Application Report
SWRA457–August 2015

Using the CC1310 Under ARIB STD-T108

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ABSTRACT

This application report outlines the expected performance when operating CC1310 under ARIB STD-T108 in the 920 MHz frequency band. It is assumed that you are familiar with CC1310 and ARIB STD-T108 regulatory limits. Lab measurements show that CC1310 meets ARIB STD-T108 requirements.

Project collateral and source code discussed in this document can be downloaded from the following URL: http://www.ti.com/lit/zip/swra445.

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1 Introduction

Table 1 shows the EM that is used for the measurements in this application report: CC13xxEM_7XD_7793_4L_R1.0.1.

Table 1. CC13xxEM_7XD_7793_4L_R1.0.1

Frequency	Measured [dBm]	Specification [dBm]	Margin [dB]
f <= 710 MHz	-50.2	-36	14.2
710 MHz < f <= 900 MHz	-65.0	-55	10.0
900 MHz < f <= 915 MHz	-63.9	-55	8.9
915 MHz < f <= 930 MHz	-41.4	-36	5.4
930 MHz < f <= 1000 MHz	-64.1	-55	9.1
1000 MHz < f <= 1215 MHz	-62.1	-45	17.1
1215 MHz < f	-40.5	-30	9.5

1.1 Acronyms Used in This Document

Table 2. Acronyms Used in This Document

Name	Description
EB	Evaluation Board
EM	Evaluation Module
PCB	Printed Circuit Board
PER	Packet Error Rate
RF	Radio Frequency
RSSI	Receive SIgnal Strength Indicator
RX	Receive, Receive Mode
TX	Transmit, Transmit Mode

2 Overview of ARIB STD-T108

The radio equipment defined in this standard utilizes the frequency band from 915 MHz to 930 MHz. The ARIB STD-T108 defines two different types of possible categories of application:

- Convenience Radio Stations
- Low-Power Radio Stations

The main differences between the possible categories are output power and which band frequency is used. The following sections give a short description of the two categories.

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2.1 Convenience Radio Stations

The contents of communication are primarily signals for telemetry, telecontrol and data transmission system. The key parameters are listed in Table 3.

Table 3. Key Parameters and Functionality

Item		Parameters and Functionality
Frequency Band		920.5 MHz - 923.5 MHz
Transmission Power		<250 mW
Transmission Method	Contents	Data Signal
	Modulation System	Not specified
Antenna Gain		3 dBi or less (absolute gain). However, in case EIRP is less than the value of 3 dBi plus 250 mW of antenna power, it is allowed to fill in the gap by the antenna gain.

A radio channel consists of up to five consecutive unit radio channels with center frequency between 920.6 MHz and 923.4 MHz, with 200 kHz separation and 200 kHz bandwidth. The permitted occupied bandwidth is (200^{x}n) kHz or less where *n* is the number of unit radio channels. The frequency tolerance should be within 20 ppm.

Two masks are defined for adjacent channel power: one for the 920.5 MHz – 922.3 MHz band and one for 922.3 MHz - 923.5 MHz band.

Table 4 describes permitted unwanted emissions.

Table 4. Permissible Values for Unwanted Emission Intensity (antenna input)

Frequency Band	Spurious Emission Strength (average power)	Reference Bandwidth
f <= 710 MHz	-36 dBm	100 kHz
710 MHz < f <= 900 MHz	-55 dBm	1 MHz
900 MHz < f <= 915 MHz	-55 dBm	100 kHz
915 MHz < f <= 920.3 MHz	-36 dBm	100 kHz
920.3 MHz < f <= 924.3 MHz (except for |f-fc| <= (200+100^{x}n) kHz)	-55 dBm	100 kHz
924.3 MHz < f <= 930 MHz	-36 dBm	100 kHz
930 MHz < f <= 1000 MHz	-55 dBm	100 kHz
1000MHz < f <= 1,215 MHz	-45 dBm	1 MHz
1,215 MHz < f	-30 dBm	1 MHz

Table 5 describes secondary radiated emission limits.

Table 5. Limit on Secondary Radiated Emissions, and so forth, at Receiver

Frequency Band	Limit on Secondary Radiated Emissions, and so Forth (antenna input)	Reference Bandwidth
f <= 710 MHz	-54 dBm	100 kHz
710 MHz < f <= 900 MHz	-55 dBm	1 MHz
900 MHz < f <= 915 MHz	-55 dBm	100 kHz
915 MHz < f <= 930 MHz	-54 dBm	100 kHz
930 MHz < f <= 1000 MHz	-55 dBm	100 kHz
1000 MHz < f	-47 dBm	1 MHz

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2.2 Low-Power Radio Stations

The contents of communication are primarily signals for telemetry, telecontrol and data transmission system. The key parameters are listed in Table 6.

Table 6. Key Parameters and Functionality

Item		Parameters and Functionality
Frequency Band		915.9 MHz – 916.9 MHz 920.5 MHz – 929.7 MHz
Transmission Power		<20 mW (13 dBm) for 920.5 MHz – 928.15 MHz <1 mW (0 dBm) for 916.0 MHz – 916.8 MHz and 928.15 MHz – 929.65 MHz
Transmission Method	Contents	Data Signal
	Modulation System	Not specified
Antenna Gain		3 dBi or less (absolute gain). However, in case EIRP is less than the value of 3 dBi plus 1 mW or 20 mW of antenna power, it is allowed to fill in the gap by the antenna gain.

