SEMTECH

SX1272

WIRELESS & SENSING PRODUCTS

Application Note:

Testing for FCC Pre-Compliance with LoRaWAN™ Modules

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1. Introduction

The purpose of this application note is to assist the engineer in understanding the requirements, including test methodology, of the Federal Communications Commission (FCC) towards compliance of end-devices utilizing the LoRa Alliance™ US Regional PHY with respect to FCC Part 15.247 [1].

This application note will describe the three permitted modes of operation:

- Systems employing digital modulation techniques
- Systems employing Frequency Hopping Spread-Spectrum (FHSS)
- Systems employing hybrid mode operation

The measurements and analysis included in this application note is based upon Semtech's interpretation of both the measurement methodology and rules. Semtech recommend that a FCC approved Telecommunications Certification Body (TCB) be consulted prior to certification testing.

For a more general description of the LoRa® PHY layer compliance with the requirements of Part 15.247, the reader is directed to the Semtech Application Note AN1200.26 [2].

2. Results Summary

The measured results are summarized below.

2.1 Systems Employing Digital Modulation

Table 1: Summary of Measured Results for Systems Employing Digital Modulation

Rule Part	Parameter	Limit	Status
15.247(a)(2)	6 dB BW	≥ 500 kHz	PASS
15.247(b)(3)	Emission Output Power	+30 dBm	PASS
15.247(e)	Power Spectral Density	+8 dBm / 3 kHz	PASS
15.247(d)	Non-Restricted Band Emissions	-30 dB	PASS
	Restricted Band Emissions	Frequency Specific (Refer 15.205, 15.209)	PASS

2.2 Systems Employing Frequency Hopping

Table 2: Summary of Measured Results for Systems Employing Frequency Hopping

Rule Part	Parameter	Limit	Status
15.247(a)(1)	20 dB BW	≤ 500 kHz	PASS
	Channel Frequency Separation	≥ 20 dB BW	PASS
15.247(b)(2)	Peak Output Power	+30 dBm (≥ 50 hopping channels)	PASS
		+24 dBm (25 ≤ hopping channels < 50)	PASS
15.247(d)	Non-Restricted Band Emissions	-20 dB	PASS
	Restricted Band Emissions	Frequency Specific (Refer 15.205, 15.209)	PASS

2.3 Systems Employing Hybrid Mode Operation

Table 3: Summary of Measured Results for Systems Employing Hybrid Mode

Rule Part	Parameter	Limit	Status
15.247(e)	Power Spectral Density	+8 dBm / 3 kHz	PASS
15.247(d)	Non-Restricted Band Emissions	-30 dB	PASS
	Restricted Band Emissions	Frequency Specific (Refer 15.205, 15.209)	PASS

3. Overview of FCC Part 15.247 Rules

The following sub-sections provide an overview of Part 15.247 rules as they apply to operation in the license-exempt 902 – 928 MHz band.

3.1 Systems Employing Digital Modulation

The FCC regulations for systems using digital modulation (often referred to as "DTS") can be summarized as follows:

- The 6 dB bandwidth of the transmitted signal shall be at least 500 kHz (ref: 15.247(a)(2))
- The maximum peak conducted output power is 1 W (+30 dBm). Part 15.247 allows for compliance with the 1 W limit to be based on the maximum conducted output power, defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at maximum output power *(ref: 15.247(b)(3))*
- The conducted output power limit is based on the use of antennas with directional gains that do not exceed 6 dBi. If antennas with a directional gain greater than 6 dBi are used, the conducted output power shall be reduced below the stated values by the amount in dB that the directional gain of the antenna exceeds 6 dBi *(ref: 15.247(b)(4))*
- The conducted power spectral density shall not exceed 8 dBm in any 3 kHz band during continuous transmission, measured in accordance with the same method as used to determine the conducted output power *(ref: 15.247(e))*
- While the FCC does not place any restriction on any spurious emissions that occur within the 902 – 928 MHz band (such as adjacent or alternate channel power limits), any spurious emissions measured in any 100 kHz bandwidth outside of this band must be at least 20 dB below the level measured in a 100 kHz bandwidth within this band. If the conducted output power was measured using averaging techniques, this limit is tightened to 30 dB *(ref: 15.247(d))*
- There are restrictions placed on radiated field strength emission limits that fall within what are referred to as Restricted Bands in Part 15.205 and tabulated below in Table 4 shall not exceed the radiated emission limits of Part 15.209, as listed in Table 5. Only spurious emissions are permitted within the restricted frequency bands.

Table 4: Part 15.205 Restricted Frequency Bands

Frequency [MHz]			
0.090–0.110	16.42–16.423	399.9–410	* 4.5–5.15 (5)
0.495–0.505	16.69475–16.69525	608–614	* 5.35–5.46 (6)
2.1735–2.1905	16.80425–16.80475	960–1240	* 7.25–7.75 (8)
4.125–4.128	25.5–25.67	1300–1427	* 8.025–8.5 (9)
4.17725–4.17775	37.5–38.25	1435–1626.5	* 9.0–9.2 (10)
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 (3) [1]	22.01–23.12
8.41425–8.41475	162.0125–167.17	3260–3267	23.6–24.0
2.29–12.293	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 (4) [1]	Above 38.6
13.36-13.41			

Table 5: Part 15.209 Radiated Emission Limits for Frequencies above 30 MHz

Frequency [MHz]	Field Strength [µV / m]	Measurement Distance [m]	Conducted Power [dBm]
30-88	100	3	-55.2
88-216	150	3	-51.7
216-960	200	3	-49.2
Above 960	500	3	-41.2

The radiated emission limits is a field strength measurement. It is expressed in µV/m. This field strength can be converted to dBm by applying the formula below:

$$P_{TX} = 20 * log_{10}\big(Field\ Strenght\ (\mu V) * d(m)\big) - 104.77$$

[1] Harmonic (n) of emission between 902 – 928 MHz may fall within a restricted band of operation

3.2 Systems Employing Frequency Hopping

The FCC regulations for systems using Frequency Hopping Spread Spectrum (FHSS), where they differ from the rules that apply to systems using digital modulation techniques, can be summarized as follows:

- Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 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 *(Ref: 15.247(a)(1))*
- 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 400 ms within a 20 second period (= 0.4 * 50 channels). 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 400 ms within a 10 second period (= 0.4 * 25 channels). In addition the maximum allowable 20 dB bandwidth of any hopping channel is 500 kHz *(Ref: 15.247(a)(1)(i))*
- The maximum peak conducted output power shall not exceed 1 W (+30 dBm) for systems employing at least 50 hopping channels and 250 mW (+24 dBm) for systems employing less than 50 hopping channels, but at least 25 hopping channels. As opposed to systems employing digital modulation, averaging measurement methods are not permitted *(Ref: 15.247(b)(2))*
- While the FCC does not place any restriction on any spurious emissions that occur within the 902 – 928 MHz band (such as adjacent or alternate channel power limits), any spurious emissions measured in any 100 kHz bandwidth outside of this band must be at least 20 dB below the level measured in a 100 kHz bandwidth within this band. *(ref: 15.247(d))*
- There are restrictions placed on radiated field strength emission limits that fall within what are referred to as Restricted Bands in Part 15.205 and tabulated below in Table 4 shall not exceed the radiated emission limits of Part 15.209, as listed in Table 5. Only spurious emissions are permitted within the restricted frequency bands.

