AN12610

QN9090 RF System Evaluation Report for Bluetooth Low Energy Applications

Rev. 1 — 20 March 2023 Application note

Document information

Information	Content
Keywords	QN9090 RF, Bluetooth LE, TX, RX
Abstract	This document provides the QN9090 RF evaluation test results

1 Introduction

This document provides the RF evaluation test results of the QN9090 for Bluetooth Low Energy (Bluetooth LE) applications on Two Frequency Shift Keying (2FSK) modulation.

It includes the test setup description and the tools used to perform the tests. To get the QN9090 radio parameters, see the *QN9090 Data Sheet*.

1.1 List of tests

Conducted tests on QN9090:

- TX tests
  - Bench setup
  - Frequency accuracy
  - Phase noise
  - TX power
  - TX power in band
  - TX spurious (H2 to H5, ETSI, and FCC)
  - Upper band edge
  - Modulation characteristics
  - Carrier frequency offset and drift
- RX tests
  - Bench setup
  - Sensitivity
  - Receiver maximum input level
  - RX spurious (from 30 MHz to 12.5 GHz)
  - Receiver interference rejection performances
    - C/I and receiver selectivity performances
    - Receiver blocking
    - Blocking interferers
  - Intermodulation
- Return loss (S11)
  - RX
  - TX

1.2 Software

Before the measurements, load a binary code (connectivity software) in the flash memory of the board. The connectivity tool supports receiver and transmitter functions of the device.

The version of the software is 1.0.2 and the name of the bin file is `QN9090x_Certi_Tools.bin`. The radio driver version is 2069.

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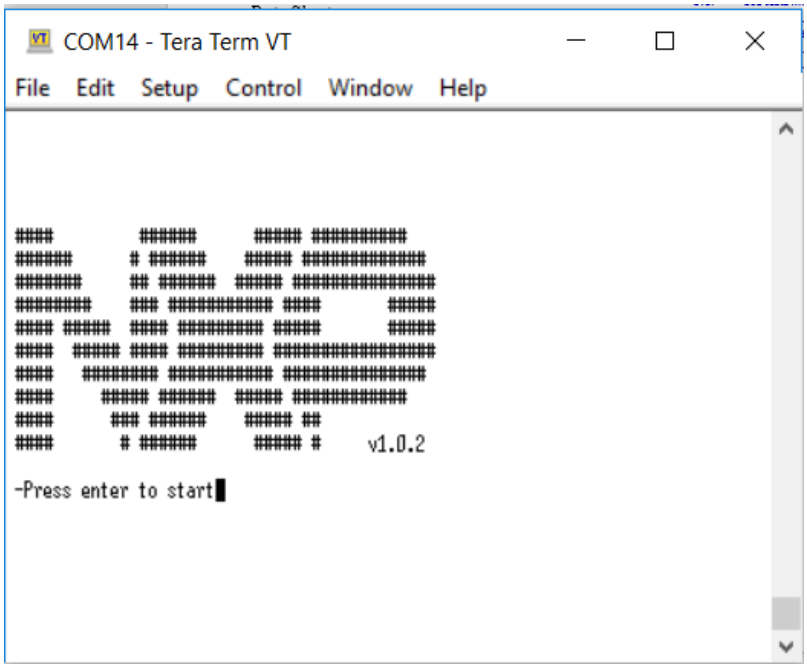

Figure 1. Certi_tool evaluation software

1.3 List of equipment

The list of equipment used for the RX and TX measurements are as follows:

- DK6 board and a QN9090 module with SMA connector. The design is same as for the modules with an M10 printed antenna.
- R&S SMBV100A signal generator.
- R&S FSV spectrum analyzer - 13 GHz for harmonic measurements up to H5.
- R&S ZND vector network analyzer for S11 measurements.
- R&S RF shielded box to avoid interferences.
- PC equipped with a GPIB card.

2 Test summary

RF PHY Bluetooth test specification: RF-PHY.TS.4.2.0 (2014-12-09)

The list of measurements is given in Table 1 for Europe and Table 2 for the US.

Table 1. List of tests for Europe

Name	Measurements	Reference	Limit	Status
Transmission	TX maximum power	Bluetooth LE 4.2, BV-01-C	-20 dBm ≤ PAVG ≤ +10 dBm EIRP	PASS
		Bluetooth LE 5.0	20 dBm ≤ PAVG ≤ +20 dBm EIRP	
	TX power in band	Bluetooth LE 4.2, BV-03-C	P_{TX} <= -20 dBm for (f_{TX} +/- 2 MHz) P_{TX} <= -20 dBm for (f_{RX} +/-4 MHz and +/-5 MHz)	PASS

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Table 1. List of tests for Europe*...continued*

Name	Measurements	Reference	Limit	Status
		Bluetooth LE 5.0	P_{TX} <= -30 dBm for (f_{TX} +/- [3 + n] MHz]); P_{TX} <= -30 dBm for (f_{RX} +/- [6+n] MHz)	
	Modulation characteristics	Bluetooth LE 4.2, BV-05-C	225 kHz <= delta $f1_{avg}$ <= 275 kHz	PASS
		Bluetooth LE 5.0	450 kHz <= delta $f1_{avg}$ <= 550 kHz	
	Carrier frequency offset and drift	Bluetooth LE 4.2, BV-06-C	f_{TX} – 150 kHz <= f_n <= f_{TX} + 150 kHz where f_{TX} is the nominal transmit frequency and n=0,1,2,3…k |f0 – fn| <= 50 kHz where n=2,3,4…k	PASS
		Bluetooth LE 5.0		
	Spurious 30 MHz – 1 GHz	ETSI EN 300 328	-36 dBm or -54 dBm (depends on frequency) (100 kHz BW)	PASS
	Spurious 1 GHz - 12.5 GHz	ETSI EN 300 328	-30 dBm (1 MHz BW)	PASS
	EIRP TX spectral density	ETSI EN 300 328	10 dBm/MHz	PASS
	Phase noise (unspread)	NA	NA	For information
Reception	RX sensitivity	Bluetooth LE 4.2, BV-01-C	Packet Error Rate (PER) 30.8 % with a minimum of 1500 packets	PASS
		Bluetooth LE 5.0		
	Co-channel	Bluetooth LE 4.2, BV-03-C	> 21 dB	PASS
		Bluetooth LE 5.0		
	Adjacent channel interference rejection (N+/- 1,2,3+MHz)	Bluetooth LE 4.2, BV-03-C	> 15 dB, -17 dB, -27 dB	PASS
		Bluetooth LE 5.0		
	Blocking interferers	Bluetooth LE 4.2, BV-04-C	-30 dBm / -35 dBm	PASS[1]
		Bluetooth LE 5.0		
	Intermodulation performance	Bluetooth LE 4.2, BV-05-C	PER 30.8 % with a minimum of 1500 packets	PASS
		Bluetooth LE 5.0		
	RX maximum input level	Bluetooth LE 4.2, BV-06-C	PER 30.8 % with a minimum of 1500 packets	PASS
		Bluetooth LE 5.0		
	RX emissions 30 MHz – 1 GHz	ETSI EN 300 328	-57 dBm (100 kHz)	PASS
	RX emissions 1 GHz - 12.5 GHz	ETSI EN 300 328	-47 dBm (1 MHz)	PASS

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Table 1. List of tests for Europe*...continued*

Name	Measurements	Reference	Limit	Status
Miscellaneous	Return loss (S11)	Return loss in TX mode	For information	
		Return loss in RX mode		

[1] Blockers below 2399 GHz and above 2484 GHz are not measured in this report.

Table 2. List of tests for the US

Name	Measurements	Reference	Limit	Status
Transmission	TX maximum power	FCC part 15.247	PAVG ≤ 100 mW +20 dBm EIRP	PASS
	Spurious 1 GHz - 12.5 GHz	FCC part 15.249	Field strength < 50 mV/m at 3 m	PASS
			-41.12 dBm (1 MHz BW)	

3 Conducted tests

3.1 TX tests

This section lists the details about TX tests.

3.1.1 Test setup

Figure 2 and Figure 3 show the TX test setups.

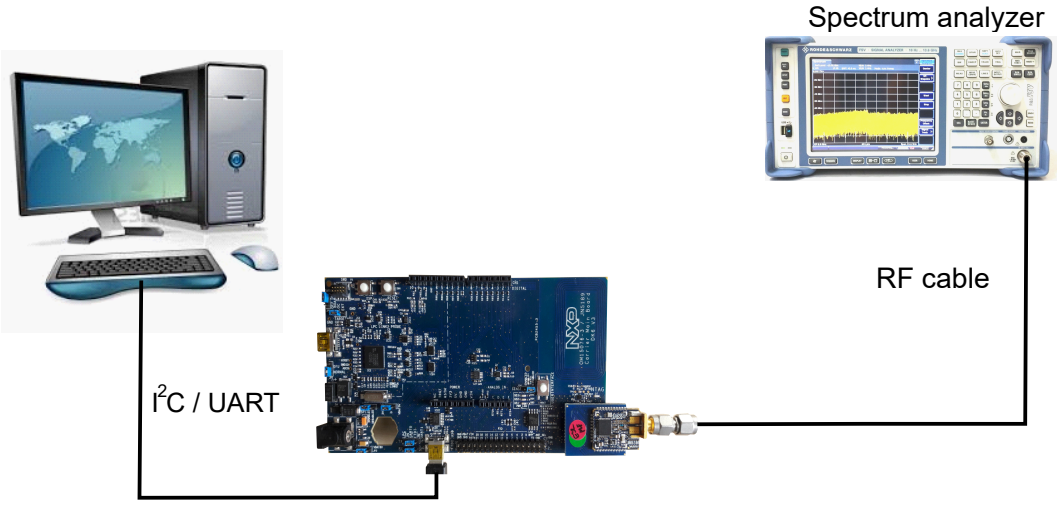

Figure 2. Conducted TX test setup

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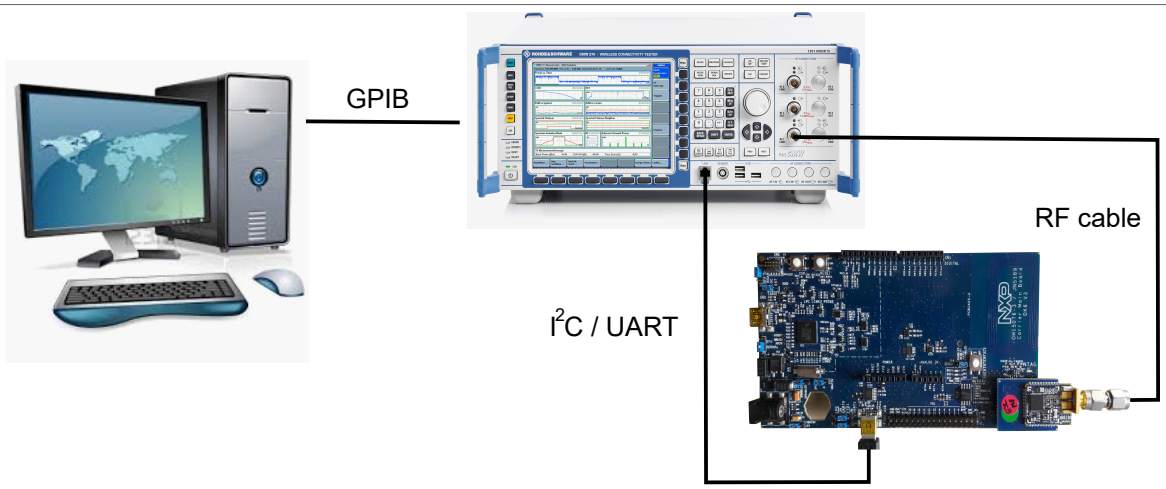

Figure 3. Specific conducted TX test setup

3.1.2 Frequency accuracy

Test method:

1. Set the radio to:
   - TX mode
   - CW
   - Continuous mode
   - Frequency: Channel 19
2. Set the analyzer to:
   - Center frequency = 2.44 GHz
   - Span = 1 MHz
   - Ref amp = 20 dBm
   - RBW = 10 kHz
   - VBW = 100 kHz
3. Measure the CW frequency with the marker of the spectrum analyzer.

