

1 **Gateway Test and Measurement Guidelines Issue 01**

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Gateway Test and Measurement Guidelines

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249 **1 Conventions**

250

251 The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD",
252 "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be
253 interpreted as described in RFC 2119.
254

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

257 **2 Introduction**

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

262 **2.1 Scope**

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

272 **2.2 Gateway Classes and Deployment Environments**

273
274 To help end-customers evaluate their gateway products, vendors can choose and
275 communicate the appropriate class identifier from Table 2-1 below that best represents the
276 targeted deployment environment. RF performance guidelines in this document have been
277 tailored for each class of gateway. Testing is performed under nominal humidity conditions.
278 Relative humidity should be measured and recorded at the time of testing.

279
280 **Table 2-1 Deployment Environments**

Class Identifier	Deployment Environment
1	Outdoor
2	Indoor

281

282 **2.3 Test Matrix**

283
284 The following abbreviations are used in Table 2-2:

- 285
286 E - tested over the operating temperature range defined by the gateway vendor.
287 N – tested at nominal temperature, nominal humidity and nominal input voltage
288 O – optional test for a given gateway class

289 **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

291
292

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

293 **2.4 Gateway Test Frequencies**

294

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

298

299

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

300

301

302 **2.5 Blocking Test Frequencies**

303

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

305

306 **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

307

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315

¹ 5MHz above anticipated ISM band extension to 933MHz

316 **2.6 Rx Intermodulation Test Frequencies**

317

318 **Table 2-5 Rx Intermodulation Test Frequencies**

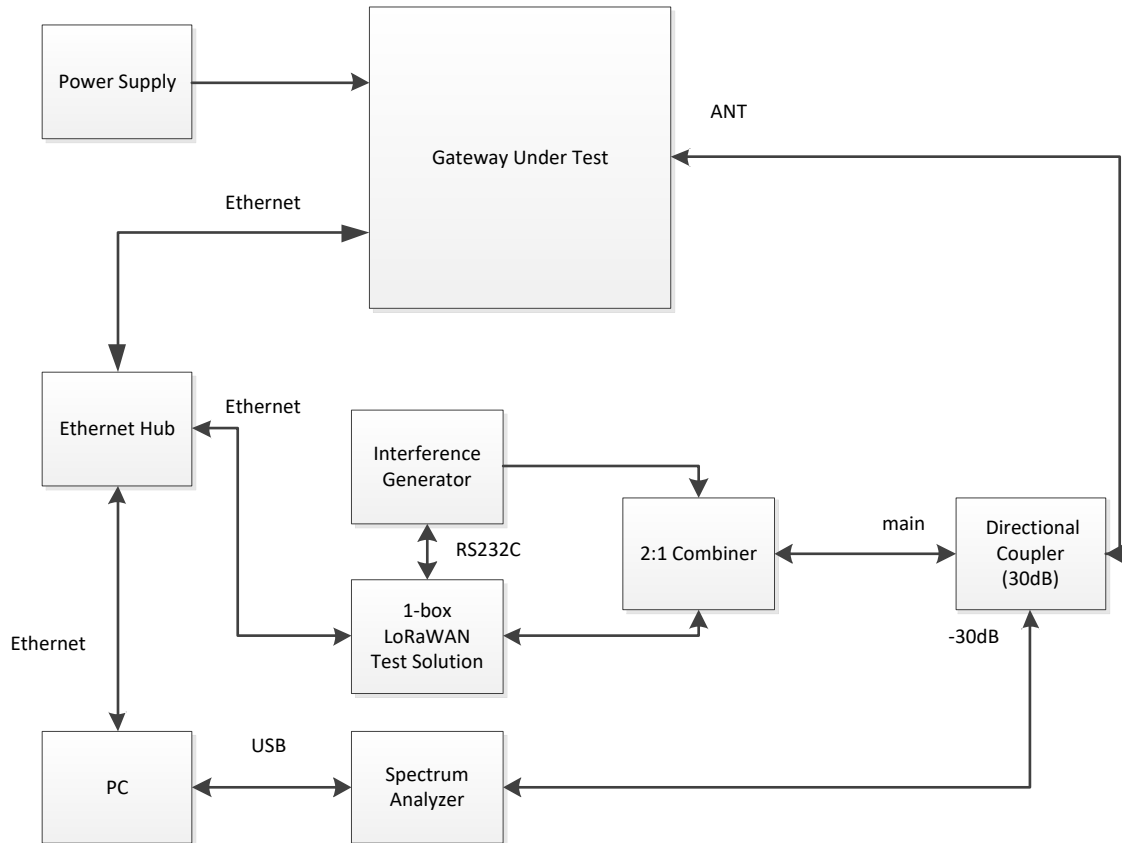
Region	OOB Interferer 1 (MHz)	OOB Interferer 2 (MHz)	Desired Rx (MHz)	Dominant Interferer
EU868	791.2	816.9	868.3	LTE B20 downlinks (5 th order products)
US915	869.1.0	890.1	911.1	LTE B5 downlinks
CN779	TBD	TBD	TBD	TBD
EU433	TBD	TBD	TBD	TBD
AU915	935.1	955	915.2	GSM B8 downlinks
CN470	TBD	TBD	TBD	TBD
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 (5 th order products)

