NXP Semiconductors
Application Note

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FRDM-KW41Z RF System Evaluation Report for 802.15.4 Applications

1. Introduction

This document provides the RF evaluation test results of FRDM-KW41Z for the 802.15.4 applications (O-QPSK modulation). It includes the test setup description and the tools for you to perform the tests on your own. To get the KW41Z radio parameters, see the *MKW41Z/31Z/21Z Data Sheet* (document MKW41Z512).

For more information about the FRDM-KW41Z Freedom Development Board, see the *FRDM-KW41Z Freedom Development Board User's Guide* (document FRDMKW41ZUG). Find the schematic and design files at this link.

Contents

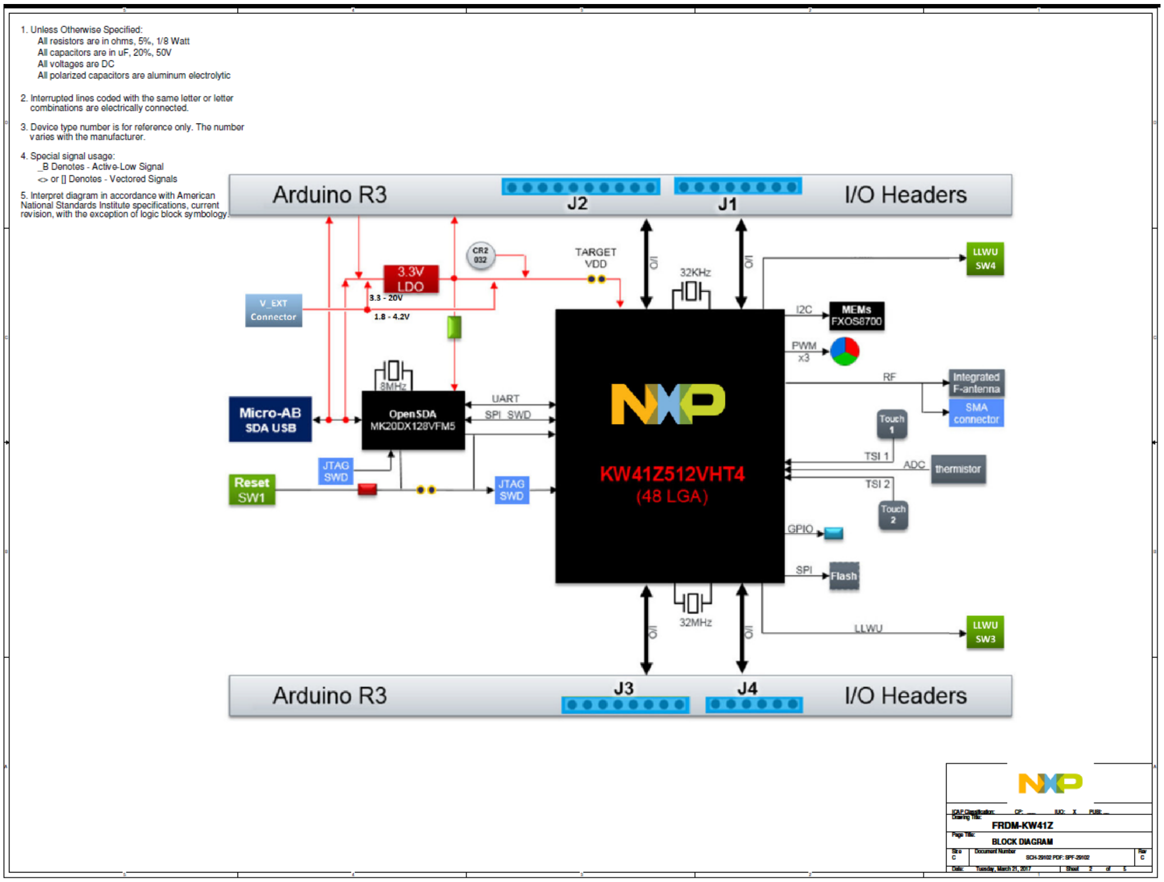

Figure 1. FRDM-KW41Z block diagram

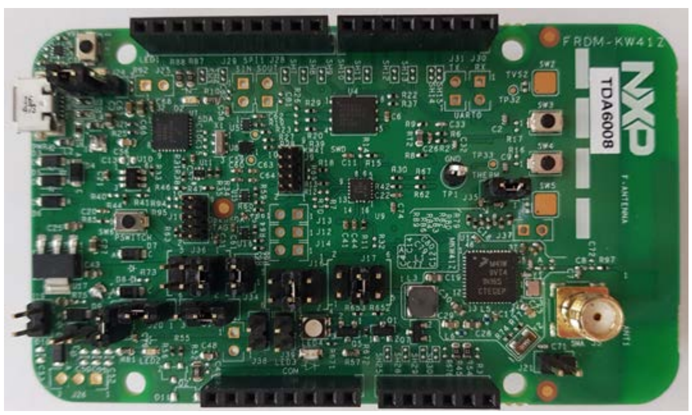

Figure 2. FRDM-KW41Z development kit

1.1. List of tests

- Conducted tests:
  - Tx tests:
    - Frequency accuracy.
    - Phase noise.
    - Tx power.
    - Tx spurious (H2 to H5, ETSI, and FCC).
    - Upper Band Edge
    - EVM, OEVM.
  - Rx tests:
    - Sensitivity.
    - Receiver maximum input level.
    - Rx spurious (from 30 MHz to 12.5 GHz).
      - Receiver interference rejection. Adjacent and alternate channels.
      - n+/-3 channels.
      - 3G blocker.
      - LTE blocker.
    - Return loss (S11):
      - Rx.
      - Tx.

1.2. Software

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

The FRDM-KW41Z: NXP® Freedom Development Kit for Kinetis® KW41Z/31Z/21Z MCUs web page describes how to use the FRDM-KW41Z to load the code. The binary code used for the following tests is the Connectivity Software package SMAC protocol (O-QPSK modulation). The TERATERM terminal emulator is used to communicate with the KW41Z MCU.

