AN4949
Application note

Using the S2-LP transceiver under FCC title 47 part 15 in the 902 – 928 MHz band

Introduction

The S2-LP is a very low power 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 915 MHz.

This application note outlines the expected performance when using the S2-LP under FCC title 47 part 15 *[2]* in the 902 to 928 MHz band. There are no specific requirements in this band, no specific use and no channel spacing are defined.

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

These can be downloaded from *www.scc-ares-races.org/FCCpartstitles.html*.

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1 An overview of FCC regulations

Low power, non-licensed devices operating in the 902 – 928 MHz band can be found everywhere, in toys, wireless security systems, wireless telemetry or wireless automatic meter reading, and so on.

The FCC is the USA body responsible for the implementation rules to limit the potential for interference to licensed operations by low power, non-licensed transmitters. These rules are documented in Part 15 of Title 47of the FCC.

For operation in the 902 – 928 MHz band, a low power, non-licensed device must meet one of the following sub-parts 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: 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 S2-LP is designed to meet the 15.247 and 15.249 sub-parts, so this document continues with a description and measurement results of these two parts.

1.1 Part 15.247

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 requirements:

- Frequency hopping systems must 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 must 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 must 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 must 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 systems employing at least 50 channels, the maximum peak conducted output power output is +30 dBm (1 W). For systems that employ 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 of operation 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.

- 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 requirements:

- 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 of operation 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.
- 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.

1.2 Part 15.249

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 at a distance of 3m 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.

1.3 Parts 15.205 and 15.209

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 and the radiated and conducted emission limits are defined in the part 15.209.

Table 1: 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 2: 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

2 Application circuit

An application board has been designed to evaluate the RF performances and to develop the connected firmware of the S2-LP transceiver. It is compatible with the Arduino UNO R3 connector layout and allows expansion of the STM32 Nucleo boards. *Figure 1: " S2-LP application daughterboard"* shows the S2-LP application board photo.

The daughterboard is provided with a 50 MHz xtal to provide the correct oscillator to the S2-LP.

The S2-LP has an internal SMPS that drastically reduces the power consumption making the S2-LP the best in class for the application on this bandwidth. The SMPS is fed from the battery (1.8 V to 3.6 V) and provides the device with a programmable voltage (1.5 V usually). An SMA connector is present to connect the board at antenna or at instrumentation to verify the correct functionality and verify the compatibility with the requested standards.

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

To reduce application costs, the S2-LP is designed to work without an external antenna switch. This daughterboard is designed to show the S2-LP functionality in this condition. Clearly, an application with antenna switch can be realized, but this is not described in this document.

A dedicated graphical user interface (GUI) has been developed to correctly set the S2-LP,see *Figure 2: "Graphical user interface"*.

Figure 1: S2-LP application daughterboard

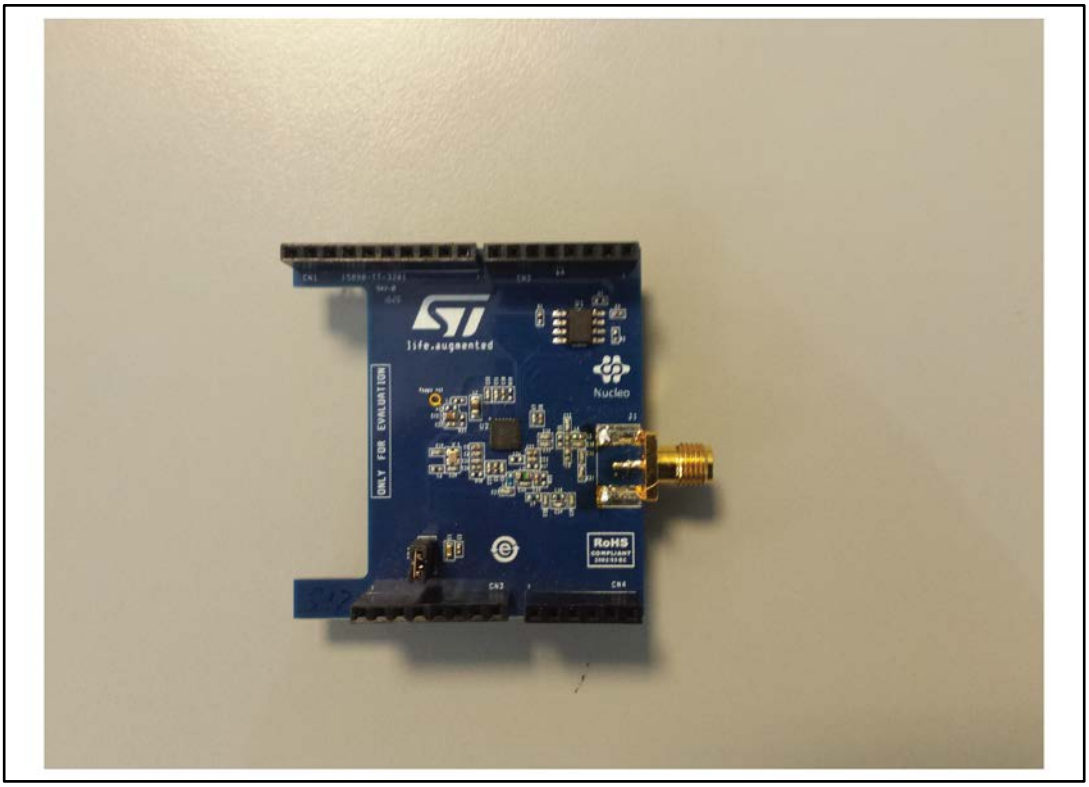
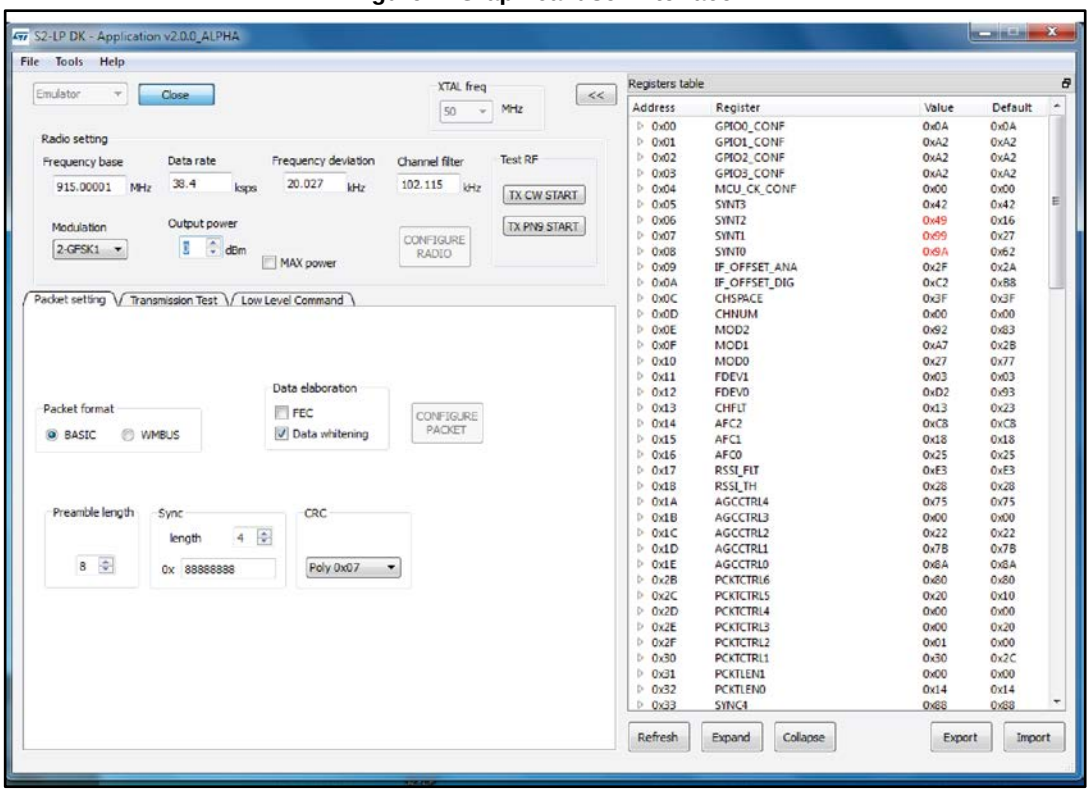


Figure 2: Graphical user interface



3 Transmitter parameter

All the measurements here reported are measured with the following parameters: Tc = 25 °C, Vdd = 3.3 V, f = 915 MHz (middle frequency of the useful bandwidth), unless otherwise specified.

