Using the BlueNRG-LP/LPS transceiver under ETSI EN 300 328 in 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 the BlueNRG-LP/LPS under ETSI EN 300 328 in the 2400 to 2483.5 MHz band.

For details on the regulatory limits in 2400 - 2483.5 MHz frequency band, refer to ETSI EN 300 328 V2.2.2 (2019-07) in www.etsi.org.

1 An overview of ETSI regulations

The use of radio equipment in most European countries is regulated through the RED directive. The European telecommunications standard institute (ETSI) is a standardization body that issues the standards for testing and type approval of transmitters and receivers. EN 300 328 covers the 2.4 GHz band and specifies in detail the requirements and test methods to be used for license-free operated radio equipment under class 3a, equipment using wideband modulation techniques (DSSS or FHSS).

The standard defines two categories of equipment based on the modulation type:

- Frequency hopping spread spectrum (FHSS)
- Other types of wide band modulation (e.g. DSSS, OFDM, etc.). It also covers both adaptive and non-adaptive equipment.

Adaptive equipment uses an automatic mechanism, which allows the equipment to adapt automatically to its environment by identifying frequencies that are being used by other equipment.

ETSI classifies BLE as adaptive equipment (when an adaptive mode is implemented) using DSSS modulation.

ETSI, in the latest version of this specification, defines three different receiver categories for which different receiver requirements and/or corresponding limits apply.

- **Receiver category 1**
  Adaptive equipment with a maximum RF output power greater than 10 dBm EIRP.
- **Receiver category 2**
  Non-adaptive equipment with a Medium Utilization (MU) factor greater than 1 % and less than or equal to 10 % (irrespective of the maximum RF output power); or an equipment (adaptive or non-adaptive) with a maximum RF output power greater than 0 dBm e.i.r.p. and less than or equal to 10 dBm e.i.r.p.
- **Receiver category 3**
  Non-adaptive equipment with a maximum Medium Utilization (MU) factor of 1 % (irrespective of the maximum RF output power); or an equipment (adaptive or non-adaptive) with a maximum RF output power of 0 dBm e.i.r.p.

BLE equipments with a maximum RF output power of 10 dBm can be classified as receiver category 2 devices.

2 Technical requirements

RF output power

The RF output power is defined as the mean equivalent isotropic radiated power (e.i.r.p.) of the equipment during a transmission burst.

The max. allowed limit is -10 dBW (20 dBm, 100 mW).

Power spectral density

It is the mean equivalent isotropically radiated power spectral density during a transmission burst.

Its value is limited to 10 dBm per MHz.

Occupied channel bandwidth

It is the bandwidth that contains 99% of the power of the signal. It falls completely within the band 2.4 GHz to 2.4835 GHz.

Transmitter unwanted emissions in the out-of-band domain

They are emissions when the equipment is in transmit mode, on frequencies immediately outside the necessary bandwidth, which results from the modulation process, but excluding spurious.

The transmitter unwanted emissions in out-of-band domain but outside the allocated band, do not exceed the values provided by the mask in Table 1.

Table 1. Transmitter in out-of-band domain

Frequency range	Transmit mask level	Domain
<2396 MHz	-	Spurious
2396 to 2398 MHz	- 20 dBm/MHz	Out of band
2398 to 2400 MHz	- 10 dBm/MHz	Out of band
2400 to 2483.5 MHz	-	Allocated band
2483.5 to 2485.5 MHz	-10 dBm/MHz	Out of band
2485.5 to 2487.5 MHz	-20 dBm/MHz	Out of band
>2487.5 MHz	-	Spurious

Transmitter unwanted emissions in the spurious domain

Transmitter unwanted emissions in the spurious domain are emissions outside the allocated band and outside the out-of-band domain (as specified in the previous table), when the equipment is in transmit mode.

The transmitter unwanted emissions in the spurious domain do not exceed the values given in Table 2.

Table 2. Transmitter spurious emissions requirements

Frequency range	Maximum power, e.r.p. (≤1GHz) e.i.r.p.(>1 GHz)	Bandwidth
30 MHz to 47 MHz	-36 dBm	100 kHz
47 MHz to 74 MHz	-54 dBm	100 kHz
74 MHz to 87.5 MHz	-36 dBm	100 kHz
87.5 MHz to 118 MHz	-54 dBm	100 kHz
118 MHz to 174 MHz	-36 dBm	100 kHz
174 MHz to 230 MHz	-54 dBm	100 kHz
230 MHz to 470 MHz	-36 dBm	100 kHz
470 MHz to 862 MHz	-54 dBm	100 kHz
862 MHz to 1 GHz	-36 dBm	100 kHz
1 GHz to 12.75 GHz	-30 dBm	1 MHz

Receiver spurious emissions

Receiver spurious emissions are emissions at any frequency when the equipment is in receive mode. They do not exceed the values given in Table 3.

The table presented in clause 4.3.2.11.4.3 of [2] is reported below and contains the Receiver Blocking parameters for Receiver Category 2 equipment.

Table 3. Receiver spurious emissions requirements

Frequency range	Maximum power, e.r.p.	Measurement bandwidth
30 MHz to 1 GHz	-57 dBm	100 kHz
1 GHz to 12.75 GHz	-47 dBm	1 MHz

Receiver blocking

Receiver blocking is a measure of the ability of the equipment to receive a wanted signal on its operating channel without exceeding a given degradation in the presence of an unwanted signal (blocking signal) at frequencies other than those of the operating band.

The minimum performance criterion is a PER less than or equal to 10%.

Table 4. Receiver blocking

Wanted signal mean power from companion devive (dBm)(1)(2)(3)	Blocking signal frequency [MHz]	Blocking signal power (dBm)(3)	Type of blocking signal
(-139 dBm + 10 × log10(OCBW) + 10 dB) or (-74 dBm + 10 dB) whichever is less(2)	2380 2504 2300 2584	-34	CW

1. *OCBW is in Hz.*
2. *In case of radiated measurements using a companion device and the level of the wanted signal from the companion device cannot be determinated, a relative test may be perfomed using a wanted signal up to P_{min} + 26 dB where P_{min} is the minumum level of wanted signal required to meet the minimum perfomance criteria as defined in clause 4.3.1.12.3 in the absence of any blocking signal.*
3. *The level specified is the level at the UUT receiver input assuming a 0 dBi antenna assembly gain. In case of conducted measurements, this level has to be corrected for the (in-band) antenna assembly gain (G). In case of radiated measurements, this level is equivalent to a power flux density (PFD) in front of the UUT antenna with the UUT being configured/positioned as recorded in clause 5.4.3.2.2.*

3 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 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

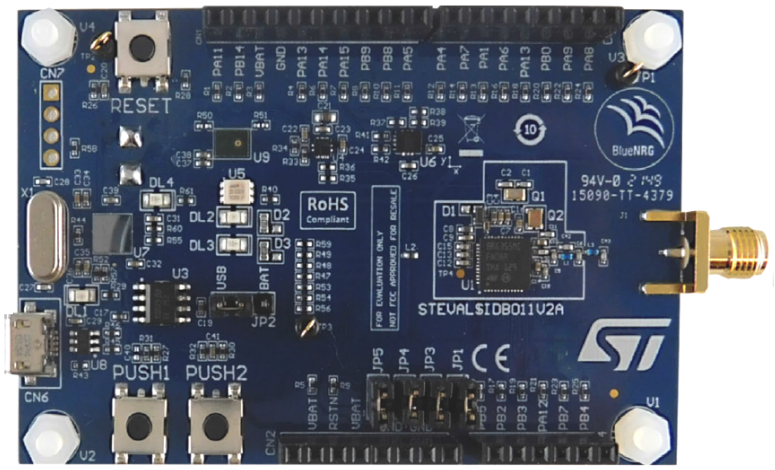

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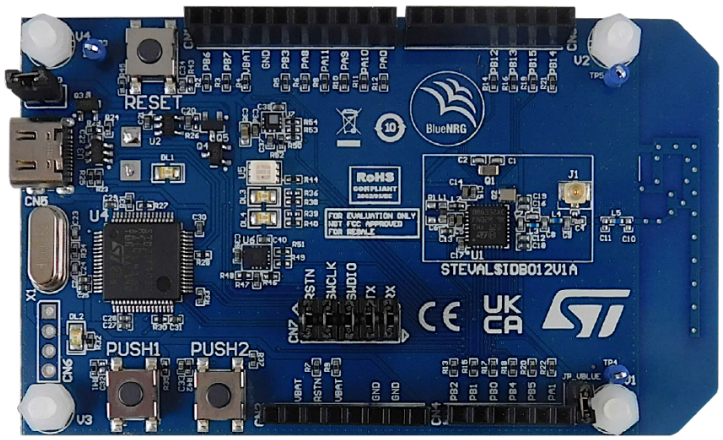
Figure 2. BlueNRG-LPS application board



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4 Transmitter parameter

All the measurements here reported 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 frequencies 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.

4.1 RF output power

In case of the RF output power conducted measurements, the equipment has to be connected to a fast power sensor suitable for 2.4 GHz and capable of minimum 1 MS/s.

The measurements have been performed using a spectrum analyzer with the following settings:

- Center frequency: 2402 MHz (ch 0), 2440 MHz (ch 19) and 2480 MHz (ch 39)
- Span = 4 MHz
- RBW = 1 MHz
- VBW = 1 MHz
- Detector = peak
- Trace = max. hold
- Sweep time = auto

The equipment is programmed to provide a single tone. The marker is set to max.

The measurement results are shown in the following table. The BlueNRG family fully satisfies with the ETSI max. permitted output power specification of +20 dBm.

Table 5. IDB011V2 - RF output power

Frequency [MHz]	Output power [dBm]	ETSI spec [dBm]
2402	+7.9	+20
2440	+7.9	+20
2480	+7.9	+20

Table 6. IDB012V1 - RF output power

Frequency [MHz]	Output power [dBm]	ETSI spec [dBm]
2402	+7.5	+20
2440	+7.3	+20
2480	+7.3	+20

4.2 Power spectral density

The measurement is performed at the lowest, the middle, and the highest channel on which the equipment can operate.

The transmitter is connected to a spectrum analyzer with the following settings:

- Center frequency: 2402 MHz (ch 37), 2440 MHz (ch 18) and 2480 MHz (ch 39)
- Span = 3 MHz
- RBW = 1 MHz
- VBW = 3 MHz
- Detector = peak
- Trace = max. hold
- Sweep time = auto

Find the peak value of the trace and place the analyzer marker on this peak. This level is the highest mean power (power spectral density) in a 1 MHz band.

The measurement in the three channels show a value in line with the limit: 10 dBm/MHz.

