AN12517

FRDM-KW38 RF System Evaluation Report for Bluetooth LE Applications

Rev. 1 — 21 December 2021 Application Note

Contents

1 Overview

This document provides the RF evaluation test results of the FRDM-KW38 for Bluetooth LE applications (2FSK modulation). It includes the test setup description and the tools used to perform the tests on your own. To get the KW38 radio parameters, see the *KW39A/38A/37A/38Z/37Z Data Sheet* (document MKW38A512).

For more information about the FRDM-KW38 Freedom Development Board, see the *FRDM-KW38 Freedom Development Board User's Guide* (document FRDMKW38ZUG). Find the schematic and design files at this link.

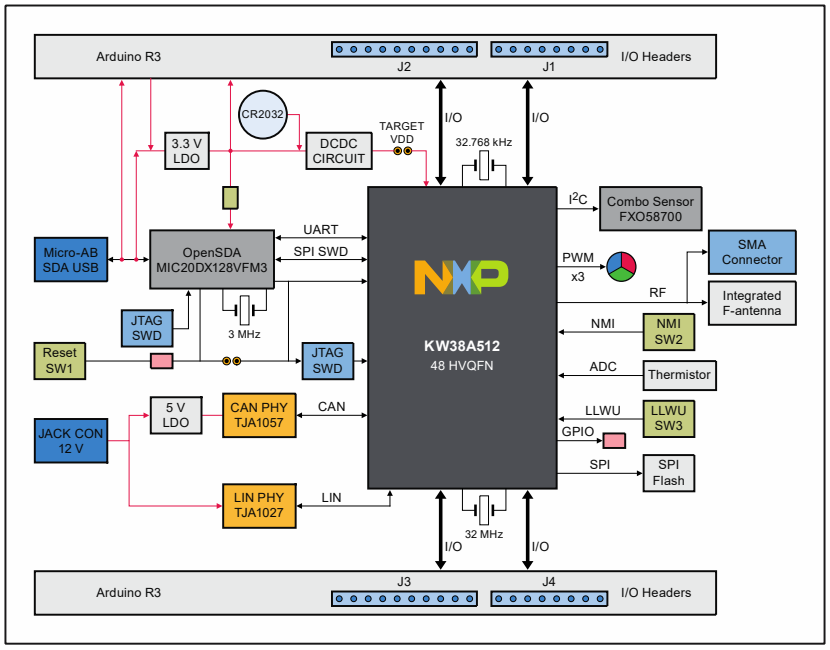


Figure 1. FRDM-KW38 block diagram

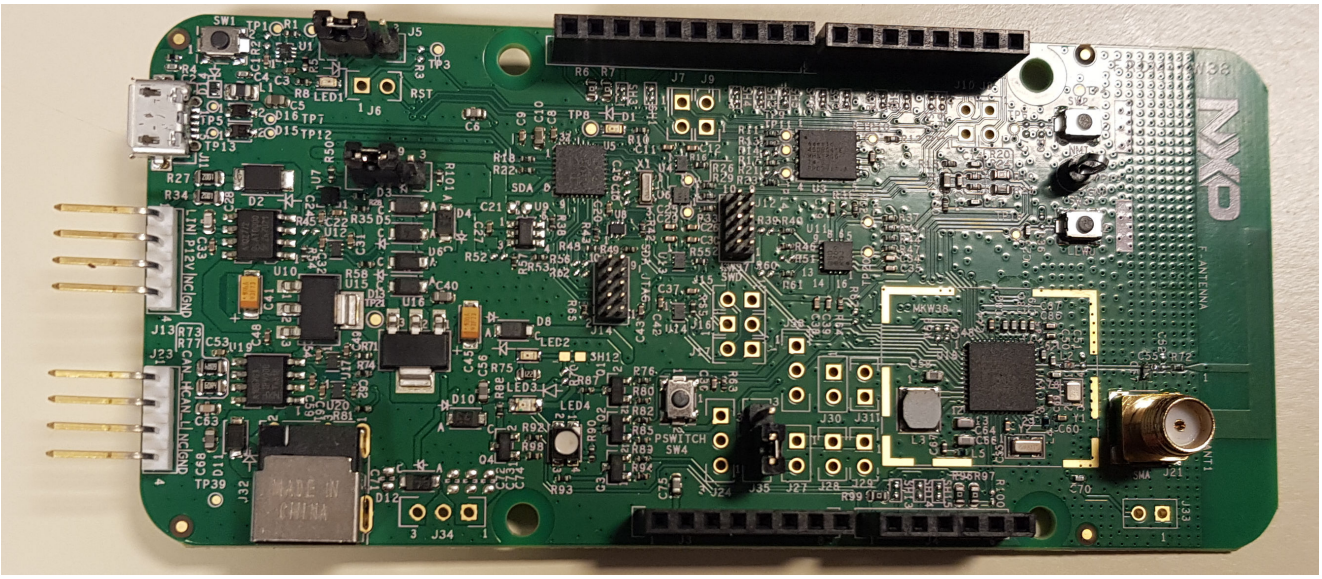


Figure 2. Freedom development kit for Kinetis/FRDM-KW38

1.1 List of tests

Conducted tests include:

- 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)
  - 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 & S=8)
  - Bathtub 1 Msps
  - Receiver maximum input level 1 Msps & 2 Msps
  - 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 – cat.1 & cat.2
- Blocking interferers

— Intermodulation

- Return loss (S11)
  - — Rx
  - — Tx

1.2 Software

Before the measurements, a binary code (connectivity software) must be loaded into the board's flash memory.

The FRDM-KW38: NXP® Freedom Development Kit for Kinetis KW39A/38A/37A/38Z/37Z MCUs web page describes how to use FRDM-KW38 to load the code. The binary code that is used for the following tests are the Connectivity Software package GenFSK protocol (2FSK modulation) and the `HCI_blackbox`. The TERATERM terminal emulator is used to communicate with the KW38 MCU.

1.3 List of equipment

The following equipment are used to perform the Rx and Tx measurements:

- Spectrum Analyzer - 25 GHz for harmonic measurements up to H10
- R&S SFU - used as an interferer source for 802.15.4 – could be any generator with ARB
- MXG (Agilent N5182A)
- R&S CMW270 (HCI_blackbox software)
- Agilent SML03
- Agilent 33250A
- R&S ZND Vector Network Analyzer – for S11 measurements
- RF Shielded box (to avoid interferers) and RF horn (for radiated measurements)
- Power supply
- PC equipped with a GPIB card

NOTE

The FRDM-KW38 LI19350010 is used to perform all RF test measurements.

2 Test summary

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

Table 1 describes the list of measurements for Europe and Table 2 for US.

Table 1. List of tests (Europe)

		EUROPE		
		Reference	Limit	Status
Transmission	TX Maximum Output Power	BLE 5.0, BV-01-C	-20 dBm ≤ PAVG ≤ +10 dBm EIRP	PASS

Table continues on the next page...

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

		EUROPE		
		Reference	Limit	Status
	Tx power In Band – 1 Msps	BLE 5.0, BV-03-C	PTX <= -20 dBm for (f_{TX} +/- 2 MHz)	PASS
			PTX <= -30 dBm for (f_{TX} +/- [3 + n] MHz]);	
	Tx power In Band – 2 Msps	BLE 5.0, BV-08-C	P TX <= -20 dBm for (f_{TX} +/- 4 MHz) & (f_{TX} +/- 5 MHz)	PASS
			P TX <= -30 dBm for (f_{TX} +/- [3 + n] MHz]);	
	Modulation characteristics 1 Msps LE coded (S=8)	BLE 5.0, BV-05-C BLE 5.0, BV-13-C	225 kHz <= delta f1 avg <= 275 kHz	PASS
	Modulation characteristics 2 Msps	BLE 5.0, BV-10-C	450 kHz <= delta f1 avg <= 550 kHz	PASS
	Carrier frequency offset and drift	BLE 5.0, BV-06-C	f_{TX} – 150 kHz <= f_n <= f_{TX} + 150 kHz where f_{TX} is the nominal transmit frequency and n=0,1,2,3…k	PASS
	1 Msps		|f0 – fn| <= 50 kHz where n=2,3,4…k	
	2 Msps	BLE 5.0, BV-12-C	|f0 – f3| <= 19.2 kHz |f0 – f(n-3)| <= 19.2 kHz where n=7,8,9,…k	
	Carrier frequency offset and drift LE coded (S=8)	Bluetooth LE 5.0, BV-14-C	f_{TX} – 150 kHz <= f_n <= f_{TX} + 150 kHz where f_{TX} is the nominal transmit frequency and n=0,1,2,3…k	PASS
			|f0 – fn| <= 50 kHz where n=2,3,4…k	
	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 v2.2.1 (2016-11)	ETSI EN 300 328	-30 dBm (1 MHz BW)	PASS
	Eirp Tx spectral density	ETSI EN 300 328 v2.2.1 (2019-04)	10 dBm/MHz	PASS

Table continues on the next page...

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

		EUROPE		
		Reference	Limit	Status
	Phase noise (unspread)	—	—	For information
Reception	RX Sensitivity - 1 Msps	BLE 5.0, BV-01-C	PER 30.8% with a minimum of 1500 packets	PASS
	RX Sensitivity - 2 Msps	BLE 5.0, BV-08-C	PER 30.8% with a minimum of 1500 packets	PASS
	RX Sensitivity - LE coded (S=2)	BLE 5.0, BV-26-C	PER 30.8% with a minimum of 1500 packets	PASS
	RX Sensitivity - LE coded (S=8)	BLE 5.0, BV-27-C	PER 30.8% with a minimum of 1500 packets	PASS
	Co-channel - 1 Msps	BLE 5.0, BV-03-C	> 21 dB	PASS
	Adjacent channel interference rejection (N+/-1,2,3+MHz) 1 Msps	BLE 5.0, BV-03-C	> 15 dB, -17 dB, -27 dB	PASS
	Co-channel - 2 Msps	BLE 5.0, BV-09-C	> 21 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+MHz) - 2 Msps	BLE 5.0, BV-09-C	> 15 dB, -17 dB, -27 dB	PASS
	Co-channel - LE coded (S=2)	BLE 5.0, BV-28-C	> 17 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+MHz) LE coded (S=2)	BLE 5.0, BV-09-C	> 11 dB, -21dB, -31 dB	PASS
	Co-channel - LE coded (S=8)	BLE 5.0, BV-28-C	> 12 dB	PASS
	Adjacent channel interference rejection (N+/-2,4,6+MHz) LE coded (S=8)	BLE 5.0, BV-09-C	> 6 dB, -26 dB, -36 dB	PASS
	Blocking Interferers			
	1 Msps	BLE 5.0, BV-04-C	-30 dBm (30 MHz-2 Ghz & 3-12.5 GHz)	PASS
	2 Msps	BLE 5.0, BV-010-C	-35 dBm (2003-2399 MHz & 2484-2997 MHz)	
	Intermodulation			
	1 Msps	BLE 5.0, BV-05-C	PER 30.8% with a minimum of 1500 packets	PASS
	2 Msps	BLE 5.0, BV-11-C		
	Rx Maximum input level			

Table continues on the next page...

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

		EUROPE		
		Reference	Limit	Status
	1 Msps	BLE 5.0, BV-06-C	PER 30.8% with a minimum of 1500 packets	PASS
	2Msps	BLE 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
	RX emissions 1GHz - 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 Rx mode	For information	

Table 2. List of tests (US)

		US		
		Reference	Limit	Status
Transmission	TX Maximum Pow	FCC part15.247	PAVG ≤ 100 mW +20 dBm EIRP	PASS
	Spurious 1 - 12.5 GHz	FCC part15.249	field strength < 50 mV/m @3m <-41.12 dBm (1 MHz BW)	PASS

3 Conducted tests

3.1 Tx tests

3.1.1 Test setup

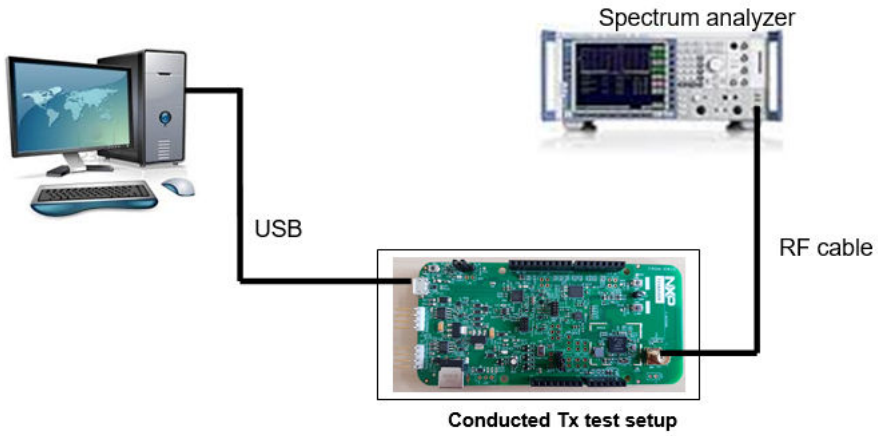


Figure 3. Conducted Tx test setup

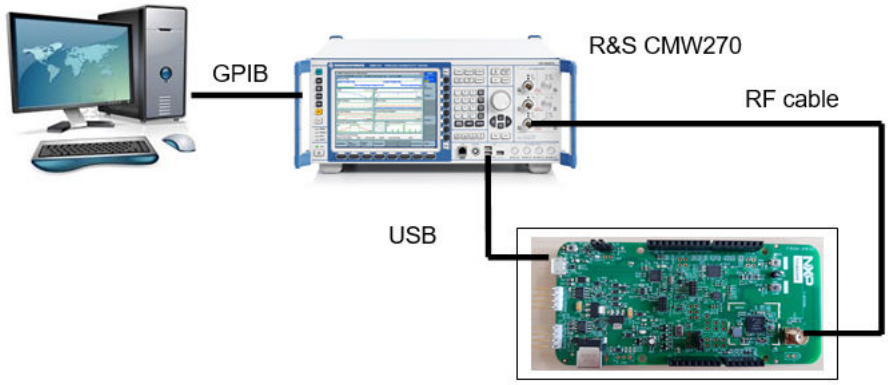


Figure 4. Specific conducted Tx test setup

3.1.2 Frequency accuracy

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Set the radio to:
    - Tx mode (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps or 125 Ksps), TX mode, CW, continuous mode, frequency: channel 19 , maximum RF output power (Hi 32)
  - 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.
- **Results**:

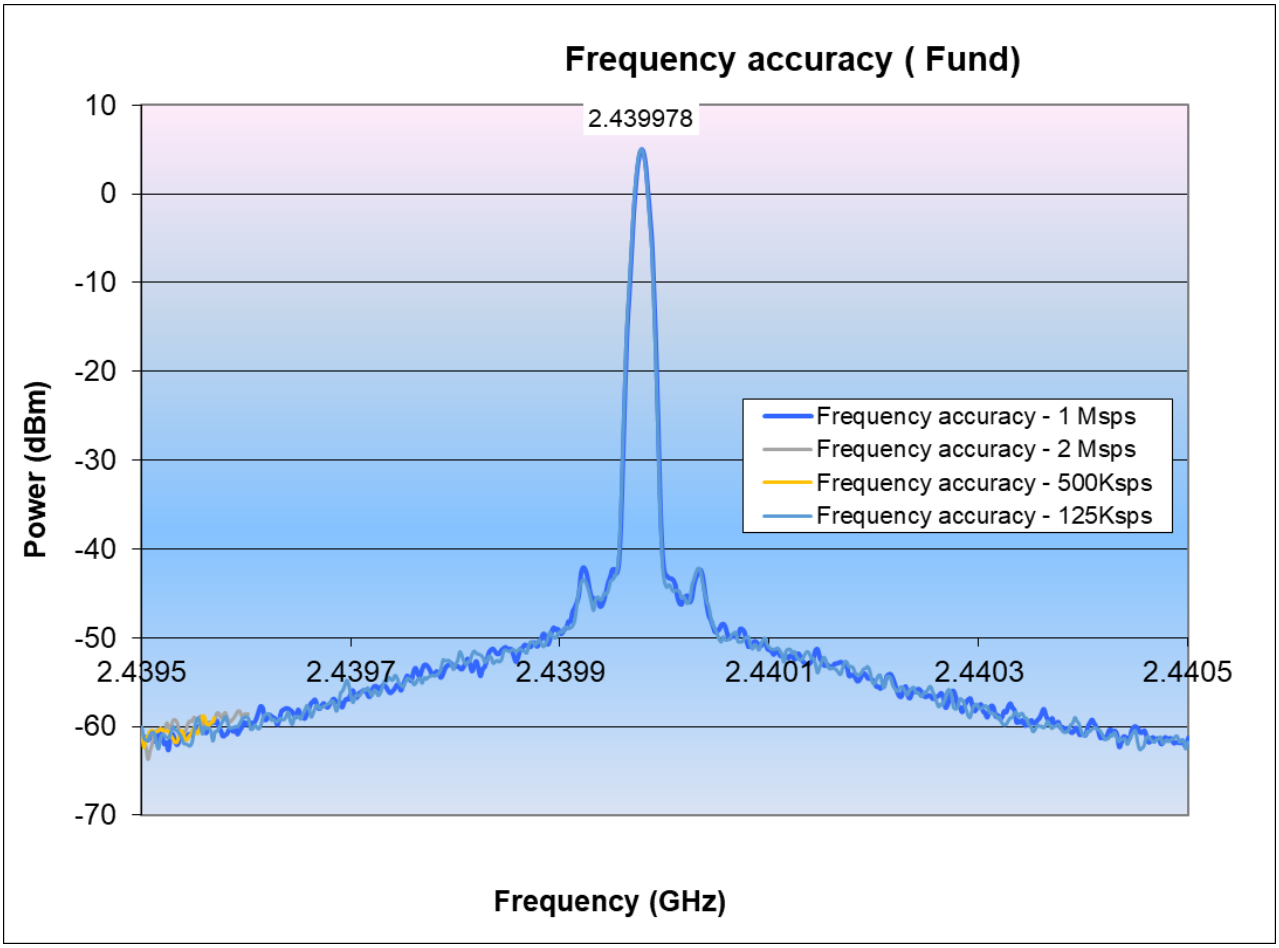


Figure 5. Frequency accuracy

- Measured frequency: 2.4 39976 GHz
- ppm value = (2439978 - 2440000) / 2.440 = -9.0 ppm

Table 3. Frequency accuracy

Result	Target
-9.0 ppm	+/-25 ppm

NOTE

The frequency accuracy depends on the XTAL model. The model used on FRDM-KW38 is NX2016SA EXS00A-CS11775 (NDK).

- **Conclusion**:
  - The frequency accuracy complies to the datasheet.

3.1.3 Phase noise

- **Flashed SW**:
  - Connectivity test
- **Test method**:

- Set the radio to:
  - TX mode (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps or 125 Ksps) , CW, continuous mode, frequency: channel 19 , maximum RF output power (Hi 32)
- Set the analyzer to:
  - Center frequency = 2.44 GHz, span = 1 MHz, Ref amp = 20 dBm, RBW = 10 KHz, VBW = 100 KHz

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

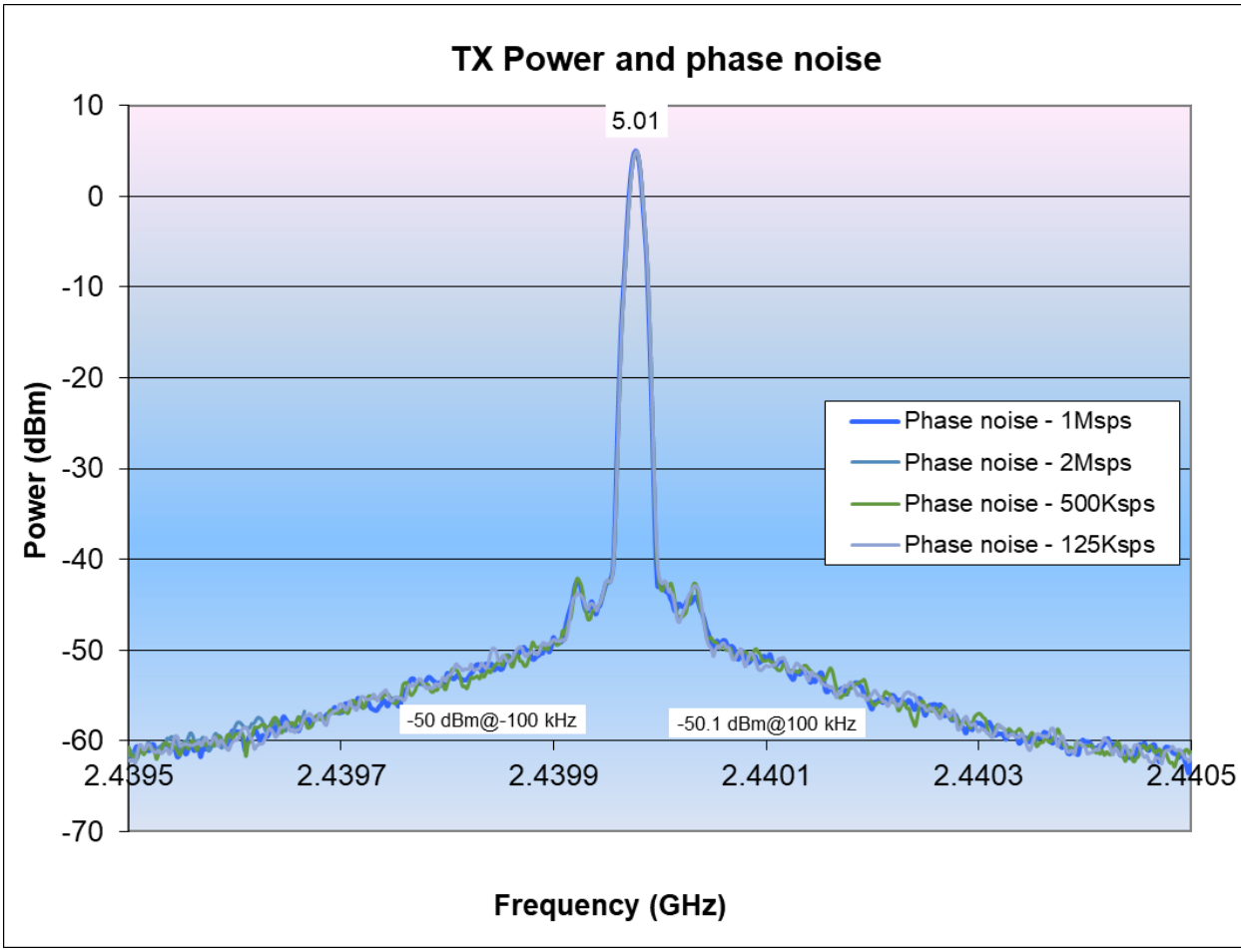


Figure 6. Conducted phase noise

- Marker value (delta) = -50 dBm / 100 kHz = -9 0.0 dBc/Hz

NOTE

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

3.1.4 Tx power

3.1.4.1 Tx power (fundamental)

- **Flashed SW**:

— Connectivity test

- **Test method**:
  - Set the radio to:
    - TX mode (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps or 125 Ksps) , modulated, continuous mode, maximum RF output power (Hi 32)
  - 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
    - Software tool allows sweep from 2.36 GHz to 4.88 GHz.

NOTE

For Tx output over +3.5 dBm powered `Vdd_RFx` has to be higher than 1.44 V.

- **Results**:

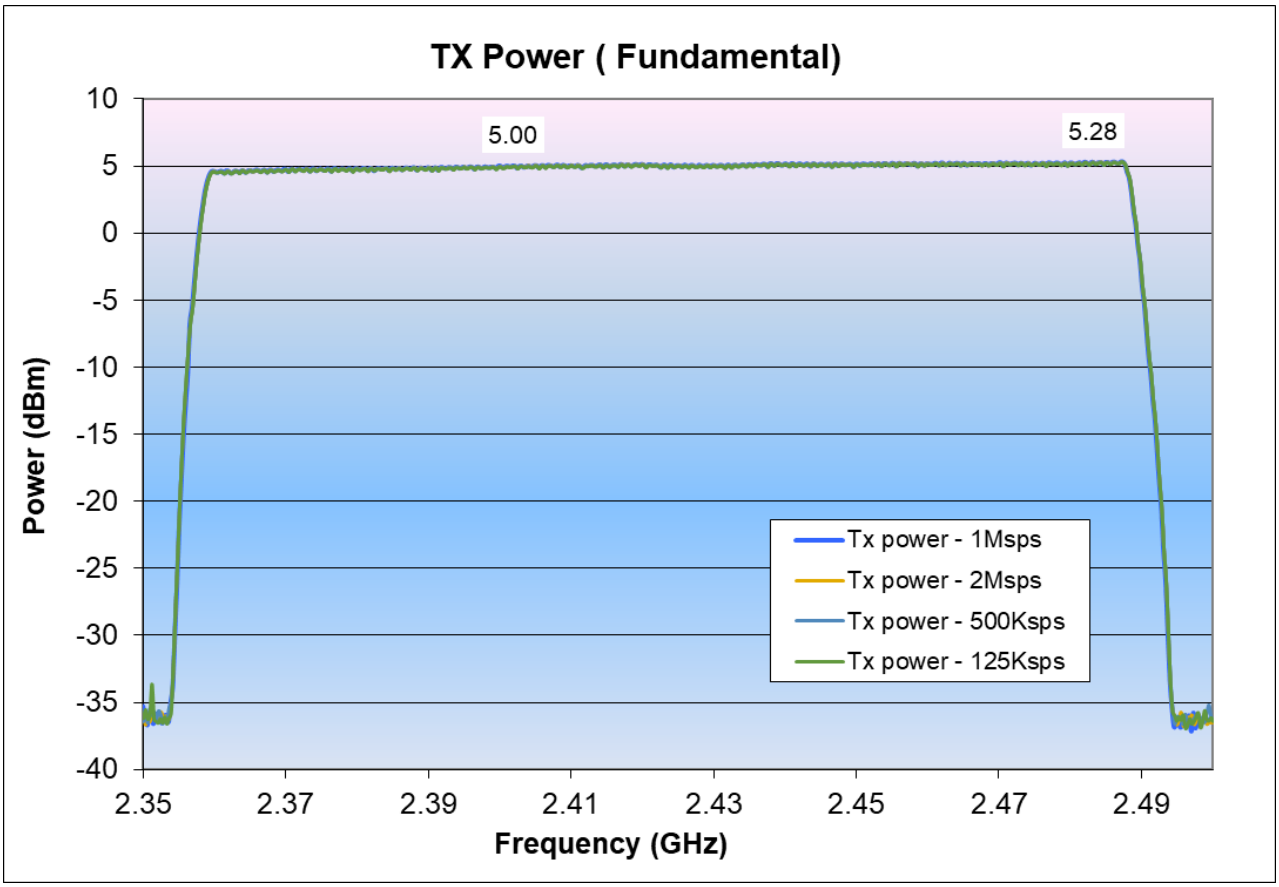


Figure 7. TX power

— Maximum power is on channel 39: 5.28 dBm

— Minimum power is on channel 0: 5.0 dBm

- Tilt over frequencies is 0. 28 dB

- **Conclusion**:
  - The default TX power is in line with the expected results (+5 dBm).
  - The power is flat over frequencies.

3.1.4.2 Tx power In Band

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Set the radio to:
    - TX mode (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps or 125Ksps) , modulated, continuous mode, maximum RF output power (Hi 32)
  - 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
- **Results**:

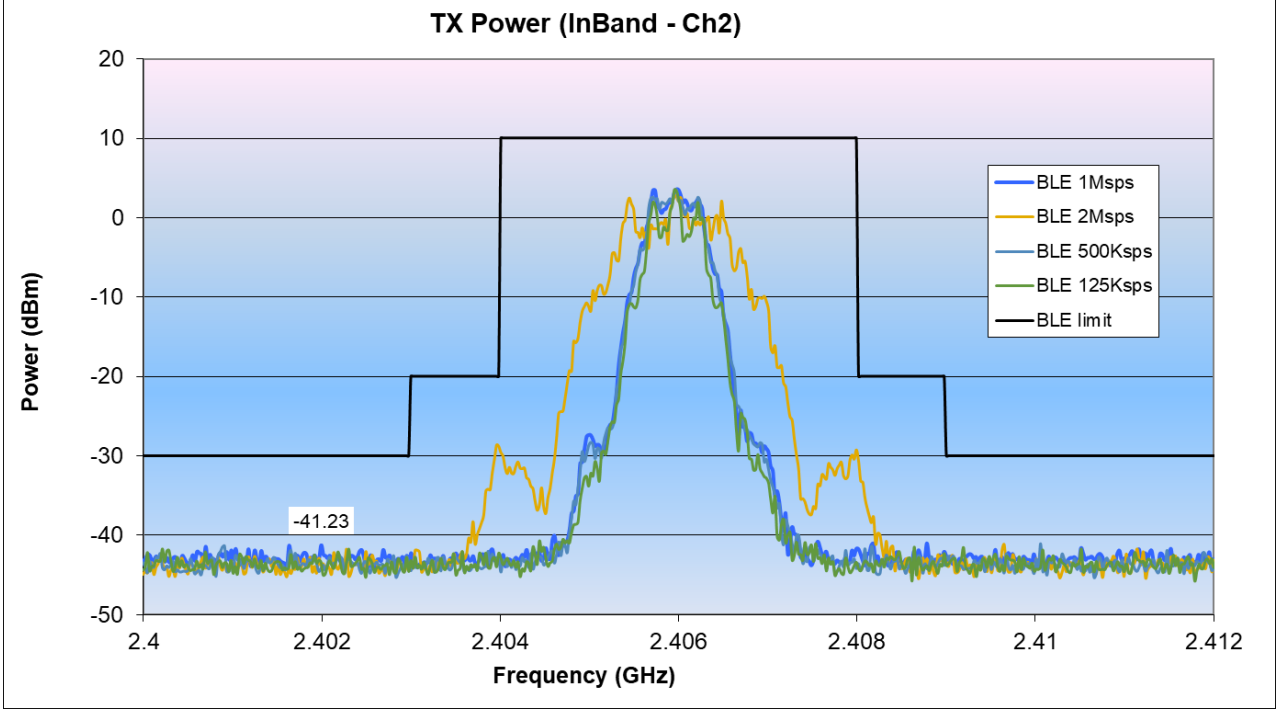


Figure 8. TX power In Band – Channel 2

Table 4. Bluetooth LE 1 Msps

Max peak level <=-2 MHz	-41.76	dBm	@	2.404	GHz
Max peak level >=+2 MHz	-41.00	dBm	@	2.409	GHz
Max peak level <=-3 MHz	-41.23	dBm	@	2.402	GHz
Max peak level >=+3 MHz	-41.62	dBm	@	2.411	GHz

Table 5. Bluetooth LE 2 Msps

Max peak level <=-2 MHz	-28.67	dBm	@	2.404	GHz
Max peak level >=+2 MHz	-30.67	dBm	@	2.408	GHz
Max peak level <=-3 MHz	-41.78	dBm	@	2.402	GHz
Max peak level >=+3 MHz	-41.20	dBm	@	2.410	GHz

Table 6. Bluetooth LE 500 Ksps

Max peak level <=-2 MHz	-42.07	dBm	@	2.404	GHz
Max peak level >=+2 MHz	-41.48	dBm	@	2.408	GHz
Max peak level <=-3 MHz	-41.39	dBm	@	2.401	GHz
Max peak level >=+3 MHz	-41.11	dBm	@	2.410	GHz

Table 7. Bluetooth LE 125 Ksps

Max peak level <=-2 MHz	-42.00	dBm	@	2.404	GHz
Max peak level >=+2 MHz	-41.43	dBm	@	2.409	GHz
Max peak level <=-3 MHz	-41.67	dBm	@	2.400	GHz
Max peak level >=+3 MHz	-41.50	dBm	@	2.409	GHz

