Guidelines for FCC standard on STM32WL3x MCUs

Introduction

The STM32WL3x MCU is a very low power radio frequency (RF) transceiver, intended for RF wireless applications in the sub-1 GHz band. It is designed to operate both in the license-free ISM and SRD frequency bands at 433, 868 and 920 MHz.

The STM32WL3x MCU is refered to a the STM32WL3 in this document.

This application note outlines the expected performance when using the STM32WL3 under FCC title 47 part 15 [2] in the 902 to 928 MHz band. There are no specific requirement in this band, no specific use requirements and no channel spacing are defined.

For details on the regulatory limits in the 902 – 928 MHz frequency band, refer to the FCC title 47 part 15 regulations [2].

These can be downloaded from eCFR : 47 CFR Part 15 -- Radio Frequency Devices.

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Table 1. Applicable products

Reference	Products
STM32WL3x	STM32WL33C8
	STM32WL33CB
	STM32WL33CC
	STM32WL33K8
	STM32WL33KB
	STM32WL33KC

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For further information contact your local STMicroelectronics sales office.

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1   General information

STM32WL3 supports STM32 32-bit products based on the Arm® Cortex® processor.

Note: *Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.*

arm

2 An overview of FCC regulations

Low power, unlicensed devices operating in the 902 – 928 MHz band are everywhere, toys, wireless security systems, wireless telemetry or wireless automatic meter reading and so on.

The FFC is the USA standards body which is responsible for the implementation of the rules to limit the potential for interference of: low power and unlicensed transmitters, with licensed operations. These rules are documented in Part 15 of Title 47 of the FCC.

For operation in the 902 – 928 MHz band, a low power, unlicensed device has to meet one of the following subparts of the regulation:

- **Part 15.243**: operation is restricted for devices to use radio frequency energy to measure the characteristic of a material. Voice communication or other data transmission is not permitted.
- **Part 15.245**: operation is limited to devices operating as field disturbance sensors, excluding perimeter protection systems.
- **Part 15.247**: Frequency Hopping and Digitally Modulated Intentional Radiators.
- **Part 15.249**: General Non-Licensed Intentional Radiators.

The STM32WL3 is designed to meet the 15.247 and 15.249 sub-parts, so this document includes the description of each of the parts and the associated measurement results.

2.1 Part 15.247 description extract

Devices that operate to FCC part 15.247 are limited to frequency hopping and digitally modulated schemes.

To be compliant with the frequency hopping system the device or system must meet the following requirement:

- Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or 20 dB bandwidth of the hopping channel, whichever is greater.
- The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter.
- If the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.
- For system employing at least 50 channels, the maximum peak conducted output power output is +30 dBm (1 W). For systems that employing less than 50 channels but at least 25 channels, the maximum output power is +24 dBm (0.25 W).
- 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 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).
- Radiated harmonic and spurious emissions 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.

To be compliant with the digital modulation scheme the devices or systems must meet the following requirement:

- The minimum 6 dB bandwidth of the signal shall be at least 500 kHz.
- 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 shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

- 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 is not required. In addition, radiated emissions which fall in the restricted bands, as defined in 5.205(a), must also comply with the radiated emission limits specified in § 15.209(a).

- Radiated harmonic and spurious emissions 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.

2.2 Part 15.249 description extract

As opposed to part 15.247, the FCC part 15.249 in the 902 – 928 MHz bandwidth does not enforce restrictions on either the modulation scheme or the end application.

To be compliant with the part 15.249 the device or system must meet the following requirements:

- The maximum permitted field strength is 50 mV/m. Since the field strength limits are specified to a distance of 3 m from the radiating source, this equates to a conducted power of about -1 dBm measured at the antenna port.

- The maximum permitted field strength of harmonic components is 500 μV/m. This equates, at a 3m distance, to a conducted power level of about -41 dBm measured at the antenna port.

- Radiated emission other than harmonics shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in the 15.209 section, whichever is the lesser attenuation.

- Subpart 15.31 duty cycle correction applies to pulse modulated transmitters and where an average limit for carrier or spurious field strength is specified.

2.3 Parts 15.205 and 15.209 description extract

As already described in the previous paragraphs, radiated harmonics and spurious emissions of devices that comply the 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 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.

Devices operating under the part 15.249 are restricted to field strength emissions of the fundamental of 50 mV/m and harmonic emissions of 500 µV/m measured at a distance of 3 m. This means approximately -1 dBm and -41 dBm respectively, when measured conducted into a 50 Ω load. Radiated emission other than harmonics shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in the 15.209 section, whichever is the lesser attenuation.

The part 15.205 shows the bands where only spurious emissions are permitted. The field strength of emissions appearing within these frequency bands shall not exceed the limits shown in the part 15.209. The following tables show the restricted bands as defined in the part 15.205 (Table 2) and the radiated and conducted emission limits defined in the part 15.209 (Table 3).

Table 2. Restricted bands defined in the 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 3. Radiated and conducted emission limits defined in the 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

3 Application circuit

An application board has been designed to evaluate the RF performances and to develop the connected firmware of the STM32WL3 transceiver. Figure 1 shows the STM32WL3 application board photo.

The Nucleo-WL33CC1 application board is fitted with a 48 MHz XTAL to provide the correct oscillator frequency to the STM32WL3.

The STM32WL3 has an internal SMPS that drastically reduces the power consumption making the STM32WL3 the best in class device for the running applications in this bandwidth. The SMPS is fed from the battery (1.8 V to 3.6 V) and provides a programmable voltage (1.4 V usually) to the device. A SMA connector is present to connect the board to the antenna or to external instrumentation to verify the correct functionality, and ensure the compatibility with the requested standards.

A few of passive components, such as inductors and capacitors, are used as matching/filtering for the power amplifier (PA) and balun network for the receiver.

To reduce the application cost, the STM32WL3 is designed to work without external antenna switch.

Figure 1. Nucleo-WL33CC1 Application kit

DT74900V2
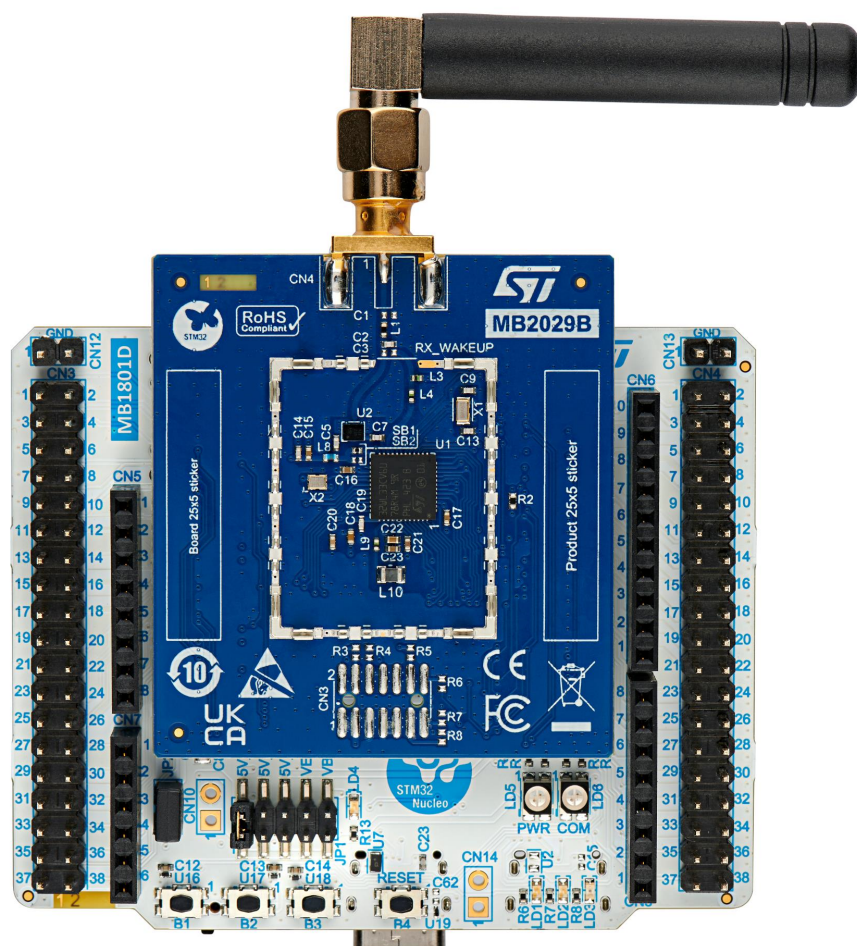
A dedicated graphical user interface (GUI) has been developed to allow the user to correctly configure the STM32WL3, see Figure 2.

