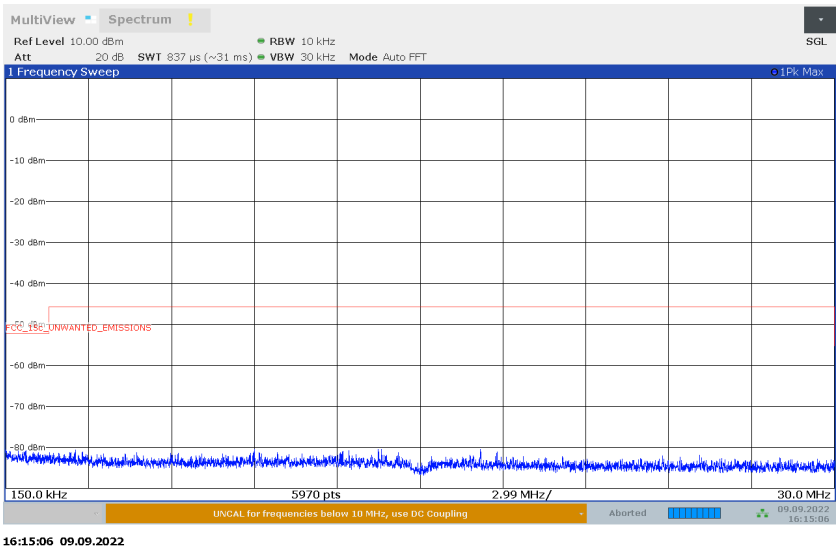
DT57122V1

Figure 23. IDB011V2 - Tx (2480 MHz) unwanted emissions full span



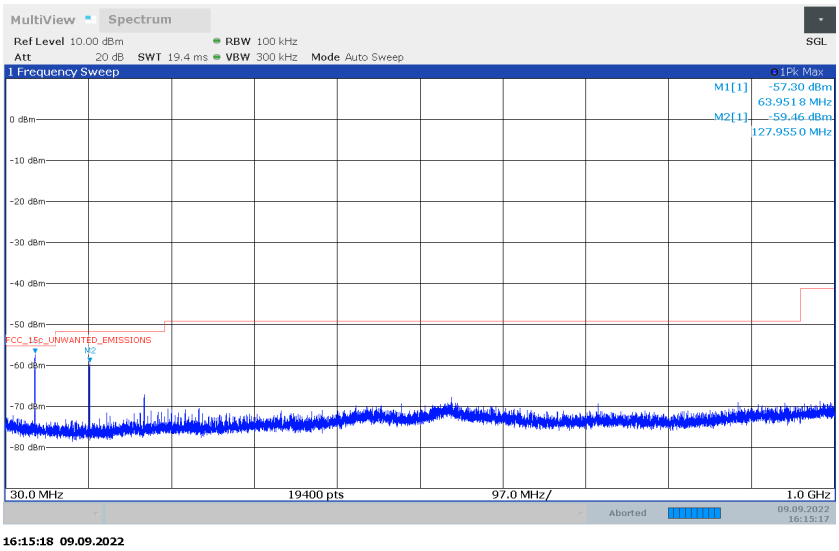
DT57123V1

Figure 24. IDB011V2 - Tx (2480 MHz) unwanted emissions in the 150 kHz - 30 MHz band



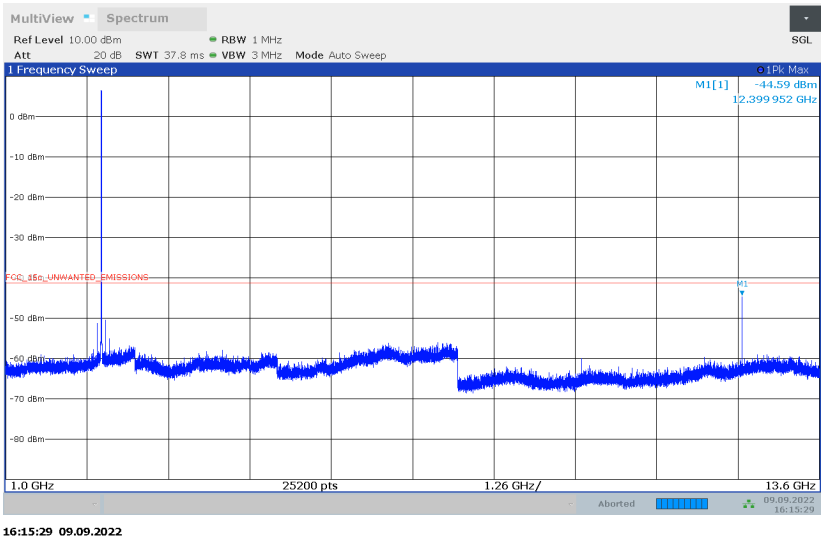
DT57124V2

Figure 25. IDB011V2 - Tx (2480 MHz) unwanted emissions in the 30 MHz - 1000 MHz band



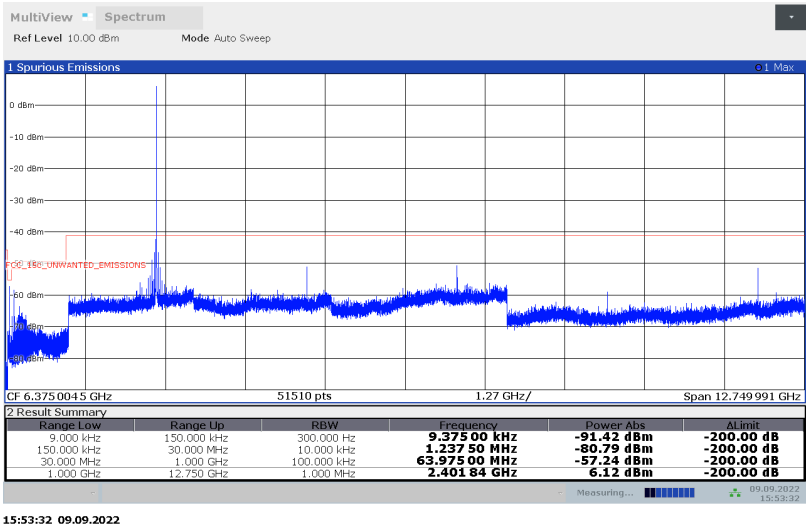
DT57125V1

Figure 26. IDB011V2 - Tx (2480 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band



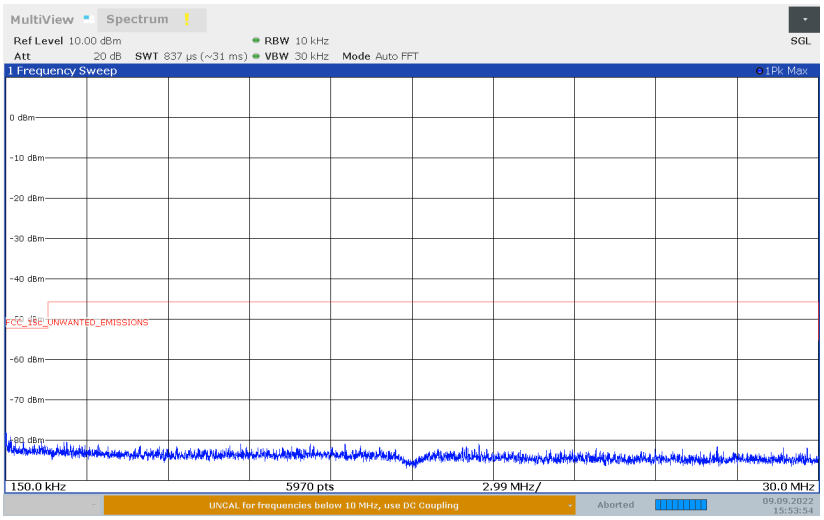
DT57126V1

Figure 27. **IDB012V1 - Tx (2402 MHz) unwanted emissions full span**



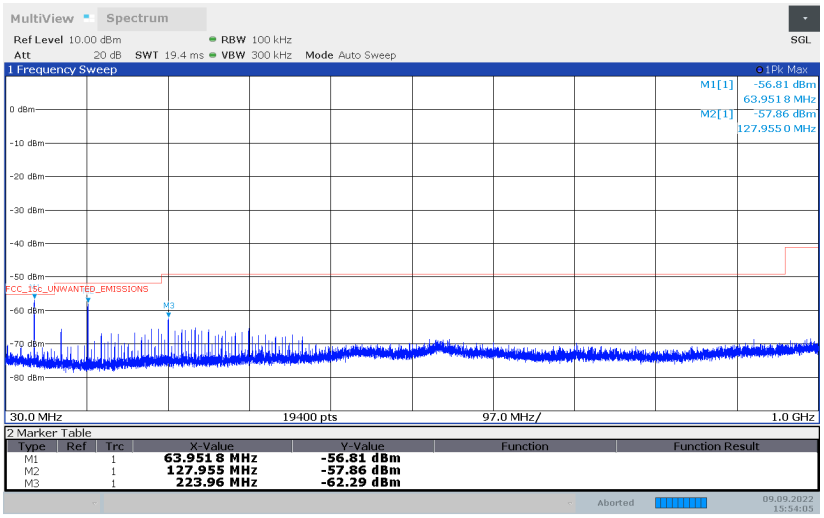
DT57127V1

Figure 28. **IDB012V1 - Tx (2402 MHz) unwanted emissions in the 150 kHz - 30 MHz band**