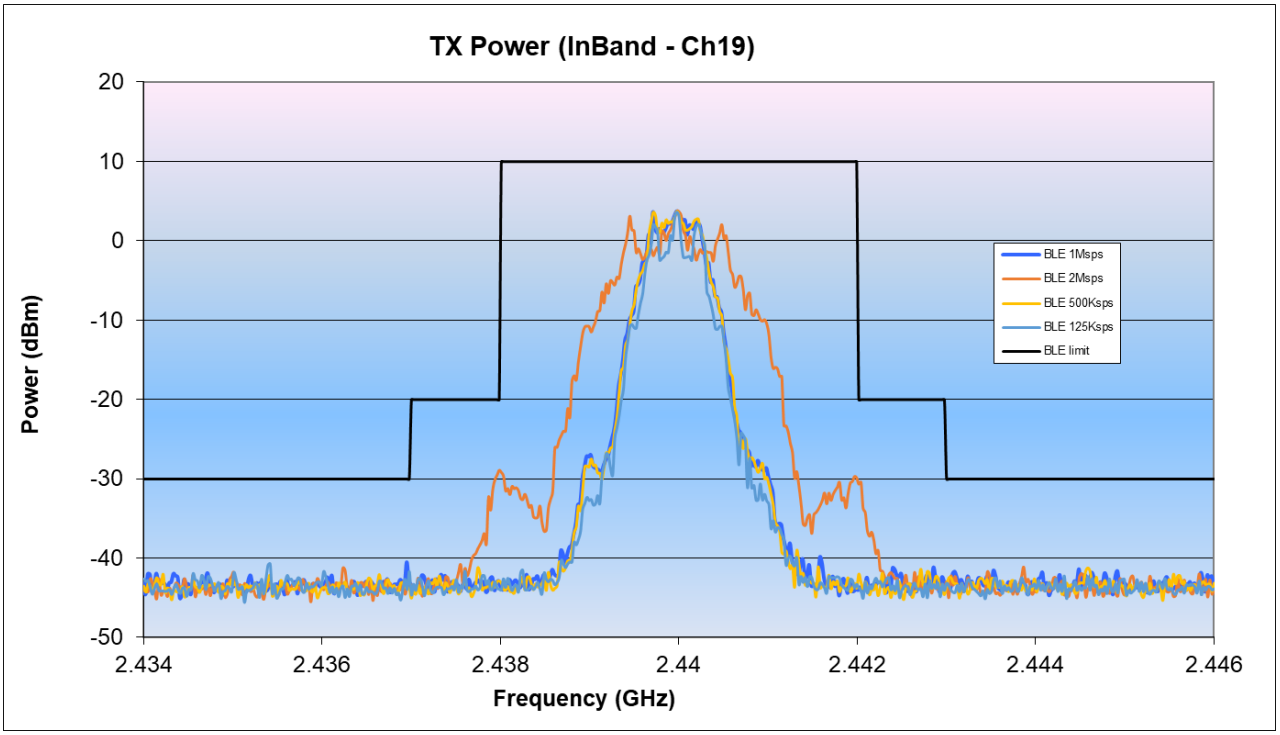


Figure 9. TX power In Band – Channel 19

Table 8. Bluetooth LE 1 Msps

Max peak level <=-2 MHz	-42.05	dBm	@	2.437	GHz
Max peak level >=+2 MHz	-41.16	dBm	@	2.443	GHz
Max peak level <=-3 MHz	-40.48	dBm	@	2.437	GHz
Max peak level >=+3 MHz	-41.36	dBm	@	2.444	GHz

Table 9. Bluetooth LE 2 Msps

Max peak level <=-2 MHz	-28.90	dBm	@	2.438	GHz
Max peak level >=+2 MHz	-30.41	dBm	@	2.442	GHz
Max peak level <=-3 MHz	-41.20	dBm	@	2.436	GHz
Max peak level >=+3 MHz	-41.08	dBm	@	2.444	GHz

Table 10. Bluetooth LE 500 Ksps

Max peak level <=-2 MHz	-41.24	dBm	@	2.438	GHz
Max peak level >=+2 MHz	-41.41	dBm	@	2.443	GHz
Max peak level <=-3 MHz	-42.05	dBm	@	2.434	GHz
Max peak level >=+3 MHz	-41.24	dBm	@	2.445	GHz

Table 11. Bluetooth LE 125 Ksps

Max peak level <=-2 MHz	-41.67	dBm	@	2.438	GHz
Max peak level >=+2 MHz	-42.53	dBm	@	2.442	GHz
Max peak level <=-3 MHz	-40.76	dBm	@	2.435	GHz
Max peak level >=+3 MHz	-42.29	dBm	@	2.444	GHz

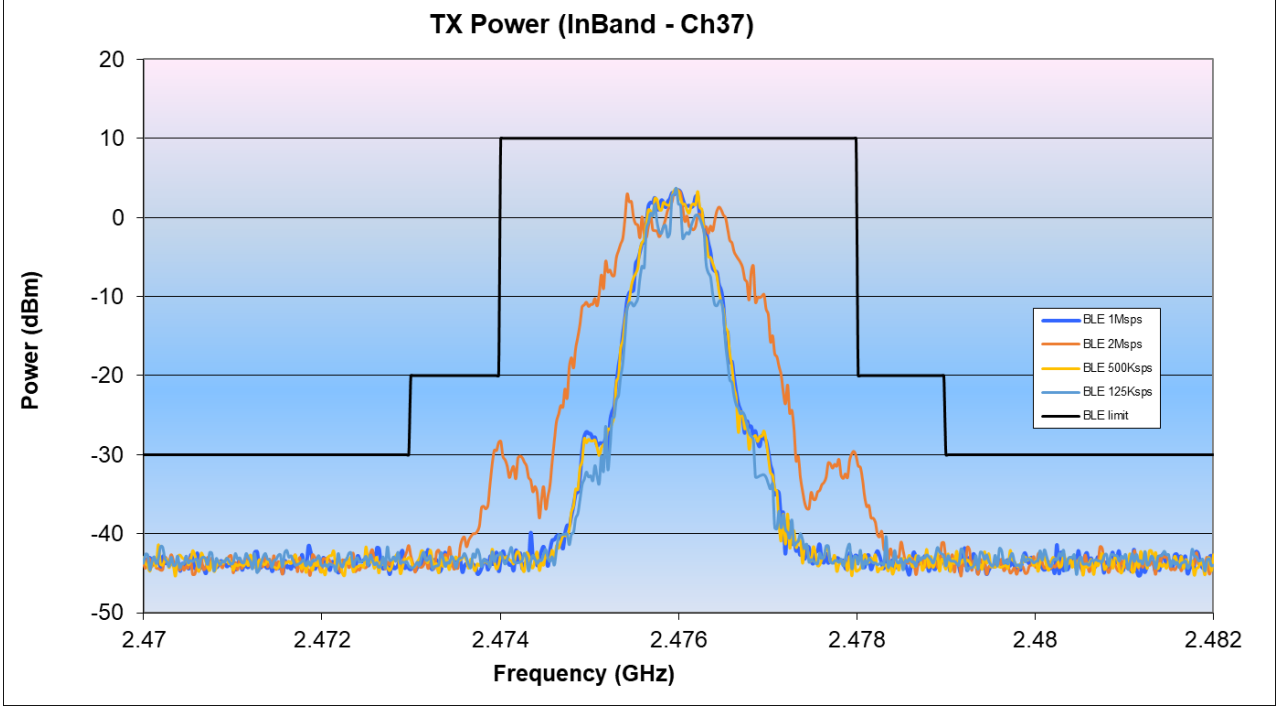


Figure 10. TX power In Band – Channel 37

Table 12. Bluetooth LE 1 Msps

Max peak level <=-2 MHz	-42.08	dBm	@	2.473	GHz
Max peak level >=+2 MHz	-42.22	dBm	@	2.478	GHz
Max peak level <=-3 MHz	-41.59	dBm	@	2.472	GHz
Max peak level >=+3 MHz	-41.43	dBm	@	2.480	GHz

Table 13. Bluetooth LE 2 Msps

Max peak level <=-2 MHz	-28.42	dBm	@	2.474	GHz
Max peak level >=+2 MHz	-31.37	dBm	@	2.478	GHz
Max peak level <=-3 MHz	-41.45	dBm	@	2.473	GHz
Max peak level >=+3 MHz	-41.60	dBm	@	2.481	GHz

Table 14. Bluetooth LE 500 Ksps

Max peak level <=-2 MHz	-41.91	dBm	@	2.474	GHz
Max peak level >=+2 MHz	-41.92	dBm	@	2.479	GHz
Max peak level <=-3 MHz	-41.35	dBm	@	2.470	GHz
Max peak level >=+3 MHz	-42.07	dBm	@	2.480	GHz

Table 15. Bluetooth LE 125 Ksps

Max peak level <=-2 MHz	-42.01	dBm	@	2.474	GHz
Max peak level >=+2 MHz	-40.39	dBm	@	2.478	GHz
Max peak level <=-3 MHz	-41.66	dBm	@	2.470	GHz
Max peak level >=+3 MHz	-41.91	dBm	@	2.480	GHz

- **Conclusion**:
  - These results are compliant to Bluetooth LE 5.0.

3.1.5 Tx spurious

3.1.5.1 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 (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps & 125 Ksps).

- **Flashed SW**:
  - Connectivity test

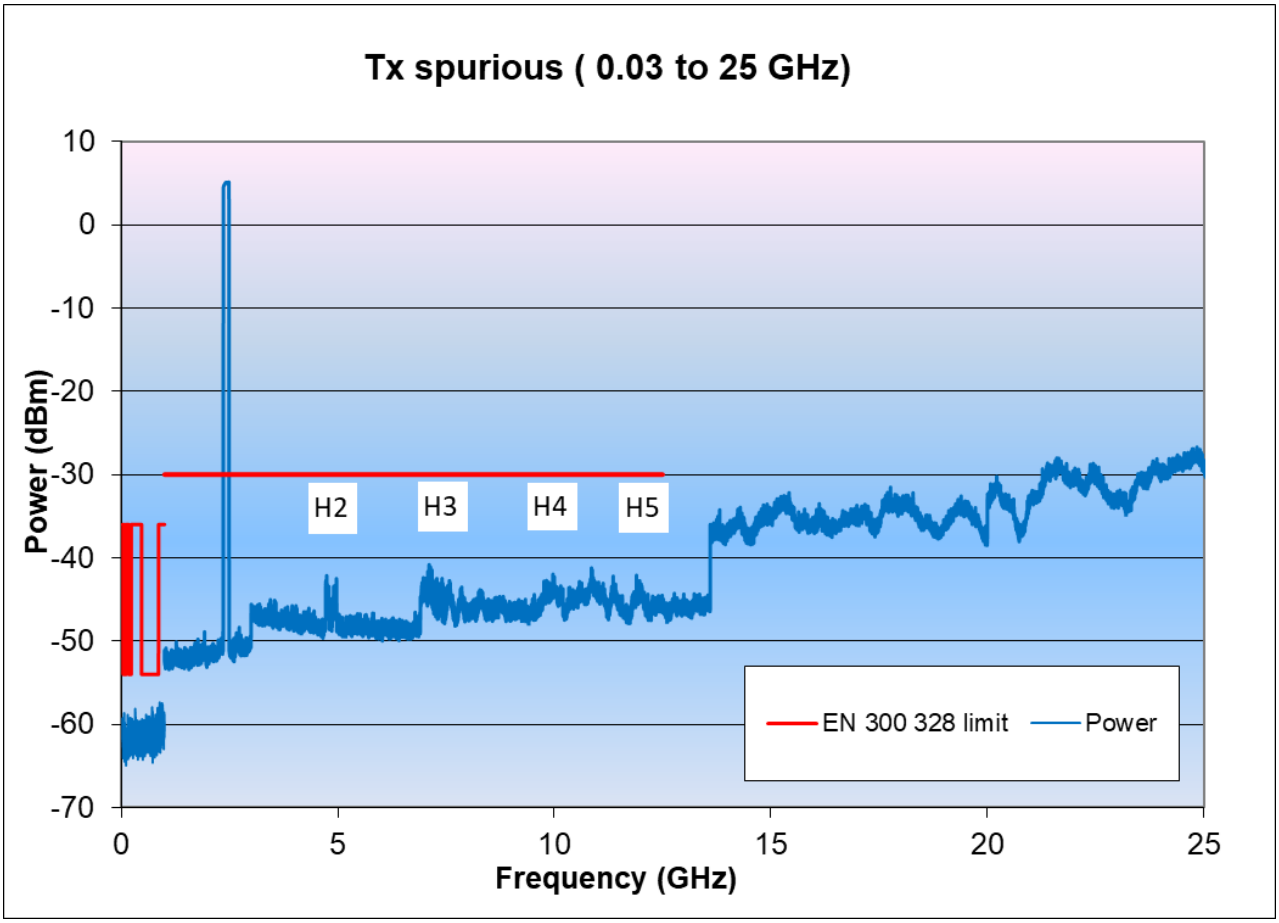


Figure 11. Conducted Tx spurious (30 MHz to 25 GHz)

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

3.1.5.2 H2 (ETSI test conditions, peak measurement)

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Set the radio to:
    - Tx mode (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps & 125 Ksps) , 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 Channel 0 to Channel 39

- **Result**:

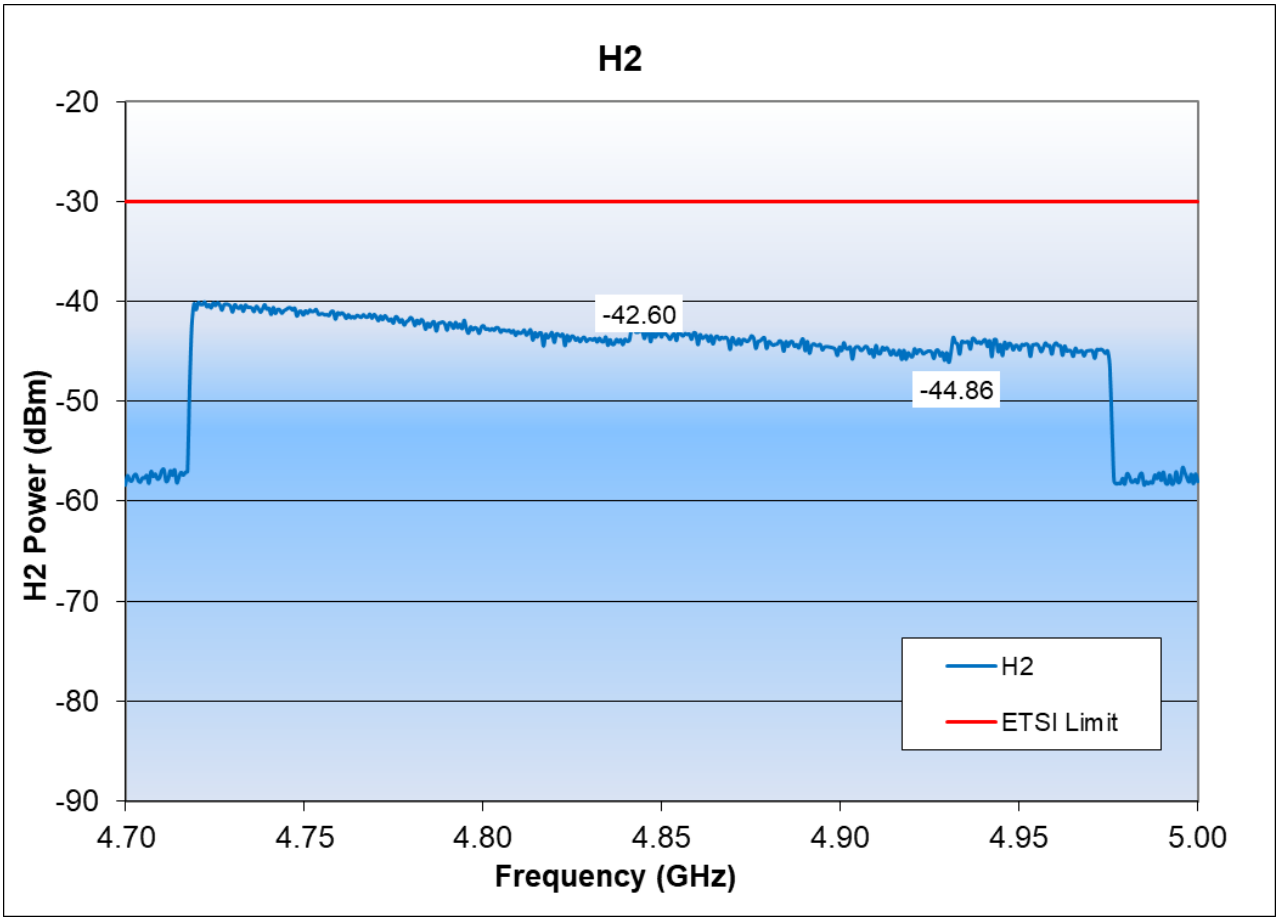


Figure 12. Conducted H2 spurious

  - Maximum power is at harmonic 2 of Channel 0: - 43.9 dBm
- **Conclusion**:
  - There is more than **13 dB** margin to the ETSI limit.

3.1.5.3 H3 (ETSI test conditions, peak measurement)

- **Test method**:
  - The same method as H2, except that the spectrum analyzer frequency start/stop is set to 7.0 and 7.5 GHz.
- **Result**:

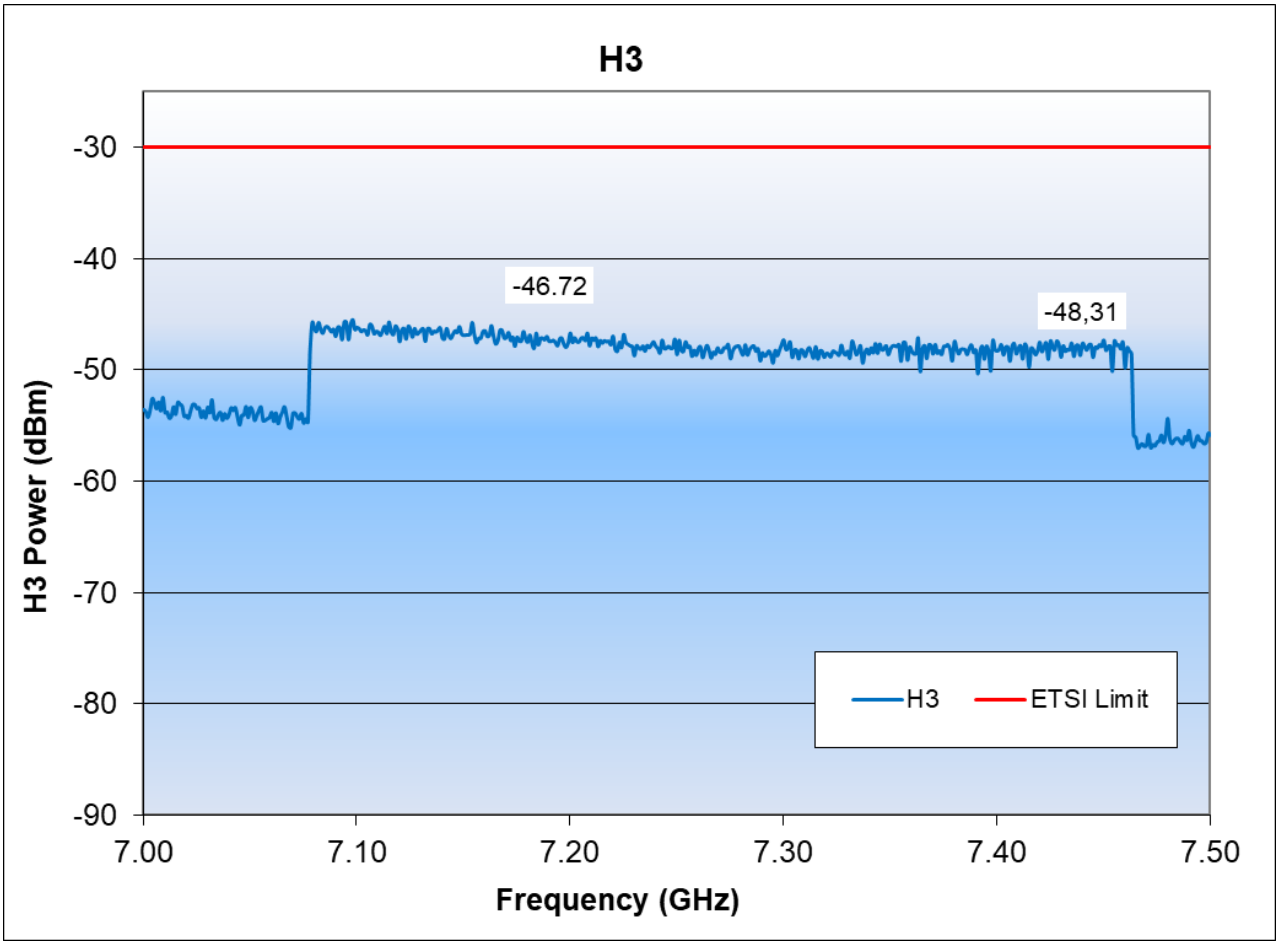


Figure 13. Conducted H3 spurious

- Maximum power is at harmonic 3 of Channel 0: - 46.72 dBm

- **Conclusion**:
  - There is more than **16 dB** margin to the ETSI limit.

3.1.5.4 H4 (ETSI test conditions, peak measurement)

- **Test method**:
  - The same method as H2, except that the spectrum analyzer frequency span is set from 9.4 to 10.0 GHz.
- **Result**:

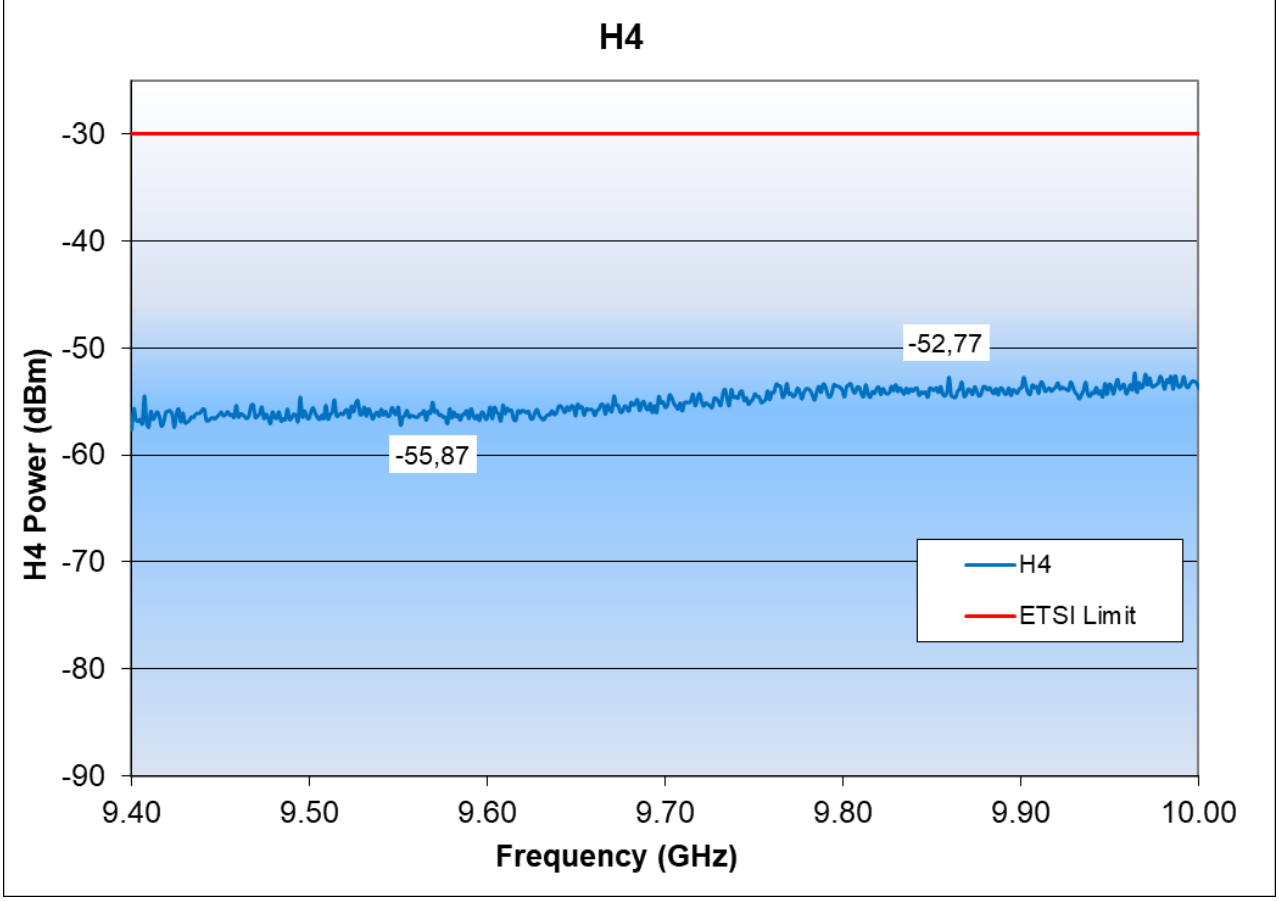


Figure 14. Conducted H4 spurious

- Maximum power is at harmonic 4 of Channel 31: - 52.77 dBm

- **Conclusion**:
  - There is more than **22 dB** margin to the ETSI limit.

3.1.5.5 H5 (ETSI test conditions, peak measurement)

- **Test method**:
  - The same method as H2, except that the spectrum analyzer frequency span is set from 11.7 to 12.5 GHz.
- **Result**:

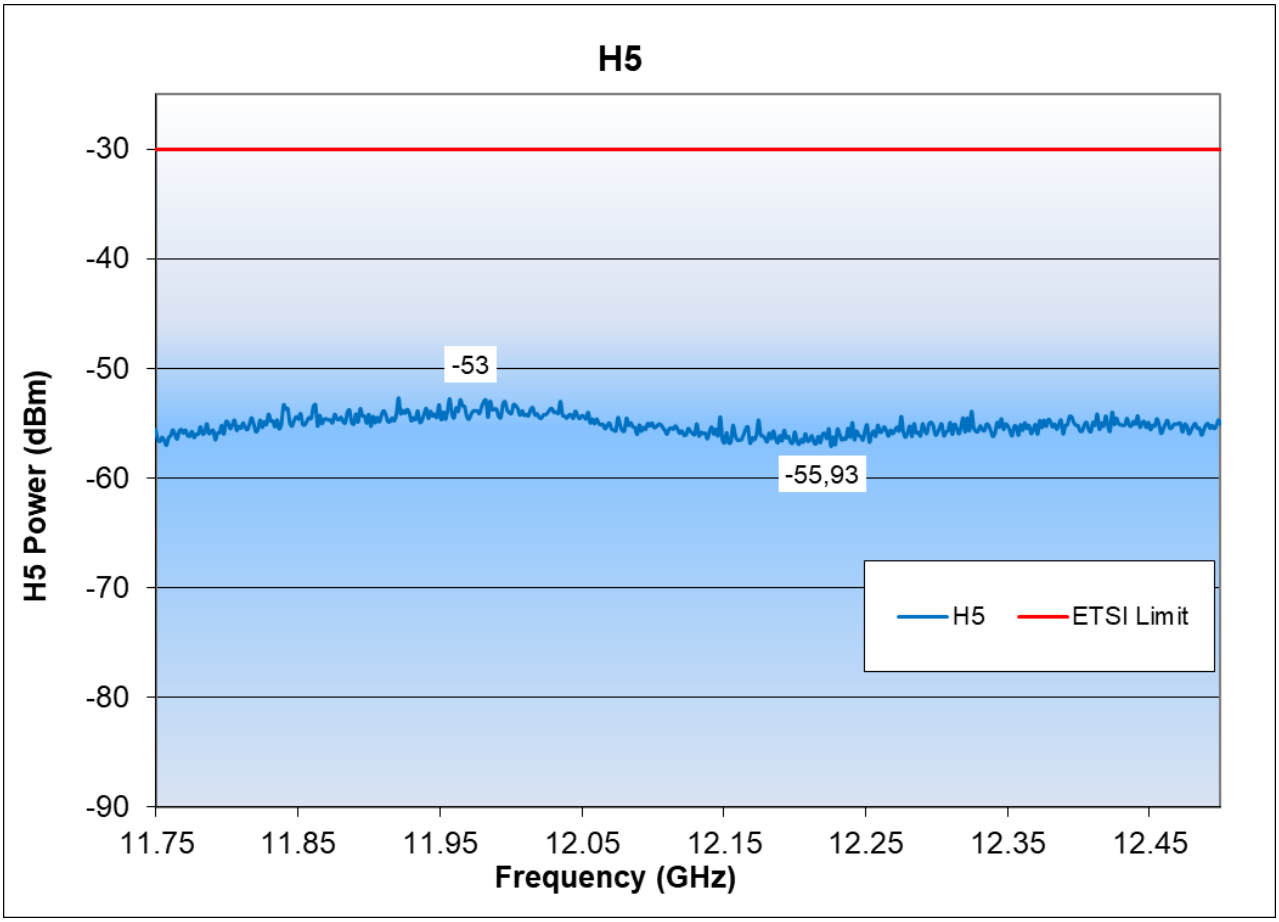


Figure 15. Conducted H5 spurious

- Maximum power is at harmonic 5 of Channel 2: -53 dBm

- **Conclusion**:
  - There is more than **22 dB** margin to the ETSI limit.

3.1.5.6 H6 (ETSI test conditions, peak measurement)

- **Test method**:
  - The same method as H2, except that the spectrum analyzer frequency span is set from 14.1 to 15 GHz.
- **Result**:

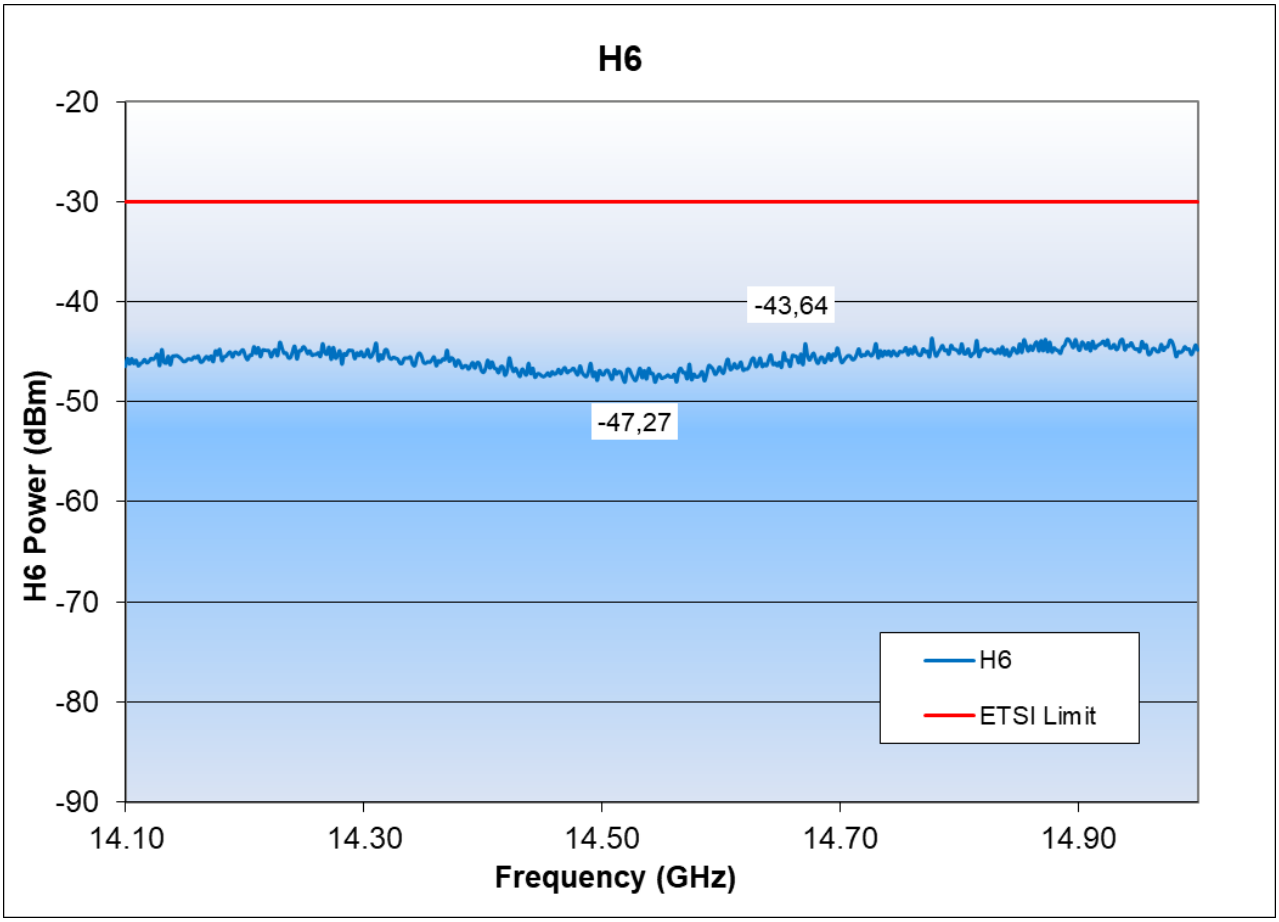


Figure 16. Conducted H6 spurious

- Maximum power is at harmonic 6 of Channel 25: -43.64 dBm

- **Conclusion**:
  - There is more than **13 dB** margin to the ETSI limit.