3.1 Part 15.247 measurement for frequency hopping systems

3.1.1 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 S2-LP application board to a spectrum analyzer.

The spectrum analyzer settings are as defined in *[4]*:

- Span = approximately 2 to 3 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 established from 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 has to be less than 500 kHz.

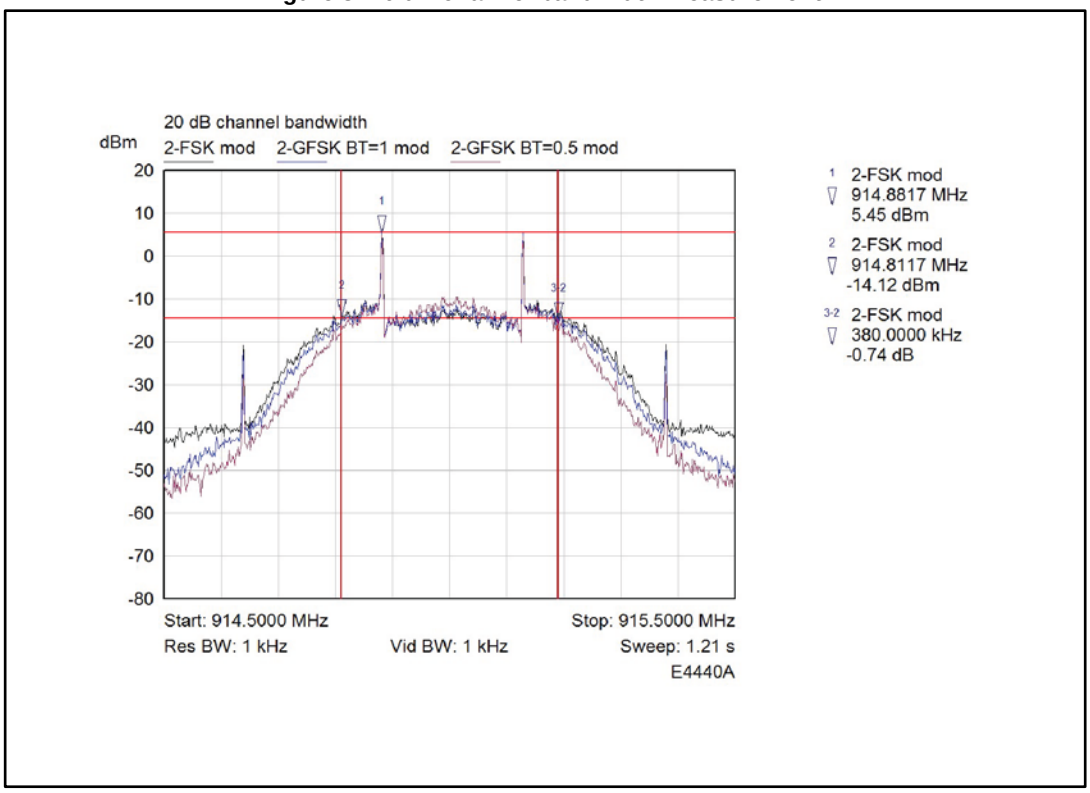
The S2-LP supports the two cases with different data rates and deviations. As example, the case with:

- Data rate = 250 kbps
- Frequency deviation = 127 kHz
- Modulations = 2-FSK, GFSK with BT = 1 and GFSK with BT = 0.5

are printed in *Figure 3: "20 dB channel bandwidth measurement"*.

The measured 20 dB bandwidth in the three cases is of 380 kHz and it is lower than 500 kHz, so it is possible to work in a frequency hopping system with 25 hopping channels with a data rate of 250 kbps or lower.

Figure 3: 20 dB channel bandwidth measurement



3.1.2 Carrier frequency separation

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

The measurement is performed in conducted mode connecting the S2-LP application board to a spectrum analyzer.

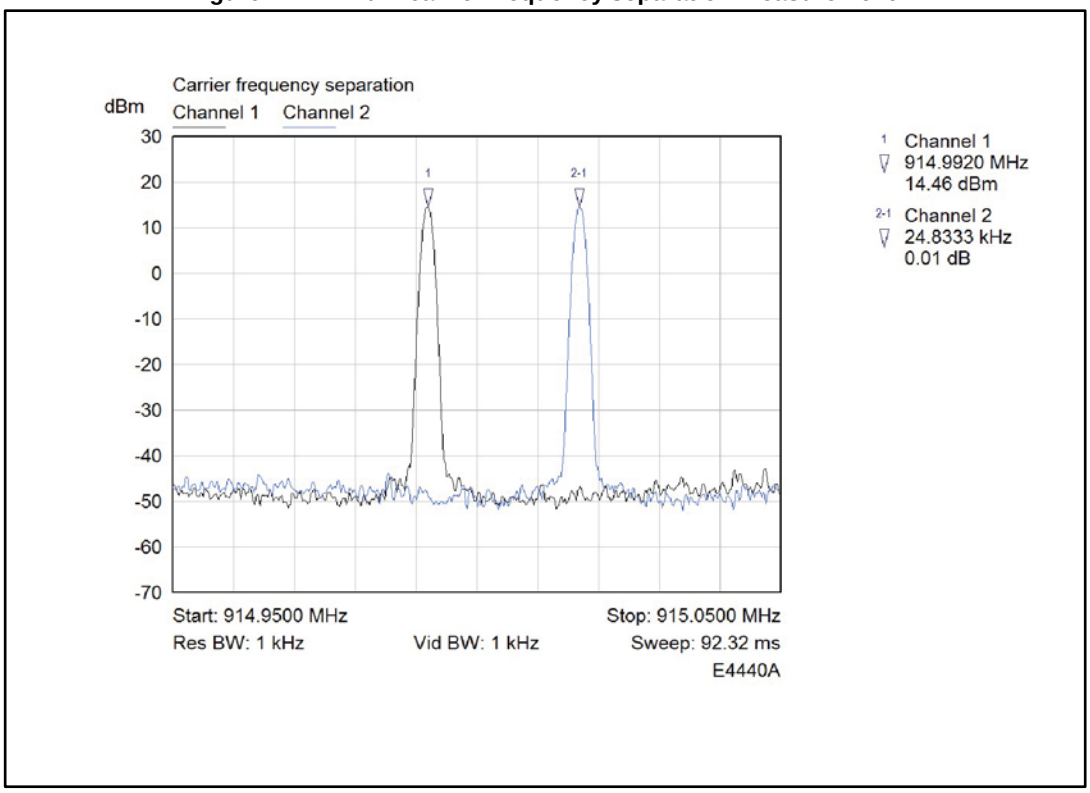
The spectrum analyzer settings are as defined in *[4]*:

- 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.

The measurement on the S2-LP is done with an un-modulated carrier. The measured channel separation is the minimum possible, 25 kHz, and the hop is shown in *Figure 4: "Minimum carrier frequency separation measurement"*. If numerous data rates and deviation setting are applied for different modes of operation, a separate measurement must be made for each mode.

