

AN13728

K32W1 RF System Evaluation Report for Bluetooth Low Energy and 802.15.4 Applications

Rev. 1 — 27 March 2023

Application note

Document information

Information	Content
Keywords	K32W148, RF system, Bluetooth LE
Abstract	This document provides the RF evaluation test results of K32W148 EVK board for Bluetooth LE (2FSK modulation) and 802.15.4 (OQPSK modulation) applications.



1 Introduction

This document provides the RF evaluation test results of the K32W148 EVK board for Bluetooth LE (2FSK modulation) and 802.15.4 (OQPSK modulation) applications. It includes the test setup description and the tools used to perform the tests on your own. To get more K32W148 Bluetooth LE and 802.15.4 radio parameters, see the *K32W14x Data Sheet* (document [K32W1480](#)).

For more information about the K32W148-EVK, see the *K32W148-EVK Board User Manual* (document [K32W148-EVKUM](#)). Find the schematic and design files at [K32W148](#) page.

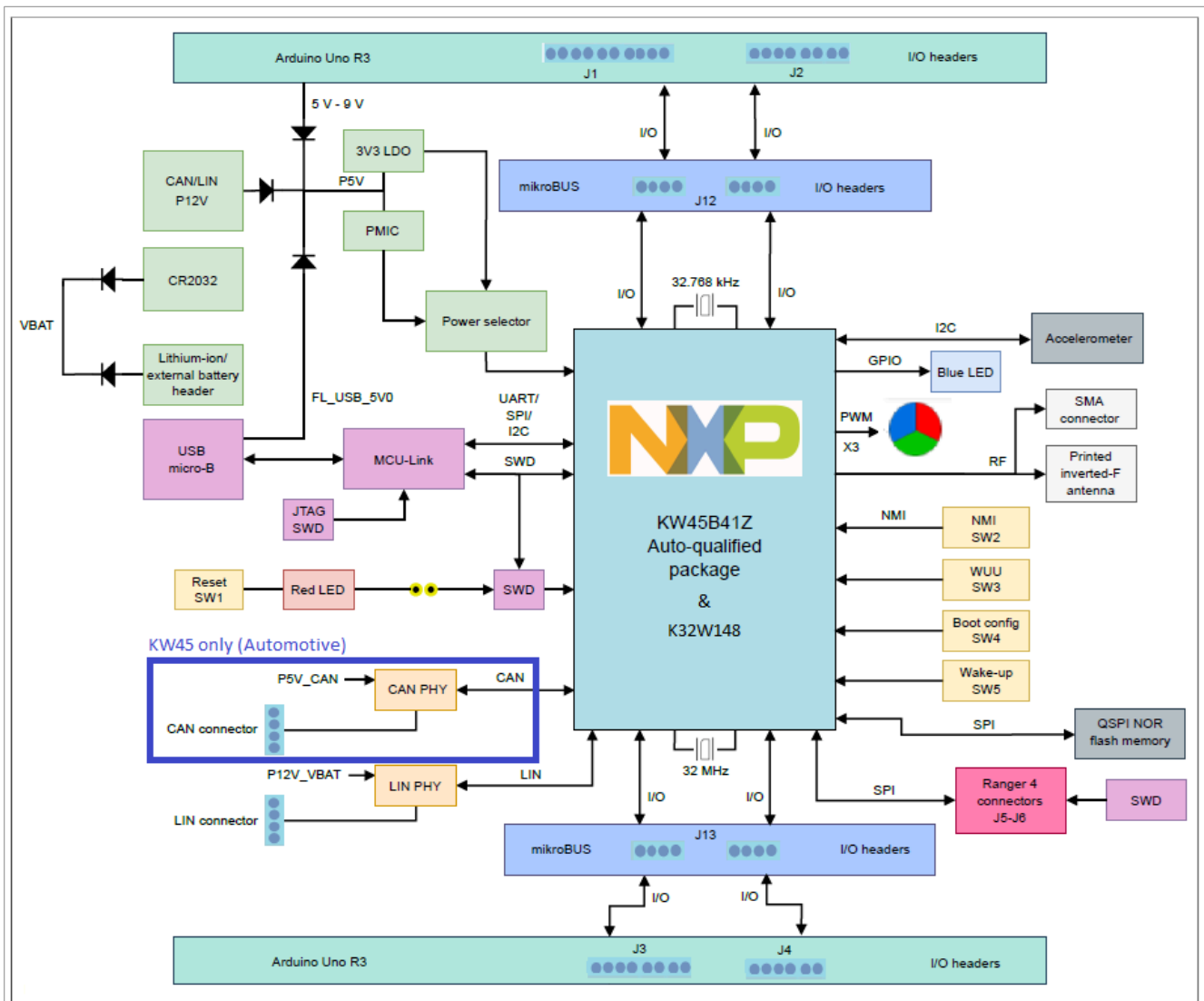


Figure 1. K32W148-EVK block diagram

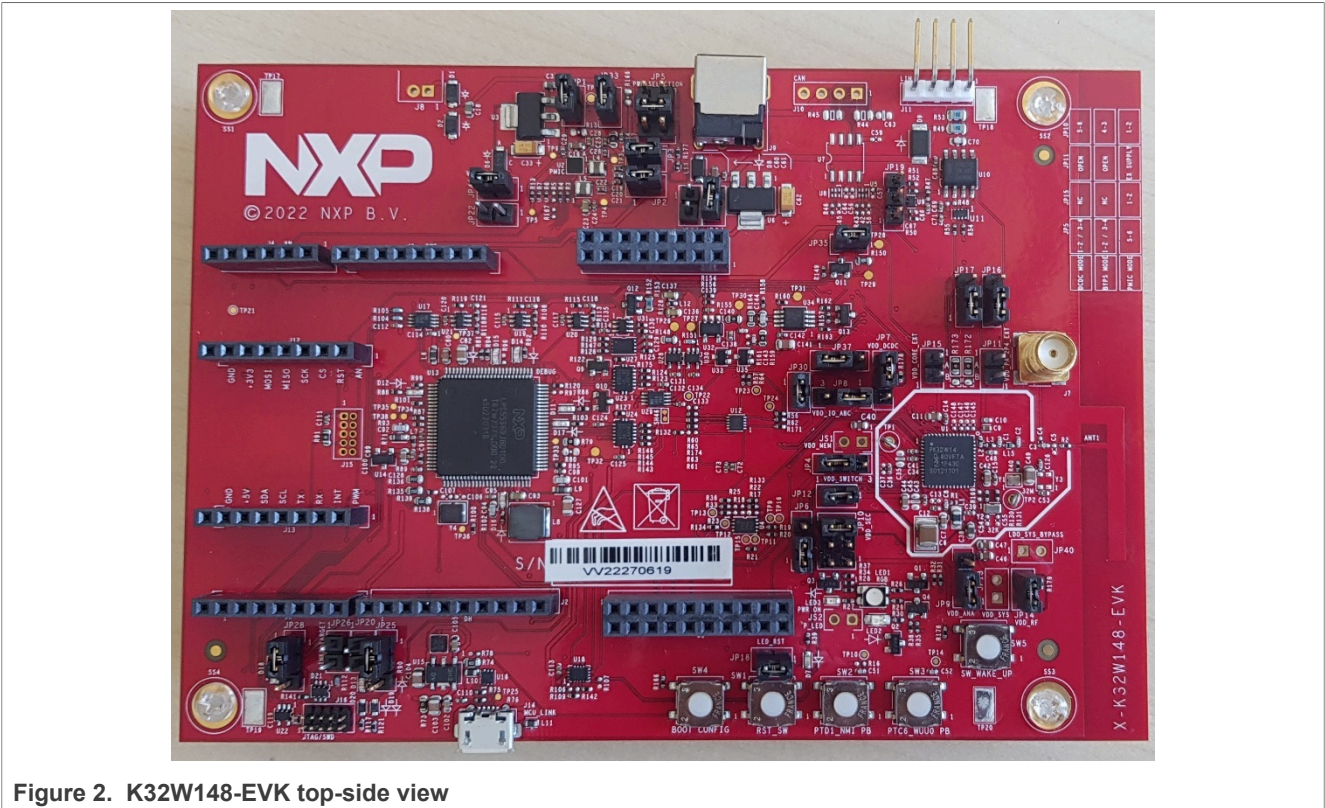


Figure 2. K32W148-EVK top-side view

2 Software and list of equipment

Before measuring, load a binary code (connectivity software) into the flash memory of the board.

The [Secure and Ultra-Low-Power MCU for Matter over Thread™ and Bluetooth® LE 5.3](#) webpage describes how to use K32W148-EVK to load the code for the Bluetooth LE or 802.15.4. The binary code used for the following tests is the Connectivity Software package for both Bluetooth LE and 802.15.4. For the explanation settings, see the *K32W148 Connectivity Test for 802.15.4 Application* (document [AN13687](#)) and the HCI_blackbox for Bluetooth LE only. The TERATERM terminal emulator is used to communicate with the K32W1 MCU.

2.1 List of equipment for Bluetooth

The equipment is used to perform the RX and TX measurements.

1. Spectrum analyzer: 25 GHz for harmonic measurements up to H10
2. R and S SFU, used as an interferer source for 802.15.4, could be any generator with ARB
3. MXG (Agilent N5182A)
4. R&S CMW270 (HCI_bbx software)
5. Agilent SML03
6. Agilent 33250A
7. R&S ZND vector network analyzer: for S11 measurements
8. RF Shielded box (to avoid interferers) and RF horn (for radiated measurements)
9. Power supply
10. PC equipped with a GPIB card

2.2 List of equipment for 802.15.4

1. R&S FSV: spectrum analyzer with 802.15.4 PHY test option
2. Keysight N5182B could be any generator with ARB
3. Keysight E8267D, used as an interferer source for 802.15.4, could be any generator with ARB
4. Spectrum analyzer: 25 GHz for harmonic measurements up to H10
5. R&S ZND vector network analyzer: for S11 measurements
6. Shielded room

Note: The K32W148 EVK VV21290023 is used to perform all 802.15.4 RF test measurements.

3 Bluetooth LE application

3.1 List of tests

Conducted tests

- TX tests
 - Bench setup
 - Frequency accuracy
 - Phase noise
 - TX power Bluetooth LE 1 Msps, 2 Msps, 500 ksps (LR S=2), 125 ksps (LR S=8)
 - TX power in-band
 - TX spurious (H2 to H10, ETSI, and FCC)
 - Lower band edge (MIIT-China)
 - Upper band edge
 - Maximum TX output power 1 Msps, 2 Msps, 500 ksps (LR S=2), 125 ksps (LR S=8)
 - Bluetooth LE TX output spectrum 1 Msps, 2 Msps
 - Modulation characteristics 1 Msps, 2 Msps, 125 ksps LR (S=8)
 - Carrier frequency offset and drift 1 Msps, 2 Msps, 125 ksps LR (S=8)
- RX tests
 - Bench setup
 - Sensitivity 1 Msps, 2 Msps, LR (S=2 and S=8)
 - Bathtub 1 Msps, 2 Msps, LR (S=2 and S=8)
 - Receiver maximum input level 1 Msps, 2 Msps, LR (S=2 and S=8)
 - RX spurious (from 30 MHz to 12.5 GHz)
 - Receiver interference rejection performances
 - Adjacent, Alternate, and Co channel rejection – 1 Msps, 2 Msps, 500 ksps (LR S=2), 125 ksps (LR S=8)
 - Receiver blocking – 1 Msps – cat.1 and cat.2
 - Blocking interferers
 - Intermodulation

3.2 Test summary

RF PHY Bluetooth Test Specification: RF-PHY.TS.5.0.2 (2017-12-07)

The list of measurements is given in [Table 1](#) for Europe and [Table 2](#) for US.

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Table 1. List of tests (Europe)

		Reference	Limit	Status
Transmission	TX maximum Output Power	Bluetooth LE 5.0, BV-01-C	-20 dBm ≤ PAVG ≤ +10 dBm EIRP	PASS
	TX power in-band – 1 Msps	Bluetooth LE 5.0, BV-03-C	P _{TX} ≤ -20 dBm for (f _{TX} +/- 2 MHz)	PASS
			P _{TX} ≤ -30 dBm for (f _{TX} +/- [3 + n] MHz);	
	TX power in-band – 2 Msps	Bluetooth LE 5.0, BV-08-C	P _{TX} ≤ -20 dBm for (f _{TX} +/- 4 MHz) and (f _{TX} +/- 5 MHz)	PASS
			P _{TX} ≤ -30 dBm for (f _{TX} +/- [3 + n] MHz);	
	Modulation characteristics 1 Msps LE coded (S=8)	Bluetooth LE 5.0, BV-05-C Bluetooth LE 5.0, BV-13-C	225 kHz ≤ delta f1avg ≤ 275 kHz	PASS
	Modulation characteristics 2 Msps	Bluetooth LE 5.0, BV-10-C	450 kHz ≤ delta f1avg ≤ 550 kHz	PASS
	Carrier frequency offset and drift 1 Msps	Bluetooth LE 5.0, BV-06-C	f _{TX} – 150 kHz ≤ fn ≤ f _{TX} + 150 kHz where f _{TX} is the nominal transmit frequency and n = 0,1,2,3...k f ₀ – fn ≤ 50 kHz where n=2,3,4...k	PASS
	Carrier frequency offset and drift 2 Msps	Bluetooth LE 5.0, BV-12-C	f ₀ – f ₃ ≤ 19.2 kHz f ₀ – f(n-3) ≤ 19.2 kHz where n=7,8,9,...k	PASS
	Carrier frequency offset and drift LE coded (S=8)	Bluetooth LE 5.0, BV-14-C	f _{TX} – 150 kHz ≤ fn ≤ f _{TX} + 150 kHz where f _{TX} is the nominal transmit frequency and n=0,1,2,3...k f ₀ – fn ≤ 50 kHz where n=2,3,4...k	PASS
	Spurious 30 MHz - 1 GHz	ETSI EN 300 328 v2.2.1 (2019-04)	-36 dBm or -54 dBm (depends on frequency) (100 kHz BW)	PASS
	Spurious 1 GHz - 25 GHz	ETSI EN 300 328 v2.2.1 (2019-04)	-30 dBm (1 MHz BW)	PASS
	Eirp TX spectral density	ETSI EN 300 328 v2.2.1 (2019-04)	10 dBm/MHz	PASS
Phase noise (unspread)	NA	NA	For information	
Reception	RX sensitivity - 1 Msps	Bluetooth LE 5.0, BV-01-C	PER 30.8 % with a minimum of 1500 packets	PASS

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Table 1. List of tests (Europe)...continued

		Reference	Limit	Status
	RX sensitivity - 2 Msps	Bluetooth LE 5.0, BV-08-C	PER 30.8 % with a minimum of 1500 packets	PASS
	RX sensitivity - LE coded (S=2)	Bluetooth LE 5.0, BV-26-C	PER 30.8 % with a minimum of 1500 packets	PASS
	RX sensitivity - LE coded (S=8)	Bluetooth LE 5.0, BV-27-C	PER 30.8 % with a minimum of 1500 packets	PASS
	Co-channel - 1 Msps	Bluetooth LE 5.0, BV-03-C	> 21 dB	PASS
	Co-channel - 2 Msps	Bluetooth LE 5.0, BV-09-C	> 21 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+MHz) - 2 Msps	Bluetooth LE 5.0, BV-09-C	> 15 dB, -17 dB, -27 dB	PASS
	Co-channel - LE coded (S=2)	Bluetooth LE 5.0, BV-28-C	> 17 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+ MHz) LE coded (S=2)	Bluetooth LE 5.0, BV-09-C	> 11 dB, -21 dB, -31 dB	PASS
	Co-channel - LE coded (S=8)	Bluetooth LE 5.0, BV-28-C	> 12 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+ MHz) LE coded (S=8)	Bluetooth LE 5.0, BV-09-C	> 6 dB, -26 dB, -36 dB	PASS
Blocking interferers				
	1 Msps	Bluetooth LE 5.0, BV-04-C	-30 dBm (30 MHz-2 GHz and 3-12.5 GHz)	PASS
	2 Msps	Bluetooth LE 5.0, BV-010-C	-35 dBm (2003-2399 MHz and 2484-2997 MHz)	
Intermodulation				
	1 Msps	Bluetooth LE 5.0, BV-05-C	PER 30.8 % with a minimum of 1500 packets	PASS
	2 Msps	Bluetooth LE 5.0, BV-11-C		
RX maximum input level				
	1 Msps	Bluetooth LE 5.0, BV-06-C	PER 30.8 % with a minimum of 1500 packets	PASS
	2 Msps	Bluetooth LE 5.0, BV-12-C		
	RX emissions 30 MHz - 1 GHz	ETSI EN 300 328 v2.2.1 (2019-04)	-57 dBm (100 kHz)	PASS

Table 1. List of tests (Europe)...continued

		Reference	Limit	Status
	RX emissions 1 GHz - 12.5 GHz	ETSI EN 300 328 v2.2.1 (2019-04)	-47 dBm (1 MHz)	PASS
Misc.	Return loss (S11)	Return loss in TX mode	For information	
		Return loss in TX mode	For information	

Table 2. List of tests (US)

		Reference	Limit	Status
Transmission	TX maximum power	FCC part15.247	PAVG ≤ 100 mW +20 dBm EIRP	PASS
	Spurious 1 GHz - 25 GHz	FCC part15.249	field strength < 50 mV/m @3m -41.12 dBm (1 MHz BW)	PASS

3.3 Conducted tests

3.3.1 TX tests

3.3.1.1 Test setup

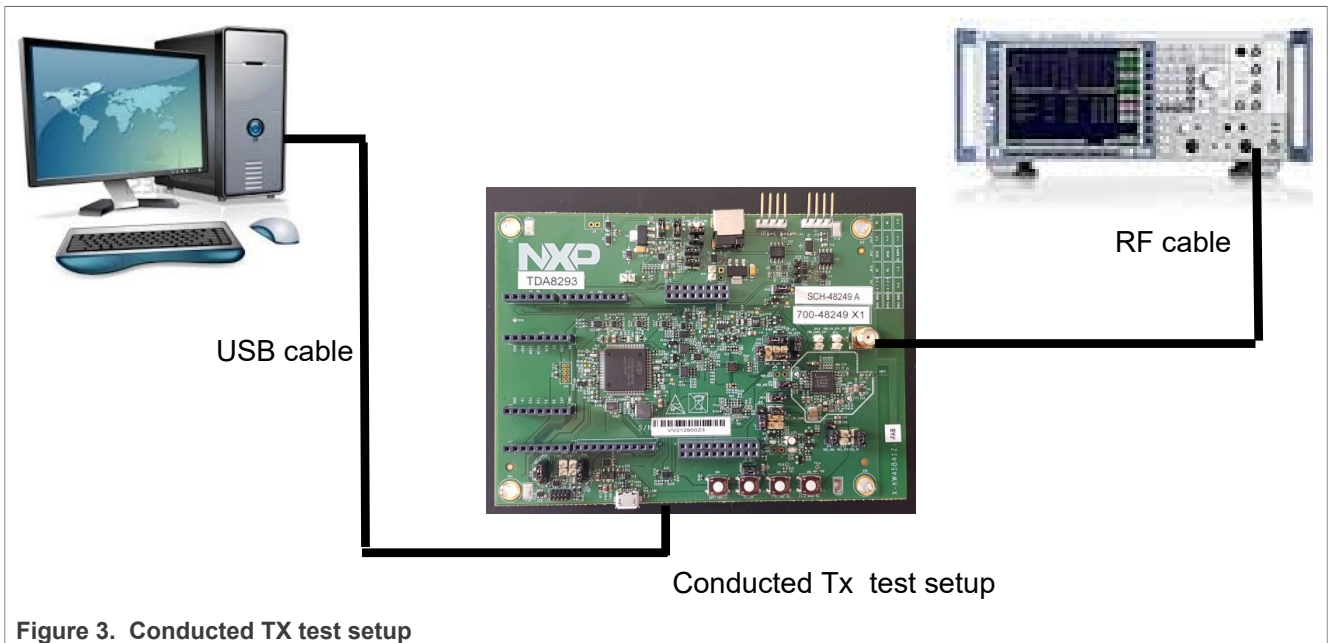


Figure 3. Conducted TX test setup

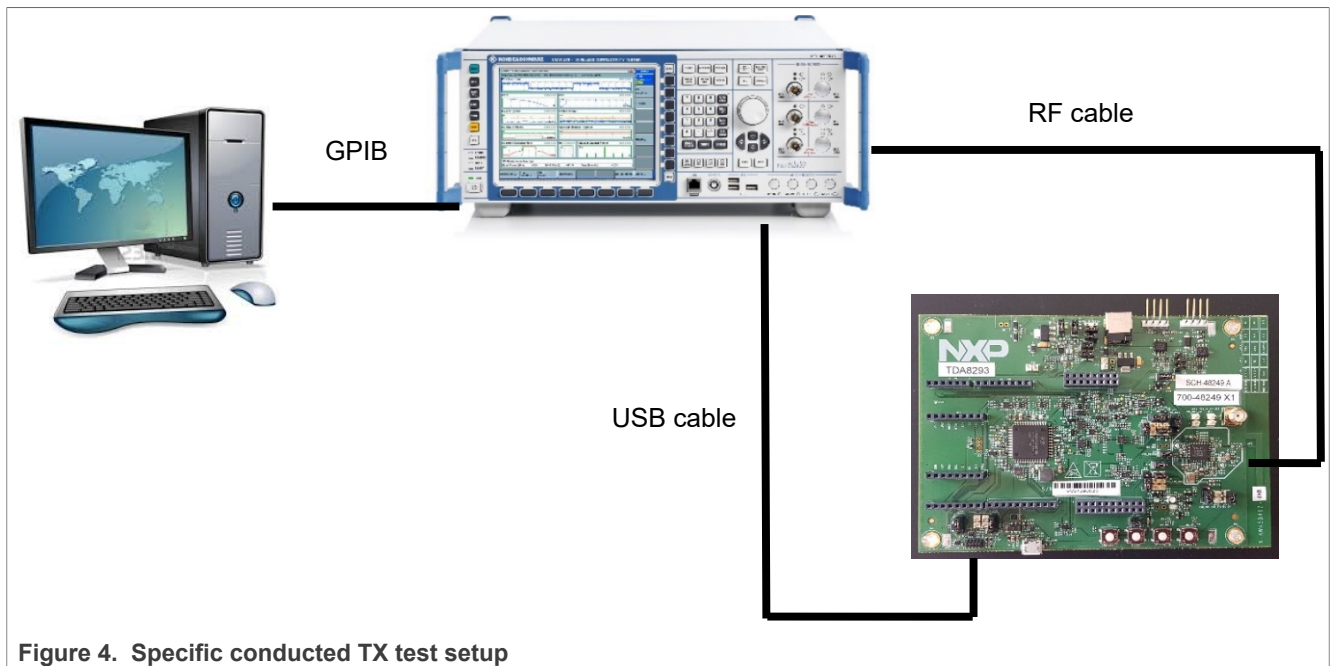


Figure 4. Specific conducted TX test setup

3.3.1.2 Frequency accuracy

Test method:

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

Result:

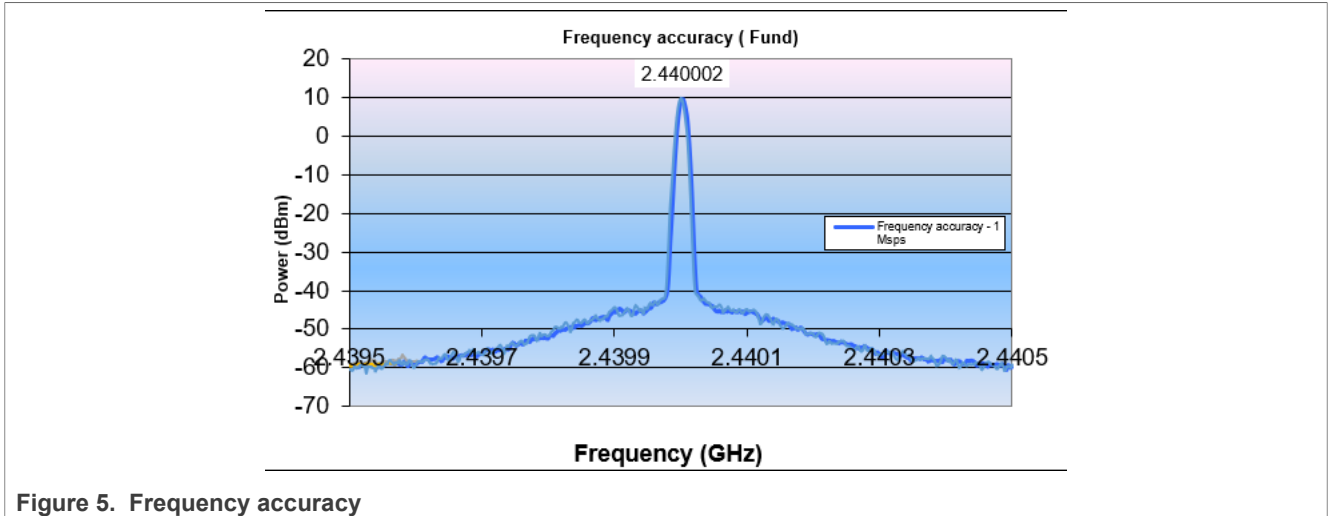


Figure 5. Frequency accuracy

- Measured frequency: 2.44004 GHz
- ppm value = $(2.440020 - 2.440000) / 2.440 = +0.8$ ppm

Table 3. Frequency accuracy

Result	Target
+0.8 ppm	+/-25 ppm

The frequency accuracy depends on the XTAL model. The model used on EVK is NX2016SA EXS00A-CS14160 (NDK).

Conclusion:

- The frequency accuracy complies with the data sheet.

3.3.1.3 Phase noise

Test method:

- Set the radio to:
 - TX mode
 - CW
 - Continuous mode
 - Frequency: Channel 19
- Set the analyzer to:
 - Center frequency = 2.44 GHz
 - Span = 1 MHz
 - Ref amp = 20 dBm
 - RBW = 10 kHz
 - VBW = 100 kHz
- Measure the CW frequency with the marker of the spectrum analyzer.
 - RBW (spectrum analyzer) = 10 kHz ($20 \log(10 \text{ kHz}) = 40$ dBc)

Result:

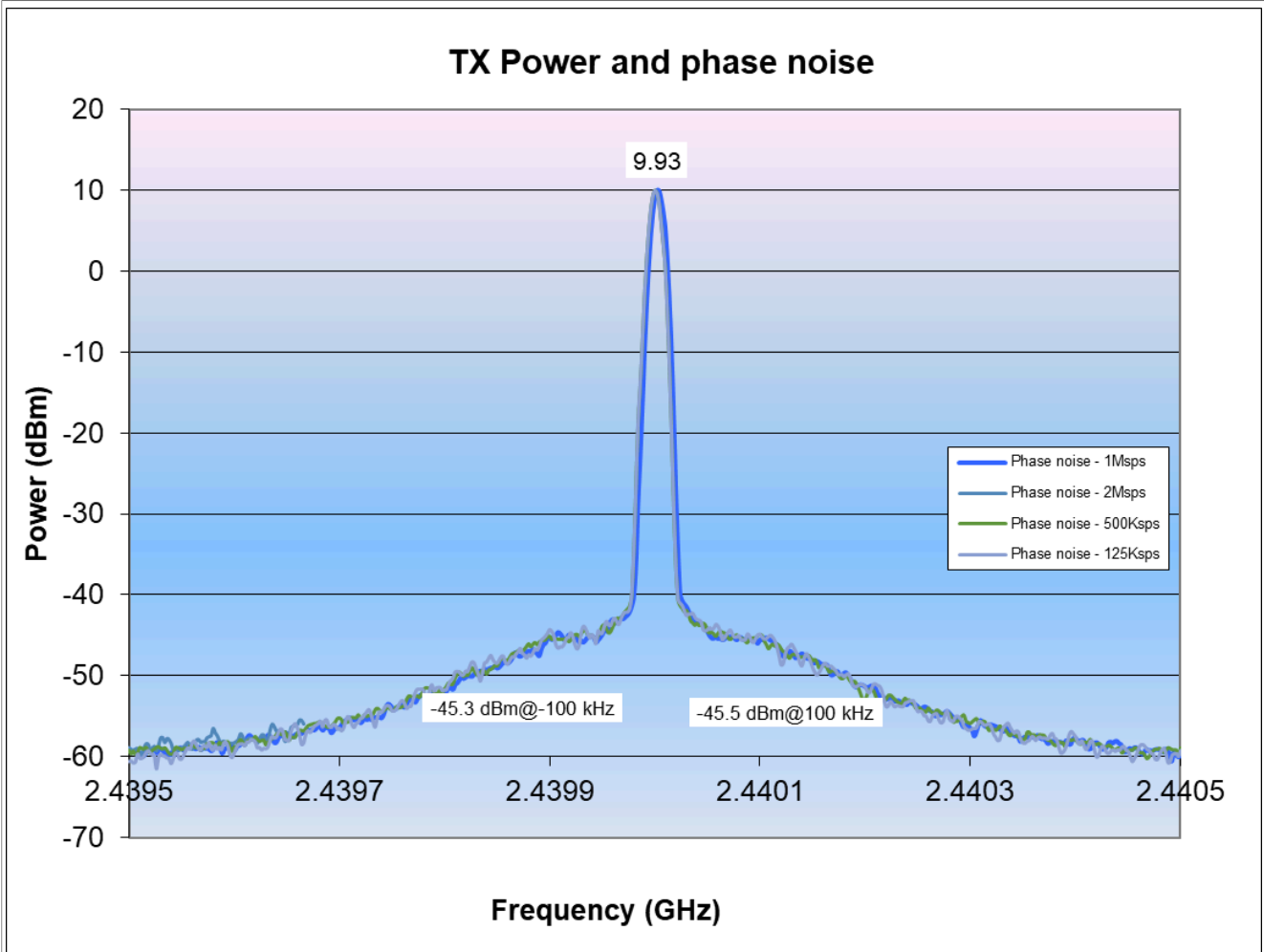


Figure 6. Conducted phase noise

- Marker value (delta) = -45.3 dBm/100 kHz = -95.3 dBc/Hz

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

3.3.1.4 TX power (fundamental)

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
 - Data rate: 1 Msps, 2 Msps, 500 ksps, 125 ksps for Bluetooth LE
- Set the analyzer to:
 - Start freq = 2.4 GHz
 - Stop freq = 2.5 GHz
 - Ref amp = 10 dBm
 - Sweep time = 100 ms
 - RBW = 3 MHz
 - VBW = 3 MHz

- Max Hold mode
- Detector = RMS
- Sweep all the channels from channel 0 to channel 39 for Bluetooth LE and channel.
 - Software tools allow sweep from 2.36 GHz to 4.88 GHz

Result:

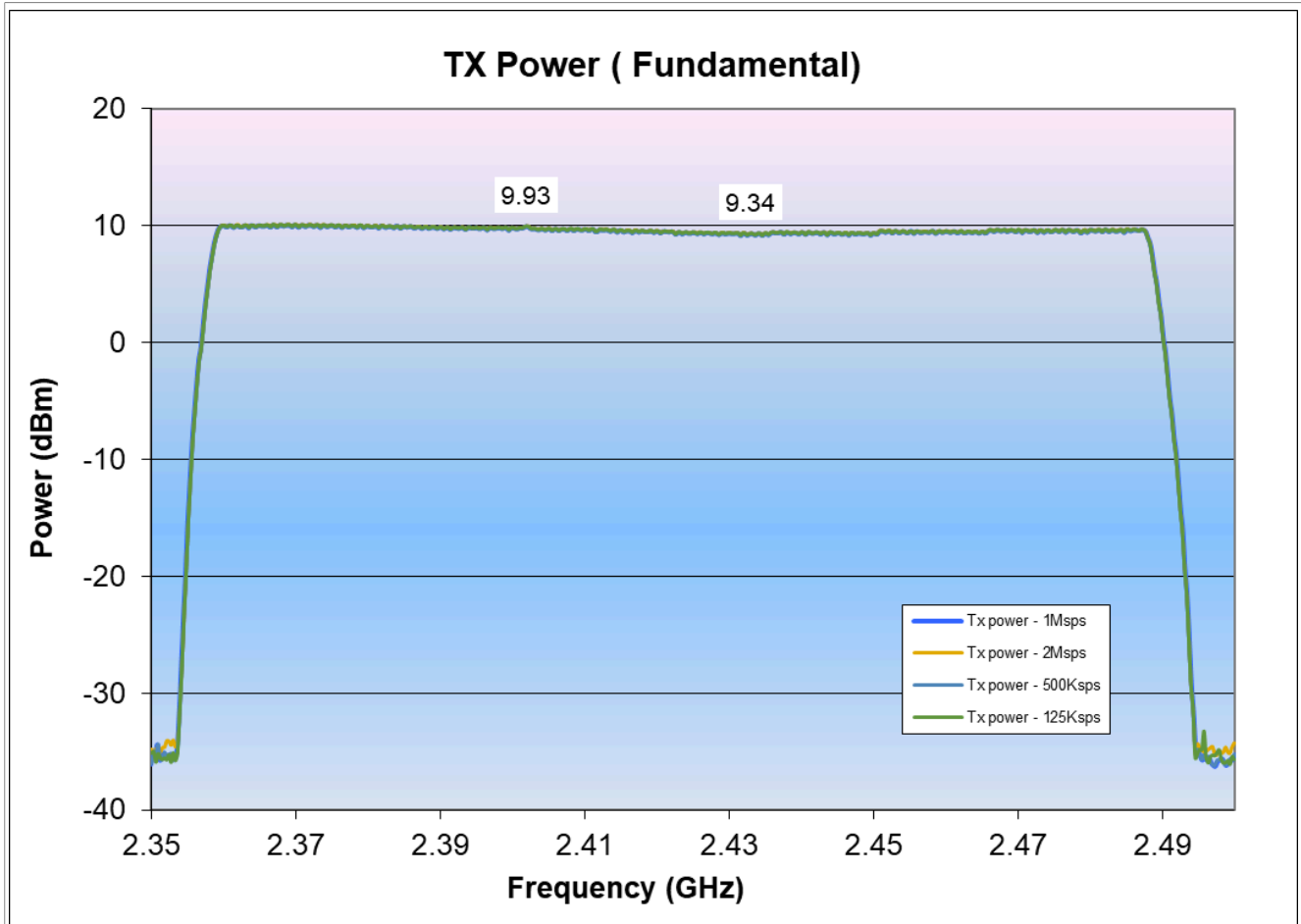


Figure 7. TX power

- Maximum power is on channel 0: 9.93 dBm
- Minimum power is on channel 15: 9.34 dBm
- Tilt over frequencies is: 0.6 dB

Conclusion:

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

3.3.1.5 TX power in-band

Test method:

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- Set the radio to:
 - TX mode, modulated, continuous mode, data rate (1 Msps, 2 Msps, 500 ksps, 125 ksps)
- Set the analyzer to:
 - Start freq = 2.35 GHz, Stop freq = 2.5 GHz, Ref amp = 10 dBm, sweep time = 100 ms
 - RBW = 100 kHz, Video BW = 300 kHz
 - Max Hold mode
 - Detector = RMS
 - Number of Sweeps = 10
- Sweep on channel 2, channel 19, and channel 37

Result:

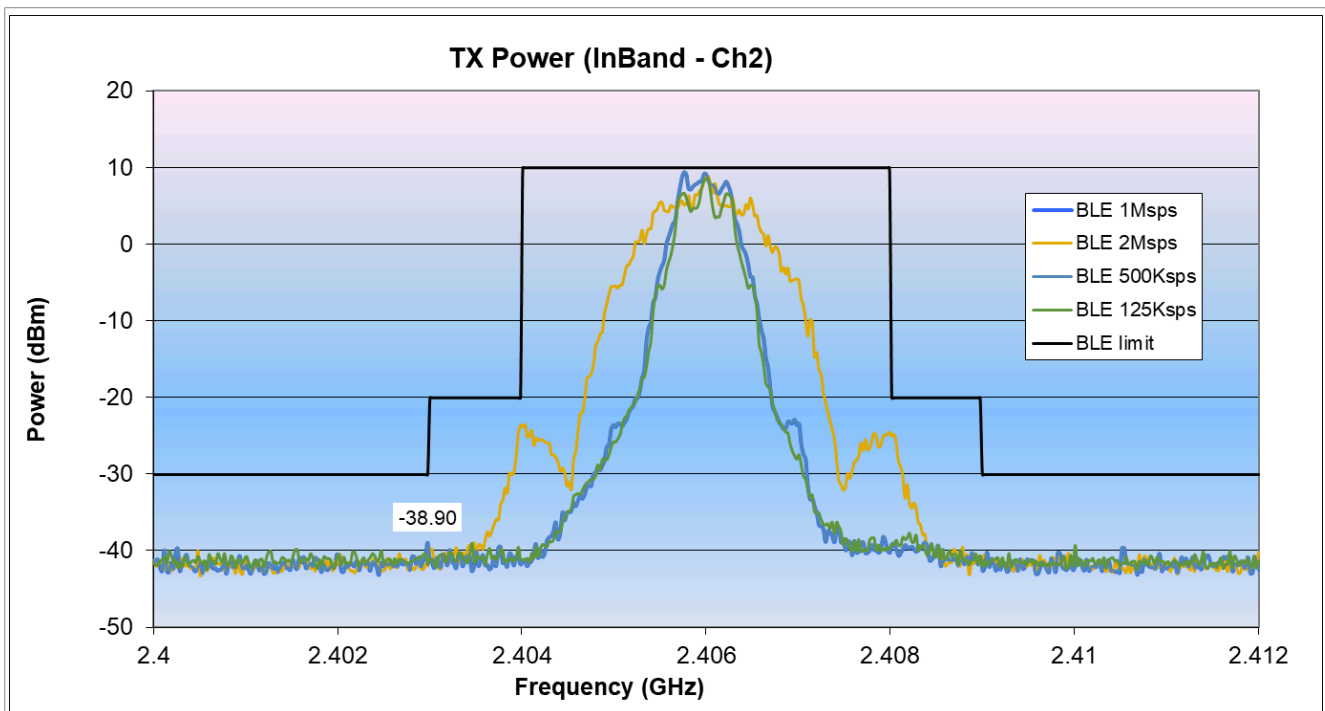


Figure 8. TX power in-band – Channel 2

Table 4. Bluetooth LE 1 Msps

Max peak level <=-2 MHz	-39.43	dBm	@	2.404	GHz
Max peak level >=+2 MHz	-38.84	dBm	@	2.408	GHz
Max peak level <=-3 MHz	-38.90	dBm	@	2.403	GHz
Max peak level >=+3 MHz	-39.62	dBm	@	2.411	GHz

Table 5. Bluetooth LE 2 Msps

Max peak level <=-2 MHz	-23.71	dBm	@	2.404	GHz
Max peak level >=+2 MHz	-24.88	dBm	@	2.408	GHz
Max peak level <=-3 MHz	-40.06	dBm	@	2.400	GHz
Max peak level >=+3 MHz	-40.27	dBm	@	2.412	GHz

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Table 6. Bluetooth LE 500 kbps

Max peak level <=-2 MHz	-39.43	dBm	@	2.404	GHz
Max peak level >=+2 MHz	-38.84	dBm	@	2.408	GHz
Max peak level <=-3 MHz	-38.90	dBm	@	2.403	GHz
Max peak level >=+3 MHz	-39.62	dBm	@	2.411	GHz

Table 7. Bluetooth LE 125 kbps

Max peak level <=-2 MHz	-39.10	dBm	@	2.403	GHz
Max peak level >=+2 MHz	-37.76	dBm	@	2.408	GHz
Max peak level <=-3 MHz	-39.93	dBm	@	2.402	GHz
Max peak level >=+3 MHz	-39.35	dBm	@	2.410	GHz

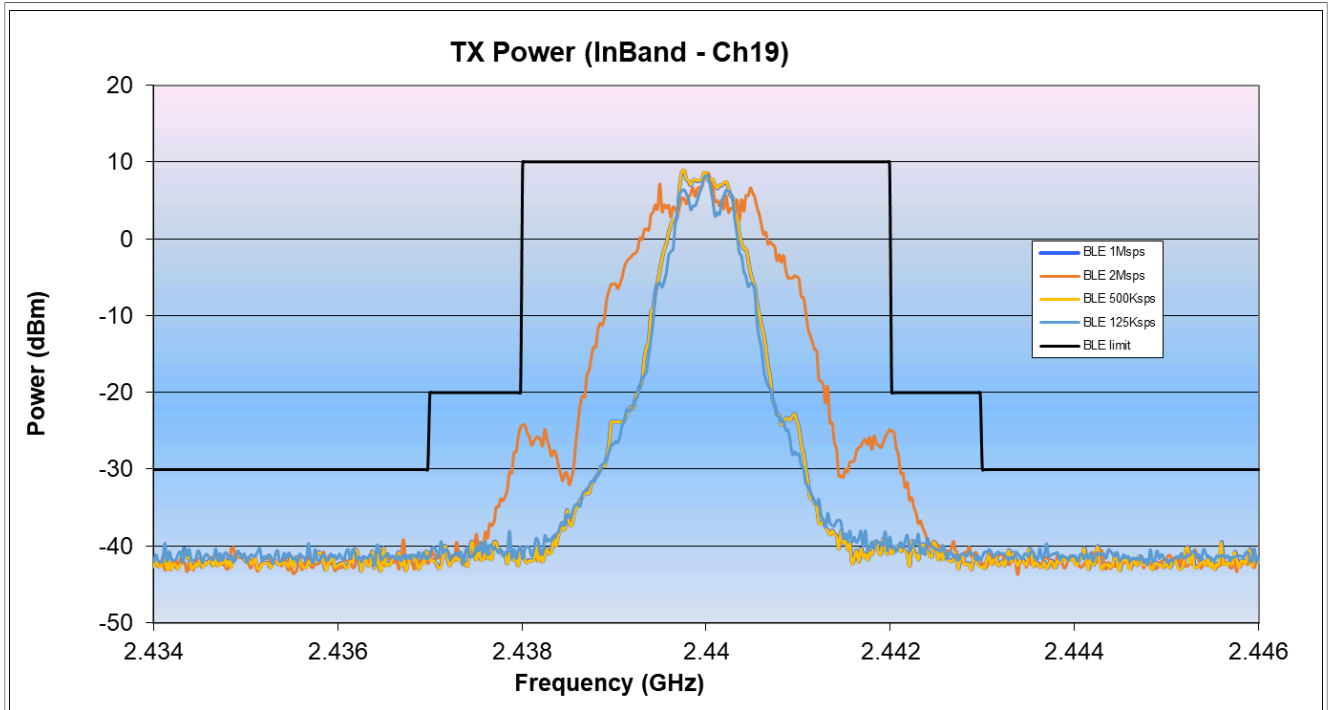


Figure 9. TX power in-band – Channel 19

Table 8. Bluetooth LE 1 Msp/s

Max peak level <=-2 MHz	-39.43	dBm	@	2.437	GHz
Max peak level >=+2 MHz	-39.37	dBm	@	2.442	GHz
Max peak level <=-3 MHz	-40.22	dBm	@	2.436	GHz
Max peak level >=+3 MHz	-39.49	dBm	@	2.446	GHz

Table 9. Bluetooth LE 2 Msp/s

Max peak level <=-2 MHz	-24.58	dBm	@	2.438	GHz
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Table 9. Bluetooth LE 2 Msps...continued

Max peak level $\geq +2$ MHz	-25.11	dBm	@	2.442	GHz
Max peak level ≤ -3 MHz	-39.18	dBm	@	2.437	GHz
Max peak level $\geq +3$ MHz	-40.54	dBm	@	2.445	GHz

Table 10. Bluetooth LE 500 kbps

Max peak level ≤ -2 MHz	-39.43	dBm	@	2.437	GHz
Max peak level $\geq +2$ MHz	-39.37	dBm	@	2.442	GHz
Max peak level ≤ -3 MHz	-40.22	dBm	@	2.436	GHz
Max peak level $\geq +3$ MHz	-39.49	dBm	@	2.446	GHz

Table 11. Bluetooth LE 125 kbps

Max peak level ≤ -2 MHz	-38.04	dBm	@	2.438	GHz
Max peak level $\geq +2$ MHz	-38.39	dBm	@	2.442	GHz
Max peak level ≤ -3 MHz	-39.60	dBm	@	2.434	GHz
Max peak level $\geq +3$ MHz	-39.63	dBm	@	2.444	GHz

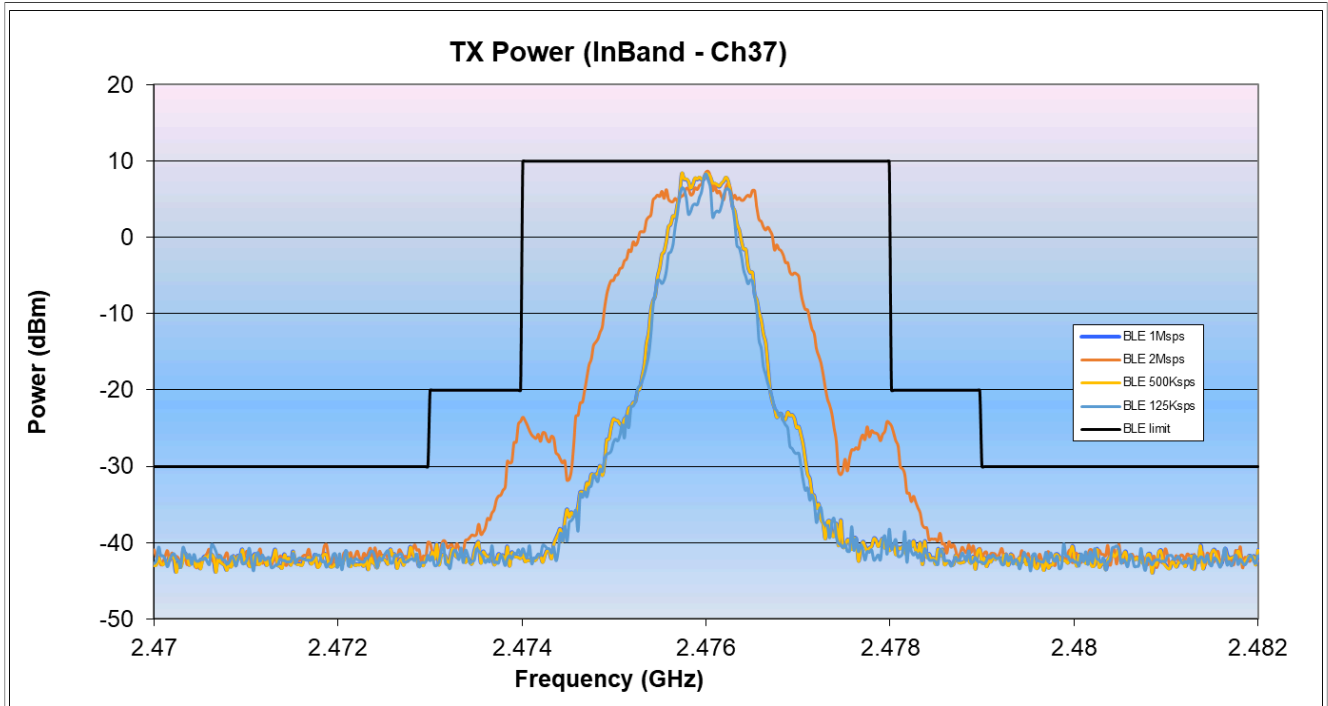


Figure 10. TX power in-band – Channel 37

Table 12. Bluetooth LE 1 Msps

Max peak level ≤ -2 MHz	-39.93	dBm	@	2.474	GHz
Max peak level $\geq +2$ MHz	-39.75	dBm	@	2.478	GHz
Max peak level ≤ -3 MHz	-40.56	dBm	@	2.473	GHz

Table 12. Bluetooth LE 1 Msps...continued

Max peak level $\geq +3$ MHz	-40.35	dBm	@	2.481	GHz
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Table 13. Bluetooth LE 2 Msps

Max peak level ≤ -2 MHz	-24.10	dBm	@	2.474	GHz
Max peak level $\geq +2$ MHz	-24.69	dBm	@	2.478	GHz
Max peak level ≤ -3 MHz	-39.96	dBm	@	2.473	GHz
Max peak level $\geq +3$ MHz	-40.21	dBm	@	2.480	GHz

Table 14. Bluetooth LE 500 ksp/s

Max peak level ≤ -2 MHz	-39.93	dBm	@	2.474	GHz
Max peak level $\geq +2$ MHz	-39.75	dBm	@	2.478	GHz
Max peak level ≤ -3 MHz	-40.56	dBm	@	2.473	GHz
Max peak level $\geq +3$ MHz	-40.35	dBm	@	2.481	GHz

Table 15. Bluetooth LE 125 ksp/s

Max peak level ≤ -2 MHz	-40.15	dBm	@	2.473	GHz
Max peak level $\geq +2$ MHz	-38.53	dBm	@	2.478	GHz
Max peak level ≤ -3 MHz	-40.24	dBm	@	2.471	GHz
Max peak level $\geq +3$ MHz	-40.15	dBm	@	2.480	GHz

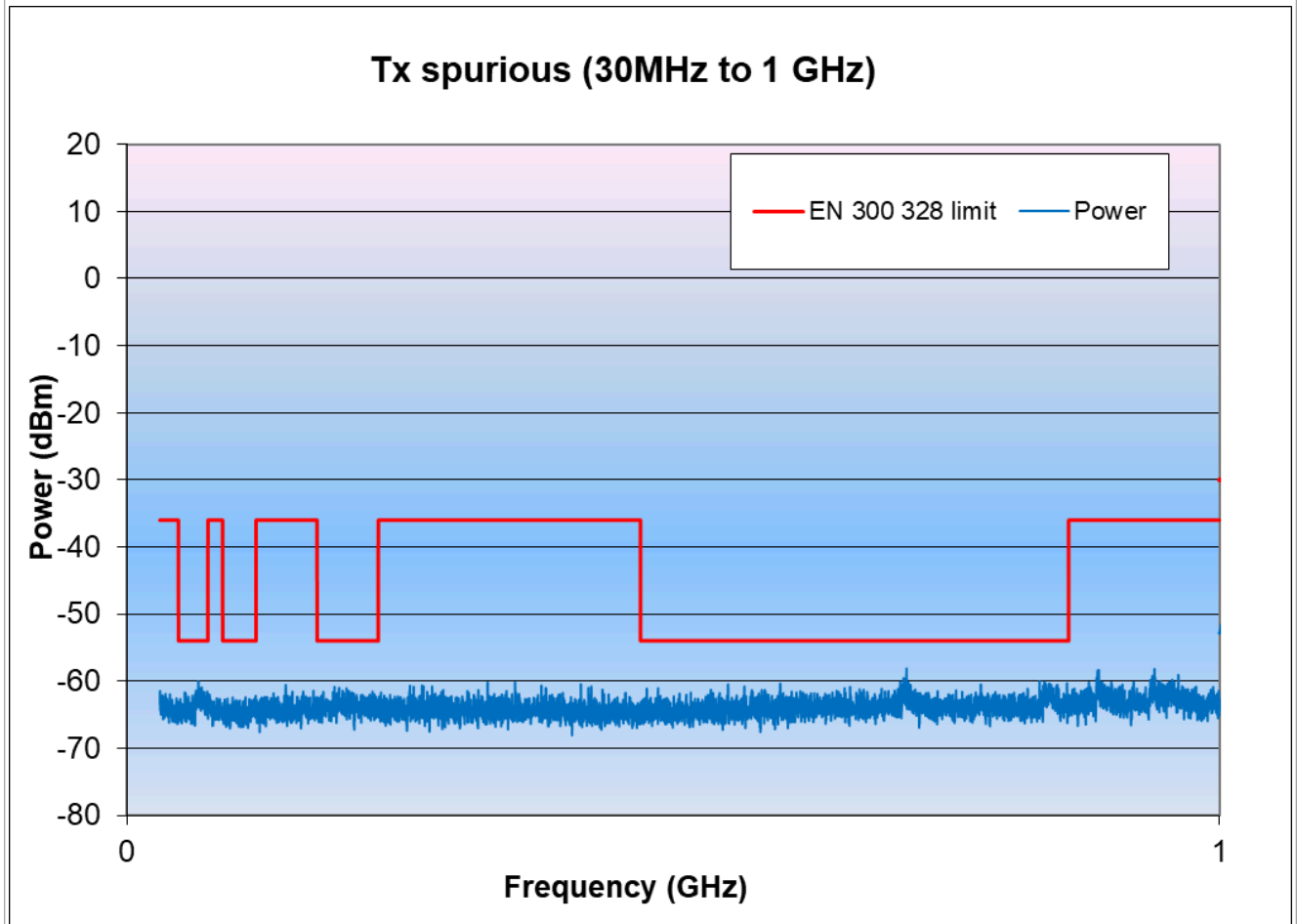
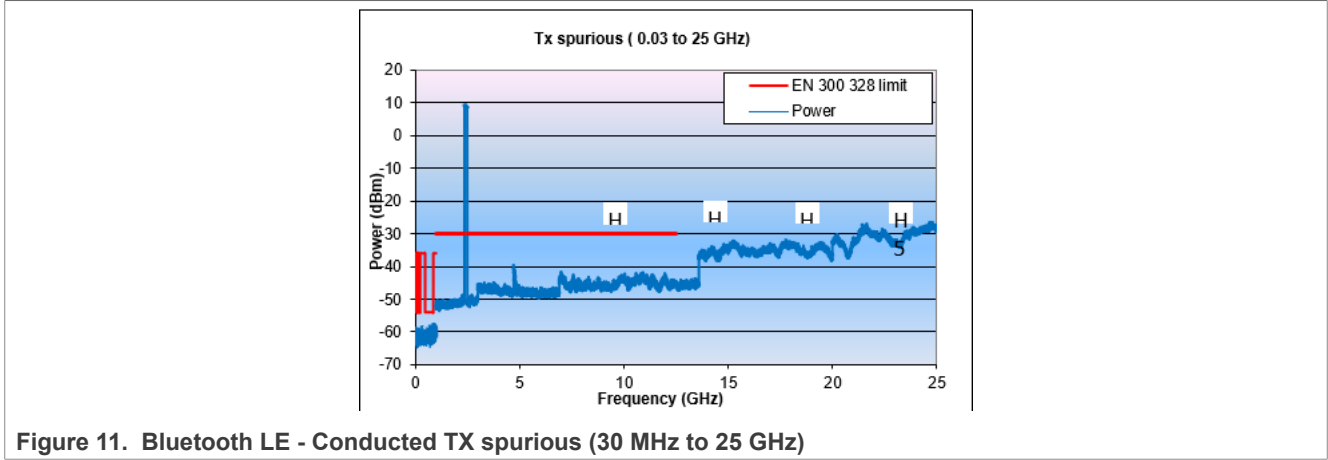
Conclusion:

- These results are compliant to Bluetooth LE 5.0.

3.3.1.6 TX spurious

3.3.1.6.1 30 MHz to 25 GHz

Spurious overview of the full band from 30 MHz to 25 GHz when the device is in the transmission mode.



Conclusion:

- There are no TX spurs above the EN 300 328 limit (more than 4 dB margin).
- Harmonics are measured in the following paragraphs.

3.3.1.6.2 H2 (ETSI test conditions, peak measurement)

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set the analyzer to:
 - Start freq = 4.7 GHz
 - Stop freq = 5 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - RBW = 1 MHz, VBW = 3 MHz
 - Max Hold mode
 - Detector: Peak
- Sweep all the channels from
 - Bluetooth LE: Channel 0 to Channel 39

Result:

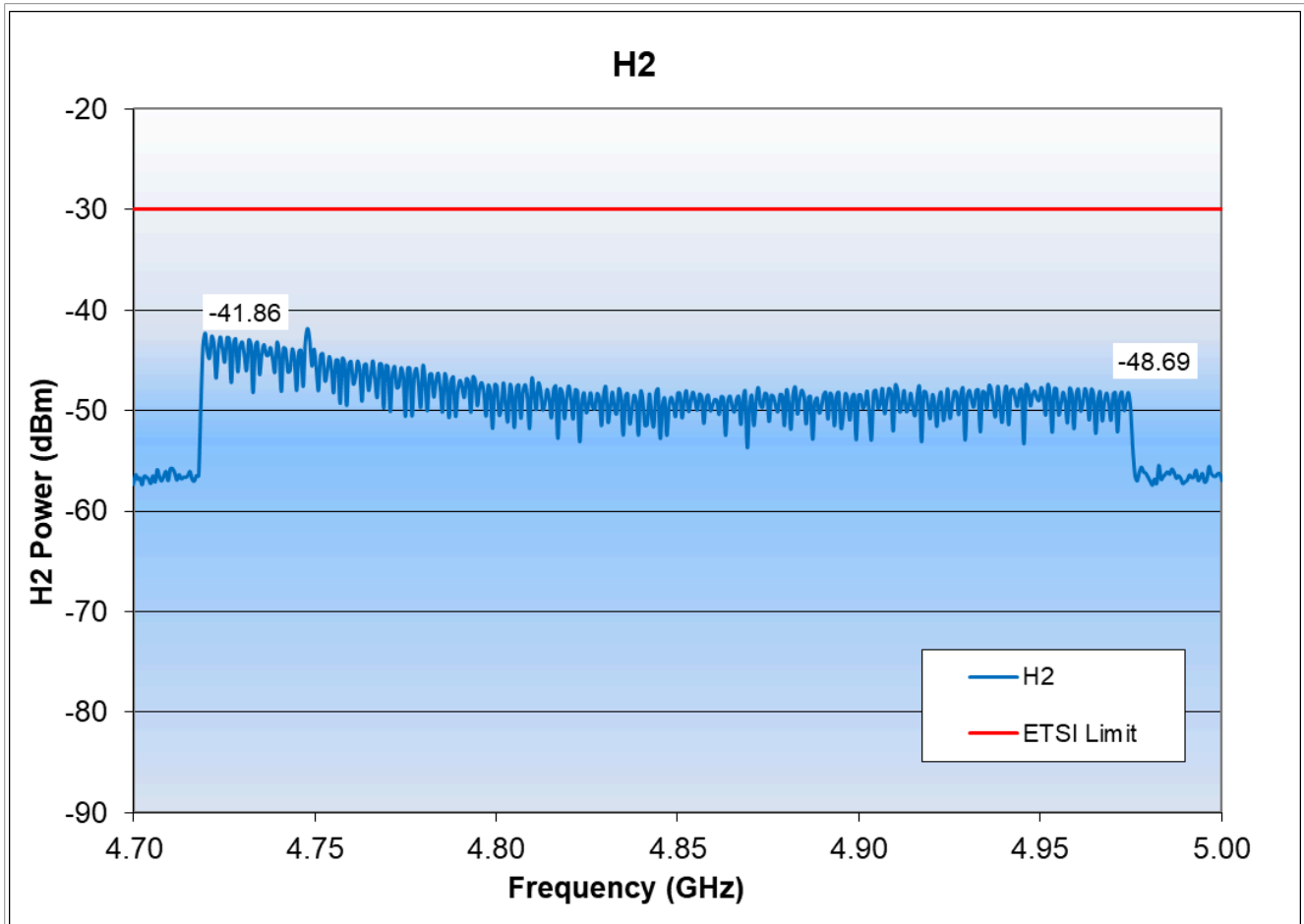


Figure 13. Bluetooth LE - Conducted H2 spurious

- Maximum power is at frequency 4.748 GHz: -41.86 dBm.

