# 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.

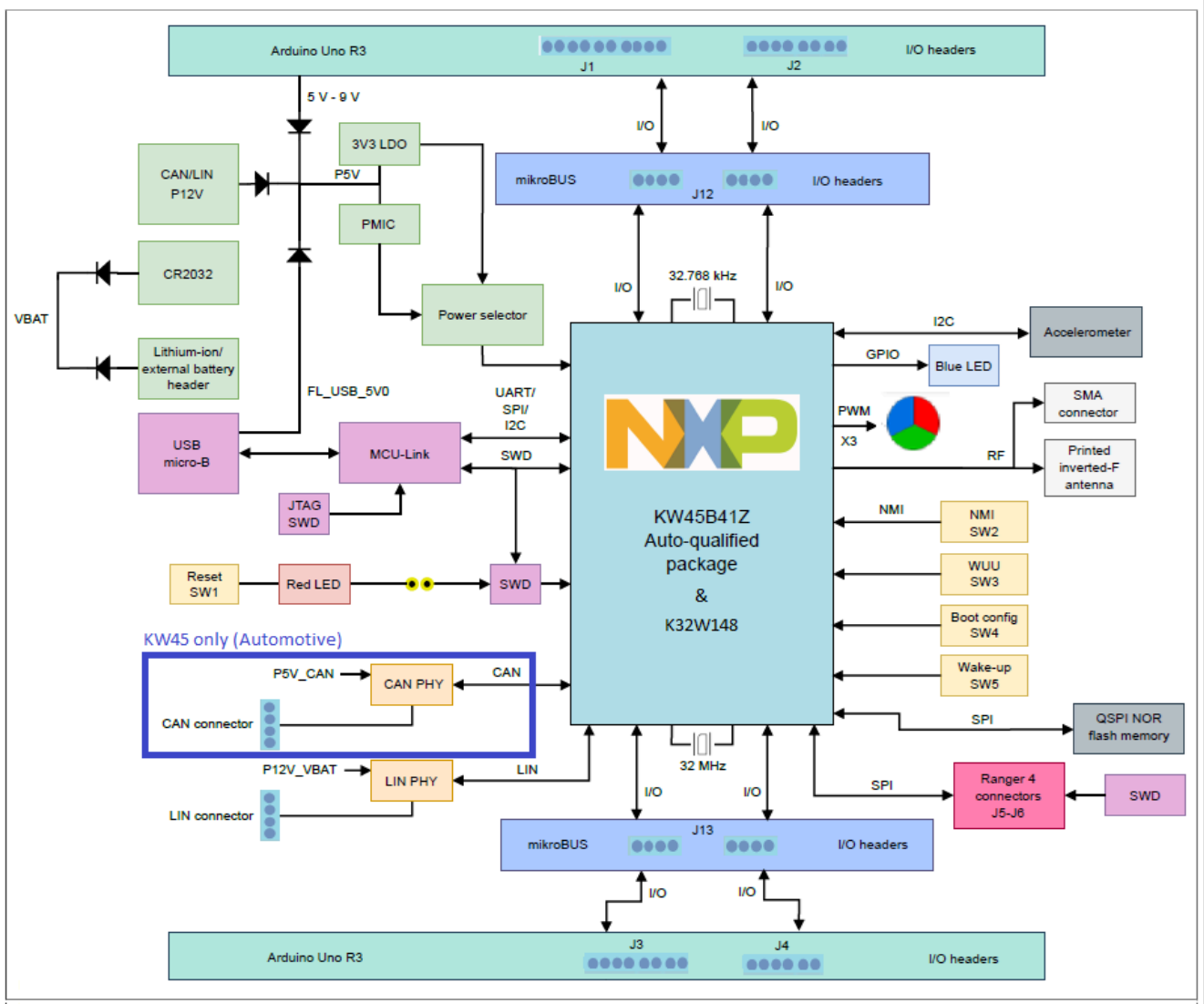



**Figure 1. K32W148-EVK block diagram**

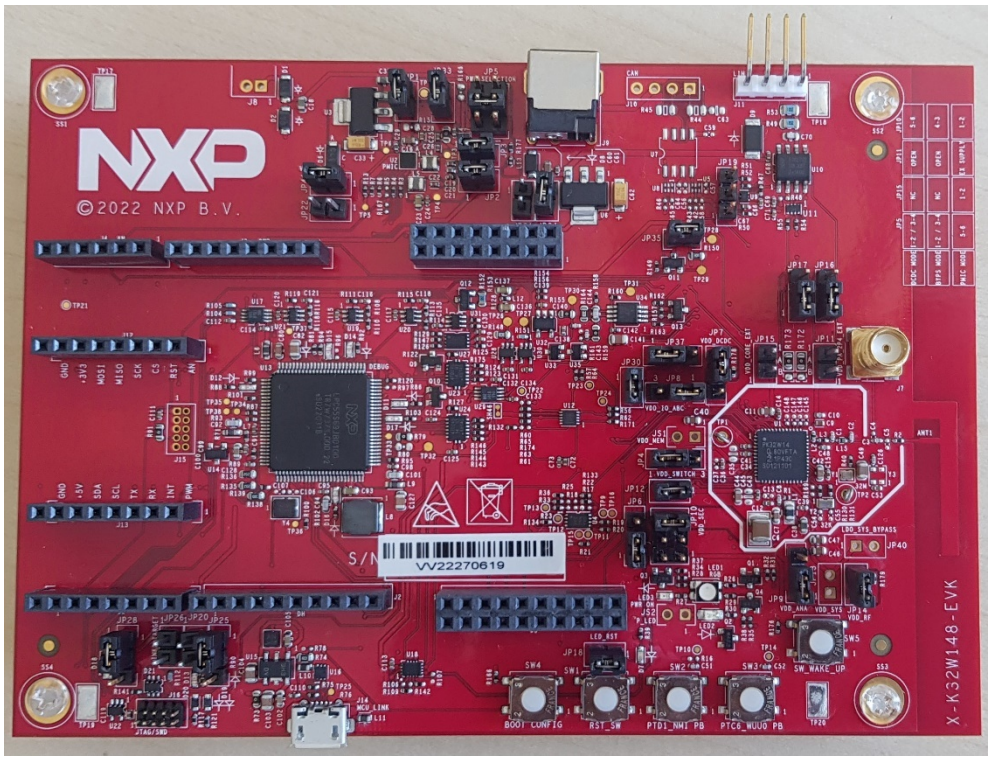



Figure 2. K32W148-EVK top-side view

## 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.

**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)<br>$P_{TX}$ <= -30 dBm for ($f_{TX}$ +/- [3 + n] MHz]); | PASS |
| | 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)<br>$P_{TX}$ <= -30 dBm for ($f_{TX}$ +/- [3 + n] MHz]); | PASS |
| | 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<br>where $f_{TX}$ is the nominal transmit frequency<br>and n = 0,1,2,3…k<br>\|f0 – fn\| <= 50 kHz<br>where n=2,3,4…k | PASS |
| | Carrier frequency offset and drift 2 Msps | Bluetooth LE 5.0, BV-12-C | \|f0 – f3\| <= 19.2 kHz<br>\|f0 – f(n-3)\| <= 19.2 kHz<br>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<br>where $f_{TX}$ is the nominal transmit frequency and n=0,1,2,3…k<br>\|f0 – fn\| <= 50 kHz<br>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)<br>(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 |

**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<br>-41.12 dBm (1 MHz BW) | PASS |

## 3.3 Conducted tests

### 3.3.1 TX tests

#### 3.3.1.1 Test setup

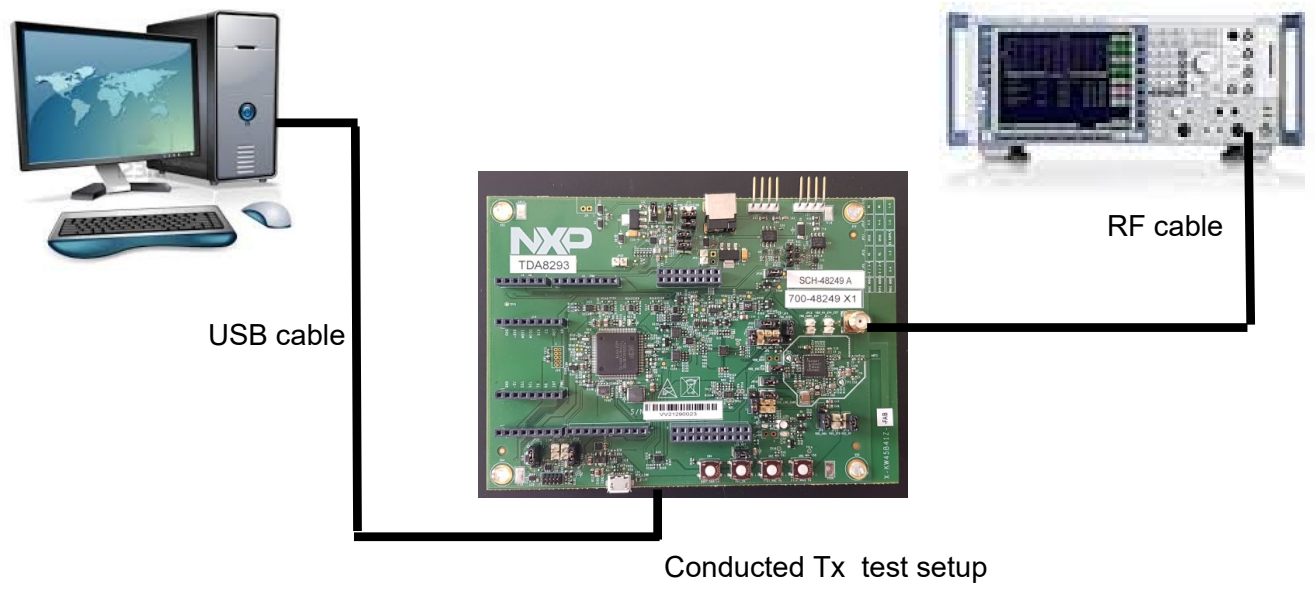



**Figure 3. Conducted TX test setup**

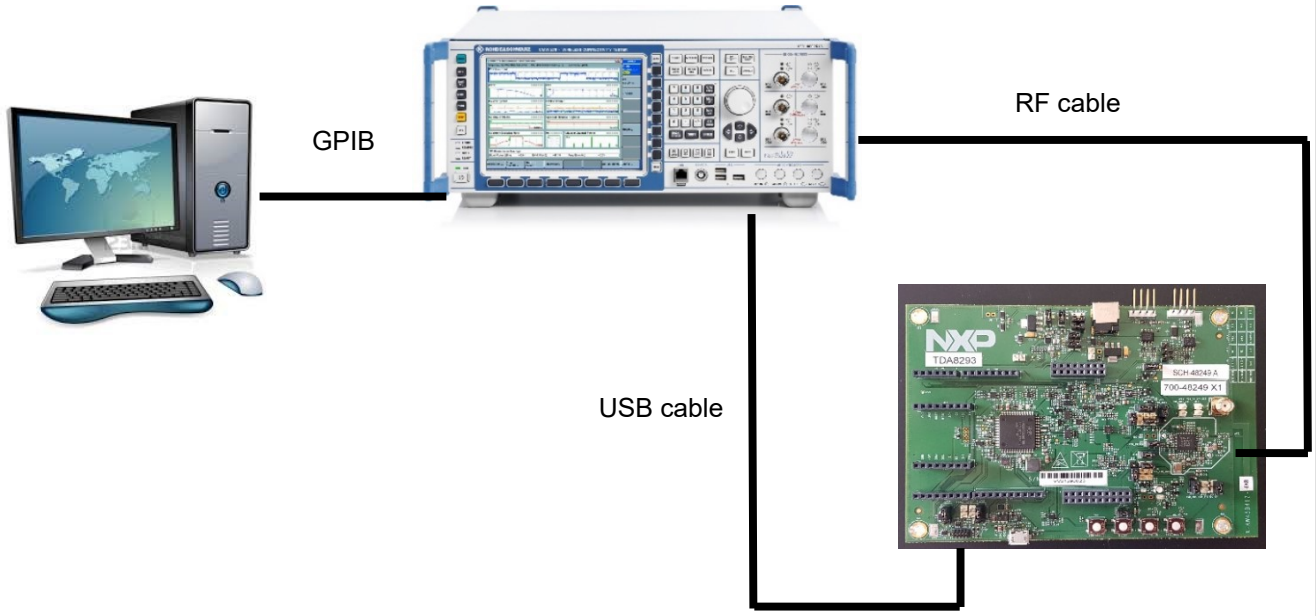



**Figure 4. Specific conducted TX test setup**

### 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:**

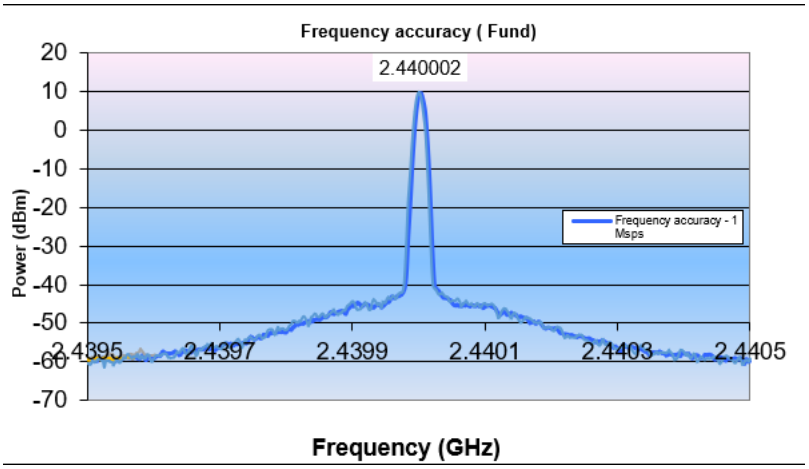



**Figure 5. Frequency accuracy**

- 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 kHz) = 40 dBc)

**Result:**

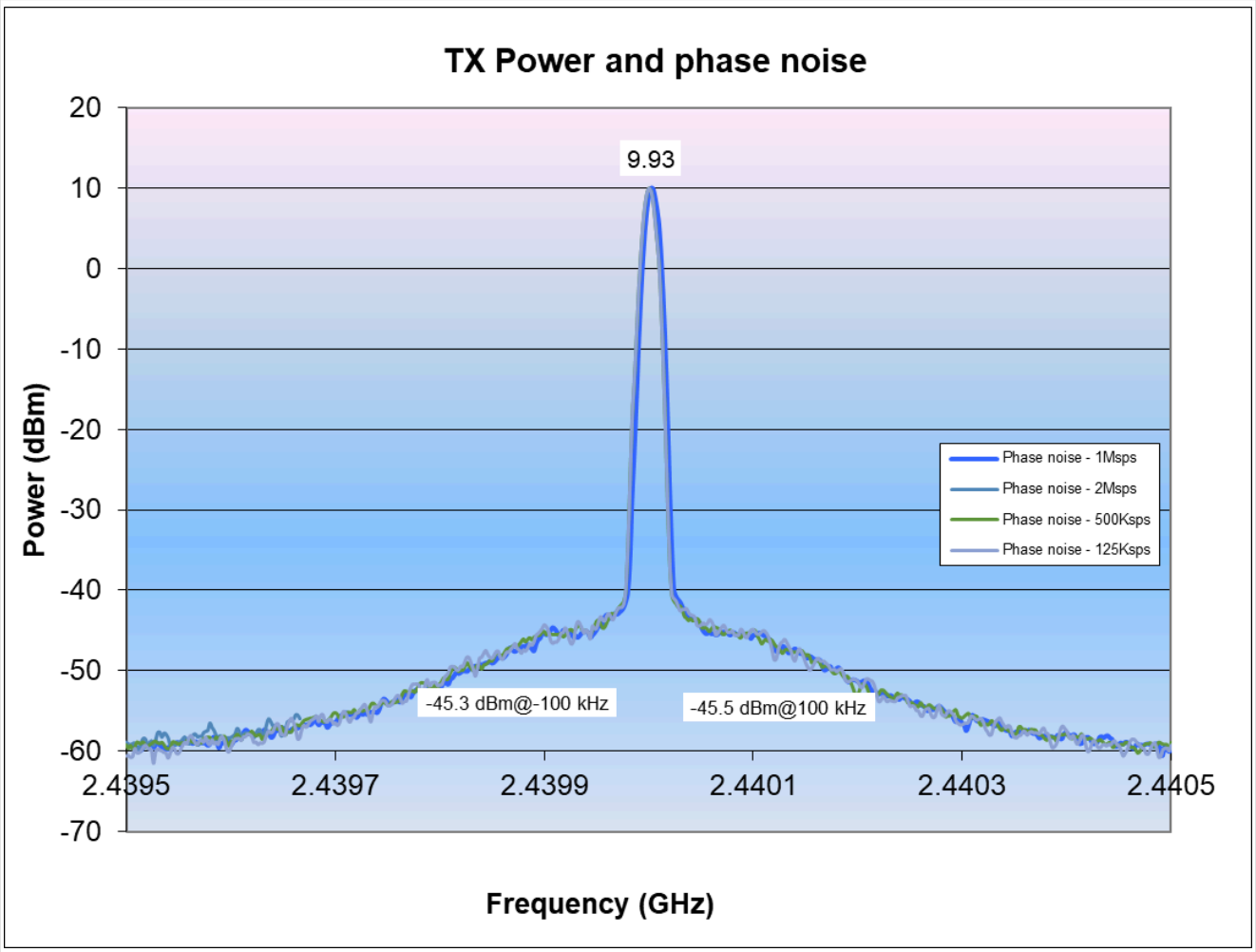



**Figure 6. Conducted phase noise**

- 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:**

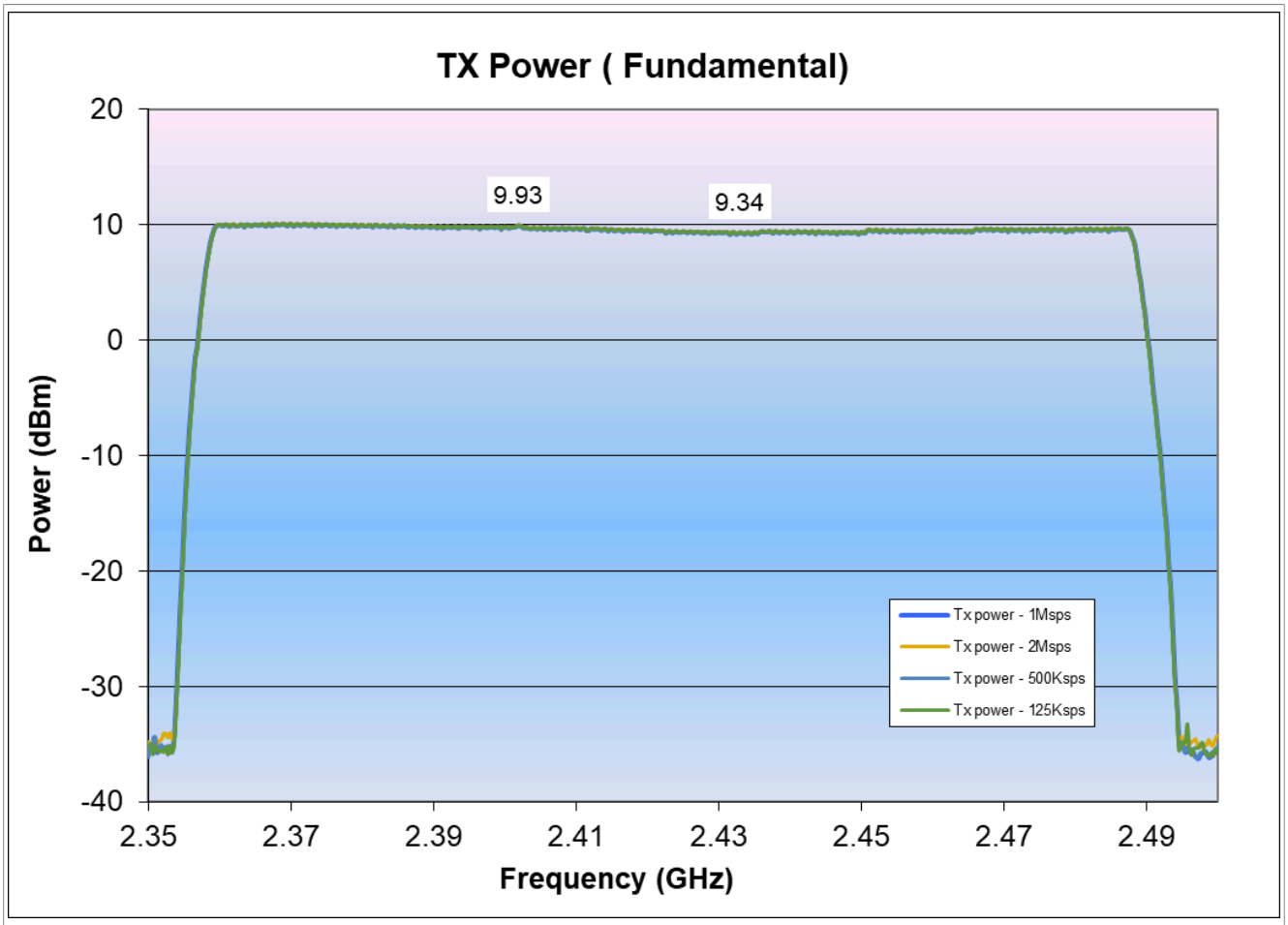



**Figure 7. TX power**

- 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:**

- 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:**

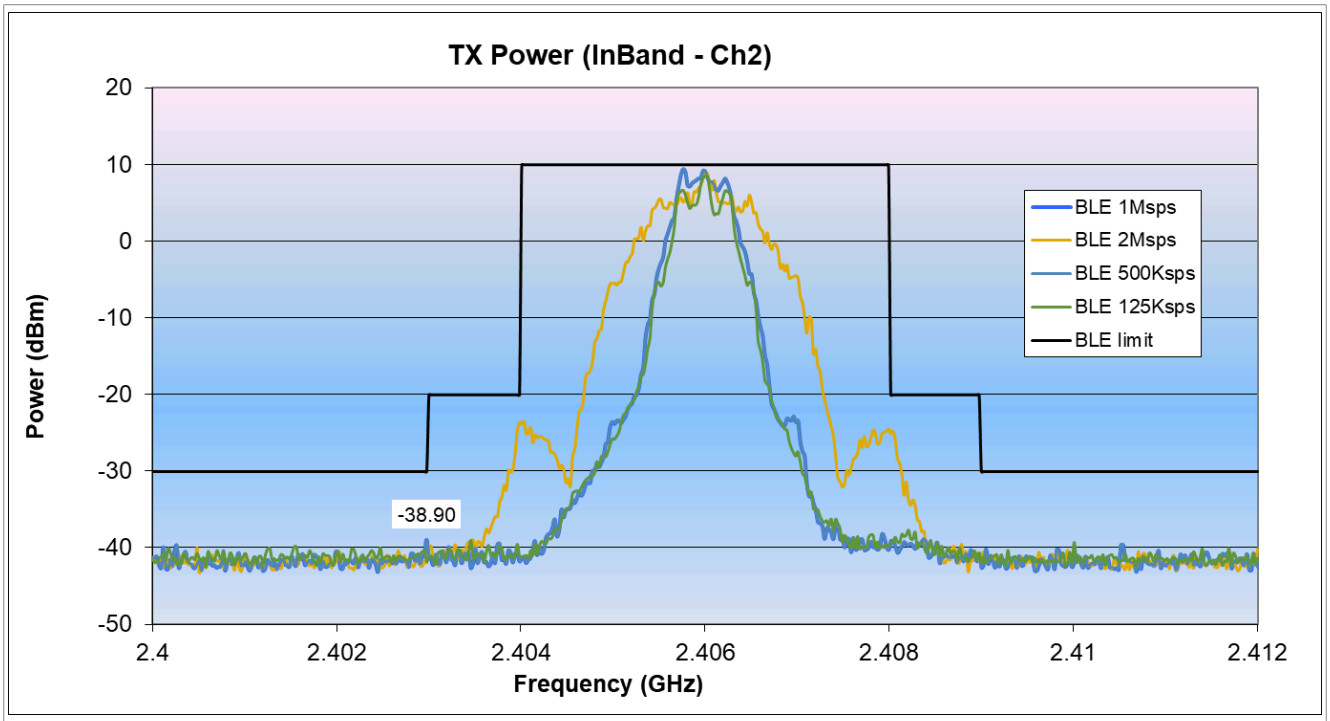



**Figure 8. TX power in-band – Channel 2**

**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 |

**Table 6. Bluetooth LE 500 ksps**

| | | | | | |
|---|---|---|---|---|---|
| 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 ksps**

| | | | | | |
|---|---|---|---|---|---|
| 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 |

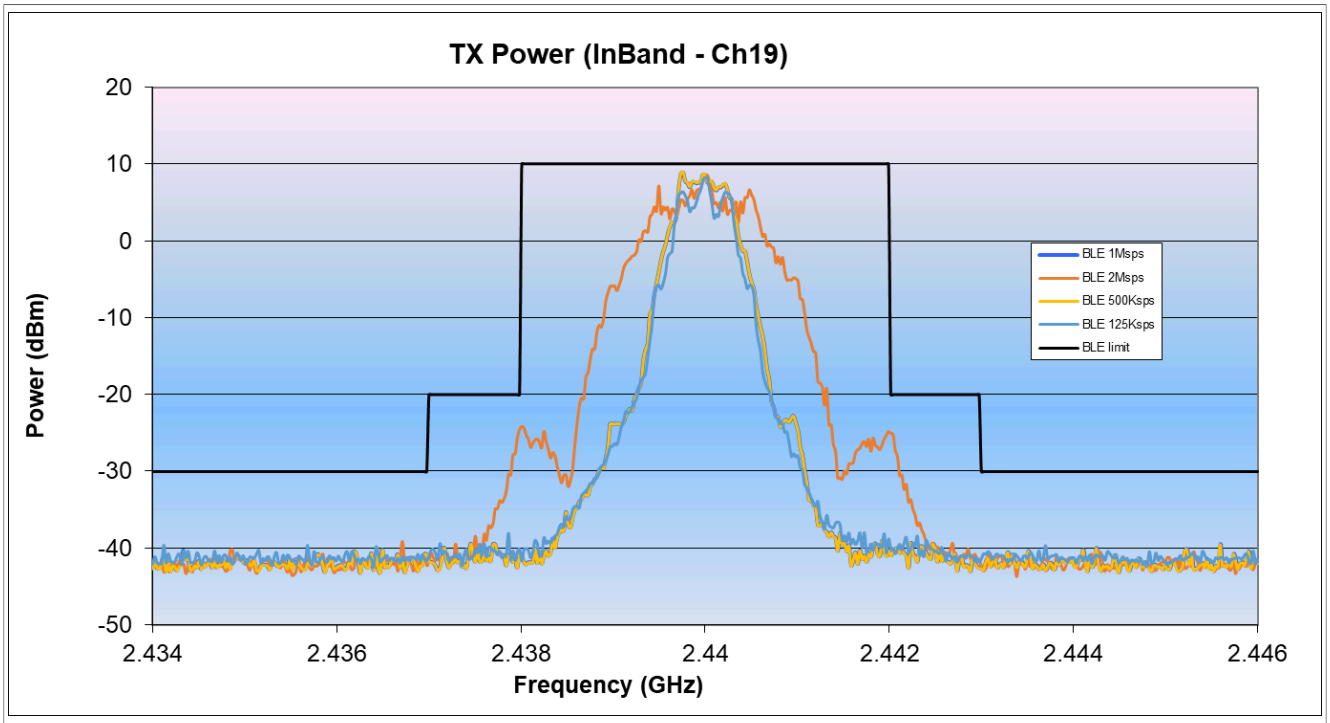



**Figure 9. TX power in-band – Channel 19**

**Table 8. Bluetooth LE 1 Msps**

| | | | | | |
|---|---|---|---|---|---|
| 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 Msps**

| | | | | | |
|---|---|---|---|---|---|
| Max peak level <=-2 MHz | -24.58 | dBm | @ | 2.438 | GHz |

**Table 9. Bluetooth LE 2 Msps*...continued***

| | | | | | |
|---|---|---|---|---|---|
| Max peak level >=+2 MHz | -25.11 | dBm | @ | 2.442 | GHz |
| Max peak level <=-3 MHz | -39.18 | dBm | @ | 2.437 | GHz |
| Max peak level >=+3 MHz | -40.54 | dBm | @ | 2.445 | GHz |

**Table 10. Bluetooth LE 500 ksps**

| | | | | | |
|---|---|---|---|---|---|
| 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 11. Bluetooth LE 125 ksps**

| | | | | | |
|---|---|---|---|---|---|
| Max peak level <=-2 MHz | -38.04 | dBm | @ | 2.438 | GHz |
| Max peak level >=+2 MHz | -38.39 | dBm | @ | 2.442 | GHz |
| Max peak level <=-3 MHz | -39.60 | dBm | @ | 2.434 | GHz |
| Max peak level >=+3 MHz | -39.63 | dBm | @ | 2.444 | GHz |

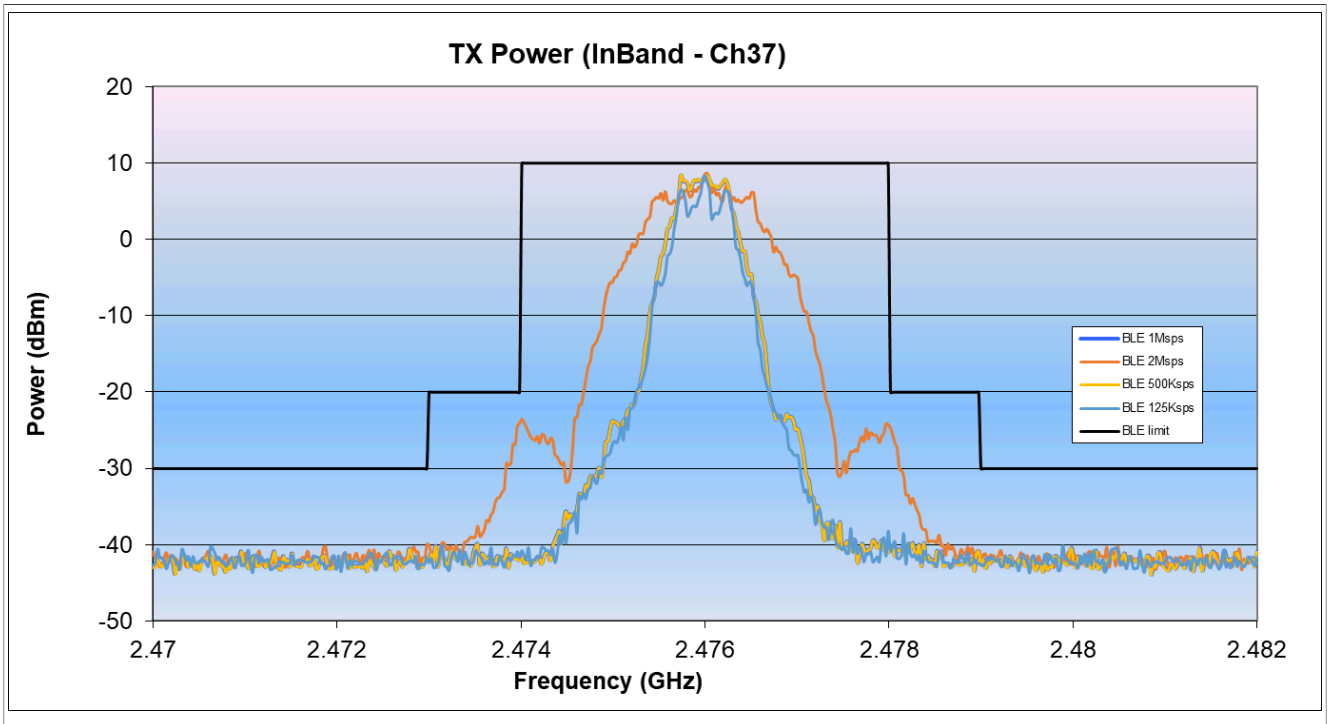



**Figure 10. TX power in-band – Channel 37**

**Table 12. Bluetooth LE 1 Msps**

| | | | | | |
|---|---|---|---|---|---|
| Max peak level <=-2 MHz | -39.93 | dBm | @ | 2.474 | GHz |
| Max peak level >=+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 >=+3 MHz | -40.35 | dBm | @ | 2.481 | GHz |

**Table 13. Bluetooth LE 2 Msps**

| | | | | | |
|---|---|---|---|---|---|
| Max peak level <=-2 MHz | -24.10 | dBm | @ | 2.474 | GHz |
| Max peak level >=+2 MHz | -24.69 | dBm | @ | 2.478 | GHz |
| Max peak level <=-3 MHz | -39.96 | dBm | @ | 2.473 | GHz |
| Max peak level >=+3 MHz | -40.21 | dBm | @ | 2.480 | GHz |

**Table 14. Bluetooth LE 500 ksps**

| | | | | | |
|---|---|---|---|---|---|
| Max peak level <=-2 MHz | -39.93 | dBm | @ | 2.474 | GHz |
| Max peak level >=+2 MHz | -39.75 | dBm | @ | 2.478 | GHz |
| Max peak level <=-3 MHz | -40.56 | dBm | @ | 2.473 | GHz |
| Max peak level >=+3 MHz | -40.35 | dBm | @ | 2.481 | GHz |

**Table 15. Bluetooth LE 125 ksps**

| | | | | | |
|---|---|---|---|---|---|
| Max peak level <=-2 MHz | -40.15 | dBm | @ | 2.473 | GHz |
| Max peak level >=+2 MHz | -38.53 | dBm | @ | 2.478 | GHz |
| Max peak level <=-3 MHz | -40.24 | dBm | @ | 2.471 | GHz |
| Max peak level >=+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.

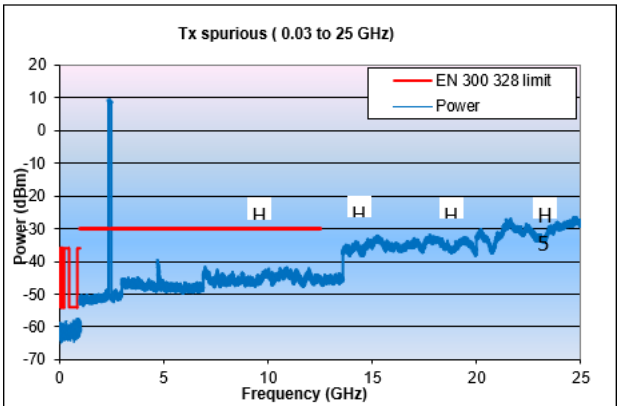



Figure 11. Bluetooth LE - Conducted TX spurious (30 MHz to 25 GHz)

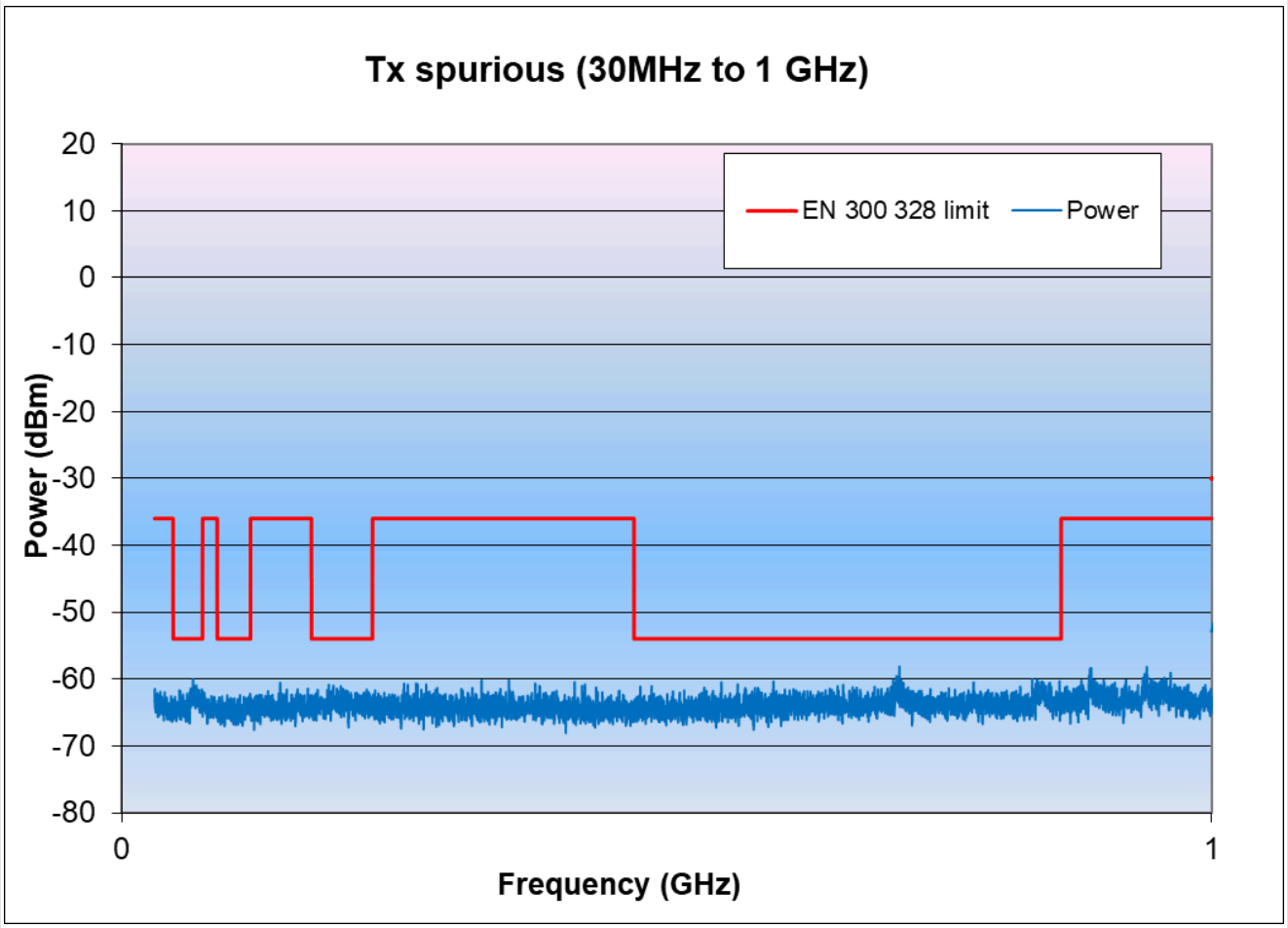



Figure 12. Bluetooth LE - Zoom In - Conducted TX spurious (30 MHz to 1 GHz)