3.1.5.7 H7 (ETSI test conditions, peak measurement)

- **Test method**:
  - The same method as H2, except that the spectrum analyzer frequency span is set from 16.45 to 17.5 GHz.
- **Result**:

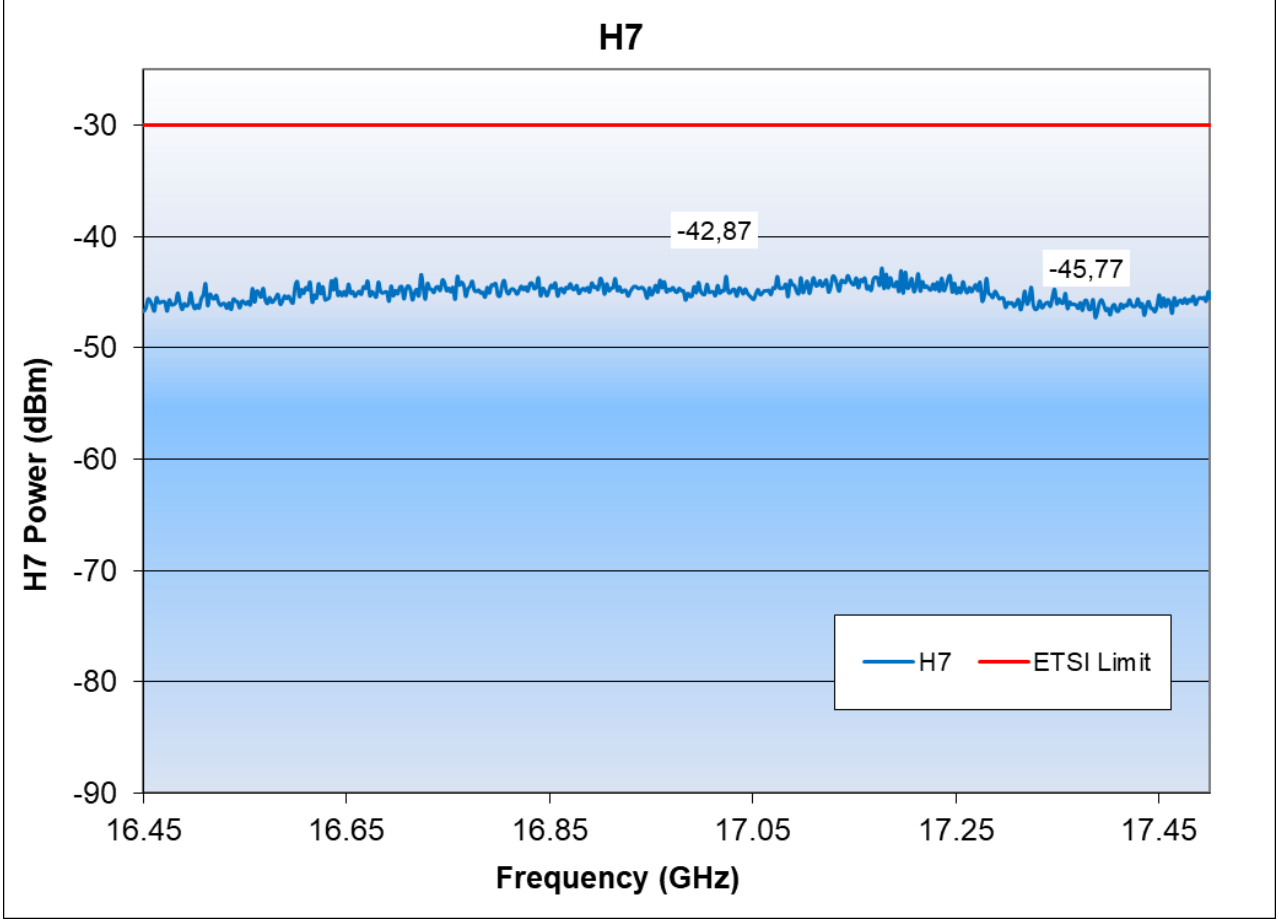


Figure 17. Conducted H7 spurious

— Maximum power is at harmonic 7 of Channel 23: -42.87 dBm

- **Conclusion**:
  - — There is more than **12 dB** margin to the ETSI limit.

3.1.5.8 H8 (ETSI test conditions, peak measurement)

- **Test method**:
  - — The same method as H2, except that the spectrum analyzer frequency span is set from 16.45 to 17.5 GHz.
- **Result**:

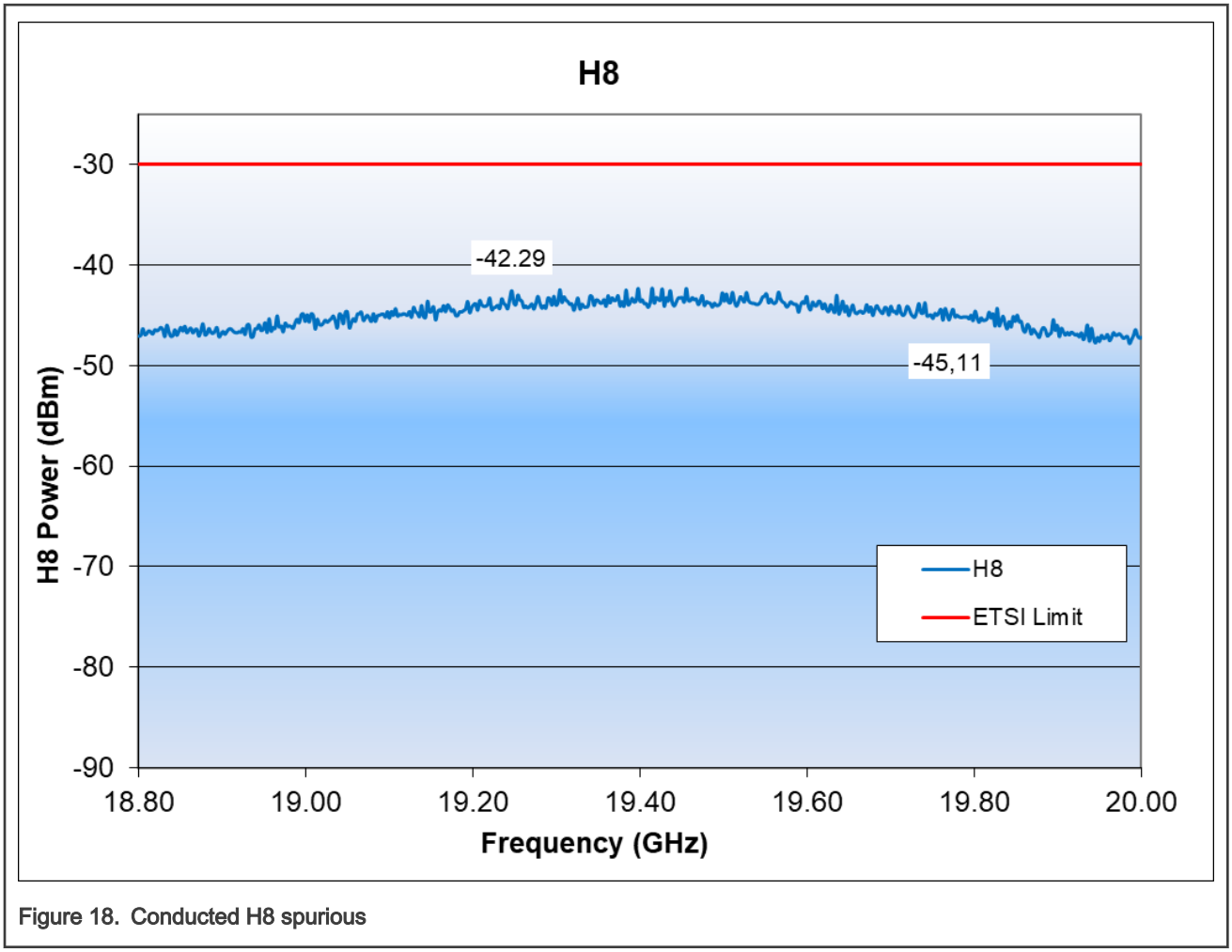


Figure 18. Conducted H8 spurious

- Maximum power is at harmonic 8 of Channel 13: -42.29 dBm

- **Conclusion**:
  - There is more than **12 dB** margin to the ETSI limit.

3.1.5.9 H9 (ETSI test conditions, peak measurement)

- **Test method**:
  - The same method as H2, except that the spectrum analyzer frequency span is set from 21.15 to 22.5 GHz.
- **Result**:

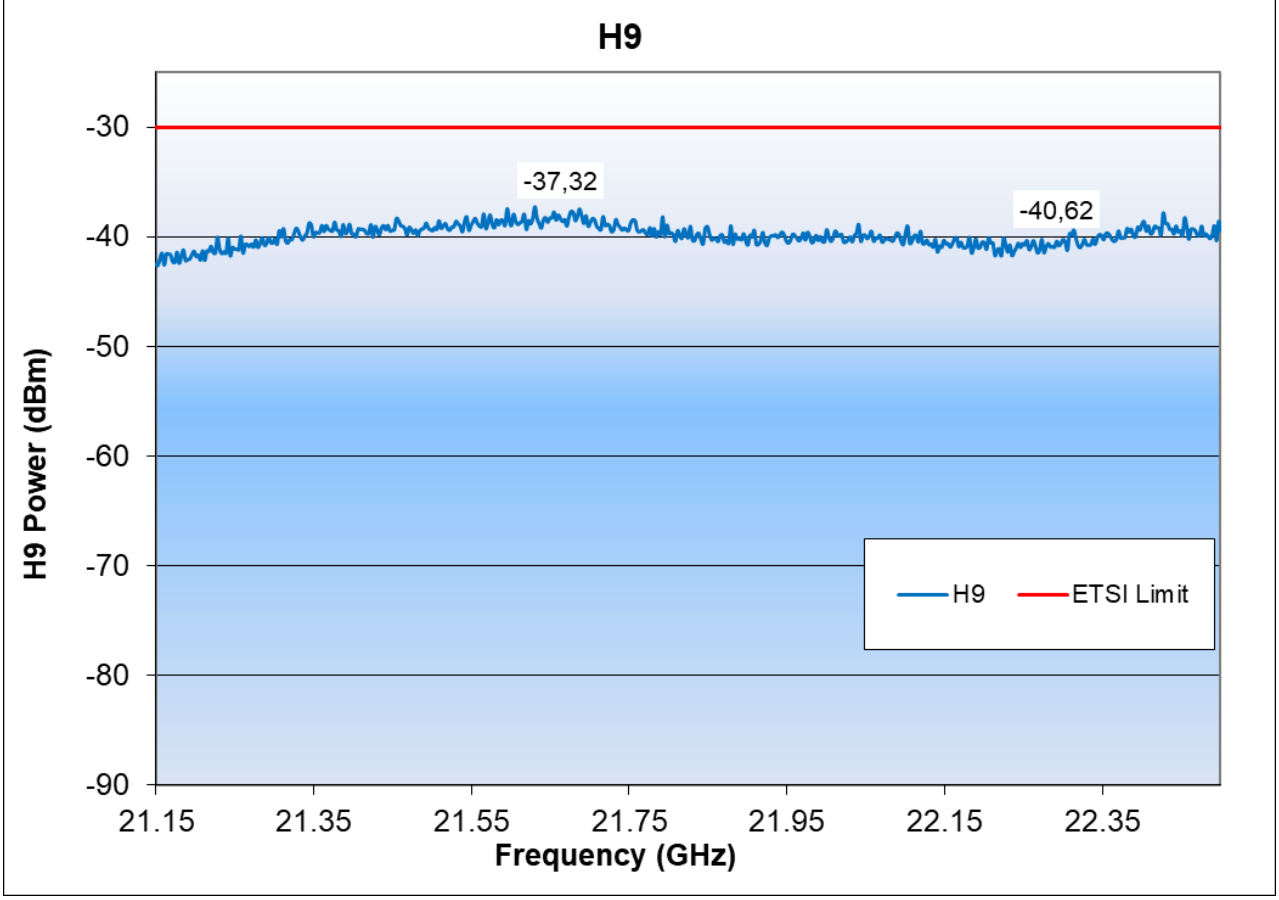


Figure 19. Conducted H9 spurious

- Maximum power is at harmonic 9 of Channel 1: -37.32 dBm

- **Conclusion**:
  - There is more than **7 dB** margin to the ETSI limit.

3.1.5.10 H10 (ETSI test conditions, peak measurement)

- **Test method**:
  - The same method as H2, except that the spectrum analyzer frequency span is set from 23.35 to 25 GHz.
- **Result**:

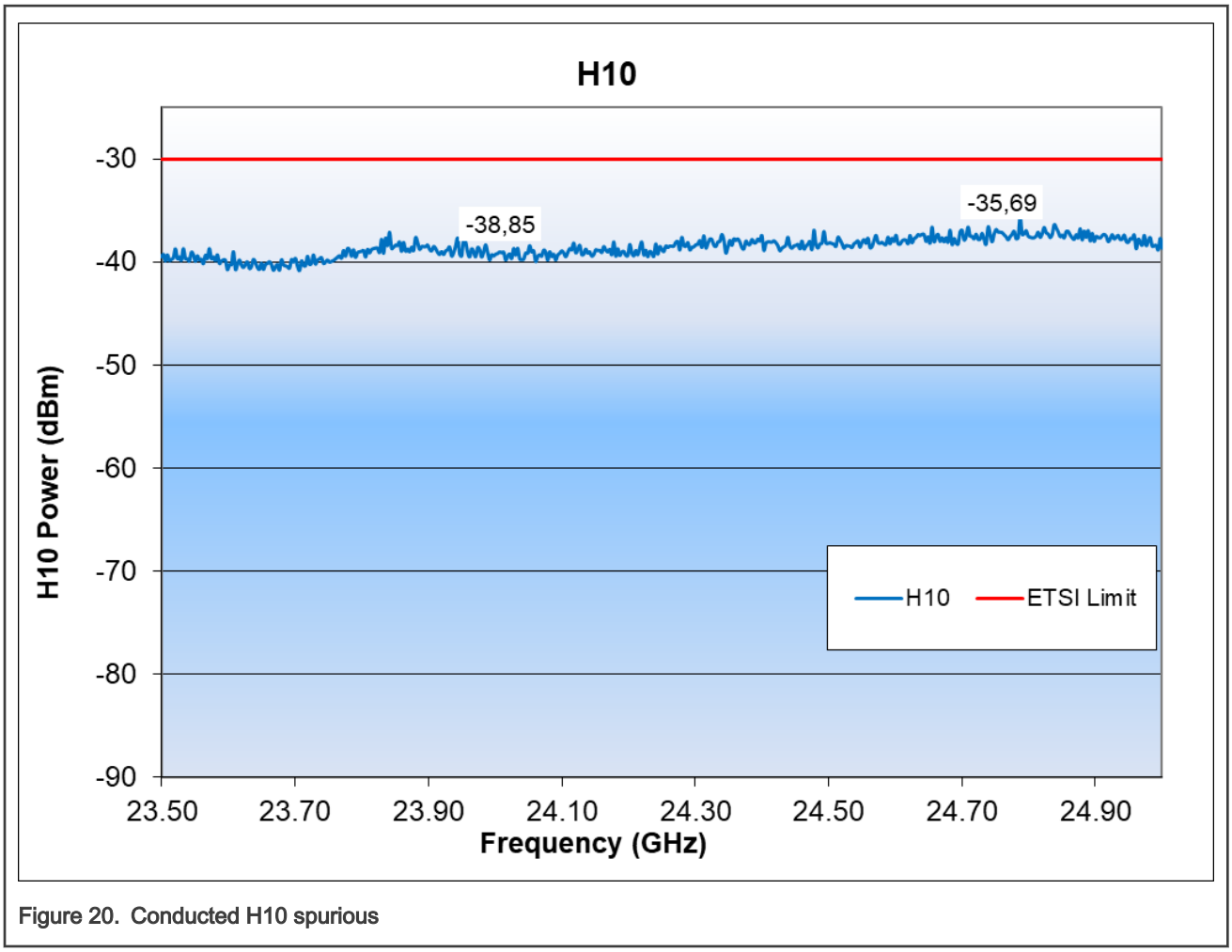


Figure 20. Conducted H10 spurious

- Maximum power is at harmonic 10 of Channel 1: -37.32 dBm

- **Conclusion**:
  - There is more than **7 dB** margin to the ETSI limit.

3.1.5.11 H2 (FCC test conditions, average measurements)

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Set the radio to:
    - Tx mode (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps & 125 Ksps), 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
    - Trace: Max Hold mode
    - Detector: RMS
  - Sweep all the channels from Channel 0 to Channel 39

- **Result**:

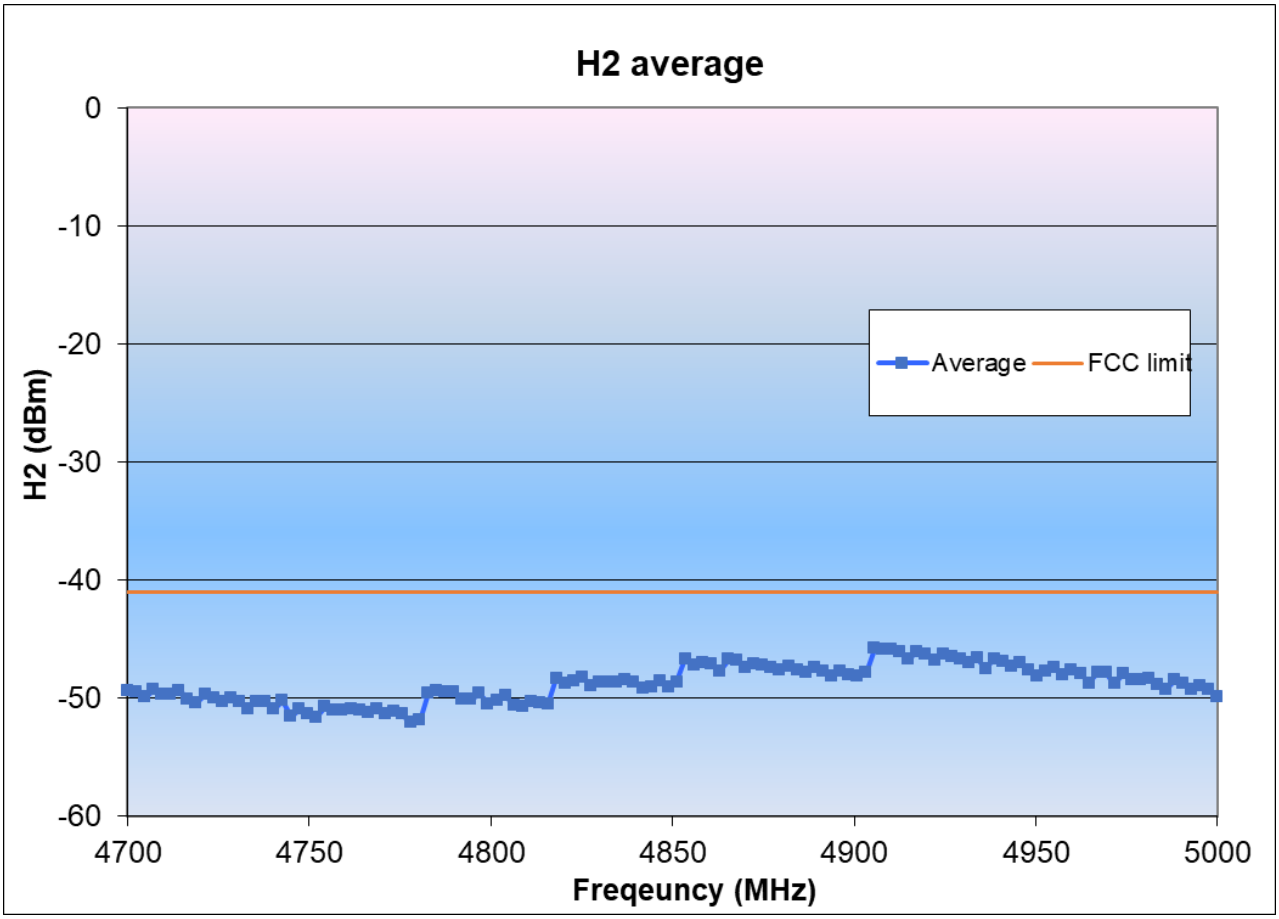


Figure 21. Conducted H2 FCC spurious

  - Maximum power is at harmonic 2 of Channel 25: - 45.79 dBm
- **Conclusion**:
  - There is more than **4 dB** margin to the FCC limit.

3.1.5.12 H3 (FCC test conditions, average measurements)

- **Test methods**:
  - Same method as H2, except that the spectrum analyzer frequency span is set from 7.0 GHz to 7.5 GHz.
- **Result**:

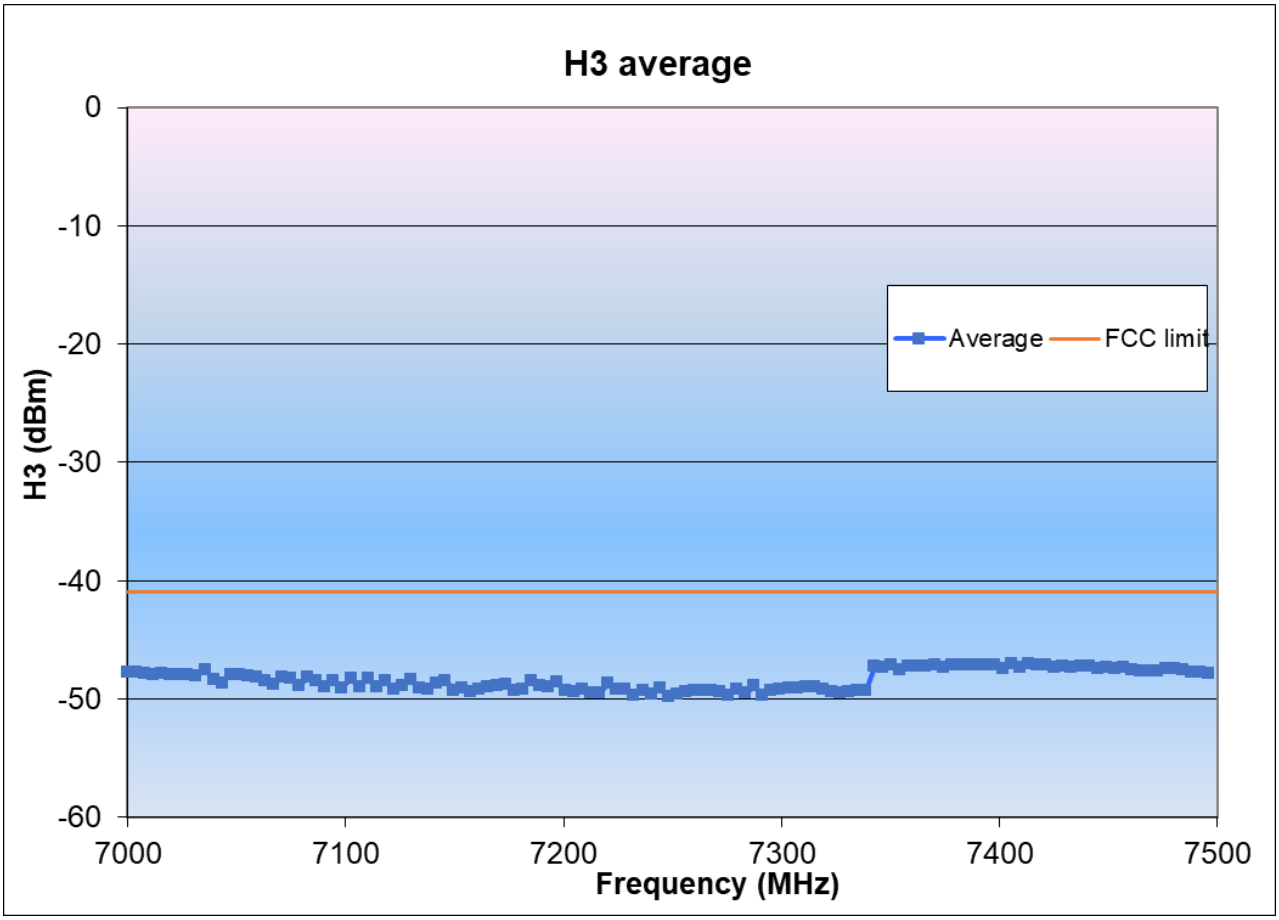


Figure 22. Conducted H3 FCC spurious

  - Maximum power is at harmonic 3 of Channel 35: - 46.99 dBm

- **Conclusion**:
  - There is more than **5 dB** margin to the FCC limit.

3.1.5.13 H4 (FCC test conditions, average measurements)

- **Test methods**:
  - Same method as H2, except that the spectrum analyzer frequency span is set from 9.4 to 10 GHz.
- **Result**:

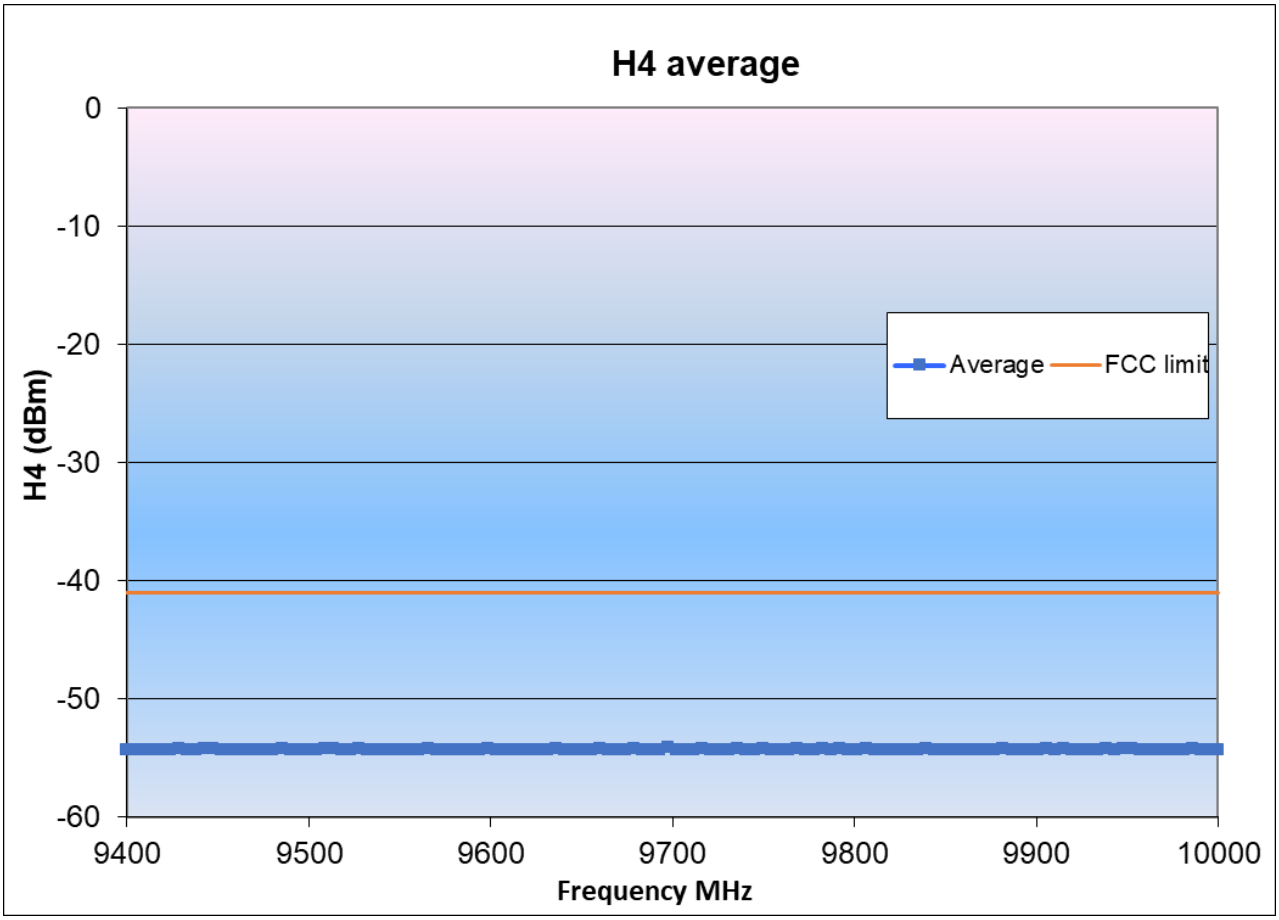


Figure 23. Conducted H4 FCC spurious

- Maximum power is at harmonic 4 of Channel 11: - 54.16 dBm

- **Conclusion**:
  - There is more than **13 dB** margin to the FCC limit.

3.1.5.14 H5 (FCC test conditions, average measurements)

- **Test methods**:
  - Same method as H2, except that the spectrum analyzer frequency span is set from 11.7 to 12.5 GHz.
- **Result**:

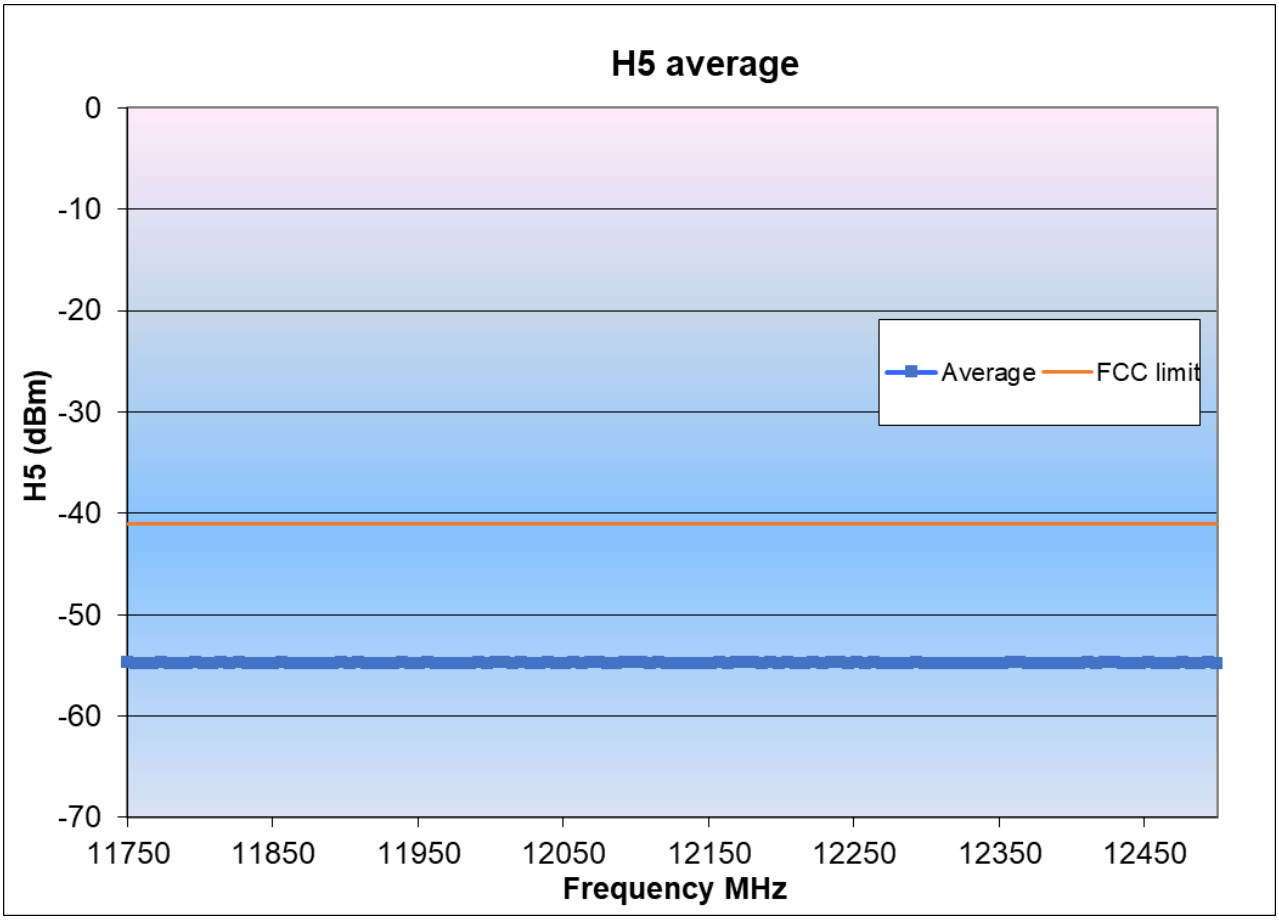


Figure 24. Conducted H5 FCC spurious

- Maximum power is at harmonic 5 of Channel 21: - 54.7 dBm

- **Conclusion**:
  - There is more than **13 dB** margin to the FCC limit.