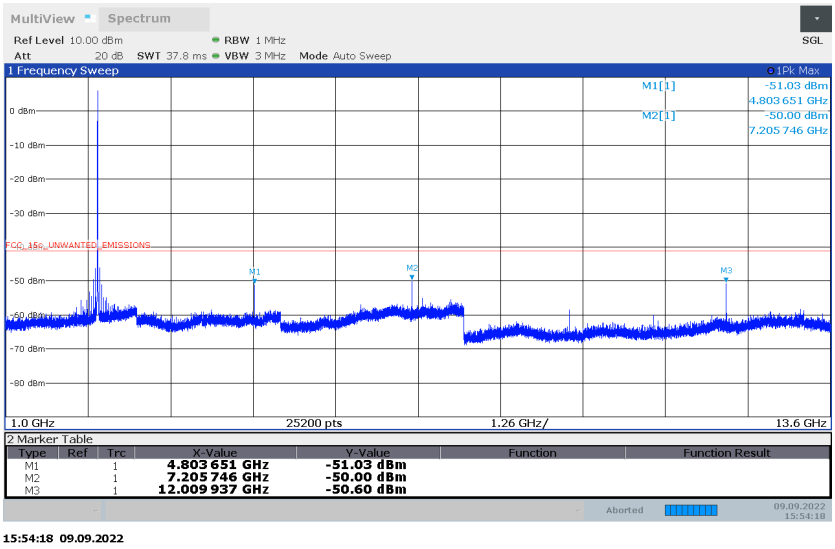
DT57128V1

Figure 29. IDB012V1 - Tx (2402 MHz) unwanted emissions in the 30 MHz - 1000 MHz band



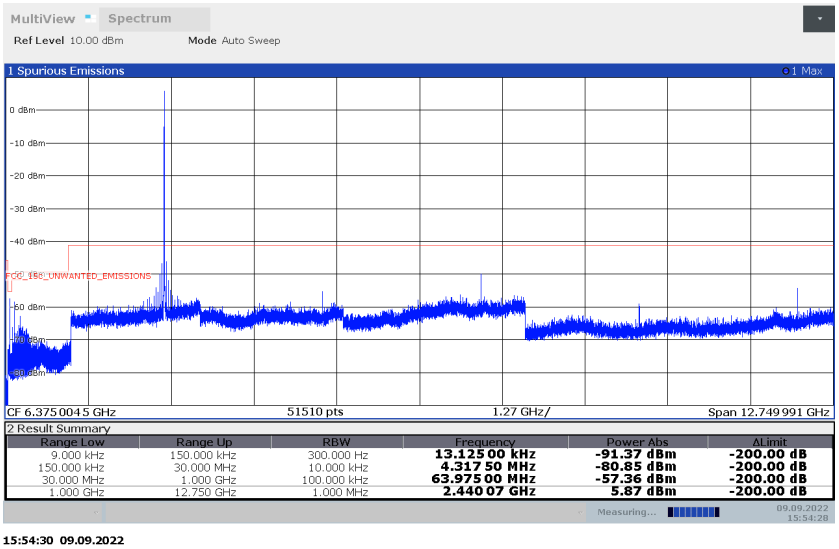
DT57129V1

Figure 30. IDB012V1 - Tx (2402 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band



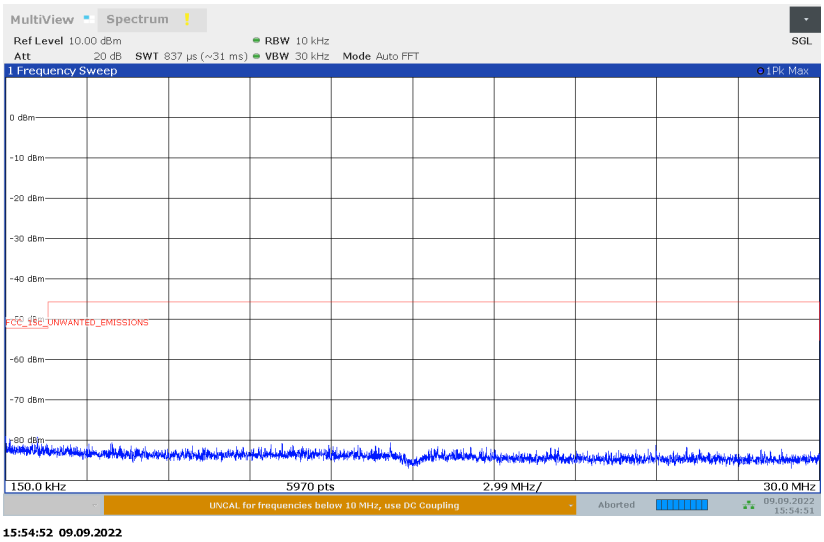
DT57130V1

Figure 31. **IDB012V1 - Tx (2440 MHz) unwanted emissions full span**



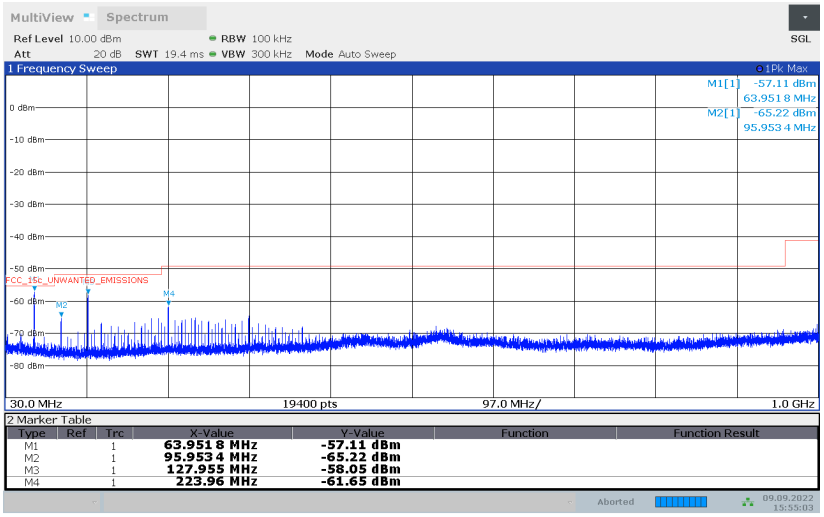
DT57131V1

Figure 32. **IDB012V1 - Tx (2440 MHz) unwanted emissions in the 150 kHz - 30 MHz band**



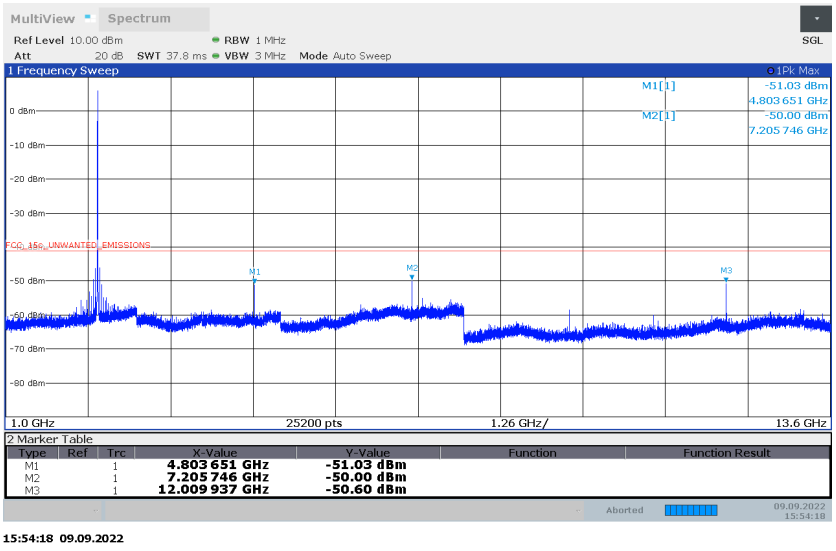
DT57132V1

Figure 33. IDB012V1 - Tx (2440 MHz) unwanted emissions in the 30 MHz - 1000 MHz band