3.3 Systems Employing Hybrid Mode

Hybrid mode permits a system to employ a combination of both frequency hopping and digital modulation techniques as summarized below *(ref: 15.247(f))*

- The frequency hopping operation, with the direct sequence or digital modulation operation turned off, shall have an average time of occupancy on any frequency not to exceed 400 ms within a time period 0.4 * number of channels
- The digital modulation operation, with the frequency hopping operation turned off, shall comply with the power density requirements of 15.247(d)

FCC KDB publication [3] provides an overview of hybrid mode implementation scenarios. For the purposes of this Application Note we reference the following example:

> "It is possible for a device to be designed to operate as a DTS, as a FHSS system, or using a combination of these two modulation types.
>
> A hybrid system uses both digital modulation and frequency hopping techniques at the same time on the same carrier. As shown in Section 15.247(f), a hybrid system must comply with the power density standard of 8 dBm in any 3 kHz band when the frequency hopping function is turned off.
>
> The transmission also must comply with a 0.4 second / channel maximum dwell time when the hopping function is turned on. There is no requirement for this type of hybrid system to comply with the 500 kHz minimum bandwidth normally associated with a DTS transmission; and, there is no minimum number of hopping channels associated with this type of hybrid system."

Thus for a typical LoRaWAN™ application scenario, consider a system operating with eight 125 kHz channels.

To comply with the requirements for hybrid operation the channel dwell time in frequency hopping mode must not exceed 400 ms in any 3.2 seconds (or 400 ms * 8 channels).

In addition, the power spectral density shall not exceed +8 dBm in any 3 kHz bandwidth.

4. LoRa Alliance™ US Regional PHY

Both the LoRaWAN™ Regional Parameters and Protocol Specification can be obtained from the LoRa Alliance™ website [4]. For the purposes of this document we consider only the US 902 – 928 MHz license-exempt ISM band uplink channel plan:

- 64 channels numbered 0 to 63 utilizing LoRa® 125 kHz BW varying from DR0 to DR3 (SF10 to SF7), using coding rate 4/5, starting at 902.3 MHz and incrementing linearly by 200 kHz to 914.9 MHz
- 8 channels numbered 64 to 71 utilizing LoRa® 500 kHz BW at DR4 (SF8) starting at 903.0 MHz and incrementing linearly by 1.6 MHz to 914.2 MHz

5. Measurement Methods for Systems Employing Digital Modulation

All measurements were performed with the EUT configured for nominally +14 dBm output power and 500 kHz LoRa® bandwidth of spreading factor, SF8 and coding rate 4/5 unless otherwise specified. Parameters were measured on the lower (903.0 MHz), middle (907.8 MHz) and upper (914.2 MHz) channel frequencies of the 500 kHz mode US regional PHY specification. In addition the EUT was set to TX continuous mode, enabling a 100% transmit duty-cycle to be achieved.

At the time of publication of this application note, the recommended test methodology was described in FCC KDB publication 558074 D01 DTS Meas Guidance v04 [5].

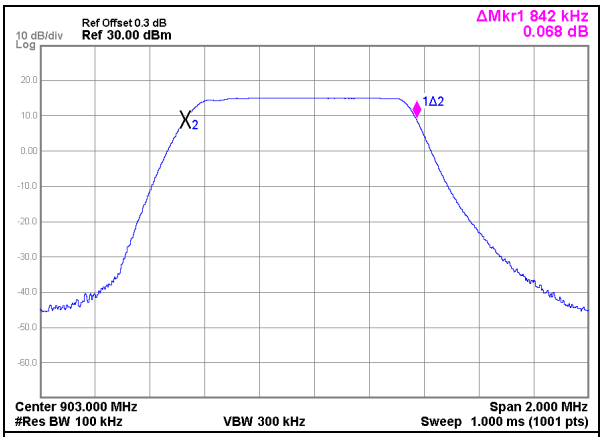
5.1 6 dB Bandwidth

As outlined in Section 8.1 of [5], the following test method is used to determine that the bandwidth of the LoRa® modulated signal complies with 6 dB bandwidth requirement of 15.247(a)(2).

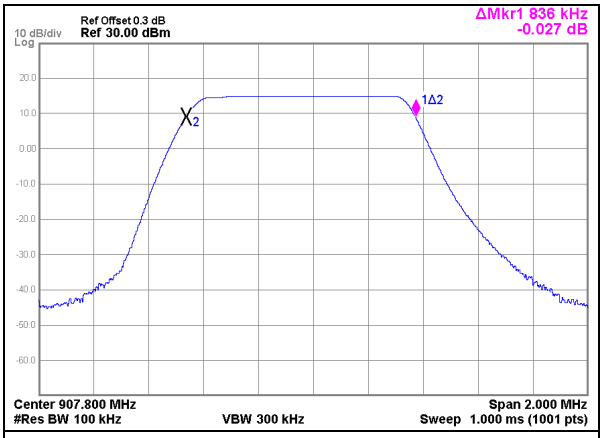
1. Set the resolution bandwidth (RBW) of the spectrum analyzer to 100 kHz and the video bandwidth (VBW) to ≥ 3 * RBW
2. Using the spectrum analyzer's peak detector and with the trace mode set to maximum hold, allow the trace to stabilize
3. Measure the maximum width of the emission between upper and lower frequency points that are attenuated by 6 dB, relative to the maximum level measured in the fundamental emission

As an alternative, the automatic bandwidth measurement capability of a spectrum analyzer may be employed using the X dB bandwidth mode with X set to 6 dB, if the instrument's configuration can be configured as defined above.

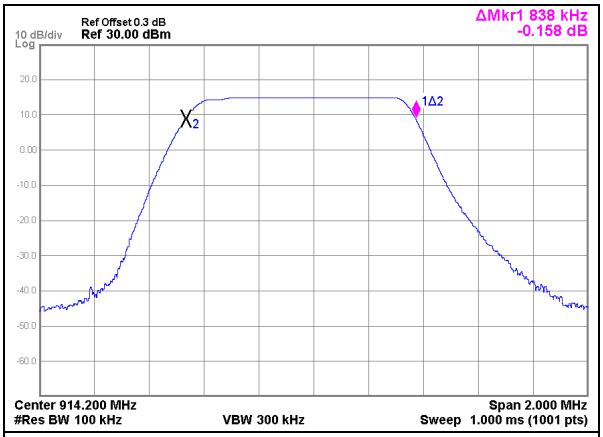
From the results illustrated below, it can be determined that in 500 kHz mode, the LoRa® modulation complies with the minimum 6 dB bandwidth requirement of 500 kHz.



Lower Channel DTS Bandwidth



Middle Channel DTS Bandwidth



Upper Channel DTS Bandwidth

Figure 1: 6 dB BW Measurement

5.2 Fundamental Emission Output Power

To demonstrate compliance with Part 15.247(b)(3) we implement the maximum conducted (average) output power method, AVGSA-1, of [5], since we will use averaging methods to show compliance with the power spectral density requirements of 15.247(e).