3.1.5.15 H6 (FCC test conditions, average measurements)

- **Test methods**:
  - Same method as H2, except that the spectrum analyzer frequency span is set from 14.1 to 15 GHz.
- **Result**:

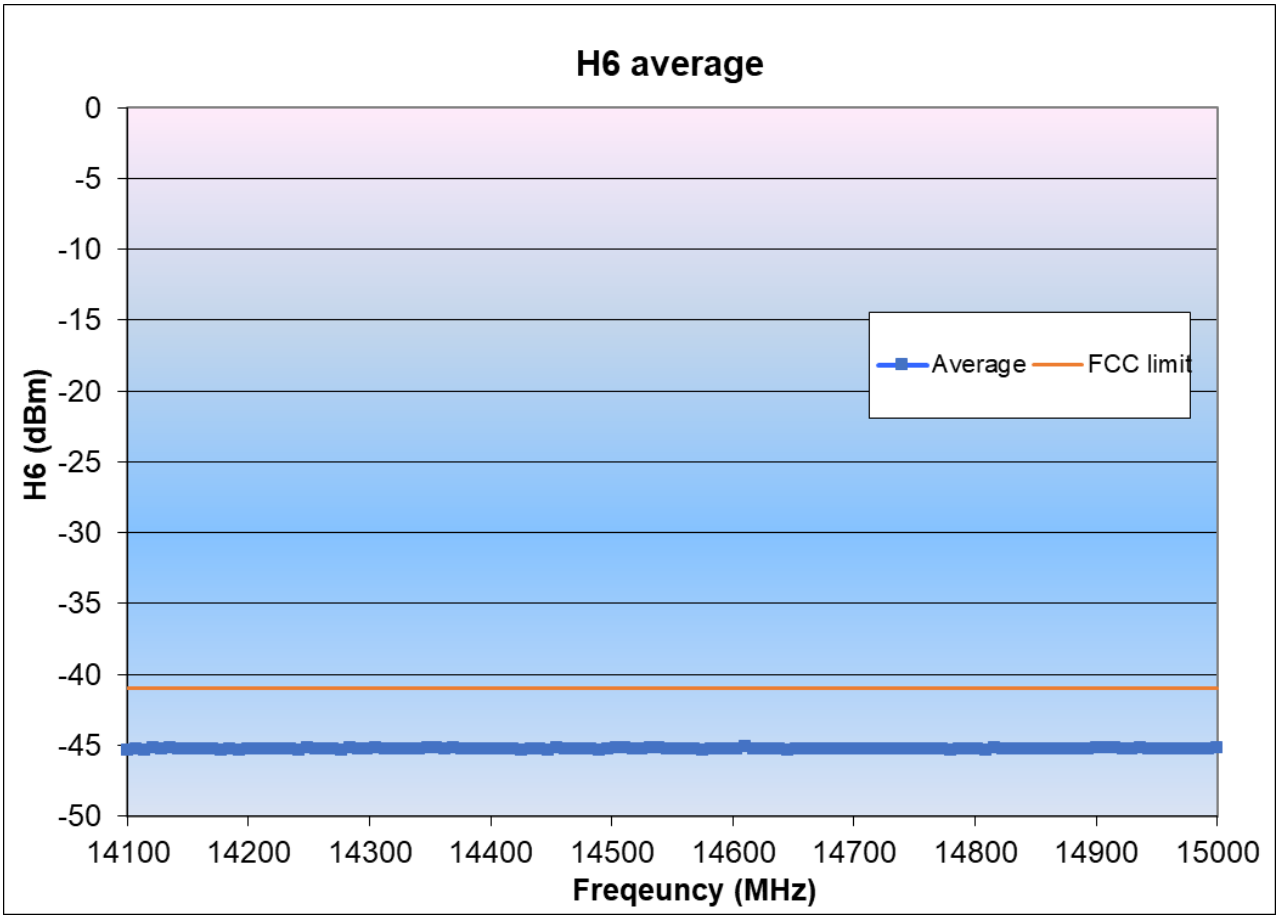


Figure 25. Conducted H6 FCC spurious

- Maximum power is at harmonic 6 of Channel 39: - 45.16 dBm

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

3.1.5.16 H7 (FCC test conditions, average measurements)

- **Test methods**:
  - Same method as H2, except that the spectrum analyzer frequency span is set from 16.45 to 17.5 GHz.
- **Result**:

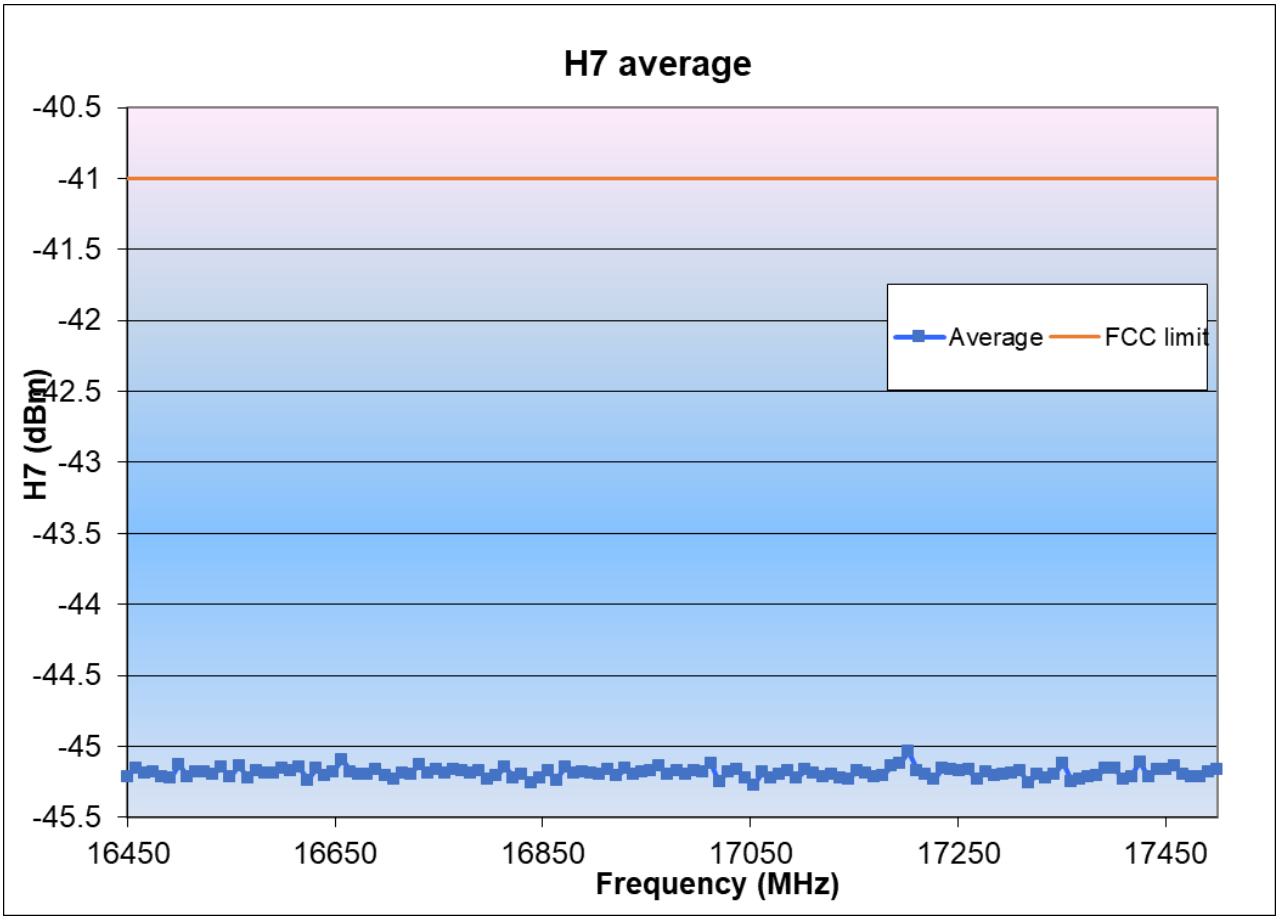


Figure 26. Conducted H7 FCC spurious

- Maximum power is at harmonic 7 of Channel 39: - 45.24 dBm

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

3.1.5.17 H8 (FCC test conditions, average measurements)

- **Test methods**:
  - Same method as H2, except that the spectrum analyzer frequency span is set from 16.45 to 17.5 GHz.
- **Result**:

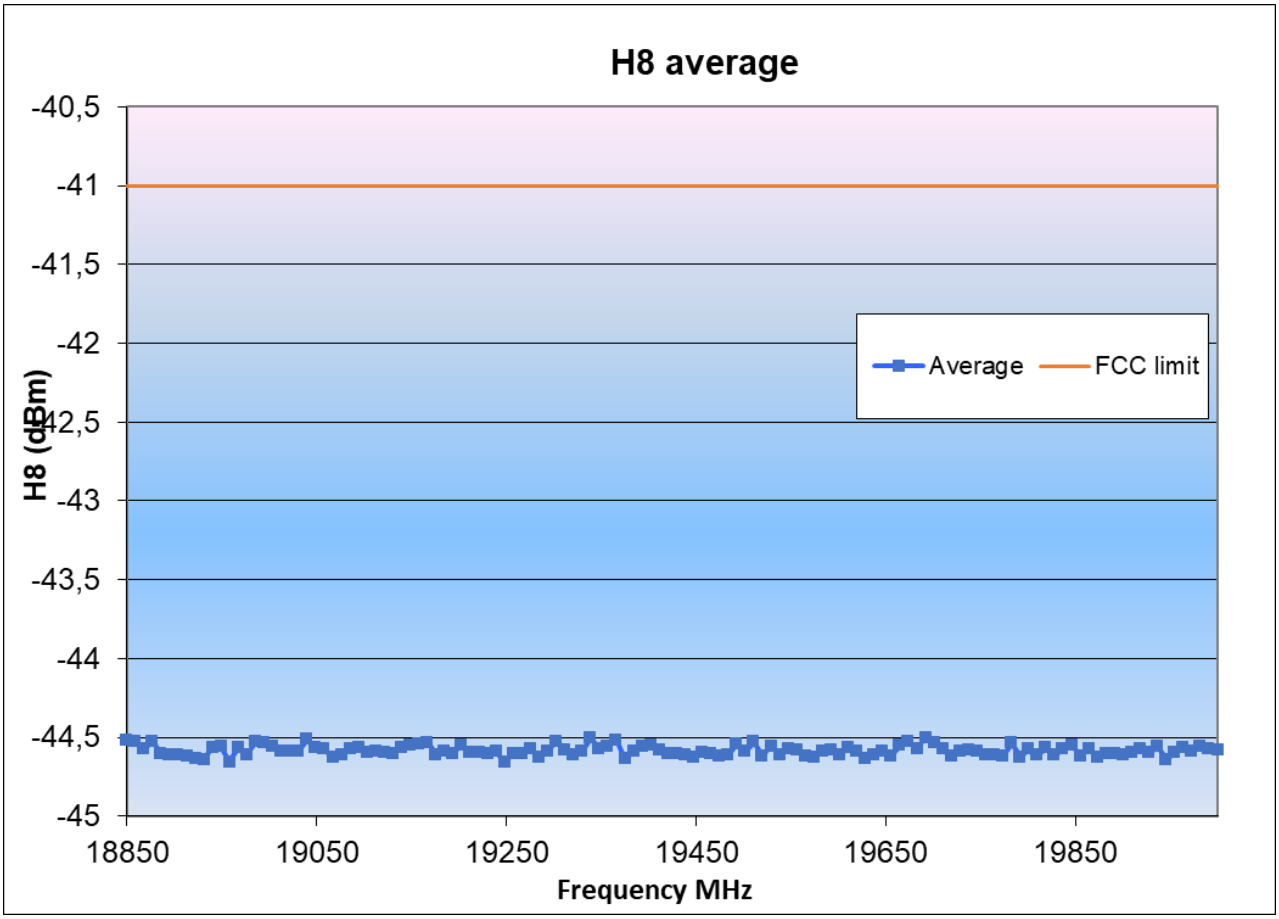


Figure 27. Conducted H8 FCC spurious

- Maximum power is at harmonic 8 of Channel 30: - 44.5 dBm

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

3.1.5.18 H9 (FCC test conditions, average measurements)

- **Test methods**:
  - Same method as H2, except that the spectrum analyzer frequency span is set from 21.15 to 22.5 GHz.
- **Result**:

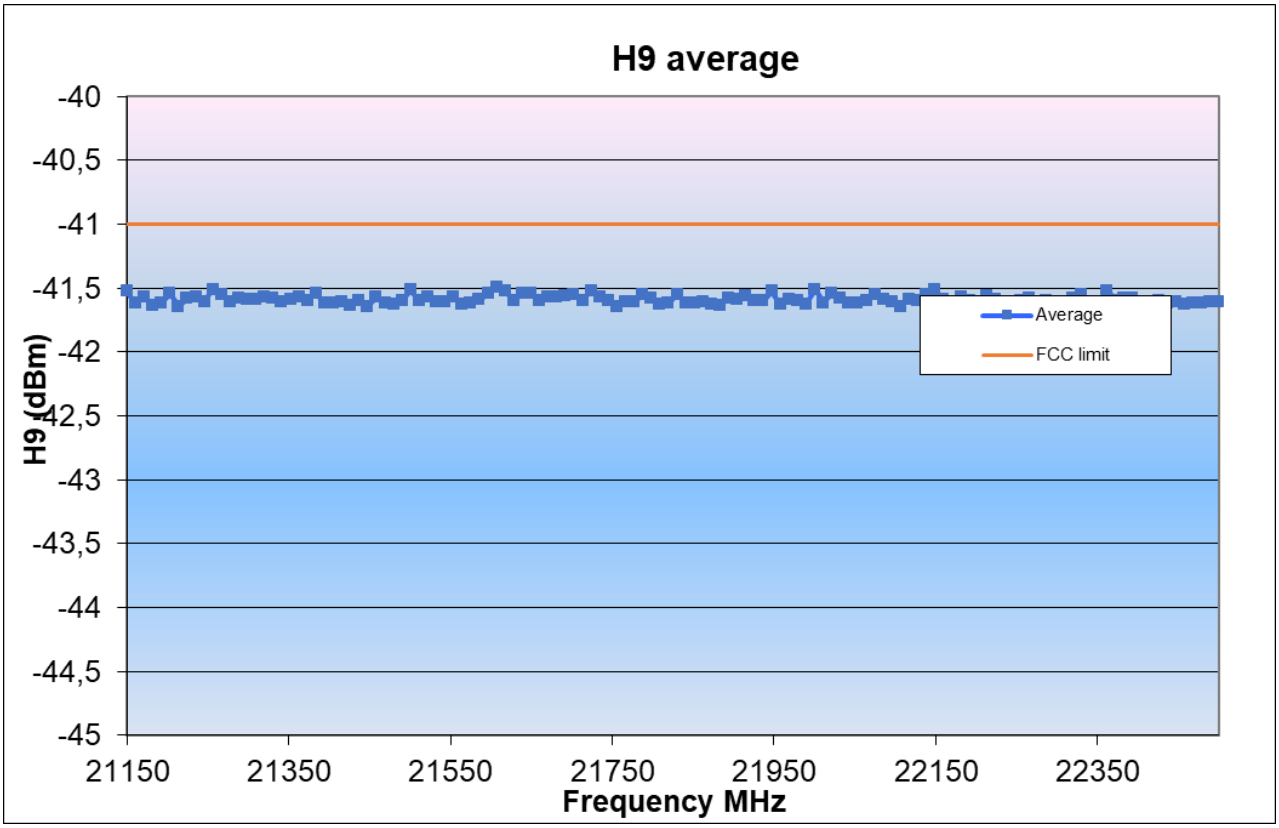


Figure 28. Conducted H9 FCC spurious

- Maximum power is at harmonic 9 of Channel 22: - 41.49 dBm

- **Conclusion**:
  - There is more than **0.3 dB** margin to the FCC limit.

3.1.5.19 H10 (FCC test conditions, average measurements)

- **Test methods**:
  - Same method as H2, except that the spectrum analyzer frequency span is set from 23.35 to 25 GHz.
- **Result**:

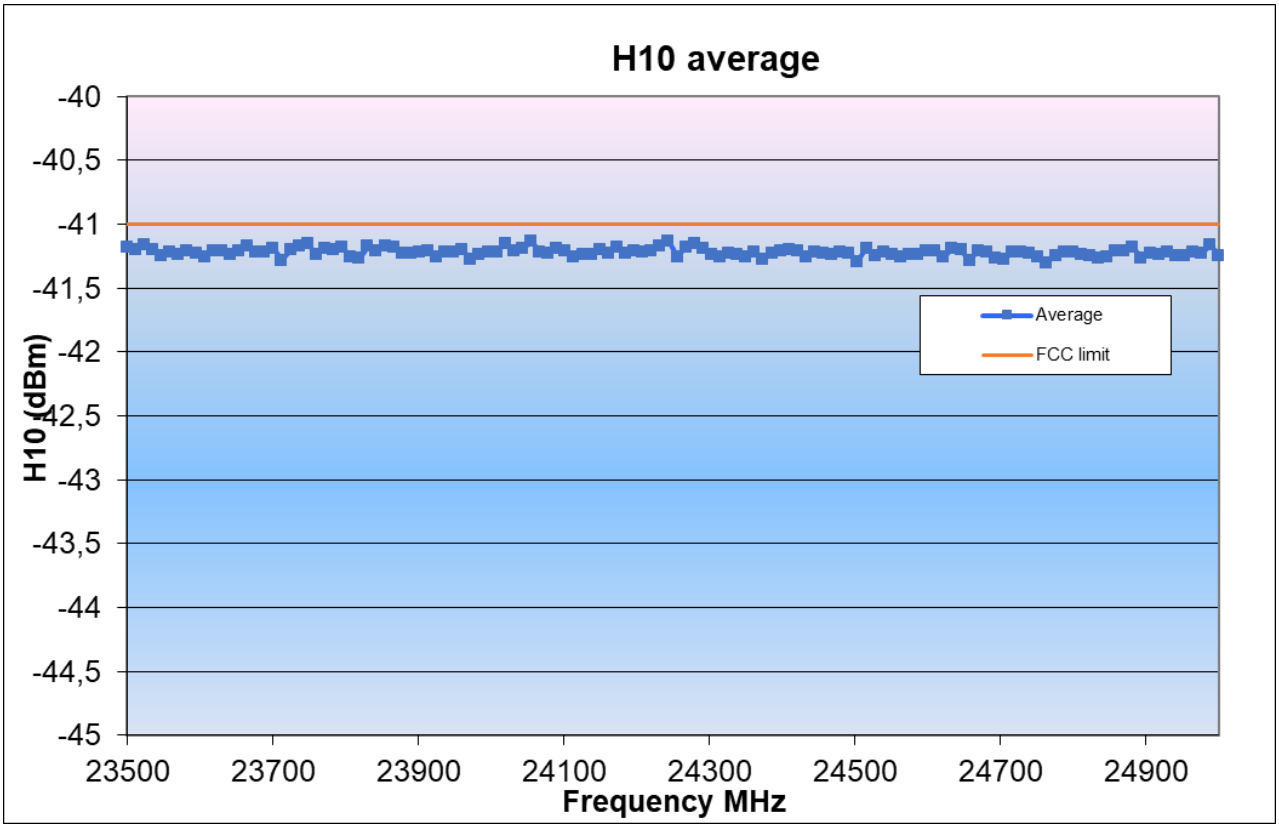


Figure 29. Conducted H10 FCC spurious

- Maximum power is at harmonic 10 of Channel 21: - 41.13 dBm

- **Conclusion**:
  - There is no margin (0 dB) margin to the FCC limit.

3.1.6 Upper band edge

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Set the radio to:
    - TX mode (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps & 125 Ksps) , modulated, continuous mode
    - **Ch39 RF output power MUST be set to -3.5 dBm (Connectivity test value = 'Hi power 13')**
  - 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 = Average
    - Average mode: power, Number of Sweeps = 100
    - Set Channel 39 (2.48 GHz)
- **Results**:

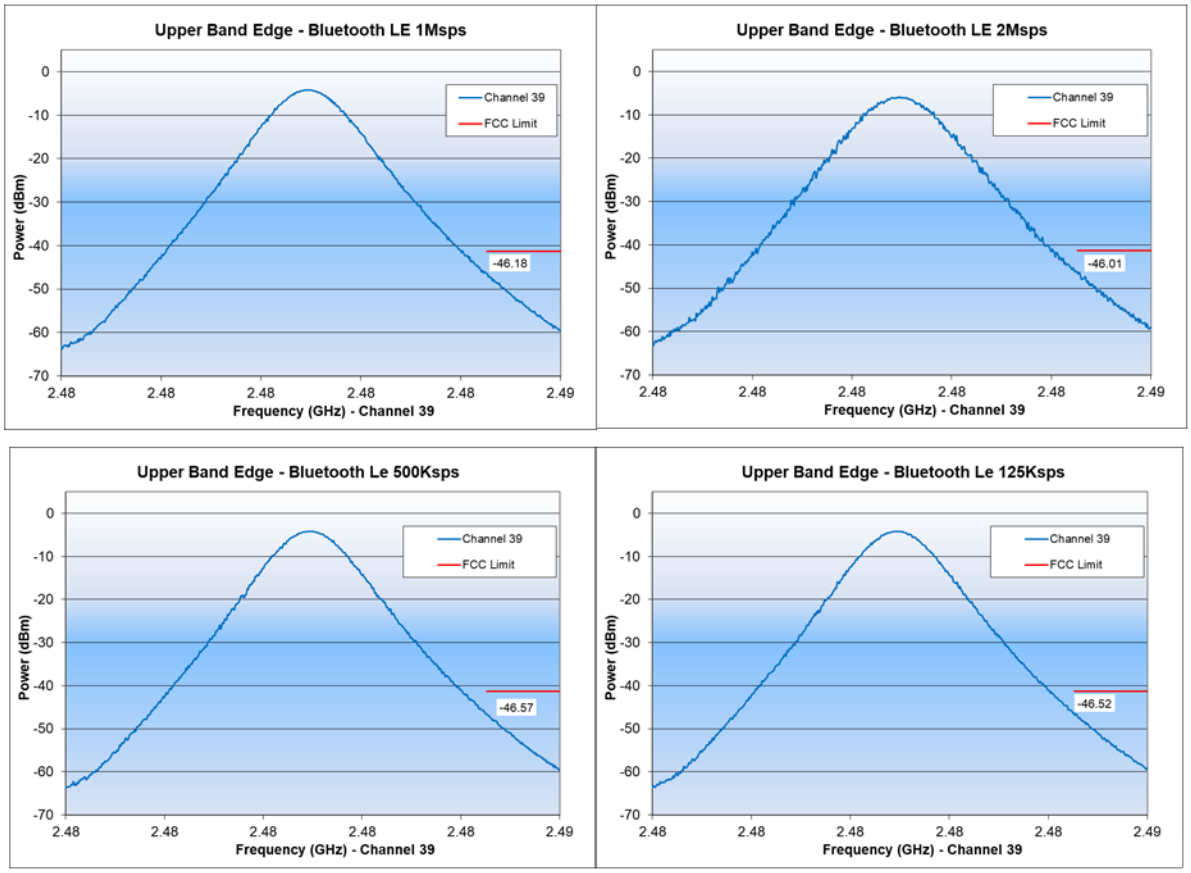


Figure 30. Upper Band Edge – Channel 39

- **Conclusion**:
  - The Upper Band Edge tests pass the FCC certification.
  - There is more than **5 dB** margin to the FCC limit.

3.1.7 Bluetooth LE Tx output spectrum

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

- **Flashed SW**:
  - 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**:

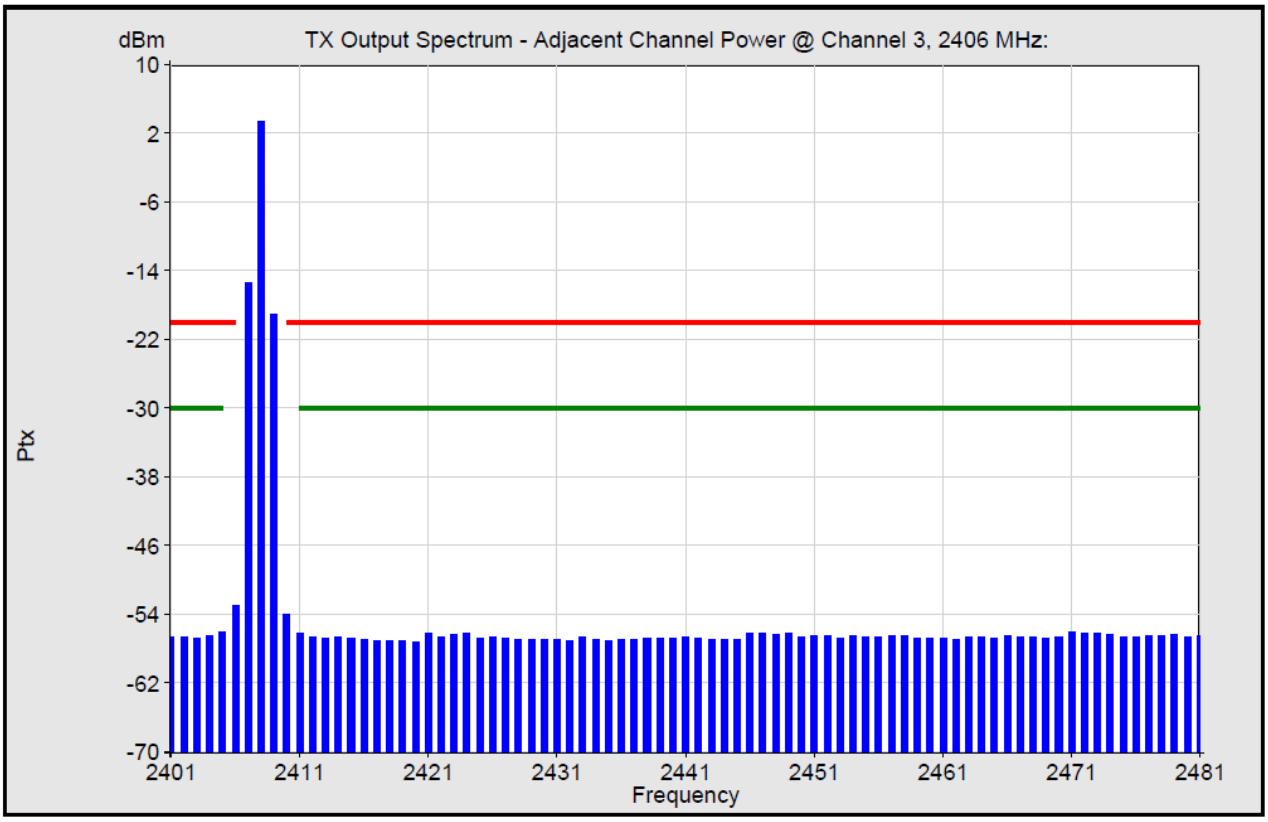


Figure 31. Channel 3 1 Msps

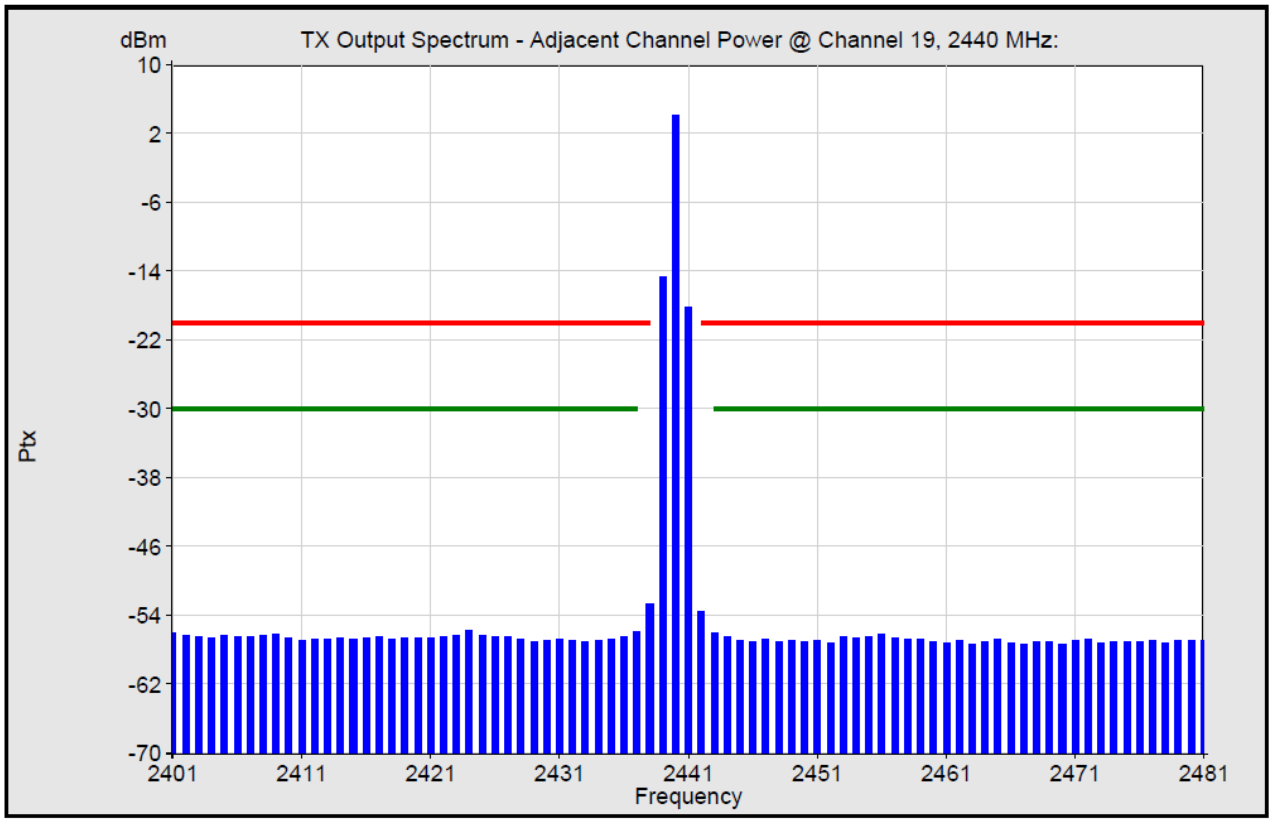


Figure 32. Channel 19 1 Msps

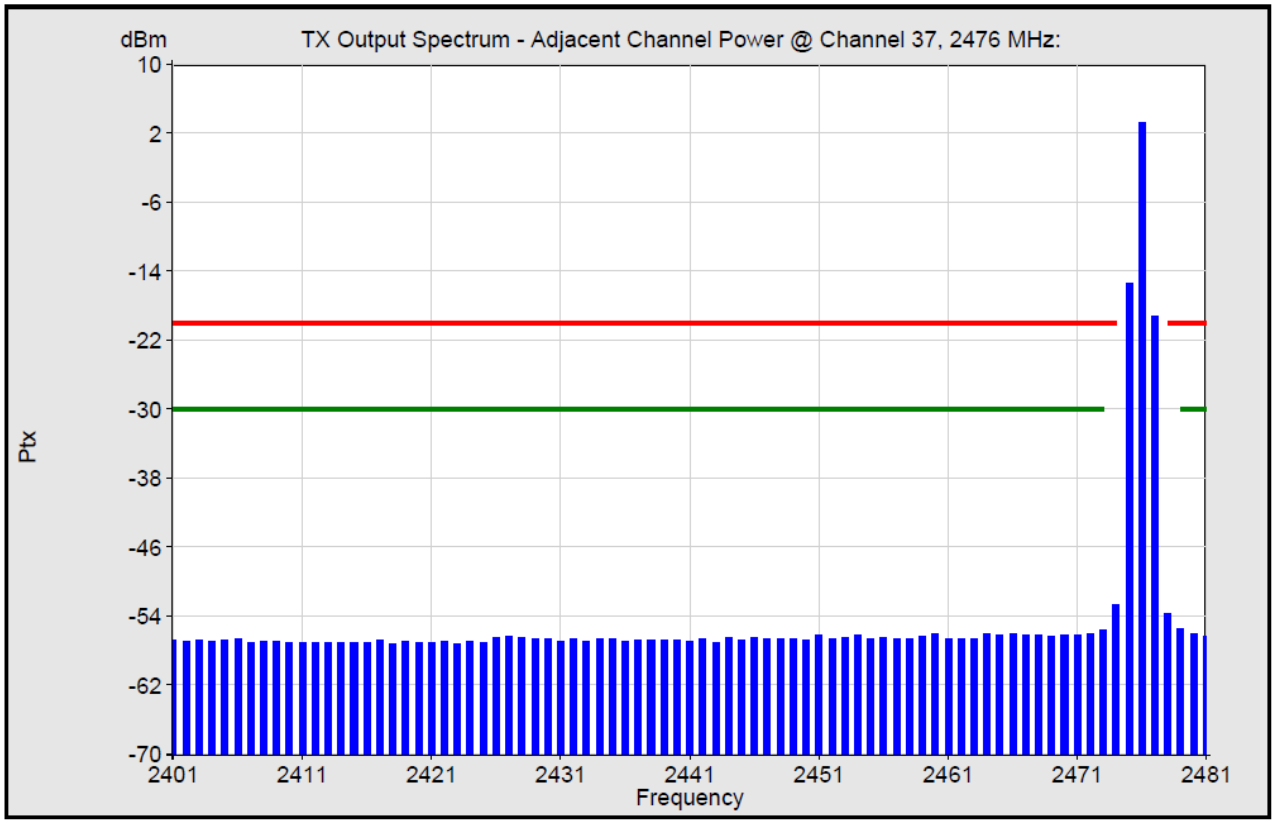


Figure 33. Channel 37 1 Msps

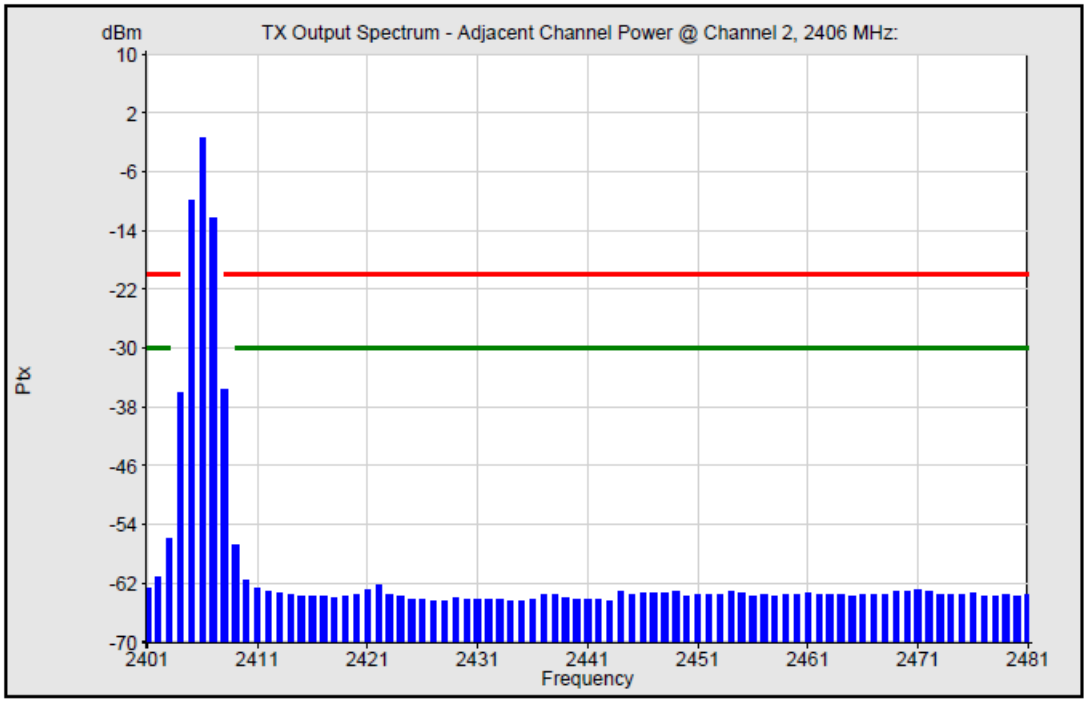


Figure 34. Channel 2 2 Msps

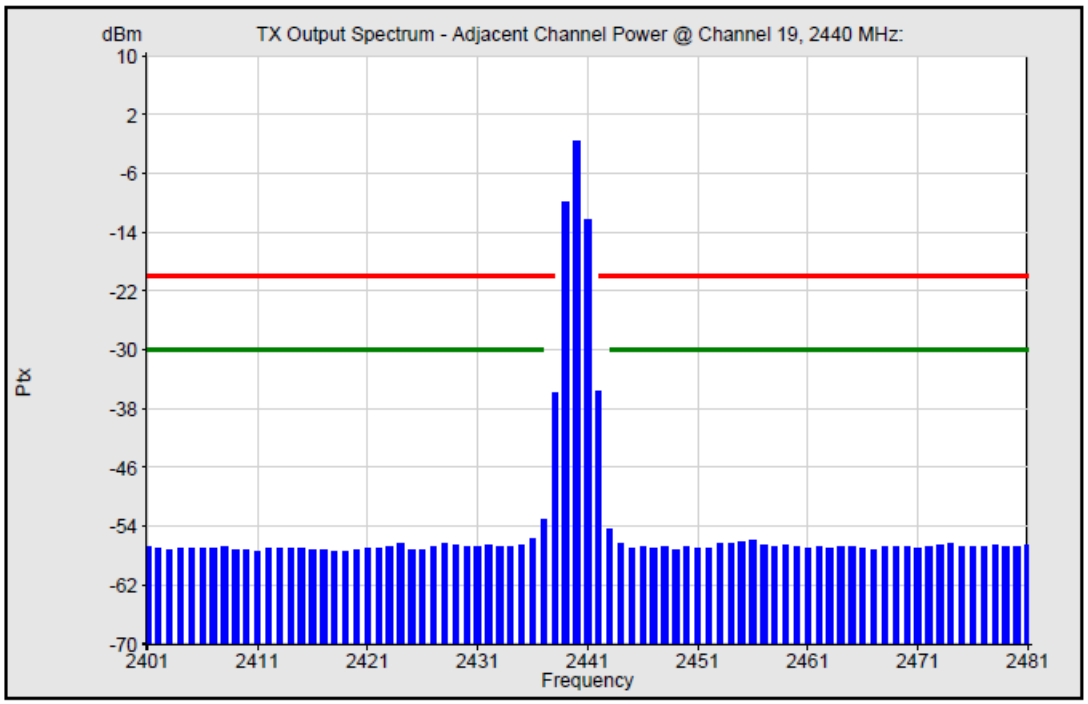


Figure 35. Channel 19 2 Msps

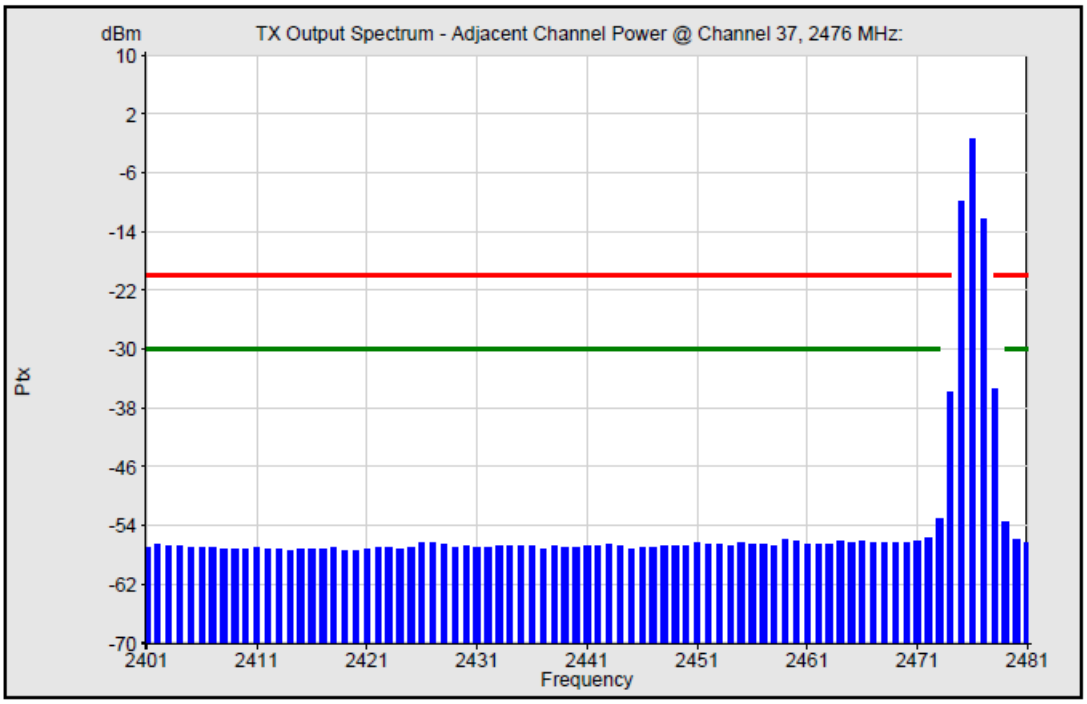


Figure 36. Channel 37 2 Msps

3.1.8 Modulation characteristics

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

- **Flashed SW**:
  - 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 16. 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					
tblContinuation_4_1					
Frequency deviation df1 Average	225	275	251.25	kHz	Passed
tblContinuation_4_2					
Frequency deviation df2 99.9%	185	—	218.93	kHz	Passed
tblContinuation_4_3					
Frequency deviation df2 Average/df1 Average	0.80	—	0.90	—	Passed
Channel 19					
tblContinuation_4_4					
Frequency deviation df1 Average	225	275	250.30	kHz	Passed
tblContinuation_4_5					
Frequency deviation df2 99.9%	185	—	216.53	kHz	Passed
Frequency deviation df2 Average/df1 Average	0.80	—	0.90	—	Passed
Channel 39					
tblContinuation_4_6					
Frequency deviation df1 Average	225	275	250.07	kHz	Passed
tblContinuation_4_7					
Frequency deviation df2 99.9%	185	—	218.03	kHz	Passed
Frequency deviation df2 Average/df1 Average	0.80	—	0.91	—	Passed

Table 17. Modulation characteristics at 2 Msps

TP/TRM-LE/CA/BV-10-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_10_1					
Frequency deviation df1 Average	450	550	504.34	kHz	Passed
tblContinuation_10_2					
Frequency deviation df2 99.9%	370	—	415.48	kHz	Passed
Frequency deviation df2 Average/df1 Average	0.80	—	0.84	—	Passed
tblContinuation_10_3					
Frequency deviation df1 Average	450	550	501.65	KHz	Passed
tblContinuation_10_4					
Frequency deviation df2 99.9%	370	—	415.48	kHz	Passed
Frequency deviation df2 Average/df1 Average	0.80	—	0.84	—	Passed
Channel 39					
tblContinuation_10_5					
Frequency deviation df1 Average	450	550	508.94	kHz	Passed
tblContinuation_10_6					
Frequency deviation df2 99.9%	370	—	413.68	kHz	Passed
tblContinuation_10_7					
Frequency deviation df2 Average/df1 Average	0.80	—	0.83	—	Passed

Table 18. 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_15_1					
Frequency deviation df1 Average	225	275	251.12	kHz	Passed
Frequency deviation df1 99.9%	185	—	241.42	kHz	Passed
Channel 19					
tblContinuation_15_2					
Frequency deviation df1 Average	225	275	249.94	KHz	Passed

Table continues on the next page...

Table 18. Modulation characteristics at LE coded (S8) (continued)

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					
tblContinuation_15_3					
Frequency deviation df1 99.9%	185	—	241.02	KHz	Passed
Channel 39					
tblContinuation_15_4					
Frequency deviation df1 Average	225	275	250.04	kHz	Passed
Frequency deviation df1 99.9%	185	—	241.02	KHz	Passed

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

3.1.9 Carrier frequency offset and drift

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

- **Flashed SW**:
  - A specific binary is flashed: `hci_bb.bin` (available in the Bluetooth application examples)
- **Test method**:
  - Generator for the desired signal: CMW270 R&S
  - Criterion: PER < 30. 8% with 1500 packets
  - Channels under test: 0, 19 and 39
- **Result**:

Table 19. Carrier frequency offset and drift at 1 Msps

TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 1 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 1 Ms/s] @ Payload length: 37, Statistic count: 10					
Channel 0					
tblContinuation_5_1					
Frequency accuracy	-150.00	150.00	-29.20	kHz	Passed
Frequency drift	-50.00	50.00	1.91	kHz	Passed
Max. drift rate	-20.00	20.00	1.68	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-29.31	kHz	Passed
Initial frequency drift	-23.00	23.00	-1.15	kHz	Passed
Channel 19					
tblContinuation_5_2					
Frequency accuracy	-150.00	150.00	-29.68	kHz	Passed

Table continues on the next page...

Table 19. Carrier frequency offset and drift at 1 Msps (continued)

TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 1 Ms/s]	Lower limit	Upper limit	Measured	Unit	Status
TP/TRM-LE/CA/BV-12-C [Carrier frequency offset and drift at 1 Ms/s] @ Payload length: 37, Statistic count: 10					
Frequency drift	-50.00	50.00	1.84	kHz	Passed
Max. drift rate	-20.00	20.00	-1.58	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-29.82	kHz	Passed
Initial frequency drift	-23.00	23.00	-1.82	kHz	Passed
Channel 39					
tblContinuation_5_3					
Frequency accuracy	-150.00	150.00	-29.69	kHz	Passed
Frequency drift	-50.00	50.00	-1.67	kHz	Passed
Max. drift rate	-20.00	20.00	1.62	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-30.30	kHz	Passed
Initial frequency drift	-23.00	23.00	-0.84	kHz	Passed

Table 20. 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_11_1					
Frequency accuracy	-150.00	150.00	-28.98	kHz	Passed
Frequency drift	-50.00	50.00	-2.14	kHz	Passed
Max. drift rate	-20.00	20.00	-2.16	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-29.79	kHz	Passed
Initial frequency drift	-23.00	23.00	-1.91	kHz	Passed
Channel 19					
tblContinuation_11_2					
Frequency accuracy	-150.00	150.00	-29.32	kHz	Passed
Frequency drift	-50.00	50.00	-1.72	kHz	Passed
Max. drift rate	-20.00	20.00	1.62	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-30.01	kHz	Passed
Initial frequency drift	-23.00	23.00	-1.62	kHz	Passed
Channel 39					
tblContinuation_11_3					

Table continues on the next page...

Table 20. 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					
Frequency accuracy	-150.00	150.00	-30.22	kHz	Passed
Frequency drift	-50.00	50.00	-2.06	kHz	Passed
Max. drift rate	-20.00	20.00	2.29	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-30.82	kHz	Passed
Initial frequency drift	-23.00	23.00	-1.45	kHz	Passed

Table 21. 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					
Channel 0					
tblContinuation_16_1					
Frequency accuracy	-150.00	150.00	-28.34	kHz	Passed
Frequency drift	-50.00	50.00	-1.41	kHz	Passed
Max. drift rate	-19.20	19.20	1.40	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-29.14	kHz	Passed
tblContinuation_16_2					
Channel 19					
tblContinuation_16_3					
Frequency accuracy	-150.00	150.00	-28.75	kHz	Passed
Frequency drift	-50.00	50.00	-1.44	kHz	Passed
Max. drift rate	-19.20	19.20	1.56	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-29.60	kHz	Passed
Channel 39					
tblContinuation_16_4					
Frequency accuracy	-150.00	150.00	-29.26	kHz	Passed
Frequency drift	-50.00	50.00	-1.39	kHz	Passed
Max. drift rate	-19.20	19.20	1.82	kHz/50 µs	Passed
Frequency offset	-150.00	150.00	-30.07	kHz	Passed

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

3.2 Rx tests

3.2.1 Test setup

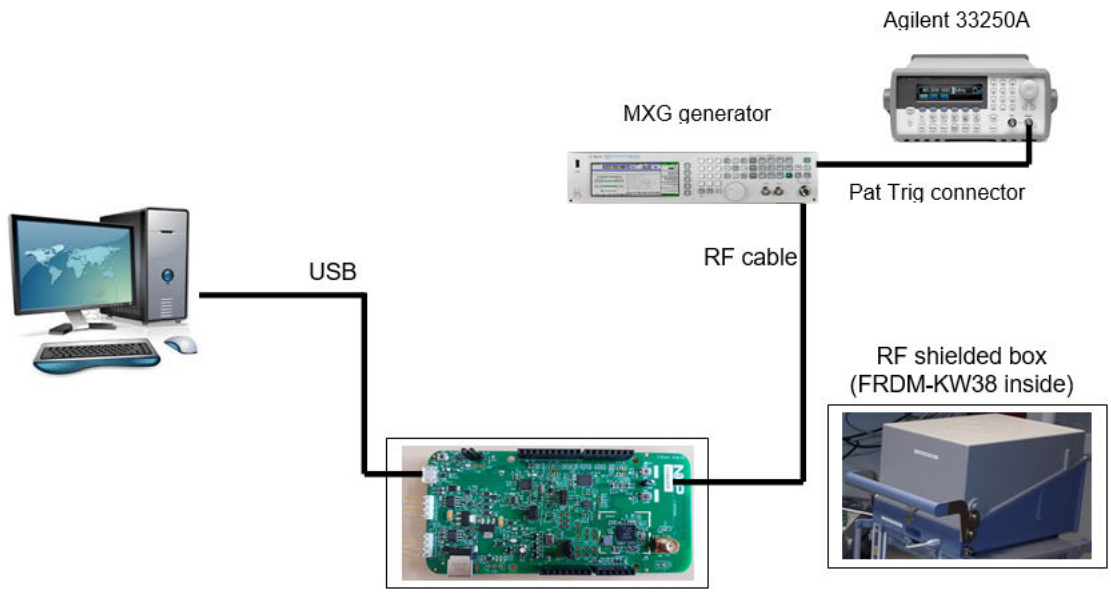


Figure 37. Conducted Rx test setup for sensitivity with RF generator and faraday box

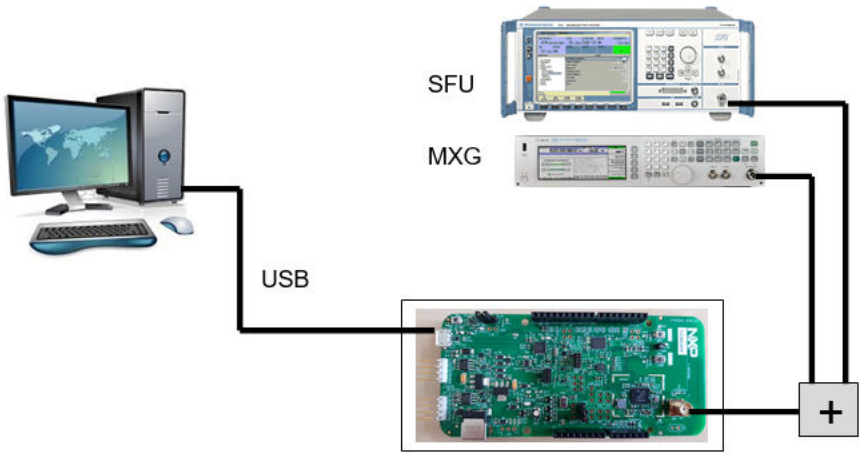


Figure 38. Conducted Rx test setup for interference rejection

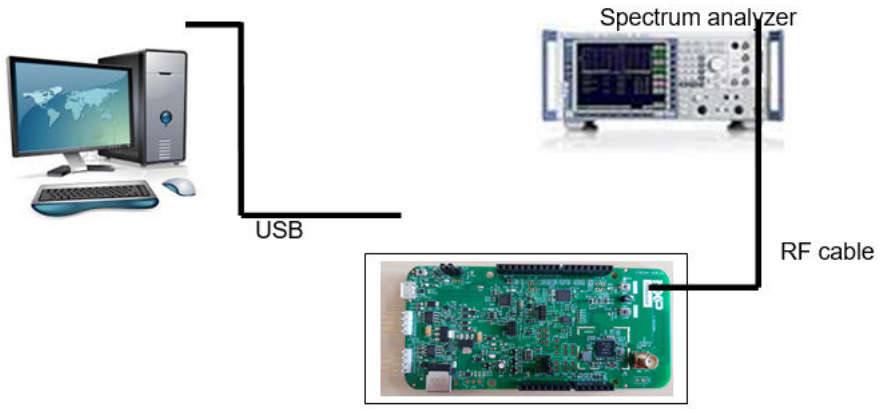


Figure 39. Conducted Rx test setup for spurious

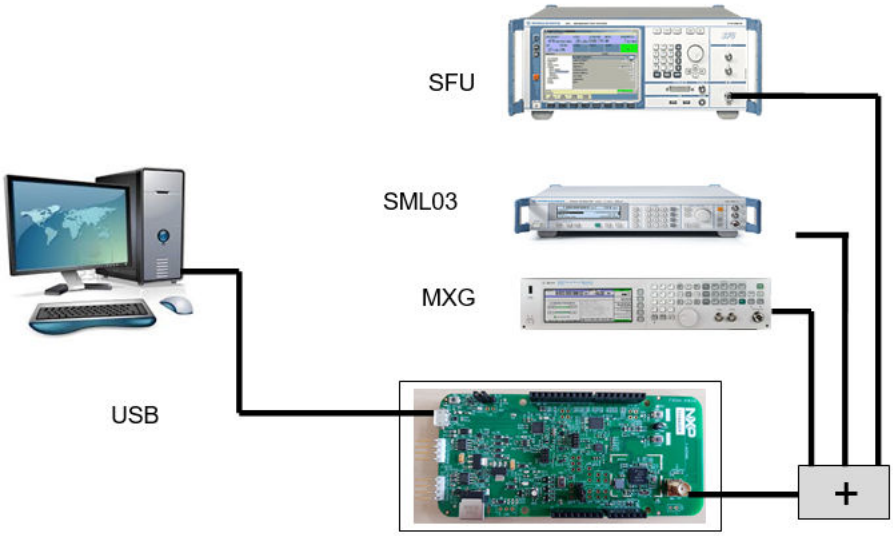


Figure 40. Conducted Rx test setup for intermodulation performances

3.2.2 Sensitivity

3.2.2.1 With the ARB generator

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - To remain immune to the external parasitic signals, put the FRDM-KW38 into an RF shielded box, as shown in Figure 41.

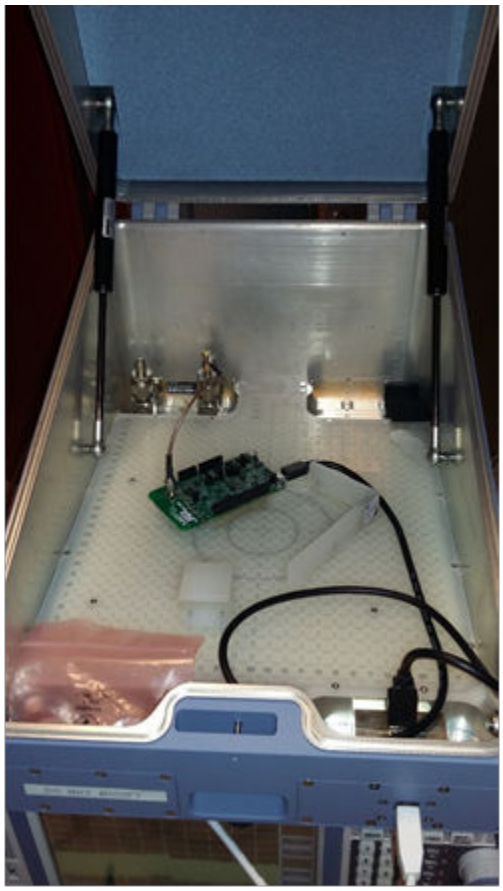


Figure 41. Sensitivity test

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: Bluetooth LE 1 Msps, 2 Msps, 500 Ksps LR (S=2) & 125 Ksps LR (S=8)
- Set it to Channel 0.
- The connection is automatically established and the PER (Packet Error Rate) 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.

- **Results**:

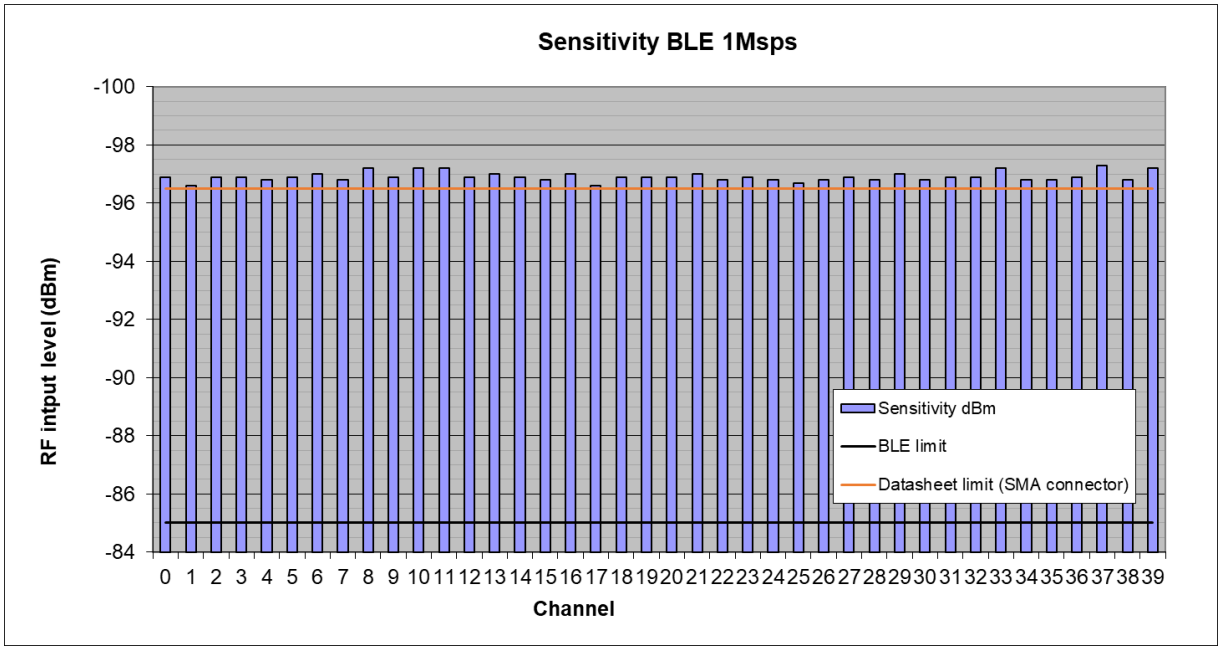


Figure 42. Sensitivity result – Bluetooth LE 1 Msps

- The best sensitivity is on Channel 37: -97.3 dBm.
- The lowest sensitivity is on Channel 17: -96.6 dBm.
- Delta over channels: 0.7 dB.

Figure 43 shows an average value of -96.9 dBm (1 Msps) at SMA connector.

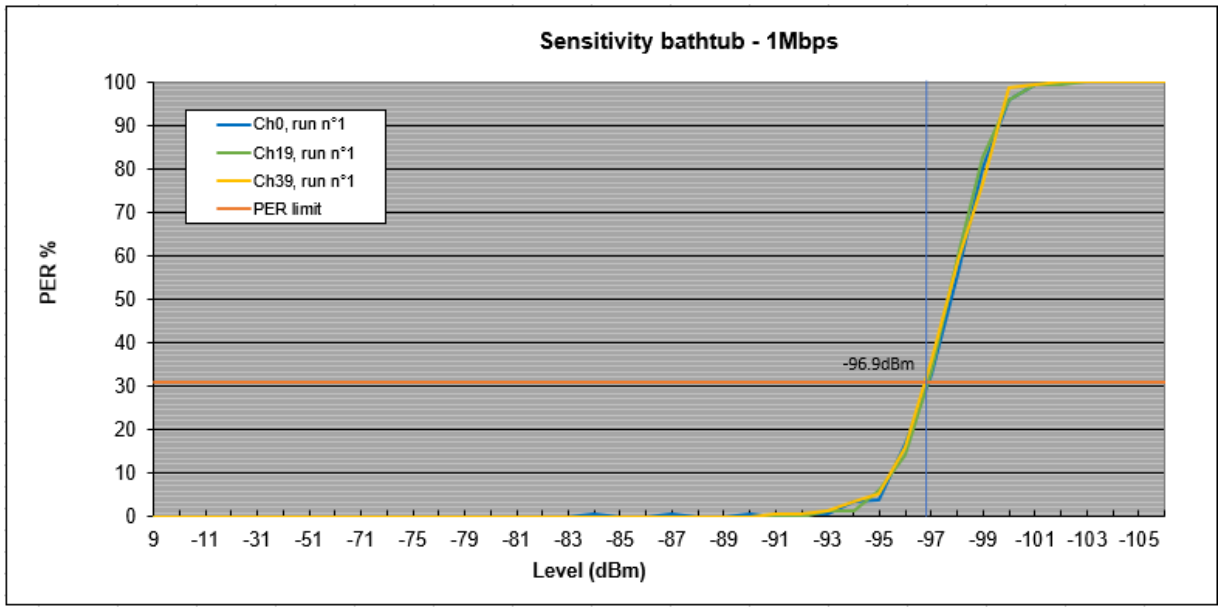


Figure 43. Sensitivity bathtub result – Bluetooth LE 1 Msps

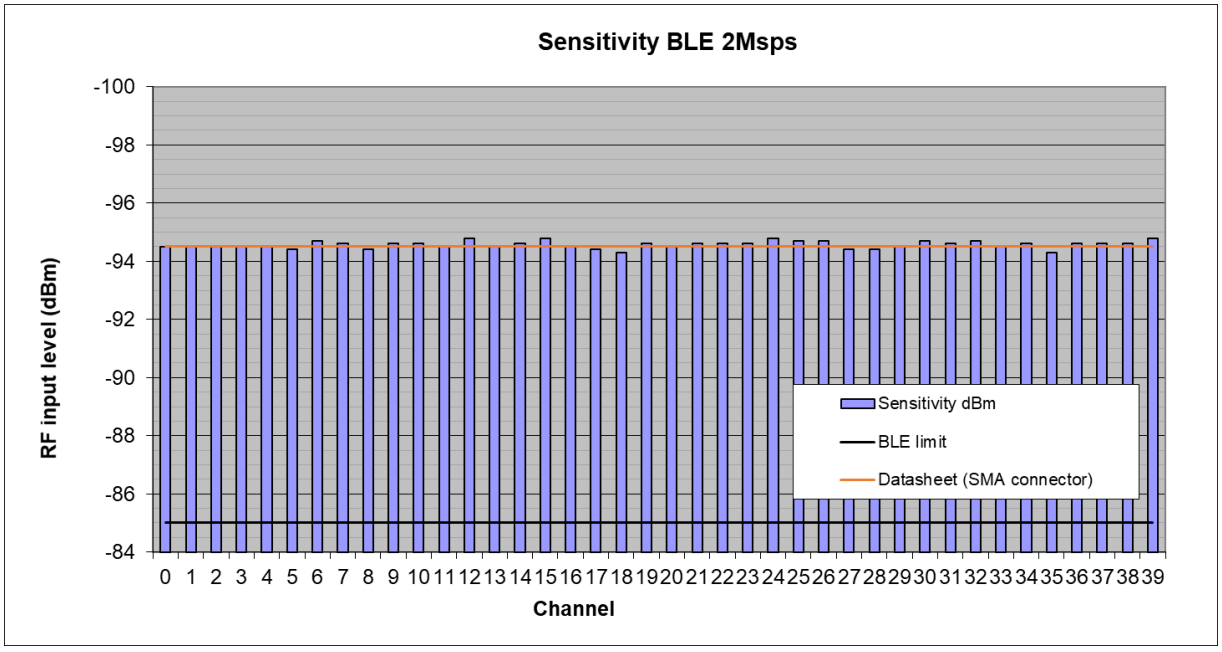


Figure 44. Sensitivity result – Bluetooth LE 2 Msps

- The best sensitivity is on Channel 39: -94.8 dBm.
- The lowest sensitivity is on Channel 18: -94.3 dBm.
- Delta over channels: 0.5 dB.

Figure 45 show s an average value of -94.6 dBm (2 Msps) at SMA connector.