A radio channel consists of up to five consecutive unit radio channels. A unit channel is 100 kHz or 200 kHz wide depending on the frequency band.

Table 7. Unit Channel Bandwidth

Center Frequency	Unit Channel Separation/Bandwidth
916.0 MHz – 916.8 MHz	200 kHz
920.6 MHz – 928.0 MHz	200 kHz
928.15 MHz – 929.65 MHZ	100 kHz

The permitted occupied bandwidth is (200^{x}n) kHz or less where *n* is the number of unit radio channels except for when the center frequency is from 928.15 MHz to 929.65 MHz where the maximum bandwidth is (100^{x}n) kHz. The frequency tolerance should be within 20 ppm.

For adjacent channel power five masks are defined:

- From 915.9 MHz to 916.9 MHz
- From 920.5 MHz to 922.3 MHz
- From 922.3 MHz to 928.1 MHz (For transmission power <0 dBm)
- From 922.3 MHz to 928.1 MHz (For transmission power between 0 dBm and 13 dBm)
- From 928.1 MHz to 929.7 MHz

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Table 8 describes permitted unwanted emissions.

Table 8. Permissible Values for Unwanted Emission Intensity (antenna input)

Frequency Band	Spurious Emission Strength (average power)	Reference Bandwidth
f <= 710 MHz	-36 dBm	100 kHz
710 MHz < f <= 900 MHz	-55 dBm	1 MHz
900 MHz < f <= 915 MHz	-55 dBm	100 kHz
915 MHz < f <= 930 MHz (Except for |f-fc| <= (200 + 100×n) kHz if bandwidth of unit radio channel is 200 kHz, except for |f-fc| <= (100 + 50×n) kHz if bandwidth of unit radio channel is 100 kHz. Except for |f-fc| <= (100 + 100×n) kHz if frequency band is 915.9 MHz <= f <= 916.9 MHz and 920.5 MHz <= 922.3 MHz. Where *n* is a number of unit radio channels constituting the radio channel and is an integer from 1 to 5)	-36 dBm	100 kHz
930 MHz < f <= 1000 MHz	-55 dBm	100 kHz
1000 MHz < f <= 1215 MHz	-45 dBm	1 MHz
1215 MHz < f	-30 dBm	1 MHz

Table 9 describes secondary radiated emission limits.

Table 9. Limit on Secondary Radiated Emissions, and so Forth, at Receiver

Frequency Band	Limit on Secondary RadiatedEmissions, and so Forth (antenna input)	Reference Bandwidth
f <= 710 MHz	-54 dBm	100 kHz
710 MHz < f <= 900 MHz	-55 dBm	1 MHz
900 MHz < f <= 915 MHz	-55 dBm	100 kHz
915 MHz < f <= 930 MHz	-54 dBm	100 kHz
930 MHz < f <= 1000 MHz	-55 dBm	100 kHz
1000 MHz < f	-47 dBm	1 MHz

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2.3 Channel Plan for 920 MHz Band Radio Equipment