Result for 1 MB/s is shown in Figure 4:

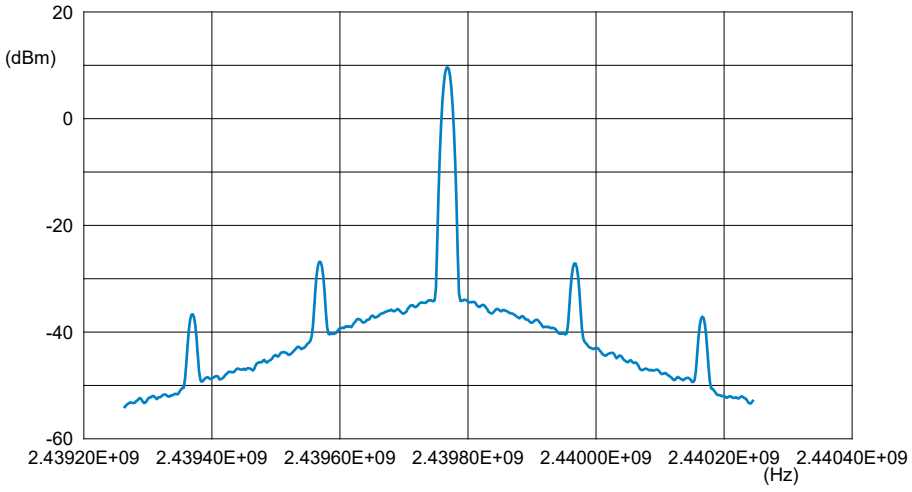

Figure 4. Frequency accuracy of TX for 1 MB/s

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- Measured frequency: 2.4397635 GHz
- ppm value = (243976350 - 24397500) / 24397500 = +5.5 ppm

Table 3. Frequency accuracy

Result	Target
+5.5 ppm	+/-25 ppm

Result for 2 MB/s is shown in Figure 5:

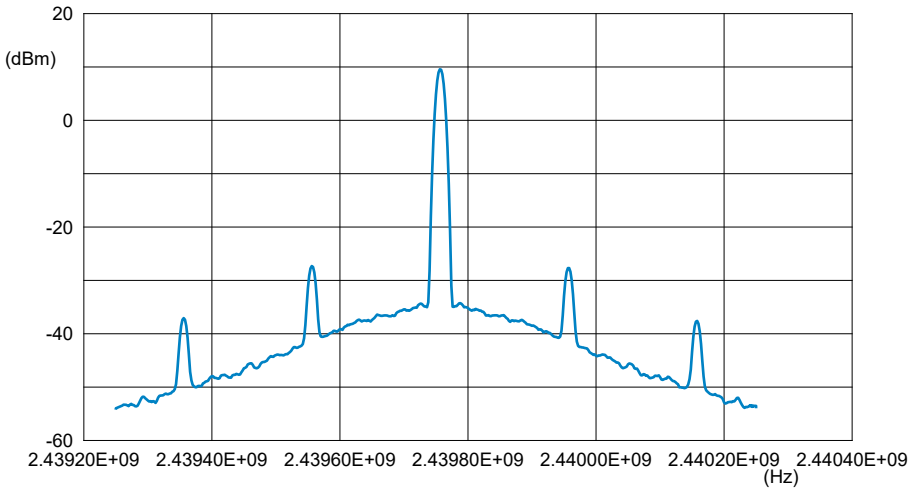

Figure 5. Frequency accuracy of TX for 2 MB/s

- Measured frequency: 2.43951 GHz
- ppm value = (243951000 - 24395000) / 24395000 = +4.1 ppm

Table 4. Frequency accuracy

Result	Target
+4.1 ppm	+/-25 ppm

Note: *The frequency accuracy depends on the XTAL model.*

Conclusion:

- The frequency accuracy complies with the data sheet.

3.1.3 Phase noise

Test method:

1. Set the radio to:
   - TX mode
   - CW
   - Continuous mode
   - Frequency: Channel 19
2. Set the analyzer to:
   - Center frequency = 2.44 GHz
   - Span = 1 MHz
   - Ref amp = 20 dBm
   - RBW = 10 kHz

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- VBW = 100 kHz

3. Measure the phase noise at the 100 kHz offset frequency:
   - RBW (spectrum analyzer) = 10 kHz (20 log (10 kHz) = 40 dBc)

Result:

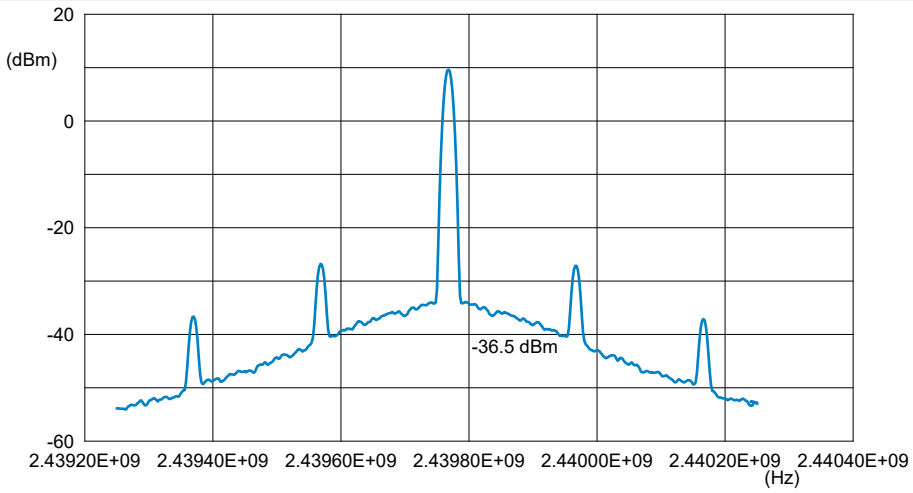

Figure 6. Conducted phase noise for 1 MB/s

- Marker value (delta) = -46.1 dBm / 100 kHz = -86.1 dBc/Hz

Note: *The phase noise is just for informational purposes. No specific issue on this parameter.*

Conclusion:

- The result is the same for 2 MB/s data rate.

3.1.4 TX power (fundamental)

Test method:

1. Set the radio to:
   - TX mode 1 M
   - Unmodulated
   - Continuous mode (00)
2. Set the analyzer to:
   - Start frequency = 2.4 GHz
   - Stop frequency = 2.5 GHz
   - Ref amp = 20 dBm
   - Sweep time = 11.3 µs
   - RBW = 3 MHz
   - VBW = 3 MHz
   - Maximum Hold mode
   - Detector = RMS
3. Sweep all the channels from channel 0 to channel 39

Result:

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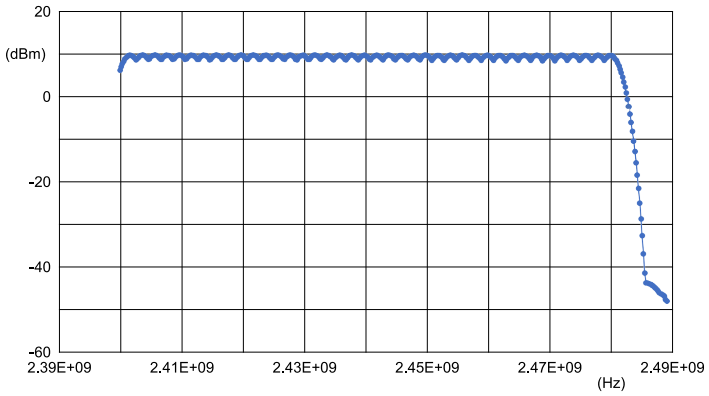

Figure 7. TX power for 1 MB/s

- Maximum power is on channel 10: 9.74 dBm
- Minimum power is on channel 20: 9.67 dBm
- Tilt over frequencies: 0.07 dB

The same test is performed when setting 2 MB/s. Figure 8 shows the result:

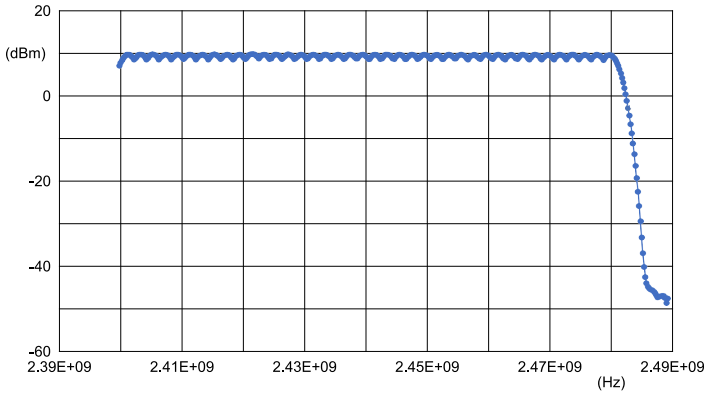

Figure 8. TX power for 2 MB/s

- Maximum power is on channel 10: 9.74 dBm
- Minimum power is on channel 11: 9.66 dBm
- Tilt over frequencies: 0.07 dB

Conclusion:

- The default TX power is in line with the expected results.
- The power is flat over frequencies.

3.1.5 TX power in band

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
2. Set the analyzer to:
   - Start frequency = 2.35 GHz

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- Stop frequency = 2.5 GHz
- Ref amp = 10 dBm
- Sweep time = 100 ms
- RBW = 100 kHz
- VBW = 300 kHz
- Maximum Hold mode
- Detector = RMS
- Number of sweeps = 10

3. Sweep on channel 2, channel 19, and channel 37

Result:

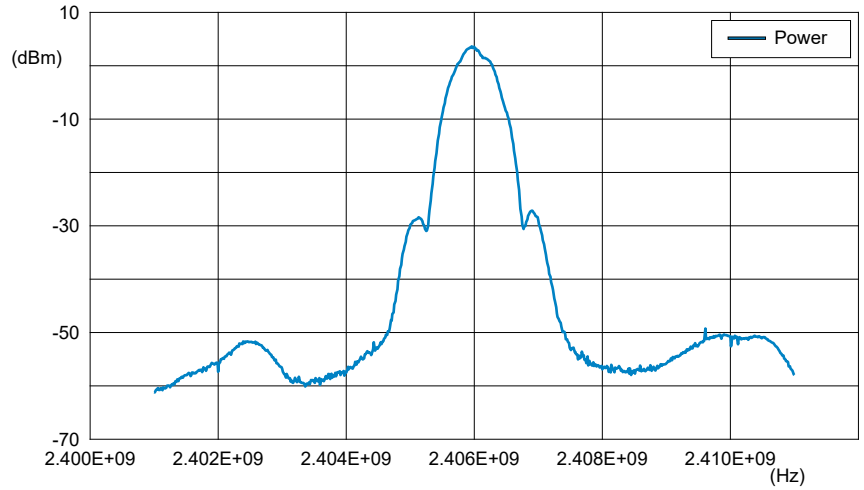

Figure 9. TX power in band, channel 2 for 1 MB/s

Table 1 shows the statistics on 1 MHz bandwidth using CMW270 equipment measurement.

Table 5. For 1 MB/s

Bandwidth	Specification	Measurement (dBm)
Max peak level <= -2 MHz	-20	-33.9
Max peak level >= +2 MHz	-20	-33.3
Max peak level <= -3 MHz	-30	-45.2
Max peak level >= +3 MHz	-30	-43.8

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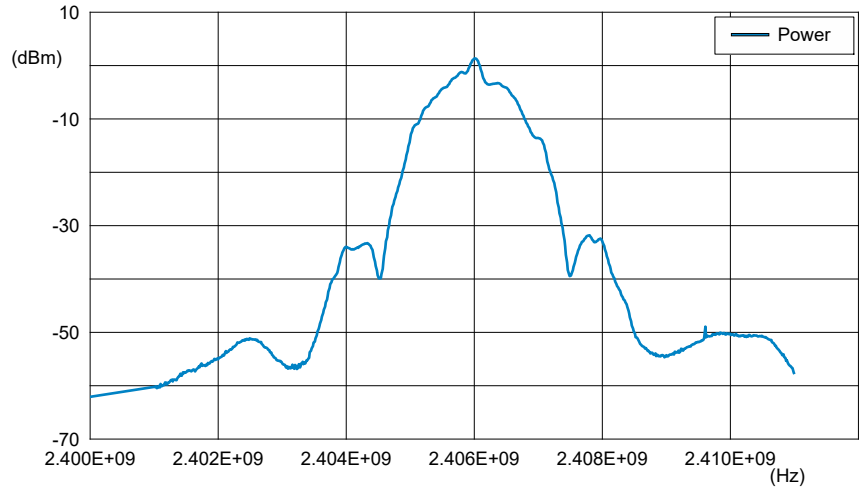

Figure 10. TX power in band, channel 2 for 2 MB/s

Table 2 shows the statistics on 1 MHz bandwidth using CMW270 equipment measurement.