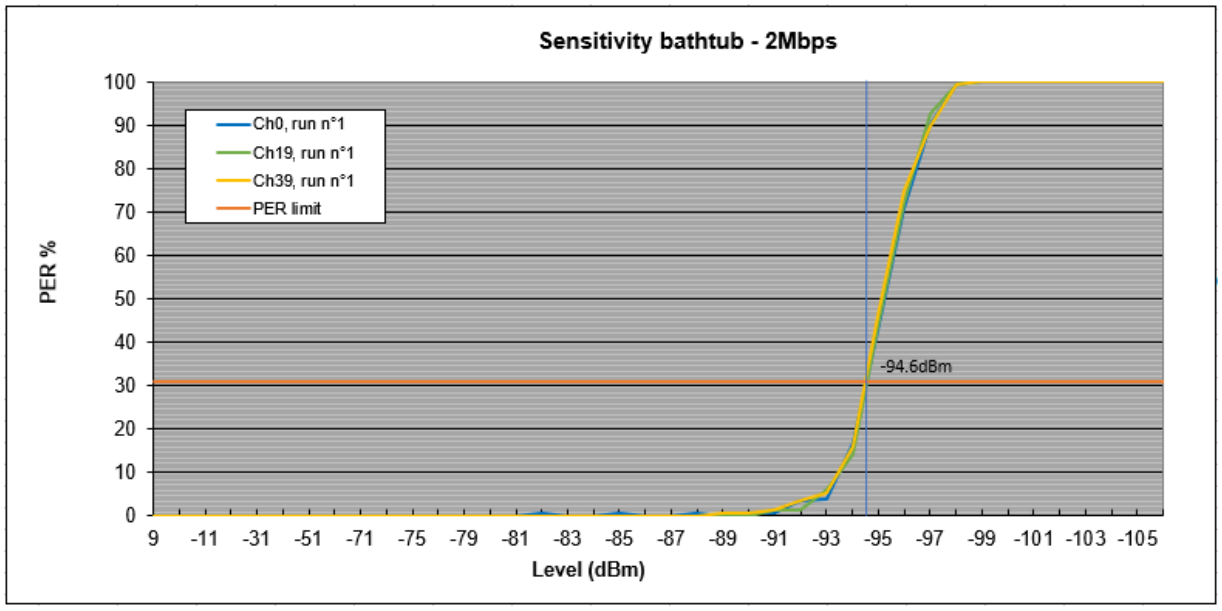


Figure 45. Sensitivity bathtub result – BLE 2 Msps

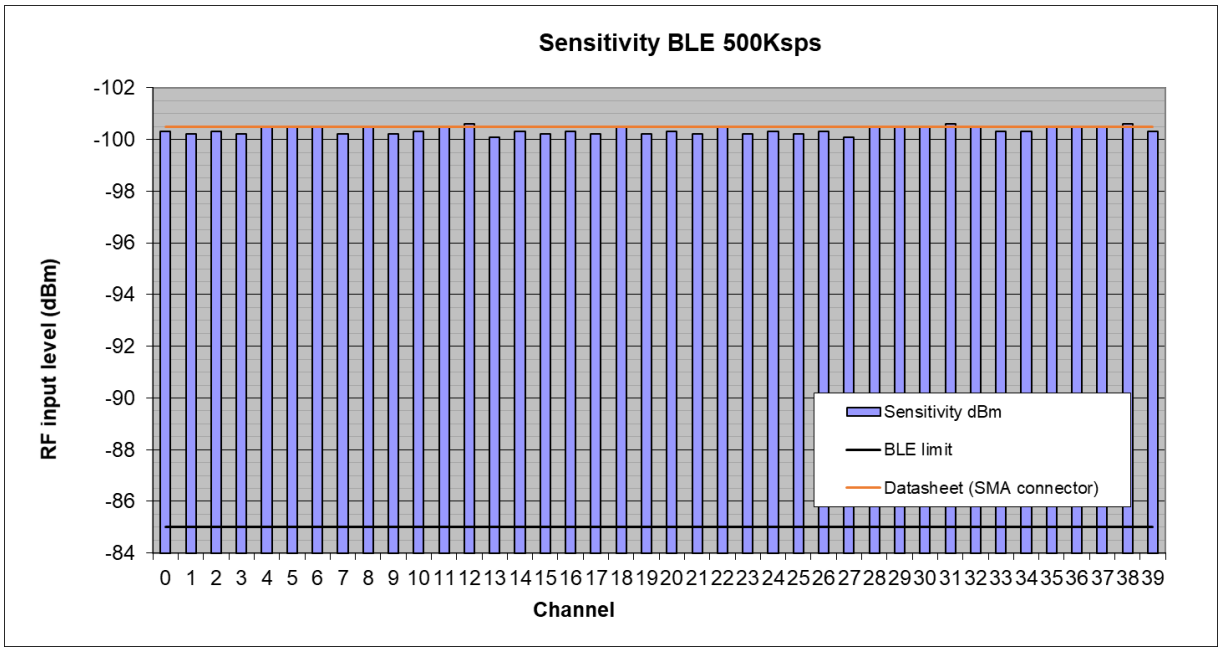


Figure 46. Sensitivity result – Bluetooth LE 500 Ksps (LR S=2)

- The best sensitivity is on Channel 31: -100.6 dBm.
- The lowest sensitivity is on Channel 13: -100.1 dBm.
- Delta over channels: 0.5 dB.

Figure 47 shows an average value of -100.4 dBm (500 Ksps) at SMA connector.

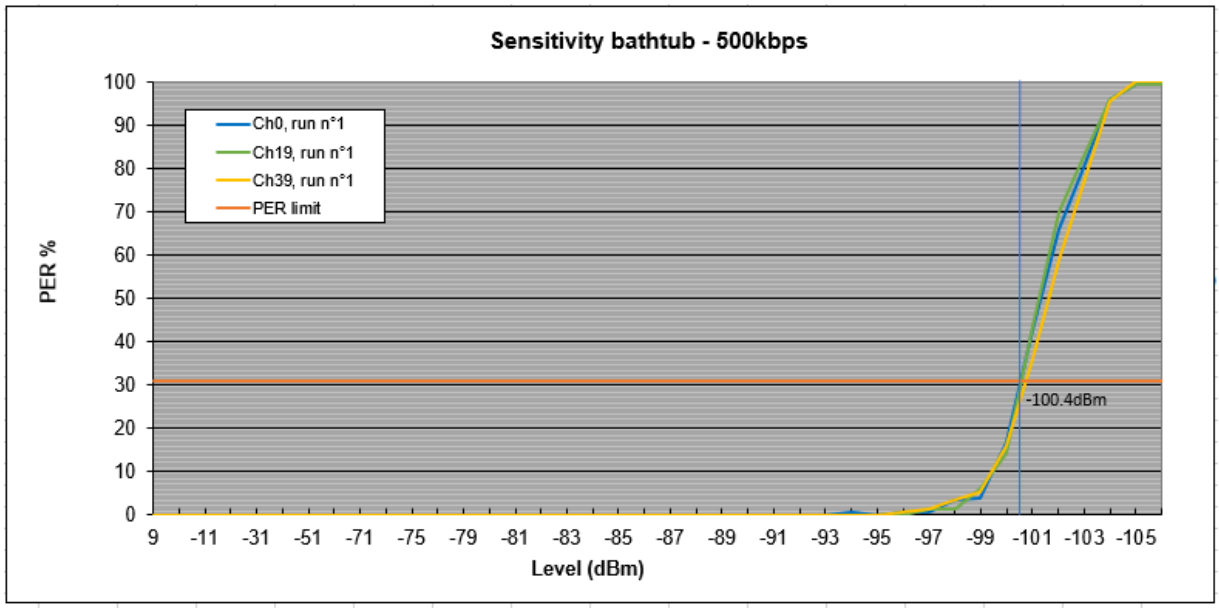


Figure 47. Sensitivity bathtub result – Bluetooth LE 500 Ksps

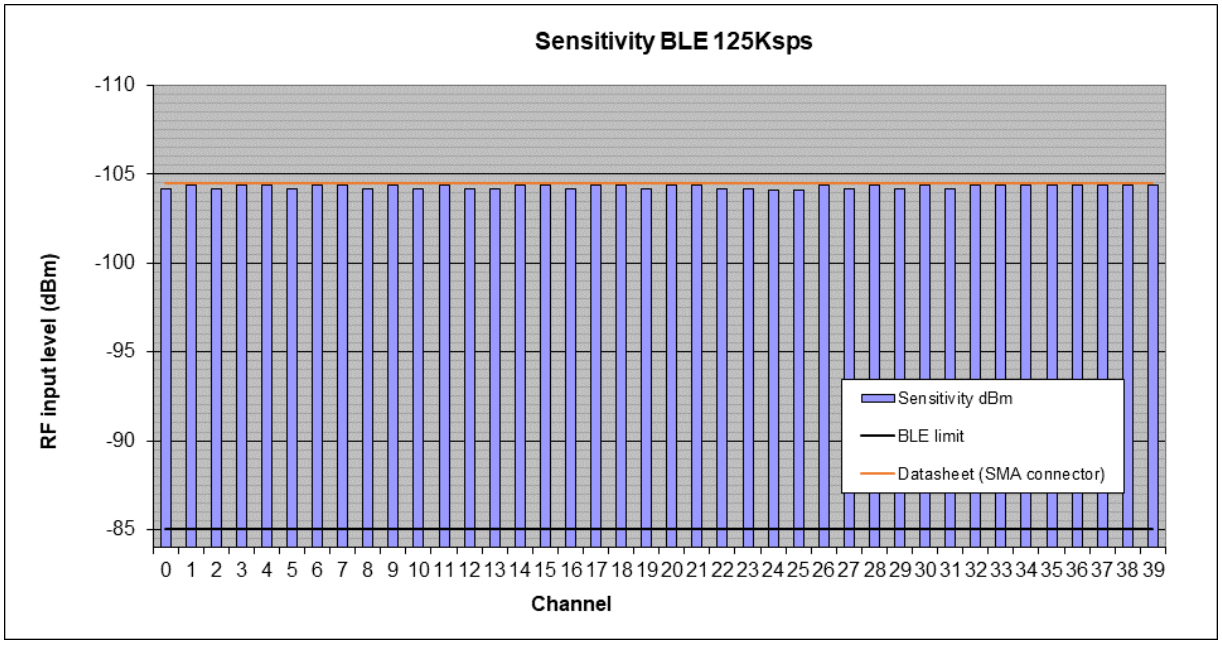


Figure 48. Sensitivity result – Bluetooth LE 125 Ksps (LR S=8)

- The best sensitivity is on Channel 38: - 104.4 dBm
- The lowest sensitivity is on Channel 10: -104.1 dBm
- Delta over channels: 0.3 dB

Figure 49 shows an average value of -104.3 dBm (125 Ksps) at SMA connector.

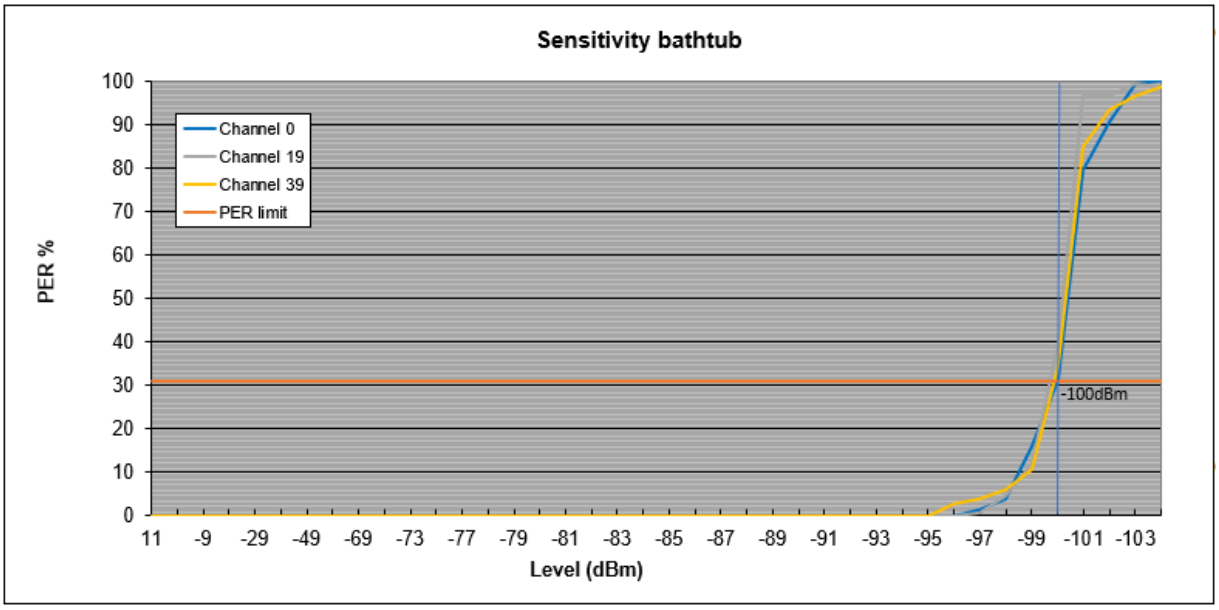


Figure 49. Sensitivity bathtub result – Bluetooth LE 125 Ksps

- **Conclusion**:
  - FRDM-KW38 widthstand an average sensitivity level of:
    - -96.9 dBm @1Msps (Data sheet typical value: -96.33 dBm at the SMA connector)

- -94.6 dBm @2Msps (Data sheet typical value: -94.33 dBm at the SMA connector)
- -100.4 dBm @LRS2 (Data sheet typical value: -100.33 dBm at the SMA connector)
- -104.3 dBm @LRS8 (Data sheet typical value: -104.33 dBm at the SMA connector)

NOTE

0.67 dB loss must be added to the sensitivity results to get the value at RF pin output (data sheet value).

Both Long Range sensitivity are out of specification. New silicon is planned to correct those limitations of performances.

3.2.3 Receiver maximum input level

- **Flashed SW**:
  - Connectivity test
- **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**:

  The Maximum input signal goes up to +17 dBm on Bluetooth LE 1 Msps & 2 Msps.
- **Conclusion**:
  - The results are limited by the maximum output power of the equipment.

3.2.4 Rx spurious

- **Flashed SW**:
  - 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
      - Start/stop frequency: 30 MHz / 1 GHz
        - RBW = 100 KHz, VBW = 300 KHz
      - Then set the start/stop frequency: 1 GHz / 30 GHz
        - RBW = 1 MHz, VBW = 3 MHz

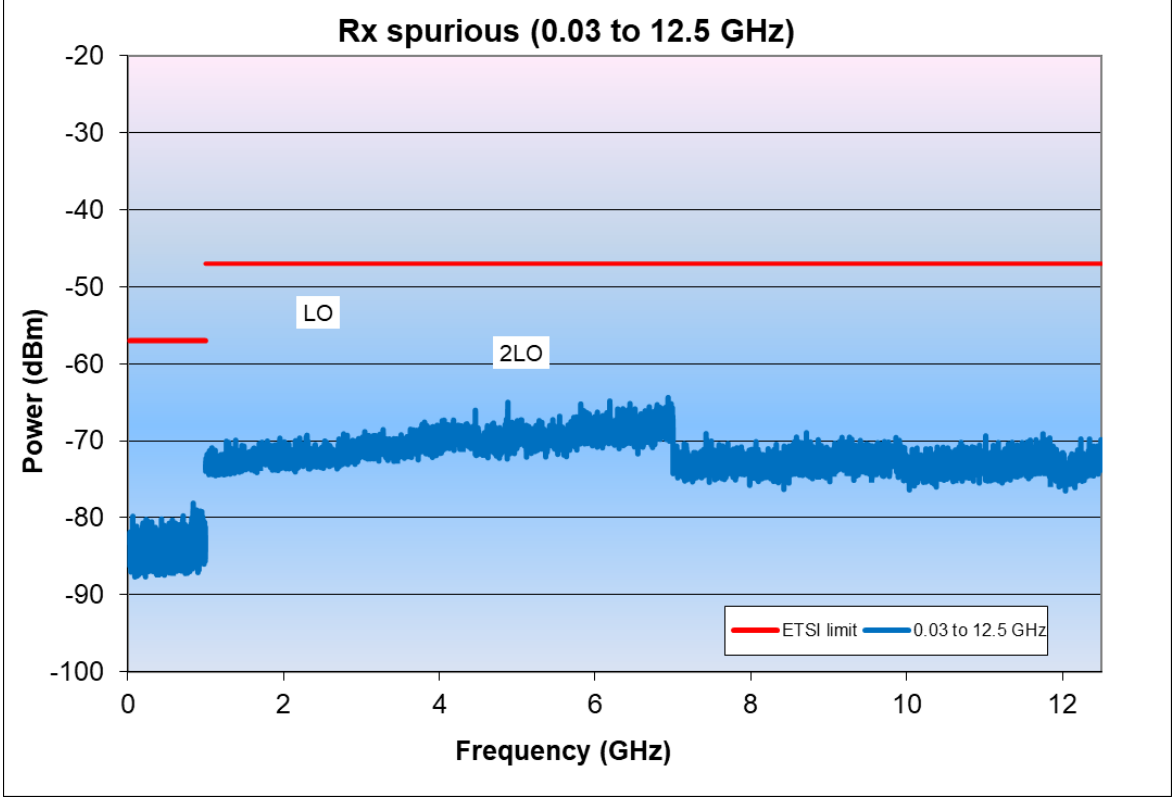


Figure 50. Conducted Rx spurious 30 MHz – 12.5 GHz

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

3.2.5 Receiver interference rejection performance

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

The interferers are located 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 wanted signal is set to -67 dBm; the interferer is increased until the PER threshold is reached
  - Channels under test: 2, 1 9, and 37
- **Results**:
  - **Bluetooth LE @1Msps**:

	ch2 2406			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2402	2404	2408	2410
Interferer level (dBm)	-26.6	-65.6	-66.1	-25.6
Interferer level (C/I dB)	-40.4	-1.4	-0.9	-41.4
BLE 5.0 limit (C/I dB)	-17	15	15	-17
Margin (dB)	23.4	16.4	15.9	24.4

	ch19 2440			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2436	2438	2442	2444
Interferer level (dBm)	-25.1	-66.1	-65.6	-25.6
Interferer level (C/I dB)	-41.9	-0.9	-1.4	-41.4
BLE 5.0 limit (C/I dB)	-17	15	15	-17
Margin (dB)	24.9	15.9	16.4	24.4

	ch37 2476			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2472	2474	2478	2480
Interferer level (dBm)	-24.6	-65.6	-64.6	-25.1
Interferer level (C/I dB)	-42.4	-1.4	-2.4	-41.9
BLE 5.0 limit (C/I dB)	-17	15	15	-17
Margin (dB)	25.4	16.4	17.4	24.9

	ch2 2406		Co-channel ch2 2406
	N-3MHz	N+3MHz	N
	2400	2412	2406
Interferer level (dBm)	-15.1	-15.1	-72.2
Interferer level (C/I dB)	**-51.9**	**-51.9**	**5.2**
BLE 5.0 limit (C/I dB)	-27	-27	21
Margin (dB)	24.9	24.9	15.8

	ch19 2440		Co-channel ch19 2440
	N-3MHz	N+3MHz	N
	2434	2446	2440
Interferer level (dBm)	-14.6	-14.6	-72.6
Interferer level (C/I dB)	**-52.4**	**-52.4**	**5.6**
BLE 5.0 limit (C/I dB)	-27	-27	21
Margin (dB)	25.4	25.4	15.4

	ch37 2476		Co-channel ch37 2476
	N-3MHz	N+3MHz	N
	2470	2482	2476
Interferer level (dBm)	-14.6	-14.6	-72.5
Interferer level (C/I dB)	**-52.4**	**-52.4**	**5.5**
BLE 5.0 limit (C/I dB)	-27	-27	21
Margin (dB)	25.4	25.4	15.5

Figure 51. Adjacent, alternate and co-channel rejection Bluetooth LE @1Msps

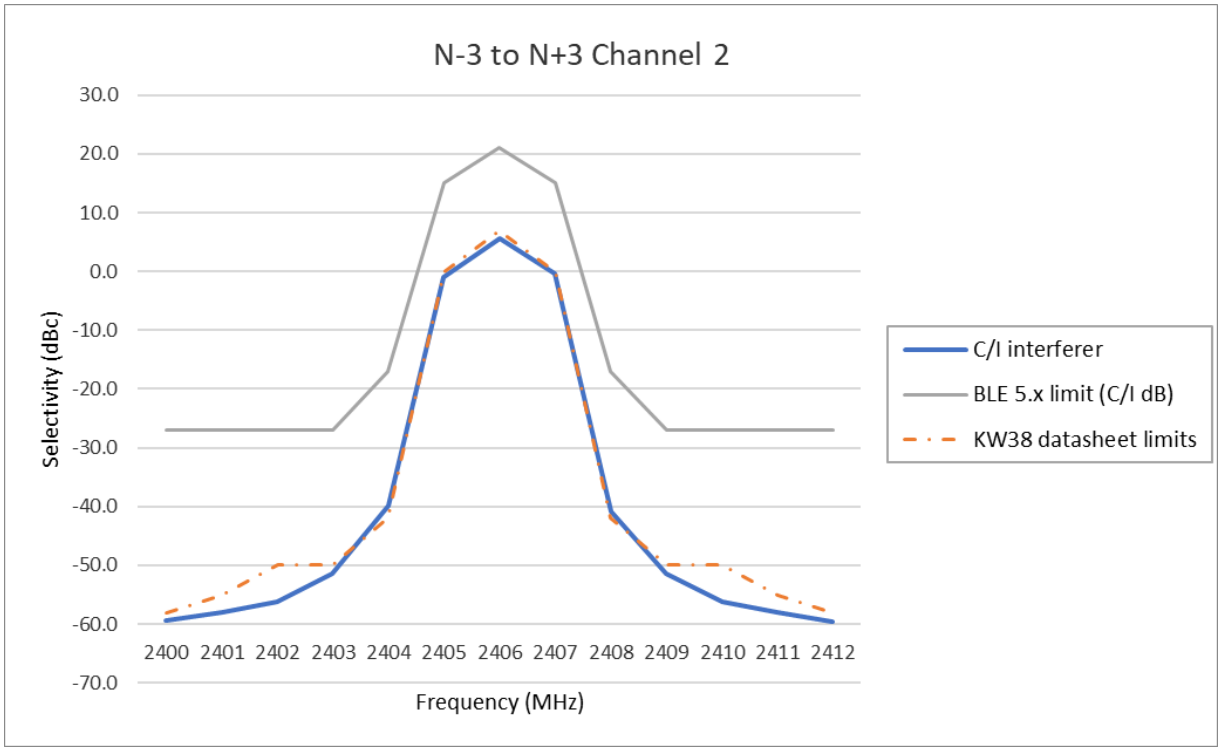


Figure 52. Adjacent, alternate and co-channel rejection Bluetooth LE @1Msps Channel 2

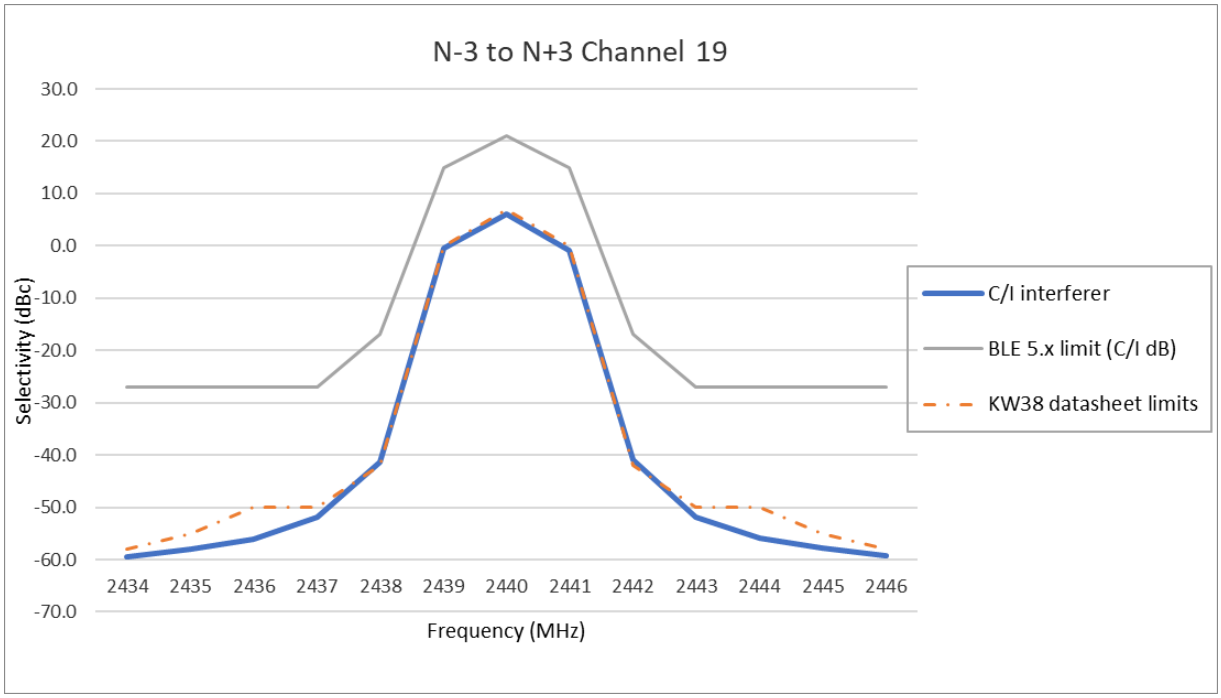


Figure 53. Adjacent, alternate and co-channel rejection Bluetooth LE @1Msps Channel 19

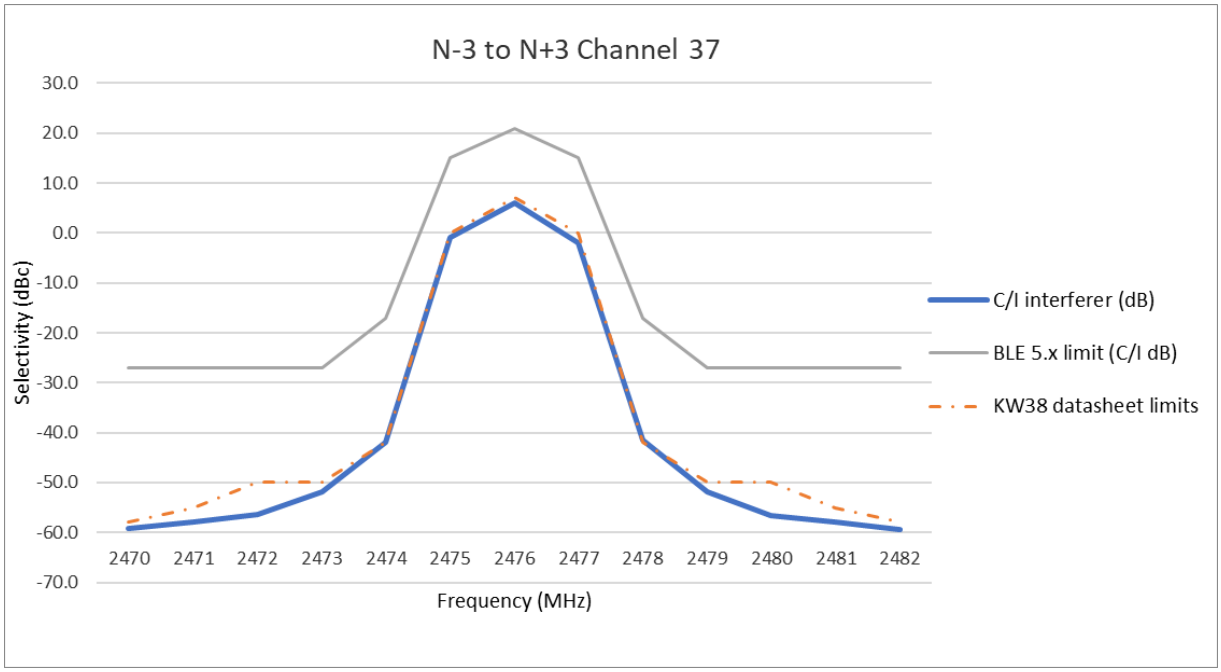


Figure 54. Adjacent, alternate and co-channel rejection Bluetooth LE @1Msps Channel 37

— **Bluetooth LE @2Msps**:

Results: Bluetooth LE @2Msps

	ch2 2406			
	N-4MHz	N-2MHz	N+2MHz	N+4MHz
	2398	2402	2410	2414
Interferer level (dBm)	-21.6	-63.0	-62.9	-21.7
Interferer level (C/I dB)	-45.4	-4.0	-4.1	-45.3
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	28.4	19.0	19.1	28.3

	ch19 2440			
	N-4MHz	N-2MHz	N+2MHz	N+4MHz
	2432	2436	2444	2448
Interferer level (dBm)	-21.7	-62.9	-62.8	-21.6
Interferer level (C/I dB)	-45.3	-4.1	-4.2	-45.4
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	28.3	19.1	19.2	28.4

	ch37 2476			
	N-4MHz	N-2MHz	N+2MHz	N+4MHz
	2468	2472	2480	2484
Interferer level (dBm)	-21.8	-63.1	-62.8	-21.6
Interferer level (C/I dB)	-45.2	-3.9	-4.2	-45.4
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	28.2	18.9	19.2	28.4

	ch2 2406		Co-channel ch2 2406
	N-6MHz	N+6MHz	N
	2400	2412	2406
Interferer level (dBm)	-13.1	-13.0	-73.8
Interferer level (C/I dB)	**-53.9**	**-54.0**	**6.8**
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	26.9	27.0	14.2

	ch19 2440		Co-channel ch19 2440
	N-6MHz	N+6MHz	N
	2434	2446	2440
Interferer level (dBm)	-13.0	-12.9	-73.8
Interferer level (C/I dB)	**-54.0**	**-54.1**	**6.8**
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	27.0	27.1	14.2

	ch37 2476		Co-channel ch37 2476
	N-6MHz	N+6MHz	N
	2470	2482	2476
Interferer level (dBm)	-13.2	-12.9	-73.8
Interferer level (C/I dB)	**-53.8**	**-54.1**	**6.8**
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	26.8	27.1	14.2

Figure 55. Adjacent, alternate and co-channel rejection Bluetooth LE @2Msps

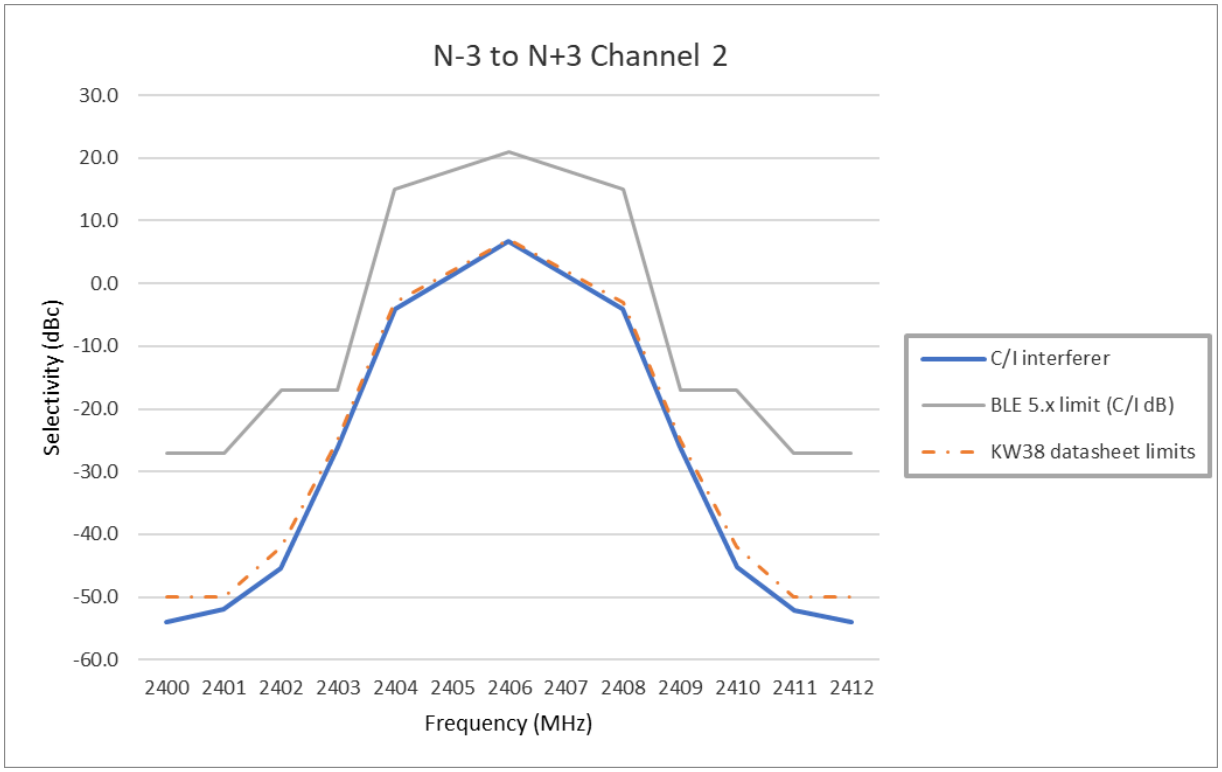


Figure 56. Adjacent, alternate and co-channel rejection Bluetooth LE @2Msps Channel 2