**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:**

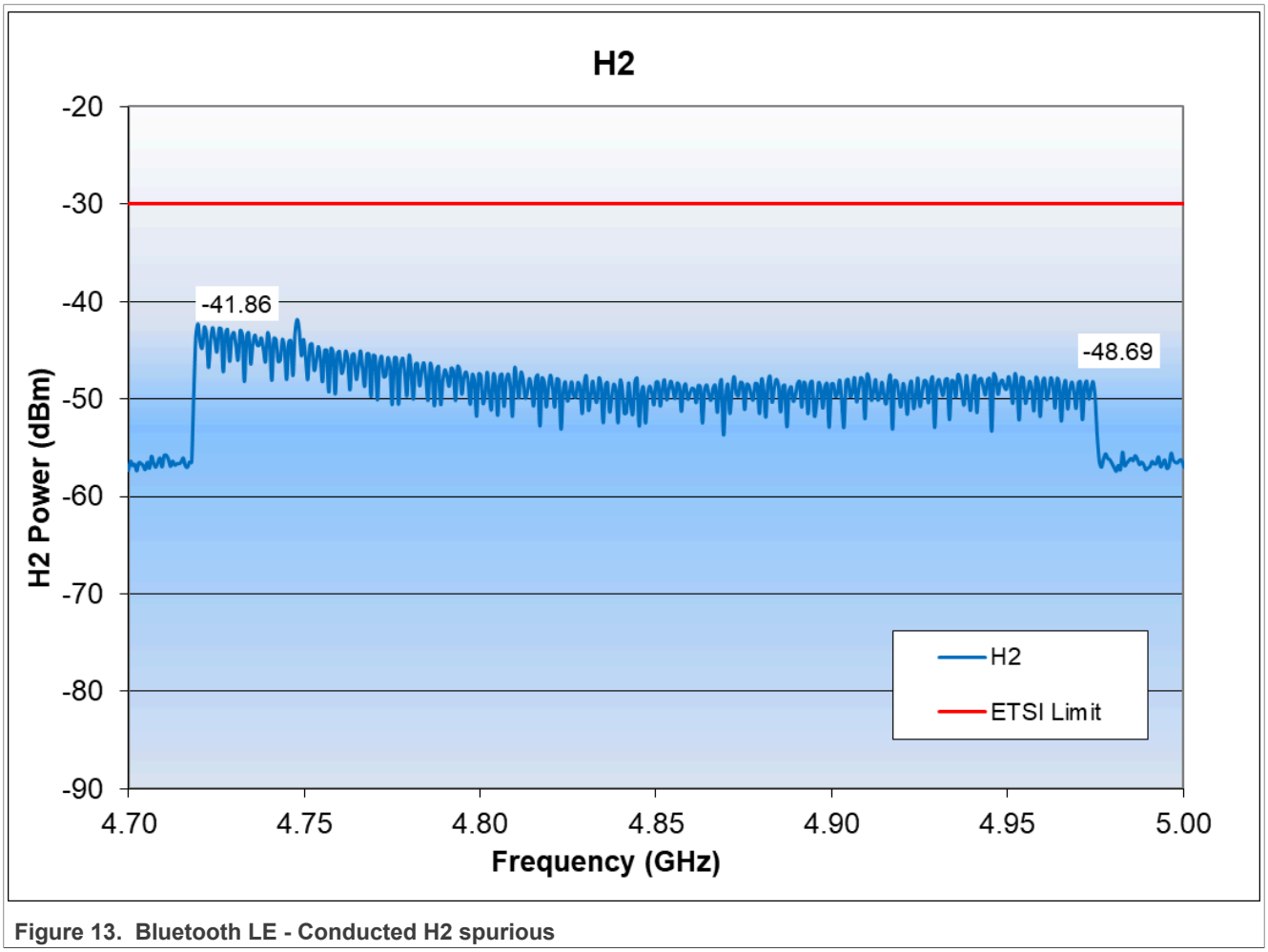



**Figure 13. Bluetooth LE - Conducted H2 spurious**

- 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:**

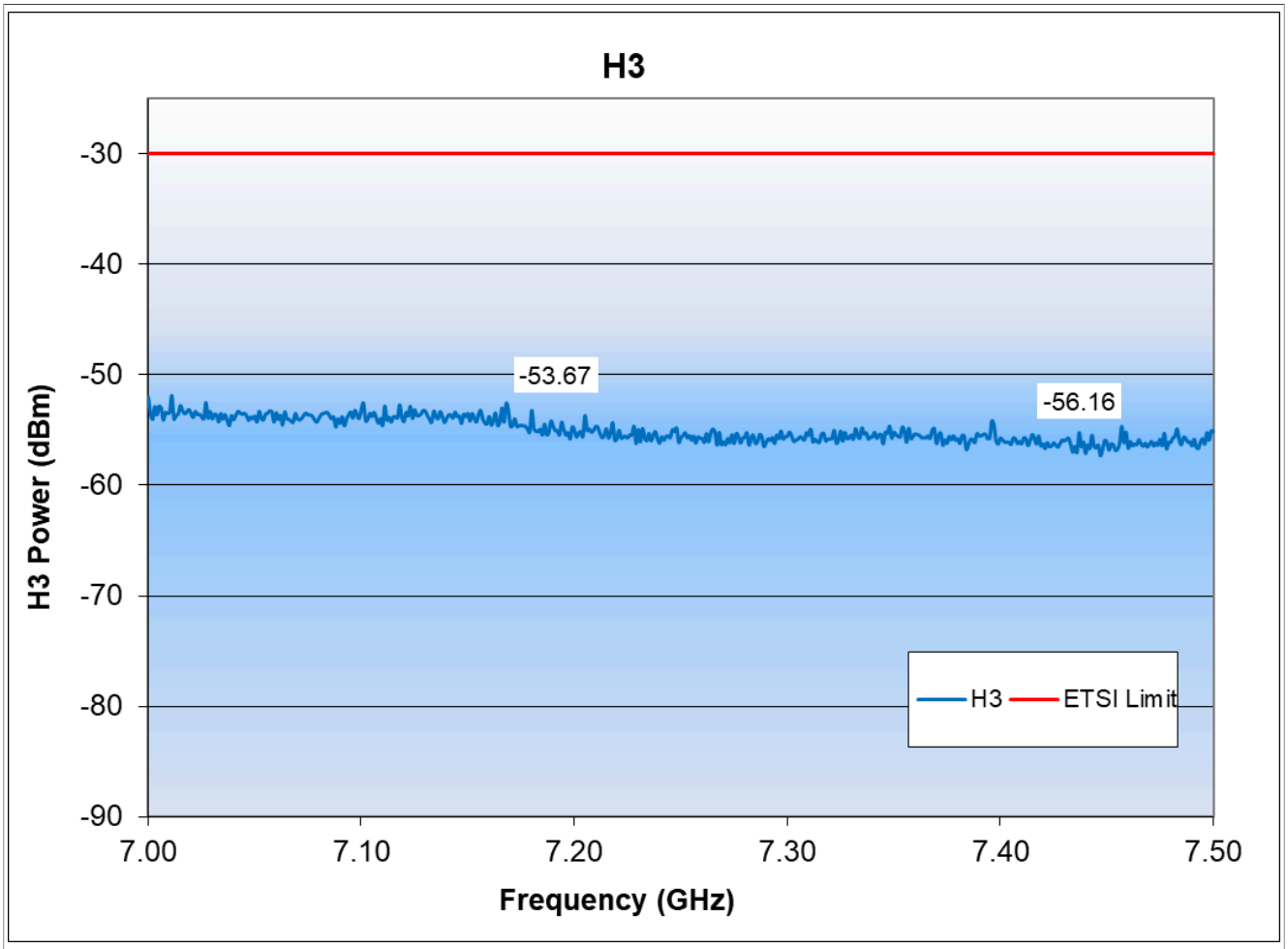



**Figure 14. Bluetooth LE - Conducted H3 spurious**

- 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:**

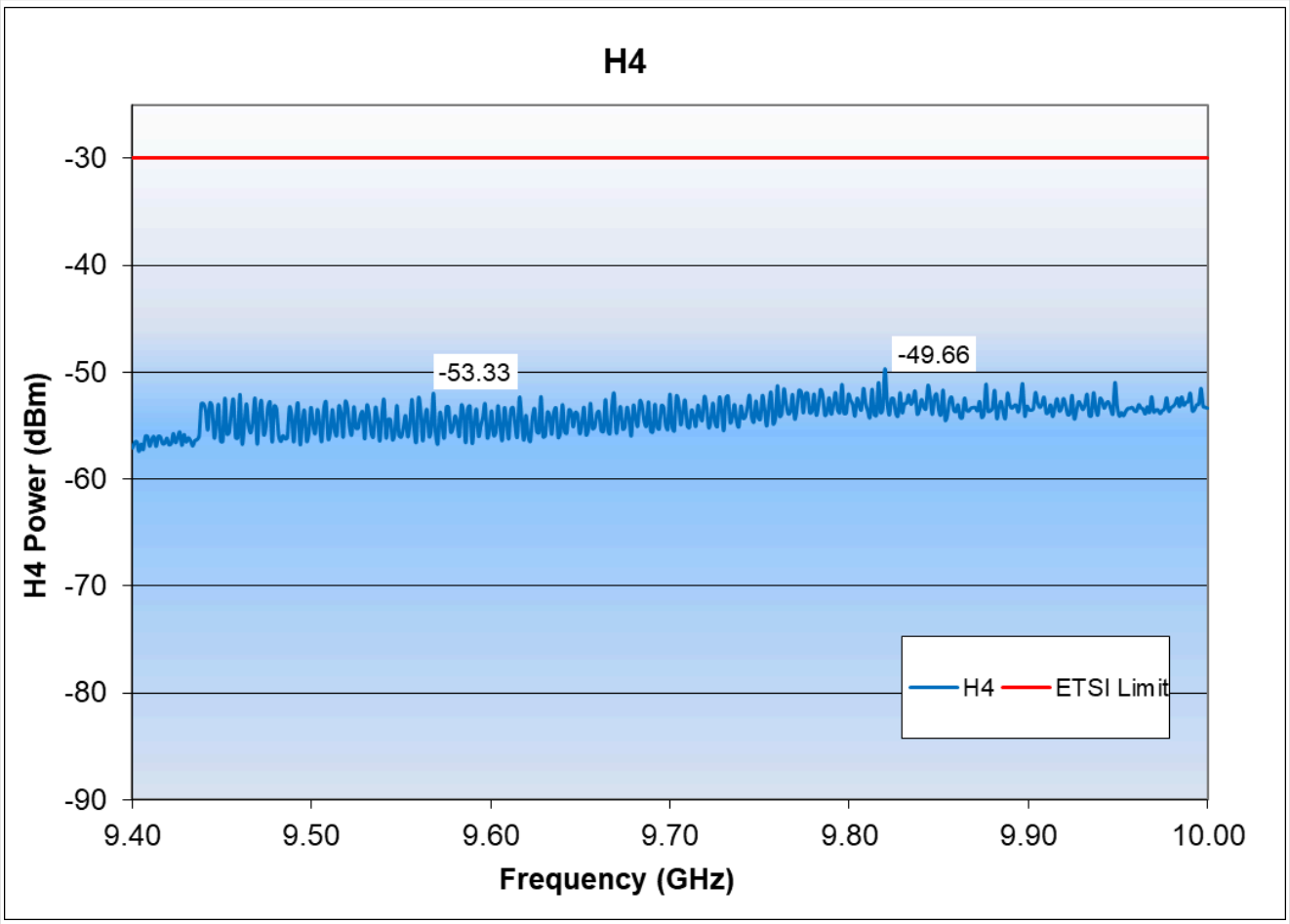



**Figure 15. Bluetooth LE - Conducted H4 spurious**

- 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:**

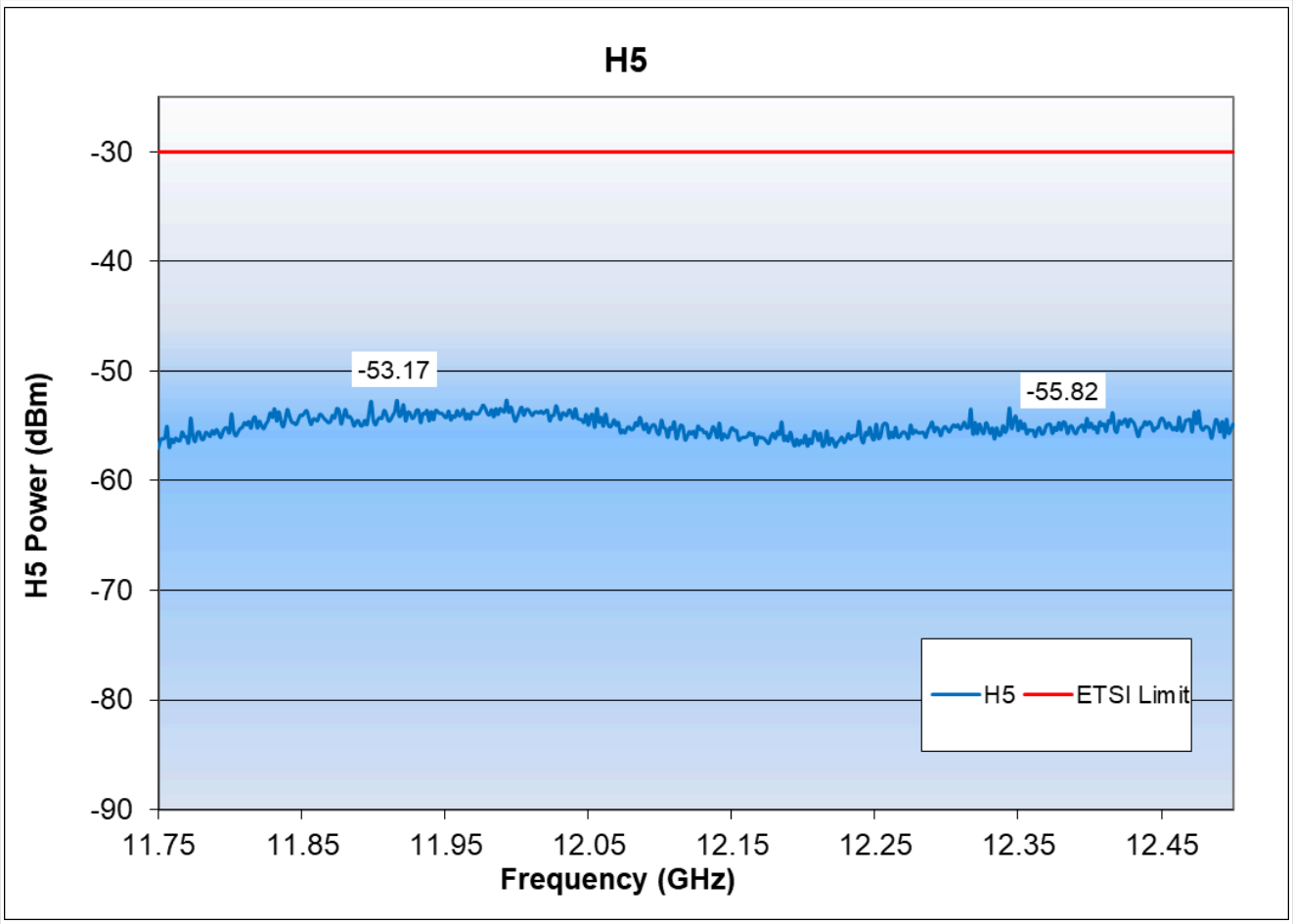



**Figure 16. Bluetooth LE - Conducted H5 spurious**

- 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:**

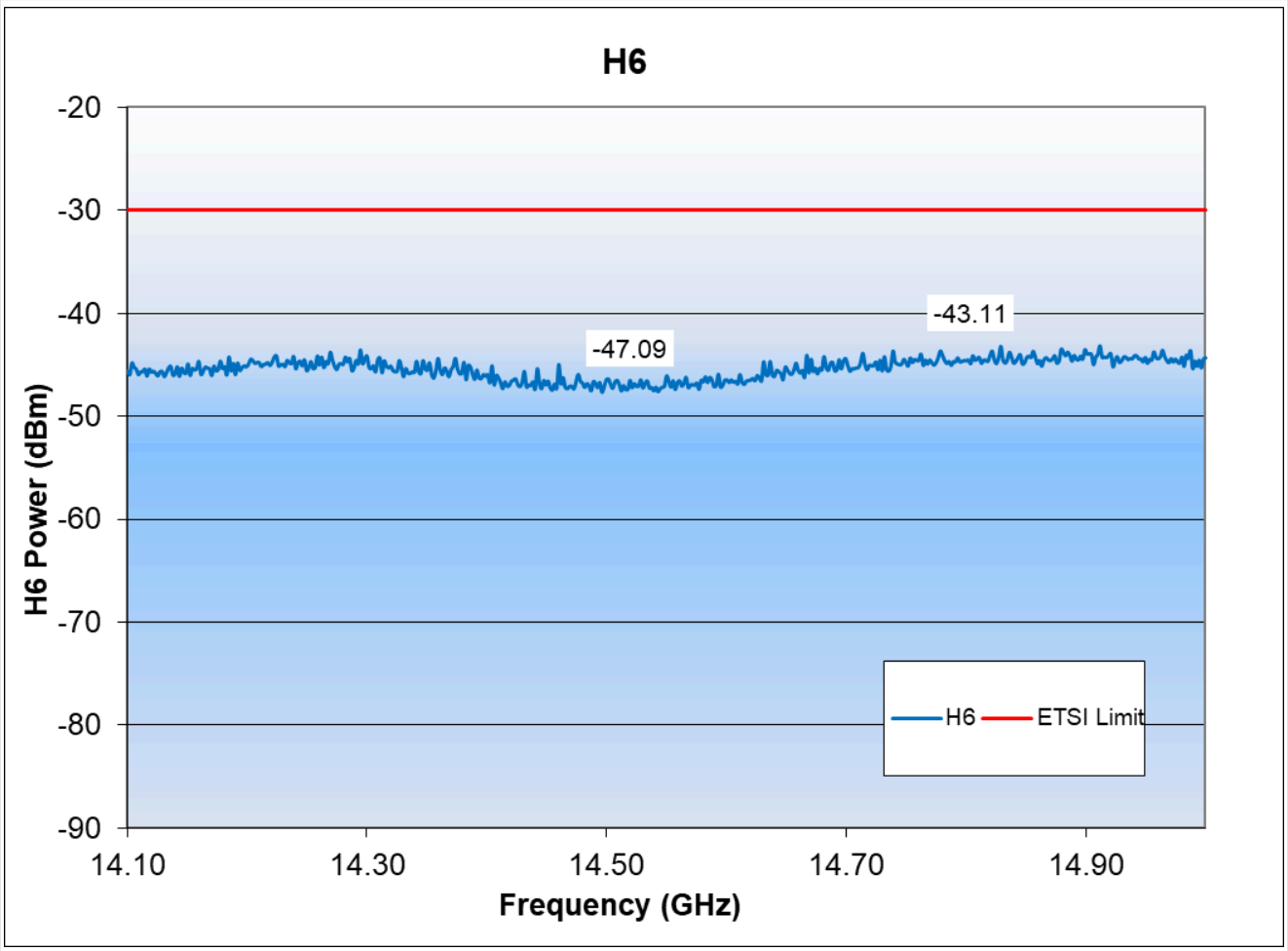



Figure 17. Bluetooth LE - Conducted H6 spurious

- 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:**

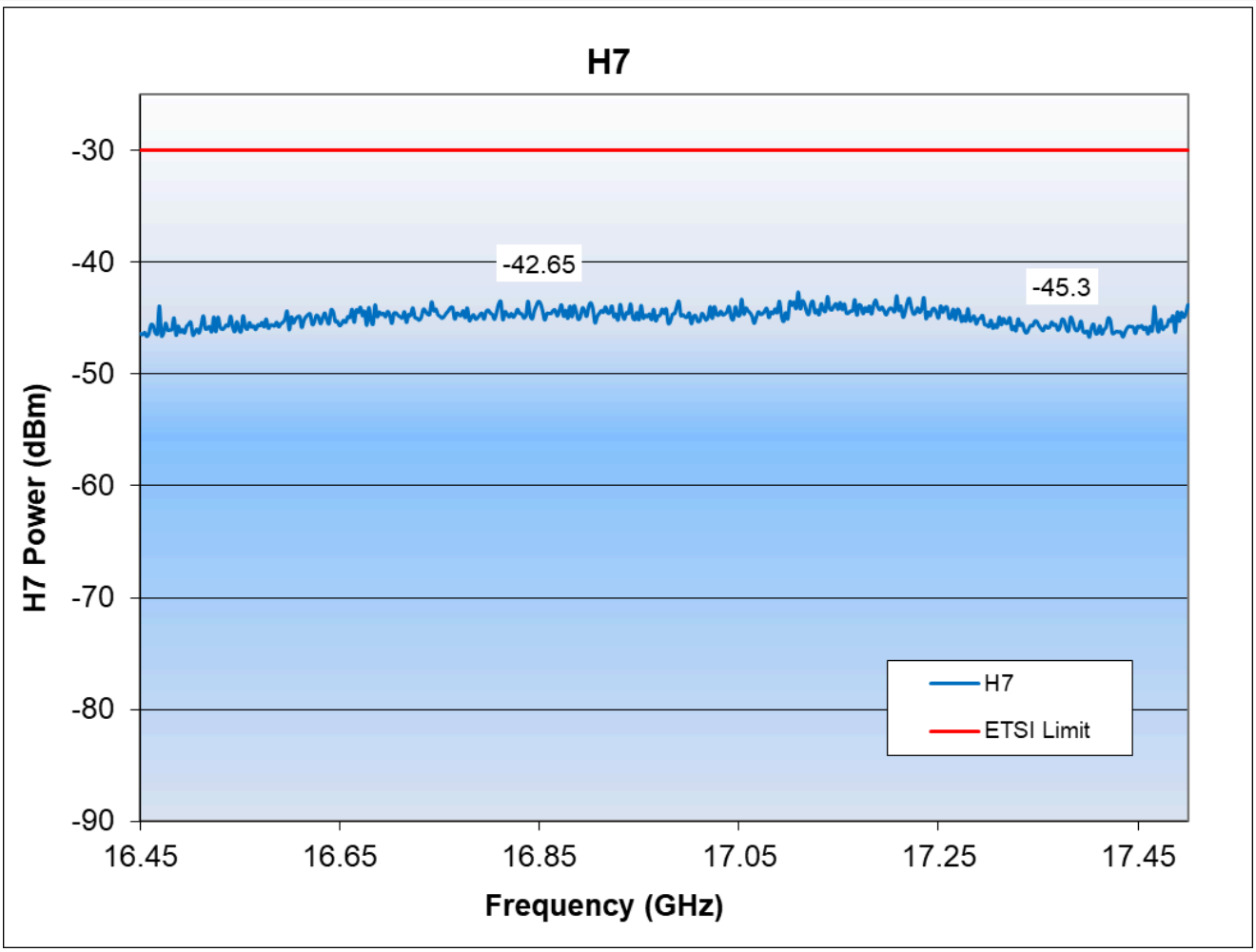



**Figure 18. Bluetooth LE - Conducted H7 spurious**

- 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:**

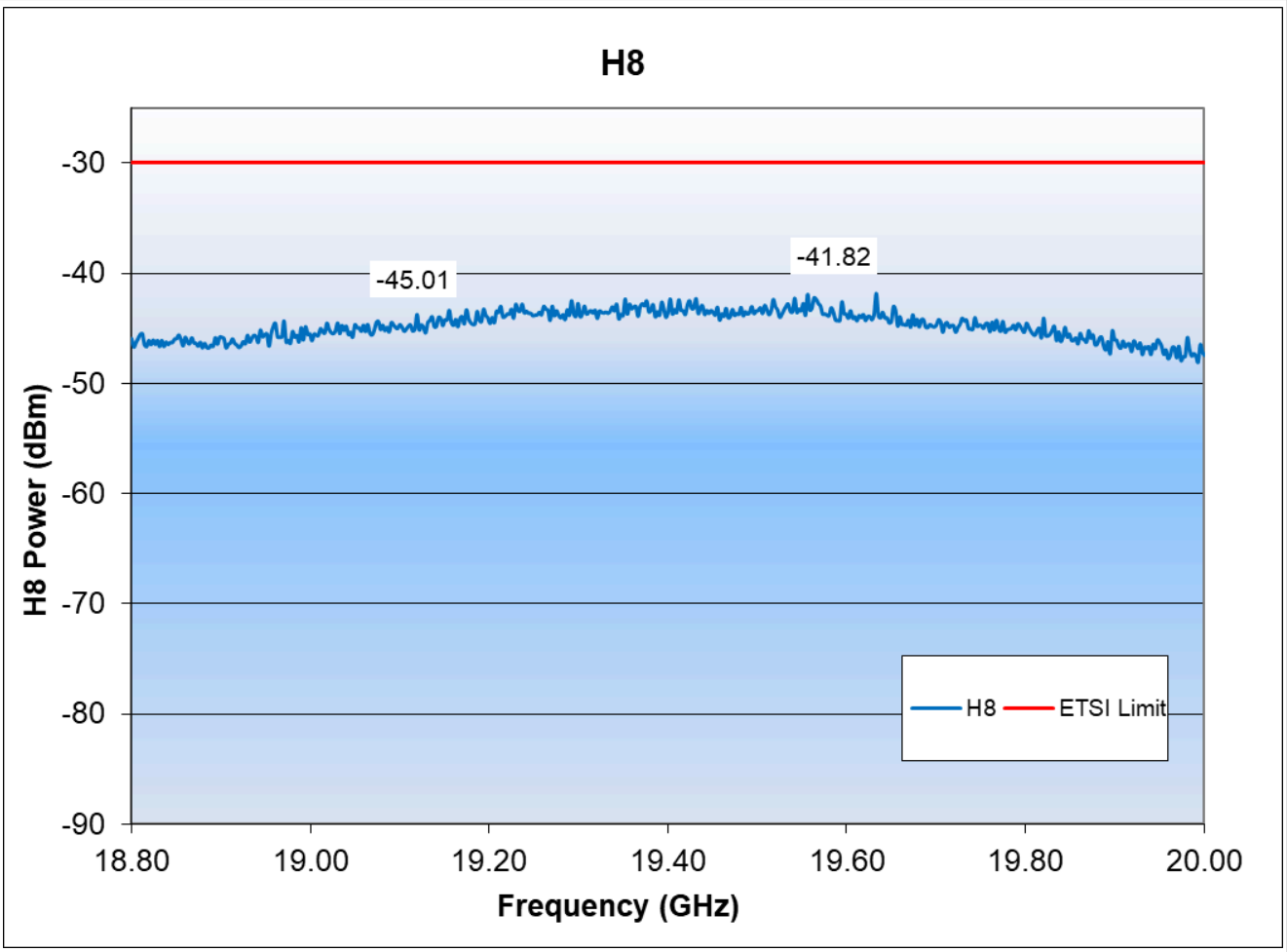



**Figure 19. Bluetooth LE - Conducted H8 spurious**

- 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:**

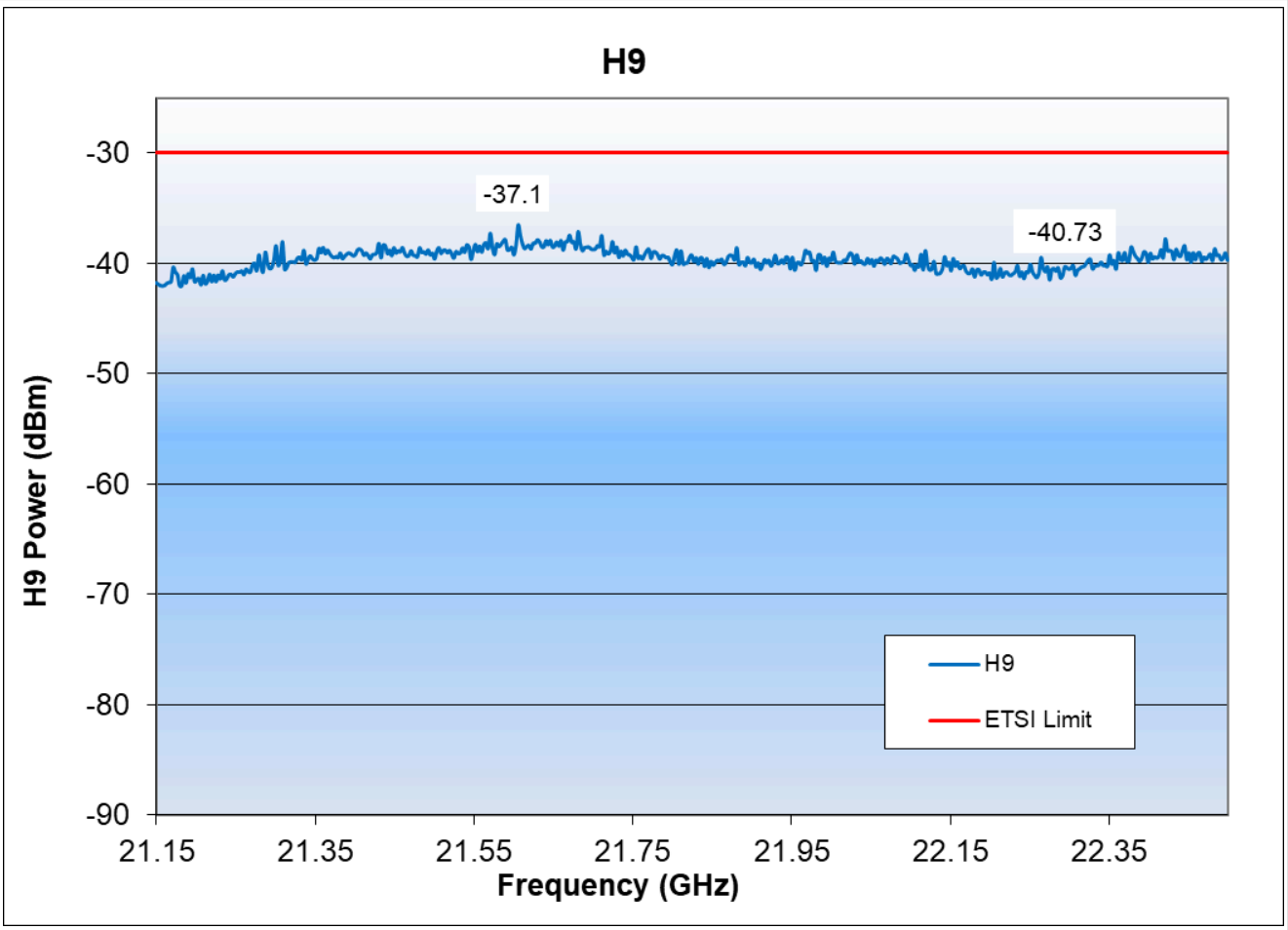



**Figure 20. Bluetooth LE - Conducted H9 spurious**

- 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:**

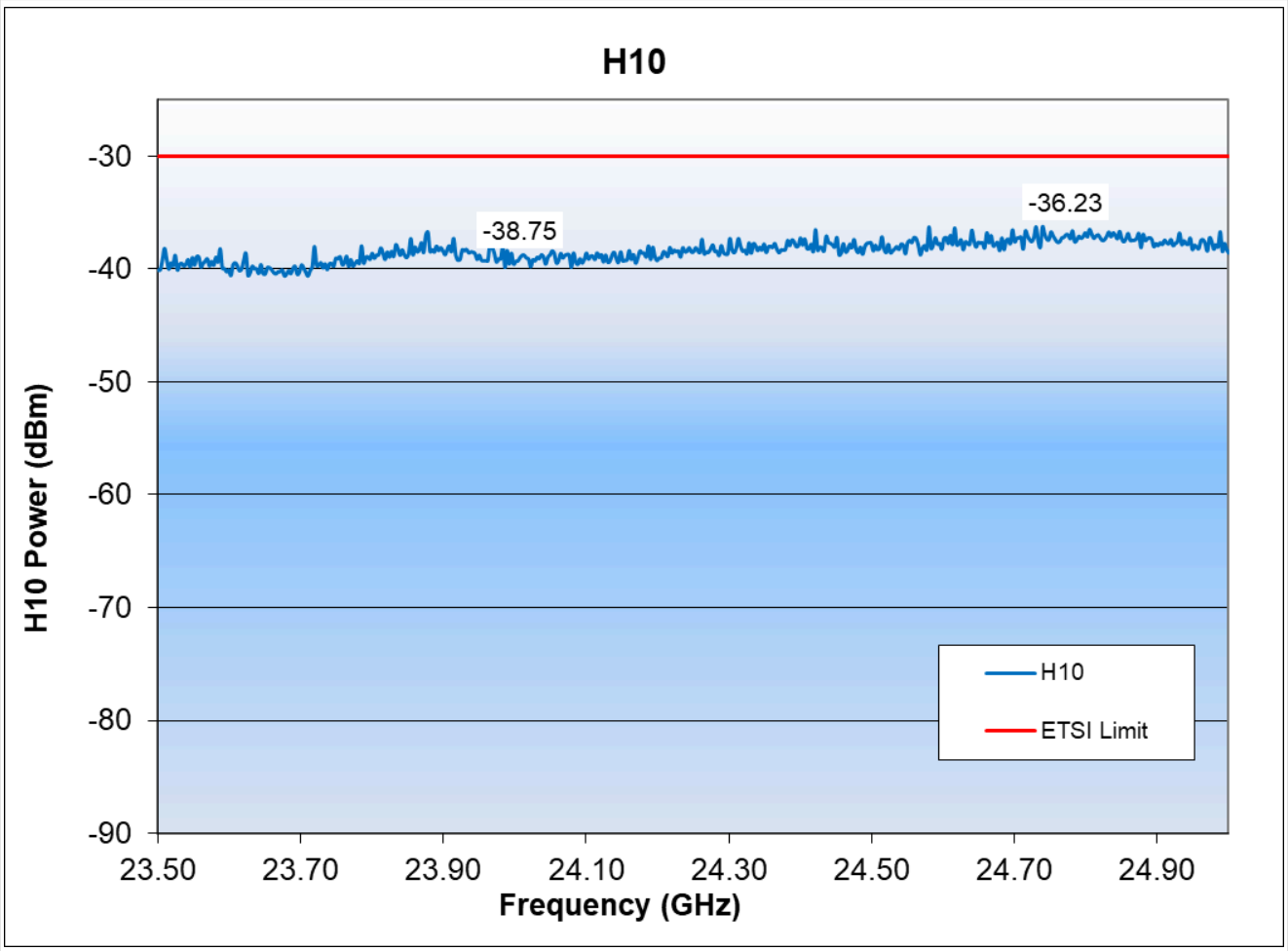



**Figure 21. Bluetooth LE - Conducted H10 spurious**

- 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:**

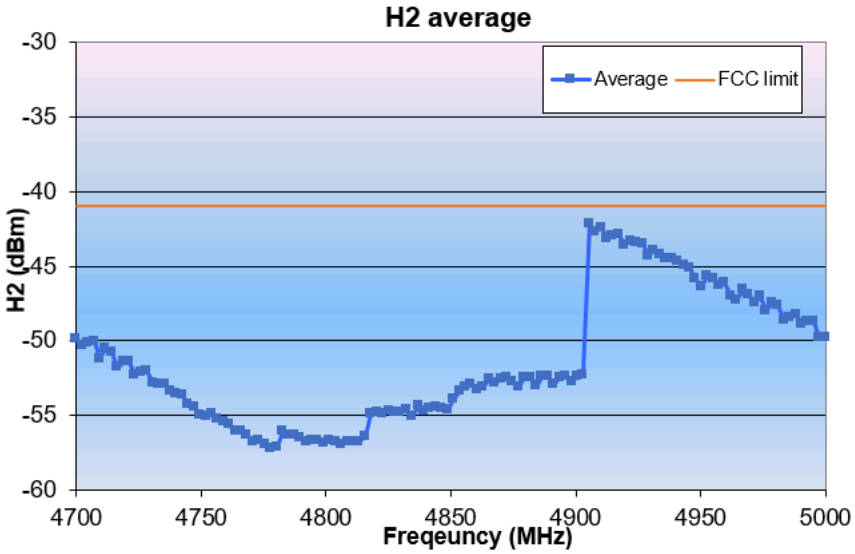



**Figure 22. Bluetooth LE - Conducted H2 FCC spurious**

- 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:**

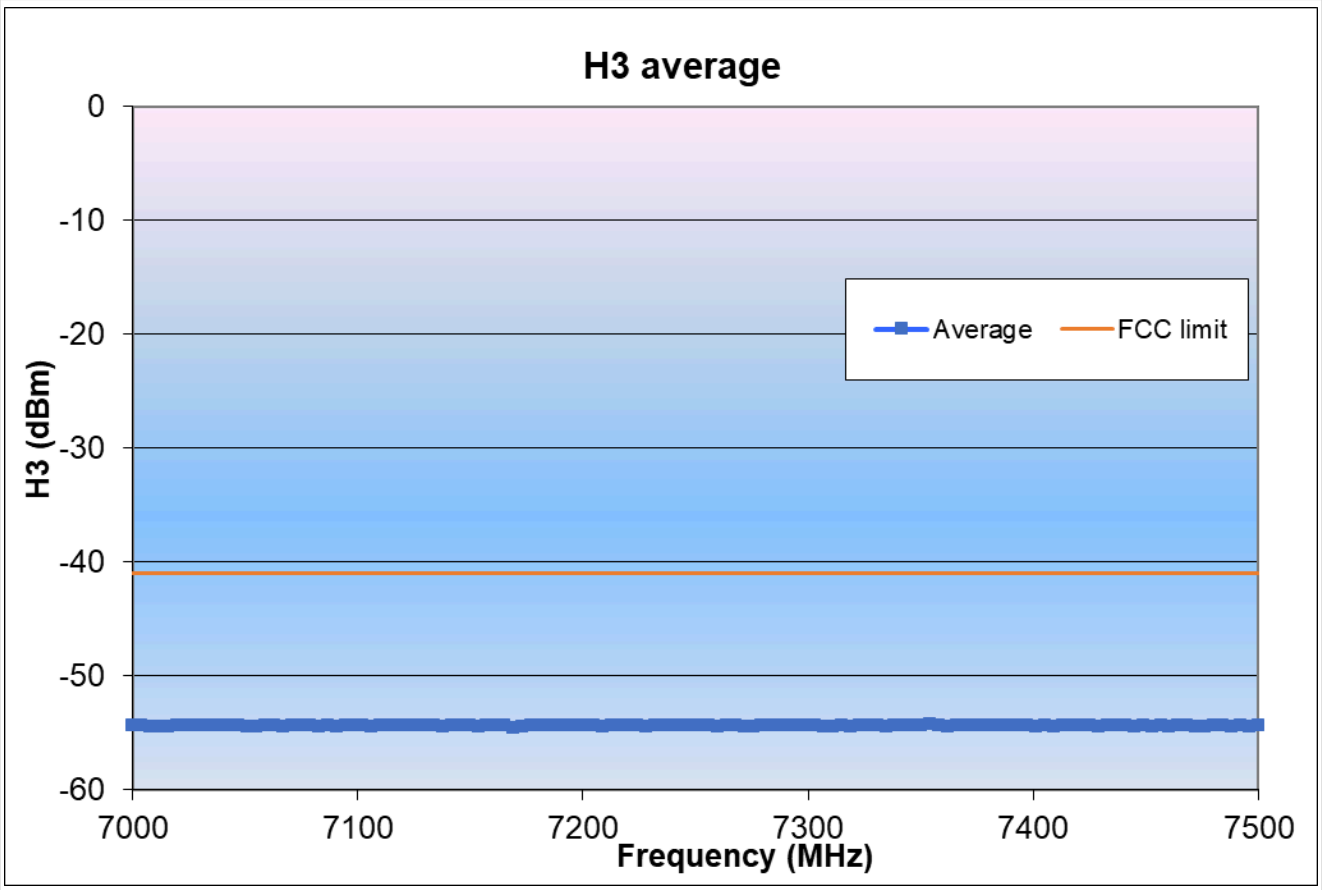



**Figure 23. Bluetooth LE - Conducted H3 FCC spurious**

- 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:**

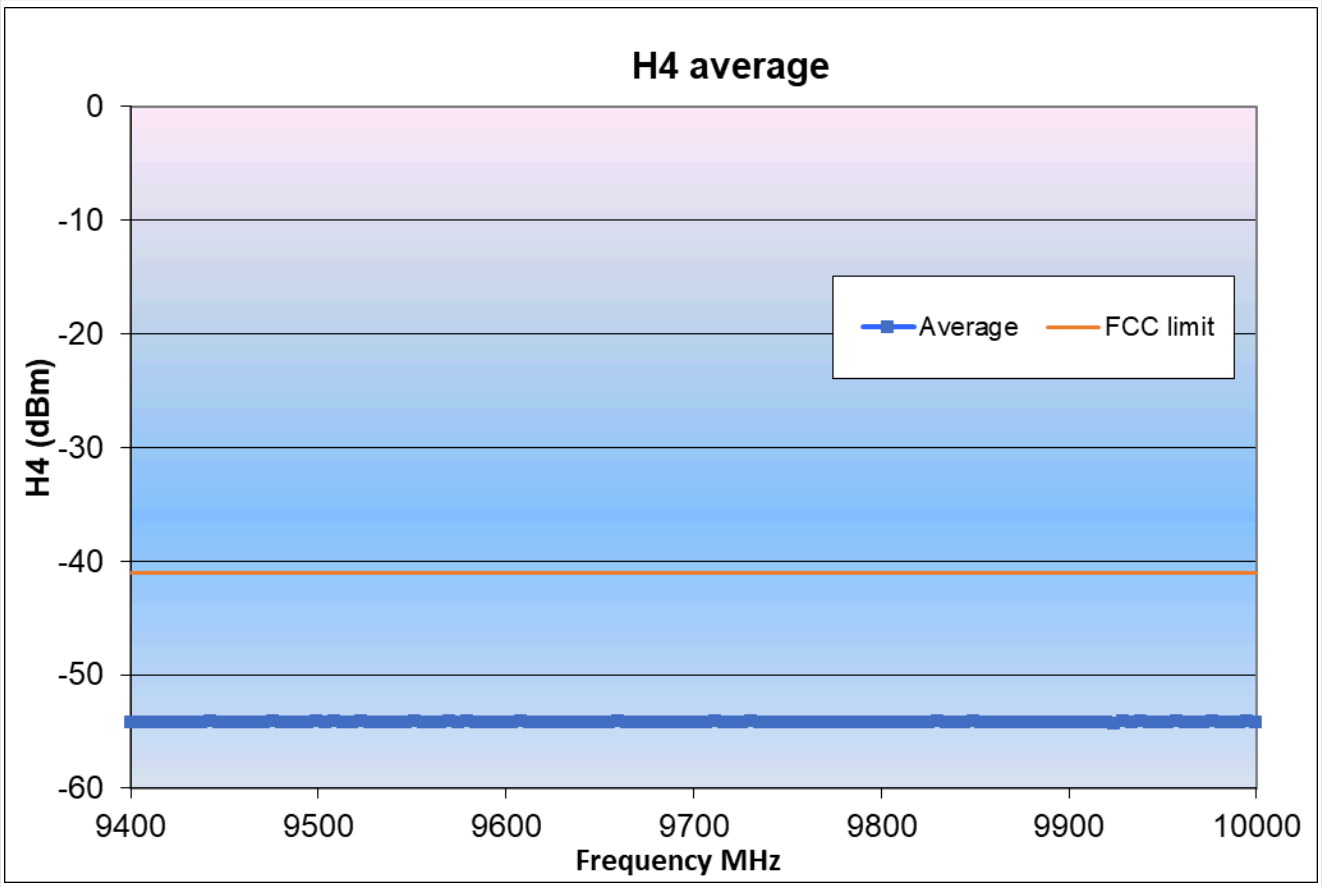



Figure 24. Bluetooth LE - Conducted H4 FCC spurious

- 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:**

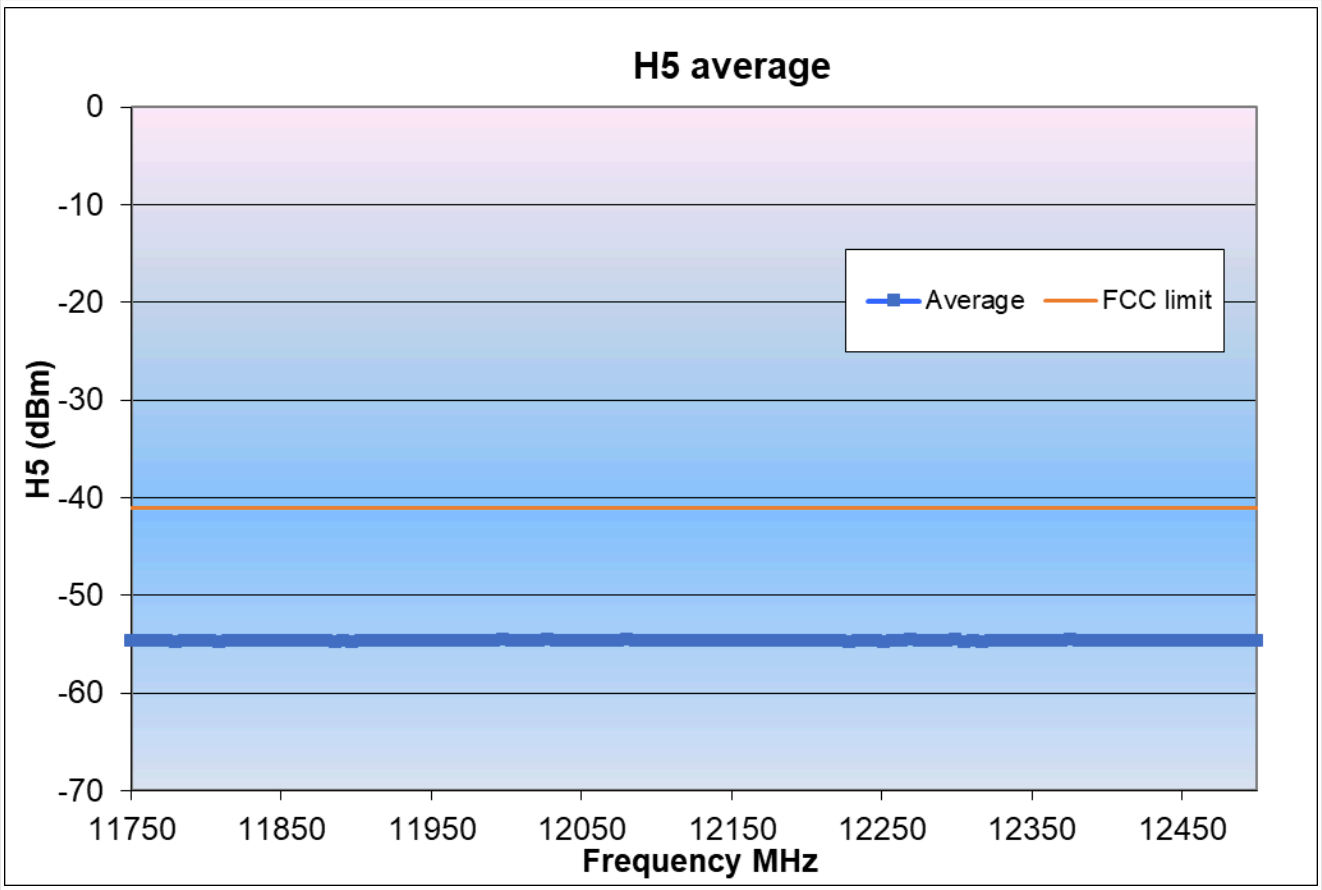



**Figure 25. Bluetooth LE - Conducted H5 FCC spurious**

- 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:**

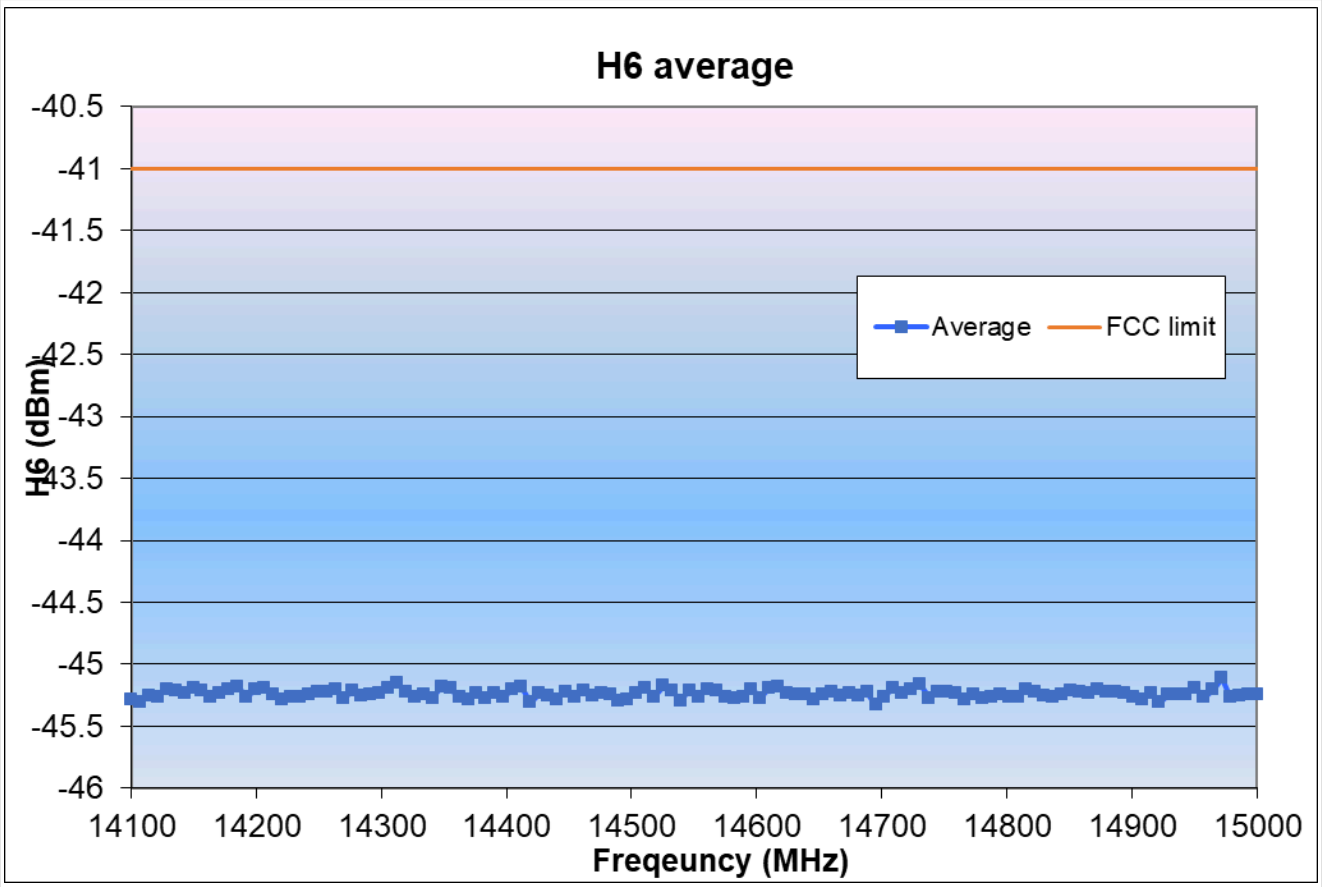



**Figure 26. Bluetooth LE - Conducted H6 FCC spurious**

- 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:**

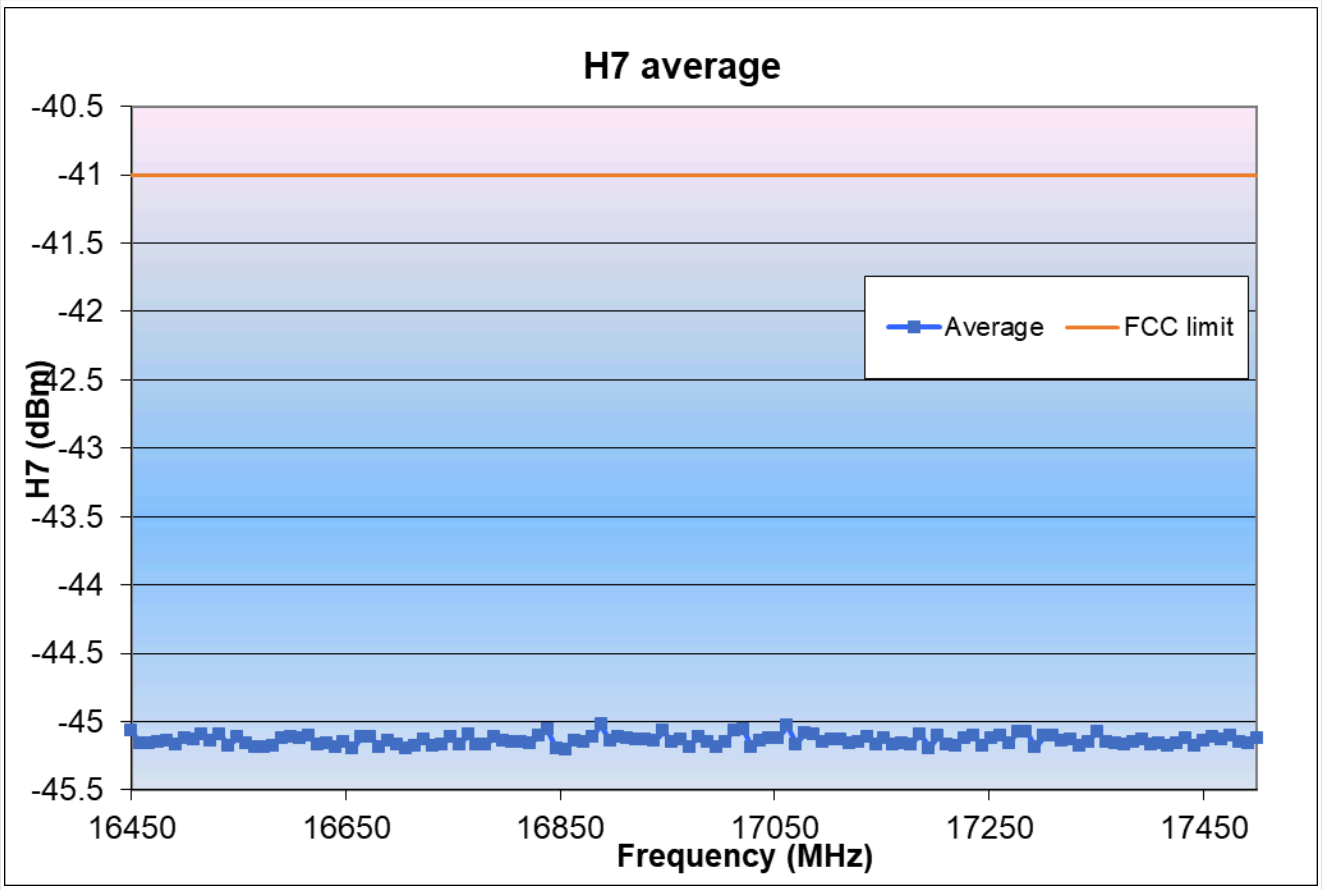



Figure 27. Bluetooth LE - Conducted H7 FCC spurious

- 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:**

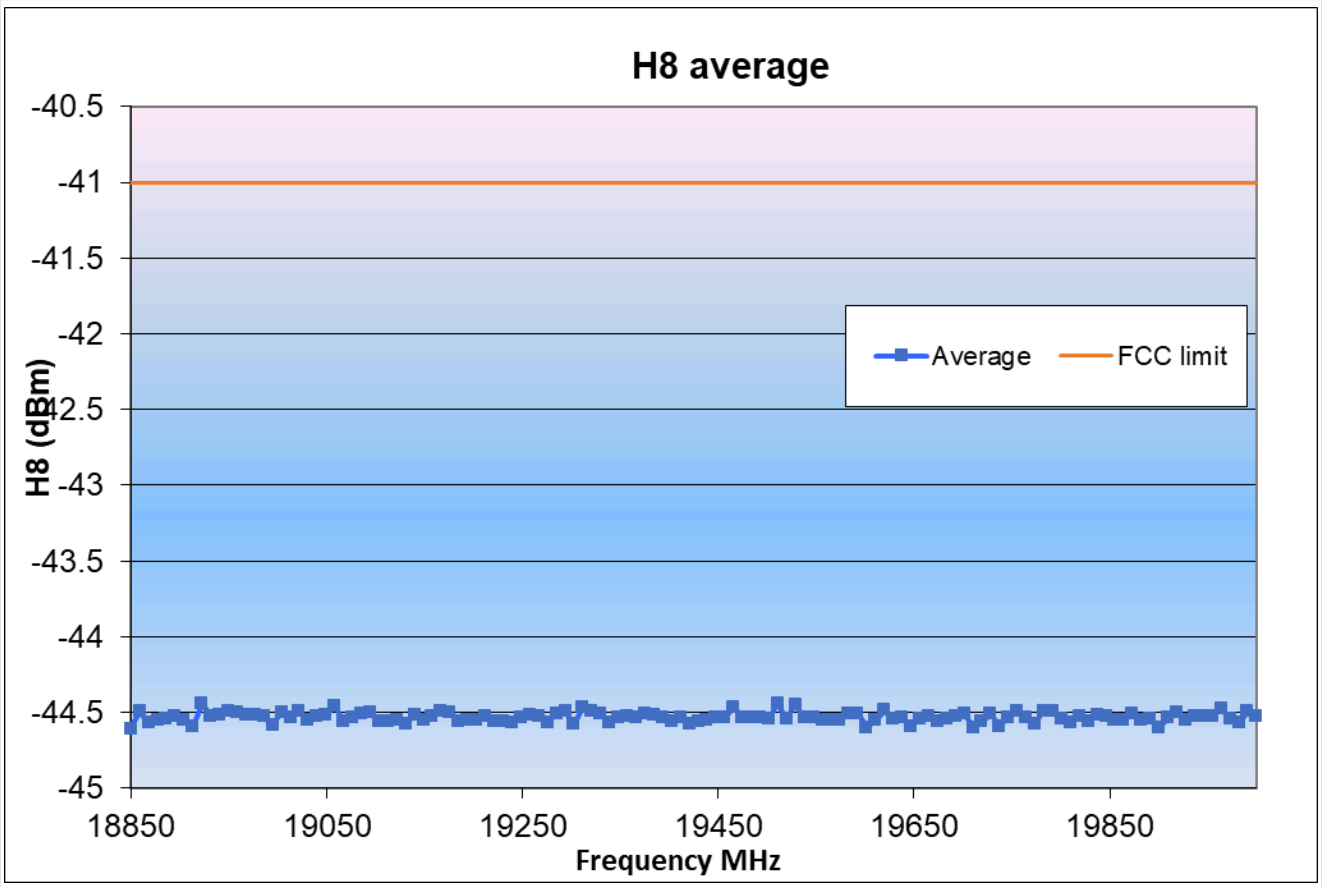



Figure 28. Bluetooth LE - Conducted H8 FCC spurious

- 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:**

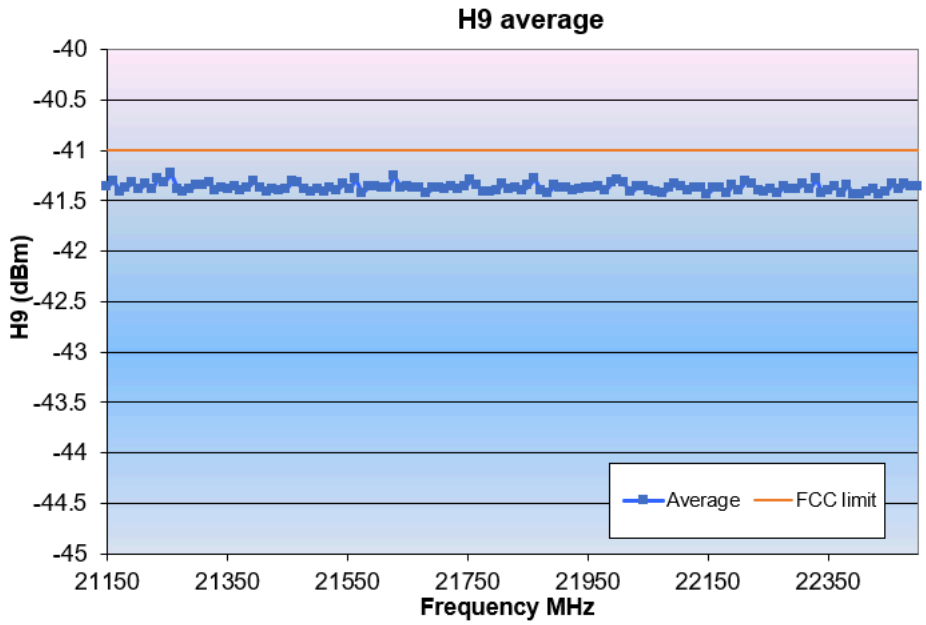



**Figure 29. Bluetooth LE - Conducted H9 FCC spurious**

- 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:**

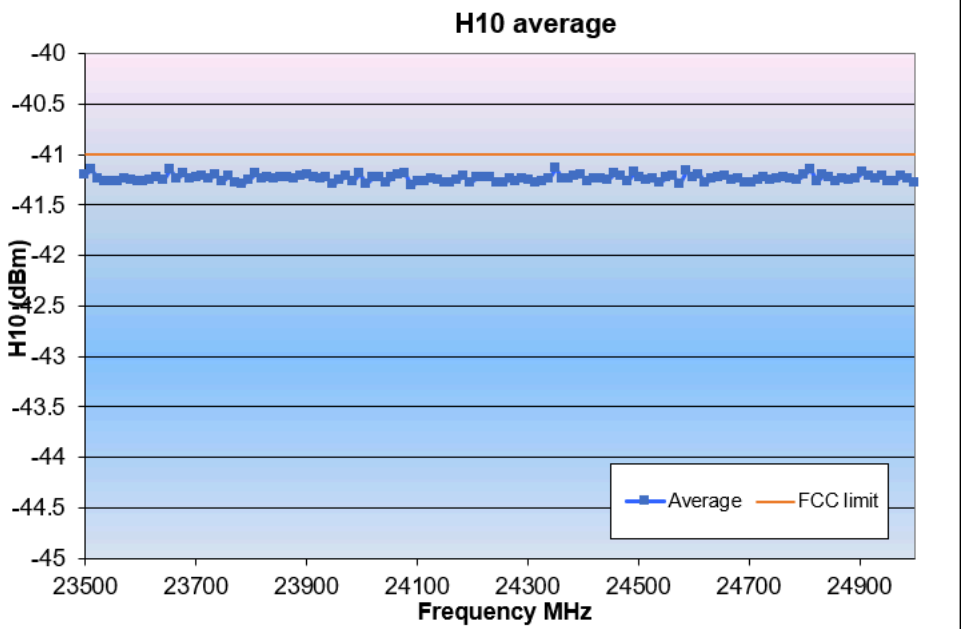



**Figure 30. Bluetooth LE - Conducted H10 FCC spurious**

- Maximum power is at frequency 24.350 GHz: -41.13 dBm.

**Conclusion:**

- There is no margin (~0.1 dB) to the FCC limit.