When using averaging methods to determine the conducted output power, the total power is calculated over the occupied bandwidth (OBW) of the fundamental emission. An OBW measurement procedure is presented in Section 6.9.3 of ANSI C63-10 [6] and is based upon the 99% power bandwidth (i.e. OBW is the frequency bandwidth that below its lower and above its upper frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission).

For the purposes of this analysis we measure the OBW for only the middle channel, using the built-in OBW measurement function of the laboratory vector signal analyzer.

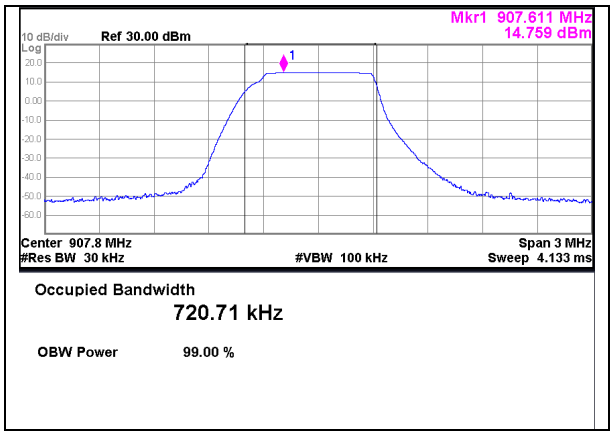
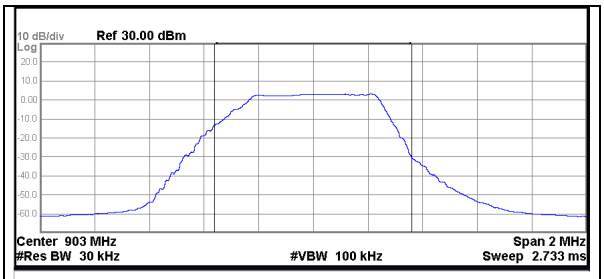


Figure 2: OBW Measurement

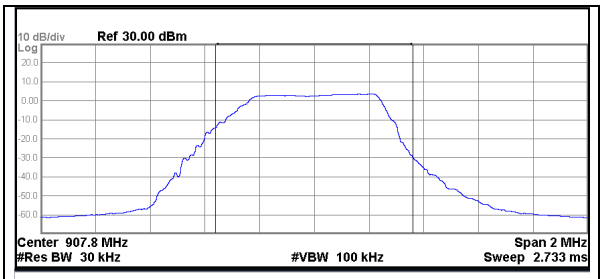
The AVGSA-1 method was used to determine the average conducted output power at the antenna port. The procedure is:

1. Set the frequency span of the spectrum analyzer to at least 1.5 times OBW (determined above)
2. Set the RBW to between 1 to 5 % of the OBW and the VBW to ≥ 3 * RBW
3. This method assumes that the number of points that the spectrum analyzer can sweep over is at least (2 * Span / RBW). Assuming a RBW setting of 30 kHz (approx. 4% of OBW) and a span of 2 MHz, the minimum number of points swept is 133 points.
4. With the sweep time set to auto and free-run, use the RMS detector (i.e. power averaging) and average over at least 100 sweeps in power-averaging mode. If an RMS detector is not available, a sample detector may be substituted.
5. Calculate the power by integrating the spectrum across the OBW of the signal, using the spectrum analyzer's band power measurement function, with the band limits set equal to the OBW band edges.

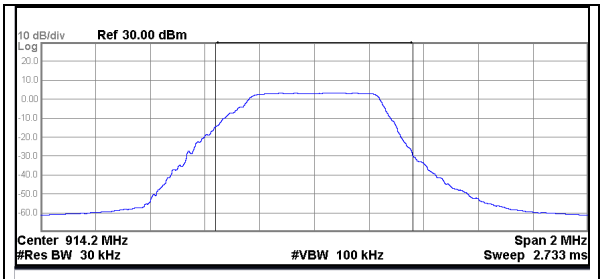
From the results, below, it can be determined that in 500 kHz mode, the maximum conducted power integrated over the OBW of the emission does not exceed the published limits.



Lower Channel Fundamental Output Power



Middle Channel Fundamental Output Power



Upper Fundamental Output Power

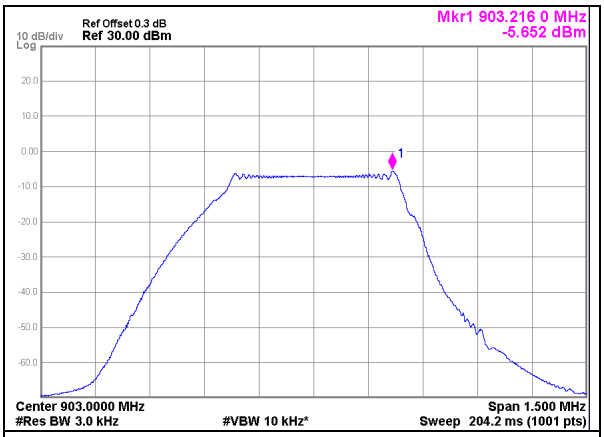
Figure 3: Fundamental Emission Output Power Measurement

5.3 Power Spectral Density of the Fundamental Emission

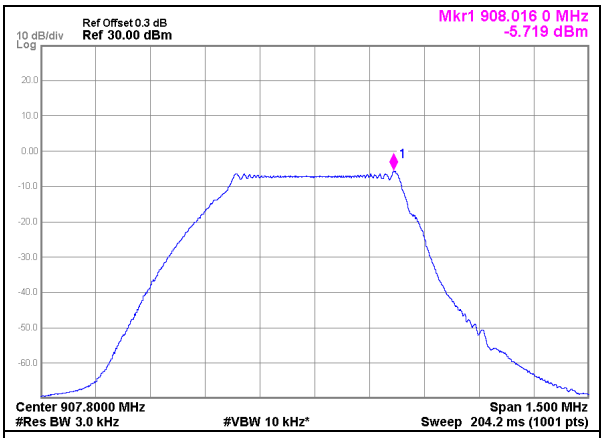
To demonstrate compliance with the PSD limit defined in 15.247(e), we use the AVGPSD-1 method described in [5]. The power averaging techniques used are identical to those used to determine the fundamental emission power.

1. Set the spectrum analyzer center frequency to DTS channel center frequency and frequency span to at least 1.5 times the OBW
2. Set the RBW such that 3 kHz ≤ RBW ≤ 100 kHz and the VBW ≥3 x RBW. Semtech recommends setting the RBW to 3 kHz
3. Set the detector to power averaging (RMS) or sample (when RMS not available)
4. Ensure that the number of measurement points in the sweep ≥ 2 x span/RBW and the sweep-time to auto
5. Employ trace averaging (RMS) mode over a minimum of 100 traces and use the peak marker function to determine the maximum amplitude level

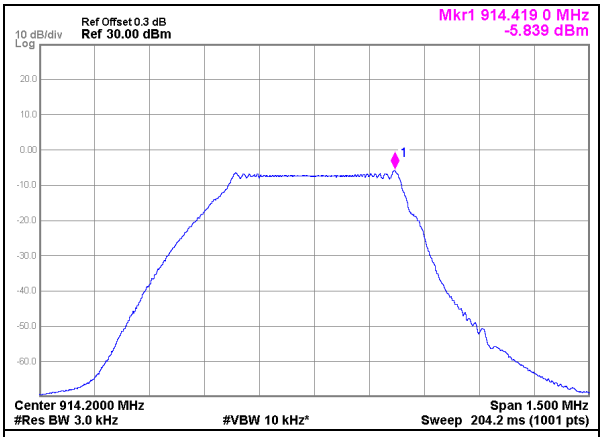
From the results, below, it can be determined that in 500 kHz mode, LoRaWAN™ modulation complies with the power spectral density limits specified.



