Gateway Test and Measurement Guidelines Issue 01

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Gateway Test and Measurement Guidelines

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1 Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119.

The octet order over the air for all multi-octet fields is **big endian** (Most significant byte is sent first).

2 Introduction

This document proposes a list of test procedures to measure the physical layer performance of LoRaWAN Gateways. The document defines what RF paraments to test and includes guidelines on how to measure them that will allow all gateways to be evaluated in a consistent manner so the results can be compared

2.1 Scope

The scope of this document covers the practical evaluation of gateway RF performance. The intent is not to cover regulatory requirements but instead to define a set of tests and procedures that can be used to baseline gateway performance in typical deployment scenarios. These deployment scenarios, along with corresponding gateway RF performance guidelines, are described in a complementary LoRa Alliance whitepaper [1]. Where appropriate, these RF performance guidelines are included in the sections of this document for reference. Failure to meet these performance guidelines does not imply that a gateway is not suitable for the specific deployment environment of a particular end-customer.

2.2 Gateway Classes and Deployment Environments

To help end-customers evaluate their gateway products, vendors can choose and communicate the appropriate class identifier from Table 2-1 below that best represents the targeted deployment environment. RF performance guidelines in this document have been tailored for each class of gateway. Testing is performed under nominal humidity conditions. Relative humidity should be measured and recorded at the time of testing.

Table 2-1 Deployment Environments

Class Identifier	Deployment Environment
1	Outdoor
2	Indoor

2.3 Test Matrix

The following abbreviations are used in Table 2-2:

E - tested over the operating temperature range defined by the gateway vendor.
N – tested at nominal temperature, nominal humidity and nominal input voltage
O – optional test for a given gateway class

Table 2-2 Recommended Test Matrix

Document Section	Test Case Description	Gateway Class (defined in Table 2-1)		Type of Test Output (Result or Pass/Fail)
		1	2	
4.1	Tx & Rx Operation and Survival with Open/Short Load	N	N[1]	Pass/Fail
4.2	Measured and Reported RF Transmit Power Relative to Transmit Power Setting	E	N (Opt E)	Result
4.3	Tx Conducted Emissions Out-of-Band	N	O (N)	Result
4.4	Tx Intermodulation	N	-	Result
4.5	Tx Frequency Error	E	N (Opt E)	Pass / Fail
4.6	Rx Sensitivity	E	N (Opt E)	Result
4.7	Rx Dynamic Range	N	N	Result
4.8	Rx In-Band Blocking/Selectivity	N	N	Result
4.9	Rx Out-of-Band Blocking/Selectivity	N	N	Result
4.10	Rx Intermodulation	N	N	Result
4.11	Cold Start	O	-	Pass / Fail
4.12	Time Accuracy	O	O	Result

[1] Test is applicable only if gateway has an external antenna connector

2.4 Gateway Test Frequencies

Table 2-3 shows the list of primary test frequencies (TxF1, RxF1) for the test cases in this document. In addition, a second set of test frequencies (TxF2, RxF2) are defined for gateways intended for deployment in specific regions that support a large RF bandwidth.

Table 2-3 Gateway Test Frequencies

Channel Plan	TxF1 (MHz)	TxF1 Modulation	TxF2 (MHz)	TxF2 Modulation	RxF1 (MHz)	RxF2 (MHz)
EU868	869.525	SF7, 250kHz	868.1	SF12, 125kHz	868.3	N/A
US915	923.3	SF7,500kHz	927.5	SF12, 500kHz	902.3	914.9
CN779	TBD	TBD	TBD	TBD	TBD	TBD
EU433	TBD	TBD	TBD	TBD	TBD	TBD
AU915	923.3	SF7,500kHz	927.5	SF12, 500kHz	915.2	927.8
CN470	TBD	TBD	TBD	TBD	TBD	TBD
AS923-1	923.2	SF7, 250kHz	923.4	SF12, 125kHz	923.2	N/A
AS923-2	921.4	SF7, 250kHz	921.6	SF12, 125kHz	921.4	N/A
AS923-3	916.6	SF7, 250kHz	916.8	SF12, 125kHz	916.6	N/A
AS923-4	TBD	TBD	TBD	TBD	TBD	TBD
KR920	922.1	SF7, 125kHz	922.5	SF12, 125kHz	922.3	N/A
IN865	865.0625	SF7, 125kHz	865.985	SF12, 125kHz	865.4025	N/A
RU864	868.9	SF7, 125kHz	869.1	SF12, 125kHz	868.9	N/A

2.5 Blocking Test Frequencies

Additional notes on interference sources by region can be found in the appendix (Table 5-7).

Table 2-4 Blocking Test Frequencies

Region	Desired Rx (MHz)	In-band Interferer Frequency (MHz)		Out-of-band Interferer Frequency (MHz)	
		Low-side	High-side	Low-side	High-Side
EU868	868.5	867.5	869.525	821.0	925.0
US915	908.7	906.7	910.7	894.0	929.0
CN779	TBD	TBD	TBD	TBD	TBD
EU433	TBD	TBD	TBD	TBD	TBD
AU915	921.4	919.4	923.4	890.0	938.0[1]
CN470	TBD	TBD	TBD	TBD	TBD
AS923-1	923.2	921.2	925.0	TBD	938.0
AS923-2	921.4	920.0	923.0	TBD	938.0
AS923-3	916.6	915.0	918.0	TBD	938.0
AS923-4	TBD	TBD	TBD	TBD	TBD
KR920	922.3	920.9	923.3	890.0	938.0
IN865	865.985	865.0	867.0	TBD	869.0
RU864	868.9	866.9	870.0	821.0	925.0

[1] 5MHz above anticipated ISM band extension to 933MHz

2.6 Rx Intermodulation Test Frequencies

Table 2-5 Rx Intermodulation Test Frequencies

Region	OOB Interferer 1 (MHz)	OOB Interferer 2 (MHz)	Desired Rx (MHz)	Dominant Interferer
EU868	791.2	816.9	868.3	LTE B20 downlinks (5th order products)
US915	869.1.0	890.1	911.1	LTE B5 downlinks
CN779	TBD	TBD	TBD	TBD
EU433	TBD	TBD	TBD	TBD
AU915	935.1	955	915.2	GSM B8 downlinks
CN470	TBD	TBD	TBD	TBD
AS923-1	930.2	937	923.4	LTE B8 downlinks
AS923-2	930.2	938.8	921.6	LTE B8 downlinks
AS923-3	930.2	943.6	916.8	LTE B8 downlinks
AS923-4	TBD	TBD	TBD	LTE B8 downlinks
KR920	930.2	937.9	922.5	LTE B8 downlinks
IN865	870.5	875.015	865.985	LTE B5 downlinks
RU864	791.7	817.5	869.1	LTE B20 downlinks (5th order products)