Figure 3. IDB011V2 - PSD 2402 MHz

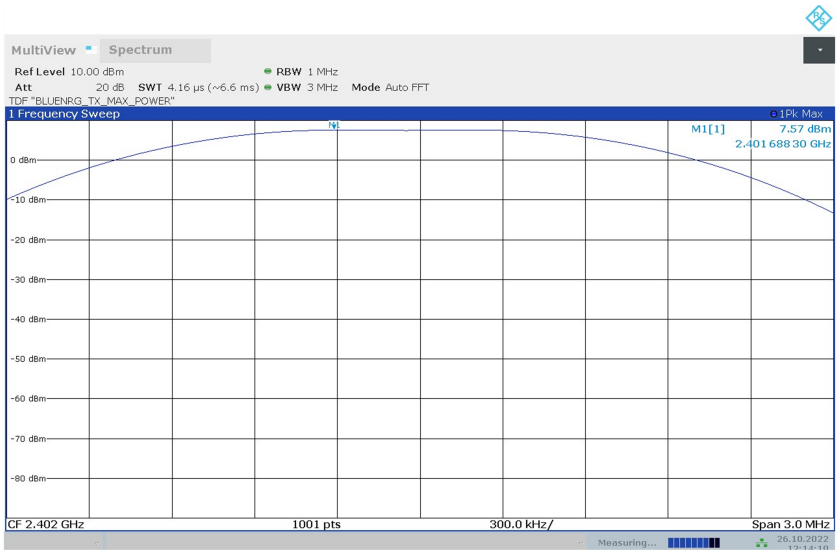

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Figure 4. IDB011V2 - PSD 2440 MHz

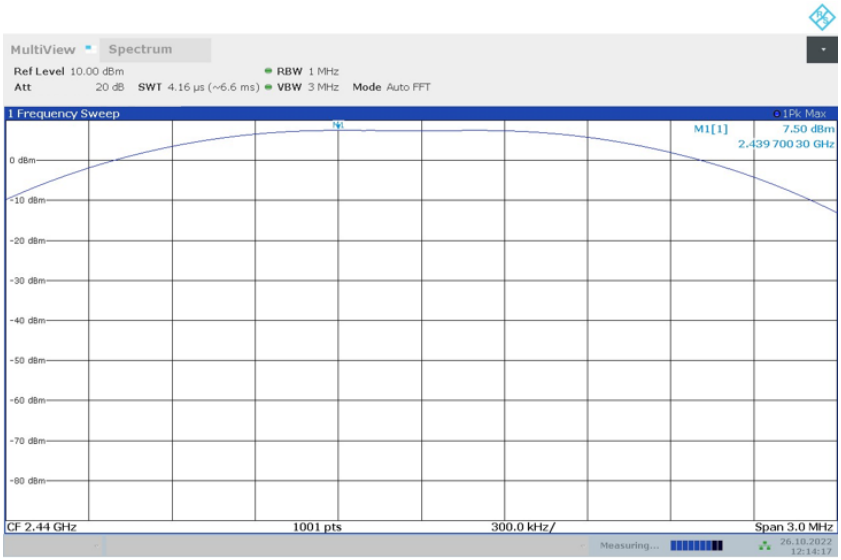

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Figure 5. **IDB011V2 - PSD 2480 MHz**

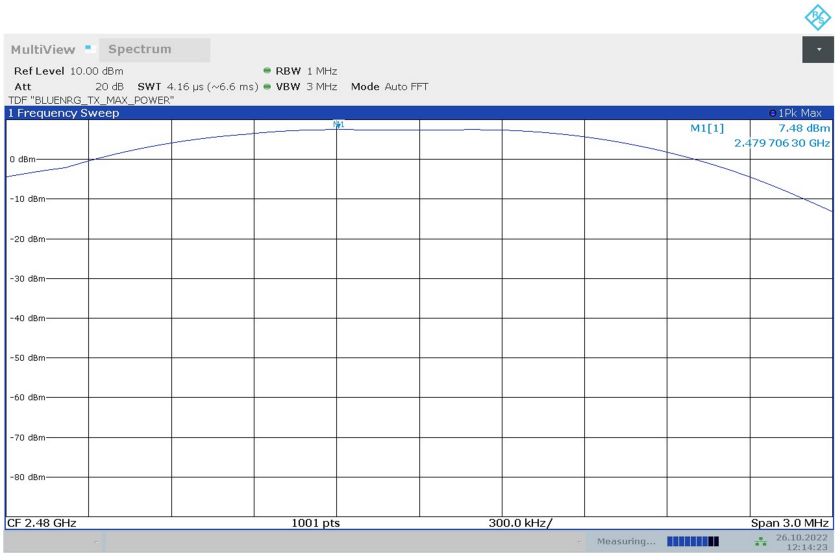

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Figure 6. **IDB012V1 - PSD 2402 MHz**

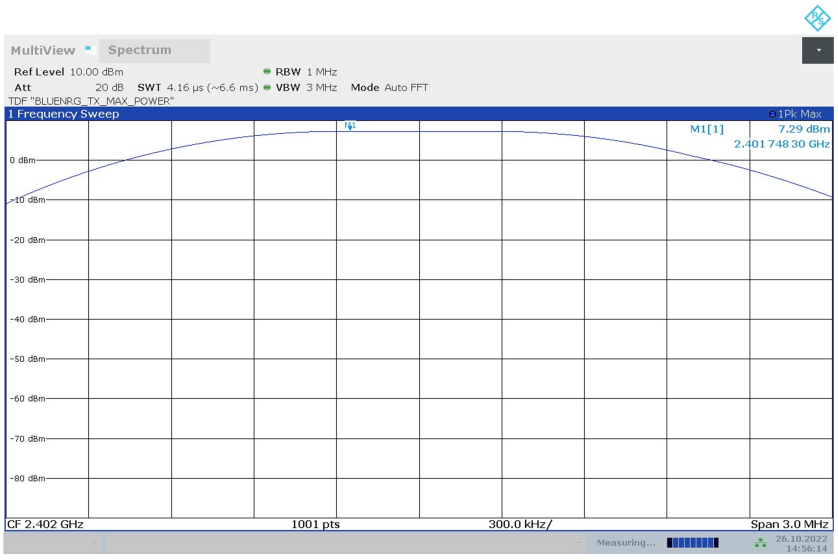

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Figure 7. **IDB012V1 - PSD 2440 MHz**

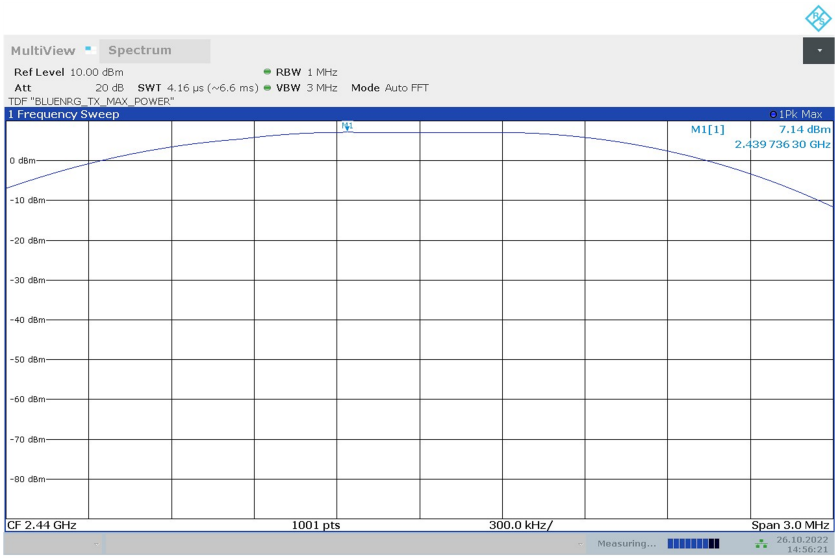

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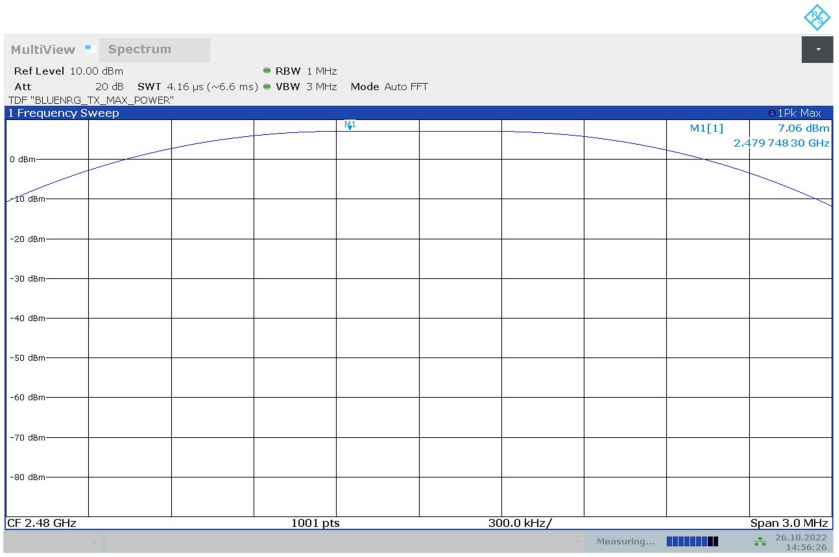
Figure 8. **IDB012V1 - PSD 2480 MHz**



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4.3 Occupied channel bandwidth

The measurement is performed at the lowest and highest frequencies within the stated frequency range.

The spectrum analyzer must be set with:

- Center frequency: 2402 MHz (ch 37) and 2480 MHz (ch 39)
- Span = 2 x nominal channel bandwidth (2 MHz), that is 4 MHz
- RBW = ≥ 1 % of the span
- VBW = 3 x RBW
- Detector = RMS
- Trace = max. hold
- Sweep time = 1 s

Find the peak value of the trace and place the analyzer marker on this peak.

Use the 99% bandwidth function of the spectrum analyzer to measure the occupied channel bandwidth of the equipment under test.

The measurements show a value of about 1 MHz for all channels; it falls completely within the band 2.4 - 2.4835 GHz.

Figure 9. IDB011V2 - OBW 2402 MHz

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Figure 10. **IDB011V2 - OBW 2480 MHz**

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Figure 11. **IDB012V1 - OBW 2402 MHz**

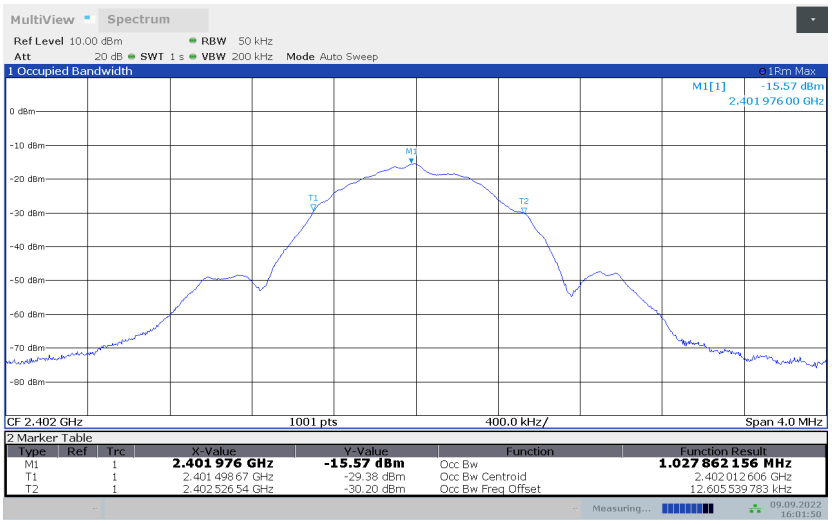

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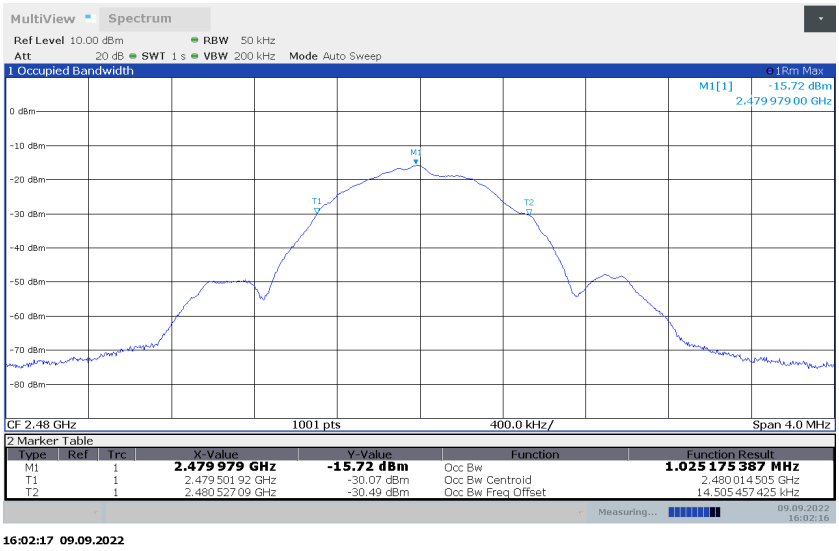
Figure 12. **IDB012V1 - OBW 2480 MHz**



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4.4 Transmitter unwanted emissions in out-of-band domain

The measurement is performed at the lowest and the highest channel on which the equipment can operate.