1.3. List of Equipment

Those equipment are used to perform the Rx and Tx measurements:

- Spectrum Analyzer - 13GHz for harmonic measurements up to H5
- R&S SFU - used as an interferer source for 802.15.4 – could be any generator with ARB
- MXG (Agilent N5182A)
- R&S CMW270 (HCI software)
- Agilent SML03
- Agilent 33250A
- R&S ZND Vector Network Analyzer – for S11 measurements
- RF Shielded box (to avoid interferers) and RF horn (for radiated measurements)
- Power supply
- PC equipped with a GPIB card

2. Tests summary

The list of measurements is provided in Table 1.

Table 1. List of tests

		EUROPE		
		Reference	*Limit*	
Transmission	TX Maximum Power	ETSI EN 300 328	20 dBm, 100 mW (radiated)	PASS
Transmission	Eirp Tx spectral density	ETSI EN 300 328	10 dBm/MHz	PASS
Transmission	TX spectral density	802.15.4_2011	-20 dBc or -30 dBm (100 kHz, f-fc > 3.5 MHz)	PASS
Transmission	Spurious 30 MHz – 1 GHz	ETSI EN 300 328	-36 dBm or -54 dBm (depends on frequency) (100 kHz BW)	PASS
Transmission	Spurious 1 GHz – 12.5 GHz	ETSI EN 300 328	-30 dBm (1 MHz BW)	PASS
Transmission	EVM	802.15.4_2011	35 %	PASS
Transmission	TX Frequency Tolerance	802.15.4_2011	+/- 40 ppm	PASS
Transmission	Reachable Low limit of max power	802.15.4_2011	-3 dBm	PASS
Transmission	Phase noise (unspread)	802.15.4_2003	NA	For information

		EUROPE		
		Reference	*Limit*	
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
	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
Misc.	Return loss (S11)	Return loss in Tx mode	For information	
		Return loss in Rx mode	For information	