3 Test Set Ups

3.1 Set Up #1

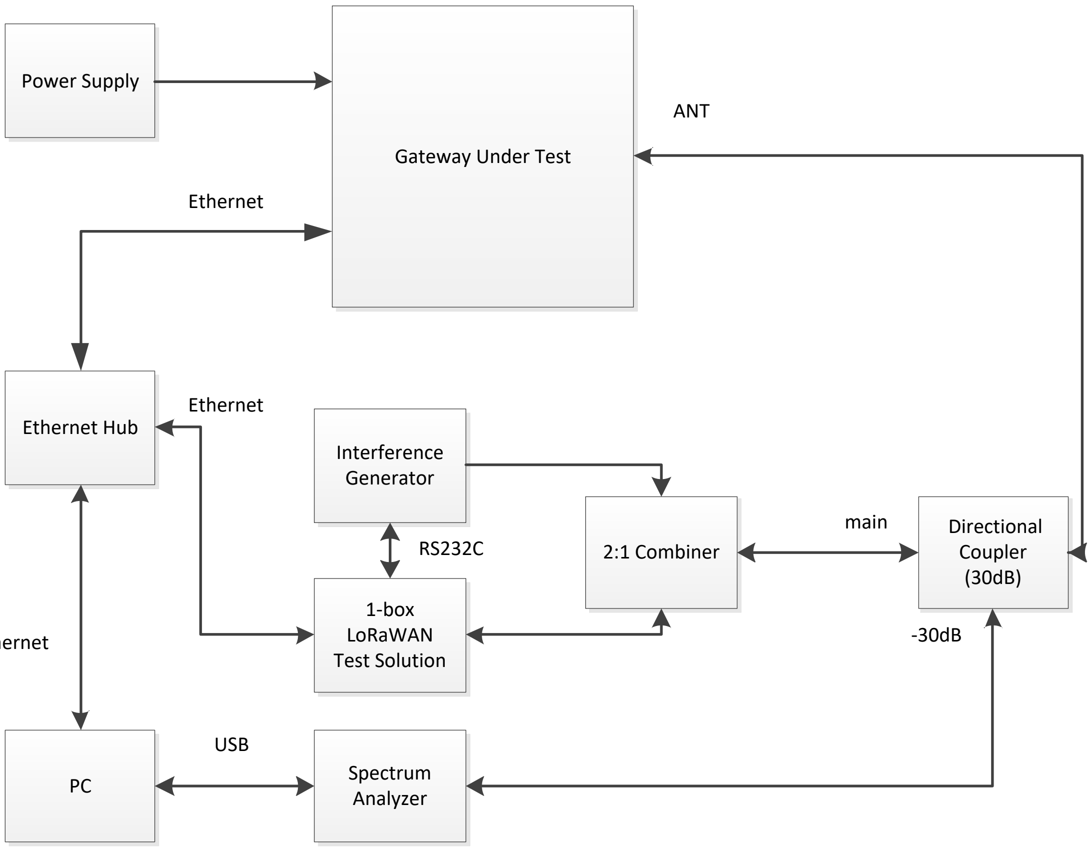

Figure 3-1 Transmit and Receive Test Set Up

4 Tests Procedures and Performance Guidelines

4.1 Tx & Rx Operation and Survival with Open/Short Load

4.1.1 Applicability

Please refer to Table 2-2.

4.1.2 Description

To ensure the RF transmitter survives RF Cable or Antenna fault condition. To minimize test time, perform this test first, then perform the remainder of the tests in this document to confirm gateway transmitter and receiver circuitry is fully functional (i.e. hasn't been damaged by this open/short test).

4.1.3 Performance Guidelines

No damage to the gateway under the test conditions.

4.1.4 Test Conditions

Operating frequencies and modulation: Please refer to Table 2-3.
RF power levels: Tx Power Max
Environmental and input voltage conditions: nominal temperature, humidity and input voltage

4.1.5 Test Procedure

1. Use Test Set up #1 or #A4.
2. Set Gateway to Tx Max power at frequency and modulation, TxF1
3. For half-duplex gateways set the transmit duty cycle to 10%. For full-duplex gateways, set the transmit duty cycle to greater than 98%.
4. Transmit at Tx Max for 5 min or until thermal stability of the device have been achieved into an RF Open circuit.
5. Repeat the same test with the RF short circuit.
6. Perform the remainder of the transmitter and receiver tests in this document to confirm gateway functionality.

4.1.6 Test Results

Table 4-1 Test Results – Tx & Rx Operation and Survival with Open/Short Load

Test Number	Test Name	Temperature range	Result (Pass/Fail)	Comment
4.1.1	Survival with Open/Short Load	Normal		Result confirmed by successful completion of subsequent tests

4.2 Measured and Reported RF Transmit Power Relative to Transmit Power Setting

4.2.1 Applicability

Please refer to Table 2-2.

4.2.2 Description

To measure accuracy of transmit RF output power relative to manufacturer's RF output power ratings across dynamic range and over deployment conditions. Deltas can be incorporated into the end to end RF link budget.

4.2.3 Performance Guidelines

Table 4-2 Transmitted and Reported Tx Power Performance Guidelines

Gateway Class	**Accuracy of Tx Power Output and Tx Power Report Relative to Manufacturer's rating**			
	Measured at Nominal Temperature, Humidity, Input Voltage		**Measured Over Input Voltage Range and Environmental Conditions.**	
	Tx Power Max[1]	**Tx Power Min**	**Tx Power Max**	**Tx Power Min**
1	+1/-2dB	+3/-3dB	+2/-3dB	+4/-4dB
2	+2/-3dB	+3/-4dB	+3/-4dB	+4/-5dB

4.2.4 Test Conditions

Operating frequencies and modulation: Please refer to Table 2-3 for definition of TxF1 and TxF2 for the specific gateway under test.
RF power levels: Tx Max power, Tx Min Power (both as defined by manufacturer)
Environmental and input voltage conditions: Tested at nominal relative humidity, over the operating temperature range defined by the gateway vendor.

4.2.5 Test Procedure

1. Use Test Set up #1 or #A1.
2. Set test environment to lower bound of operational temperature range defined by gateway vendor. Note and record the relative humidity.
3. Set Gateway to Tx Power Max at operating frequency and modulation TxF1.

[1] Ensure that Measured Tx Power Max does not exceed local regulatory limits

4. Measure Tx power and record Tx power reported by Gateway.
5. Set Gateway to Tx Power Min and repeat the measurement.
6. Repeat steps 3 through 5 for operating frequency and modulation TxF2, if applicable for the gateway region under test.
7. Set test environment to the upper bound of operational temperature range defined by gateway vendor.
8. Repeat steps 3 through 6.