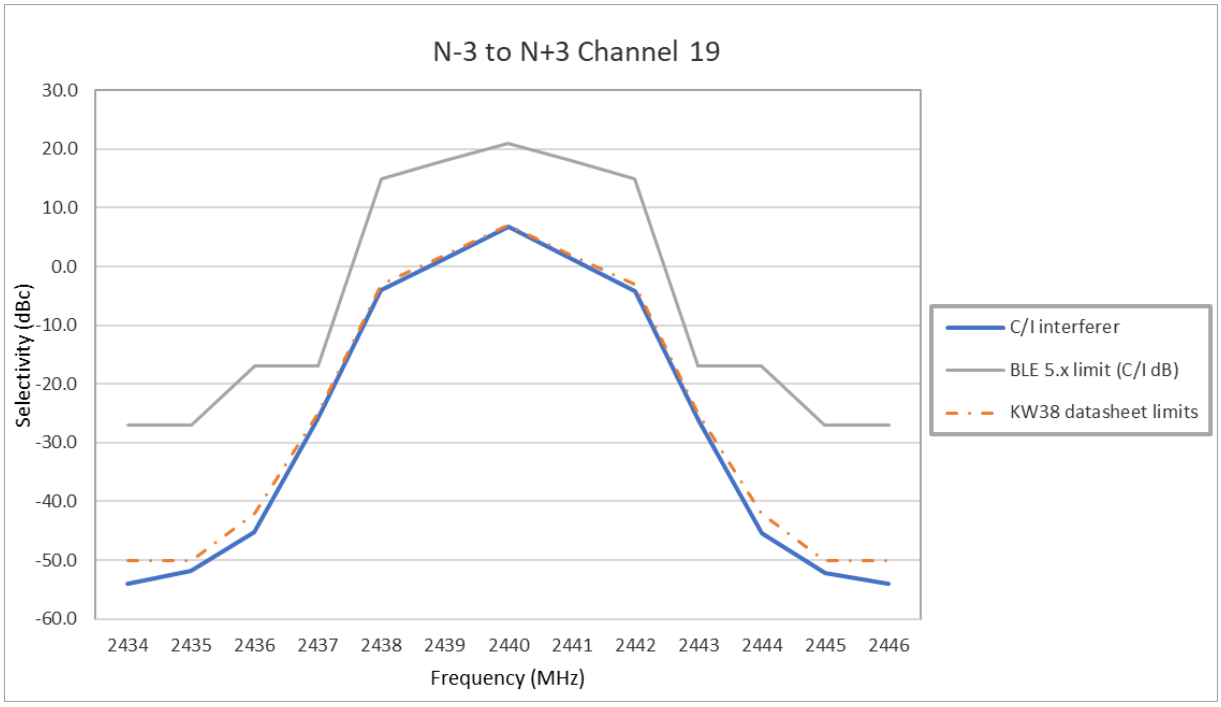


Figure 57. Adjacent, alternate and co-channel rejection Bluetooth LE @2Msps Channel 19

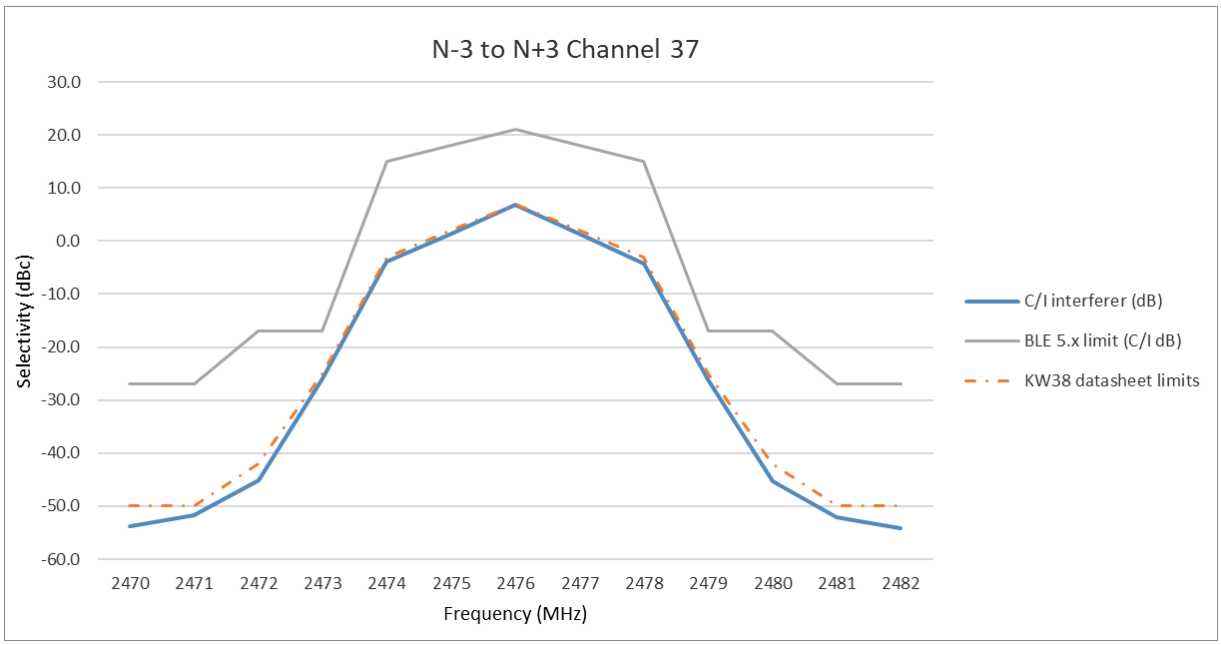


Figure 58. Adjacent, alternate and co-channel rejection Bluetooth LE @2Msps Channel 37

— **Bluetooth LE @500Ksps (LR S=2)**:

	ch2			
	2406			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2402	2404	2408	2410
Interferer level (dBm)	-17.9	-59.3	-59.2	-18.0
Interferer level (C/I dB)	-49.1	-7.7	-7.8	-49.0
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	32.1	22.7	22.8	32.0

	ch19			
	2440			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2436	2438	2442	2444
Interferer level (dBm)	-17.8	-59.2	-59.1	-17.9
Interferer level (C/I dB)	-49.2	-7.8	-7.9	-49.1
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	32.2	22.8	22.9	32.1

	ch37			
	2476			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2472	2474	2478	2480
Interferer level (dBm)	-17.7	-59.1	-59.0	-18.0
Interferer level (C/I dB)	-49.3	-7.9	-8.0	-49.0
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	32.3	22.9	23.0	32.0

	ch2		Co-channel
	2406		ch2
	N-3MHz	N+3MHz	2406
	2400	2412	N
			2406
Interferer level (dBm)	-11.6	-11.7	-72.0
Interferer level (C/I dB)	-55.4	-55.3	5.0
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	28.4	28.3	16.0

	ch19		Co-channel
	2440		ch19
	N-3MHz	N+3MHz	2440
	2434	2446	N
			2440
Interferer level (dBm)	-11.5	-11.6	-71.9
Interferer level (C/I dB)	-55.5	-55.4	4.9
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	28.5	28.4	16.1

	ch37		Co-channel
	2476		ch37
	N-3MHz	N+3MHz	2476
	2470	2482	N
			2476
Interferer level (dBm)	-11.6	-11.7	-71.8
Interferer level (C/I dB)	-55.4	-55.3	4.8
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	28.4	28.3	16.2

Figure 59. Adjacent, alternate and co-channel rejection Bluetooth LE @500Ksps (LR S=2)

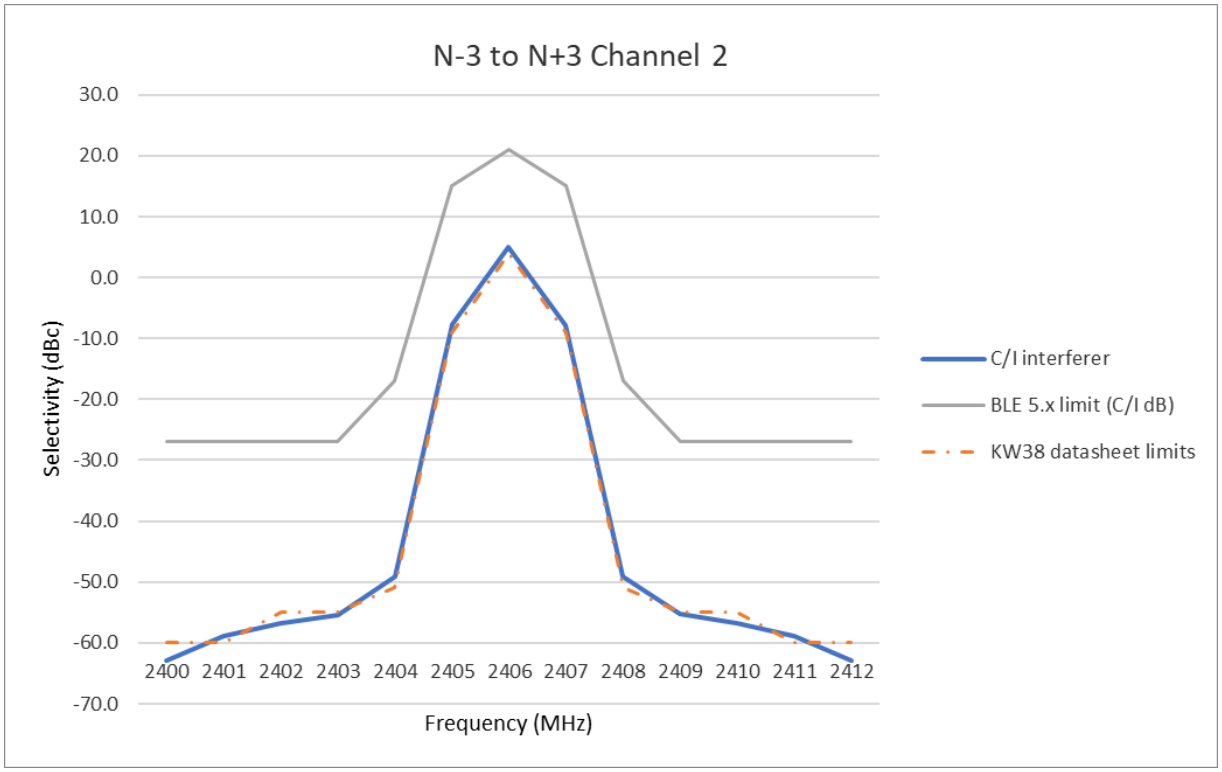


Figure 60. Adjacent, alternate and co-channel rejection Bluetooth LE @500Ksps (LR S=2) Channel 2

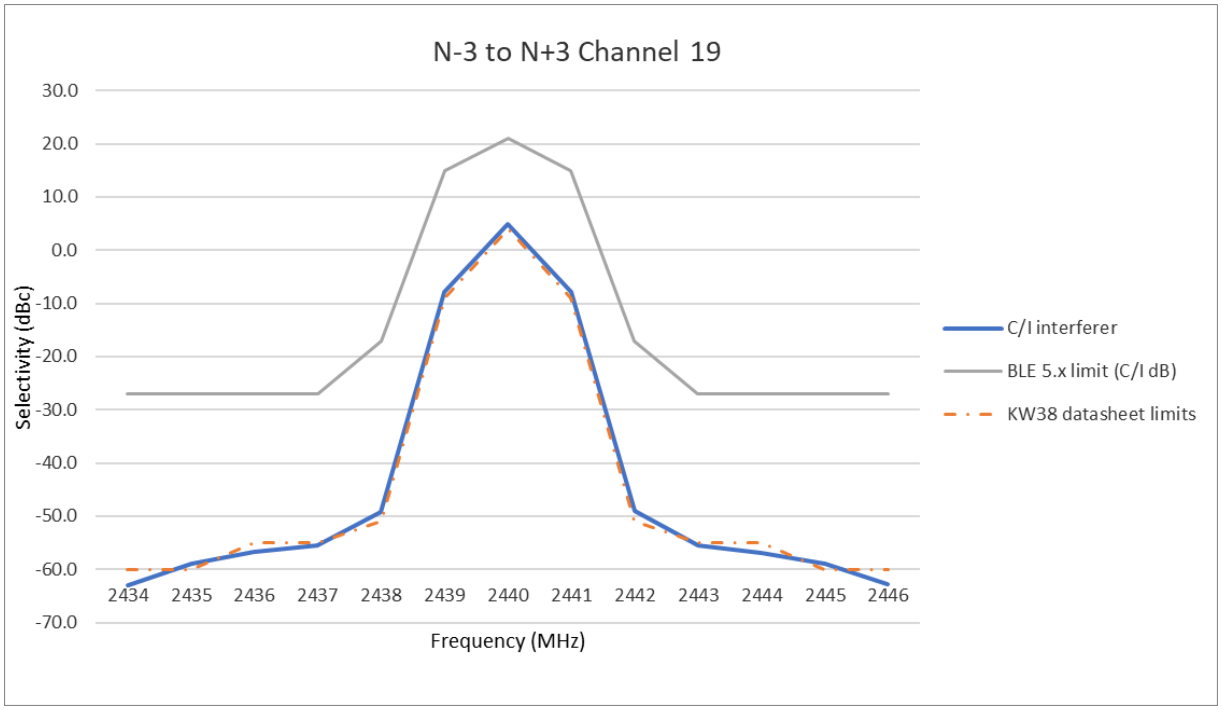


Figure 61. Adjacent, alternate and co-channel rejection Bluetooth LE @500Ksps (LR S=2) Channel 19

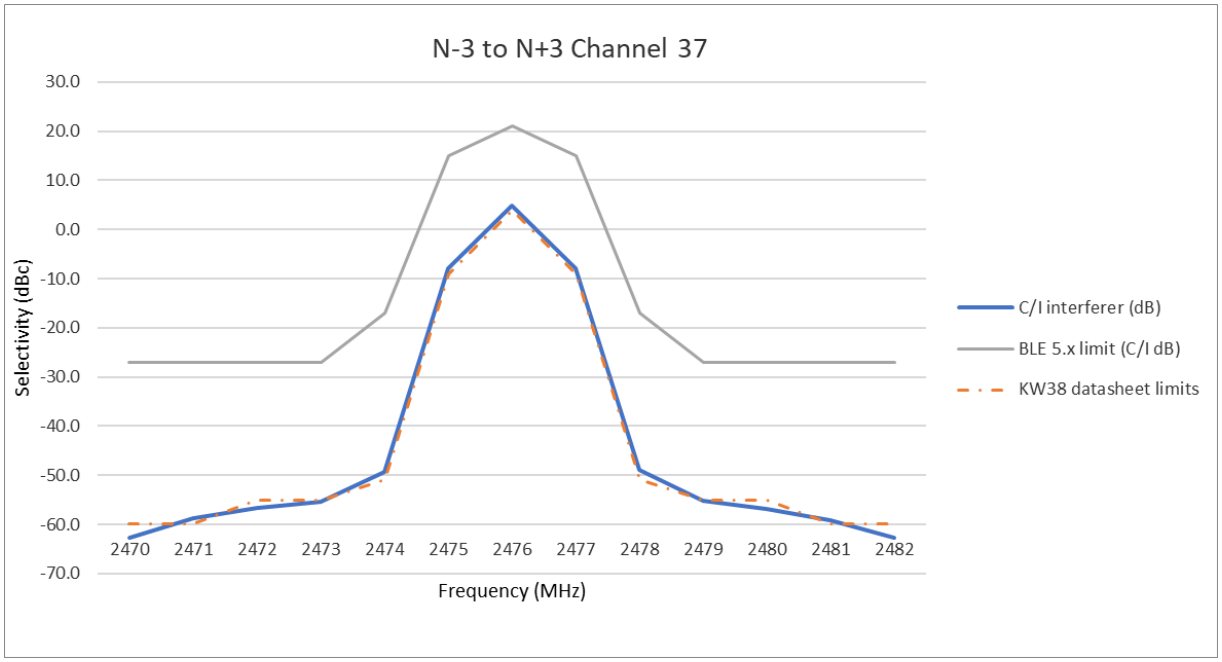


Figure 62. Adjacent, alternate and co-channel rejection Bluetooth LE @500Ksps (LR S=2) Channel 37

— **Bluetooth LE @125Ksps (LR S=8)**:

	ch2			
	2406			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2402	2404	2408	2410
Interferer level (dBm)	-19.2	-57.0	-56.9	-19.2
Interferer level (C/I dB)	-47.8	-10.0	-10.1	-47.8
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	30.8	25.0	25.1	30.8

	ch19			
	2440			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2436	2438	2442	2444
Interferer level (dBm)	-19.1	-56.9	-57.0	-19.1
Interferer level (C/I dB)	-47.9	-10.1	-10.0	-47.9
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	30.9	25.1	25.0	30.9

	ch37			
	2476			
	N-2MHz	N-1MHz	N+1MHz	N+2MHz
	2472	2474	2478	2480
Interferer level (dBm)	-19.0	-56.8	-57.0	-19.0
Interferer level (C/I dB)	-48.0	-10.2	-10.0	-48.0
BLE 5.x limit (C/I dB)	-17	15	15	-17
Margin (dB)	31.0	25.2	25.0	31.0

	ch2		Co-channel
	2406		ch2
	N-3MHz	N+3MHz	N
	2400	2412	2406
Interferer level (dBm)	-16.1	-16.2	-83.4
Interferer level (C/I dB)	-50.9	-50.8	16.4
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	23.9	23.8	4.6

	ch19		Co-channel
	2440		ch19
	N-3MHz	N+3MHz	N
	2434	2446	2440
Interferer level (dBm)	-16.0	-16.1	-83.4
Interferer level (C/I dB)	-51.0	-50.9	16.4
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	24.0	23.9	4.6

	ch37		Co-channel
	2476		ch37
	N-3MHz	N+3MHz	N
	2470	2482	2476
Interferer level (dBm)	-16.1	-16.0	-83.2
Interferer level (C/I dB)	-50.9	-51.0	16.2
BLE 5.x limit (C/I dB)	-27	-27	21
Margin (dB)	23.9	24.0	4.8

Figure 63. Adjacent, alternate and co-channel rejection Bluetooth LE @125Ksps (LR S=8)

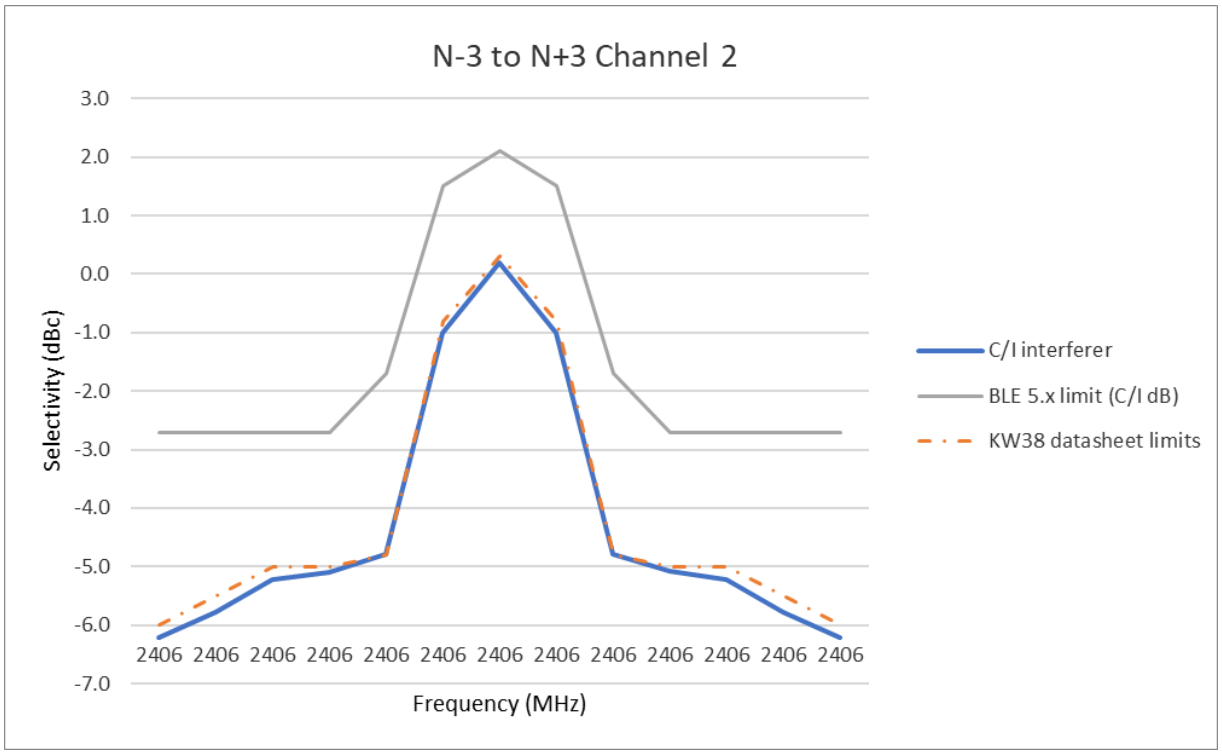


Figure 64. Adjacent, alternate and co-channel rejection Bluetooth LE @125Ksps (LR S=8) Channel 2

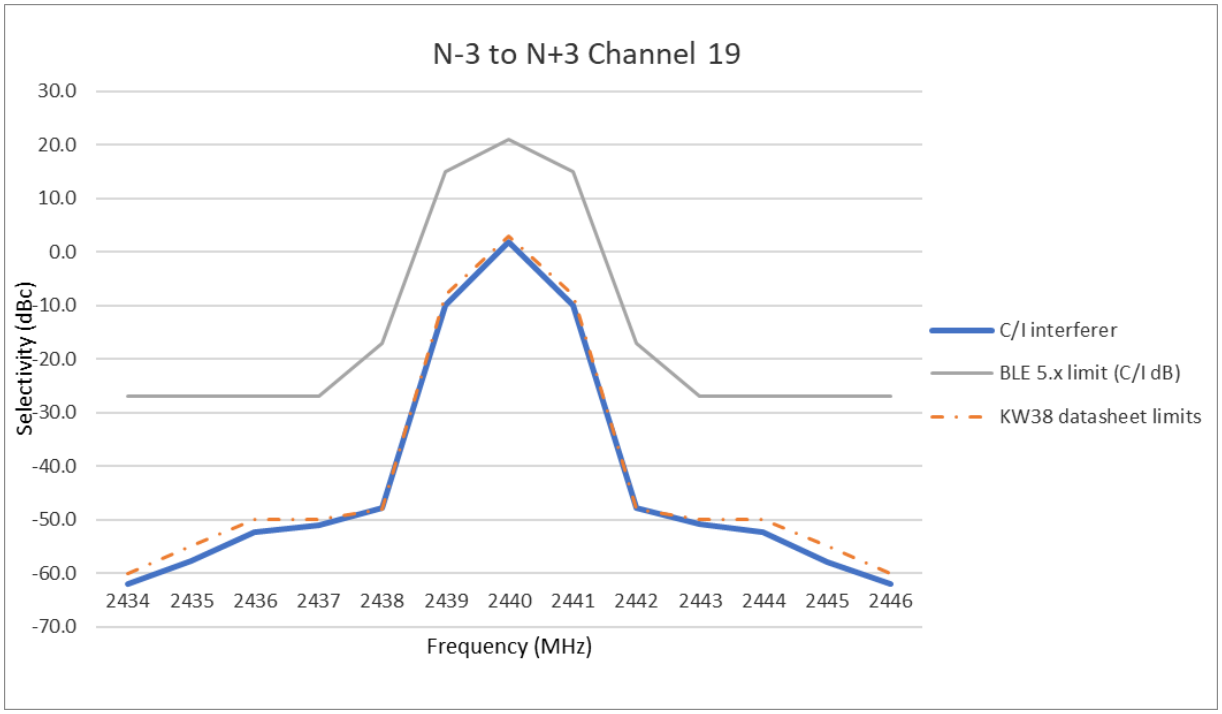


Figure 65. Adjacent, alternate and co-channel rejection Bluetooth LE @125Ksps (LR S=8) Channel 19

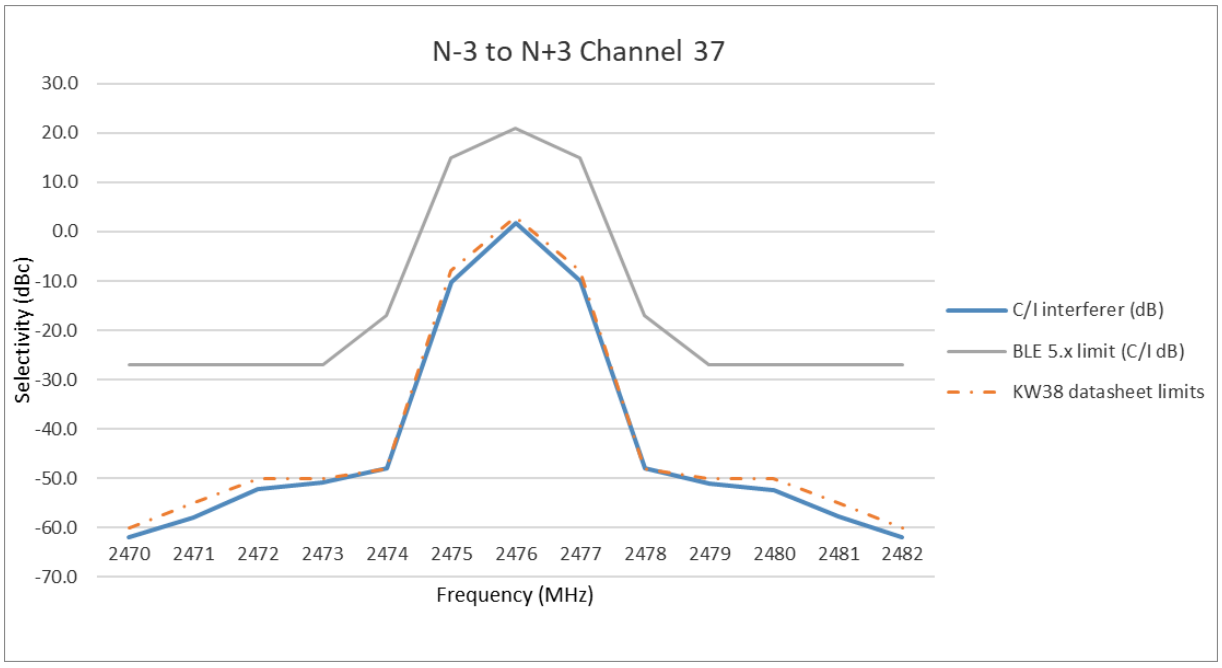


Figure 66. Adjacent, alternate and co-channel rejection Bluetooth LE @125Ksps (LR S=8) Channel 37

- **Conclusion**
  - **Bluetooth LE @1Msps**:

    Good margin, in line with the expected results.
  - **Bluetooth LE @2Msps**:

Good margin, in line with the expected results.

- **Bluetooth LE @500Ksps (LR S=2)**:

  Good margin, in line with the expected results.

- **Bluetooth LE @125Ksps (LR S=8)**:

  Good margin, in line with the expected results.

  Results are compliant with Bluetooth LE 5.0.

3.2.5.2 Receiver blocking

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

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 SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-1Msps**): Agilent N5182A
  - Generator for interferers: R&S SFU
  - Criterion: PER < 10%
  - The wanted signal is set to Pmin+6dB (-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)	-21.1	-16.6	-17.6	-17.6
300 328 limit (dBm)	-53	-53	-53	-53
Margin (dB)	31.9	36.4	35.4	35.4

	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)	-17.1	-17.6	-17.6	-17.1	-17.1	-17.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	29.9	29.4	29.4	29.9	29.9	29.4

	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)	-16.6	-15.6	-15.6	-15.6	-15.1	-15.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	30.4	31.4	31.4	31.4	31.9	31.4

	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)	-17.6	-17.1	-16.6	-16.6	-15.6	-16.6
300 328 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	29.4	29.9	30.4	30.4	31.4	30.4

Figure 67. Receiver Blocking (Out Of Band) rejection - Bluetooth LE-1 Msps

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

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 SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-1Msps**): Agilent N5182A
  - Generator for interferers: R&S SFU
  - Criterion: PER < 10%

— The wanted signal is set to Pmin+6 dB (-82 dBm) and 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	**Low**	**High**	**High**
	2380	2503.5	2380	2503.5
Interferer level (dBm)	**-19.6**	**-17.6**	**-19.6**	**-18.1**
300 328 limit (dBm)	-57	-57	-57	-57
Margin (dB)	37.4	39.4	37.4	38.9

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	**Low**	**High**	**High**
	2300	2583.5	2300	2583.5
Interferer level (dBm)	**-18.1**	**-17.6**	**-18.1**	**-17.6**
300 328 limit (dBm)	-47	-47	-47	-47
Margin (dB)	28.9	29.4	28.9	29.4

Figure 68. Receiver Blocking (Out Of Band) rejection - Bluetooth LE-1 Msps

- **Conclusion**:

— Good margin, in line with the expected results.

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 SW**:

— Connectivity test

- **Test method**:

— Generator for the desired signal (**Bluetooth LE-2Msps**): Agilent N5182A

— Generator for interferers: R&S SFU

— Criterion: PER < 10%

— The wanted signal is set to Pmin+6 dB (-82 dBm) and 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)	-21.1	-17.6	-19.6	-21.1
802.15.4 limit (dBm)	-53	-53	-53	-53
Margin (dB)	31.9	35.4	33.4	31.9

	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)	-18.6	-18.6	-19.1	-17.6	-17.6	-18.6
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	28.4	28.4	27.9	29.4	29.4	28.4

	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)	-17.6	-18.1	-17.6	-17.1	-17.1	-17.1
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	29.4	28.9	29.4	29.9	29.9	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)	-18.6	-17.6	-18.6	-19.1	-18.6	-19.1
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	28.4	29.4	28.4	27.9	28.4	27.9

Figure 69. Receiver Blocking (Out Of Band) rejection - Bluetooth LE-2 Msps

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

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 SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-2Msps**): Agilent N5182A
  - Generator for interferers: R&S SFU
  - Criterion: PER < 10%

- The wanted signal is set to Pmin+6 dB (-82 dBm) and 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	Low	High	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-23.6	-20.1	-22.1	-23.6
802.15.4 limit (dBm)	-57	-57	-57	-57
Margin (dB)	33.4	36.9	34.9	33.4

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-21.1	-21.1	-20.1	-20.1
802.15.4 limit (dBm)	-47	-47	-47	-47
Margin (dB)	25.9	25.9	26.9	26.9

Figure 70. Receiver Blocking (Out Of Band) rejection - Bluetooth LE-2 Msps

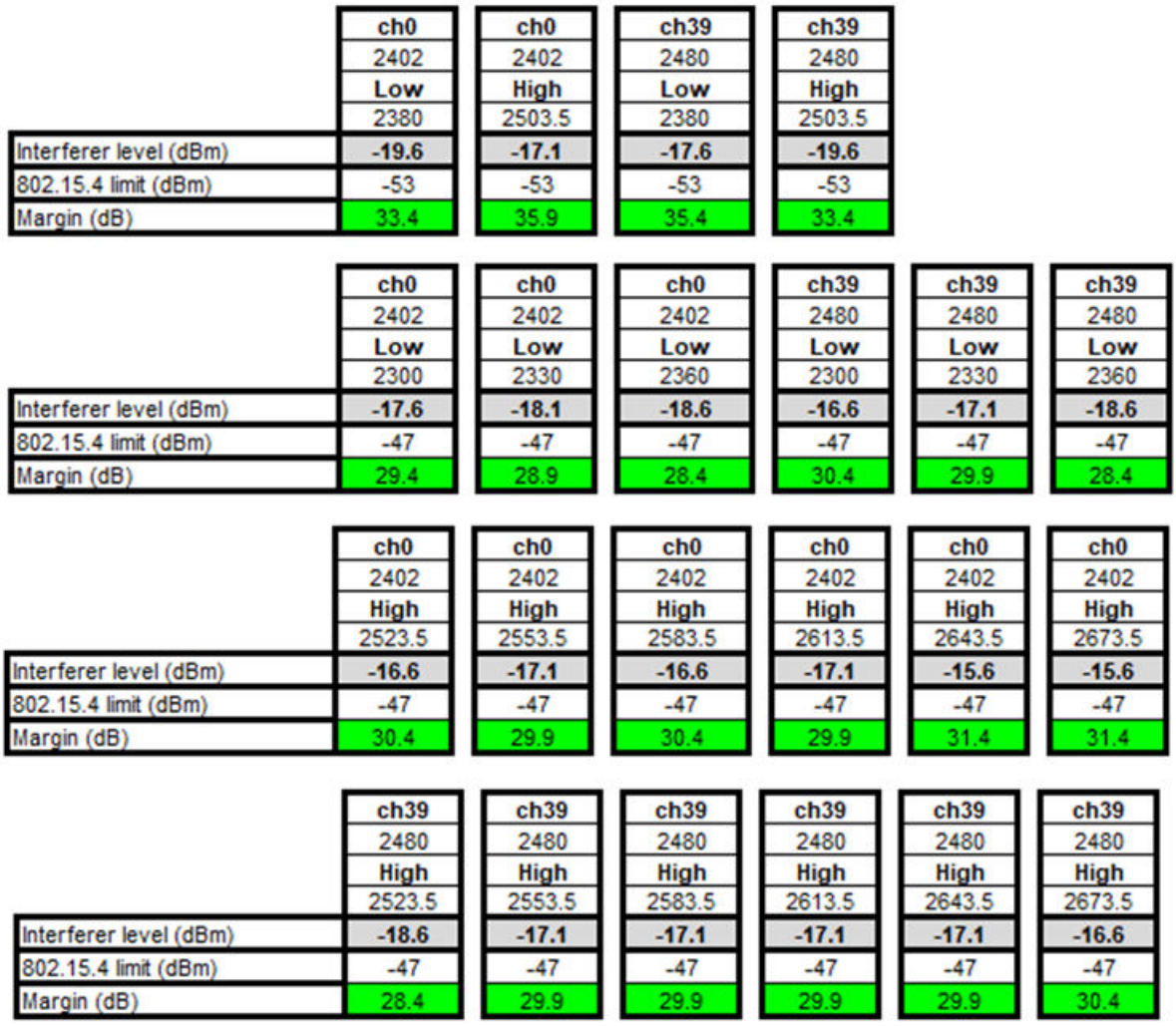
- **Conclusion**:
  - Good margin, in line with the expected results.