Conclusion:

- There is more than **11 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.3 H3 (ETSI test conditions, peak measurement)

Test method:

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

Result:

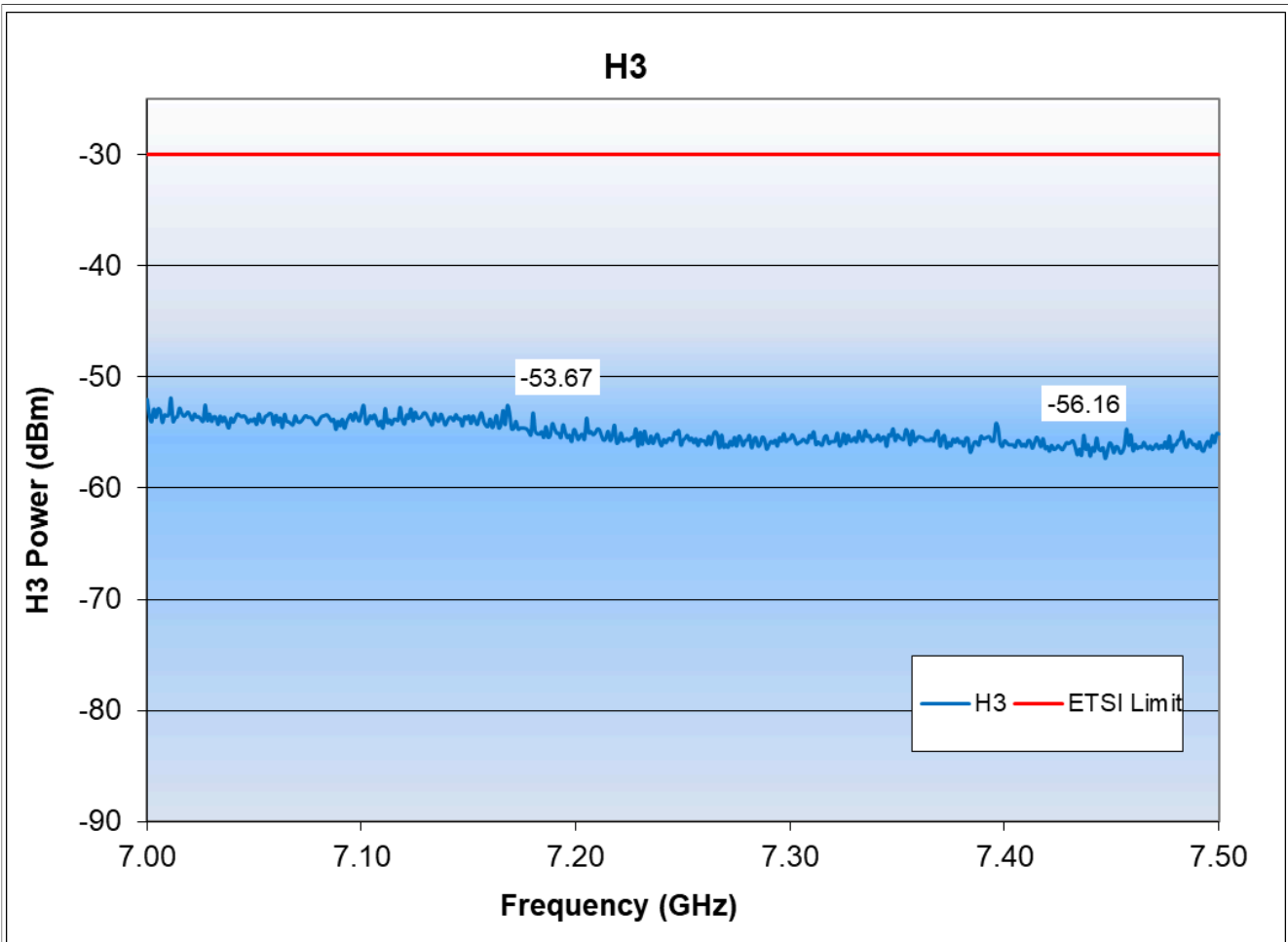


Figure 14. Bluetooth LE - Conducted H3 spurious

- Maximum power is at frequency 7.098 GHz: -53.67 dBm.

Conclusion:

- There is more than **23 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.4 H4 (ETSI test conditions, peak measurement)

Test method:

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

Result:

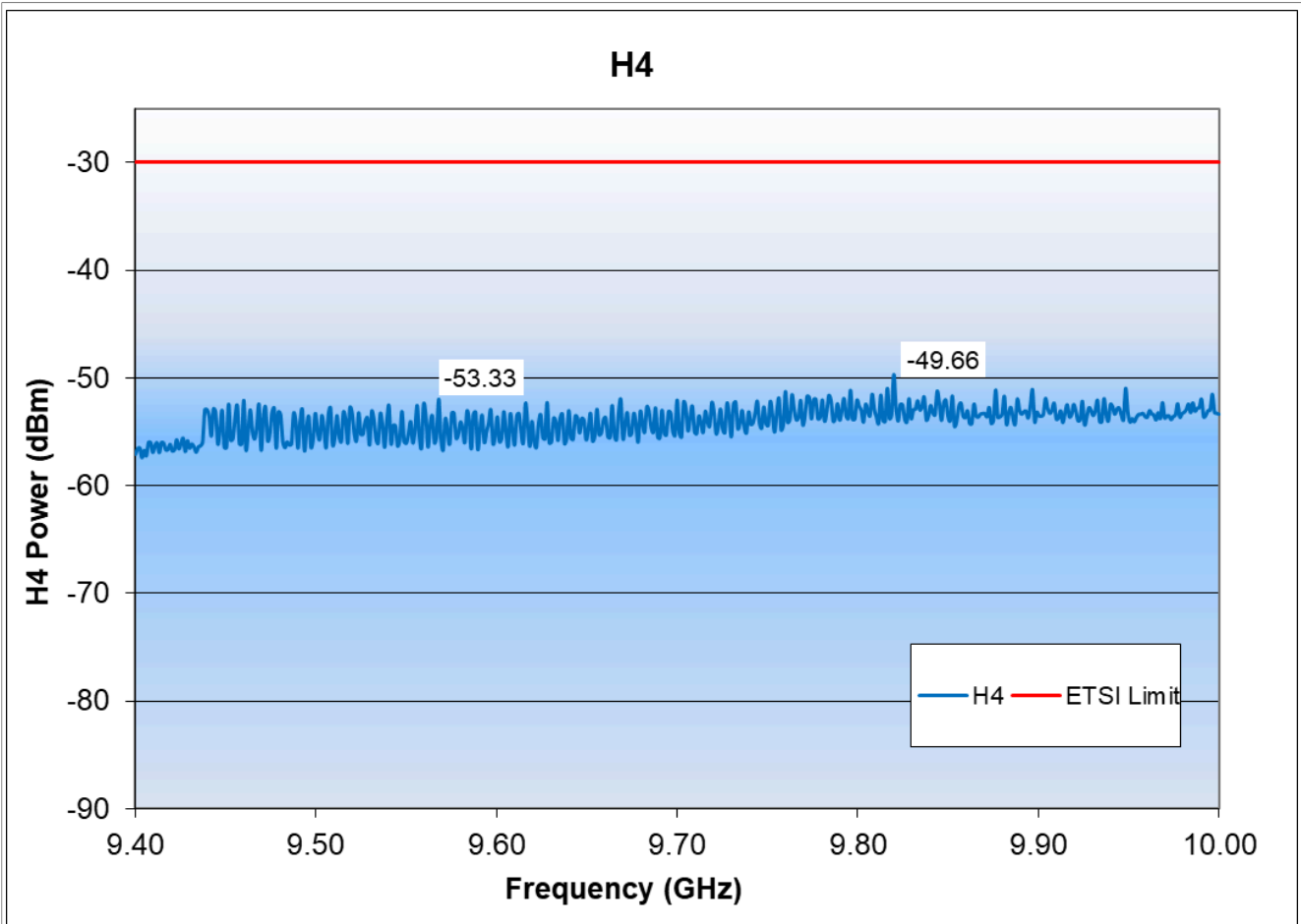


Figure 15. Bluetooth LE - Conducted H4 spurious

- Maximum power is at frequency 9.82 GHz: -49.66 dBm.

Conclusion:

- There is more than **19 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.5 H5 (ETSI test conditions, peak measurement)

Test method:

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

Result:

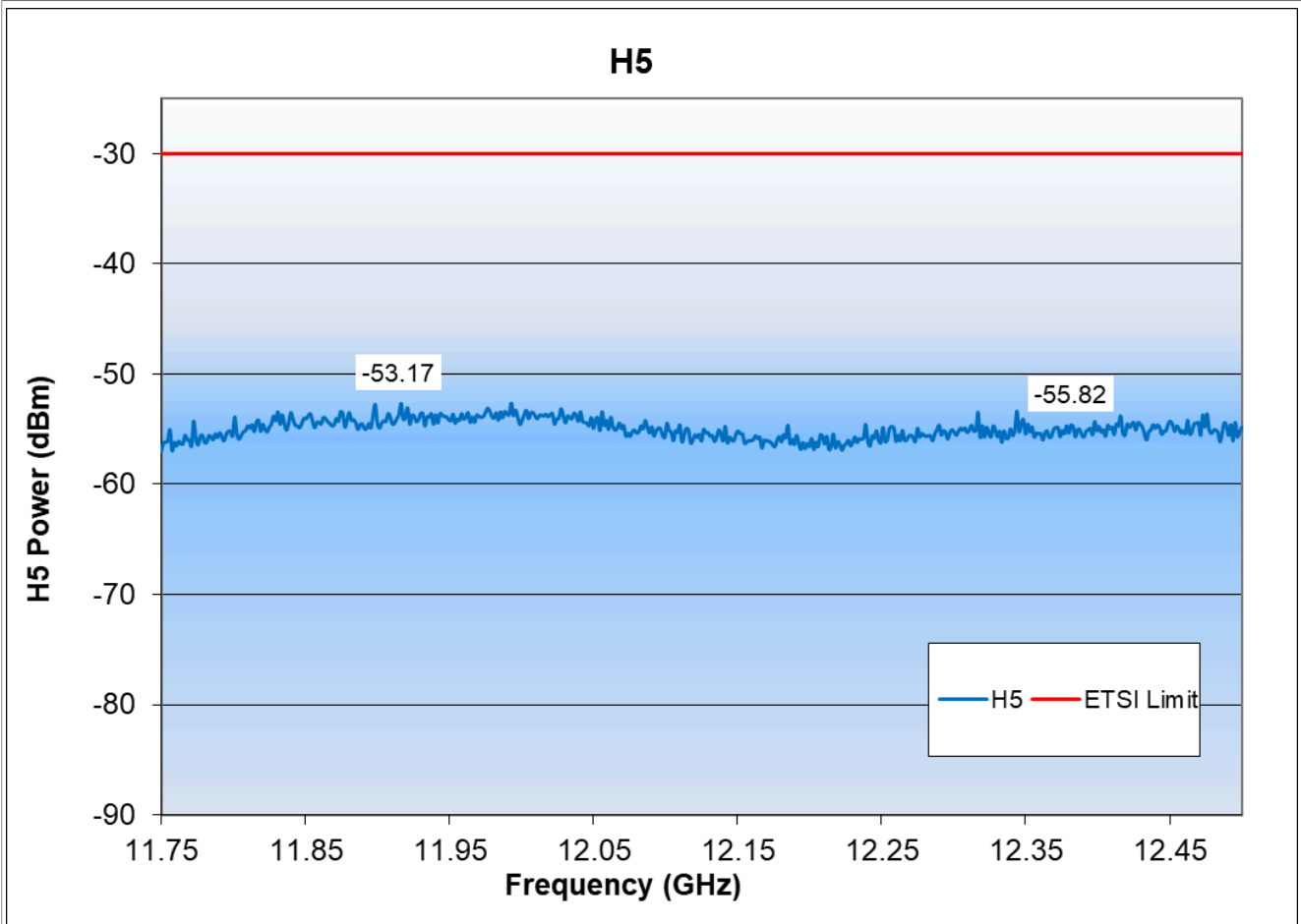


Figure 16. Bluetooth LE - Conducted H5 spurious

- Maximum power is at frequency 12.0275 GHz: -53.17 dBm.

Conclusion:

- There is more than **23 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.6 H6 (ETSI test conditions, peak measurement)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 14.1 GHz to 15 GHz.

Result:

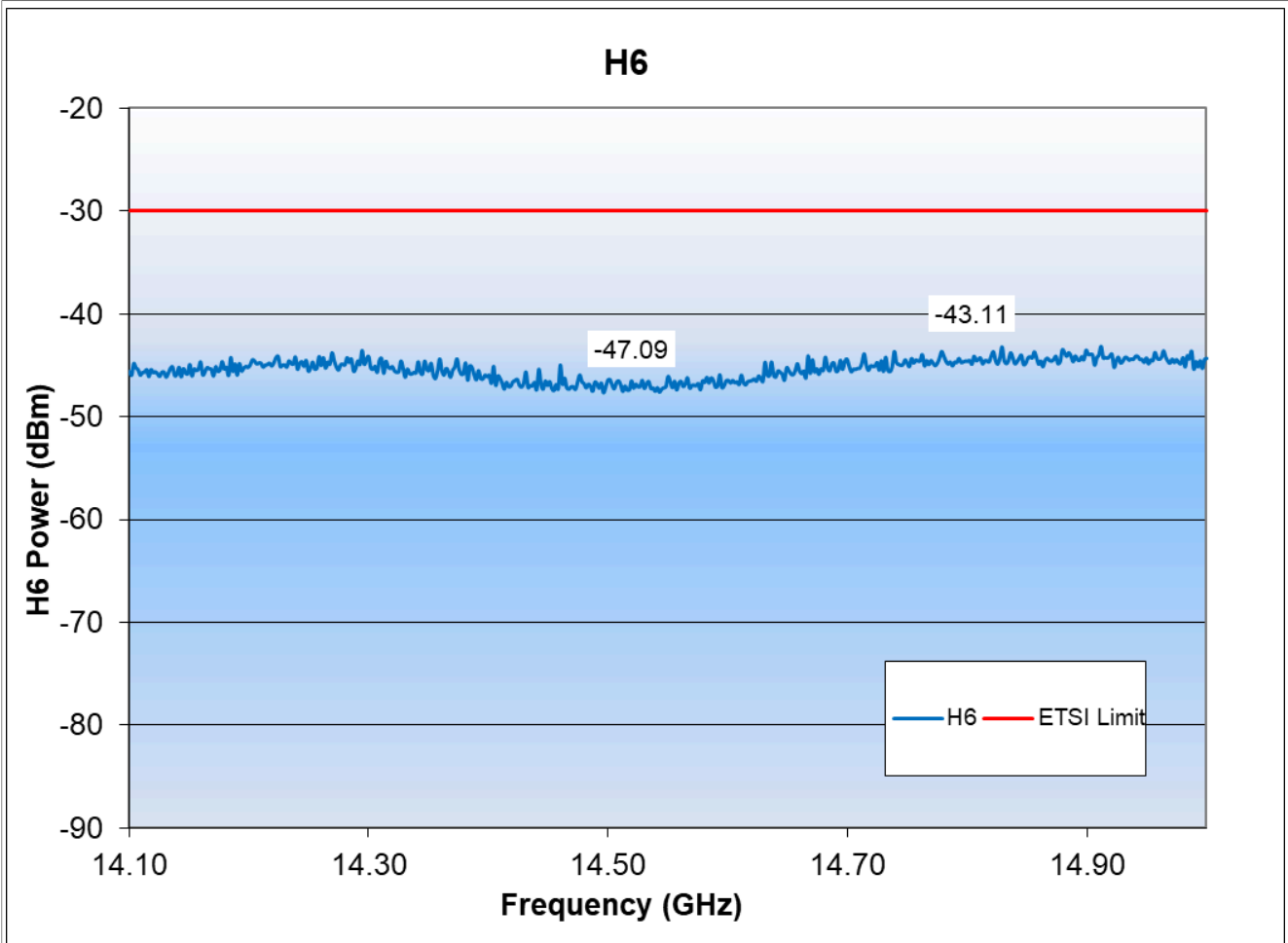


Figure 17. Bluetooth LE - Conducted H6 spurious

- Maximum power is at frequency 14.9118 GHz: -43.11 dBm.

Conclusion:

- There is more than **13 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.7 H7 (ETSI test conditions, peak measurement)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 16.45 GHz to 17.5 GHz.

Result:

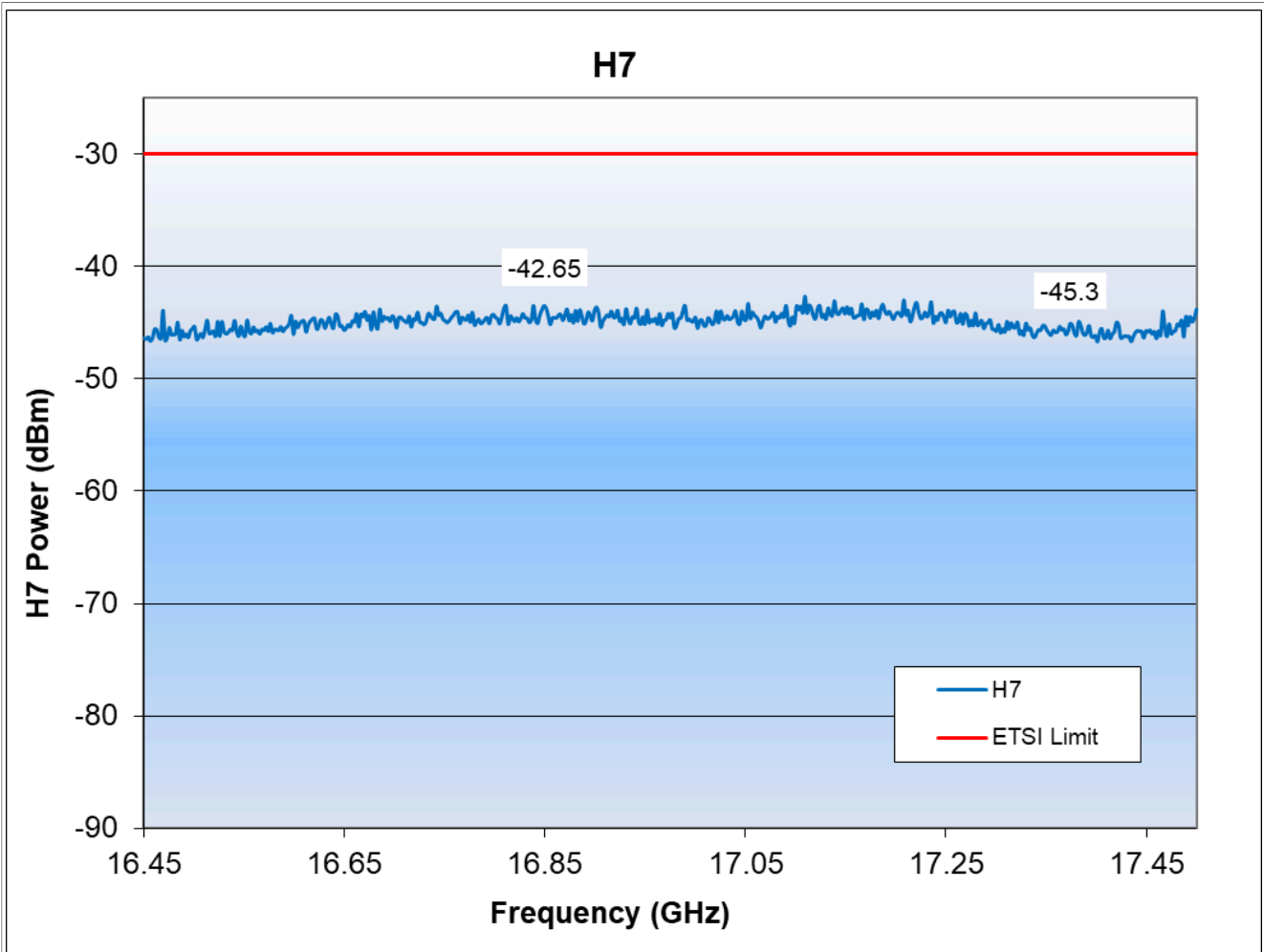


Figure 18. Bluetooth LE - Conducted H7 spurious

- Maximum power is at frequency 17.1199 GHz: -42.65 dBm.

Conclusion:

- There is more than **12 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.8 H8 (ETSI test conditions, peak measurement)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 16.45 GHz to 17.5 GHz.

Result:

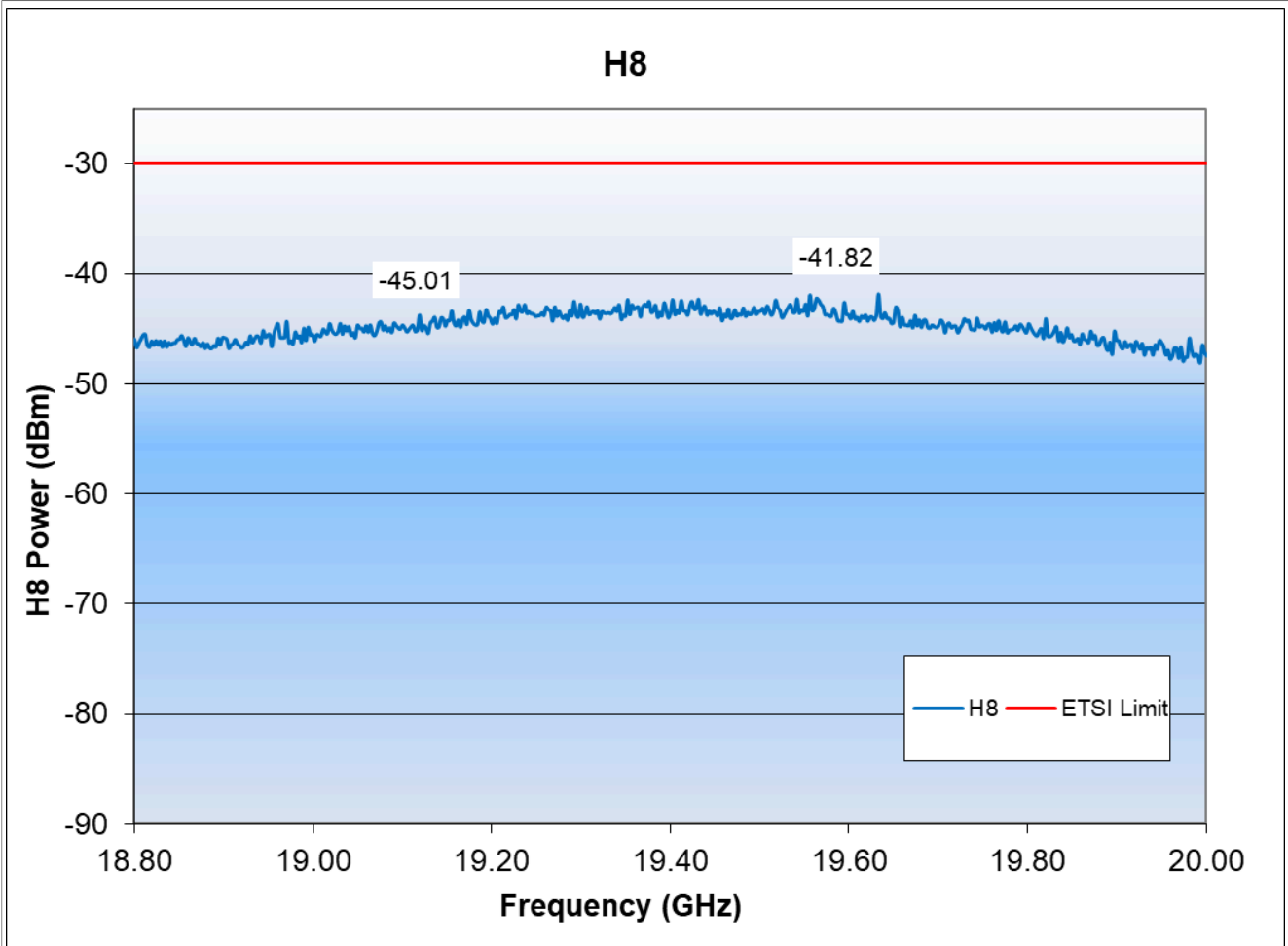


Figure 19. Bluetooth LE - Conducted H8 spurious

- Maximum power is at frequency 19.6328 GHz: -41.82 dBm.

Conclusion:

- There is more than **11 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.9 H9 (ETSI test conditions, peak measurement)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 21.15 GHz to 22.5 GHz.

Result:

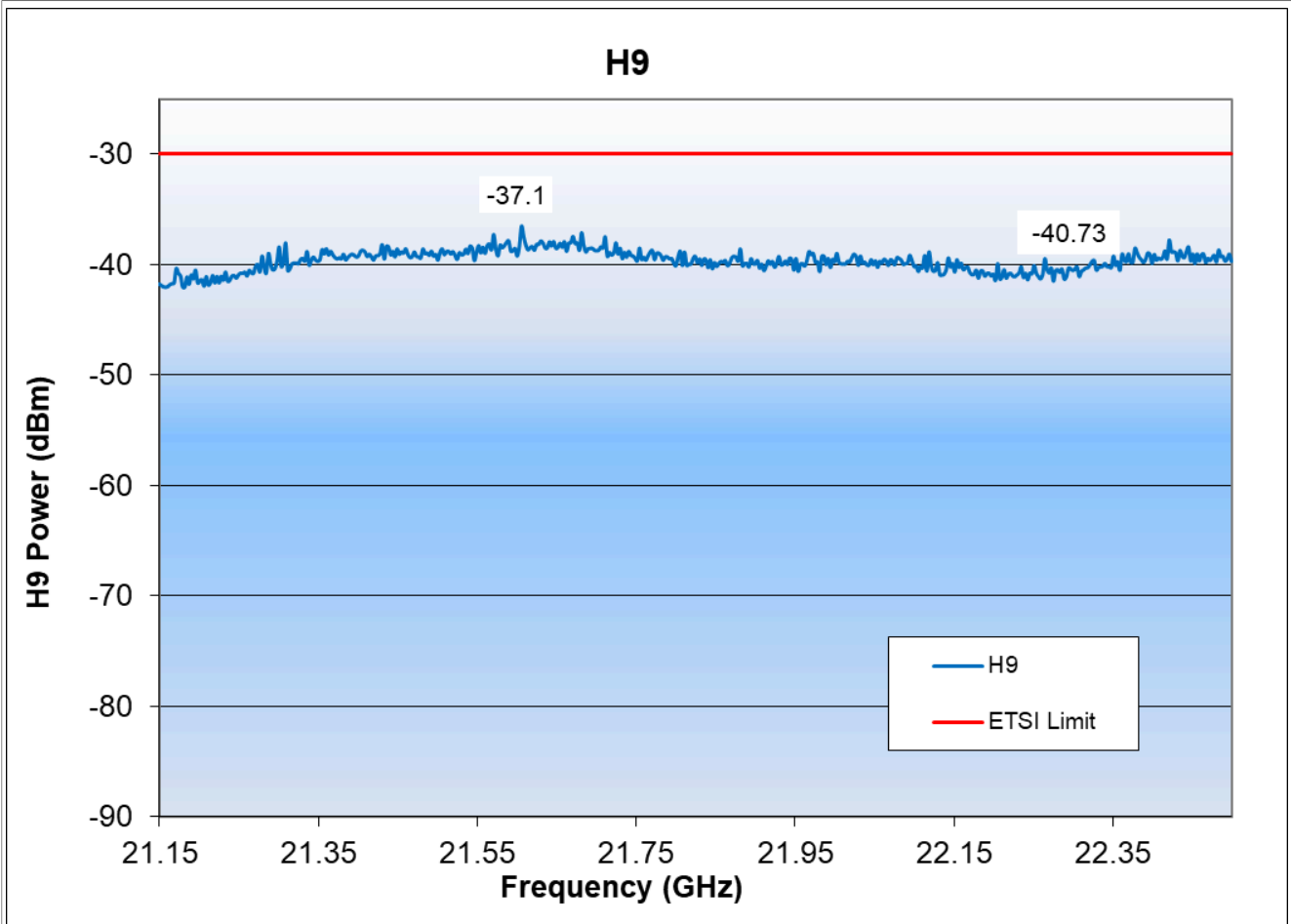


Figure 20. Bluetooth LE - Conducted H9 spurious

- Maximum power is at frequency 21.6819 GHz: -37.1 dBm.

Conclusion:

- There is more than **7 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.10 H10 (ETSI test conditions, peak measurement)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 23.35 GHz to 25 GHz.

Result:

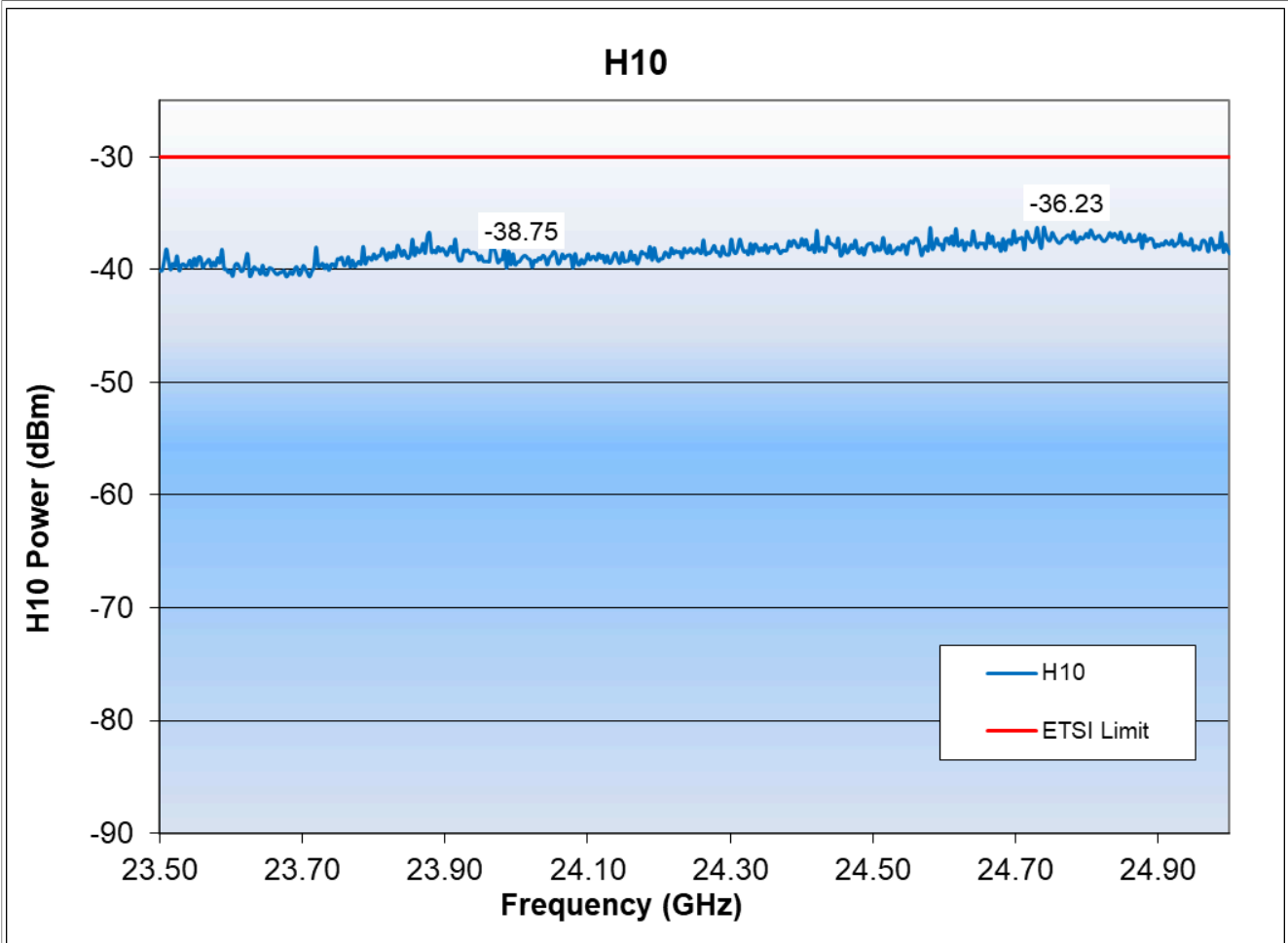


Figure 21. Bluetooth LE - Conducted H10 spurious

- Maximum power is at frequency 24.739 GHz: -36.23 dBm.

Conclusion:

- There is more than **6 dB** margin for Bluetooth LE to the ETSI limit.

3.3.1.6.11 H2 (FCC test conditions, average measurements)

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set the analyzer to:
 - Start freq = 4.7 GHz
 - Stop freq = 5 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - RBW = 1 MHz
 - VBW = 3 MHz

- Max Hold mode
- Detector: RMS
- Sweep all the channels from
 - Bluetooth LE: Channel 0 to Channel 39

Result:

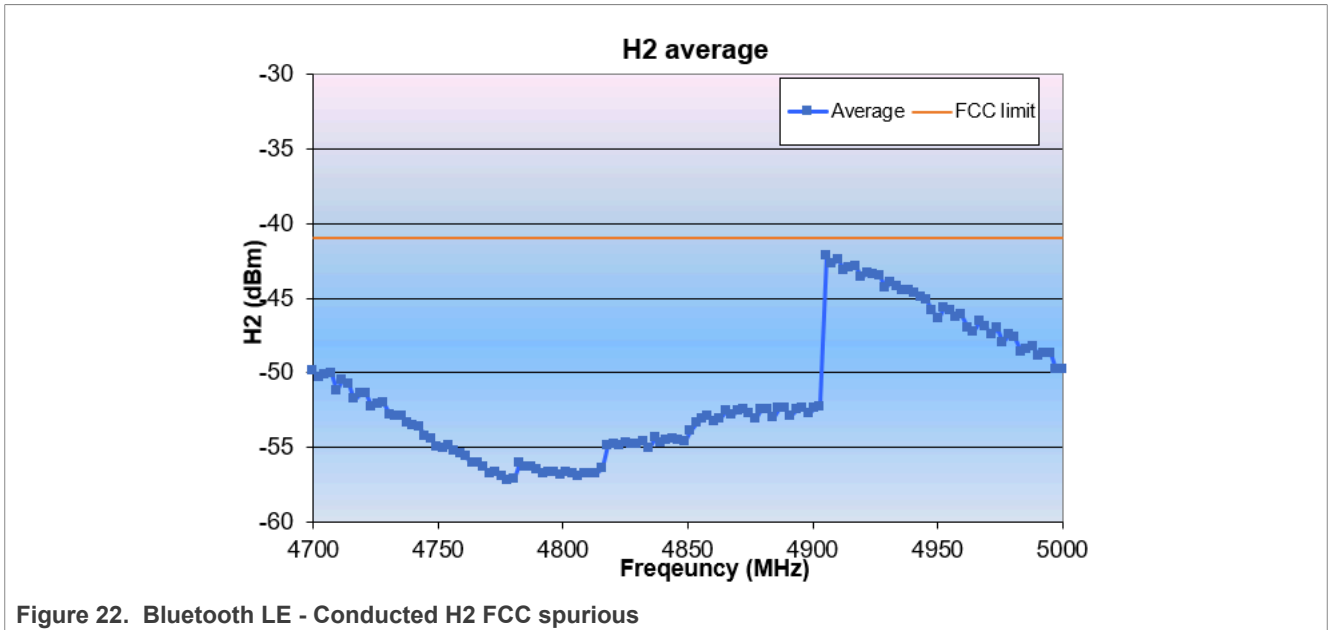


Figure 22. Bluetooth LE - Conducted H2 FCC spurious

- Maximum power is at frequency 4.906 GHz: -42.14 dBm.

Conclusion:

- There is more than **1 dB** margin for Bluetooth LE to the FCC limit.

3.3.1.6.12 H3 (FCC test conditions, average measurements)

Test method:

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

Result:

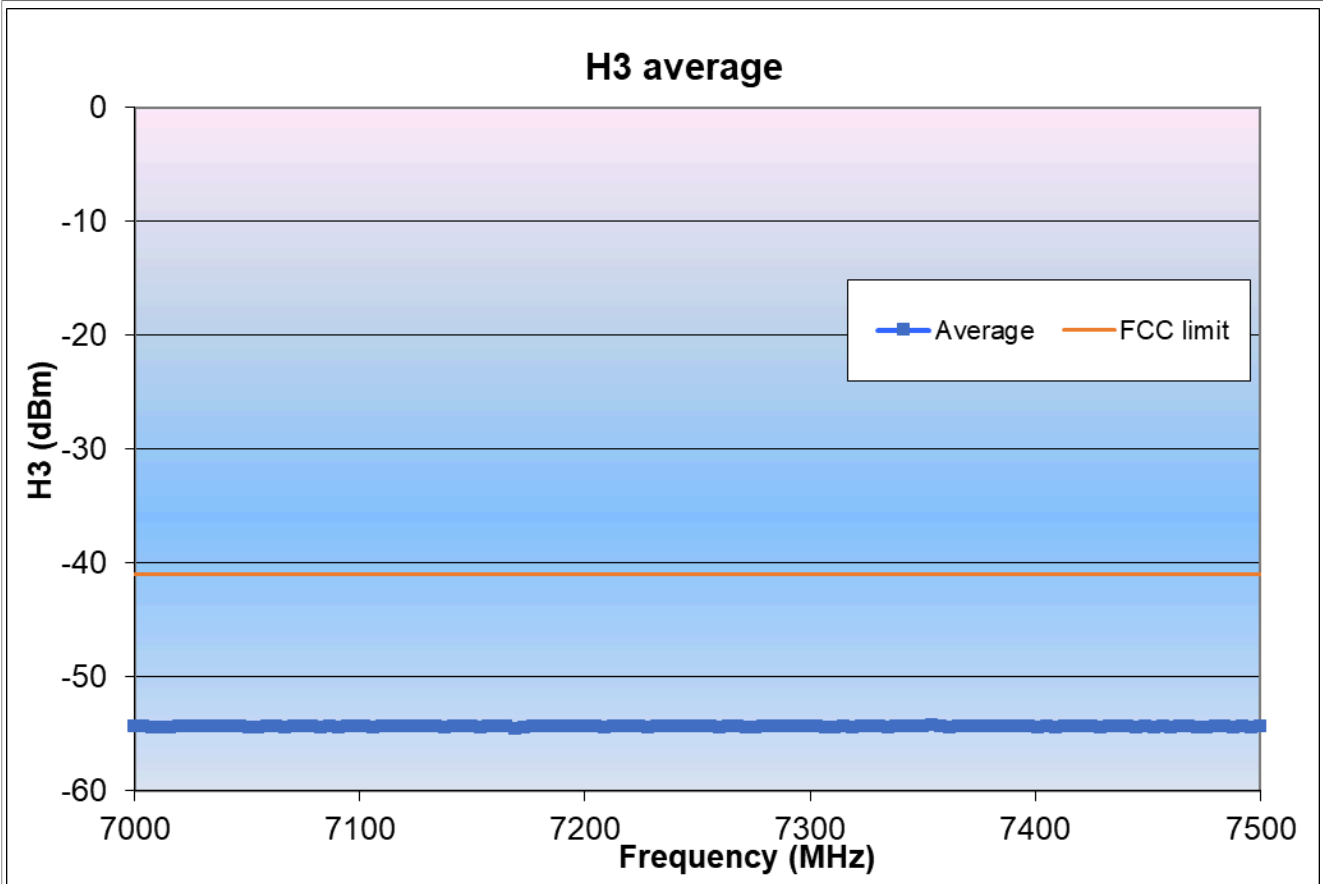


Figure 23. Bluetooth LE - Conducted H3 FCC spurious

- Maximum power is at frequency 7.354 GHz: -54.27 dBm.

Conclusion:

- There is more than **13 dB** margin for Bluetooth LE to the FCC limit.

3.3.1.6.13 H4 (FCC test conditions, average measurements)

Test method:

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

Result:

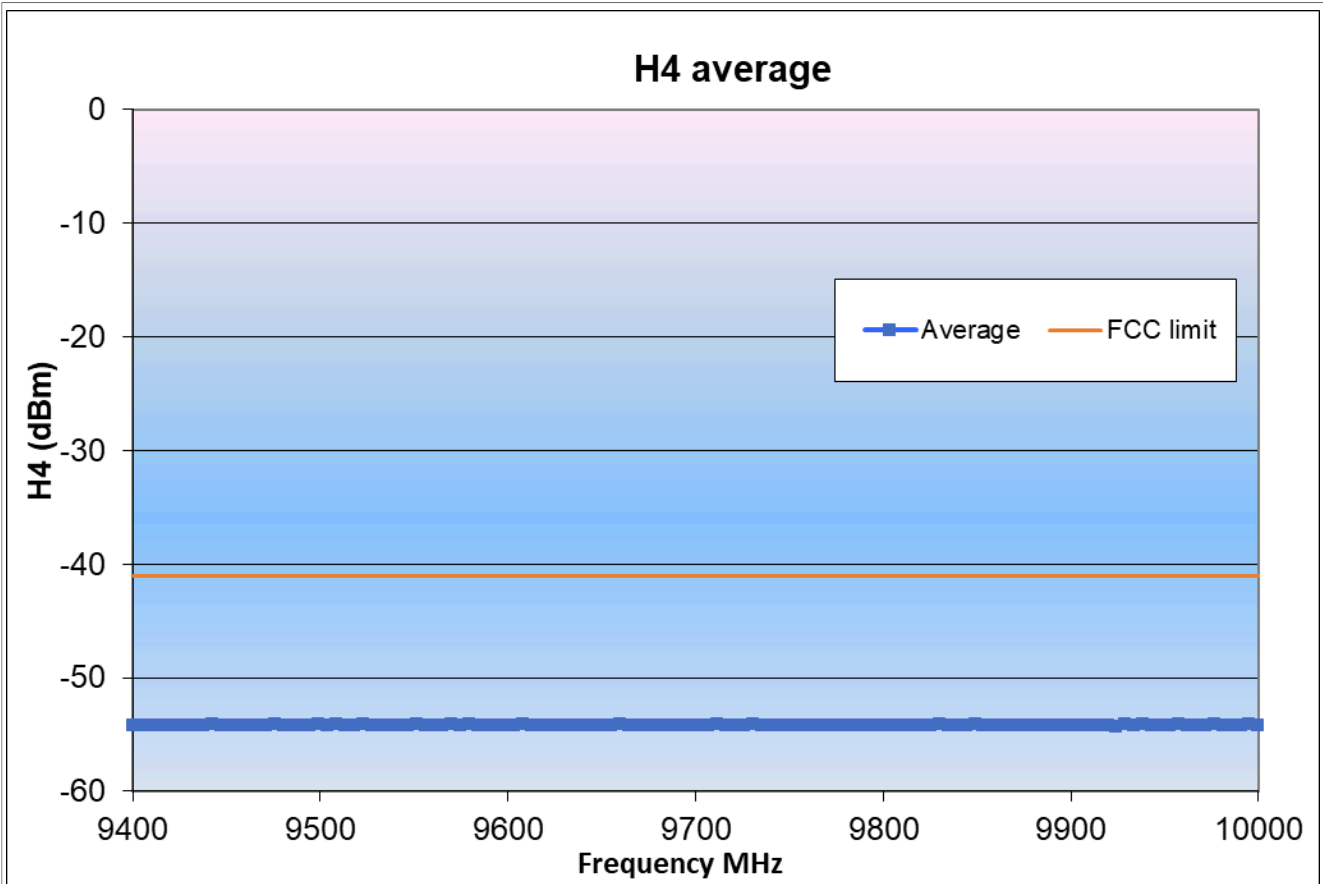


Figure 24. Bluetooth LE - Conducted H4 FCC spurious

- Maximum power is at frequency 9.939 GHz: -54.09 dBm.

Conclusion:

- There is more than **5 dB** margin for Bluetooth LE to the FCC limit.

3.3.1.6.14 H5 (FCC test conditions, average measurements)

Test method:

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

Result:

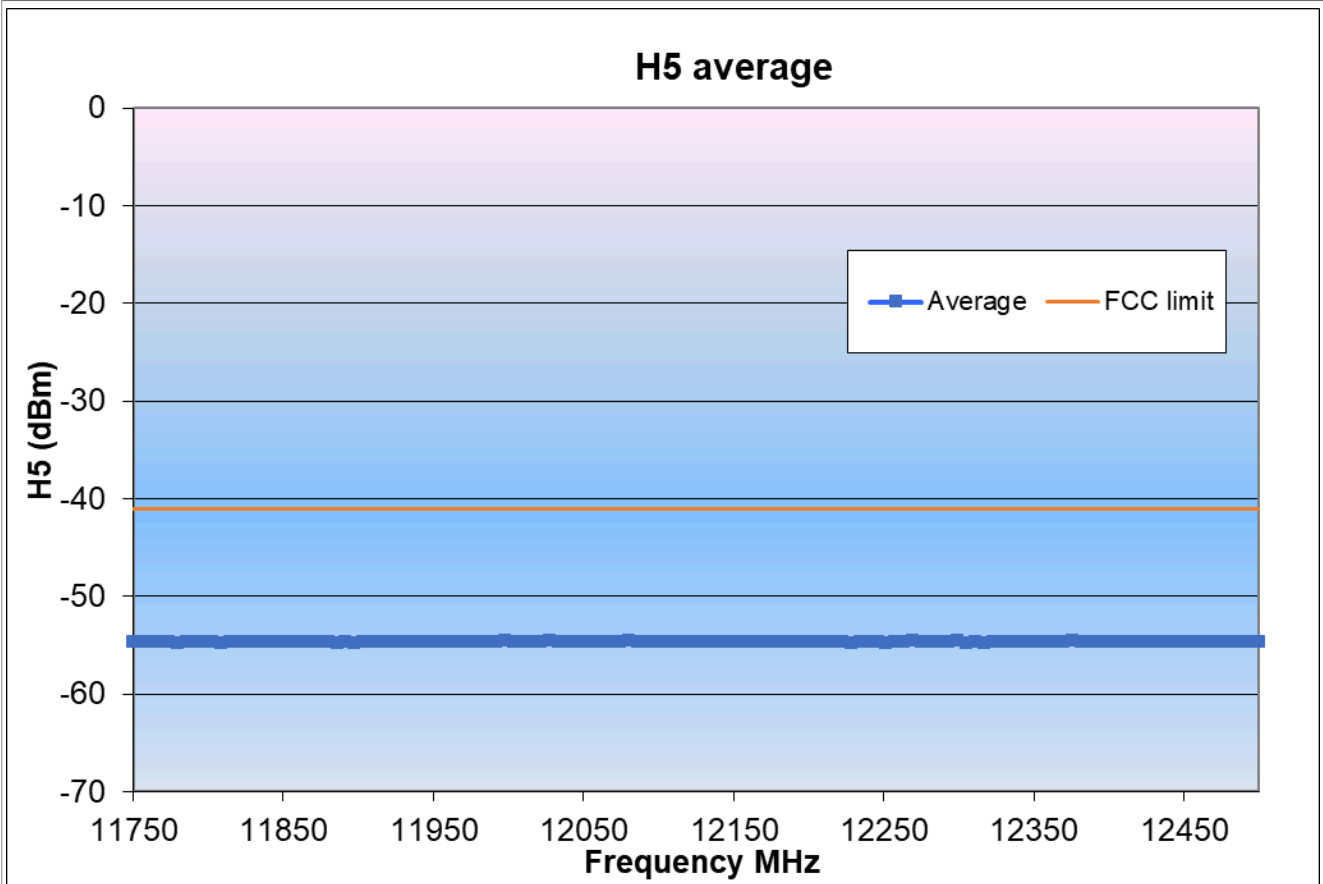


Figure 25. Bluetooth LE - Conducted H5 FCC spurious

- Maximum power is at frequency 12.081 GHz: -54.59 dBm.

Conclusion:

- There is more than **13 dB** margin for Bluetooth LE to the FCC limit.

3.3.1.6.15 H6 (FCC test conditions, average measurements)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 14.1 GHz to 15 GHz.

Result:

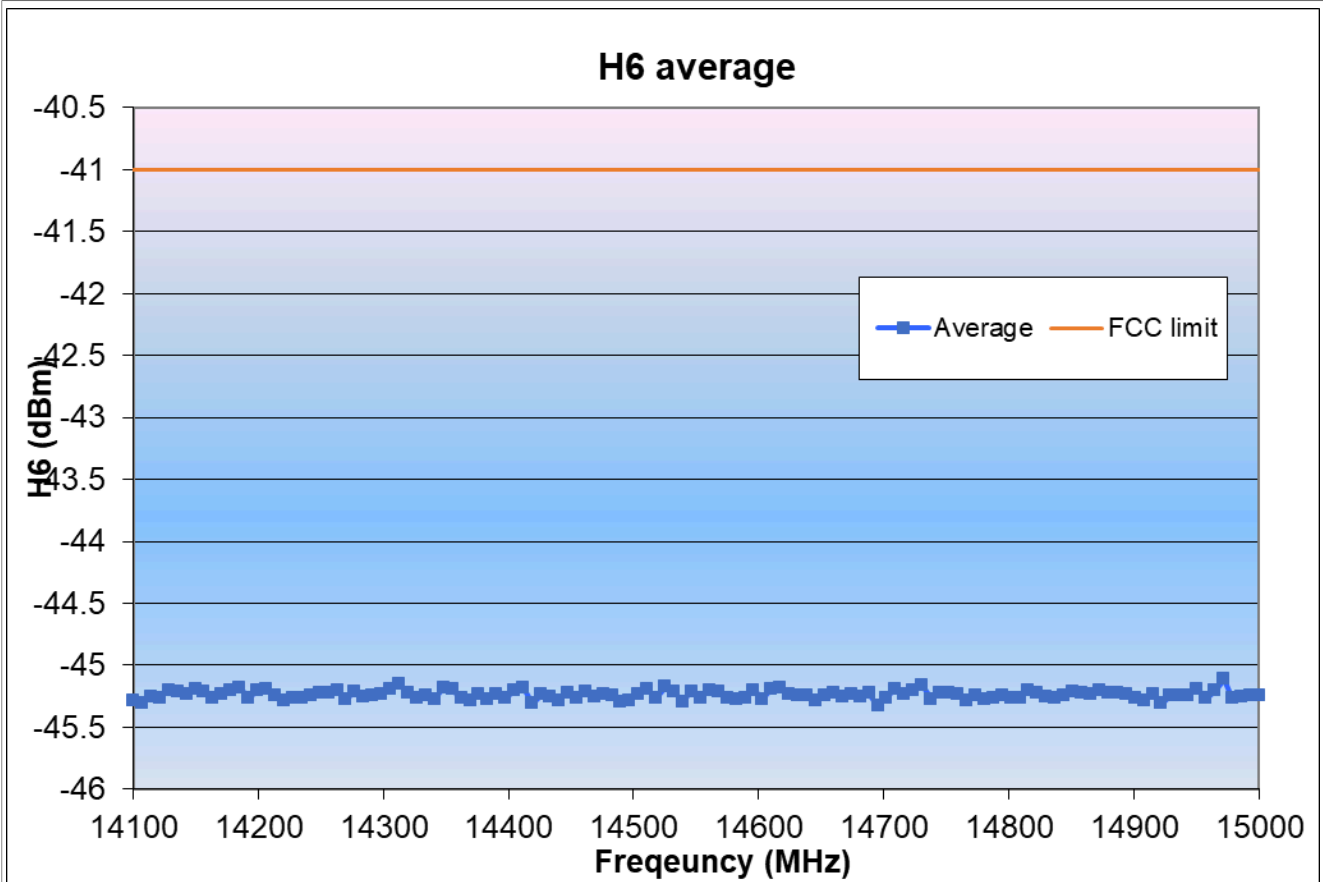


Figure 26. Bluetooth LE - Conducted H6 FCC spurious

- Maximum power is at frequency 14.972 GHz: -45.11 dBm.

Conclusion:

- There is more than **4 dB** margin to the FCC limit.

3.3.1.6.16 H7 (FCC test conditions, average measurements)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 16.45 GHz to 17.5 GHz.

Result:

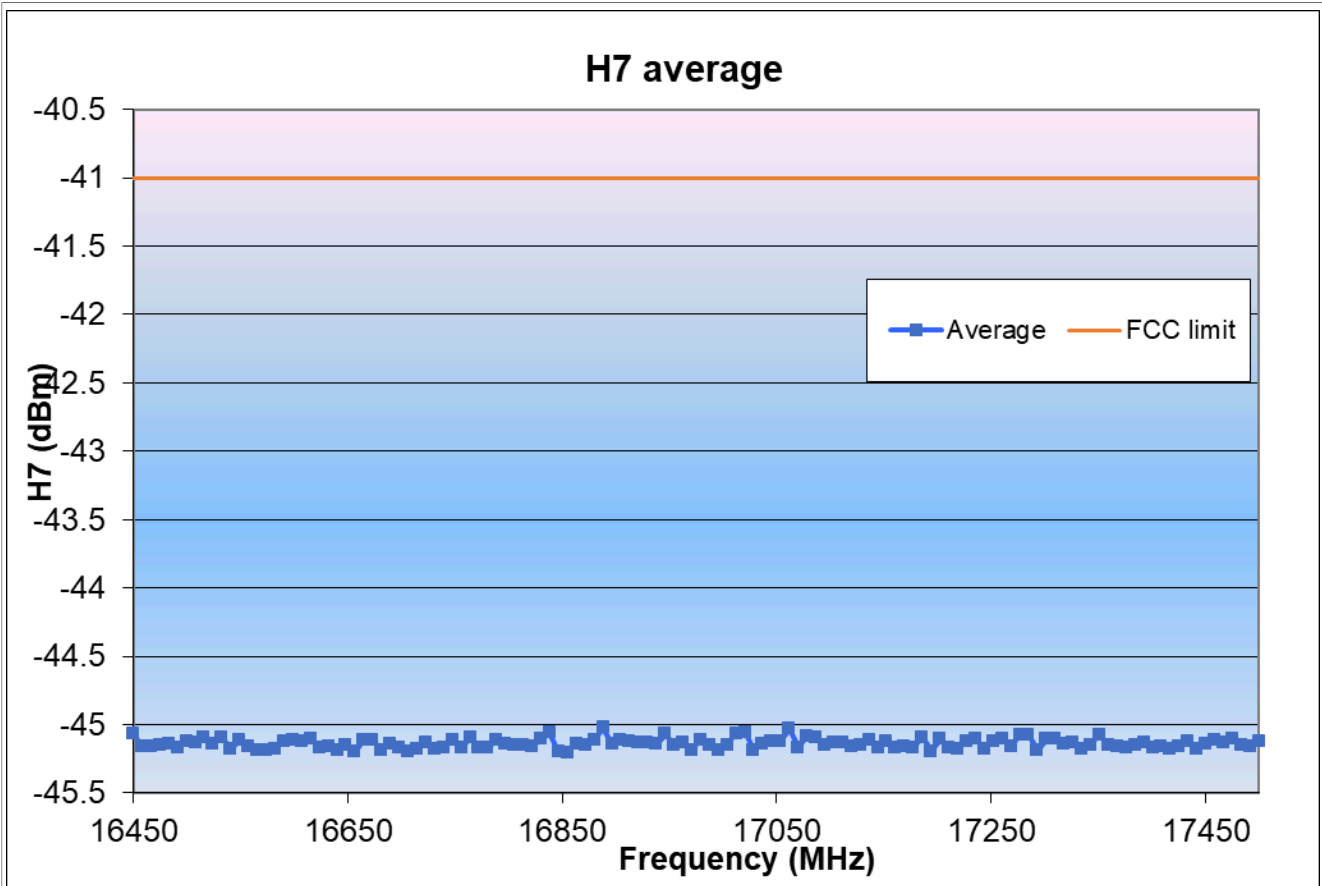


Figure 27. Bluetooth LE - Conducted H7 FCC spurious

- Maximum power is at frequency 16.888 GHz: -45.02 dBm.

Conclusion:

- There is more than **4 dB** margin to the FCC limit.

3.3.1.6.17 H8 (FCC test conditions, average measurements)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 16.45 GHz to 17.5 GHz.

Result:

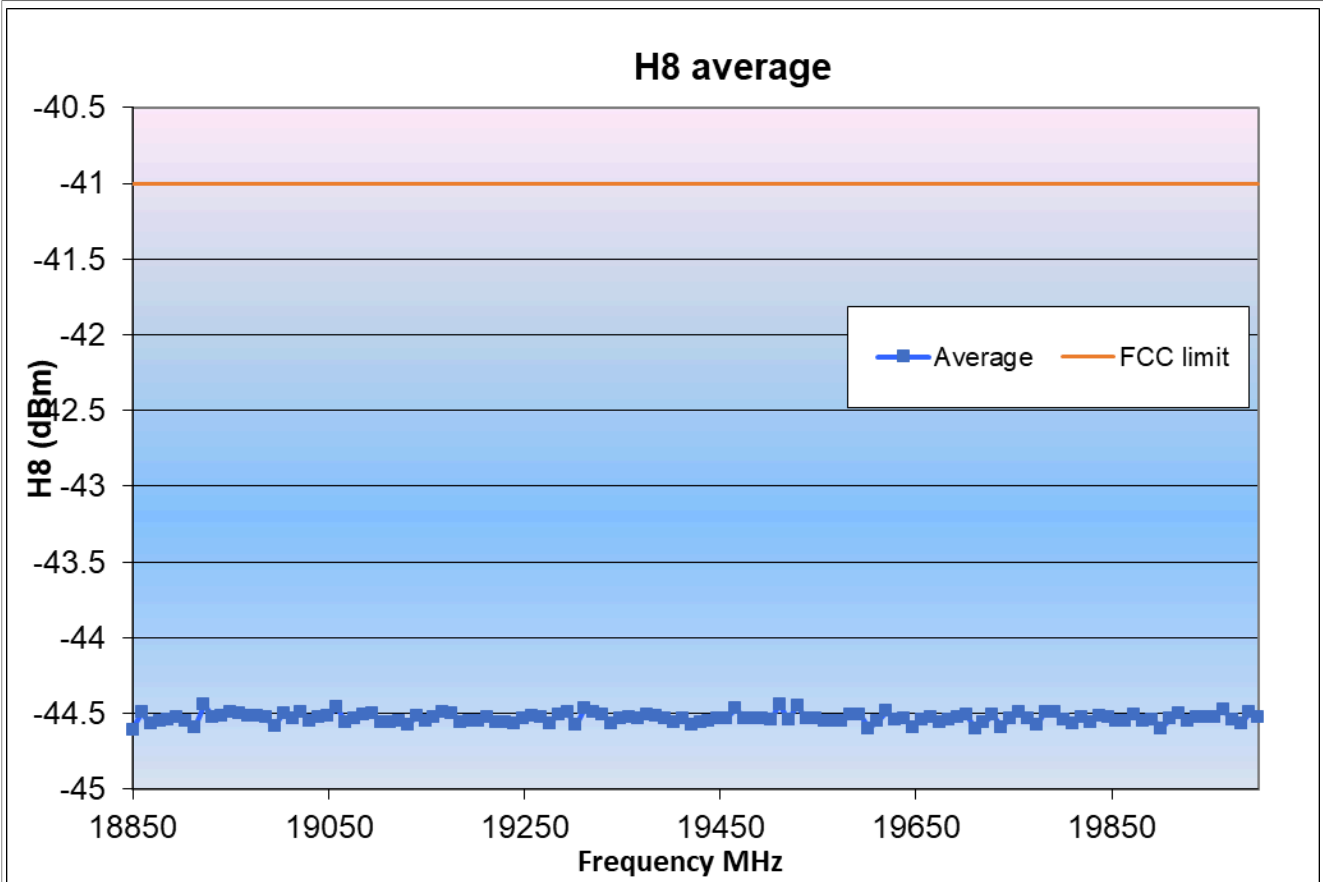


Figure 28. Bluetooth LE - Conducted H8 FCC spurious

- Maximum power is at frequency 19.511 GHz: -44.44 dBm.