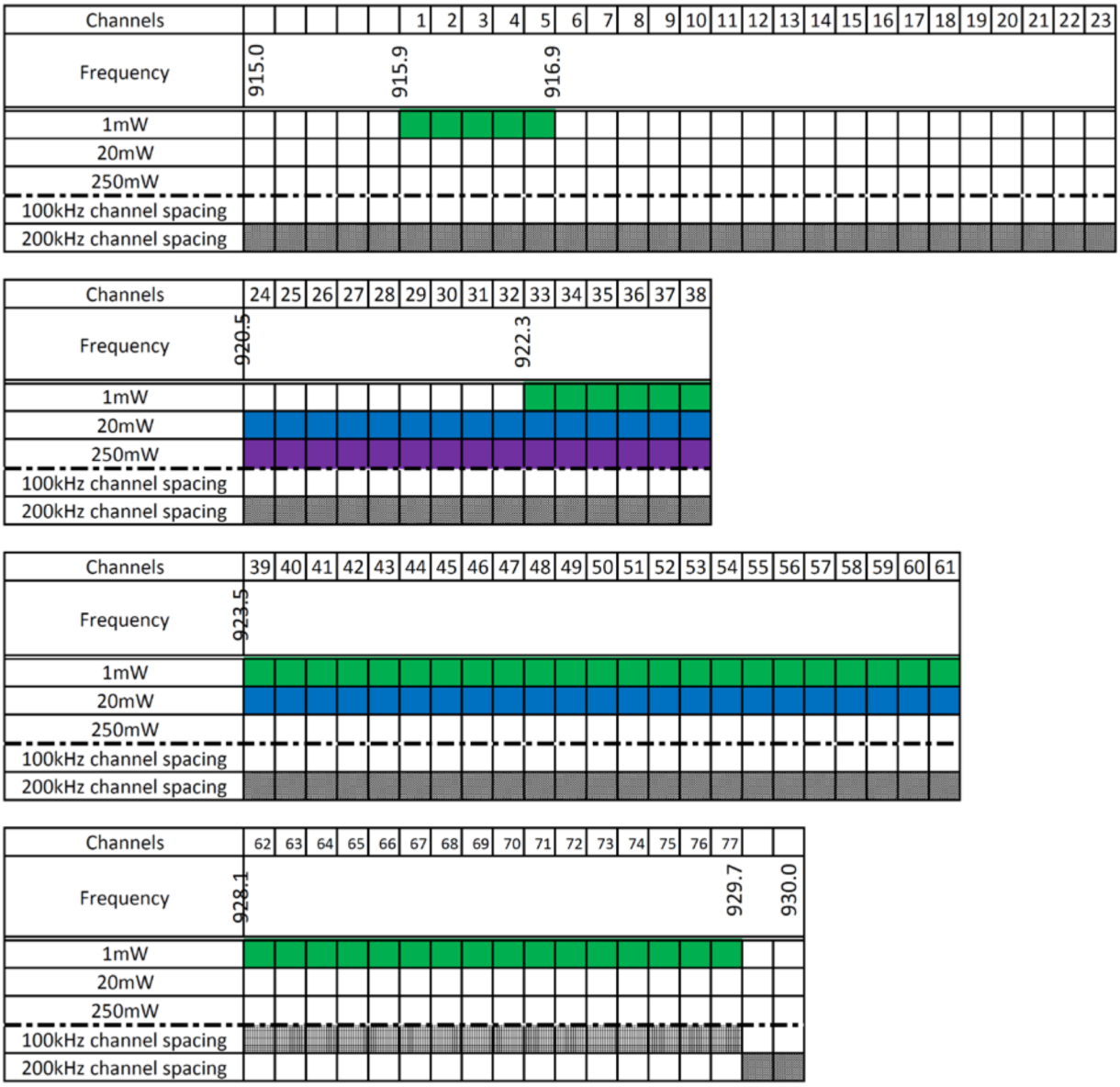

Figure 1. Channel Plan for 920 MHz Band Radio Equipment

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3 TX Conducted Measurements

The TX conducted measurements are measured according to the “low-power radio station” standard.

Dependent on frequency band the maximum output power is 1 mW (0 dBm) or 20 mW (+13 dBm). The measurements are done with a modulated 50 kbps, 25 kHz deviation GFSK signal.

3.1 Occupied Bandwidth (OBW)

The permitted occupied bandwidth is defined as 99% of the power within n^xUnit Channel bandwidth where the Unit Channel Bandwidth is 100 kHz or 200 kHz depending on the sub frequency band and *n* is the number of Unity Channels. The OBW is dependent on the modulation.

Limit:	200 kHz (one unit channel)
Measured:	108 kHz
Margin:	92 kHz (Pass)

3.2 ACP

The Adjacent Channel leakage power requirements are divided into four different masks dependent on the frequency. The measurements are done with the stated data rate and unit channels.

3.2.1 ACP Mask 1

Table 10. ACP Mask 1 Results

Frequency	915.9 MHz – 916.8 MHz. Max 0 dBm		
Specification	Required [dBm]	Measured [dBm]	
Power @channel edge	-20	-31	@50 kbps, unit ch num 1
ACP	<-26	-30	@50 kbps, unit ch num 1

3.2.2 ACP Mask 2

Table 11. ACP Mask 2 Results

Frequency	920.5 MHz – 922.3 MHz. Max +13 dBm		
Specification	Required [dBm]	Measured [dBm]	
Power @channel edge	-7	-22	@50 kbps, unit ch num 24
ACP	<-15	-19	@50 kbps, unit ch num 24

If the output power is less than 0 dBm, the ACP limit changes to < -26 dB. The ACP mask 2 measurements were performed using +13 dBm output power in this application report.

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3.2.3 ACP Mask 3

Table 12. ACP Mask 3 Results

Frequency	922.3 MHz – 928.1 MHz		
Specification	Required [dBm]	Measured [dBm]	
ACP (output power < 0 dBm)	<-26	-31	@50 kbps, unit ch num 33
ACP (0 dBm < output power < +13 dBm)	<-15	-21	@50 kbps, unit ch num 33

3.2.4 ACP Mask 4

Table 13. ACP Mask 4 Results

Frequency	928.1 MHz – 929.7 MHz. Max 0 dBm		
Specification	Required [dBm]	Measured [dBm]	
ACP	<-26	-32	@50 kbps, unit ch num 62

3.3 Unwanted Emission Intensity

The allowed levels for spurious emissions are described in Table 8.

The measurement method that should be used is outlined in TELEC-T245. According to 2(3) in TELEC-T245 the frequency band between 30 MHz and 5 GHz with exception of 915 MHz to 930 MHz should be measured using max peak detector and a single sweep. To measure the spurious found by the sweep, 0 Hz span and sample detector should be used. The measurement method description for this test in T-245 state the following: Then, set the spectrum analyzer as shown in 2(4) and perform single sweeping for each frequency exceeding the standard value, to find the average value of the spurious emission (for burst signal, average value within each burst) as measurement value. The method described in T-245 is equivalent to using rms detector and single sweep. The measurements in this section are done with the rms detector and single sweep with the exception of close to the carrier (915 MHz – 930 MHz).

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3.3.1 Spurious Emission 40 MHz – 710 MHz

The allowed level of spurious emissions within the 40 MHz -710 MHz frequency band is specified as less than -36 dBm in any 100 kHz bandwidth. The channel center frequency selected for this measurement is 920.6 MHz. The measured spurious emissions within this frequency band are shown in Figure 2.