### 3.3.1.7 Lower band edge – MIIT China

**Test method:**

- Set the radio to:
  - TX mode
  - Modulated
  - Burst mode
  - Set the channel 0 (2.402 GHz)
- Set the analyzer to:
  - Start freq = 2.375 GHz
  - Stop freq = 2.405 GHz
  - Ref amp = -20 dBm
  - Sweep time = 100 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 `0x02h` (2 µs)
  - Modification: XCVR_TX_DIG_PA_CTRL_PA_RAMP_SEL(**2**) in the *nxp_xcvr_common_config.c* file

**Bluetooth LE result:**

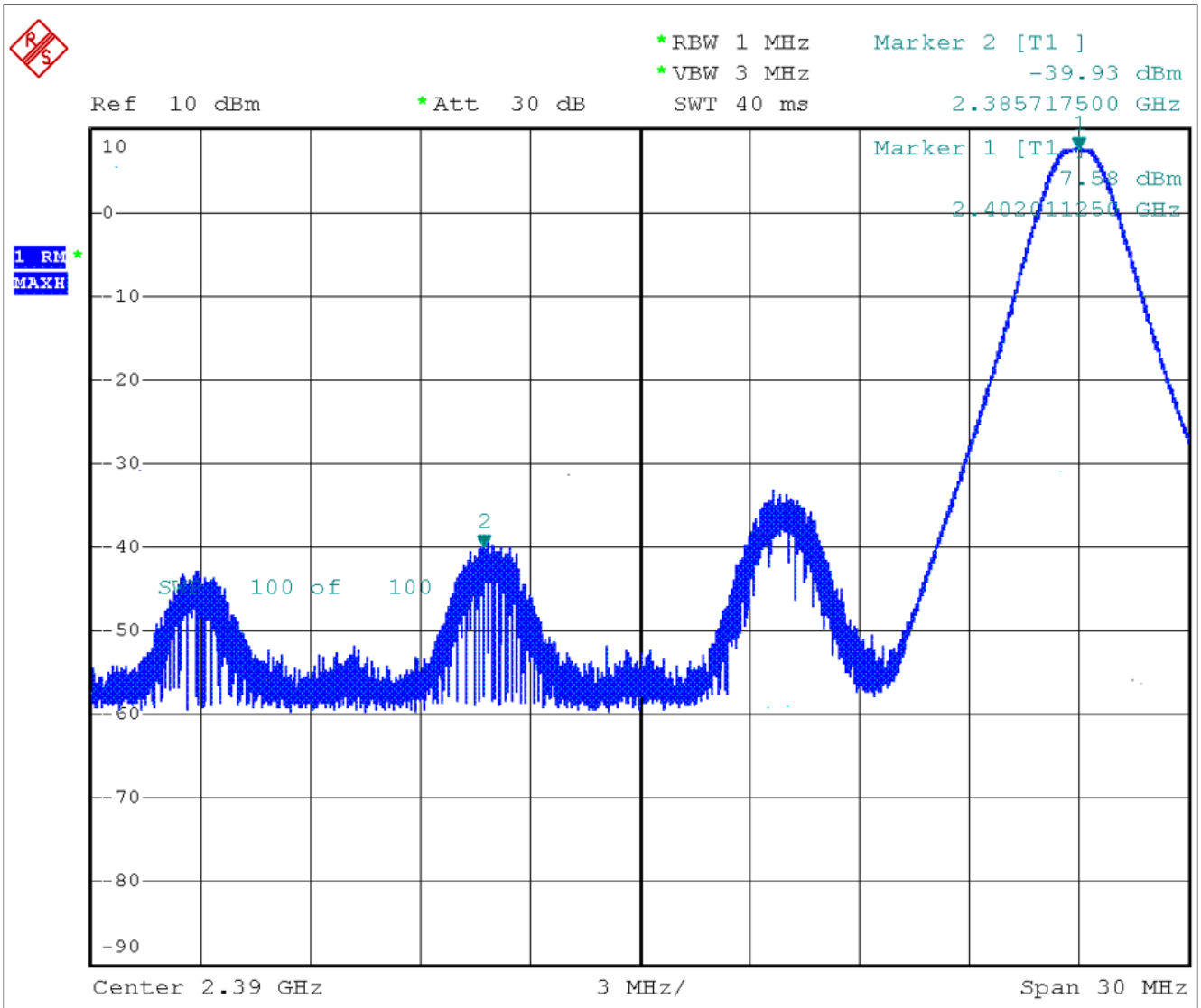



**Figure 31. Lower band edge – Channel 0**

**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

– 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:**

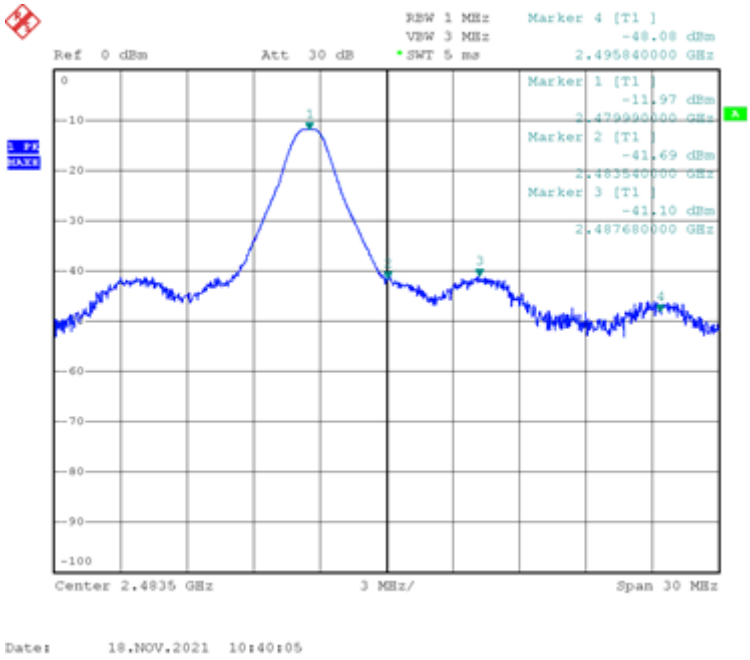



**Figure 32. Bluetooth LE - Upper band edge – Channel 39**

**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

– 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:**

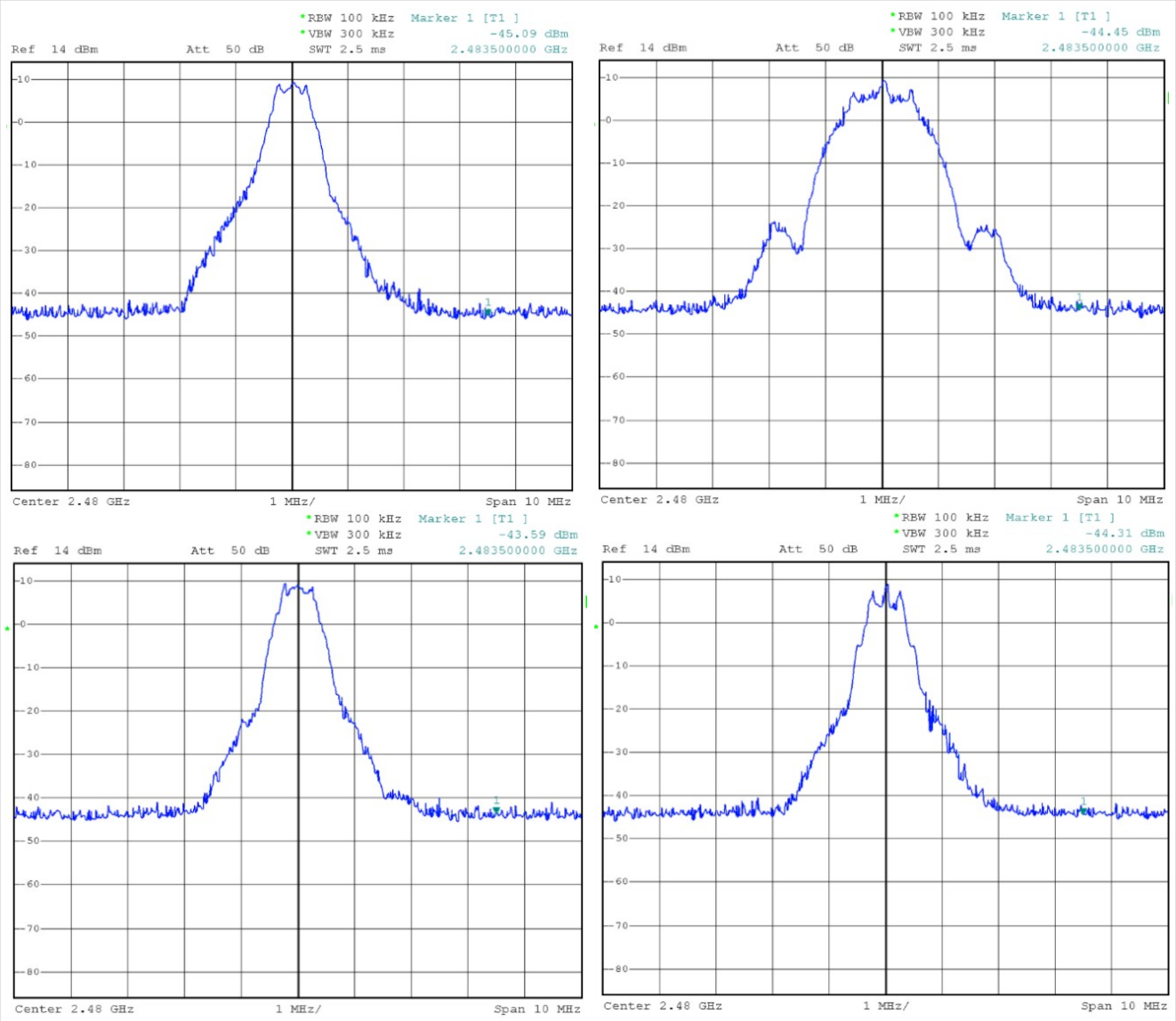



**Figure 33. Upper Band Edge – Channel 39**

| 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:**

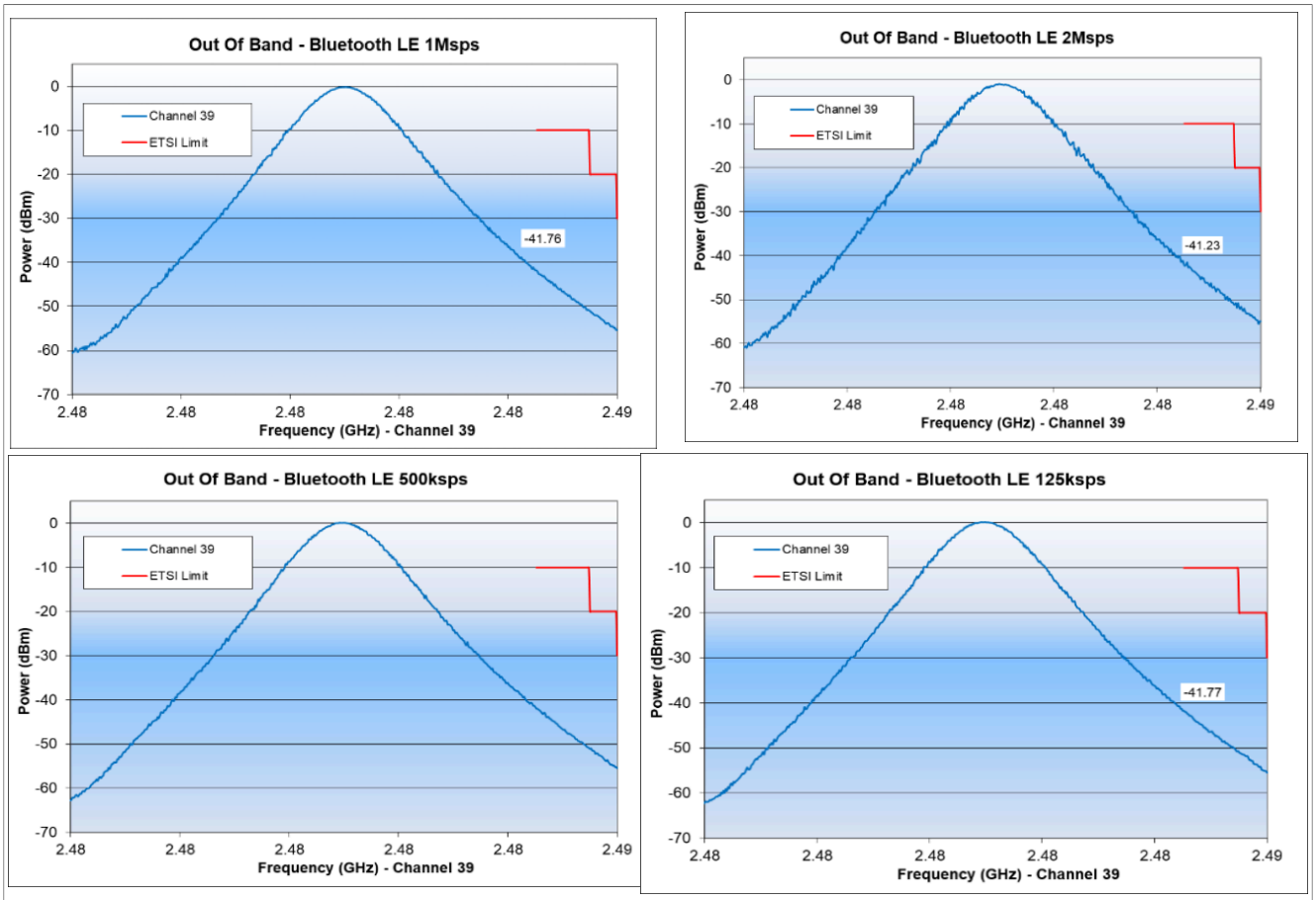



**Figure 34. Out of band – Channel 39**

**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:**

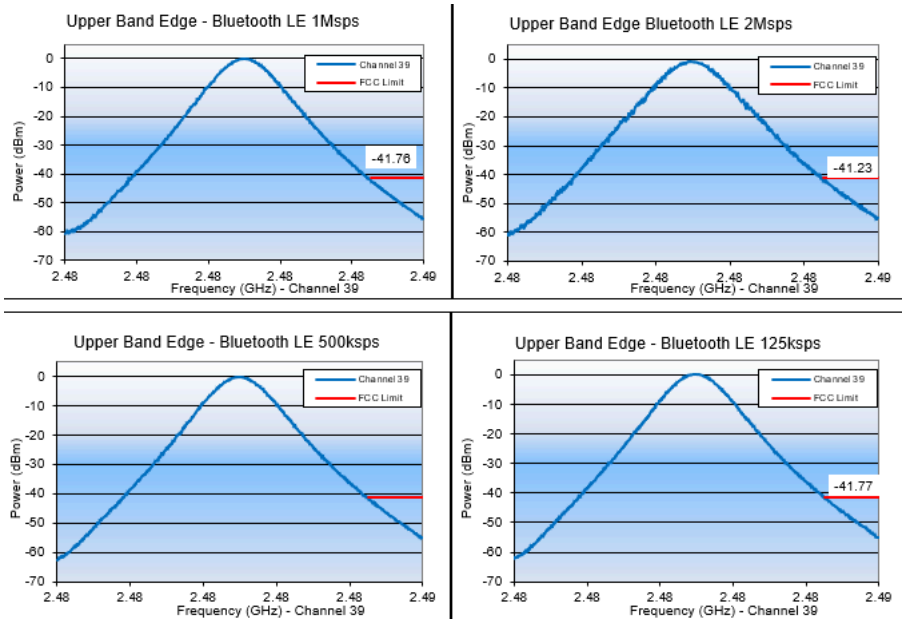



**Figure 35. Out of band – Channel 0 - ARIB**

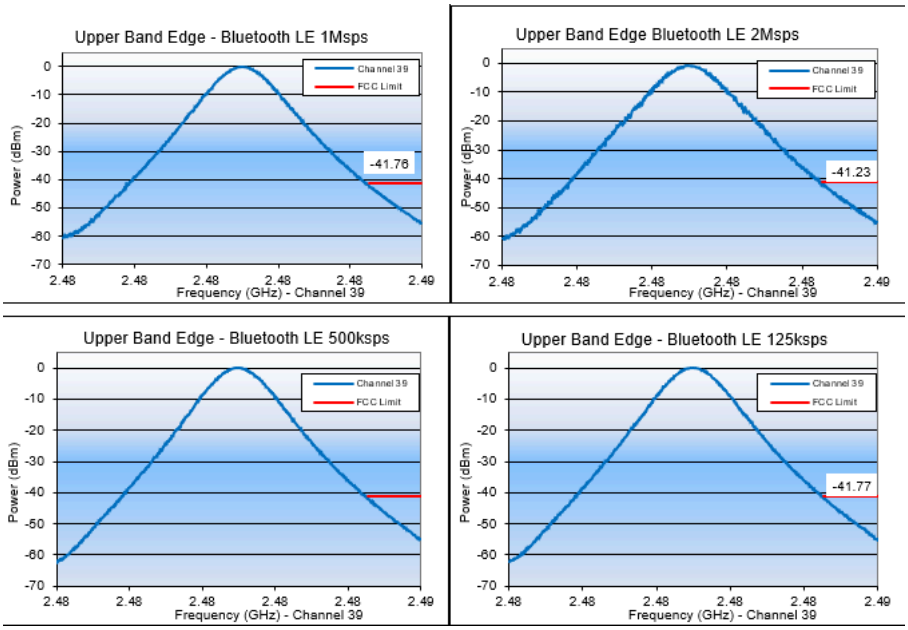



**Figure 36. Out of band – Channel 39 - ARIB**

**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:**

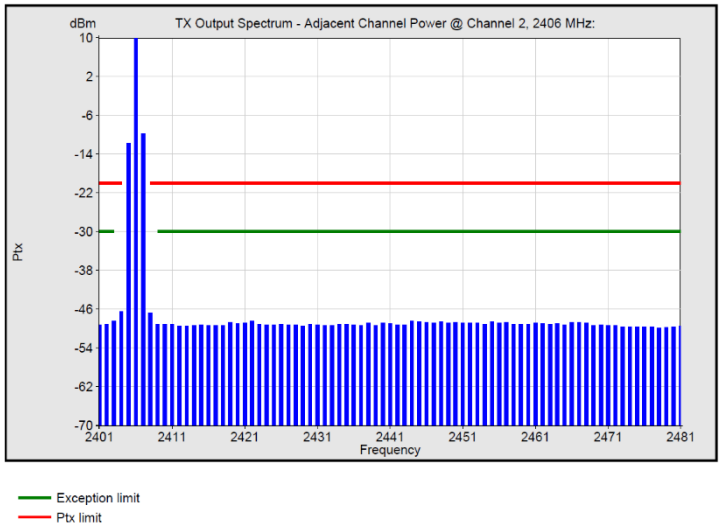



**Figure 37. Channel 3, 1 Msps**

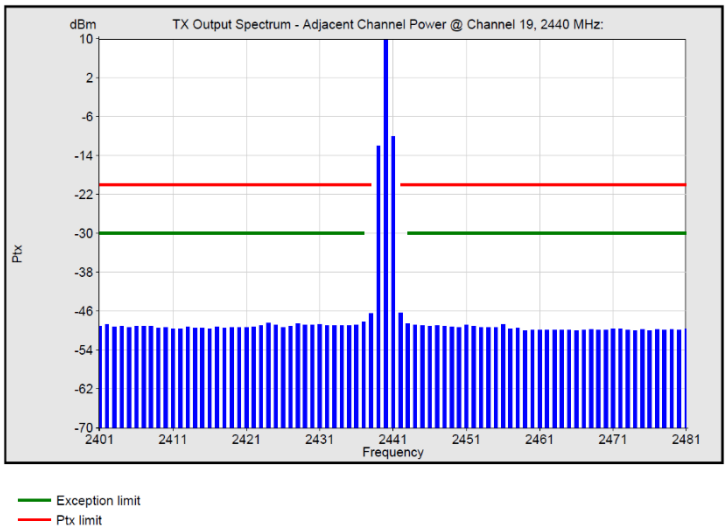



**Figure 38. Channel 19, 1 Msps**

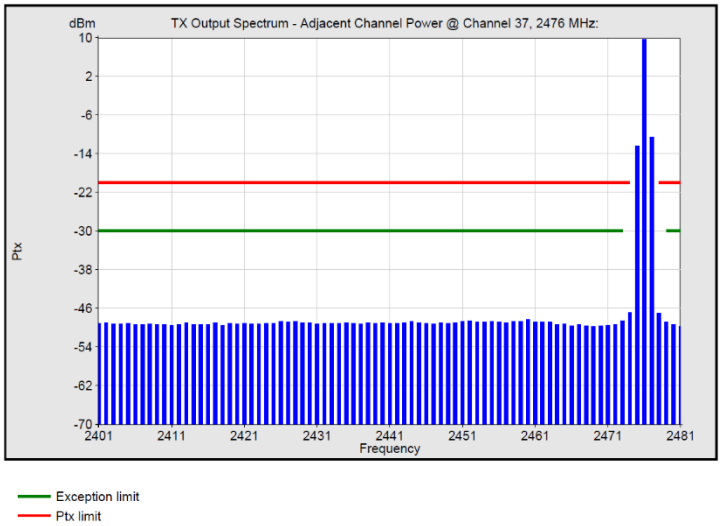



Figure 39. Channel 37, 1 Msps

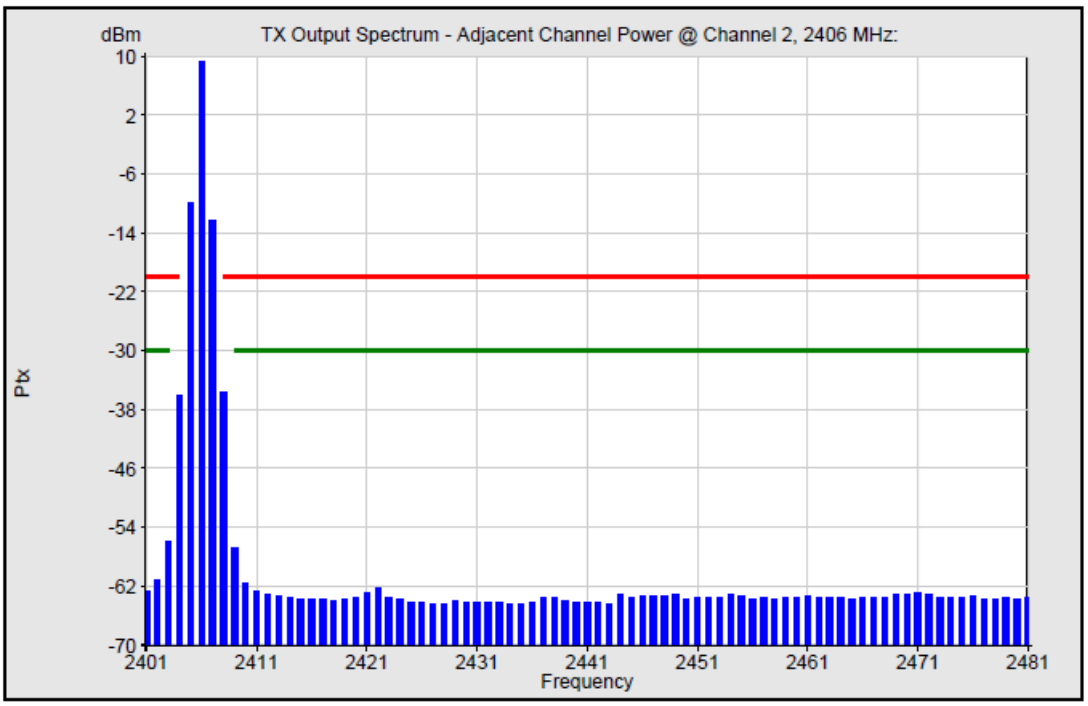



Figure 40. Channel 2, 2 Msps

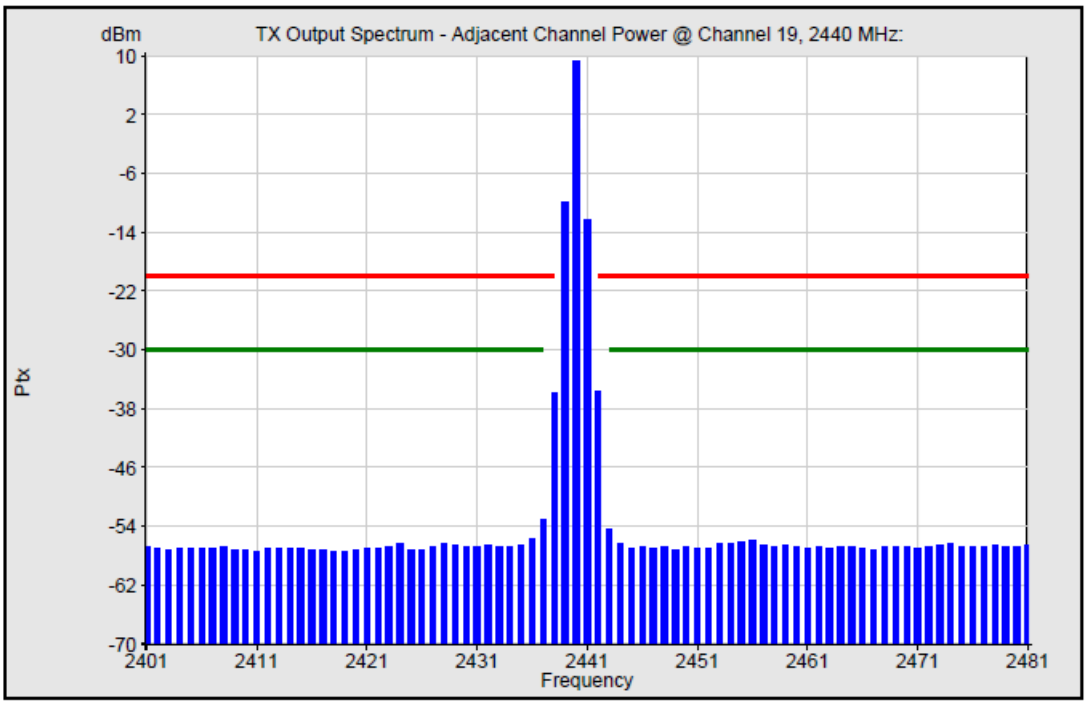



**Figure 41. Channel 19, 2 Msps**

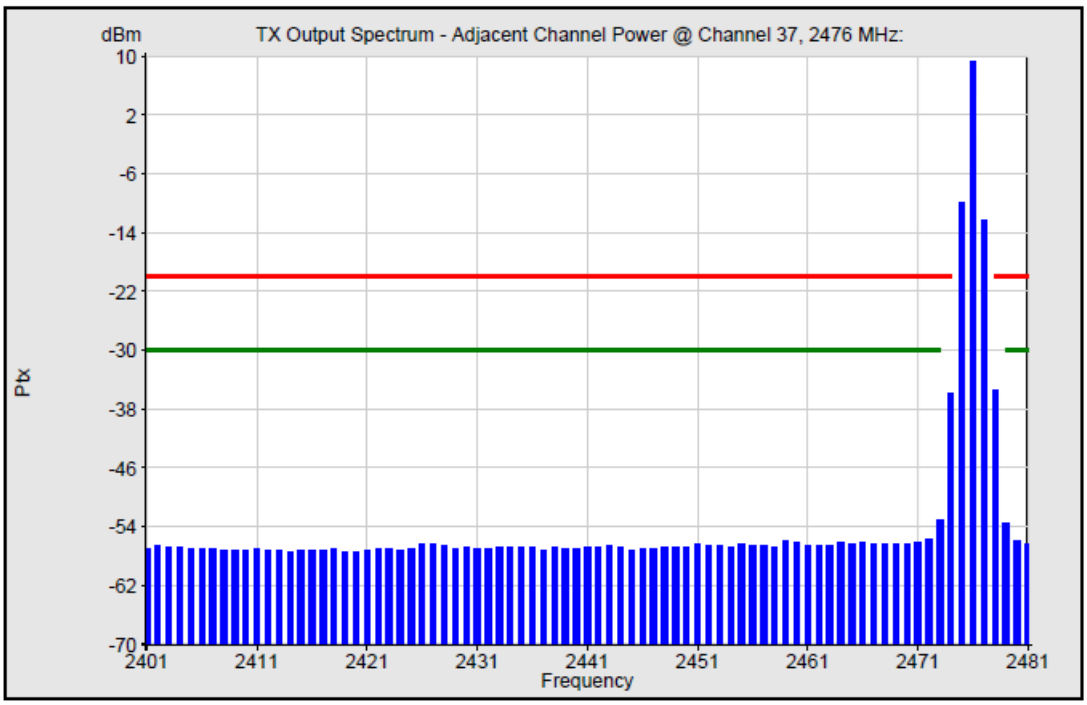



**Figure 42. Channel 37, 2 Msps**

### 3.3.1.14 Modulation characteristics

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

**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 | | | | | |

**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:**

- 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 |

**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

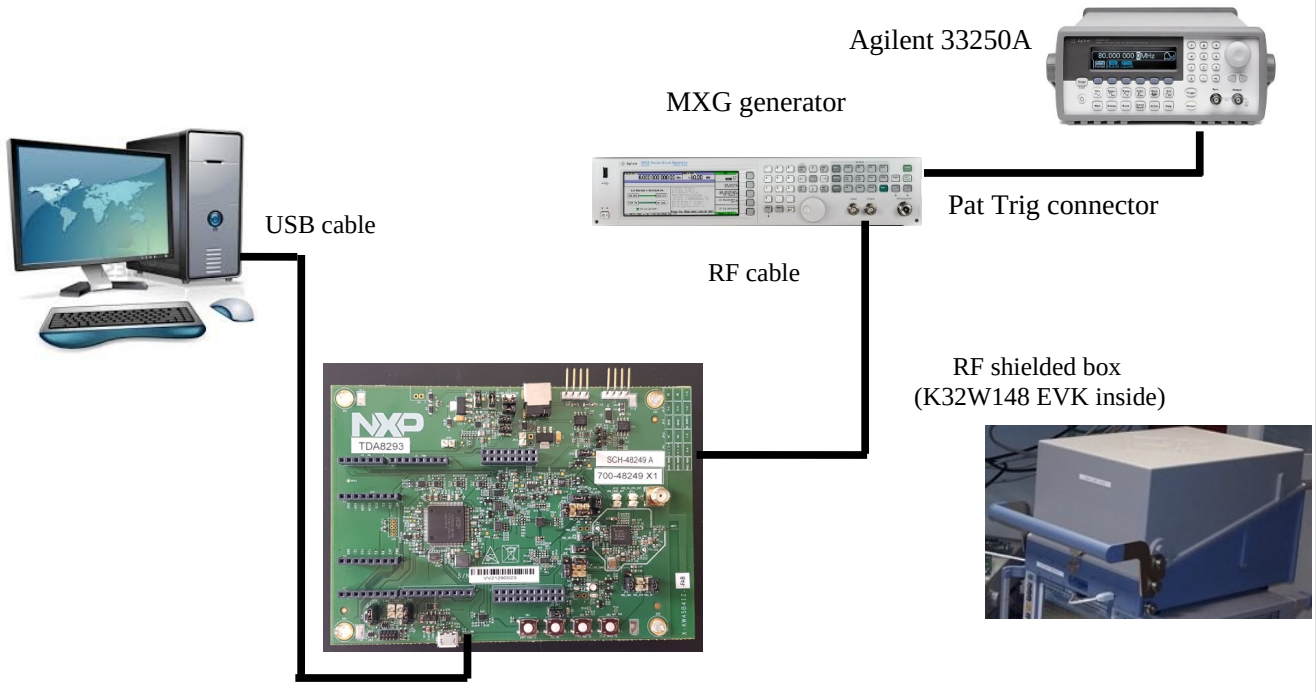



**Figure 43. Conducted RX test setup for sensitivity with RF generator and faraday box**

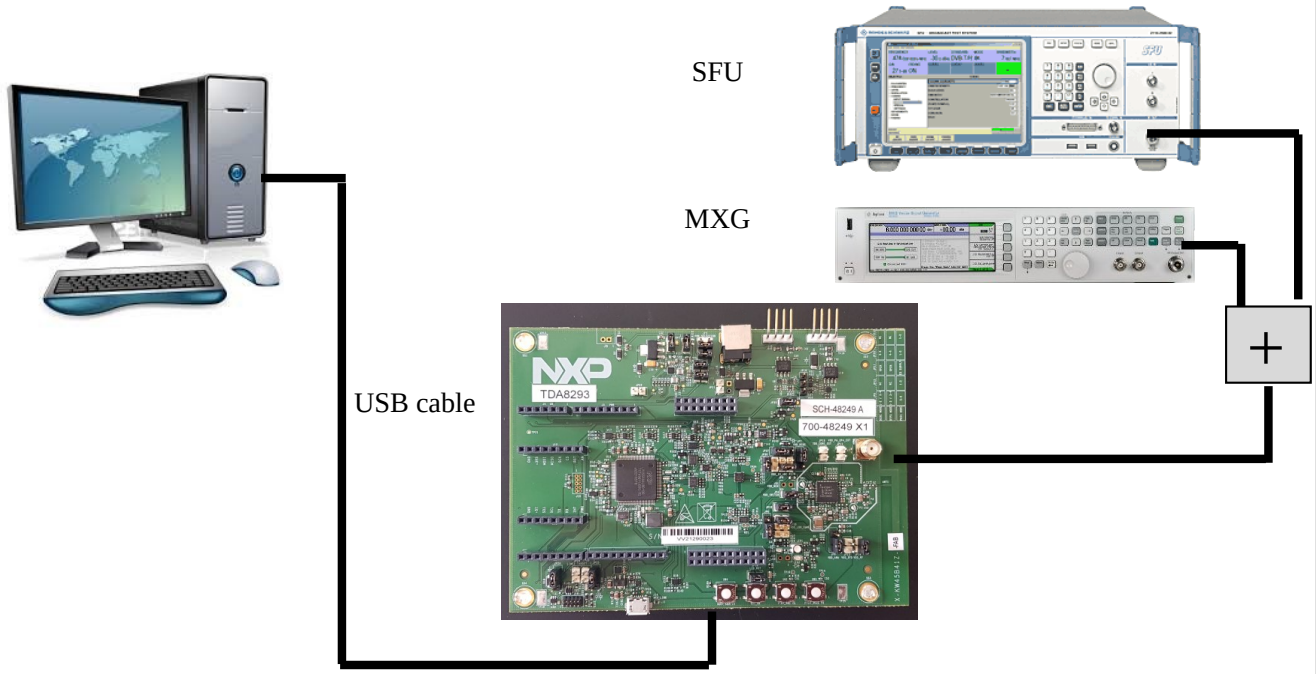



Figure 44. Conducted RX test setup for interference rejection

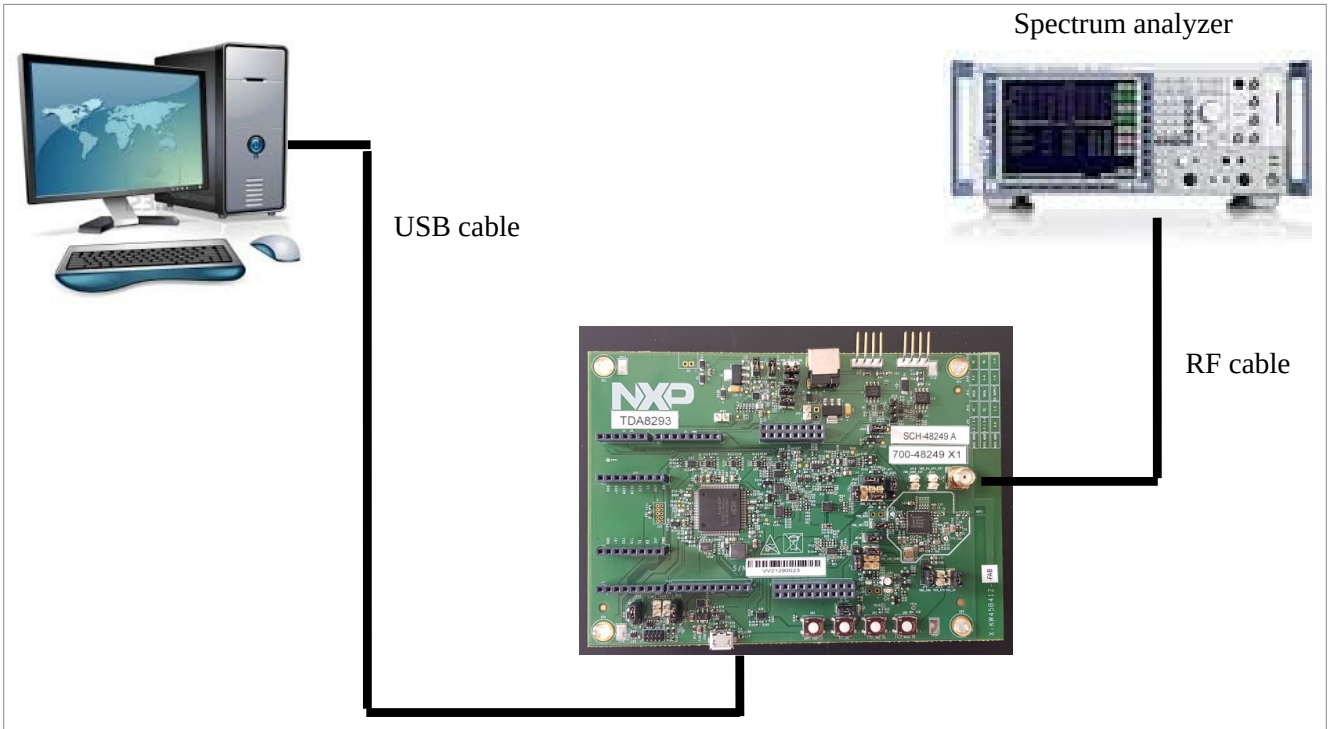



Figure 45. Conducted RX test setup for spurious

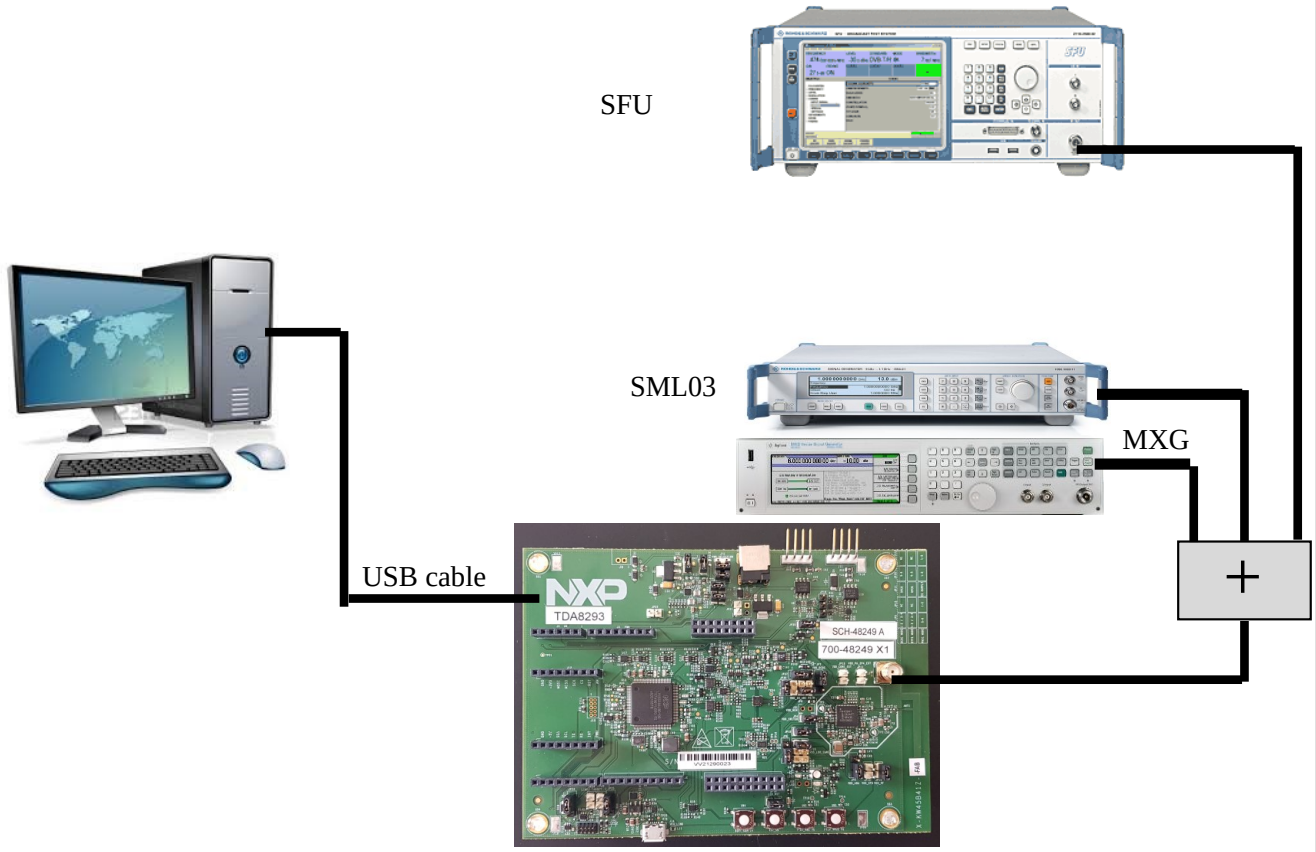



**Figure 46. Conducted RX test setup for intermodulation performances**

### 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.

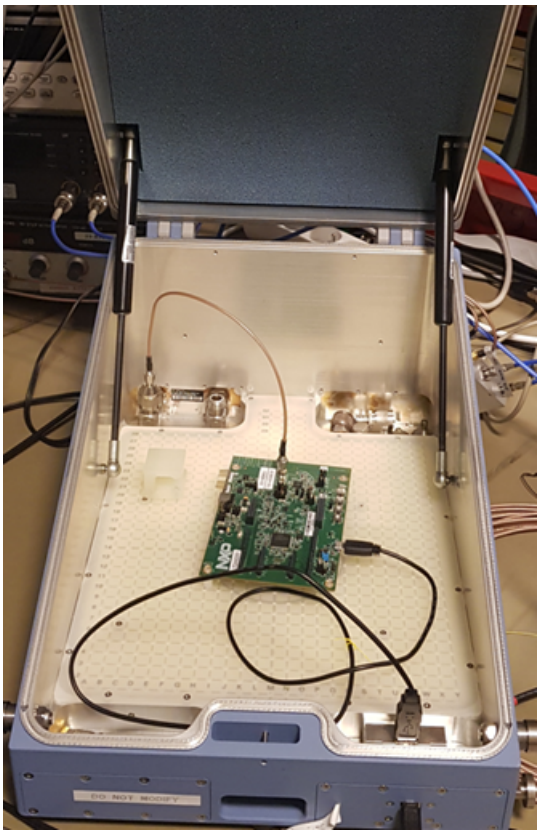


Figure 47. Sensitivity test

**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):**

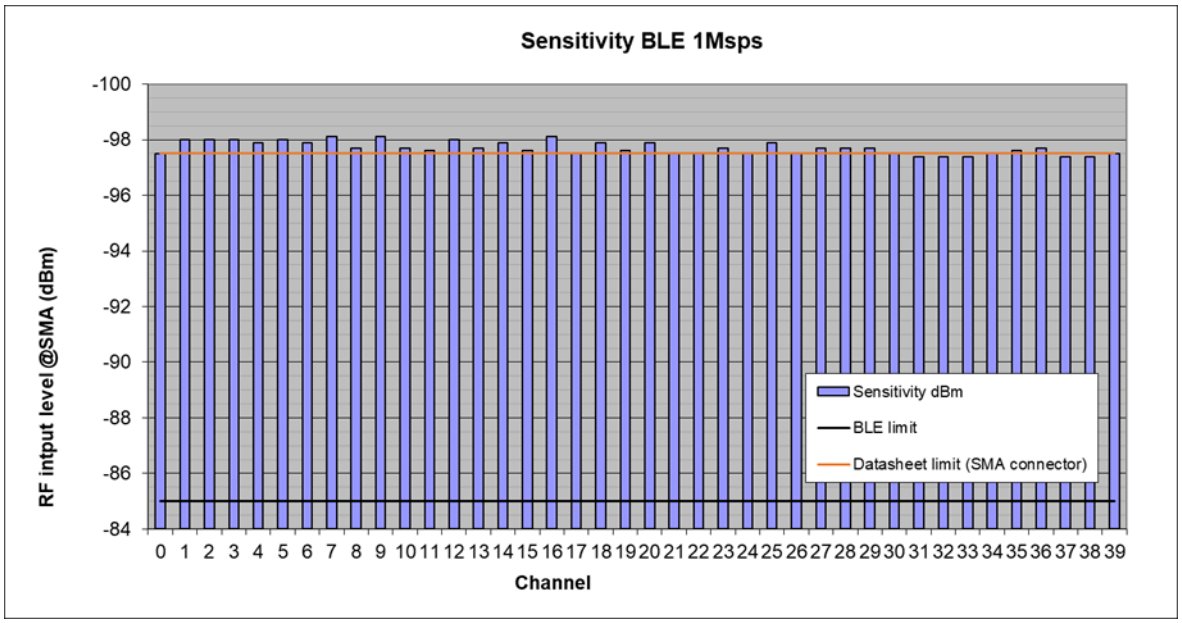



**Figure 48. Sensitivity result – 1 Msps**

- 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 Msps) at SMA connector.