Figure 2. Graphical user interface
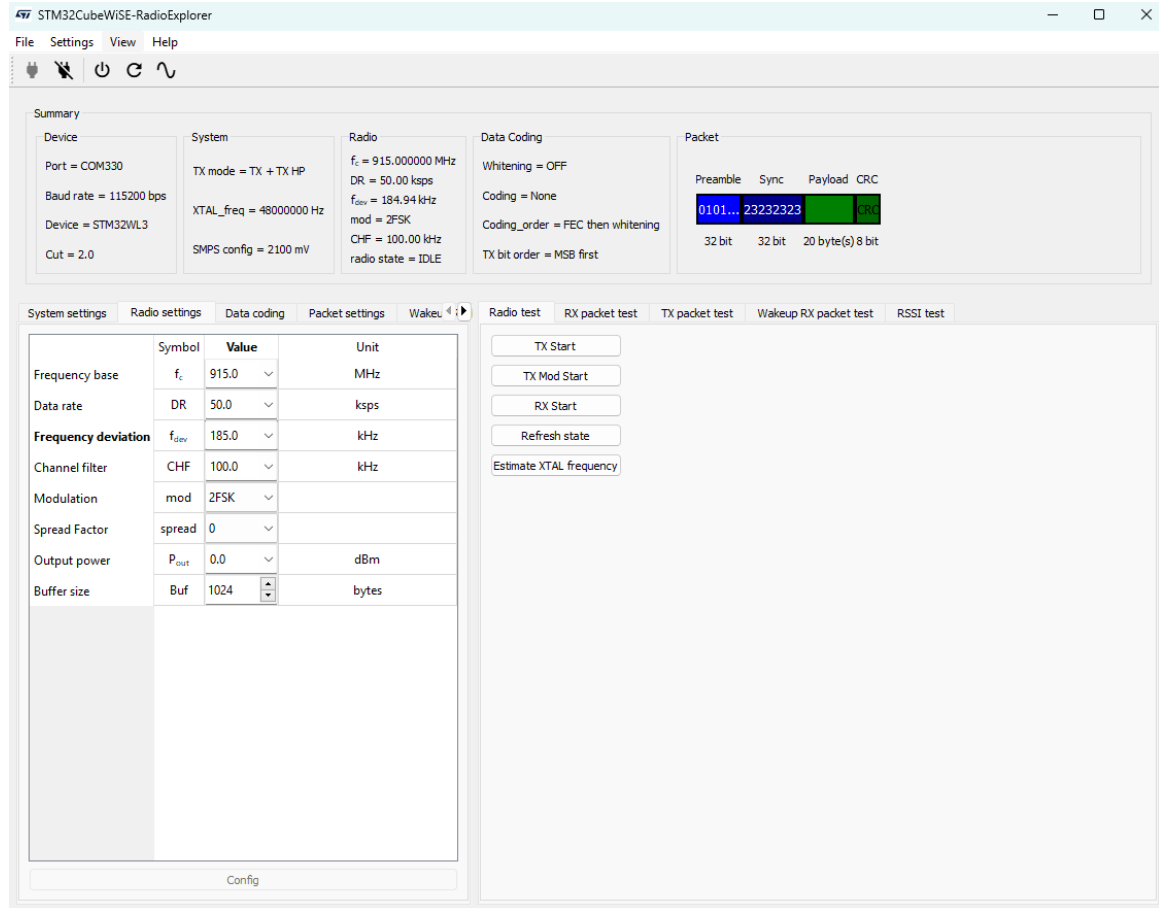
4 Device Measurements

All the measurement stated in this document are measured with the following parameters unless it is otherwise specified:

- Tc =25°C
- Vdd = 3.3 V
- f = 915 MHz (middle frequency of the useful bandwidth).

The spectrum analyzer settings are described in the ANSI C63.10-2020 [5].

4.1 Part 15.247 measurement for frequency hopping systems

The section 15.247(a) describes how the equipment under test (EUT) meets the definition of a frequency hopping spread spectrum system.

4.1.1 20 dB channel bandwidth

The 20 dB channel bandwidth is defined as the difference between the upper and lower frequencies that are -20 dB relative to the peak. The measurement is performed in conducted mode connecting the STM32WL3 application board to a spectrum analyzer.

The spectrum analyzer settings are as defined as follows:

- Span = approximately two to three times the 20 dB bandwidth, centered on a hopping channel
- RBW ≥ 1% of the 20 dB bandwidth
- VBW ≥ RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

Some limits are set by the FCC for frequency hopping system operating in the 902 – 928 MHz bandwidth:

- For systems with at least 50 hopping frequency channels, the 20 dB bandwidth has to be less than 250 kHz;
- For systems with at least 25 hopping frequency channels, the 20 dB bandwidth must be less than 500 kHz.

The STM32WL3 supports the two cases with different data rates and frequency deviations. As example, the case with:
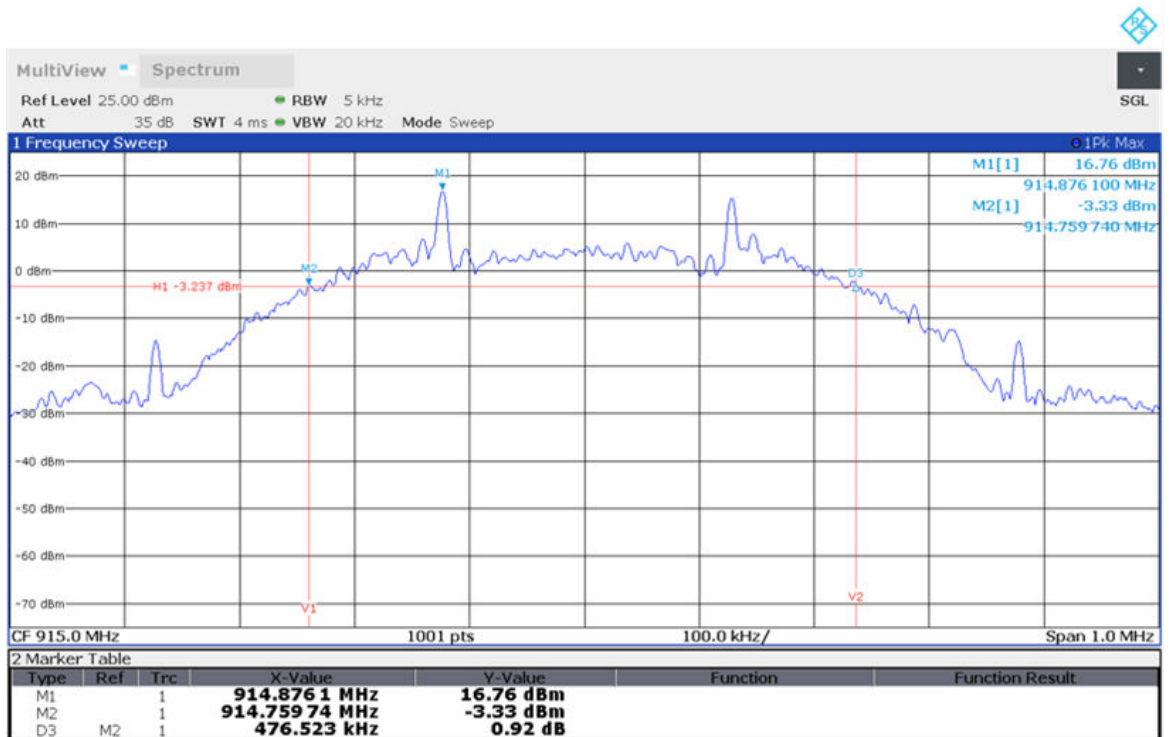
- Data rate = 250 kbps
- Frequency deviation = 127 kHz
- Modulations = GFSK with BT = 1 and GFSK with BT = 0.5

Figure 3. 20 dB channel bandwidth (2GFSK05)
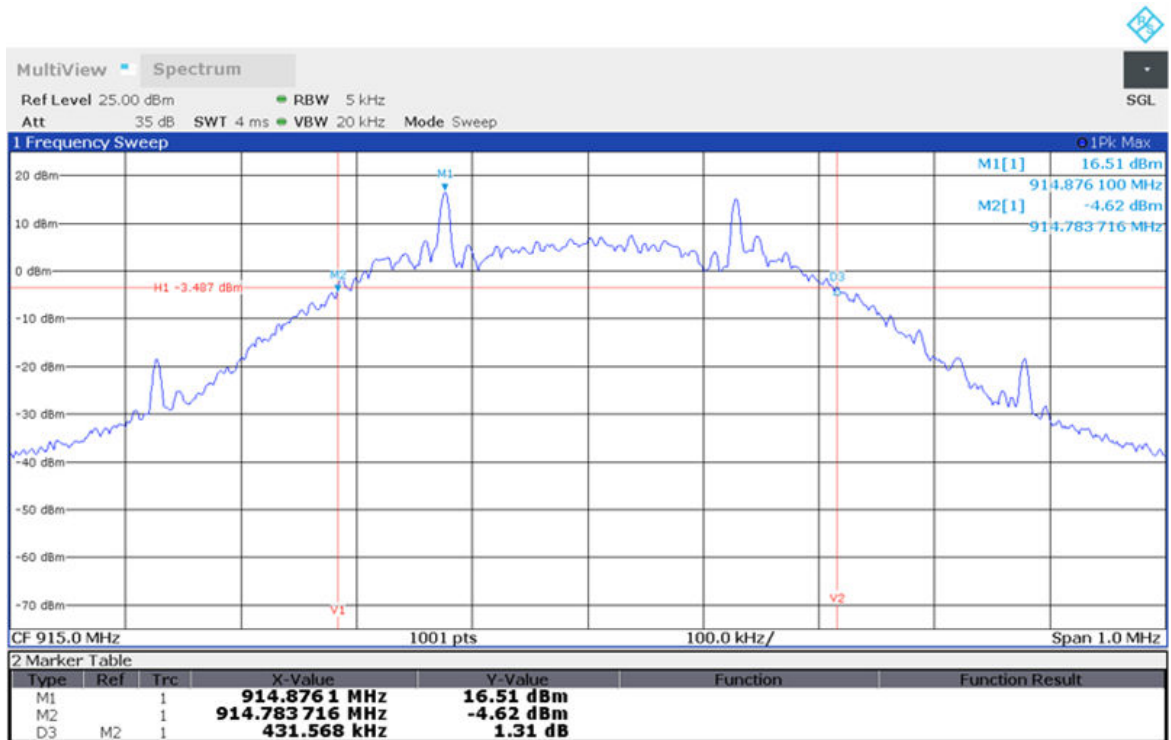
Figure 4. 20 dB channel bandwidth (2GFSK1)

In both Figure 3 and Figure 4, the measured bandwidth of 20 dB is lower than 500 kHz, so it is possible to work in a frequency hopping system with 25 hopping channels and a data rate of 250 kbps or lower.