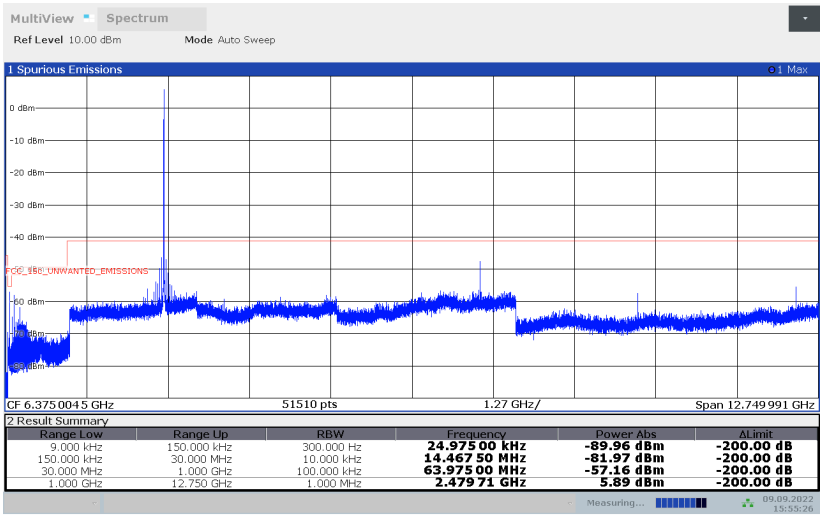
DT57133V1

Figure 34. IDB012V1 - Tx (2440 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band



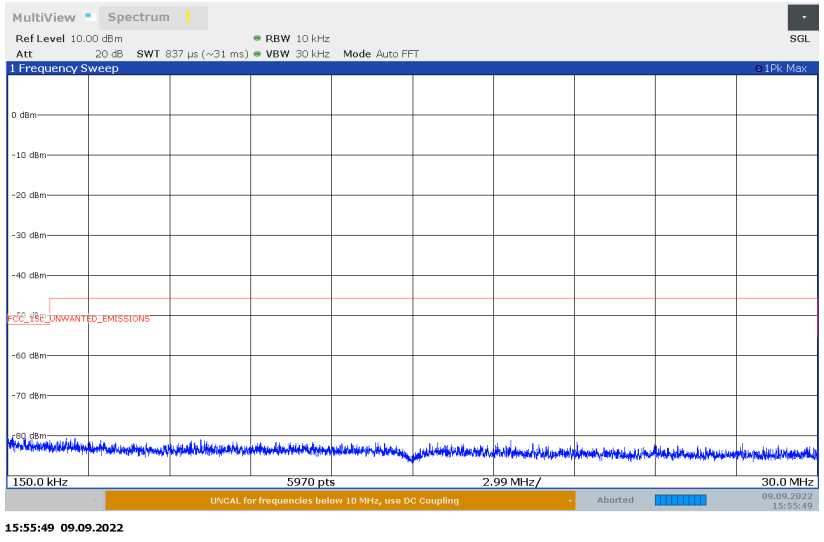
DT57134V1

Figure 35. **IDB012V1 - Tx (2480 MHz) unwanted emissions full span**



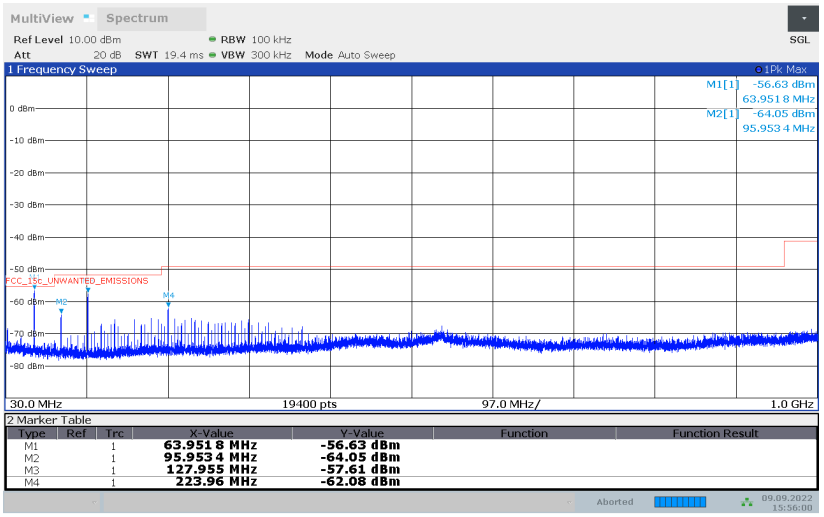
DT57135V1

Figure 36. **IDB012V1 - Tx (2480 MHz) unwanted emissions in the 150 kHz - 30 MHz band**



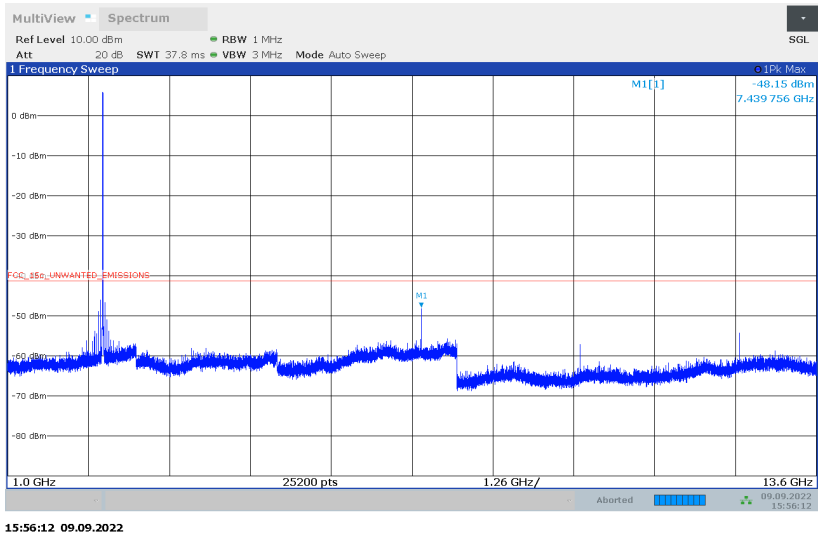
DT57136V1

Figure 37. **IDB012V1 - Tx (2480 MHz) unwanted emissions in the 30 MHz - 1000 MHz band**



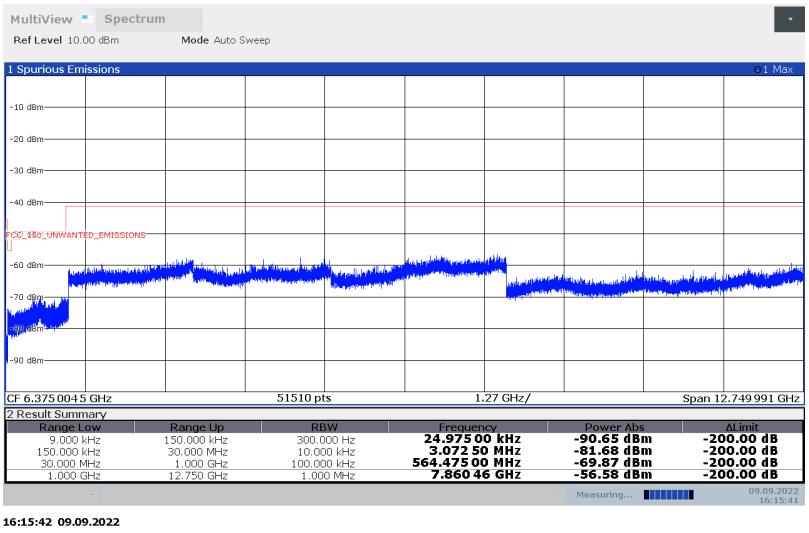
DT57137V1

Figure 38. **IDB012V1 - Tx (2480 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band**