3. Conducted tests

3.1. TX tests

3.1.1. Test setup

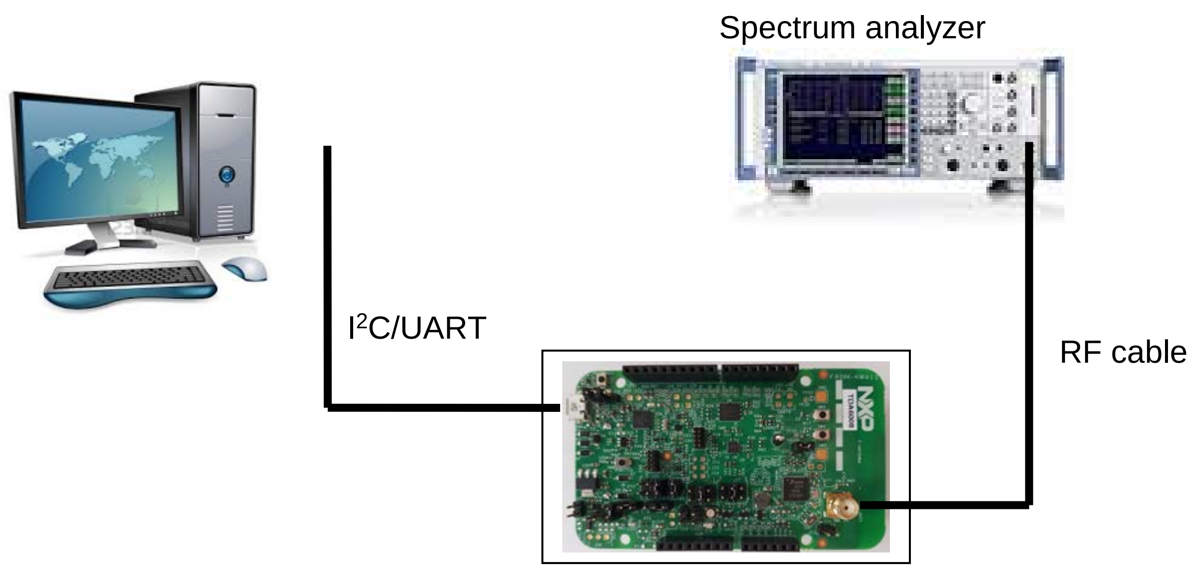

Figure 3. Conducted Tx test setup

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:

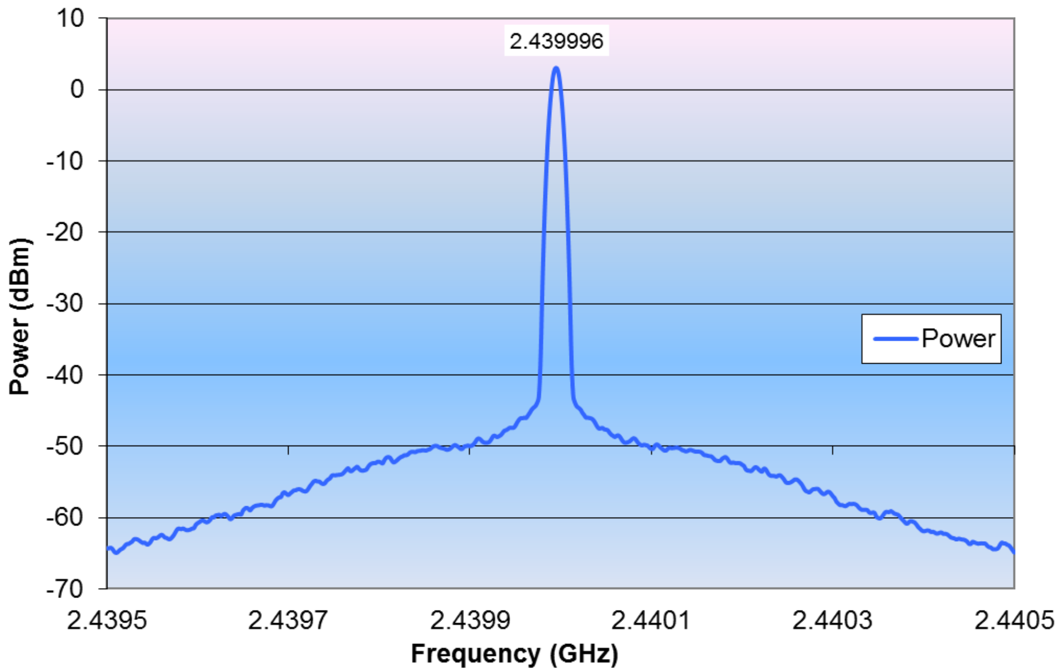

Figure 4. Frequency accuracy

- Measured frequency: 2.439996 GHz.
- ppm value = (2439996 - 2440000) / 2.440 = -1.6 ppm.

Table 2. Frequency accuracy

Result	Target	802.15.4 limit
-1.6 ppm	+/-25 ppm	+/-40 ppm

NOTE

The frequency accuracy depends on the XTAL model. The model used on the FRDM-KW41Z is Q22FA12800092 (Epson).

Conclusion:

- The frequency accuracy complies to the 802.15.4 specifications.

3.1.3. Phase noise

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 the 100-kHz offset frequency.
  - RBW (spectrum analyzer) = 10 kHz (40 dBc).

Result:

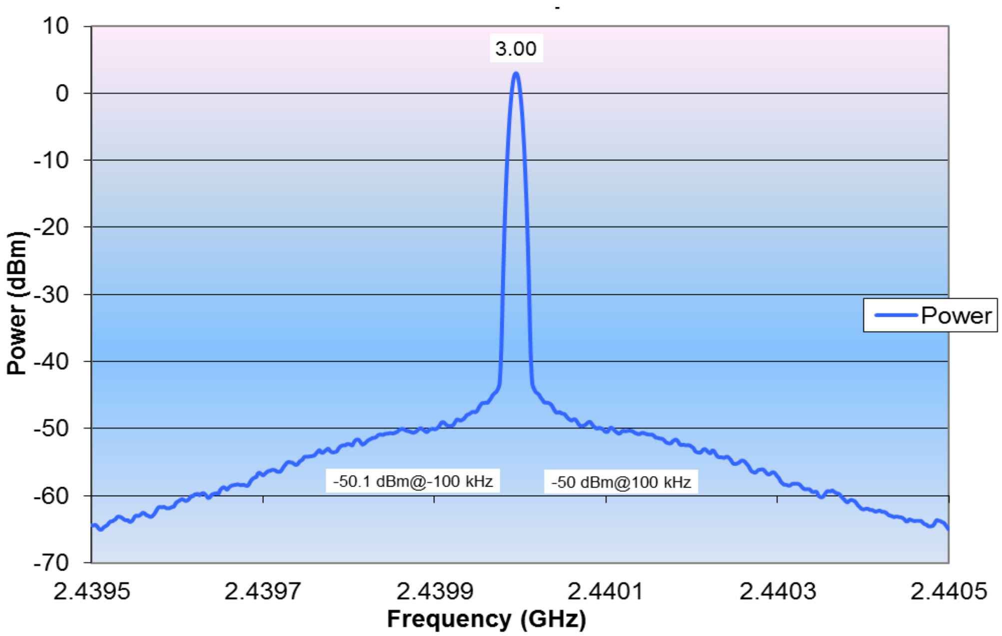

Figure 5. Conducted phase noise

- Marker value (delta) = -50 dBm / 100 kHz = -90 dBc/Hz.

NOTE

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

3.1.4. TX power (fundamental)

Test method:

- Set the radio to:
  - TX mode, modulated, continuous mode.
- 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.
  - Max Hold mode.
  - Detector = RMS.
- Sweep all the channels from channel 11 to channel 26.

Result:

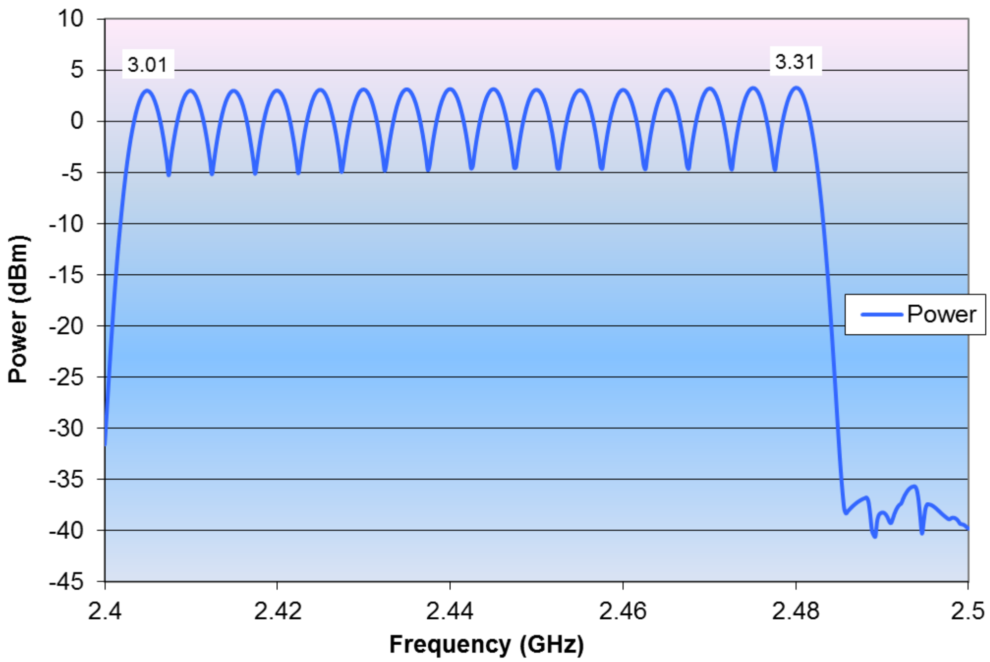

Figure 6. TX power

- The maximum power is on channel 26: 3.3 dBm.
- The minimum power is on channel 11: 3.0 dBm.
- Tilt over frequencies: 0.3 dB.

Conclusion:

- These results are compliant with ETSI 300 328.