4.2.6 Test Results

Table 4-3 - Test Results - Measured and Reported RF Transmit Power Relative to Transmit Power Setting

Test Number	Test Name	Temperature Range	Result (dBm)	Comment
4.2.1	Measured Max RF Tx Power – TxF1	Low		Mandatory for class 1 gateways, optional for class 2 gateways
4.2.2	Measured Min RF Tx Power – TxF1	Low		
4.2.3	Measured Max RF Tx Power – TxF1	High		
4.2.4	Measured Min RF Tx Power – TxF1	High		
4.2.5	Measured Max RF Tx Power – TxF1	Nominal		N/A for class 1 gateways, mandatory for class 2 gateways
4.2.6	Measured Min RF Tx Power – TxF1	Nominal		
4.2.7	Measured Max RF Tx Power – TxF2	Low		Mandatory for class 1 gateways, optional for class 2 gateways
4.2.8	Measured Min RF Tx Power – TxF2	Low		
4.2.9	Measured Max RF Tx Power – TxF2	High		
4.2.10	Measured Min RF Tx Power – TxF2	High		
4.2.11	Measured Max RF Tx Power – TxF2	Nominal		N/A for class 1 gateways, mandatory for class 2 gateways
4.2.12	Measured Min RF Tx Power – TxF2	Nominal		

4.3 Tx Conducted Emissions Out-of-Band

4.3.1 Applicability

Please refer to Table 2-2.

4.3.2 Description

The purpose of this test case is to quantify the impact of the transmitter spurious emissions on a co-located cellular e-NodeB receiver. To minimize the dynamic range requirements of the test equipment (spectrum analyzer), measurements will be made at the edge of the LoRaWAN passband and, if a cavity filter is present in the gateway, the result will be adjusted to take into account the rejection of this filter in the nearest cellular receive band.

4.3.3 Performance Guidelines

A typical LTE receiver noise floor is -116.4dBm/360kHz assuming a 2dB noise figure. With an antenna isolation of 45dB [1] and incorporating an additional 6dB of protection to limit the LTE receiver sensitivity degradation to 1dB, the transmitter spurious emissions guideline in the closest LTE uplink band is -77.4dBm/360kHz or equivalently, -83dBm/100kHz.

Table 4-4 Tx Conducted Emissions Out-of-Band

Gateway Class	Cellular Band Emission Guideline (dBm/100kHz)
1	-83
2	N/A

4.3.4 Test Conditions

Operating frequencies and modulation: Please refer to Table 2-3 for definition of TxF1 and TxF2 for the specific gateway under test.
RF power levels: Tx power Max (for EU region, test at 14dBm, TXF2 only)
Environmental and input voltage conditions: nominal temperature, humidity and input voltage

4.3.5 Test Procedure

1. Use Test Set up #1 or #A1.
2. Set Gateway to transmit a continuous (> 98% duty cycle) LoRa waveform at Tx Max power at frequency and modulation TxF1. Continuous transmission can be achieved by using utilities developed by Semtech, such as tx_continuous and send_pkt.
3. Select spectrum analyzer settings as per section 5.1. Set the measurement marker such that the edge of the resolution bandwidth touches the band edge of interest.
4. Measure and record Tx Conducted Emissions at the first emissions test frequency listed in Table 4-5.

5. Repeat the test at the second emissions test frequency, if applicable (see Table 4-5).
6. Repeat steps 2 through 7 for operating frequency and modulation TxF2, if applicable for the gateway region under test.

Table 4-5 3GPP Rx Bands and Test Frequencies

Channel Plan	3GPP Rx Band	Emissions Test Frequency (MHz)
EU868	LTE B20 LTE B8	862.0 880.0
US915	LTE B5	849.0
CN779	TBD	TBD
EU433	TBD	TBD
AU915	LTE B8	915.0
CN470	LTE B8	880.0
AS923 (-1 to -4)	LTE B8	915.0
KR920	LTE B8	915.0
IN865	LTE B8	880.0
RU864	LTE B20	862.0

4.3.6 Test Results

Table 4-6 - Test Results - Tx Conducted Emissions Out-of-Band

Test Number	Test Name	Temperature Range	Result (dBm)	Comment
4.3.1	Conducted Emissions at first Emissions Test Frequency when gateway transmitting on TxF1	Nominal		
4.3.2	Conducted Emissions at second Emissions Test Frequency when gateway transmitting on TxF1	Nominal		If second Emissions Test Frequency defined in Table 4-5.
4.3.3	Conducted Emissions at first Emissions Test Frequency when gateway transmitting on TxF2	Nominal		If applicable
4.3.4	Conducted Emissions at second Emissions Test Frequency when gateway transmitting on TxF2	Nominal		If applicable

4.4 Tx Intermodulation

4.4.1 Applicability

Please refer to Table 2-2.

4.4.2 Description

To measure transmit emissions performance in the presence of strong Out of Band signal at the Gateway ANT port. This test is based on the Tx intermodulation examples in [1]. The examples are based on a gateway transmitter output third-order-intercept-point (OIP3) of 40dBm, minimum cavity filter interferer rejection of 40dB, an antenna to antenna isolation of 45dB, and LTE and LoRa antennas as described in sections 3.2.1 and 3.2.1 respectively, in [1].

4.4.3 Performance Guidelines

The spurious emissions should be less than the value specified in Table 4-7.

4.4.4 Test Conditions

Operating frequencies and modulation: as per table Table 4-7.

Desired Tx signal RF power level: as per table Table 4-7

Interferer levels are set as per Table 4-7.

Environmental and input voltage conditions: nominal temperature, humidity and input voltage

Table 4-7 Tx Intermodulation Settings

	LoRaWAN Tx settings				**CW Interferer settings**		**Intermodulation (IMD) Tone**	
Region	**Freq. (MHz)**	**Power (dBm)**	**SF**	**BW (kHz)**	**Freq. (MHz)**	**Power (dBm)**	**Freq. (MHz)**	**Power (dBm)**
EU	869.525	27	7	250	925	-14	814.1	Less than -80
NA	923.3	30	7	500	869	-14	977.6	Less than -74
APAC/ LATAM	923.4	27	12	125	890	-14	956.8	Less than -80

4.4.5 Test Procedure

1. Use Test Set up #1 or #A2.
2. Set Gateway to transmit a continuous (> 98% duty cycle) LoRa waveform as specified in Table 4-7. Continuous transmission can be achieved by using utilities developed by Semtech, such as tx_continuous and send_pkt.
3. Inject the CW interferer signal defined in Table 4-7.
4. Select spectrum analyzer settings as per section 5.1. Set the measurement marker at the intermodulation tone frequency (seeTable 4-7).

5. Measure the Tx intermodulation level in a 100kHz resolution bandwidth (RBW).

4.4.6 Test Results

Table 4-8 - Test Results - Tx Intermodulation

Test Number	Test Name	Temperature Range	Gateway Region	IMD Freq. (dBm)	IMD Power (dBm)	Comment
4.4.1	Tx Intermodulation	Nominal				

4.5 Tx Frequency Error

4.5.1 Applicability

Please refer to Table 2-2.