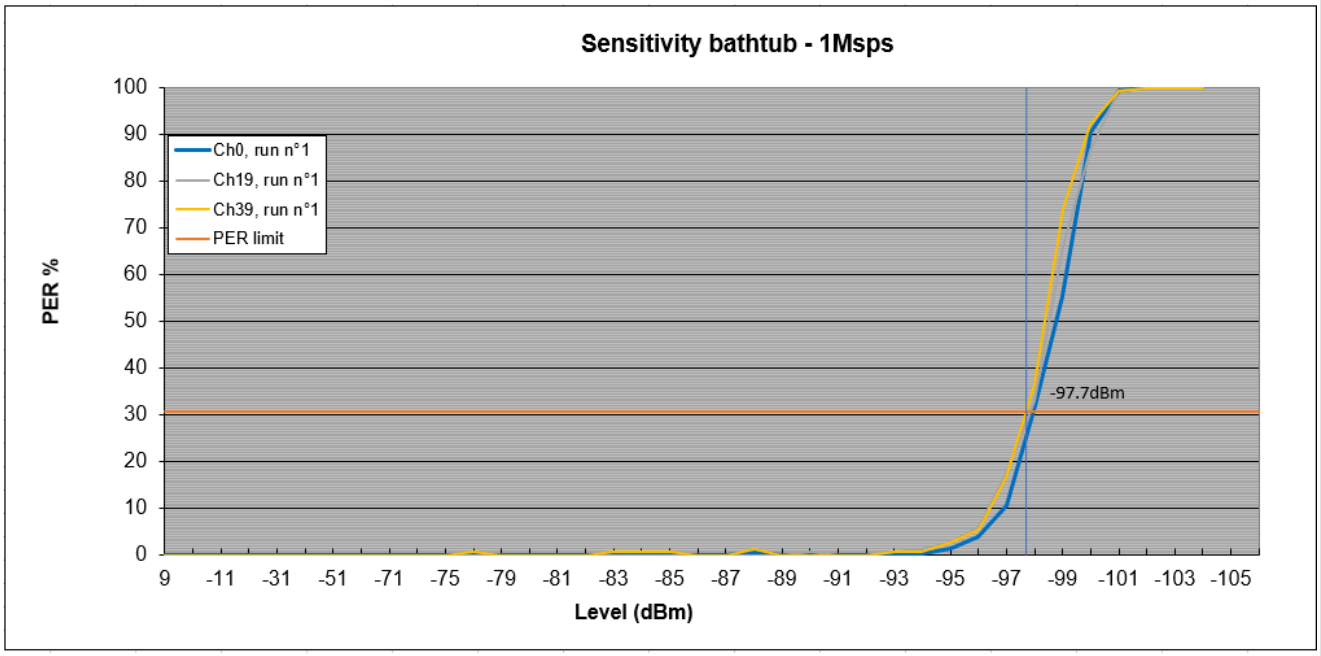



**Figure 49. Sensitivity bathtub result – 1 Msps**

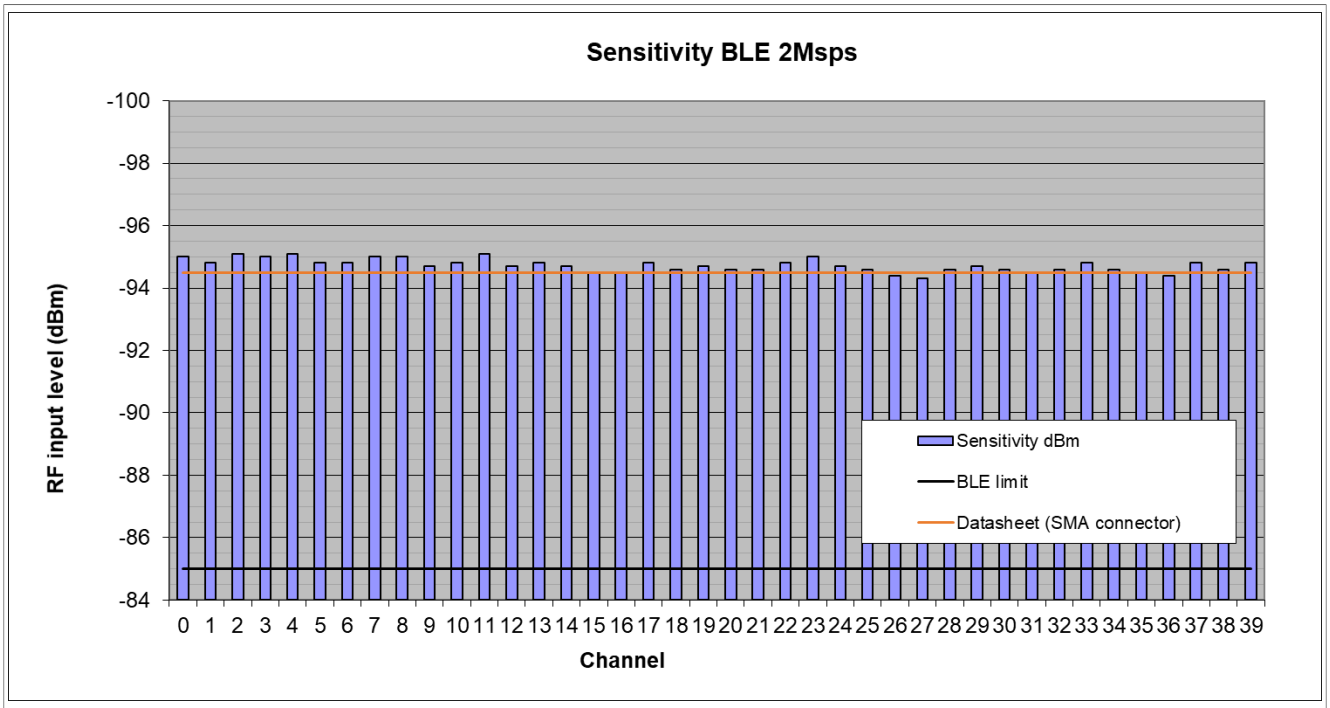



**Figure 50. Sensitivity result – 2 Msps**

- 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 Msps) at SMA connector.

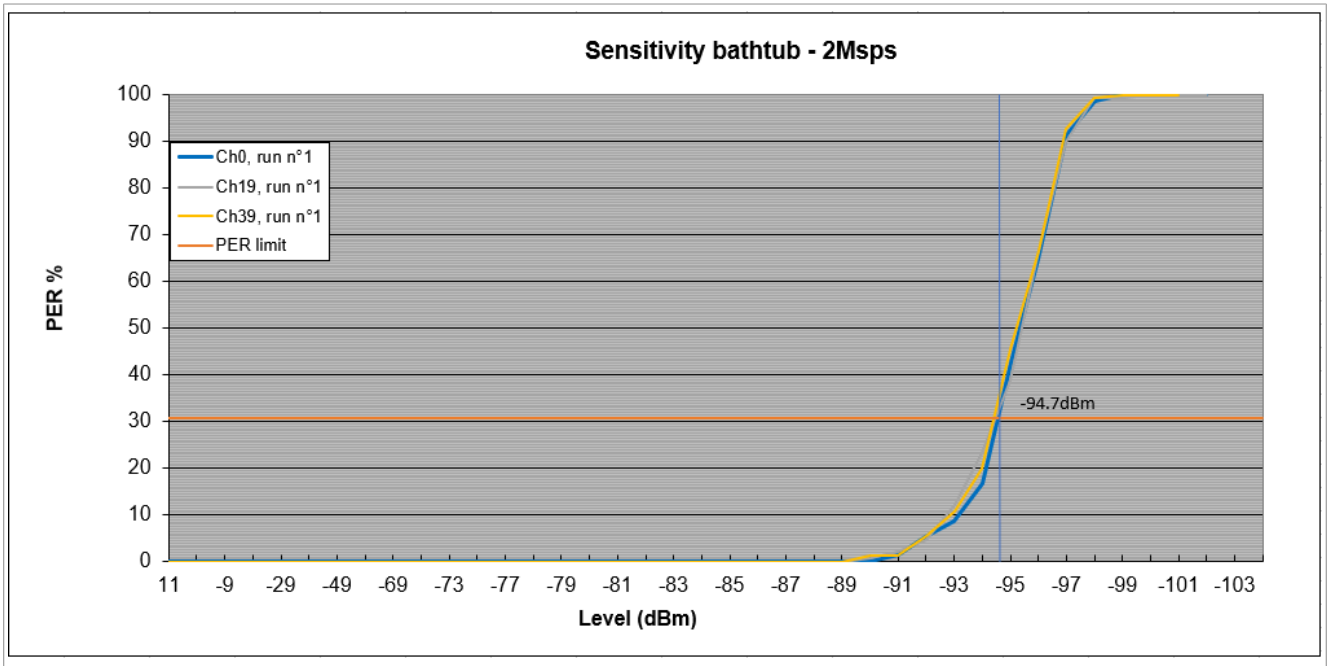



**Figure 51. Sensitivity bathtub result – 2 Msps**

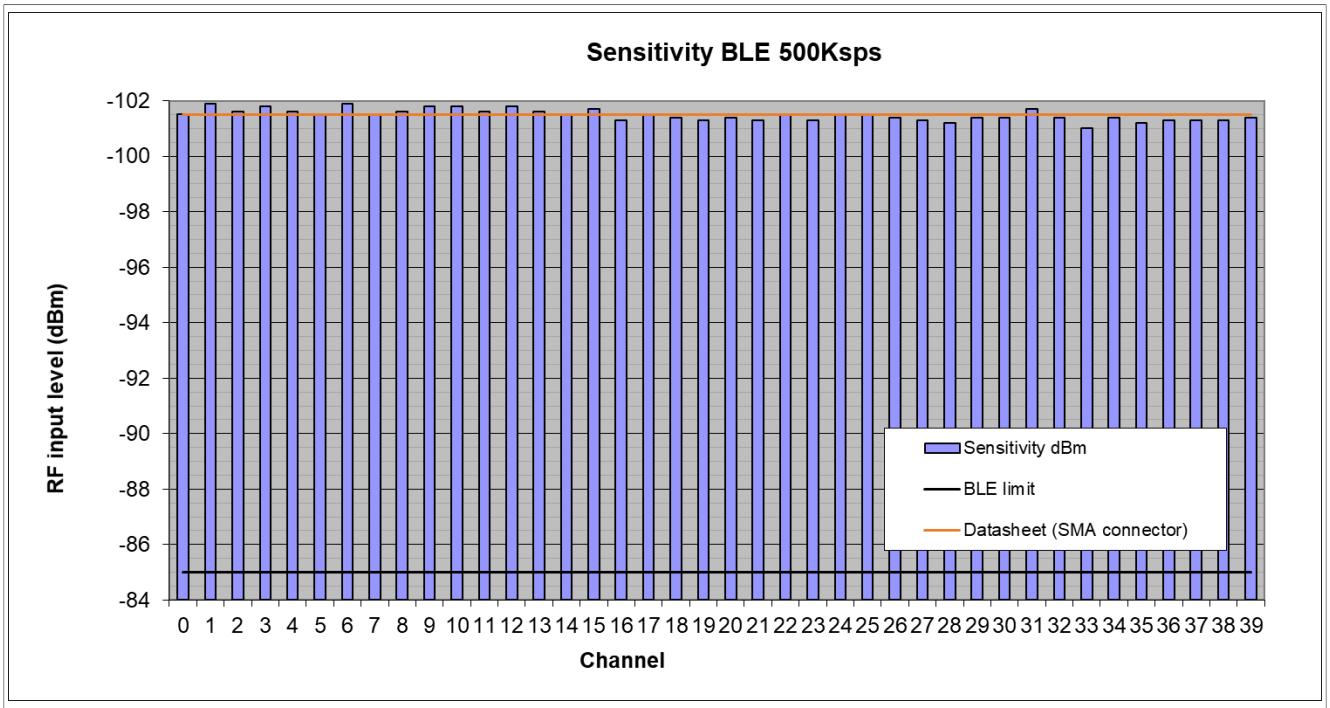



**Figure 52. Sensitivity result – LR (S=2)**

- 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.

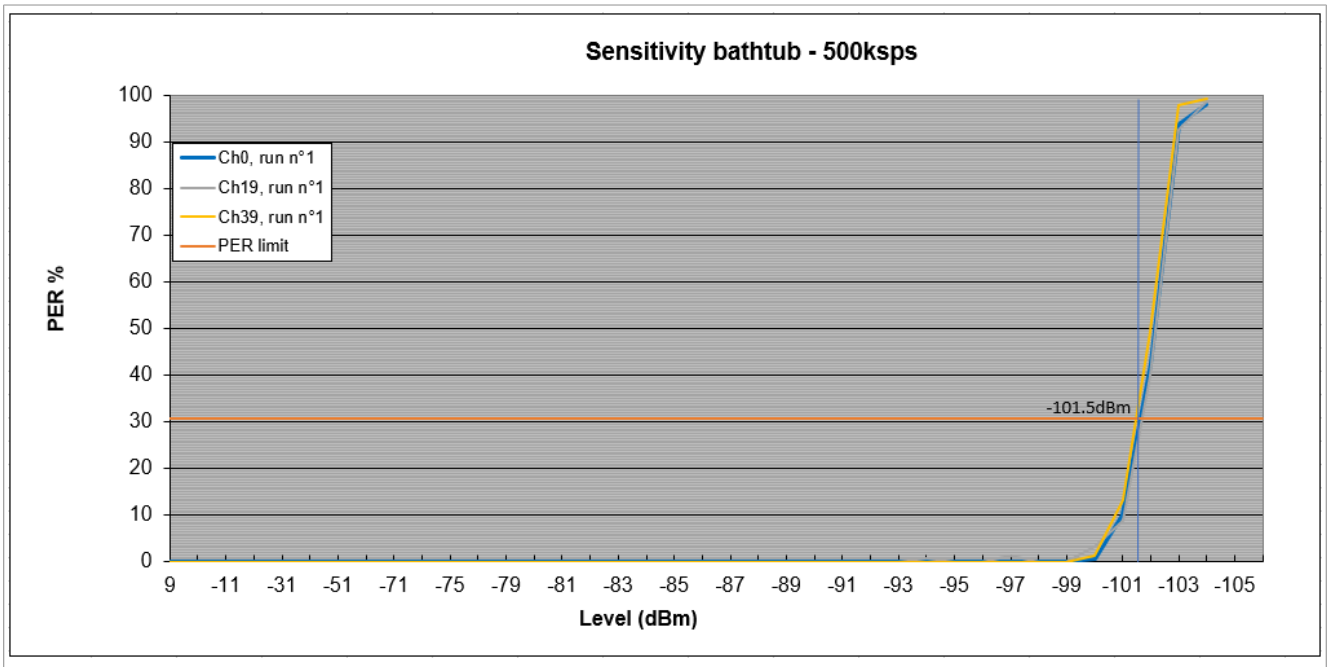



**Figure 53. Sensitivity bathtub result – 500 ksps**

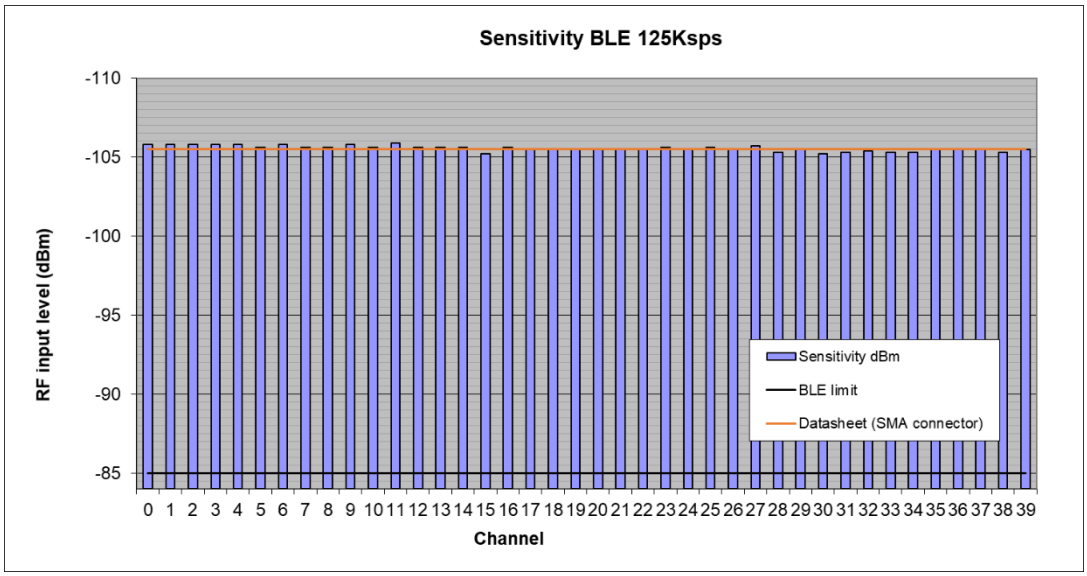



**Figure 54. Sensitivity result – LR (S = 8)**

- 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.

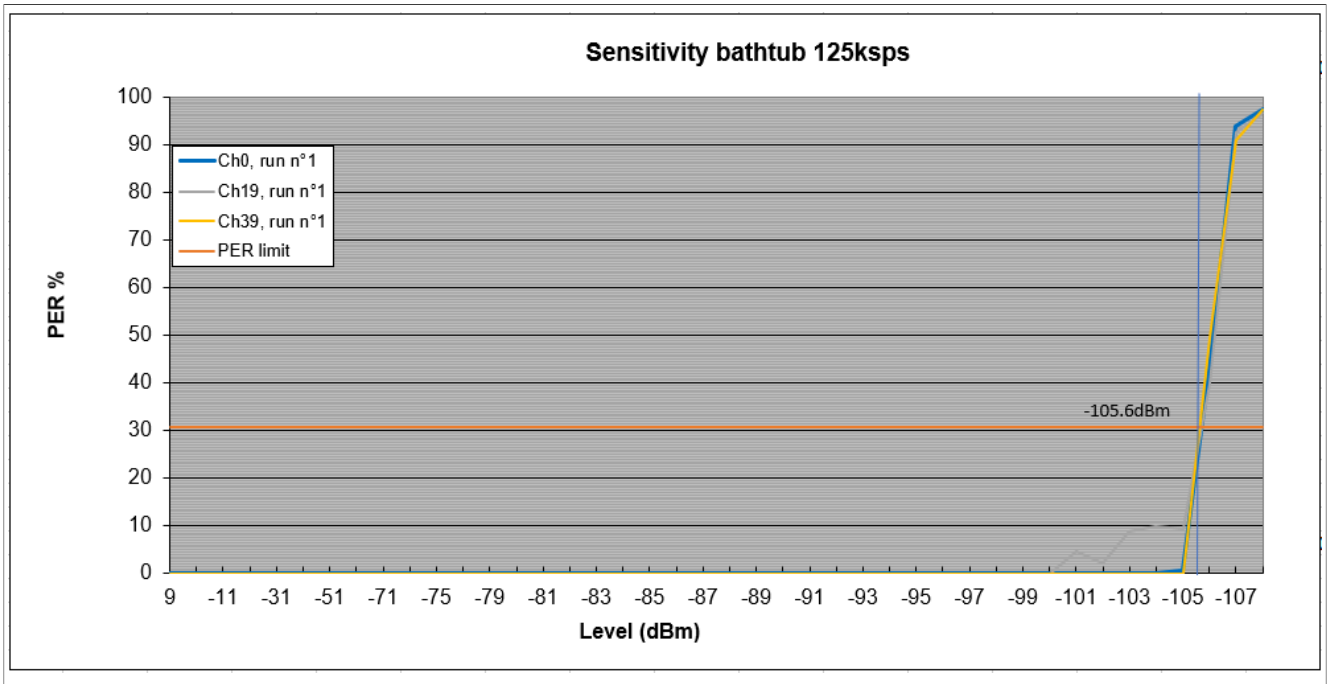



**Figure 55. Sensitivity bathtub result – 125 ksps**

**Conclusion:**

K32W148 EVK withstands an average sensitivity level of:

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

- -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:**

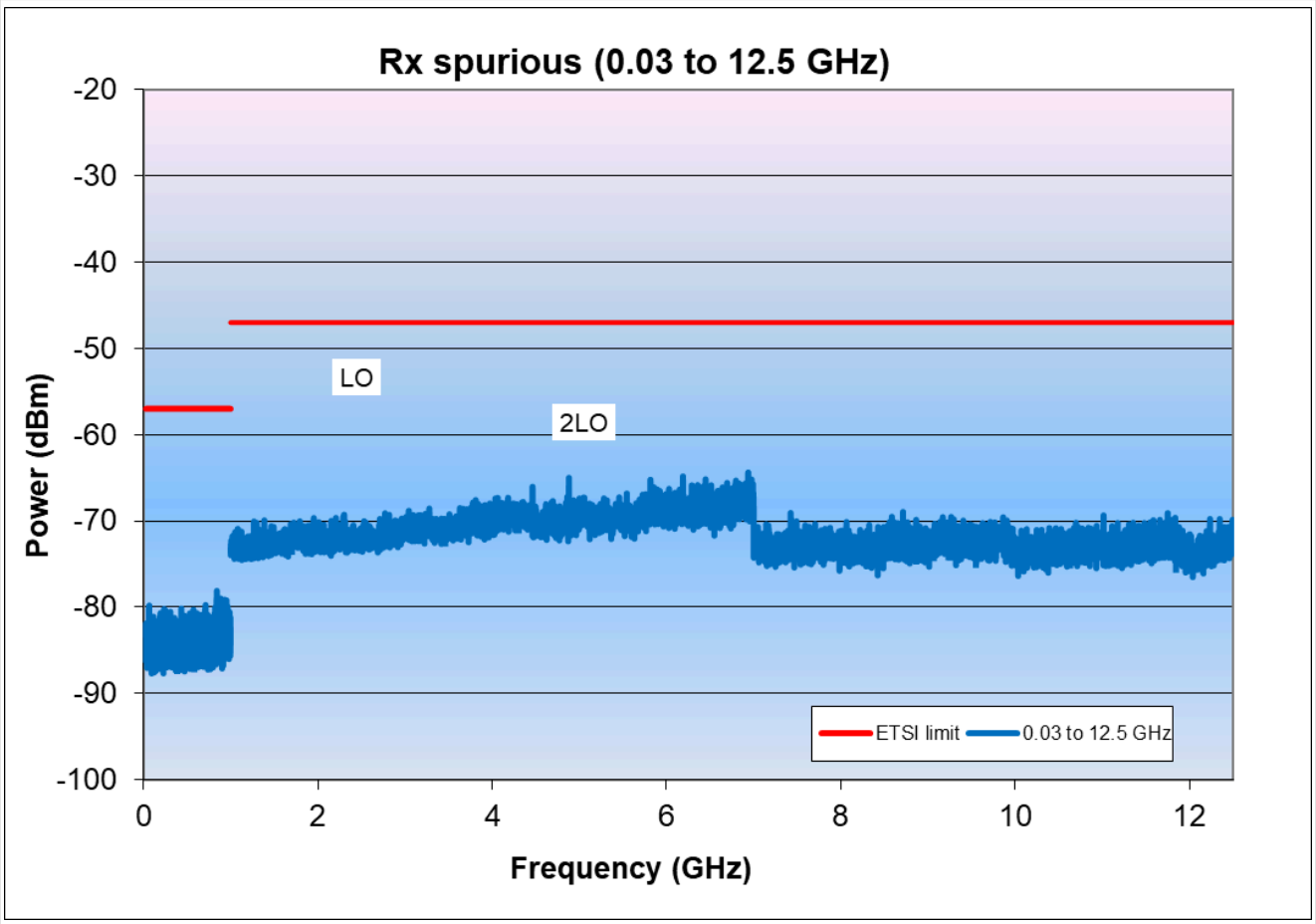



Figure 56. Bluetooth LE - Conducted RX spurious 30 MHz – 12.5 GHz

**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

- Channels under test: 2, 19, and 37

**Bluetooth LE @ 1 Msps:**

- Results

| | ch2 | | | | ch19 | | | | ch37 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2406 | | | | 2440 | | | | 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) | -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 | | Co-channel | ch19 | | Co-channel | ch37 | | Co-channel |
|---|---|---|---|---|---|---|---|---|---|
| | 2406 | | ch2 | 2440 | | ch19 | 2476 | | ch37 |
| | N-3MHz | N+3MHz | 2406 | N-3MHz | N+3MHz | 2440 | N-3MHz | N+3MHz | 2476 |
| | 2400 | 2412 | N | 2434 | 2446 | N | 2470 | 2482 | N |
| Interferer level (dBm) | -10.1 | -8.6 | -70.1 | -9.6 | -8.6 | -70.1 | -9.6 | -8.6 | -70.1 |
| Interferer level (C/I dB) | -56.9 | -58.4 | 3.1 | -57.4 | -58.4 | 3.1 | -57.4 | -58.4 | 3.1 |
| BLE 5.x limit (C/I dB) | -27 | -27 | 21 | -27 | -27 | 21 | -27 | -27 | 21 |
| Margin (dB) | 29.9 | 31.4 | 17.9 | 30.4 | 31.4 | 17.9 | 30.4 | 31.4 | 17.9 |

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

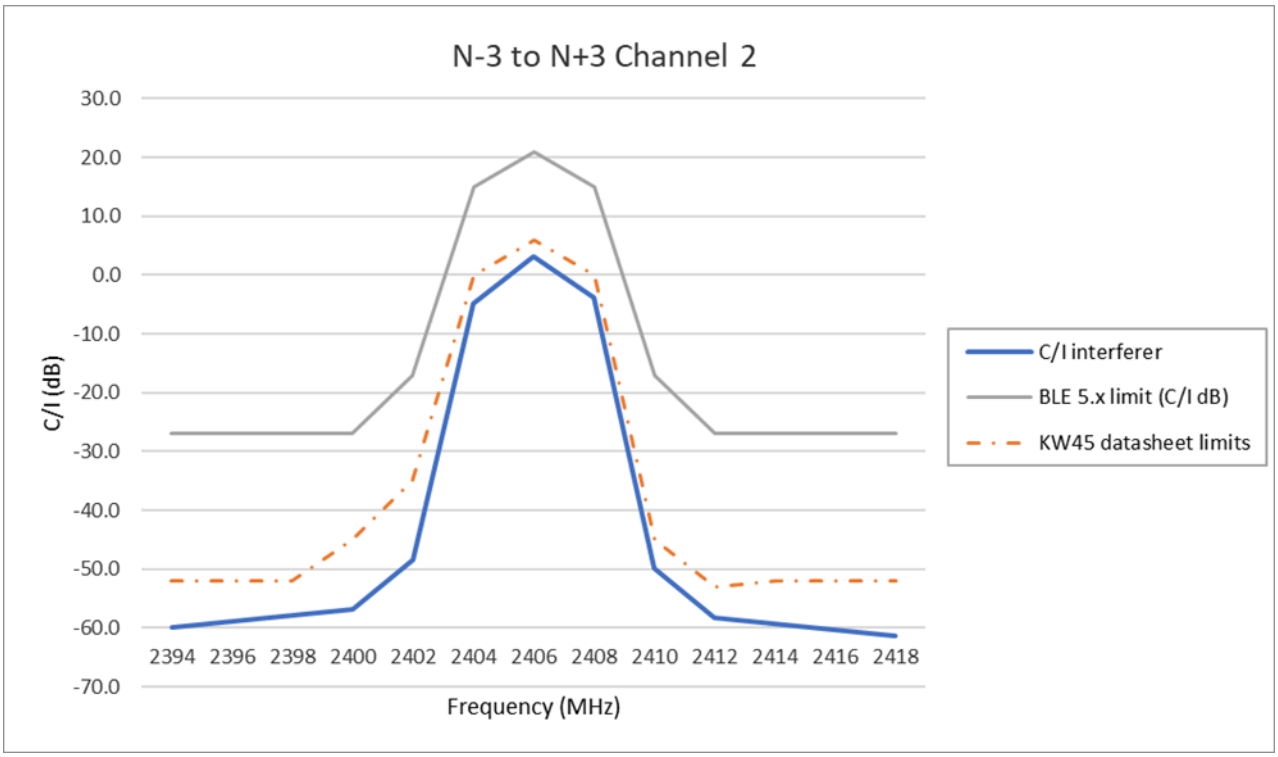



**Figure 58. Adjacent, alternate, and co-channel rejection Bluetooth LE @1 Msps channel 2**

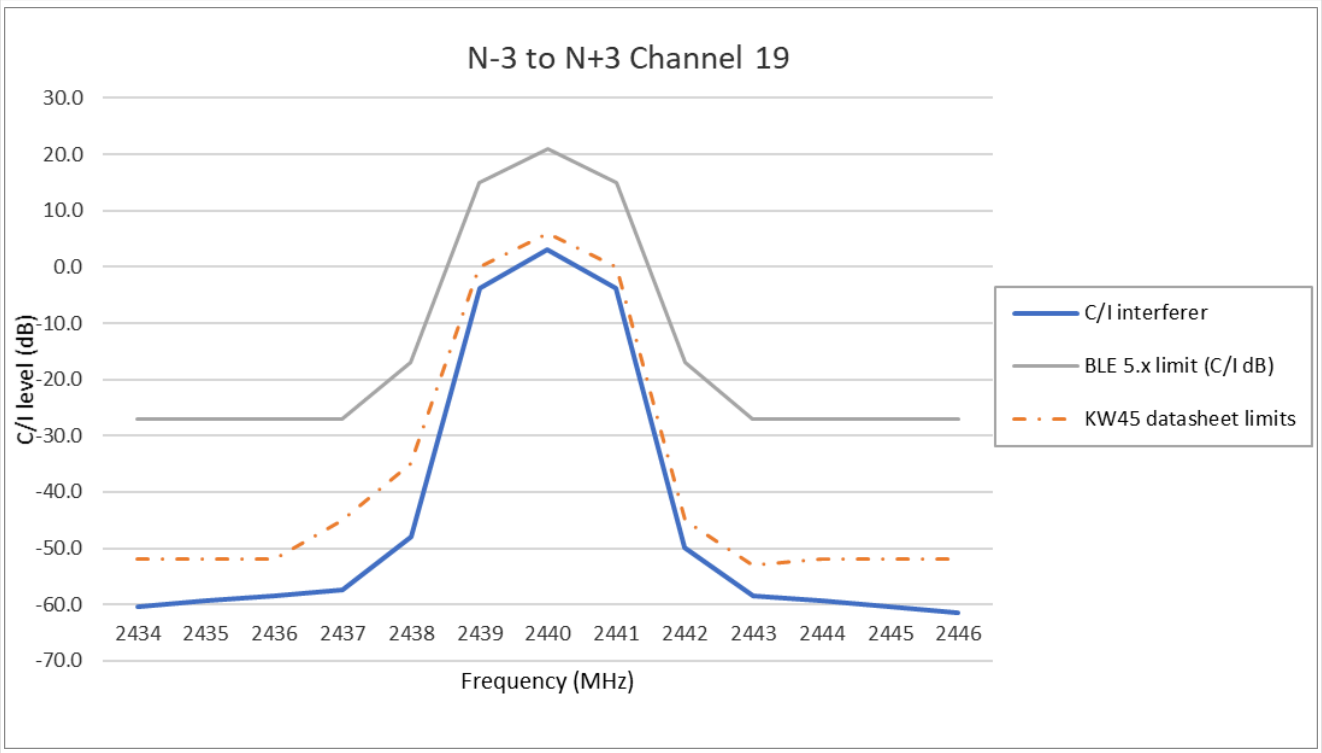



**Figure 59. Adjacent, alternate, and co-channel rejection Bluetooth LE @1 Msps channel 19**

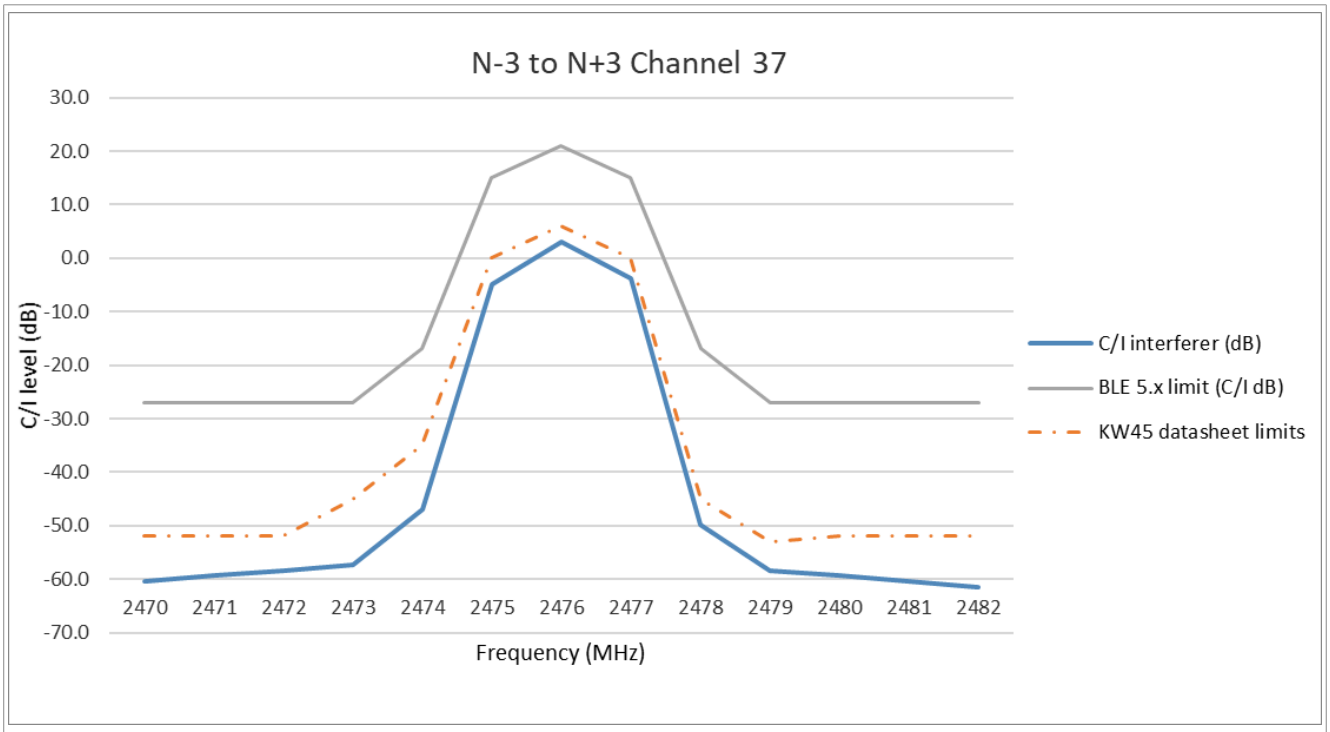



**Figure 60. Adjacent, alternate, and co-channel rejection Bluetooth LE @1 Msps channel 37**

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

**Bluetooth LE @ 2 Msps:**

- Results

| | ch2 | | | | ch19 | | | | ch37 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2406 | | | | 2440 | | | | 2476 | | | |
| | N-4MHz | N-2MHz | N+2MHz | N+4MHz | N-4MHz | N-2MHz | N+2MHz | N+4MHz | N-4MHz | N-2MHz | N+2MHz | N+4MHz |
| | 2398 | 2402 | 2410 | 2414 | 2432 | 2436 | 2444 | 2448 | 2468 | 2472 | 2480 | 2484 |
| Interferer level (dBm) | -32.1 | -57.6 | -55.6 | -22.1 | -33.1 | -59.6 | -60.6 | -22.1 | -32.6 | -58.1 | -60.6 | -21.6 |
| Interferer level (C/I dB) | -34.9 | -9.4 | -11.4 | -44.9 | -33.9 | -7.4 | -6.4 | -44.9 | -34.4 | -8.9 | -6.4 | -45.4 |
| BLE 5.x limit (C/I dB) | -17 | 15 | 15 | -17 | -17 | 15 | 15 | -17 | -17 | 15 | 15 | -17 |
| Margin (dB) | 17.9 | 24.4 | 26.4 | 27.9 | 16.9 | 22.4 | 21.4 | 27.9 | 17.4 | 23.9 | 21.4 | 28.4 |

| | ch2 | | Co-channel | ch19 | | Co-channel | ch37 | | Co-channel |
|---|---|---|---|---|---|---|---|---|---|
| | 2406 | | ch2 | 2440 | | ch19 | 2476 | | ch37 |
| | N-6MHz | N+6MHz | 2406 | N-6MHz | N+6MHz | 2440 | N-6MHz | N+6MHz | 2476 |
| | 2400 | 2412 | N | 2434 | 2446 | N | 2470 | 2482 | N |
| Interferer level (dBm) | -11.1 | -11.1 | -70.1 | -11.1 | -11.1 | -70.1 | -11.1 | -10.6 | -70.1 |
| Interferer level (C/I dB) | -55.9 | -55.9 | 3.1 | -55.9 | -55.9 | 3.1 | -55.9 | -56.4 | 3.1 |
| BLE 5.x limit (C/I dB) | -27 | -27 | 21 | -27 | -27 | 21 | -27 | -27 | 21 |
| Margin (dB) | 28.9 | 28.9 | 17.9 | 28.9 | 28.9 | 17.9 | 28.9 | 29.4 | 17.9 |