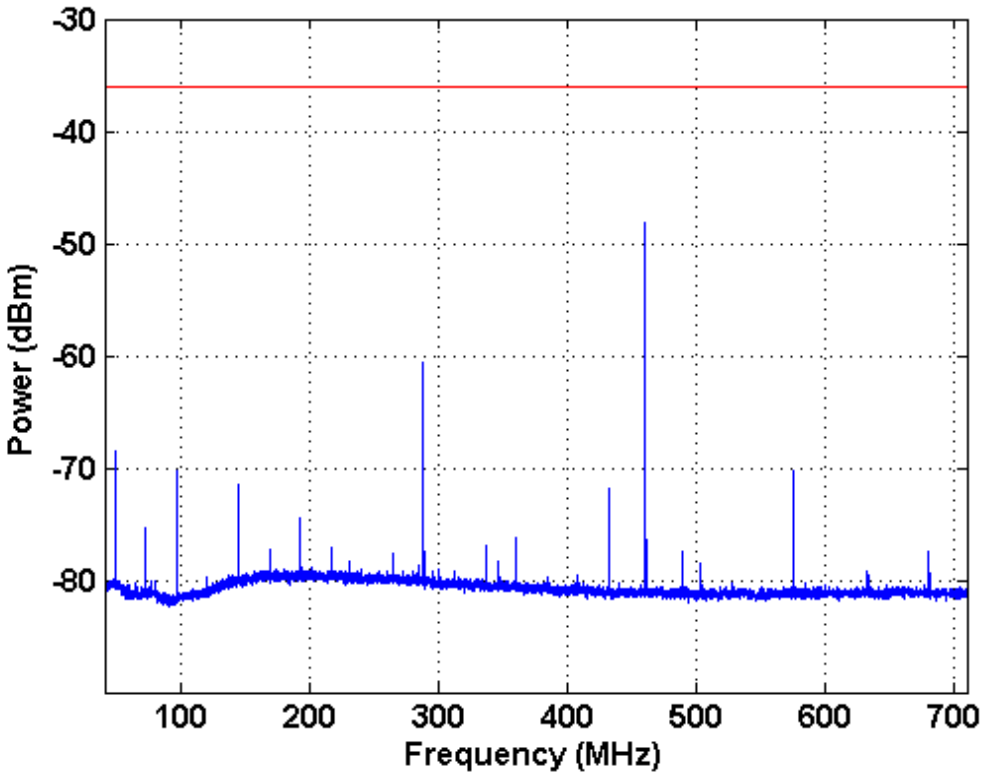

Figure 2. Spurious Emission 40 MHz - 710 MHz

Limit:	-36 dBm/100 kHz
Measured:	-50.2 dBm (max over 3 samples)
Margin:	14.2 dB (Pass)

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3.3.2 Spurious Emission 710 MHz – 900 MHz

The allowed level of spurious emissions within the 710 MHz – 900 MHz frequency band is specified as less than -55 dBm in any 1 MHz bandwidth. The channel center frequency selected for this measurement is 920.6 MHz. The measured spurious emissions within this frequency band are shown in Figure 3.

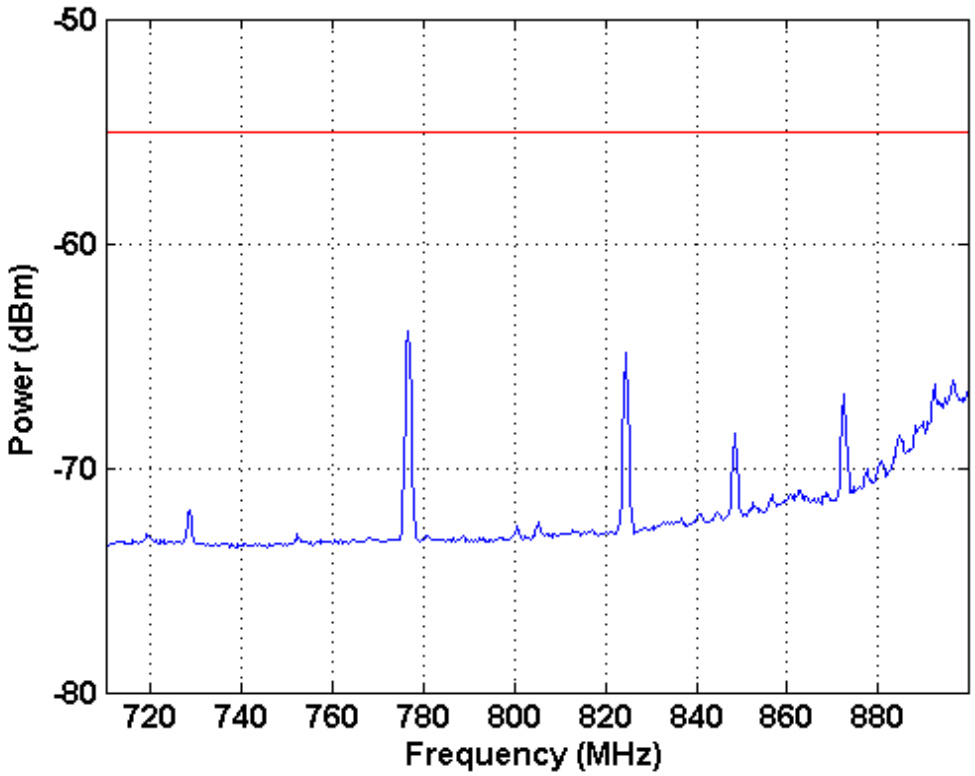

Figure 3. Spurious Emission 710 MHz - 900 MHz

Limit:	-55 dBm/1 MHz
Measured:	-65.0 dBm (max of 3 samples)
Margin:	10 dB (Pass)

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3.3.3 Spurious Emission 900 MHz – 915 MHz

The allowed level of spurious emissions within the 900 MHz – 915 MHz frequency band is specified as less than -55 dBm in any 100 kHz bandwidth. The channel center frequency selected for this measurement is 920.6 MHz. The measured spurious emissions within this frequency band are shown in Figure 4.