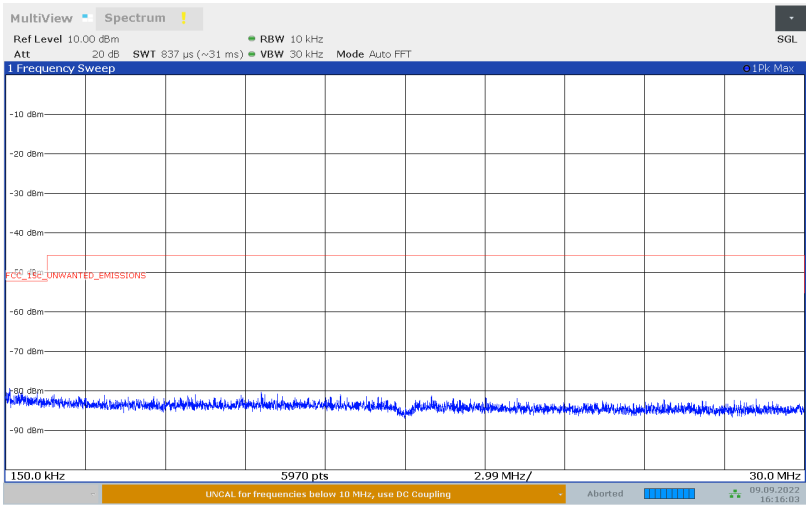
DT57138V1

Figure 39. **IDB011V2 - Rx (2402 MHz) unwanted emissions full span**



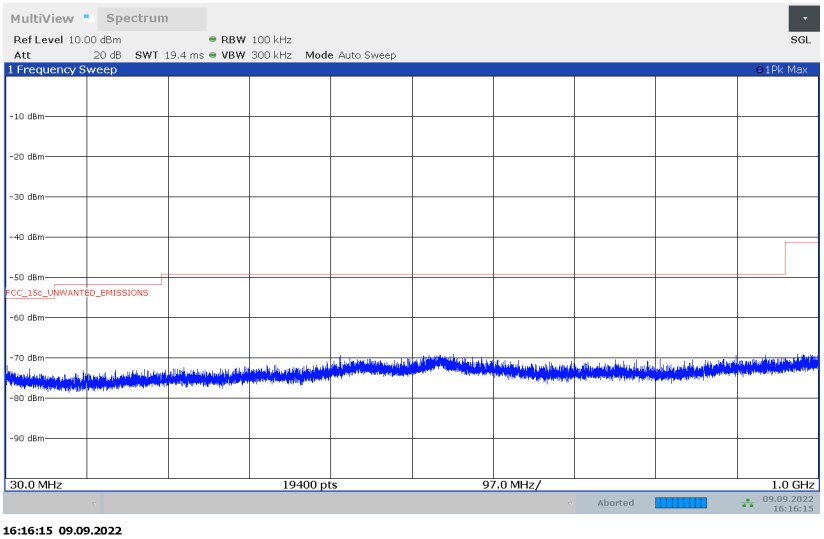
DT57139V1

Figure 40. **IDB011V2 - Rx (2402 MHz) unwanted emissions in the 150 kHz - 30 MHz band**



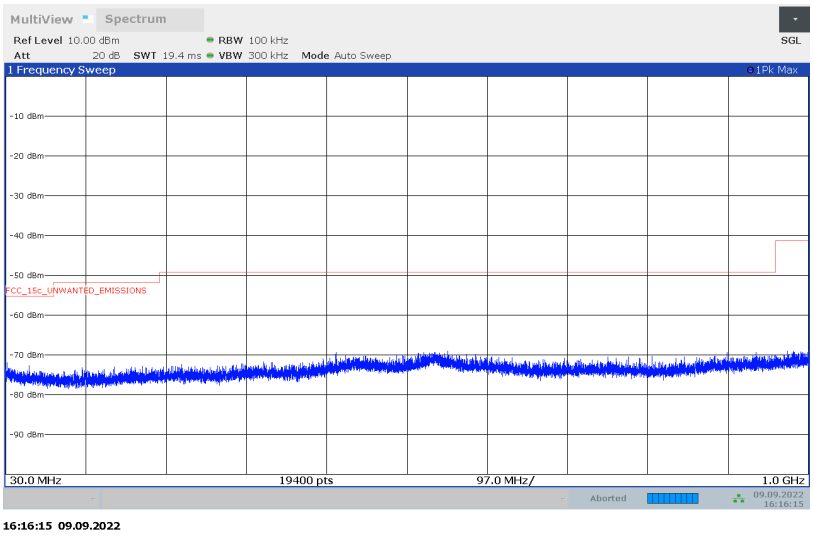
DT57140V1

Figure 41. **IDB011V2 - Rx (2402 MHz) unwanted emissions in the 30 MHz - 1000 MHz band**



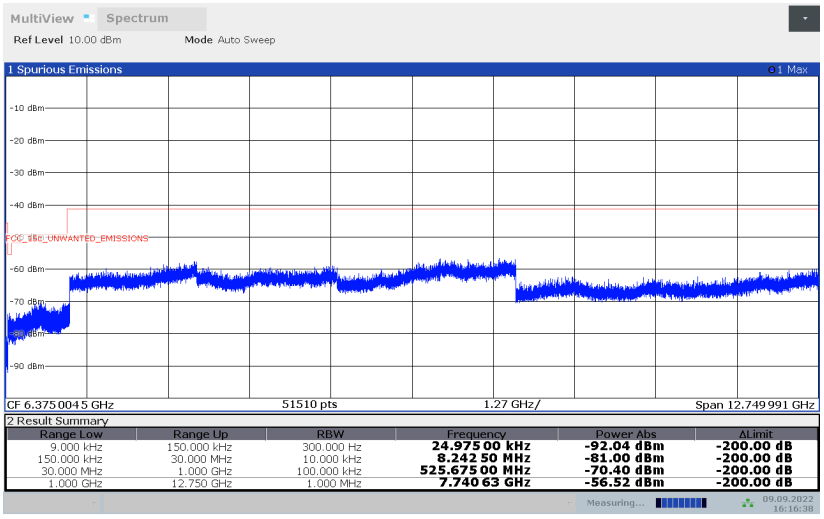
DT57141V1

Figure 42. **IDB011V2 - Rx (2402 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band**



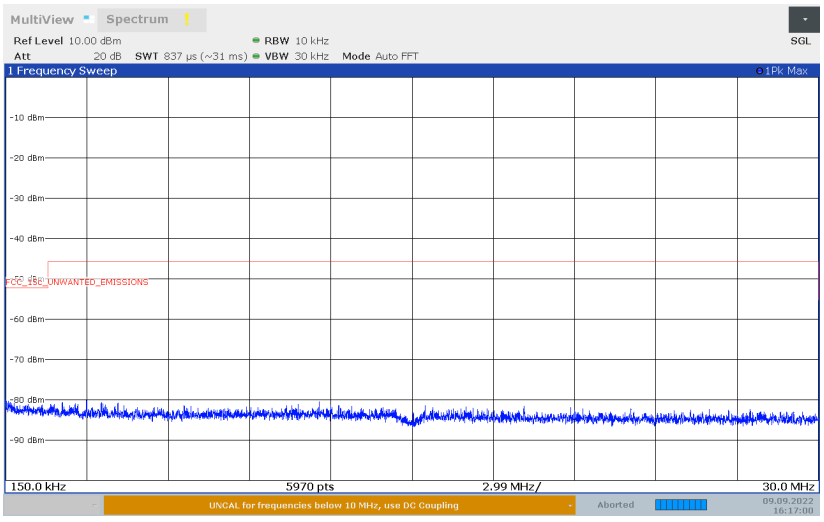
DT57142V1

Figure 43. IDB011V2 - Rx (2440 MHz) unwanted emissions full span



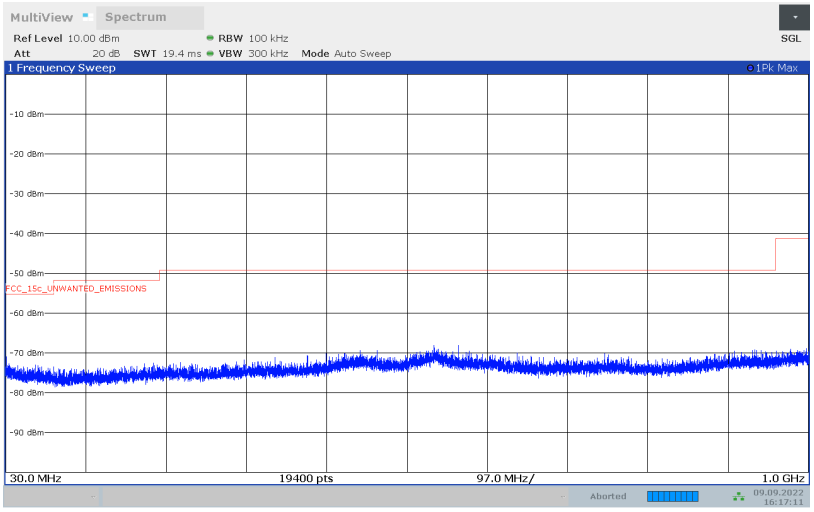
DT57143V1

Figure 44. IDB011V2 - Rx (2440 MHz) unwanted emissions in the 150 kHz - 30 MHz band



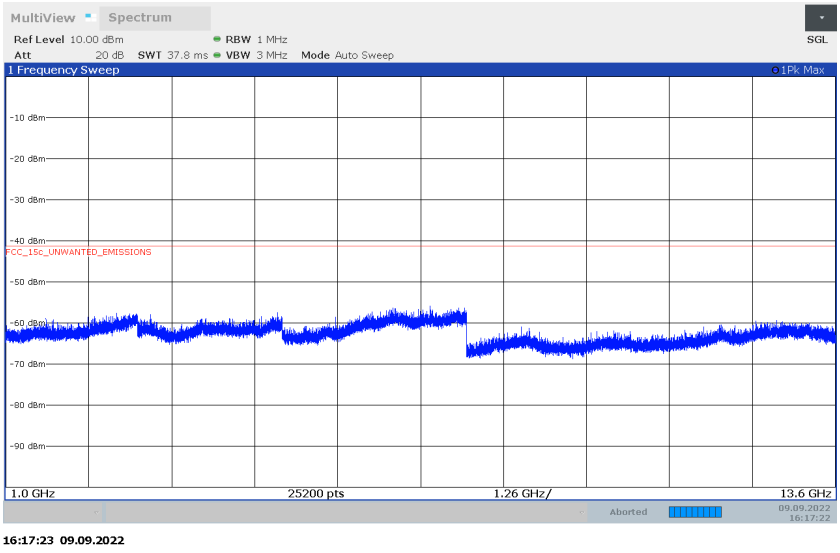
DT57144V1

Figure 45. IDB011V2 - Rx (2440 MHz) unwanted emissions in the 30 MHz - 1000 MHz band