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

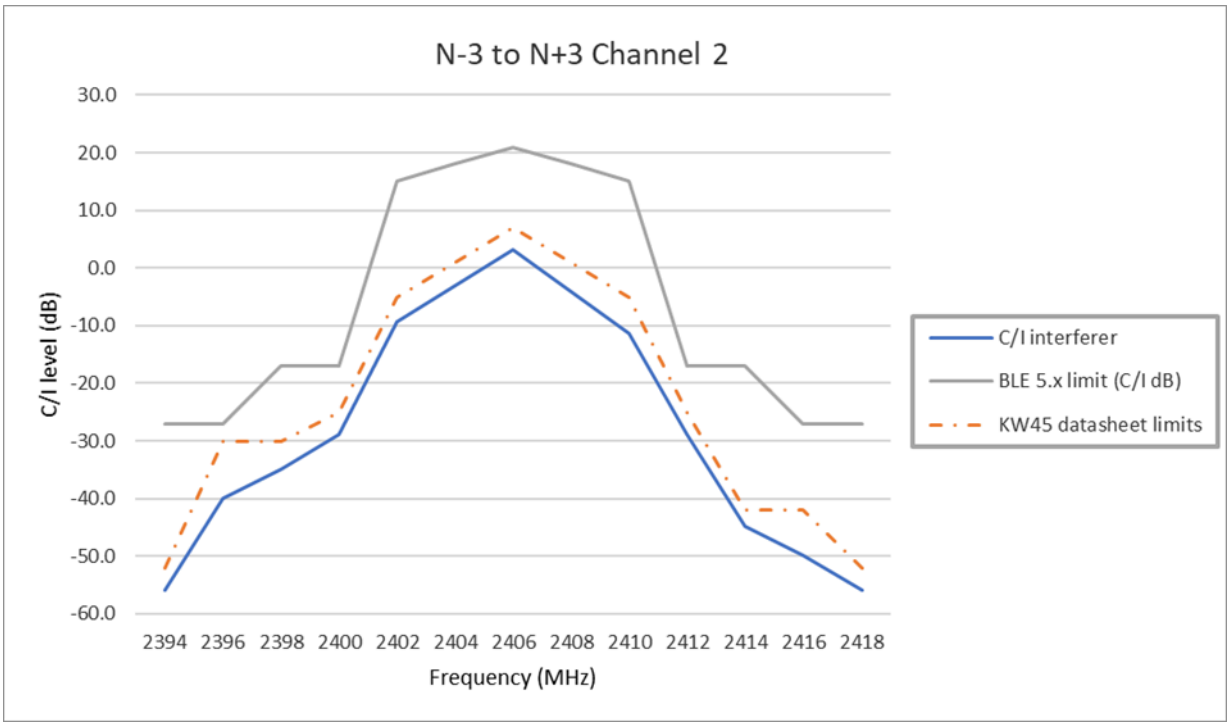



**Figure 62. Adjacent, alternate, and co-channel rejection Bluetooth LE @2 Msps channel 2**

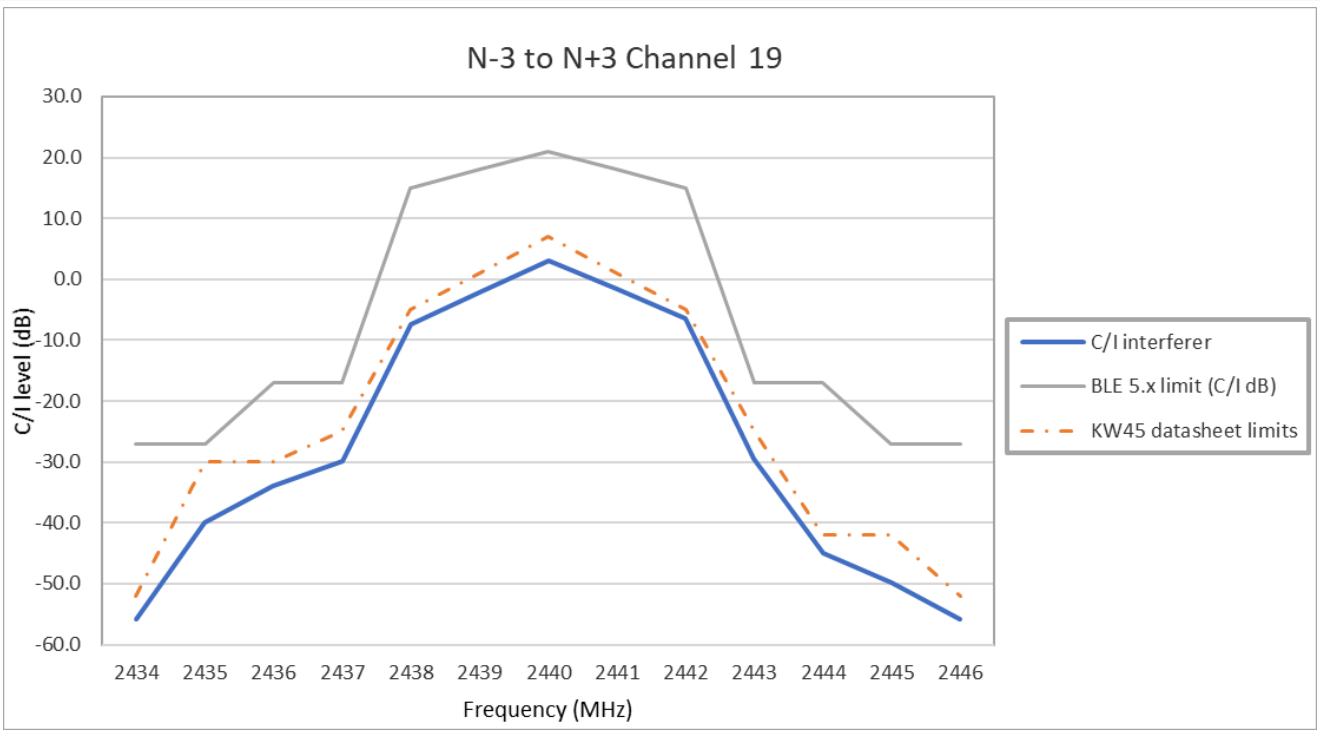



**Figure 63. Adjacent, alternate, and co-channel rejection Bluetooth LE @2 Msps channel 19**

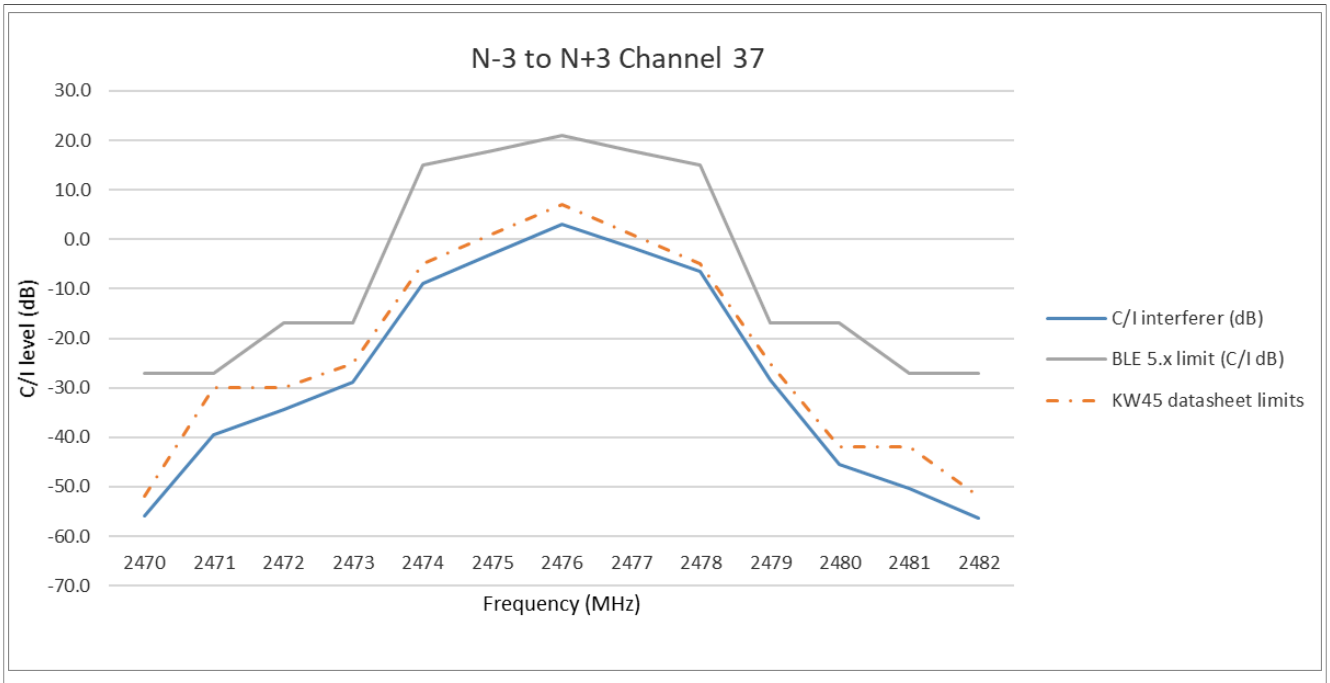



**Figure 64. Adjacent, alternate, and co-channel rejection Bluetooth LE @2 Msps channel 37**

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

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

- **Results:**

| | ch2 | | | |
|---|---|---|---|---|
| | 2406 | | | |
| | N-2MHz | N-1MHz | N+1MHz | N+2MHz |
| | 2402 | 2404 | 2408 | 2410 |
| Interferer level (dBm) | -25.1 | -55.1 | -55.1 | -16.6 |
| Interferer level (C/I dB) | -41.9 | -11.9 | -11.9 | -50.4 |
| BLE 5.x limit (C/I dB) | -17 | 15 | 15 | -17 |
| Margin (dB) | 24.9 | 26.9 | 26.9 | 33.4 |

| | ch19 | | | |
|---|---|---|---|---|
| | 2440 | | | |
| | N-2MHz | N-1MHz | N+1MHz | N+2MHz |
| | 2436 | 2438 | 2442 | 2444 |
| Interferer level (dBm) | -25.6 | -55.1 | -55.1 | -11.6 |
| Interferer level (C/I dB) | -41.4 | -11.9 | -11.9 | -55.4 |
| BLE 5.x limit (C/I dB) | -17 | 15 | 15 | -17 |
| Margin (dB) | 24.4 | 26.9 | 26.9 | 38.4 |

| | ch37 | | | |
|---|---|---|---|---|
| | 2476 | | | |
| | N-2MHz | N-1MHz | N+1MHz | N+2MHz |
| | 2472 | 2474 | 2478 | 2480 |
| Interferer level (dBm) | -26.1 | -55.6 | -55.6 | -12.1 |
| Interferer level (C/I dB) | -40.9 | -11.4 | -11.4 | -54.9 |
| BLE 5.x limit (C/I dB) | -17 | 15 | 15 | -17 |
| Margin (dB) | 23.9 | 26.4 | 26.4 | 37.9 |

| | ch2 | | Co-channel |
|---|---|---|---|
| | 2406 | | ch2 |
| | N-3MHz | N+3MHz | 2406 |
| | 2400 | 2412 | N |
| Interferer level (dBm) | -15.1 | -4.6 | 2406 |
| Interferer level (C/I dB) | -51.9 | -62.4 | -64.6 |
| BLE 5.x limit (C/I dB) | -27 | -27 | -2.4 |
| Margin (dB) | 24.9 | 35.4 | 21 |
| | | | 23.4 |

| | ch19 | | Co-channel |
|---|---|---|---|
| | 2440 | | ch19 |
| | N-3MHz | N+3MHz | 2440 |
| | 2434 | 2446 | N |
| Interferer level (dBm) | -12.1 | -7.1 | 2440 |
| Interferer level (C/I dB) | -54.9 | -59.9 | -64.6 |
| BLE 5.x limit (C/I dB) | -27 | -27 | -2.4 |
| Margin (dB) | 27.9 | 32.9 | 21 |
| | | | 23.4 |

| | ch37 | | Co-channel |
|---|---|---|---|
| | 2476 | | ch37 |
| | N-3MHz | N+3MHz | 2476 |
| | 2470 | 2482 | N |
| Interferer level (dBm) | -12.1 | -7.6 | 2476 |
| Interferer level (C/I dB) | -54.9 | -59.4 | -64.1 |
| BLE 5.x limit (C/I dB) | -27 | -27 | -2.9 |
| Margin (dB) | 27.9 | 32.4 | 21 |
| | | | 23.9 |

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

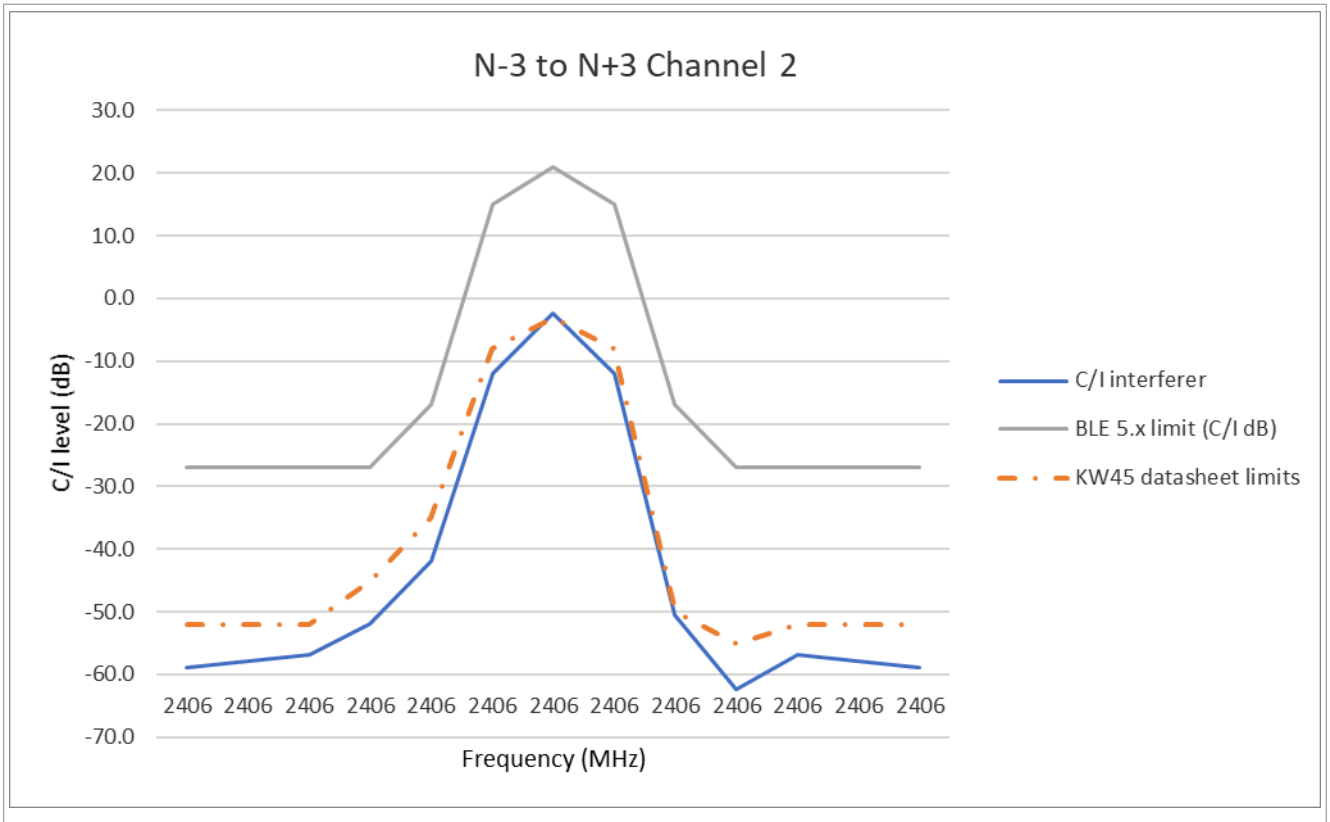



Figure 66. Adjacent, alternate, and co-channel rejection Bluetooth LE @500 ksps (LR S = 2) channel 2

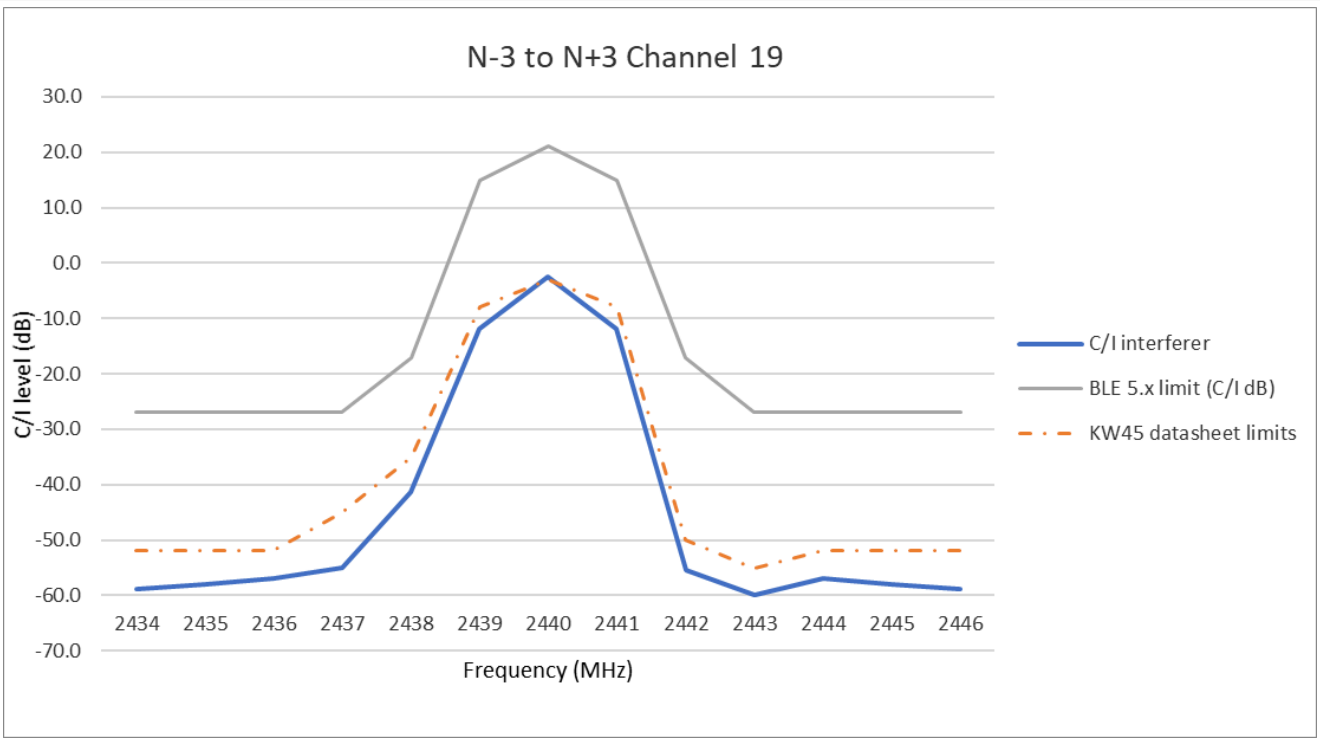



**Figure 67. Adjacent, alternate, and co-channel rejection Bluetooth LE @500 ksps (LR S = 2) channel 19**

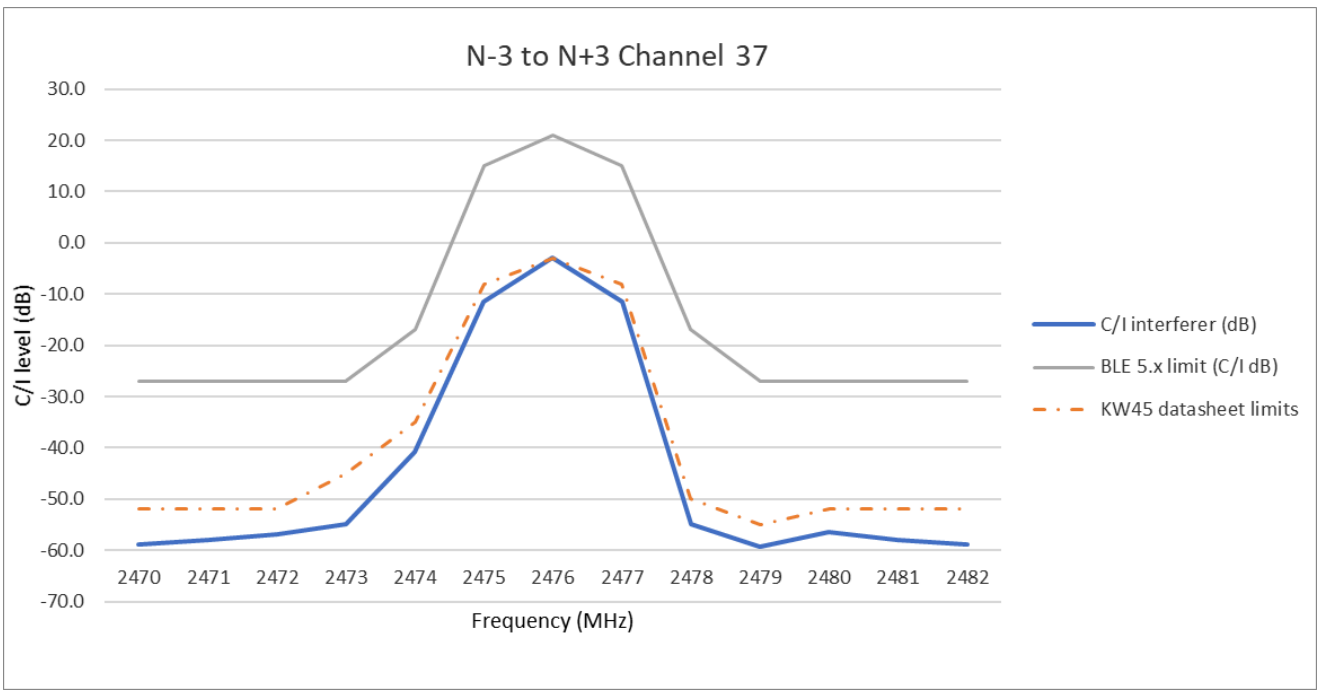



**Figure 68. Adjacent, alternate, and co-channel rejection Bluetooth LE @500 ksps (LR S = 2) channel 37**

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

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

- **Results:**

| | ch2 | | | |
|---|---|---|---|---|
| | 2406 | | | |
| | N-2MHz | N-1MHz | N+1MHz | N+2MHz |
| | 2402 | 2404 | 2408 | 2410 |
| Interferer level (dBm) | -27.1 | -58.6 | -58.6 | -17.6 |
| Interferer level (C/I dB) | -39.9 | -8.4 | -8.4 | -49.4 |
| BLE 5.x limit (C/I dB) | -17 | 15 | 15 | -17 |
| Margin (dB) | 22.9 | 23.4 | 23.4 | 32.4 |

| | ch19 | | | |
|---|---|---|---|---|
| | 2440 | | | |
| | N-2MHz | N-1MHz | N+1MHz | N+2MHz |
| | 2436 | 2438 | 2442 | 2444 |
| Interferer level (dBm) | -28.1 | -59.1 | -58.6 | -16.6 |
| Interferer level (C/I dB) | -38.9 | -7.9 | -8.4 | -50.4 |
| BLE 5.x limit (C/I dB) | -17 | 15 | 15 | -17 |
| Margin (dB) | 21.9 | 22.9 | 23.4 | 33.4 |

| | ch37 | | | |
|---|---|---|---|---|
| | 2476 | | | |
| | N-2MHz | N-1MHz | N+1MHz | N+2MHz |
| | 2472 | 2474 | 2478 | 2480 |
| Interferer level (dBm) | -29.6 | -58.1 | -58.6 | -16.6 |
| Interferer level (C/I dB) | -37.4 | -8.9 | -8.4 | -50.4 |
| BLE 5.x limit (C/I dB) | -17 | 15 | 15 | -17 |
| Margin (dB) | 20.4 | 23.9 | 23.4 | 33.4 |

| | ch2 | | Co-channel |
|---|---|---|---|
| | 2406 | | ch2 |
| | N-3MHz | N+3MHz | 2406 |
| | 2400 | 2412 | N |
| Interferer level (dBm) | -12.6 | -11.1 | 2406 |
| Interferer level (C/I dB) | -54.4 | -55.9 | -65.1 |
| BLE 5.x limit (C/I dB) | -27 | -27 | -1.9 |
| Margin (dB) | 27.4 | 28.9 | 21 |
| | | | 22.9 |

| | ch19 | | Co-channel |
|---|---|---|---|
| | 2440 | | ch19 |
| | N-3MHz | N+3MHz | 2440 |
| | 2434 | 2446 | N |
| Interferer level (dBm) | -12.6 | -9.1 | 2440 |
| Interferer level (C/I dB) | -54.4 | -57.9 | -65.1 |
| BLE 5.x limit (C/I dB) | -27 | -27 | -1.9 |
| Margin (dB) | 27.4 | 30.9 | 21 |
| | | | 22.9 |

| | ch37 | | Co-channel |
|---|---|---|---|
| | 2476 | | ch37 |
| | N-3MHz | N+3MHz | 2476 |
| | 2470 | 2482 | N |
| Interferer level (dBm) | -12.6 | -11.1 | 2476 |
| Interferer level (C/I dB) | -54.4 | -55.9 | -65.1 |
| BLE 5.x limit (C/I dB) | -27 | -27 | -1.9 |
| Margin (dB) | 27.4 | 28.9 | 21 |
| | | | 22.9 |

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

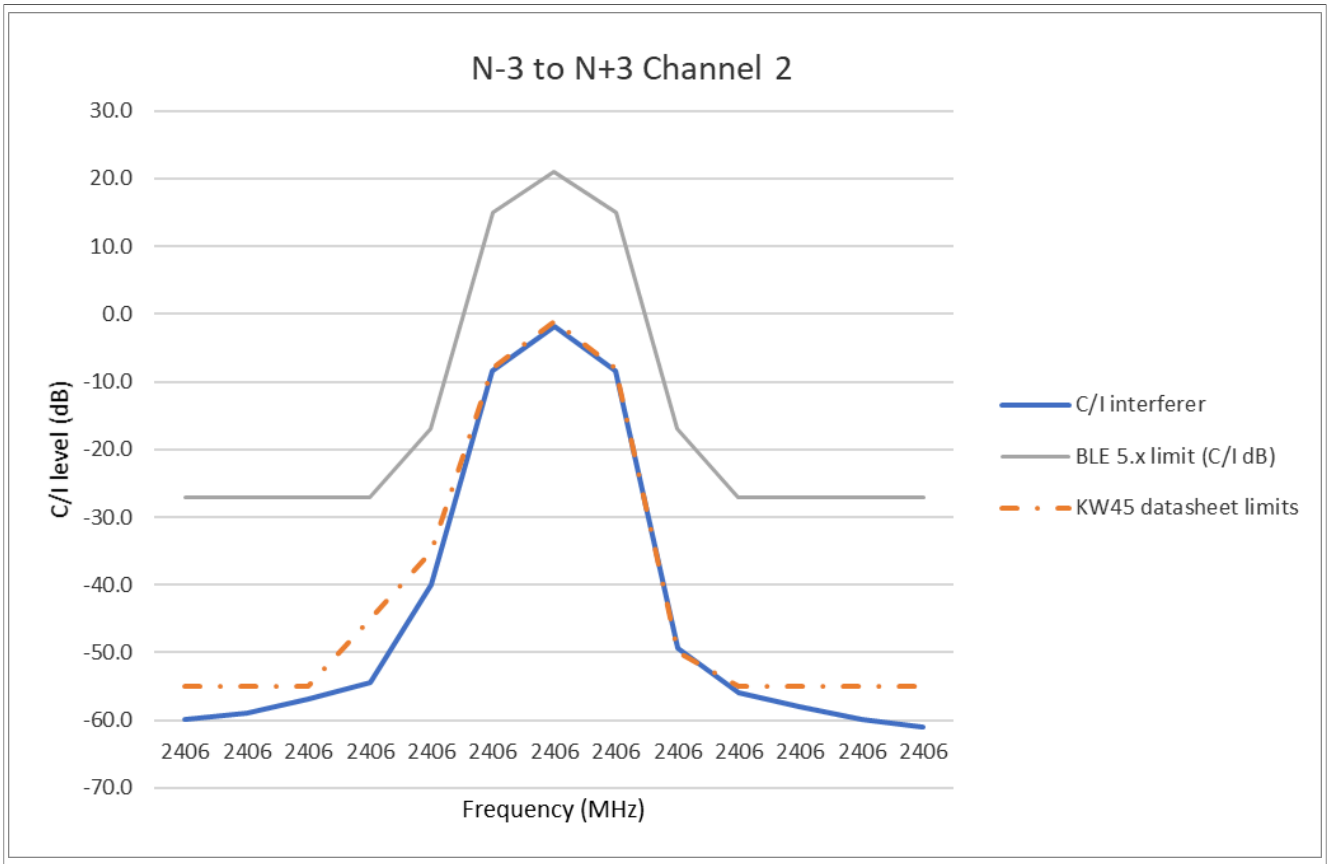



**Figure 70. Adjacent, alternate, and co-channel rejection Bluetooth LE @125 ksps (LR S = 8) channel 2**

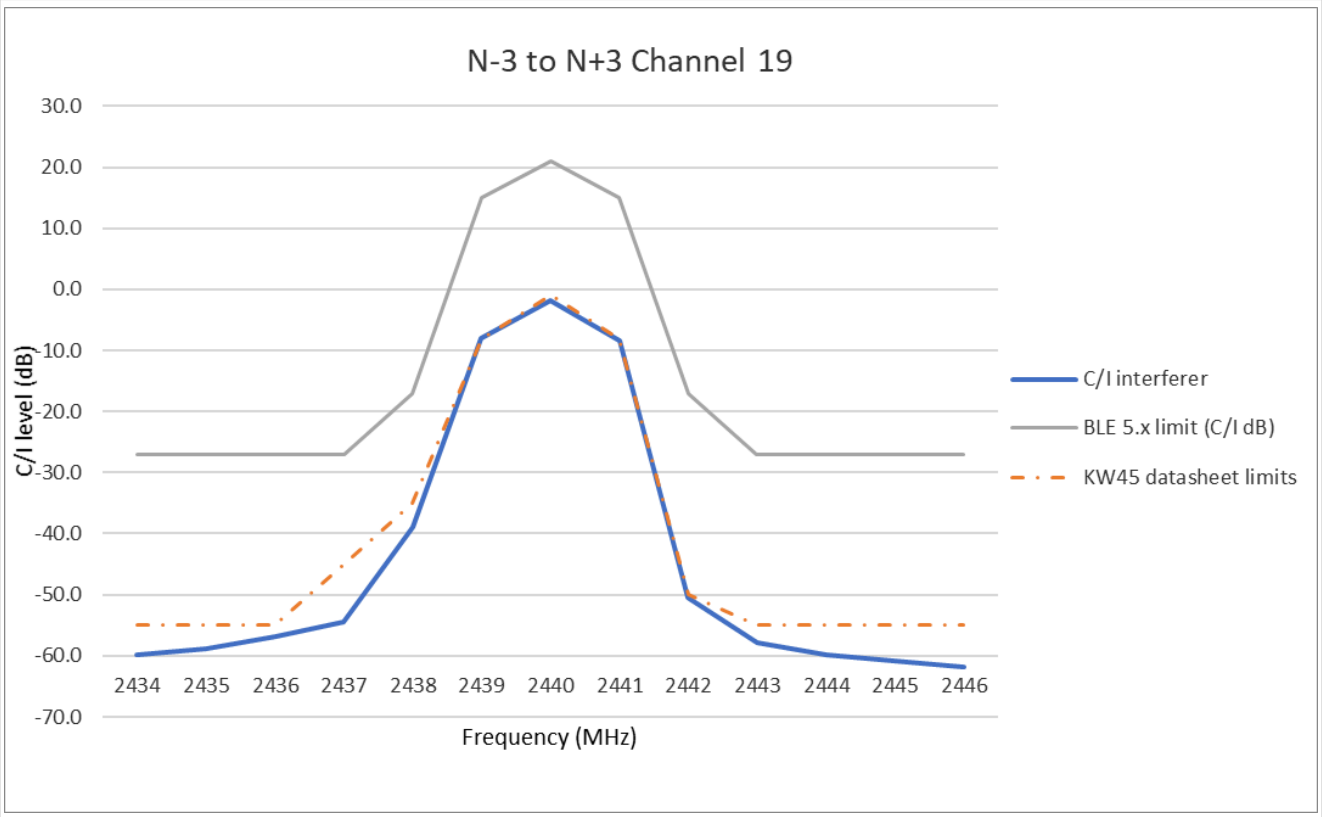



**Figure 71. Adjacent, alternate, and co-channel rejection Bluetooth LE @125 ksps (LR S = 8) channel 19**

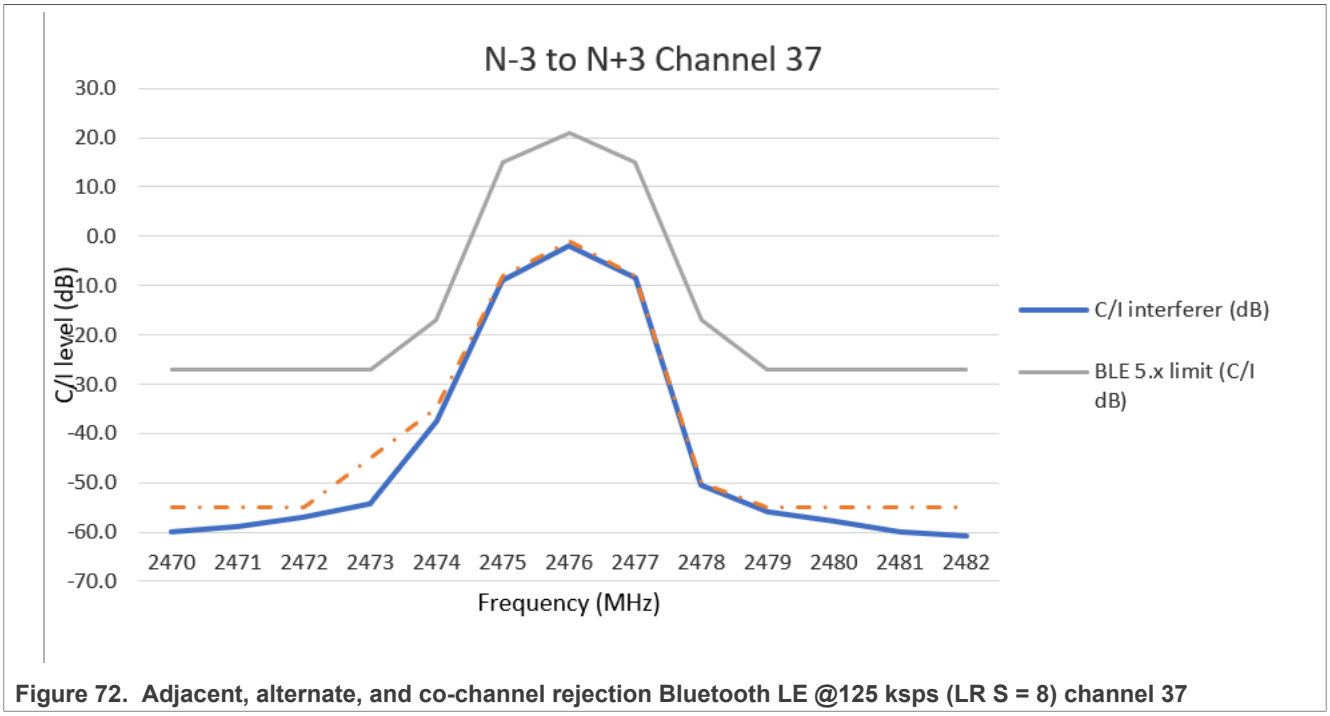



**Figure 72. Adjacent, alternate, and co-channel rejection Bluetooth LE @125 ksps (LR S = 8) channel 37**

- **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 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<br>2402<br>Low<br>2380 | ch0<br>2402<br>High<br>2503.5 | ch39<br>2480<br>Low<br>2380 | ch39<br>2480<br>High<br>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<br>2402<br>Low<br>2300 | ch0<br>2402<br>High<br>2583.5 | ch39<br>2480<br>Low<br>2300 | ch39<br>2480<br>High<br>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 2402 Low 2380 | ch0 2402 High 2503.5 | ch39 2480 Low 2380 | ch39 2480 High 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 2402 Low 2300 | ch0 2402 Low 2330 | ch0 2402 Low 2360 | ch39 2480 Low 2300 | ch39 2480 Low 2330 | ch39 2480 Low 2360 |
| 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 2402 High 2523.5 | ch0 2402 High 2563.5 | ch0 2402 High 2583.5 | ch0 2402 High 2613.5 | ch0 2402 High 2643.5 | ch0 2402 High 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 2480 High 2523.5 | ch39 2480 High 2563.5 | ch39 2480 High 2583.5 | ch39 2480 High 2613.5 | ch39 2480 High 2643.5 | ch39 2480 High 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 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) | -57 | -57 | -57 | -57 |
| Margin (dB) | 40.9 | 42.4 | 41.4 | 40.4 |

| | ch0 | ch0 | ch39 | ch39 |
|---|---|---|---|---|
| | 2402 | 2402 | 2480 | 2480 |
| | Low | High | Low | High |
| | 2300 | 2583.5 | 2300 | 2583.5 |
| Interferer level (dBm) | -14.1 | -15.6 | -14.1 | -15.6 |
| 300 328 limit (dBm) | -47 | -47 | -47 | -47 |
| Margin (dB) | 32.9 | 31.4 | 32.9 | 31.4 |

**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 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 software:** Connectivity test

**Test method:**

- Generator for the desired signal (**Bluetooth LE 500 ksps [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:**

| | ch0 2402 Low 2380 | ch0 2402 High 2503.5 | ch39 2480 Low 2380 | ch39 2480 High 2503.5 |
|---|---|---|---|---|
| Interferer level (dBm) | -20.6 | -19.6 | -20.1 | -21.6 |
| 300 328 limit (dBm) | -53 | -53 | -53 | -53 |
| Margin (dB) | 32.4 | 33.4 | 32.9 | 31.4 |

| | ch0 2402 Low 2300 | ch0 2402 Low 2330 | ch0 2402 Low 2360 | ch39 2480 Low 2300 | ch39 2480 Low 2330 | ch39 2480 Low 2360 |
|---|---|---|---|---|---|---|
| Interferer level (dBm) | -18.1 | -19.1 | -20.1 | -19.6 | -19.1 | -21.1 |
| 300 328 limit (dBm) | -47 | -47 | -47 | -47 | -47 | -47 |
| Margin (dB) | 28.9 | 27.9 | 26.9 | 27.4 | 27.9 | 25.9 |

| | ch0 2402 High 2523.5 | ch0 2402 High 2553.5 | ch0 2402 High 2583.5 | ch0 2402 High 2613.5 | ch0 2402 High 2643.5 | ch0 2402 High 2673.5 |
|---|---|---|---|---|---|---|
| Interferer level (dBm) | -19.1 | -20.1 | -19.6 | -21.1 | -19.1 | -19.1 |
| 300 328 limit (dBm) | -47 | -47 | -47 | -47 | -47 | -47 |
| Margin (dB) | 27.9 | 26.9 | 27.4 | 25.9 | 27.9 | 27.9 |

| | ch39 2480 High 2523.5 | ch39 2480 High 2553.5 | ch39 2480 High 2583.5 | ch39 2480 High 2613.5 | ch39 2480 High 2643.5 | ch39 2480 High 2673.5 |
|---|---|---|---|---|---|---|
| Interferer level (dBm) | -20.6 | -19.6 | -21.1 | -21.1 | -21.1 | -21.1 |
| 300 328 limit (dBm) | -47 | -47 | -47 | -47 | -47 | -47 |
| Margin (dB) | 26.4 | 27.4 | 25.9 | 25.9 | 25.9 | 25.9 |

**Figure 77. Receiver blocking (out of band) rejection - Bluetooth LE 500 ksps [LR S = 2]**

**Conclusion:**

Good margin, in line with the expected results.

### 3.3.2.5.2.6 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 software:** Connectivity test

**Test method:**

- Generator for the desired signal (**Bluetooth LE 500 ksps [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:**

| | ch0 | ch0 | ch39 | ch39 |
|---|---|---|---|---|
| | 2402 | 2402 | 2480 | 2480 |
| | Low | Low | High | High |
| | 2380 | 2503.5 | 2380 | 2503.5 |
| Interferer level (dBm) | -21.1 | -19.6 | -21.1 | -21.6 |
| 300 328 limit (dBm) | -57 | -57 | -57 | -57 |
| Margin (dB) | 35.9 | 37.4 | 35.9 | 35.4 |

| | ch0 | ch0 | ch39 | ch39 |
|---|---|---|---|---|
| | 2402 | 2402 | 2480 | 2480 |
| | Low | Low | High | High |
| | 2300 | 2583.5 | 2300 | 2583.5 |
| Interferer level (dBm) | -18.6 | -19.1 | -21.1 | -21.1 |
| 300 328 limit (dBm) | -47 | -47 | -47 | -47 |
| Margin (dB) | 28.4 | 27.9 | 25.9 | 25.9 |

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

**Conclusion:**

Good margin, in line with the expected results.

### 3.3.2.5.2.7 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 software:** Connectivity test

**Test method:**

- Generator for the desired signal (**Bluetooth LE 125 ksps [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:**

| | ch0 2402 Low 2380 | ch0 2402 High 2503.5 | ch39 2480 Low 2380 | ch39 2480 High 2503.5 |
|---|---|---|---|---|
| Interferer level (dBm) | -31.1 | -31.1 | -31.1 | -31.1 |
| 300 328 limit (dBm) | -53 | -53 | -53 | -53 |
| Margin (dB) | 21.9 | 21.9 | 21.9 | 21.9 |

| | ch0 2402 Low 2300 | ch0 2402 Low 2330 | ch0 2402 Low 2360 | ch39 2480 Low 2300 | ch39 2480 Low 2330 | ch39 2480 Low 2360 |
|---|---|---|---|---|---|---|
| Interferer level (dBm) | -30.1 | -31.1 | -31.1 | -31.1 | -31.1 | -31.1 |
| 300 328 limit (dBm) | -47 | -47 | -47 | -47 | -47 | -47 |
| Margin (dB) | 16.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 |

| | ch0 2402 High 2523.5 | ch0 2402 High 2553.5 | ch0 2402 High 2583.5 | ch0 2402 High 2613.5 | ch0 2402 High 2643.5 | ch0 2402 High 2673.5 |
|---|---|---|---|---|---|---|
| Interferer level (dBm) | -31.1 | -28.6 | -30.6 | -31.1 | -30.6 | -30.6 |
| 300 328 limit (dBm) | -47 | -47 | -47 | -47 | -47 | -47 |
| Margin (dB) | 15.9 | 18.4 | 16.4 | 15.9 | 16.4 | 16.4 |

| | ch39 2480 High 2523.5 | ch39 2480 High 2553.5 | ch39 2480 High 2583.5 | ch39 2480 High 2613.5 | ch39 2480 High 2643.5 | ch39 2480 High 2673.5 |
|---|---|---|---|---|---|---|
| Interferer level (dBm) | -31.1 | -31.1 | -31.1 | -31.1 | -31.1 | -31.1 |
| 300 328 limit (dBm) | -47 | -47 | -47 | -47 | -47 | -47 |
| Margin (dB) | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 | 15.9 |

**Figure 79. Receiver blocking (out of band) rejection - Bluetooth LE 125 ksps [LR S = 8]**

**Conclusion:**

Good margin, in line with the expected results.

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

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 ksps [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:**

| | ch0 | ch0 | ch39 | ch39 |
|---|---|---|---|---|
| | 2402 | 2402 | 2480 | 2480 |
| | Low | Low | High | High |
| | 2380 | 2503.5 | 2380 | 2503.5 |
| Interferer level (dBm) | -21.1 | -19.1 | -31.1 | -31.1 |
| 802.15.4 limit (dBm) | -57 | -57 | -57 | -57 |
| Margin (dB) | 35.9 | 37.9 | 25.9 | 25.9 |

| | ch0 | ch0 | ch39 | ch39 |
|---|---|---|---|---|
| | 2402 | 2402 | 2480 | 2480 |
| | Low | Low | High | High |
| | 2300 | 2583.5 | 2300 | 2583.5 |
| Interferer level (dBm) | -19.6 | -19.1 | -31.1 | -31.1 |
| 802.15.4 limit (dBm) | -47 | -47 | -47 | -47 |
| Margin (dB) | 27.4 | 27.9 | 15.9 | 15.9 |

**Figure 80. Receiver blocking (out of band) rejection - Bluetooth LE 125 ksps [LR S = 8]**

**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 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.

#### 3.3.2.5.4 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:**

| | 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) | **-21.6** | **-21.6** | **-22.6** | **-22.6** | **-22.6** | **-23.1** |
| Datasheet limit (dBm) | -24 | -23 | -23 | -23 | -23 | -24 |
| Margin (dB) | 14.5 | 13.5 | 12.5 | 12.5 | 12.5 | 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) | **-22.6** | **-22.6** | **-22.6** | **-22.6** | **-22.6** | **-23.1** |
| Datasheet limit (dBm) | -24 | -23 | -23 | -23 | -23 | -24 |
| Margin (dB) | 13.5 | 12.5 | 12.5 | 12.5 | 12.5 | 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) | **-23.1** | **-22.6** | **-23.1** | **-23.6** | **-23.1** | **-23.6** |
| Datasheet limit (dBm) | -24 | -23 | -23 | -23 | -23 | -24 |
| Margin (dB) | 13.0 | 12.5 | 12.0 | 11.5 | 12.0 | 12.5 |

**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<br>-54 dBm (depends on frequency)<br>(100 kHz BW) | PASS |
| | Spurious 1 GHz - 12.5 GHz | ETSI EN 300 328 | -30 dBm<br>(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.