Table 6. For 2 MB/s

Bandwidth	Specification	Measurement (dBm)
Max peak level <= -4 MHz	-20	-49.8
Max peak level >= +4 MHz	-20	-47.4
Max peak level <= -6 MHz	-	-
Max peak level >= +6 MHz	-30	-54.4

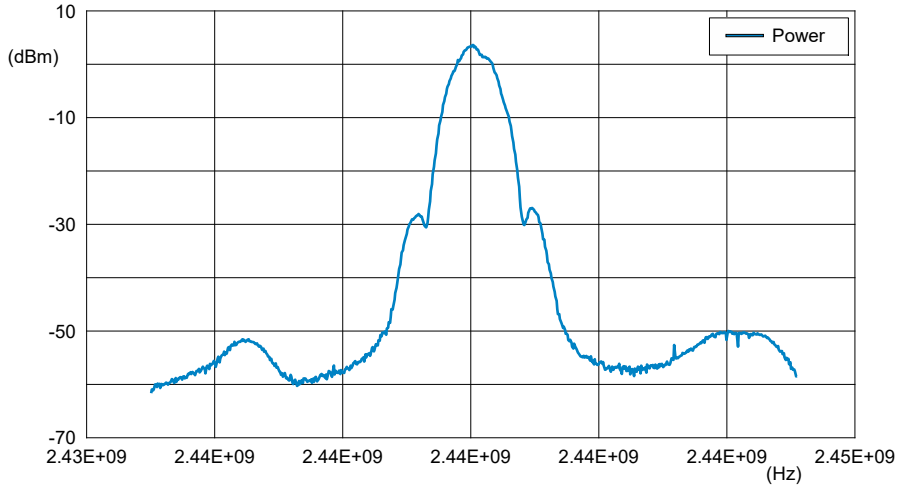

Figure 11. TX power in band, channel 19 for 1 MB/s

Table 3 shows the statistics on 1 MHz bandwidth using CMW270 equipment measurement.

Table 7. For 1 MB/s

Bandwidth	Specification	Measurement (dBm)
Max peak level <= -2 MHz	-20	-45.3
Max peak level >= +2 MHz	-20	-45.6
Max peak level <= -3 MHz	-30	-49.6

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Table 7. For 1 MB/s*...continued*

Bandwidth	Specification	Measurement (dBm)
Max peak level >= +3 MHz	-30	-48.8

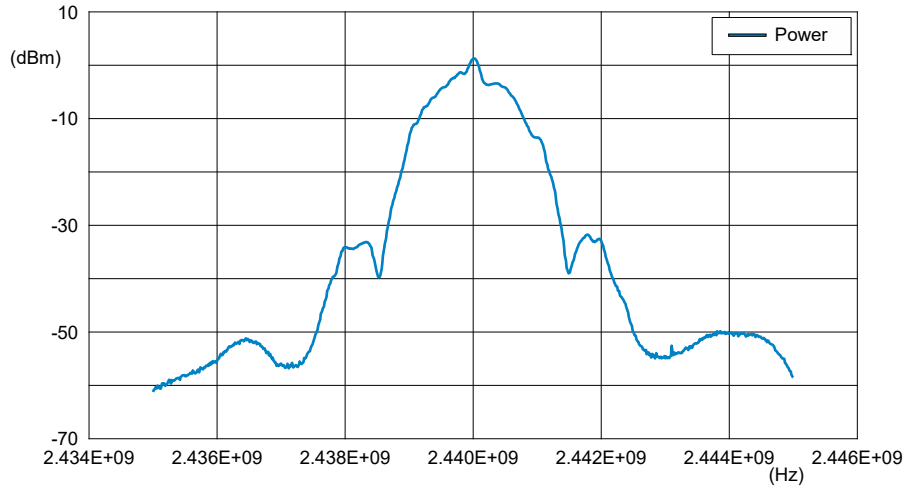

Figure 12. TX power in band, channel 19 for 2 MB/s

Table 4 shows the statistics on 1 MHz bandwidth using CMW270 equipment measurement.

Table 8. For 2 MB/s

Bandwidth	Specification	Measurement (dBm)
Max peak level <= -4 MHz	-20	-49.6
Max peak level >= +4 MHz	-20	-47.3
Max peak level <= -6 MHz	-30	-54.2
Max peak level >= +6 MHz	-30	-54.2

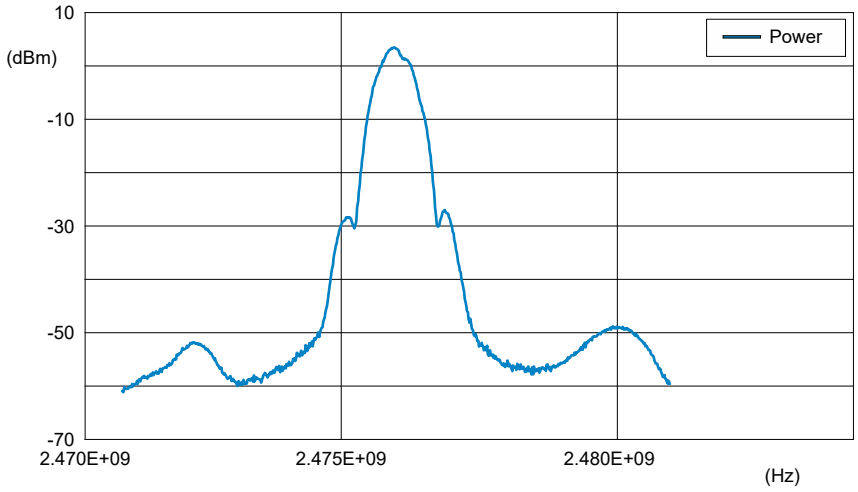

Figure 13. TX power in band, channel 37 for 1 MB/s

Table 5 shows the statistics on 1 MHz bandwidth using CMW270 equipment measurement.

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Table 9. For 1 MB/s

Bandwidth	Specification	Measurement (dBm)
Max peak level <= -2 MHz	-20	-45.0
Max peak level >= +2 MHz	-20	-45.2
Max peak level <= -3 MHz	-30	-49.6
Max peak level >= +3 MHz	-30	-48.6

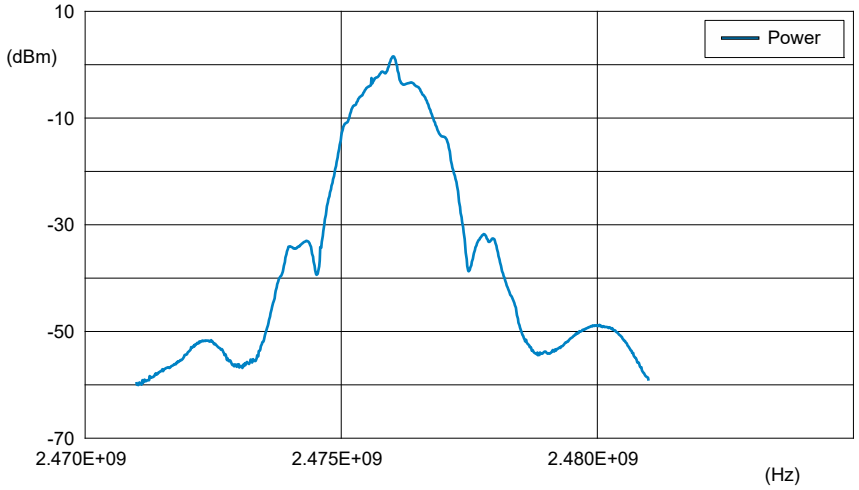

Figure 14. TX power in band, channel 37 for 2 MB/s

Table 6 shows the statistics on 1 MHz bandwidth using CMW270 equipment measurement.

Table 10. For 2 MB/s

Bandwidth	Specification	Measurement (dBm)
Max peak level <= -4 MHz	-20	-46.3
Max peak level >= +4 MHz	-20	-44.9
Max peak level <= -6 MHz	-30	-48.8
Max peak level >= +6 MHz	-	-

Conclusion:

- These results are compliant with Bluetooth LE 4.2 and Bluetooth LE 5.0.

3.1.6 TX spurious

3.1.6.1 30 MHz to 12.5 GHz

Spurious overview of the full band from 30 MHz to 12.5 GHz when the device is in the transmission mode is as follows:

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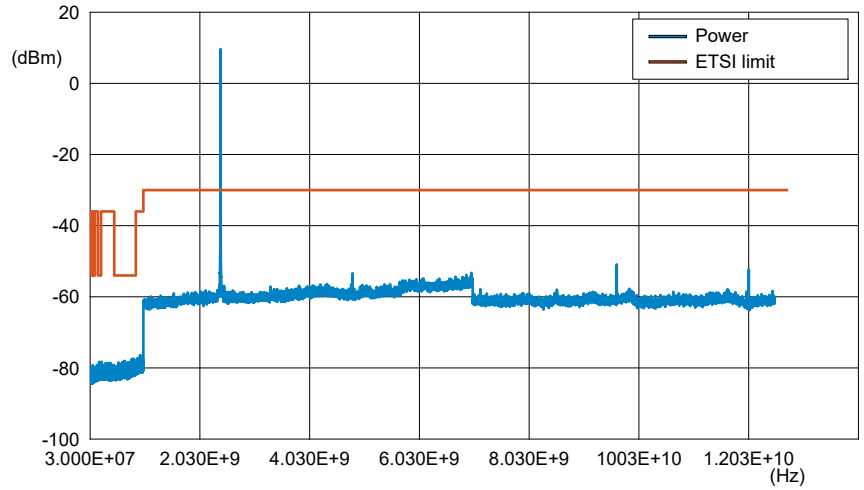

Figure 15. Conducted TX spurious for 1 MB/s (30 MHz to 12.5 GHz)

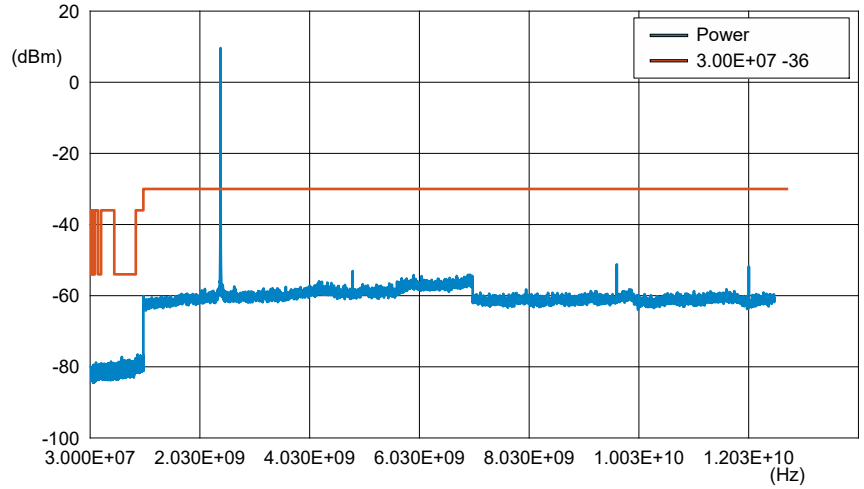

Figure 16. Conducted TX spurious for 2 MB/s (30 MHz to 12.5 GHz)

Conclusion:

- There are no TX spurs above the EN 300 328 limit (more than 15 dB margin).
- Harmonics are measured in the following sections.