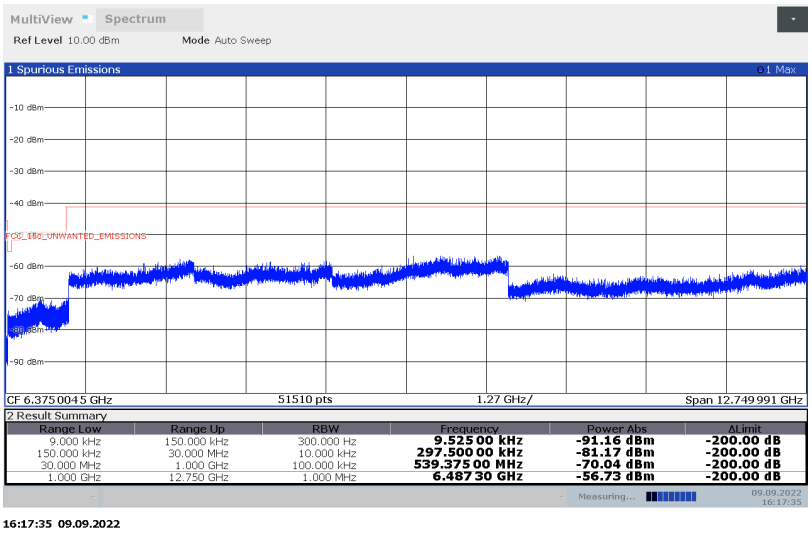
DT57145V1

Figure 46. IDB011V2 - Rx (2440 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band



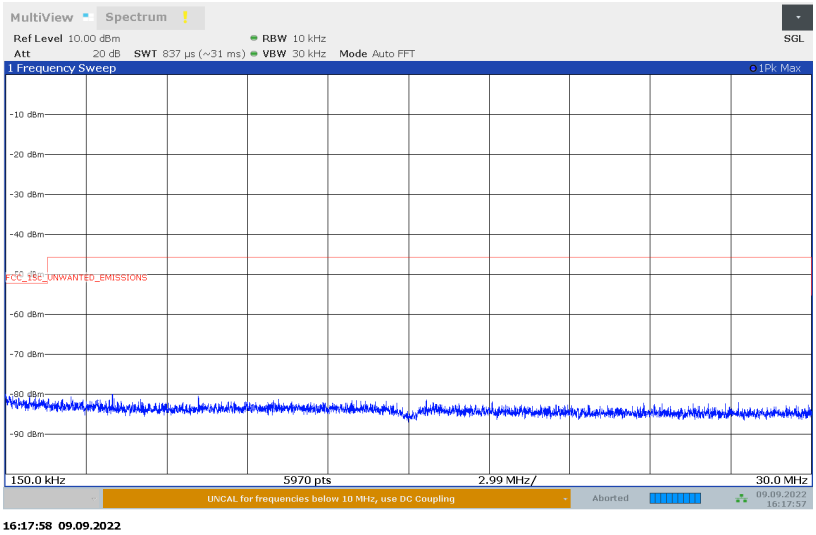
DT57146V1

Figure 47. **IDB011V2 - Rx (2480 MHz) unwanted emissions full span**



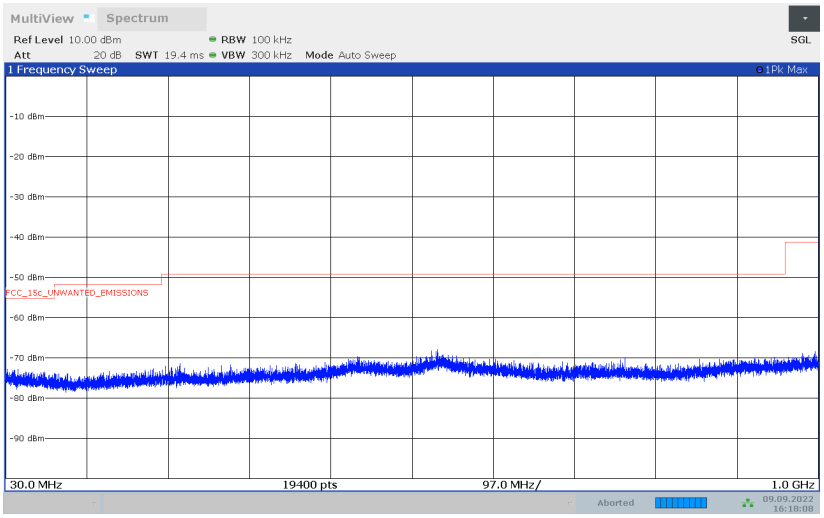
DT57147V1

Figure 48. **IDB011V2 - Rx (2480 MHz) unwanted emissions in the 150 kHz - 30 MHz band**



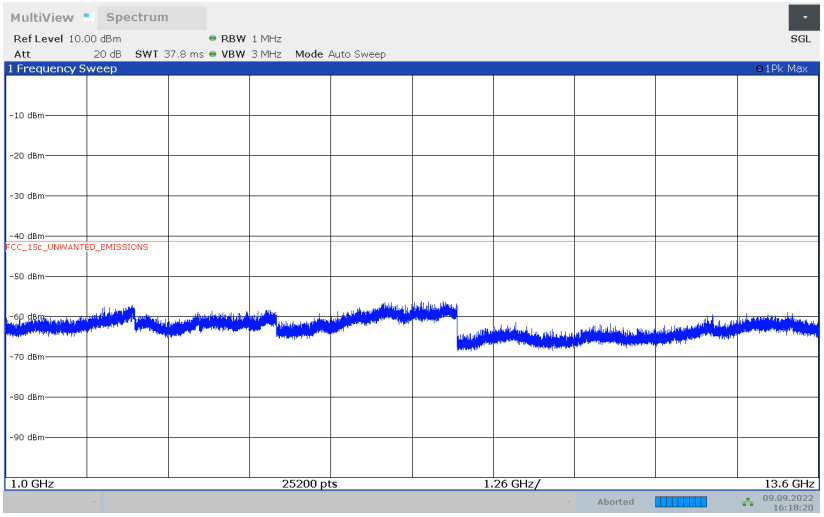
DT57148V1

Figure 49. **IDB011V2 - Rx (2480 MHz) unwanted emissions in the 30 MHz - 1000 MHz band**



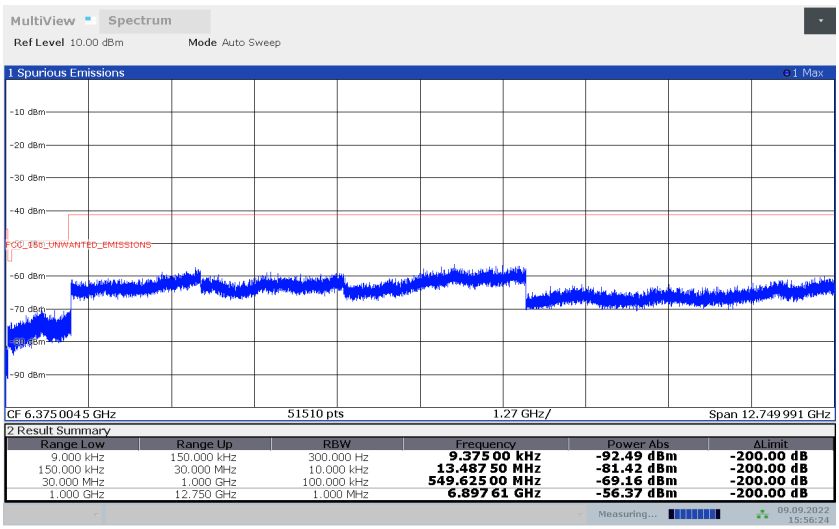
DT57149V1

Figure 50. **IDB011V2 - Rx (2480 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band**