319

320 **3 Test Set Ups**

321 **3.1 Set Up #1**

322



323
324

Figure 3-1 Transmit and Receive Test Set Up

325 **4 Tests Procedures and Performance Guidelines**

326 **4.1 Tx & Rx Operation and Survival with Open/Short Load**

327 **4.1.1 Applicability**

328 Please refer to Table 2-2.

329

330 **4.1.2 Description**

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

335 **4.1.3 Performance Guidelines**

336 No damage to the gateway under the test conditions.

337 **4.1.4 Test Conditions**

338 Operating frequencies and modulation: Please refer to Table 2-3.

339 RF power levels: Tx Power Max

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

341 **4.1.5 Test Procedure**

342 1. Use Test Set up #1 or #A4.

343 2. Set Gateway to Tx Max power at frequency and modulation, Tx F1

344 3. For half-duplex gateways set the transmit duty cycle to 10%. For full-duplex gateways,
345 set the transmit duty cycle to greater than 98%.

346 4. Transmit at Tx Max for 5 min or until thermal stability of the device have been achieved
347 into an RF Open circuit.

348 5. Repeat the same test with the RF short circuit.

349 6. Perform the remainder of the transmitter and receiver tests in this document to confirm
350 gateway functionality.

351 **4.1.6 Test Results**

352

353 **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

354 **4.2 Measured and Reported RF Transmit Power Relative to Transmit**
355 **Power Setting**

356 **4.2.1 Applicability**

357 Please refer to Table 2-2.

358 **4.2.2 Description**

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

362 **4.2.3 Performance Guidelines**

363

364 **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

365

366

367 **4.2.4 Test Conditions**

368 Operating frequencies and modulation: Please refer to Table 2-3 for definition of TxF1 and
369 TxF2 for the specific gateway under test.

370 RF power levels: Tx Max power, Tx Min Power (both as defined by manufacturer)

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

373

374 **4.2.5 Test Procedure**

375 1. Use Test Set up #1 or #A1.

376 2. Set test environment to lower bound of operational temperature range defined by gateway
377 vendor. Note and record the relative humidity.

378 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

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

386

387 **4.2.6 Test Results**

388

389

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		

390

391 **4.3 Tx Conducted Emissions Out-of-Band**

392 **4.3.1 Applicability**

393 Please refer to Table 2-2.

394 **4.3.2 Description**

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

400 **4.3.3 Performance Guidelines**

401
402 A typical LTE receiver noise floor is -116.4dBm/360kHz assuming a 2dB noise figure. With
403 an antenna isolation of 45dB [1] and incorporating an additional 6dB of protection to limit the
404 LTE receiver sensitivity degradation to 1dB, the transmitter spurious emissions guideline in
405 the closest LTE uplink band is -77.4dBm/360kHz or equivalently, -83dBm/100kHz.