3.1.6.2 H2 (ETSI test conditions, peak measurement)

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
2. Set the analyzer to:
   - Start frequency = 4.7 GHz
   - Stop frequency = 5 GHz
   - Ref amp = -20 dBm
   - Sweep time = 100 ms

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- RBW = 1 MHz
- VBW = 3 MHz
- Maximum Hold mode
- Detector: Peak

3. Sweep all the channels from channel 0 to channel 39.

Result:

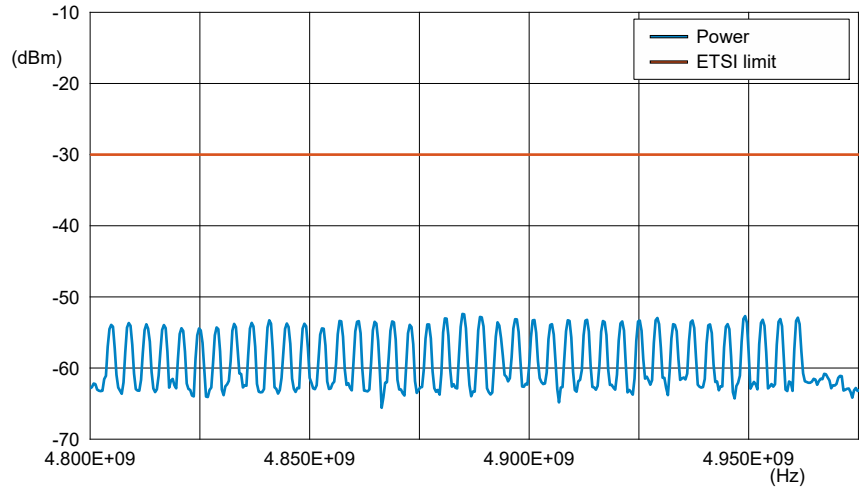

Figure 17. Conducted H2 spurious

- Maximum power is at channel 21: -52.4 dBm

Conclusion:

- There is 22.4 dB margin to the ETSI limit.

3.1.6.3 H3 (ETSI test conditions, peak measurement)

The test method is the same as for the H2, except the spectrum analyzer frequency start/stop is set to 7.0 GHz and 7.5 GHz.

Result:

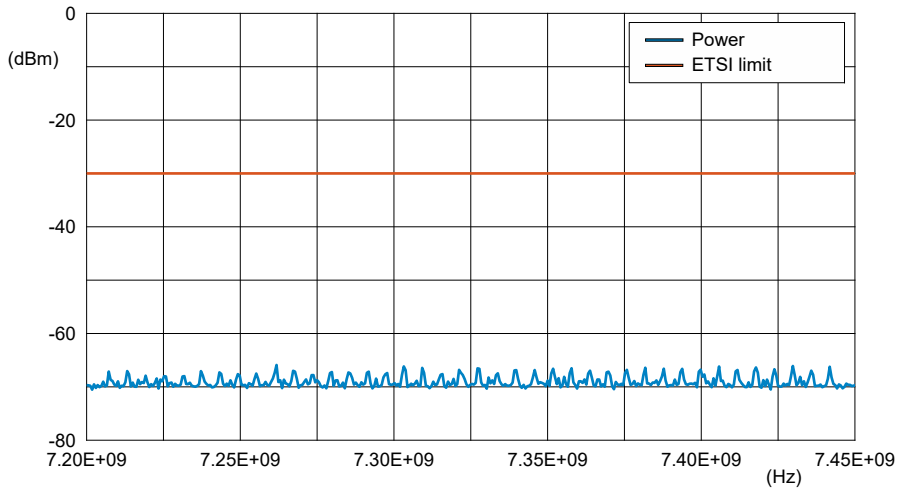

Figure 18. Conducted H3 spurious

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- H3 maximum power is at channel 17: -66.9 dBm

Conclusion:

- There is 36.9 dB margin to the ETSI limit.

3.1.6.4 H4 (ETSI test conditions, peak measurement)

The test method is the same as for the H2, except that the spectrum analyzer frequency span is set from 9.4 GHz to 10.0 GHz.

Result:

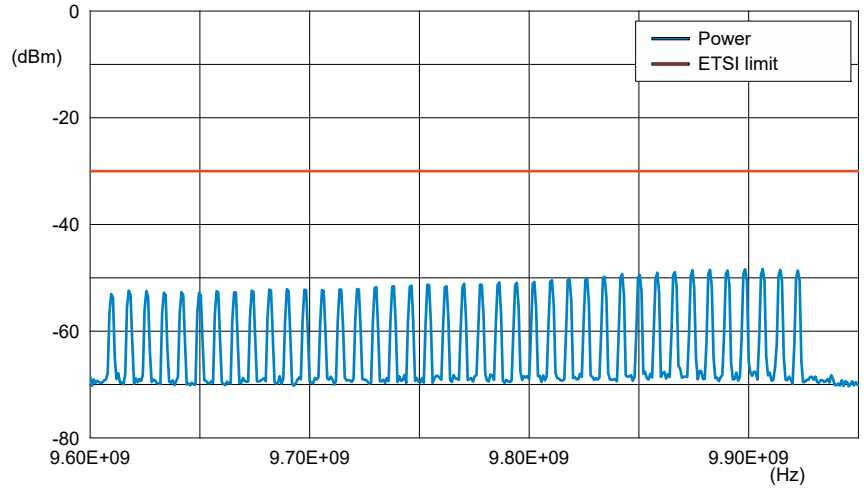

Figure 19. Conducted H4 spurious

- Maximum power is at channel 37: -48.4 dBm

Conclusion:

- There is 18.4 dB margin to the ETSI limit.

3.1.6.5 H5 (ETSI test conditions, peak measurement)

The test method is the same as for the H2, except that the spectrum analyzer frequency span is set from 11.7 GHz to 12.5 GHz.

Result:

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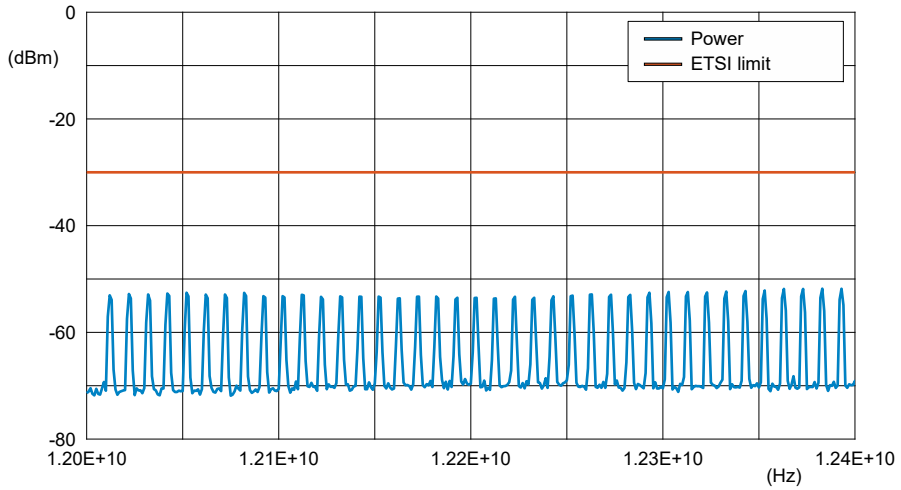

Figure 20. Conducted H5 spurious

- Maximum power is at channel 37: -47.95 dBm

Conclusion:

- There is 17.95 dB margin to the ETSI limit.

3.1.6.6 H2 (FCC test conditions, average measurements)

Test method:

1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
2. Set the analyzer to:
   - Start frequency = 4.7 GHz
   - Stop frequency = 5 GHz
   - Ref amp = -20 dBm
   - Sweep time = 100 ms
   - RBW = 1 MHz
   - VBW = 3 MHz
   - Trace: Maximum Hold mode
   - Detector: RMS
3. Sweep all the channels from channel 0 to channel 39. For this case and in the next sections, only 4 is represented.

Result:

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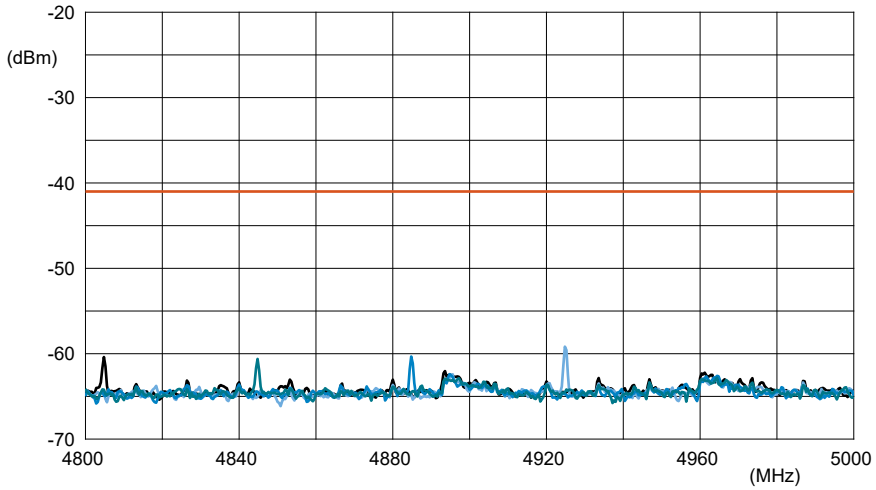

Figure 21. Conducted H2 FCC spurious

Conclusion:

- There is around 20 dB margin to the FCC limit.

3.1.6.7 H3 (FCC test conditions, average measurements)

The test method is the same as for the H2, except that the spectrum analyzer frequency span is set from 7.0 GHz to 7.5 GHz.

Result:

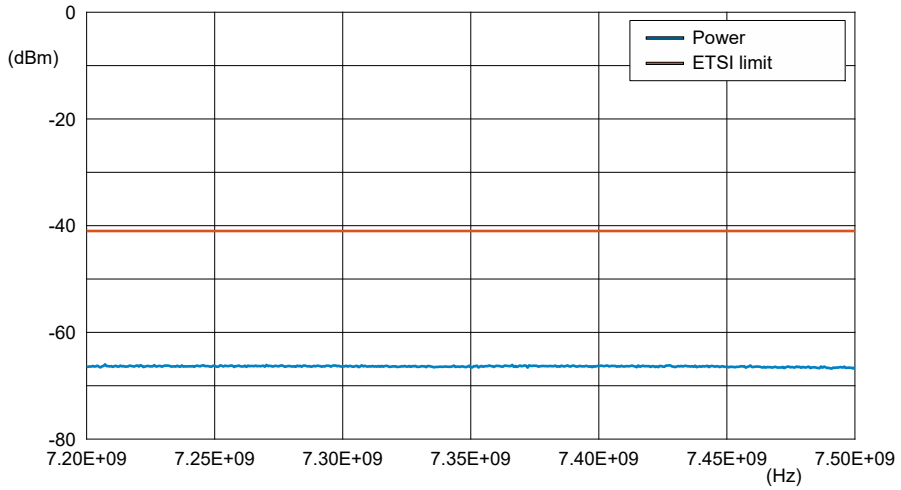

Figure 22. Conducted H3 FCC spurious

- Power is -66 dBm below noise floor of this measurement.

Conclusion:

- There is 25 dB margin to the FCC limit.

3.1.6.8 H4 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 9.4 GHz to 10 GHz.

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Result:

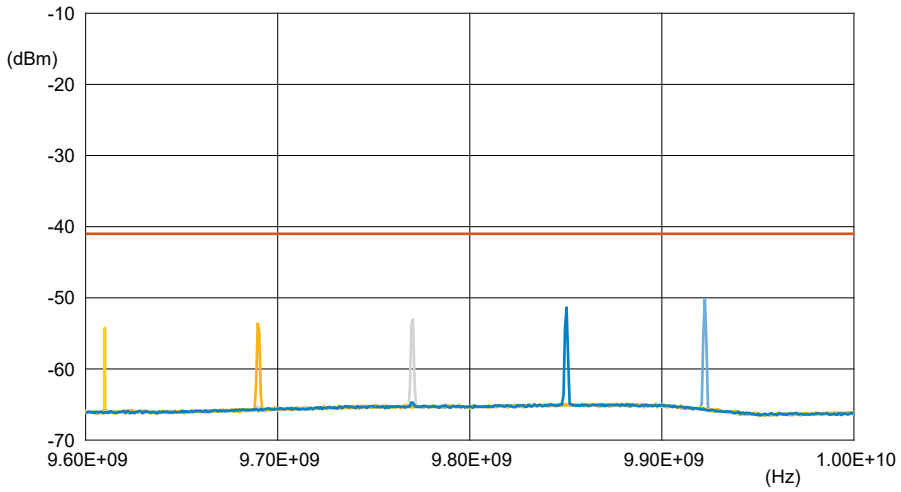

Figure 23. Conducted H4 FCC spurious

Conclusion:

- There is around 9 dB margin to the FCC limit.