3.1.5. TX spurious

3.1.5.1. 30 MHz to 12.5 GHz

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

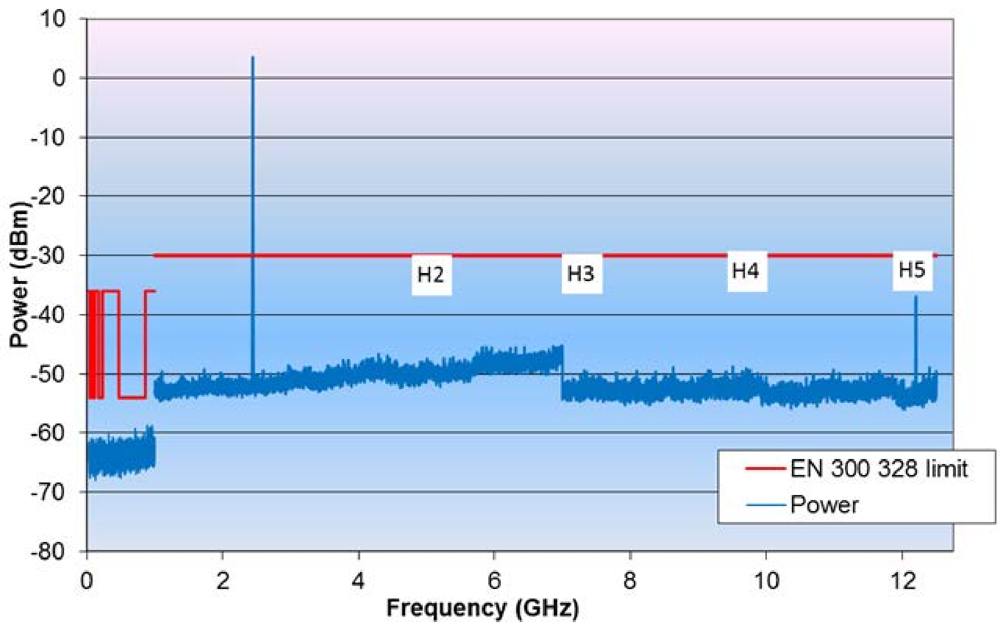

Figure 7. Conducted Tx spurious (30 MHz to 1 GHz)

Conclusion:

- There is more than 5-dB margin to the EN 300 328 limit.

3.1.5.2. H2

Test method:

- Set the radio to:
  - Tx mode, modulated, continuous mode.
- Set the analyzer to:
  - Start freq = 4.8 GHz, Stop freq = 5 GHz, Ref amp = -20 dBm, sweep time = 100 ms RBW = 1 MHz.
  - Max Hold mode.
  - Detector: Peak.
- Sweep all the channels from channel 11 to channel 26.

Result:

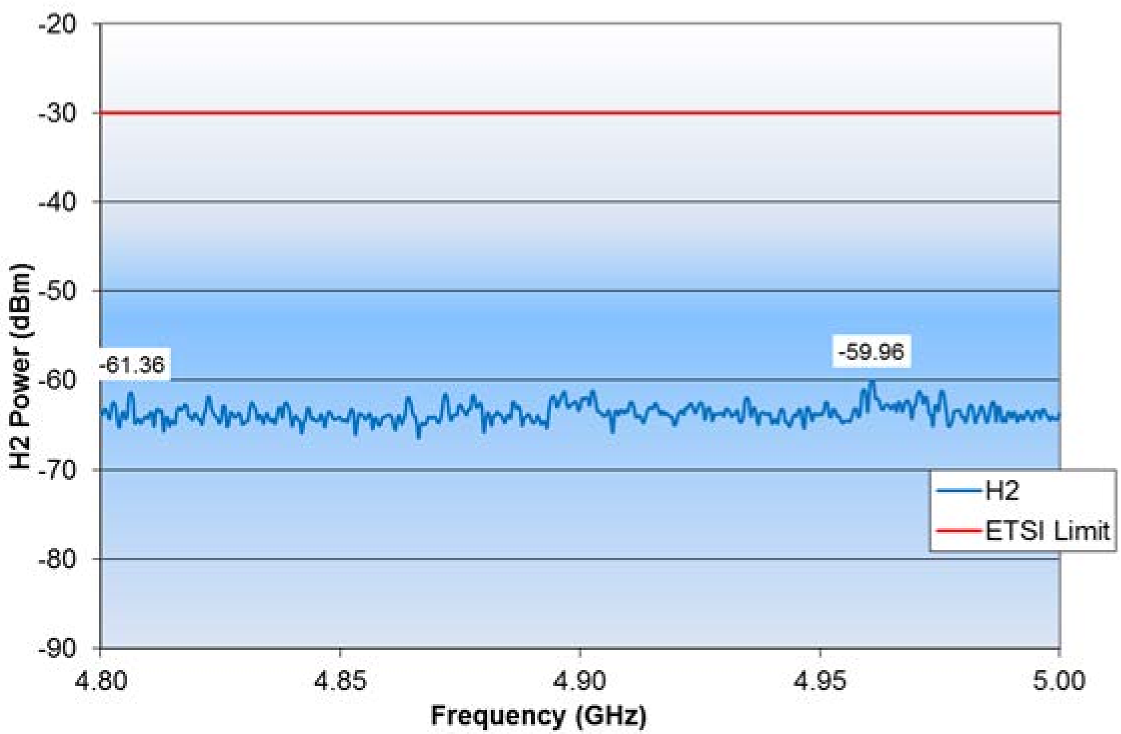

Figure 8. Conducted H2 spurious

- The maximum power is at channel 26: -59.9 dBm.