406
407 **Table 4-4 Tx Conducted Emissions Out-of-Band**

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

409

410 **4.3.4 Test Conditions**

411 Operating frequencies and modulation: Please refer to Table 2-3 for definition of TxF1 and
412 TxF2 for the specific gateway under test.

413 RF power levels: Tx power Max (for EU region, test at 14dBm, TxF2 only)

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

415 **4.3.5 Test Procedure**

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

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

427 **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

428 **4.3.6 Test Results**

429 **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

430 **4.4 Tx Intermodulation**

431 **4.4.1 Applicability**

432 Please refer to Table 2-2.

433 **4.4.2 Description**

434 To measure transmit emissions performance in the presence of strong Out of Band signal at
 435 the Gateway ANT port. This test is based on the Tx intermodulation examples in [1]. The
 436 examples are based on a gateway transmitter output third-order-intercept-point (OIP3) of
 437 40dBm, minimum cavity filter interferer rejection of 40dB, an antenna to antenna isolation of
 438 45dB, and LTE and LoRa antennas as described in sections 3.2.1 and 3.2.1 respectively, in
 439 [1].

440 **4.4.3 Performance Guidelines**

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

442 **4.4.4 Test Conditions**

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

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

445 Interferer levels are set as per Table 4-7.

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

447

448 **Table 4-7 Tx Intermodulation Settings**

Region	LoRaWAN Tx settings				CW Interferer settings		Intermodulation (IMD) Tone	
	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

449

450 **4.4.5 Test Procedure**

451 1. Use Test Set up #1 or #A2.

452 2. Set Gateway to transmit a continuous (> 98% duty cycle) LoRa waveform as specified in
 453 Table 4-7. Continuous transmission can be achieved by using utilities developed by
 454 Semtech, such as tx_continuous and send_pkt.

455 3. Inject the CW interferer signal defined in Table 4-7.

456 4. Select spectrum analyzer settings as per section 5.1. Set the measurement marker at
 457 the intermodulation tone frequency (seeTable 4-7).

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

459 **4.4.6 Test Results**

460 **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				

461

462 **4.5 Tx Frequency Error**

463 **4.5.1 Applicability**

464 Please refer to Table 2-2.

465

466 **4.5.2 Description**

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

471 **4.5.3 Performance Guidelines**

472 [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 $5 \times 10^{-6} \times \text{Tx Frequency}$	Frequency Error for a new gateway should not exceed $0.1 \times 10^{-6} \times \text{Tx Frequency}$

473

474 **4.5.4 Test Conditions**

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

477 RF power levels: Tx Power Max

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

480 **4.5.5 Test Procedure**

481 1. Use Test Set up #1 or #A1 (ensure spectrum analyzer has vector signal analyzer
482 functionality)

483 2. Set test environment to lower bound of operational temperature range defined by gateway
484 vendor. Note and record the relative humidity.

485 3. Set Gateway to transmit at Tx Max power at operating frequency and modulation TxF1.

486 4. Read the Vector Signal Analyzer Frequency Errors over 30 seconds and record the Max
487 and Min values.

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

490 6. Repeat steps 3 through 4.

491
492

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

493

494 **4.6 Rx Sensitivity**

 495 **4.6.1 Applicability**

 496 Please refer to Table 2-2.

497

 498 **4.6.2 Description**

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

 500 **4.6.3 Performance Guidelines**

 501 [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

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

 507 **4.6.4 Test Conditions**

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

510 RF power levels: as per test procedure

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

 513 **4.6.5 Test Procedure**

 514 1. Use Test Set Up #1 or #A3. For test set up #1 follow the steps in the 1-box LoRaWAN
 515 test solution software, then skip to step 8 in the procedure below. For the alternative test
 516 set up #A3, follow steps 3 through 7 in the procedure below.