3.1.6.9 H5 (FCC test conditions, average measurements)

The test method is same as for the H2, except that the spectrum analyzer frequency span is set from 11.7 GHz to 12.5 GHz.

Result:

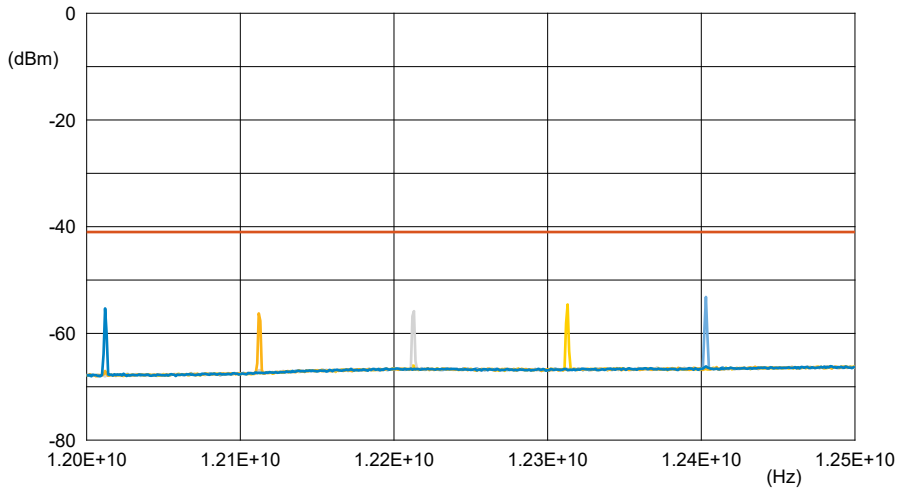

Figure 24. Conducted H5 FCC spurious

Conclusion:

- There is around 12 dB margin to the FCC limit.

3.1.7 Upper band edge

Test method:

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1. Set the radio to:
   - TX mode
   - Modulated
   - Continuous mode
2. Set the analyzer to:
   - Start frequency = 2.475 GHz
   - Stop frequency = 2.485 GHz
   - Ref amp = -20 dBm
   - Sweep time=100 ms
   - RBW = 1MHz
   - VBW = 3MHz
   - Detector = Average
   - Average mode = Power
   - Number of sweeps = 100
   - Set the channel 39 (2.48 GHz)

Results:

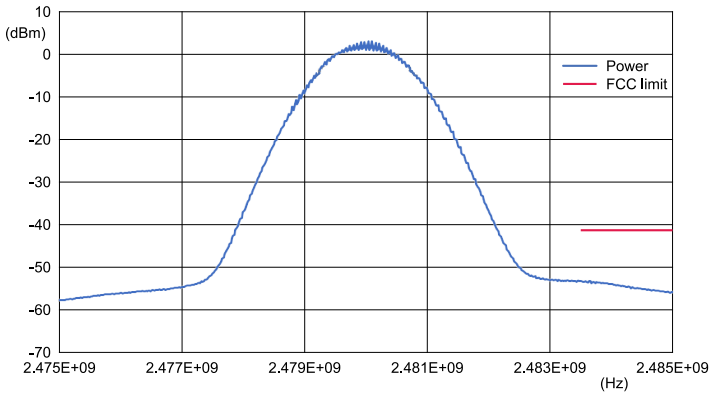

Figure 25. Upper band edge for 1 MB/s, channel 39

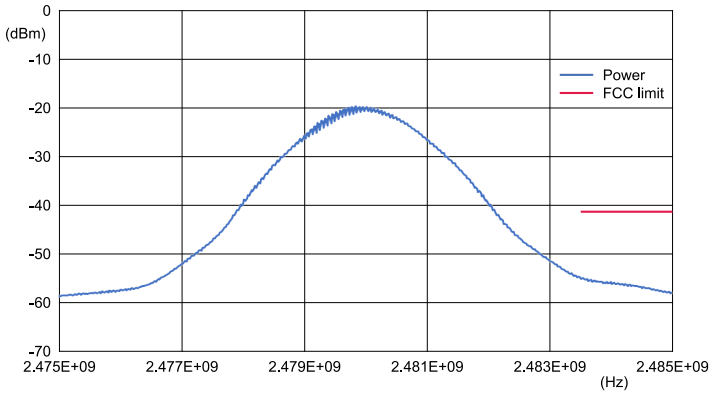

Figure 26. Upper band edge for 2 MB/s, channel 39

Conclusion:

- The upper band edge test passes the FCC certification.
- There is 12.7 dB margin for 1 MB/s and 13.5 dB margin for 2 MB/s to the FCC limit.

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3.1.8 Modulation characteristics

A CMW equipment is used to measure the frequency deviation df1 and df2. A specific binary is flashed from the SDK: `hci_blackbox_bm.bin`. The version V1 is used here.

Test method:

- Generator for the desired signal: CMW R&S
- Criterion: PER < 30.8 % with 1500 packets
- Channels under test: 0, 2, 12, 19, 37, and 39

Result:

Table 11. Modulation characteristics at 1 MB/s

Frequency deviation	Channel number						Specification	
	0	2	12	19	37	39	min	max
Frequency deviation df1 Average (kHz)	250.54	248.77	250.11	250.47	249.72	250.65	225	275
Frequency deviation df2 99.9 % (kHz)	204.14	204.84	201.35	204.84	209.44	206.34	185	-
Frequency deviation df2 Average / df1 Average	0.904	0.918	0.899	0.916	0.908	0.9	0.8	-

Table 12. Modulation characteristics at 2 MB/s

Frequency deviation	Channel number						Specification	
	0	2	12	19	37	39	min	max
Frequency deviation df1 Average (kHz)	509.94	502.86	508.01	509.61	508.37	510.28	450	550
Frequency deviation df2 99.9 % (kHz)	421.28	423.67	416.28	427.87	424.67	422.27	370	-
Frequency deviation df2 Average / df1 Average	0.874	0.89	0.871	0.884	0.878	0.872	0.8	-

Conclusion:

- The margins are good and in line with the expected results.

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3.1.9 Carrier frequency offset and drift

A CMW equipment is used to measure the frequency deviation df1 and df2. A specific binary is flashed from the SDK: `hci_blackbox_bm.bin`. The version 2.11 is used here.

Test method:

- Generator for the desired signal: CMW270 R&S
- Criterion: PER < 30.8 % with 1500 packets
- Channels under test: 0, 2, 12, 19, 37, and 39

Result:

Table 13. Carrier frequency offset and drift at 1 MB/s

Frequency offset and drift	Channel number						Specification	
	0	2	12	19	37	39	min	max
Frequency drift (kHz)	-5.14	-5.65	-3.87	0.03	2.25	2.49	-50	50
Max drift rate (kHz/50 µs)	-0.14	-0.41	0.17	0.7	0.07	0.12	-20	20
Frequency offset (kHz)	9.39	9.8	8.13	7.86	7.72	7.93	-150	150
Initial frequency drift (kHz)	-3.15	-2.95	-1.43	0.39	1.05	1.58	-23	23

Table 14. Carrier frequency offset and drift at 2 MB/s

Frequency offset and drift	Channel number						Specification	
	0	2	12	19	37	39	min	max
Frequency drift (kHz)	-4.97	-4.34	-1.87	1.53	4.73	3.35	-50	50
Max drift rate (kHz/50 µs)	-1.82	-3.09	-2.11	-1.55	-1.63	-1.89	-20	20
Frequency offset (kHz)	9.42	9.4	8.54	8.35	7.89	8.05	-150	150
Initial frequency drift (kHz)	-1.76	-0.74	-0.45	2.43	4.39	3.13	-23	23

Conclusion:

- Good margins, in line with the expected results.

For the receiver measurements in next sections, the software used is the connectivity tool 1.0.2.

3.2 RX tests

This section lists the details about RX tests.

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3.2.1 Test setup

Figure 27 to Figure 30, shows the conducted RX test setups.

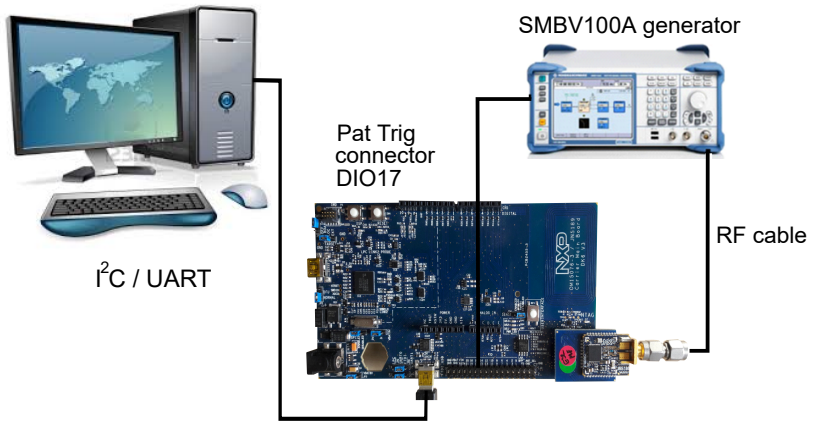

Figure 27. Conducted RX test setup for sensitivity with RF generator and faraday box