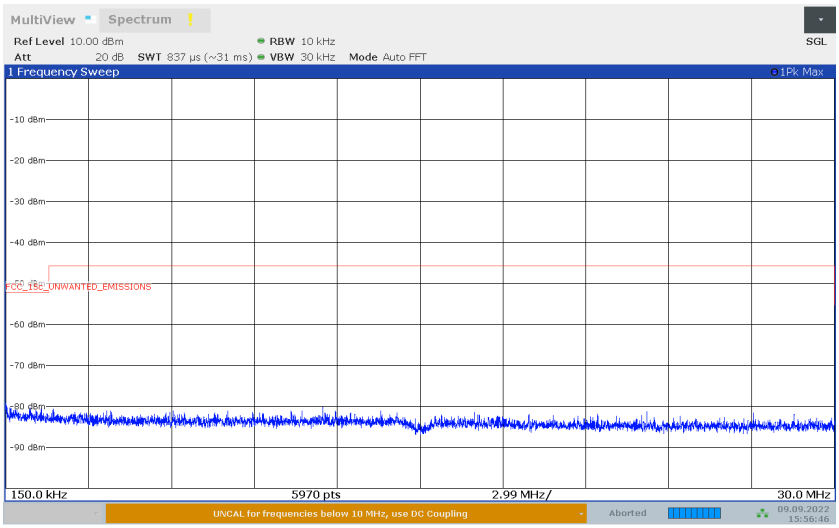
DT57150V1

Figure 51. IDB012V1 - Rx (2402 MHz) unwanted emissions full span



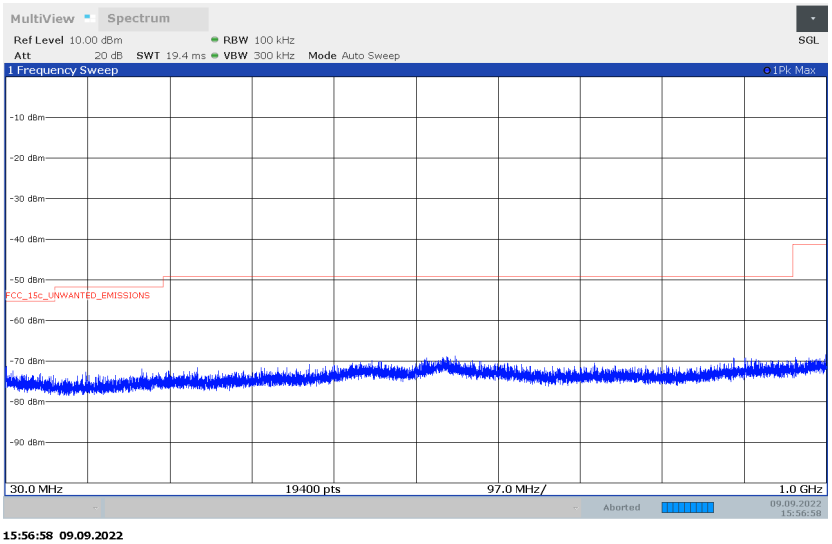
DT571151V1

Figure 52. IDB012V1 - Rx (2402 MHz) unwanted emissions in the 150 kHz - 30 MHz band



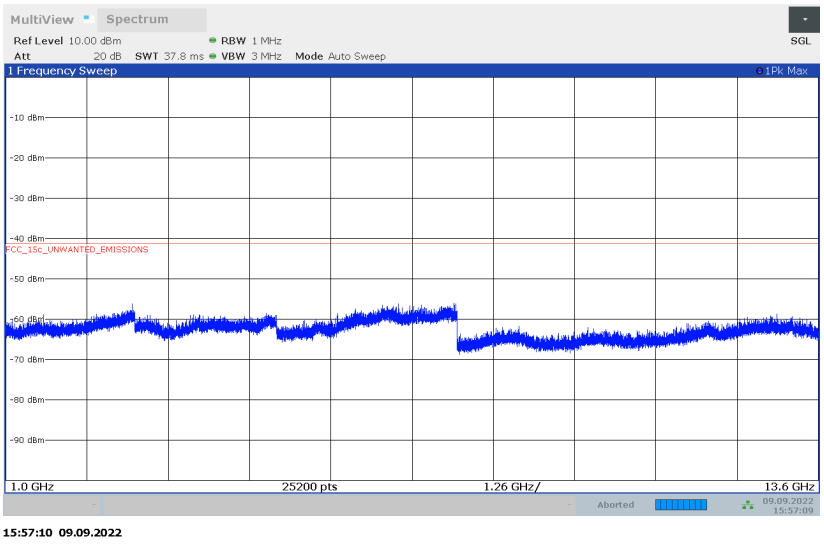
DT571152V1

Figure 53. **IDB012V1 - Rx (2402 MHz) unwanted emissions in the 30 MHz - 1000 MHz band**



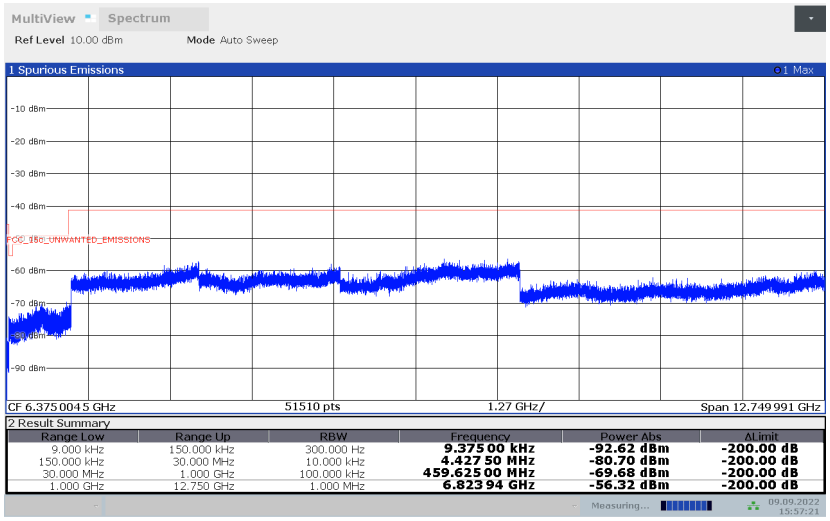
DT57153V1

Figure 54. **IDB012V1 - Rx (2402 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band**



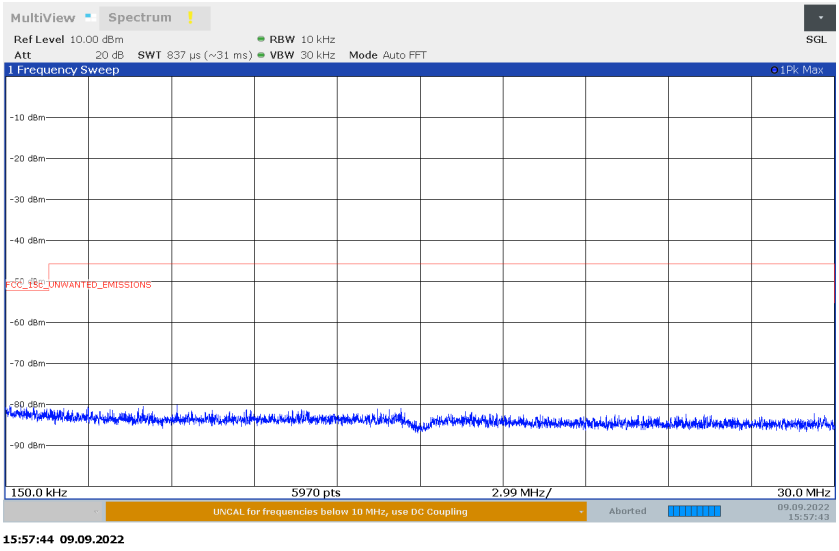
DT57154V1

Figure 55. **IDB012V1 - Rx (2440 MHz) unwanted emissions full span**



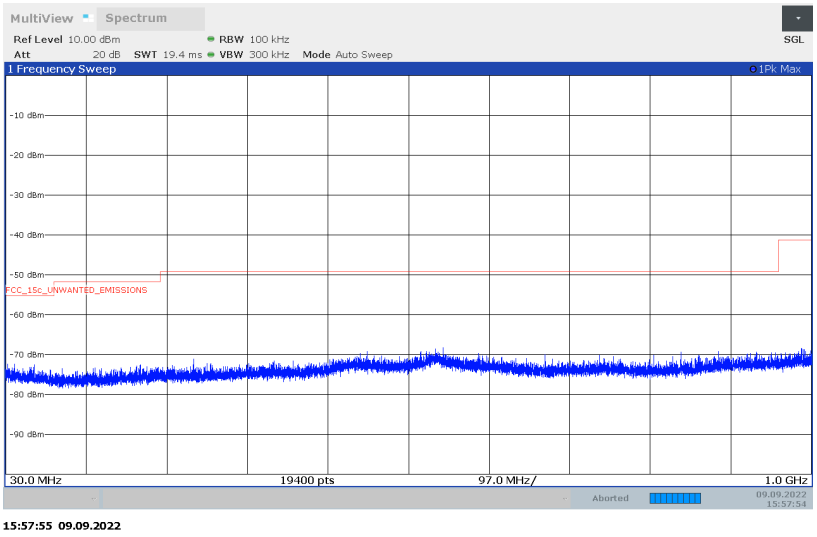
DT57155V1

Figure 56. **IDB012V1 - Rx (2440 MHz) unwanted emissions in the 150 kHz - 30 MHz band**