 517 2. Set test environment to lower bound of operational temperature range defined by gateway
 518 vendor. Note and record the relative humidity.

 519 3. Using LoRaWAN reference waveforms, set up the test so that 300 packets are
 520 transmitted by the vector signal generator.

521 4. Enable a packet logger utility on the gateway to count receive packets

- 522 5. Turn on the signal generator at frequency RxF1 at a level of -100dBm and record the
523 number of packets received with proper CRC. Calculate the PER. Also record the
524 reported RSSI and SNR values.
- 525 6. Decrease the input Rx desired signal by 1dB and repeat step 4 until the PER is 100%.
- 526 7. Note RF power level at 10% PER. Based on a 95% confidence interval, the maximum
527 number of packet errors allowed in a set of 300 packets is 19 to ensure that a packet error
528 rate of 10% is not exceeded. Please refer to Table 11.2 in [2] for more details on Monte
529 Carlo method and Poisson approximations to binomial distributions
- 530 8. Repeat steps 3 through 7 for operating frequency RxF2, if applicable for the gateway
531 region under test.
- 532 9. Set test environment to the upper bound of operational temperature range defined by
533 gateway vendor.
- 534 10. Repeat steps 3 through 8.

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549 **4.6.6 Test Results**

550

551 **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	
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.			

552

553 **4.7 Rx Dynamic Range**

554 **4.7.1 Applicability**

555 Please refer to Table 2-2.

556

557 **4.7.2 Description**

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

560 **4.7.3 Performance Guidelines**

561 [Table 4-13 Rx Dynamic Range Performance Guidelines](#)

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

562 **4.7.4 Test Conditions**

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

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

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

567 **4.7.5 Test Procedure**

- 568 1. Use Test Set Up #1 and follow 1-box LoRaWAN test solution software or use Test
569 Set Up #A2 and follow the procedure below.
- 570 2. Measure gateway Rx Sensitivity frequency RxF1 at SF10, 125kHz (10% PER) using
571 procedure described in section 4.6.
- 572 3. Decrease input signal attenuation by 10dB and measure PER.
- 573 4. Decrease input signal attenuation until 10% PER is observed at high power. Add
574 10dB attenuation and repeat step 3 with 1dB steps until 10% PER is observed
- 575 5. Calculate dynamic range. Dynamic range = RF power level from step 4 @ 10% PER
576 minus Rx sensitivity power level.

577 **4.7.6 Test Results**

578 [Table 4-14 Test Results – Rx Dynamic Range](#)

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

579

580 **4.8 Rx In-Band Blocking/Selectivity**

581 **4.8.1 Applicability**

582 Please refer to Table 2-2.

583

584 **4.8.2 Description**

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

587 **4.8.3 Performance Guidelines**

588

589 **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

590

591 **4.8.4 Test Conditions**

592 Operating frequencies: Please refer to Table 2-4.

593 RF power levels: Receiver input levels as per test procedure

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

595

596 **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

597

598 **4.8.5 Test Procedure**

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

600 2. Set up desired signal such that input RF level is above sensitivity limit by the amount
601 shown in Table 4-16.