4.1.2 Carrier frequency separation

Frequency hopping systems shall have hopping channel carrier frequencies separated by minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater.

The measure is performed in conducted mode connecting the STM32WL3 application board to a spectrum analyzer.

The spectrum analyzer settings are defined as follows:

- Span = wide enough to capture the peaks of two adjacent channels
- RBW ≥ 1% of the span
- VBW ≥ RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

Since the FCC refers to the carrier frequency separation, this parameter can be measured on either an un-modulated or the modulated signal.

This test has been carried out with an un-modulated carrier. The measured channel separation is kept to the lowest possible value, in this case it is 25 kHz, and the hop is shown in Figure 5. If numerous data rates and deviation settings are applied for different operating modes, a separate measurement must be made for each mode.

Figure 5. Minimum carrier frequency separation
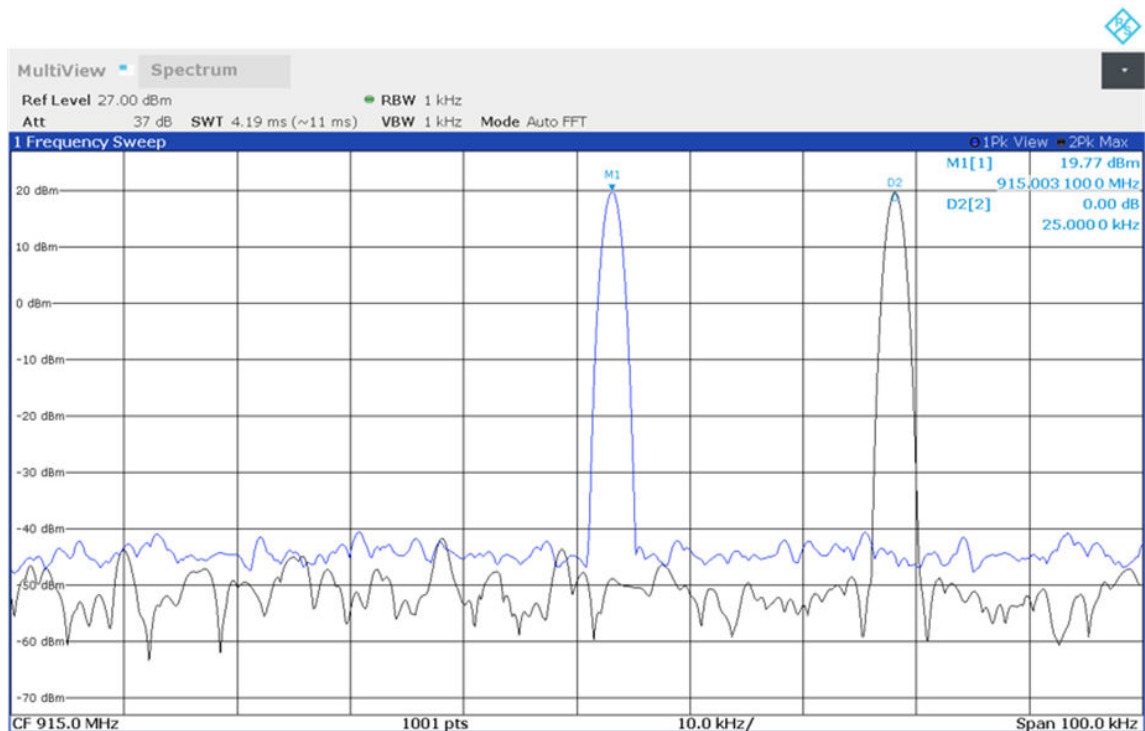
4.1.3 Number of hopping channels

For frequency hopping systems operating in the 902–928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

The spectrum analyzer settings are defined as follows:

- Span = the frequency band of operation 902 - 928 MHz
- RBW ≥ 1% of the span
- VBW ≥ RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

In the STM32WL3, the full bandwidth coverage is measured with 25 jumps from 902 MHz to 928 MHz in a steps of 1 MHz. It demonstrates that 25 hopping channels are covered by the STM32WL3, making it paticularly adapted for the applications that must comply with FCC part 15.247 frequency hopping systems. The full band channel hopping is illustrated in Figure 6.

Figure 6. Full band hopping channels
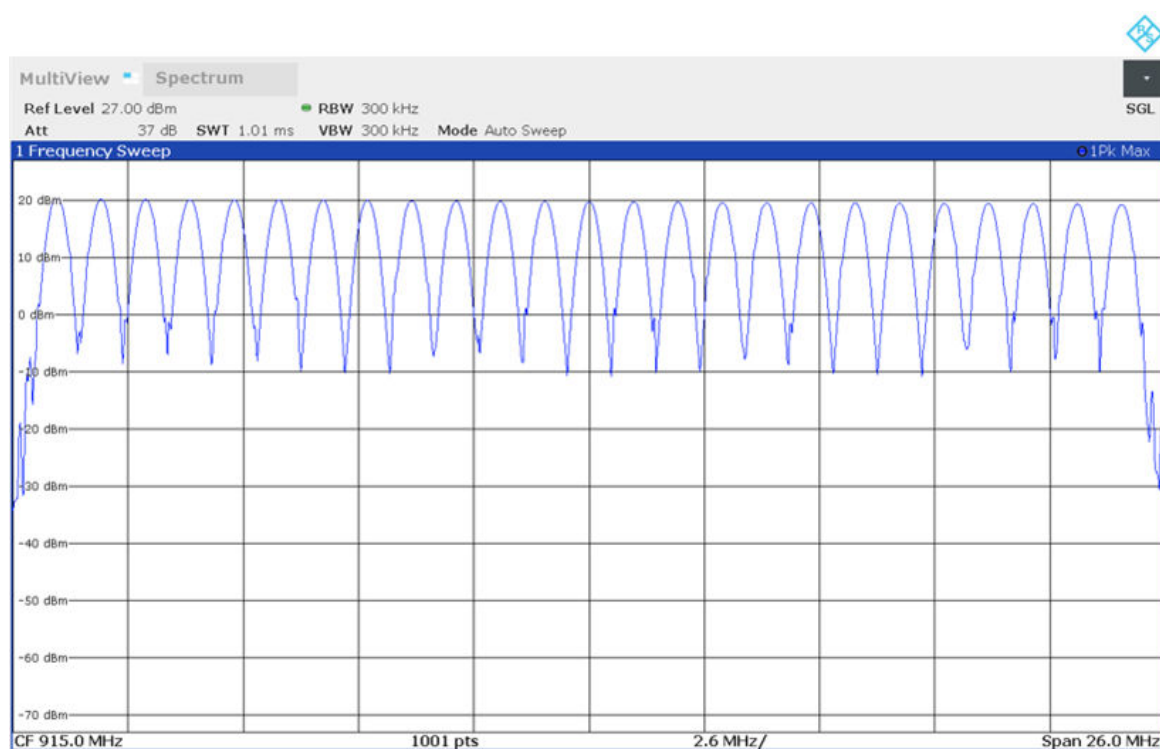
4.1.4 Peak output power

The maximum peak conducted output power of the intentional radiator shall not exceed 1 watt for systems employing at least 50 hopping channels and 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels.

To measure the peak output power, center the spectrum analyzer on a hopping channel and put the STM32WL3 in modulated mode.

The spectrum analyzer settings are defined as follows:

- Span = approximately 5 times the 20 dB bandwidth
- RBW ≥ the 20 dB bandwidth of the emission being measured
- VBW ≥ RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

STM32WL3 has been set as following:

- Modulation = 2-FSK
- Data rate = 250 kbps
- Frequency deviation = 127 kHz
- Output power = max output power

The measured output power, 19.7 dBm (see Figure 7), is lower than the maximum permitted output power (24 dBm for systems with at least 25 channels).

Figure 7. Peak output power

4.1.5 Band Edge conducted emissions

According to the FCC 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 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. 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 FCC part 15.209.

To perform these measurements, select the channels closest to the frequency band edges at 902 MHz and 928 MHz.

The spectrum analyzer settings are as defined in [5]:

- Span = wide enough to capture the peak level of the emission operating on the channel closest to the band-edge, as well as any modulation products which fall outside of the authorized band of operation
- RBW = 100 kHz
- VBW = 300 kHz
- Sweep = auto
- Detector function = peak
- Trace = max hold

STM32WL3 is configured as follows:

- Modulation = 2-FSK
- Data rate = 250 kbps
- Frequency deviation = 127 kHz
- Output power = max output power
- Center frequency = 902.5 MHz and 927.5 MHz

The band edge compliance of the RF conducted emission are shown in Figure 8 and Figure 9.