The spectrum analyzer must be set with:

- Center frequency: 2484 MHz
- Span = 0 Hz
- RBW = 1 MHz
- VBW = 3 MHz
- Filter mode = channel filter
- Detector = RMS
- Trace = max. hold
- Sweep time = continuous
- Sweep points = sweep time [s] / (1 us) or 5000 whichever is greater
- Trigger mode = video trigger; in case video triggering is not possible, an external trigger source may be used
- Sweep time = > 120% of the duration of the longest burst detected during the measurement of the RF power.

For the segment 2483.5 MHz to 2485.5 MHz (2483.5 MHz to 2483.5 MHz + BW):

- Adjust the trigger level to select the transmissions with the highest power level
- Set a window (start and stop lines) to match with the start and the end of the burst and in which the RMS power is measured using the time domain power function
- Select RMS power to be measured within the selected window and note the result which is the RMS power within this 1 MHz segment (2483.5 MHz to 2484.5 MHz)
- Compare this value with the applicable limit provided by the mask
- Increase the center frequency in steps of 1 MHz and repeat this measurement for every 1 MHz segment within the range 2483.5 MHz to 2485.5 MHz. The center frequency of the last 1 MHz segment is set to 2485.5 MHz - 0.5 MHz (which means this may partly overlap with the previous 1 MHz segment).

For the segment 2485.5 MHz to 2487.5 MHz (2483.5 MHz + BW to 2483.5 MHz + 2BW):

- Change the center frequency of the analyzer to 2486 MHz and perform the measurement for the first 1 MHz segment within range 2485.5 MHz to 2487.5 MHz
- Increase the center frequency in 1 MHz steps and repeat the measurements to cover this whole range
- The center frequency of the last 1 MHz segment is set to 2487.5 MHz - 0.5 MHz

For the segment 2398 MHz to 2400 MHz (2400 MHz - BW to 2400 MHz):

- Change the center frequency of the analyzer to 2399.5 MHz and perform the measurement for the first 1 MHz segment within range 2398 MHz to 2400 MHz
- Reduce the center frequency in 1 MHz steps and repeat the measurements to cover this whole range
- The center frequency of the last 1 MHz segment shall be set to 2398 MHz + 0.5 MHz

For the segment 2396 MHz to 2398 MHz (2400 MHz - 2BW to 2400 MHz- BW):

- Change the center frequency of the analyzer to 2397.5 MHz and perform the measurement for the first 1 MHz segment within range 2396 MHz to 2398 MHz
- Reduce the center frequency in 1 MHz steps and repeat the measurements to cover this whole range
- The center frequency of the last 1 MHz segment is set to 2396 MHz + 0.5 MHz.

Follow the detailed analysis in all the ranges specified by the mask; the BlueNRG-LP/LPS meets the requirement with large margin.

Figure 13. IDB011V2 - Out-of-band emission 2484 MHz

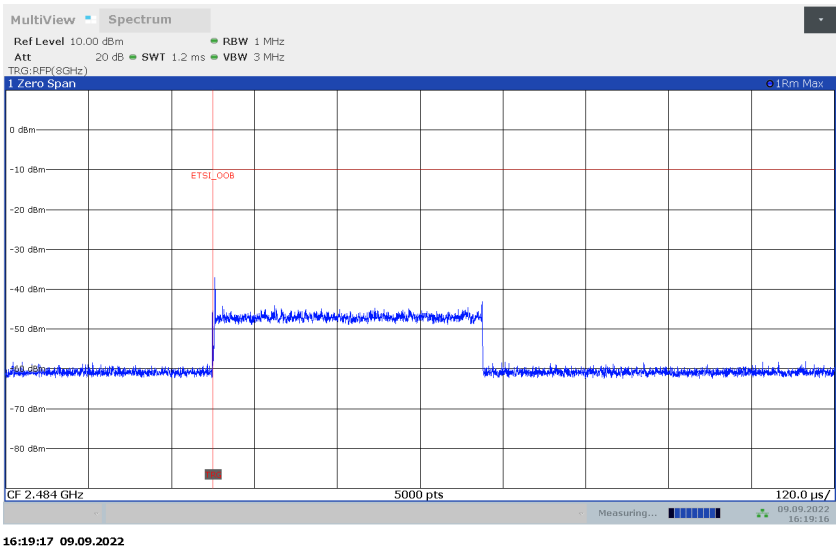

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Figure 14. IDB011V2 - Out-of-band emission 2485 MHz

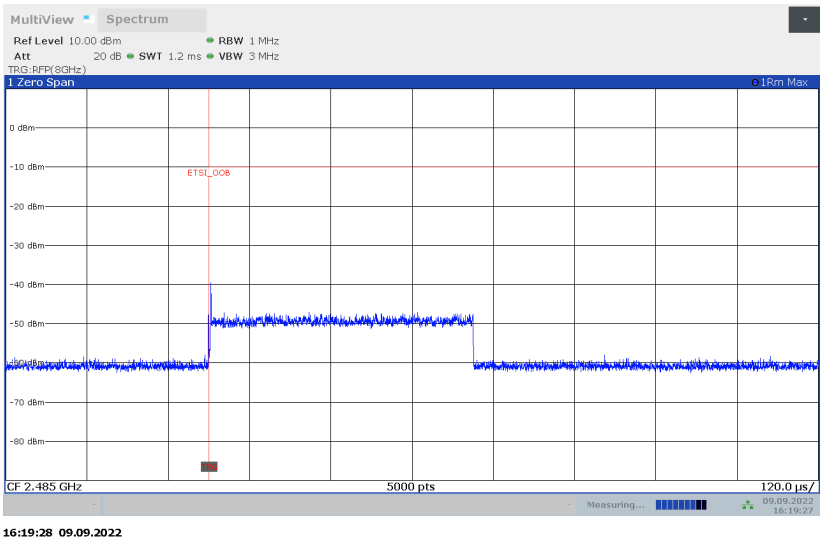

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Figure 15. **IDB011V2 - Out-of-band emission 2486 MHz**

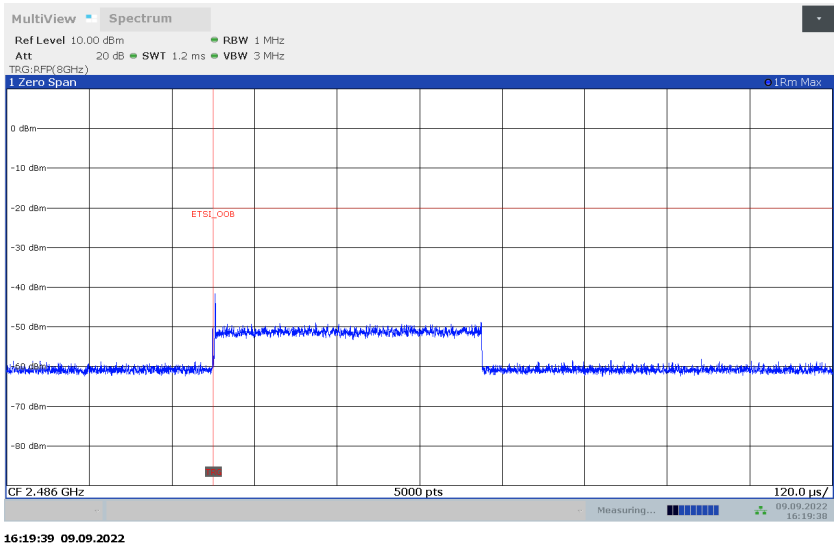

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Figure 16. **IDB011V2 - Out-of-band emission 2487 MHz**

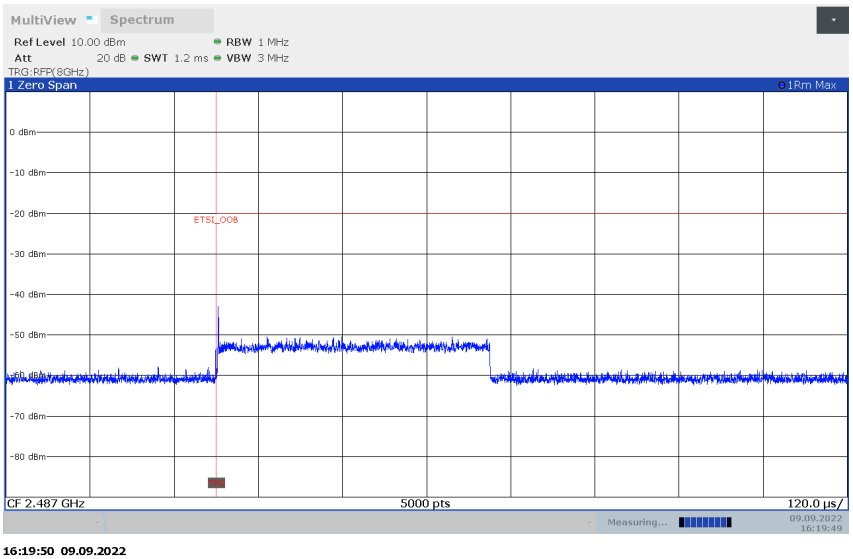

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Figure 17. **IDB011V2 - Out-of-band emission 2396.5 MHz**

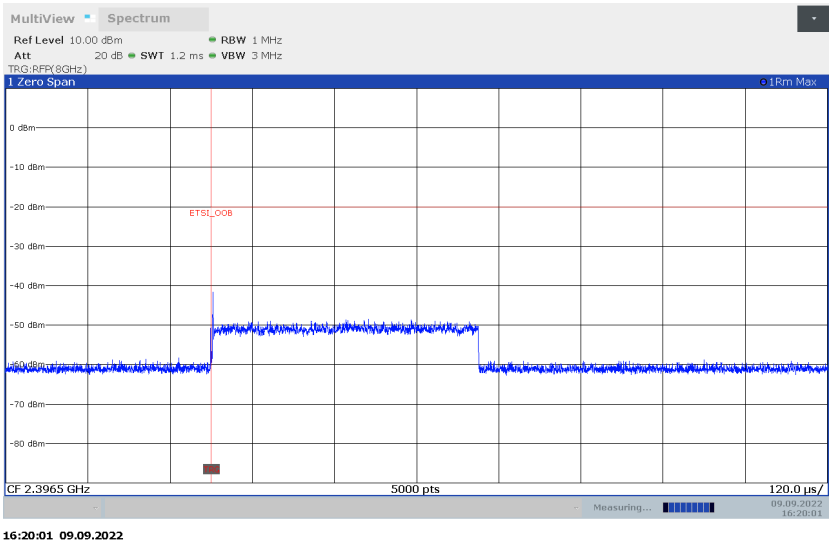

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Figure 18. **IDB011V2 - Out-of-band emission 2397.5 MHz**

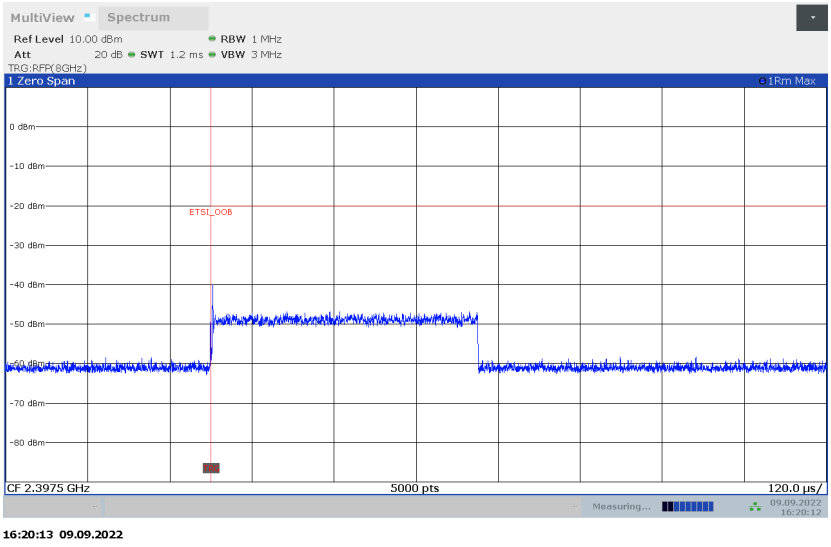

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Figure 19. IDB011V2 - Out-of-band emission 2398.5 MHz