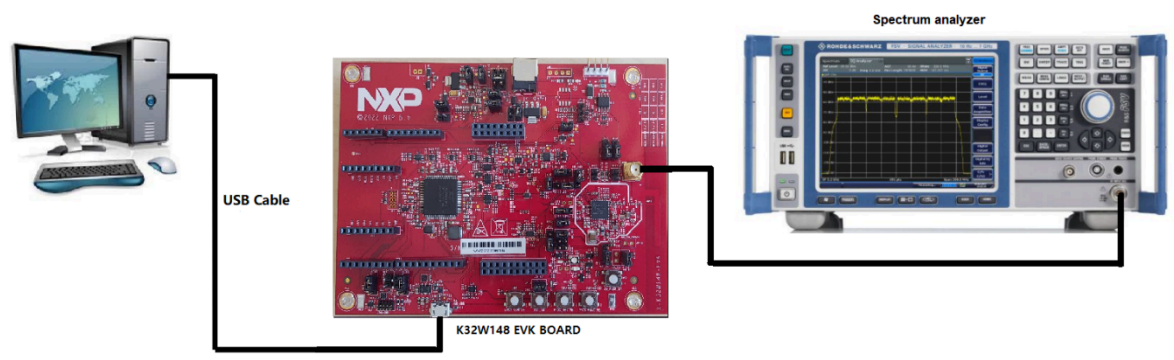



**Figure 83. Conducted TX test setup**

#### 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:**

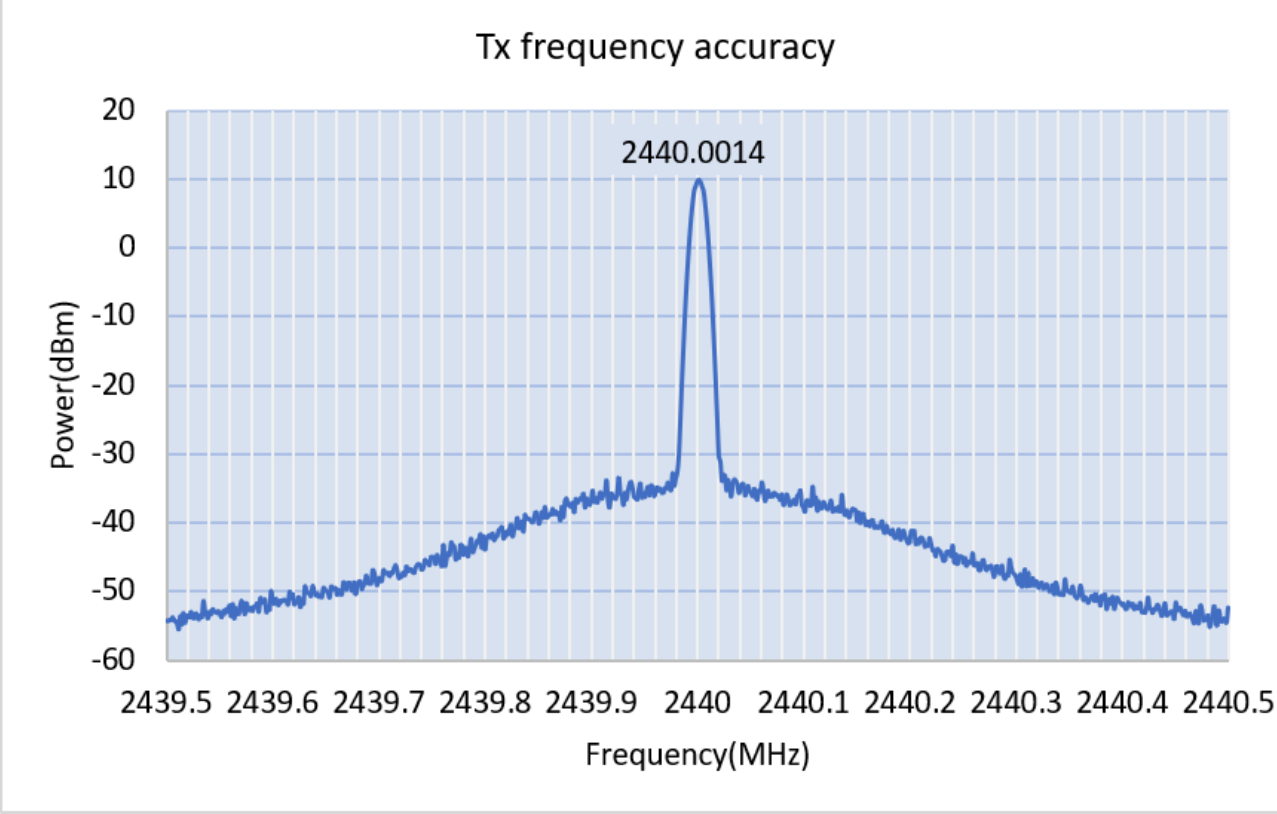



**Figure 84. Frequency accuracy**

- 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)