Conclusion:

- There is more than **3 dB** margin to the FCC limit.

3.3.1.6.18 H9 (FCC test conditions, average measurements)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 21.15 GHz to 22.5 GHz.

Result:

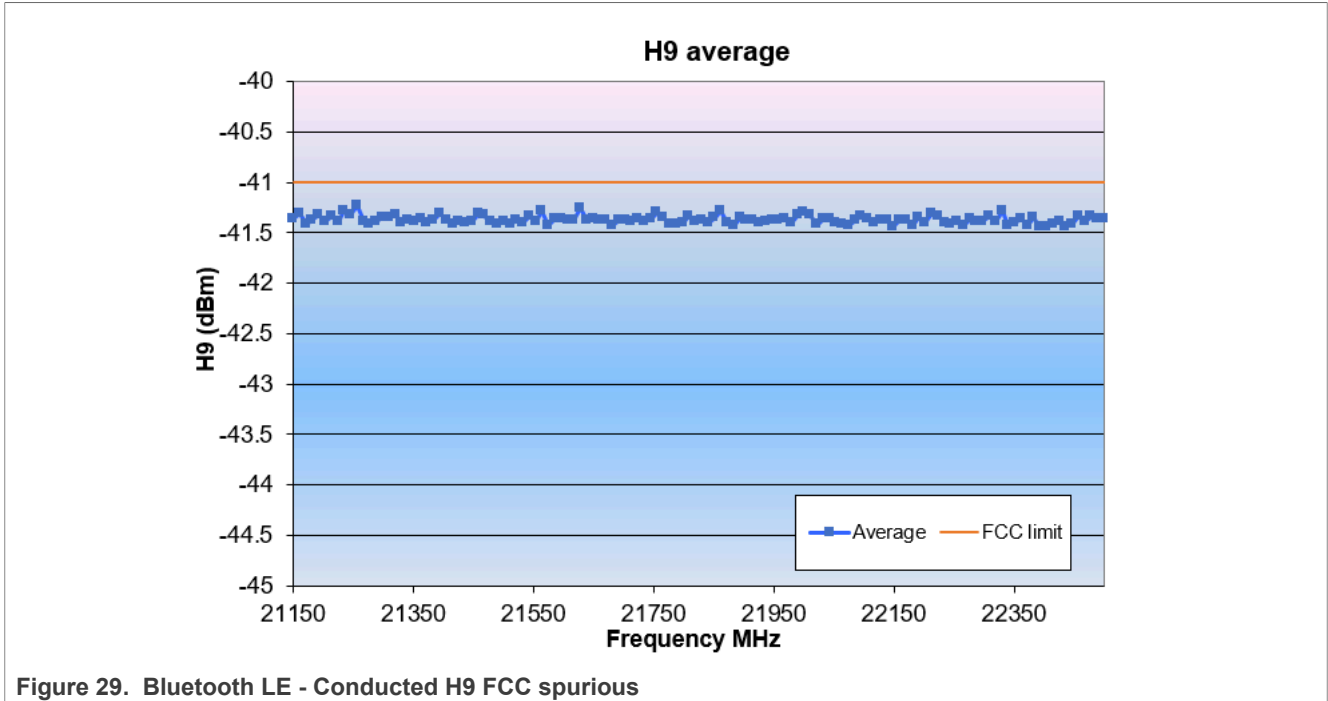


Figure 29. Bluetooth LE - Conducted H9 FCC spurious

- Maximum power is at frequency 21.256 GHz: -41.22 dBm.

Conclusion:

- There is no margin (~0.2 dB) to the FCC limit.

3.3.1.6.19 H10 (FCC test conditions, average measurements)

Test method:

The same method as for H2, except that the spectrum analyzer frequency span is set from 23.35 GHz to 25 GHz.

Result:

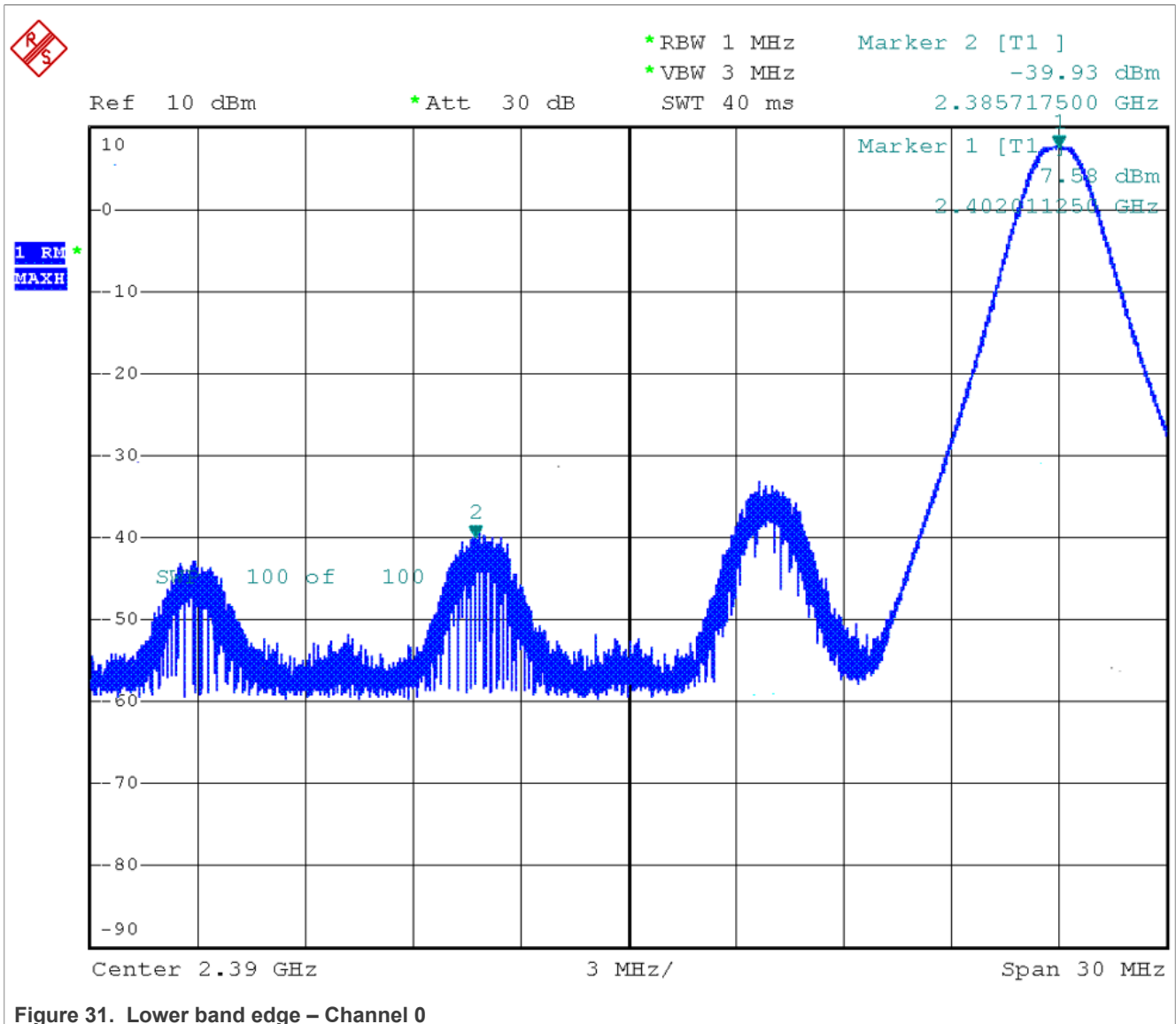


Figure 31. Lower band edge – Channel 0

Conclusion:

- The lower band edge test passes the Bluetooth SIG (MIIT-China) certification.
- There is no margin to the Bluetooth SIG (MIIT-China) limit (-40 dBm below 2.39 GHz).

3.3.1.8 Upper band edge – MIIT China

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Burst mode
 - Set the channel 39 (2.48 GHz)
 - Set the power to 3 (-12 dBm) for Bluetooth LE
- Set the analyzer to:
 - Start freq = 2.477 GHz

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- Stop freq = 2.507 GHz
- Ref amp = -20 dBm
- Sweep time = 40 ms
- Sweep point: 8001 pts
- RBW = 1 MHz
- Video BW = 3 MHz
- Detector = RMS
- MaxHold
- Software settings:
 - PA_RAMP_SEL value must be set to 0x03h (4 μs)
 - Modification: XCVR_TX_DIG_PA_CTRL_PA_RAMP_SEL(2) in the nxp_xcvr_common_config.c file

Bluetooth LE result:

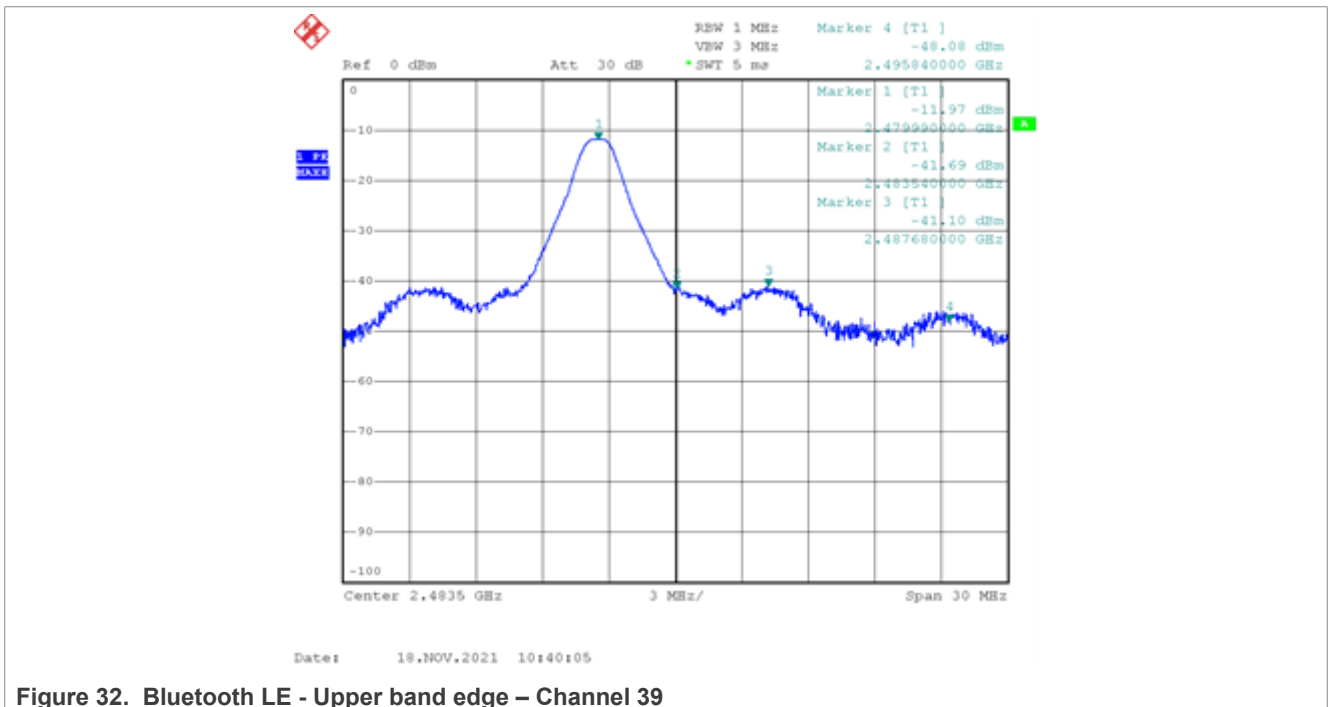


Figure 32. Bluetooth LE - Upper band edge – Channel 39

Conclusion:

- The upper band edge test passes the Bluetooth SIG (MIIT-China) certification.
- There is no margin to the Bluetooth SIG (MIIT-China) limit (-40 dBm higher than 2.4835 GHz).

3.3.1.9 Upper band edge (FCC ANSI C63.10, 558074 D01 DTS)

Test method:

- Set the radio to:
 - TX mode
 - Modulated (1 Msps, 2 Msps, 500 ksps, 125 ksps)
 - Continuous mode
 - Maximum RF output power +10 dBm
- Set the analyzer to:
 - Start freq = 2.475 GHz

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- Stop freq = 2.485 GHz
- Ref amp = -20 dBm
- Sweep time = 100 ms
- RBW = 100 kHz
- Video BW = 300 kHz
- Detector = Average
- Average mode: Power
- Number of Sweeps = 100
- Set the channel 39 (2.48 GHz)
- Trace mode: Max hold

Bluetooth LE result:

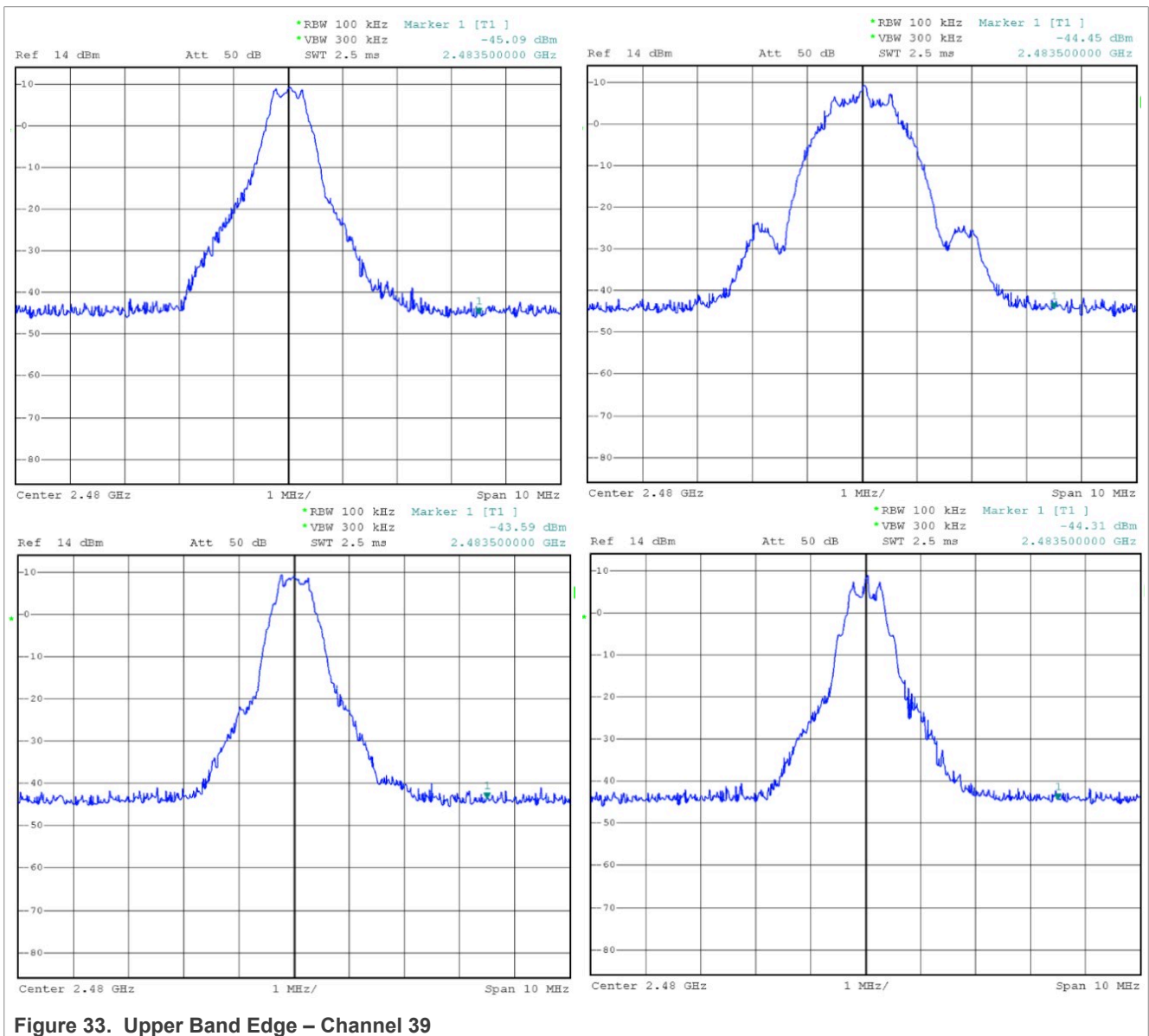


Figure 33. Upper Band Edge – Channel 39

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Modulation	1 Msps	2 Msps	500 ksps	125 ksps
Level @2.4835 GHz	-45.09 dBm	-44.45 dBm	-43.59 dBm	-44.31 dBm

FCC limit: -41.15 dBm

Conclusion:

- The upper band edge test passes the FCC certification (< 41.15 dBm@2.4835 GHz).
- There is a minimum of 2 dB margin.

3.3.1.10 Out of band (ETSI 300 328 chapter 5.4.8.2.1)**Test method:**

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set the analyzer to:
 - Start freq = 2.475 GHz
 - Stop freq = 2.485 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - RBW = 1 MHz
 - Video BW = 3 MHz
 - Detector = RMS
 - Average mode: Power
 - Number of Sweeps = 100
 - Set the channel 39 (2.48 GHz)
 - Trace mode: Max hold

Bluetooth LE result:

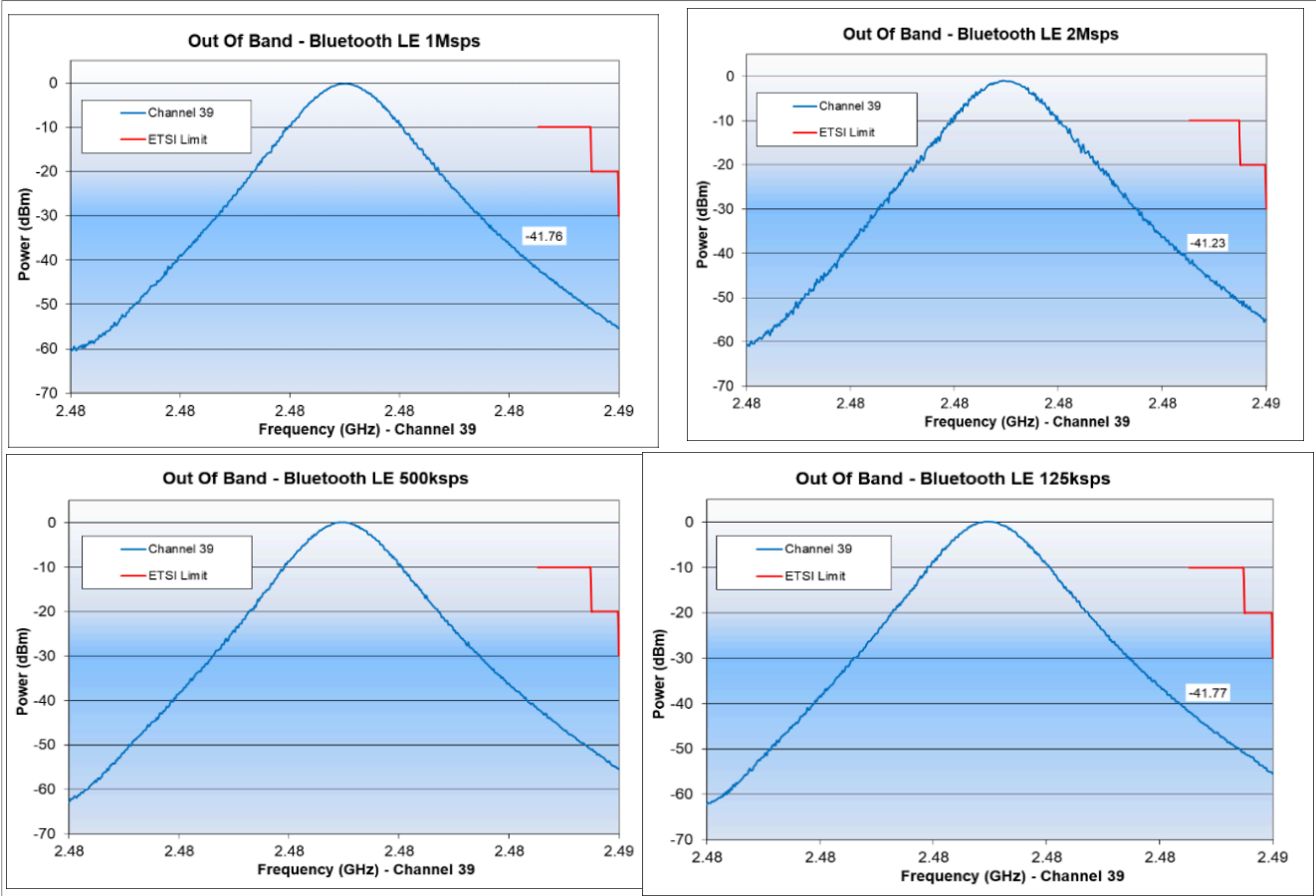


Figure 34. Out of band – Channel 39

Conclusion:

- The upper band edge test passes the FCC certification (< 41.15 dBm@2.4835 GHz).
- There is no margin by setting the RF output power to +0 dBm to the FCC limit.
- Decrease the RF output level to the channel 0 to fix your margin.

3.3.1.11 Out of band (ARIB STD T-66)

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set the analyzer to:
 - Start freq = 2.475 GHz
 - Stop freq = 2.485 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - RBW = 1 MHz
 - Video BW = 3 MHz
 - Detector = RMS

- Average mode: Power
- Number of Sweeps = 100
- Set the channel 39 (2.48 GHz), Trace mode: Max hold

Summary results:

Table 16. Result for Channel 0

Frequency band		2402 MHz (Ch0)				Limit
Data rate		1 Mbps	2 Mbps	LR S2	LR S8	
Unexpected Emission Intensity	Band I					-36 dBm/100 kHz
	(dBm/100 kHz)					(0.25 uW/100 kHz)
	Band II					-26 dBm/MHz
	(dBm/MHz)					(2.5 uW/MHz)
	Band III					-16 dBm/MHz
	(dBm/MHz)					(25 uW/MHz)
	Band IV					-16 dBm/MHz
	(dBm/MHz)					(25 uW/MHz)
	Band V					-26 dBm/MHz
(dBm/MHz)					(2.5 uW/MHz)	

Table 17. Result for Channel 39

Frequency band		2480 MHz (Ch39)				Limit
Data rate		1 Mbps	2 Mbps	LR S2	LR S8	
Unexpected Emission Intensity	Band I					-36 dBm/100kHz
	(dBm/100 kHz)					(0.25 uW/100kHz)
	Band II					-26 dBm/MHz
	(dBm/MHz)					(2.5 uW/MHz)
	Band III					-16 dBm/MHz
	(dBm/MHz)					(25 uW/MHz)
	Band IV					-16 dBm/MHz
	(dBm/MHz)					(25 uW/MHz)
	Band V					-26 dBm/MHz
(dBm/MHz)					(2.5 uW/MHz)	

- Band I: 30 MHz – 1000 MHz
- Band II: 1000 MHz – 2387 MHz
- Band III: 2387 MHz – 2400 MHz
- Band IV: 2483.5 MHz – 2496.5 MHz
- Band V: 2496.5 MHz – 12500 MHz

Detailed results:

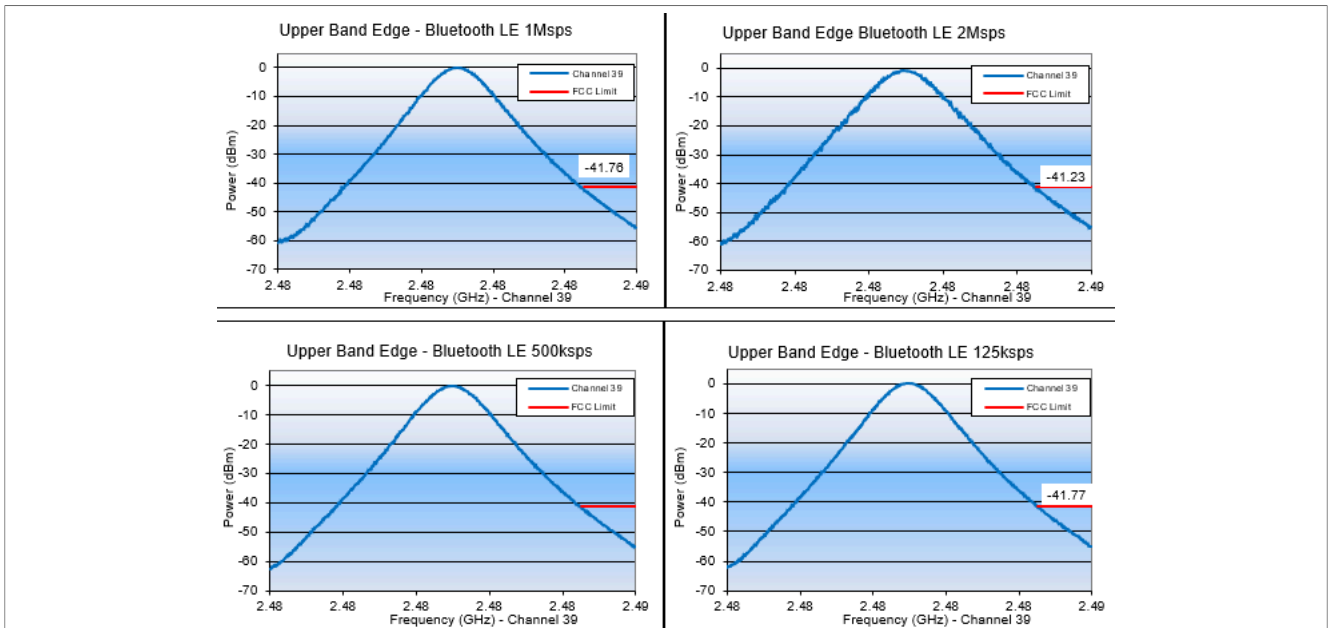


Figure 35. Out of band – Channel 0 - ARIB

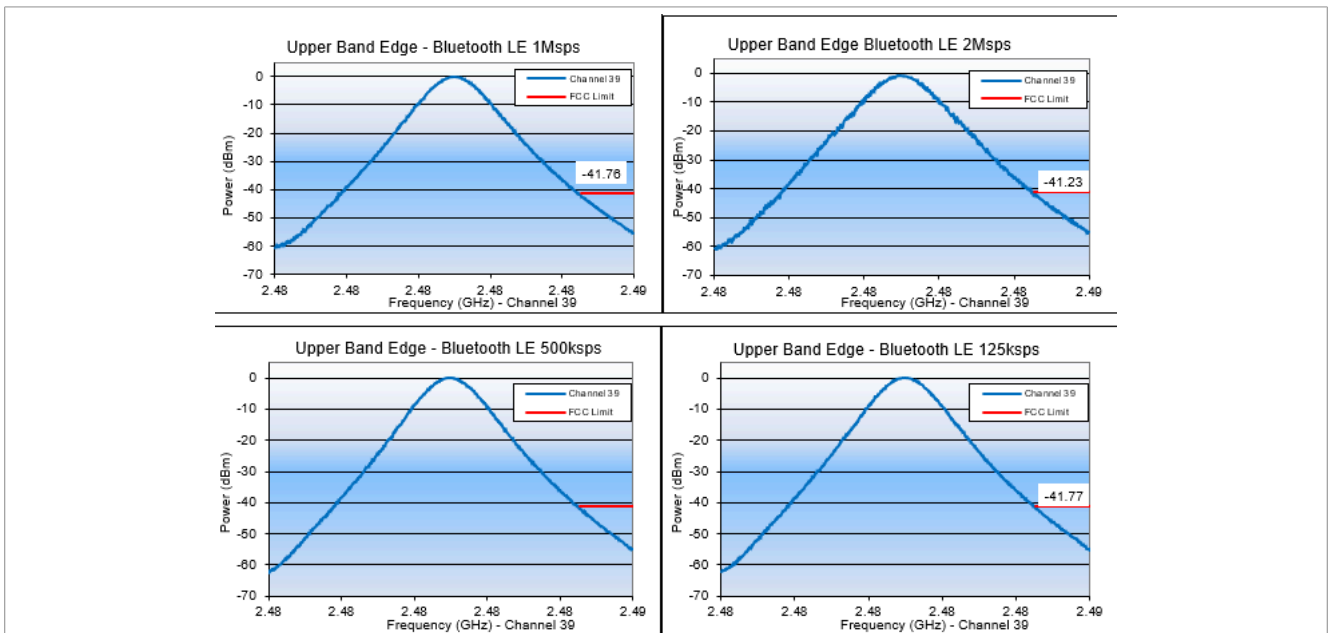


Figure 36. Out of band – Channel 39 - ARIB

Conclusion:

- The out of band test passes the ARIB STD T-66 certification.
- There is no margin by setting the RF output power to +0 dBm to the FCC limit.

3.3.1.12 Maximum TX output power

A CMW equipment is used to measure the PER at the maximum TX output power.

Flashed software: A specific binary is flashed: `hci_bb.bin` (available in the Bluetooth application examples).

Test method:

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

Result:

Table 18. Bluetooth LE 1 Msps

TP/TRM-LE/CA/BV-01-C [Output power at 1 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-01-C [Output power at 1 Ms/s] @ Payload length: 37, Statistic Count: 1					
Channel 0					
Average Power	-20.0	20.0	10.72	dBm	Passed
Peak Power	-	13.72	11.13	dBm	Passed
Channel 19					
Average Power	-20.0	20.0	10.58	dBm	Passed
Peak Power	-	13.58	11.01	dBm	Passed
Channel 39					
Average Power	-20.0	20.0	10.35	dBm	Passed
Peak Power	-	13.35	10.77	dBm	Passed

Conclusion:

In line with the expected results.

3.3.1.13 Bluetooth LE TX output spectrum

A CMW equipment is used to measure the adjacent channel power.

Flashed software: A specific binary is flashed: `hci_bb.bin` (available in the Bluetooth application examples)

Test method:

- Generator for the desired signal: CMW R&S
- Criterion: PER < 30.8 % with 1500 packets
- Channels under test: 3, 19 and 37

Result:

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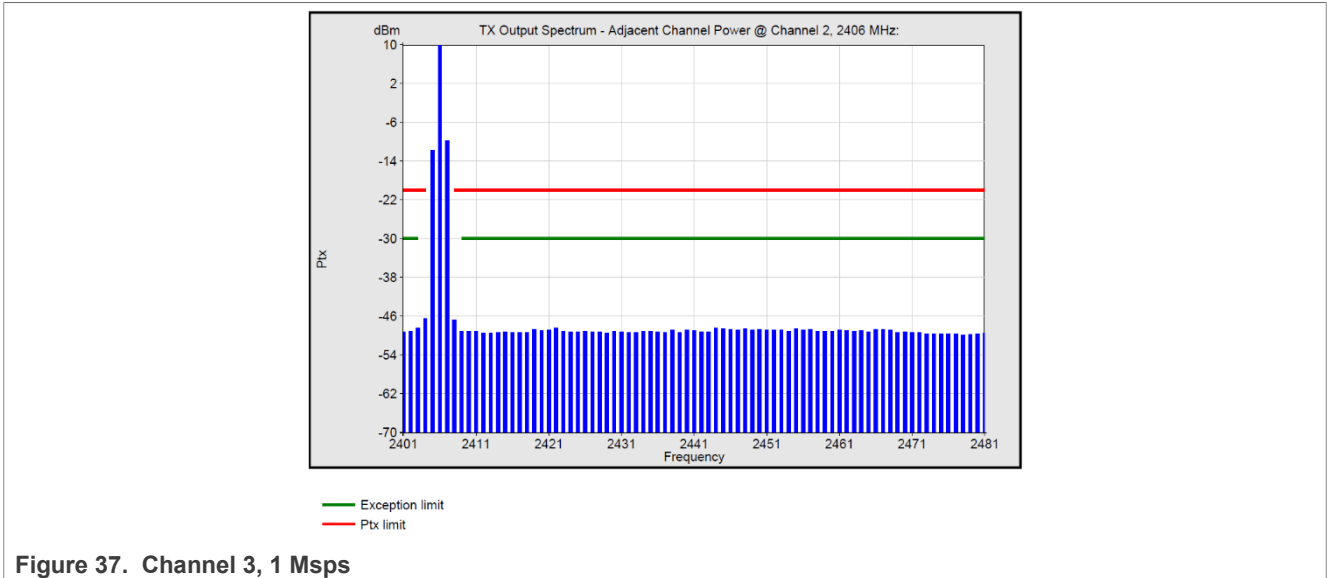


Figure 37. Channel 3, 1 MspS

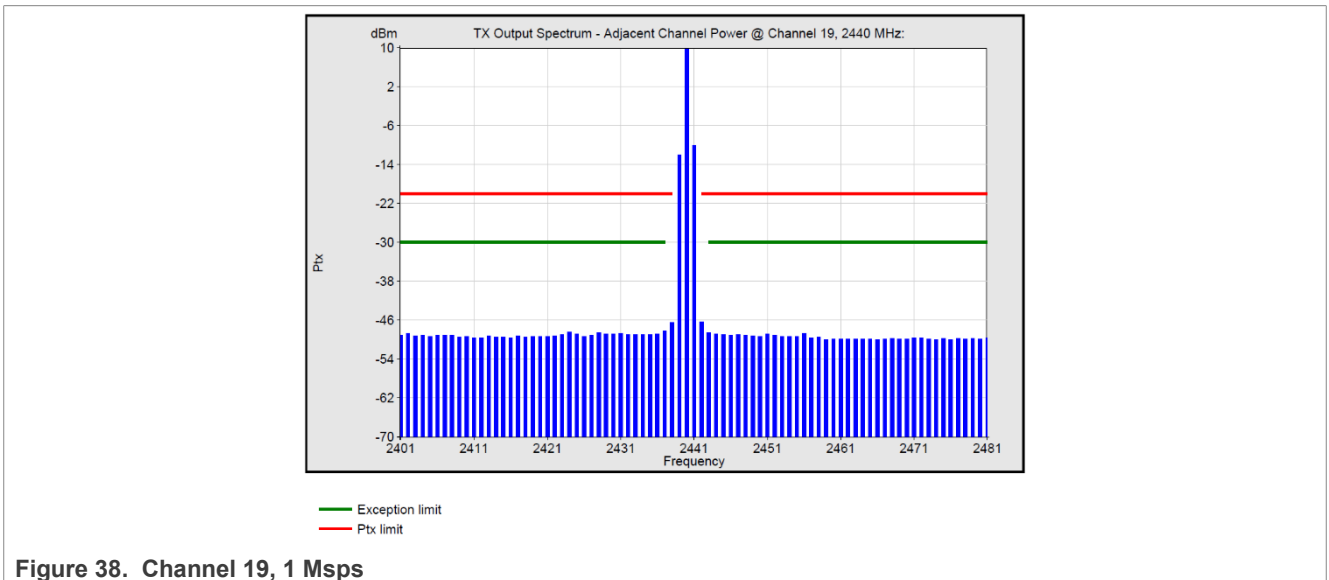
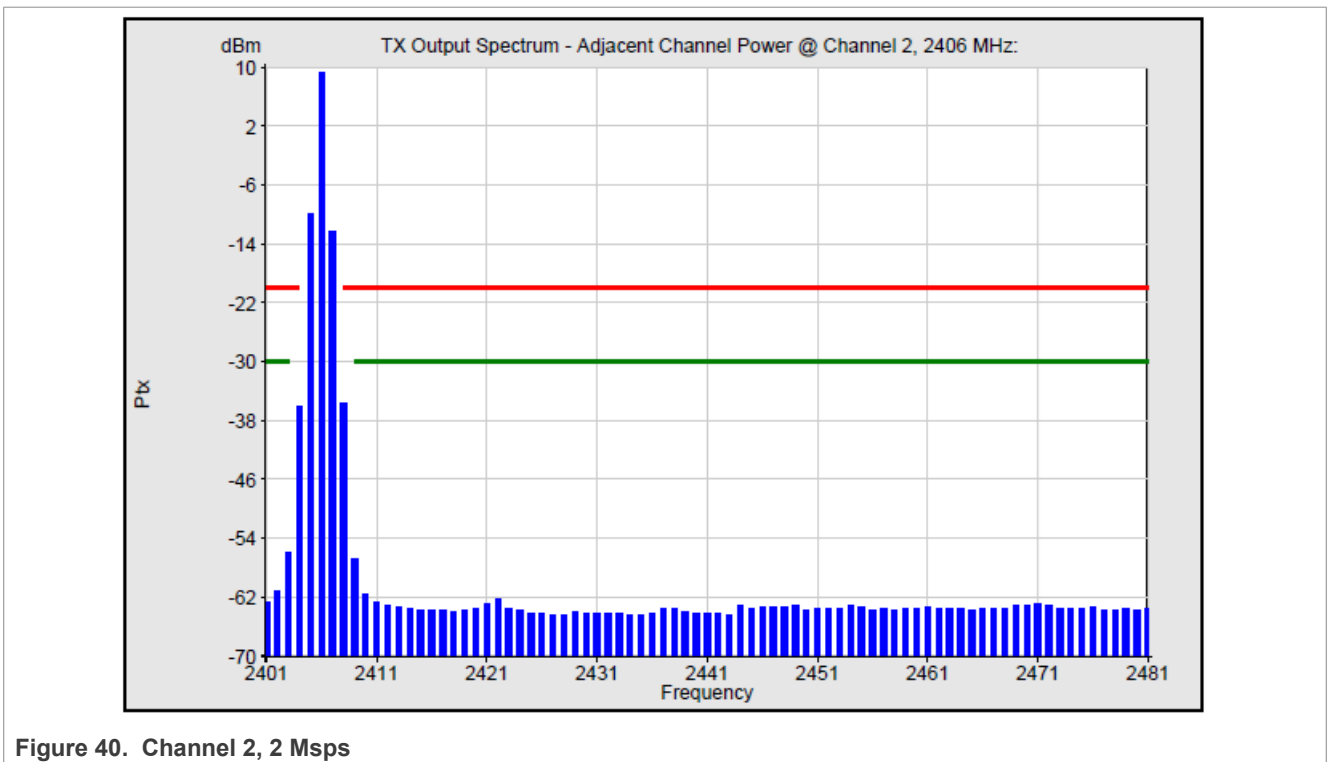
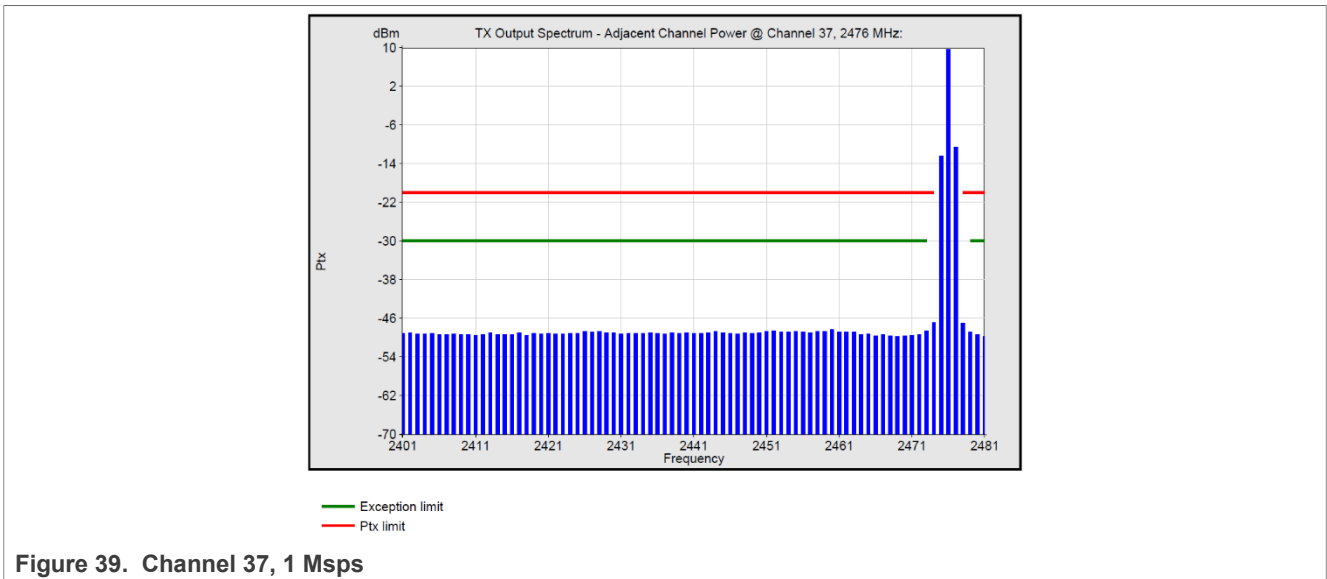


Figure 38. Channel 19, 1 MspS



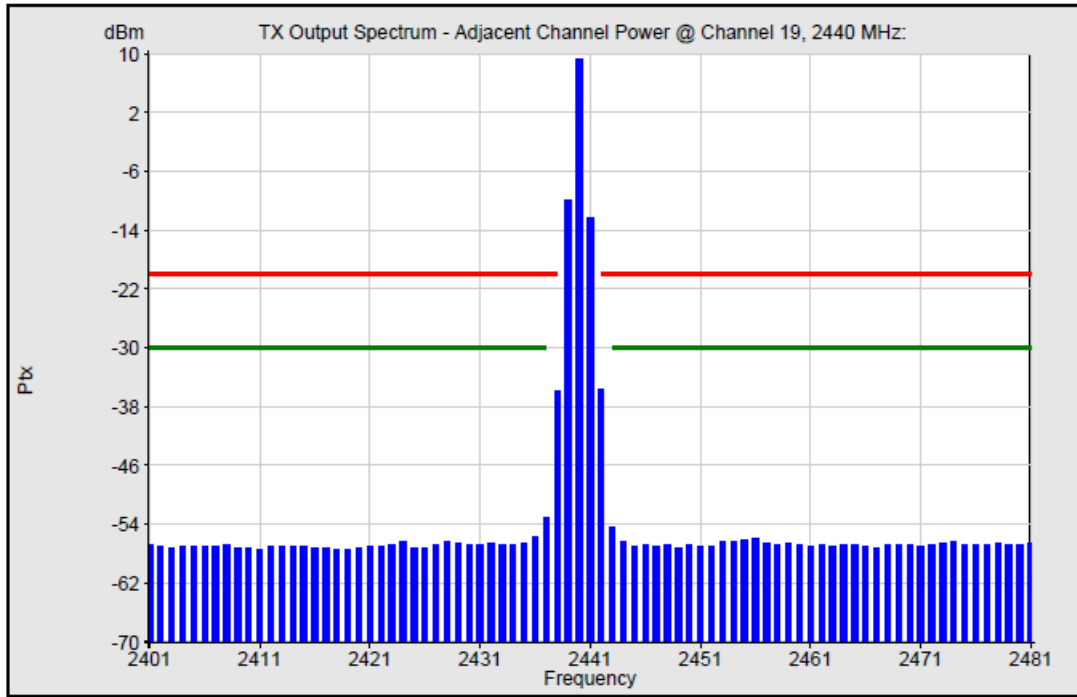


Figure 41. Channel 19, 2 Msps

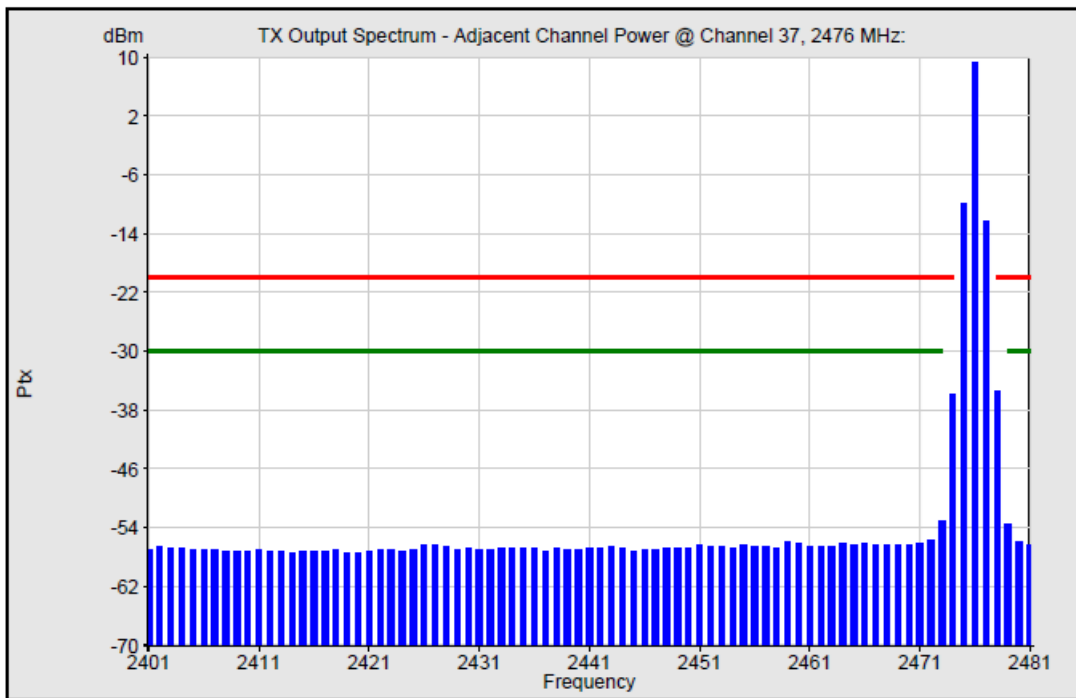


Figure 42. Channel 37, 2 Msps

3.3.1.14 Modulation characteristics

A CMW equipment is used to measure the frequency deviation df_1 and df_2 .

Flashed software: A specific binary is flashed: `hci_bb.bin` (available in the Bluetooth application examples).

Test method:

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

Result:

Table 19. Modulation characteristics at 1 Msps

TP/TRM-LE/CA/BV-05-C [Modulation Characteristics at 1 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-05-C [Modulation Characteristics at 1 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 0					
Frequency Deviation df1 Average	225	275	250.10	kHz	Passed
Frequency Deviation df2 99.9 %	185	–	204.84	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	–	0.84	–	Passed
Channel 19					
Frequency Deviation df1 Average	225	275	256.61	kHz	Passed
Frequency Deviation df2 99.9 %	185	–	209.14	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	–	0.84	–	Passed
Channel 39					
Frequency Deviation df1 Average	225	275	250.52	kHz	Passed
Frequency Deviation df2 99.9 %	185	–	210.94	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	–	0.86	–	Passed

Table 20. Modulation characteristics at 2 Msps

TP/TRM-LE/CA/BV-05-C [Modulation Characteristics at 2 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-10-C [Modulation Characteristics at 2 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 0					
tblContinuation_7_1					
Frequency Deviation df1 Average	450	550	506.34	kHz	Passed
tblContinuation_7_2					
Frequency Deviation df2 99.9 %	370	–	400.70	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	–	0.81	–	Passed
Channel 19					
tblContinuation_7_3					
Frequency Deviation df1 Average	450	550	500.85	kHz	Passed
tblContinuation_7_4					

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Table 20. Modulation characteristics at 2 Msps...continued

TP/TRM-LE/CA/BV-05-C [Modulation Characteristics at 2 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-10-C [Modulation Characteristics at 2 Ms/s] @ Payload length: 37, Statistic Count: 10					
Frequency Deviation df2 99.9 %	370	–	402.89	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	–	0.83	–	Passed
Channel 39					
tblContinuation_7_5					
Frequency Deviation df1 Average	450	550	505.42	kHz	Passed
tblContinuation_7_6					
Frequency Deviation df2 99.9 %	370	–	402.30	kHz	Passed
Frequency Deviation df2 Average/df1 Average	0.80	–	0.82	–	Passed

Table 21. Modulation characteristics at LE coded (S8)

TP/TRM-LE/CA/BV-13-C [Modulation Characteristics, LE Coded (S = 8)]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-13-C [Modulation Characteristics, LE Coded (S = 8)] @ Payload length: 37, Statistic Count: 10					
Channel 0					
tblContinuation_9_1					
Frequency Deviation df1 Average	225	275	252.43	kHz	Passed
tblContinuation_9_2					
Frequency Deviation df1 99.9 %	185	–	242.22	kHz	Passed
Channel 19					
tblContinuation_9_3					
Frequency Deviation df1 Average	225	275	250.74	kHz	Passed
Frequency Deviation df1 99.9 %	185	–	241.82	kHz	Passed
Channel 39					
tblContinuation_9_4					
Frequency Deviation df1 Average	225	275	251.84	kHz	Passed
Frequency Deviation df1 99.9 %	185	–	241.22	kHz	Passed

Conclusion:

Good margins, in line with the expected results.

3.3.1.15 Carrier frequency offset and drift

A CMW equipment is used to measure the frequency deviation df1 and df2.

Flashed software: A specific binary is flashed: hci_bb.bin (available in the Bluetooth application examples).

Test method:

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

Result:

Table 22. Carrier frequency offset and drift at 1 Msps

TP/TRM-LE/CA/BV-06-C [Carrier frequency offset and drift at 1 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-06-C [Carrier frequency offset and drift at 1 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 0					
Frequency Accuracy	-150.00	150.00	7.31	kHz	Passed
Frequency Drift	-50.00	50.00	3.32	kHz	Passed
Maximum Drift Rate	-20.00	20.00	1.43	kHz/50 µs	Passed
Frequency Offset	-150.00	150.00	8.82	kHz	Passed
Initial Frequency Drift	-23.00	23.00	2.20	kHz	Passed
Channel 19					
Frequency Accuracy	-150.00	150.00	8.22	kHz	Passed
Frequency Drift	-50.00	50.00	1.96	kHz	Passed
Maximum Drift Rate	-20.00	20.00	1.44	kHz/50 µs	Passed
Channel 39					
Frequency Accuracy	-150.00	150.00	7.87	kHz	Passed
Frequency Drift	-50.00	50.00	2.06	kHz	Passed
Maximum Drift Rate	-20.00	20.00	1.47	kHz/50 µs	Passed
Frequency Offset	-150.00	150.00	9.19	kHz	Passed
Initial Frequency Drift	-23.00	23.00	1.70	kHz	Passed

Table 23. Carrier frequency offset and drift at 2 Msps

TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 2 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 2 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 0					
tblContinuation_8_1					
Frequency Accuracy	-150.00	150.00	-24.33	kHz	Passed
Frequency Drift	-50.00	50.00	-4.54	kHz	Passed
Maximum Drift Rate	-20.00	20.00	-2.25	kHz/50 µs	Passed
Frequency Offset	-150.00	150.00	-27.50	kHz	Passed
Initial Frequency Drift	-23.00	23.00	-2.49	kHz	Passed

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Table 23. Carrier frequency offset and drift at 2 Msps...continued

TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 2 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 2 Ms/s] @ Payload length: 37, Statistic Count: 10					
Channel 19					
tblContinuation_8_2					
Frequency Accuracy	-150.00	150.00	-24.48	kHz	Passed
Frequency Drift	-50.00	50.00	-5.12	kHz	Passed
Maximum Drift Rate	-20.00	20.00	-2.69	kHz/50 µs	Passed
Frequency Offset	-150.00	150.00	-27.86	kHz	Passed
Initial Frequency Drift	-23.00	23.00	-2.69	kHz	Passed
Channel 39					
tblContinuation_8_3					
Frequency Accuracy	-150.00	150.00	-24.91	kHz	Passed
Frequency Drift	-50.00	50.00	-5.47	kHz	Passed
Maximum Drift Rate	-20.00	20.00	-1.91	kHz/50 µs	Passed
Frequency Offset	-150.00	150.00	-28.63	kHz	Passed
Initial Frequency Drift	-23.00	23.00	-2.73	kHz	Passed

Table 24. Carrier frequency offset and drift at LR (S=8)

TP/TRM-LE/CA/BV-14-C [Carrier frequency offset and drift, LE Coded (S = 8)]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-14-C [Carrier frequency offset and drift, LE Coded (S = 8)] @ Payload length: 37, Statistic Count: 10					
tblContinuation_10_1					
Channel 0					
tblContinuation_10_2					
Frequency Accuracy	-150.00	150.00	-25.51	kHz	Passed
Frequency Drift	-50.00	50.00	-2.66	kHz	Passed
Maximum Drift Rate	-19.20	19.20	-2.59	kHz/50 µs	Passed
Frequency Offset	-150.00	150.00	-26.71	kHz	Passed
Channel 19					
tblContinuation_10_3					
Frequency Accuracy	-150.00	150.00	-25.92	kHz	Passed
Frequency Drift	-50.00	50.00	-3.04	kHz	Passed
Maximum Drift Rate	-19.20	19.20	-2.71	kHz/50 µs	Passed

Table 24. Carrier frequency offset and drift at LR (S=8)...continued

TP/TRM-LE/CA/BV-14-C [Carrier frequency offset and drift, LE Coded (S = 8)]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-14-C [Carrier frequency offset and drift, LE Coded (S = 8)] @ Payload length: 37, Statistic Count: 10					
Frequency Offset	-150.00	150.00	-27.24	kHz	Passed
Channel 39					
tblContinuation_10_4					
Frequency Accuracy	-150.00	150.00	-26.35	kHz	Passed
Frequency Drift	-50.00	50.00	-3.00	kHz	Passed
Maximum Drift Rate	-19.20	19.20	-3.00	kHz/50 µs	Passed
Frequency Offset	-150.00	150.00	-27.66	kHz	Passed

Conclusion:

Good margins, in line with the expected results.