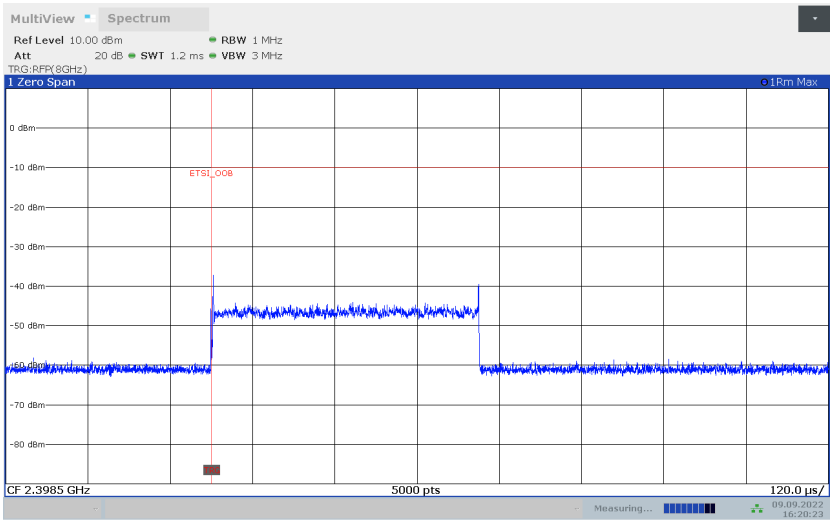

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Figure 20. IDB011V2 - Out-of-band emission 2399.5 MHz

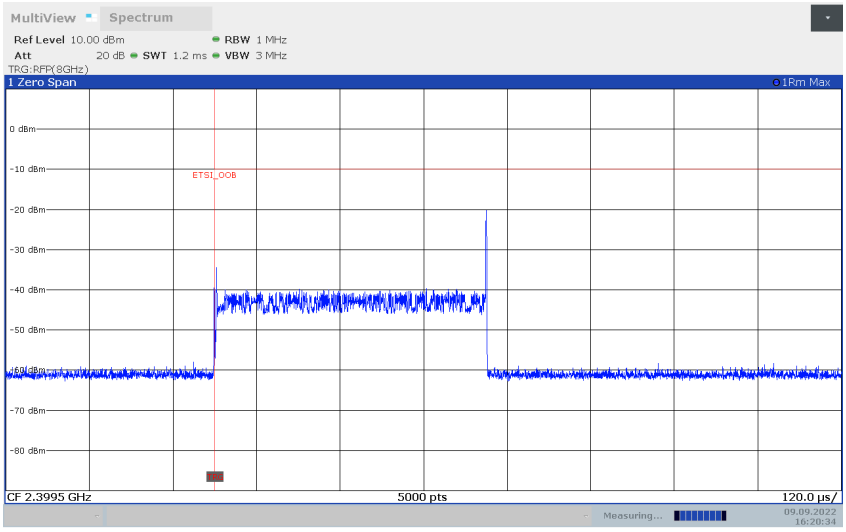

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Figure 21. **IDB012V1 - Out-of-band emission 2484 MHz**

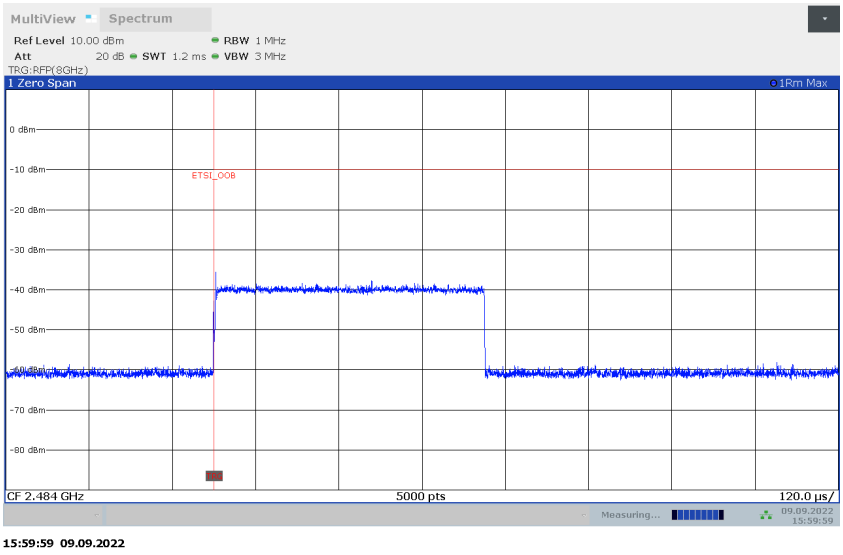

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Figure 22. **IDB012V1 - Out-of-band emission 2485 MHz**

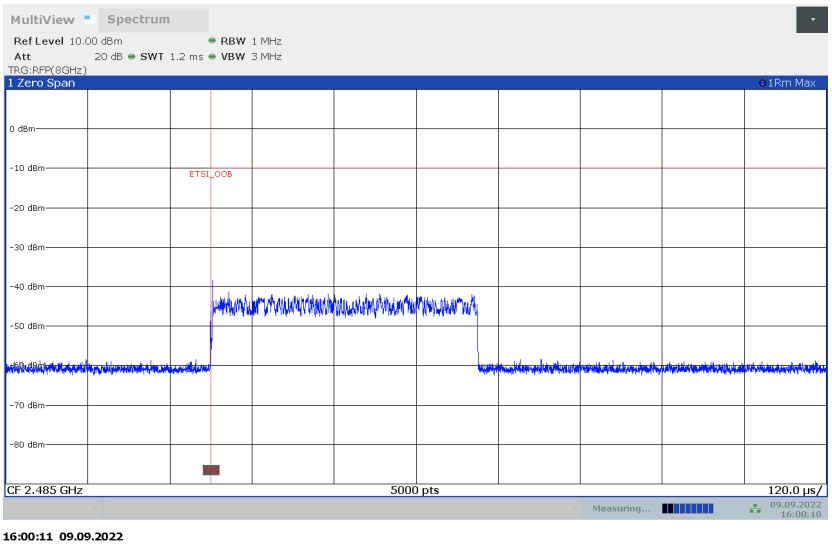

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Figure 23. **IDB012V1 - Out-of-band emission 2486 MHz**

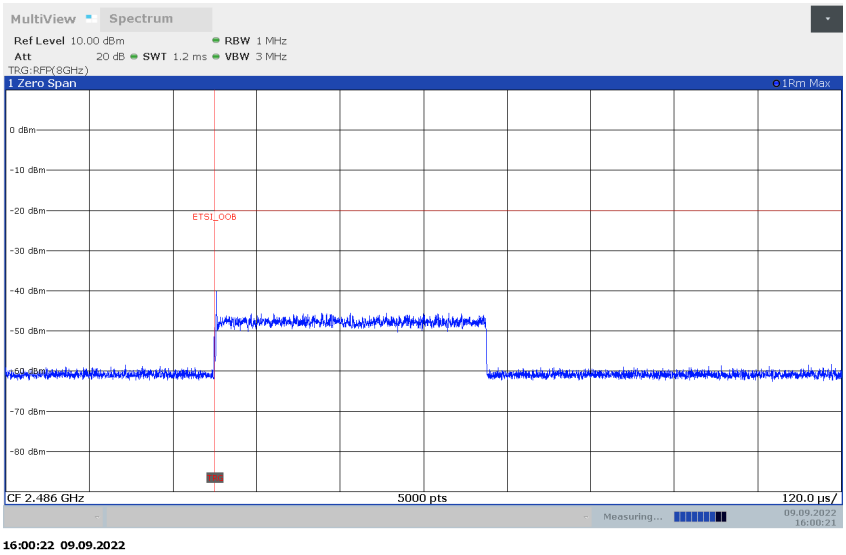

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Figure 24. **IDB012V1 - Out-of-band emission 2487 MHz**

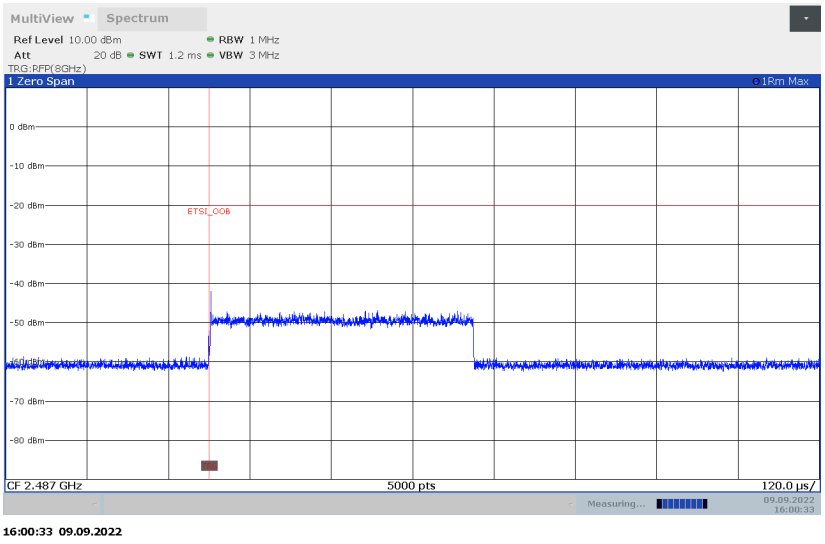

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Figure 25. **IDB012V1 - Out-of-band emission 2396.5 MHz**

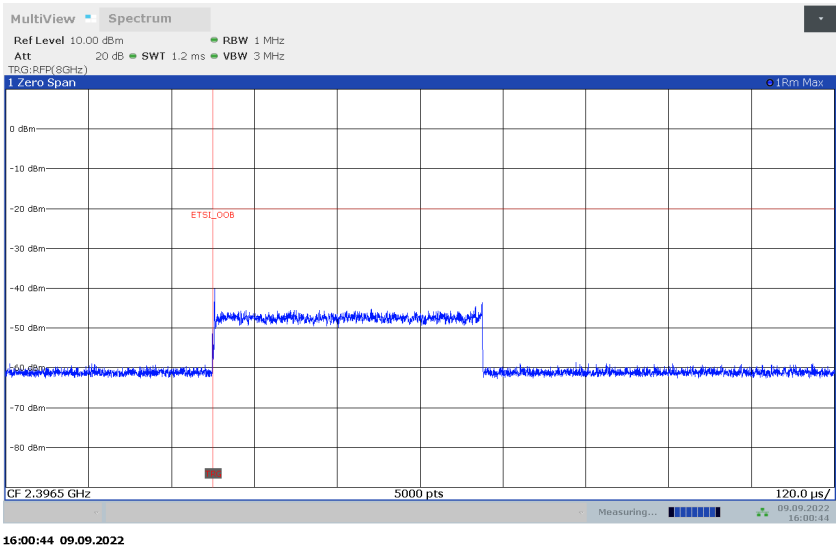

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Figure 26. **IDB012V1 - Out-of-band emission 2397.5 MHz**