4.5.2 Description

To purpose of this test is to measure the error in the center frequency of the transmit waveform. For correct LoRaWAN network functionality, an overall system frequency error budget has to be maintained. The performance guidelines below are based on assigning the majority of the budgeted frequency variation to end devices.

4.5.3 Performance Guidelines

Table 4-9 Tx Frequency Error Performance Guidelines

Gateway without GPS Synchronization: Performance Guidelines	Gateway with GPS Synchronization: Performance Guidelines
Frequency Error for a new gateway should not exceed 5 x 10^{-6} x Tx Frequency	Frequency Error for a new gateway should not exceed 0.1 x 10^{-6} x Tx Frequency

4.5.4 Test Conditions

Operating frequencies and modulation: Please refer to Table 2-3 for definition of TxF1 for the specific gateway under test.

RF power levels: Tx Power Max

Environmental and input voltage conditions: Tested at nominal relative humidity, over the operating temperature range defined by the gateway vendor.

4.5.5 Test Procedure

1. Use Test Set up #1 or #A1 (ensure spectrum analyzer has vector signal analyzer functionality)
2. Set test environment to lower bound of operational temperature range defined by gateway vendor. Note and record the relative humidity.
3. Set Gateway to transmit at Tx Max power at operating frequency and modulation TxF1.
4. Read the Vector Signal Analyzer Frequency Errors over 30 seconds and record the Max and Min values.
5. Set test environment to the upper bound of operational temperature range defined by gateway vendor.
6. Repeat steps 3 through 4.

4.5.6 Test Results

Table 4-10 - Test Results - Tx Frequency Error

Test Number	Test Name	Temperature Range	Result (Pass/ Fail)	Comment
4.5.1	Tx Frequency Error – TxF1	Low		Mandatory for class 1 gateways, optional for class 2 gateways
4.5.2	Tx Frequency Error – TxF1	High		
4.5.3	Tx Frequency Error – TxF1	Nominal		N/A for class 1 gateways, mandatory for class 2 gateways

4.6 Rx Sensitivity

4.6.1 Applicability

Please refer to Table 2-2.

4.6.2 Description

Ensure Gateway supports a sufficient uplink range for its intended deployment environment.

4.6.3 Performance Guidelines

Table 4-11 Rx Sensitivity Performance Guidelines

Rx Sensitivity Guidelines
125kHz SF7: -126 dBm
125kHz SF10: -134 dBm
125kHz SF12: -139 dBm
500kHz SF8: -124dBm

The sensitivity values provided in Table 4-11 are guidelines only and are based on gateway receiver incorporating a cavity filter with an insertion loss of approximately 2dB. For regions with stringent colocation requirements, gateways may have cavity filter insertion losses approaching 4dB – when testing these gateways, the sensitivity guidelines in the table should be adjusted accordingly.

4.6.4 Test Conditions

Operating frequencies: Please refer to Table 2-3 for definition of RxF1 and RxF2 for the specific gateway under test.

RF power levels: as per test procedure

Environmental and input voltage conditions: Tested at nominal relative humidity, over the operating temperature range defined by the gateway vendor.

4.6.5 Test Procedure

1. Use Test Set Up #1 or #A3. For test set up #1 follow the steps in the 1-box LoRaWAN test solution software, then skip to step 8 in the procedure below. For the alternative test set up #A3, follow steps 3 through 7 in the procedure below.
2. Set test environment to lower bound of operational temperature range defined by gateway vendor. Note and record the relative humidity.
3. Using LoRaWAN reference waveforms, set up the test so that 300 packets are transmitted by the vector signal generator.
4. Enable a packet logger utility on the gateway to count receive packets

5. Turn on the signal generator at frequency RxF1 at a level of -100dBm and record the number of packets received with proper CRC. Calculate the PER. Also record the reported RSSI and SNR values.

6. Decrease the input Rx desired signal by 1dB and repeat step 4 until the PER is 100%.

7. Note RF power level at 10% PER. Based on a 95% confidence interval, the maximum number of packet errors allowed in a set of 300 packets is 19 to ensure that a packet error rate of 10% is not exceeded. Please refer to Table 11.2 in [2] for more details on Monte Carlo method and Poisson approximations to binomial distributions

8. Repeat steps 3 through 7 for operating frequency RxF2, if applicable for the gateway region under test.

9. Set test environment to the upper bound of operational temperature range defined by gateway vendor.

10. Repeat steps 3 through 8.

4.6.6 Test Results

Table 4-12 - Test Results - Rx Sensitivity

Test Number	Test Name	Rx Freq.	Temp	Result (dBm)	Comment
4.6.1	Rx Sensitivity – 125kHz SF7	RxF1	Low		Mandatory for class 1 gateways, optional for class 2 gateways
4.6.2	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region)		Low		
4.6.3	Rx Sensitivity – 500kHz SF8 (NA Region only)		Low		
4.6.4	Rx Sensitivity – 125kHz SF7		High		
4.6.5	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region)		High		
4.6.6	Rx Sensitivity – 500kHz SF8 (NA Region only)		High		
4.6.7	Rx Sensitivity – 125kHz SF7		Nom.		N/A for class 1 gateways, mandatory for class 2 gateways
4.6.8	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region)		Nom.		
4.6.9	Rx Sensitivity – 500kHz SF8 (NA Region only)		Nom.		
4.6.10	Rx Sensitivity – 125kHz SF7	RxF2	Low		Mandatory for class 1 gateways, optional for class 2 gateways
4.6.11	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region)		Low		
4.6.12	Rx Sensitivity – 500kHz SF8 (NA Region only)		Low		
4.6.13	Rx Sensitivity – 125kHz SF7		High		
4.6.14	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region)		High		
4.6.15	Rx Sensitivity – 500kHz SF8 (NA Region only)		High		
4.6.16	Rx Sensitivity – 125kHz SF7		Nom.		N/A for class 1 gateways, mandatory for class 2 gateways
4.6.17	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region)		Nom.		
4.6.18	Rx Sensitivity – 500kHz SF8 (NA Region only)		Nom.		

4.7 Rx Dynamic Range

4.7.1 Applicability

Please refer to Table 2-2.

4.7.2 Description

Gateway should handle a range of RF input power from Rx sensitivity limit to a high level to successfully handle high power in-band desired signal

4.7.3 Performance Guidelines

Table 4-13 Rx Dynamic Range Performance Guidelines

Gateway Class	Dynamic Range (dB, SF10, 125kHz BW)
1	110
2	110

4.7.4 Test Conditions

Operating frequencies: Please refer to Table 2-3 for definition of RxF1 for the specific gateway under test.