3.3.2 RX tests

3.3.2.1 Test set up – Bluetooth LE

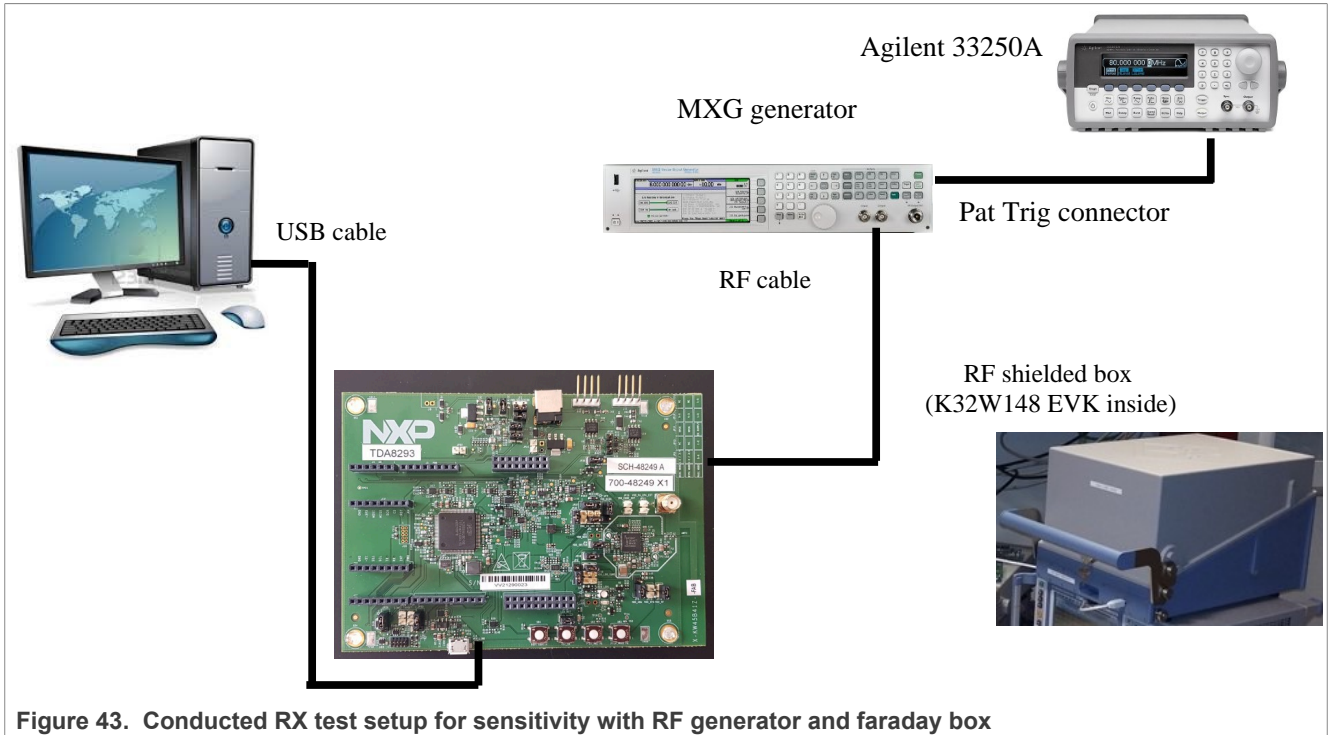


Figure 43. Conducted RX test setup for sensitivity with RF generator and faraday box

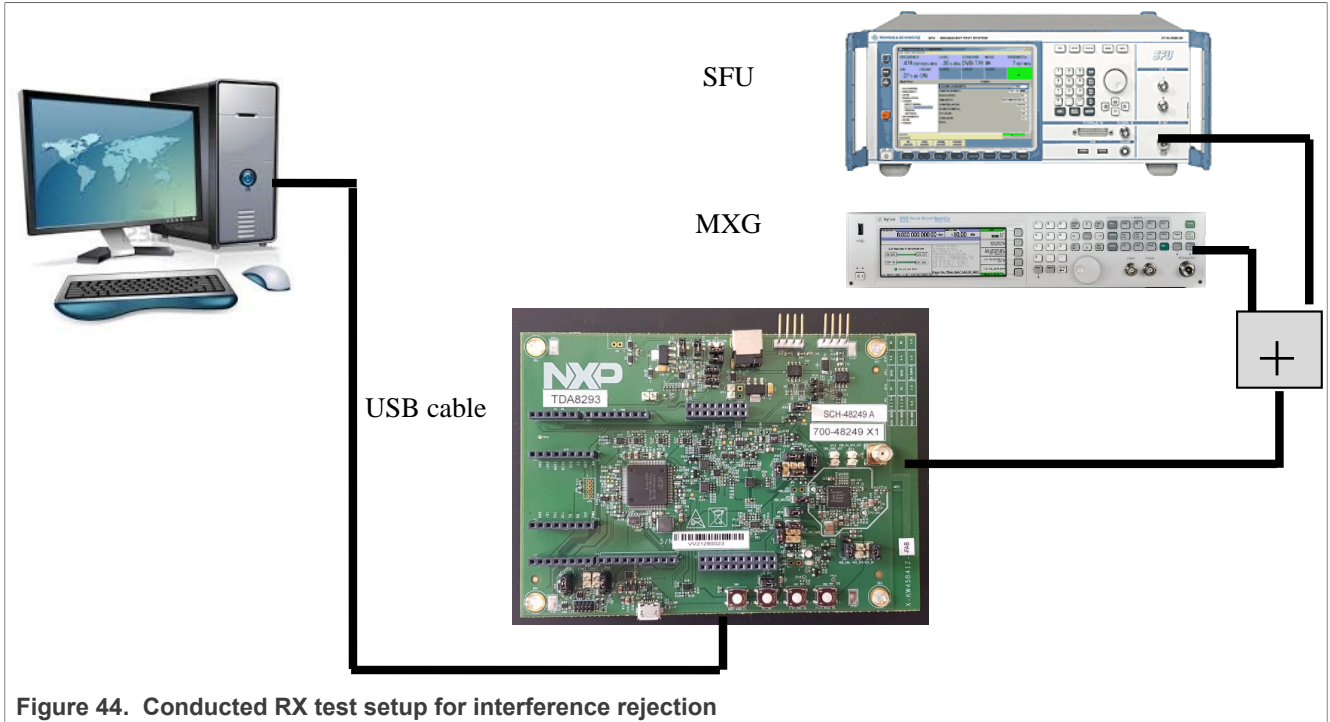


Figure 44. Conducted RX test setup for interference rejection

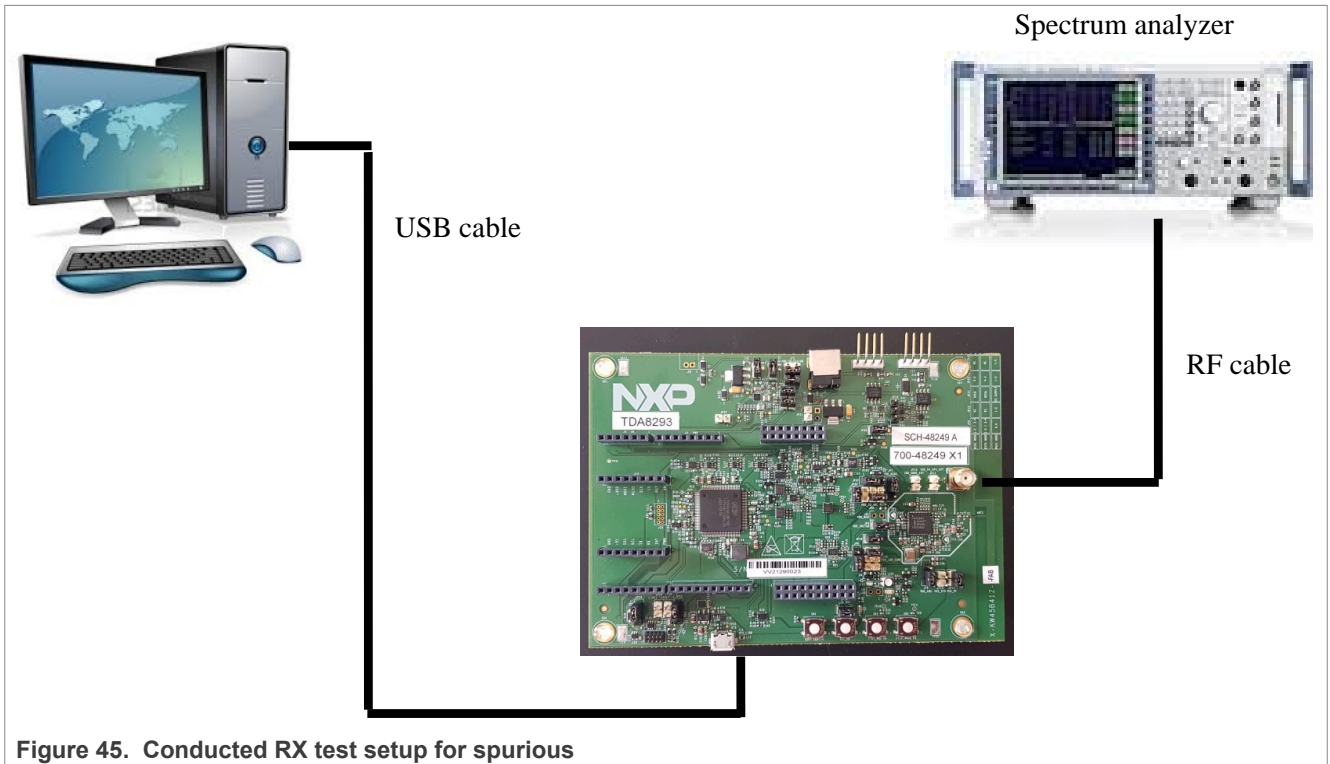


Figure 45. Conducted RX test setup for spurious

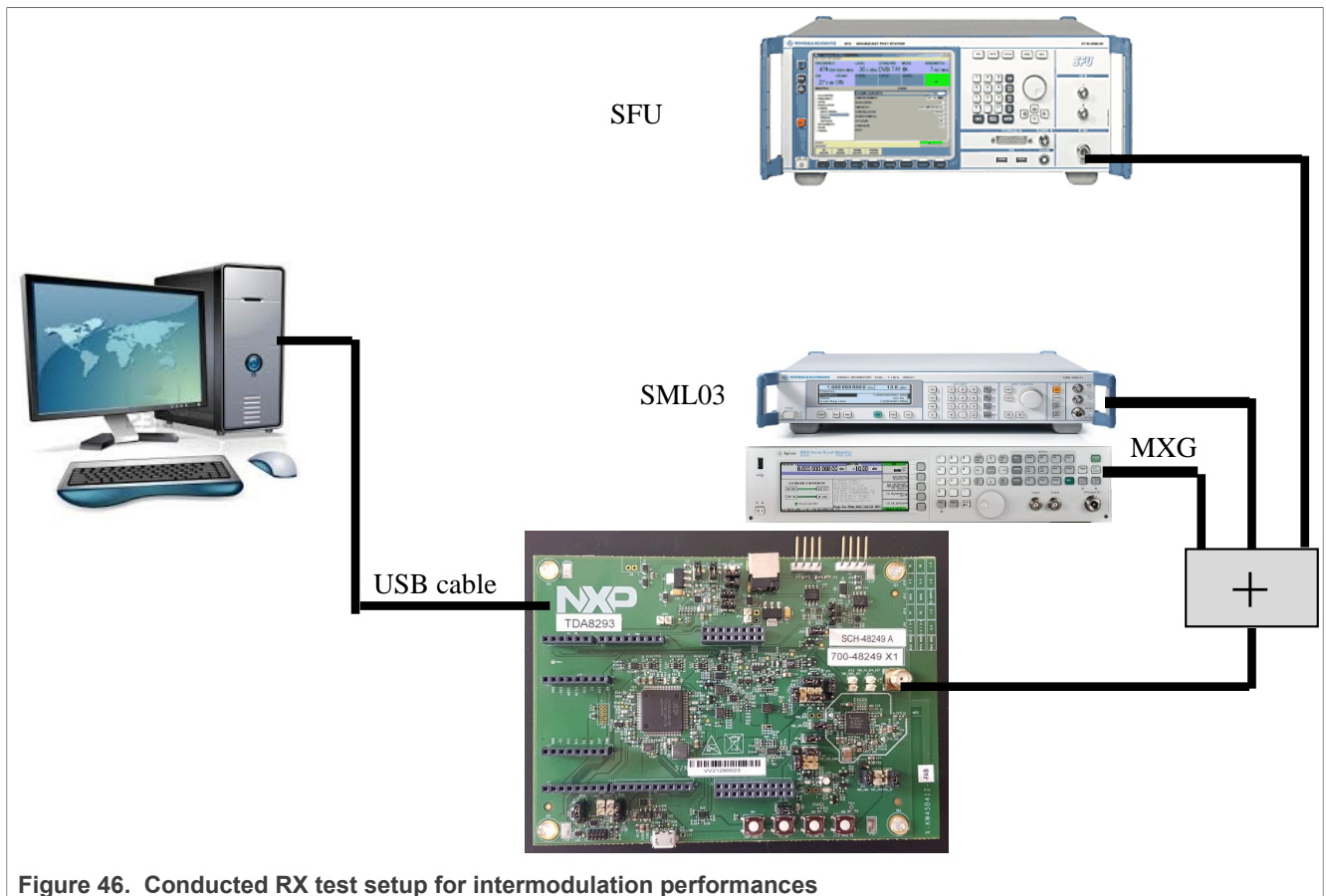


Figure 46. Conducted RX test setup for intermodulation performances

3.3.2.2 Sensitivity

3.3.2.2.1 With the ARB generator

Flashed software: Connectivity test

Test method:

- To remain immune to the external parasitic signals, put the K32W148 EVK into an RF shielded box.

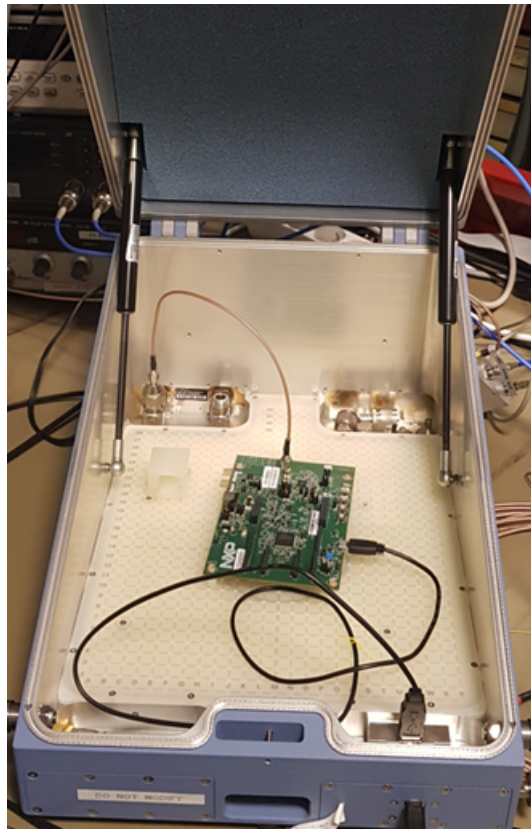


Figure 47. Sensitivity test

Bluetooth LE:

The generator (Agilent NX5181 MXG) is used in the ARB mode to generate a pattern of 1500 packets. The TERATERM window is used to control the module.

- Four modes are checked: 1 Msps, 2 Msps, LR (S=2), and LR (S=8).
- Set it to channel 0.
- The connection is automatically established and the Packet Error Rate (PER) is measured.
- Decrease the level of the SFU at the RF input of the module until PER = 30.8 %.
- Repeat it up to channel 39.

Bluetooth LE results (@SMA connector):

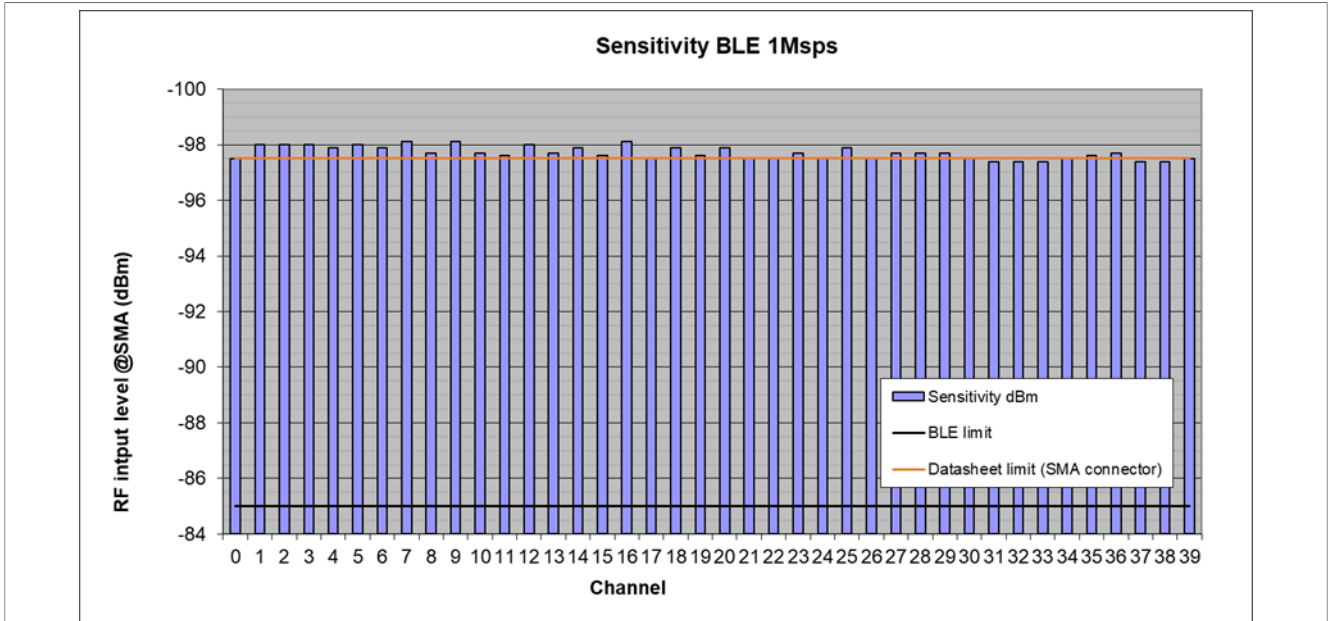


Figure 48. Sensitivity result – 1 Mps

- The best sensitivity is on channel 9: -98.1 dBm
- The lowest sensitivity is on channel 31: -97.4 dBm
- Delta over channels: 0.7 dB

K32W148 EVK shows an average value of -97.7 dBm (1 Mps) at SMA connector.

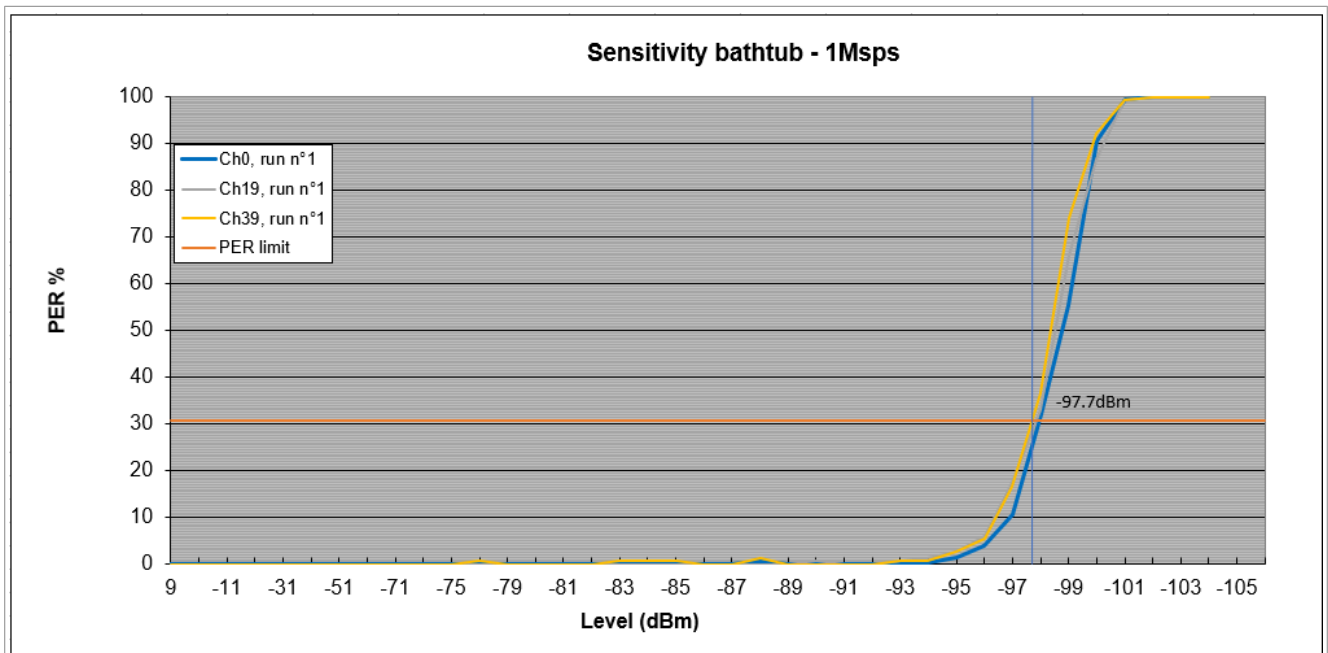


Figure 49. Sensitivity bathtub result – 1 Mps

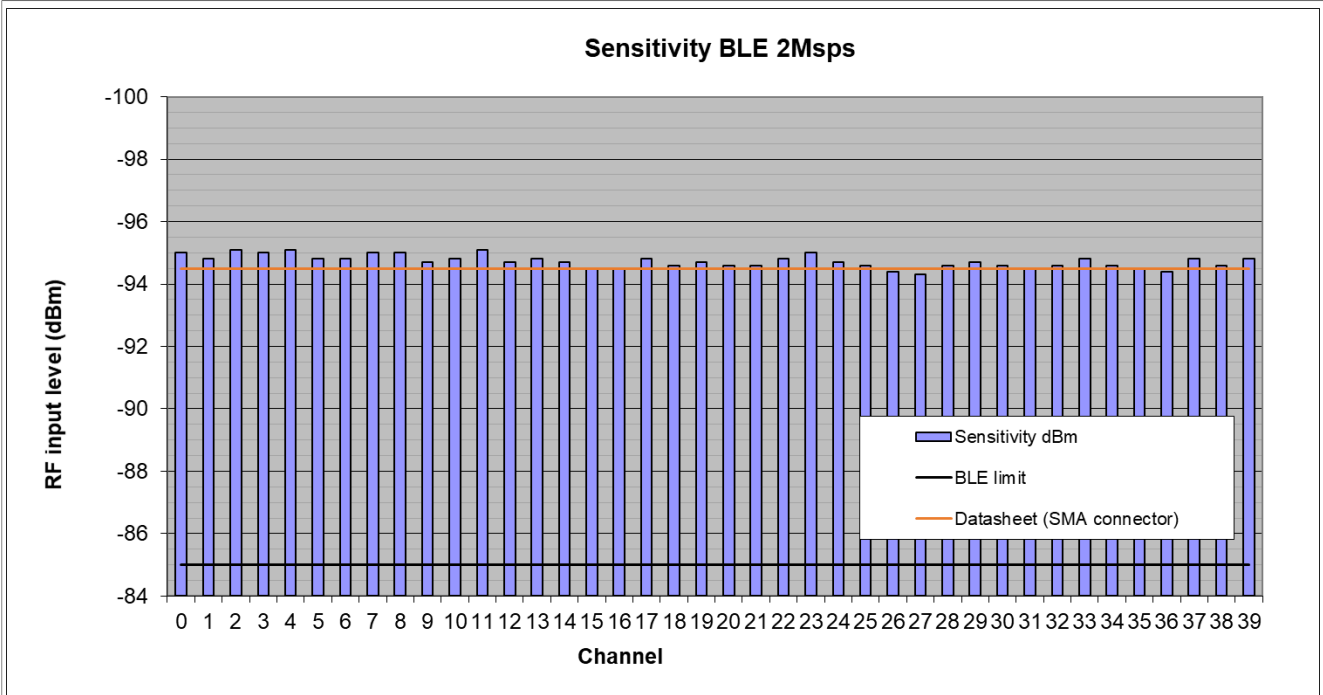


Figure 50. Sensitivity result – 2 Mps

- The best sensitivity is on channel 39: -95.9 dBm
- The lowest sensitivity is on channel 27: -95.2 dBm
- Delta over channels: 0.7 dB

K32W148 EVK shows an average value of -94.7 dBm (2 Mps) at SMA connector.

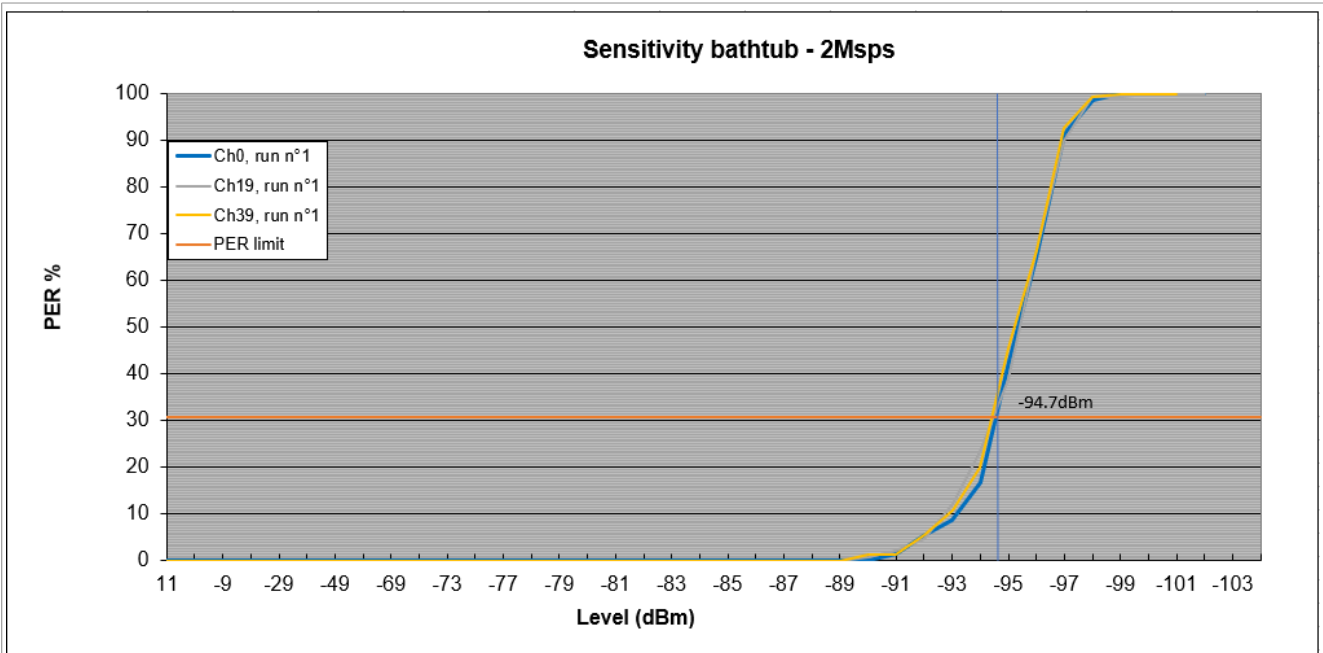


Figure 51. Sensitivity bathtub result – 2 Mps

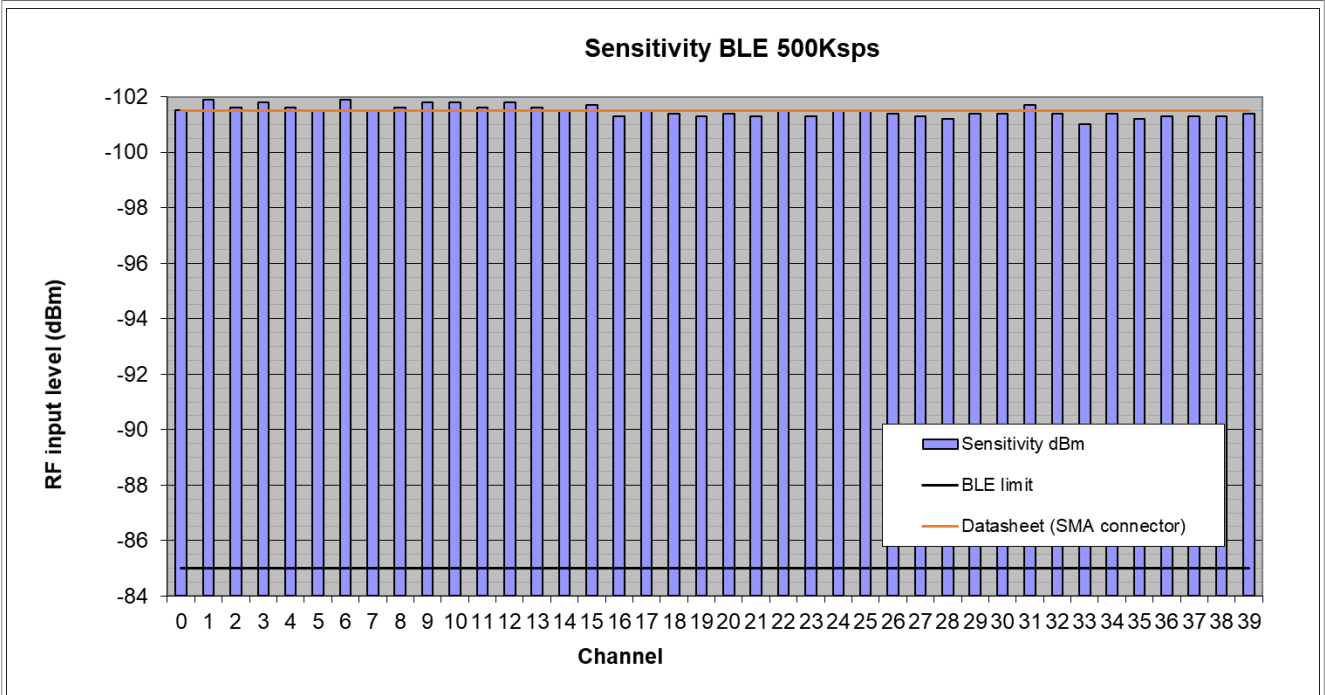


Figure 52. Sensitivity result – LR (S=2)

- The best sensitivity is on channel 31: -101.9 dBm
- The lowest sensitivity is on channel 13: -101.0 dBm
- Delta over channels: 0.9 dB

K32W148 EVK shows an average value of -101.5 dBm (500 ksps) at SMA connector.

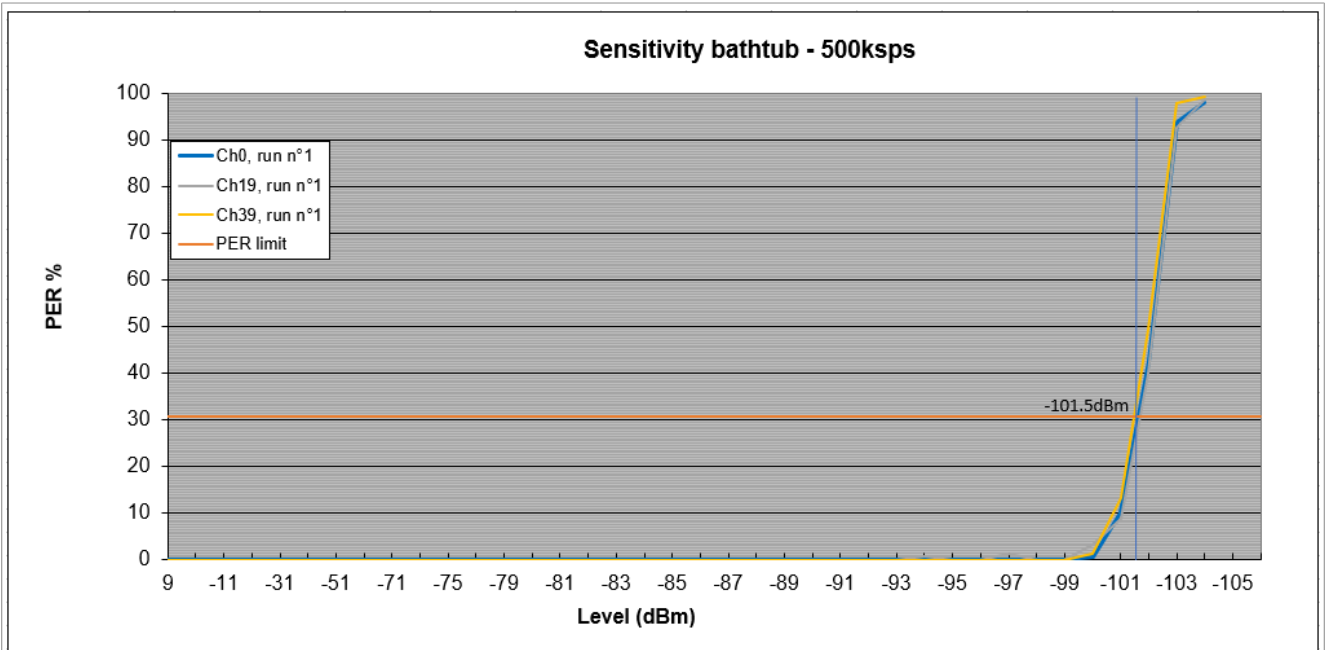


Figure 53. Sensitivity bathtub result – 500 ksps

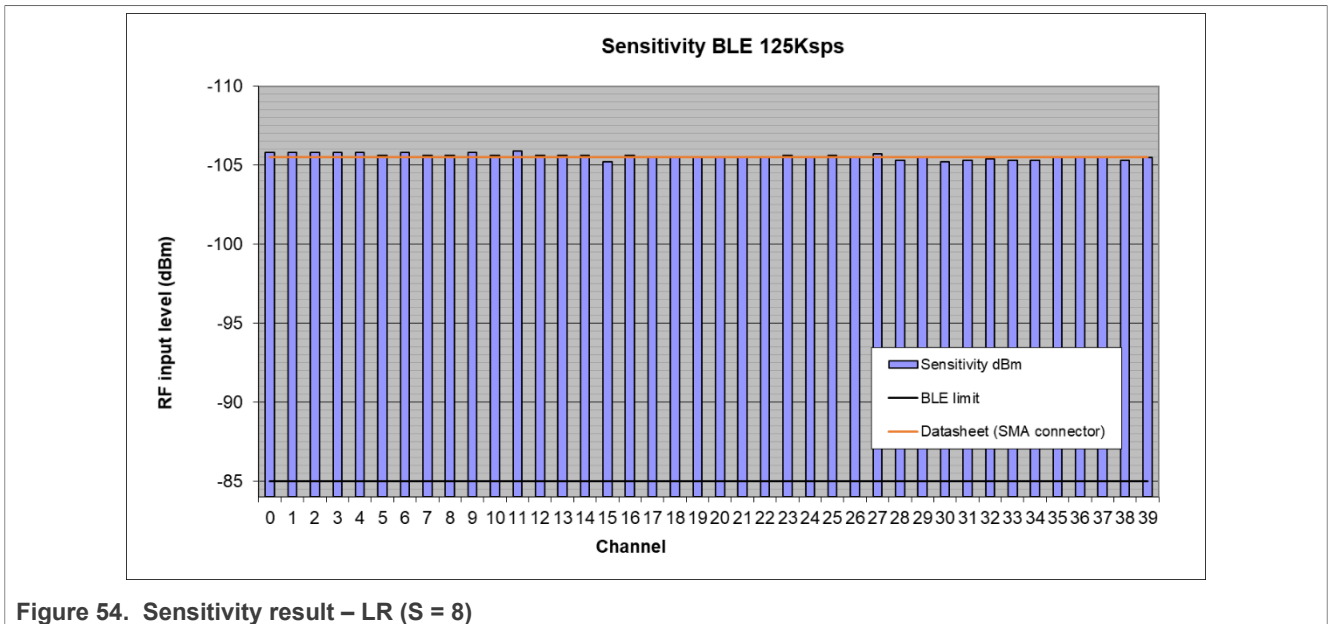


Figure 54. Sensitivity result – LR (S = 8)

- The best sensitivity is on channel 11: -105.9 dBm
- The lowest sensitivity is on channel 28: -105.2 dBm
- Delta over channels: 0.7 dB

K32W148 EVK shows an average value of -105.6 dBm (125 ksps) at SMA connector.

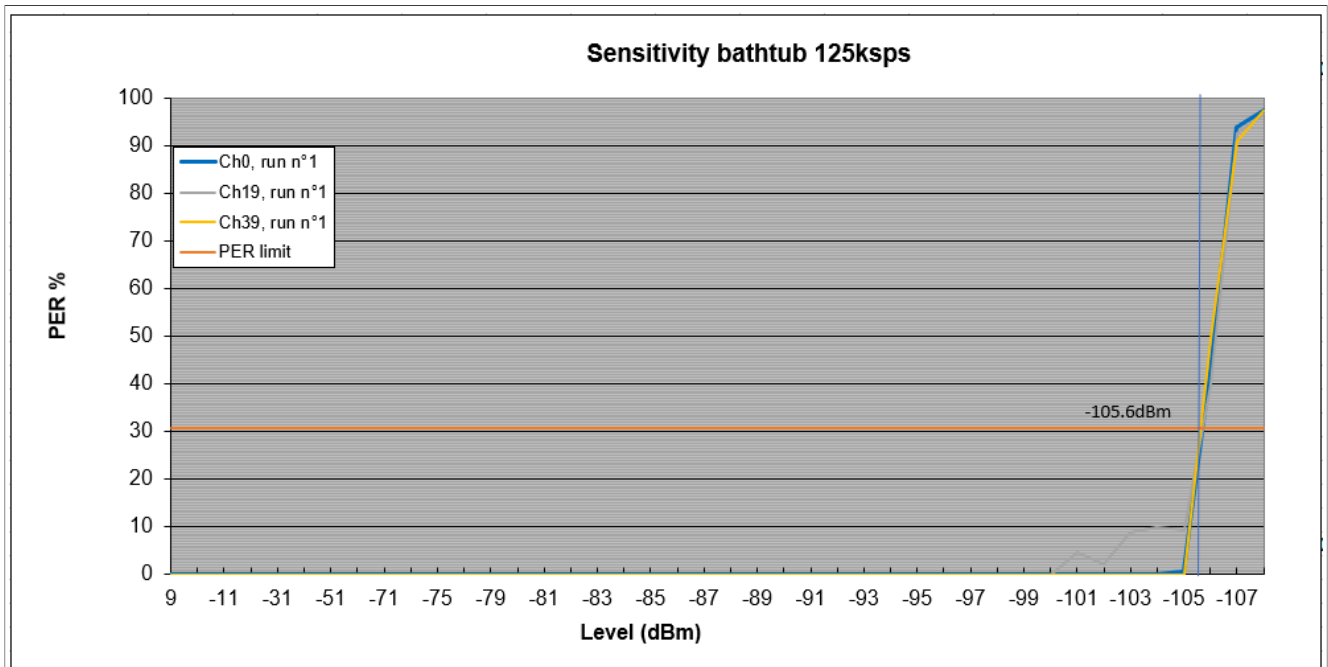


Figure 55. Sensitivity bathtub result – 125 kps

Conclusion:

K32W148 EVK withstands an average sensitivity level of:

- -97.7 dBm @1 Msp (Data sheet typical value: -97.65 dBm at the SMA connector)
- -94.7 dBm @2 Msp (Data sheet typical value: -94.65 dBm at the SMA connector)

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- -101.5 dBm @LRS2 (Data sheet typical value: -101.65 dBm at the SMA connector)
- -105.6 dBm @LRS8 (Data sheet typical value: -105.65 dBm at the SMA connector)

Note: To get the value at RF pin output (data sheet value), add 0.35 dB loss to the sensitivity results.

3.3.2.3 Receiver maximum input level

3.3.2.3.1 Bluetooth LE

Flashed software: HCI_BB

Test method:

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

Results:

Table 25. Maximum input power – 1 Msps

TP/RCV-LE/CA/BV-06-C [Maximum input signal level at 1 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/RCV-LE/CA/BV-06-C [Maximum input signal level at 1 Ms/s] @ Payload length: 37, No. of Packets: 1500, RF Level: 0 dBm					
Channel 0					
tblContinuation_7_1					
PER	–	30.8	16.66667	%	Passed
Correct Packets	–	–	1250		Passed
Channel 19					
tblContinuation_7_2					
PER	–	30.8	16.53333	%	Passed
Correct Packets	–	–	1252		Passed
Channel 39					
tblContinuation_7_3					
PER	–	30.8	14.73333	%	Passed
Correct Packets	–	–	1279		Passed

Table 26. Maximum input power – 2 Msps

TP/RCV-LE/CA/BV-12-C [Maximum input signal level at 2 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/RCV-LE/CA/BV-12-C [Maximum input signal level at 2 Ms/s] @ Payload length: 37, No. of Packets: 1500, RF Level: 0 dBm					
Channel 0					
tblContinuation_13_1					
PER	–	30.8	12.80000	%	Passed
Correct Packets	–	–	1308		Passed

Table 26. Maximum input power – 2 Msps...continued

TP/RCV-LE/CA/BV-12-C [Maximum input signal level at 2 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/RCV-LE/CA/BV-12-C [Maximum input signal level at 2 Ms/s] @ Payload length: 37, No. of Packets: 1500, RF Level: 0 dBm					
Channel 19					
tblContinuation_13_2					
PER	–	30.8	10.53333	%	Passed
Correct Packets	–	–	1342		Passed
Channel 39					
tblContinuation_13_3					
PER	–	30.8	12.86667	%	Passed
Correct Packets	–	–	1307		Passed

Conclusion:

The results are limited by the maximum output power of the equipment.

3.3.2.4 RX spurious

Flashed software: Connectivity test

Test method:

- Set the radio to:
 - Receiver mode, frequency: channel 18
- Set the analyzer to:
 - Ref amp = - 20 dBm, Trace = max hold, detector = max peak
- Set 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

Bluetooth LE results:

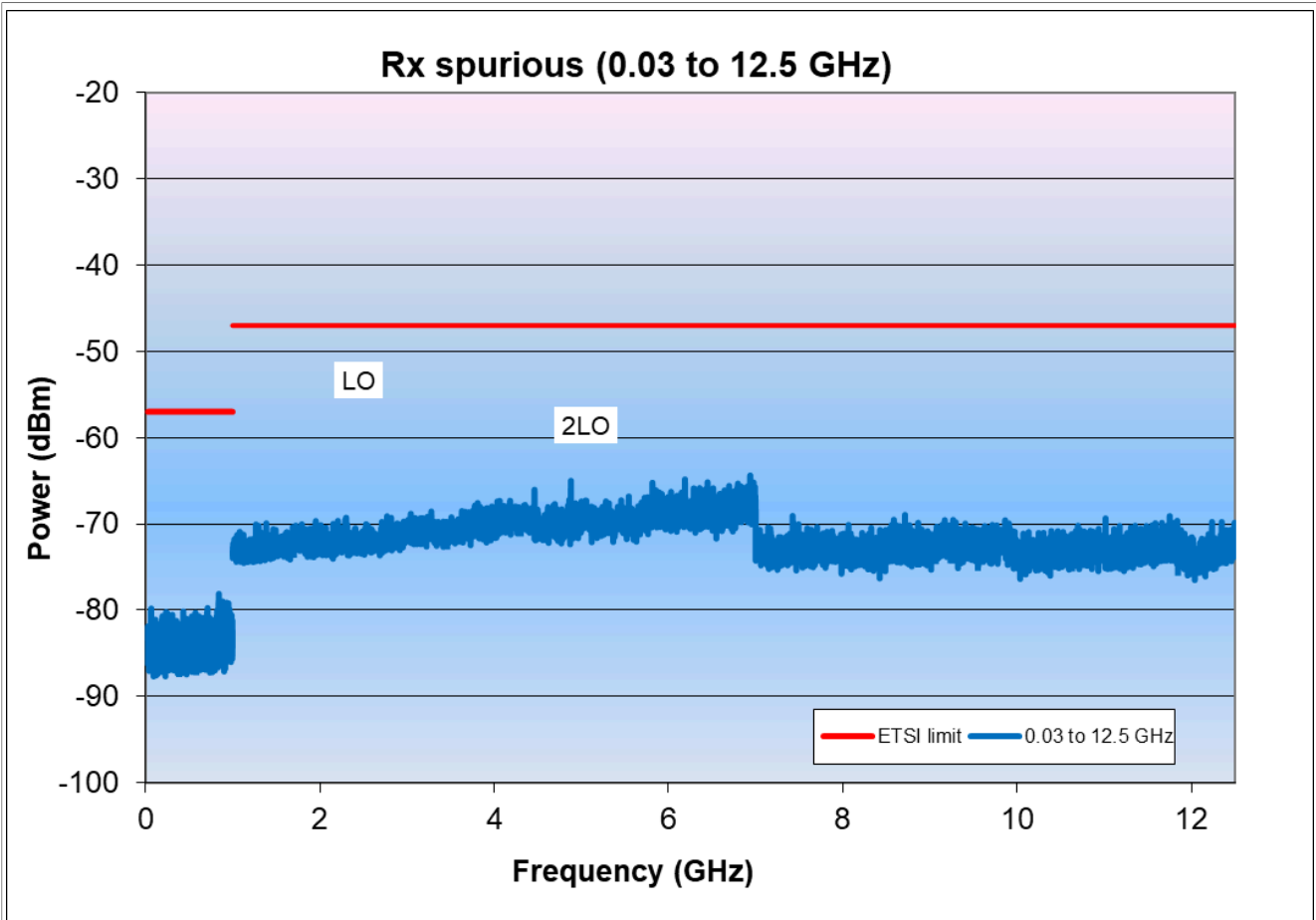


Figure 56. Bluetooth LE - Conducted RX spurious 30 MHz – 12.5 GHz

Conclusion:

- There are no spurs above the spectrum analyzer noise floor, except for 2xLO.
- More than -18 dB margin

3.3.2.5 Interferer results in Bluetooth

3.3.2.5.1 Receiver interference rejection performances

3.3.2.5.1.1 Adjacent, Alternate, and Co-channel rejection – Bluetooth LE @1 Msps, @2 Msps, @500 ksps (LR S=2), @125 ksps (LR S=8)

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: Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- The expected signal is set to -67 dBm; the interferer is increased until the PER threshold is reached

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- Channels under test: 2, 19, and 37

Bluetooth LE @ 1 Msps:

- Results

ch2 2406					ch19 2440				ch37 2476			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz
Interferer level (dBm)	-18.6	-62.1	-63.1	-17.1	-19.1	-63.1	-63.1	-17.1	-20.1	-62.1	-63.1	-17.1
Interferer level (C/I dB)	-48.4	-4.9	-3.9	-49.9	-47.9	-3.9	-3.9	-49.9	-46.9	-4.9	-3.9	-49.9
BLE 5.x limit (C/I dB)	-17	15	15	-17	-17	15	15	-17	-17	15	15	-17
Margin (dB)	31.4	19.9	18.9	32.9	30.9	18.9	18.9	32.9	29.9	19.9	18.9	32.9

ch2 2406		Co-channel ch2 2406		ch19 2440		Co-channel ch19 2440		ch37 2476		Co-channel ch37 2476	
	N-3MHz	N+3MHz	N	N	N-3MHz	N+3MHz	N	N	N-3MHz	N+3MHz	N
Interferer level (dBm)	-10.1	-8.6	-70.1	-70.1	-9.6	-8.6	-70.1	-70.1	-9.6	-8.6	-70.1
Interferer level (C/I dB)	-56.9	-58.4	3.1	3.1	-57.4	-58.4	3.1	3.1	-57.4	-58.4	3.1
BLE 5.x limit (C/I dB)	-27	-27	21	21	-27	-27	21	21	-27	-27	21
Margin (dB)	29.9	31.4	17.9	17.9	30.4	31.4	17.9	17.9	30.4	31.4	17.9

Figure 57. Adjacent, alternate, and co-channel rejection Bluetooth LE @1 Msps

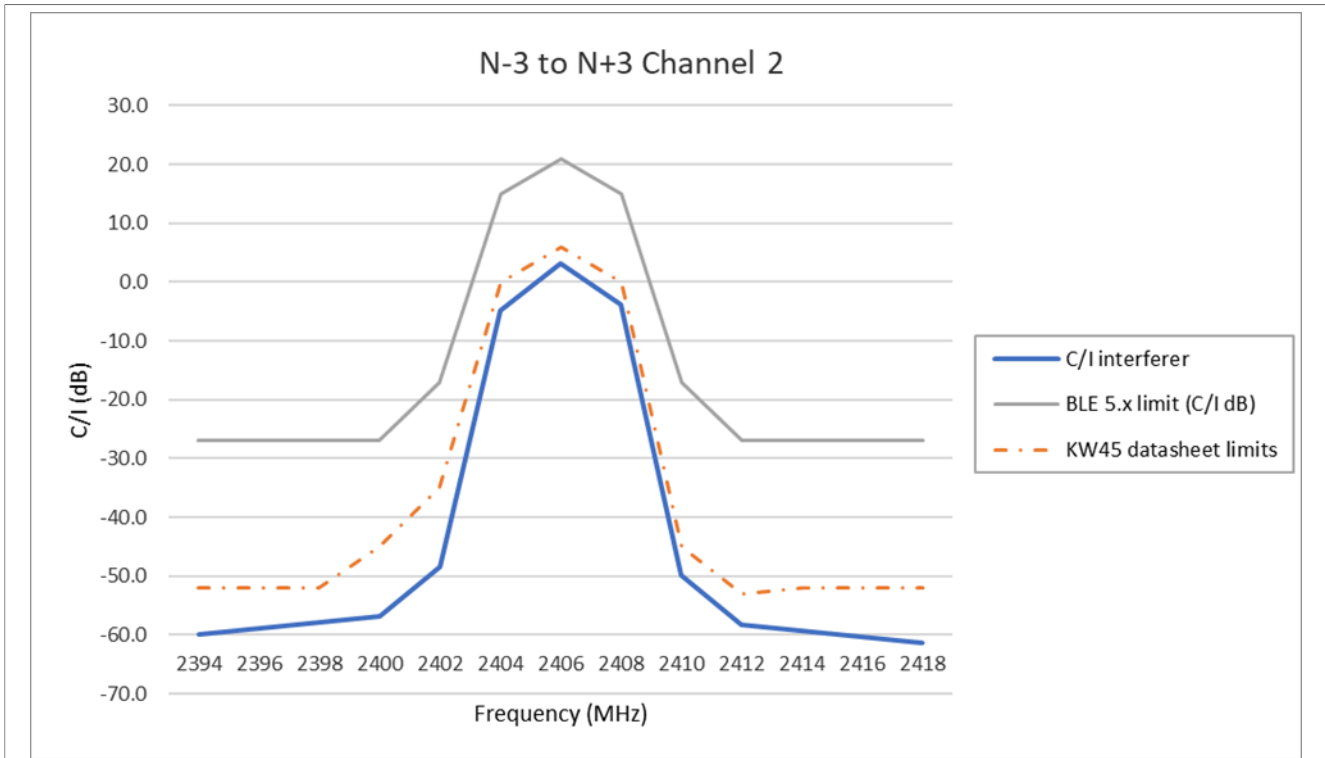


Figure 58. Adjacent, alternate, and co-channel rejection Bluetooth LE @1 Msps channel 2

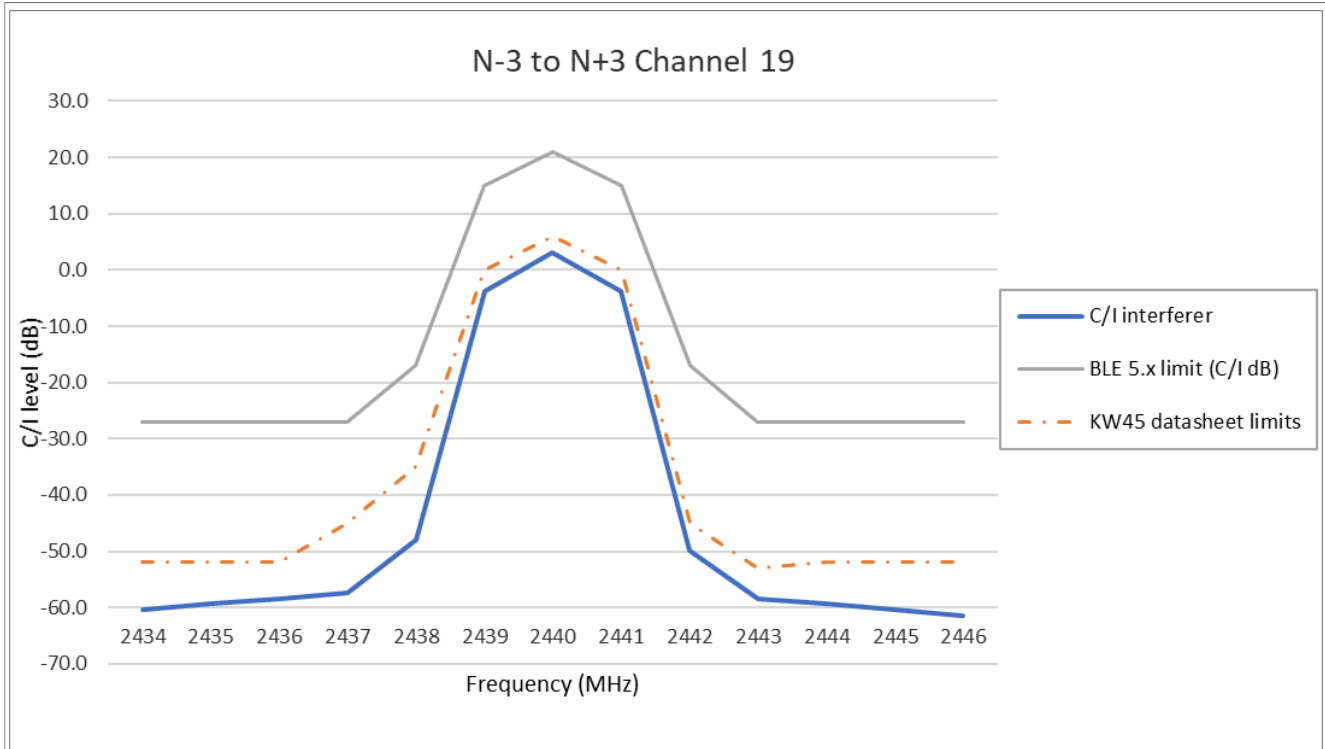


Figure 59. Adjacent, alternate, and co-channel rejection Bluetooth LE @1 Msp channel 19

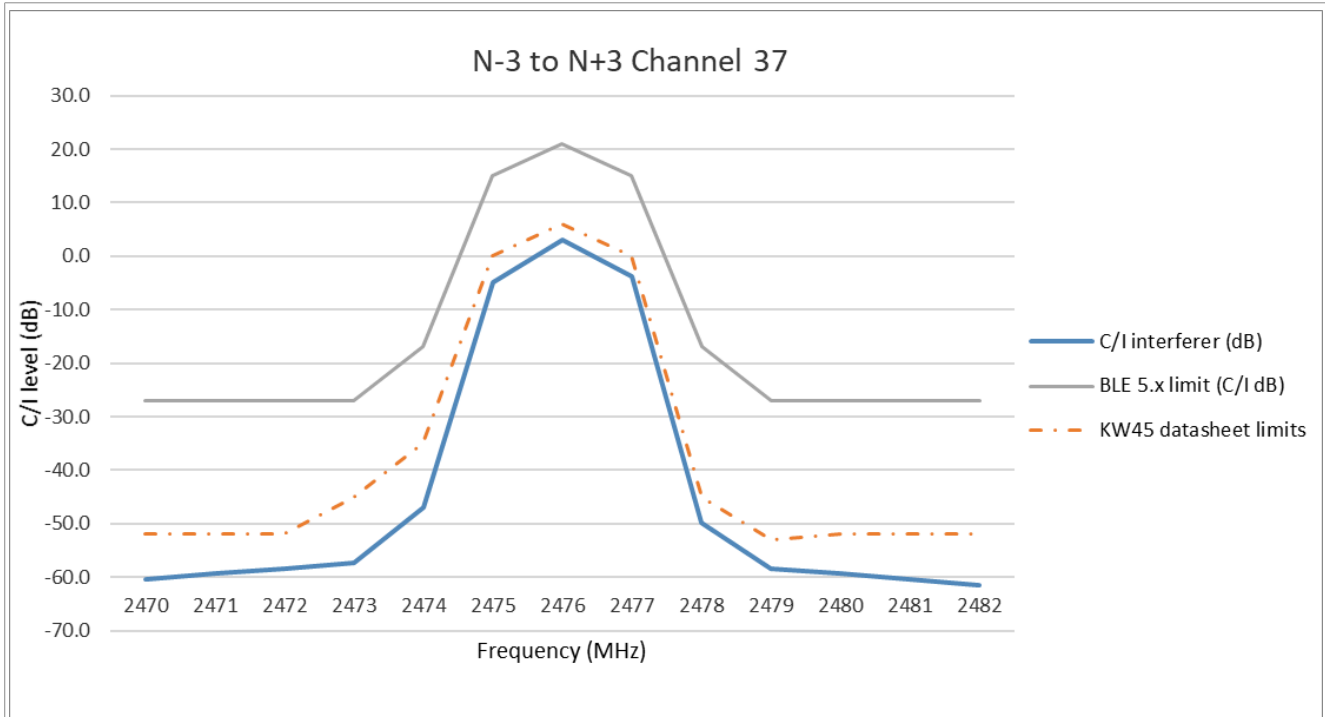


Figure 60. Adjacent, alternate, and co-channel rejection Bluetooth LE @1 Msp channel 37

- Conclusion
Good margin, in line with the expected results.

Bluetooth LE @ 2 Msp:

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• Results

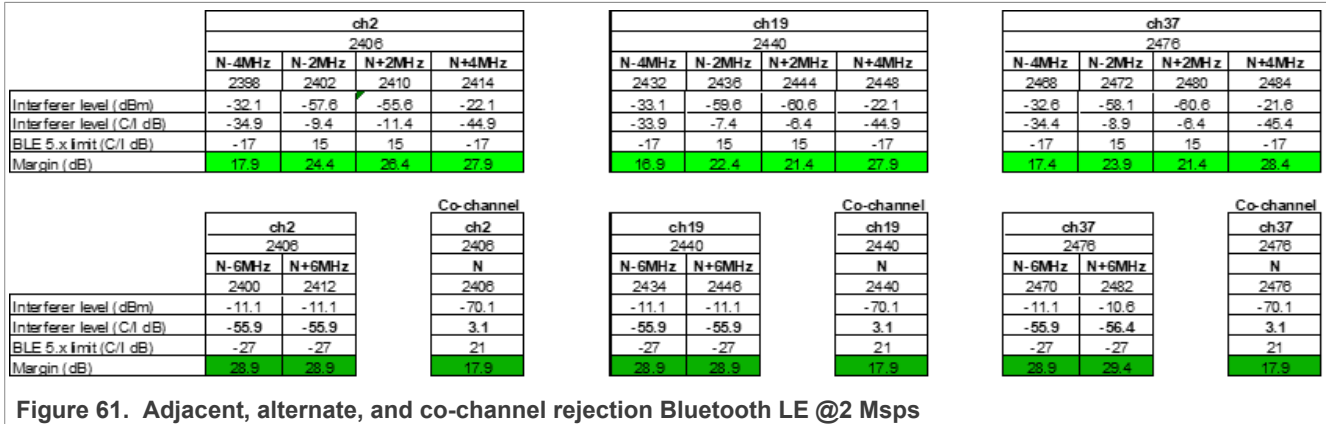


Figure 61. Adjacent, alternate, and co-channel rejection Bluetooth LE @2 Msp

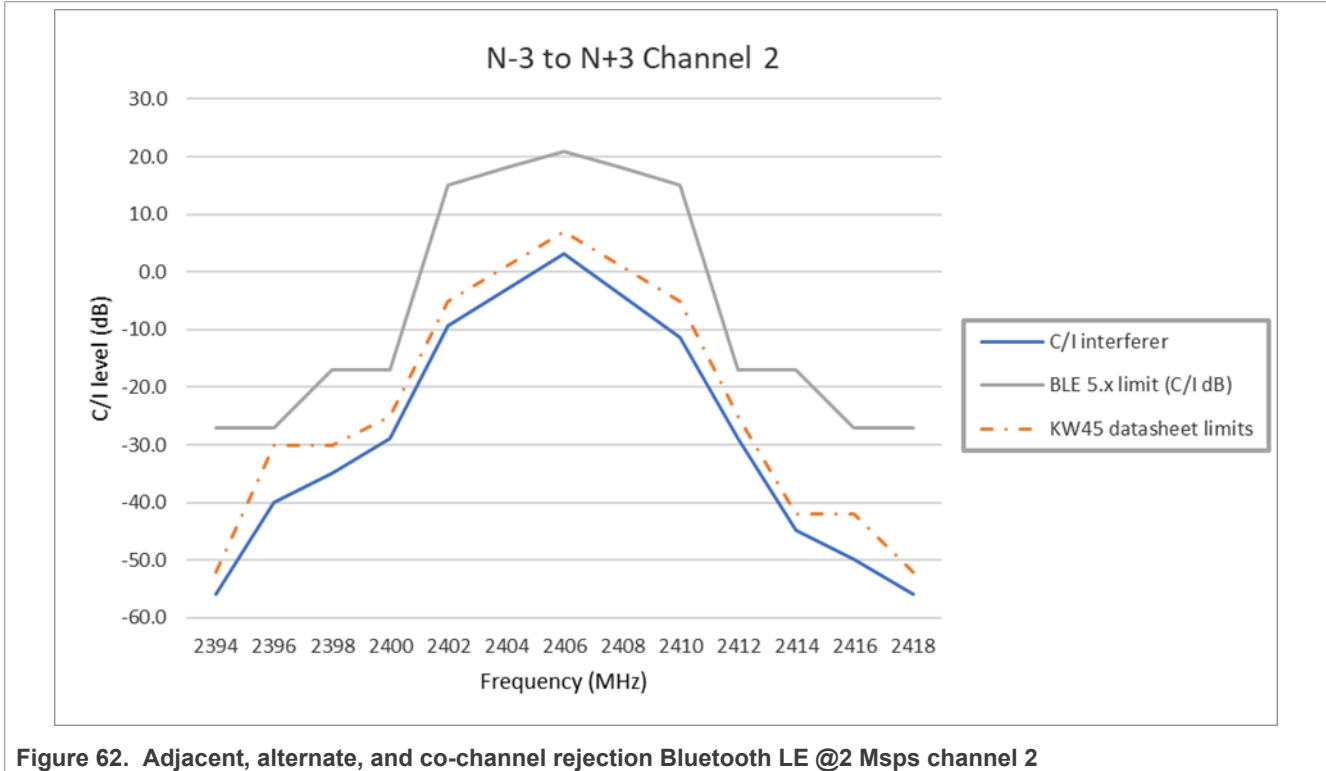


Figure 62. Adjacent, alternate, and co-channel rejection Bluetooth LE @2 Msp channel 2

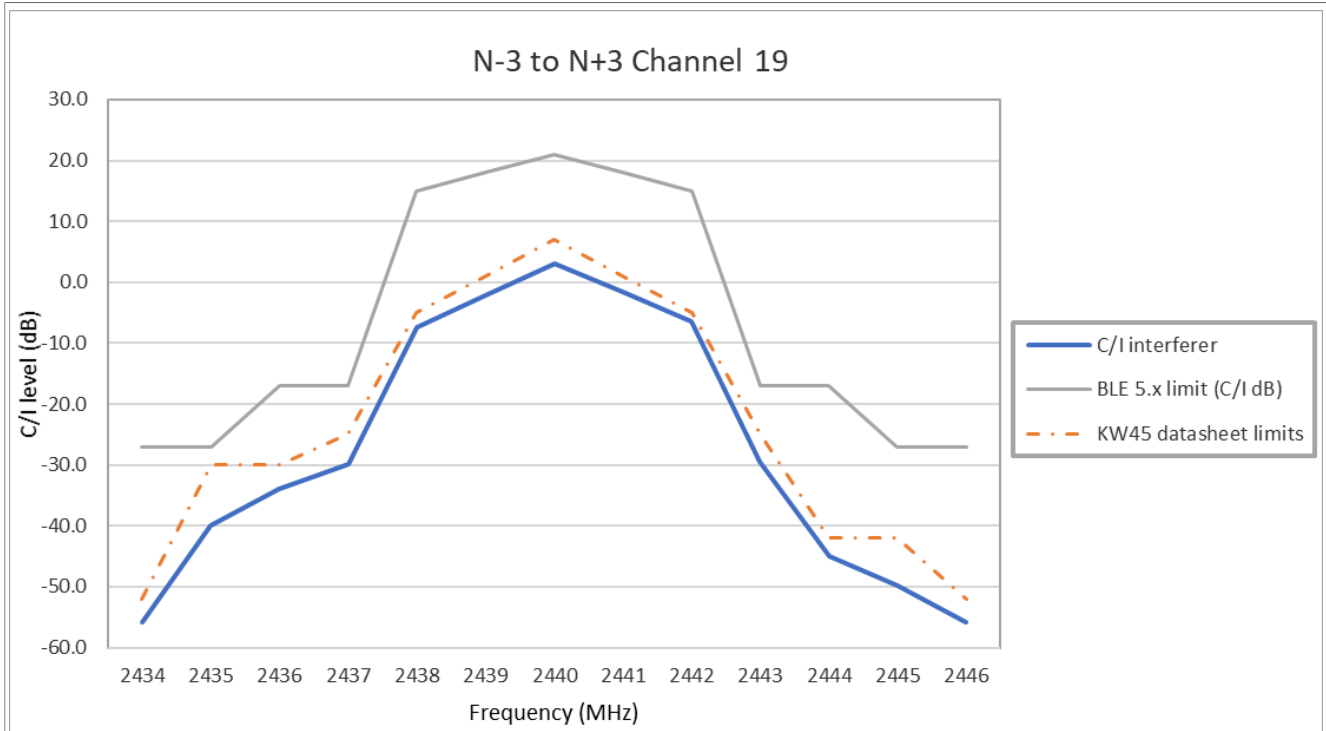


Figure 63. Adjacent, alternate, and co-channel rejection Bluetooth LE @2 Msps channel 19

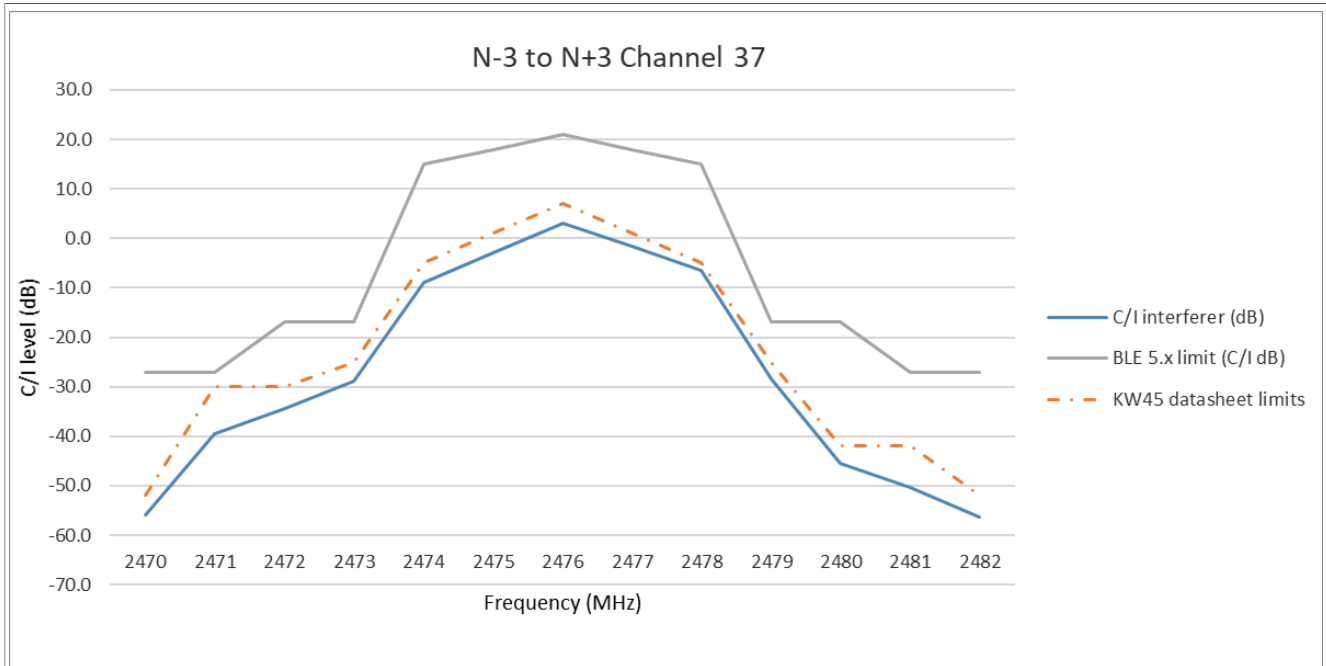


Figure 64. Adjacent, alternate, and co-channel rejection Bluetooth LE @2 Msps channel 37

- **Conclusion:**
Good margin, in line with the expected results.