Figure 8. 902 MHz band edge conducted emission

Figure 9. 928 MHz band edge conducted emission
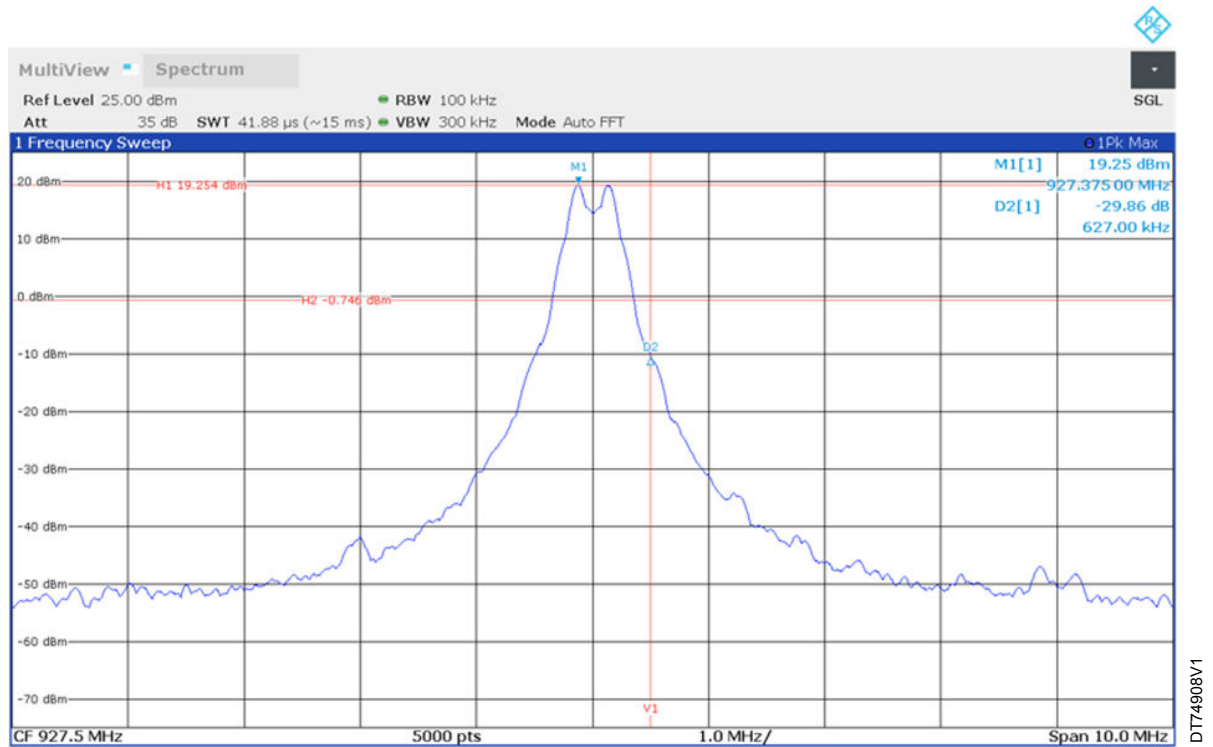
The conducted emissions in the band edges are lower than the 20 dB integrated in 100 kHz bandwidth, making STM32WL3 usable for the FCC part 15.247 in a frequency hopping system.

4.1.6 Spurious RF conducted emission

According to FCC part 15.247, all the other emissions outside these bands shall not exceed the general radiated emission limits specified in the FCC part 15.209. According to FCC part 15.33, for an intentional radiator operating below 10 GHz, the frequency range of measurements must be done up to the tenth harmonic of the highest fundamental frequency or up to 40 GHz, whichever is lower. The STM32WL3 highest fundamental frequency is 928 MHz, so the tenth harmonic is 9.28 GHz that is the measuring frequency range.

The spectrum analyzer settings are as defined in [5]:

- Span = wide enough to capture the peak level of the in-band emission and all spurious emissions, such as harmonics, from the lowest frequency generated in the EUT up through the 10th harmonic.
- RBW = 100 kHz
- VBW = 300 kHz
- Sweep = auto
- Detector function = peak
- Trace = max hold

STM32WL3 is configured as follows:

- Modulation = 2-FSK
- Data rate = 250 kbps
- Frequency deviation = 127 kHz
- Output power = max output power

The spurious conducted emissions and the FCC emission mask are shown in Figure 10 and Figure 11. The STM32WL3 fully complies with the conducted spurious emission requirements.

Figure 10. Spurious conducted emission below 1 GHz
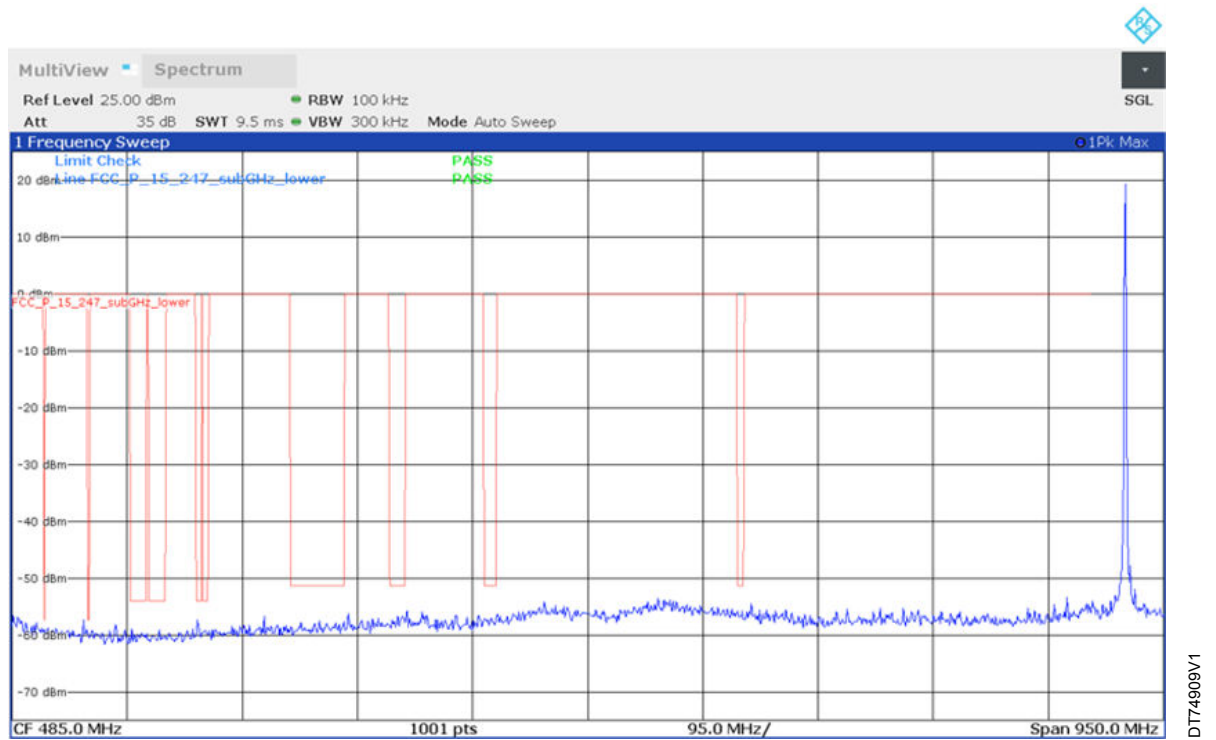
Figure 11. Spurious conducted emission above 1 GHz
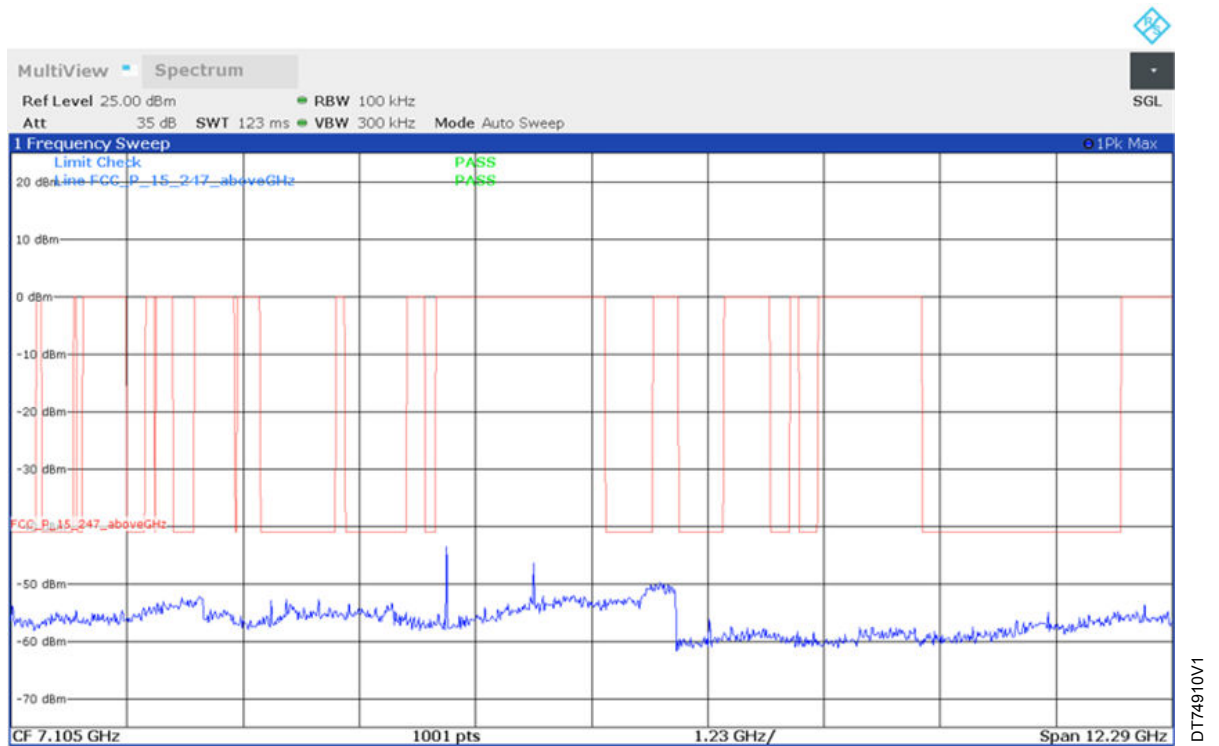
4.2 Part 15.247 measurement for digital modulation schemes

Modulation, data rate, and frequency deviation have been selected to meet the requirements of the tests detailed in :

- Section 4.2.1: 6 dB channel bandwidth
- Section 4.2.2: Maximum average conducted output power
- Section 4.2.3: Average power spectral density in the fundamental emission
- Section 4.2.4: Band-edge compliance of RF conducted emissions
- Section 4.2.5: Emission in non-restricted and restricted frequency bands

4.2.1 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 STM32WL3 application board to a spectrum analyzer.