Figure 4: Minimum carrier frequency separation measurement



3.1.3 Number of hopping channels

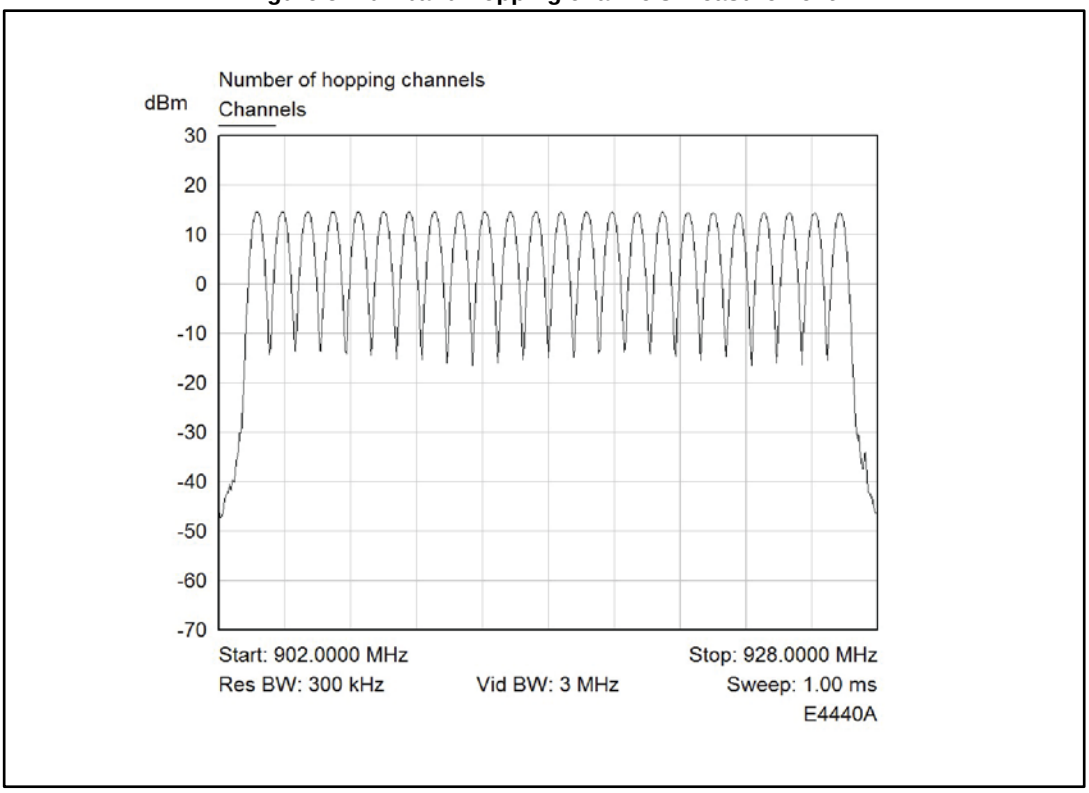
Frequency hopping systems operating in the 902 – 928 MHz band will use at least 25 or 50 hopping frequencies.

The spectrum analyzer settings are as defined in *4*:

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

In the S2-LP the full bandwidth coverage is measured with 26 jumps from 902 MHz to 928 MHz with a step of 1 MHz. So it is possible to show that more than 25 hopping channels are covered from S2-LP, making it useful in the applications that want to work on the FCC part 15.247 frequency hopping systems.

Figure 5: Full band hopping channels measurement



3.1.4 Peak output power

To measure the peak output power, center the spectrum analyzer on a hopping channel and put the S2-LP in modulated mode.

The spectrum analyzer settings are as defined in *[4]*:

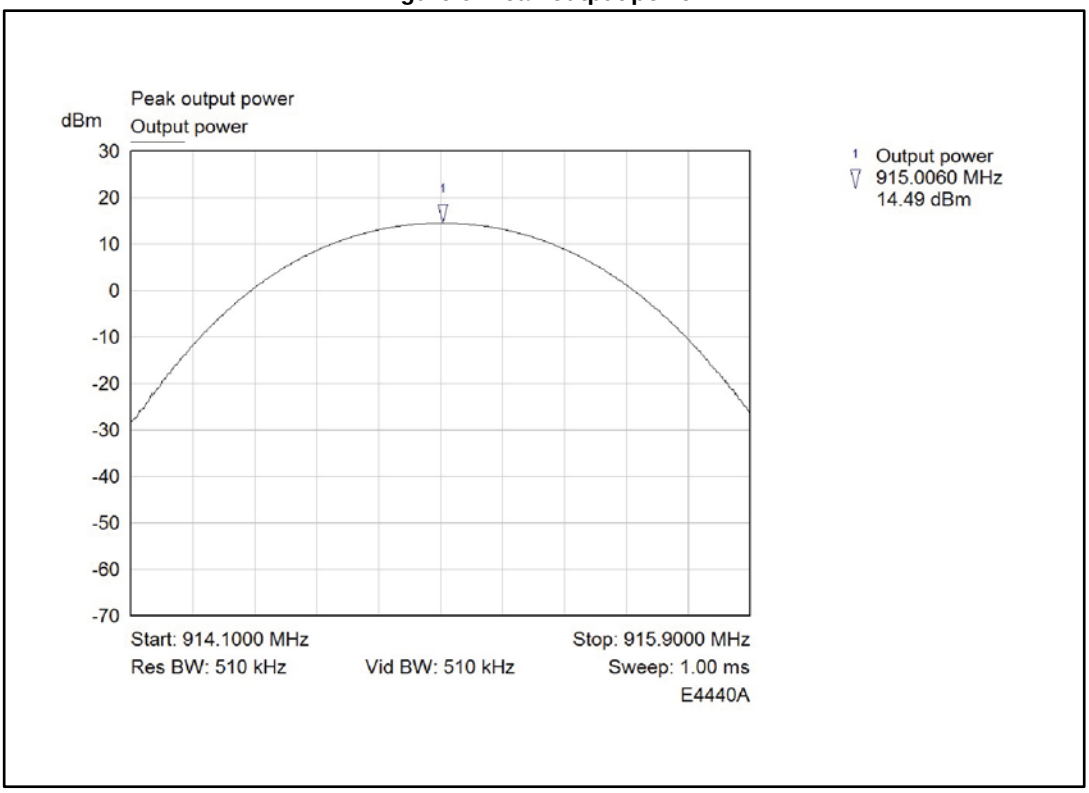
- Span = approximately 5 times the 20 dB bandwidth
- RBW ≥ the 20 dB bandwidth of the emission being measured
- VBW ≥ RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

S2-LP 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, 14.5 dBm (see *Figure 6: "Peak output power"*), is lower than the maximum permitted output power. An external PA has to be used to reach the maximum output power.

Figure 6: Peak output power



3.1.5 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, 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.

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 *4*:

- 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 ≥ 1% of the span
- VBW ≥ RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

S2-LP has been set as following:

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

The band edge compliance of the RF conducted emission are shown in *Figure 7: "902 MHz band edge conducted emission"* and *Figure 8: "928 MHz band edge conducted emission measurement"*.

The conducted emissions in the band edges are lower than 20 dB integrated in 100 kHz bandwidth, making S2-LP usable for the FCC part 15.247 in a frequency hopping system.