- 602 3. Turn on the interference signal at the low-side blocking frequency listed in Table 2-4. Refer
603 to Table 4-16 for interferer RF power levels at the start of the test.
- 604 4. Set up the test so that 300 packets are transmitted by the vector signal generator. If using
605 the 1-box LoRaWAN test solution limit the range of the sensitivity measurement to just
606 around the RF level specified in step 2 above (this will optimize test time).
- 607 5. Enable a packet logger utility on the gateway to count receive packets and the number of
608 errors. Record the packet error rate. If using the 1-box solution, run the sensitivity test.
- 609 6. Increase the RF power level of the interfering signal by 2dB. Repeat steps 2 through 5.
- 610 7. Note the Interferer power levels when the packet error rate (PER) crosses the 50%
611 boundary
- 612 8. Stop the test when the packet error rate reaches 100%.
- 613 9. Repeat steps 3 through 8 for the high-side blocking frequency.
- 614

615 **4.8.6 Test Results**

616 **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		

617
618

619 **4.9 Rx Out-of-Band Blocking/Selectivity**

620 **4.9.1 Applicability**

621 Please refer to Table 2-2.

622

623 **4.9.2 Description**

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

626 **4.9.3 Performance Guidelines**

627

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

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

629

630 **4.9.1 Test Conditions**

631 Operating frequencies: please refer to Table 2-4.

632 RF power levels: as per test procedure

633 Environmental and input voltage conditions: nominal temperature, humidity and input
634 voltage.

635

636 **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

637

638 **4.9.2 Test Procedure**

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

640 2. Set up desired signal such that input RF level is above sensitivity limit by the amount
641 shown in Table 4-19.

- 642 3. Turn on the interference signal at the low-side blocking frequency listed in Table 2-4. Refer
643 to Table 4-19 for interferer RF power levels at the start of the test.
- 644 4. Set up the test so that 300 packets are transmitted by the vector signal generator. . If
645 using the 1-box LoRaWAN test solution limit the range of the sensitivity measurement to
646 just around the RF level specified in step 2 above (this will optimize test time)
- 647 5. Enable a packet logger utility on the gateway to count receive packets and the number of
648 errors. Record the packet error rate. If using the 1-box solution, run the sensitivity test.
- 649 6. Increase the RF power level of the interfering signal by 2dB. Repeat steps 2 through 5.
- 650 7. Note the Interferer power levels when the packet error rate crosses the 10% boundary
- 651 8. Stop the test when the packet error rate reaches 100%.
- 652 9. Repeat steps 3 through 8 for the high-side blocking frequency.

653 **4.9.3 Test Results**

654 **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		

656
657

658 **4.10 Rx Intermodulation**

659 **4.10.1 Applicability**

660 Refer to Table 2-2 for applicability.

661 **4.10.2 Description**

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

665 **4.10.3 Performance Guidelines**

666 [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

667

668 **4.10.4 Test Conditions**

669 Operating frequencies: refer to Table 2-5.

670 Desired signal RF power level: refer to Table 4-22.

671 Environmental and input voltage conditions: nominal temperature, humidity and input voltage
672 Interferer levels are set as per table Table 4-22. Interferer frequencies are set as per Table
673 2-5.

674

675 [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

676

677 **4.10.5 Test Procedure**

678 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].

- 679 2. Set up desired signal such that input RF level is above sensitivity limit by the amount
680 shown in Table 4-22.
- 681 3. Turn on the two interference signals at the frequencies listed in Table 2-5. Refer to Table
682 4-22 for interferer RF power levels at the start of the test.
- 683 4. Set up the test so that 300 packets are transmitted by the vector signal generator. If using
684 the 1-box LoRaWAN test solution limit the range of the sensitivity measurement to just
685 around the RF level specified in step 2 above (this will optimize test time).
- 686 5. Enable a packet logger utility on the gateway to count receive packets and the number of
687 errors. Record the packet error rate. If using the 1-box solution, run the sensitivity test.
- 688 6. Increase the RF power level of each interfering signal by 2dB. Repeat steps 2 through 5.
- 689 7. Note the Interferer power levels when the packet error rate crosses the 10% boundary
690 (i.e. 19 errors in 300 packets for a 10% PER with 95% confidence).
- 691 8. Stop the test when the packet error rate reaches 100%.