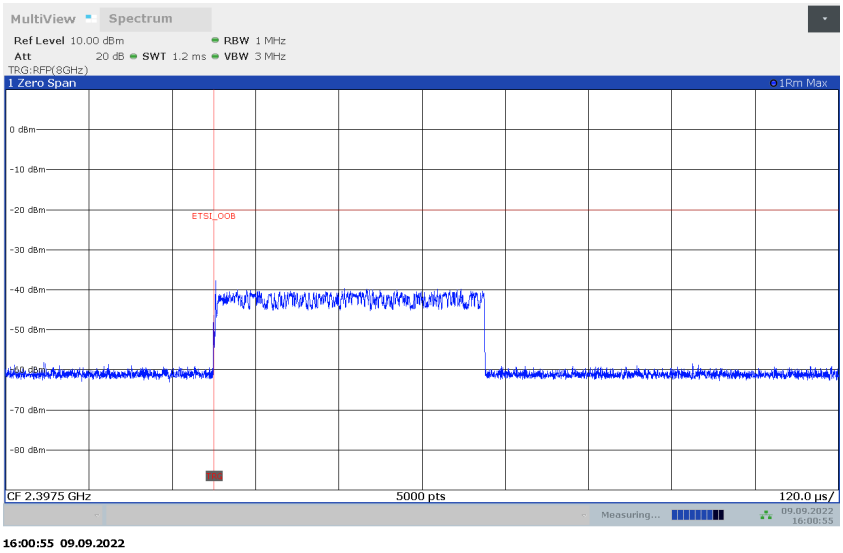

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Figure 27. **IDB012V1 - Out-of-band emission 2398.5 MHz**

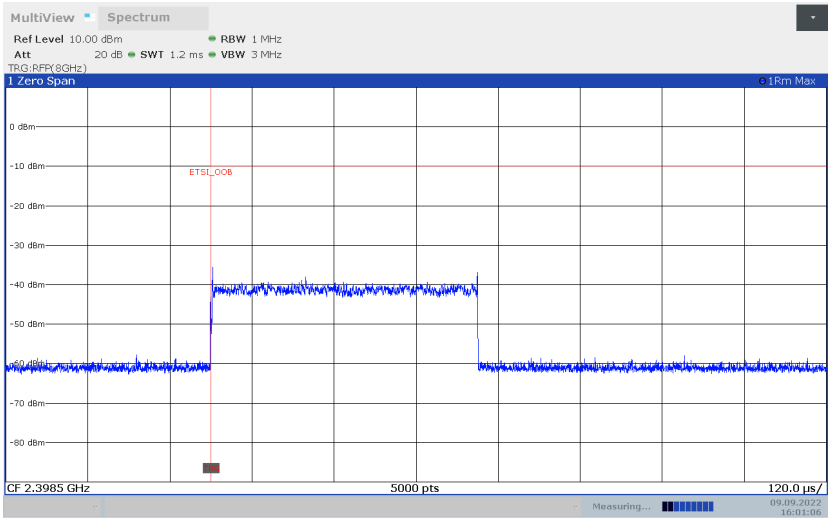

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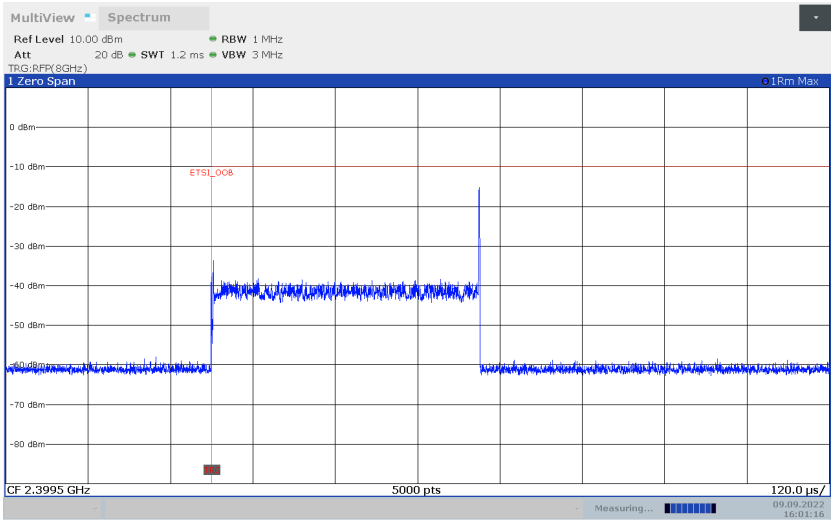
Figure 28. **IDB012V1 - Out-of-band emission 2399.5 MHz**



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4.5 Transmitted unwanted emissions in spurious domain

The measurement is performed at the lowest and the highest channel on which the equipment can operate.

To identify potential unwanted emissions, a pre-scan is done.

The spectrum analyzer settings for the range 30 MHz to 1000 MHz are:

- Resolution bandwidth = 100 kHz
- Video bandwidth = 300 kHz
- Detector mode = Peak
- Trace Mode = Max. Hold
- Sweep Points: ≥19400; for spectrum analyzers not supporting this high number of sweep points, the frequency band may be segmented

The spectrum analyzer settings for the range 1 GHz to 12.75 GHz are:

- Resolution bandwidth = 1 MHz
- Video bandwidth = 3 MHz

- Detector mode = Peak
- Trace Mode = Max. Hold
- Sweep Points: ≥23500; for spectrum analyzers not supporting this high number of sweep points, the frequency band may be segmented

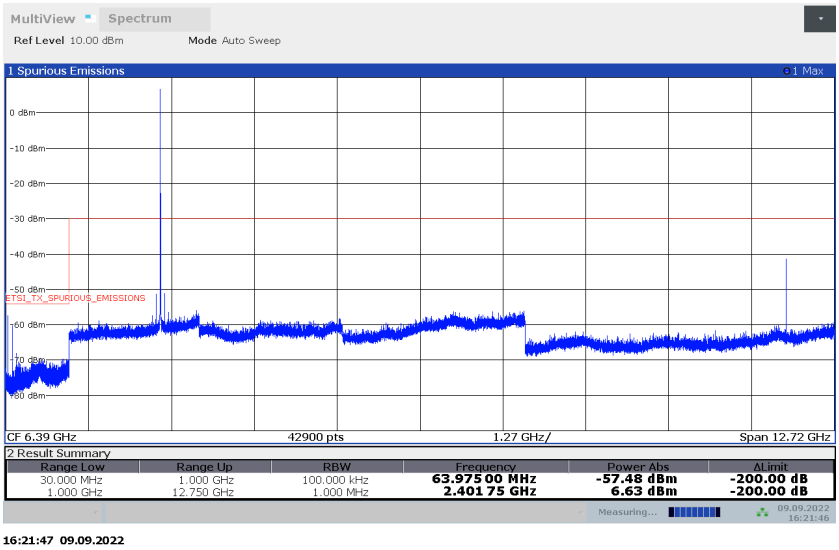
Any emissions identified during the sweeps above that fall within the 6 dB range below the applicable limit or above, are individually measured using the following procedure:

- Measurement mode = time domain power
- Center frequency = frequency of the emission identified during the pre-scan
- Resolution bandwidth = 100 kHz (< 1 GHz) / 1 MHz (> 1 GHz)
- Video bandwidth = 300 kHz (< 1 GHz) / 3 MHz (> 1 GHz)
- Frequency span = zero span
- Detector mode = RMS
- Sweep mode = single sweep
- Sweep time = > 120% of the duration of the longest burst detected during the measurement of the RF output power
- Sweep points sweep time [us] / (1 us) with a maximum of 30000
- Trigger = video (burst signals) or manual (continuous signals).

The BlueNRG-LP/LPS has been configured to transmit a continuous wave to prove the compliance.

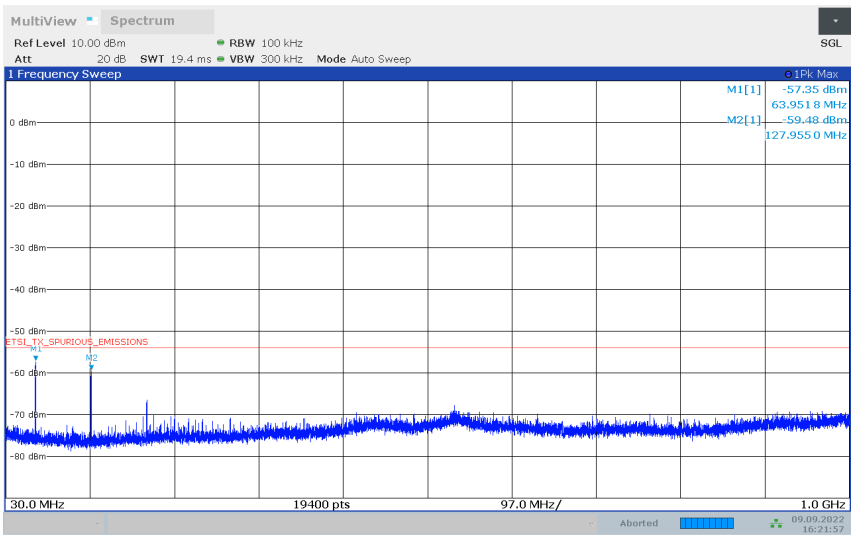
The lowest limits below and over 1000 MHz have been taken into account.