RF power levels: range over which packet error rate < 10%

Environmental and input voltage conditions: nominal temperature, humidity and input voltage

4.7.5 Test Procedure

1. Use Test Set Up #1 and follow 1-box LoRaWAN test solution software or use Test Set Up #A2 and follow the procedure below.
2. Measure gateway Rx Sensitivity frequency RxF1 at SF10, 125kHz (10% PER) using procedure described in section 4.6.
3. Decrease input signal attenuation by 10dB and measure PER.
4. Decrease input signal attenuation until 10% PER is observed at high power. Add 10dB attenuation and repeat step 3 with 1dB steps until 10% PER is observed
5. Calculate dynamic range. Dynamic range = RF power level from step 4 @ 10% PER minus Rx sensitivity power level.

4.7.6 Test Results

Table 4-14 Test Results – Rx Dynamic Range

Test Number	Test Name	Temperature range	Result (dB)	Comment
4.7.1	Rx Dynamic Range	Normal		

4.8 Rx In-Band Blocking/Selectivity

4.8.1 Applicability

Please refer to Table 2-2.

4.8.2 Description

Measure the ability of Gateway to receive a low level desired signal in the presence of a strong in-band interferer.

4.8.3 Performance Guidelines

Table 4-15 Rx In-band Blocking Tolerated Interferer Power Performance Guidelines

Gateway Class	Tolerable In-band Interferer Power level (dBm)
1	-43
2	-69

4.8.4 Test Conditions

Operating frequencies: Please refer to Table 2-4.

RF power levels: Receiver input levels as per test procedure

Environmental and input voltage conditions: nominal temperature, humidity and input voltage

Table 4-16 In-Band Blocking Interferer Settings

Gateway Class	In-band Interferer Type	In-band Interferer Power level at start of test (dBm)	Desired signal level power (dB above SF10 RF sensitivity)
1	CW	-60	6dB
2	CW	-85	6dB

4.8.5 Test Procedure

1. Use Test Set Up #1 or #A4 (see section 5.1.4)
2. Set up desired signal such that input RF level is above sensitivity limit by the amount shown in Table 4-16.

3. Turn on the interference signal at the low-side blocking frequency listed in Table 2-4. Refer to Table 4-16 for interferer RF power levels at the start of the test.

4. Set up the test so that 300 packets are transmitted by the vector signal generator. If using the 1-box LoRaWAN test solution limit the range of the sensitivity measurement to just around the RF level specified in step 2 above (this will optimize test time).

5. Enable a packet logger utility on the gateway to count receive packets and the number of errors. Record the packet error rate. If using the 1-box solution, run the sensitivity test.

6. Increase the RF power level of the interfering signal by 2dB. Repeat steps 2 through 5.

7. Note the Interferer power levels when the packet error rate (PER) crosses the 50% boundary

8. Stop the test when the packet error rate reaches 100%.

9. Repeat steps 3 through 8 for the high-side blocking frequency.

4.8.6 Test Results

Table 4-17 Test Results – Rx In-Band Blocking/Selectivity

Test Number	Test Name	Temperature range	Interferer Power @ 50% PER (dBm)	Comment
4.8.1	In-band blocking – low side blocker	Normal		
4.8.2	In-band blocking – high side blocker	Normal		

4.9 Rx Out-of-Band Blocking/Selectivity

4.9.1 Applicability

Please refer to Table 2-2.

4.9.2 Description

To measure capability of gateway to reject very large cellular or paging transmitters outside of the ISM band of operation. The goal is to maintain sensitivity and range.

4.9.3 Performance Guidelines

Table 4-18 Rx In-band Blocking Tolerated Interferer Power Performance Guidelines

Gateway Class	Tolerable Interferer Power level (dBm)
1	+10
2	-40

4.9.1 Test Conditions

Operating frequencies: please refer to Table 2-4.
RF power levels: as per test procedure
Environmental and input voltage conditions: nominal temperature, humidity and input voltage.

Table 4-19 Out-of-band Interferer Settings

Gateway Class	Out-of-band Interferer Type	Interferer Power level at start of test(dBm)	Desired signal level power (dB above SF10 RF sensitivity)
1	CW	-20	6dB
2	CW	-60	6dB

4.9.2 Test Procedure

1. Use Test Set Up #1 or #A4 (see section 5.1.4)
2. Set up desired signal such that input RF level is above sensitivity limit by the amount shown in Table 4-19.

3. Turn on the interference signal at the low-side blocking frequency listed in Table 2-4. Refer to Table 4-19 for interferer RF power levels at the start of the test.

4. Set up the test so that 300 packets are transmitted by the vector signal generator. . If using the 1-box LoRaWAN test solution limit the range of the sensitivity measurement to just around the RF level specified in step 2 above (this will optimize test time)

5. Enable a packet logger utility on the gateway to count receive packets and the number of errors. Record the packet error rate. If using the 1-box solution, run the sensitivity test.

6. Increase the RF power level of the interfering signal by 2dB. Repeat steps 2 through 5.

7. Note the Interferer power levels when the packet error rate crosses the 10% boundary

8. Stop the test when the packet error rate reaches 100%.

9. Repeat steps 3 through 8 for the high-side blocking frequency.

4.9.3 Test Results

Table 4-20 Test Results – Rx Out-of-Band Blocking/Selectivity

Test Number	Test Name	Temperature range	Interferer Power @ 10% PER (dBm)	Comment
4.9.1	Out-of-band blocking – low side blocker	Normal		
4.9.2	Out-of-band blocking – high side blocker	Normal		

4.10 Rx Intermodulation

4.10.1 Applicability

Refer to Table 2-2 for applicability.

4.10.2 Description

Ensure Gateway can receive a desired Rx signal in presence of two strong out of band interferers. This test case exists to measure the gateway performance for the case where there are two strong out-of-band cellular transmitters near the gateway receiver.

4.10.3 Performance Guidelines

Table 4-21 Rx Intermodulation Tolerated Interferer Power Performance Guidelines

Gateway Class	Tolerable IOut of band Interferer 1 Power level (dBm)	Tolerable Out of band Interferer 2 Power level(dBm)
1	-14[1]	-14
2	-60	-60

4.10.4 Test Conditions

Operating frequencies: refer to Table 2-5.
Desired signal RF power level: refer to Table 4-22.
Environmental and input voltage conditions: nominal temperature, humidity and input voltage
Interferer levels are set as per table Table 4-22. Interferer frequencies are set as per Table 2-5.

Table 4-22 Interferer Settings

Gateway Class	In-band Interferer Type	In-band Interferer Power level at start of test (dBm)	Out-of-band Interferer Type	Out-of-band Interferer Power level at start of test(dBm)	Desired signal level power (dB above SF10 RF sensitivity)
1	CW	-30	LTE	-30	6dB
2	CW	-80	LTE	-80	6dB

4.10.5 Test Procedure

1. Use Test Set Up #1 or #A4 (see section 5.1.4)

[1] Assumes Gateway RF filtering of 57dB and an IIP3 of -43dBm as described in [1].