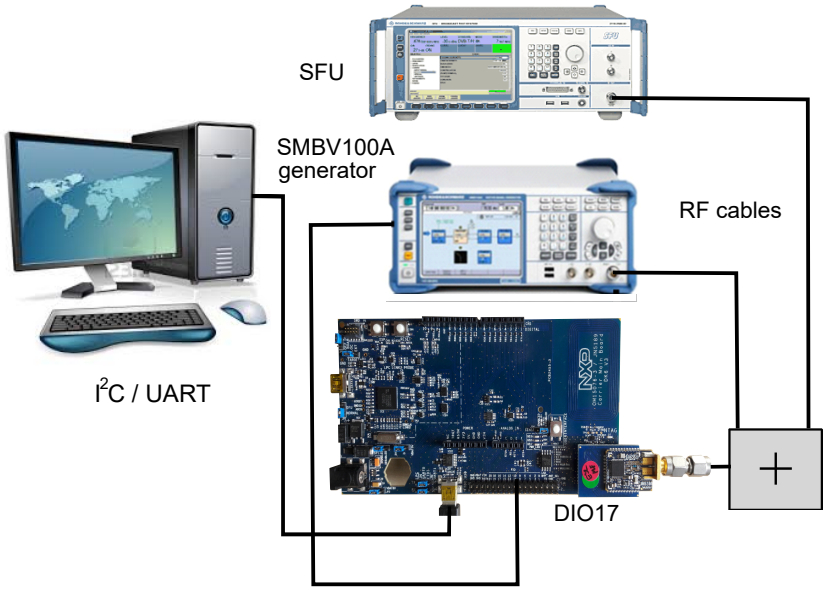

Figure 28. Conducted RX test setup for interference rejection

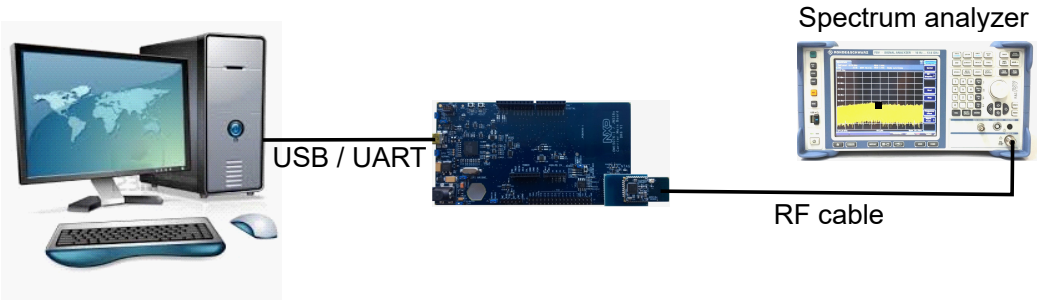

Figure 29. Conducted RX test setup for spurious

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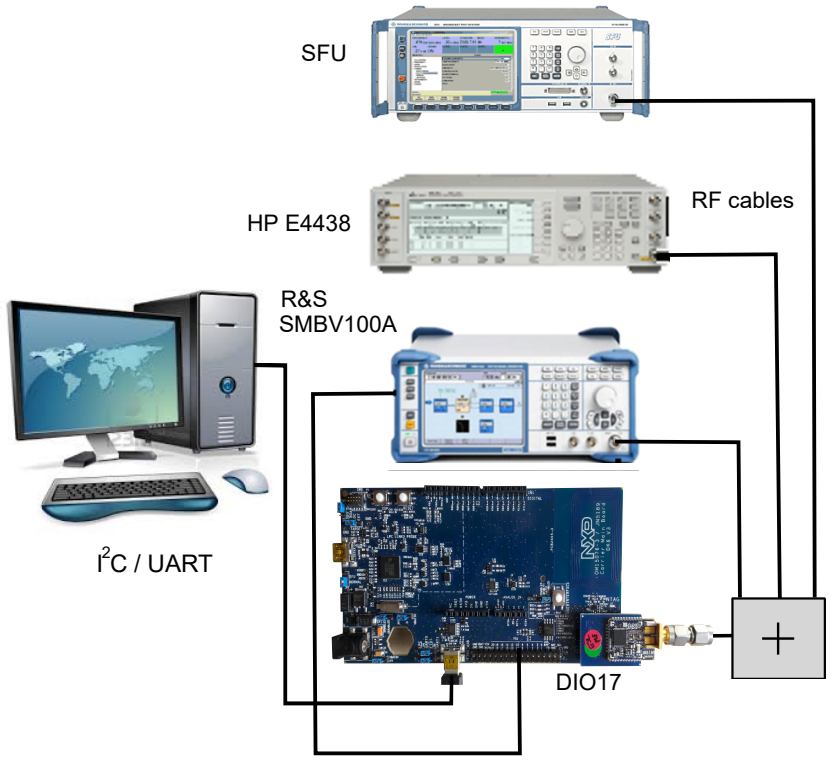

Figure 30. Conducted RX test setup for intermodulation performances

3.2.2 Sensitivity

3.2.2.1 With the ARB generator

To remain immune to the external parasitic signals, DK6 board is put in an RF shielded box.

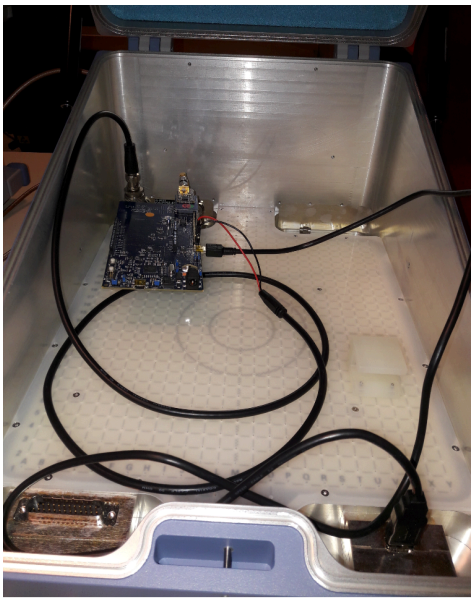

Figure 31. Sensitivity test

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The generator, SMBV100A, is used in the ARB mode to generate a pattern of 1500 packets (triggered on DIO17 from DK6). The Tera Term window is used to control the module.

Test method:

1. Set it to channel 0.
2. The connection is automatically established and the Packet Error Rate (PER) is measured.
3. Decrease the level of the SFU at the RF input of the module until PER = 30.8 %.
4. Repeat it up to channel 39.

The results of the few channels measured manually are as follows:

Results for 1 MB/s data rate:

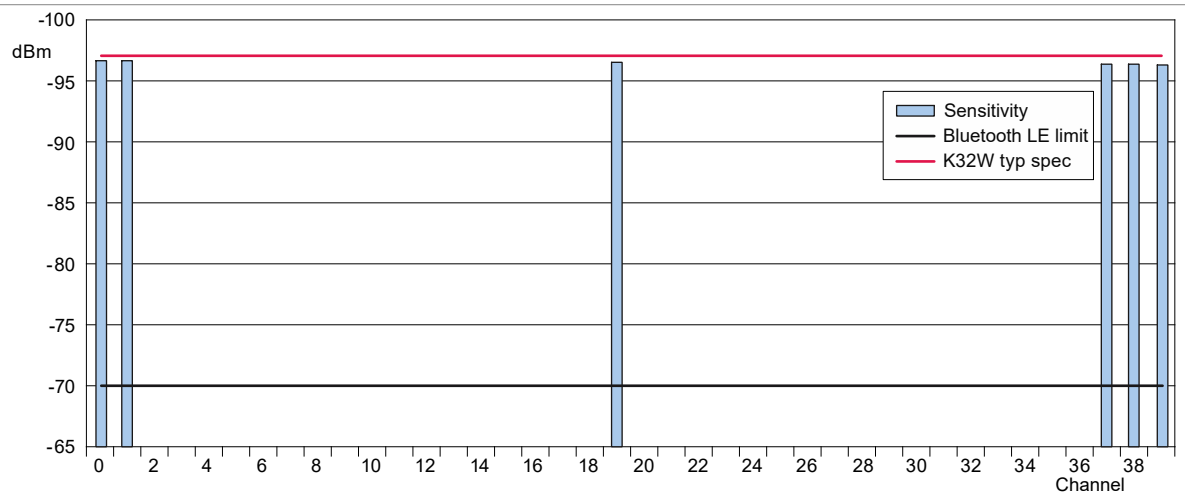

Figure 32. 1 MB/s sensitivity result

- The best sensitivity is on channel 1: -96.7 dBm
- The lowest sensitivity is: -96.3 dB
- Delta over channels: 0.4 dB

Results for 2 MB/s data rate:

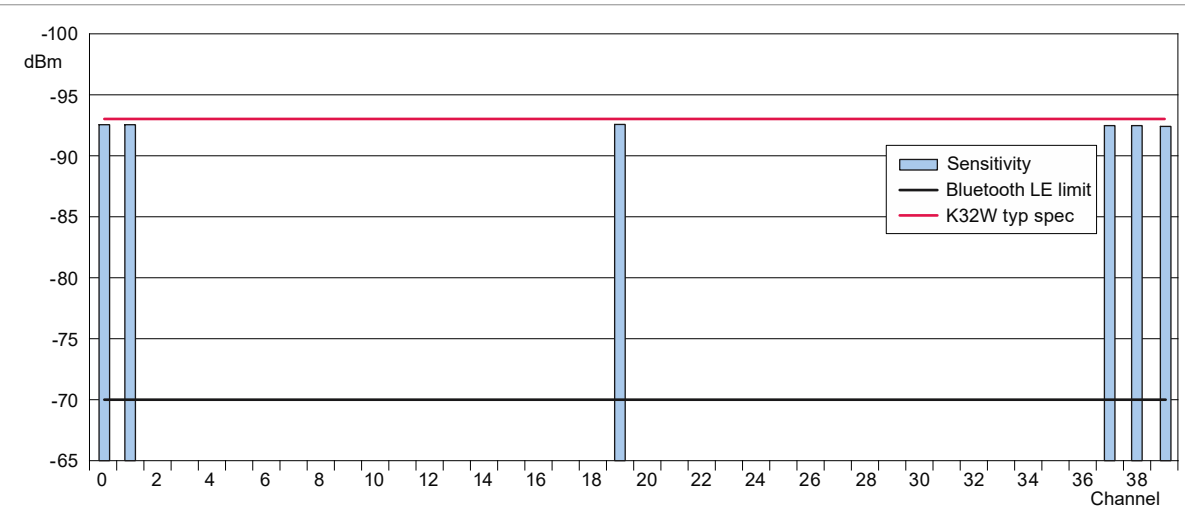

Figure 33. 2 MB/s sensitivity result

- The best sensitivity is on channel 0, 1, 19: -92.7 dBm

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- The lowest sensitivity is: -92.6 dB
- Delta over channels: 0.1 dB

Conclusion:

- Sensitivity average value is -96.5 dBm for 1 MB/s and -92.7 dBm for 2 MB/s. These results are in line with characterization results.

3.2.3 Receiver maximum input level

Test method:

- The test setup is same as for the sensitivity test.
- The signal level is increased up to the PER = 30.8 % with 1500 packets.

Results at 1 MB/s:

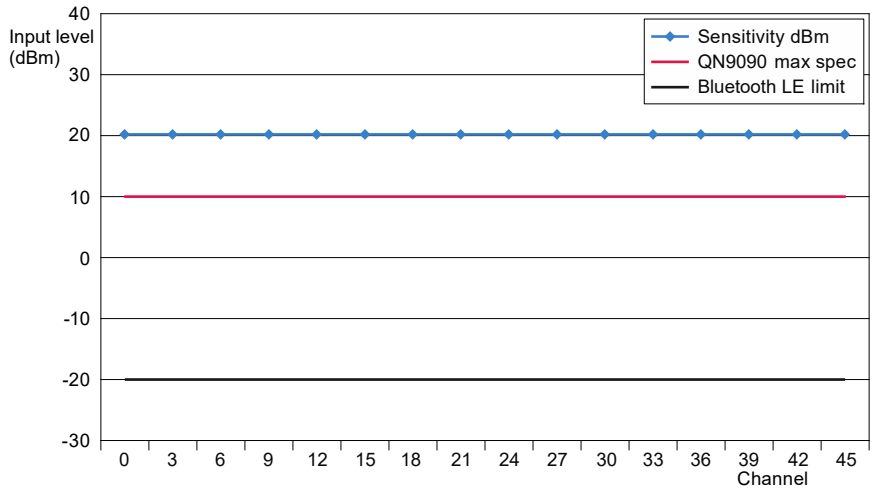

Figure 34. Maximum input power for 1 MB/s

Results at 2 MB/s:

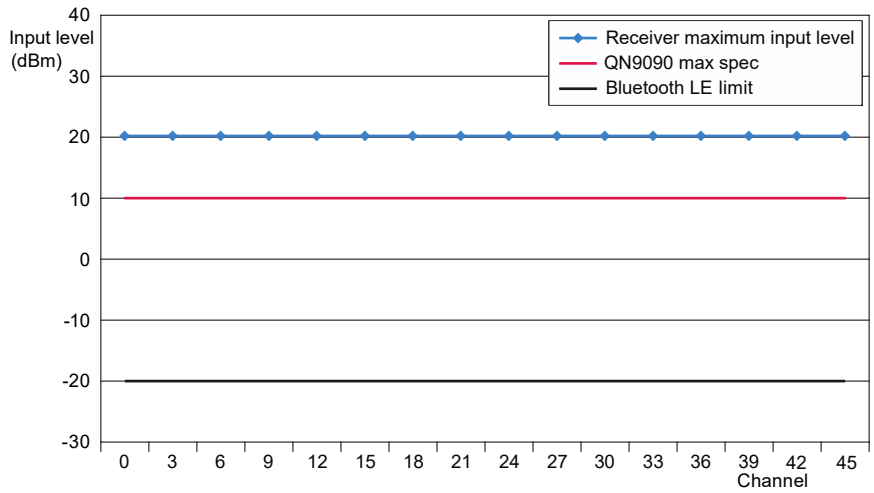

Figure 35. Maximum input power for 2 MB/s

Conclusion:

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- The value specified by data sheet is only for the information purpose.
- According to the test results from above, there is a margin to increase the input power level up to 20 dBm.
- Therefore, from a system perspective, these results are consistent with the expected values.