Figure 29. IDB011V2 - Tx (2402 MHz) unwanted emissions full span



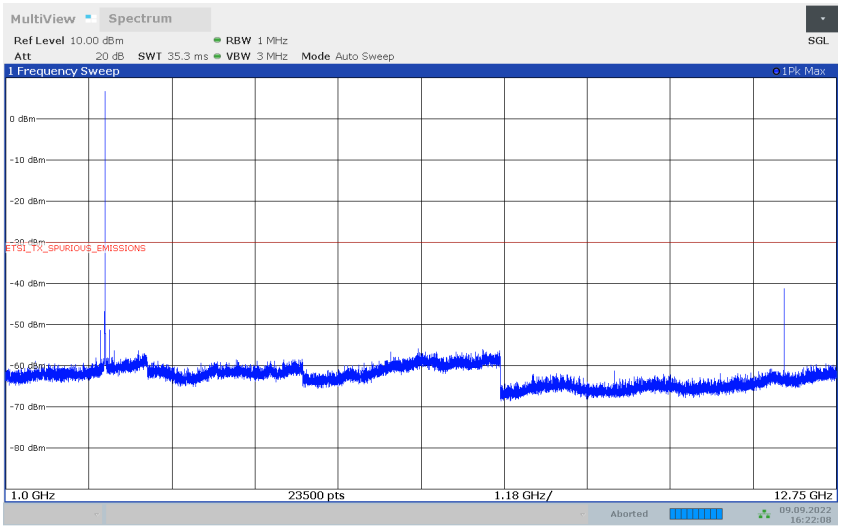
DT57193V1

Figure 30. IDB011V2 - Tx (2402 MHz) unwanted emission 30 MHz to 1000 MHz



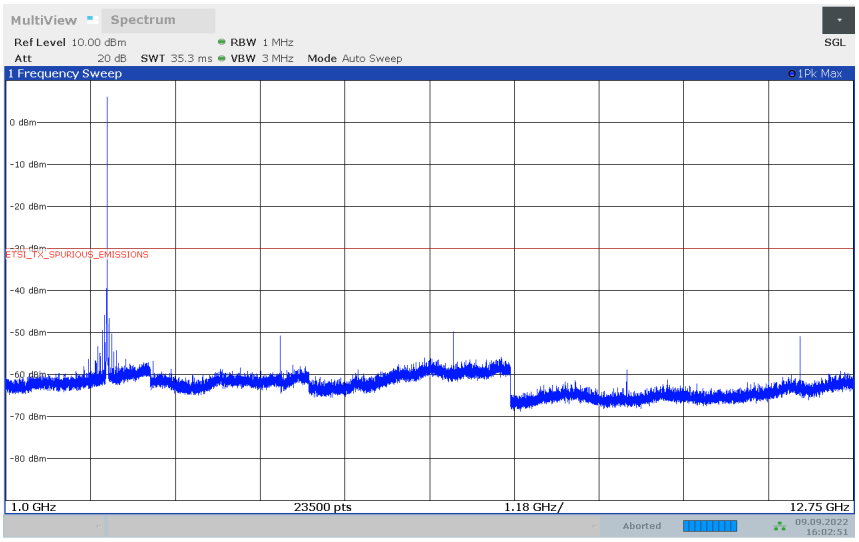
DT57194V1

Figure 31. IDB011V2 - Tx (2402 MHz) unwanted emission 1 GHz to 12.75 GHz



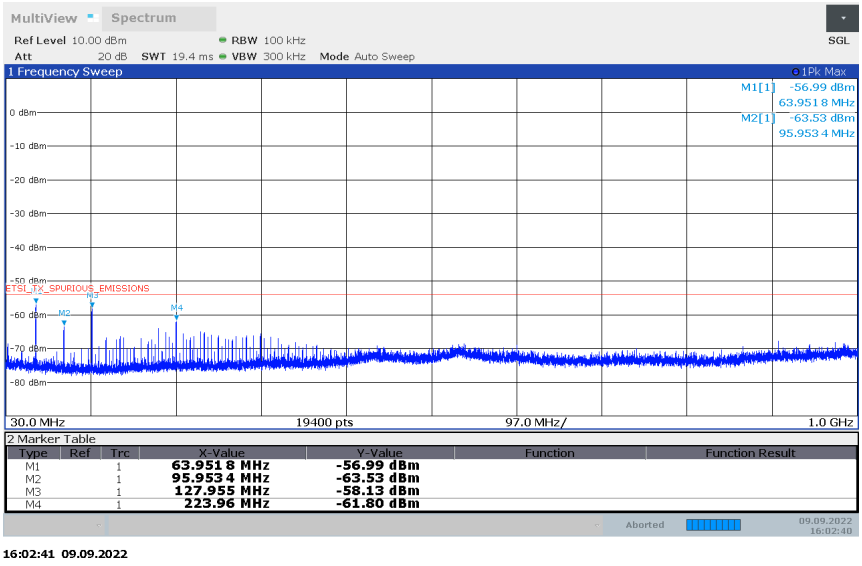
DT57195V1

Figure 32. **IDB012V1 - Tx (2402 MHz) unwanted emission 1 GHz to 12.75 GHz**



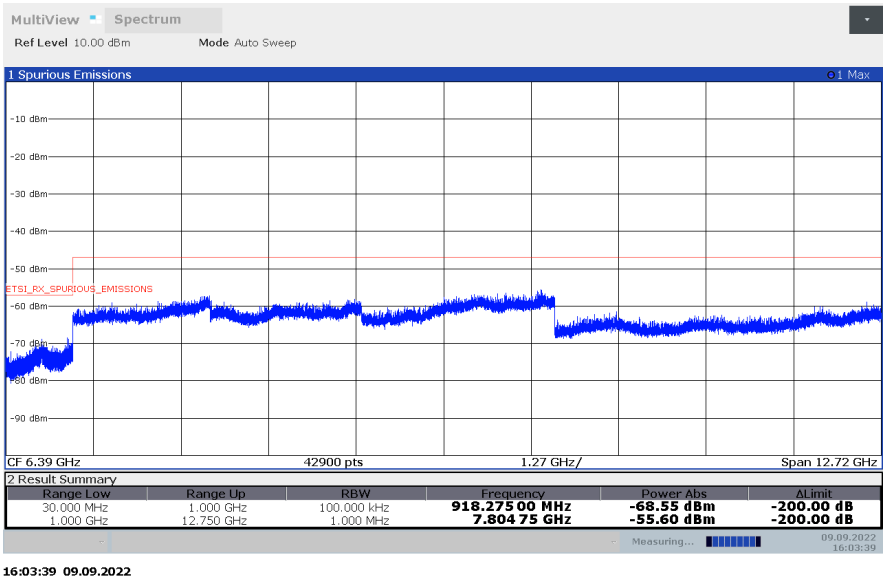
DT57260V1

Figure 33. **IDB012V1 - Tx (2402 MHz) unwanted emission 30 MHz to 1000 MHz**



DT57259V1

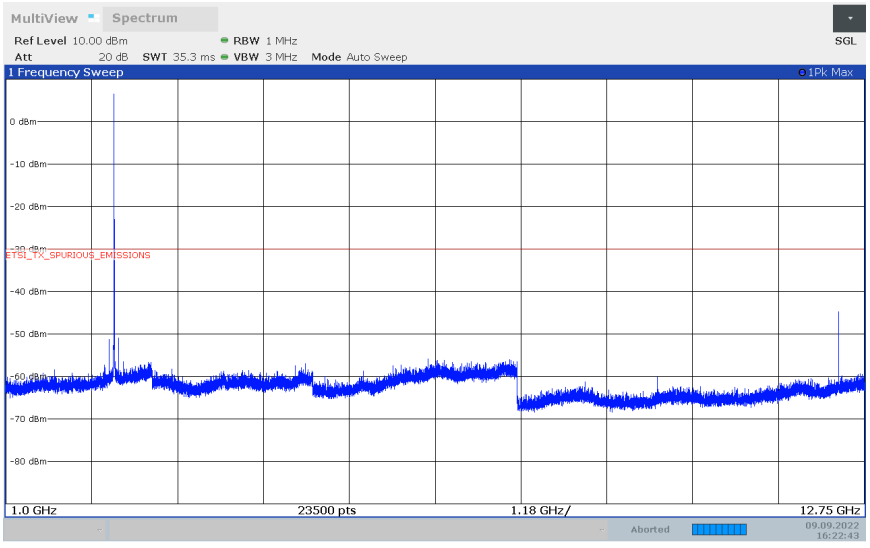
Figure 34. **IDB012V1 - Tx (2402 MHz) unwanted emissions full span**



16:03:39 09.09.2022

DT57258V1

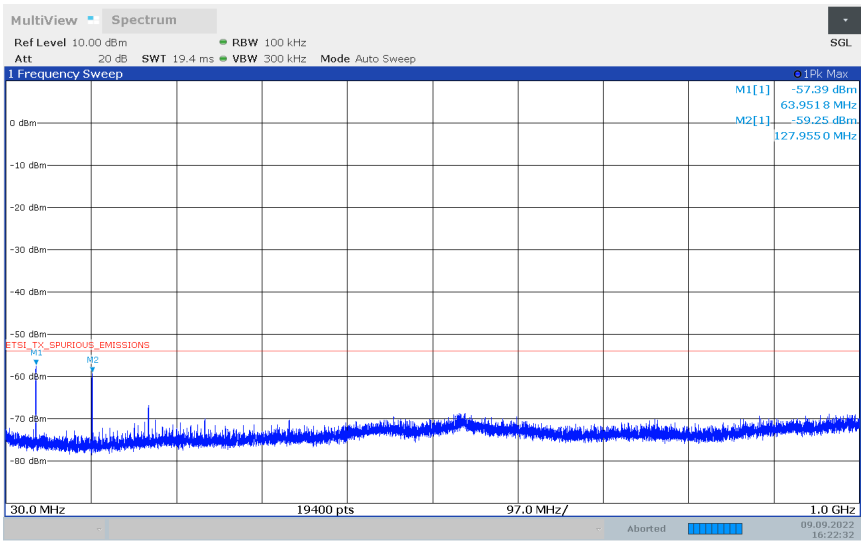
Figure 35. **IDB011V2 - Tx (2480 MHz) unwanted emission 1 GHz to 12.75 GHz**



16:22:44 09.09.2022

DT57257V1

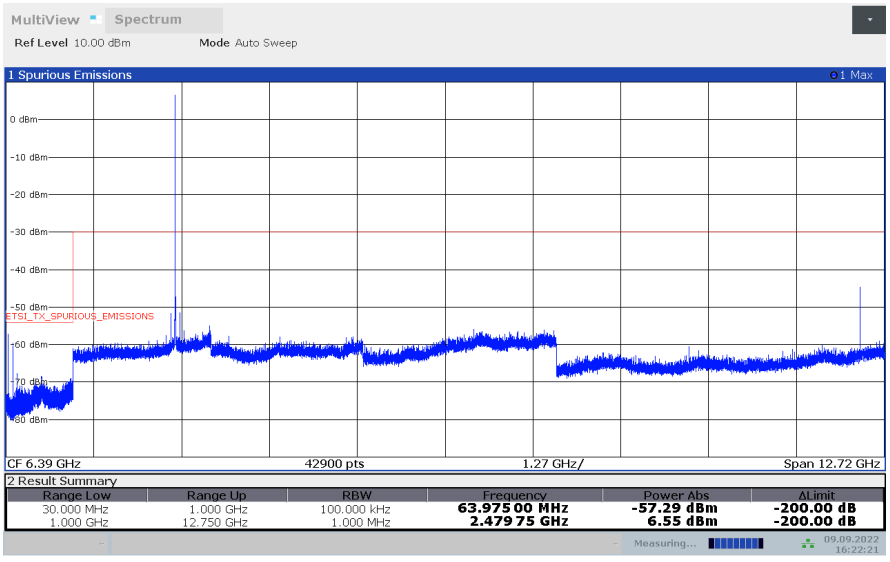
Figure 36. **IDB011V2 - Tx (2480 MHz) unwanted emission 30 MHz to 1000 MHz**



16:22:32 09.09.2022

DT57256V1

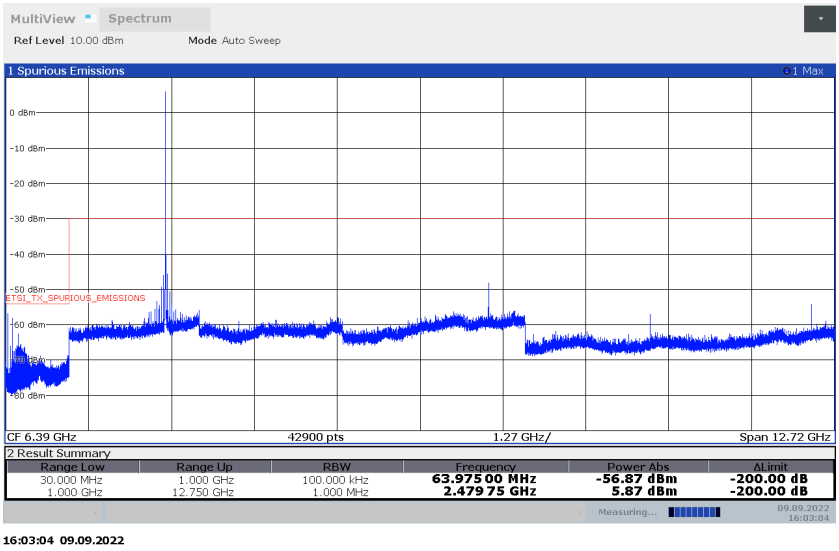
Figure 37. **IDB011V2 - Tx (2480 MHz) unwanted emissions full span**