Bluetooth LE @500 ksps (LR S = 2):

- **Results:**

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ch2 2408					ch19 2440				ch37 2478			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz	N-2MHz	N-1MHz	N+1MHz	N+2MHz
Interferer level (dBm)	-25.1	-55.1	-55.1	-18.8	-25.6	-55.1	-55.1	-11.6	-26.1	-55.6	-55.6	-12.1
Interferer level (C/I dB)	-41.9	-11.9	-11.9	-50.4	-41.4	-11.9	-11.9	-55.4	-40.9	-11.4	-11.4	-54.9
BLE 5.x limit (C/I dB)	-17	15	15	-17	-17	15	15	-17	-17	15	15	-17
Margin (dB)	24.9	26.9	26.9	33.4	24.4	26.9	26.9	38.4	23.9	26.4	26.4	37.9

ch2 2408		Co-channel ch2 2408		ch19 2440		Co-channel ch19 2440		ch37 2478		Co-channel ch37 2478	
	N-3MHz	N+3MHz	N	N	N-3MHz	N+3MHz	N	N	N-3MHz	N+3MHz	N
Interferer level (dBm)	-15.1	-4.6	-64.6	-64.6	-12.1	-7.1	-64.6	-64.6	-12.1	-7.6	-64.1
Interferer level (C/I dB)	-51.9	-62.4	-2.4	-2.4	-54.9	-59.9	-2.4	-2.4	-54.9	-59.4	-2.9
BLE 5.x limit (C/I dB)	-27	-27	21	21	-27	-27	21	21	-27	-27	21
Margin (dB)	24.9	35.4	23.4	23.4	27.9	32.9	23.4	23.4	27.9	32.4	23.9

Figure 65. Adjacent, alternate, and co-channel rejection Bluetooth LE @500 kps (LR S = 2)

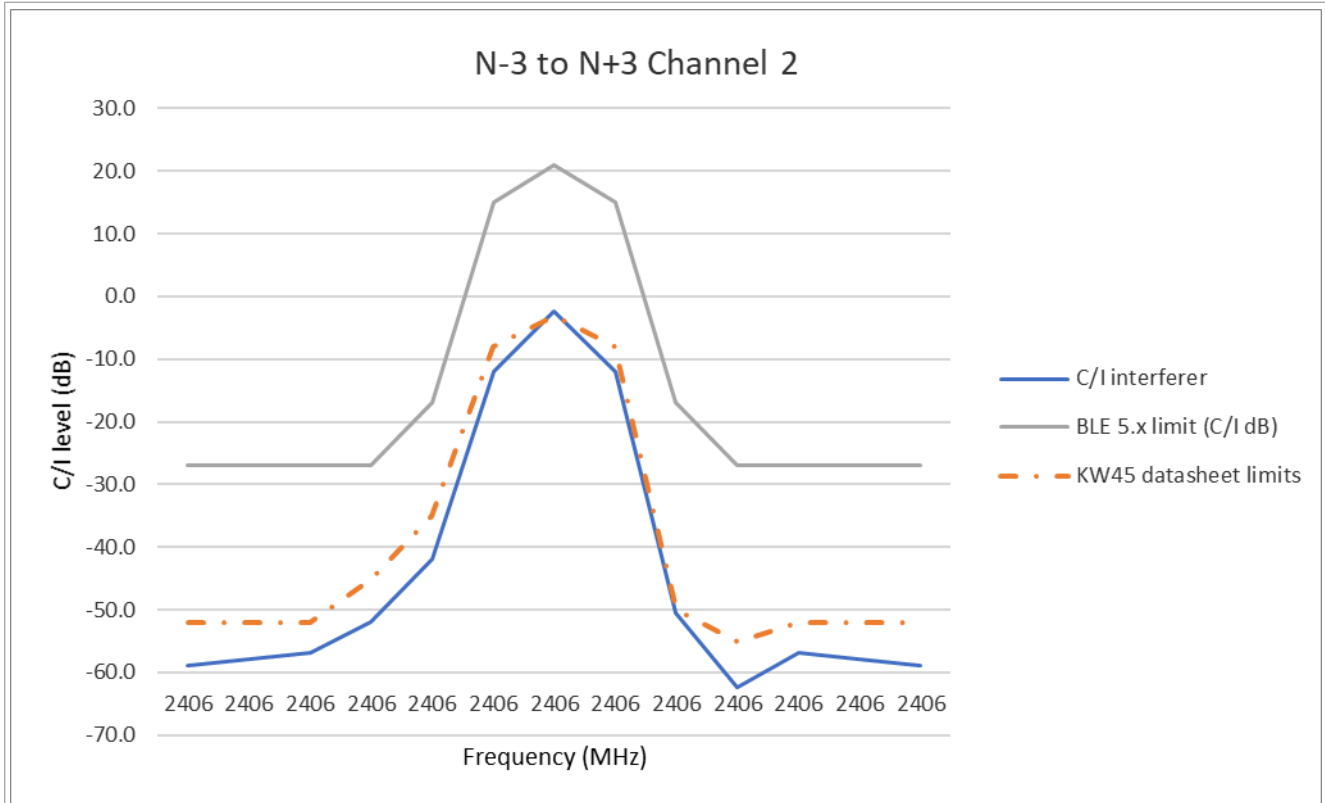


Figure 66. Adjacent, alternate, and co-channel rejection Bluetooth LE @500 kps (LR S = 2) channel 2

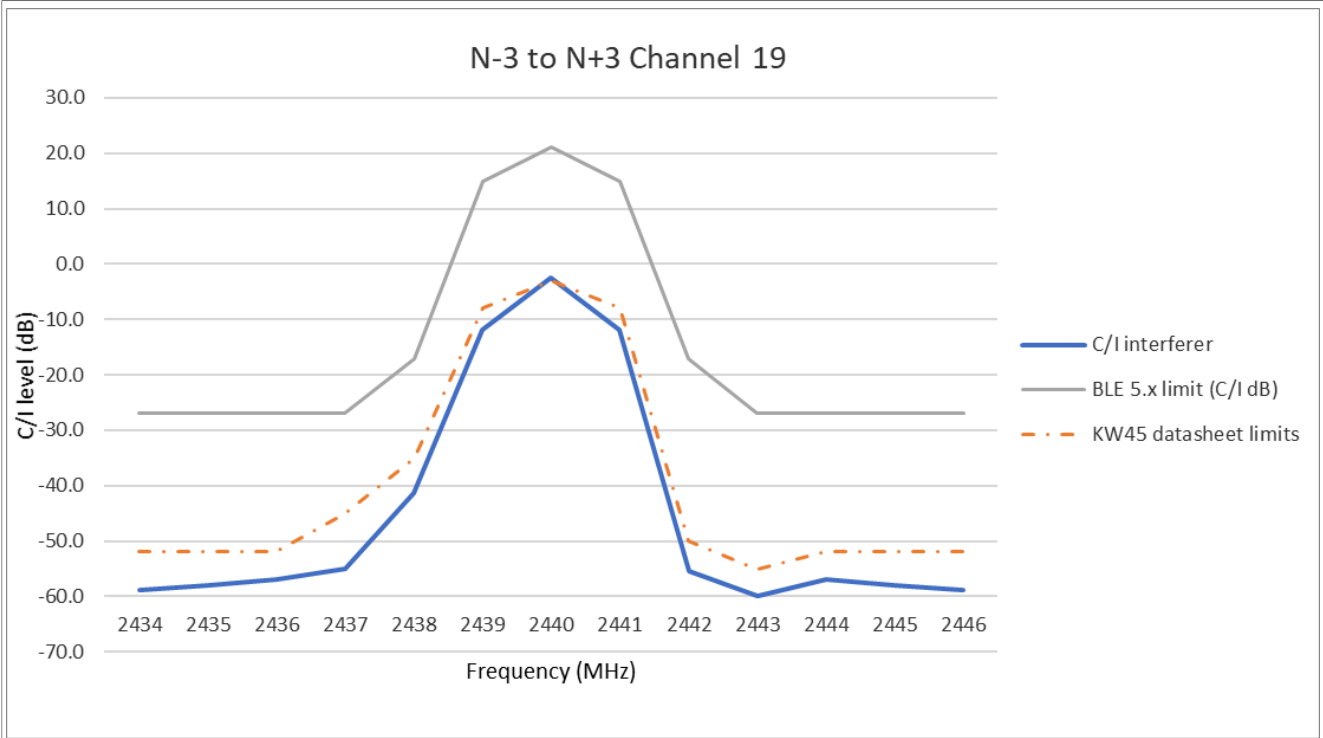


Figure 67. Adjacent, alternate, and co-channel rejection Bluetooth LE @500 kbps (LR S = 2) channel 19

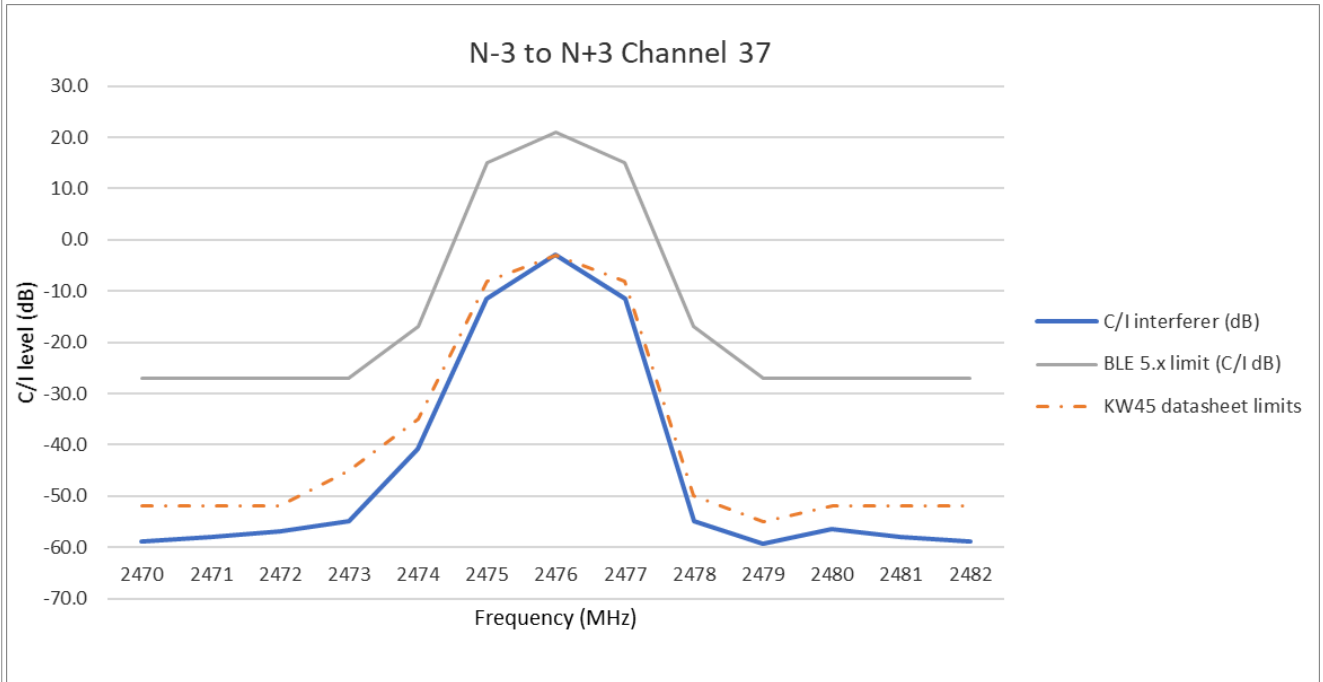


Figure 68. Adjacent, alternate, and co-channel rejection Bluetooth LE @500 kbps (LR S = 2) channel 37

- **Conclusion:**
Good margin, in line with the expected results

Bluetooth LE @125 kbps (LR S = 8):

- **Results:**

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ch2 2408				ch19 2440				ch37 2476						
	N-2MHz	N-1MHz	N+1MHz	N+2MHz		N-2MHz	N-1MHz	N+1MHz	N+2MHz		N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2402	2404	2408	2410		2436	2438	2442	2444		2472	2474	2478	2480
Interferer level (dBm)	-27.1	-58.6	-58.6	-17.6		-28.1	-59.1	-58.6	-16.6		-29.6	-58.1	-58.6	-16.6
Interferer level (C/I dB)	-39.9	-8.4	-8.4	-49.4		-38.9	-7.9	-8.4	-50.4		-37.4	-8.9	-8.4	-50.4
BLE 5.x limit (C/I dB)	-17	15	15	-17		-17	15	15	-17		-17	15	15	-17
Margin (dB)	22.9	23.4	23.4	32.4		21.9	22.9	23.4	33.4		20.4	23.9	23.4	33.4

ch2 2408		Co-channel ch2 2408		ch19 2440		Co-channel ch19 2440		ch37 2476		Co-channel ch37 2476		
	N-3MHz	N+3MHz		N	N-3MHz	N+3MHz		N	N-3MHz	N+3MHz		N
	2400	2412	2408	2408	2434	2446	2440	2440	2470	2482	2476	2476
Interferer level (dBm)	-12.6	-11.1		-65.1	-12.6	-9.1		-65.1	-12.6	-11.1		-65.1
Interferer level (C/I dB)	-54.4	-55.9		-1.9	-54.4	-57.9		-1.9	-54.4	-55.9		-1.9
BLE 5.x limit (C/I dB)	-27	-27		21	-27	-27		21	-27	-27		21
Margin (dB)	27.4	28.9		22.9	27.4	30.9		22.9	27.4	28.9		22.9

Figure 69. Adjacent, alternate, and co-channel rejection Bluetooth LE @125 kbps (LR S = 8)

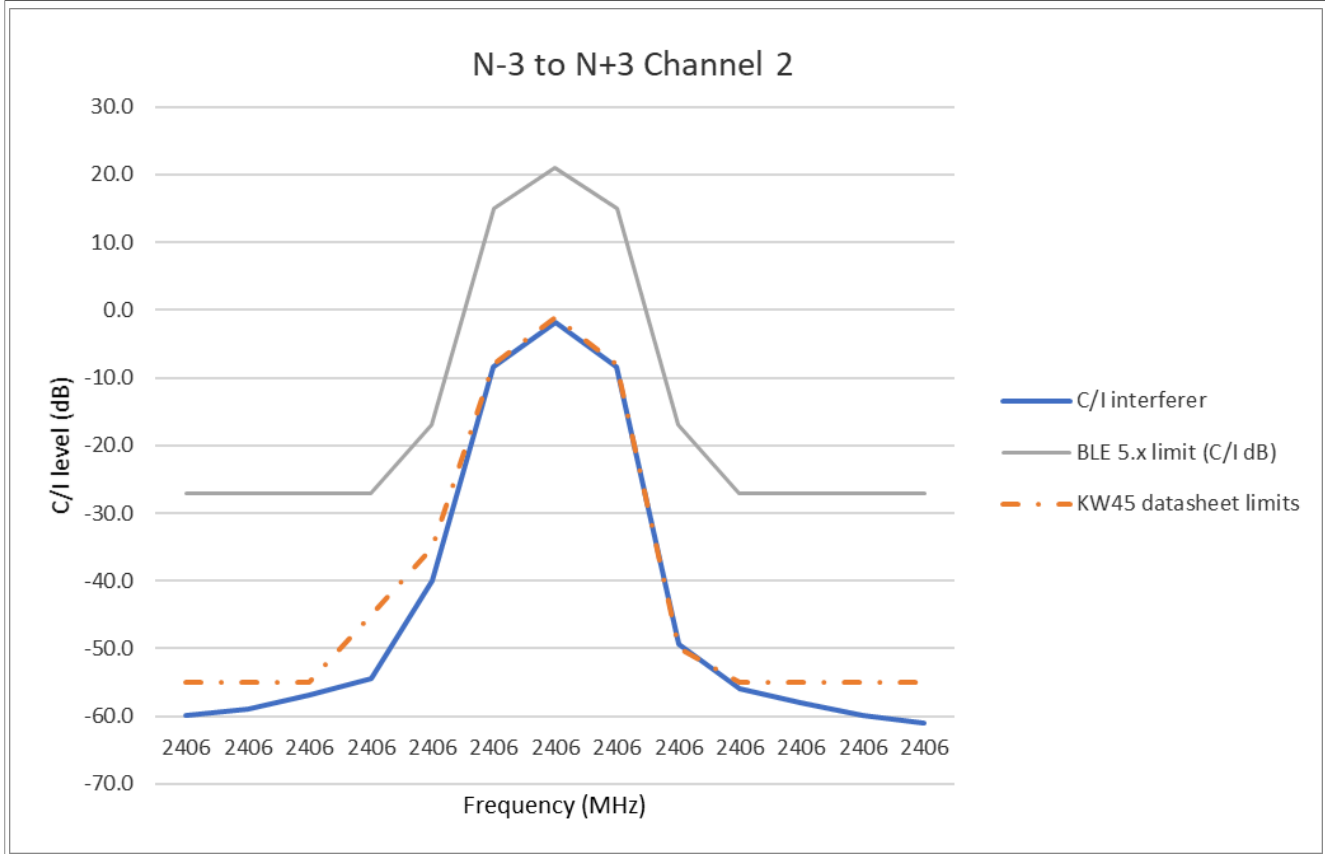


Figure 70. Adjacent, alternate, and co-channel rejection Bluetooth LE @125 kbps (LR S = 8) channel 2

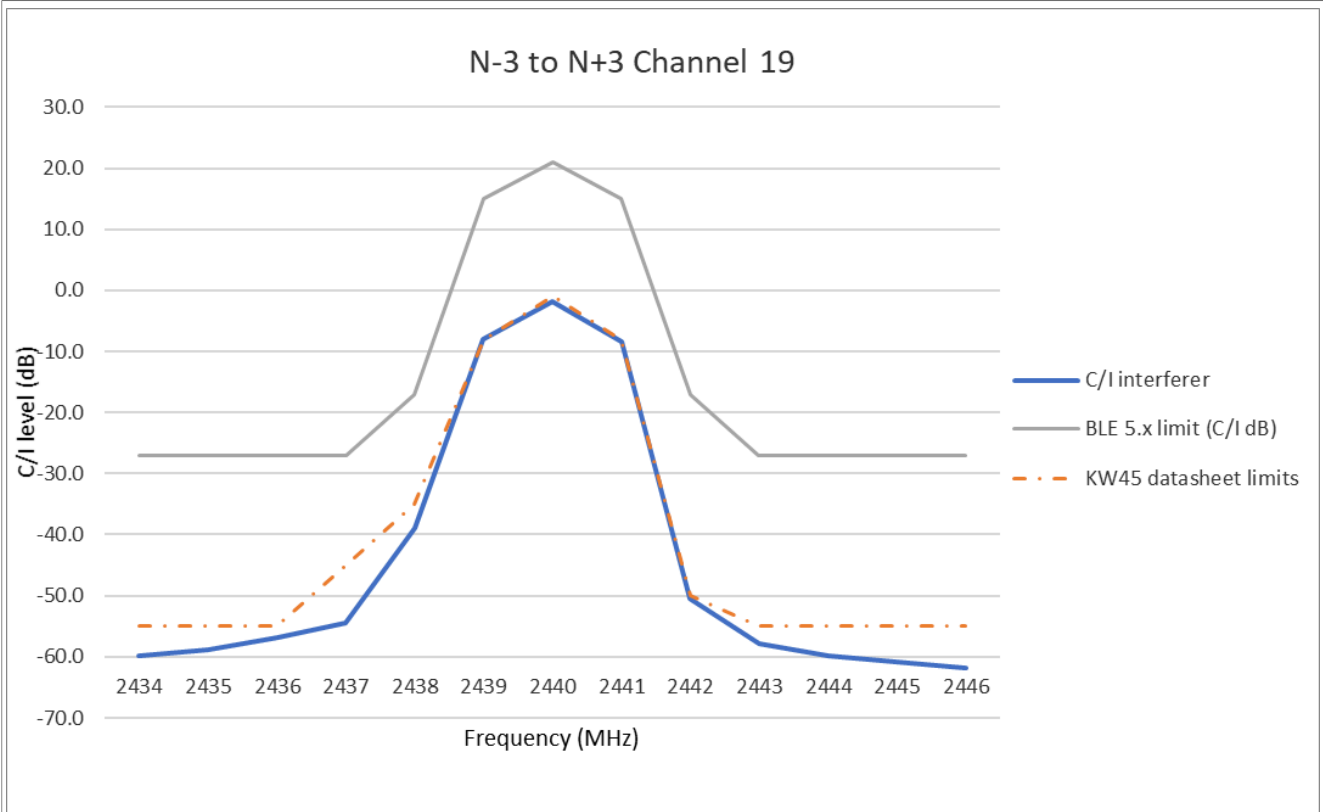


Figure 71. Adjacent, alternate, and co-channel rejection Bluetooth LE @125 kbps (LR S = 8) channel 19

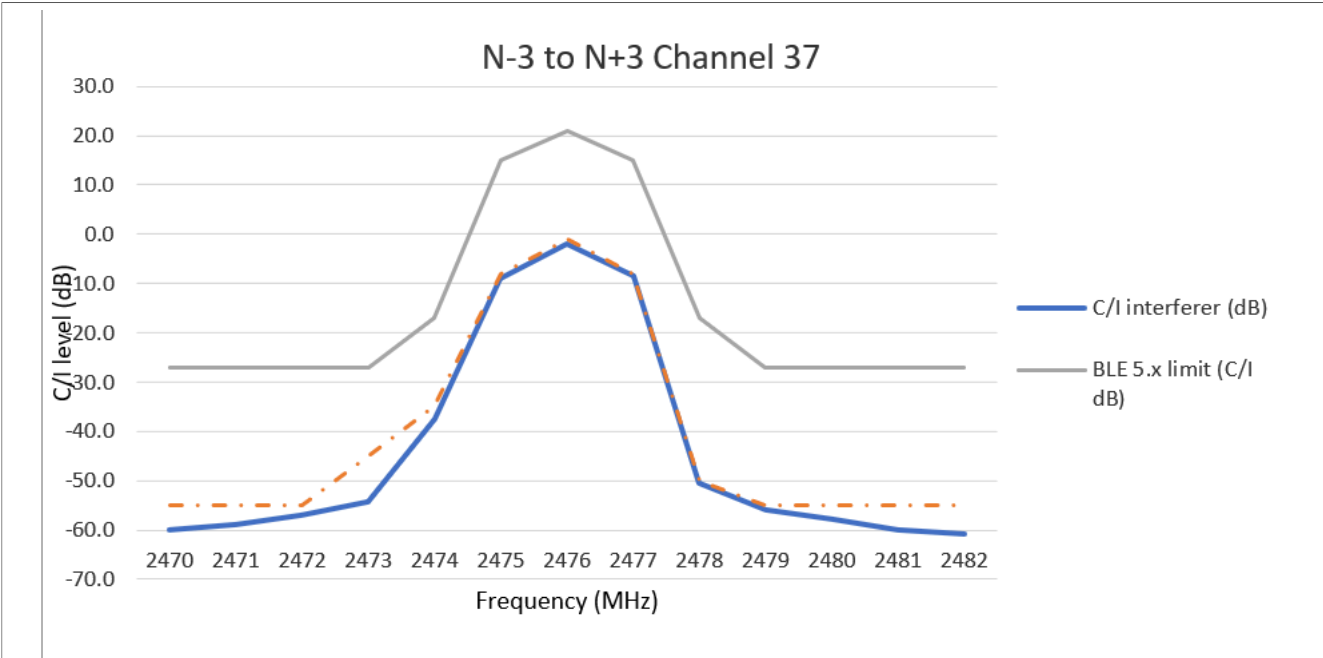


Figure 72. Adjacent, alternate, and co-channel rejection Bluetooth LE @125 kbps (LR S = 8) channel 37

- **Conclusion:**
Good margin, in line with the expected results

3.3.2.5.2 Receiver blocking

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

3.3.2.5.2.1 Receiver category 1 - Bluetooth LE 1 Msps (Refer to the 300.328 2.1.1 chapter 4.3.1.12.4.2)

The test is performed with only one interfering signal at a time.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 1 Msps**): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The expected signal is set to $P_{min} + 6 \text{ dB}$ (-82 dBm). The interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39		
	2402	2402	2480	2480		
	Low	High	Low	High		
	2380	2503.5	2380	2503.5		
Interferer level (dBm)	-16.1	-18.1	-17.1	-19.1		
300 328 limit (dBm)	-53	-53	-53	-53		
Margin (dB)	36.9	34.9	35.9	33.9		
	ch0	ch0	ch0	ch39	ch39	ch39
	2402	2402	2402	2480	2480	2480
	Low	Low	Low	Low	Low	Low
	2300	2330	2360	2300	2330	2360
Interferer level (dBm)	-16.1	-16.1	-16.6	-16.1	-16.1	-18.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	30.9	30.9	30.4	30.9	30.9	28.9
	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-16.6	-16.6	-17.1	-17.1	-16.9	-17.1
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	30.4	30.4	29.9	29.9	30.1	29.9
	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-17.6	-17.6	-17.6	-17.6	-17.6	-17.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	29.4	29.4	29.4	29.4	29.4	29.4

Figure 73. Receiver blocking (out of band) rejection - Bluetooth LE 1 Msps

Conclusion:

Good margin, in line with the expected results.

3.3.2.5.2.2 Receiver category 2 - Bluetooth LE 1 Msps (Refer to the 300.328 2.1.1 chapter 4.3.1.12.4.3)

The test is performed with only one interfering signal at a time.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 1 Msps**): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The expected signal is set to $P_{min} + 6$ dB (-82 dBm). The interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-16.1	-18.1	-17.1	-19.1
300 328 limit (dBm)	-57	-57	-57	-57
Margin (dB)	40.9	38.9	39.9	37.9
	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	High	Low	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-16.1	-17.1	-16.1	-17.6
300 328 limit (dBm)	-47	-47	-47	-47
Margin (dB)	30.9	29.9	30.9	29.4

Figure 74. Receiver blocking (out of band) rejection - Bluetooth LE 1 Msps

Conclusion:

Good margin, in line with the expected results.

3.3.2.5.2.3 Receiver category 1 - Bluetooth LE 2 Msps (Refer to the 300.328 2.1.1 chapter 4.3.1.12.4.2)

The test is performed with only one interfering signal at a time.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 2 Msps**): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The expected signal is set to $P_{min} + 6$ dB (-82 dBm). The interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39

Result:

	ch0	ch0	ch39	ch39		
	2402	2402	2480	2480		
	Low	High	Low	High		
	2380	2503.5	2380	2503.5		
Interferer level (dBm)	-16.1	-14.6	-15.6	-16.6		
300 328 limit (dBm)	-53	-53	-53	-53		
Margin (dB)	36.9	38.4	37.4	36.4		
	ch0	ch0	ch0	ch39	ch39	ch39
	2402	2402	2402	2480	2480	2480
	Low	Low	Low	Low	Low	Low
	2300	2330	2380	2300	2330	2380
Interferer level (dBm)	-14.1	-13.6	-15.6	-14.1	-14.6	-15.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	32.9	33.4	31.4	32.9	32.4	31.4
	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-15.6	-13.6	-21.1	-13.6	-13.6	-13.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	31.4	33.4	25.9	33.4	33.4	33.4
	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	-15.6	-14.6	-15.6	-14.6	-14.6	-14.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	31.4	32.4	31.4	32.4	32.4	32.4

Figure 75. Receiver blocking (out of band) rejection - Bluetooth LE 2 Msps

Conclusion:

Good margin, in line with the expected results.

3.3.2.5.2.4 Receiver category 2 - Bluetooth LE 2 Msps (Refer to the 300.328 2.1.1 chapter 4.3.1.12.4.3)

The test is performed with only one interfering signal at a time.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 2 Msps**): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The expected signal is set to $P_{min} + 6 \text{ dB}$ (-82 dBm). The interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39

Result:

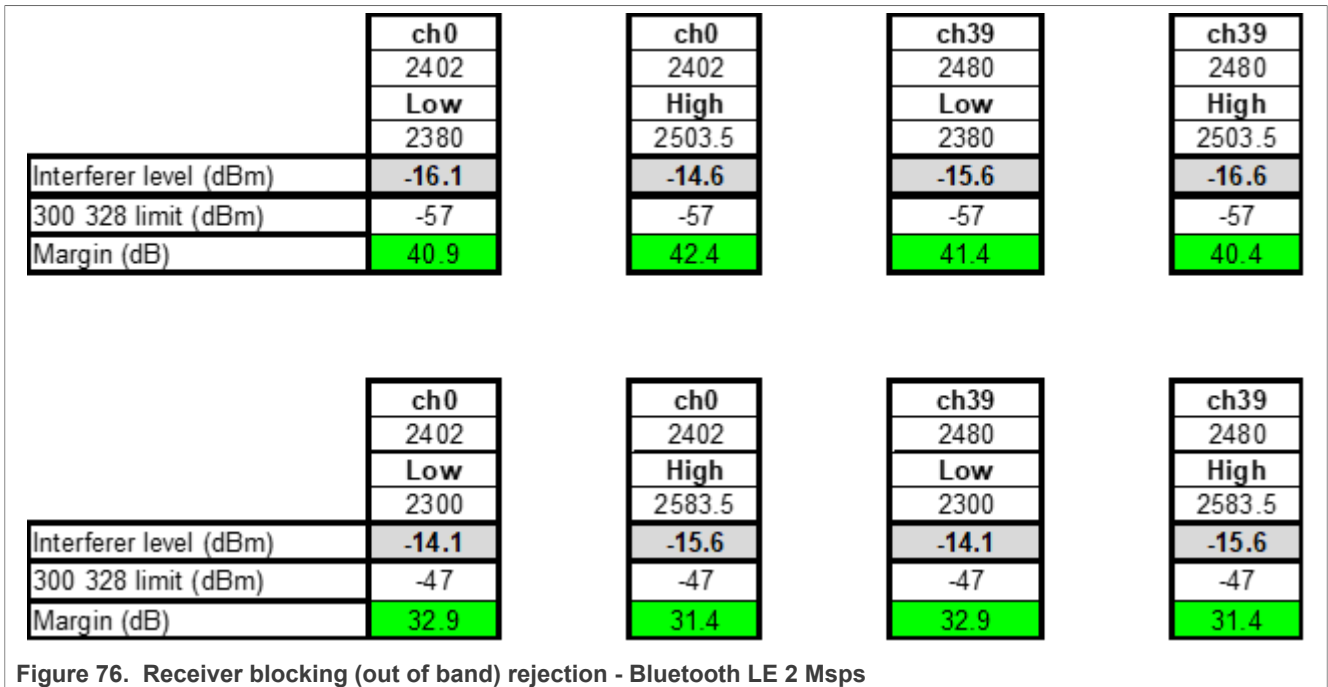


Figure 76. Receiver blocking (out of band) rejection - Bluetooth LE 2 Msps

Conclusion:

Good margin, in line with the expected results.

3.3.2.5.2.5 Receiver category 1 - Bluetooth LE 500 kbps (LR S = 2) (Refer to the 300.328 2.1.1 chapter 4.3.1.12.4.2)

The test is performed with only one interfering signal at a time.

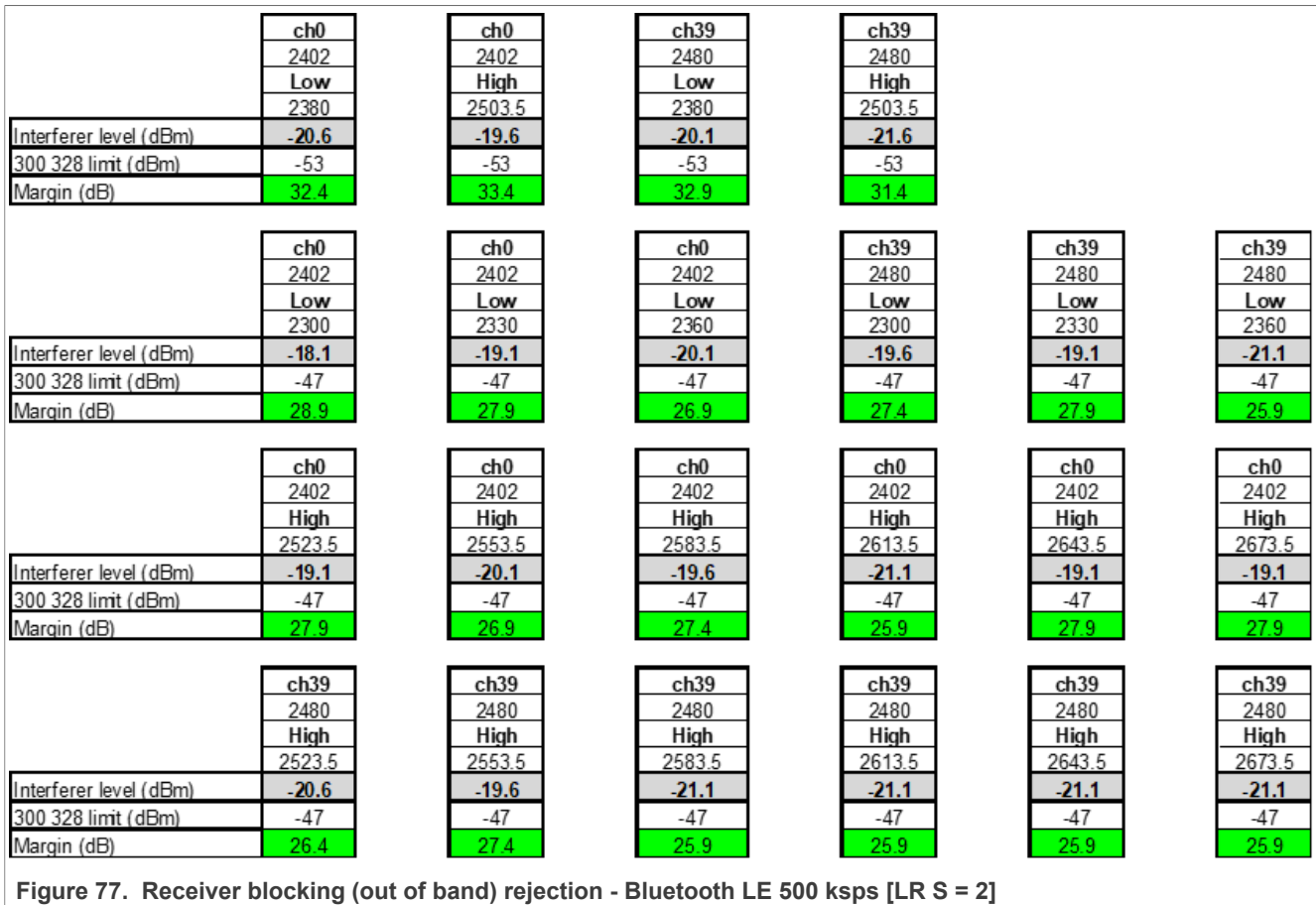
Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 500 kbps [LR S = 2]**): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The expected signal is set to $P_{min} + 6 \text{ dB}$ (-82 dBm). The interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39

Result:

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Conclusion:

Good margin, in line with the expected results.

3.3.2.5.2.6 Receiver category 2 - Bluetooth LE 500 kbps (LR S = 2) (Refer to the 300.328 2.1.1 chapter 4.3.1.12.4.3)

The test is performed with only one interfering signal at a time.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 500 kbps [LR S = 2]**): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The expected signal is set to $P_{min} + 6$ dB (-82 dBm). The interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39

Result:

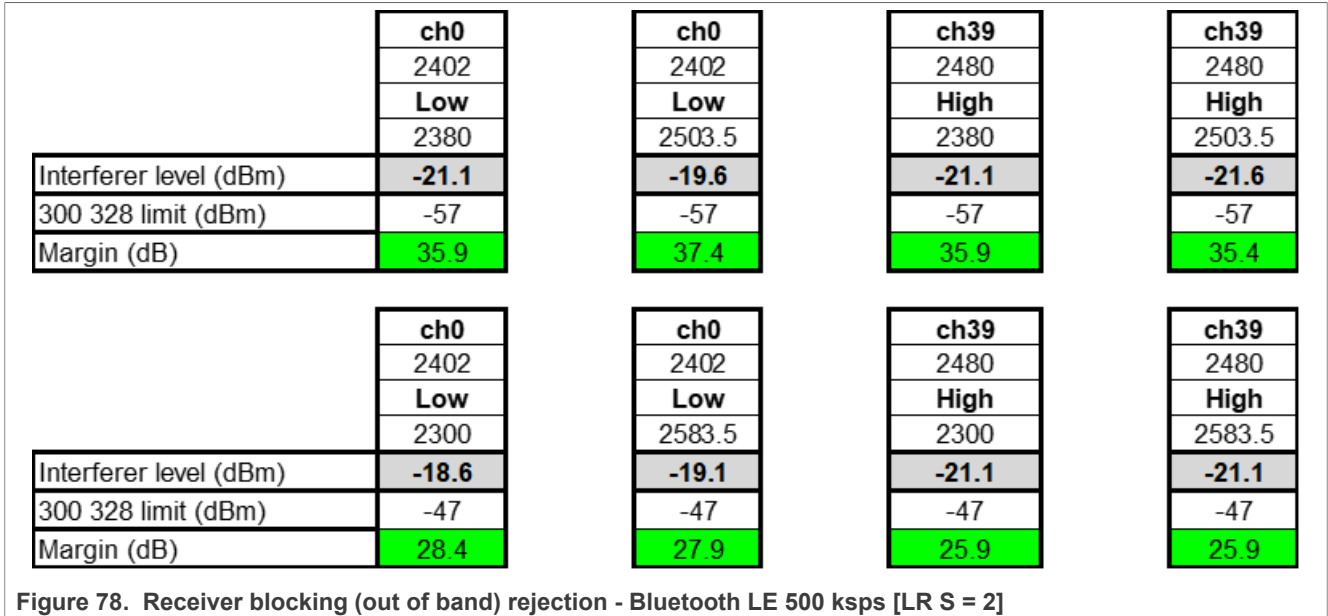


Figure 78. Receiver blocking (out of band) rejection - Bluetooth LE 500 kbps [LR S = 2]

Conclusion:

Good margin, in line with the expected results.

3.3.2.5.2.7 Receiver category 1 - Bluetooth LE 125 kbps (LR S = 8) (Refer to the 300.328 2.1.1 chapter 4.3.1.12.4.2)

The test is performed with only one interfering signal at a time.

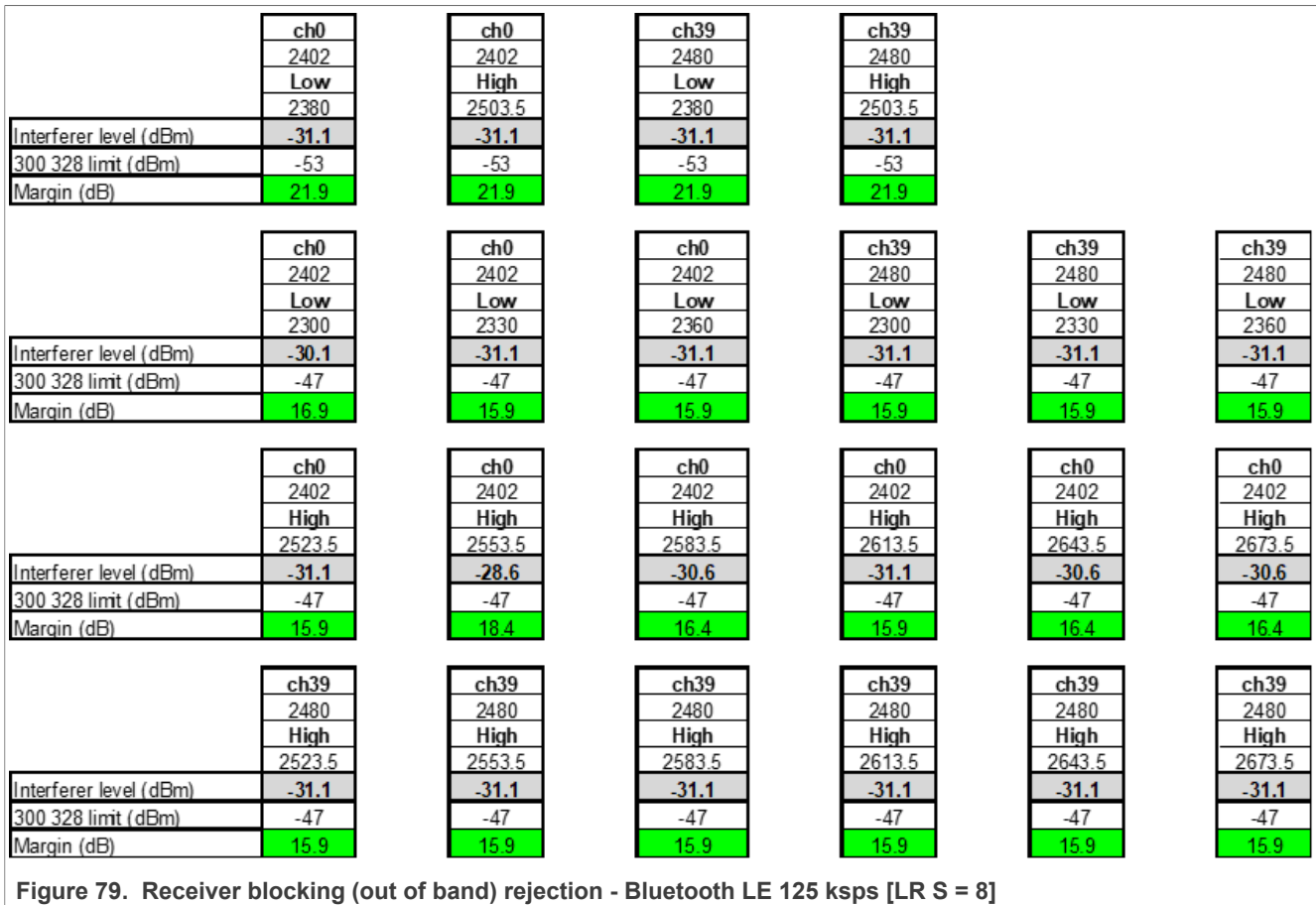
Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 125 kbps [LR S = 8]**): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The expected signal is set to $P_{min} + 6 \text{ dB}$ (-82 dBm). The interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39

Result:

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Conclusion:

Good margin, in line with the expected results.

3.3.2.5.2.8 Receiver category 2 - Bluetooth LE 125 kbps (LR S = 8) (Refer to the 300.328 2.1.1 chapter 4.3.1.12.4.3)

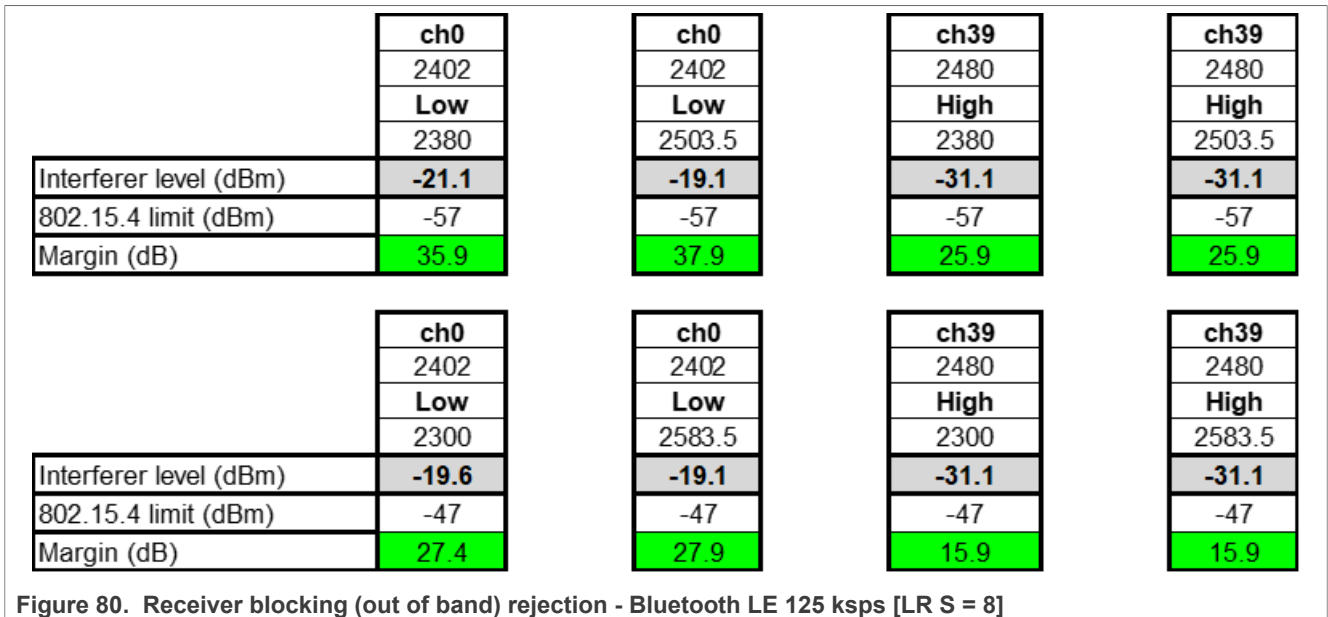
The test is performed with only one interfering signal at a time.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 125 kbps [LR S = 8]**): Agilent N5182A
- Generator for interferers: R&S SFU
- Criterion: PER < 10 %
- The expected signal is set to $P_{min} + 6$ dB (-82 dBm). The interferer is increased until the PER threshold is reached.
- Channels under test: 0 and 39

Result:



Conclusion:

Good margin, in line with the expected results.

3.3.2.5.3 Blocking interferers

3.3.2.5.3.1 Bluetooth LE 1 Msps

To verify that the receiver performs satisfactorily with frequency outside the 2400 MHz-2483.5 MHz, a CW is used as the interferer source.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 1 Msps**): Agilent N5182A
- Generator for the blocker: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- The expected signal is set to -67 dBm. The interferer level is increased until the PER threshold is reached.
- Channel under test: 12 (2426 MHz)

Result:

Table 27. Blocking interferers – 1 Msps

Expected signal 2426 MHz @-67 dBm	ch12	ch12	ch12	ch12	
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	
Interferer (MHz)	30 - 2000 (step 10 MHz)	2003 – 2399 (step 3 MHz)	2484 – 2997 (step 3 MHz)	3 GHz - 12.75 GHz (step 25 MHz)	
Unexpected level (dBm)	-30	-35	-35	-30	
Status (unexpected level)	PASS	PASS	PASS	PASS	

Table 27. Blocking interferers – 1 Msps...continued

Expected signal 2426 MHz @-67 dBm	ch12	ch12	ch12	ch12	
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	
Number of blocking fail	0	0	0	0	Failed blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Failed blockers must not exceed 3

Conclusion:

- Good margin, in line with the expected results.

3.3.2.5.3.2 Bluetooth LE 2 Msps

To verify that the receiver performs satisfactorily with frequency outside the 2400 MHz-2483.5 MHz, a CW is used as the interferer source.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 2 Msps**): Agilent N5182A
- Generator for the blocker: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- The expected signal is set to -67 dBm. The interferer level is increased until the PER threshold is reached.
- Channel under test: 12 (2426 MHz)

Result:

Table 28. Blocking interferers – 2 Msps

Expected signal 2426 MHz @-67 dBm	ch12	ch12	ch12	ch12	
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	
Interferer (MHz)	30 - 2000 (step 10 MHz)	2003 – 2399 (step 3 MHz)	2484 – 2997 (step 3 MHz)	3 GHz - 12.75 GHz (step 25 MHz)	
Unexpected level (dBm)	-30	-35	-35	-30	
Status (unexpected level)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Failed blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Failed blockers must not exceed 3

Conclusion:

- Good margin, in line with the expected results.

3.3.2.5.3.3 Bluetooth LE 500 ksps (LR S = 2)

To verify that the receiver performs satisfactorily with frequency outside the 2400 MHz-2483.5 MHz, a CW is used as the interferer source.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 500 ksps (LR S = 2)**): Agilent N5182A
- Generator for the blocker: R&S SFU
- Criterion: PER < 30.8 % with 1500 packets
- The expected signal is set to -67 dBm. The interferer level is increased until the PER threshold is reached.
- Channel under test: 12 (2426 MHz)

Result:

Table 29. Blocking interferers – 500 ksps

Expected signal 2426 MHz @-67 dBm	ch12	ch12	ch12	ch12	
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	
Interferer (MHz)	30 - 2000 (step 10 MHz)	2003 – 2399 (step 3 MHz)	2484 – 2997 (step 3 MHz)	3 GHz - 12.75 GHz (step 25 MHz)	
Unexpected level (dBm)	-30	-35	-35	-30	
Status (unexpected level)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Failed blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Failed blockers must not exceed 3

Conclusion:

- Good margin, in line with the expected results.

3.3.2.5.3.4 Bluetooth LE 125 ksps (LR S = 8)

To verify that the receiver performs satisfactorily with frequency outside the 2400 MHz-2483.5 MHz, a CW is used as the interferer source.

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE 125 ksps (LR S = 8)**): Agilent N5182A
- Generator for the blocker: R&S SFU

- Criterion: PER < 30.8 % with 1500 packets
- The expected signal is set to -67 dBm. The interferer level is increased until the PER threshold is reached.
- Channel under test: 12 (2426 MHz)

Result:

Table 30. Blocking interferers – 125 kbps

Expected signal 2426 MHz @-67 dBm	ch12	ch12	ch12	ch12	
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	
Interferer (MHz)	30 - 2000 (step 10 MHz)	2003 – 2399 (step 3 MHz)	2484 – 2997 (step 3 MHz)	3 GHz - 12.75 GHz (step 25 MHz)	
Unexpected level (dBm)	-30	-35	-35	-30	
Status (unexpected level)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Failed blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Failed blockers must not exceed 3

Conclusion:

- Good margin, in line with the expected results.

3.3.2.5.4 Intermodulation

This test verifies that the receiver intermodulation performance is satisfactory.

Two interferers are used in combination with the expected signal: a sinusoid non-modulated signal and a modulated signal with PRSB15 data.

3.3.2.5.4.1 Bluetooth LE 1 Msps

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE – 1 Msps**): Agilent N5182A
- Generator for the first interferer (CW): R&S SML03
- Generator for the second interferer (PRBS15): R and S SFU
- Criterion: PER < 30.8 % with 1500 packets
- The expected signal is set to -67 dBm; the interferer levels are set to the data sheet specification values.
- Channels under test: 0, 19, and 39.

Results:

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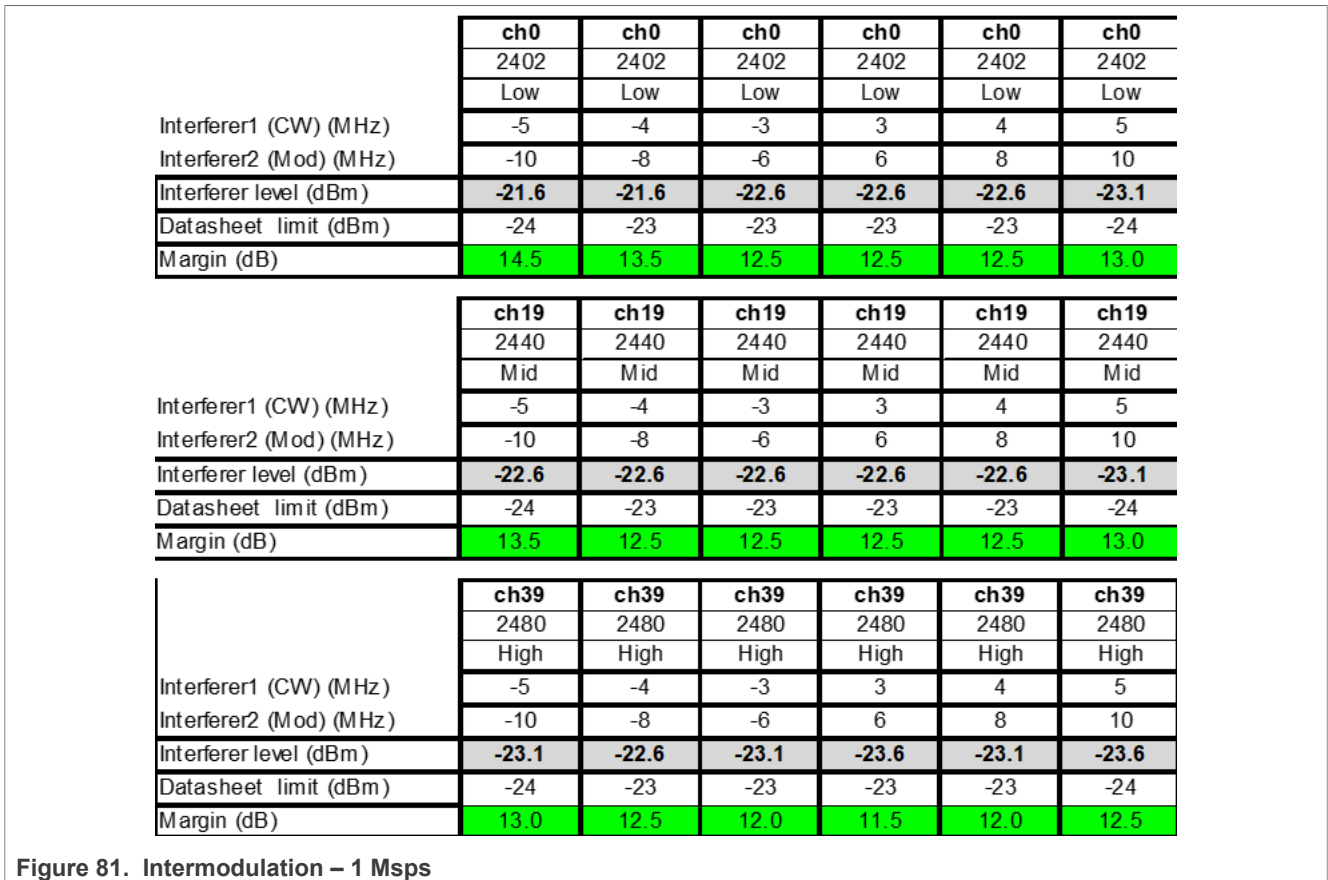


Figure 81. Intermodulation – 1 Msps

Conclusion:

Good margin, in line with the expected results.

3.3.2.5.4.2 Bluetooth LE 2 Msps

Flashed software: Connectivity test

Test method:

- Generator for the desired signal (**Bluetooth LE – 2 Msps**): Agilent N5182A
- Generator for the first interferer (CW): R&S SML03
- Generator for the second interferer (PRBS15): R and S SFU
- Criterion: PER < 30.8 % with 1500 packets
- The expected signal is set to -64 dBm; the interferer levels are set to the data sheet specification values.
- Channels under test: 0, 19, and 39.

Results:

	ch0	ch0	ch0	ch0	ch0	ch0
	2402	2402	2402	2402	2402	2402
	Low	Low	Low	Low	Low	Low
Interferer1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer2 (Mod) (MHz)	-20	-16	-12	6	8	10
Interferer level (dBm)	-20.6	-20.6	-21.6	-21.6	-23.6	-24.1
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	15.5	14.5	13.5	13.5	11.5	12.0
	ch19	ch19	ch19	ch19	ch19	ch19
	2440	2440	2440	2440	2440	2440
	Mid	Mid	Mid	Mid	Mid	Mid
Interferer1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer2 (Mod) (MHz)	-20	-16	-12	6	8	10
Interferer level (dBm)	-23.6	-23.6	-23.6	-23.6	-23.6	-24.1
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	12.5	11.5	11.5	11.5	11.5	12.0
	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
Interferer1 (CW) (MHz)	-10	-8	-6	6	8	10
Interferer2 (Mod) (MHz)	-20	-16	-12	6	8	10
Interferer level (dBm)	-24.1	-23.6	-24.1	-24.6	-24.1	-24.6
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	12.0	11.5	11.0	10.5	11.0	11.5

Figure 82. Intermodulation – 2 Msps

Conclusion:

Good margin, in line with the expected results.