692 **4.10.6 Test Results**

693 **Table 4-23 Test Results – Rx Intermodulation**
694

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

695

696 **4.11 Cold Start**

697 **4.11.1 Applicability**

698 Please refer to Table 2-2.

699

700 **4.11.2 Description**

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

702 **4.11.3 Performance Guidelines**

703 See sections 4.2.3 and 4.11.3.

704 **4.11.4 Test Conditions**

705 Operating frequencies: Please refer to Table 2-3 for definition of TxF1 and RxF1 for the
706 gateway under test.

707 RF power levels: Tx Power Max

708 Input voltage: nominal

709 Environmental conditions: minimum rated temperature

710 **4.11.5 Test Procedure**

711 1. Use Test Set Up #1 or #A1 and #A2.

712 2. Leave the unit under test unpowered at its minimum rated operating temperature for 6
713 hours or more.

714 3. Power up the unit under test and ensure the unit initializes correctly.

715 4. Let the unit warm up 30 minutes.

716 5. Execute Measured and Reported RF Transmit Power Relative to Transmit Power Setting
717 test case (see section 4.1) at frequency TxF1.

718 6. Measure Rx sensitivity (see section 4.6) at frequency RxF1.

719

720 **4.11.6 Test Results**

721 **Table 4-24 Test Results – Cold Start**

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

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727 **4.12 Time Accuracy**

728

729 **4.12.1 Applicability**

730 Please refer to Table 2-2.

731

732 **4.12.2 Description**

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

734 **4.12.3 Performance Guidelines**

735 TBD

736 **4.12.4 Test Conditions**

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

739 RF power levels: Tx Power Max

740 Input voltage: nominal

741 Environmental conditions: nominal

742 **4.12.5 Test Procedure**

743 TBD

744

745 **4.12.6 Test Results**

746 TBD

747 **5 Appendix**

748 **5.1 Alternative Test Set Ups**

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

753 **5.1.1 Set Up #A1: Transmitter Test**

754
755 A generalized test set up for RF transmitter testing is shown in Figure 5-1.

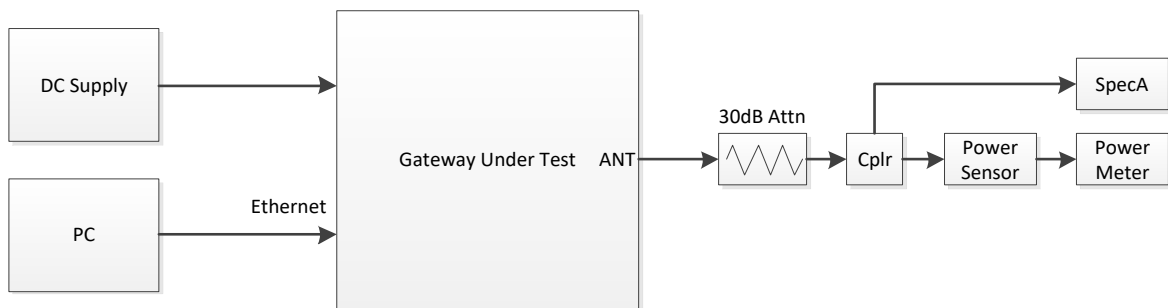


Figure 5-1: Transmitter Test Set Up

756

757 **5.1.2 Set up #A2 Transmitter Intermodulation Test**

758
759 A generalized test set up for RF Tx intermodulation testing is shown in Figure 5-2.