Lower Channel Power Spectral Density



Middle Channel Power Spectral Density



Upper Channel Power Spectral Density

Figure 4: Power Spectral Density Measurement

5.4 Emissions in Non-Restricted Frequency Bands

As noted by 15.247(d), since power averaging was used to determine the conducted emission output power, the limit for emissions falling outside of the 902-928 MHz band is 30 dB below the maximum emission within the band.

Firstly the reference level of the wanted emission in the band is determined as described below:

1. Set the spectrum analyzer center frequency to DTS channel center frequency and frequency span to at least 1.5 times the DTS bandwidth.
2. Set the RBW to 100 kHz and the VBW ≥3 x RBW
3. Set the detector to peak
4. Set the sweep time to auto and the trace mode to maximum hold
5. Use the peak marker function to determine the maximum power level

The indicated wanted emission reference level is illustrated below:

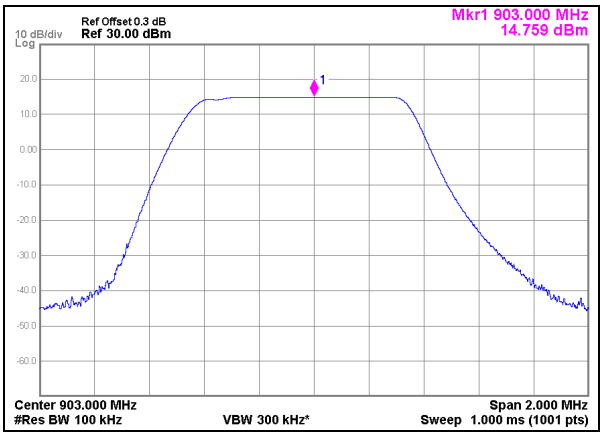


Figure 5: Wanted Emission Reference Level

To determine the emissions in the non-restricted bands set the span of the spectrum analyzer to cover the frequency band of interest.

In the example below we look at the lower band-edge of the 902-928 MHz band.

As illustrated, emissions in the non-restricted band are greater than 30 dB below the reference emission level and hence LoRa® modulation can be seen to comply with the 15.247(d).

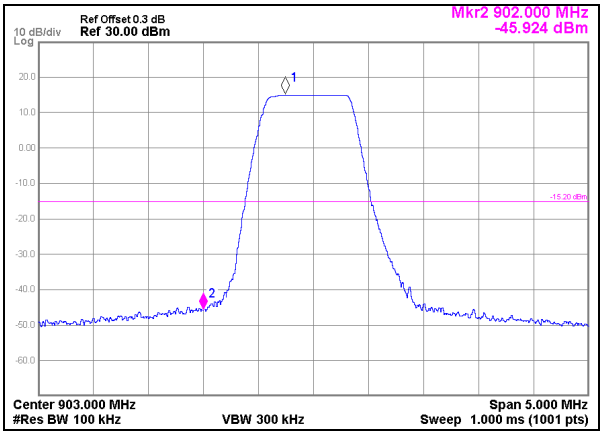


Figure 6: Non-Restricted Band Emissions

6. Measurement Methods for Systems Employing Frequency Hopping

All measurements were performed with the EUT configured for nominally +14 dBm output power and 125 kHz LoRa® bandwidth of spreading factor, SF10 and coding rate 4/5 unless otherwise specified. Parameters were measured on the lower (902.3 MHz), middle (908.7 MHz) and upper (914.9 MHz) channel frequencies of the 125 kHz mode US regional PHY specification. In addition the EUT was set to TX continuous mode, enabling a 100% transmit duty-cycle to be achieved.

At the time of publication of this application note, the recommended test methodology was described in FCC Public Notice DA 00-705 [7].

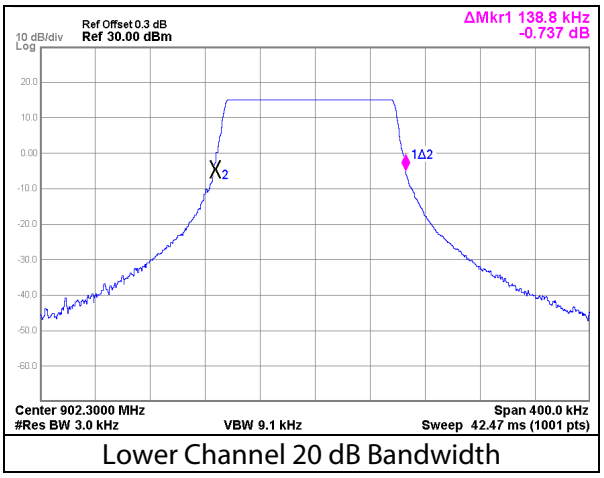
6.1 20 dB Bandwidth

The maximum 20 dB bandwidth of a hopping channel is 500 kHz as defined in 15.247(a)(1) and the following test methodology is used to ensure compliance:

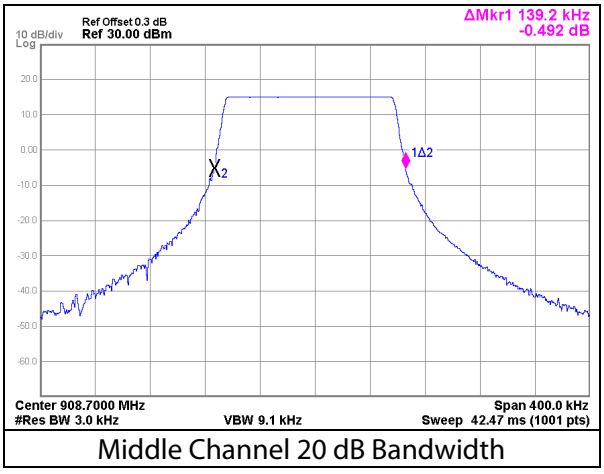
1. Set the frequency span of the spectrum analyzer to approximately 2 to 3 times the 20 dB BW, centered on the hopping channel
2. Set the RBW to approximately 1% of the 20 dB BW and the VBW ≥ RBW. For the purposes of the analysis VBW is set to 3 * RBW
3. Set the sweep to auto, the analyzer's detector function to peak and use the max hold when displaying the trace

   Alternatively, the automatic measurement function of the spectrum analyzer may be utilized

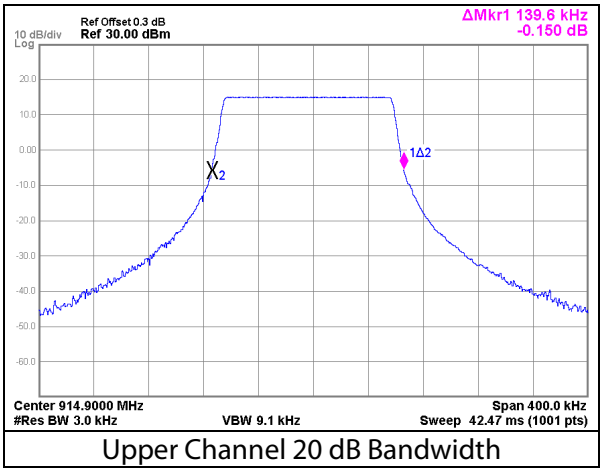
As is illustrated below, the 20 dB BW of a 125 kHz BW LoRa® modulated signal does not exceed the 20 dB bandwidth limit specified.