4 802.15.4 application

4.1 Test presentation

4.1.1 List of tests

1. Conducted tests
 - a. TX tests
 - i. Frequency accuracy
 - ii. Phase noise
 - iii. TX power
 - iv. TX spurious
 - v. Harmonics
 - vi. EVM and offset EVM

- vii. Upper band edge
- b. RX tests
 - i. Sensitivity
 - ii. Sensitivity bathtub
 - iii. Maximum Input Level
 - iv. RX spurious
 - v. LO leakage
 - vi. Interferers (as per 802.15.4 requirements)
 - vii. Co-channel
 - viii. Receiver Blocking (as per ETSI 300 328 requirements)

4.2 Test summary

Table 31 and Table 32 synthesize the main tests performed on the K32W148 modules. This document details most of the test results. To get further information, contact your NXP local contact.

Table 31. List of tests (Europe)

		Reference	Limit	Status
Transmission	TX maximum power	ETSI EN 300 328	20 dBm, 100 mW (radiated)	PASS
	Eirp TX spectral density	ETSI EN 300 328	10 dBm/MHz	PASS
	TX spectral density	802.15.4_2011	-20 dBc or -30 dBm (100 kHz, f-fc > 3.5 MHz)	PASS
	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
	EVM	802.15.4_2011	35 %	PASS
	TX frequency tolerance	802.15.4_2011	+/- 40 ppm	PASS
	Reachable low limit of maximum power	802.15.4_2011	-3 dBm	PASS
	Phase noise (unspread)	802.15.4_2003	NA	For information
Reception	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
	RX sensitivity	802.15.4	-85 dBm	PASS
	Adjacent channel interference rejection N+/-1	802.15.4_2011	0 dB	PASS

Table 31. List of tests (Europe)...continued

		Reference	Limit	Status
	Alternate channel interference rejection N+/-2	802.15.4_2011	30 dB	PASS
	Receiver blocking	ETSI EN 300 328	-57 dBm/-47 dBm	PASS
	RX maximum input level	802.15.4_2011	-20 dBm	PASS
Miscellaneous	Return loss (S11)	Return loss in TX mode	For information	
		Return loss in RX mode	For information	

Table 32. List of tests (US)

		Reference	Limit	Status
Transmission	Spurious 1 GHz - 12.5 GHz	FCC part15	-41 dBm (1 MHz BW)	PASS

4.3 Conducted tests

4.3.1 TX tests

4.3.1.1 Test setup

The TX power of the K32W148 is set to **+10 dBm**.

Connect the RF port of the module to the spectrum analyzer via RF cable.

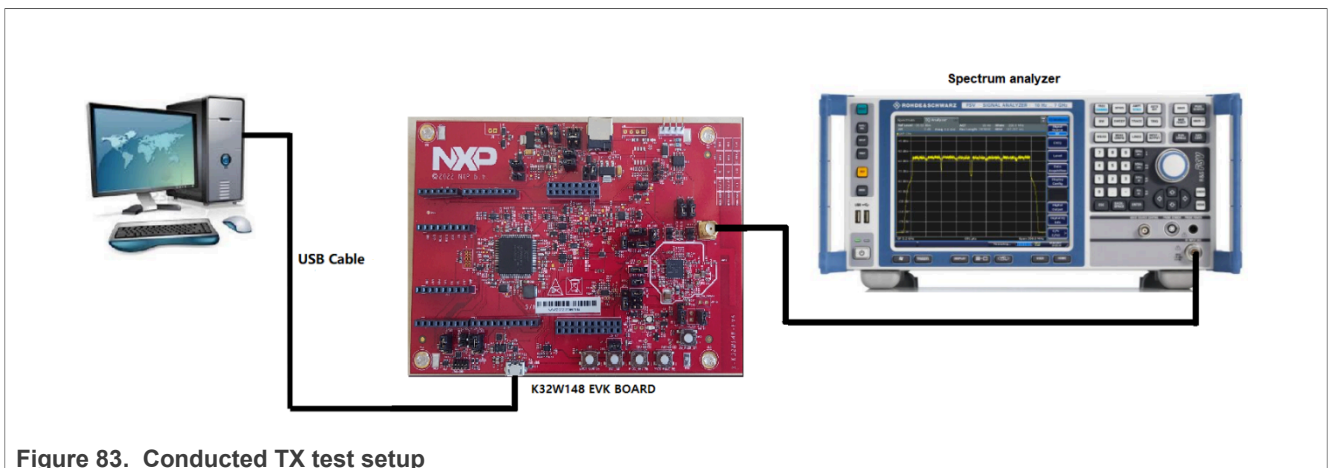


Figure 83. Conducted TX test setup

4.3.1.2 Frequency accuracy

Test method:

- Set the radio to:
 - TX mode
 - CW
 - Continuous mode
 - Frequency: Channel 18
- Set the analyzer to:
 - Center frequency = 2.44 GHz
 - Span = 1 MHz
 - Ref amp = 20 dBm
 - RBW = 10 kHz
- Measure the CW frequency with the marker of the spectrum analyzer.

Result:

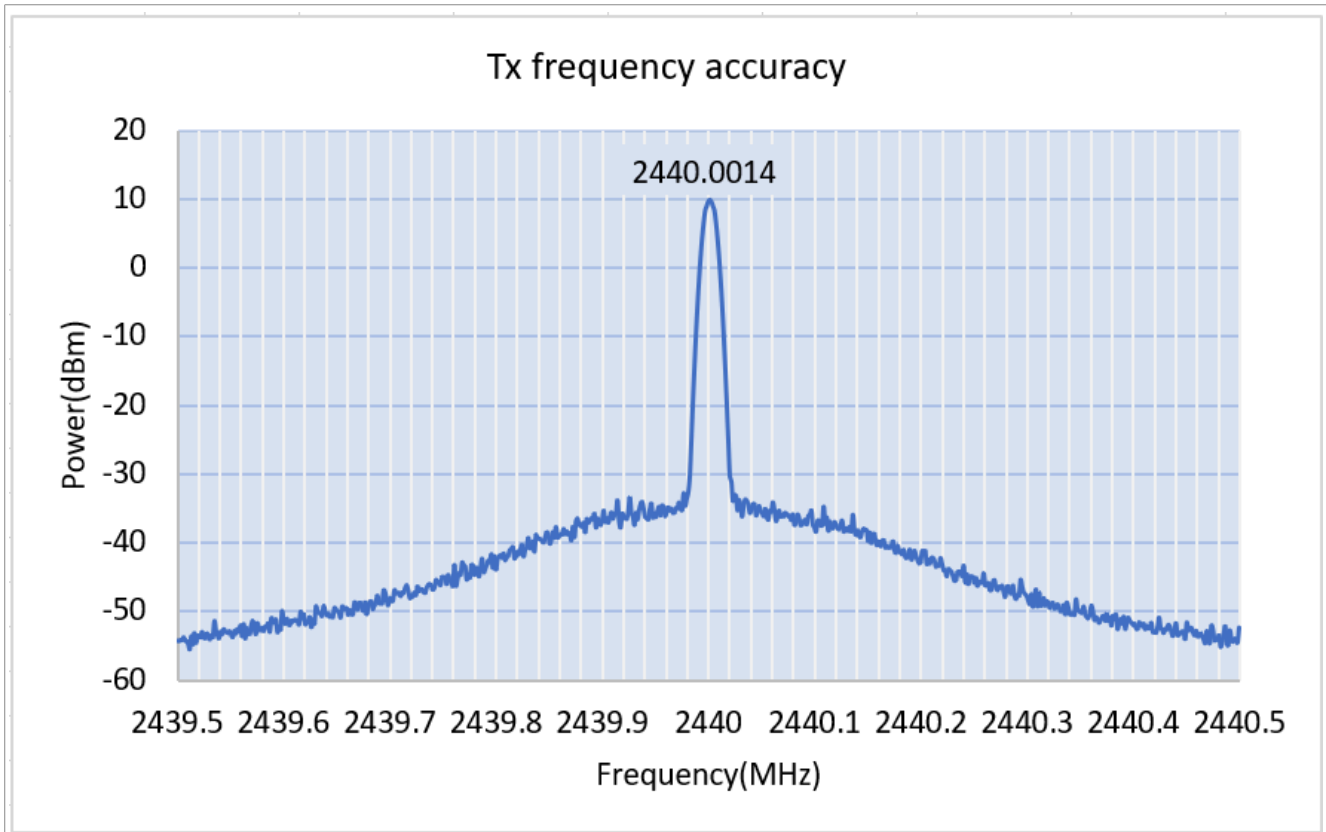


Figure 84. Frequency accuracy

- Measured frequency: 2440.0014 MHz
- ppm value = 0.57 ppm

Table 33. Frequency accuracy

Result	Target	802.15.4 limit
0.57 ppm	+/-25 ppm	+/-40 ppm

Note: The frequency accuracy depends on the XTAL model. The model used on the EVK is NX2016SA EXS00A-CS11775 from NDK. And set the XtalTrim to 15.

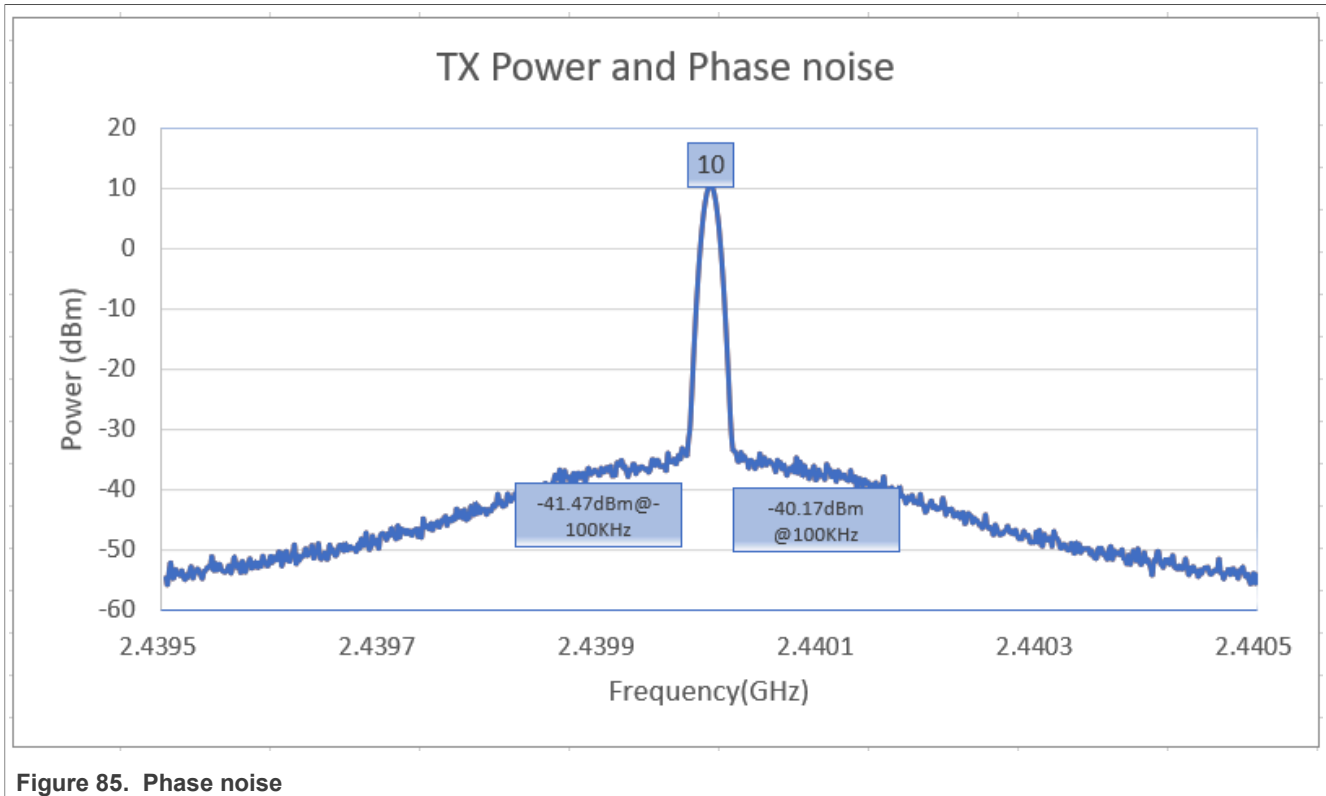
Conclusion:

- The channel frequency is correctly centered therefore fully compliant with the 802.15.4 specifications.

4.3.1.3 Phase noise @ 100 kHz offset

Test method:

- Set the radio to:
 - TX mode
 - CW
 - Continuous mode
 - Frequency: Channel 18
- Set the analyzer to:
 - Center frequency = 2.44 GHz
 - Span = 1 MHz
 - Ref amp = 20 dBm
- Measure the phase noise at 100 kHz offset frequency.
 - RBW = 10 kHz (40 dBc)



Result:

- Marker value = - 41.1 dBm within 10 kHz RBW
 - Marker delta = 10.0 - (-41.1) = 51.1 dB
 - Phase noise at 100 kHz offset = - 51.1-10 Log (10 kHz) = - 91.1 dBc/Hz

Conclusion:

- Phase noise is for information only.

4.3.1.4 TX power (fundamental)

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set the analyzer to:
 - Start frequency = 2.4 GHz
 - Stop frequency = 2.5 GHz
 - Ref amp = 20 dBm
 - Sweep time = 100 ms
 - RBW = 3 MHz
 - Max Hold mode
 - Detector: Peak
- Sweep all the channels from ch11 to ch26.

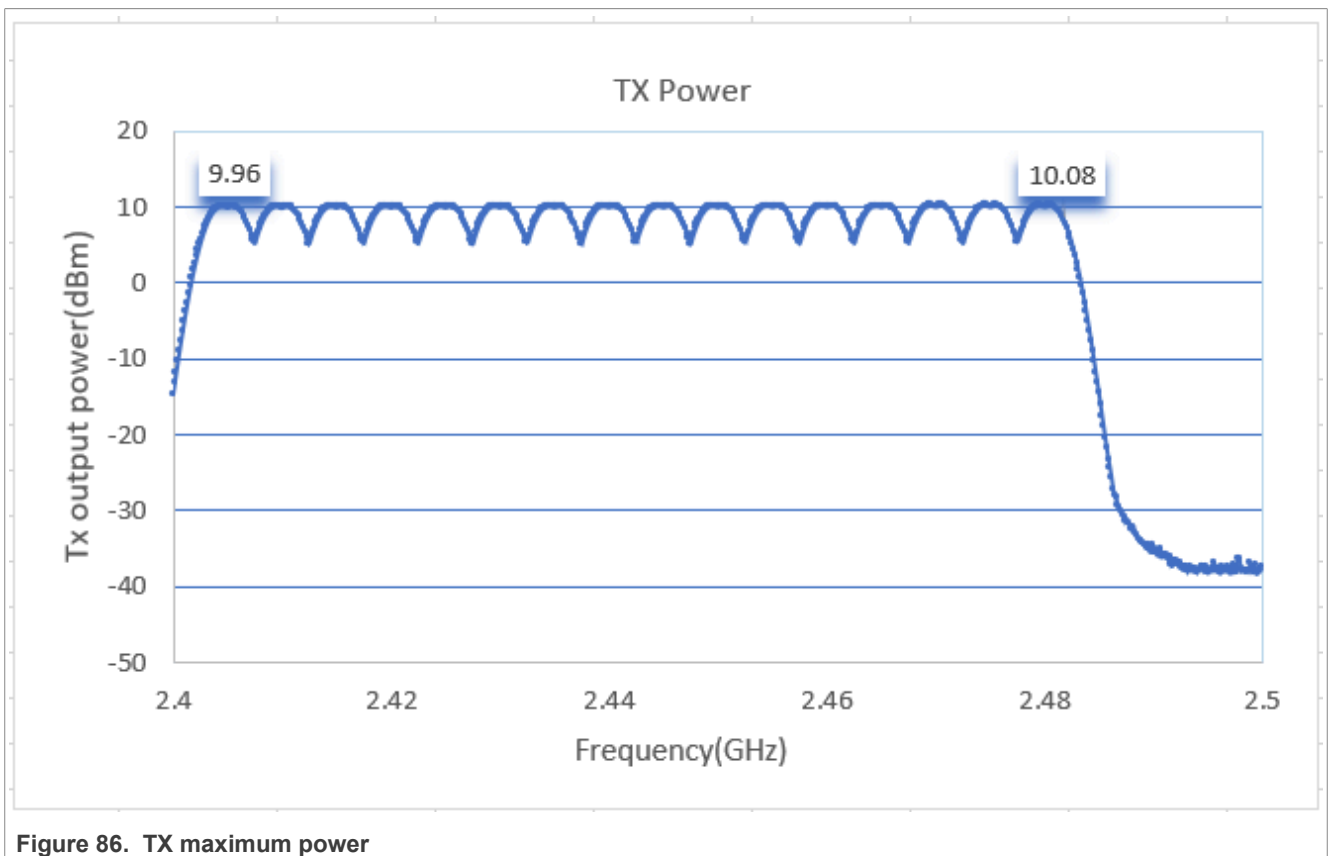


Figure 86. TX maximum power

Result:

- Maximum power is on channel 26: **+10.08 dBm**.
- Minimum power is on channel 11: **+9.96 dBm**.
- Tilt over frequencies is **0.1 dB**.

Conclusion:

- The power is flat over frequency.

4.3.1.5 TX power in-band

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
 - Data rate (1 Msps, 2 Msps, 500 ksps, 125 ksps)
- Set the analyzer to:
 - Start freq = 2.35 GHz
 - Stop freq = 2.5 GHz
 - Ref amp = 10 dBm
 - Sweep time = 100 ms
 - RBW = 100 kHz
 - Video BW = 300 kHz
 - Max Hold mode
 - Detector = RMS
 - Number of Sweeps = 10
- Sweep on Channel 11, Channel 18, and Channel 26.

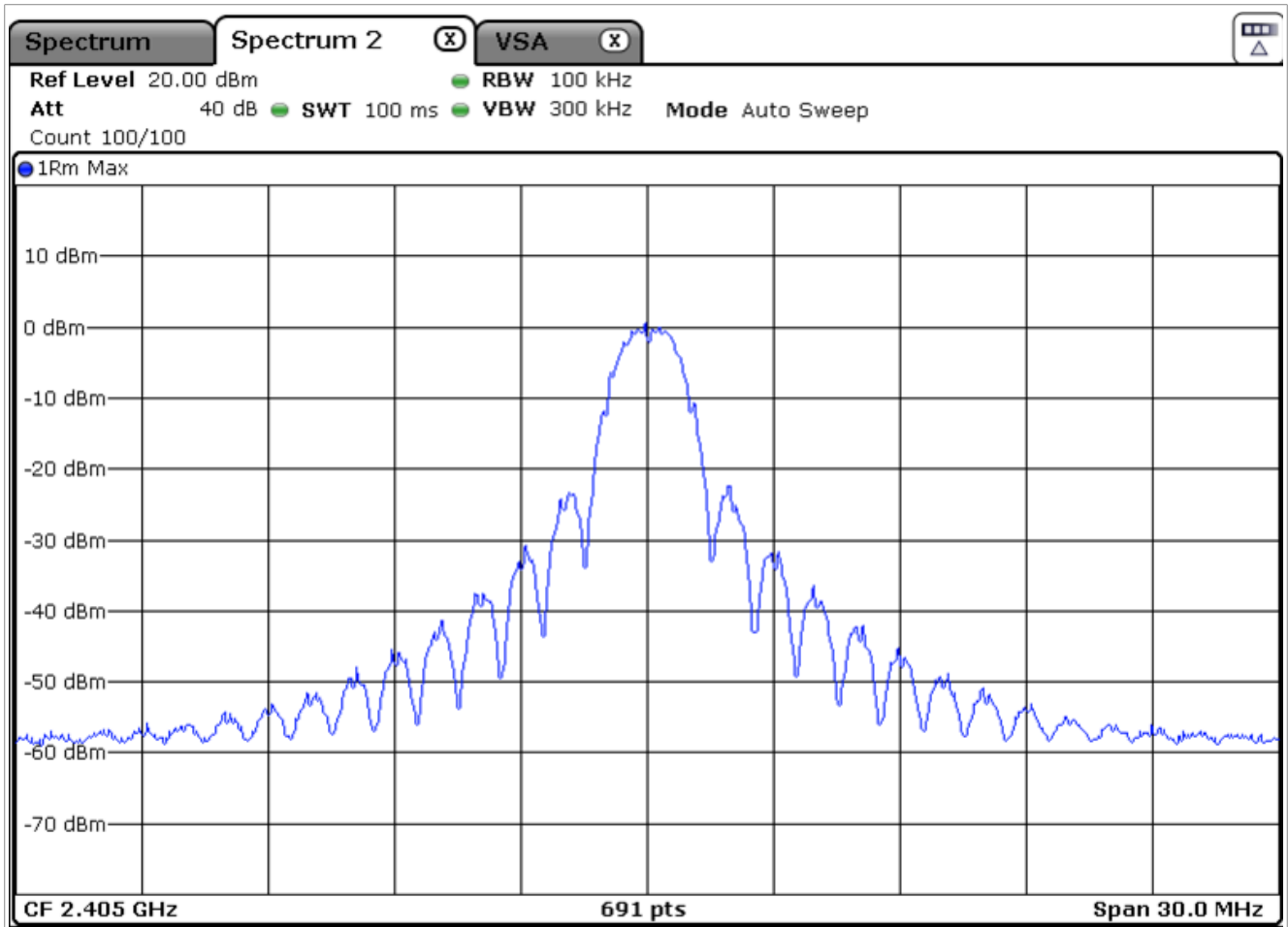


Figure 87. TX power in-band – Channel 2

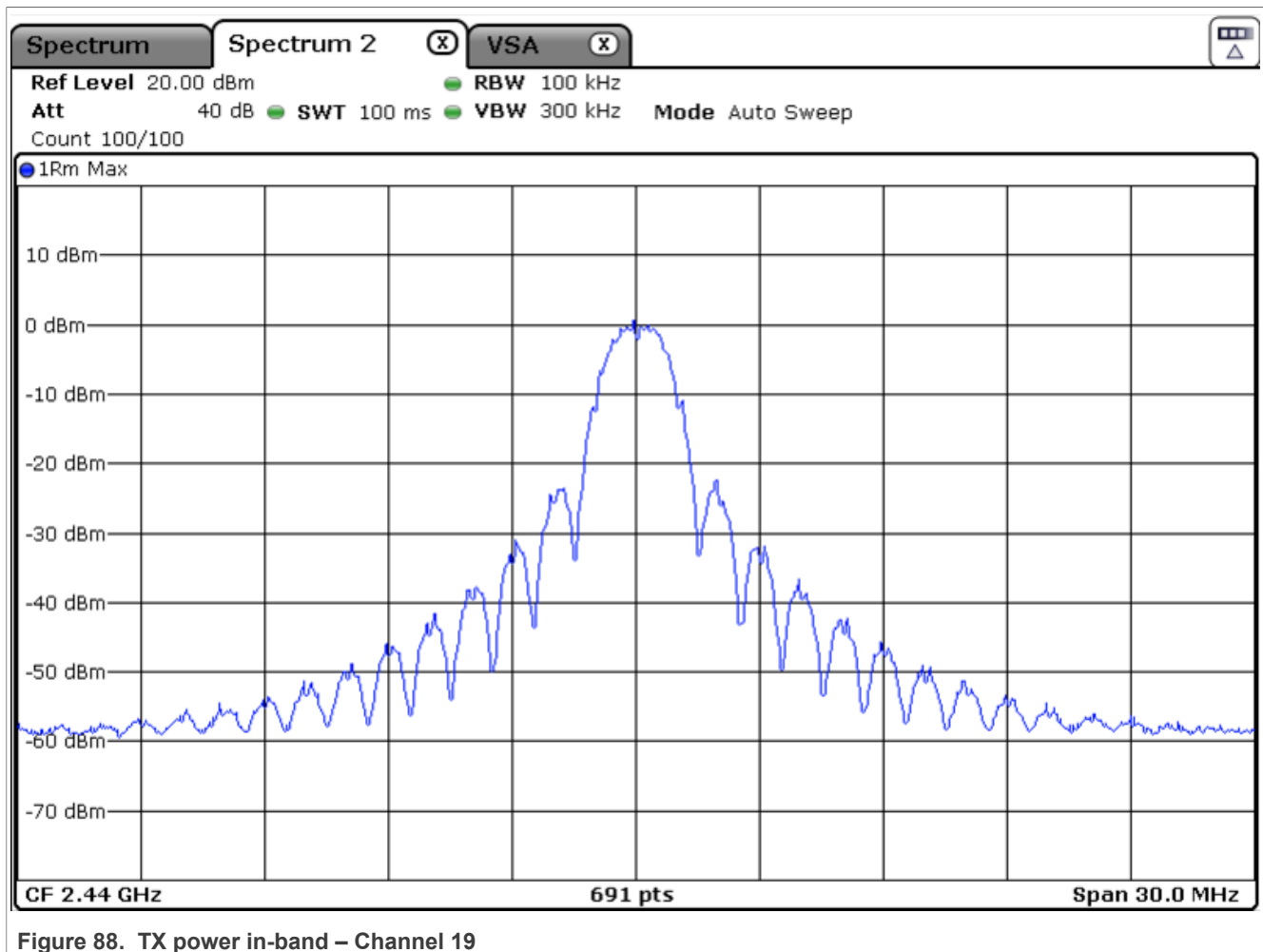


Figure 88. TX power in-band – Channel 19

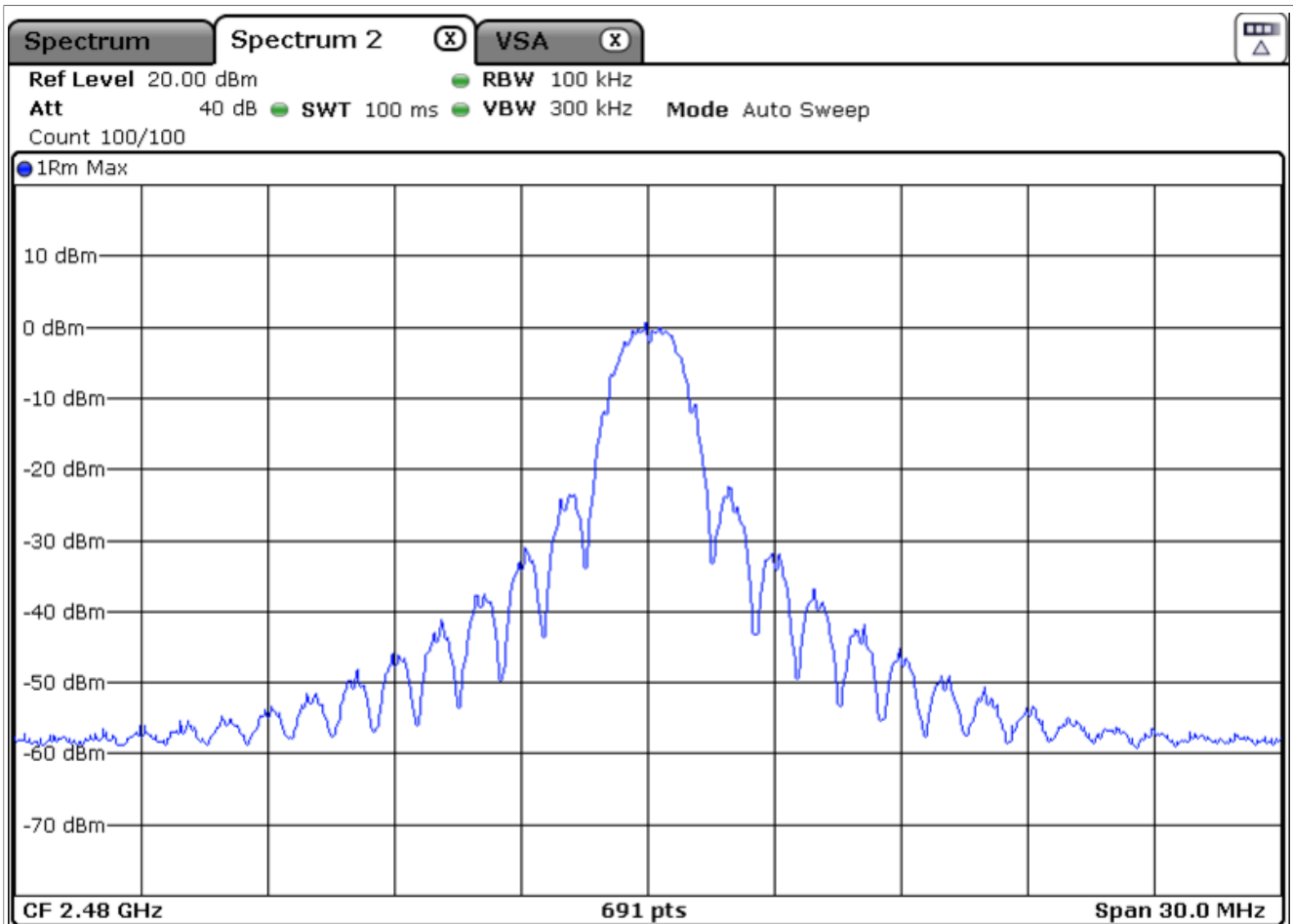


Figure 89. TX power in-band – Channel 26

Conclusion:

- These results are compliant to 802.15.4.

4.3.1.6 TX spurious

4.3.1.6.1 Global view from 0.3 GHz to 12.5 GHz (expected = channel 18)

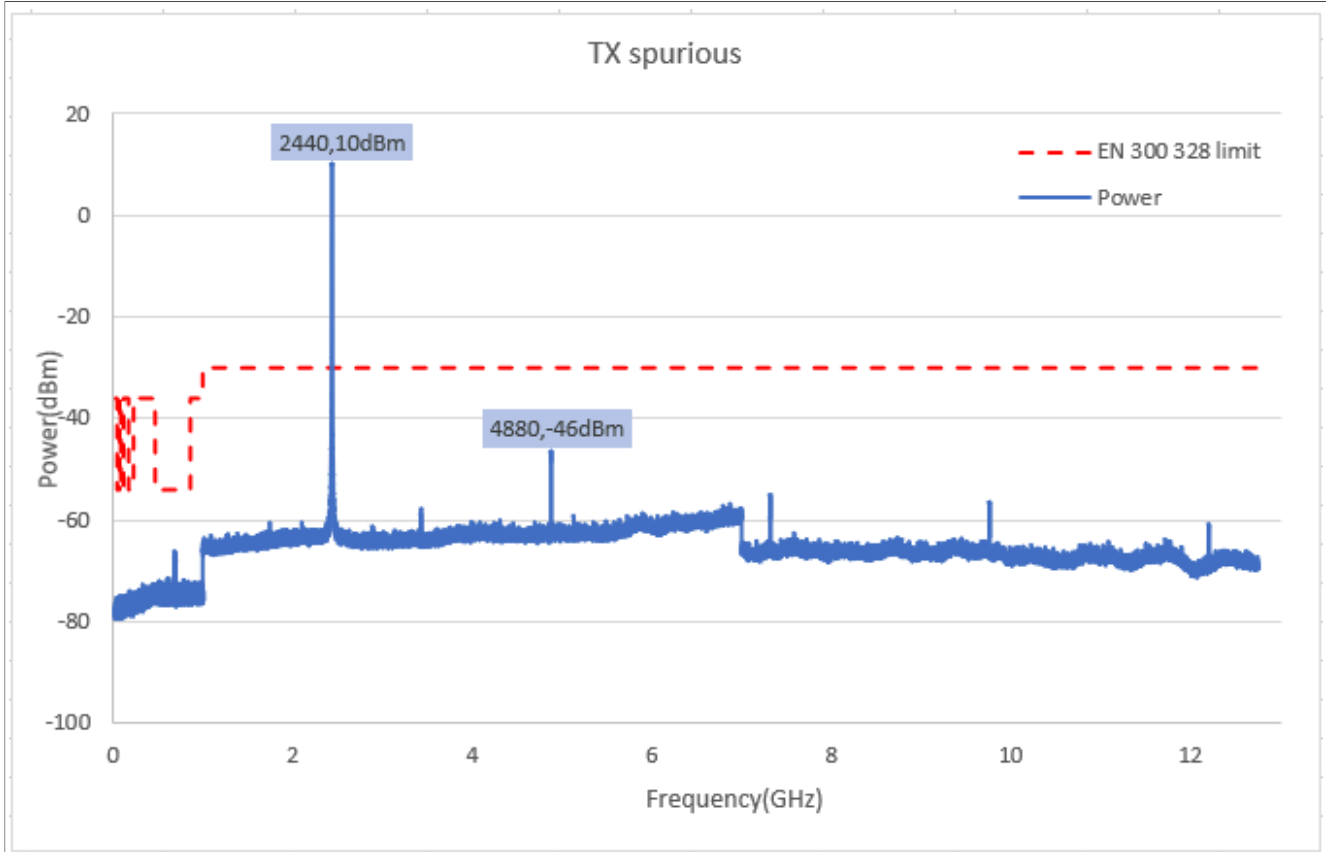


Figure 90. Conducted TX spurious

Conclusion:

- There are no TX spurs above the EN 300 328 limit. It is 16 dB margin.
- Harmonics are measured in the following paragraphs.

4.3.1.6.2 H2 (ETSI test conditions)

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set analyzer to:
 - Start frequency = 4.8 GHz
 - Stop frequency = 5 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - RBW = 1 MHz
 - Max hold mode
 - Detector peak
- Sweep all the channels from Ch11 to Ch26.

Results:

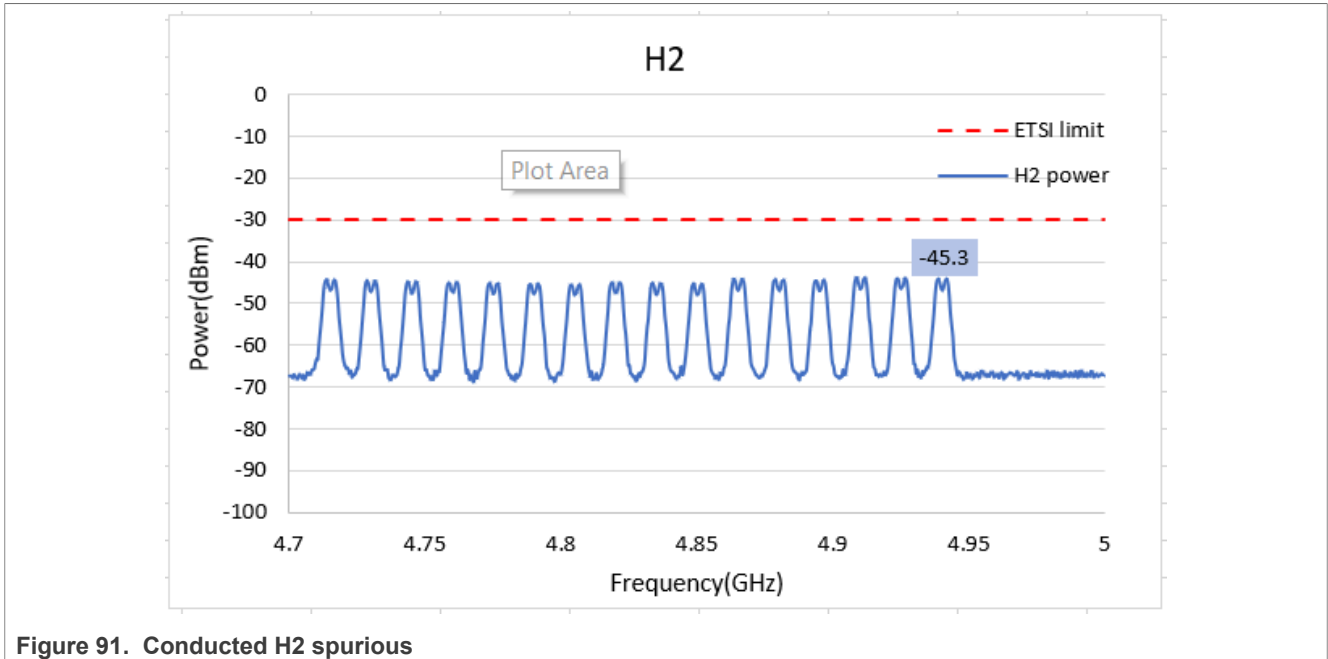


Figure 91. Conducted H2 spurious

Maximum power is on channel 11: **-45.3 dBm**.

Conclusion:

- There is **15.3 dB** margin to ETSI limit.

4.3.1.6.3 H3 (ETSI test conditions)

Test method:

The test method is similar as for the H2, except that the spectrum analyzer frequency start/stop are set to 7.2 GHz and 7.5 GHz.

Results:

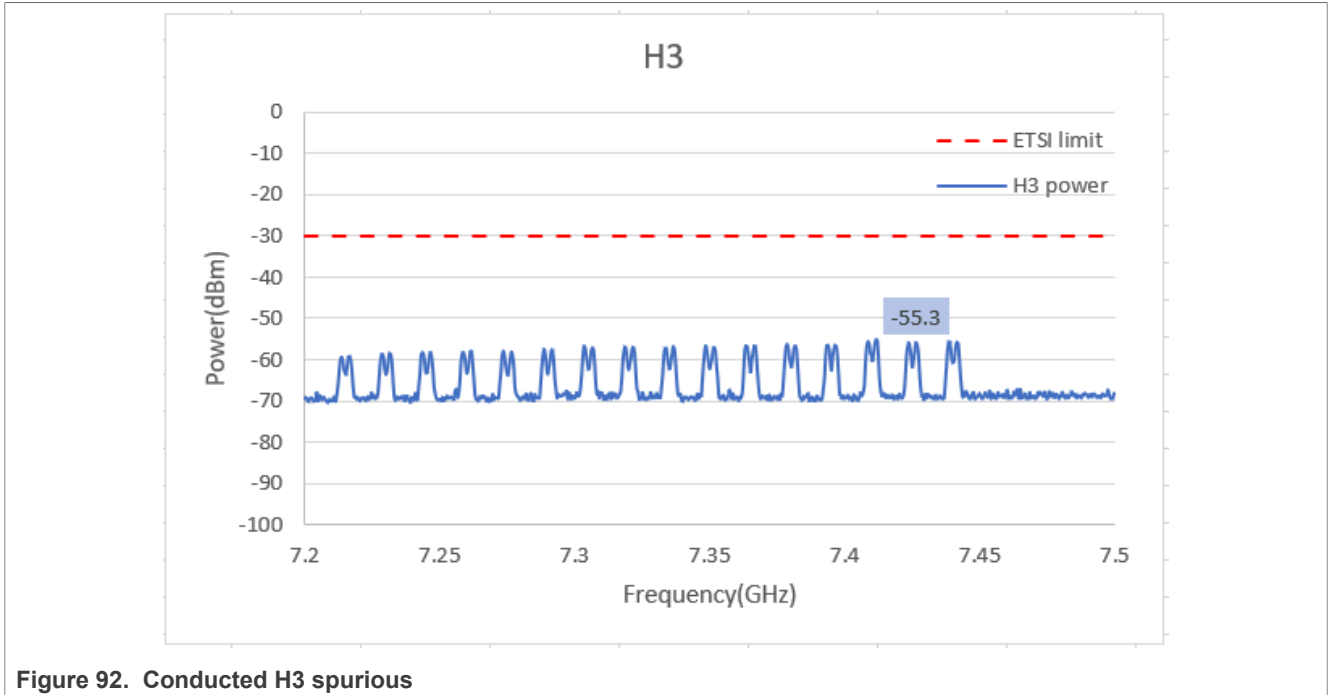


Figure 92. Conducted H3 spurious

Maximum power is on channel 19: **-55.3 dBm**.

Conclusion:

- There is **25.3 dB** margin to ETSI limit.

4.3.1.6.4 H4 (ETSI test conditions)

Test method:

The test method is similar as for the H2, except that the spectrum analyzer frequency span is set from 9.6 GHz to 10.0 GHz.

Results:

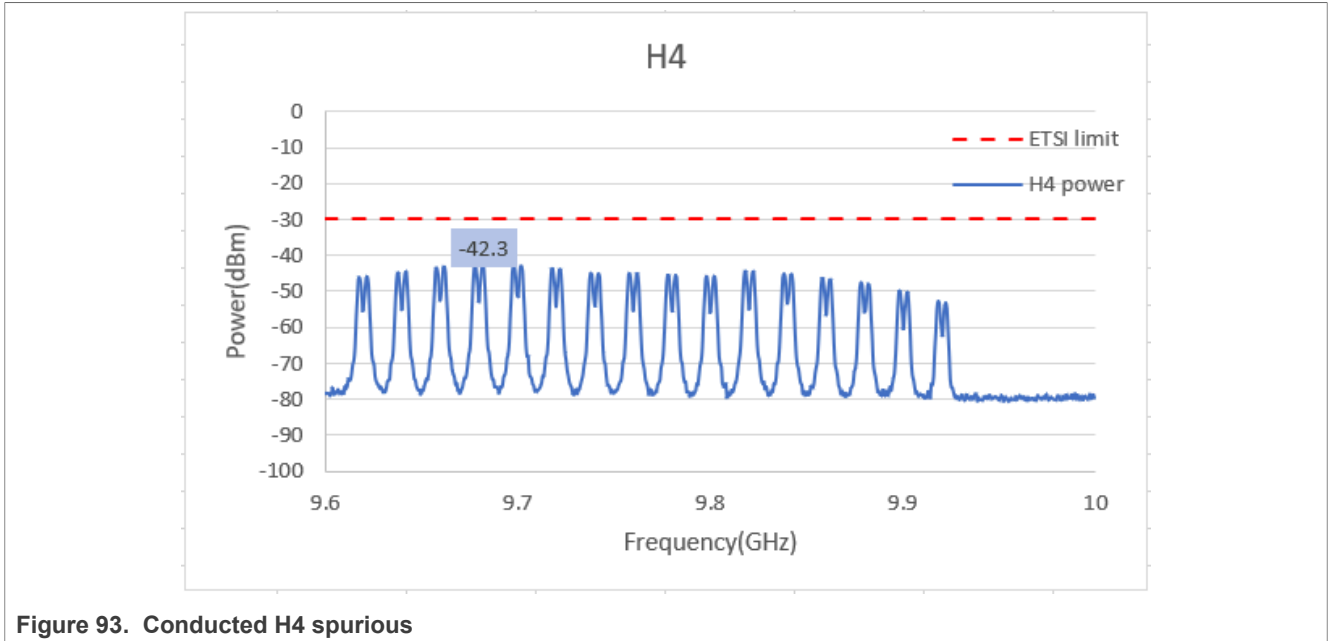


Figure 93. Conducted H4 spurious

Maximum power is on channel 16: **-42.3 dBm**.

Conclusion:

- There is **12.3 dB** margin to ETSI limit.

4.3.1.6.5 H5 (ETSI test conditions)

Test method:

The test method is similar as for the H2, except that the spectrum analyzer frequency start/stop are set to 12.0 GHz to 12.5 GHz.

Results:

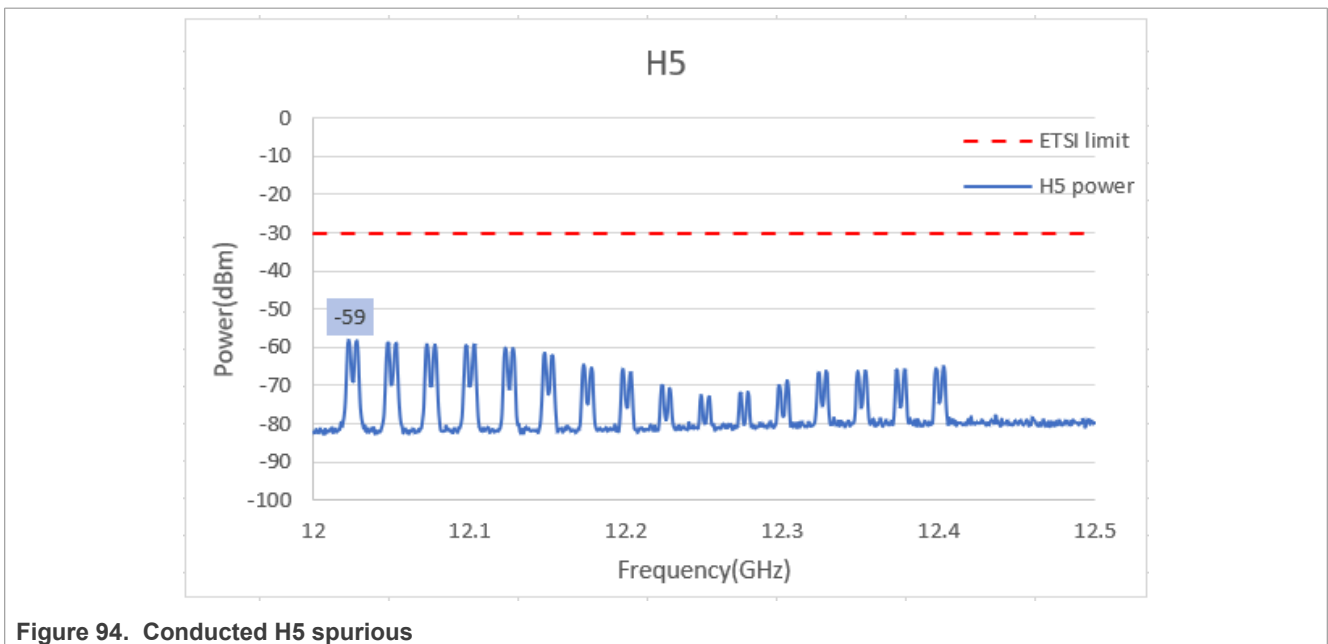


Figure 94. Conducted H5 spurious

Maximum power is on channel 16: **-59 dBm**.

Conclusion:

- There is **29 dB** margin to ETSI limit.

4.3.1.6.6 H6 to H10 (ETSI test conditions)

Test method:

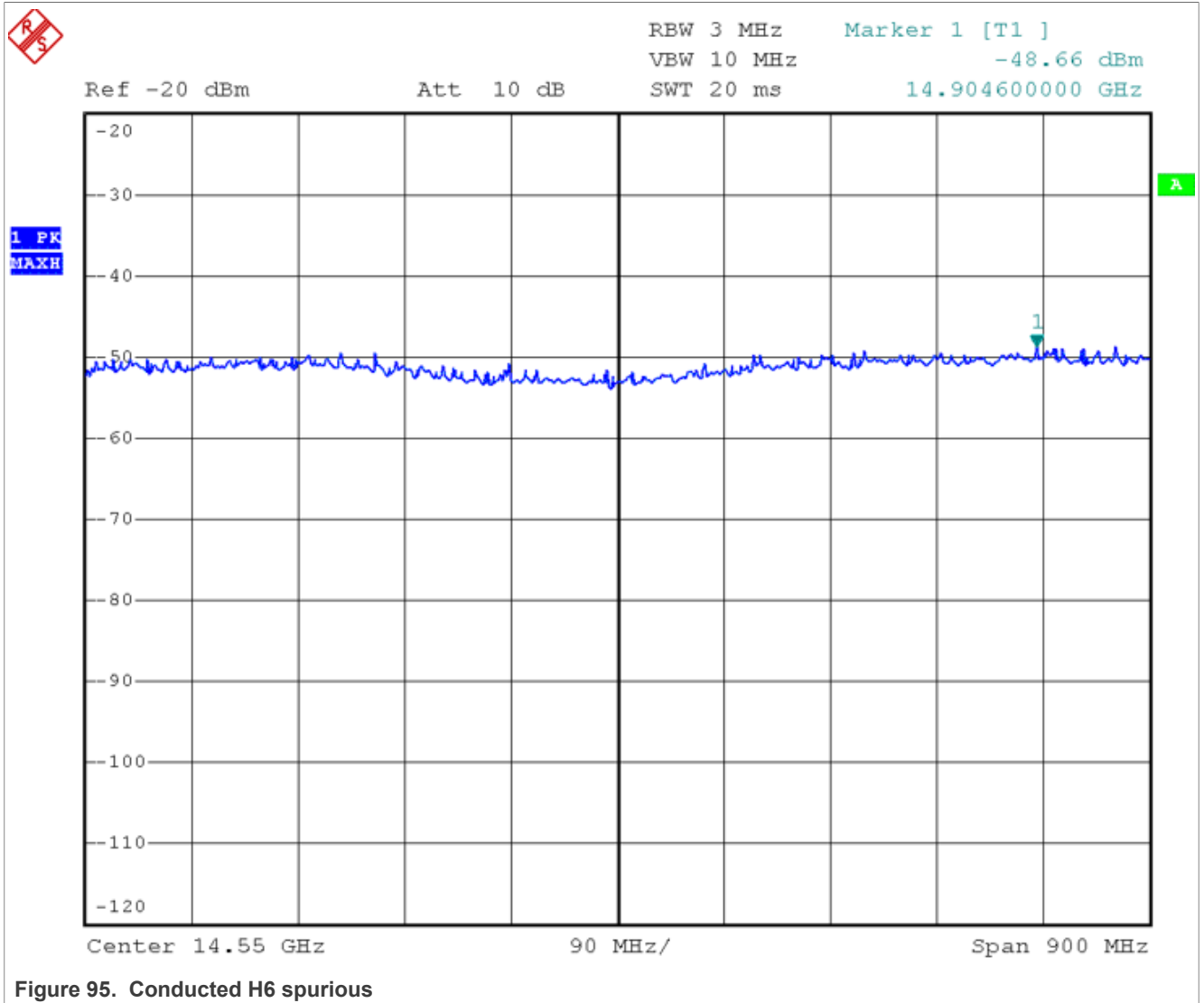
The test method is similar as for the H2, except that the spectrum analyzer frequency span is set to corresponding frequency range.

Table 34. Conducted H6 to H10 spurious

	H6	H7	H8	H9	H10
EN limit	-30	-30	-30	-30	-30
Spurious Power	-48.6	-55.6	-55.2	-48.3	-47.3
Margin	18.6	25.6	25.2	18.3	17.3

Results:

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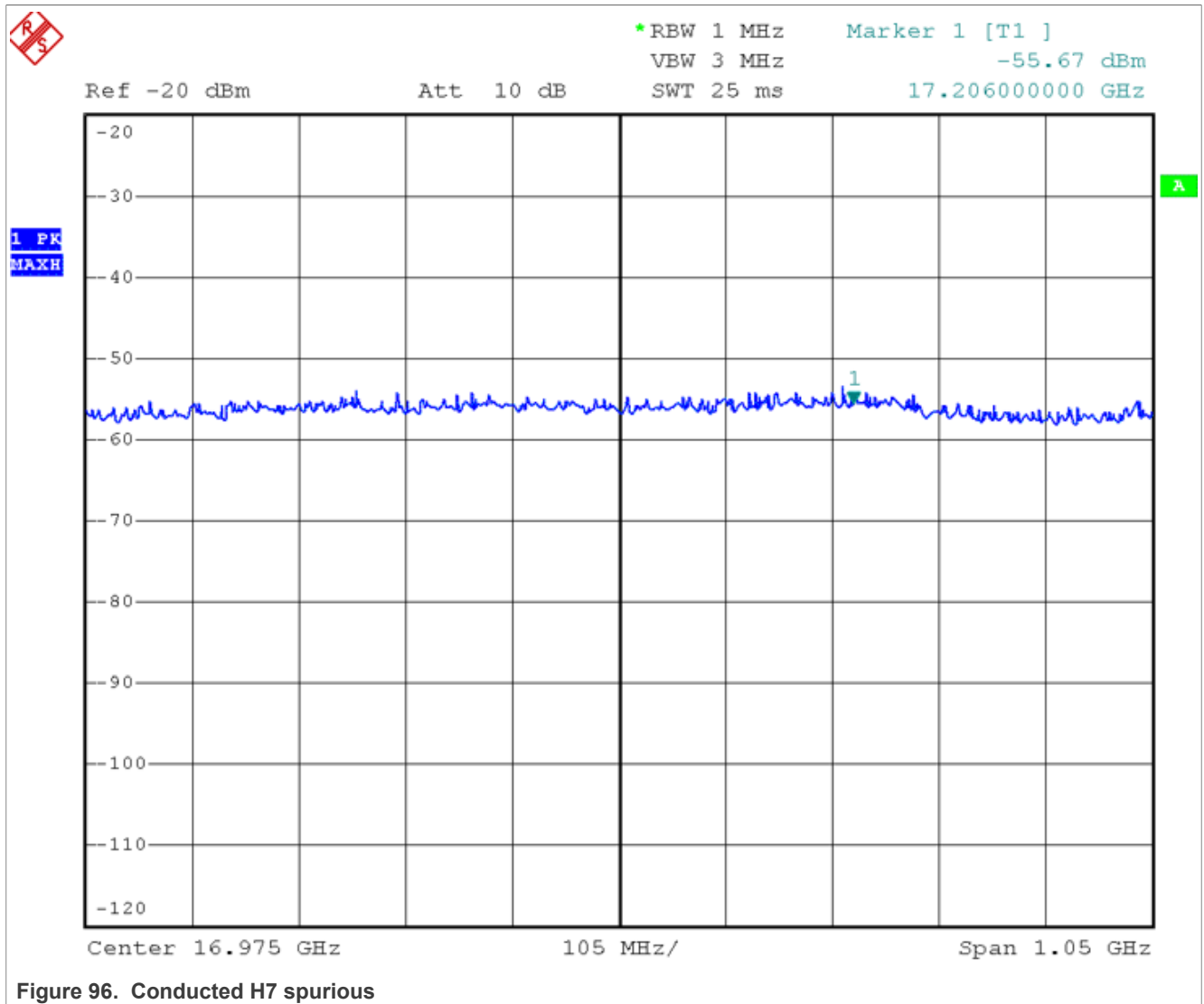


Figure 96. Conducted H7 spurious

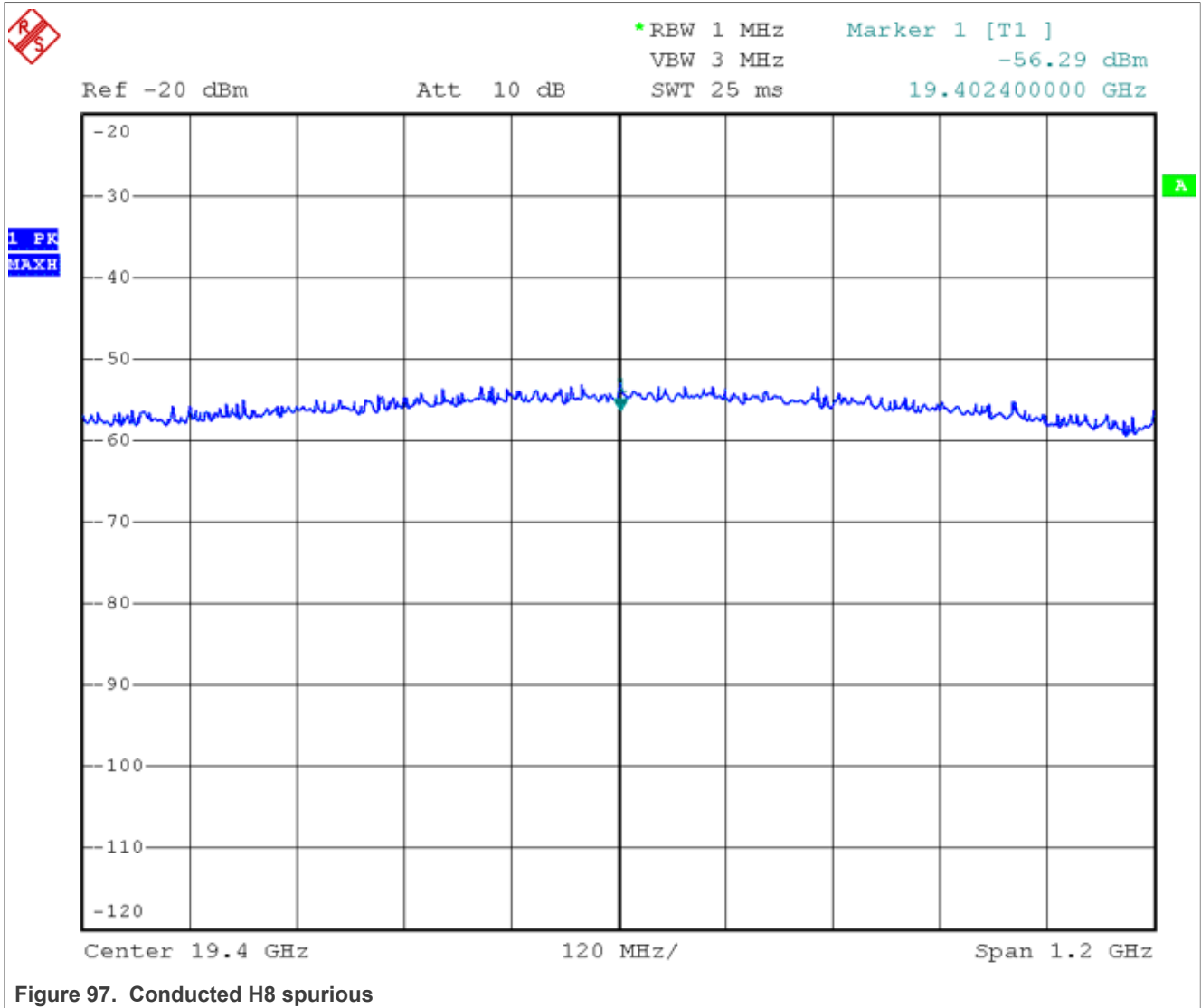


Figure 97. Conducted H8 spurious

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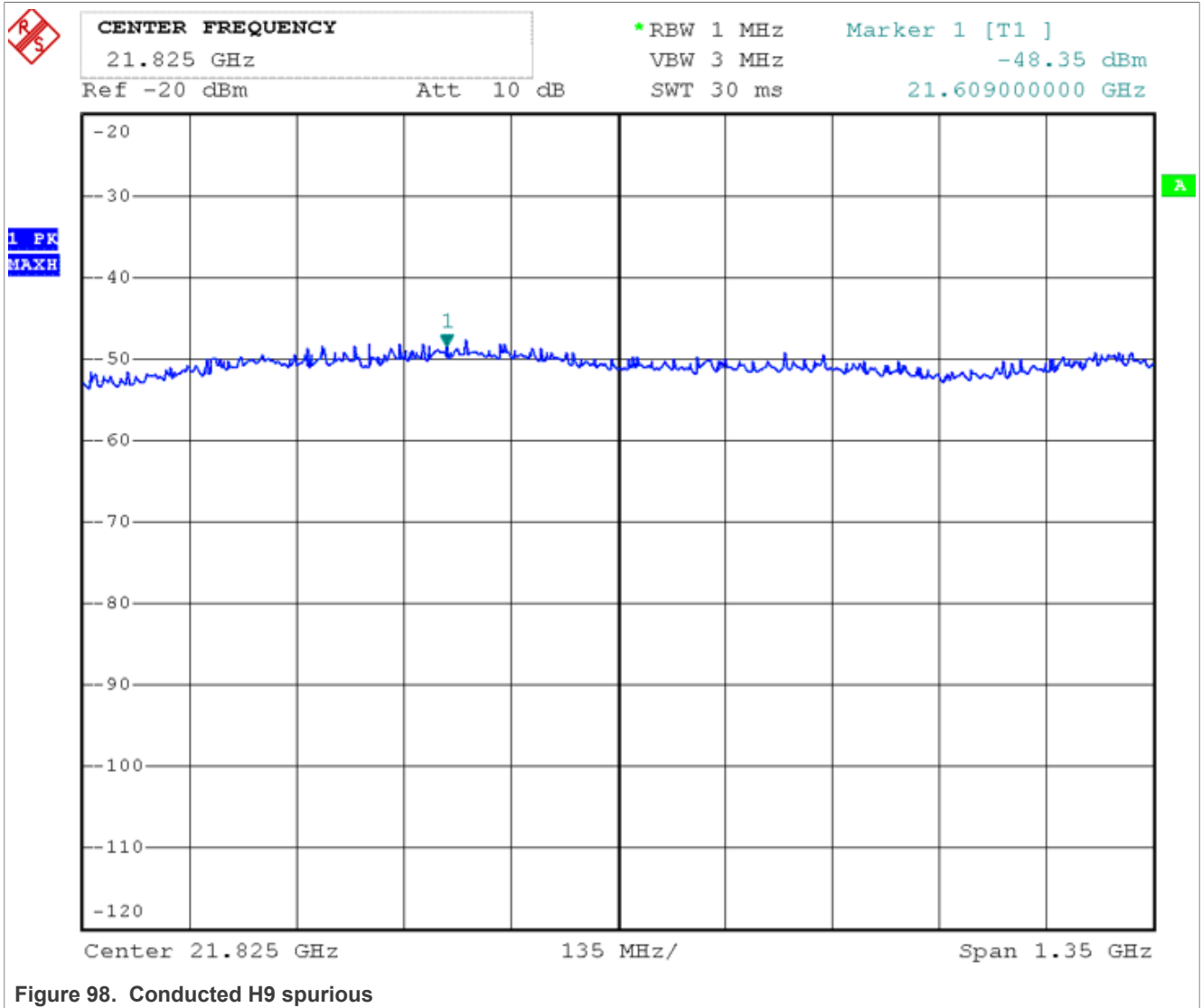
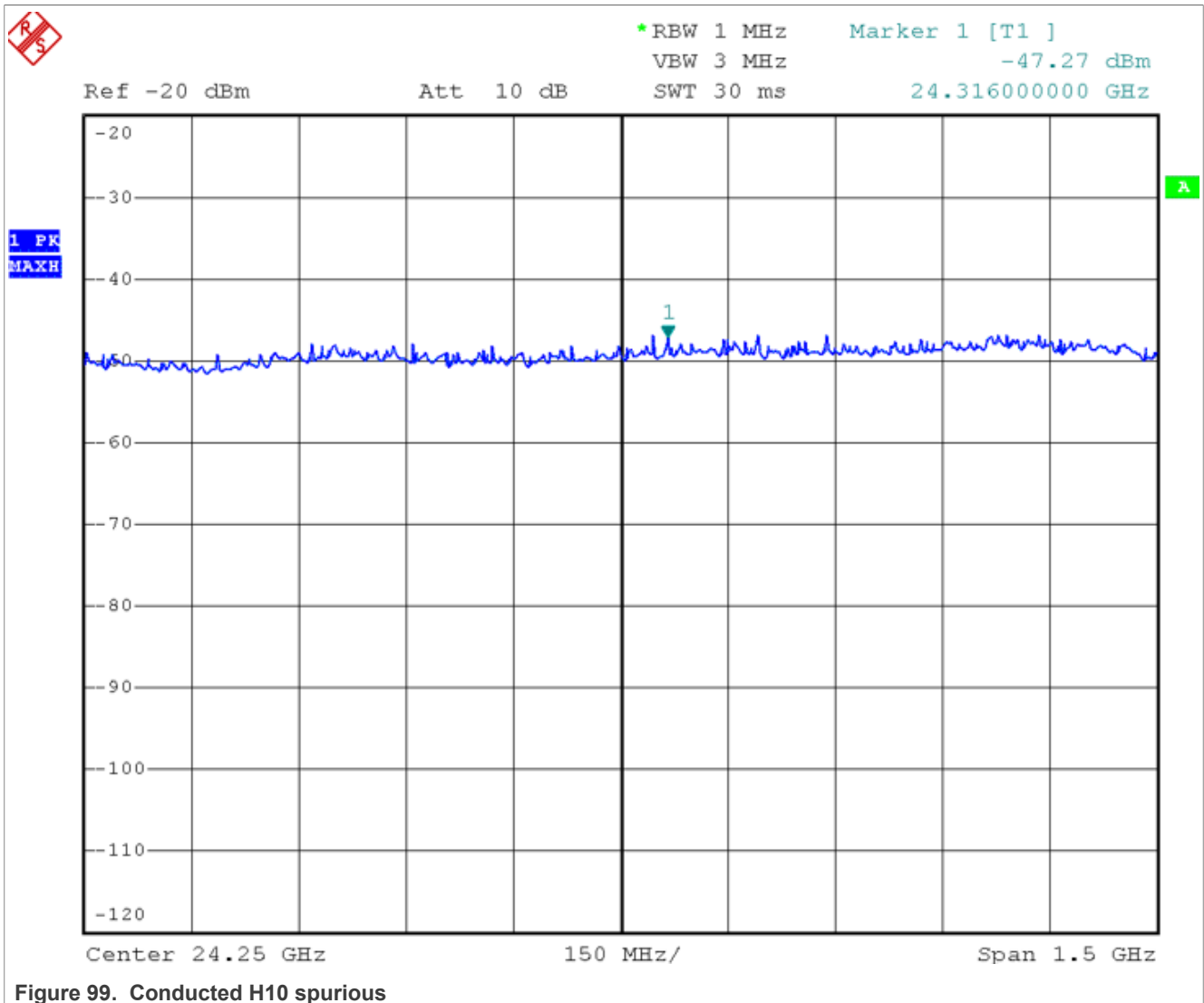


Figure 98. Conducted H9 spurious



Conclusion:

- There is **good** margin to the ETSI limit.