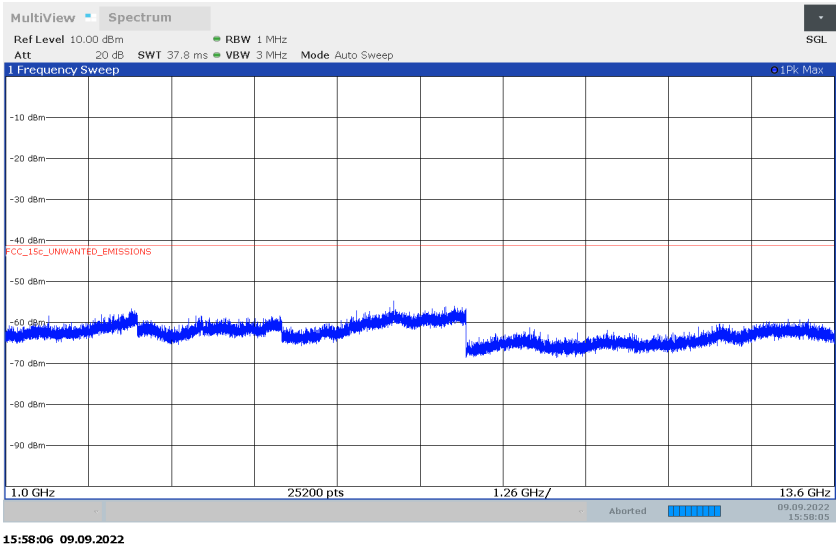
DT57156V1

Figure 57. **IDB012V1 - Rx (2440 MHz) unwanted emissions in the 30 MHz - 1000 MHz band**



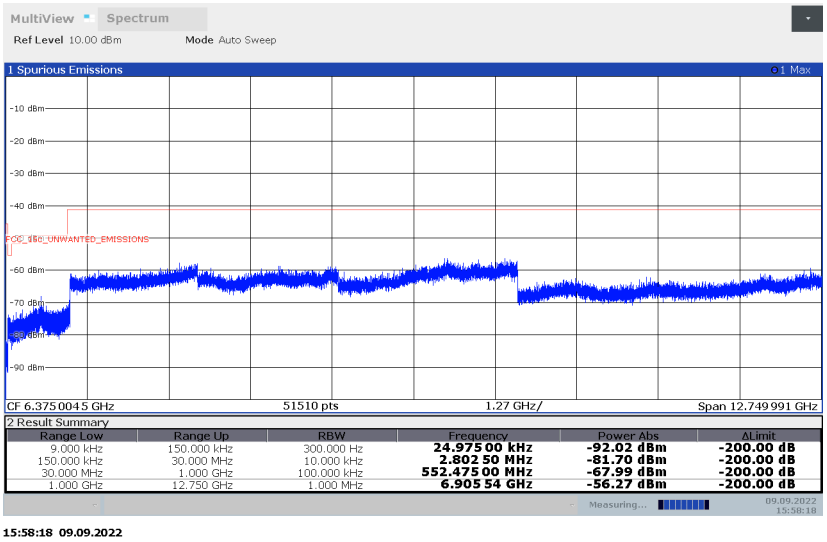
DT57157V1

Figure 58. **IDB012V1 - Rx (2440 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band**



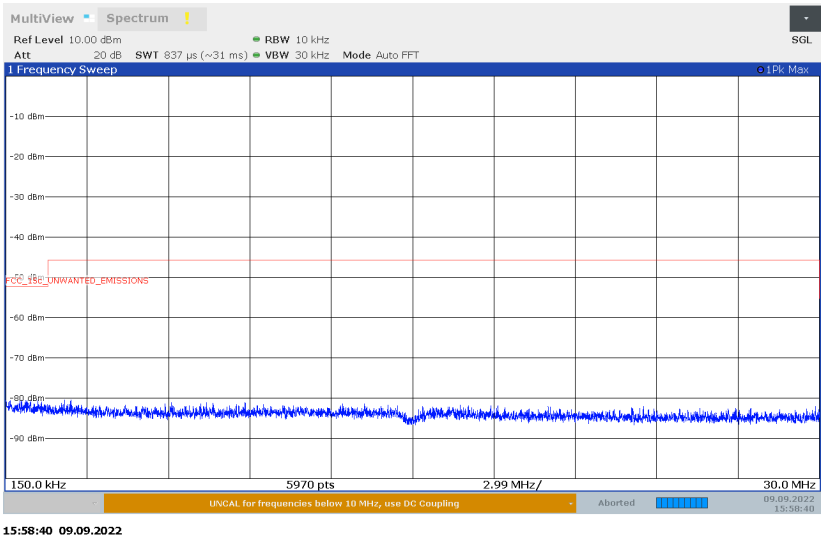
DT57158V1

Figure 59. **IDB012V1 - Rx (2480 MHz) unwanted emissions full span**



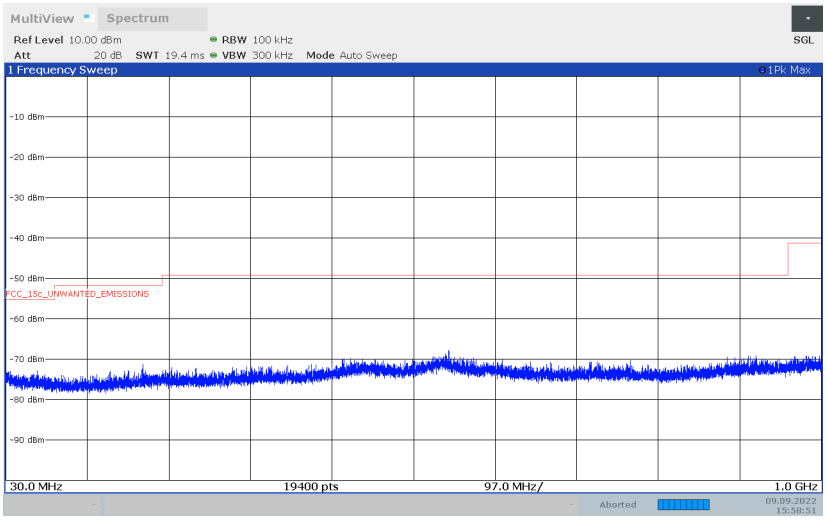
DT57159V1

Figure 60. **IDB012V1 - Rx (2480 MHz) unwanted emissions in the 150 kHz - 30 MHz band**



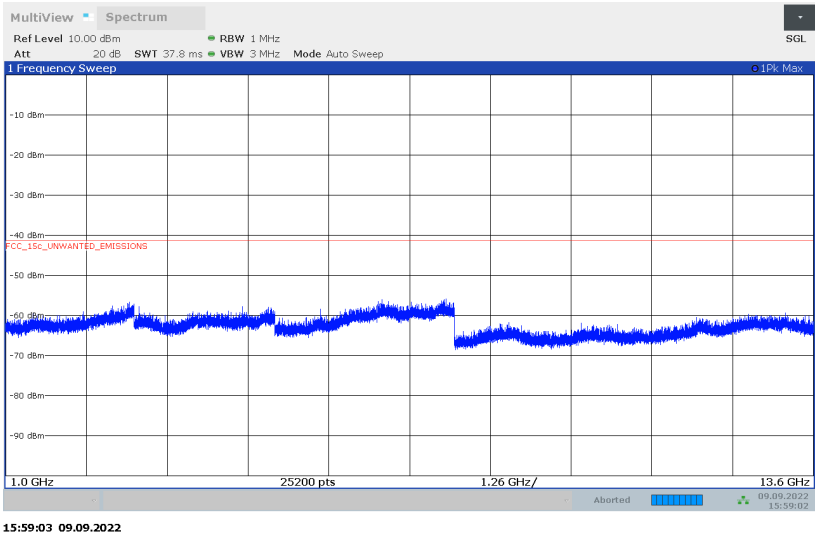
DT57160V1

Figure 61. IDB012V1 - Rx (2480 MHz) unwanted emissions in the 30 MHz - 1000 MHz band



DT57161V1

Figure 62. IDB012V1 - Rx (2480 MHz) unwanted emissions in the 1 GHz - 13.6 GHz band



DT57162V1

3.5 Band-edge compliance of RF conducted emissions

According to part 15.247, in any 100 kHz bandwidth outside the frequency bands in which the spread spectrum intentional radiator is operating, the radio frequency power that is produced by the intentional radiator is at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power. In addition, radiated emissions which fall in the restricted bands, as defined in part 15.205, must also comply with the radiated emission limits specified in part 15.209.