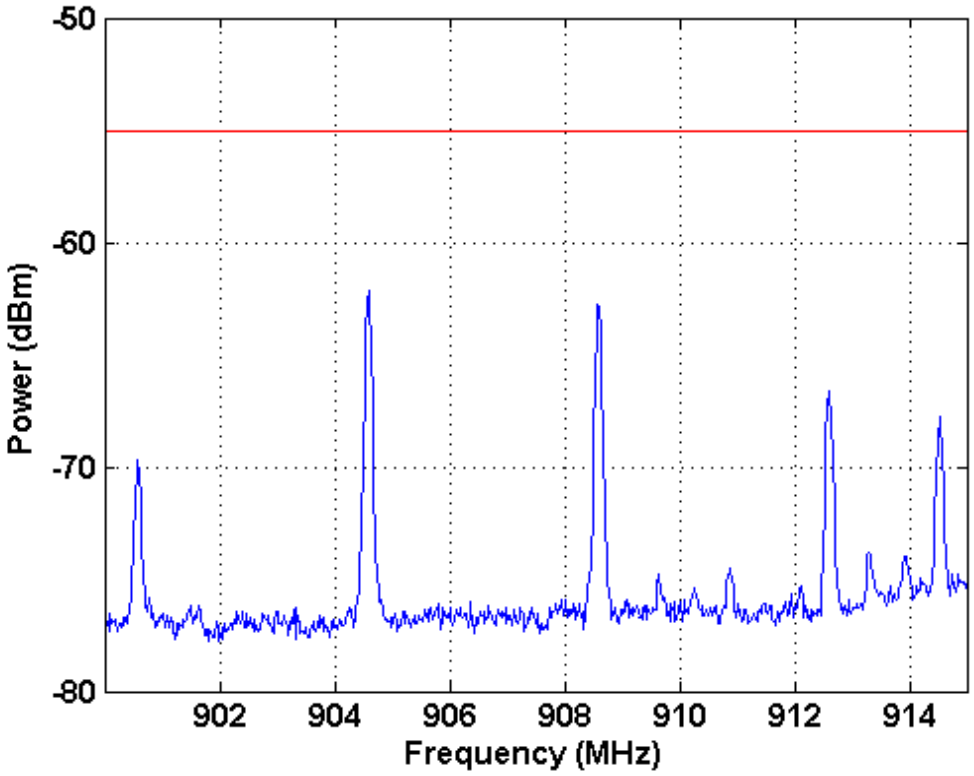

Figure 4. Spurious Emission 900 MHz - 915 MHz

Limit:	-55 dBm/100 kHz
Measured:	-63.9 dBm (max over 3 samples)
Margin:	8.9 dB (Pass)

3.3.4 Spurious Emission 915 MHz - 930 MHz

The allowed level of spurious emissions within the 915 MHz – 930 MHz frequency band is specified as less than -36 dBm in any 100 kHz bandwidth (1).

The measurement method that should be used is outlined in TELEC-T245. According to 2(5) in TELEC-T245, the frequency band between 915 MHz and 930 MHz should be measured with a RBW equal to 3 kHz (2) with max peak detector with a single sweep. The result of this measurement is shown in Figure 5 and Figure 6.

(1) Except for |f-fc| > (200+100^{x}n) kHz for unit channel bandwidth 200 kHz and |f-fc| < (100+50^{x}n) kHz for 100 kHz unit channel bandwidth For 915.9 MHz < f < 916.9 MHz and 920.5 MHz < f < 922.3 MHz: Except |f-fc| < (100+100^{x}n) kHz.

(2) The limit is then adjusted by 10*log10(100 kHz/3 kHz).

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If the measured amplitude of spurious emission using single sweep exceeds the standard the spurious emission should be calculated according to TELEC-T245 in Chapter 4 (7) to (16):

- Measure the total average power (Pb)
- Measure the average power in the used unit channel(s) (Pc) in watts
- Measure the average power of the spurious emission for all frequencies that exceed the limit in watts. (Ps)
- Calculate the unwanted emission power as (Ps/Pc)*Pb

A Matlab® script was developed to simplify the calculation [3]. The result of the Matlab calculation is shown in Figure 5.