3.2.4 RX spurious

Test method

1. Set the radio to:
   - Receiver mode
   - Frequency: Channel 18
2. Set the analyzer to:
   - Ref amp = -20 dBm
   - Trace = Max Hold
   - Detector = Max Peak
   - Start/stop frequency: 30 MHz /1 GHz
     - RBW = 100 kHz, VBW = 300 kHz
   - Then set the start/stop frequency: 1 GHz /30 GHz
     - RBW = 1 MHz, VBW = 3 MHz

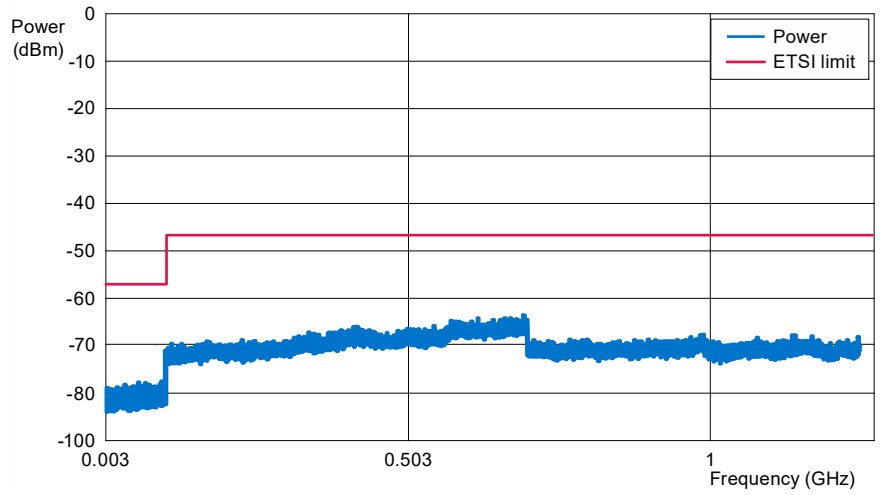

Figure 36. Conducted RX spurious 30 MHz – 12.5 GHz

Conclusion:

- There are no spurs above the spectrum analyzer noise floor.
- More than 13 dB margin.

3.2.5 Receiver interference rejection performances

3.2.5.1 Adjacent, alternate, and co-channel rejection

The interferers are at the adjacent channel (+/-1 MHz, +/-2 MHz, +/-3 MHz) or co-channel. The test is performed with only one interfering unmodulated signal at a time.

Test method:

- Generator for the desired signal: SMBV100A.

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- Generator for interferers: R&S SFU.
- Criterion: PER < 30.8 % with 1500 packets.
- The desired signal is set to -67 dBm; the interferer is increased until the PER threshold is reached.
- Channel under test = 2.

Results for 1 MB/s:

	ch2			
	2406			
	N-2 MHz	**N-1 MHz**	**N+1 MHz**	**N+2 MHz**
	2404	2405	2407	2408
Interferer Read value	-27.4	-26.9	-27.7	-13.9
Interferer level (dBm)	-32.4	-31.9	-32.7	-18.9
Interferer level (C/I dB)	-34.6	-35.1	-34.3	-48.1
Bluetooth LE 4.2 limit (C/I dB)	-17	15	15	-17
Margin (dB)	17.6	50.1	49.3	31.1

	ch2		Co-channel
	2406		ch2
	N-3 MHz	**N+3 MHz**	2406
	2403	2409	**N**
Interferer Read value	-13.7	-7.5	2406
Interferer level (dBm)	-18.7	-12.5	-63
Interferer level (C/I dB)	**-48.3**	**-54.5**	-68.0
Bluetooth LE 4.2 limit (C/I dB)	-27	-27	**1.0**
Margin (dB)	21.3	27.5	21
			20.0

Figure 37. Adjacent, alternate, and co-channel rejection

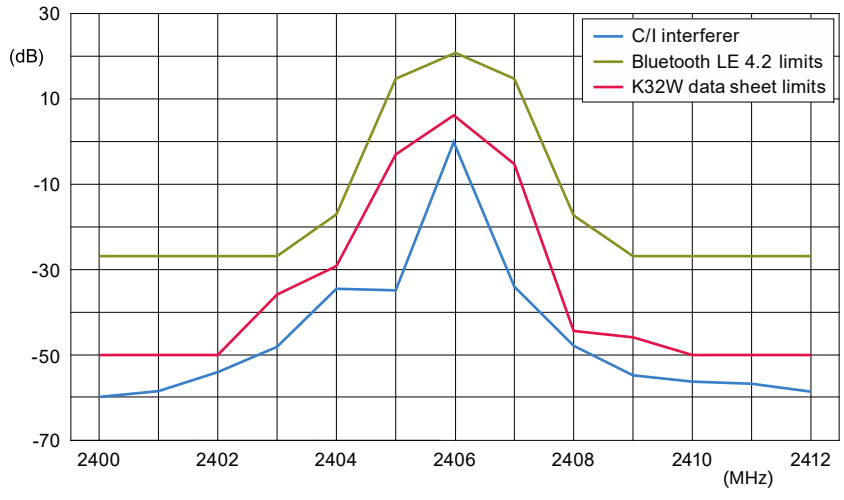

Figure 38. Adjacent, alternate, and co-channel rejection at channel 2

Results for 2 MB/s:

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	ch2			
	2406			
	N-4 MHz	**N-2 MHz**	**N+2 MHz**	**N+4 MHz**
	2402	2404	2408	2410
Interferer Read value	-32.0	-26.9	-22	-13.4
Interferer level (dBm)	-37.0	-31.9	-27.0	-18.4
Interferer level (C/I dB)	-30.0	-35.1	-40.0	-48.6
Bluetooth LE 5.0 limit (C/I dB)	-17	15	15	-17
Margin (dB)	13.0	50.1	55.0	31.6

	ch2		Co-channel
	2406		ch2
	N-6 MHz	**N+6 MHz**	2406
	2400	2412	**N**
			2406
Interferer Read value	-13.7	-11.5	-65.1
Interferer level (dBm)	-18.7	-16.5	-70.1
Interferer level (C/I dB)	**-48.3**	**-50.5**	**3.1**
Bluetooth LE 5.0 limit (C/I dB)	-27	-27	21
Margin (dB)	21.3	23.5	17.9

Figure 39. Adjacent, alternate, and co-channel rejection

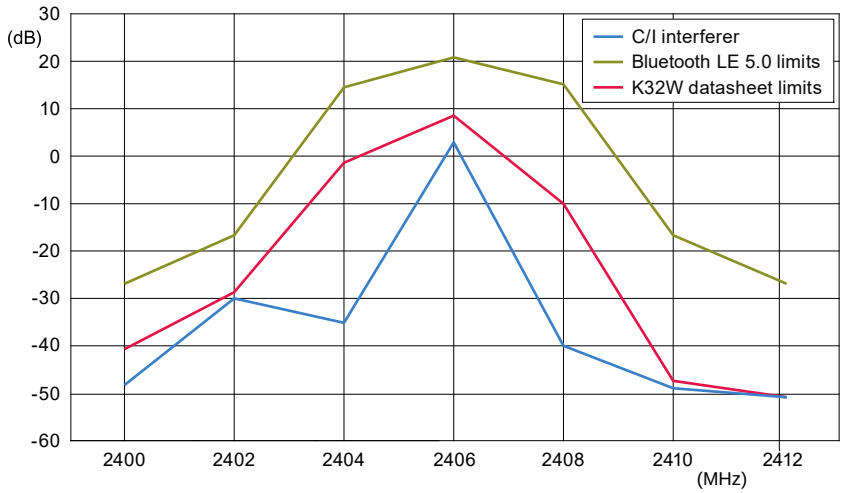

Figure 40. Adjacent, alternate, and co-channel rejection at channel 2

Conclusion:

- The shape of the curve is due to CW interferer.
- The results are compliant with the QN9090 specification and Bluetooth LE limits.

3.2.5.2 Receiver blocking

The blocking interferers are at the out of band channels depending on the receiver category.

3.2.5.2.1 Receiver category 2

The test is performed with only one interfering signal at a time, for more details see the *ETSI 300.328 2.1.1 chapter 4.3.1.12.4.3*.

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Test method:

- Generator for the desired signal: R&S SMBV100A.
- Generator for interferers: R&S SFU.
- Criterion: PER < 10 % (sensitivity at 10 % PER must be measured before).
- The desired signal is set to Pmin at 10 % PER + 6 dB; the interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39.
- Test is performed for 1 MB/s first and then for 2 MB/s.

Result for 1 MB/s:

	1 MB/s			
	ch0	**ch0**	**ch39**	**ch39**
	2402	2402	2480	2480
	Low	**Low**	**High**	**High**
	2380	2503.5	2380	2503.5
Interferer level (dBm)	**-22.6**	**-16.7**	**-18.4**	**-19.7**
Interferer level (dBc)	67.4	73.3	71.6	70.3
802.15.4 limit (dBm)	-57	-57	-57	-57
Margin (dB)	34.4	40.3	38.6	37.3

	1 MB/s			
	ch0	**ch0**	**ch39**	**ch39**
	2402	2402	2480	2480
	Low	**Low**	**High**	**High**
	2300	2583.5	2300	2583.5
Interferer level (dBm)	**-18.4**	**-15.7**	**-18.1**	**-15.9**
Interferer level (dBc)	71.6	74.3	71.9	74.1
802.15.4 limit (dBm)	-47	-47	-47	-47
Margin (dB)	28.6	31.3	28.9	31.1

Figure 41. Receiver blocking (out of band) rejection for 1 MB/s (Pmin at 10 % PER + 6 dB = -90.0 dBm)

Result for 2 MB/s:

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	2 MB/s			
	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-23.0	-16.7	-18.3	-20.4
Interferer level (dBc)	67.0	73.3	71.7	69.6
802.15.4 limit (dBm)	-57	-57	-57	-57
Margin (dB)	34.0	40.3	38.7	36.6

	2 MB/s			
	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-18.4	-15.8	-18.4	-15.9
Interferer level (dBc)	71.6	74.2	71.6	74.1
802.15.4 limit (dBm)	-47	-47	-47	-47
Margin (dB)	28.6	31.2	28.6	31.1

Figure 42. Receiver blocking (out of band) rejection for 2 MB/s (Pmin at 10 % PER + 6 dB = -86.3 dBm)

Conclusion:

- There is a good margin to ETSI specification for blockers category 2.

3.2.6 Intermodulation

This test verifies that the receiver intermodulation performance is satisfactory. Two interferers are used in combination with the desired signal. One interferer is a sinusoid non-modulated signal and the second interferer is a modulated signal with PRSB15 data.

Test method:

- Generator for the desired signal: R&S SMBV100A.
- Generator for the first interferer (CW): Agilent E4438.
- Generator for the second interferer (PRBS15): R&S SFU.
- Criterion: PER < 30.8 % with 1500 packets.
- The desired signal is set to -64 dBm.
- Channels under test: 0, 19 and 39.