The spectrum analyzer settings are as defined in [5]:

- 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

STM32WL3 is configured as follows:

- Modulation = 2-FSK
- Data rate = 50 kbps
- Frequency deviation = 185 kHz
- Output power = max output power

The measured 6 dB bandwidth 563kHz is more than 500 kHz, so the device is usable for the digital modulation schemes as defined in the FCC part 15.247 (see Figure 12).

Figure 12. 6dB channel bandwidth
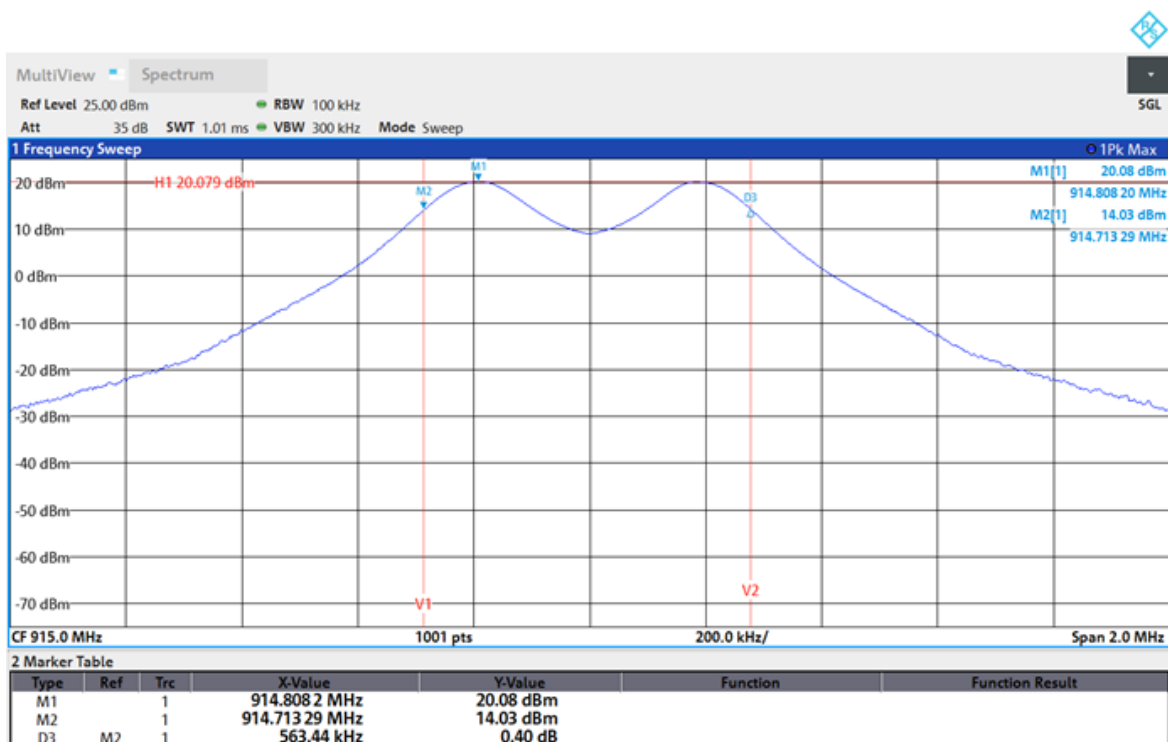
4.2.2 Maximum average conducted output power

To measure the average output power, center the spectrum analyzer on the required channel and configure the STM32WL3 in modulated mode.

The spectrum analyzer settings are as defined in [5], AVGSA-1 method:

- Span ≥ 1.5 x DTS bandwidth (6 dB channel bandwidth)
- RBW = 1% to 5% of the DTS bandwidth (6 dB channel bandwidth)
- VBW ≥ 3 x RBW
- Number of sweep points ≥ 2 x Span/RBW
- Sweep = auto
- Detector function = RMS
- Trace = average with at least 100 traces

STM32WL3 is configured as follows:

- • Modulation = 2-FSK
- • Data rate = 50 kbps
- • Frequency deviation = 185 kHz
- • Output power = max output power

The maximum permitted conducted output power is 30 dBm (1 W).

The measured average output power, 18.51 dBm, is lower than the maximum permitted output power. An external PA can be used to reach the maximum output power. See Figure 13.

Figure 13. Maximum average output power
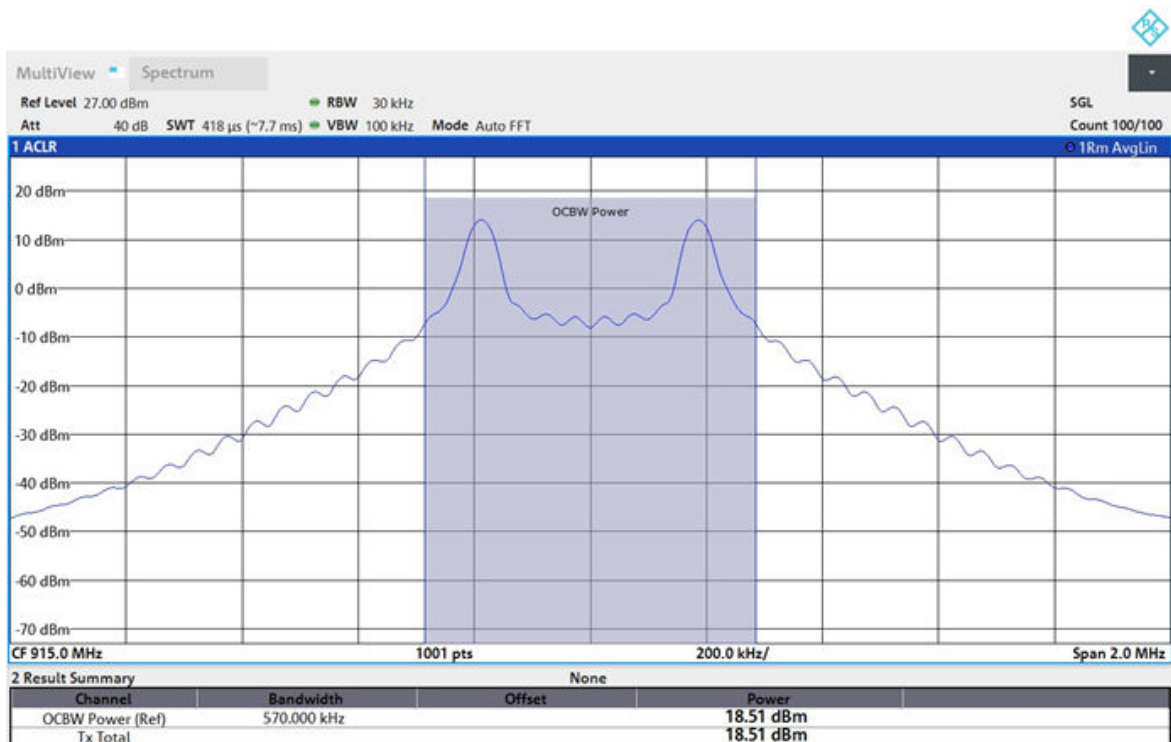
4.2.3 Average power spectral density in the fundamental emission

The power spectral density conducted from the intentional radiator to the antenna must 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 [5], AVGSA-1 method:

- Span ≥ 1.5 x DTS bandwidth (6 dB channel bandwidth)
- 3 kHz ≤ RBW ≤ 100 kHz
- VBW ≥ 3 x RBW
- Number of sweep points ≥ 2 x Span/RBW
- Sweep = auto
- Detector function = RMS
- Trace = average with at least 100 traces

Use the peak marker function to determine the maximum amplitude level within the RBW.

The peak measured signal level must not exceed +8 dBm.

If the measured level exceeds the limit, reduce the RBW (no less than 3kHz) and repeat.

STM32WL3 is configured as follows:

- • Modulation = 2-FSK
- • Data rate = 50 kbps
- • Frequency deviation = 185 kHz
- • Output power = maximum output power

The STM32WL3 meets the power spectral density requirement as shown in Figure 14.