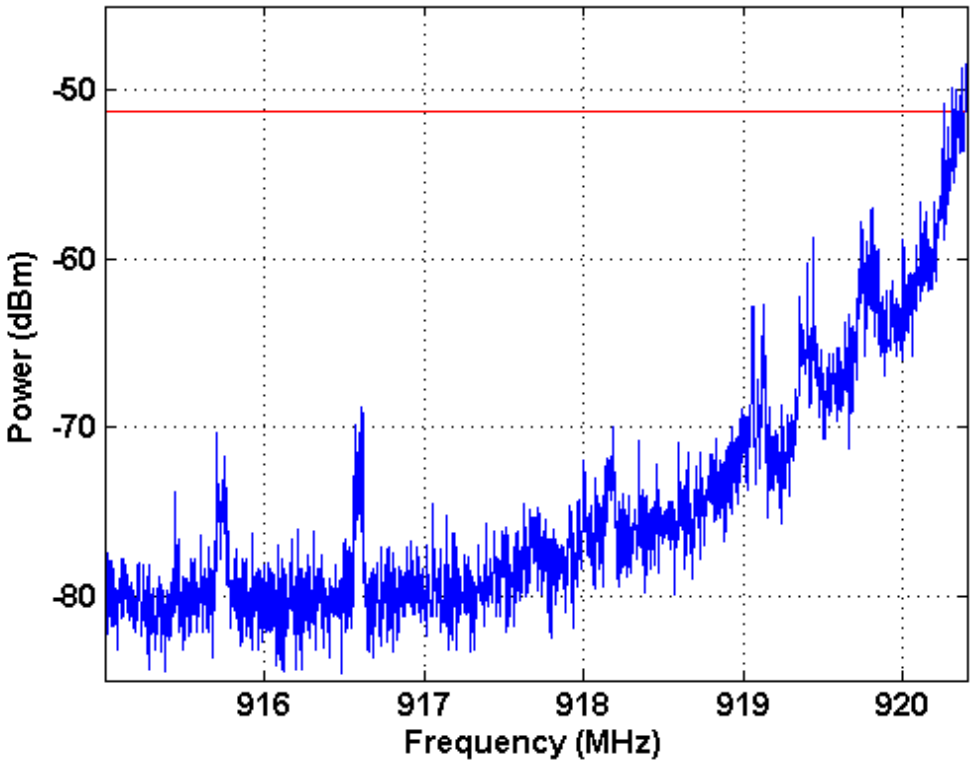

Figure 5. Spurious Emission 915 MHz - 920.4 MHz

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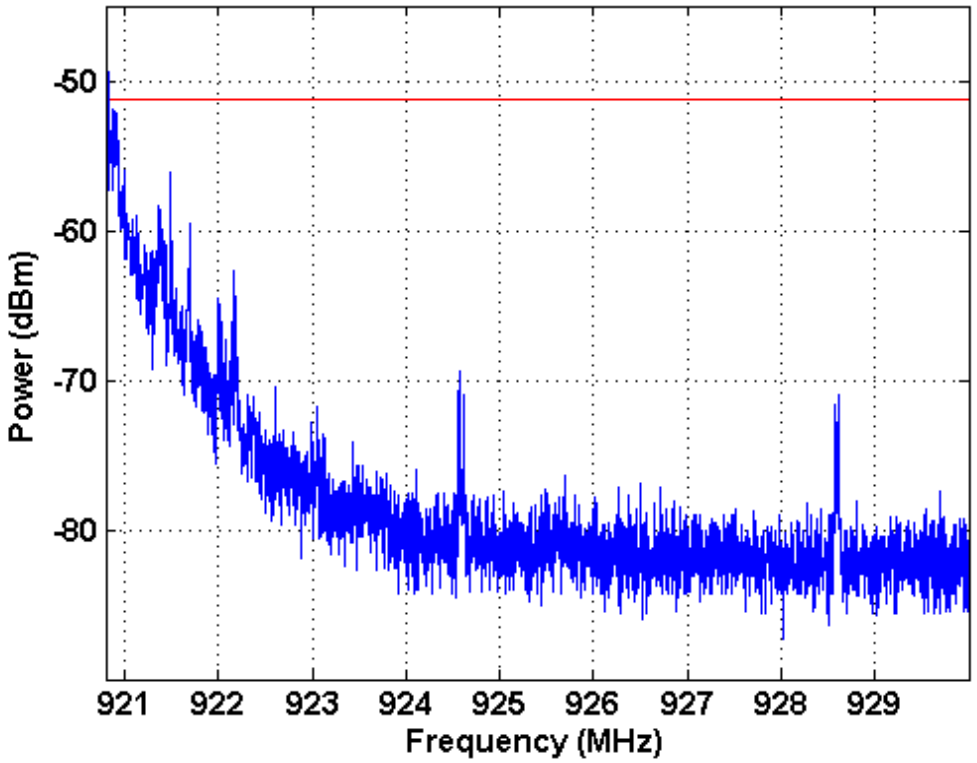

Figure 6. Spurious Emission 920.8 MHz - 930 MHz

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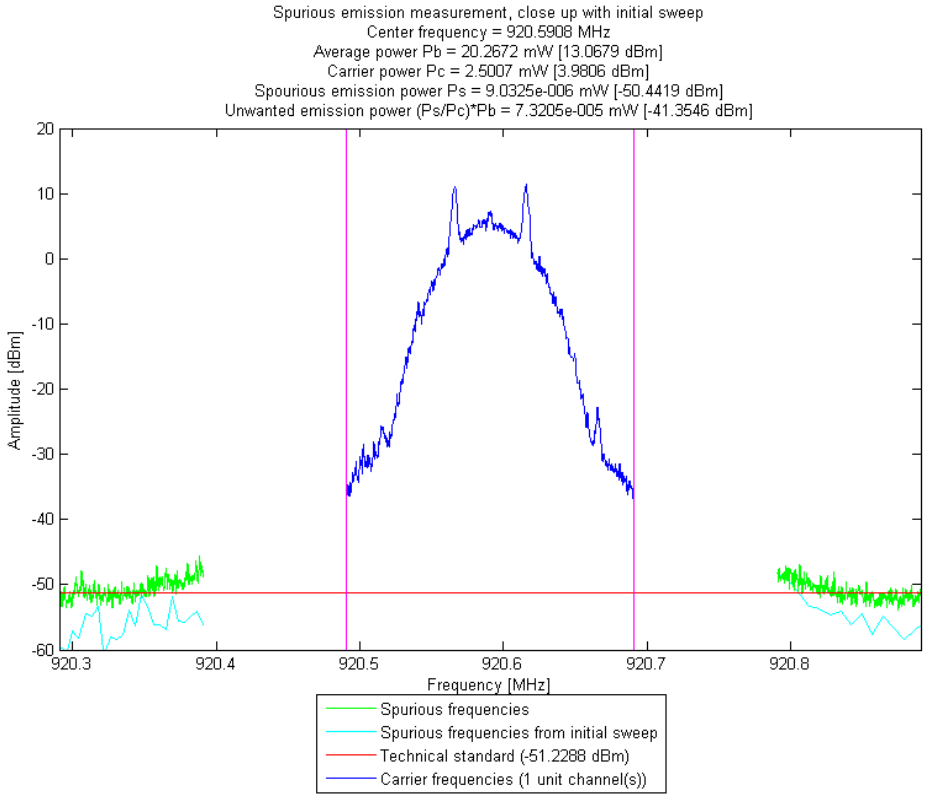