Figure 7: 902 MHz band edge conducted emission

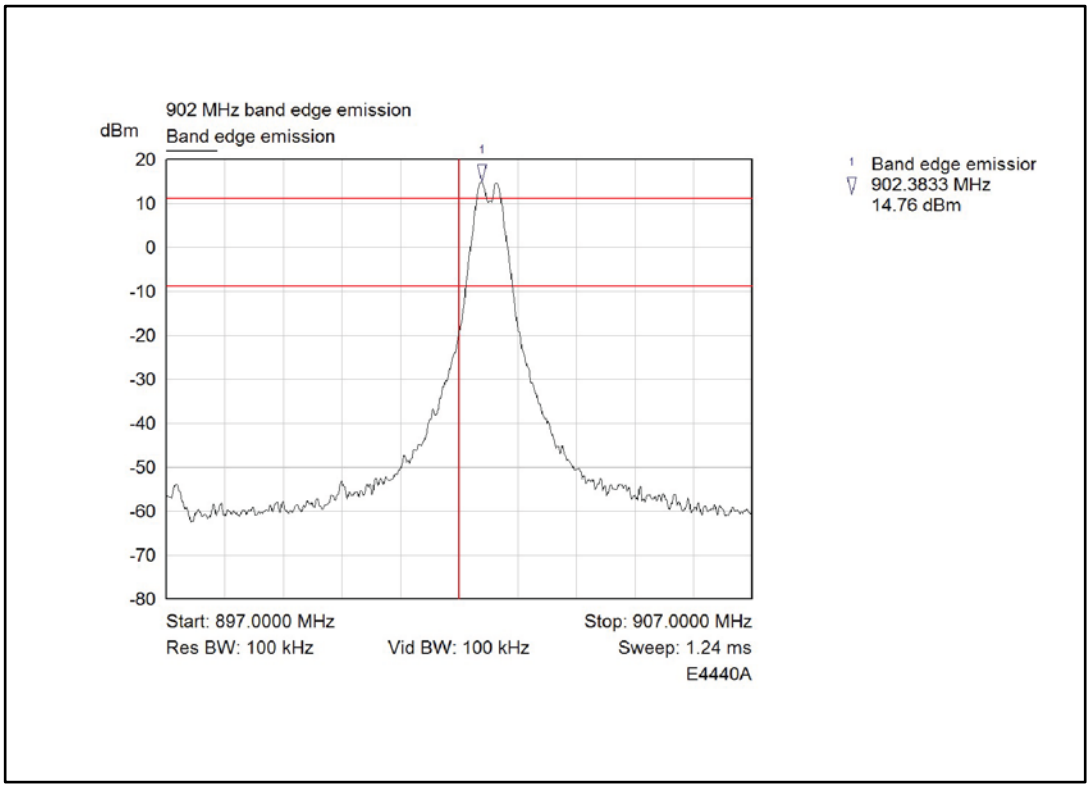
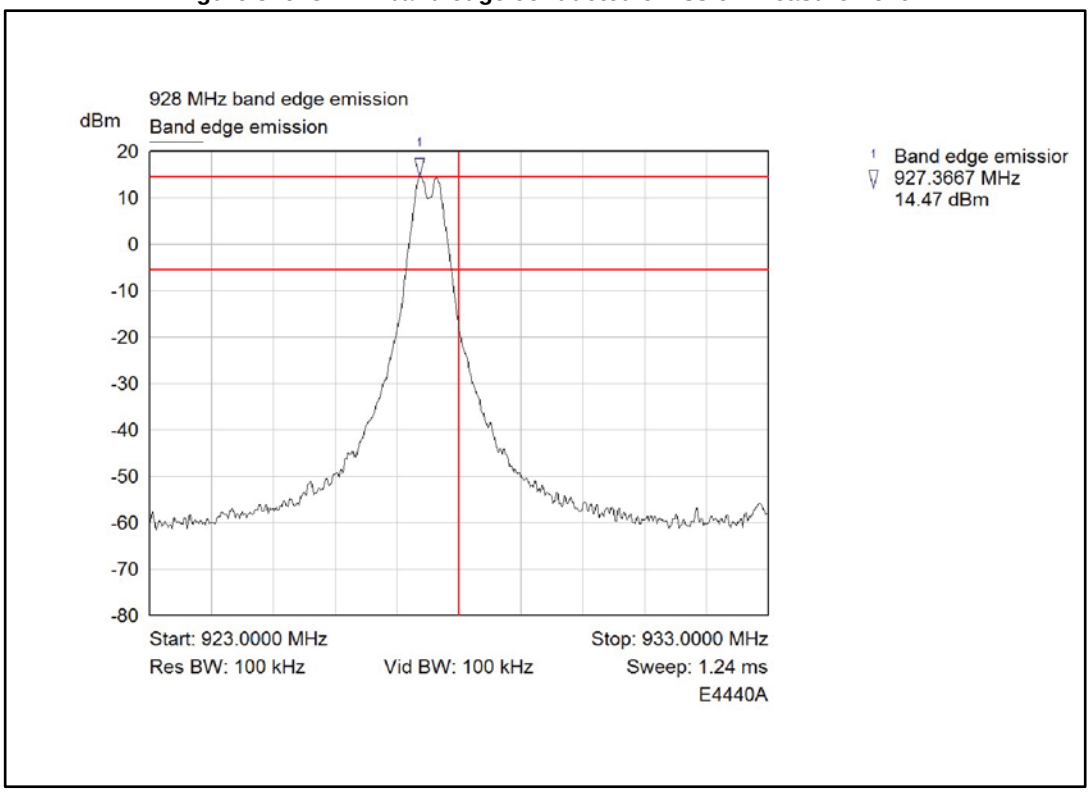


Figure 8: 928 MHz band edge conducted emission measurement



3.1.6 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 part 15.209. According to part 15.33, for an intentional radiator operates below 10 GHz, the frequency range of measurements has to be until the tenth harmonic of the highest fundamental or to 40 GHz, whichever is lower. The S2-LP highest fundamental frequency is 928 MHz, so the tenth harmonic is 9.28 GHz that is the frequency range of measurement.

The spectrum analyzer settings are as defined in *4*:

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

S2-LP has been set as following:

- 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 9: "Spurious conducted emission below 1 GHz measurement"* and *Figure 10: "Spurious*

conducted emission above 1 GHz measurement". The S2-LP is fully complying with the conducted spurious emission requirements.

Figure 9: Spurious conducted emission below 1 GHz measurement

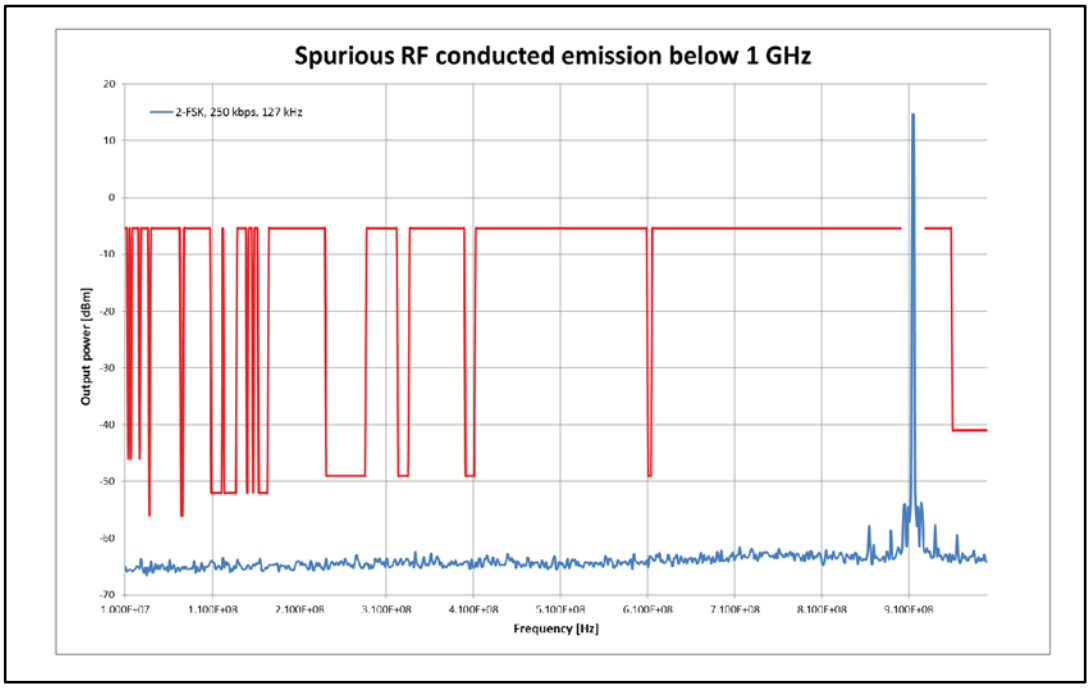
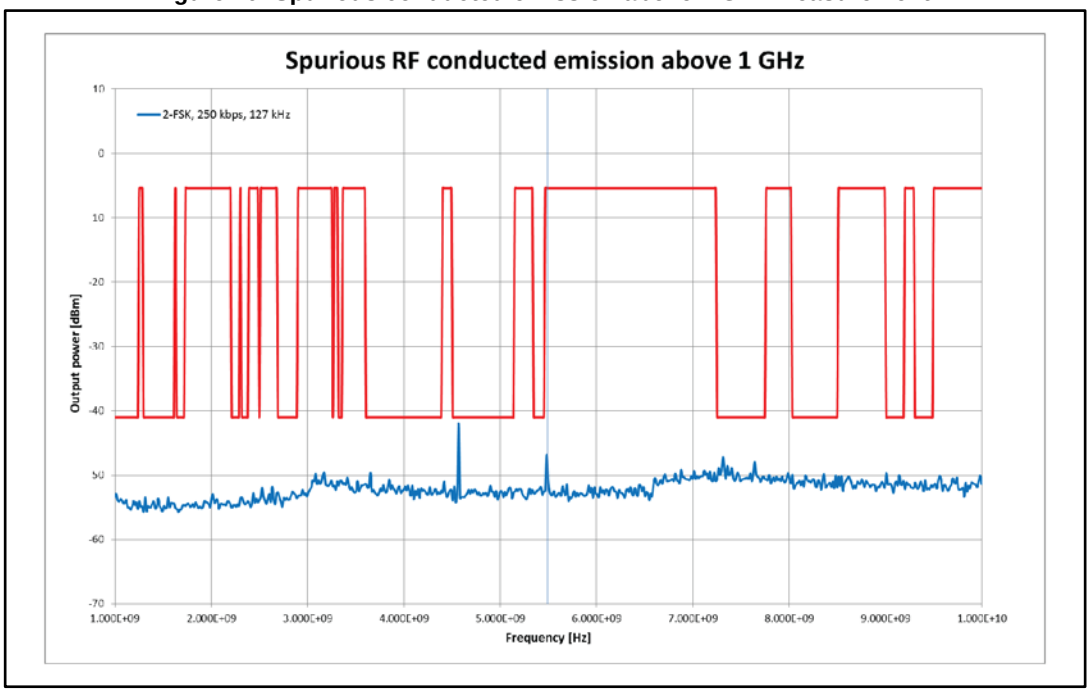