Conclusion:

- Margin > 30 dB.

3.1.5.3. H3

The same method as H2, except that the spectrum analyzer frequency start/stop is set to 7.2 and 7.5 MHz.

Result:

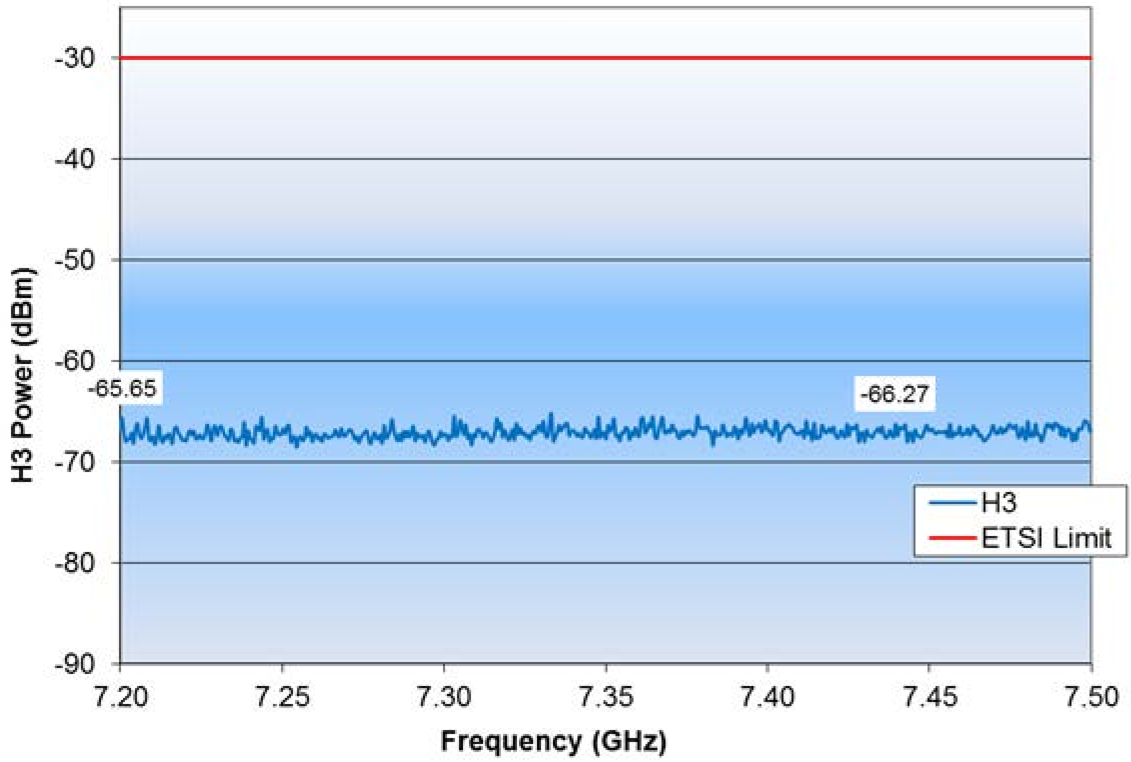

Figure 9. Conducted H3 spurious

- The maximum power is at channel 26: -66.27 dBm.

Conclusion:

- Margin > 26 dB.

3.1.5.4. H4

Same method as H2, except that the spectrum analyzer frequency span is set from 9.6 to 10.0 GHz.

Result:

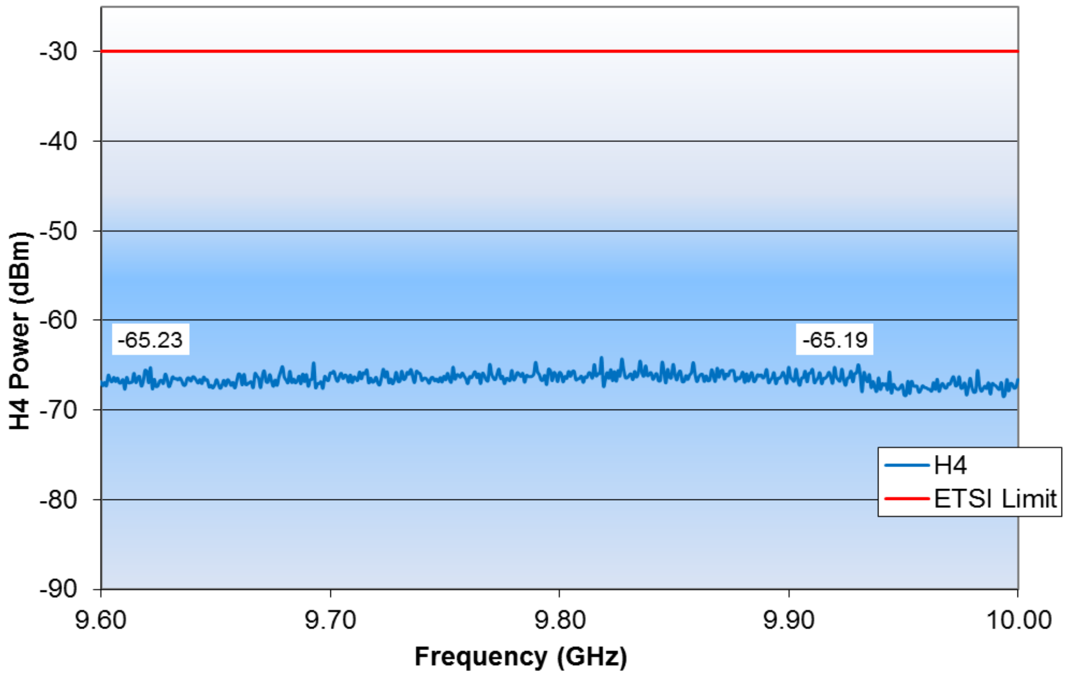

Figure 10. Conducted H4 spurious

- The maximum power is at channel 26: -65.19 dBm.

Conclusion:

- Margin > 25 dB.

3.1.5.5. H5

Same method as H2, except that the spectrum analyzer frequency span is set from 12 GHz to 12.5 GHz.

Result:

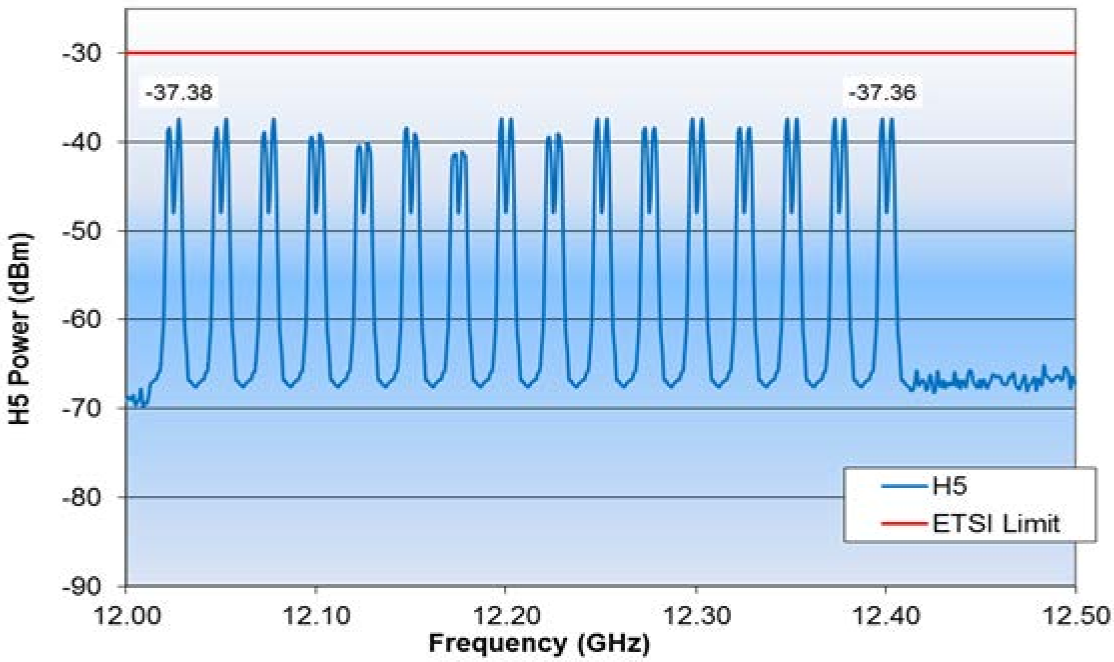

Figure 11. Conducted H5 spurious

- The maximum power is at channel 26: -37.36 dBm.

Conclusion:

- Margin > 7 dB

3.1.5.6. H2 FCC

Test method:

- Set the radio to:
  - Tx mode, modulated, continuous mode.
- Set the analyzer to:
  - Start freq = 4.8 GHz, Stop freq = 5 GHz, Ref amp = -20 dBm, sweep time = 100 ms, RBW = 1 MHz, VBW = 3 MHz.
  - Trace: Max Hold mode.
  - Detector: RMS.
- Sweep all the channels from channel 11 to channel 26.