3.2.5.2.5 Receiver category 1 - Bluetooth LE-500 Ksps (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 SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-500Ksps [LR S=2]**): Agilent N5182A
  - Generator for interferers: R&S SFU
  - Criterion: PER < 10%
  - The wanted signal is set to Pmin+6 dB (-82 dBm) and 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)	-19.6	-17.1	-17.6	-19.6
802.15.4 limit (dBm)	-53	-53	-53	-53
Margin (dB)	33.4	35.9	35.4	33.4

	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)	-17.6	-18.1	-18.6	-16.6	-17.1	-18.6
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	29.4	28.9	28.4	30.4	29.9	28.4

	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)	-16.6	-17.1	-16.6	-17.1	-15.6	-15.6
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	30.4	29.9	30.4	29.9	31.4	31.4

	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)	-18.6	-17.1	-17.1	-17.1	-17.1	-16.6
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	28.4	29.9	29.9	29.9	29.9	30.4

Figure 71. Receiver Blocking (Out Of Band) rejection - Bluetooth LE-500 Ksps (LR S=2)

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

3.2.5.2.6 Receiver category 2 - Bluetooth LE-500 Ksps (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 SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-500Ksps [LR S=2]**): Agilent N5182A
  - Generator for interferers: R&S SFU
  - Criterion: PER < 10%
  - The wanted signal is set to Pmin+6 dB (-82 dBm) and 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	Low	High	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-20.1	-17.6	-18.1	-20.1
802.15.4 limit (dBm)	-57	-57	-57	-57
Margin (dB)	36.9	39.4	38.9	36.9

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-17.6	-16.6	-17.1	-18.1
802.15.4 limit (dBm)	-47	-47	-47	-47
Margin (dB)	29.4	30.4	29.9	28.9

Figure 72. Receiver Blocking (Out Of Band) rejection - Bluetooth LE-500 Ksps (LR S=2)

- **Conclusion**:

  - Good margin, in line with the expected results.

3.2.5.2.7 Receiver category 1 - Bluetooth LE-125 Ksps (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 SW**:

  - Connectivity test

- **Test method**:

  - Generator for the desired signal (**Bluetooth LE-125Ksps [LR S=8]**): Agilent N5182A
  - Generator for interferers: R&S SFU
  - Criterion: PER < 10%
  - The wanted signal is set to Pmin+6 dB (-82 dBm) and 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)	-11.0	-8.5	-8.5	-10.5
802.15.4 limit (dBm)	-53	-53	-53	-53
Margin (dB)	42.0	44.5	44.5	42.5

	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)	-9.5	-9.0	-9.0	-9.0	-9.5	-10.5
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	37.5	38.0	38.0	38.0	37.5	36.5

	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)	-8.5	-9.0	-10.0	-10.5	-10.5	-10.5
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	38.5	38.0	37.0	36.5	36.5	36.5

	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)	-8.5	-8.5	-9.5	-10.5	-10.5	-10.5
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	38.5	38.5	37.5	36.5	36.5	36.5

Figure 73. Receiver Blocking (Out Of Band) rejection - Bluetooth LE-125 Ksps (LR S=8)

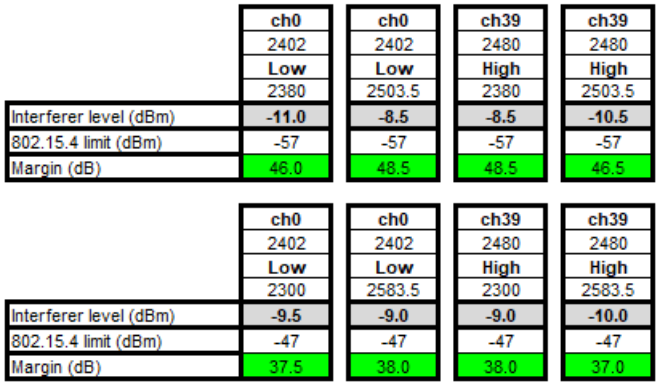
- **Conclusion**:
  - Good margin, in line with the expected results.

3.2.5.2.8 Receiver category 2 - Bluetooth LE - 125 Ksps (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 SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-125Ksps [LR S=8]**): Agilent N5182A
  - Generator for interferers: R&S SFU
  - Criterion: PER < 10%
  - The wanted signal is set to Pmin+6 dB (-82 dBm) and 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	Low	High	High
	2380	2503.5	2380	2503.5
Interferer level (dBm)	-11.0	-8.5	-8.5	-10.5
802.15.4 limit (dBm)	-57	-57	-57	-57
Margin (dB)	46.0	48.5	48.5	46.5

	ch0	ch0	ch39	ch39
	2402	2402	2480	2480
	Low	Low	High	High
	2300	2583.5	2300	2583.5
Interferer level (dBm)	-9.5	-9.0	-9.0	-10.0
802.15.4 limit (dBm)	-47	-47	-47	-47
Margin (dB)	37.5	38.0	38.0	37.0

Figure 74. Receiver Blocking (Out Of Band) rejection - Bluetooth LE-125Ksps (LR S=8)

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

3.2.5.3 Blocking interferers

3.2.5.3.1 Bluetooth LE 1 Msps

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

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-1Msps**): Agilent N5182A
  - Generator for the blocker: R&S SFU
  - Criterion: PER < 30. 8% with 1500 packets
  - The wanted signal is set to -67 dBm and the interferer level is increased until the PER threshold is reached.
  - Channel under test: 12 (2426 MHz)

Table 22. Blocking interferers

Wanted signal 2426 MHz @-67dBm	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 - 12.75 GHz (step 25 MHz)	
Unwanted level (dBm)	-30	-35	-35	-30	
Status (unwanted level)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	

Table continues on the next page...

Table 22. Blocking interferers (continued)

Wanted signal 2426 MHz @-67dBm	ch12	ch12	ch12	ch12	
	2426 MHz	2426 MHz	2426 MHz	2426 MHz	
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 3

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

3.2.5.3.2 Bluetooth LE 2 Msps

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

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-2Msps**): Agilent N5182A
  - Generator for the blocker: R&S SFU
  - Criterion: PER < 30. 8% with 1500 packets
  - The wanted signal is set to -67 dBm and the interferer level is increased until the PER threshold is reached.
  - Channel under test: 12 (2426 MHz)

Table 23. Blocking interferers

Wanted signal 2426 MHz @-67dBm	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 - 12.75 GHz (step 25 MHz)	
Unwanted level (dBm)	-30	-35	-35	-30	
Status (unwanted level)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 3

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

3.2.5.3.3 Bluetooth LE 500 Ksps (LR S=2)

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

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-500Ksps [LR S=2]**): A gilent N5182A
  - Generator for the blocker: R&S SFU
  - Criterion: PER < 30. 8% with 1500 packets
  - The wanted signal is set to -67 dBm and the interferer level is increased until the PER threshold is reached.
  - Channel under test: 12 (2426 MHz)

Table 24. Blocking interferers

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

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

3.2.5.3.4 Bluetooth LE 125 Ksps (LR S=8)

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

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE-125Ksps [LR S=8]**): A gilent N5182A
  - Generator for the blocker: R&S SFU
  - Criterion: PER < 30. 8% with 1500 packets
  - The wanted signal is set to -67 dBm and the interferer level is increased until the PER threshold is reached.

— Channel under test: 12 (2426 MHz)

Table 25. Blocking interferers

Wanted signal 2426 MHz @-67dBm	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 - 12.75 GHz (step 25 MHz)	
Unwanted level (dBm)	-30	-35	-35	-30	
Status (unwanted level)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 10
Status (UnW level -50 dBm)	PASS	PASS	PASS	PASS	
Number of blocking fail	0	0	0	0	Fail blockers must not exceed 3

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

3.2.6 Intermodulation

This test verifies that the receiver intermodulation performance is satisfactory.

Two interferers are used in combination with the wanted signal. One interferer is a sinusoid non-modulated signal and the second interferer is a modulated signal with PRSB15 data.

3.2.6.1 Bluetooth LE - 1 Msps

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE – 1Msps**): Agilent N5182A
  - Generator for the first interferer (CW) : R&S SML03
  - Generator for the second interferer (PRBS15) : R&S SFU
  - Criterion: PER < 30.8% with 1500 packets
  - The wanted signal is set to -64 dBm; the interferer level s 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)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-25.7**	**-26.2**	**-28.2**	**-27.2**	**-27.2**	**-29.2**
300.328 limit (dBm)	-35	-38.5	-42	-42	-38.5	-35
Margin (dB)	17.0	20.0	21.5	22.5	19.0	13.5

	ch19	ch19	ch19	ch19	ch19	ch19
	2440	2440	2440	2440	2440	2440
	Mid	Mid	Mid	Mid	Mid	Mid
Interferer1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
	-26.2	**-27.2**	**-27.2**	**-29.2**	**-28.7**	**-28.2**
300.328 limit (dBm)	-35	-38.5	-42	-42	-38.5	-35
Margin (dB)	16.5	19.0	22.5	20.5	17.5	14.5

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
Interferer1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
	-29.2	**-28.2**	**-28.7**	**-29.7**	**-28.7**	**-29.2**
300.328 limit (dBm)	-35	-38.5	-42	-42	-38.5	-35
Margin (dB)	13.5	18.0	21.0	20.0	17.5	13.5

Figure 75. Intermodulation - Bluetooth LE-1 Msps

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

3.2.6.2 Bluetooth LE - 2 Msps

- **Flashed SW**:
  - Connectivity test
- **Test method**:
  - Generator for the desired signal (**Bluetooth LE – 2Msps**): Agilent N5182A
  - Generator for the first interferer (CW) : R&S SML03
  - Generator for the second interferer (PRBS15) : R&S SFU
  - Criterion: PER < 30.8% with 1500 packets
  - The wanted 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)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-21.8**	**-21.8**	**-22.3**	**-22.8**	**-23.3**	**-23.3**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	14.5	13.5	13.0	12.5	12.0	13.0

	ch19	ch19	ch19	ch19	ch19	ch19
	2440	2440	2440	2440	2440	2440
	Mid	Mid	Mid	Mid	Mid	Mid
Interferer1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-21.3**	**-21.8**	**-22.3**	**-22.8**	**-23.3**	**-23.3**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	15.0	13.5	13.0	12.5	12.0	13.0

	ch39	ch39	ch39	ch39	ch39	ch39
	2480	2480	2480	2480	2480	2480
	High	High	High	High	High	High
Interferer1 (CW) (MHz)	-5	-4	-3	3	4	5
Interferer2 (Mod) (MHz)	-10	-8	-6	6	8	10
Interferer level (dBm)	**-21.3**	**-20.8**	**-22.3**	**-22.8**	**-22.8**	**-23.3**
Datasheet limit (dBm)	-24	-23	-23	-23	-23	-24
Margin (dB)	15.0	14.5	13.0	12.5	12.5	13.0

Figure 76. Intermodulation - Bluetooth LE-2 Msps

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

3.3 Return loss

3.3.1 RF path with matching components

Measurements are done using the SMA connector. Therefore, the C57 capacitor is mounted and the C55 capacitor is not mounted.

- **Flashed SW**:
  - Connectivity test

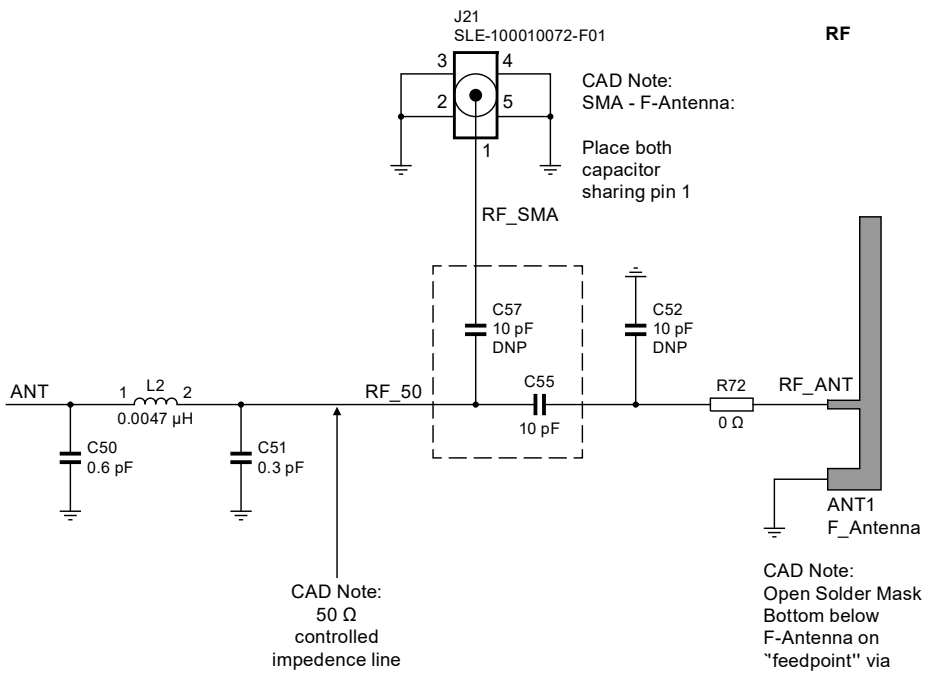


Figure 77. RF matching

- Matching components are:
  - L2 = 4.7 nH

Description	Mfr. name	Mfr. part number
IND -- 0.0047 m H @ 500 MHz 300 mA +/-0.1 nH 0402	MURATA	LQG15HH4N7S02D

  - C50 = 0.6 pF

Description	Mfr. name	Mfr. part number
CAP CER 0.6 pF 50 V 0.1 pF C0G 0402	MURATA	GCM1555C1HR60BA16

  - C5 1 = 0. 3 pF

Description	Mfr. name	Mfr. part number
CAP CER 0.3 pF 50 V 0.1 pF C0G 0402	MURATA	GCM1555C1HR30BA16

3.3.2 Rx

NOTE

In the Rx mode, the return loss measurement is performed by setting the LNA gain of KW38 to the maximum.

- **Hardware**:
  - FRDM-KW38
- **Flashed SW**:

— Connectivity test

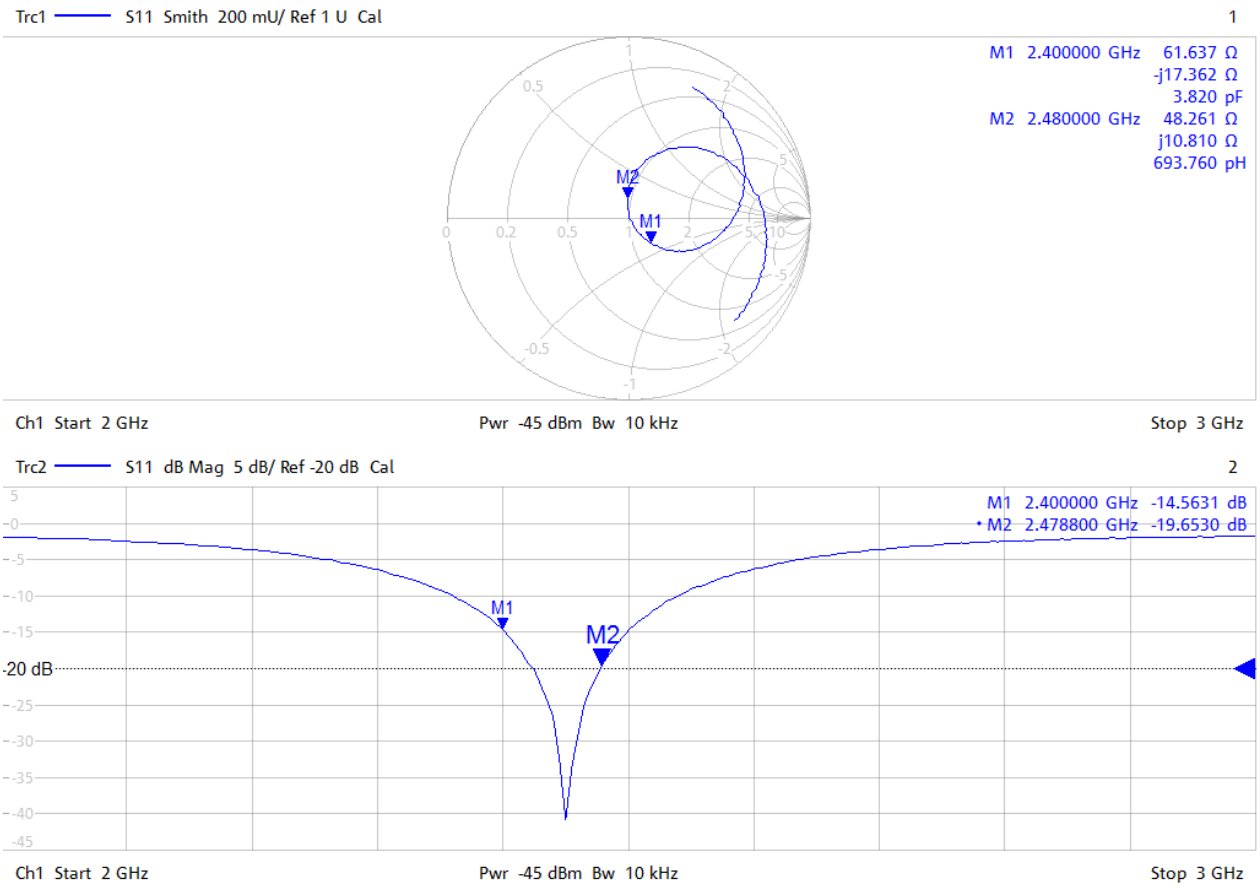


Figure 78. S11 diagram (Rx mode)

- **Results**:
  - — Return loss: -19.65 dB (2.48 GHz) < S11 < -14.56 dB (2.4 GHz)

NOTE

There is no specification for the return loss.

- **Conclusion**:
  - — The return loss (S11) is lower than -14 dB.

3.3.3 Tx

NOTE

In the Tx mode, the return loss measurement is performed by setting the KW38 RF output power to the minimum.

- **Hardware**:
  - — FRDM-KW38
- **Flashed SW**:
  - — Connectivity test

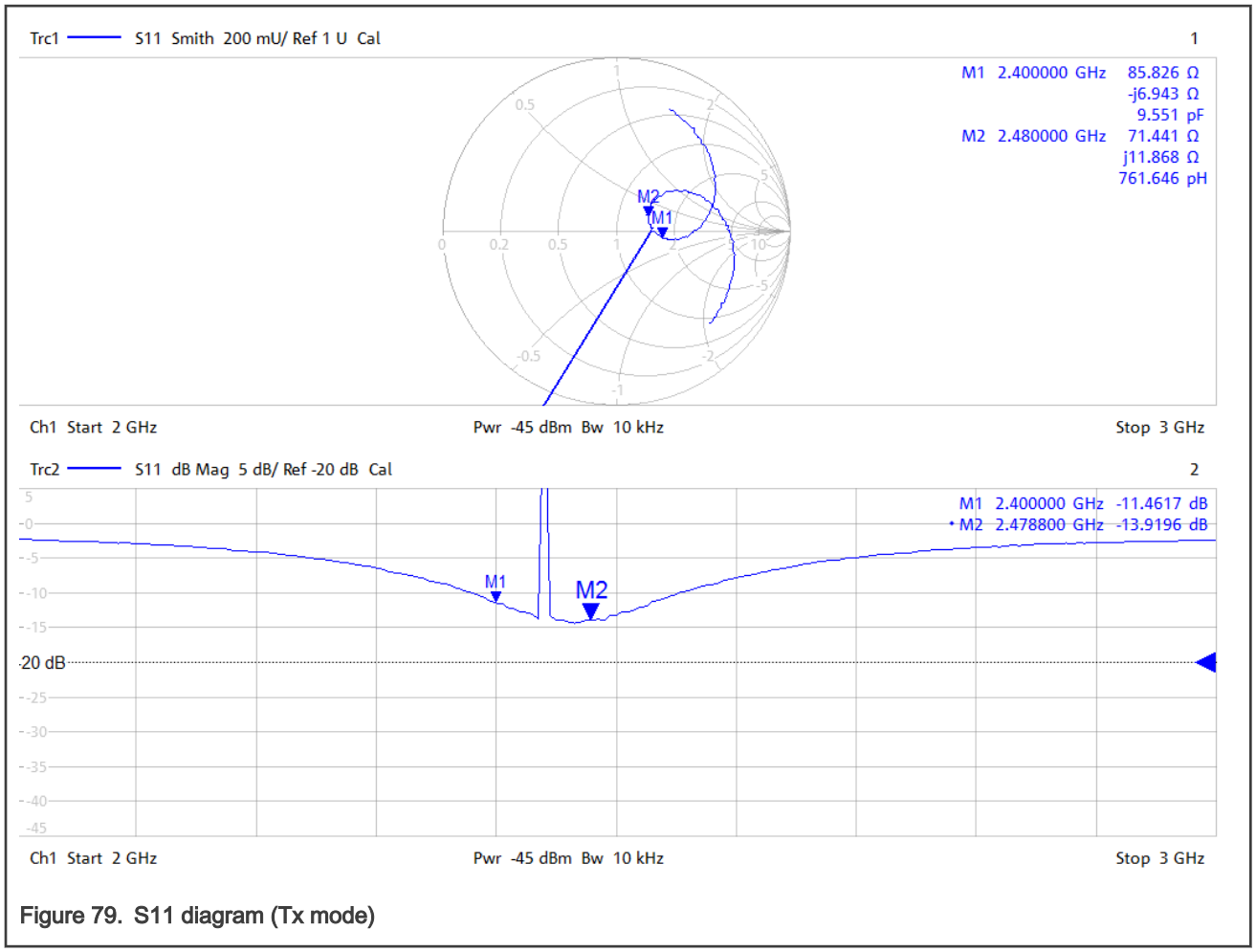


Figure 79. S11 diagram (Tx mode)

- **Results**:
  - Return loss: -13.91 dBm (2.48 GHz) < S11 < -11.46 dB (2.4 GHz)

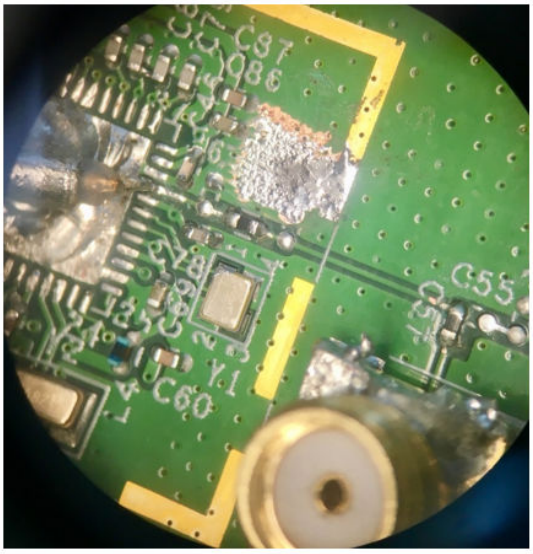
NOTE

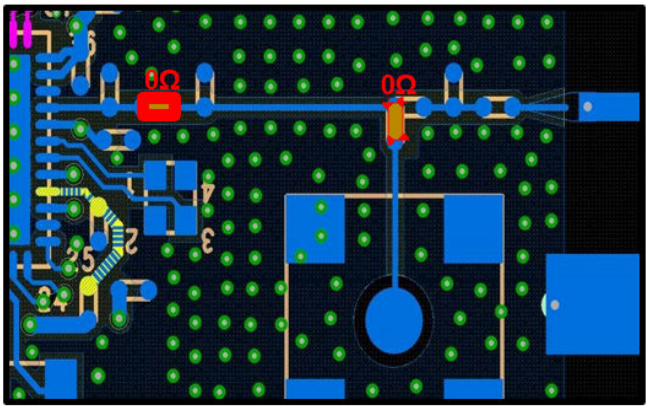
There is no specification for the return loss.

- **Conclusion**:
  - The return loss (S11) is lower than -11 dB.

3.3.4 RF line insertion loss

To extract RF line insertion loss, removed KW38 from FRDM Board and solder RF probe on Pin 33 ANT, and replace default matching by 0 Ω resistor.





To quantify RF line insertion loss, measure S12.

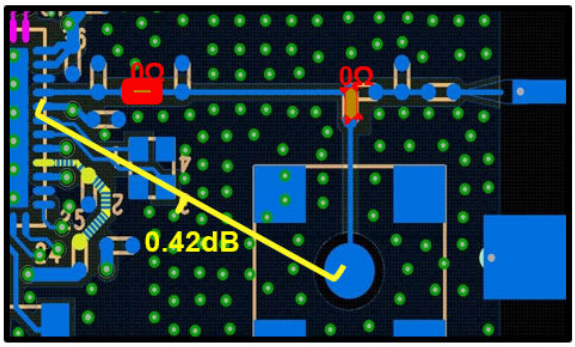
RF probe have been taken in account in VNA port calibration and soldered ANT IC Pin.

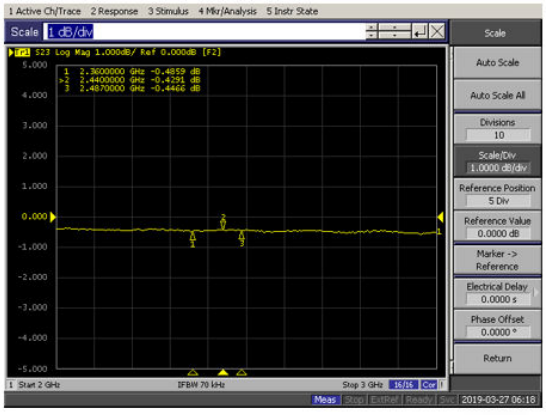
Matching components have been removed and L1 replace by 0 Ω.

S12 = 0.42 dB

RF matching components insertion loss have been simulate at 0.25 dB (C50 = 0.8 pF & L2 = 4.7 nH)

Overall loss (from RF pin to SMA connector) = 0.67 dB





4 Antenna measurements

4.1 Return loss

- The measurement of the return loss antenna (S11) is performed by disconnecting the C55 and C57 capacitors and making a connection marked by the green line in Figure 80 (antenna link to the SMA only).

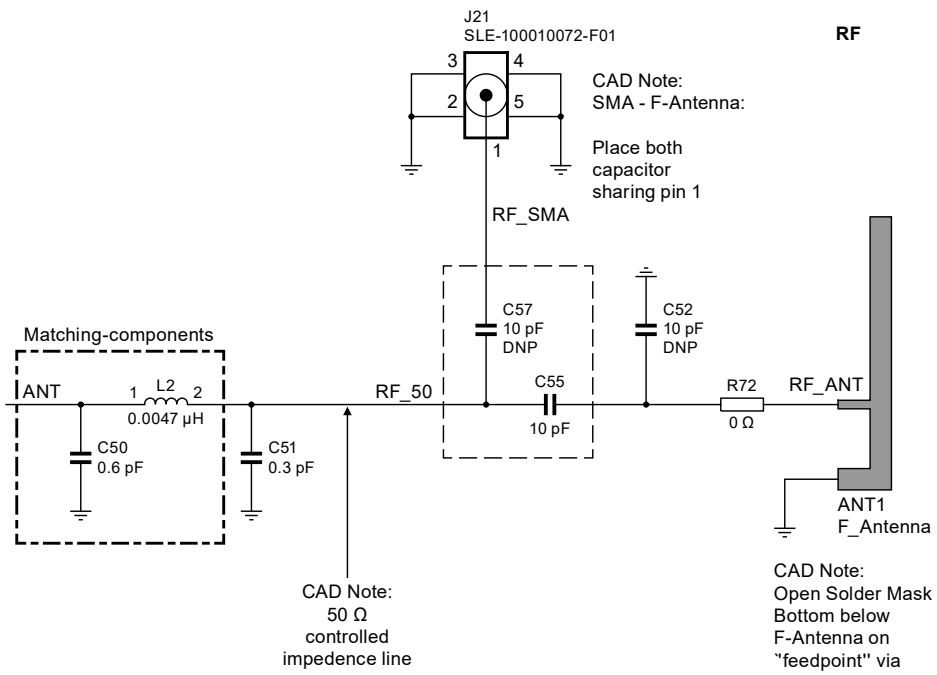


Figure 80. RF path connection (S11 antenna)

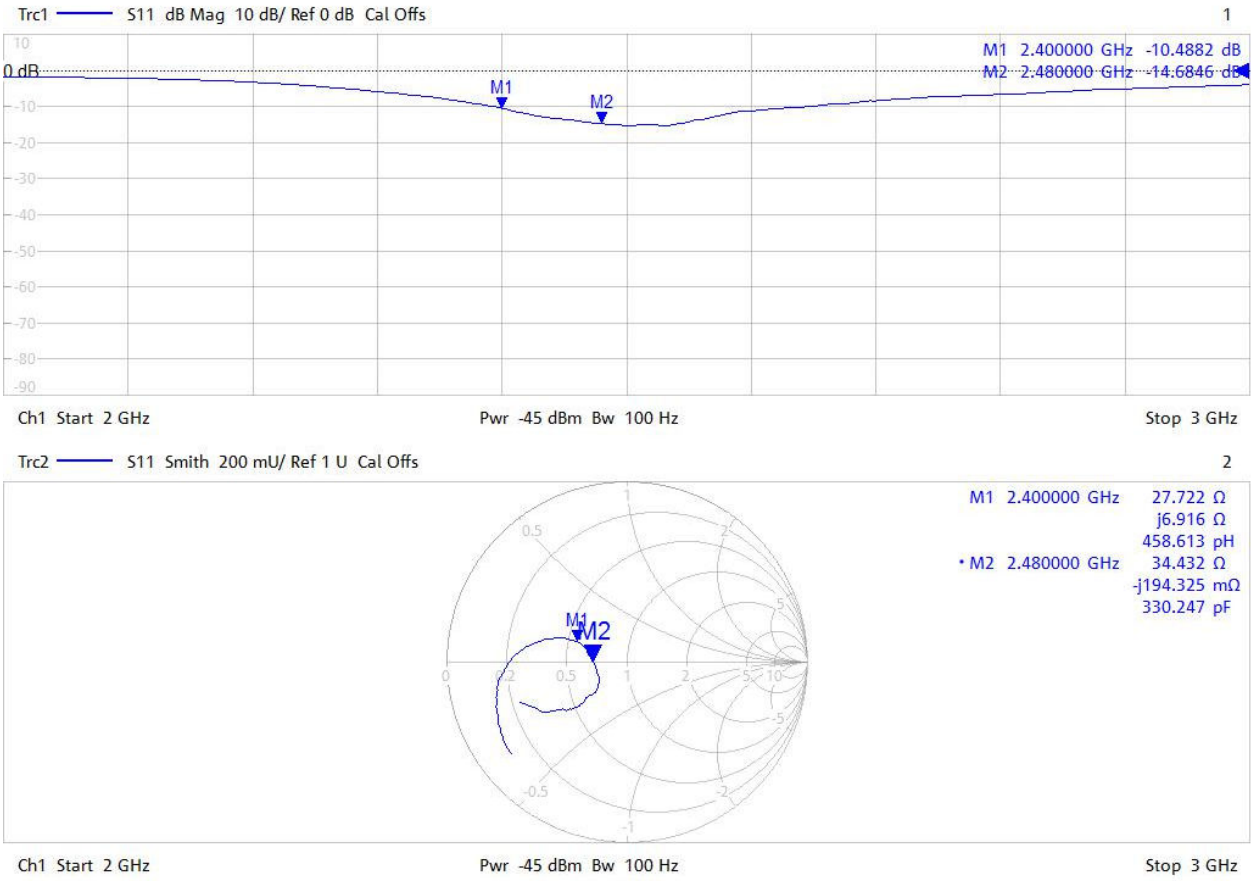


Figure 81. Antenna return loss (S11)

- **Results**:
  - Return loss: -10.5 (2.4 GHz) < S11 < -14.7 dB (2.48 GHz)

NOTE

There is no specification for the return loss.

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

5 Conclusion

Beyond the RED and BLE 5.0 compliances, these radio tests prove a good performance of the KW38 wireless MCU.

6 References

- **ETS EN 300 328 2.2.1 (11-2016)**: 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 5.0.2 (12-2017)**: Bluetooth Test Specification. This document defines test structures and procedures for qualification testing of Bluetooth implementations of the Bluetooth LE RF PHY.
- **FCC Part 15**: Operation to FCC Part 15 is subject to two conditions.
  1. The device may not cause harmful interference.
  2. 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.

7 Revision history

The following table lists the substantive changes done to this document since the initial release.

Table 26. Revision history

Revision number	Date	Substantive changes
1	21 December 2021	• Changed "ETSI EN 300 328 v2.2.1 (2016-11)" to "ETSI EN 300 328 v2.2.1 (2019-04)" • Editorial updates
0	28 April 2020	Initial release

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