Figure 10: Spurious conducted emission above 1 GHz measurement



3.2 Part 15.247 measurement for digital modulation schemes

3.2.1 Signal 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 measured is performed in conducted mode connecting the S2-LP application board to a spectrum analyzer.

The spectrum analyzer settings are as defined in *3*:

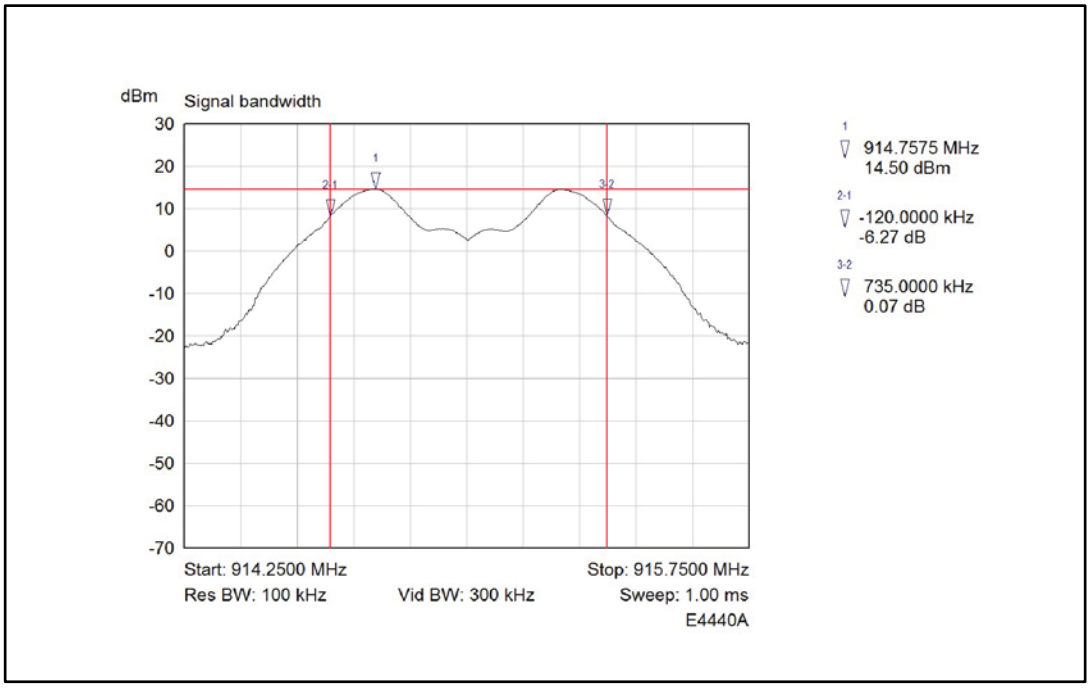
- Span = no requirement, set to approximately 2 to 3 times the 6 dB bandwidth
- RBW ≥ 100 kHz
- VBW ≥ 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

S2-LP has been set as following:

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

The measured 6 dB bandwidth, 735 KHz, is more than 500 kHz, so the S2-LP is usable for the digital modulation schemes as defined in the FCC part 15.247.

Figure 11: 6 dB bandwidth measurement



3.2.2 Maximum peak conducted output power

To measure the peak output power, center the spectrum analyzer on the wanted channel and put the S2-LP in modulated 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

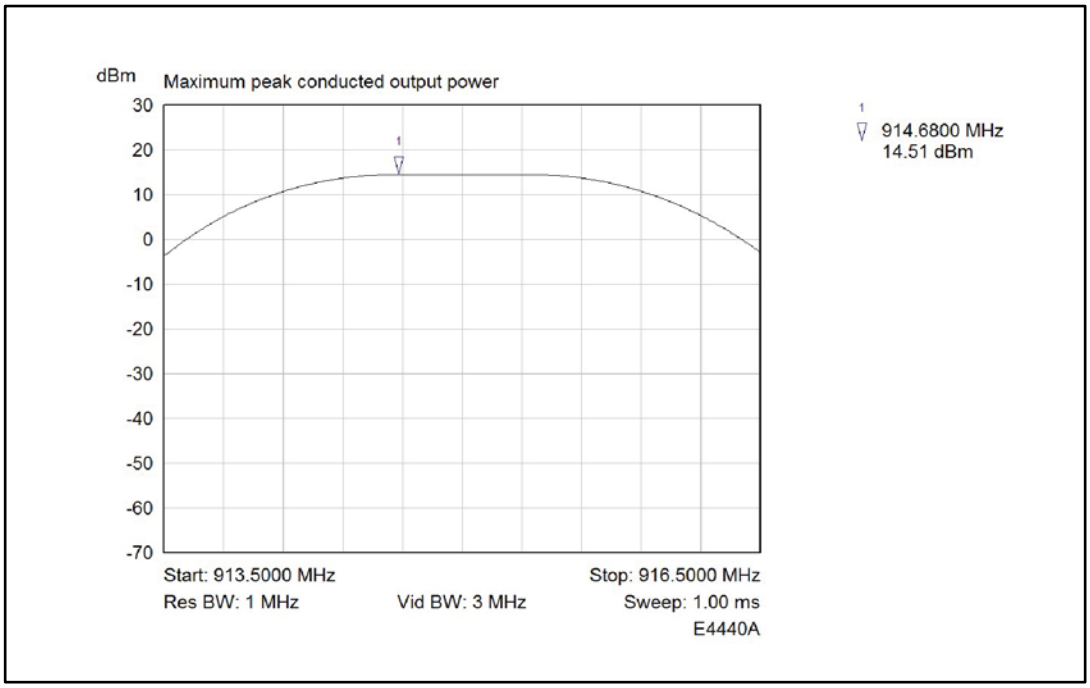
The maximum permitted peak conducted output power is 30 dBm (1 W). The S2-LP output power is lower than the maximum permitted output power. An external PA can be used to reach the maximum output power.