4.3.1.6.7 H2 (FCC test conditions)

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set analyzer to:
 - Start frequency = 4.8 GHz
 - Stop frequency = 5 GHz
 - Ref amp = -20 dBm
 - RF attenuation = sweep time = 100 ms
 - RBW = 1 MHz

- Trace mode: Average
- Detector RMS
- Sweep all the channels from ch11 to ch26.

Results:

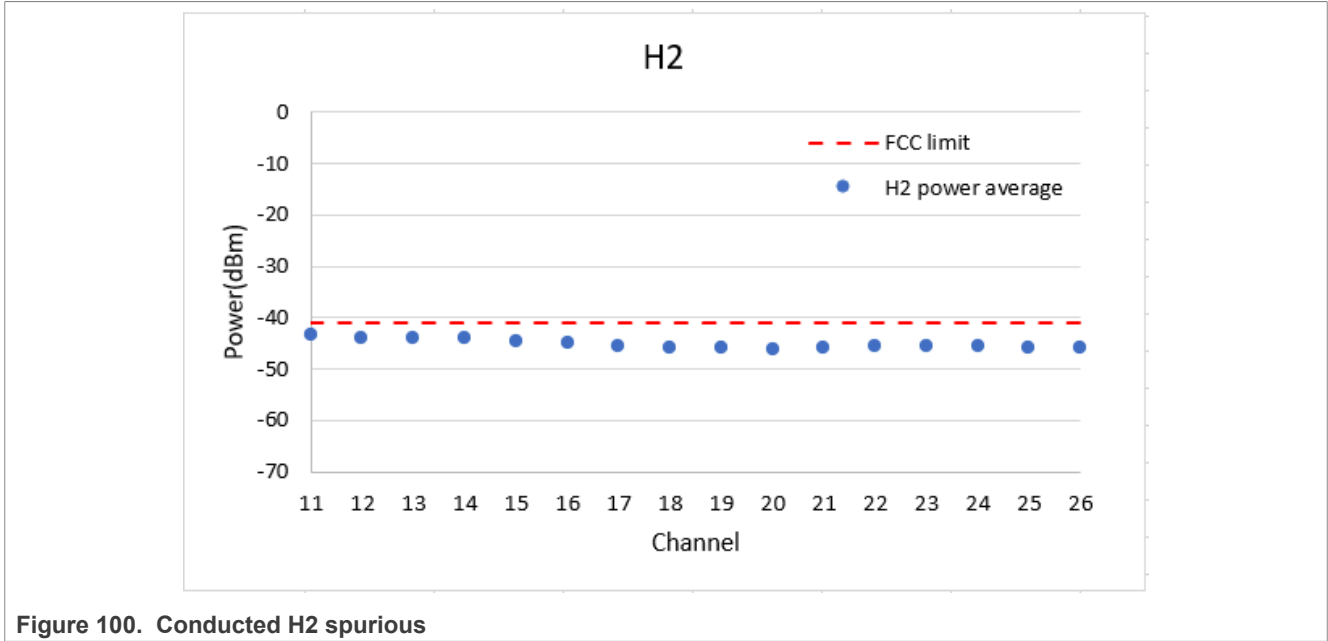


Figure 100. Conducted H2 spurious

Maximum power is on channel 11: **-43.5 dBm**.

Conclusion:

- There is **2.5 dB** margin to FCC limit.

4.3.1.6.8 H3 (FCC test conditions)

Test method:

The test method is similar as for the H2, except that the spectrum analyzer frequency start/stop are set to 7.2 GHz and 7.5 GHz.

Results:

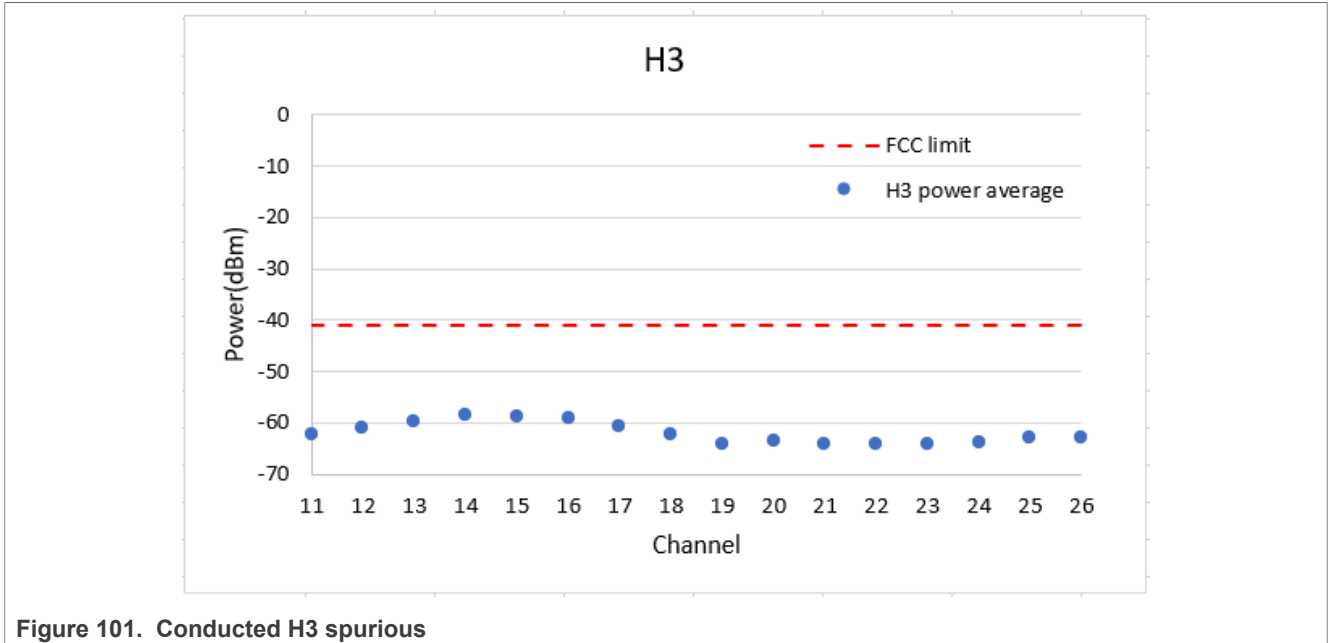


Figure 101. Conducted H3 spurious

Maximum power is on channel 18 to 26: **-58 dBm**.

Conclusion:

- There is **17 dB** margin to FCC limit.

4.3.1.6.9 H4 (FCC test conditions)

Test method:

The test method is similar as for the H2, except that the spectrum analyzer frequency span is set from 9.6 GHz to 10.0 GHz.

Results:

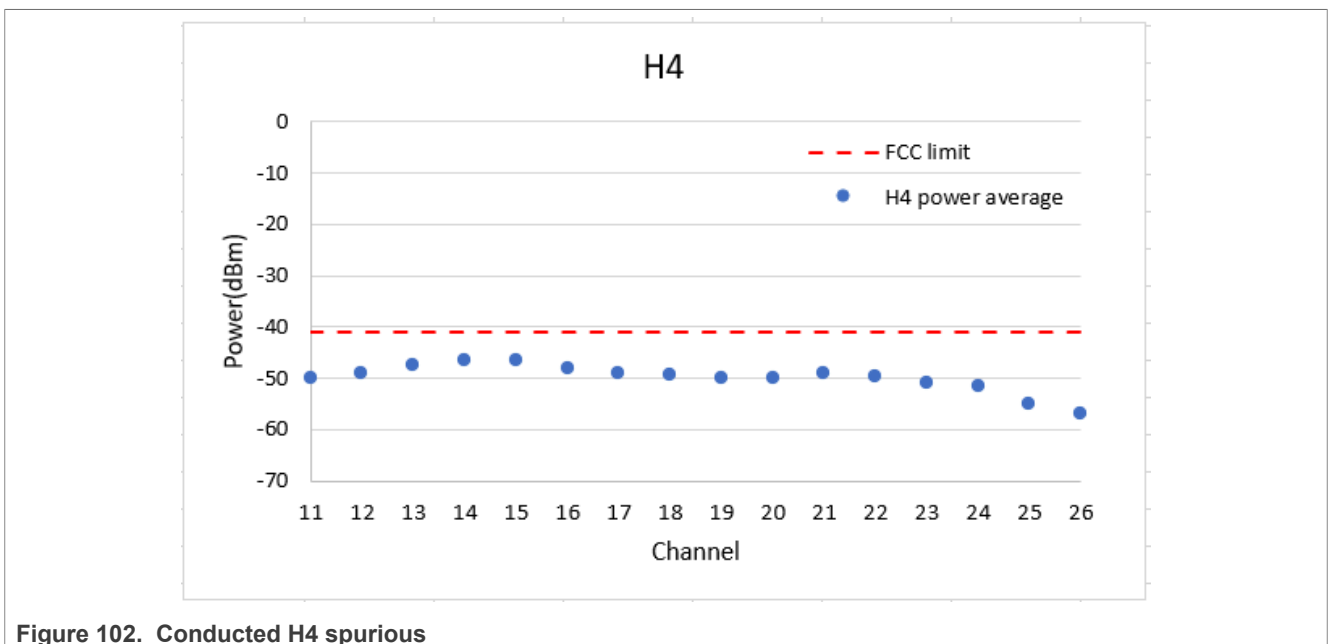


Figure 102. Conducted H4 spurious

Maximum power is on channel 17: **-46 dBm**.

Conclusion:

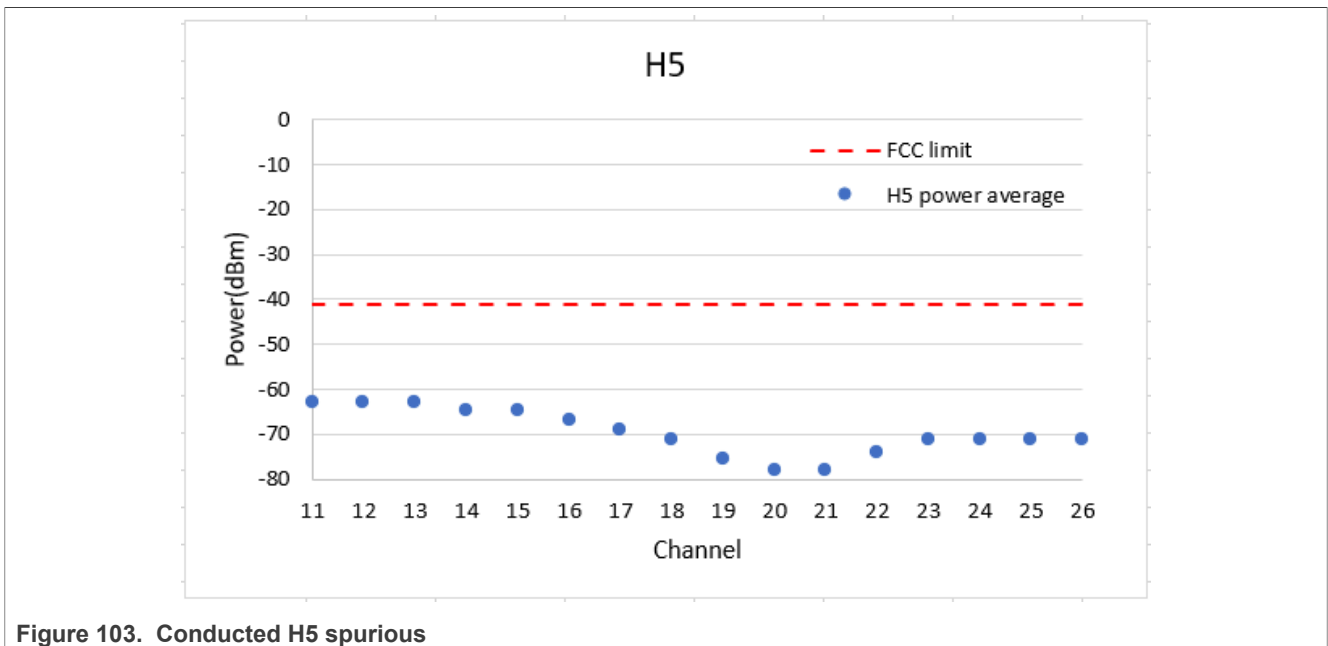
- There is **5 dB** margin to FCC limit.

4.3.1.6.10 H5 (FCC test conditions)

Test method:

The test method is similar as for the H2, except that the spectrum analyzer frequency span is set from 12 GHz to 12.5 GHz.

Results:



Maximum power is on channel 17: **-63 dBm**.

Conclusion:

- There is **22 dB** margin to FCC limit.

4.3.1.6.11 H6 to h10 (FCC test conditions)

Test method:

The test method is similar as for the H2, except that the spectrum analyzer frequency span is set to corresponding frequency range.

Table 35. Conducted H6 to H10 spurious

	H6	H7	H8	H9	H10
FCC limit	-41.5	-41.5	-41.5	-41.5	-41.5
Spurious Power	-59.5	-63.2	-62.9	-57.4	-58.3
Margin	18	21.7	21.4	15.9	16.8

Results:

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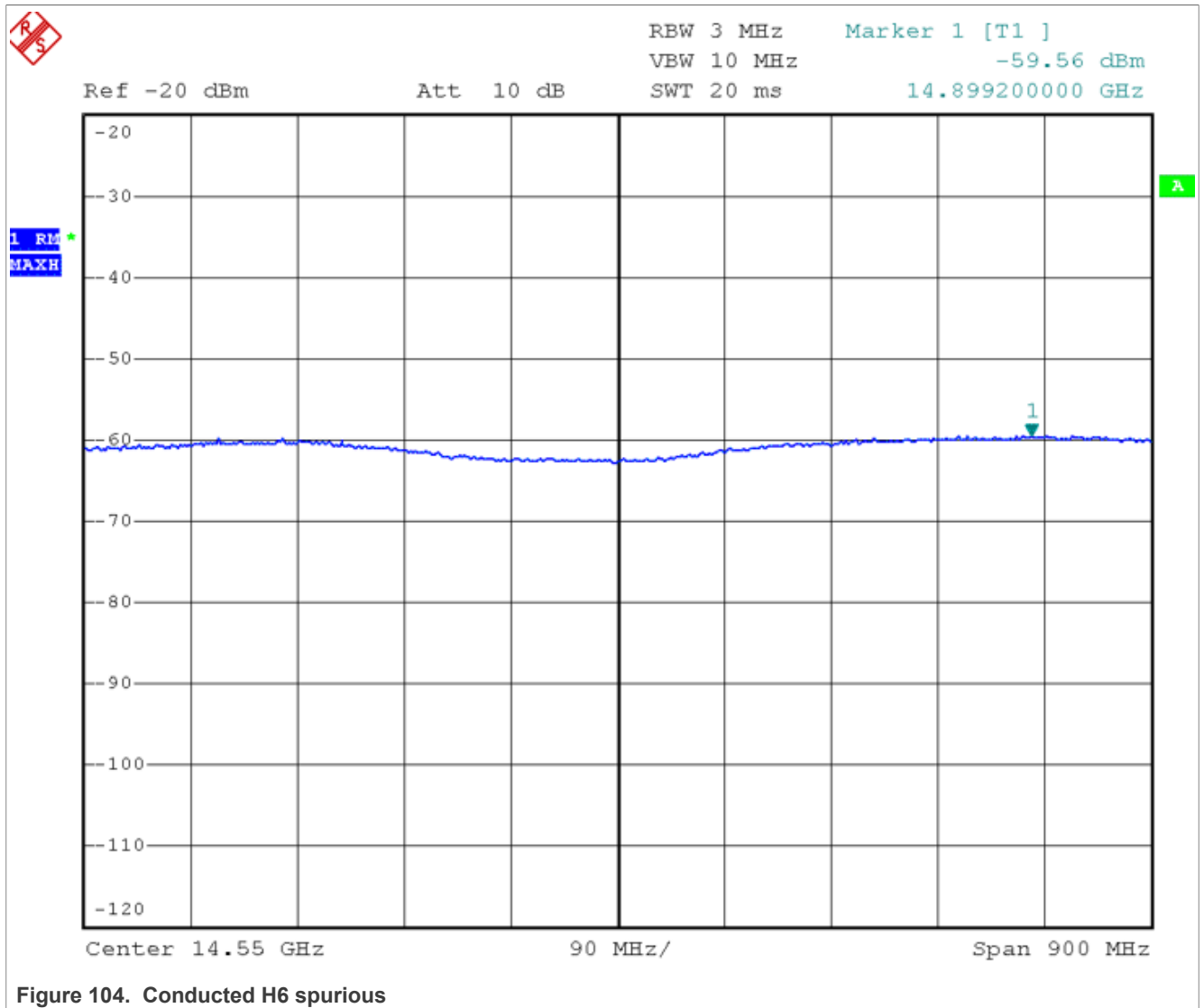


Figure 104. Conducted H6 spurious

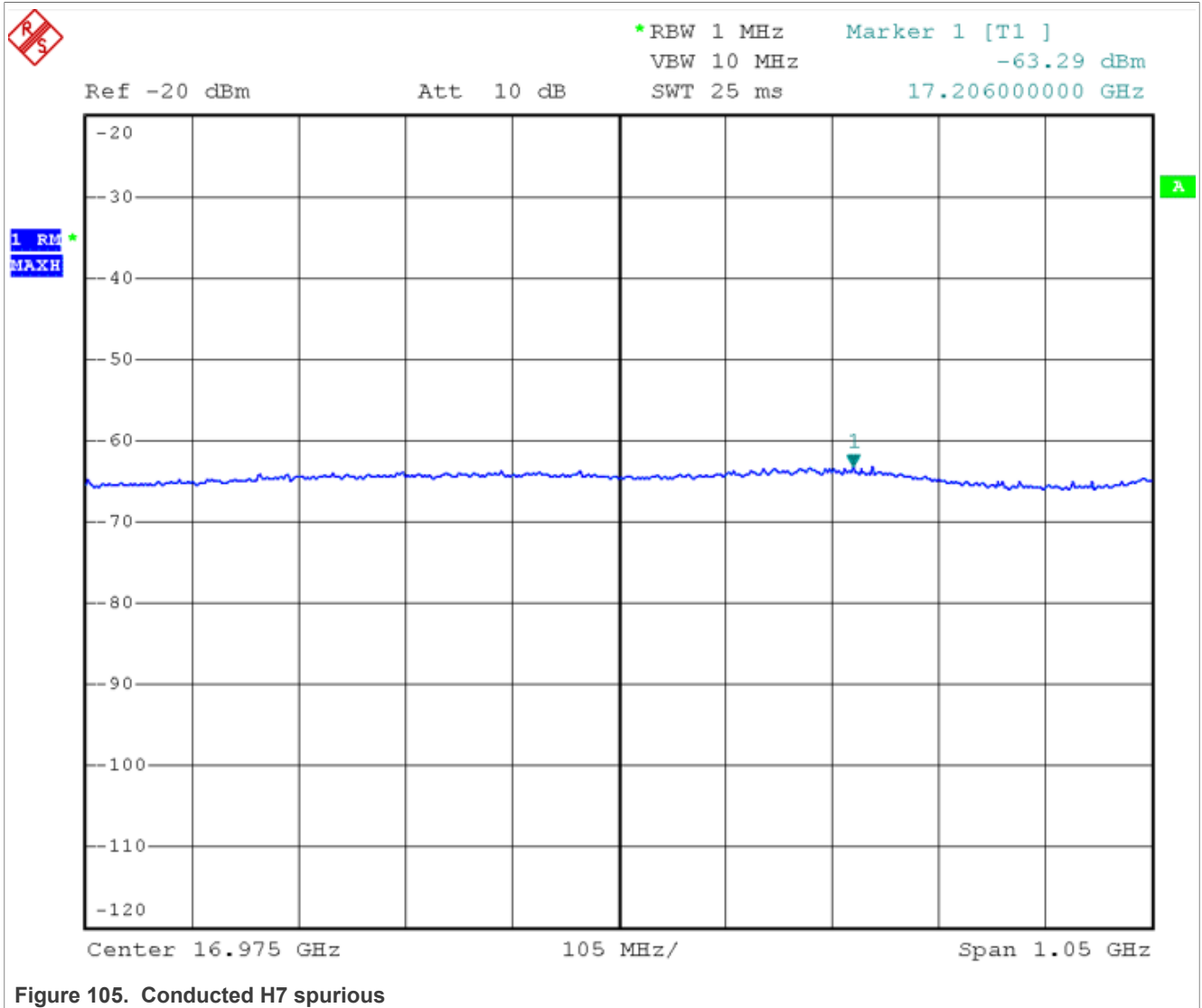


Figure 105. Conducted H7 spurious

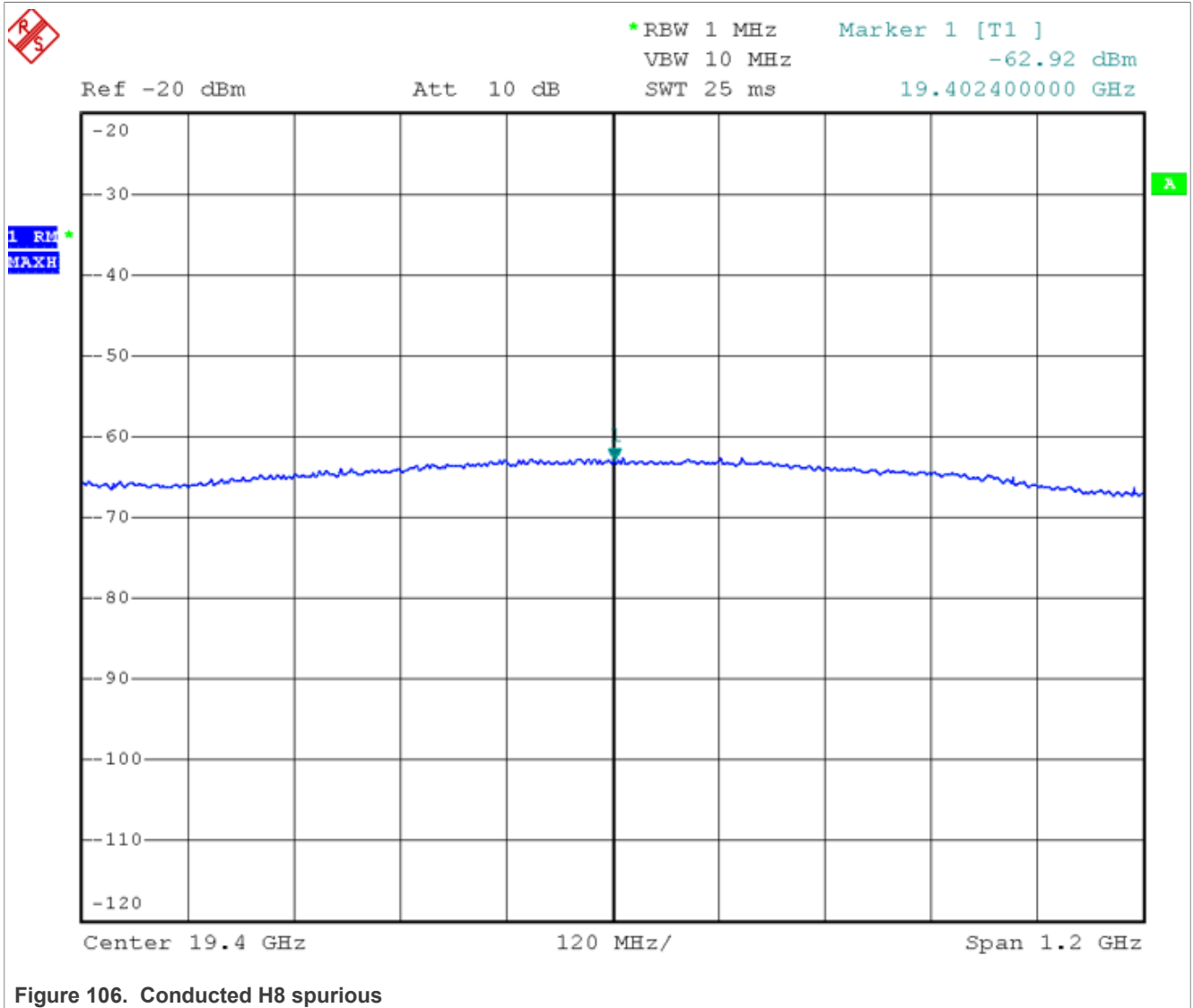


Figure 106. Conducted H8 spurious

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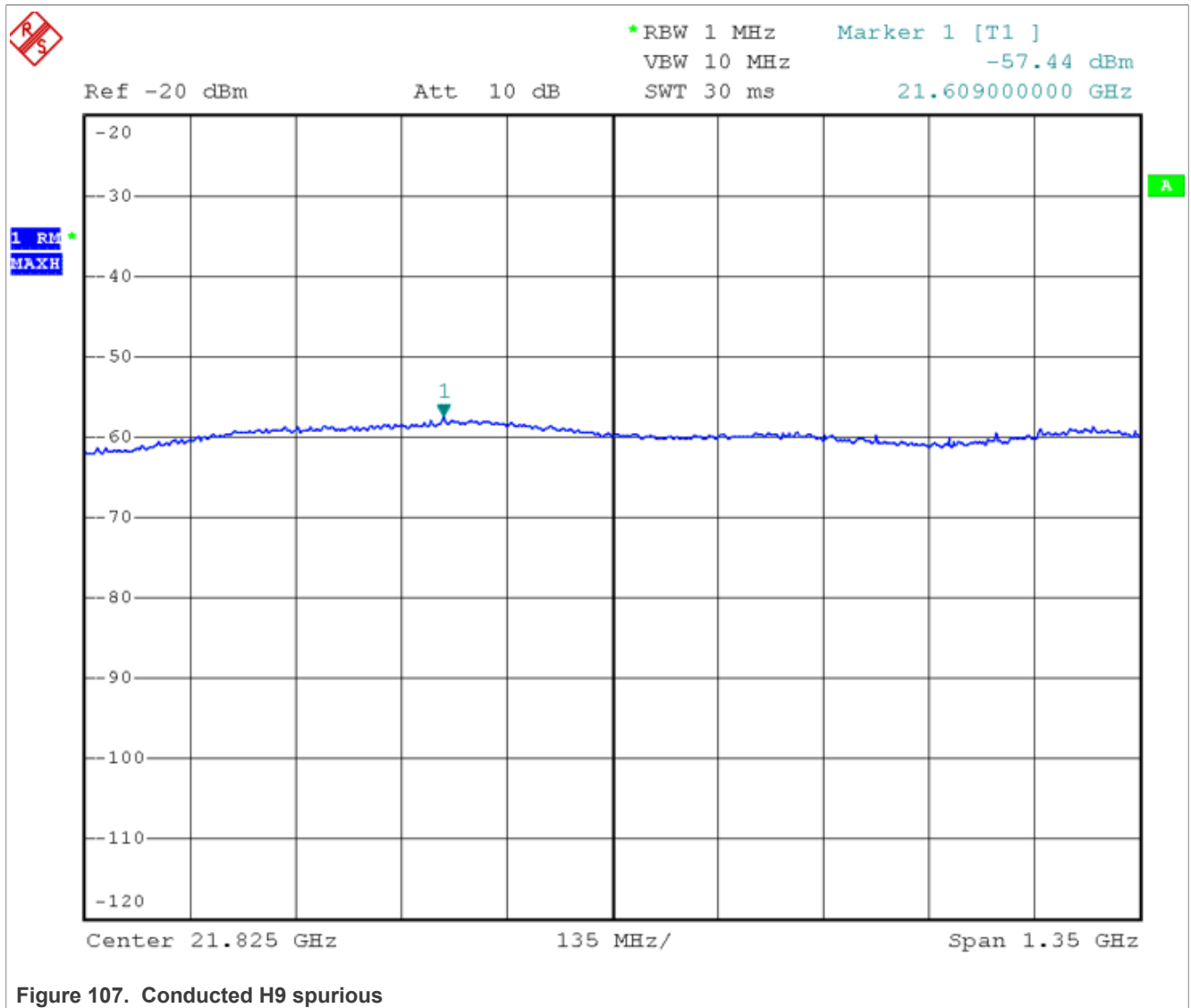
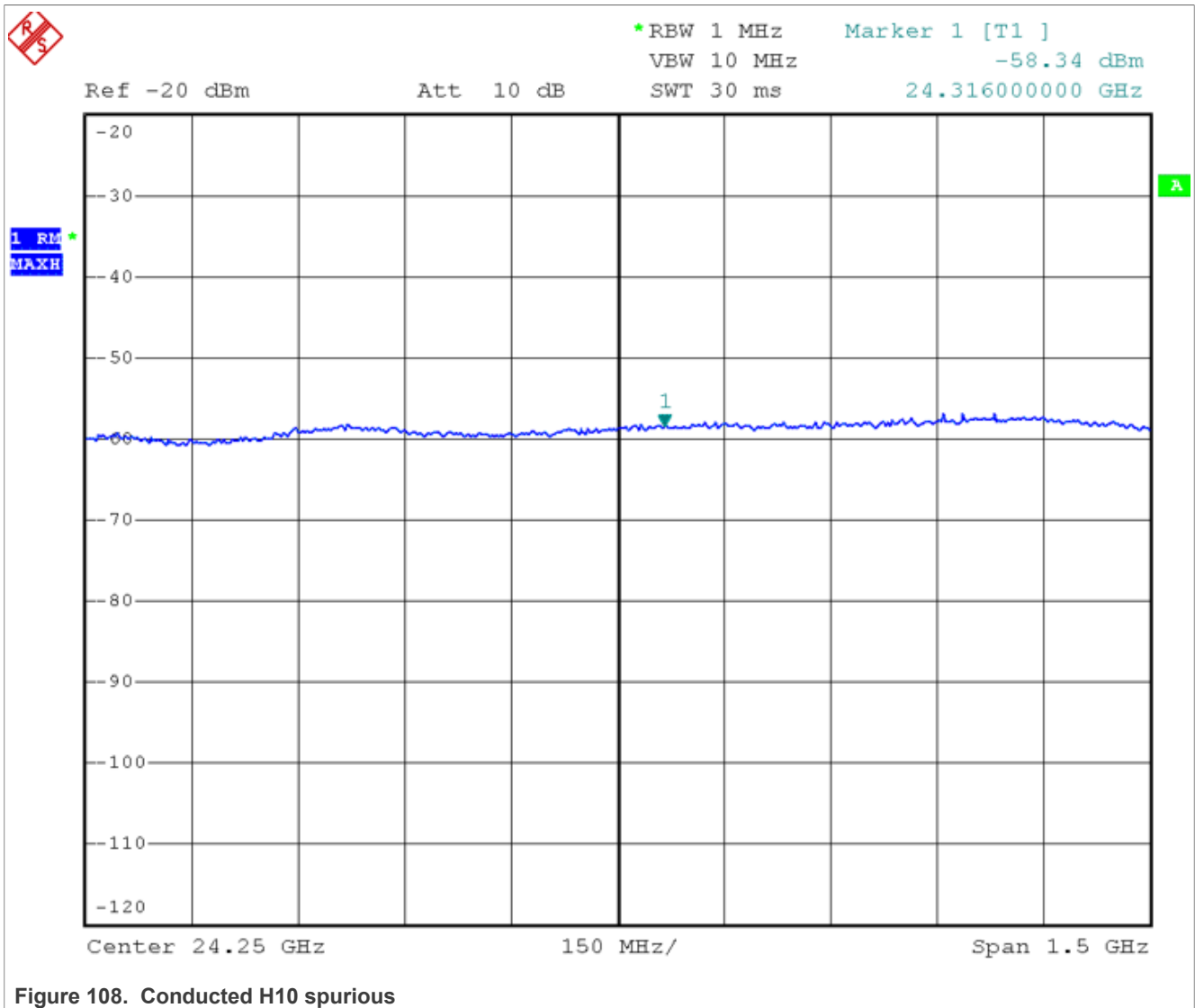


Figure 107. Conducted H9 spurious



Conclusion:

- There is **good** margin to the FCC limit on H6, H7, H8, H9, and H10.

4.3.1.7 TX modulation

4.3.1.7.1 EVM

Test method:

- Connect the RF port of the module to the R&S FSV spectrum analyzer. To do the EVM measurement, use the specific menu of the SA.
- Set the K45W in continuous modulated mode.
- Set the TX frequency to Channel 11.
- Measure the offset EVM value.
- Repeat the test for each channel.

Result:

Figure 109 shows the EVM test result.

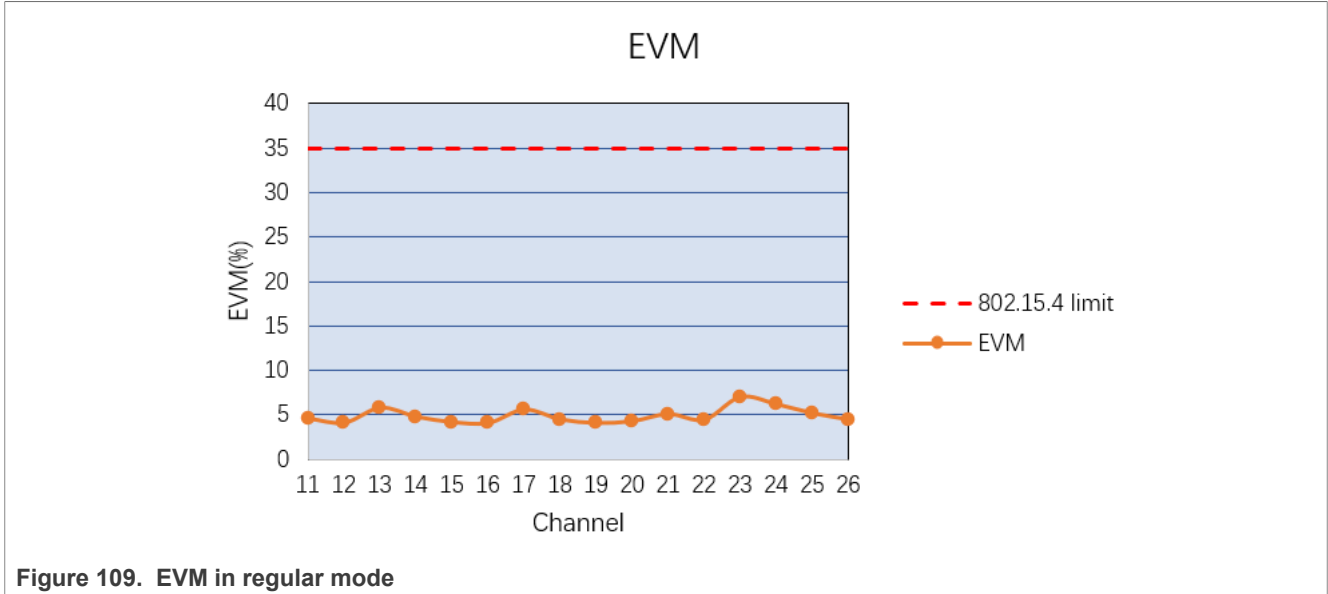


Figure 109. EVM in regular mode

Maximum value is on channel 23 = 7.0 %.

Conclusion:

- Very good margin.

4.3.1.7.2 Offset EVM

Test method:

Similar method as for the EVM measurement

Result:

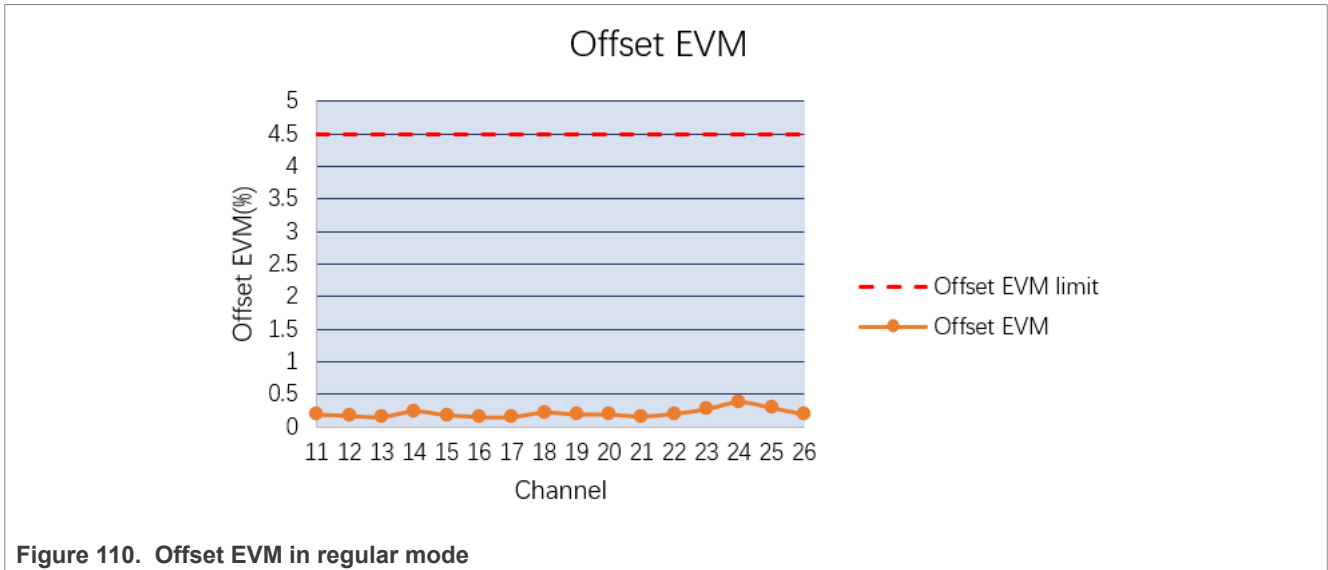


Figure 110. Offset EVM in regular mode

Maximum value is on channel 23 = 0.38 %.

Conclusion:

- Very good margin vs 802.15.4 limit.

4.3.1.8 Lower band edge – MIIT China

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Burst mode
 - Set the Channel 11 (2.405 GHz)
- Set analyzer to:
 - Start freq = 2.385 GHz
 - Stop freq = 2.415 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - Sweep point: 8001 pts
 - RBW = 1 MHz
 - Video BW = 3 MHz
 - Detector = RMS MaxHold

Results:

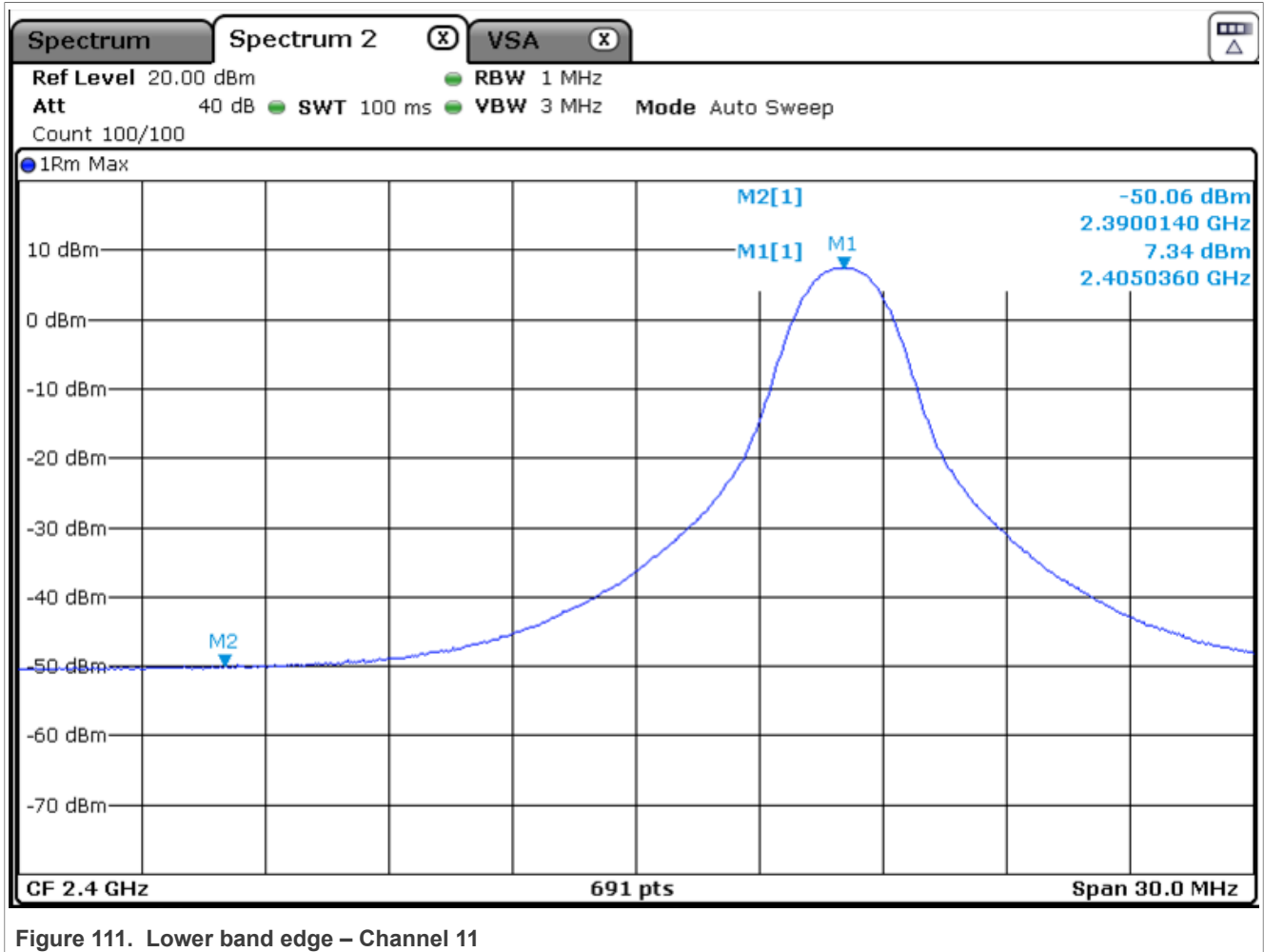


Figure 111. Lower band edge – Channel 11

Conclusion:

- The lower band edge test passes the Bluetooth SIG (MIIT-China) certification.
- There is good margin to MIIT-China) limit (-50 dBm below 2.39 GHz).

4.3.1.9 Upper band edge – MIIT China

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
 - Maximum RF output power +10 dBm (not passing the FCC requirement)
 - Set the channel 26 (2.48 GHz).
 - Set the power -5 dBm for 802.15.4.
- Set analyzer to:
 - Start freq = 2.477 GHz
 - Stop freq = 2.507 GHz
 - Ref amp = -20 dBm
 - Sweep time = 40 ms

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- Sweep point: 8001 pts
- RBW = 1 MHz
- Video BW = 3 MHz
- Detector = RMS, Max Hold

Results:

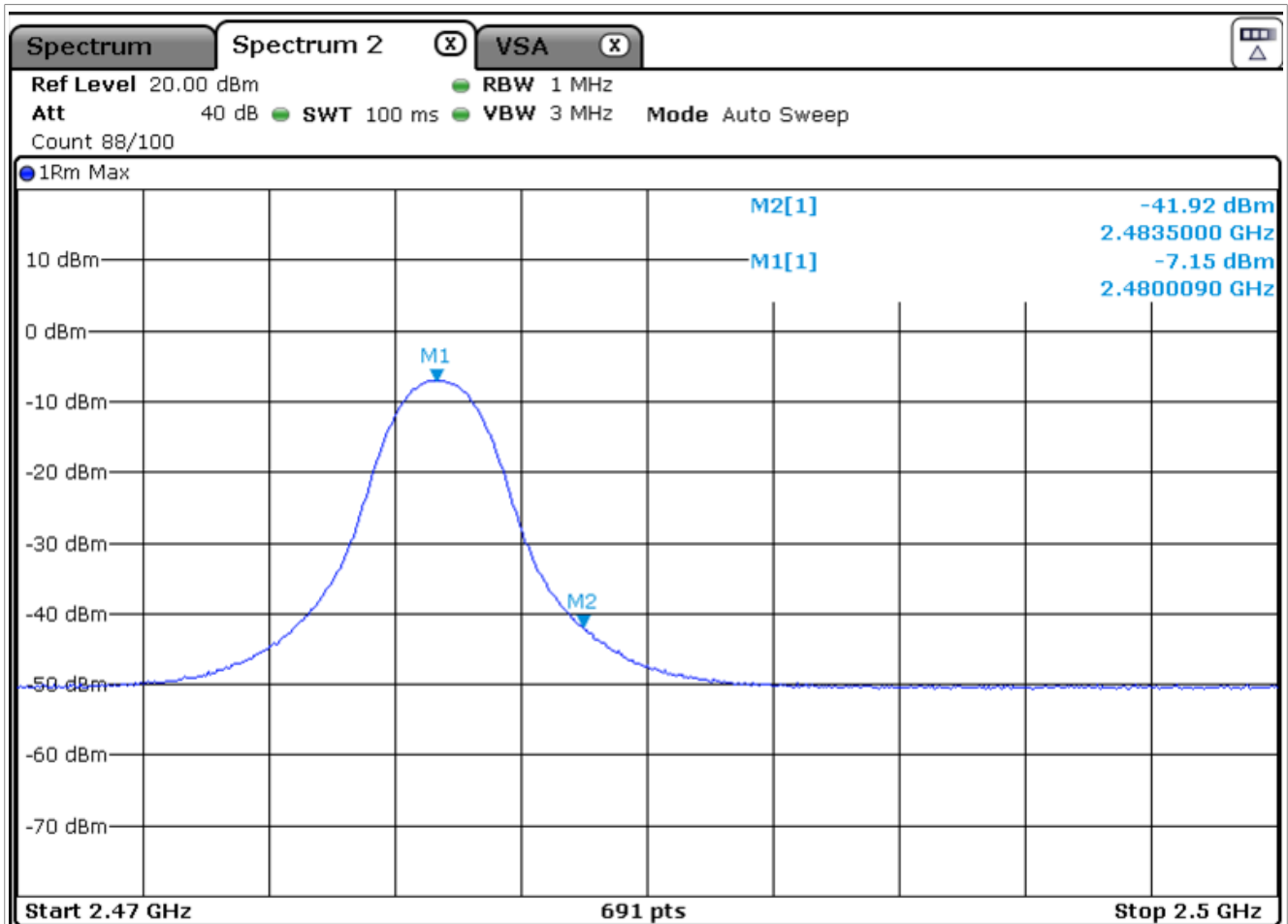


Figure 112. Bluetooth LE - Upper band edge – Channel 26

Conclusion:

- The upper band edge test passes the Bluetooth SIG (MIIT-China) certification in TX power have to set down to **-5 dBm from +10 dBm on ch26**.

4.3.1.10 Upper band edge (FCC ANSI C63.10, 558074 D01 DTS)

Test method:

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
 - Maximum RF output power +10 dBm (does not pass the FCC requirement)

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- Set the RF output power +5 dBm.
- Set analyzer to:
 - Start freq = 2.475 GHz
 - Stop freq = 2.485 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - RBW = 100 kHz
 - Video BW = 300 kHz
 - Detector = Average
 - Average mode: power
 - Number of Sweeps = 100
 - Set Channel 26 (2.48 GHz)
 - Trace mode: Max hold

Results:

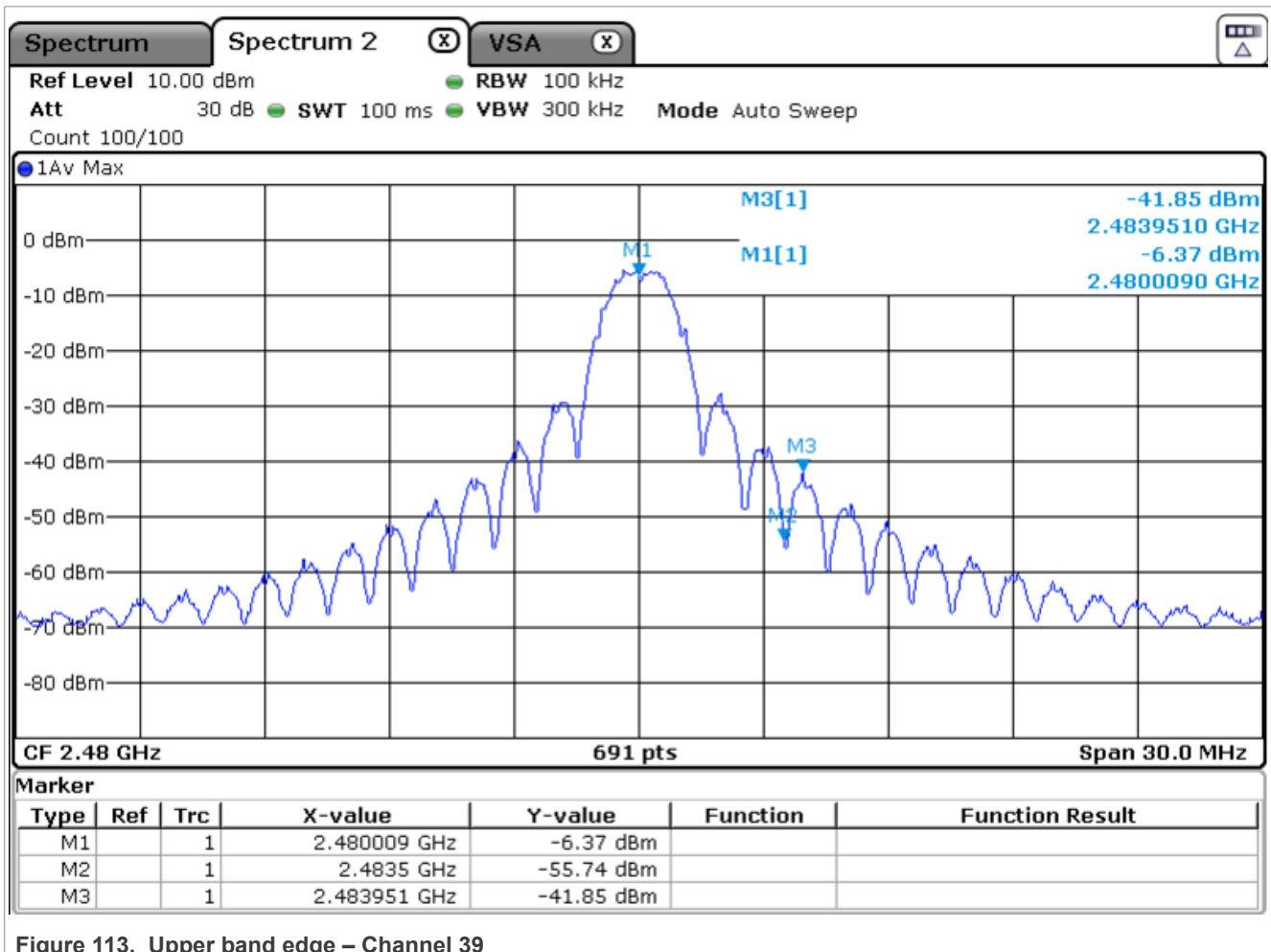


Figure 113. Upper band edge – Channel 39

Modulation	TX power +5 dBm
Level @2.4835 GHz	-42 dBm

FCC limit: < -41.15 dBm

Conclusion:

- The upper band edge test passes the FCC certification (<41.15dBm@2.4835GHz) in TX power have to set down to **+5 dBm from +10 dBm on ch26**.