16:22:21 09.09.2022

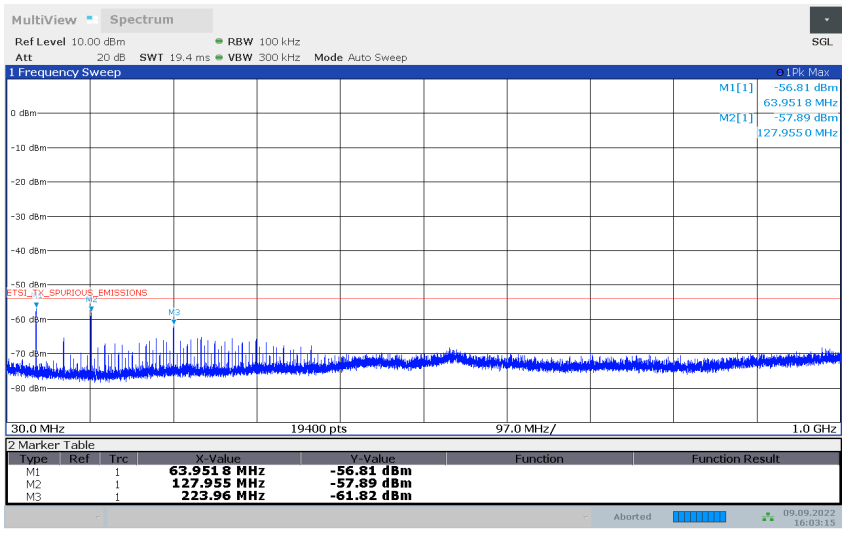
DT57255V1

Figure 38. **IDB012V1 - Tx (2480 MHz) unwanted emissions full span**



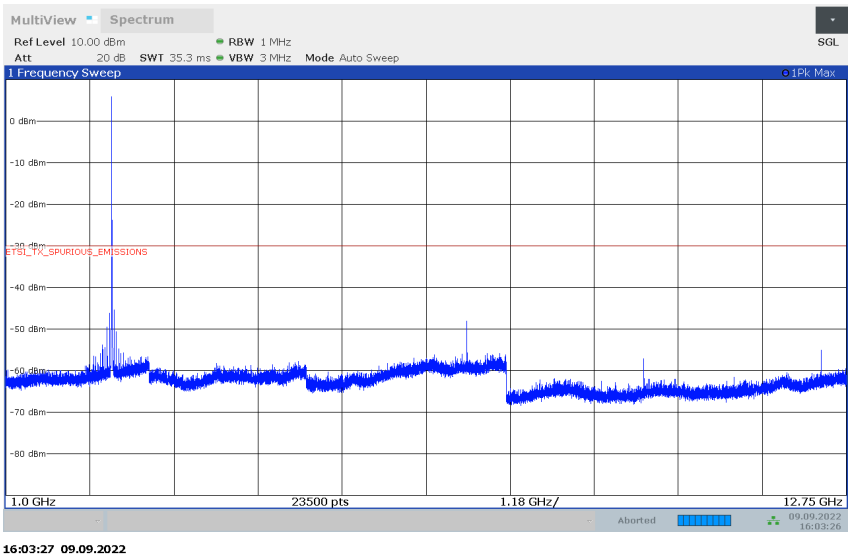
DT57196V1

Figure 39. **IDB012V1 - Tx (2480 MHz) unwanted emission 30 MHz to 1000 MHz**



DT57197V1

Figure 40. IDB012V1 - Tx (2480 MHz) unwanted emission 1 GHz to 12.75 GHz



DT57198V1

5 Receiver parameter

5.1 Receiver spurious emissions

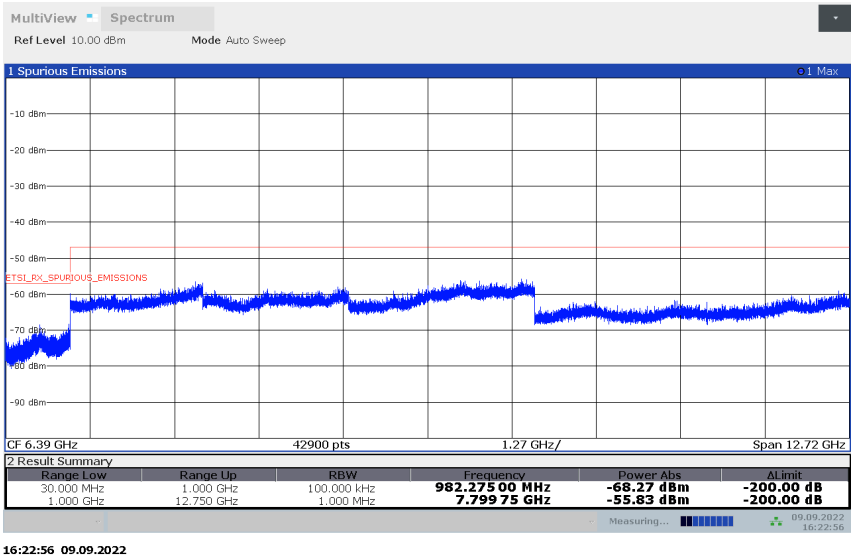
The measurement is performed at the lowest and the highest channel on which the equipment can operate.

Testing is performed when the equipment is in a receive-only mode.

The spectrum analyzer settings are equivalent to those used for the transmitted unwanted emissions in spurious domain. No particular issues were registered for this test.

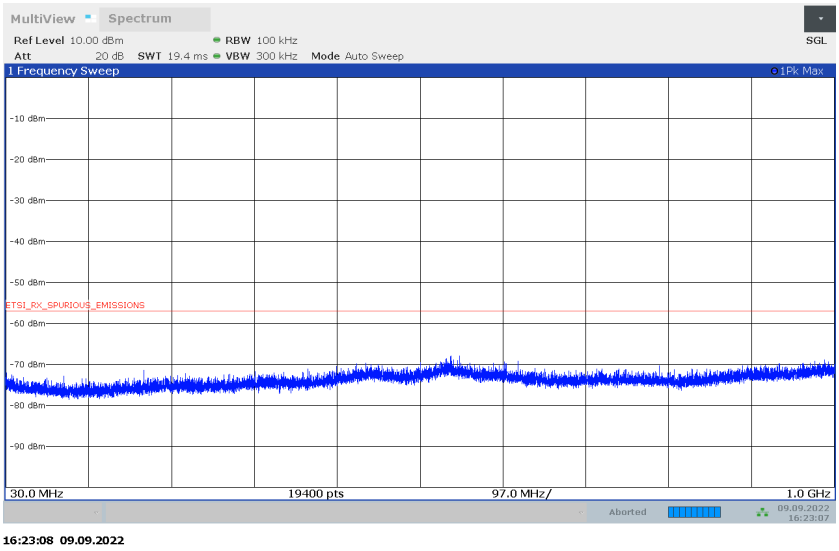
The receiver spurious emission requirements are fully met by the device, so no further investigations are necessary.