2. Set up desired signal such that input RF level is above sensitivity limit by the amount shown in Table 4-22.
3. Turn on the two interference signals at the frequencies listed in Table 2-5. Refer to Table 4-22 for interferer RF power levels at the start of the test.
4. Set up the test so that 300 packets are transmitted by the vector signal generator. If using the 1-box LoRaWAN test solution limit the range of the sensitivity measurement to just around the RF level specified in step 2 above (this will optimize test time).
5. Enable a packet logger utility on the gateway to count receive packets and the number of errors. Record the packet error rate. If using the 1-box solution, run the sensitivity test.
6. Increase the RF power level of each interfering signal by 2dB. Repeat steps 2 through 5.
7. Note the Interferer power levels when the packet error rate crosses the 10% boundary (i.e. 19 errors in 300 packets for a 10% PER with 95% confidence).
8. Stop the test when the packet error rate reaches 100%.

4.10.6 Test Results

Table 4-23 Test Results – Rx Intermodulation

Test Number	Test Name	Temperature range	Interferer Power @ 10% PER (dBm)	Comment
4.10.1	Rx Intermodulation	Normal		

4.11 Cold Start

4.11.1 Applicability

Please refer to Table 2-2.

4.11.2 Description

The purpose of this test case is to characterize the cold start performance of the gateway.

4.11.3 Performance Guidelines

See sections 4.2.3 and 4.11.3.

4.11.4 Test Conditions

Operating frequencies: Please refer to Table 2-3 for definition of TxF1 and RxF1 for the gateway under test.
RF power levels: Tx Power Max
Input voltage: nominal
Environmental conditions: minimum rated temperature

4.11.5 Test Procedure

1. Use Test Set Up #1 or #A1 and #A2.
2. Leave the unit under test unpowered at its minimum rated operating temperature for 6 hours or more.
3. Power up the unit under test and ensure the unit initializes correctly.
4. Let the unit warm up 30 minutes.
5. Execute Measured and Reported RF Transmit Power Relative to Transmit Power Setting test case (see section 4.1) at frequency TxF1.
6. Measure Rx sensitivity (see section4.6) at frequency RxF1.

4.11.6 Test Results

Table 4-24 Test Results – Cold Start

Test Number	Test Name	Temperature range	Result (Pass/Fail)	Comment
4.11.1	Cold Start	Low		

4.12 Time Accuracy

4.12.1 Applicability

Please refer to Table 2-2.

4.12.2 Description

The purpose of this test case is to characterize the Class B Beacon time accuracy.

4.12.3 Performance Guidelines

TBD

4.12.4 Test Conditions

Operating frequencies and modulation: Please refer to Table 2-3 for definition of TxF1 for the gateway under test.
RF power levels: Tx Power Max
Input voltage: nominal
Environmental conditions: nominal

4.12.5 Test Procedure

TBD

4.12.6 Test Results

TBD

5 Appendix

5.1 Alternative Test Set Ups

Note: The alternative test set ups use a large number of discrete test instruments and care must be taken to ensure all the RF levels at each point in the test fixture are optimized for each of the instruments. Failure to take these factors into account will result in inaccurate measurements. In most cases, the default Test Set up #1 is the preferred option.

5.1.1 Set Up #A1: Transmitter Test

A generalized test set up for RF transmitter testing is shown in Figure 5-1.

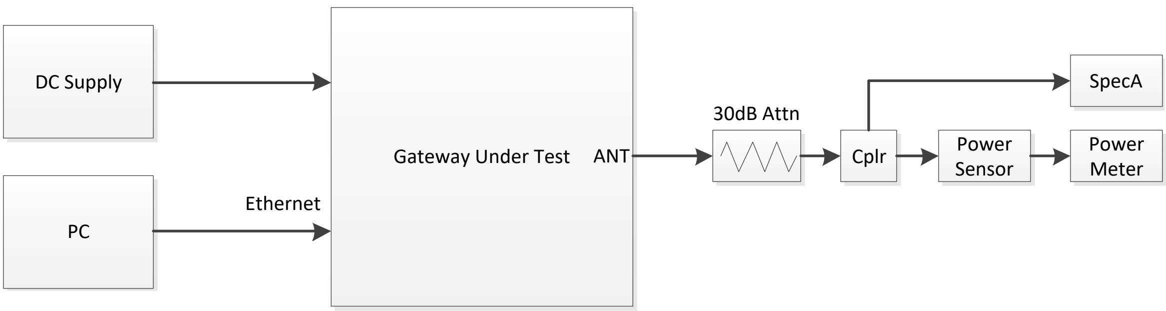

Figure 5-1: Transmitter Test Set Up

5.1.2 Set up #A2 Transmitter Intermodulation Test

A generalized test set up for RF Tx intermodulation testing is shown in Figure 5-2.

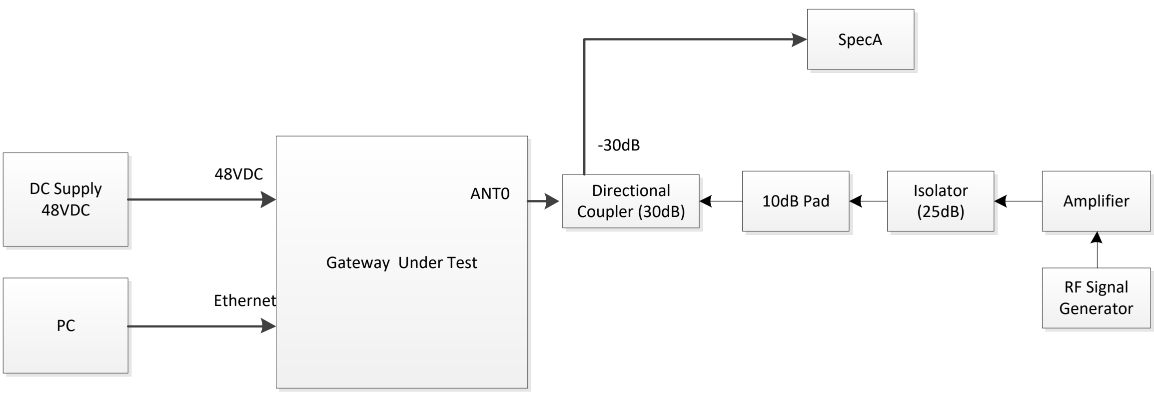

Figure 5-2 Transmitter Intermodulation Test Set Up

5.1.3 Set Up #A3 Receiver Test

The basic test set up for RF receiver testing is shown in Figure 5-3.