Lower Channel 20 dB Bandwidth



Middle Channel 20 dB Bandwidth



Upper Channel 20 dB Bandwidth

Figure 7: 20 dB BW Measurement

6.2 Carrier Frequency Separation

15.247(a)(1) stipulates that frequency hopping systems must have a hopping channel separation that is the greater of 25 kHz or the 20 dB BW of the modulated hopping channel signal.

To measure the character frequency separation, the following methodology is implemented:

1. Set the frequency span wide enough to capture the peaks of two adjacent channels
2. Set the (RBW) to ≥ 1% of the span and VBW ≥ RBW
3. Set the sweep to auto the analyzer's detector function to peak and use the max hold when displaying the trace
4. Allow the trace to stabilize. Use the marker-delta function to determine the separation between the peaks of the adjacent channels.

Here we determine the peak conducted output power level for channel 32 (908.7 MHz) and set the spectrum analyzer's reference level to 20 dB below this level. With the LoRaWAN™ regional PHY specification mandating a 200 kHz channel separation it can be seen that the channel separation between channel 32 and channel 33 (908.9 MHz) exceeds the 20 dB BW of the modulated signal.

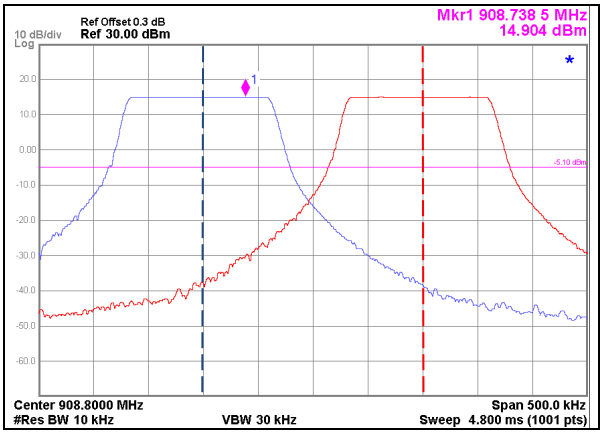


Figure 8: Measurement of Carrier Frequency Separation

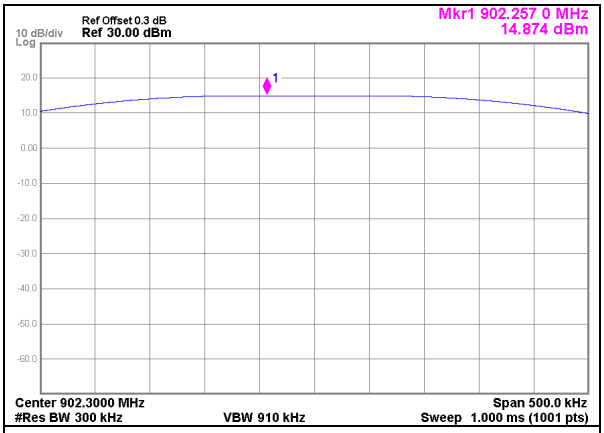
6.3 Maximum Peak Conducted Output Power

Frequency hopping systems employing 125 kHz BW LoRa® modulation must use at least 50 hopping channels. 15.247(b)(2) stipulates that the maximum peak conducted output power in this scenario is 1 W (+30 dBm).

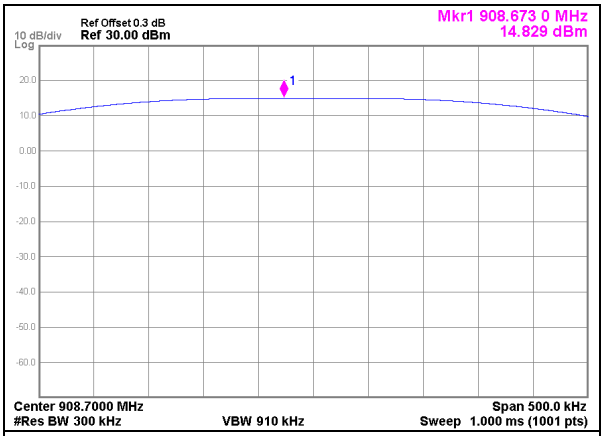
To measure the maximum peak conducted output power the following methodology is used:

1. Set the span to approximately 5 times the 20 dB BW, centered on a hopping channel
2. Set RBW to be higher than the 20 dB bandwidth of the emission being measured, with VBW higher than RBW
3. Set the sweep to auto the analyzer's detector function to peak and use the max hold when displaying the trace
4. Allow the trace to stabilize. Use the marker-to-peak function to set the marker to the peak of the emission. The indicated level is the peak output power (ensure that any external attenuation and cable loss are taken into account)

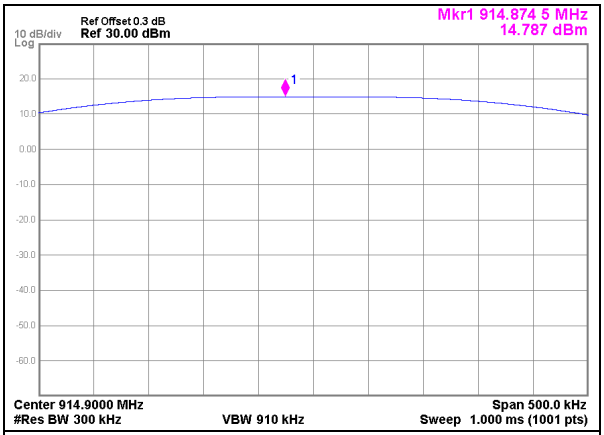
The maximum peak conducted output power of the EUT is nominally +14 dBm and from the results, below, complies with this ruling.



Lower Channel Maximum Output Power



Middle Channel Maximum Output Power



Upper Channel Maximum Output Power

Figure 9: Peak Conducted Output Power Measurement

6.4 Band-Edge Compliance

The following methodology is used to verify that emissions falling outside of the 902-928 MHz band are 20 dB below the peak emission within the band.

1. Set the 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
2. Set the sweep to auto the analyzer's detector function to peak and use the max hold when displaying the trace
3. Allow the trace to stabilize. Set the marker on the emission at the band edge, or on the highest modulation product outside of the band, if this level is greater than that at the band edge. Enable the marker-delta function then use the marker-to-peak function to move the marker to the peak of the in-band emission. The marker-delta value now displayed must comply with the limit
4. Now, using the same instrument settings, enable the hopping function of the EUT. Allow the trace to stabilize. Follow the same procedure listed above to determine if any spurious emissions caused by the hopping function also comply with the specified limit.

Again we consider lower band-edge of the 902-928 MHz band. From the results below, we observe the band edge emissions are greater than 20 dB below the peak output power level within the band.