Figure 14. Average power spectral density
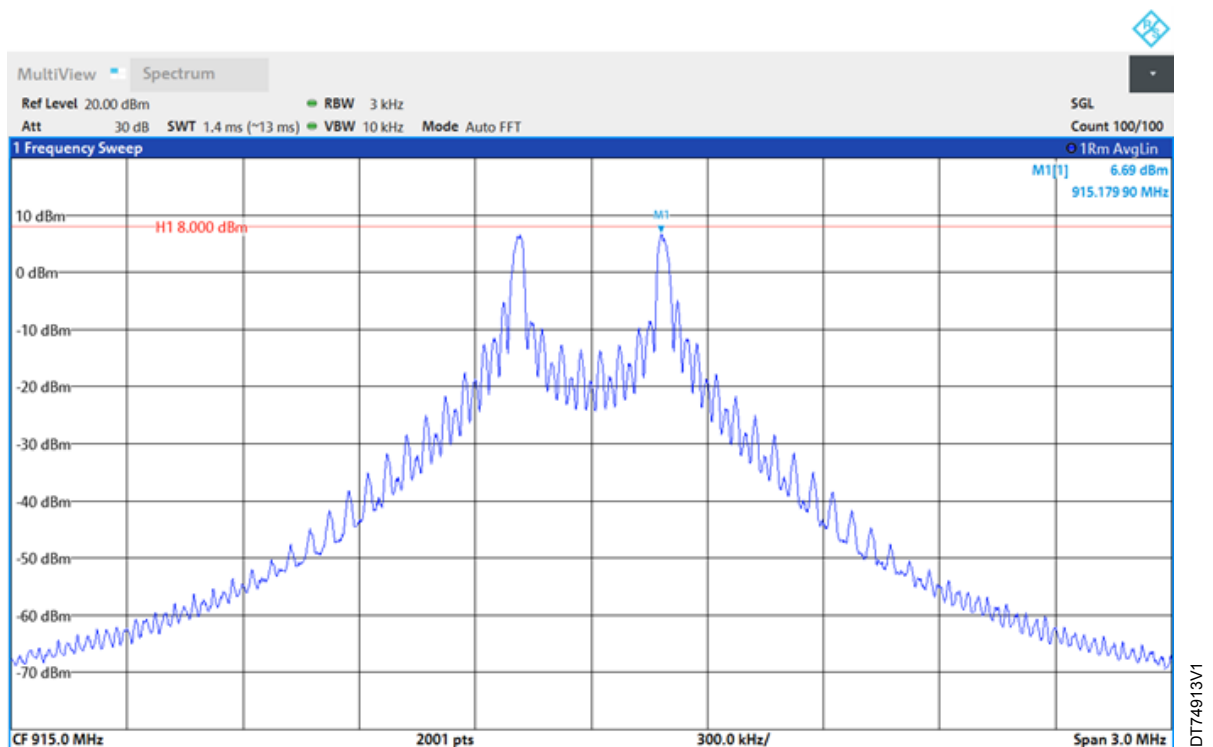
4.2.4 Band-edge compliance of RF conducted emissions

According to the 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 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. In addition, 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 [5]:

• Marker-delta method
• Integration method with three different cases
    – EUT can be configured to transmit continuously.
    – EUT cannot be configured to transmit continuously but the duty cycle is constant.
    – EUT cannot be configured to transmit continuously, and the duty cycle is not constant.

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.

STM32WL3 can be programmed to transmit continuously so the marker-delta method is used.

The instrument setting is done in according to [5]:

• Span = 10 MHz
• RBW = 100 kHz
• VBW ≥ 3 x RBW
• Sweep time = auto
• Detector function = peak
• Trace = max hold

STM32WL3 is configured as follows:

• Modulation = 2-FSK
• Data rate = 50 kbps
• Frequency deviation = 185 kHz
• Output power = maximum output power
• Output frequency = 902.5 MHz and 927.5 MHz

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. See Figure 15 and Figure 16.

Figure 15. **902MHz band edge conducted emission**
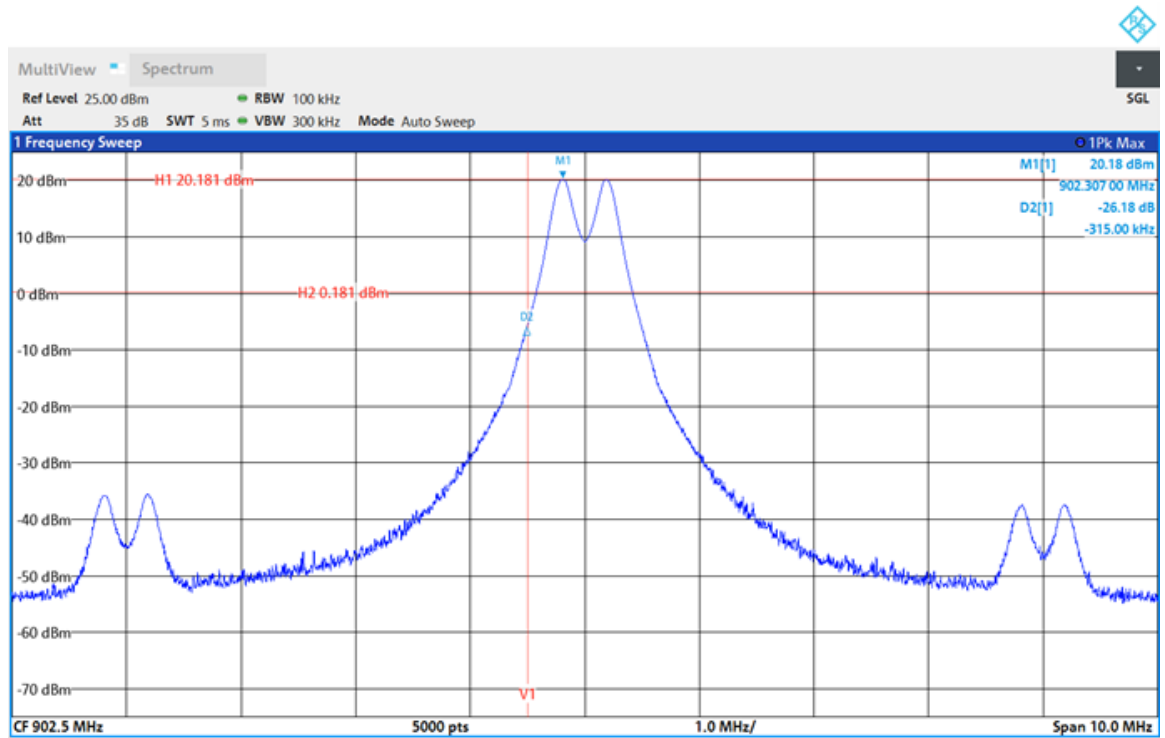
Break

Figure 16. **928MHz band edge conducted emission**
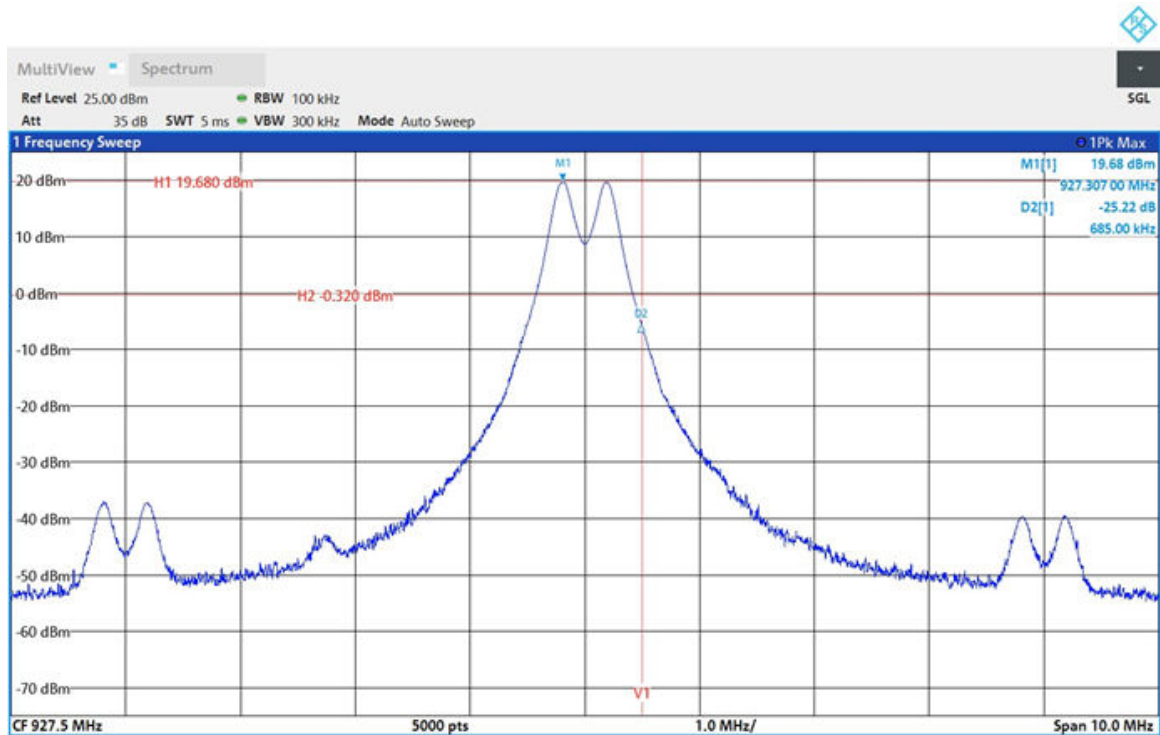
The conducted emissions in the band edges are lower than 20 dB integrated in 100 kHz bandwidth, making STM32WL3 suitable for the FCC part 15.247 digital modulation scheme.

4.2.5 Emission in non-restricted and restricted frequency bands

FCC part 15.247 defines two different cases for the emission outside the 902 – 928 MHz band:

- Emission that falls in a unrestricted band
- Emission that falls in a restricted band as defined in the 15.205

For the emission in the unrestricted band, the DTS [4] rules specify that in any 100 kHz bandwidth the power shall be 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 shall be 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 shall be 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 STM32WL3 has be demonstrated using the average conducted output power procedure, so the 30 dBc limit must be considered.*

STM32WL3 is configured as follows:

- Modulation = 2-FSK
- Data rate = 50 kbps
- Frequency deviation = 185 kHz
- Output power = maximum output power

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 must 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.