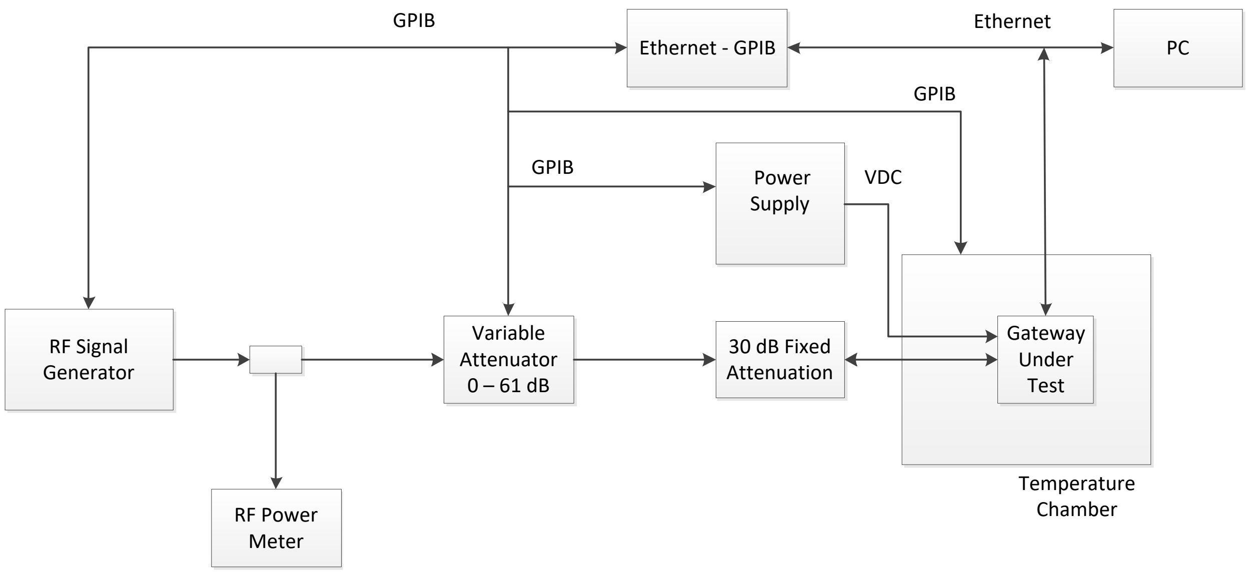

Figure 5-3: Receiver Test Set Up

5.1.4 Set Up #A4 Receiver Interference Test

The test set up for RF receiver interference testing is shown in Figure 5-4. The notch filter is tuned to the desired LoRa Rx frequency to attenuate in-channel phase noise from CW1 and CW2.

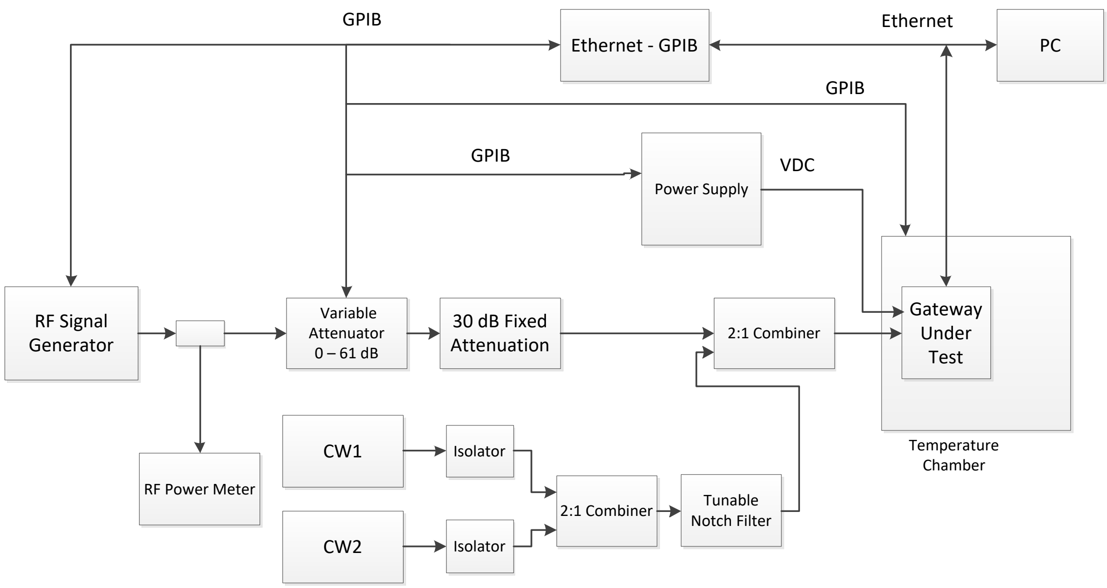

Figure 5-4: Receiver Interference Test Set Up

5.2 Spectrum Analyzer Settings

5.2.1 North America (for Tx Channel Occupied Bandwidth Measurements) settings based on FCC KDB 558074

Table 5-1 Spectrum Analyzer Test Parameters – OBW Tests (North American type gateways)

Setting	Value	Notes
RBW	100kHz	
VBW	300kHz	
Span	1MHz	
Detector Mode	Peak	
Trace	Max Hold	

5.2.2 North America (for Tx Conducted Emissions Out-of-Band Measurements) settings based on FCC KDB 558074

Table 5-2 Spectrum Analyzer Test Parameters – OOB Emissions (North American type gateways)

Setting	Value	Notes
RBW	100kHz	
VBW	300kHz	
Span	1MHz	
Detector Mode	RMS	
Trace	Average	

5.2.3 EU (for Tx Channel Occupied Bandwidth Measurements) settings based on ETSI EN 300 220-1

Table 5-3 Spectrum Analyzer Test Parameters – OBW Tests (EU type gateways)

Setting	Value	Notes
RBW	3kHz	
VBW	10kHz	
Span	400kHz	
Detector Mode	RMS	
Trace	Max Hold	

5.2.4 EU (for Tx Conducted Emissions Out-of-Band Measurements below 1GHz)

Table 5-4 Spectrum Analyzer Test Parameters – OOB Emissions below 1GHz (EU type gateways)

Setting	Value	Notes
RBW	100kHz	
VBW	300kHz	
Span	Band	
Detector Mode	RMS	
Trace	Max Hold	

5.2.5 EU (for Tx Conducted Emissions Out-of-Band Measurements above 1GHz)

Table 5-5 Spectrum Analyzer Test Parameters – OOB Emissions above 1GHz (EU type gateways)

Setting	Value	Notes
RBW	1MHz	
VBW	1MHz	
Span	Band	
Detector Mode	RMS	
Trace	Max Hold	

5.3 Test Equipment Examples

Table 5-6 Test Equipment Examples

Instrument	Vendor	Model Number	Comments
1-box LoRaWAN Test Solution	RedwoodComm	RWC5020M	