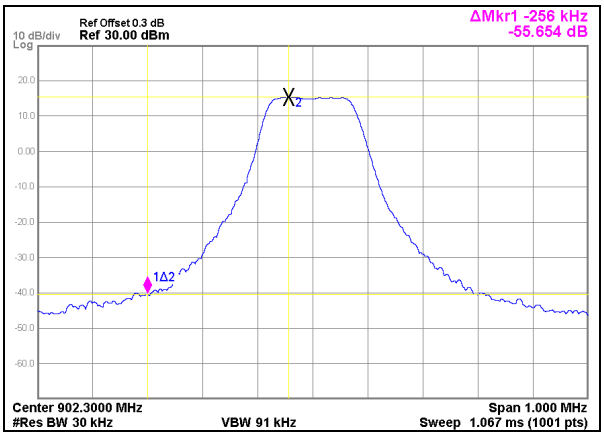


Figure 10: Non-Restricted Band Emissions

6.5 Additional System Level Considerations

Part 15.247 states that a frequency hopping system is not required to employ all available hopping channels during each transmission or use the entire available frequency band. However the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the applicable regulations should the transmitter be presented with a continuous data stream.

In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified *(Ref: 15.247(g))*.

The user must also demonstrate that the hopping sequence is pseudo-random and that the system receiver bandwidths match the bandwidth of the hopping transmitter and that frequency hopping occurs in synchronization with the transmitted signal *(Ref: 15.247(a)(1))*.

Finally, a system may incorporate intelligence that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hopping sequence to avoid hopping on occupied channels is permitted. However, the coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted *(Ref: 15.247(h))*.

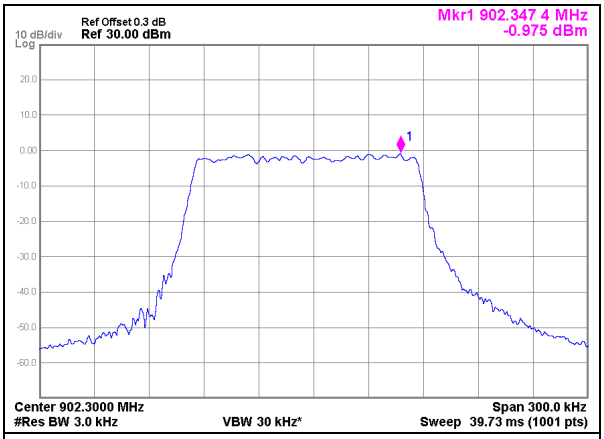
The requirements summarized above are considered out of the scope of this document.

7. Measurement Methods for Systems Employing Hybrid Mode

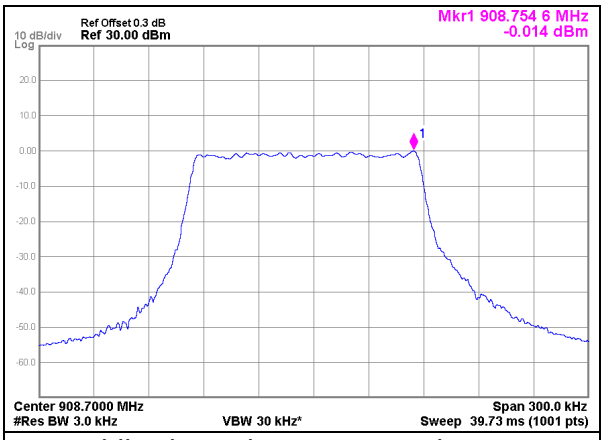
As has been previously documented, hybrid mode operation permits a system to employ a combination of both frequency hopping and digital modulation techniques.

All measurements were performed with the EUT configured for nominally +14 dBm output power and 125 kHz LoRa® bandwidth of spreading factor, SF10 and coding rate 4/5 unless otherwise specified. Parameters were measured on the middle channel (908.7 MHz) frequencies of the 125 kHz mode US regional PHY specification. In addition the EUT was set to TX continuous mode, enabling a 100% transmit duty-cycle to be achieved.

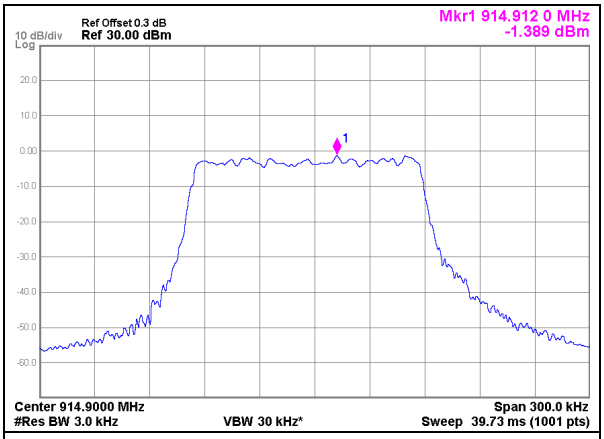
For the purposes of this document, only the power spectrum density of the 125 kHz LoRa® mode is measured, using the AVGPSD-1 method described in [5].



Lower Channel Power Spectral Density



Middle Channel Power Spectral Density



Upper Channel Power Spectral Density

Figure 11: Power Spectral Density Measurement

8. Measurement of Emissions in Restricted Frequency Bands

All the parameters previously described in this document are to demonstrate compliance with the requirements of Part 15.247. They are obtained using conducted measurement techniques and can thus be easily performed in the laboratory as part of any pre-scan procedure prior to the formal certification process.

However, emissions in the restricted bands as defined in Part 15.205(c) must comply with radiated emission limits. While [5] describes a general procedure for measuring such emissions using conducted techniques, this can only be used for guidance purposes.

For this application note, radiated emission measurements were undertaken at the 5 m facilities of a local TCB, Compatible-Electronics [8], following the procedures described in [6].

All measurements were performed with the EUT configured for nominally +14 dBm output power and measured on the lower (902.3 MHz), middle (908.7 MHz) and upper (914.9 MHz) channel frequencies of the 125 kHz mode US regional PHY specification. In addition the EUT was set to transmit with a 100% duty-cycle.

The results obtained are summarized below and illustrate compliance with the radiated emission limits of Part 15.209(a).

Unless otherwise specified, only the radiated emissions of the harmonics of each fundamental frequency are tabulated.