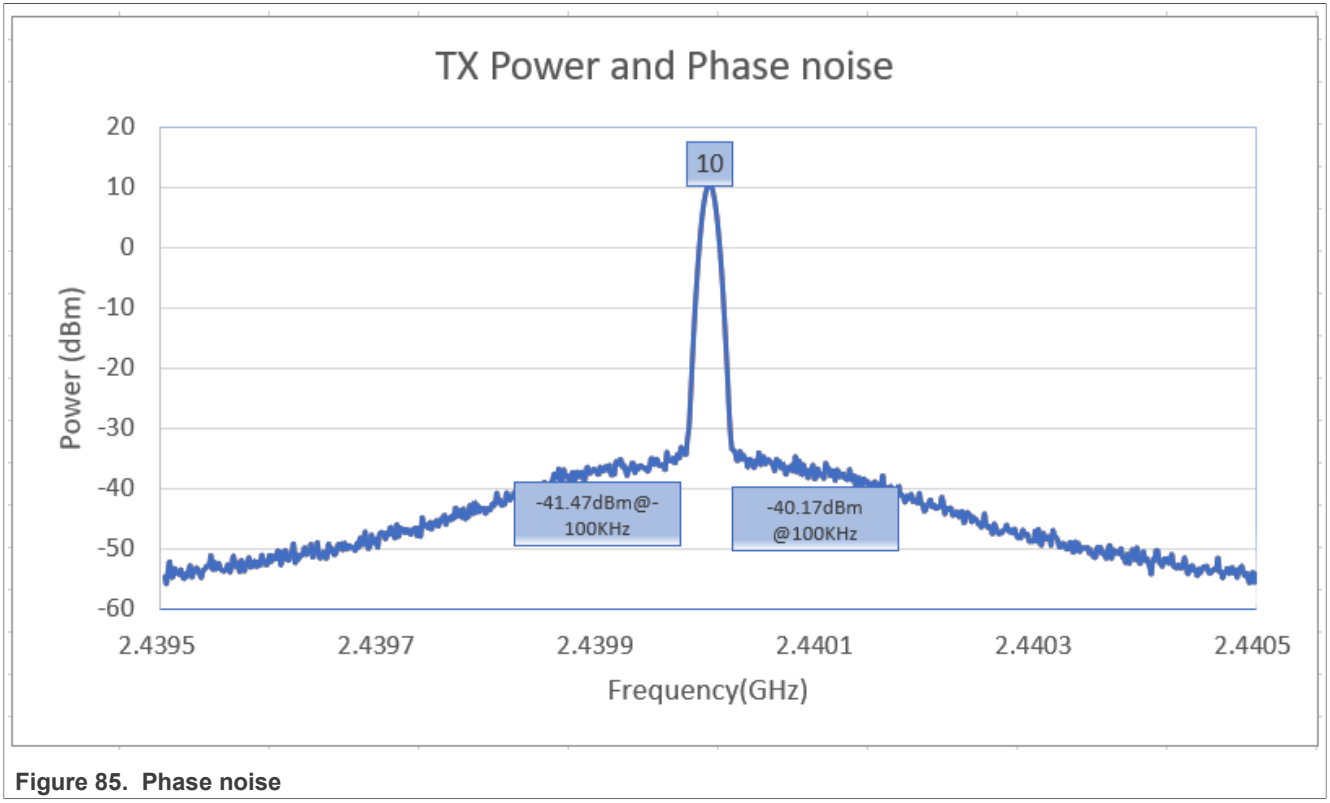



**Figure 85. Phase noise**

**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.

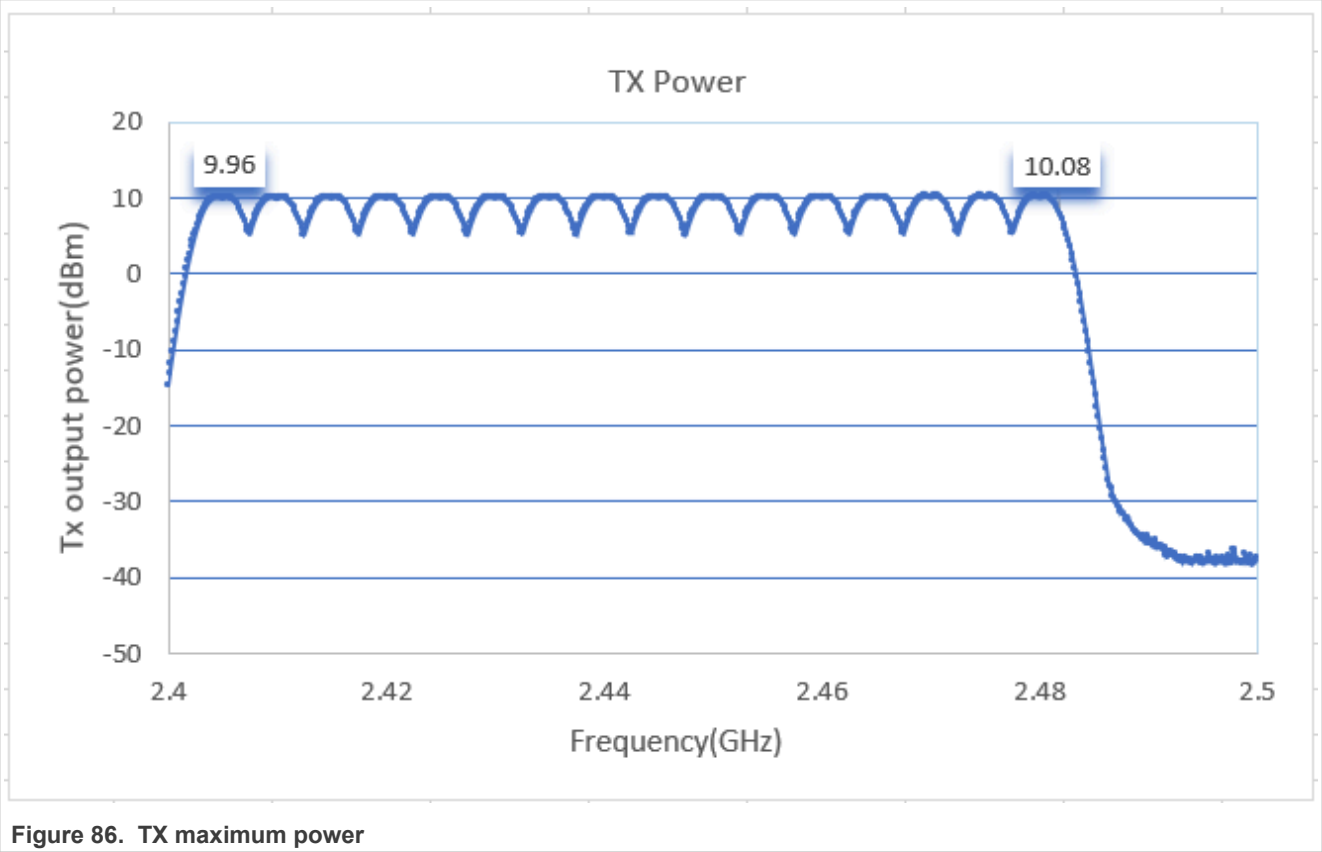



**Figure 86. TX maximum power**

**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.

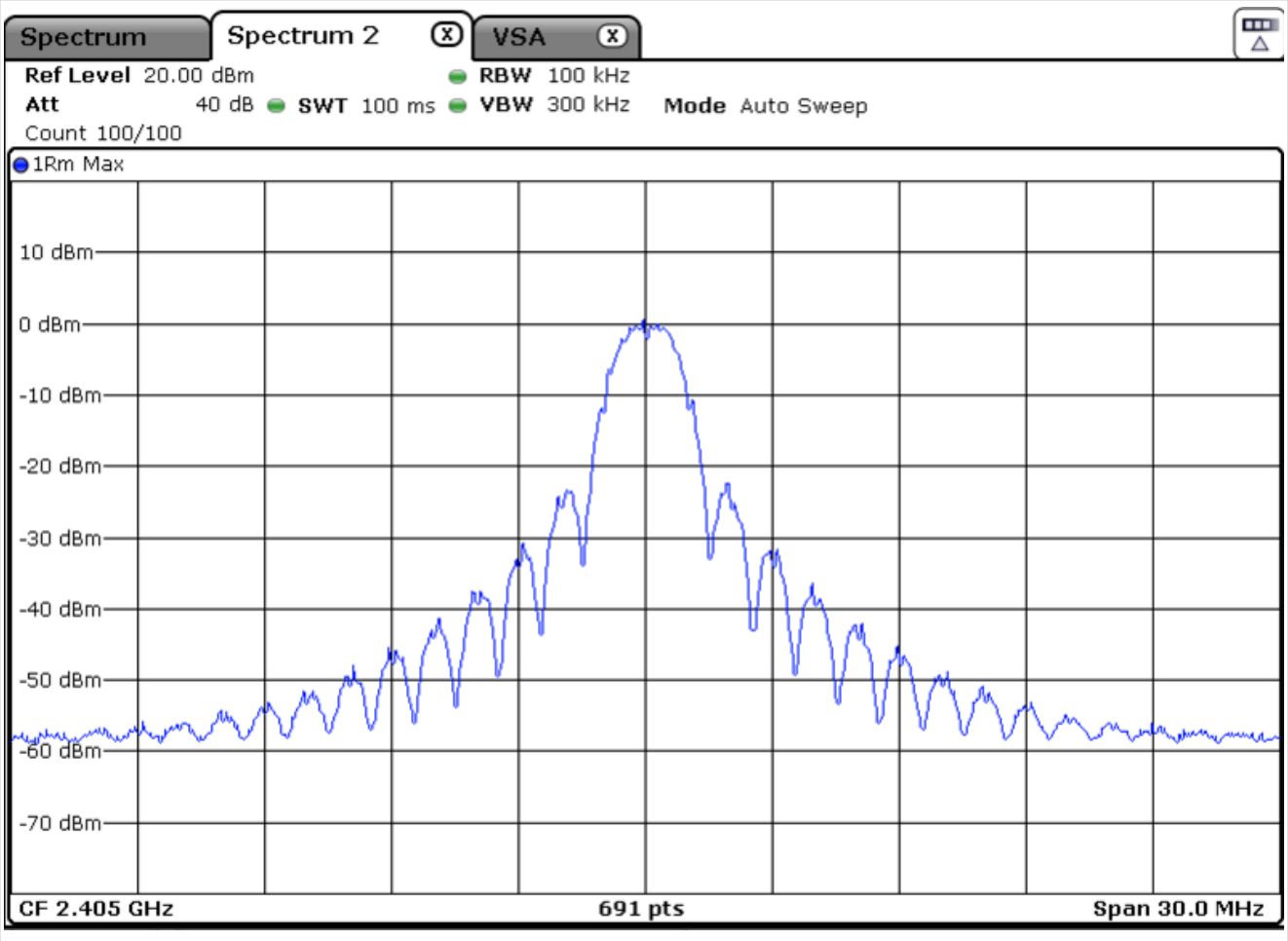



**Figure 87. TX power in-band – Channel 2**

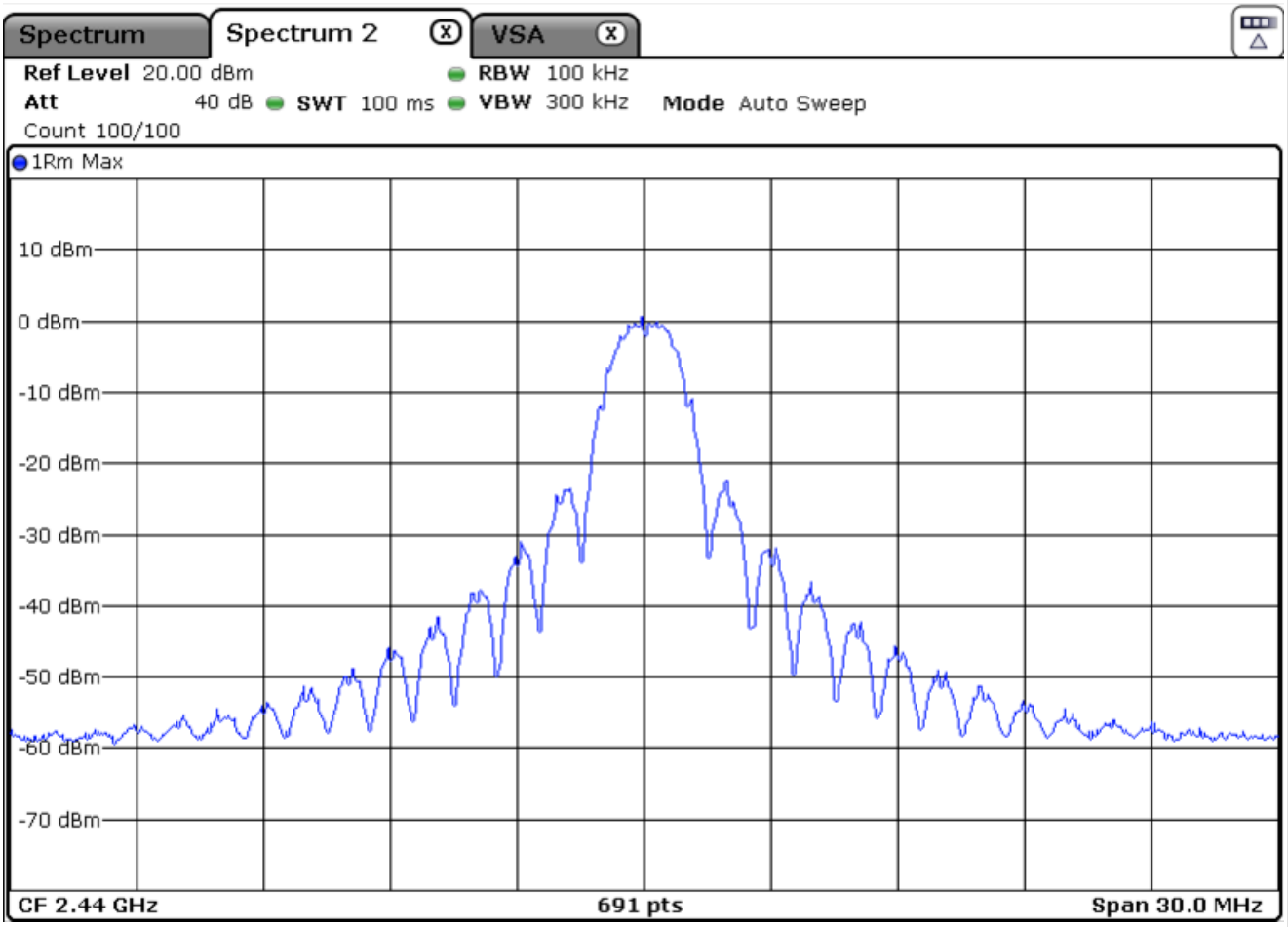



**Figure 88. TX power in-band – Channel 19**

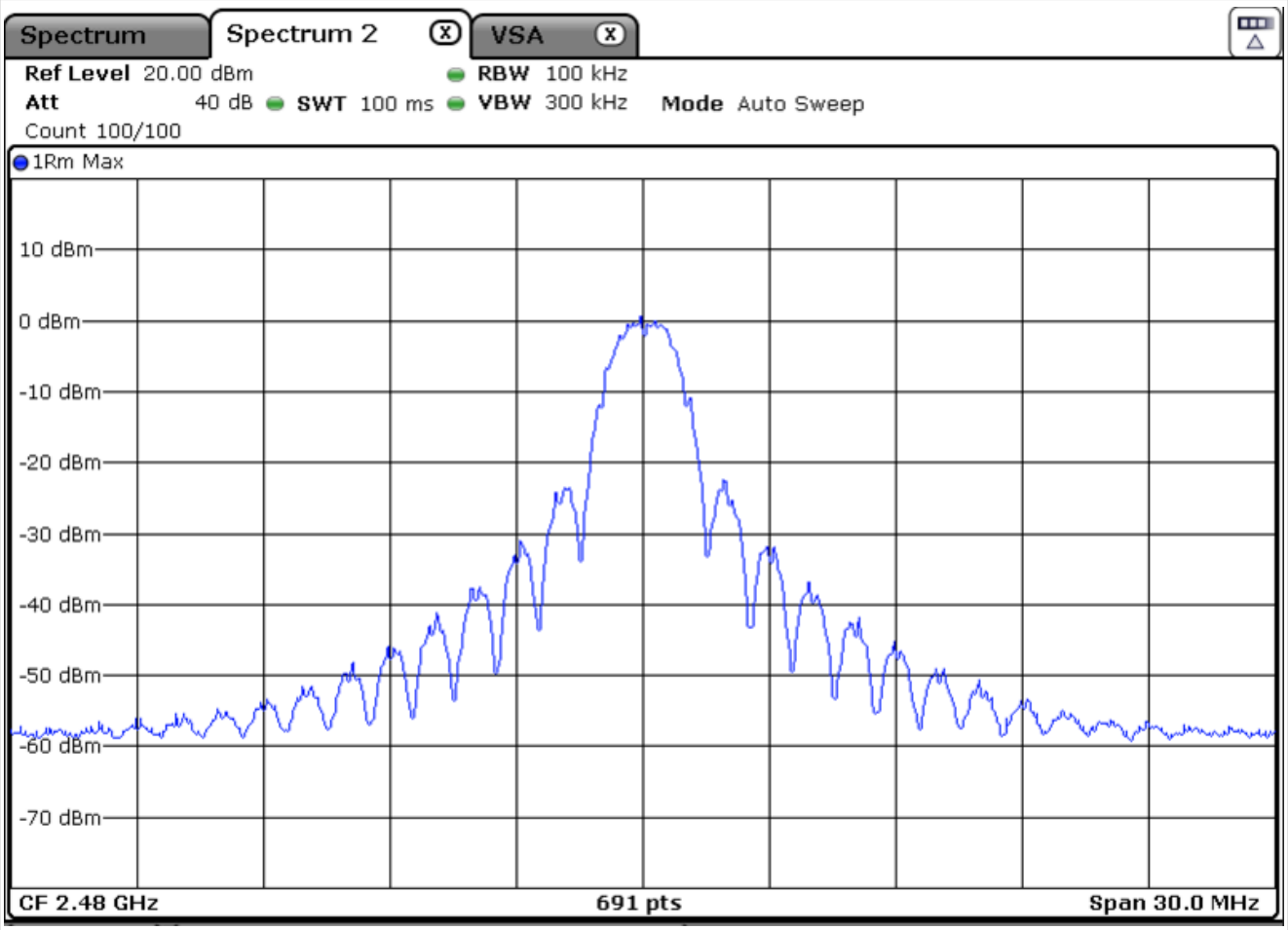



Figure 89. TX power in-band – Channel 26

**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)

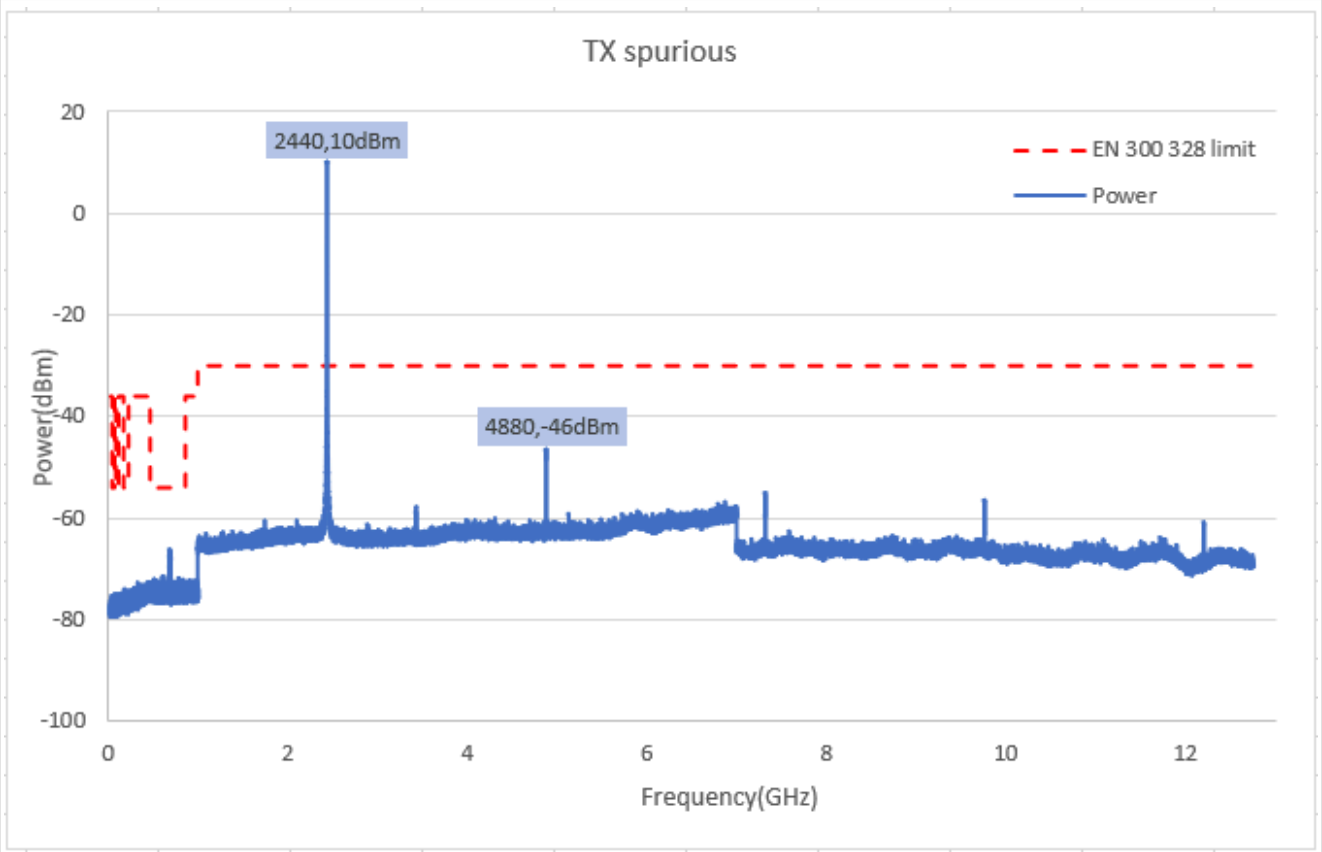



**Figure 90. Conducted TX spurious**

**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:**

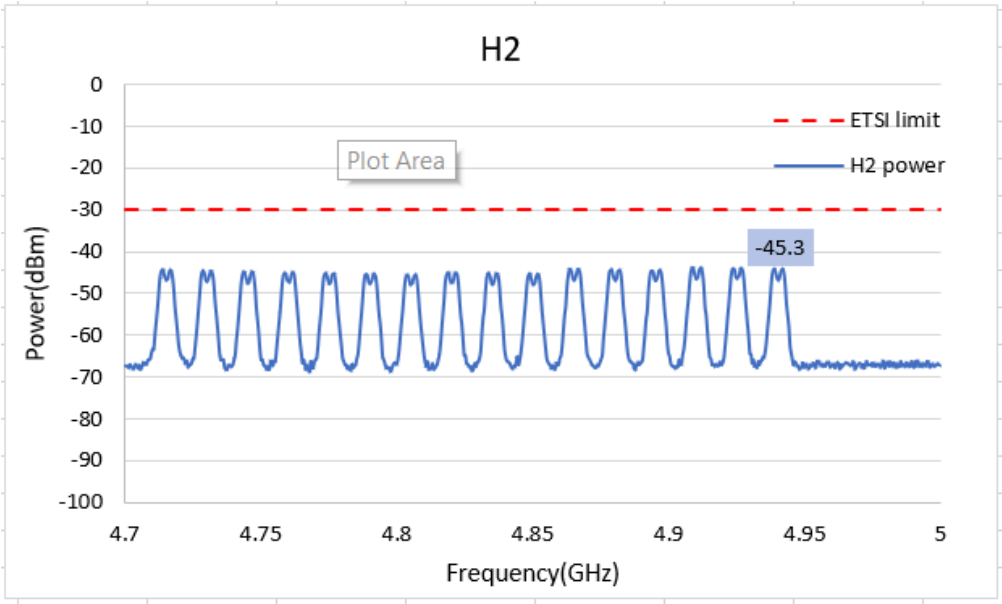



**Figure 91. Conducted H2 spurious**

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:**

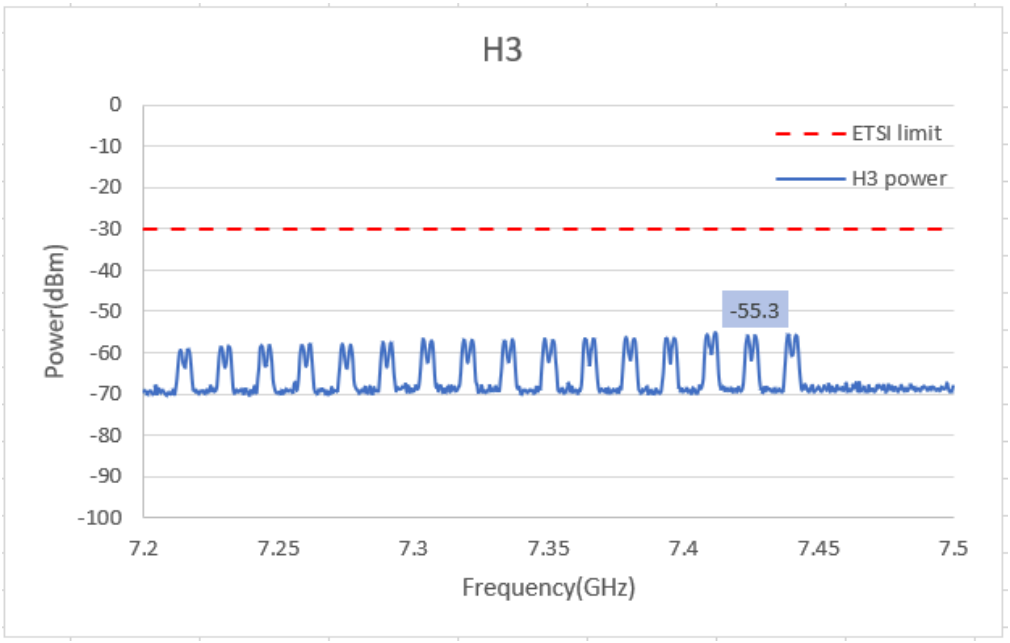



**Figure 92. Conducted H3 spurious**

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:**

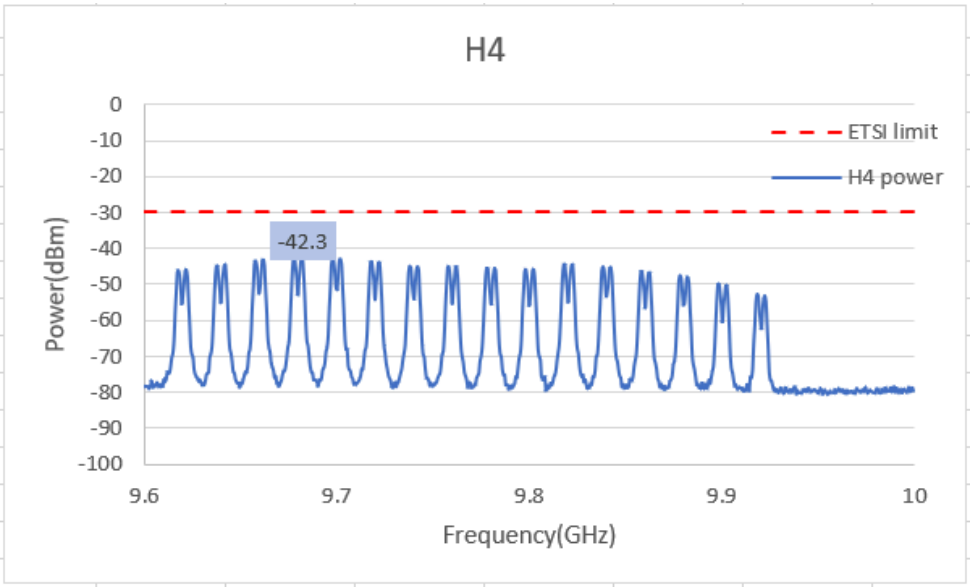



**Figure 93. Conducted H4 spurious**

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:**

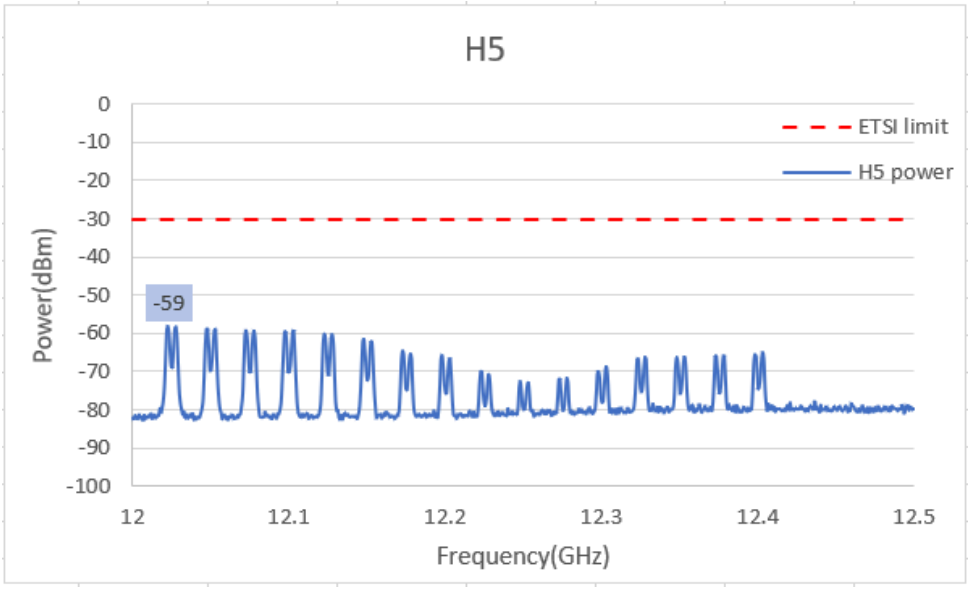



**Figure 94. Conducted H5 spurious**

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:**

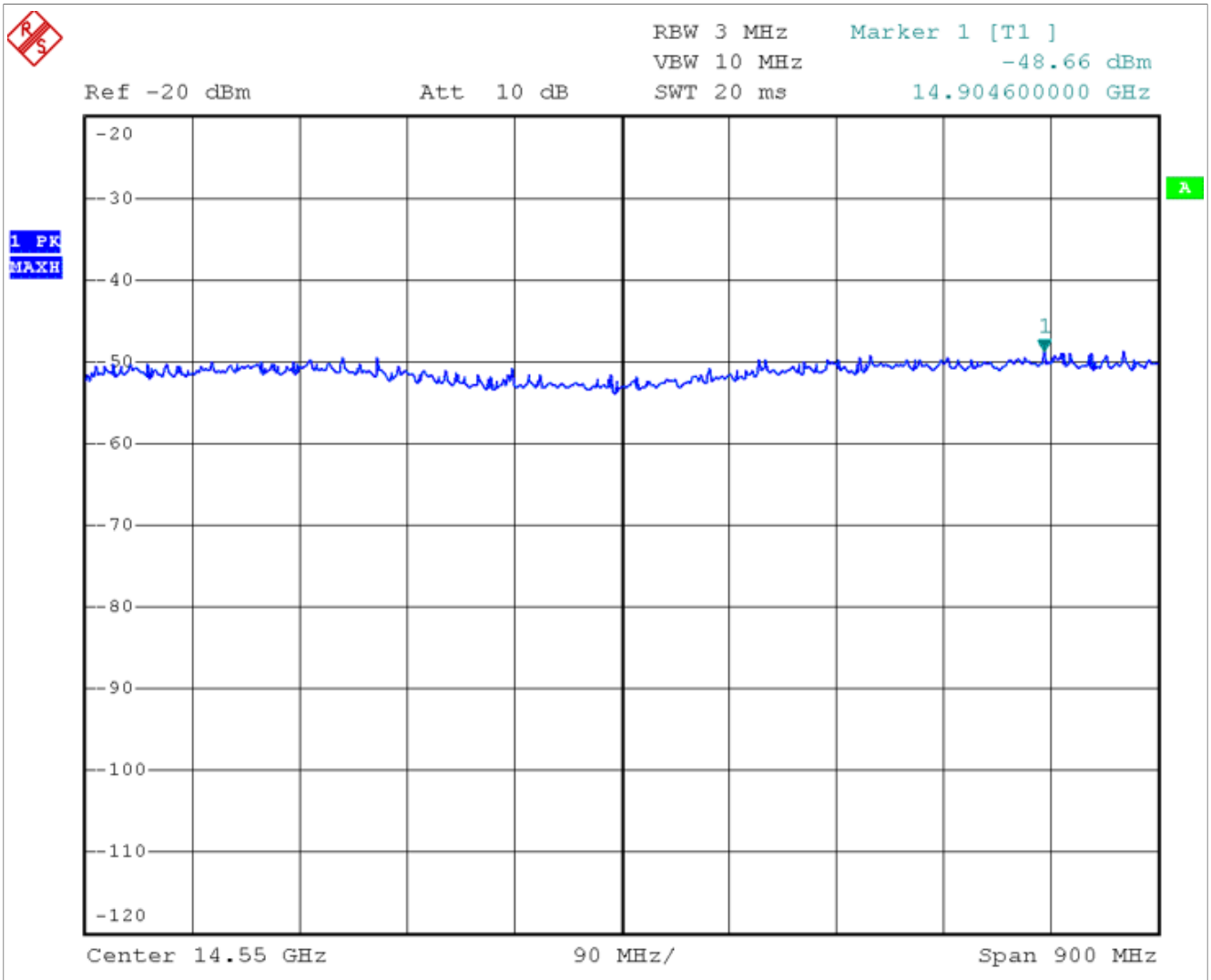



**Figure 95. Conducted H6 spurious**

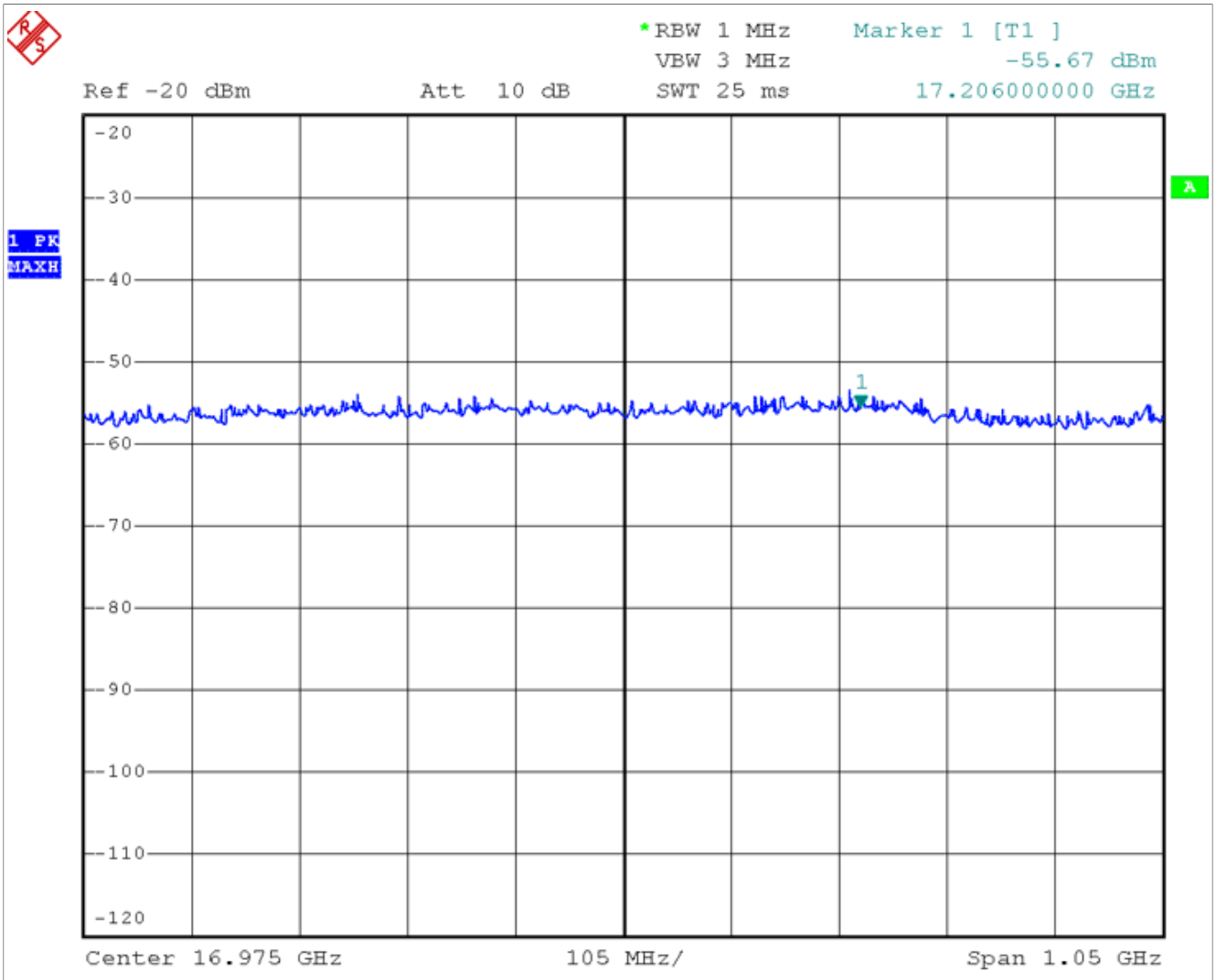



**Figure 96. Conducted H7 spurious**

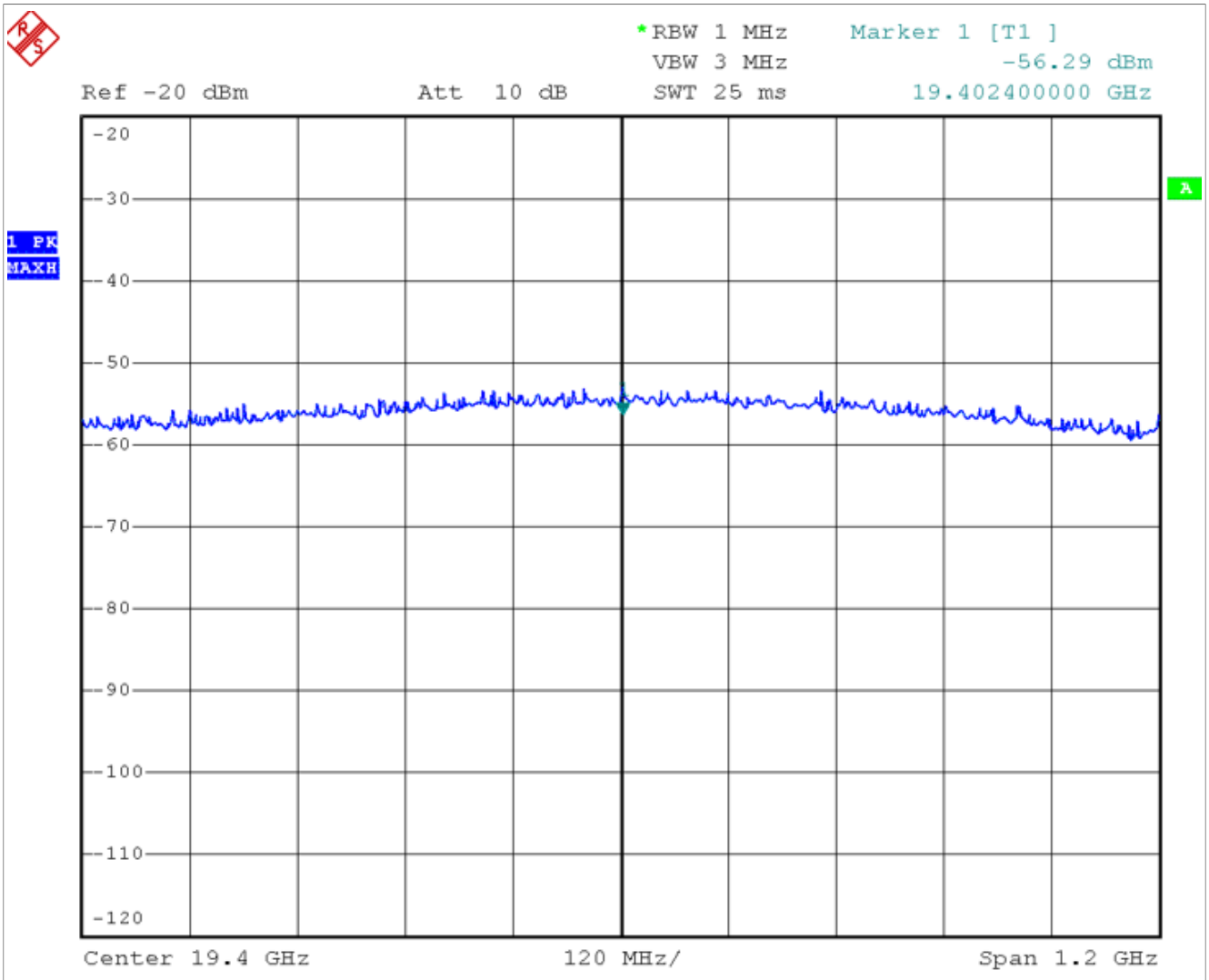



Figure 97. Conducted H8 spurious

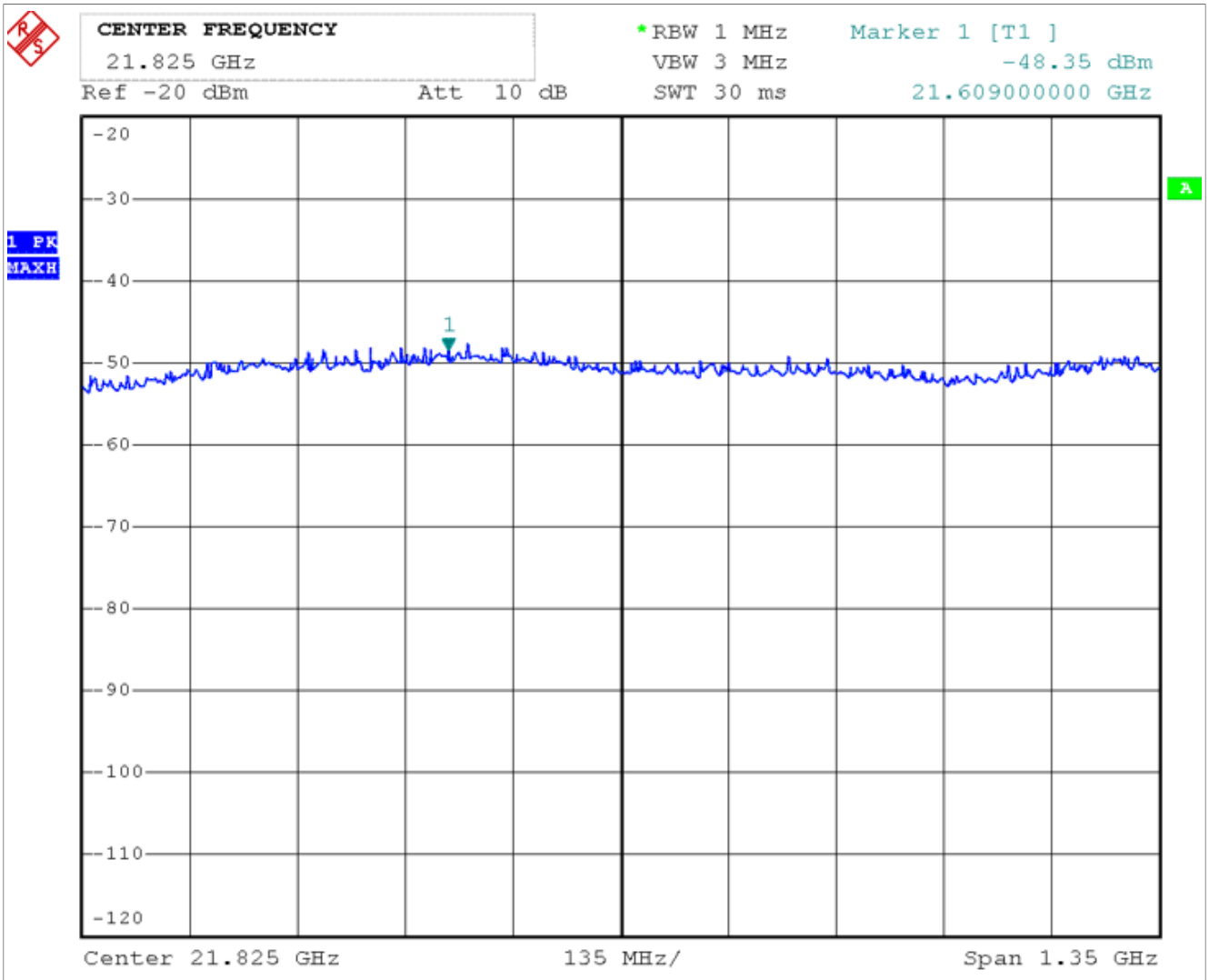



Figure 98. Conducted H9 spurious

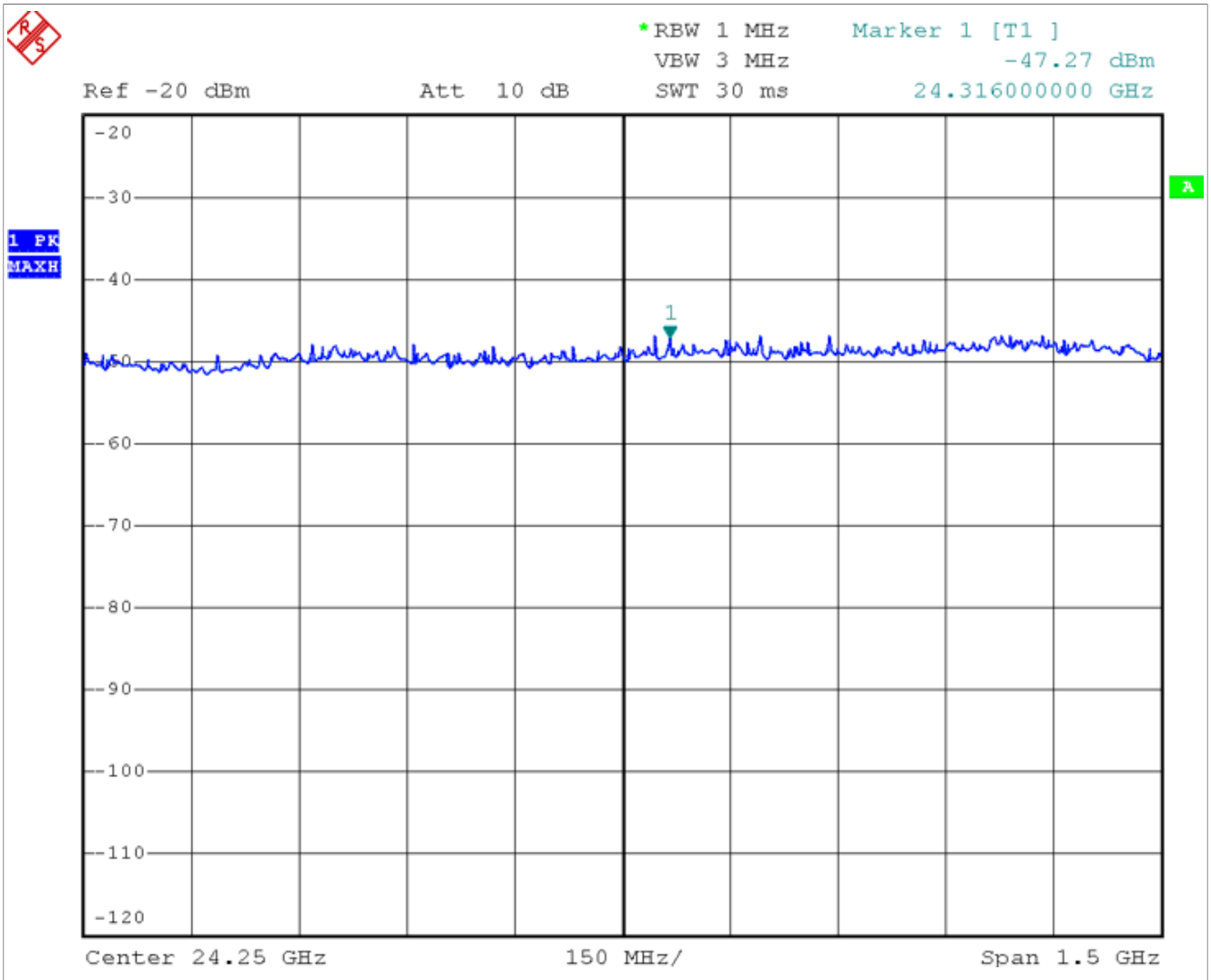



**Figure 99. Conducted H10 spurious**

**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:**

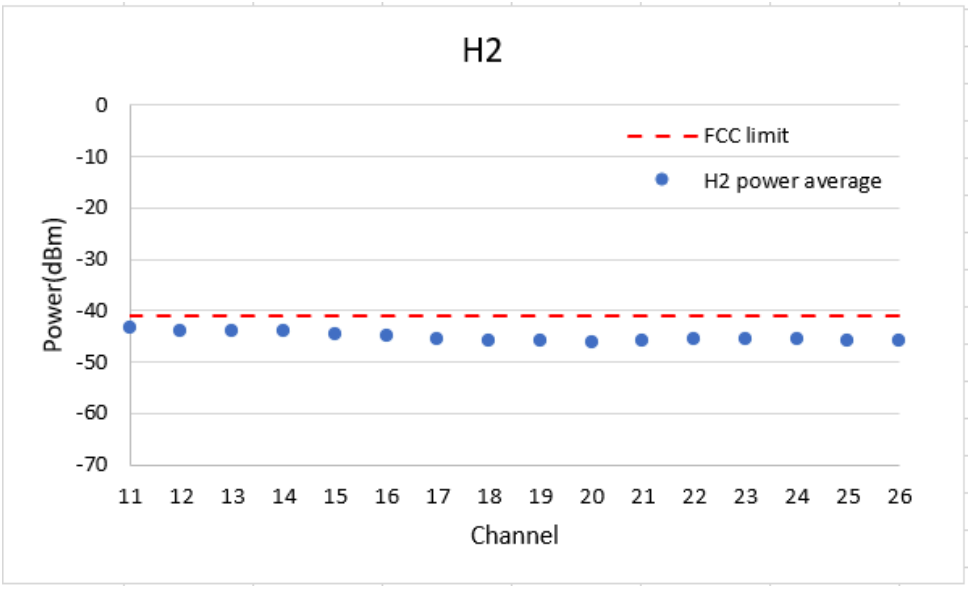



**Figure 100. Conducted H2 spurious**

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:**

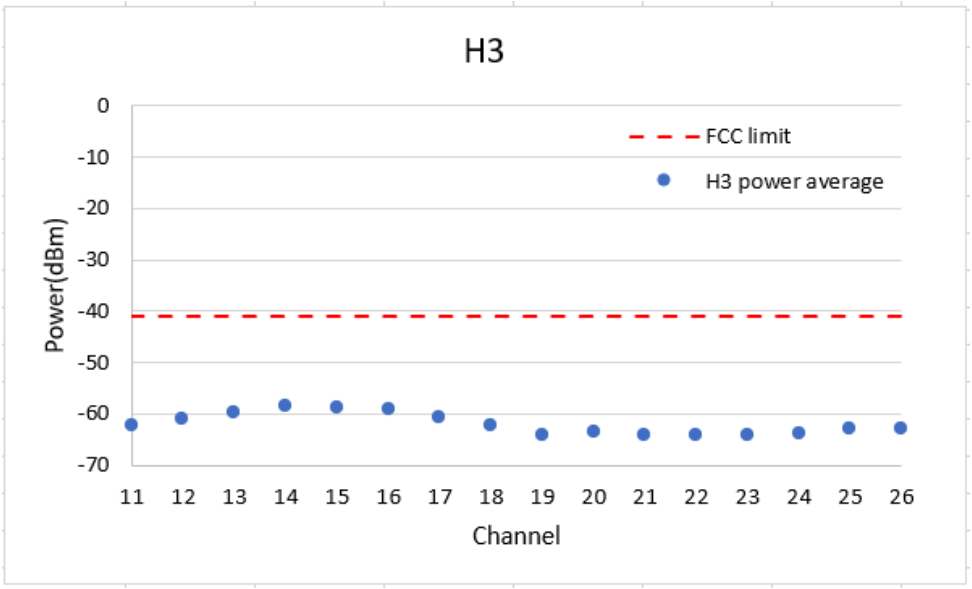



**Figure 101. Conducted H3 spurious**

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:**

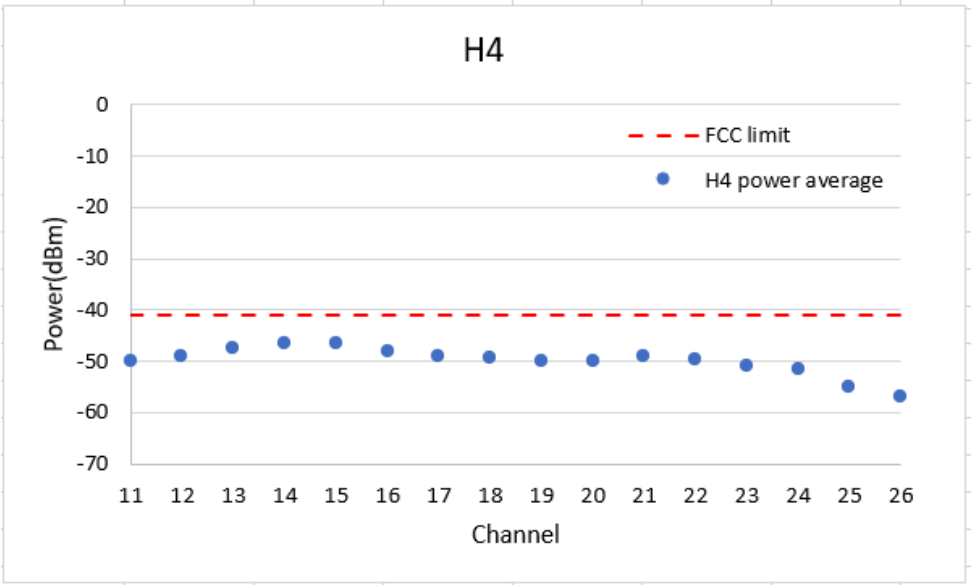



**Figure 102. Conducted H4 spurious**

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:**

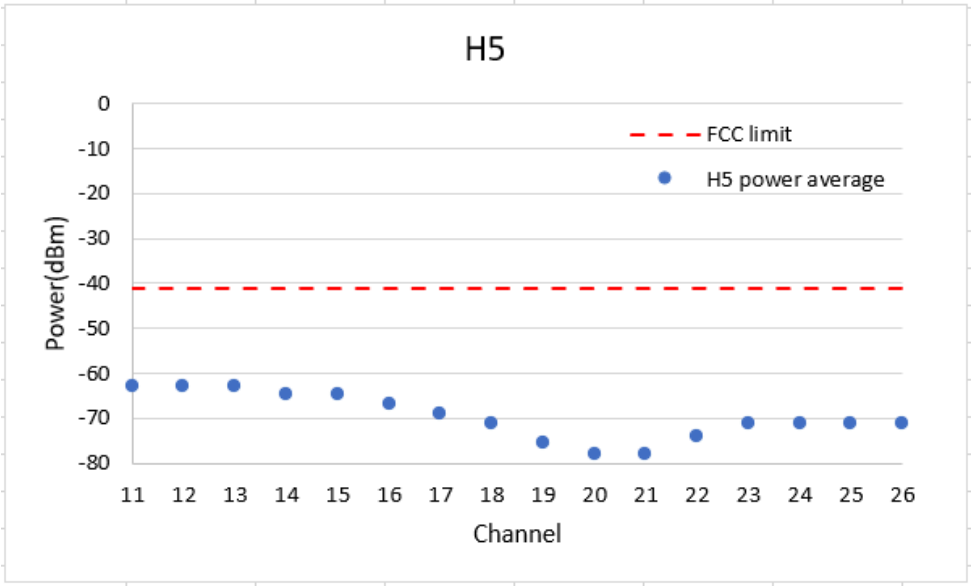



**Figure 103. Conducted H5 spurious**

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:**

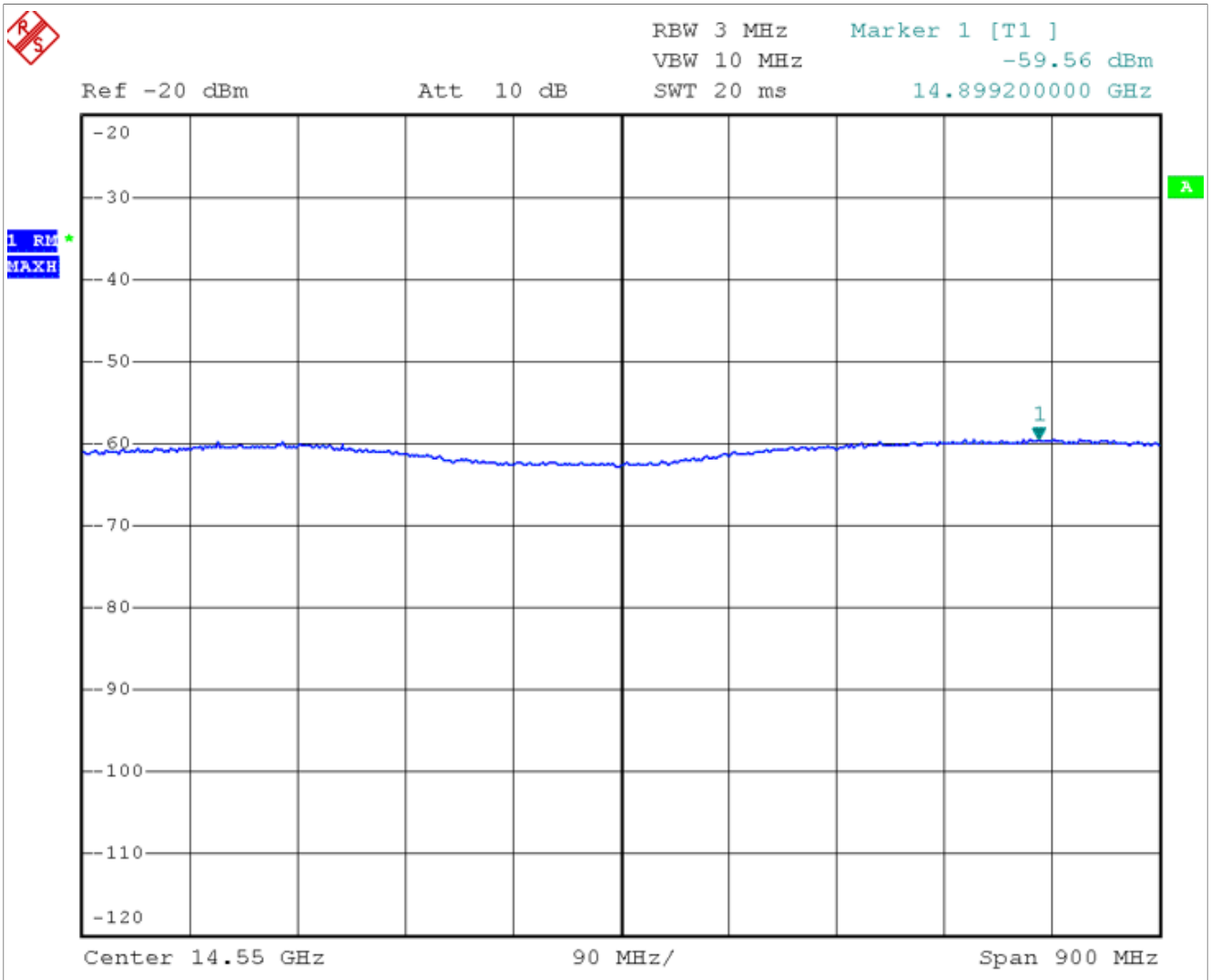



**Figure 104. Conducted H6 spurious**

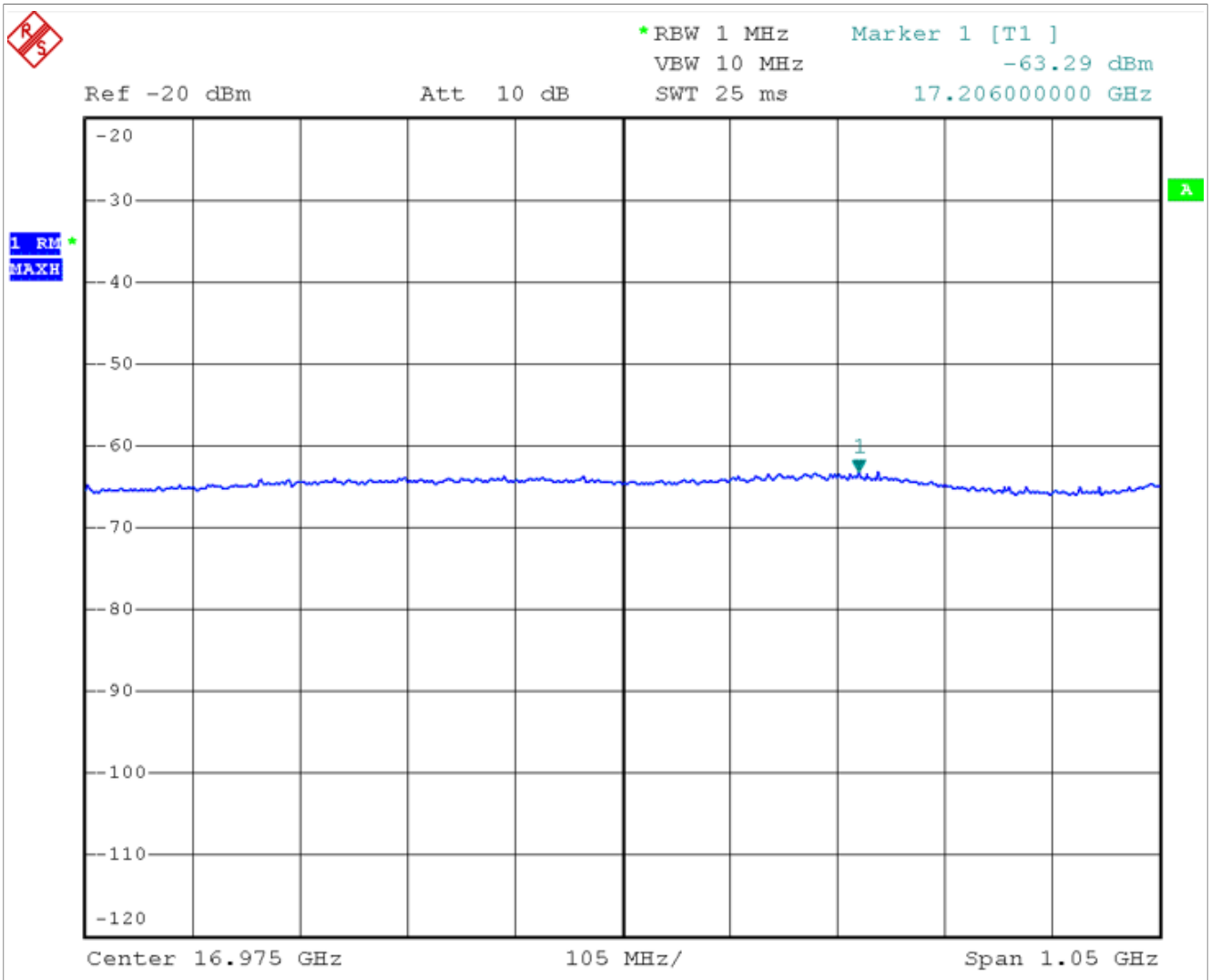



**Figure 105. Conducted H7 spurious**

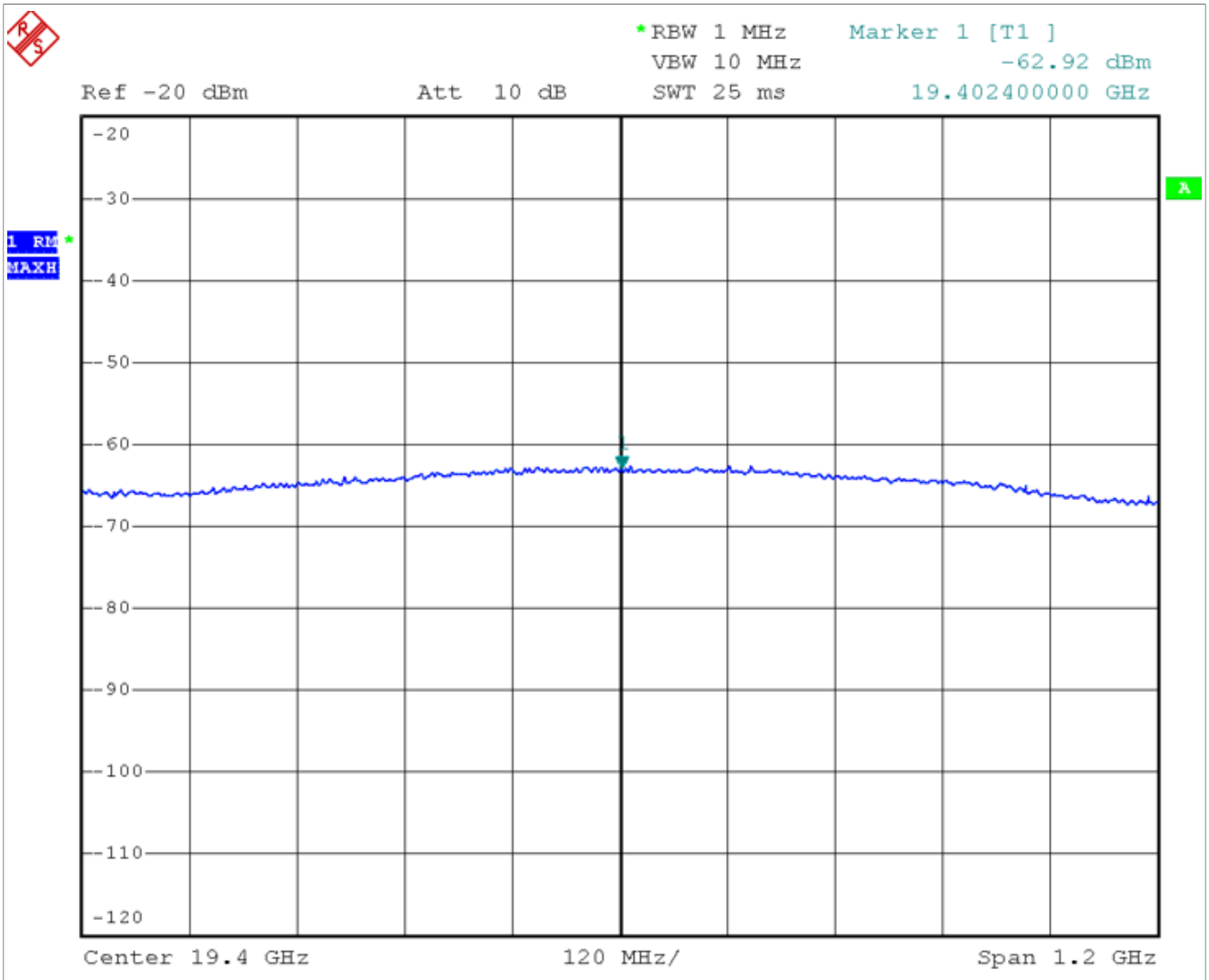



**Figure 106. Conducted H8 spurious**

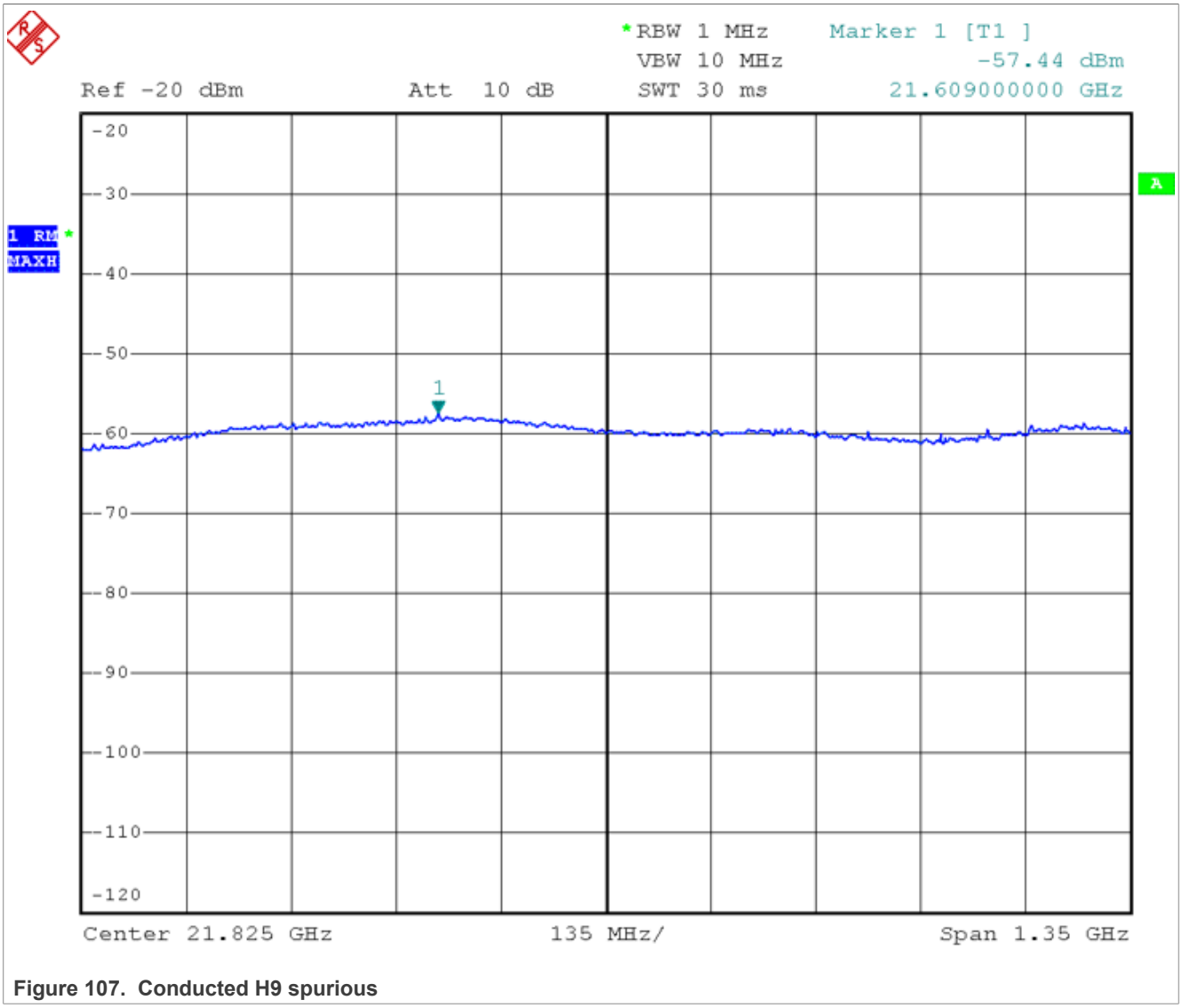



**Figure 107. Conducted H9 spurious**

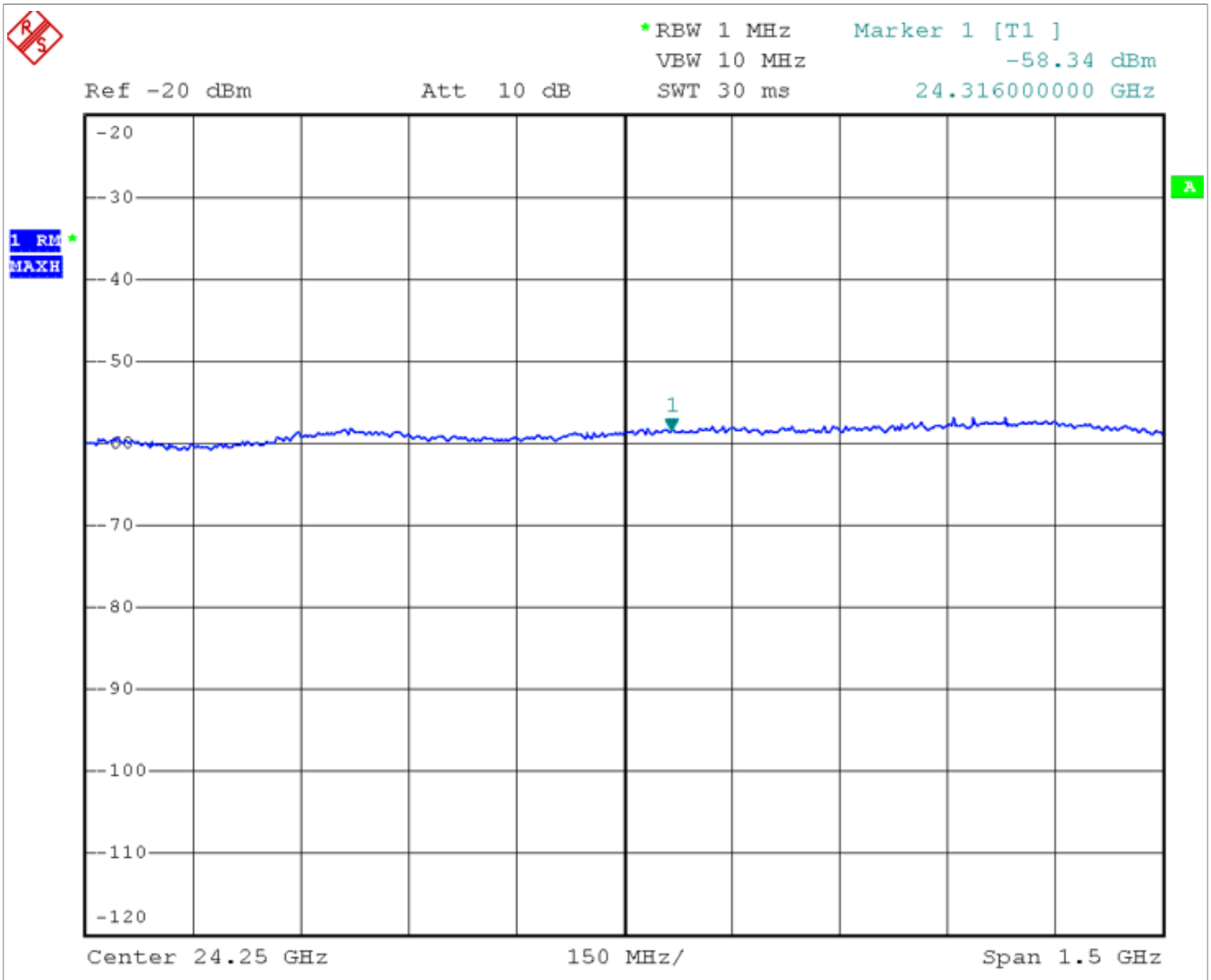



**Figure 108. Conducted H10 spurious**

**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.

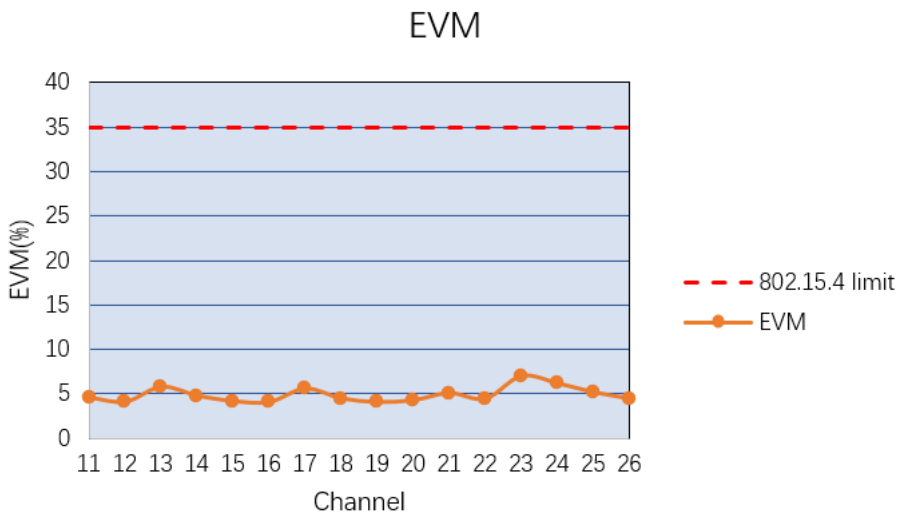



**Figure 109. EVM in regular mode**

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:**

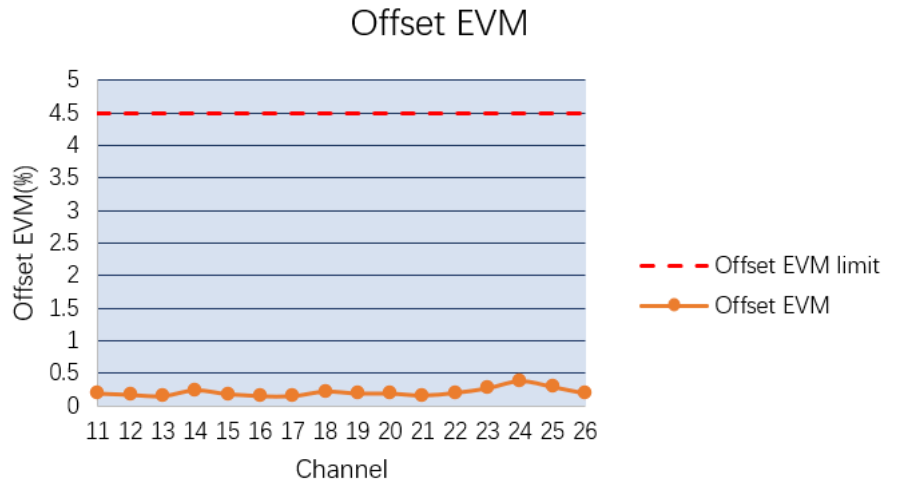



**Figure 110. Offset EVM in regular mode**

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:**

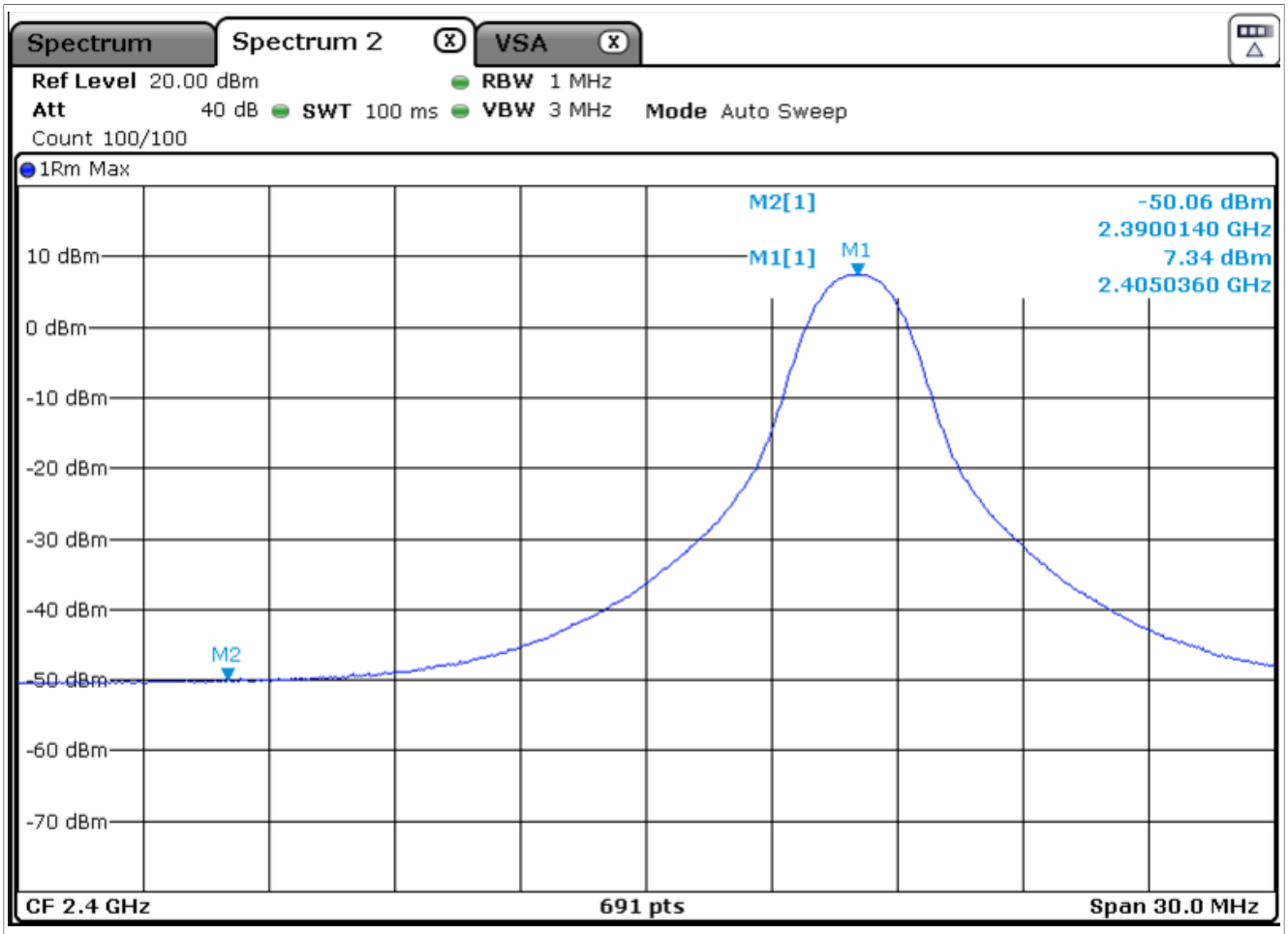



Figure 111. Lower band edge – Channel 11

**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

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

Results:

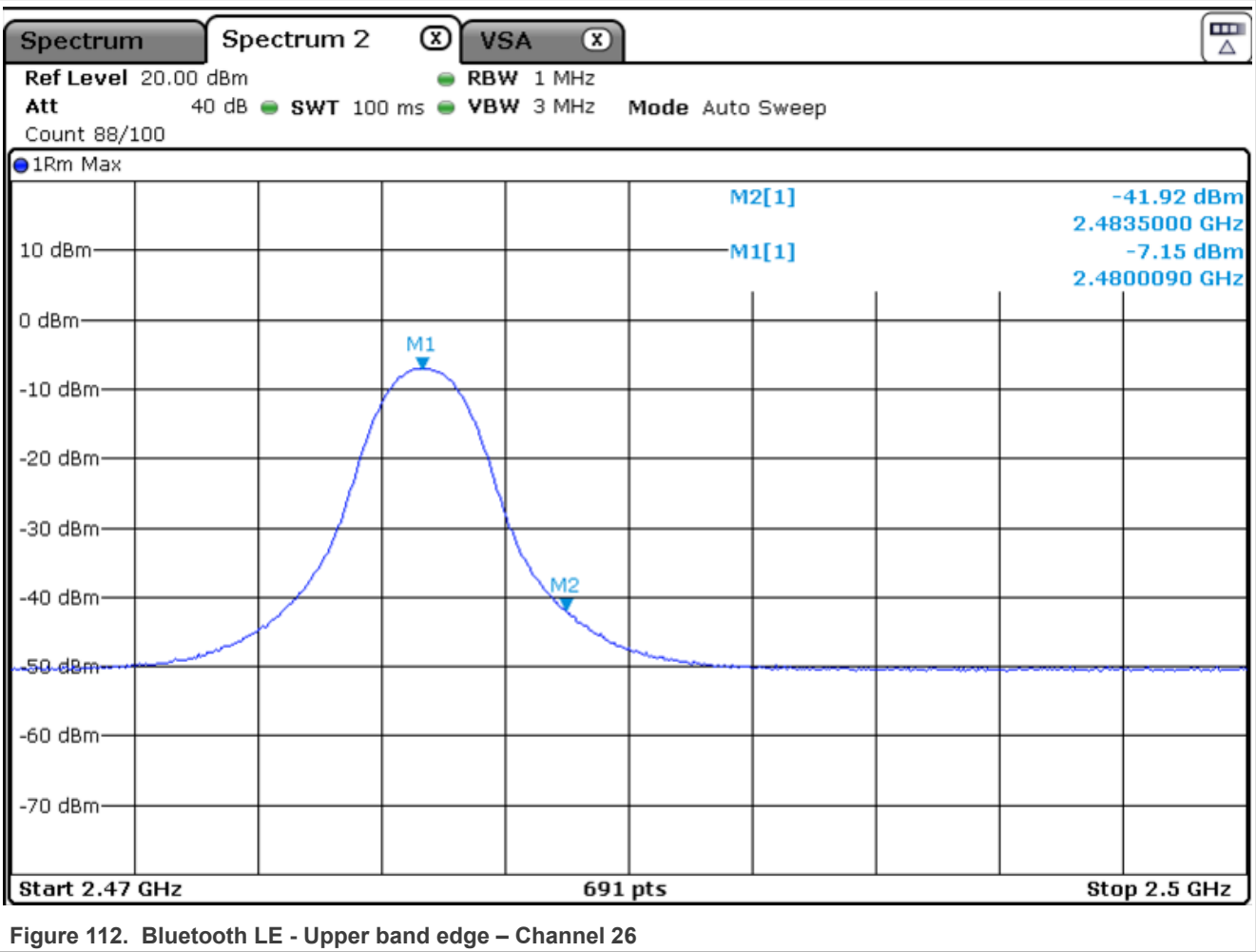



**Figure 112. Bluetooth LE - Upper band edge – Channel 26**

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)