S2-LP has been set as following:

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

The measured output power, 14.5 dBm (see), is lower than the maximum permitted output power. An external PA has to be used to reach the maximum output power.

Figure 12: Maximum peak output power



3.2.3 Maximum 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 *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

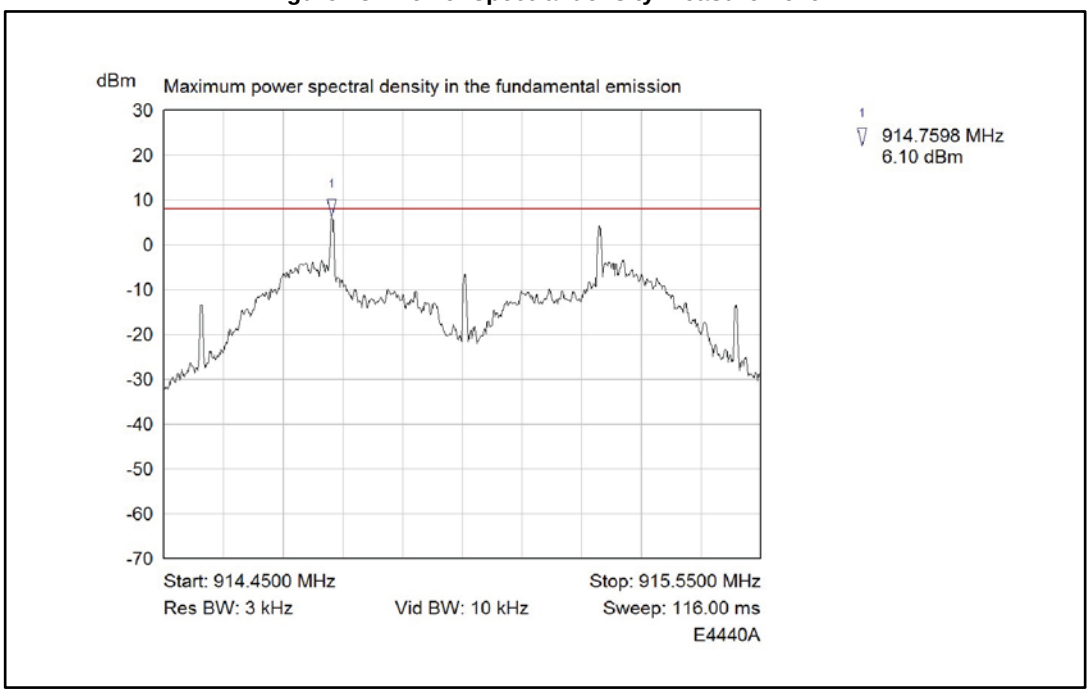
Use the peak marker function to determine the maximum amplitude level within the RBW. The peak measured signal level should not exceed +8 dBm.

S2-LP has been set as following:

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

The measurement result is shown in the *Figure 13: " Power spectral density measurement"*. The S2-LP meets the power spectral density requirement with margin.

Figure 13: Power spectral density measurement



3.2.4 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, 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.

S2-LP can be programmed to transmit continuously so the marker-delta method is used. The instrument setting is done in according to *5*:

- 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

S2-LP has been set as following:

- Modulation = 2-FSK
- Data rate = 250 kbps
- Frequency deviation = 250 kHz
- Output power = maximum output power
- Output frequency = 903 MHz and 927 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.

The conducted emissions in the band edges are lower than 20 dB integrated in 100 kHz bandwidth, making S2-LP usable for the FCC part 15.247 digital modulation scheme.

Figure 14: 902 MHz band edge conducted emission measurement

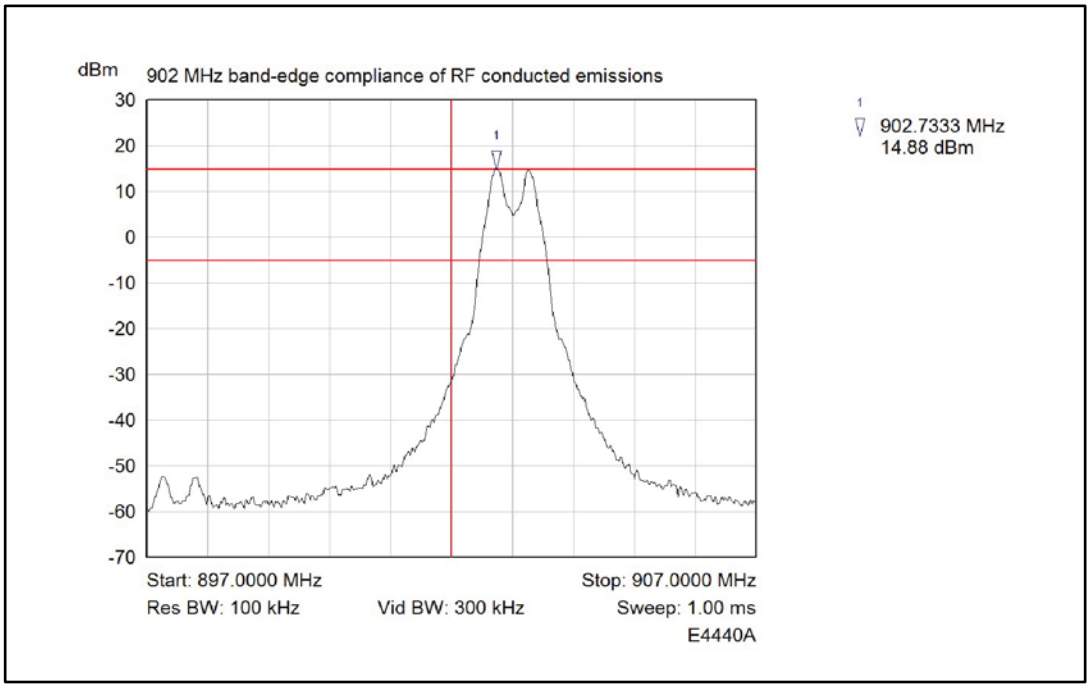
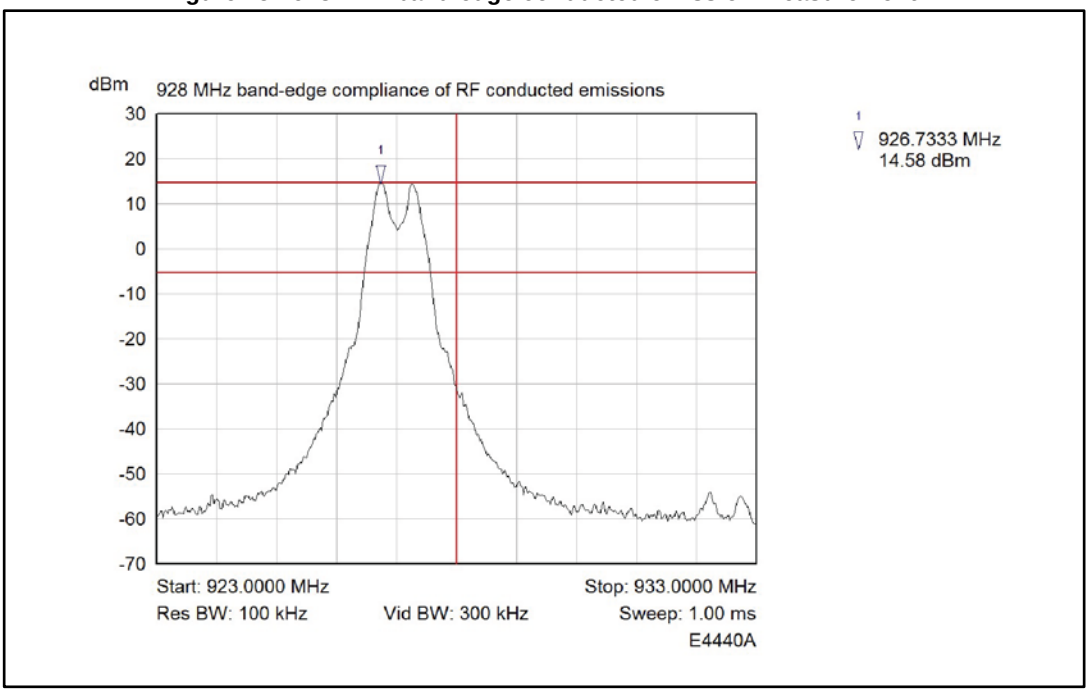