Results for 1 MB/s:

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	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	Low	Low	Low	Low	Low	Low
Interferer 1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer 2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-29.7**	**-28.7**	**-29.0**	**-22.3**	**-26.9**	**-28.9**
Interferer level (dBc)	34.3	35.3	35.0	41.7	37.1	35.1
Data sheet limit (dBm)	-30	-29	-27	-27	-29	-30
Margin (dB)	9.5	9.5	7.2	13.9	11.3	10.3

	ch19	ch19	ch19	ch19	ch19	ch19
	2440	2440	2440	2440	2440	2440
	Mid	Mid	Mid	Mid	Mid	Mid
Interferer 1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer 2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-30.0**	**-29.0**	**-29.3**	**-22.4**	**-27.2**	**-29.0**
Interferer level (dBc)	34.0	35.0	34.7	41.6	36.8	35.0
Data sheet limit (dBm)	-30	-29	-27	-27	-29	-30
Margin (dB)	9.2	9.2	6.9	13.8	11.0	10.2

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
Interferer 1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer 2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-29.7**	**-28.7**	**-29.0**	**-22.2**	**-27.8**	**-28.8**
Interferer level (dBc)	34.3	35.3	35.0	41.8	36.2	35.2
Data sheet limit (dBm)	-30	-29	-27	-27	-29	-30
Margin (dB)	9.5	9.5	7.2	14.0	10.4	10.4

Figure 43. Intermodulation results for 1 MB/s

Results for 2 MB/s:

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	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	Low	Low	Low	Low	Low	Low
Interferer 1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer 2 (Mod) (MHz)	-20	-16	-12	12	16	20
Interferer level (dBm)	**-29.2**	**-31.3**	**-31.2**	**-30.7**	**-30.7**	**-30.2**
Interferer level (dBc)	34.8	32.7	32.8	33.3	33.3	33.8
Data sheet limit (dBm)	-30.5	-32.5	-32	-32	-32.5	-30.5
Margin (dB)	10.5	10.4	10.0	10.5	11.0	9.5

	ch19	ch19	ch19	ch19	ch19	ch19
	2440	2440	2440	2440	2440	2440
	Mid	Mid	Mid	Mid	Mid	Mid
Interferer 1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer 2 (Mod) (MHz)	-20	-16	-12	12	16	20
Interferer level (dBm)	**-29.2**	**-31.3**	**-31.4**	**-30.9**	**-30.5**	**-30.3**
Interferer level (dBc)	34.8	32.7	32.6	33.1	33.5	33.7
Data sheet limit (dBm)	-30.5	-32.5	-32	-32	-32.5	-30.5
Margin (dB)	10.5	10.4	9.8	10.3	11.2	9.4

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
Interferer 1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer 2 (Mod) (MHz)	-20	-16	-12	12	16	20
Interferer level (dBm)	**-29.0**	**-31.0**	**-31.0**	**-30.6**	**-30.5**	**-29.9**
Interferer level (dBc)	35.0	33.0	33.0	33.4	33.5	34.1
Data sheet limit (dBm)	-30.5	-32.5	-32	-32	-32.5	-30.5
Margin (dB)	10.7	10.7	10.2	10.6	11.2	9.8

Figure 44. Intermodulation results for 2 MB/s

Conclusion:

- The results are compliant with the specified values from data sheet.

3.3 Return loss

Measurements are done using the SMA connector.

3.3.1 RX

In the RX mode, the return loss measurement is performed by setting the LNA gain of QN9090 to the maximum.

Hardware: DK6 board

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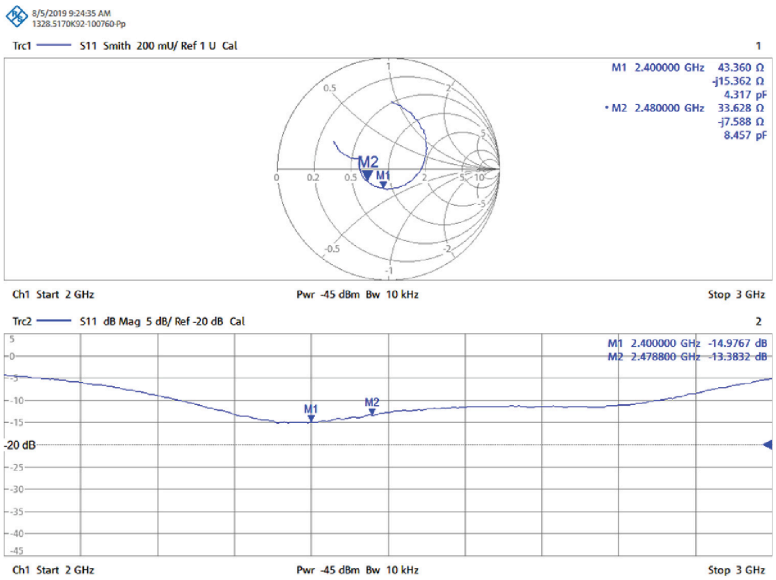

Figure 45. S11 diagram (RX mode)

Results:

- Return loss: -15.0 dB (2.4 GHz) < S11 < -13.3 dB (2.48 GHz)

Note: *There is no specification for the return loss.*

Conclusion:

- The return loss (S11) is lower than -10 dB.

3.3.2 TX

In the TX mode, the return loss measurement is performed by setting the QN9090 RF output power to the minimum.

Hardware: DK6 board

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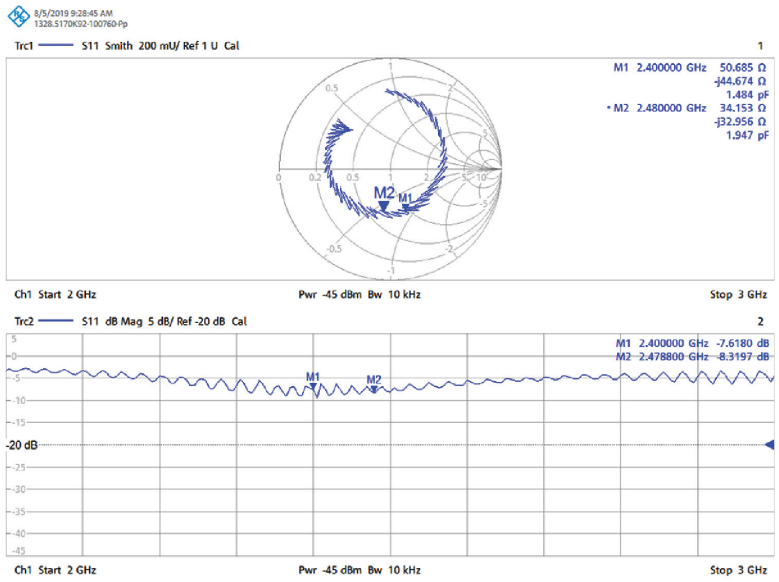

Figure 46. S11 diagram (TX mode)

Results:

- Return loss: -8.3 dBm (2.48 GHz) < S11 < -7.6 dB (2.4 GHz)

Note: *There is no specification for the return loss.*

Conclusion:

- The return loss (S11) is lower than -7 dB.

3.4 Conclusion

The preliminary results are compliant with the specification and Bluetooth LE standard.

4 Configuring the QN9090 with the certi_tool software

This section explains how to configure the QN9090 with the certi_tool software mentioned in Section 1.2:

1. For tests in Transmit mode:

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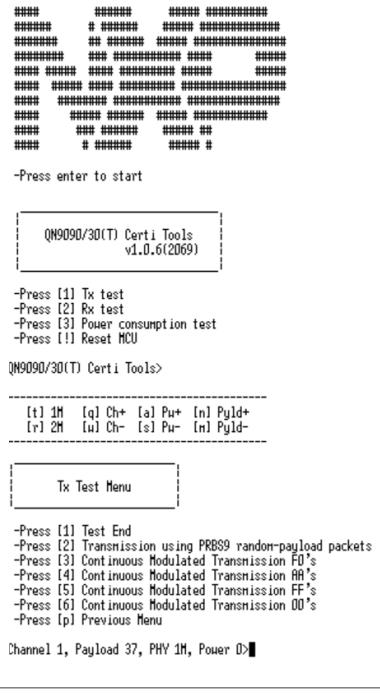
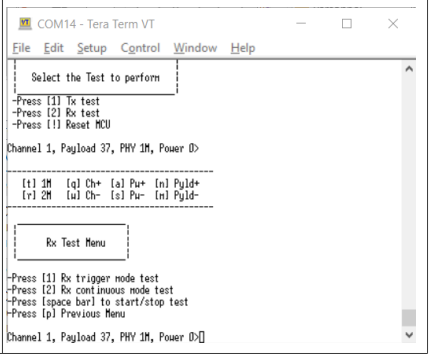
Section	K32W_certi_tool selection	Certi_tool evaluation software
Section 3.1.2 Frequency accuracy	[1], [5] or [6]	
Section 3.1.3 Phase noise	[1], [5] or [6]	
Section 3.1.4 TX power (fundamental)	[1], [5] or [6], then [q] or [w]	
Section 3.1.5 TX power in band	[1], [2], [t] or [r]	
Section 3.1.6 TX spurious	[1], [2], [t] or [r]	
Section 3.1.7 Upper band edge	[1], [2], [t] or [r], [q] up to channel 39	
Section 3.1.8 Modulation characteristics	On CMW equipment	
Section 3.1.9 Carrier frequency offset and drift	On CMW equipment	

2. For tests in Receive mode:

Section	K32W_certi_tool selection	Certi_tool evaluation software
Section 3.2.4 RX Spurious	[2], [2]	
Section 3.3 RX return loss		

3. For PER test and interferer test:

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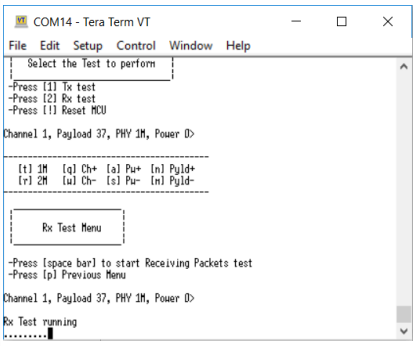
Section	K32W_certi_tool selection	Certi_tool evaluation software
Section 3.2.2 RX sensitivity Section 3.2.3 Receiver maximum input level	[2], [q] or [w], [t] or [r], Space bar	
Section 3.2.5.1 Adjacent and alternate channels with standard interferers Section 3.2.5.1 N-3 and N+3 channels with standard interferers Section 3.2.5.1 Co-channel Section 3.2.5.2 Receiver blocking		

Received packets are counted during 15 seconds and ratio of **packets received** to **sent packets** is calculated and displayed.
If no packets are received, PER is 100 % as follows:

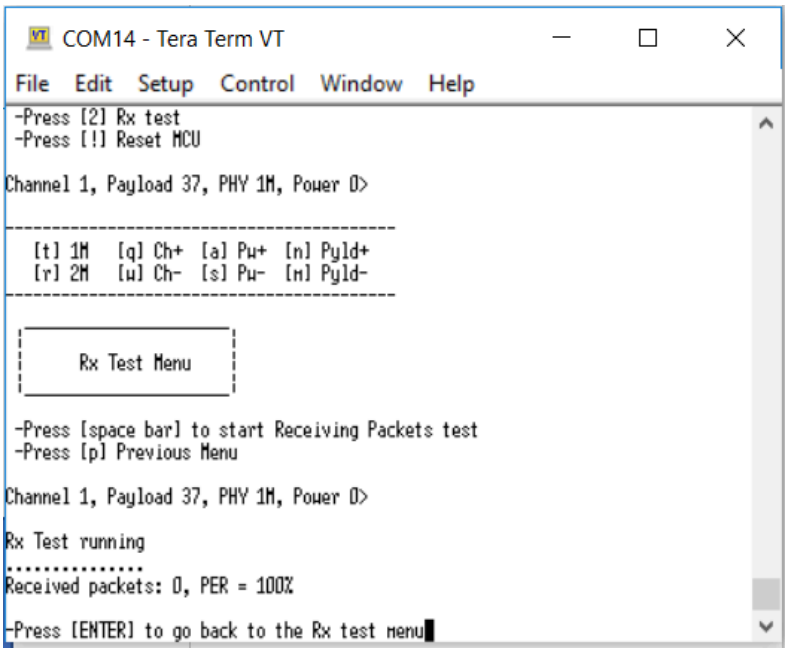


Figure 47. Example for no received packets

5 References

The references used to supplement this application note are as follows:

- **ETSI EN 300 328:** European telecommunication standard - Radio Equipment and Systems (RES) wideband data transmission systems, technical characteristics, and test conditions for data transmission equipment operating in the 2.4 GHz ISM band, using spread spectrum modulation techniques.
- **RF-PHY TS 4.2.0/5.0:** Bluetooth Test Specification. This document defines test structures and procedures for qualification testing of Bluetooth implementations of the Bluetooth Low Energy RF PHY.
- **FCC Part 15:** Operation to FCC Part 15 is subject to two conditions. First, the device may not cause harmful interference and, second, the device must accept any interference received, including interference that may cause undesired operation. Therefore, there is no guaranteed quality of service when operating a Part 15 device.

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6 Revision history

The Table 1 lists the substantive changes done to this document since the initial release.

Table 15. Revision history

Revision number	Date	Substantive changes
0	30 October 2020	Initial release
1	20 March 2023	• Added metadata to this document • Image updates • Multiple editorial changes • Multiple images and graphs are updated to SVG format • Revision history section added

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Date of release: 20 March 2023
Document identifier: AN12610