  - 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:**

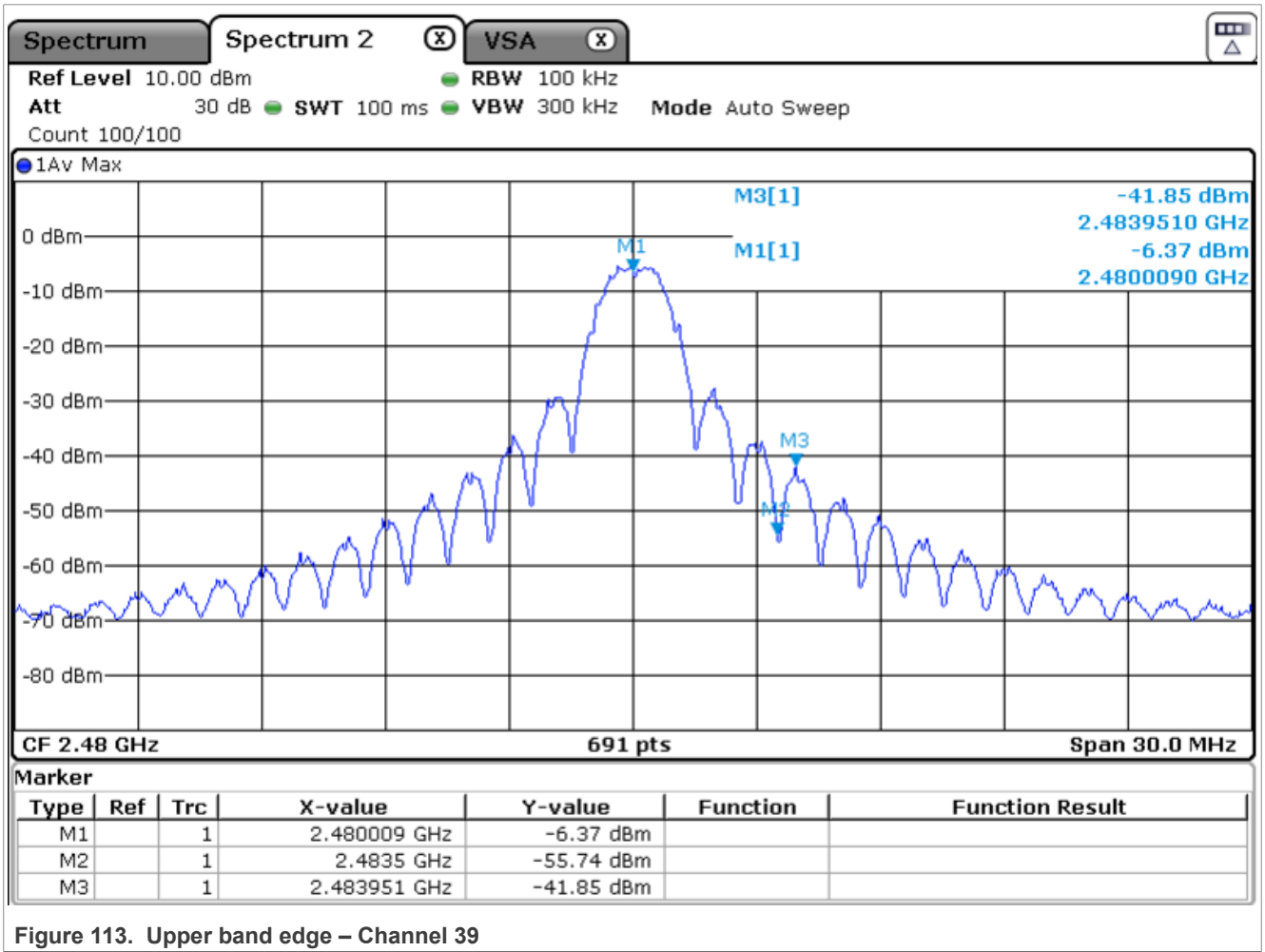



**Figure 113. Upper band edge – Channel 39**

| 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:**

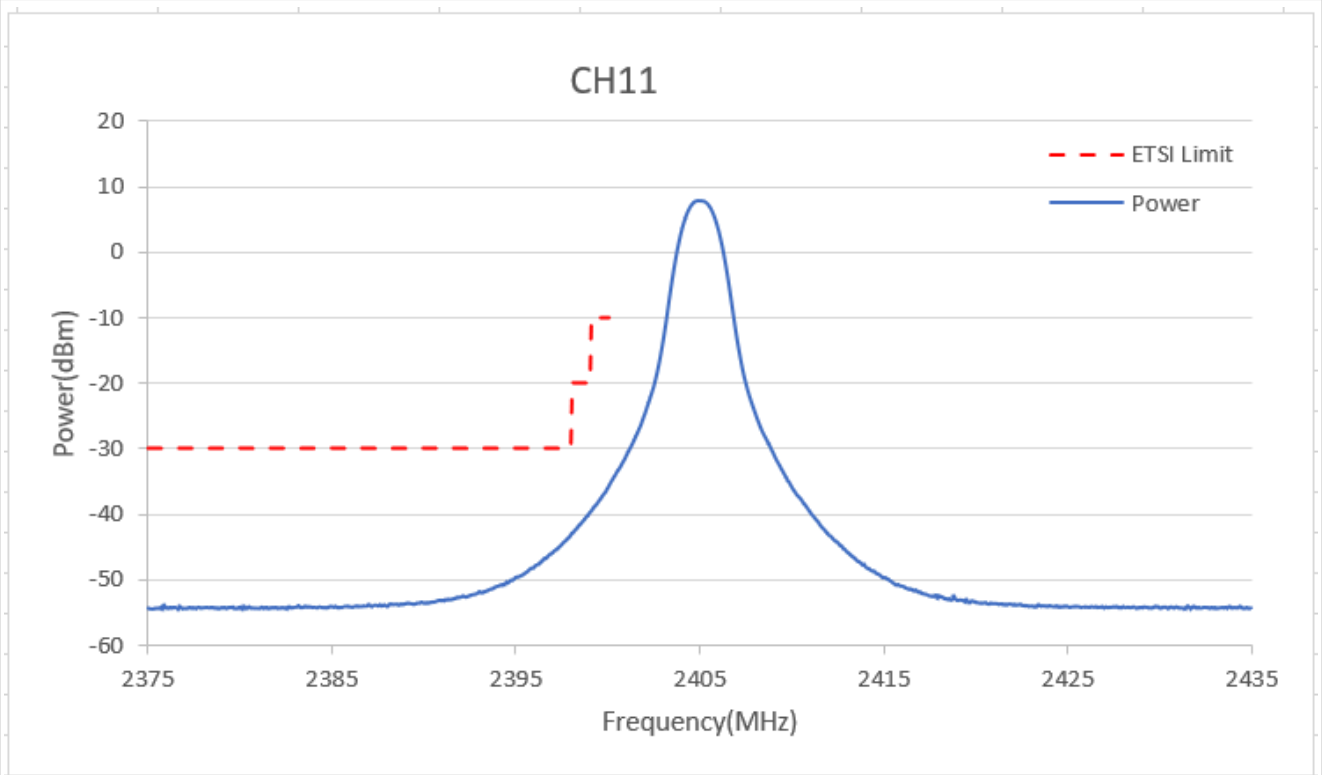



Figure 114. Out of band – Channel 11

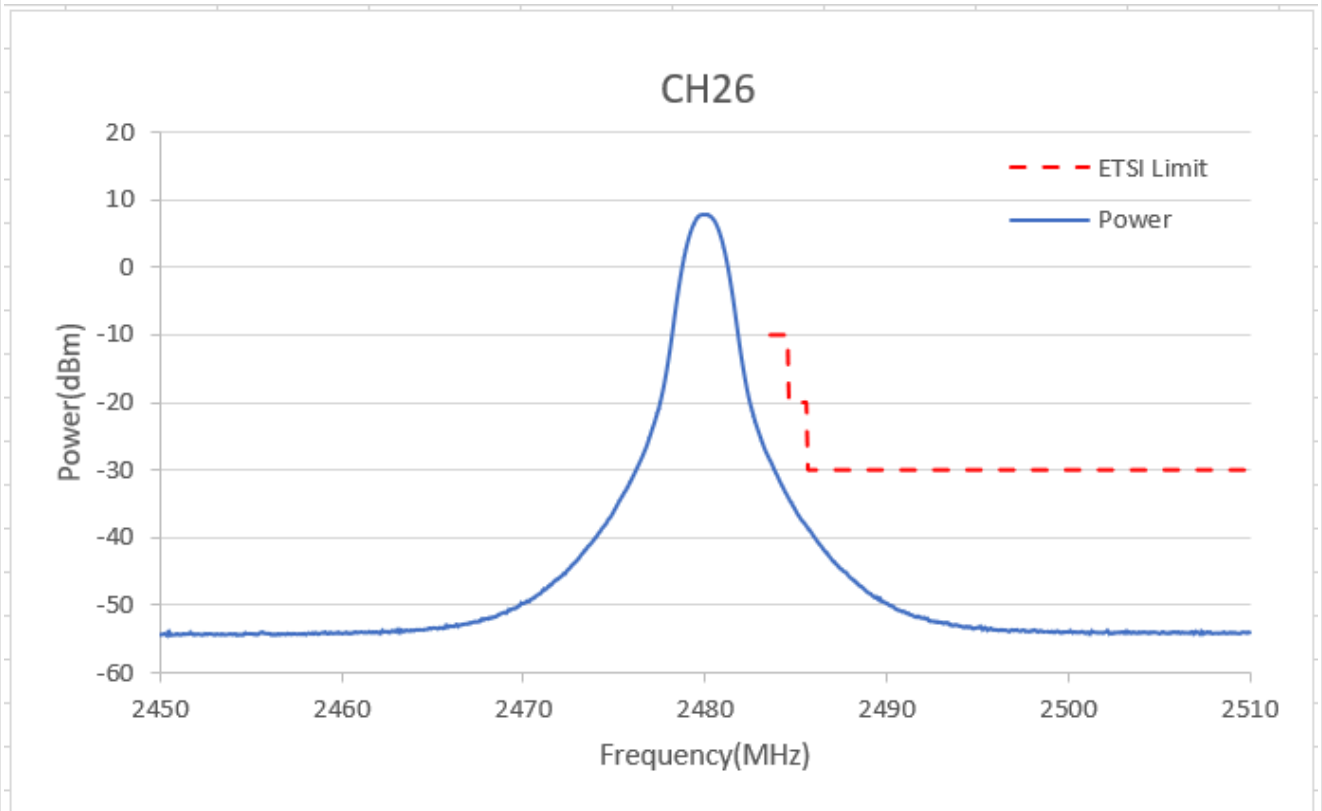



Figure 115. Out of band – Channel 11

**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:**

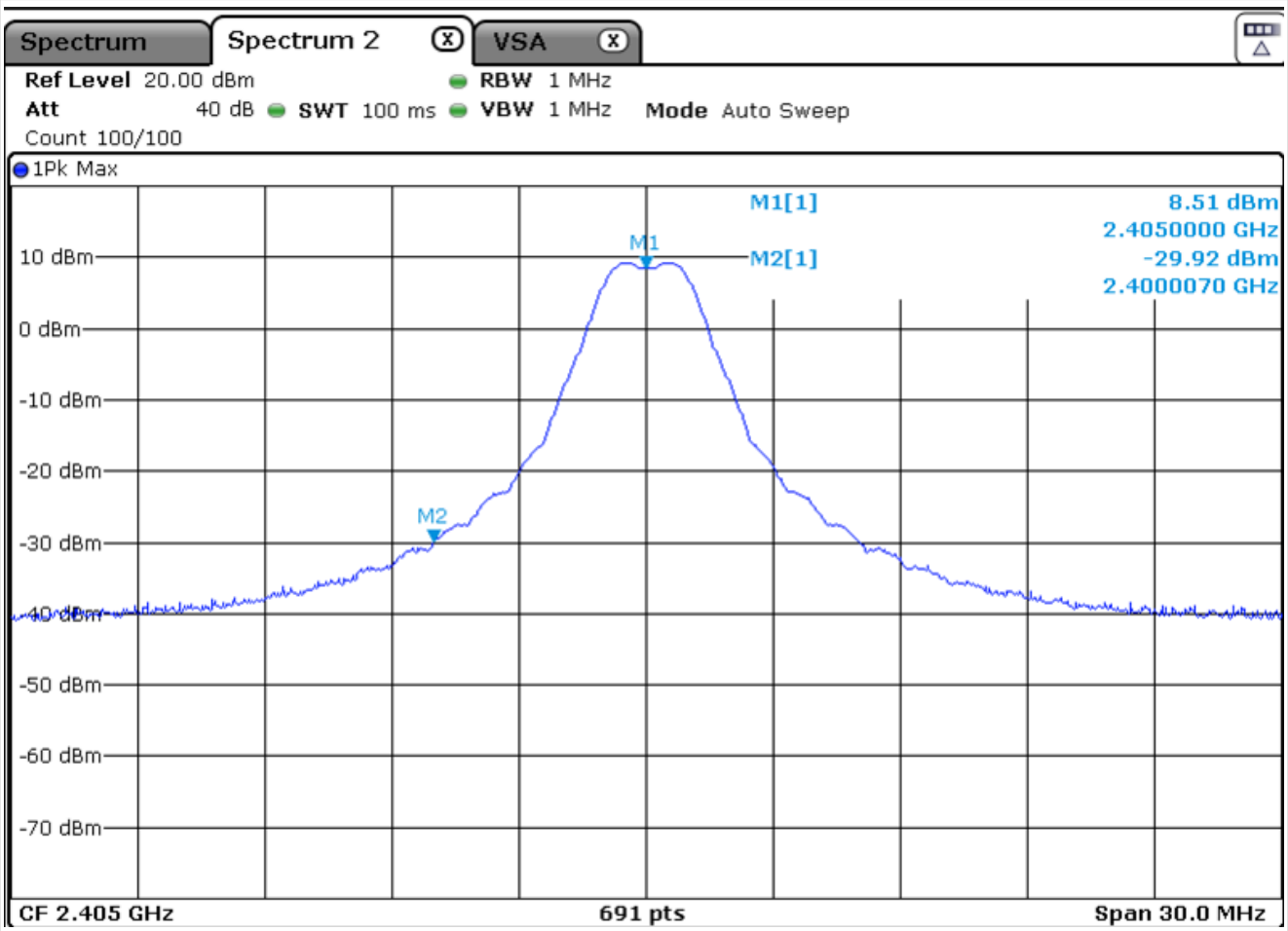



Figure 116. Out of band – Channel 11

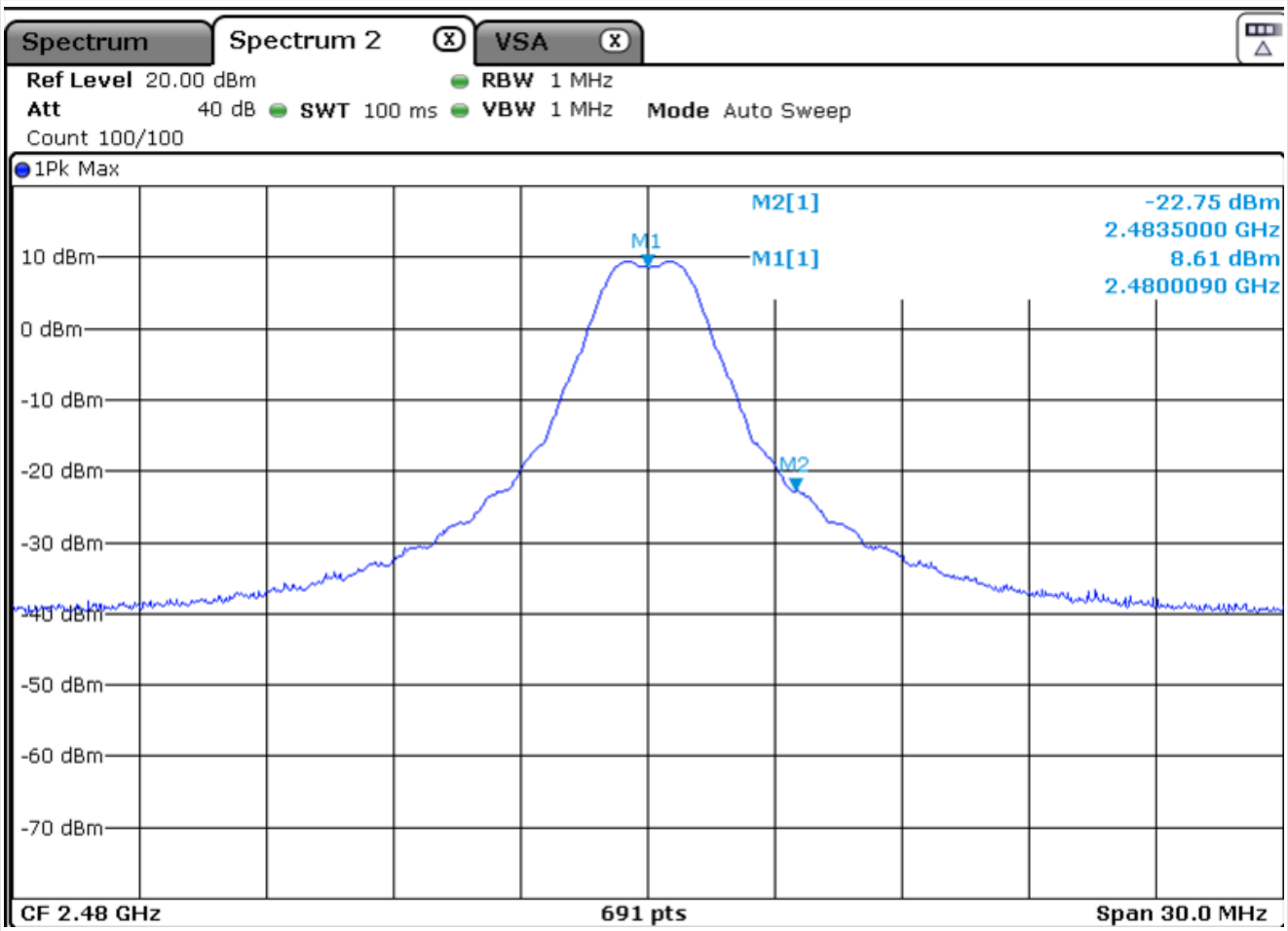



Figure 117. Out of band – Channel 11

**Conclusion:**

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

### 4.3.2 RX tests

### 4.3.2.1 Test setup

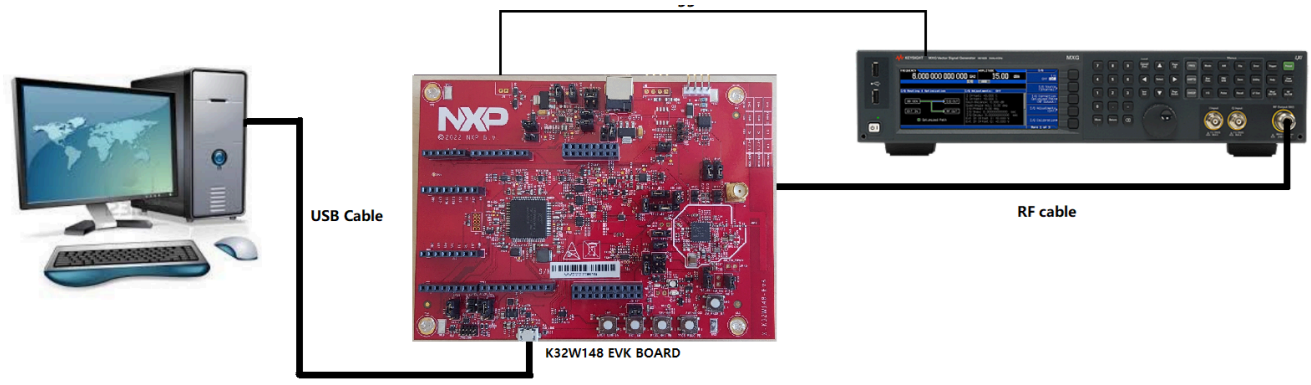



**Figure 118. Conducted RX test setup for sensitivity and receiver maximum input level**

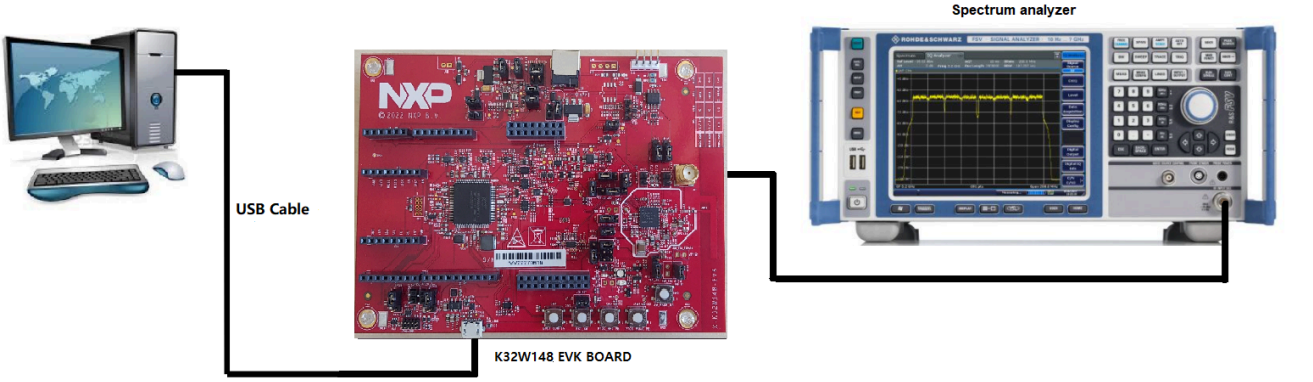



**Figure 119. Conducted RX test setup for spurious**

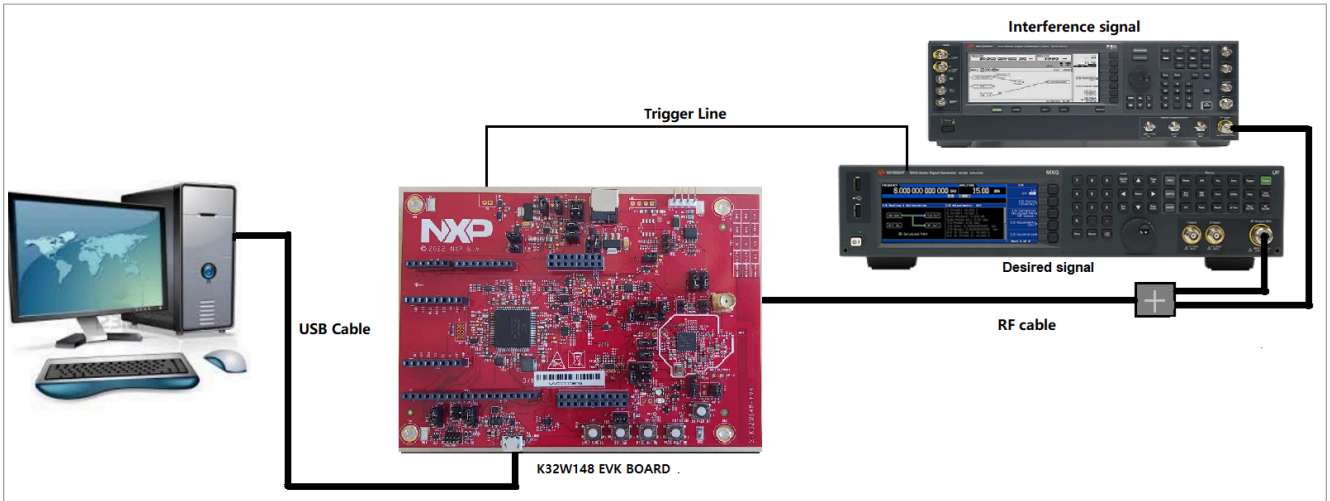



**Figure 120. Conducted RX test setup for interference rejection**

### 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:**

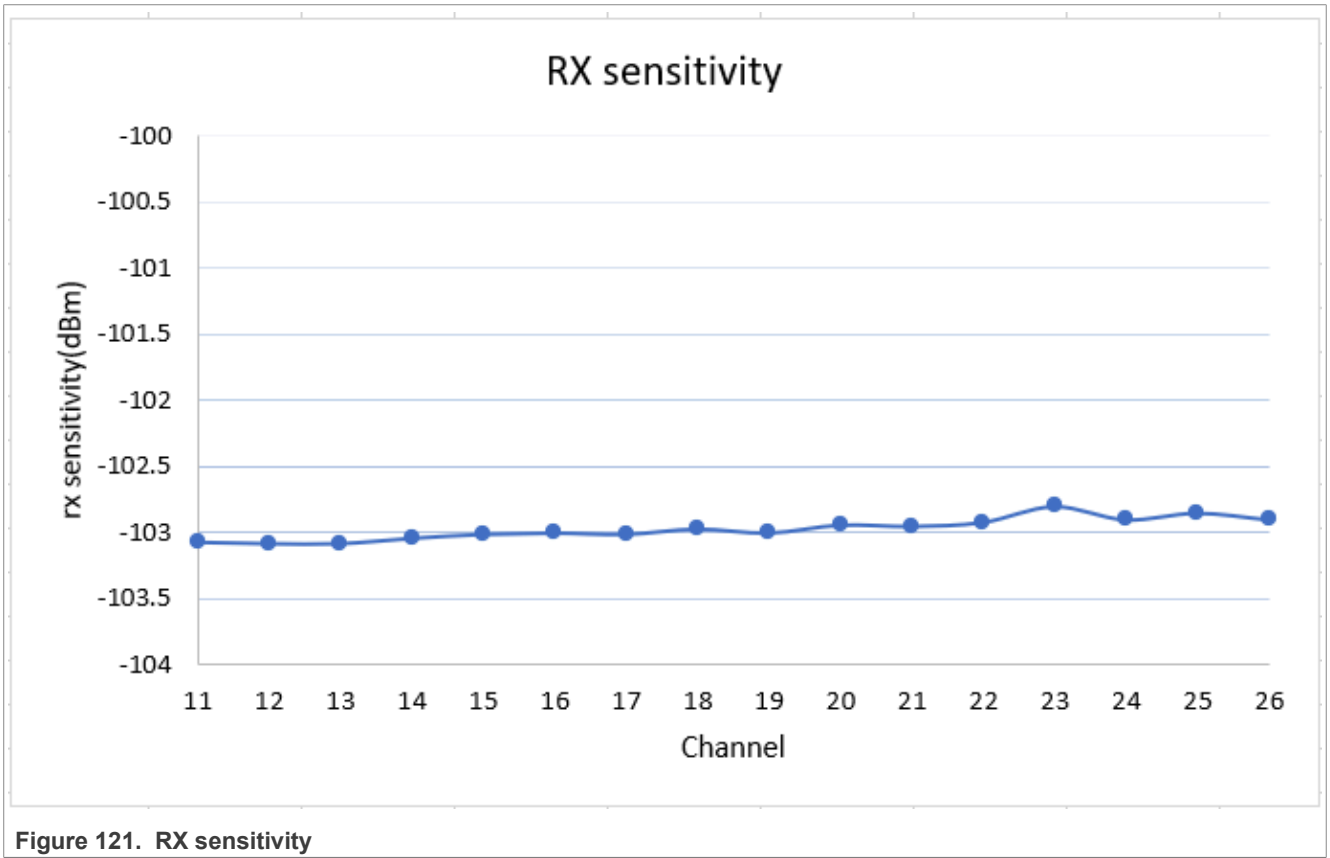



**Figure 121. RX sensitivity**

**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:**

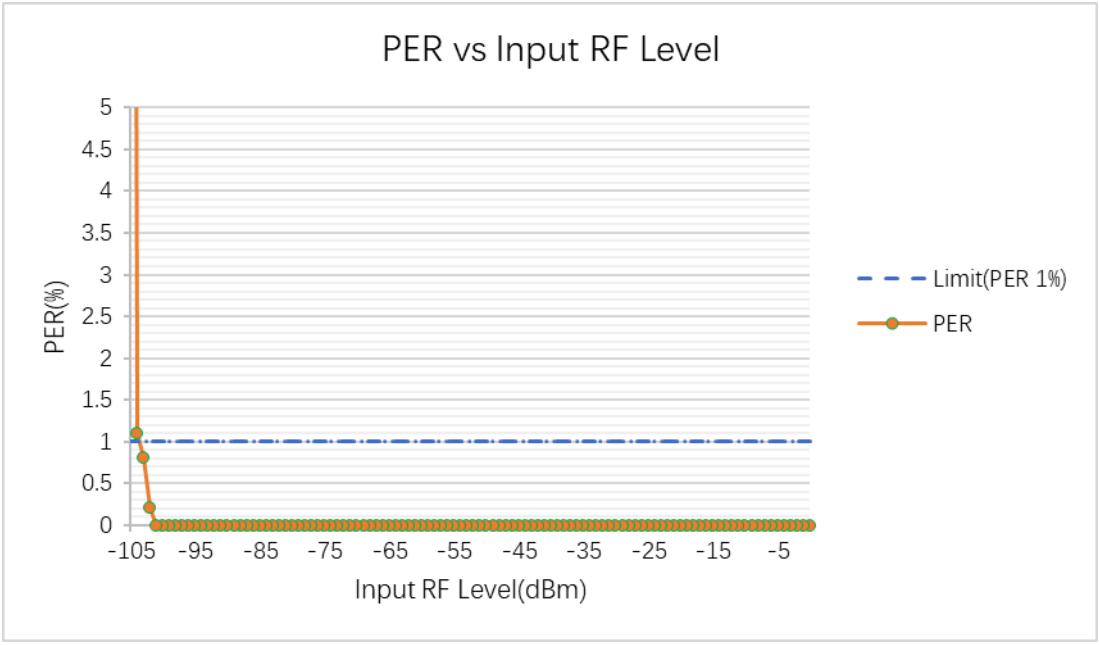



**Figure 122. Sensitivity bathtub**

#### 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:**

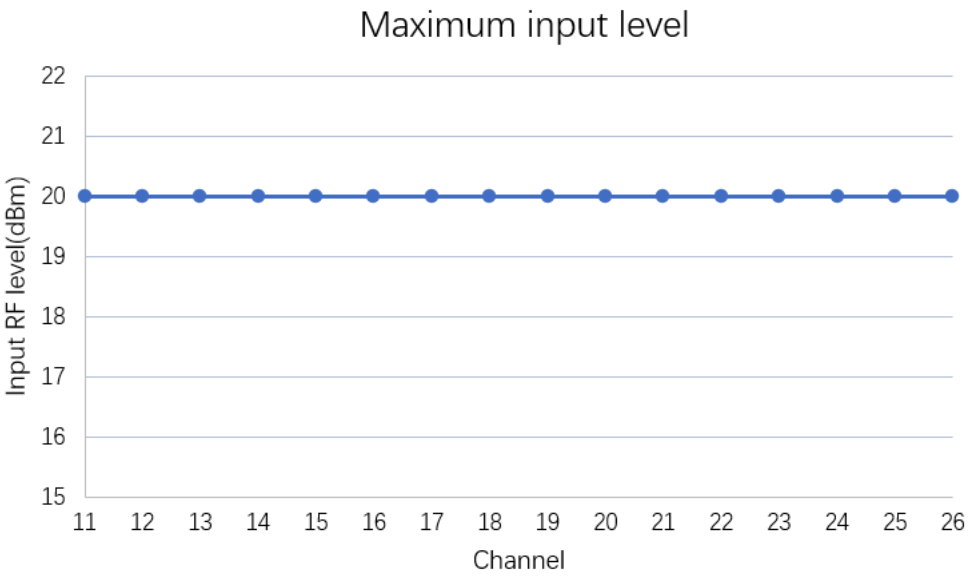



**Figure 123. Maximum input power**

**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:**

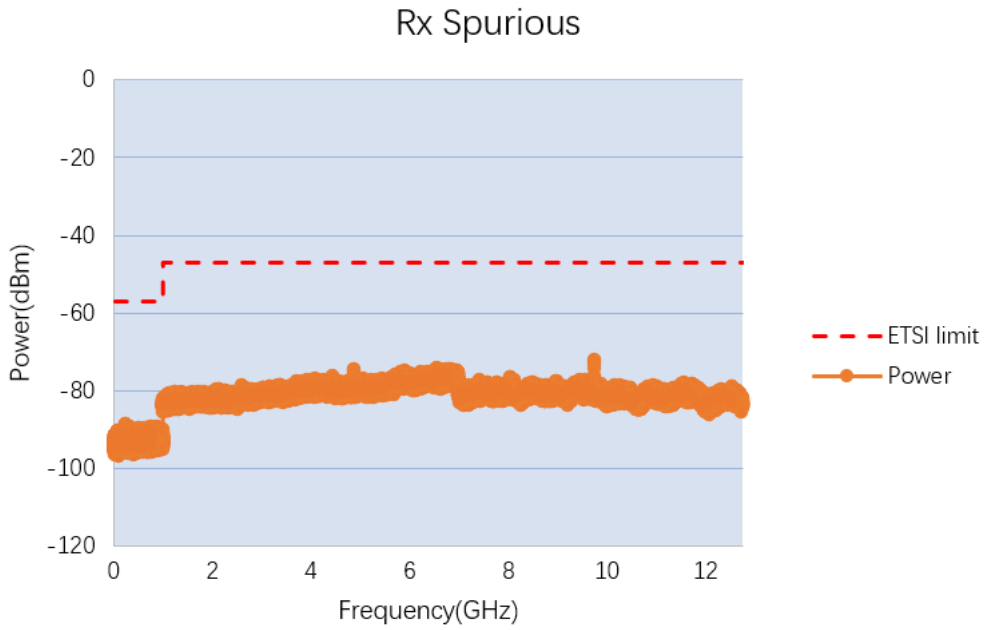



**Figure 124. Conducted RX spurious**

***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.

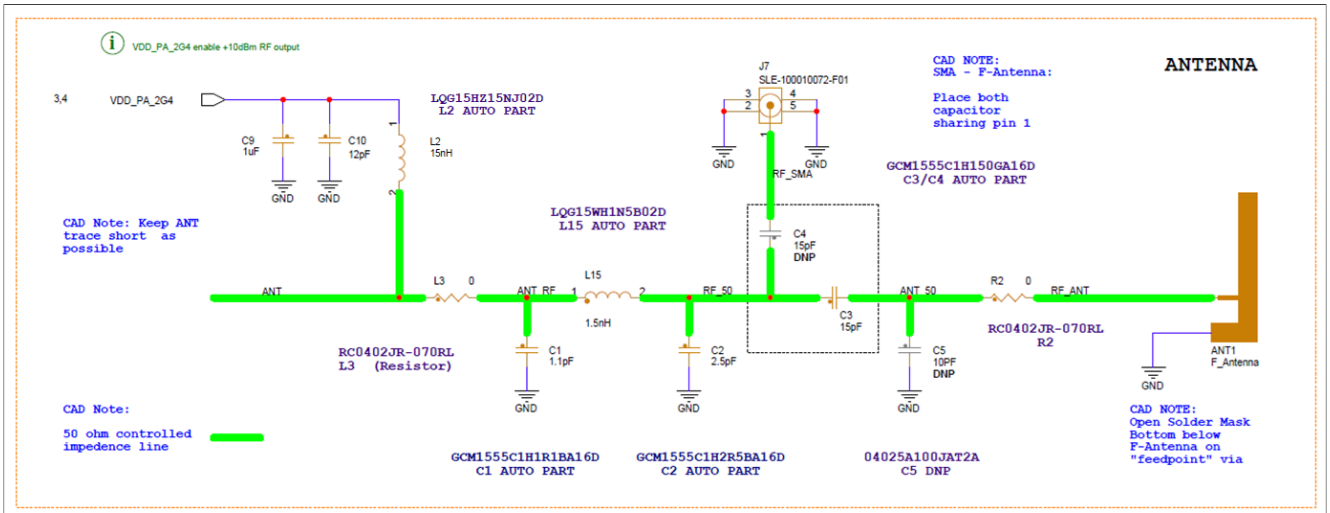



Figure 128. RF matching

Matching components are:

- Inductors

| Reference | Value | Description | Mfr. name | Mfr. part number |
|---|---|---|---|---|
| L2 | 15 nH | IND -- 0.015 µH @ 100 MHz 450 mA +/-5% 0402 | MURATA | LQG15HZ15NJ02D |
| L3 | 0 ohm | Resistor shunt | — | — |
| L15 | 1.5 nH | IND -- 0.0015 µH @ 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 µF | CAP CER 1 µF 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

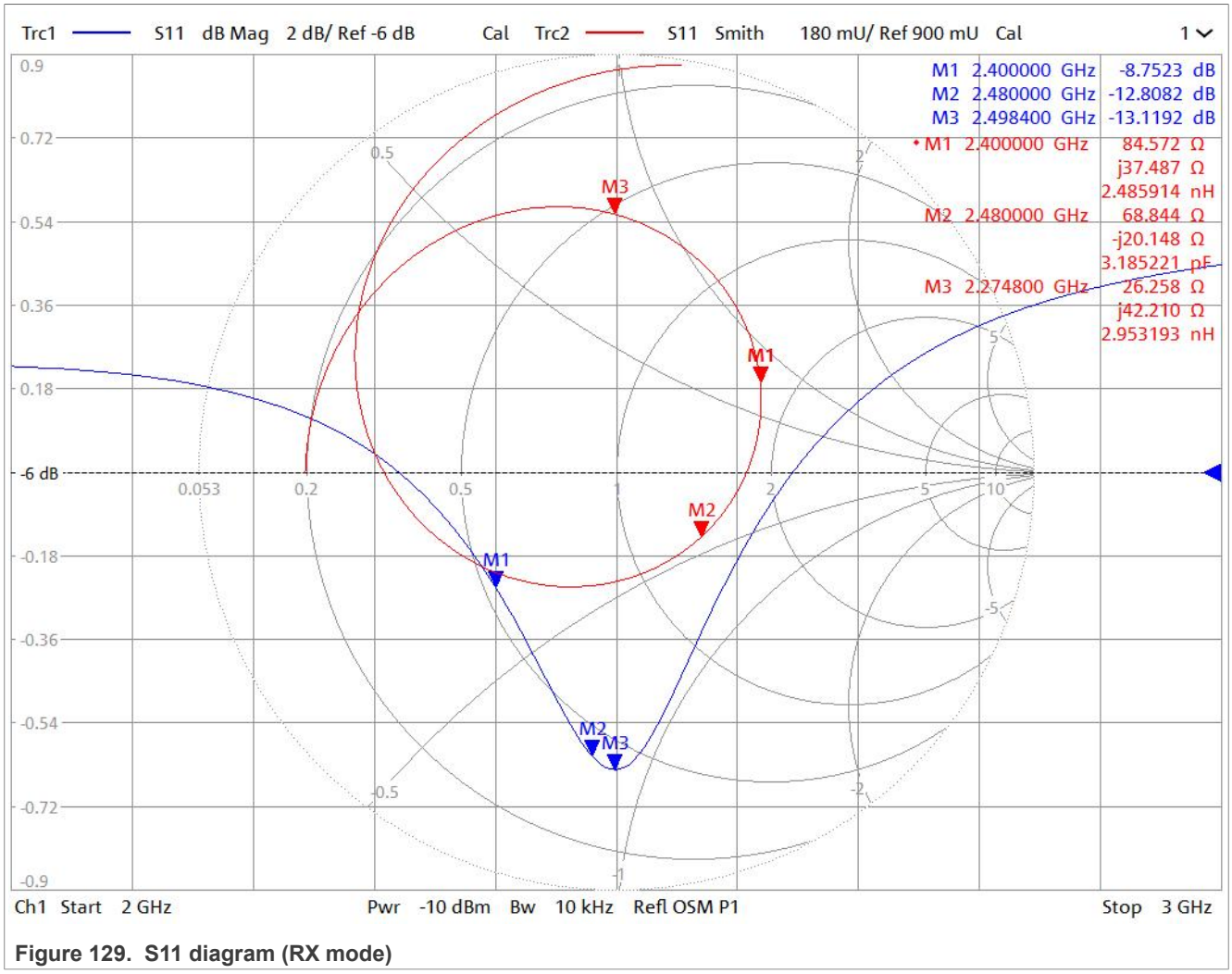



**Figure 129. S11 diagram (RX mode)**

**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

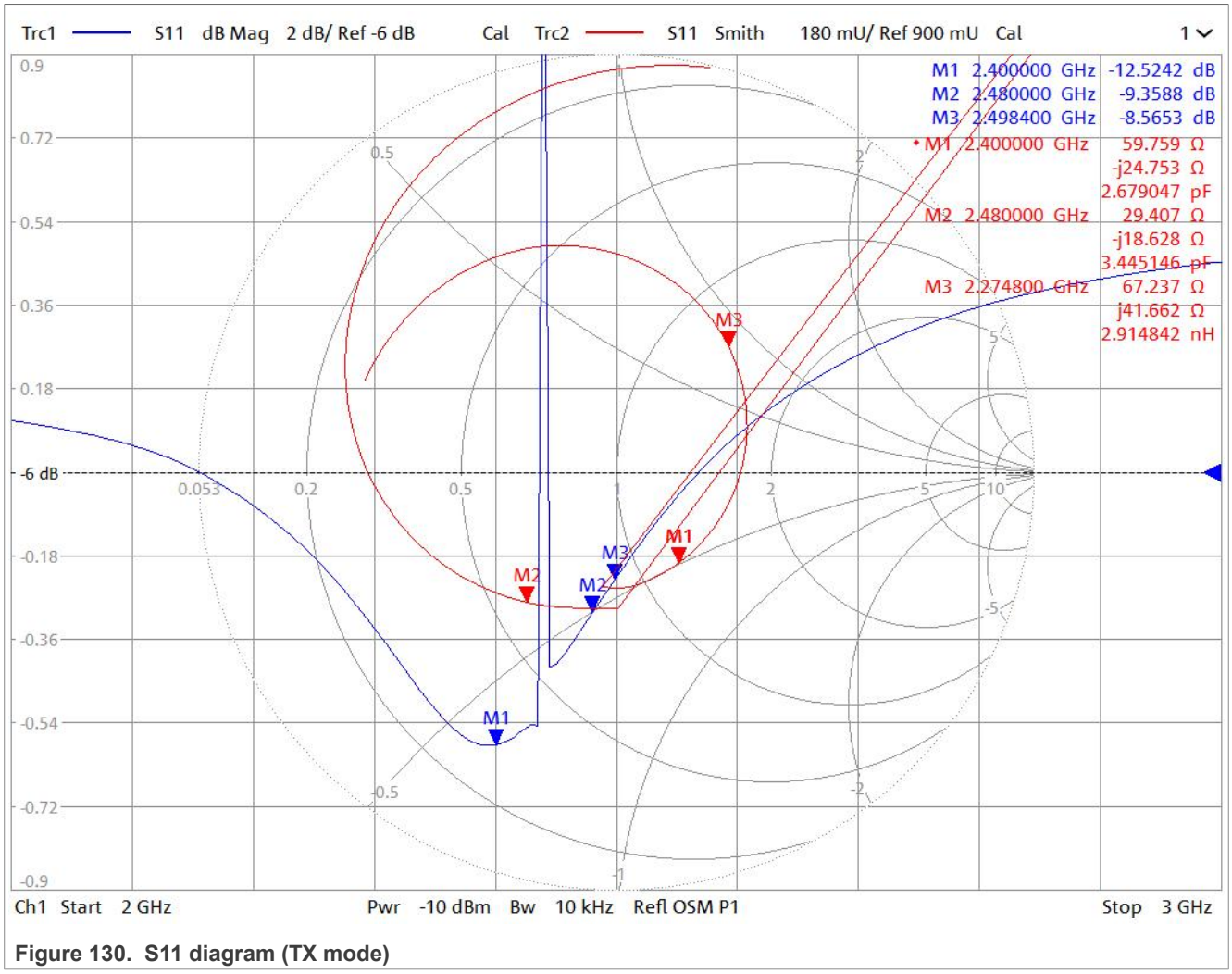



**Figure 130. S11 diagram (TX mode)**

**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.

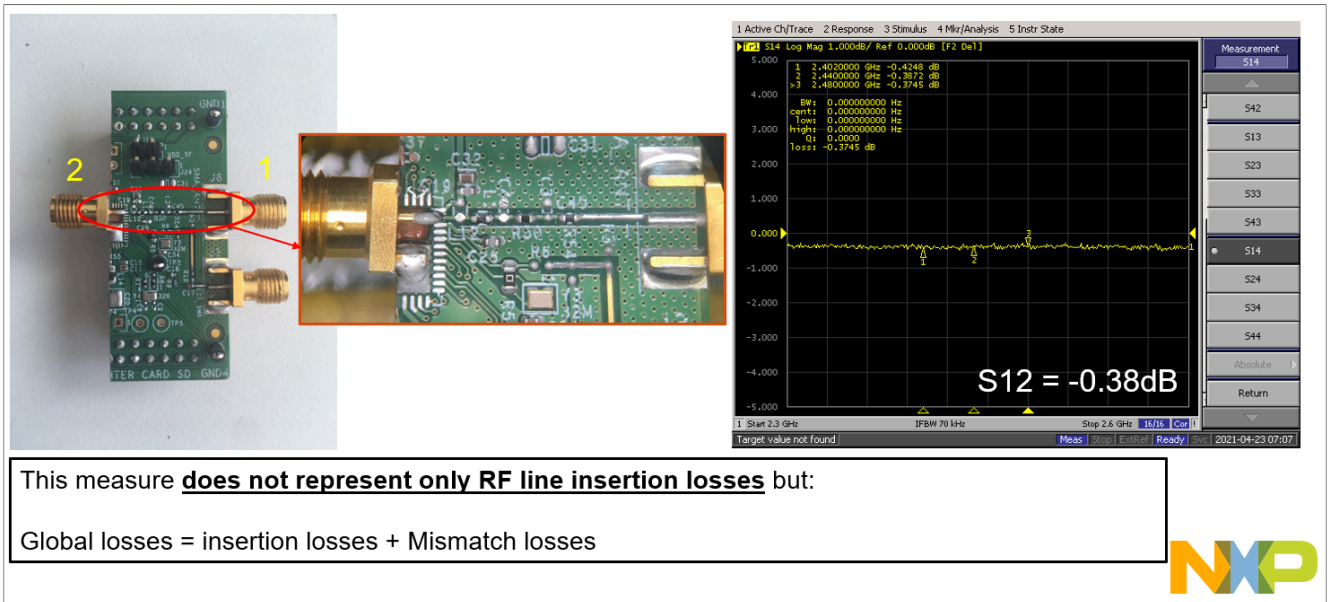



**Figure 131. RF line insertion loss**

$$Insertion\ losses = \frac{1}{1 - |S11|^2}\ X\ |S12|^2 \quad (1)$$

Thanks to Equation 1, we can quantify insertion losses and mismatch losses.

$$Mismatch\ losses = -10\ x \log(1 - \Gamma ?2)$$

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

$$Mismatch\ losses = -10\log\ (1 - 0.171791 ?2) = -0.13\ dB$$

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

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

**Insertion losses** $= -0.25$ **dB**

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

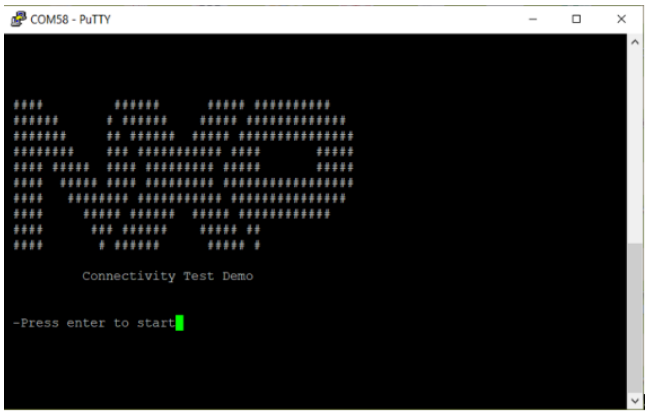
# 6 Conclusion

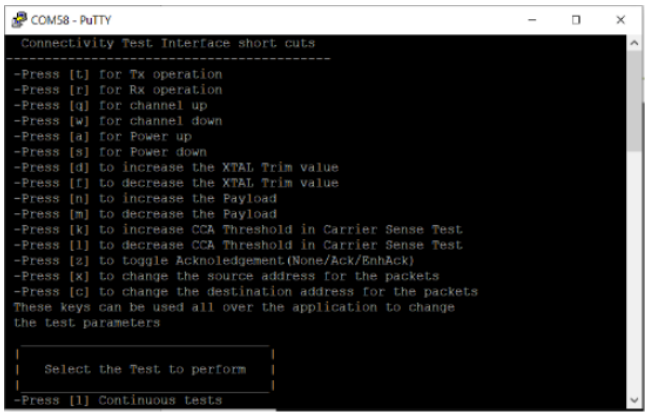
Beyond the RED, FCC, Bluetooth LE 5.0, and 802.15.4 compliance, these radio tests prove a good performance of the K32W1 wireless MCUs.

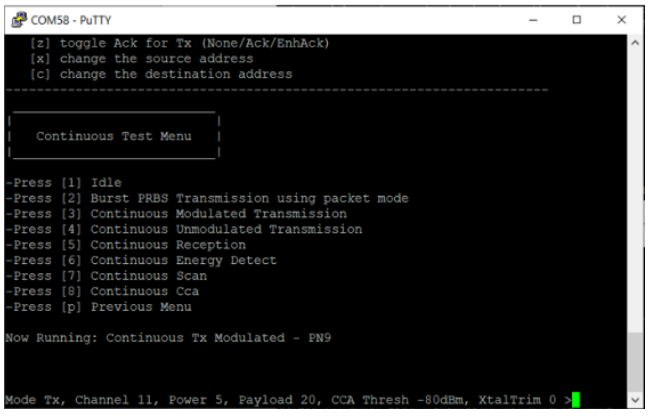
# 7 Connectivity test tool settings

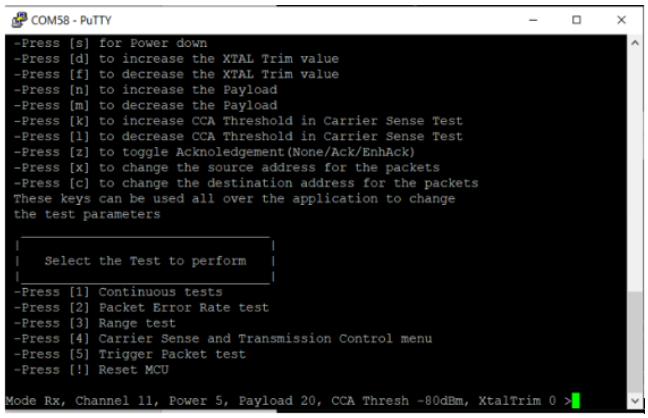
This application note presents the connectivity test tools settings for the tests.

- For test in transmit modes:



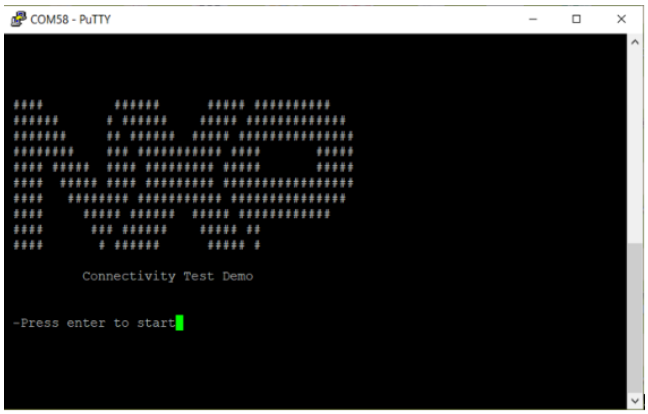



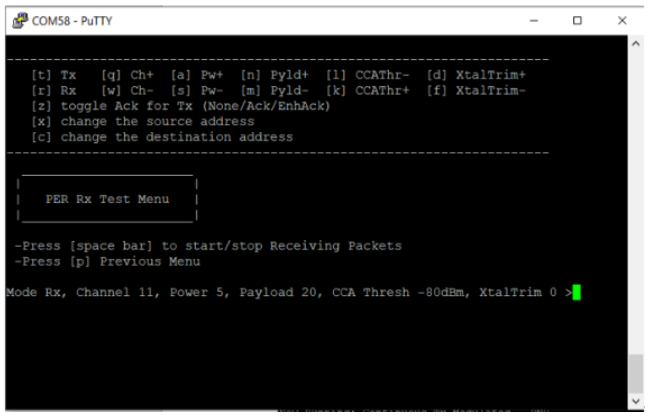



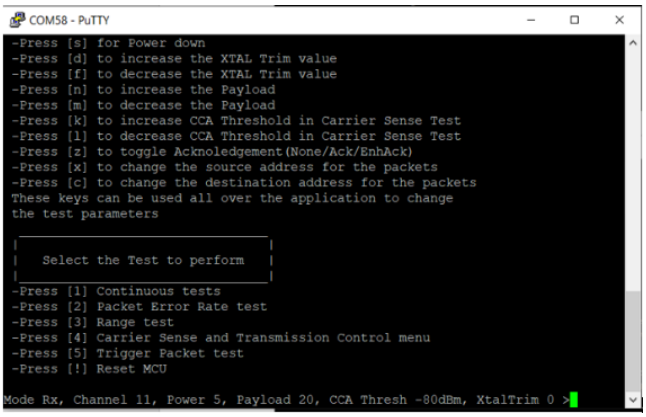



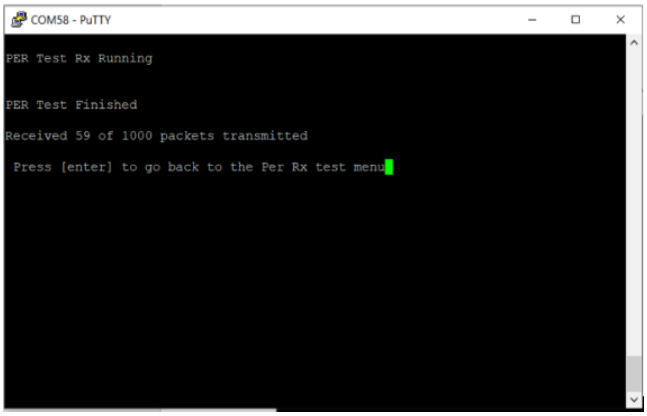
| Chapter | CMET selection |
|---|---|
| Section 3.3.1.2 | 1) 4) |
| Section 4.3.1.3 | 1) 4) |
| Section 3.3.1.4 | 1) 3) 2)+/- |
| Section 3.3.1.6 | 1) 3) 2) |
| Section 4.3.1.7 | 1) 3) 2) |
| Section 4.3.1.7.1 | 1) 3) 2 |
| Section 4.3.1.7.2 | 1) 4) |
| Section 3.3.1.8 | 1) 3) ch26 |
| Tx return loss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

# 10 Legal information

## 10.1 Definitions

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