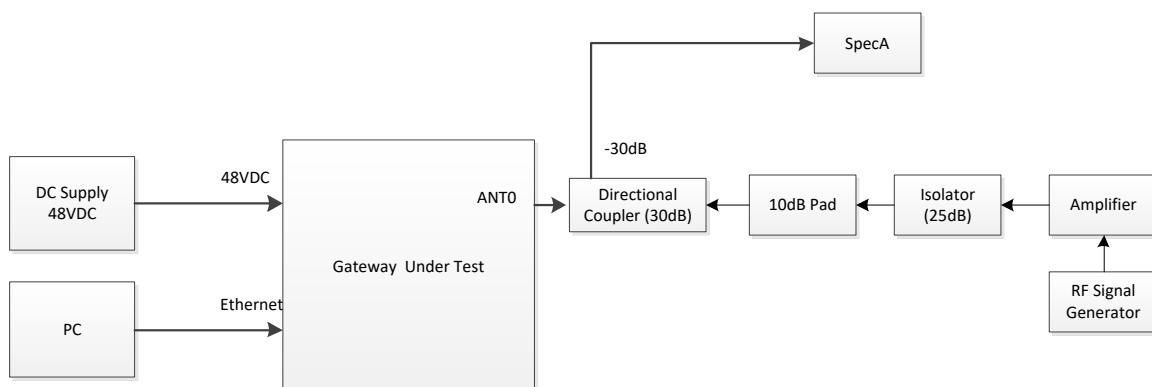


Figure 5-2 Transmitter Intermodulation Test Set Up

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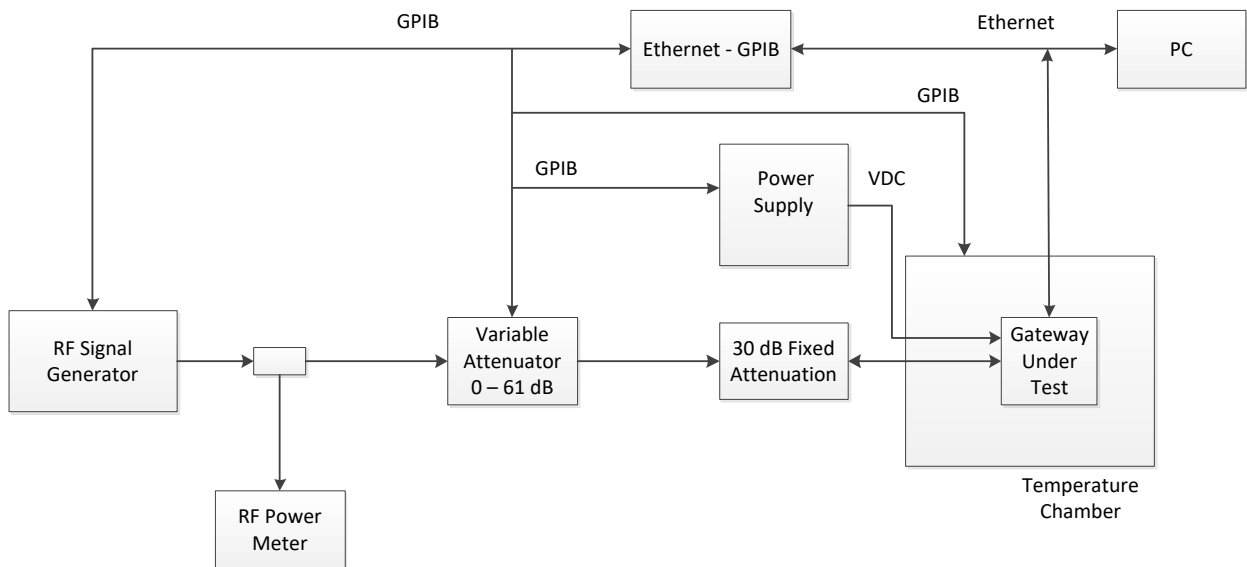
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771 **5.1.3 Set Up #A3 Receiver Test**