Figure 7. Result From Matlab Script

Limit:	-36 dBm/ 100 kHz
Measured:	-41.4 dBm (1)
Margin:	5.4 dB (Pass)

(1) Measured using the Matlab script

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3.3.5 Spurious Emission 930 MHz - 1000 MHz

The allowed level of spurious emissions within the 930 MHz – 1000 MHz frequency band is specified as less than -55 dBm in any 100 kHz bandwidth. The channel center frequency selected for this measurement is 920.6 MHz. The measured spurious emissions within this frequency band are shown in Figure 8.

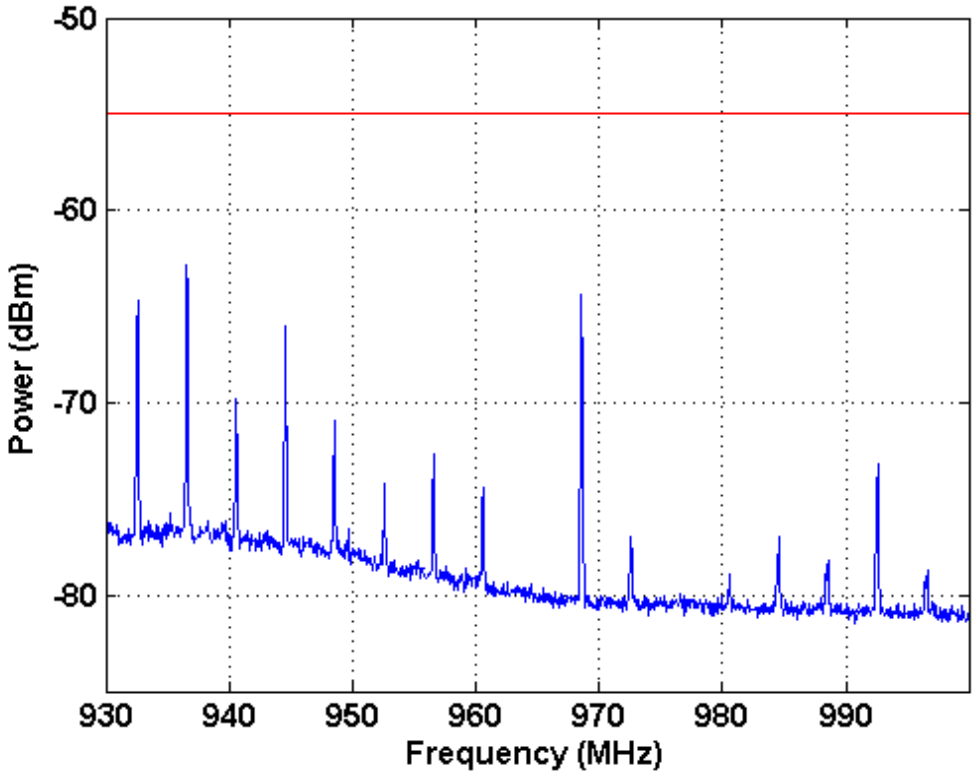

Figure 8. Spurious Emission 930 MHz - 1000 MHz

Limit:	-55 dBm/100 kHz
Measured:	-64.1 dBm (max over 3 samples)
Margin:	9.1 dB (Pass)

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3.3.6 Spurious Emission 1000 MHz - 1215 MHz

The allowed level of spurious emissions within the 1000 MHz – 1215 MHz frequency band is specified as less than -45 dBm in any 1 MHz bandwidth. The channel center frequency selected for this measurement is 920.6 MHz. The measured spurious emissions within this frequency band are shown in Figure 9.