The compliance of the emission in restricted bands of the STM32WL3 is shown using the conducted measurement. The peak power measurement procedure (paragraph 11.12.2.4 of [5]) is used with the following settings:

- RBW = as specified in Table 4
- VBW ≥ 3 x RBW
- Number of sweep points ≥ 2 x Span/RBW
- Sweep time = auto
- Detector function = RMS
- Trace = average with at least 100 traces

Table 4. RBW as a function of frequency

Frequency	RBW
9 kHz to 150 kHz	200 Hz to 300 Hz
0.15 MHz to 30 MHz	9 kHz to 10 kHz
30 MHz to 1000 MHz	100 kHz to 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)
- EUT cannot be configured to transmit continuously but the duty cycle is constant (paragraph 11.12.2.5.2)

- EUT cannot be configured to transmit continuously and the duty cycle is not constant (paragraph 11.12.2.5.3)

STM32WL3 compliance is not demonstrated by the peak-detected amplitude method, so it is necessary to perform the average amplitude measurements.

The spurious conducted emissions and the FCC emission mask are shown in Figure 17 and Figure 18 the following figures.

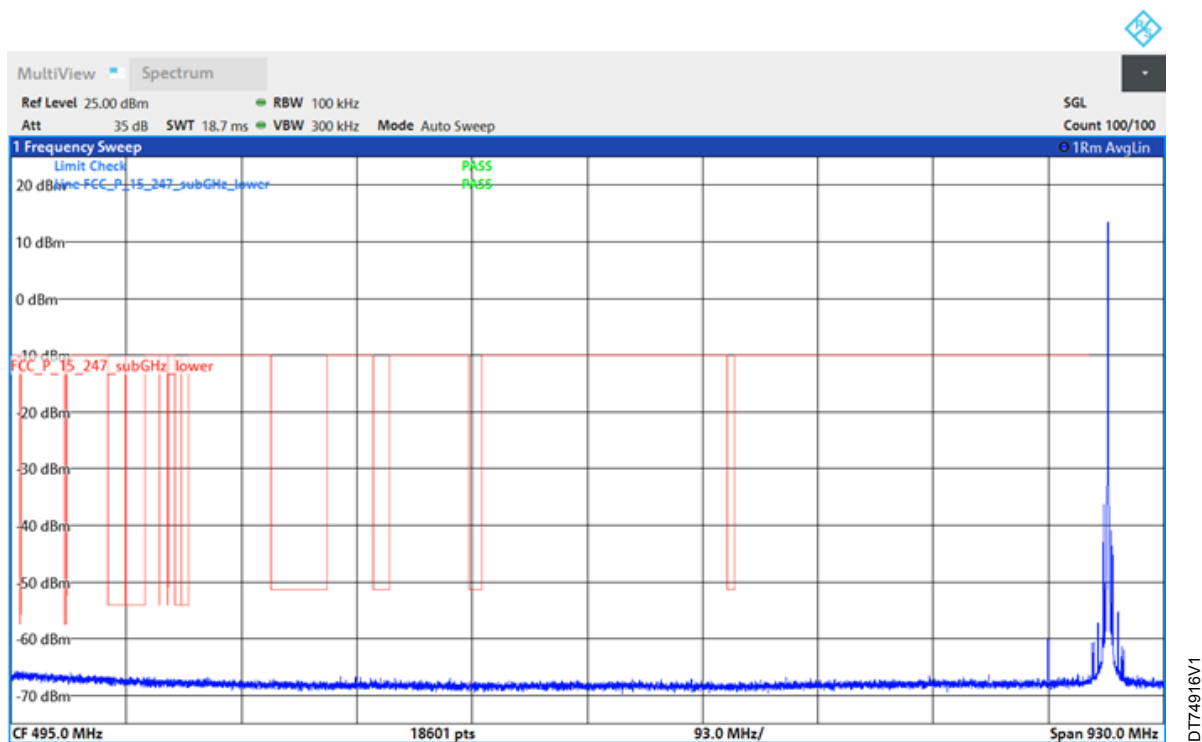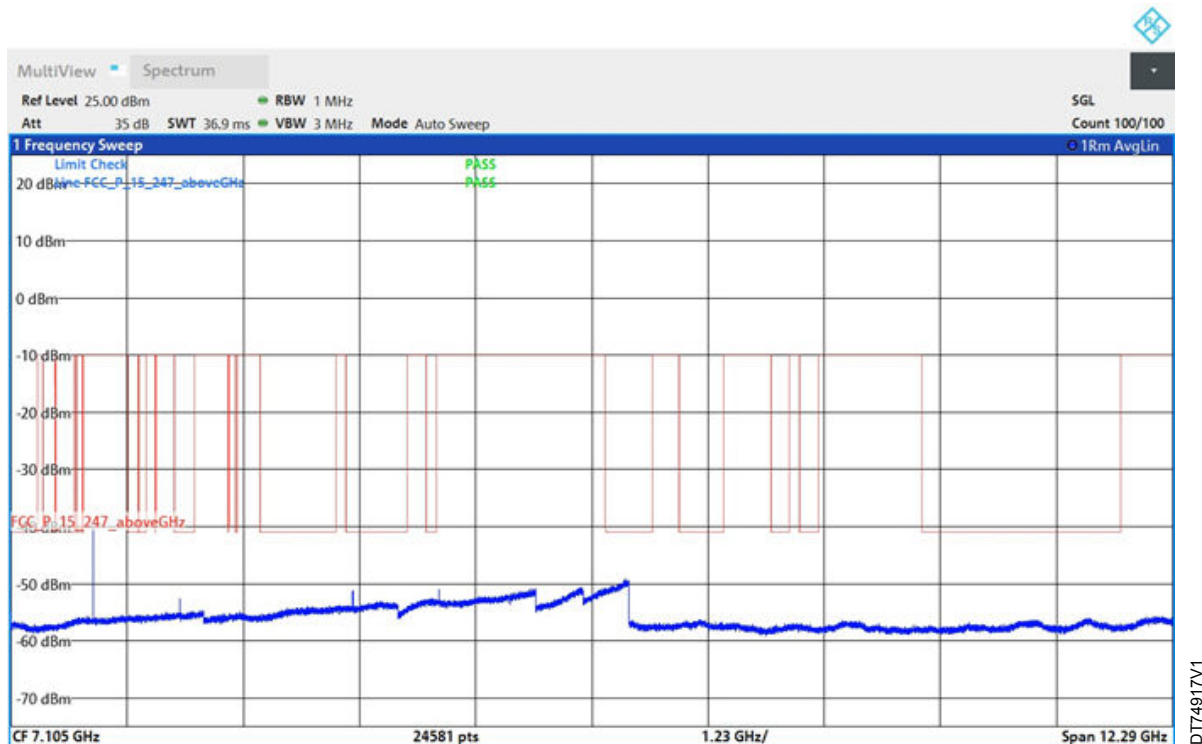**Figure 17. Spurious conducted emission (non-restricted and restricted) below 1 GHz**

Figure 18. **Spurious conducted emission (unrestricted and restricted) above 1 GHz**

4.3 Part 15.249 measurements

4.3.1 Peak output power

The maximum output power has to be about -1 dBm and no restrictions are defined for the modulation scheme or the end application.

The spectrum analyzer settings are the following:

- Span ≥ 2 MHz
- RBW ≥ 1 MHz
- VBW ≥ 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

STM32WL3 is configured as follows:

- Modulation = 2-FSK
- Data rate = 250 kbps
- Frequency deviation = 250 kHz
- Output power = -1 dBm
- Output frequency = 915 MHz

The measured STM32WL3 output power is -1.39 dBm. This output power is the maximum permitted output power in according to the FCC part 15.249 requirements. See the figure below.

Figure 19. Peak output power at -1 dBm
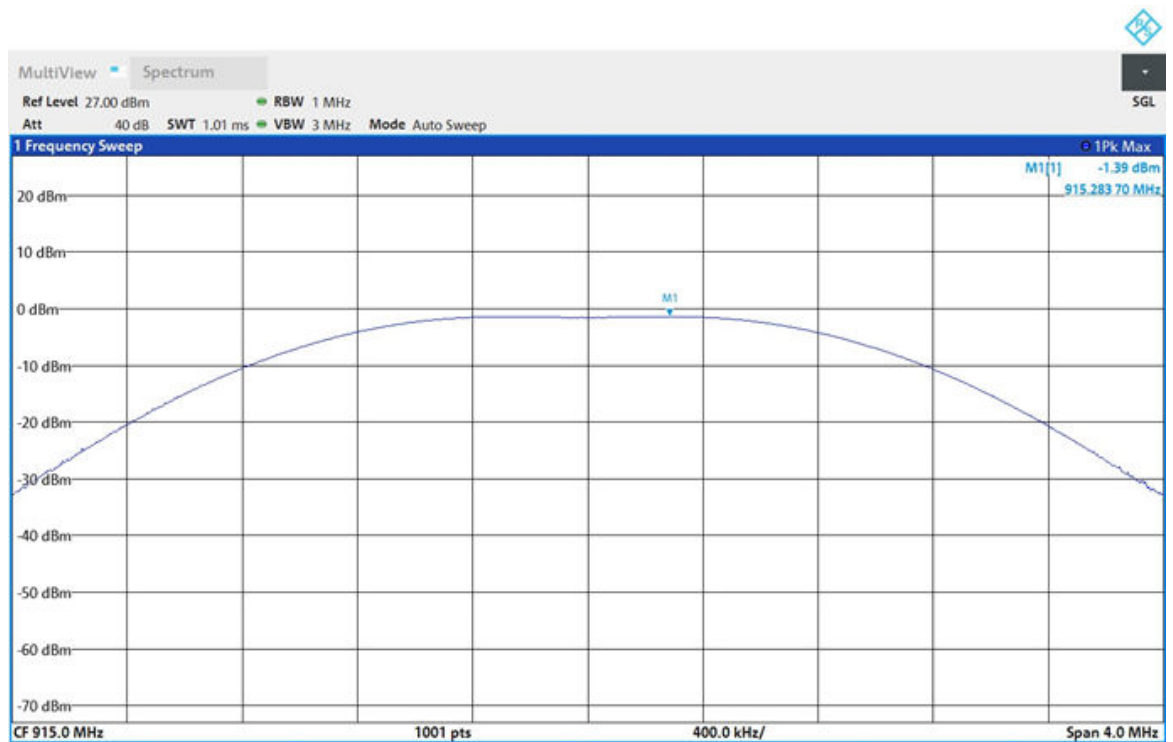
4.3.2 Conducted harmonics and other than harmonics emissions

FCC 15.249 establishes different limits for unwanted harmonic emissions and unwanted non-harmonic emissions as following:

- Unwanted harmonic emission: maximum permitted field strength of harmonic components for the device working on the 902 – 928 MHz band is 500 μV/m at a distance of 3m. This equates to a conducted power level of about -41 dBm.