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



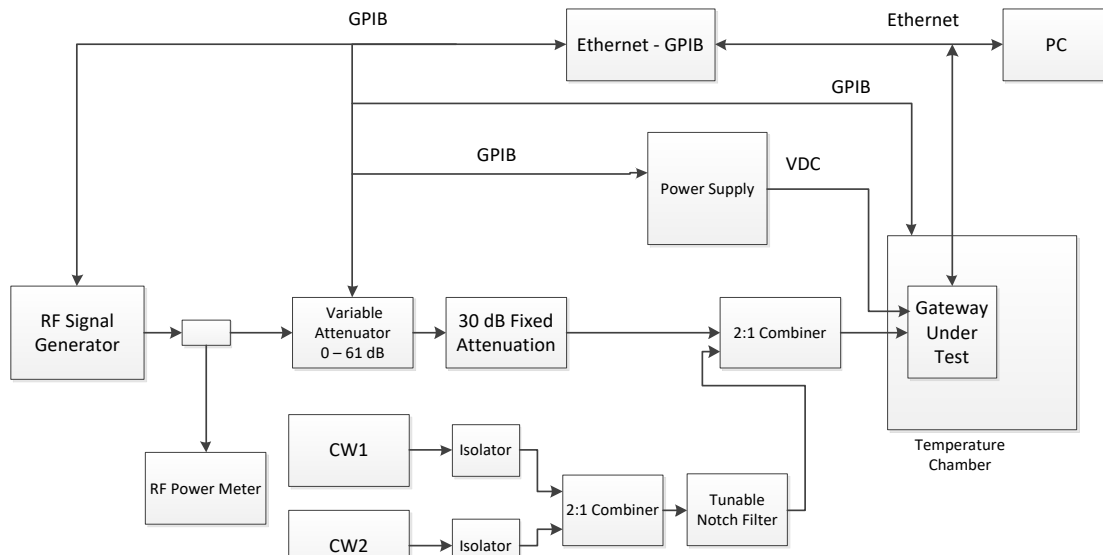
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776 **Figure 5-3: Receiver Test Set Up**

777 **5.1.4 Set Up #A4 Receiver Interference Test**

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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.



783
784 **Figure 5-4: Receiver Interference Test Set Up**

785

786 **5.2 Spectrum Analyzer Settings**

787

788 **5.2.1 North America (for Tx Channel Occupied Bandwidth Measurements)**
789 **settings based on FCC KDB 558074**

790
791

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	

792
793

794 **5.2.2 North America (for Tx Conducted Emissions Out-of-Band**
795 **Measurements) settings based on FCC KDB 558074**

796 **Table 5-2 Spectrum Analyzer Test Parameters – OOB Emissions (North American type gateways)**
797

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

798
799
800

801 **5.2.3 EU (for Tx Channel Occupied Bandwidth Measurements) settings based**
802 **on ETSI EN 300 220-1**

803 **Table 5-3 Spectrum Analyzer Test Parameters – OBW Tests (EU type gateways)**
804

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

805
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807
808
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811 **5.2.4 EU (for Tx Conducted Emissions Out-of-Band Measurements below**
812 **1GHz)**

813 **Table 5-4 Spectrum Analyzer Test Parameters – OOB Emissions below 1GHz (EU type gateways)**
814

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

815

816 **5.2.5 EU (for Tx Conducted Emissions Out-of-Band Measurements above**
817 **1GHz)**

818 **Table 5-5 Spectrum Analyzer Test Parameters – OOB Emissions above 1GHz (EU type gateways)**
819

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

820

821 **5.3 Test Equipment Examples**

822 **Table 5-6 Test Equipment Examples**
823
824

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	

826 **5.4 Interference Details by Region**

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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)

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831 **5.5 Test Result Summary**

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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	

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835 6 Glossary

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837	ABP	Activation by Personalization
838	ADR	Adaptive Data Rate
839	CW	Continuous Wave
840	DR	Data Rate
841	DUT	Device Under Test
842	LAS	LoRaWAN Application Server
843	LGW	LoRaWAN Gateway
844	LNS	LoRaWAN Network Server
845	MAC	Media Access Control
846	OTAA	Over-the-Air-Activation
847	TCL	Test Control Layer of the Test Harness

848 **7 References**

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