8.1 Lower Channel Horizontal and Vertical Polarization Radiated Emissions

Table 6: Lower Channel Horizontal and Vertical Polarized Radiated Emissions Measurements

HARMONIC EMISSIONS LOW CHANNEL

FCC 15.247
Company: Semtech — Date: 12/20/2017
EUT: Shield — Lab: T
Model: SX1272MB2DAS — Test ENG: R. Ramirez

Compatible Electronics, Inc. FAC-3 (Lab T)

Freq. (MHz)	Level (dBuV)	Pol (v/h)	Limit	Margin	Peak / QP / Avg	Ant. Height (m)	Table Angle (deg)	Comments
1804.60	39.00	H	74.93	-35.93	Peak			
1804.60	27.45	H	54.93	-27.48	Avg			
2706.90	41.73	H	74.93	-33.20	Peak	1.51	205.4	In Restricted Band
2706.90	30.43	H	54.93	-24.50	Avg	1.51	205.4	In Restricted Band
3609.20	45.14	H	73.98	-28.84	Peak	3.70	75.5	In Restricted Band
3609.20	34.21	H	53.98	-19.77	Avg	3.70	75.5	In Restricted Band
4511.50	45.22	H	73.98	-28.76	Peak	3.70	79.1	In Restricted Band
4511.50	34.91	H	53.98	-19.07	Avg	3.70	79.1	In Restricted Band
5413.80	48.38	H	74.93	-26.55	Peak	3.70	192.4	In Restricted Band
5413.80	37.85	H	54.93	-17.08	Avg	3.70	192.4	In Restricted Band
6316.10	50.94	H	74.93	-23.99	Peak			
6316.10	40.24	H	54.93	-14.69	Avg			
7218.40	53.33	H	74.93	-21.60	Peak			
7218.40	41.91	H	54.93	-13.02	Avg			
8120.70	55.03	H	73.98	-18.95	Peak			
8120.70	43.54	H	53.98	-10.44	Avg			
9023.00	57.14	H	74.93	-17.79	Peak	3.70	181.6	In Restricted Band
9023.00	45.85	H	54.93	-9.08	Avg	3.70	181.6	In Restricted Band

Test distance
3 meter

HARMONIC EMISSIONS LOW CHANNEL

FCC 15.247
Company: Semtech — Date: 12/20/2017
EUT: Shield — Lab: T
Model: SX1272MB2DAS — Test ENG: R. Ramirez

Compatible Electronics, Inc. FAC-3 (Lab T)

Freq. (MHz)	Level (dBuV)	Pol (v/h)	Limit	Margin	Peak / QP / Avg	Ant. Height (m)	Table Angle (deg)	Comments
1804.60	39.59	V	74.93	-35.34	Peak			
1804.60	27.63	V	54.93	-27.30	Avg			
2706.90	42.48	V	74.93	-32.45	Peak	3.262	248	In Restricted Band
2706.90	30.74	V	54.93	-24.19	Avg	3.262	248	In Restricted Band
3609.20	45.03	V	73.98	-28.95	Peak	2.086	330.1	In Restricted Band
3609.20	34.18	V	53.98	-19.80	Avg	2.086	330.1	In Restricted Band
4511.50	46.41	V	73.98	-27.57	Peak	1.85	322.8	In Restricted Band
4511.50	35.23	V	53.98	-18.75	Avg	1.85	322.8	In Restricted Band
5413.80	50.10	V	74.93	-24.83	Peak	2.057	318	In Restricted Band
5413.80	37.87	V	54.93	-17.06	Avg	2.057	318	In Restricted Band
6316.10	52.08	V	74.93	-22.85	Peak			
6316.10	40.03	V	54.93	-14.90	Avg			
7218.40	53.48	V	74.93	-21.45	Peak			
7218.40	42.30	V	54.93	-12.63	Avg			
8120.70	55.46	V	73.98	-18.52	Peak			
8120.70	44.32	V	53.98	-9.66	Avg			
9023.00	57.69	V	74.93	-17.24	Peak	3.324	124.6	In Restricted Band
9023.00	45.83	V	54.93	-9.10	Avg	3.324	124.6	In Restricted Band

Test distance
3 meter

8.2 Middle Channel Horizontal and Vertical Polarization Radiated Emissions

Table 7: Middle Channel Horizontal and Vertical Polarized Radiated Emissions Measurements

HARMONIC EMISSIONS MID CHANNEL

FCC 15.247
Company: Semtech — Date: 12/20/2017
EUT: Shield — Lab: T
Model: SX1272MB2DAS — Test ENG: R. Ramirez

Compatible Electronics, Inc. FAC-3 (Lab T)

Freq. (MHz)	Level (dBuV)	Pol (v/h)	Limit	Margin	Peak / QP / Avg	Ant. Height (m)	Table Angle (deg)	Comments
1817.40	36.68	H	74.93	-38.25	Peak			
1817.40	27.60	H	54.93	-27.33	Avg			
2726.10	44.92	H	74.93	-30.01	Peak	1.94	0.1	In Restricted Band
2726.10	36.62	H	54.93	-18.31	Avg	1.94	0.1	In Restricted Band
3634.80	45.81	H	73.98	-28.17	Peak	3.44	52.4	In Restricted Band
3634.80	34.31	H	53.98	-19.67	Avg	3.44	52.4	In Restricted Band
4543.50	46.28	H	73.98	-27.70	Peak	3.29	84.3	In Restricted Band
4543.50	35.87	H	53.98	-18.11	Avg	3.29	84.3	In Restricted Band
5452.20	49.57	H	74.93	-25.36	Peak	3.69	358.3	In Restricted Band
5452.20	38.15	H	54.93	-16.78	Avg	3.69	358.3	In Restricted Band
6360.90	51.85	H	74.93	-23.08	Peak			
6360.90	40.63	H	54.93	-14.30	Avg			
7269.60	56.00	H	74.93	-18.93	Peak	2.13	0.1	In Restricted Band
7269.60	43.20	H	54.93	-11.73	Avg	2.13	0.1	In Restricted Band
8178.30	55.59	H	73.98	-18.39	Peak	2.14	238.9	In Restricted Band
8178.30	43.75	H	53.98	-10.23	Avg	2.14	238.9	In Restricted Band
9087.00	57.23	H	74.93	-17.70	Peak	3.72	309.9	In Restricted Band
9087.00	45.80	H	54.93	-9.13	Avg	3.72	309.9	In Restricted Band

Test distance
3 meter

HARMONIC EMISSIONS MID CHANNEL

FCC 15.247
Company: Semtech — Date: 12/20/2017
EUT: Shield — Lab: T
Model: SX1272MB2DAS — Test ENG: R. Ramirez

Compatible Electronics, Inc. FAC-3 (Lab T)

Freq. (MHz)	Level (dBuV)	Pol (v/h)	Limit	Margin	Peak / QP / Avg	Ant. Height (m)	Table Angle (deg)	Comments
1817.40	39.52	V	74.93	-35.41	Peak			
1817.40	27.37	V	54.93	-27.56	Avg			
2726.10	41.97	V	74.93	-32.96	Peak	2.453	200.5	In Restricted Band
2726.10	30.66	V	54.93	-24.27	Avg	2.453	200.5	In Restricted Band
3634.80	45.83	V	73.98	-28.15	Peak	3.219	337.9	In Restricted Band
3634.80	34.26	V	53.98	-19.72	Avg	3.219	337.9	In Restricted Band
4543.50	46.49	V	73.98	-27.49	Peak	3.653	161.4	In Restricted Band
4543.50	35.38	V	53.98	-18.60	Avg	3.653	161.4	In Restricted Band
5452.20	48.48	V	74.93	-26.45	Peak	1.563	25.3	In Restricted Band
5452.20	37.63	V	54.93	-17.30	Avg	1.563	25.3	In Restricted Band
6360.90	53.26	V	74.93	-21.67	Peak	1.553	255.6	
6360.90	40.72	V	54.93	-14.21	Avg	1.553	255.6	
7269.60	53.38	V	74.93	-21.55	Peak	1.547	339.8	In Restricted Band
7269.60	42.59	V	54.93	-12.34	Avg	1.547	339.8	In Restricted Band
8178.30	56.32	V	73.98	-17.66	Peak	2.588	181.7	In Restricted Band
8178.30	44.71	V	53.98	-9.27	Avg	2.588	181.7	In Restricted Band
9087.00	57.04	V	74.93	-17.89	Peak	2.27	212.2	In Restricted Band
9087.00	45.84	V	54.93	-9.09	Avg	2.27	212.2	In Restricted Band