Two different measurement methods are defined in [3]:

- Marker-delta method
- Integration method with three different cases
  - EUT can be configured to transmit continuously (paragraph 13.3.1)
  - EUT cannot be configured to transmit continuously but the duty cycle is constant (paragraph 13.3.2)
  - EUT cannot be configured to transmit continuously and the duty cycle is not constant (paragraph 13.3.3)

When performing peak or average radiated measurements, emission within 2 MHz of the authorized band edge may be measured using the marker-delta method. The integration method can be used when performing conducted or radiated average measurements.

The BlueNRG-LP/LPS devices can be programmed to transmit continuously so the marker-delta method is used. The instrument setting is done according to [3]:

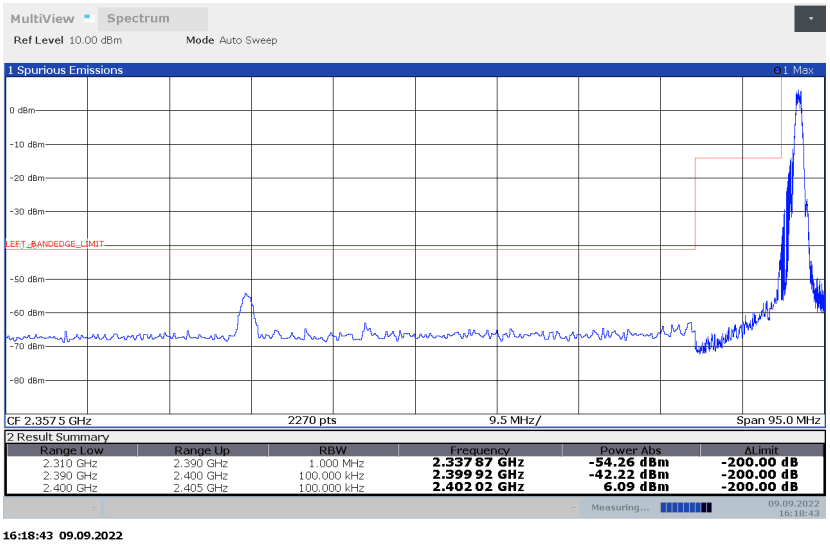
- Set the instrument center frequency to the frequency of the band edge to be measured
- Span = 10 MHz
- RBW = 100 kHz
- VBW ≥ 3 x RBW
- Sweep time = auto
- Detector function = peak
- Trace = max hold

Record the peak level of the fundamental emission at the relevant band edge emission. Then measure the amplitude delta between the peak of the fundamental and the peak of the band edge emission. This is not a field strength measurement, it is only a relative measurement to determine the amount by which the emission drops at the band edge relative to the highest fundamental emission level.

The conducted emissions in the band edge @ 2.4 GHz are fully compliant with the specification.

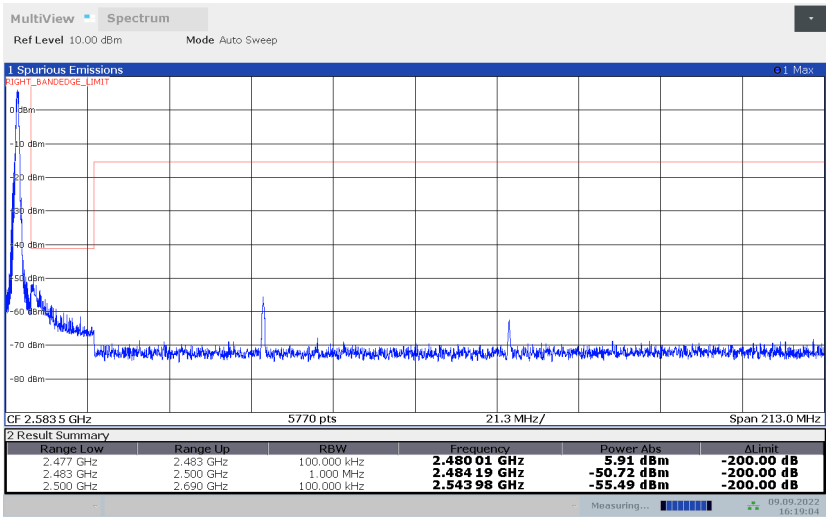
The level of the unwanted emission for frequencies higher than 2.4835 GHz has to be below -41 dBm. In this case a 1 MHz bandwidth has been used.

Figure 63. IDB011V2 Band edge measurement at 2.4 GHz



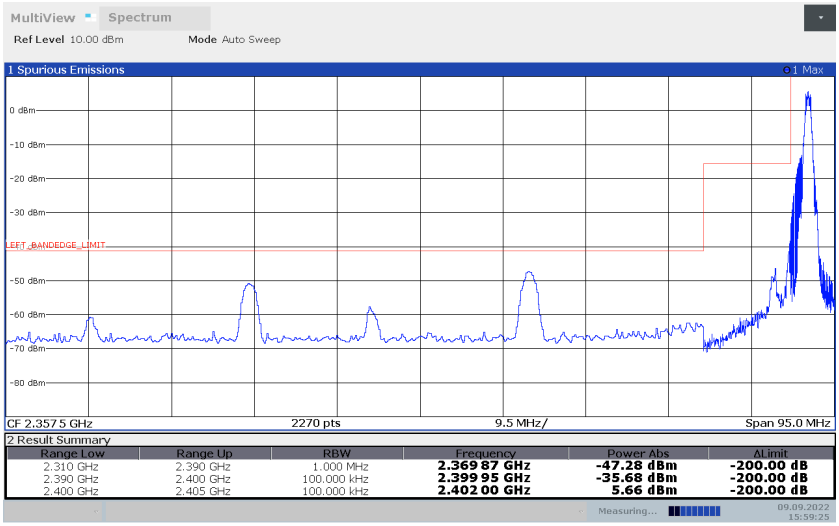
DT57163V1

Figure 64. **IDB011V2 Band edge measurement at 2.4835 GHz**



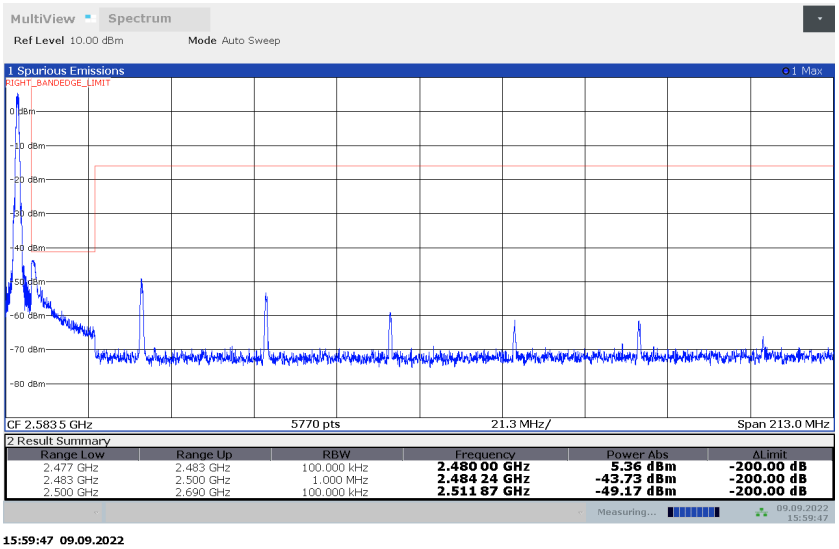
DT57164V1

Figure 65. **IDB012V1 Band edge measurement at 2.4 GHz**



DT57165V1

Figure 66. **IDB012V1 Band edge measurement at 2.4835 GHz**



DT57166V1

4 Receiver parameter

No specific requirements are defined for FCC compliance of the receiver in US FCC Title 47 Part 15 [2] in the 2400 to 2483.5 MHz band.

The only requirement is about the level of the unwanted emission when the BlueNRG-LP/LPS devices are in RX. This point has been reported in Section 3.4 Unwanted emissions, so no further measurements have been done.

5 Reference

Table 6. Document reference

Reference	Document
[1]	BlueNRG-LP/LPS datasheet
[2]	FCC title 47 part 15: “Radio frequency devices”
[3]	"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", 558074 D01 15.247 Meas Guidance v05r02, April 2, 2019
[4]	ANSI C63.10-2013
[5]	http://www.scc-ares-races.org/FCCpartstitles.html
[6]	https://www.fcc.gov/general/equipment-authorization-measurement-procedures

Revision history

Table 7. **Document revision history**

Date	Version	Changes
30-Oct-2020	1	Initial release.
09-Dec-2022	2	Updated: • Replaced any occurrence of BlueNRG-LP with BlueNRG-LP/LPS • Section 2 Application circuit, Section 3 Transmitter parameter, Section 3.4 Unwanted emissions • Figure 1 • Table 3 Added: • Figure 2, Figure 3 to Figure 8, Figure 9 to Figure 14, Figure 15 to Figure 62, Figure 63 to Figure 66 • Table 4

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