- Unwanted non-harmonic emission: emissions radiated outside the specified frequency band, except for harmonics, must be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in the part 15.209, whichever is the lowest attenuation.

According to part 15.33, for an intentional radiator operates below 10 GHz, the frequency range of measurements has to be up to the tenth harmonic of the highest fundamental or up to 40 GHz, whichever is lower. The STM32WL3 highest fundamental frequency is 928 MHz, so the tenth harmonic is 9.28 GHz that is the frequency limit of measurement.

The instrument setting is done according to [5]:

- Span = 1 GHz for frequencies < 1 GHz, 8 GHz for frequencies ≥ 1 GHz
- RBW = 100 kHz for frequencies < 1 GHz, 1 MHz for frequencies ≥ 1 GHz
- VBW ≥ 3 x RBW
- Number of sweep points ≥ 2 x Span/RBW
- Sweep time = auto
- Detector function = RMS
- Trace = average with at least 100 traces

STM32WL3 has been set as following:

- Modulation = 2-FSK
- Data rate = 250 kbps
- Frequency deviation = 250 kHz
- Output power = -1 dBm
- Output frequency = 928 MHz

The harmonics and other than harmonics conducted emissions are shown in the Figure 20 and Figure 21. The FCC emission mask according to the part 15.249 and 15.209 requirements is also reported. Table 3 summarizes the limits.

Figure 20. Spurious conducted emission below 1 GHz
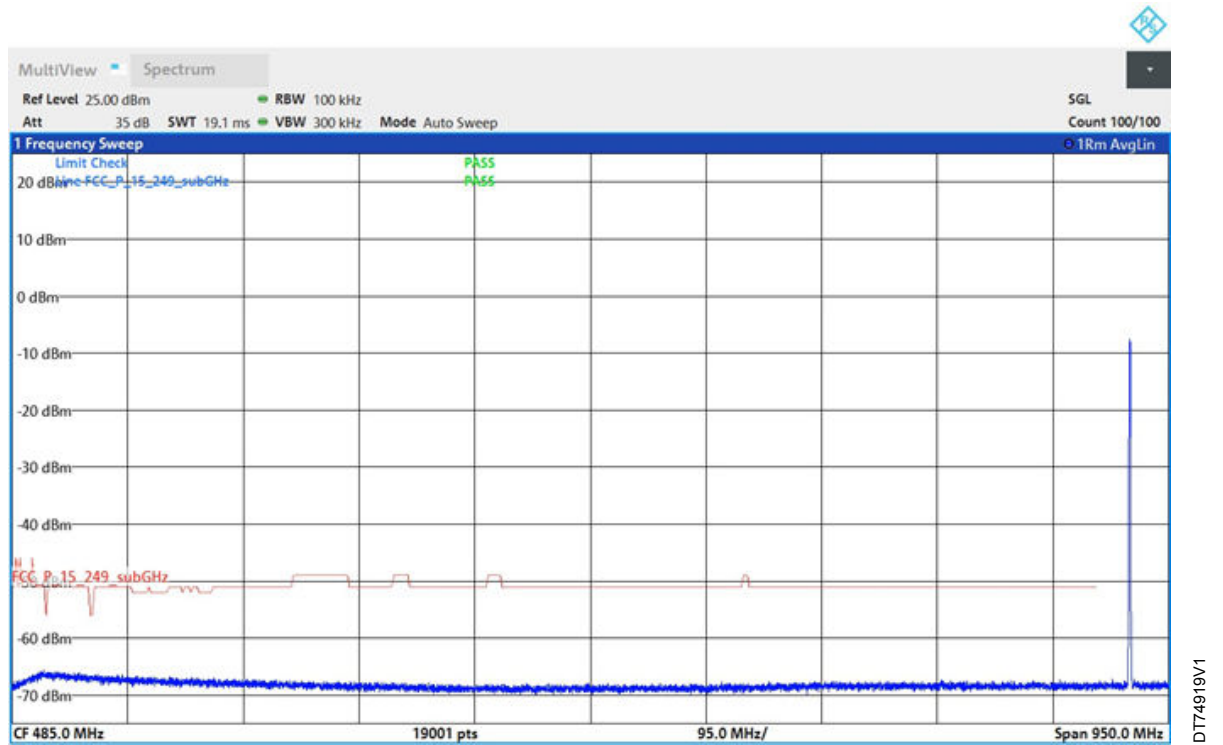
Break

Figure 21. Spurious conducted emission above 1 GHz
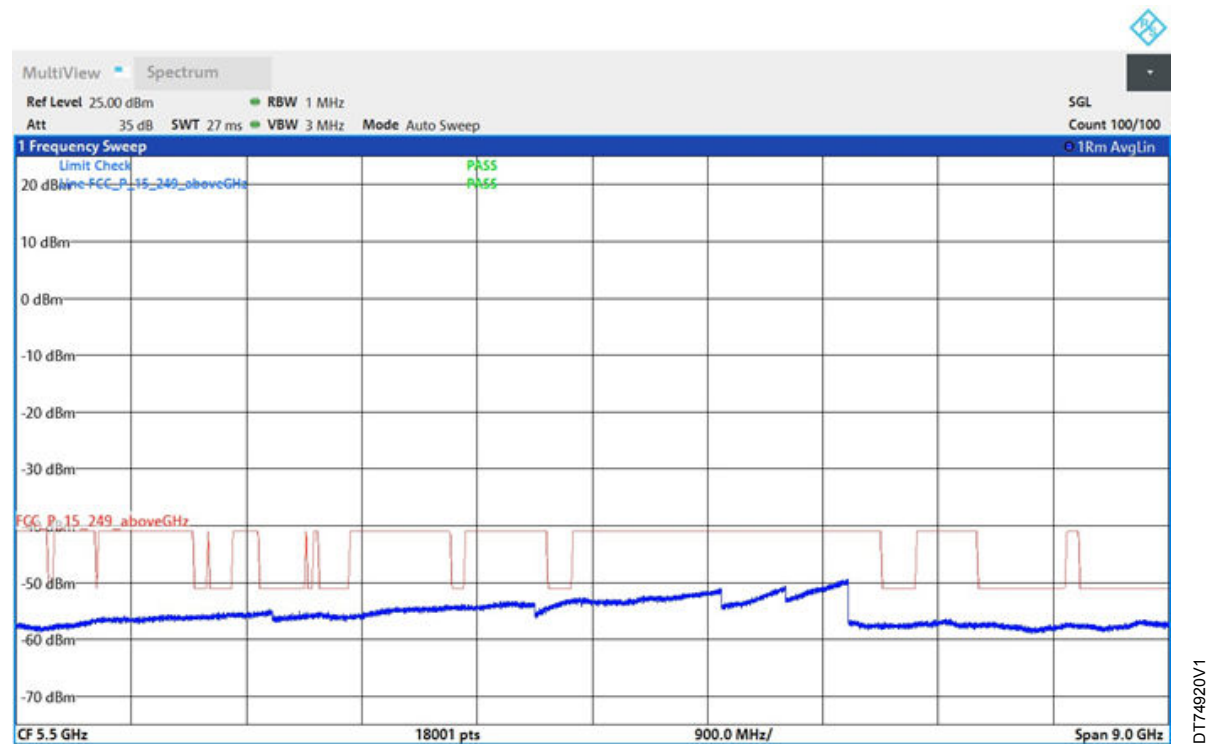
5 Receiver parameter

No specific requirements are defined for the FCC compliance of the receiver in the US FCC title 47 part 15 [2] in the 902 to 928 MHz band. No measurements were done for the receiver.

6   Reference

Table 5. Reference documents

Document reference	Title
[1]	STM32WL3 Datasheet
[2]	FCC title 47 part 15: Radio frequency devices
[3]	*Guidance for performing compliance measurements on digital transmission systems (DTS) operating under §15.247*, FCC, 558074 D01 DTS Meas Guidance v05r02, 02/04/2019
[4]	*Measurement of radiated emissions at the band edge of the band for a part 15 RF device*, FCC, publication number 913591, publication date 03/26/2007
[5]	*American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.* ANSI C63.10-2020 (redline)

Revision history

Table 6. Document revision history

Date	Version	Changes
18-Dec-2024	1	Initial release.

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