Figure 41. IDB011V2 - Rx (2402 MHz) unwanted emissions full span



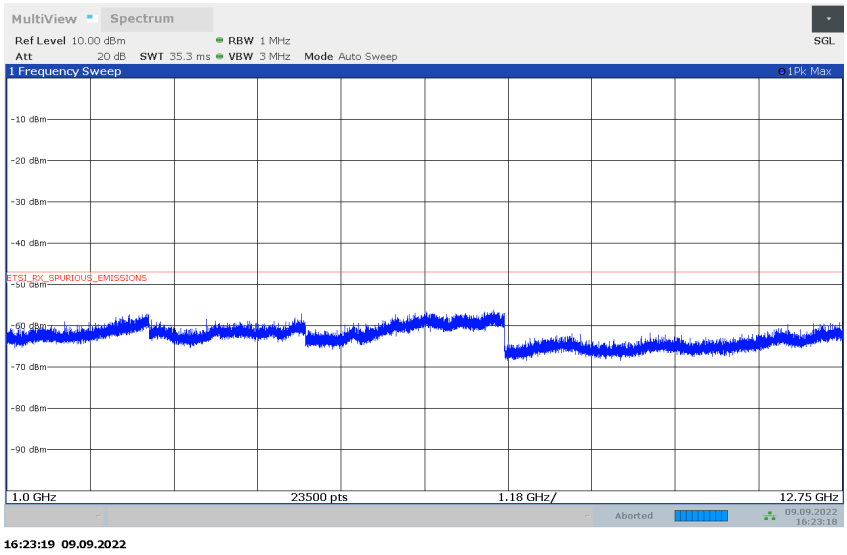
DT57199V1

Figure 42. IDB011V2 - Rx (2402 MHz) unwanted emission 30 MHz to 1000 MHz



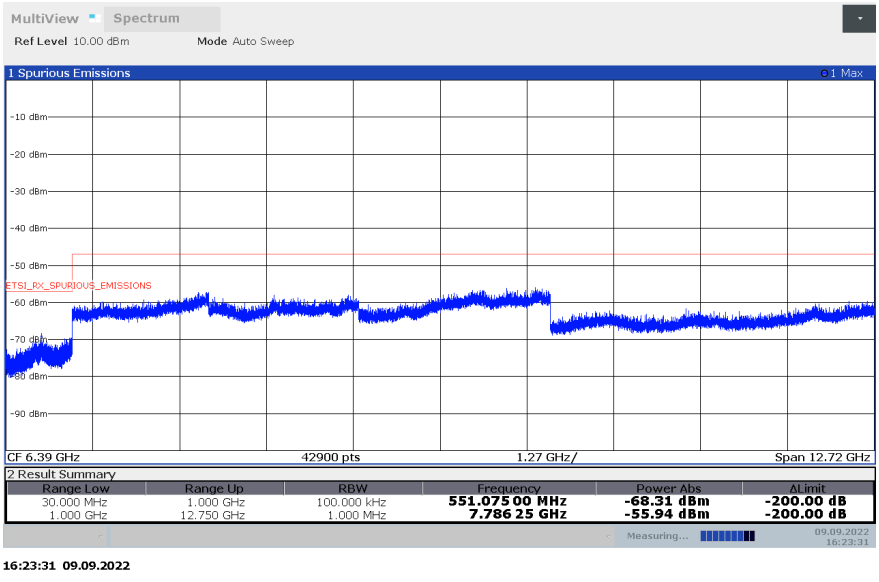
DT57200V1

Figure 43. IDB011V2 - Rx (2402 MHz) unwanted emission 1 GHz to 12.75 GHz



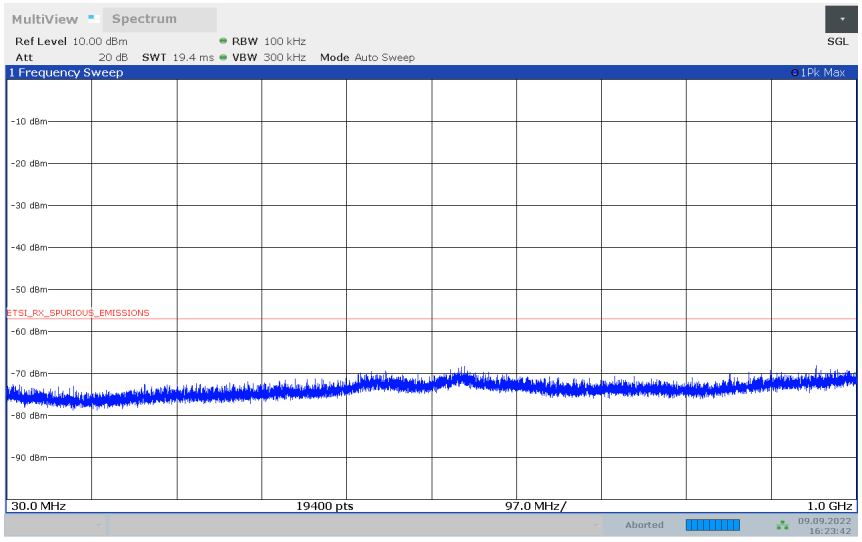
DT57201V1

Figure 44. IDB011V2 - Rx (2480 MHz) unwanted emissions full span



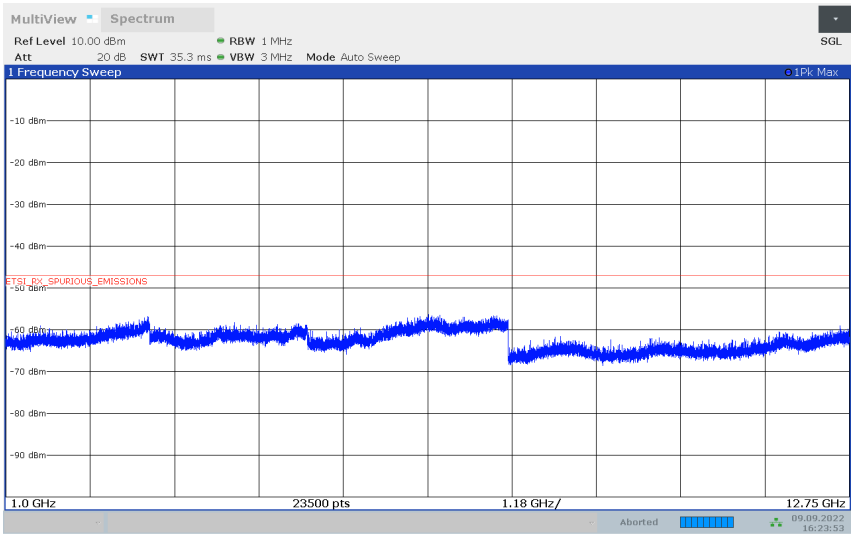
DT57261V1

Figure 45. IDB011V2 - Rx (2480 MHz) unwanted emission 30 MHz to 1000 MHz



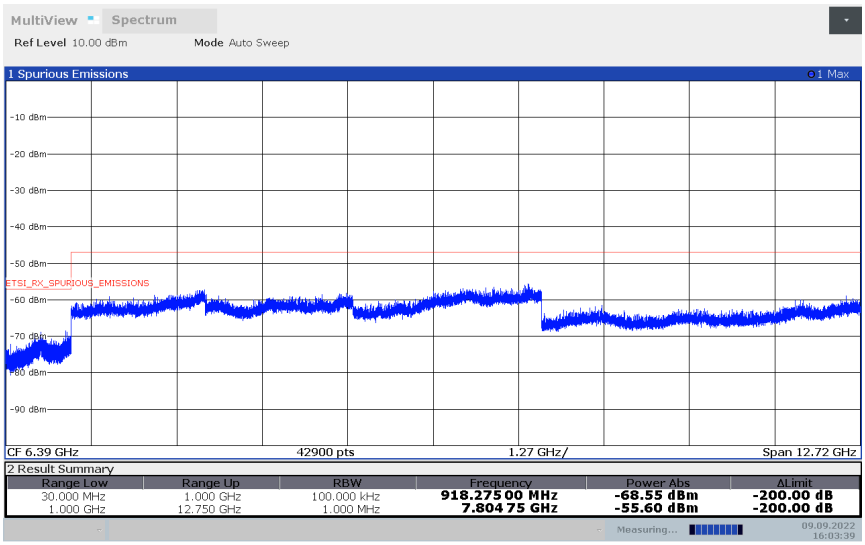
DT57262V1

Figure 46. IDB011V2 - Rx (2480 MHz) unwanted emission 1 GHz to 12.75 GHz



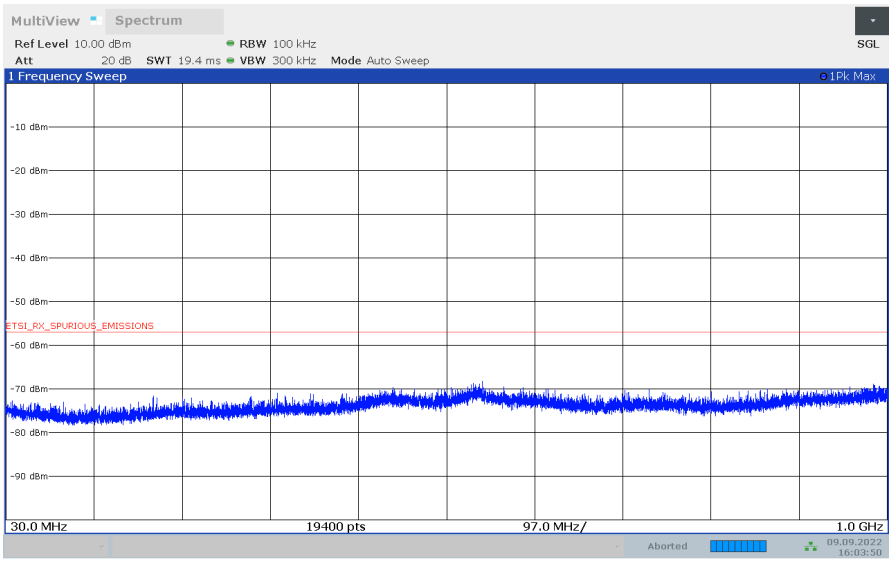
DT57263V1

Figure 47. **IDB012V1 - Rx (2402 MHz) unwanted emissions full span**



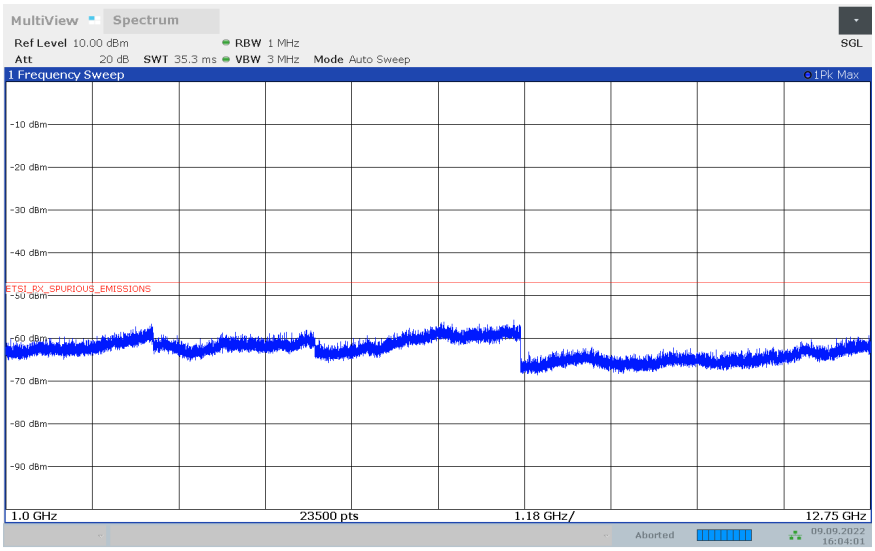
DT57264V1

Figure 48. **IDB012V1 - Rx (2402 MHz) unwanted emission 30 MHz to 1000 MHz**



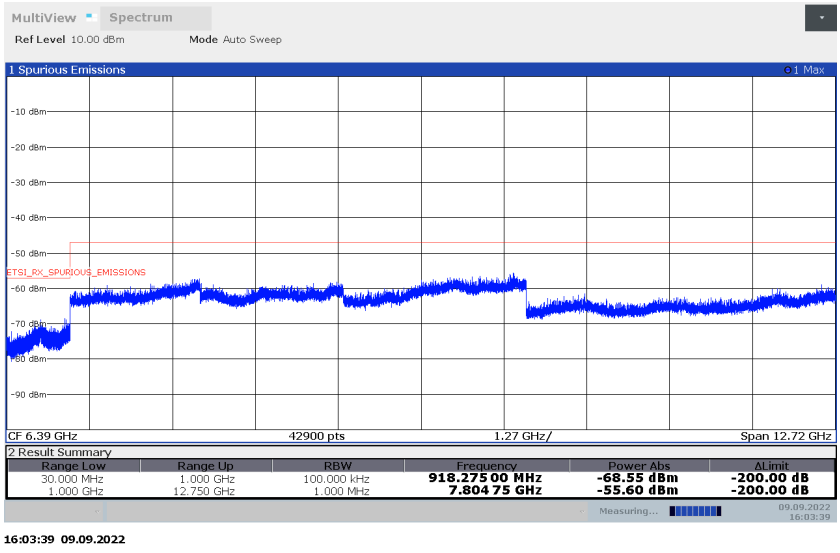
DT57265V1

Figure 49. **IDB012V1 - Rx (2402 MHz) unwanted emission 1 GHz to 12.75 GHz**



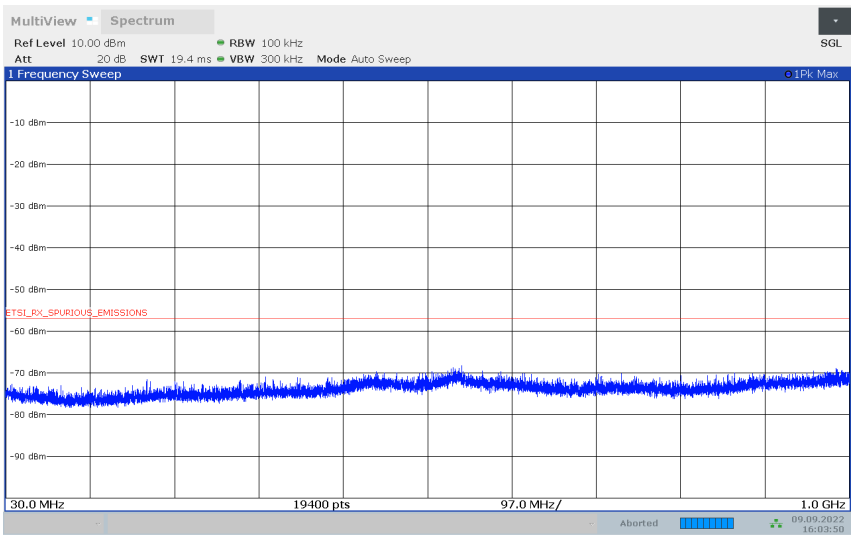
DT57266V1

Figure 50. **IDB012V1 - Rx (2480 MHz) unwanted emissions full span**



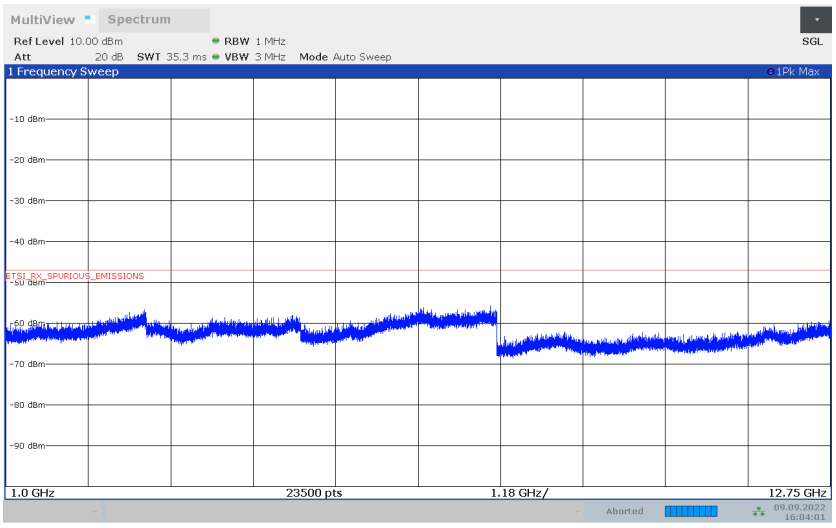
DT57202V1

Figure 51. IDB012V1 - Rx (2480 MHz) unwanted emission 30 MHz to 1000 MHz



DT57203V1

Figure 52. IDB012V1 - Rx (2480 MHz) unwanted emission 1 GHz to 12.75 GHz



DT57204V1

5.2 Receiver blocking

The measurement is performed at the lowest and the highest channel on which the equipment can operate.

The frequency tested and the blocking level are defined in Table 4.

The receiver blocking measurements are reported in Table 7. The BlueNRG-LP/LPS family devices meet the specifications with large margin.

Table 7. Receiver blocking measurements

Wanted signal from companion device (dBm)	Wanted signal from companion frequency (MHz)	Blocking signal frequency (MHz)	Blocking signal power (dBm])	PER (%) limit	PER (%)
-69	1402	2380	-34	10	0
	2480	2504		10	0
	2402	2300		10	0
	2480	2584		10	0

6 Reference

Table 8. **Document reference**

Reference	Document
[1]	BlueNRG-LP/LPS datasheet
[2]	ETSI EN 300 328 V2.2.2 (2019-07)
[3]	Bluetooth® core specification

Revision history

Table 9. **Document revision history**

Date	Version	Changes
29-Oct-2020	1	Initial release.
09-Dec-2022	2	Updated: • Replaced any occurrence of BlueNRG-LP with BlueNRG-LP/LPS • Section 3 Application circuit, Section 4 Transmitter parameter, Section 4.3 Occupied channel bandwidth • Figure 1 • Table 5 Added: • Figure 2, Figure 3 to Figure 8, Figure 9 to Figure 12, Figure 13 to Figure 28, Figure 29 to Figure 40, Figure 41 to Figure 52 • Table 6

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