Figure 15: 928 MHz band edge conducted emission measurement



3.2.5 Emission in non-restricted and restricted frequency bands

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

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

For the emission in the not-restricted 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 S2-LP has be 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 *4*:

- 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

S2-LP has been set as following:

- Modulation = 2-FSK
- Data rate = 250 kbps
- Frequency deviation = 250 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 shall 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 S2-LP is shown using the conducted measurement. The peak power measurement procedure (paragraph 12.2.4 of *[4]*) is used with the following settings:

- RBW = as specified in *Table 3: "RBW as a function of frequency"*
- VBW ≥ 3 x RBW
- Sweep time = auto
- Detector function = peak
- Trace = max hold

Table 3: 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 12.2.5.1)
- EUT cannot be configured to transmit continuously but the duty cycle is constant (paragraph 12.2.5.2)
- EUT cannot be configured to transmit continuously and the duty cycle is not constant (paragraph 12.2.5.3)

S2-LP compliance is already demonstrated by the peak-detected amplitude method, so it is not necessary to perform the average amplitude measurements.

The spurious conducted emissions and the FCC emission mask are shown in *Figure 16: "Spurious conducted emission below 1 GHz measurement"* and *Figure 17: " Spurious conducted emission above 1 GHz measurement"*.

Figure 16: Spurious conducted emission below 1 GHz measurement

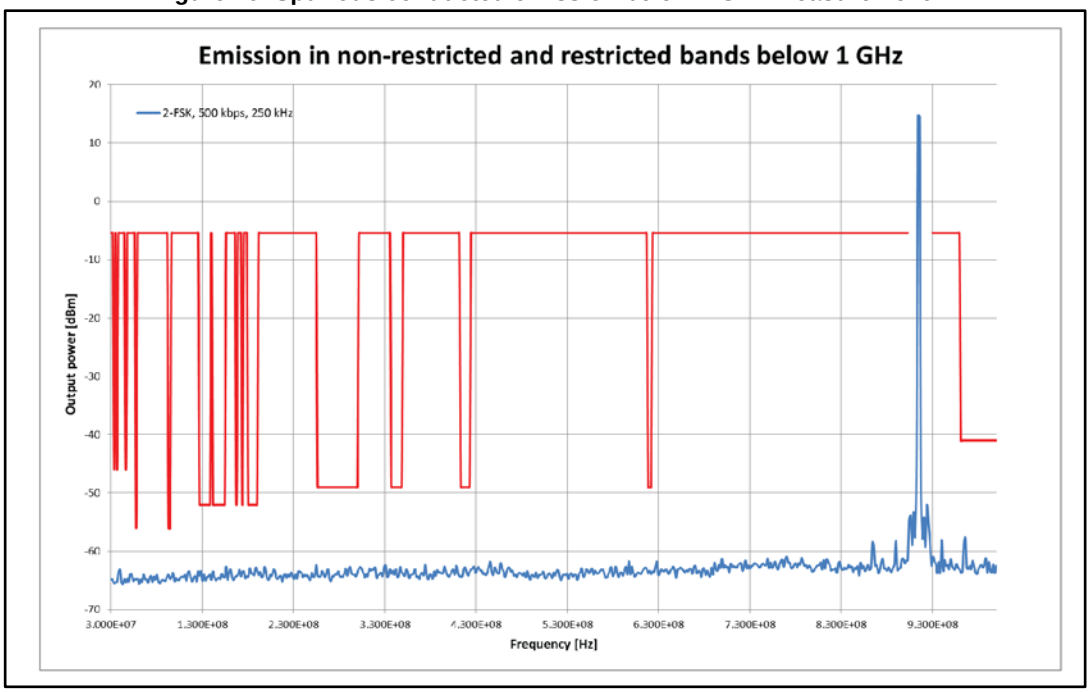
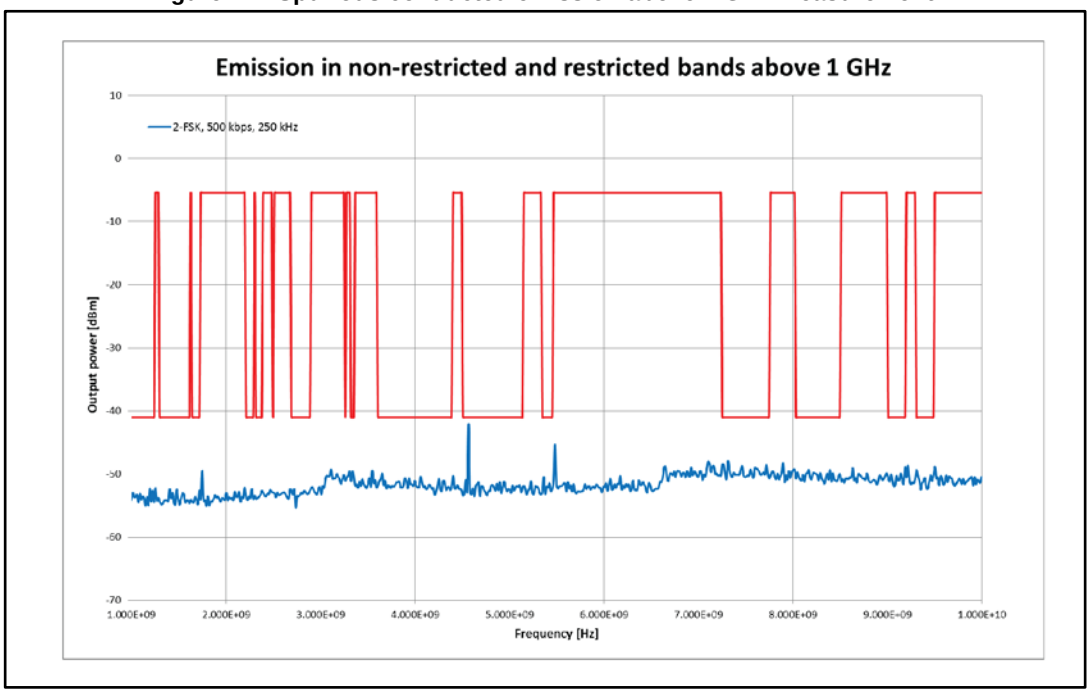


Figure 17: Spurious conducted emission above 1 GHz measurement



3.3 Part 15.249 measurements

3.3.1 Peak output power

There are no particular requirements about the maximum permitted peak output power. The max 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:

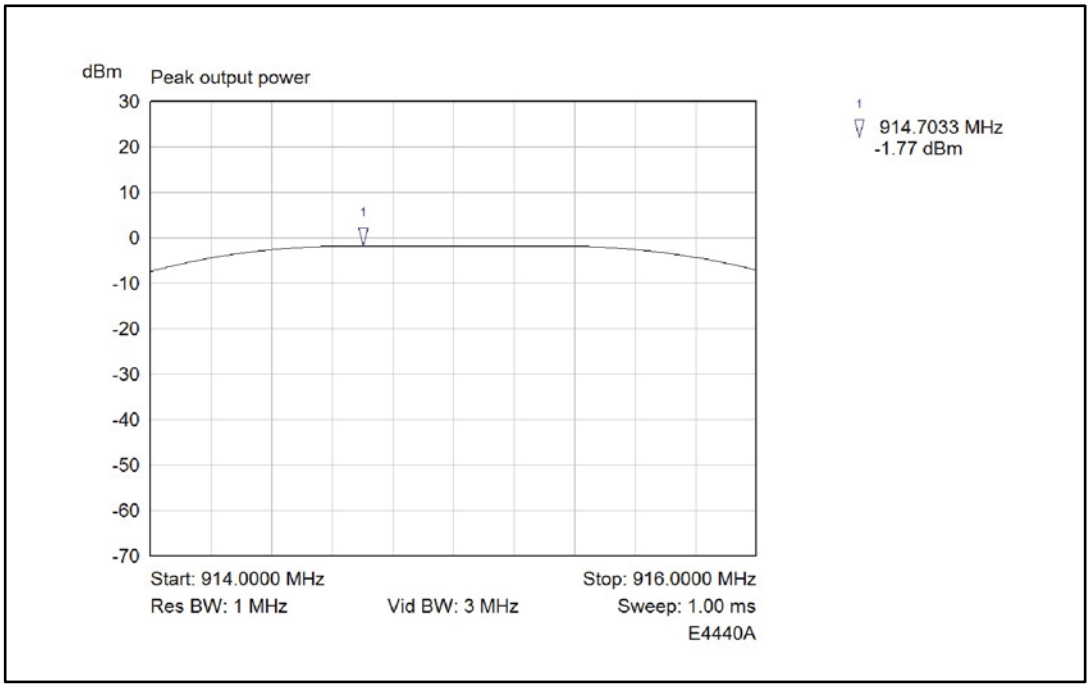
- Span ≥ 2 MHz
- RBW ≥ 1 MHz
- VBW ≥ 3 x RBW
- Sweep = auto
- Detector function = peak
- Trace = max hold

S2-LP has been set as following:

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

The measured S2-LP output power is -1 dBm. This output power is the maximum permitted output power in according to the FCC part 15.249 requirements.

Figure 18: Peak output power at -1 dBm



3.3.2 Conducted harmonics and other than harmonics emissions

FCC 15.249 establishes different limits for harmonic unwanted emissions and not-harmonic unwanted emissions as following:

- **Harmonic unwanted emission**: maximum permitted field strength of harmonic components for the device working on the 902 – 928 MHz band is 500 µV/m at 3 m distance that equates to a conducted power level of about -41 dBm.
- **Not-harmonic unwanted emission**: emissions radiated outside the specified frequency band, except for harmonics, shall 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 lesser attenuation.

According to part 15.33, for an intentional radiator operates below 10 GHz, the frequency range of measurements has to be until the tenth harmonic of the highest fundamental or to 40 GHz, whichever is lower. The S2-LP 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 in according to *2*:

- 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
- Sweep time = auto
- Detector function = peak
- Trace = max hold

S2-LP has been set as following:

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

The harmonics and other than harmonics conducted emissions are shown in *Figure 19: " Spurious conducted emission below 1 GHz measurement"* and *Figure 20: " Spurious conducted emission above 1 GHz measurement"*. The FCC emission mask in according to the part 15.249 and 15.209 requirements is also reported.

Figure 19: Spurious conducted emission below 1 GHz measurement

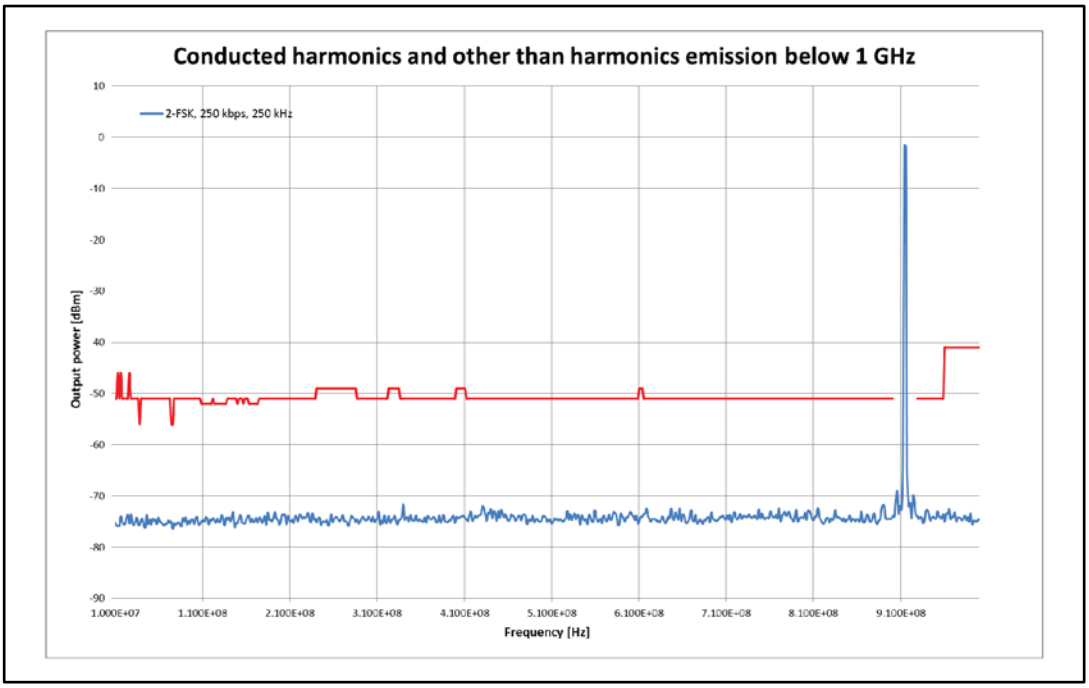
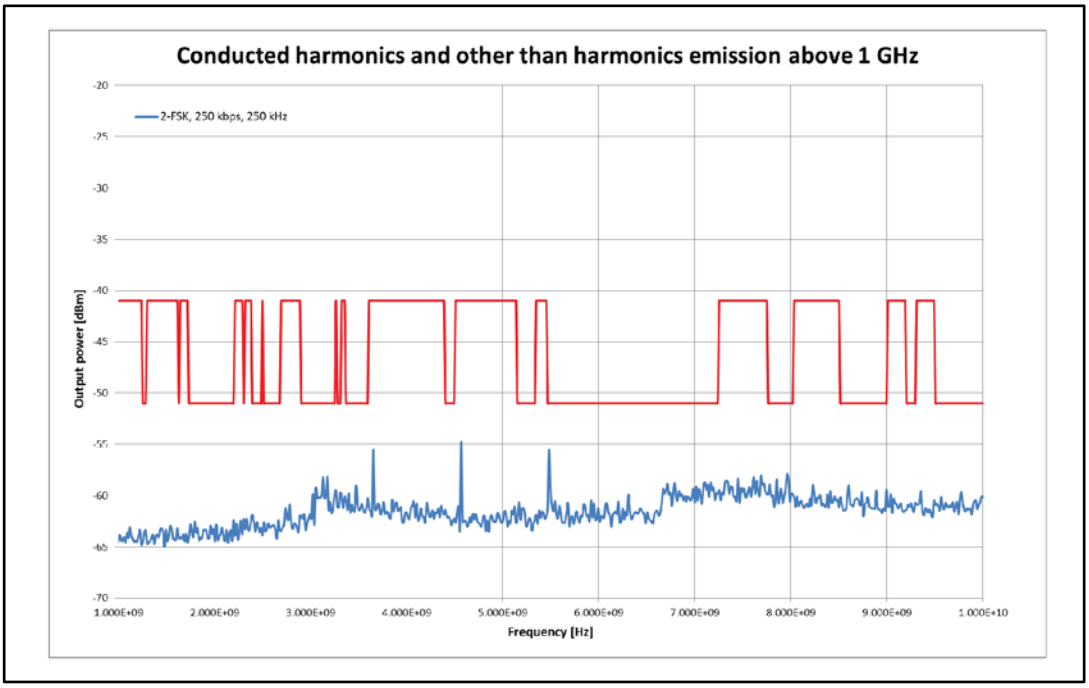


Figure 20: Spurious conducted emission above 1 GHz measurement



4 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

5 References

1. S2-LP 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 v03r05, 04/08/2016
4. “Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems” FCC, Public Notice DA 00-705, 03/30/2000
5. “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

6 Revision history

Date	Version	Changes
09-Nov-2016	1	Initial release.

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