4.3.1.11 Out of band (ETSI 300 328 chapter 5.4.8.2.1)**Test method:**

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set analyzer to:
 - Start freq = 2.375 GHz
 - Stop freq = 2.510 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - RBW = 1 MHz
 - Video BW = 3 MHz
 - Detector = Average
 - Average mode: Power
 - Number of Sweeps = 100
 - Set Channel 0 (2.402 GHz) and 39 (2.48 GHz)
 - Trace mode: Max hold

Results:

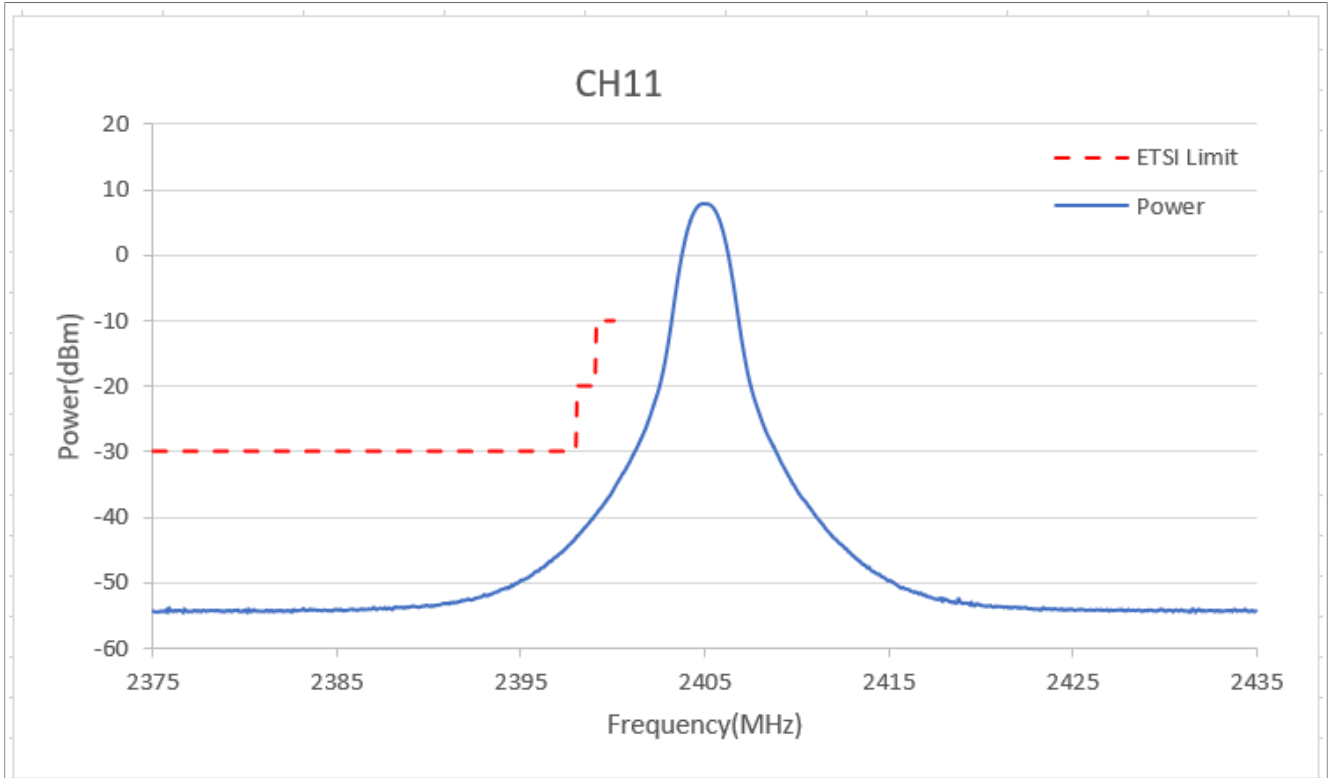


Figure 114. Out of band – Channel 11

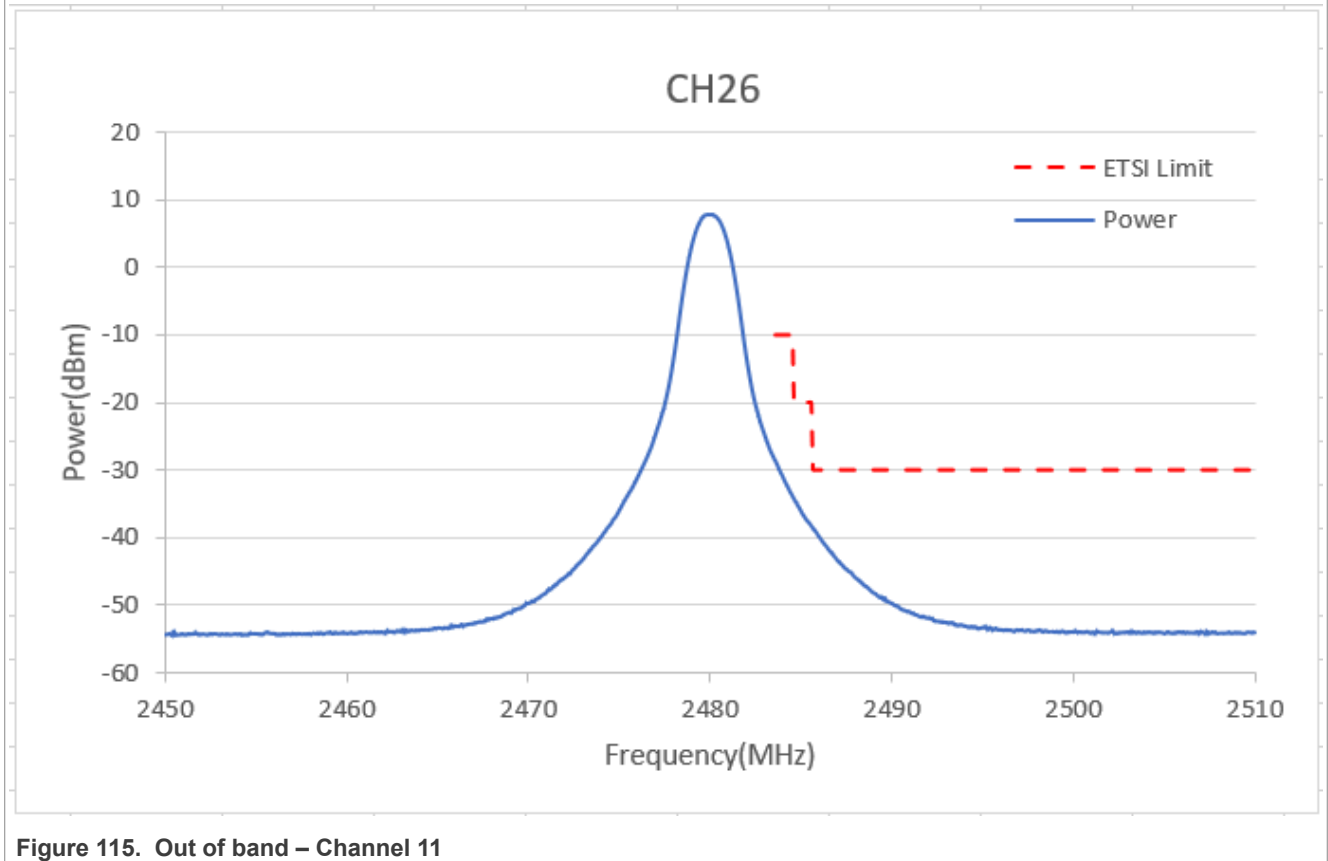


Figure 115. Out of band – Channel 11

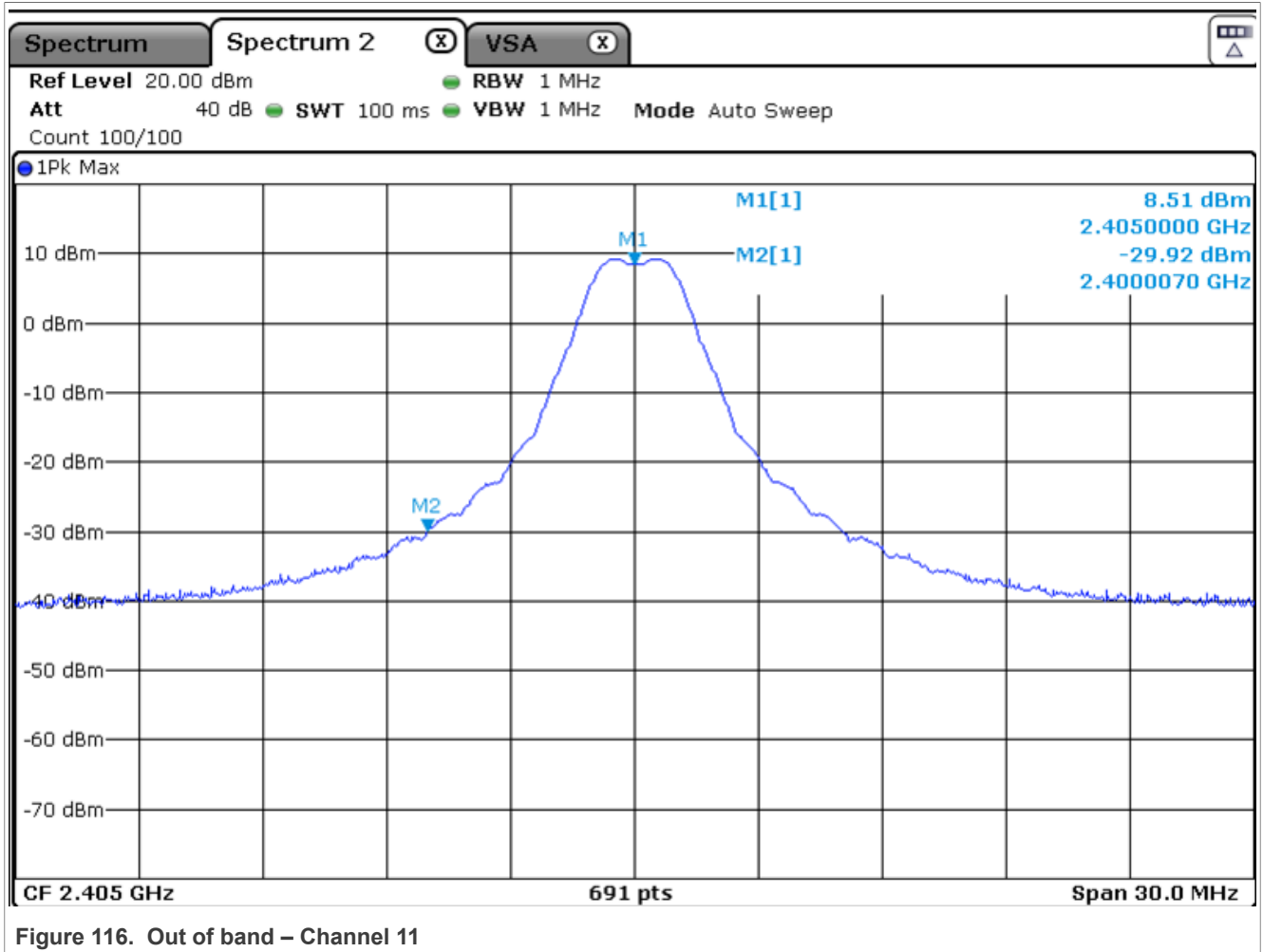
Conclusion:

- The out of band test passes the ETSI certification.

4.3.1.12 Out of band (ARIB STD T-66)**Test method:**

- Set the radio to:
 - TX mode
 - Modulated
 - Continuous mode
- Set analyzer to:
 - Start freq = 2.475 GHz
 - Stop freq = 2.485 GHz
 - Ref amp = -20 dBm
 - Sweep time = 100 ms
 - RBW = 1 MHz
 - Video BW = 1 MHz
 - Detector = Peak
 - Average mode: Power
 - Number of Sweeps = 100
 - Set Channel 0 (2.402 GHz) and 39 (2.48 GHz)
 - Trace mode: Max hold

Results:



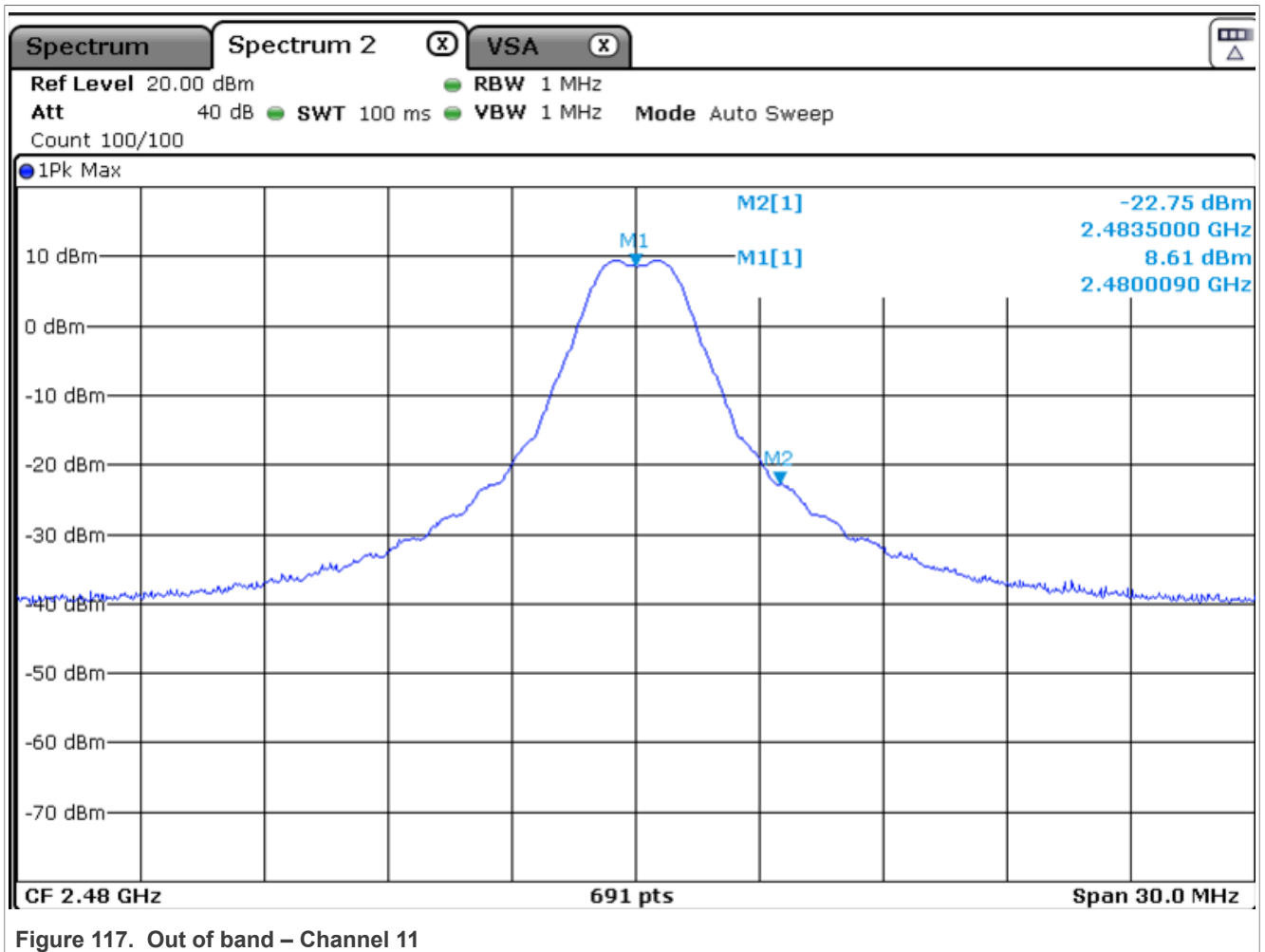


Figure 117. Out of band – Channel 11

Conclusion:

- The out of band test passes the ARIB STD T-66 certification.

4.3.2 RX tests

4.3.2.1 Test setup

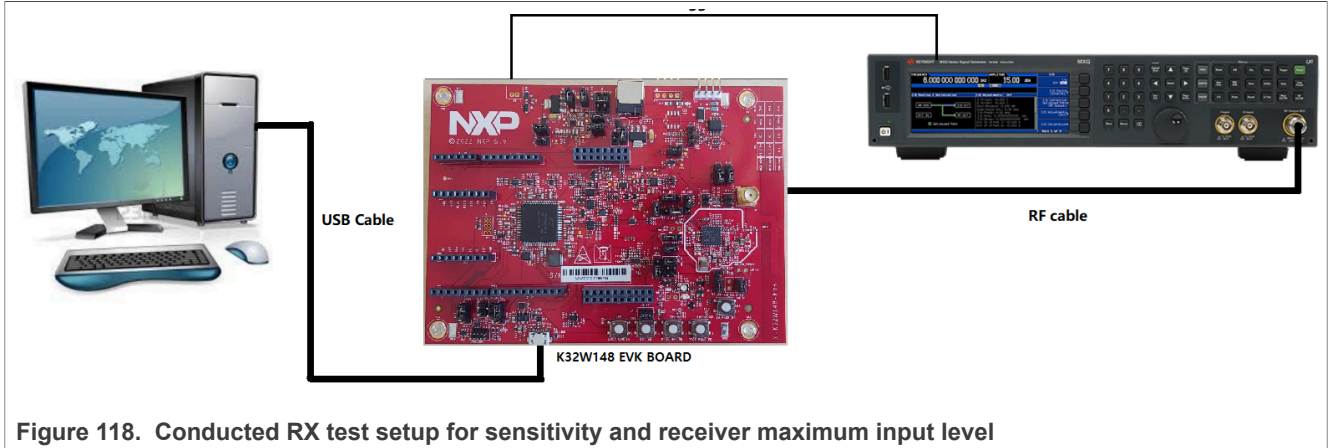


Figure 118. Conducted RX test setup for sensitivity and receiver maximum input level

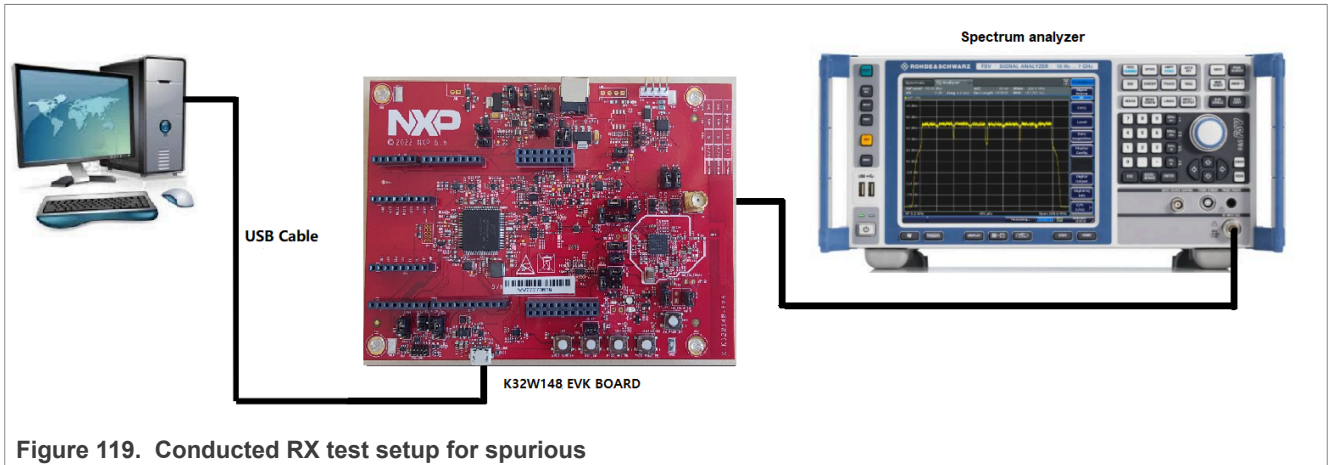


Figure 119. Conducted RX test setup for spurious

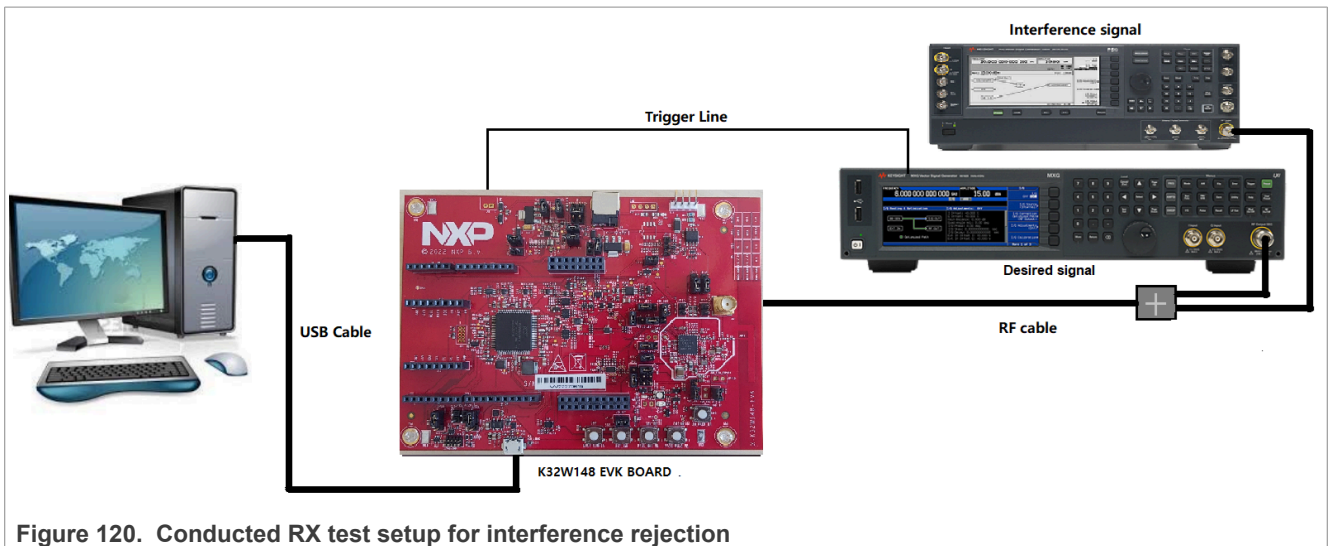


Figure 120. Conducted RX test setup for interference rejection

4.3.2.2 RX sensitivity

Test method:

To avoid any interference, place the carrier board and K32W148 module in an RF shield room.

Generator: Keysight N5182B

The generator is used in ARB mode. It generates a pattern of 1000 packets of 20 octets. The DIO19 of the K32W148 is connected to the trigger input of the generator.

A TERATERM window is used to control the module.

- Set the receive frequency to Channel 11.
- Set the module in Trigger packet test.
- The connection is automatically established and the Packet Error Rate (PER) is measured.
- Decrease the level of the generator at the RF input of the module until PER = 1 %.
- Do the same for other channels.

Results:

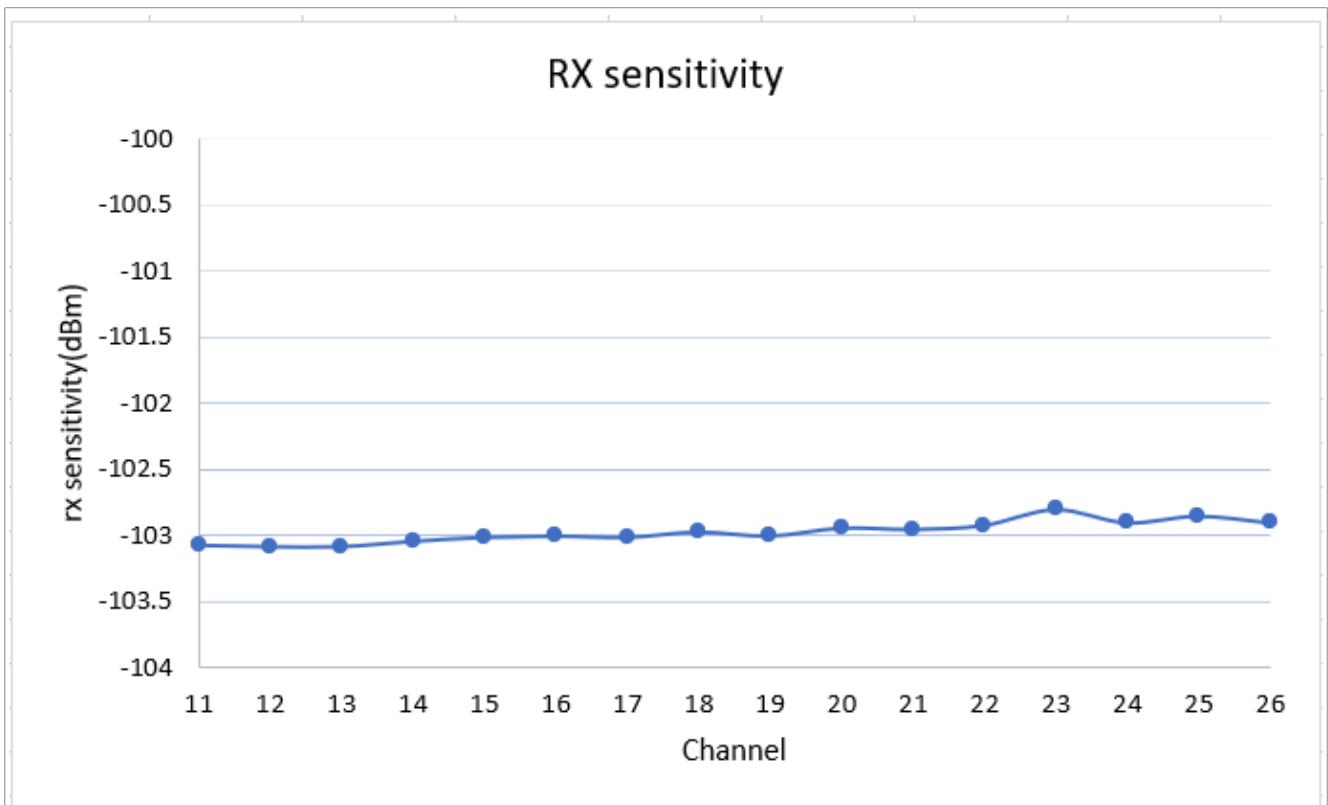


Figure 121. RX sensitivity

Conclusion:

- Minimum value: - 103.1 dBm on channel 12
- Maximum value: -102.8 dBm on channel 23

Note:

In RX test, K32W148 is not able to receive all packages when set interval time < 1.6 ms between two packets. Through our calculation, in below and 832 μs is OK.

All frames are 20 bytes = 40 bytes + 12 symbols for PHY header = 52 symbols.

Time delta between two 20 bytes frames is 832 μs = 52 symbols.

Time delta = SFD2 - SFD1 = [4 bytes preamble, 1 byte SFD] of frame2 + [IFS] + [length + PHY payload] of frame 1 = 10 symbols + IFS + 42 symbols = 52 symbols + IFS => IFS = 0

4.3.2.3 RX sensitivity bathtub

Test method:

To avoid any interference, place the carrier board and K32W148 module in an RF shield room.

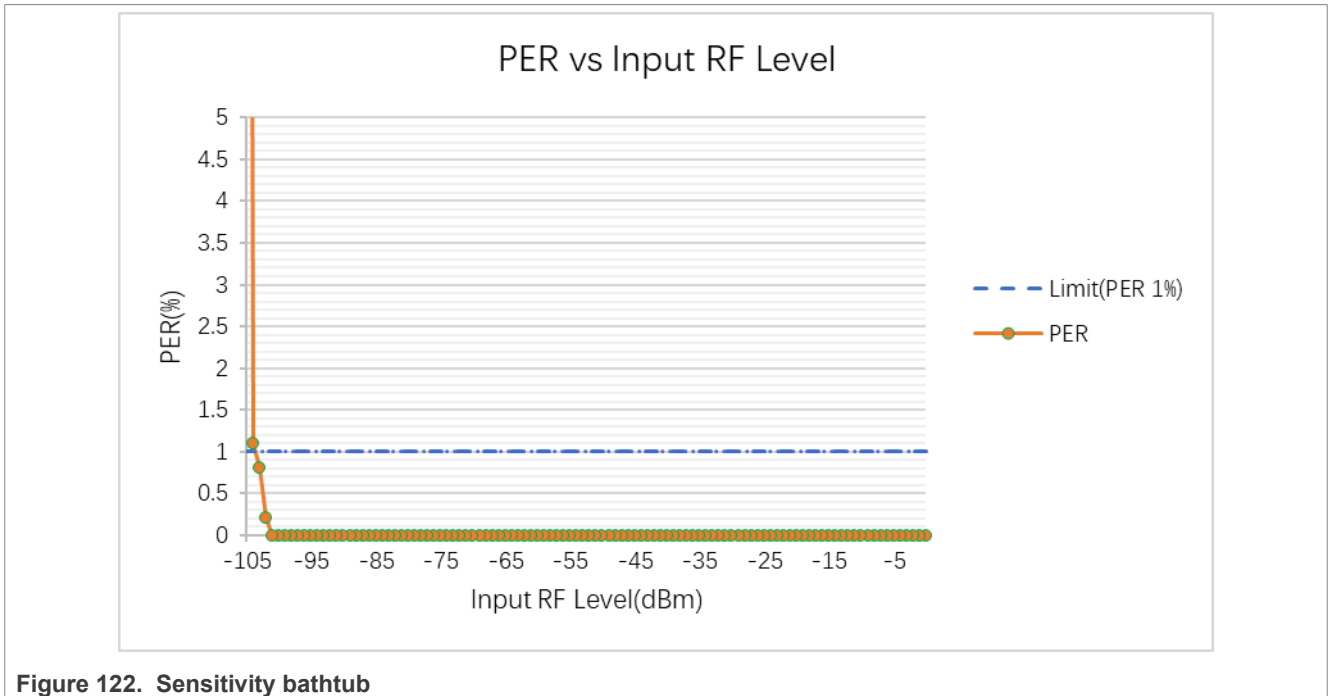
Generator: Keysight N5182B

The generator is used in ARB mode. It generates a pattern of 1000 packets of 20 octets. The DIO19 of the K32W148 is connected to the trigger input of the generator.

A TERATERM window is used to control the module.

- Set the receive frequency to Channel 11.
- Set the module in Trigger packet test.
- The connection is automatically established and the PER is measured.
- Decrease the level of the generator at the RF input of the module until PER = 1 %.

Results:



4.3.2.4 Receiver maximum input level

Test method:

Generator: Keysight N5182B

The generator is used in ARB mode. It generates a pattern of 1000 packets of 20 octets. The DIO19 of the K32W148 is connected to the trigger input of the generator.

A TERATERM window is used to control the module.

- Set the receive frequency to channel 11.
- Set the module in Trigger packet test.
- The connection is automatically established and the PER is measured.
- Decrease the level of the generator at the RF input of the module until PER = 1 %.

- Do the same for other channels.

Results:

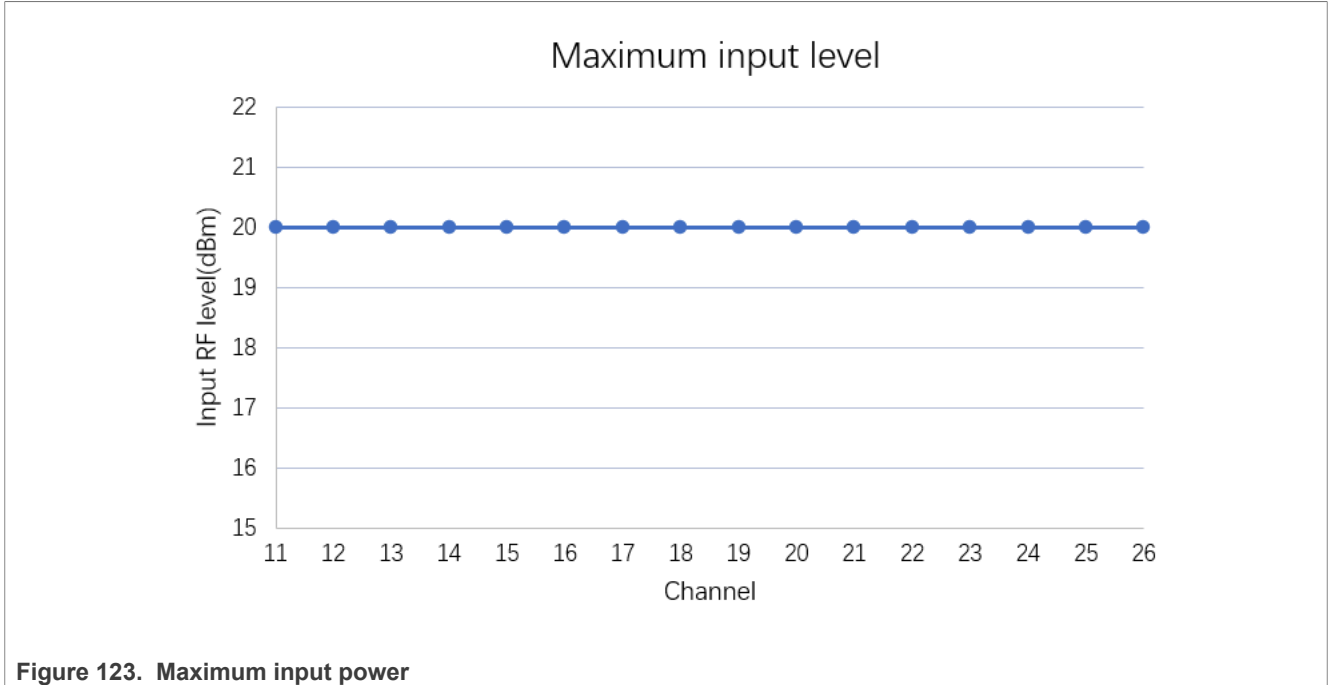


Figure 123. Maximum input power

Conclusion:

The actual maximum input level cannot be measured with the test environment. The maximum level that can be delivered to the K32W148 is limited by the maximum output power of the generator.

The maximum input level of K32W148 is higher than **20 dBm** on all channels.

4.3.2.5 RX spurious

Test method:

- Set the radio to:
 - Receiver mode
 - Frequency: Channel 18
- Set the analyzer to:
 - Ref amp = - 20 dBm
 - Trace = max hold
 - Detector = max peak
 - Start/stop frequency: 30 MHz/1 GHz
 - RBW = 100 kHz
 - Start/stop frequency: 1 GHz/12.75 GHz
 - RBW = 1 MHz

Results:

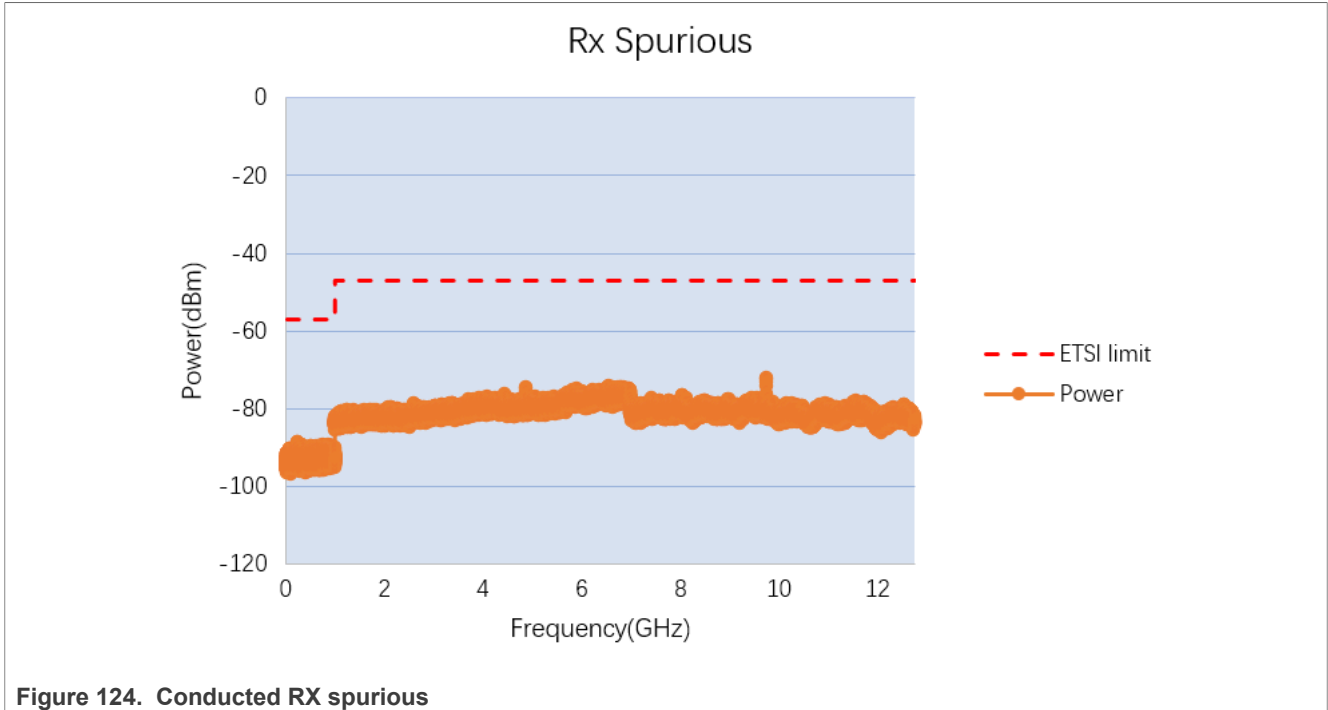


Figure 124. Conducted RX spurious

Note: No spurious has been detected.

4.3.2.6 Receiver interference rejection

4.3.2.6.1 Adjacent and alternate channels with standard interferers

Interferers are located in the adjacent channel (n-1 and n+1) or alternate channels (n-2 and n+2).

The test is performed with only one interfering signal at a time.

Test method:

Generator for desired signal: Keysight N5182B generator (modulated)

Generator for interferers: Keysight E8267D (modulated)

Criterion: PER < 1 %

The expected signal is set to - 82 dBm. The interferer is increased until the PER threshold has been reached.

Channels under test: 11, 18, and 26 (although n-1, n-2 are not system relevant for channel 11 and n+, n+2 are not system relevant for channel 26).

Results:

Table 36. Adjacent and alternate rejection

	2405				2440				2480			
	n-2	n-1	n+1	n+2	n-2	n-1	n+1	n+2	n-2	n-1	n+1	n+2
	2395	2400	2410	2415	2430	2435	2445	2450	2470	2475	2485	2490
interfere (dBm)	-35	-45	-45	-36	-36	-45	-45	-35	-36	-45	-45	-36
Interfere (dBc)	47	37	37	46	46	37	37	47	46	37	37	46

Table 36. Adjacent and alternate rejection...continued

802.15.4 limit	30	0	0	30	30	0	0	30	30	0	0	30
Margin	17	37	37	16	16	37	37	17	16	37	37	16

Conclusion:

Good margin, in line with the expected results.

4.3.2.6.2 N-3 and n+3 channels with standard interferers

Test method:

Similar as for the adjacent and alternate channels but the interferer is set at +/- 15 MHz offset from the desired channel.

Results:

Table 37. N-/±3 band rejection

	2405		2440		2480	
	n-3	n+3	n-3	n+3	n-3	n+3
	2400	2405	2425	2455	2465	2495
Interfere (dBm)	-31	-31	-31	-31	-31	-31
Interfere (dBc)	51	51	51	51	51	51

Conclusion:

In line with expected values.

4.3.2.6.3 Co-channel

Results:

Table 38. Co-channel

	2405	2440	2480
expected	-82	-82	-82
interfere (dBm)	-85	-86	-85
interfere (dBm)	-3	-4	-3

Table 39. Co-channel with worst case

	2405	2440	2480
expected (sensi + 3 dB)	-100	-100	-100
interfere (dBm)	-104	-104	-103
interfere (dBm)	-4	-4	-3

Conclusion:

In line with expected values.

4.3.2.7 Receiver blocking

The K32W148 is the equipment of category 1 as defined by the ETSI 300 328 (TX signal higher than 10 dBm).

Tests and limits are used according to category 1.

Interferer is a CW signal.

4.3.2.7.1 Test 1

Results:

	ch11	ch11	ch26	ch26
	2405	2405	2480	2480
	Low	High	Low	High
	2380	2504	2380	2504
interferer level(dBm)	3.7	5.8	5.5	3.3
interferer level(dBc)	72.9	75	74.7	72.5
802.15.4 limit(dBm)	-34	-34	-34	-34
Margin(dB)	37.7	39.8	39.5	37.3

Figure 125. Receiver blocking test 1

Conclusion:

Very good margin.

4.3.2.7.2 Test 2

Results:

	ch11	ch11	ch11	ch26	ch26	ch26
	2405	2405	2405	2480	2480	2480
	Low	Low	Low	Low	Low	Low
	2300	2330	2360	2300	2330	2360
interferer level(dBm)	0.2	-0.5	0.5	0	0	-0.2
interferer level(dBc)	79	78	77	79	77	78
802.15.4 limit(dBm)	-34	-34	-34	-34	-34	-34
Margin(dB)	34.2	33.5	34.5	34	34	33.8

Figure 126. Receiver blocking test 2

Conclusion:

Very good margin.

4.3.2.7.3 Test 3

Results:

	ch11	ch11	ch11	ch11	ch11	ch11
	2405	2405	2405	2405	2405	2405
	High	High	High	High	High	High
	2524	2554	2584	2614	2644	2674
interferer level(dBm)	0.3	0.3	0.7	1	0.8	1
interferer level(dBc)	77	77	78	78	78	78
802.15.4 limit(dBm)	-34	-34	-34	-34	-34	-34
Margin(dB)	34.3	34.3	34.7	35	34.8	35

	ch26	ch26	ch26	ch26	ch26	ch26
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
	2524	2554	2584	2614	2644	2674
interferer level(dBm)	-0.7	0	0.1	0.5	0.5	0.6
interferer level(dBc)	76	77	77	77	77	77
802.15.4 limit(dBm)	-34	-34	-34	-34	-34	-34
Margin(dB)	33.3	34	34.1	34.5	34.5	34.6

Figure 127. Receiver blocking test 3

Conclusion:

Very good margin.

5 Return loss

5.1 RF path with matching components using VDD_PA_2G4 pin.

Measurements are done using the SMA connector. Therefore, the C4 capacitor is mounted and the C3 capacitor is not mounted.

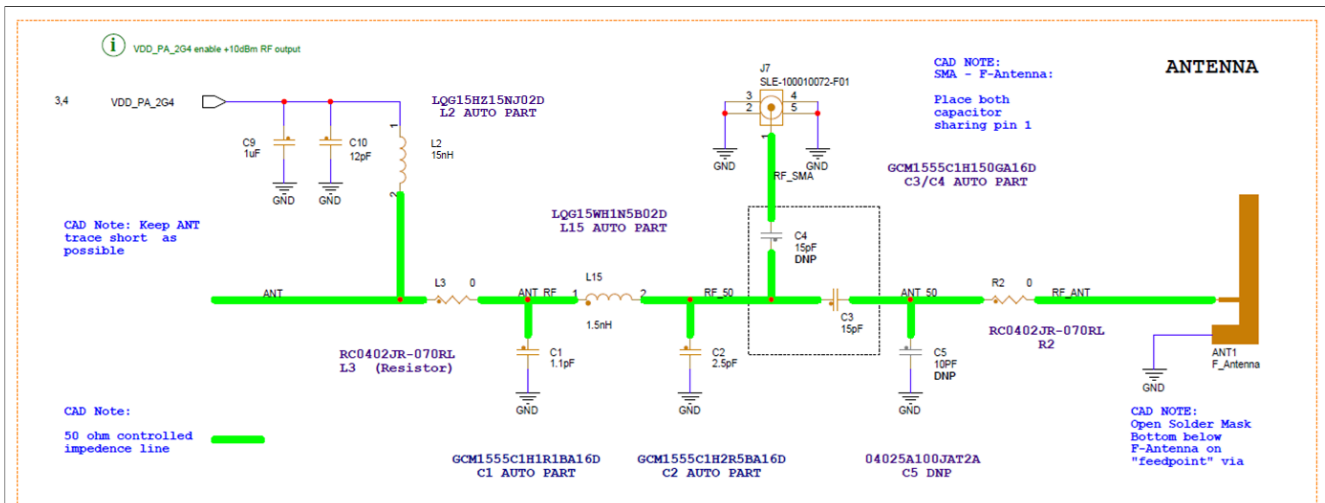


Figure 128. RF matching

Matching components are:

- Inductors

Reference	Value	Description	Mfr. name	Mfr. part number
L2	15 nH	IND -- 0.015 μ H @ 100 MHz 450 mA +/-5% 0402	MURATA	LQG15HZ15NJ02D
L3	0 ohm	Resistor shunt	—	—
L15	1.5 nH	IND -- 0.0015 μ H @ 100 MHz 1000 mA +/-0.1 nH 0402	MURATA	LQG15WH1N5B02

- Capacitors

Reference	Value	Description	Mfr. name	Mfr. part number
C2	2.5 pF	CAP CER 2.5 pF 50 V 0.1 pF C0G 0402	MURATA	GCM1555C1 H2R5BA16
C1	1.1 pF	CAP CER 1.1 pF 50 V 0.1 pF C0G 0402	MURATA	GCM1555C1 H1R1BA16
C10	12 pF	CAP CER 12 pF 50 V 5 % C0G AEC-Q200 0402	MURATA	GCM1555C1 H120JA16D
C9	1 μ F	CAP CER 1 μ F 10 V 10 % X7S AEC-Q200 0402	MURATA	GCM155C71 A105KE38D

Note: C3 value populated on the X-K32W1-EVK is 15 pF. To improve the IFA antenna matching, the preferred value is 1.5 pF.

5.2 RX

In the RC mode, the return loss measurement is performed by setting the LNA gain of K32W148 to the maximum.

Hardware: X-K32W148-EVK

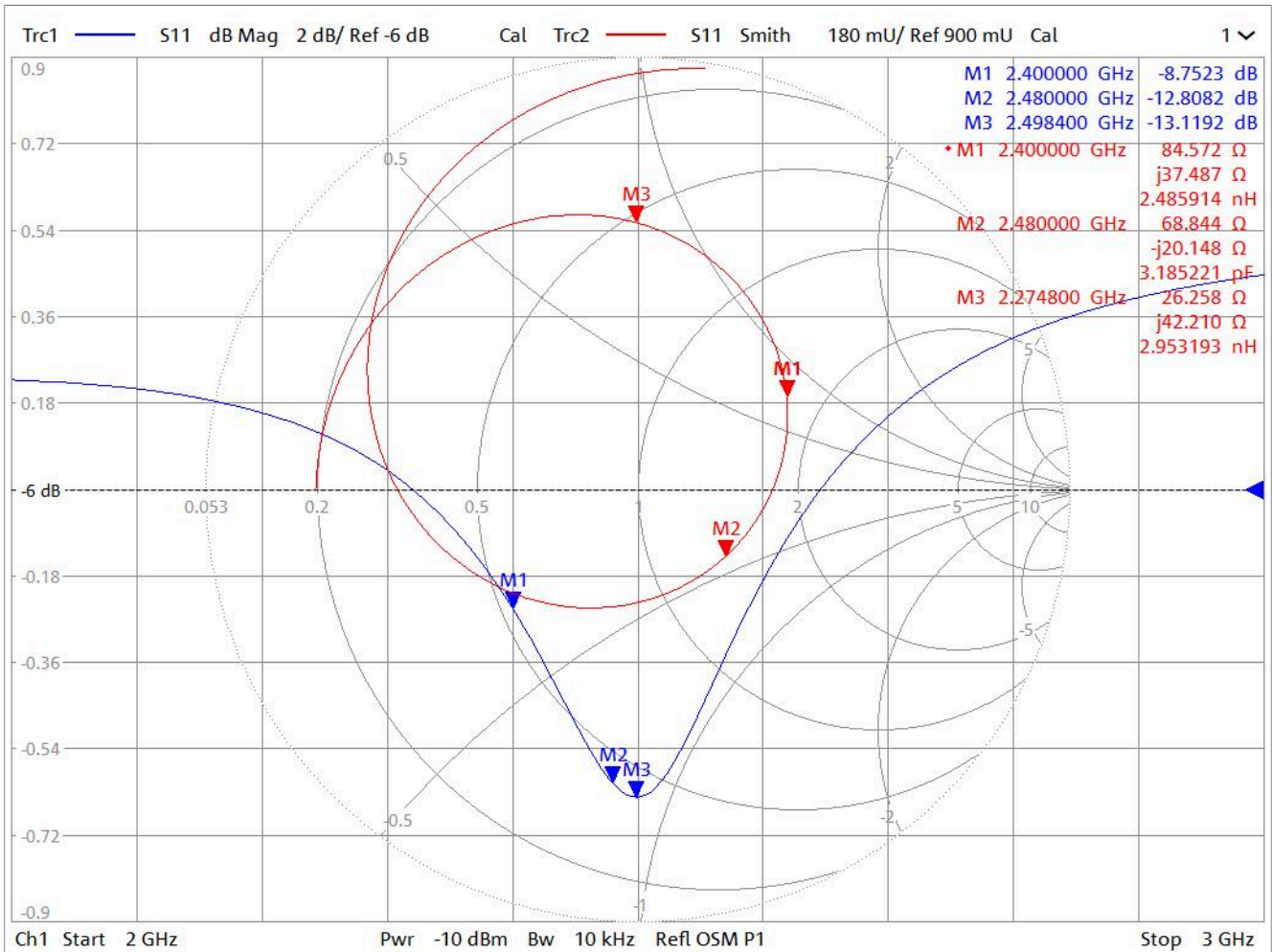


Figure 129. S11 diagram (RX mode)

Results:

- Return loss: -12.8 dB (2.48 GHz) < S11 < -8.7 dB (2.4 GHz)

There is no specification for the return loss.

Conclusion:

- The return loss (S11) is lower than -8 dB.

5.3 TX

In the TX mode, the return loss measurement is performed by setting the K32W148 RF output power to the minimum.

Hardware: K32W148 EVK

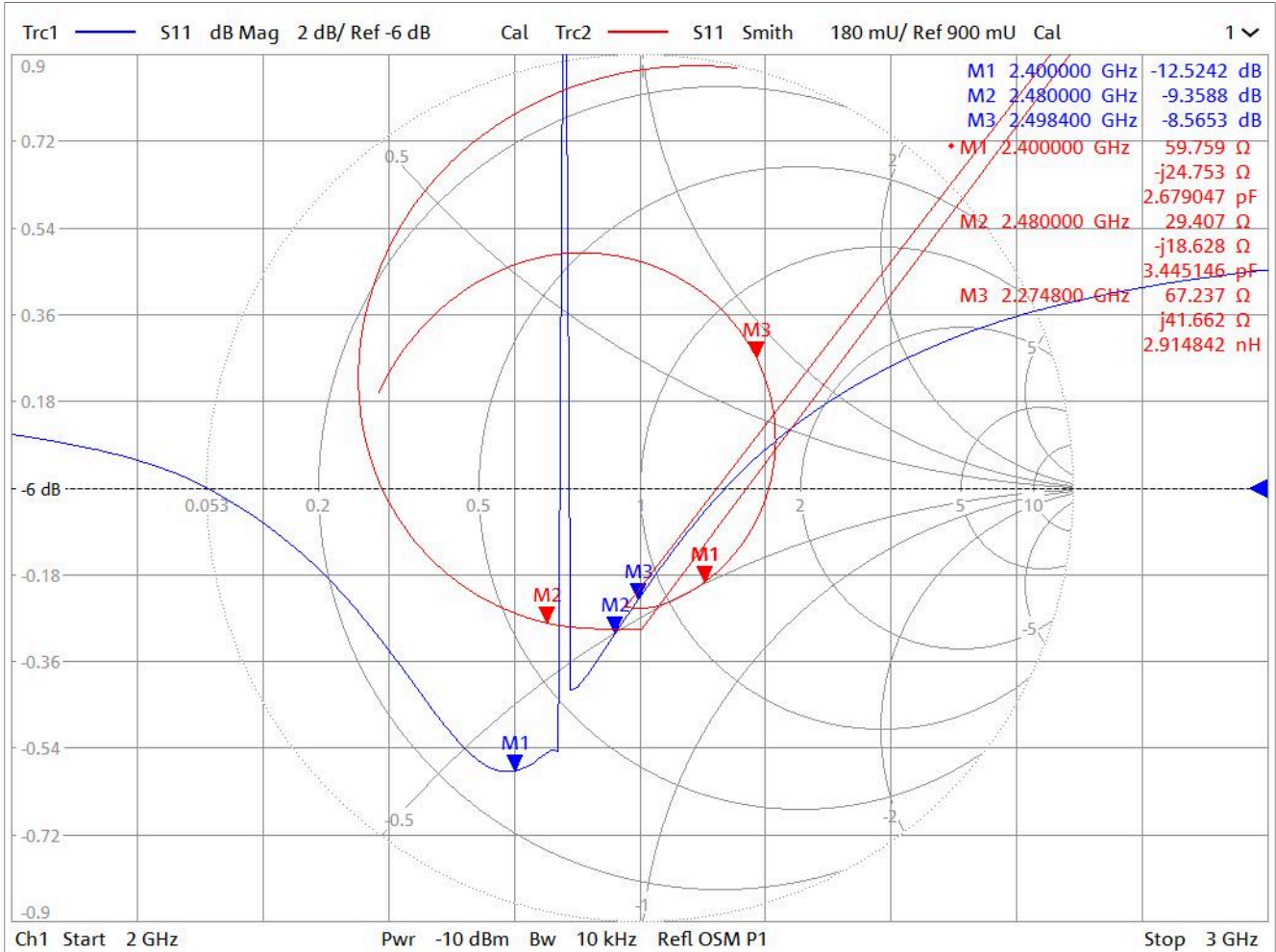


Figure 130. S11 diagram (TX mode)

Results:

- Return loss: -12.5 dBm (2.4 GHz) < S11 < -9.3 dB (2.48 GHz)

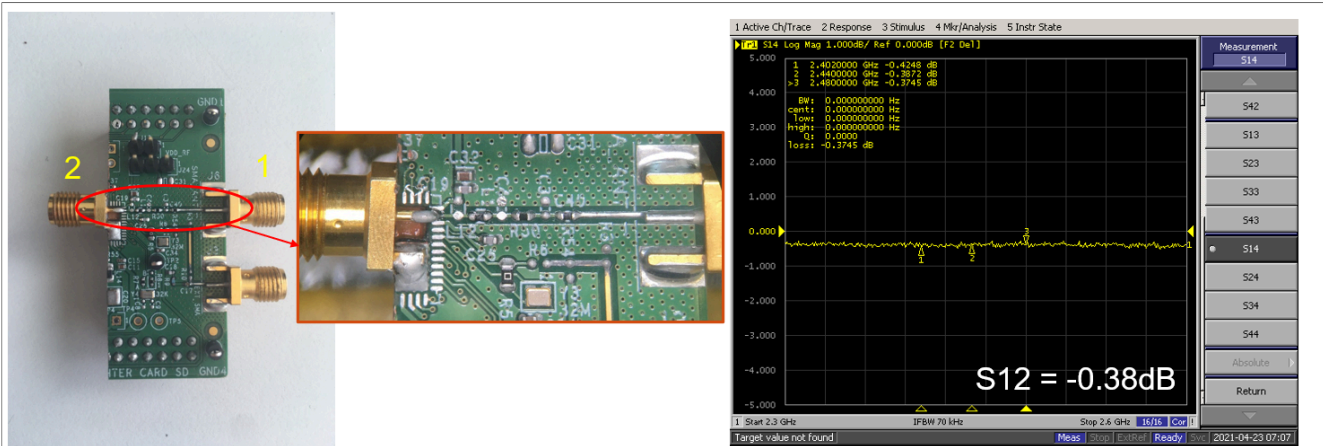
There is no specification for the return loss.

Conclusion:

- The return loss (S11) is lower than -9 dB.

5.4 RF line insertion loss

To extract RF line insertion loss, we have cut the board and solder SMA on Pin ANT_2P4GHZ to isolate the RF line. Remove default component matching and replace by 0 Ω resistor.



This measure **does not represent only RF line insertion losses** but:
 Global losses = insertion losses + Mismatch losses



Figure 131. RF line insertion loss

$$Insertion\ losses = \frac{1}{1 - |S_{11}|^2} \times |S_{12}|^2 \tag{1}$$

Thanks to [Equation 1](#), we can quantify insertion losses and mismatch losses.

$$Mismatch\ losses = -10 \times \log(1 - |\Gamma|^2)$$

$$\Gamma = 10^{-15.3/20} = 0.171791$$

$$Mismatch\ losses = -10 \log(1 - 0.171791^2) = -0.13\text{ dB}$$

$$Insertion\ losses = Global\ losses - Mismatch\ losses$$

$$Insertion\ losses = -0.38 - (-0.13)$$

$$Insertion\ losses = -0.25\text{ dB}$$

In addition to insertion line losses, we should add SMD insertion losses estimate at 0.1 dB.

6 Conclusion

Beyond the RED, FCC, Bluetooth LE 5.0, and 802.15.4 compliance, these radio tests prove a good performance of the K32W1 wireless MCUs.

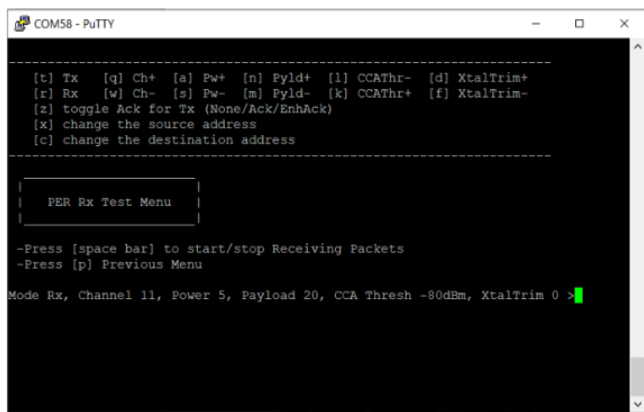
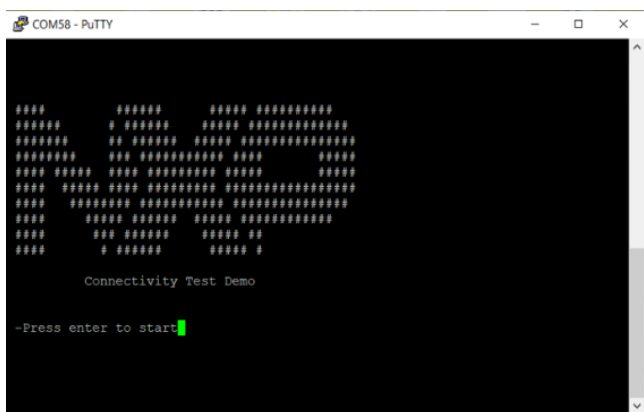
7 Connectivity test tool settings

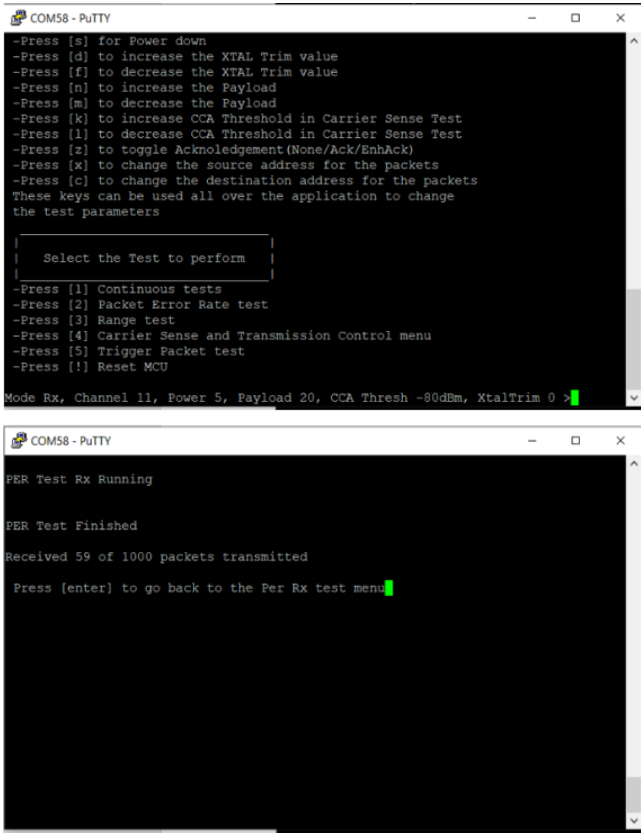
This application note presents the connectivity test tools settings for the tests.

- For test in transmit modes:

Chapter	CMET selection
Section 3.3.1.2	1) 4)
Section 4.3.1.3	1) 4)
Section 3.3.1.4	1) 3) 2)+/-
Section 3.3.1.6	1) 3) 2)
Section 4.3.1.7	1) 3) 2)
Section 4.3.1.7.1	1) 3) 2)
Section 4.3.1.7.2	1) 4)
Section 3.3.1.8	1) 3) ch26
Tx return loss	1) 3) 2)

- For PER test:





Chapter	CMET selection
Section 4.3.2.2	5) bar)+/-
Section 4.3.2.3	5) bar)
Section 4.3.2.4	5) bar)+/-
Section 4.3.2.5	5) bar)
Section 4.3.2.6	5) bar)+/-
Section 4.3.2.7	5) bar)+/-
Section 5.2	

A signal generator sends packets to the K32W148 device.

Then, packets received by K32W148 are counted about 6 seconds and the test is done.

Packets received out to **sent packets** is calculated and displayed.

8 References

- FCC: 47 CFR Part 15C
- RED: European Radio Equipment Directive applied from June 2016
- R&TTE: Radio and Telecommunications Terminal Equipment Directive (R&TTED) (1999/5/EC) was stopped on June 2016

- ETSI EN 300 328 v2.2.2: 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 and using spread spectrum modulation techniques
- IEEE 802.15.4: IEEE standard for Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements – Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personnel Area Networks (LR-WPANs)
- ETS 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 and 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.
 - The device may not cause harmful interference.
 - The device must accept any interference received, including interference that may cause undesired operation.
 Hence, there is no guaranteed quality of service when operating a Part 15 device.

9 Revision history

Rev.	Date	Description
0	5 September 2022	Initial release
1	27 March 2023	Removed the KW45-related description

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