Instrument	Vendor	Model Number	Comments
Interference Generator	RedwoodComm	RWC2020A	
Spectrum Analyzer (Set Up #1)	SignalHound	BB60C	
Power Supply	Instek	PSW 80-27	80Vdc, 27A
30dB Attenuator	Aeroflex/Weinschel	24-30-34	N-female, N-male connector
Cplr	Mini-circuits	ZAPD-1-N+	N-female connectors
Power Sensor	Keysight	9300A	
Power Meter	Keysight	N1914A EPM	
Spectrum Analyzer	Keysight	N9020A	8.4 GHz option
10dB Pad	Mini-circuits	VAT-10W2+	SMA-female, SMA-male connector (2W power handling)
Isolator (25dB)	RF-Lambda	RFLI-201-1	
Directional Coupler (30dB)	Mini-circuits	ZADC-30-10-S+	SMA-female connectors
Amplifier	Mini-circuits	ZHL-1000-3W+	SMA-female connector
RF Power Meter	Keysight	9300A + N1914A EPM	
Variable Attenuator	Mini-circuits	RCDAT-4000-120	USB/ETH programmable
Ethernet - GPIB	National Instruments	GPIB-USB-HS+	
RF Signal Generator	Keysight	N5172B-503	9kHz-3GHz,
CW1	Keysight	N5172B-503	
CW2	Keysight	N5172B-503	
2:1 Combiner	Mini-circuits	ZAPD-2-272-N+	N-female connectors
Tunable Notch Filter	K&L Microwave	D3TNF-800/1000-0.2	

5.4 Interference Details by Region

Table 5-7 Additional Interference Details, Listed by Region [1]

Zone / Countries	Unlicensed bands	LTE UL bands	LTE DL bands
Europe	868 - 870MHz	832 – 862MHz (B20)	791 – 821MHz (B20)
	863 - 873MHz		
	915 - 918MHz	880 – 915MHz (B8)	925 – 960MHz (B8)
	915 - 921MHz		
North America	902 - 928MHz	824 – 849MHz (B5)	869 – 894MHz (B5)
Australia / New-Zealand	915 - 928MHz	880 – 915MHz (B8)	925 – 960MHz (B8)
		825 – 845MHz (B5)	870 – 890MHz (B5)
Asia / Thailand, Taiwan and Singapore	920 - 925MHz	885 – 915MHz (B8)	930 – 960MHz (B8)
Asia / Malaysia	919 - 924MHz	880 – 915MHz (B8)	925 – 960MHz (B8)

5.5 Test Result Summary

Table 5-8 Test Result Summary

Test Number	Test Name	Result
4.1.1	Survival with Open/Short Load	
4.2.1	Measured Max RF Tx Power – TxF1 – low temperature	
4.2.2	Measured Min RF Tx Power – TxF1 – low temperature	
4.2.3	Measured Max RF Tx Power – TxF1 – high temperature	
4.2.4	Measured Min RF Tx Power – TxF1 – high temperature	
4.2.5	Measured Max RF Tx Power – TxF1 – nominal temperature	
4.2.6	Measured Min RF Tx Power – TxF1 – nominal temperature	
4.2.7	Measured Max RF Tx Power – TxF2 – low temperature	
4.2.8	Measured Min RF Tx Power – TxF2 – low temperature	
4.2.9	Measured Max RF Tx Power – TxF2 – high temperature	
4.2.10	Measured Min RF Tx Power – TxF2 – high temperature	
4.2.11	Measured Max RF Tx Power – TxF2 – nominal temperature	
4.2.12	Measured Min RF Tx Power – TxF2 – nominal temperature	
4.3.1	Conducted Emissions at first Emissions Test Frequency when gateway transmitting on TxF1	
4.3.2	Conducted Emissions at second Emissions Test Frequency when gateway transmitting on TxF1	
4.3.3	Conducted Emissions at first Emissions Test Frequency when gateway transmitting on TxF2	
4.3.4	Conducted Emissions at second Emissions Test Frequency when gateway transmitting on TxF2	
4.4.1	Tx Intermodulation	
4.5.1	Tx Frequency Error – TxF1 – low temperature	

Test Number	Test Name	Result
4.5.2	Tx Frequency Error – TxF1 – high temperature	
4.5.3	Tx Frequency Error – TxF1 – nominal temperature	
4.6.1	Rx Sensitivity – 125kHz SF7 – RxF1 – low temp	
4.6.2	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region) – RxF1 – low temp	
4.6.3	Rx Sensitivity – 500kHz SF8 (NA Region only) – RxF1 – low temp	
4.6.4	Rx Sensitivity – 125kHz SF7 – RxF1 – high temp	
4.6.5	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region) – RxF1 – high temp	
4.6.6	Rx Sensitivity – 500kHz SF8 (NA Region only) – RxF1 – high temp	
4.6.7	Rx Sensitivity – 125kHz SF7 – RxF1 - nominal temp	
4.6.8	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region) – RxF1 - nominal temp	
4.6.9	Rx Sensitivity – 500kHz SF8 (NA Region only) – RxF1 - nominal temp	
4.6.10	Rx Sensitivity – 125kHz SF7 – RxF2 – low temp	
4.6.11	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region) – RxF2 – low temp	
4.6.12	Rx Sensitivity – 500kHz SF8 (NA Region only) – RxF2 – low temp	
4.6.13	Rx Sensitivity – 125kHz SF7 – RxF2 – high temp	
4.6.14	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region) – RxF2 – high temp	
4.6.15	Rx Sensitivity – 500kHz SF8 (NA Region only) – RxF2 – high temp	
4.6.16	Rx Sensitivity – 125kHz SF7 – RxF2 - nominal temp	
4.6.17	Rx Sensitivity – 125kHz, SF10 (NA Region) or SF12 (EU Region) – RxF2 - nominal temp	
4.6.18	Rx Sensitivity – 500kHz SF8 (NA Region only) – RxF2 - nominal temp	
4.7.1	Rx Dynamic Range	

Test Number	Test Name	Result
4.8.1	In-band blocking – low side blocker	
4.8.2	In-band blocking – high side blocker	
4.9.1	Out-of-band blocking – low side blocker	
4.9.2	Out-of-band blocking – high side blocker	
4.10.1	Rx Intermodulation	
4.11.1	Cold Start	

6 Glossary

ABP	Activation by Personalization
ADR	Adaptive Data Rate
CW	Continuous Wave
DR	Data Rate
DUT	Device Under Test
LAS	LoRaWAN Application Server
LGW	LoRaWAN Gateway
LNS	LoRaWAN Network Server
MAC	Media Access Control
OTAA	Over-the-Air-Activation
TCL	Test Control Layer of the Test Harness

7 References

[1] M. Gilbert, "Whitepaper LoRaWAN Gateways, Radio coexistence issues and solutions," LoRa Alliance, 2021.

[2] M. B. P. B. S. K. S. Jeruchim, "Simulation of Communications Systems: Modeling, Methodology and Techniques," New York, Kluwer Academic/Plenum Publishers, 2000, p. 692.

[3] FCC, *558074 D01 15.247 Measurement Guidance,* Washington, DC: FCC, 2019.

[4] ETSI, *ETSI EN 300 220-1 v3.1.1 (2017-02),* ETSI, 2017.

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