Test distance
3 meter

8.3 Middle Channel Horizontal and Vertical Polarization Radiated Emissions

Table 8: Upper Channel Horizontal and Vertical Polarized Radiated Emissions Measurements

HARMONIC EMISSIONS HIGH CHANNEL

FCC 15.247

Company:	Semtech	Date:	12/20/2017
EUT:	Shield	Lab:	T
Model:	SX1272MB2DAS	Test ENG:	R. Ramirez

Compatible Electronics, Inc. FAC-3 (Lab T)

Freq. (MHz)	Level (dBuV)	Pol (v/h)	Limit	Margin	Peak / QP / Avg	Ant. Height (m)	Table Angle (deg)	Comments
1829.80	38.90	H	74.93	-36.03	Peak			
1829.80	27.72	H	54.93	-27.21	Avg			
2744.70	45.02	H	74.93	-29.91	Peak	1.471	30	In Restricted Band
2744.70	36.28	H	54.93	-18.65	Avg	1.471	30	In Restricted Band
3659.60	45.59	H	73.98	-28.39	Peak	3.653	220.9	In Restricted Band
3659.60	34.06	H	53.98	-19.92	Avg	3.653	220.9	In Restricted Band
4574.50	47.37	H	73.98	-26.61	Peak	3.227	200.1	In Restricted Band
4574.50	36.26	H	53.98	-17.72	Avg	3.227	200.1	In Restricted Band
5489.40	49.48	H	74.93	-25.45	Peak	1.053	241.7	
5489.40	38.48	H	54.93	-16.45	Avg	1.053	241.7	
6404.30	52.22	H	74.93	-22.71	Peak	2.823	322.7	
6404.30	40.81	H	54.93	-14.12	Avg	2.823	322.7	
7319.20	53.76	H	74.93	-21.17	Peak	3.242	59.5	In Restricted Band
7319.20	42.67	H	54.93	-12.26	Avg	3.242	59.5	In Restricted Band
8234.10	57.07	H	73.98	-16.91	Peak	2.565	356.3	In Restricted Band
8234.10	44.53	H	53.98	-9.45	Avg	2.565	356.3	In Restricted Band
9149.00	57.21	H	74.93	-17.72	Peak	2.572	140.5	In Restricted Band
9149.00	46.41	H	54.93	-8.52	Avg	2.572	140.5	In Restricted Band

Test distance
3 meter

Upper Channel Horizontal Polarization Emissions

HARMONIC EMISSIONS HIGH CHANNEL

FCC 15.247

Company:	Semtech	Date:	12/20/2017
EUT:	Shield	Lab:	T
Model:	SX1272MB2DAS	Test ENG:	R. Ramirez

Compatible Electronics, Inc. FAC-3 (Lab T)

Freq. (MHz)	Level (dBuV)	Pol (v/h)	Limit	Margin	Peak / QP / Avg	Ant. Height (m)	Table Angle (deg)	Comments
1829.80	38.84	V	74.93	-36.09	Peak			
1829.80	27.06	V	54.93	-27.87	Avg			
2744.70	41.95	V	74.93	-32.98	Peak	1.286	126.5	In Restricted Band
2744.70	30.67	V	54.93	-24.26	Avg	1.286	126.5	In Restricted Band
3659.60	43.83	V	73.98	-30.15	Peak	3.656	122.8	In Restricted Band
3659.60	32.90	V	53.98	-21.08	Avg	3.656	122.8	In Restricted Band
4574.50	46.46	V	73.98	-27.52	Peak	3.631	105	In Restricted Band
4574.50	35.33	V	53.98	-18.65	Avg	3.631	105	In Restricted Band
5489.40	49.29	V	74.93	-25.64	Peak			
5489.40	38.03	V	54.93	-16.90	Avg			
6404.30	52.17	V	74.93	-22.76	Peak			
6404.30	40.39	V	54.93	-14.54	Avg			
7319.20	54.33	V	74.93	-20.60	Peak	1.723	86.1	In Restricted Band
7319.20	43.10	V	54.93	-11.83	Avg	1.723	86.1	In Restricted Band
8234.10	55.40	V	73.98	-18.58	Peak	3.418	122	In Restricted Band
8234.10	44.03	V	53.98	-9.95	Avg	3.418	122	In Restricted Band
9149.00	57.87	V	74.93	-17.06	Peak	3.404	185.1	In Restricted Band
9149.00	46.78	V	54.93	-8.15	Avg	3.404	185.1	In Restricted Band

Test distance
3 meter

Upper Channel Vertical Polarization Emissions

9. Conclusion

This application note demonstrates that the SX1272MB2DAS shield when configured as a US region LoRaWAN™ end-node can be shown to be compliant with the requirements of Part 15.247.

10. Revision History

Version	Date	Modifications
1.0	February 2018	First Release

11. Glossary

ANSI	American National Standards Institute
AVGSA	AVerage Detector Spectrum Analyzer
BW	BandWidth
FCC	Federal Communications Commission
DTS	Digital Transmission Systems
EUT	Equipment Under Test
FHSS	Frequency Hopping Spread-Spectrum
KDB	Knowledge DataBase
ISM	Industrial, Scientific and Medical (radio spectrum)
LoRa®	LOng RAnge modulation technique
LoRaWAN™	LoRa® low power Wide Area Network protocol
OBW	Occupied BandWidth
PA	Power Amplifier
PHY	PHysical Layer
PSD	Power Spectral Density
RF	Radio-Frequency
RBW	Resolution BandWidth
RMS	Root Mean Square
TCB	Telecommunications Certification Body
TX	Transmitter
US	United States
VBW	Video BandWidth

12. References

[1] Code of Federal Regulations, Title 47, Part 15
https://www.gpo.gov/fdsys/pkg/CFR-2016-title47-vol1/pdf/CFR-2016-title47-vol1-part15.pdf

[2] Semtech Application Note AN1200.26 "LoRa™ and FCC Part 15.247: Measurement Guidance"
https://www.semtech.com/uploads/documents/an1200.26.pdf

[3] FCC KDB Publication 453039; March 23rd 2007
https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?id=20265&switch=P

[4] LoRa Alliance™ Website
https://www.lora-alliance.org/

[5] FCC KDB publication 558074 "D01 DTS Measurement Guidance v04"; April 5th 2017
https://apps.fcc.gov/oetcf/kdb/forms/FTSSearchResultPage.cfm?switch=P&id=21124

[6] ANSI C63.10 – 2013 "American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices"
https://standards.ieee.org/findstds/standard/C63.10-2013.html

[7] FCC Public Notice DA 00-705 "Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems"; March 30th 2000
https://www.fcc.gov/document/filing-and-measurement-guidelines-frequency-hopping-spread-spectrum-systems

[8] Compatible-Electronics
https://celectronics.com/

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