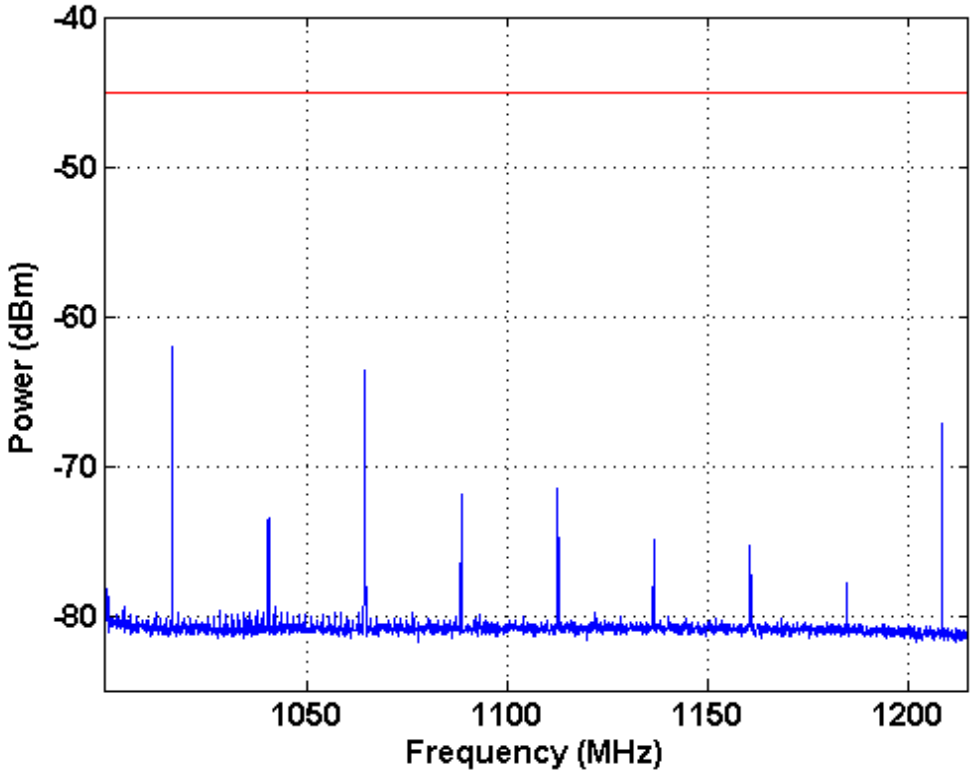

Figure 9. Spurious Emission 1000 MHz - 1215 MHz

Limit:	-45 dBm/1 MHz
Measured:	-62.1 dBm (max over 6 samples)
Margin:	17.1 dB (Pass)

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3.3.7 Spurious Emission 1215 MHz –>

The allowed level of spurious emissions above 1215 MHz frequency is specified as less than -30 dBm in any 1 MHz bandwidth. The channel center frequency selected for this measurement is 920.6 MHz. The measured spurious emissions within this frequency band are shown in Figure 10.

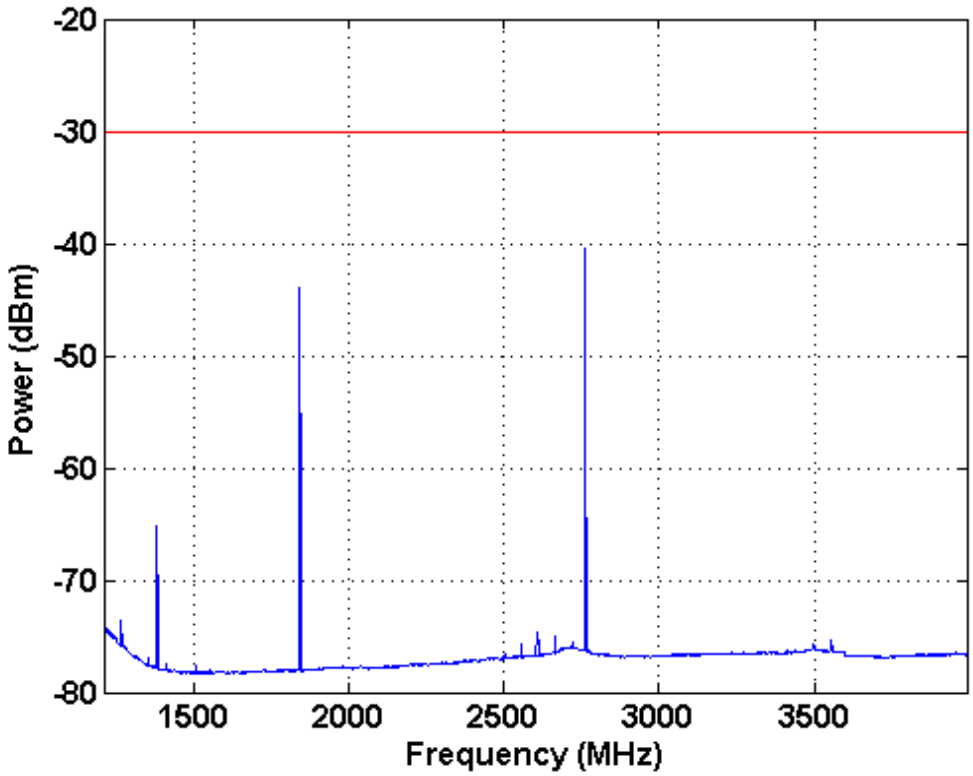

Figure 10. Spurious Emission Above 1215 MHz

Limit:	-30 dBm/1 MHz
Measured:	-40.5 dBm (max over 6 samples)
Margin:	9.5 dBm (Pass)

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4 RX Conducted Measurements

Sensitivity is measured using the information in Table 14.

Table 14. Sensitivity

Data Rate	Sensitivity [dBm]
50 kbps, 25 kHz deviation GFSK	-109

5 References

1. T108: http://www.arib.or.jp/english/html/overview/doc/5-STD-T108v1_0-E2.pdf
2. TELEC_T245: http://www.telec.or.jp/eng/services/index.html. For more information, contact TELEC.
3. Matlab script: http://www.ti.com/lit/zip/swra445

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