Result:

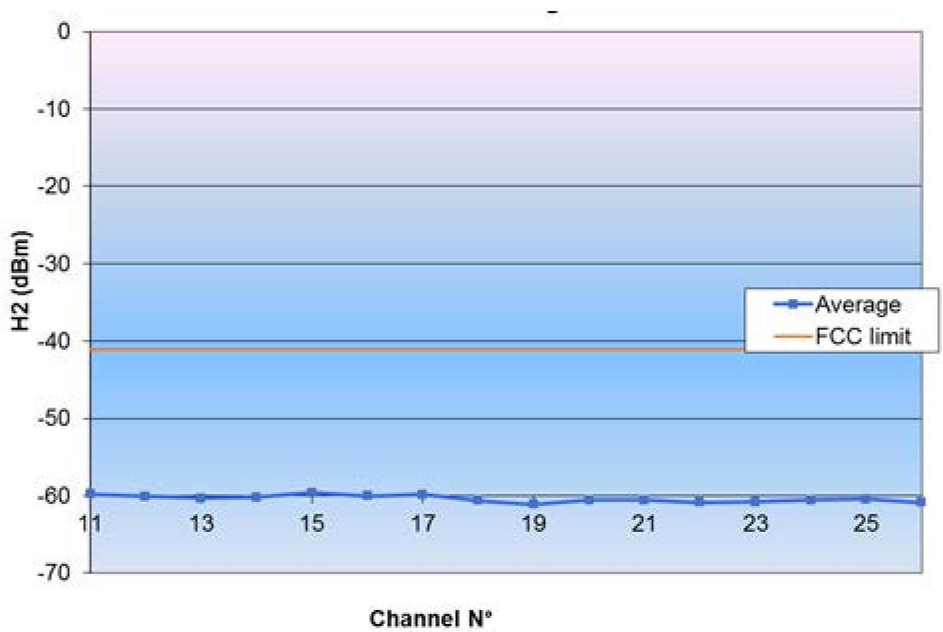

Figure 12. Conducted H2 FCC spurious

- The maximum power is at channel 15: -59.8 dBm.

Conclusion:

- Margin > 18 dB.

3.1.5.7. H3 FCC

Same method as H2, except that the spectrum analyzer frequency span is set from 7.2 GHz to 7.5 GHz.

Result:

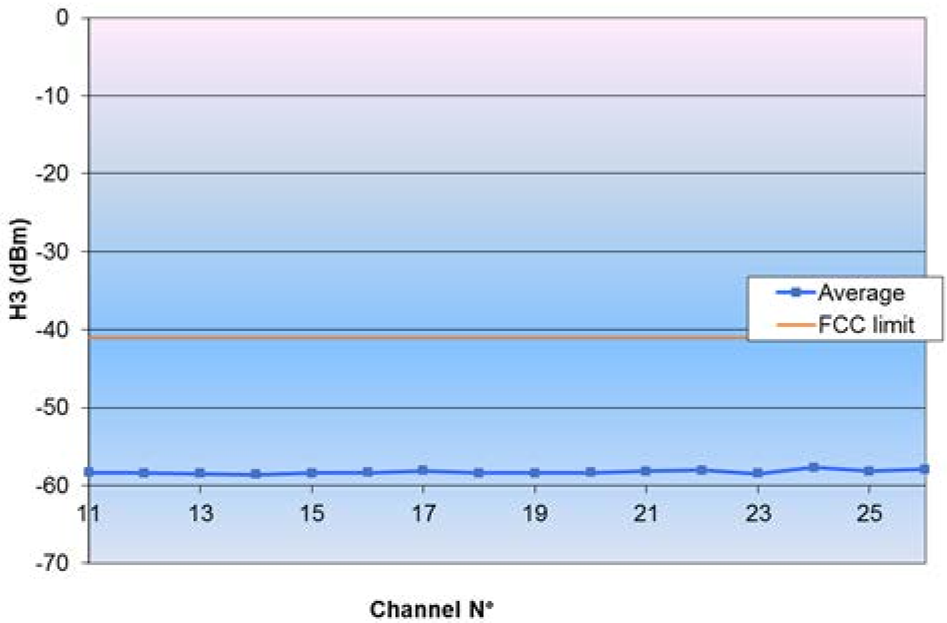

Figure 13. Conducted H3 FCC spurious

- The maximum power is at channel 24: -57.7 dBm.

Conclusion:

- Margin > 16 dB.

3.1.5.8. H4 FCC

Same method as H2, except that the spectrum analyzer frequency span is set from 9.6 GHz to 10 GHz.

Result:

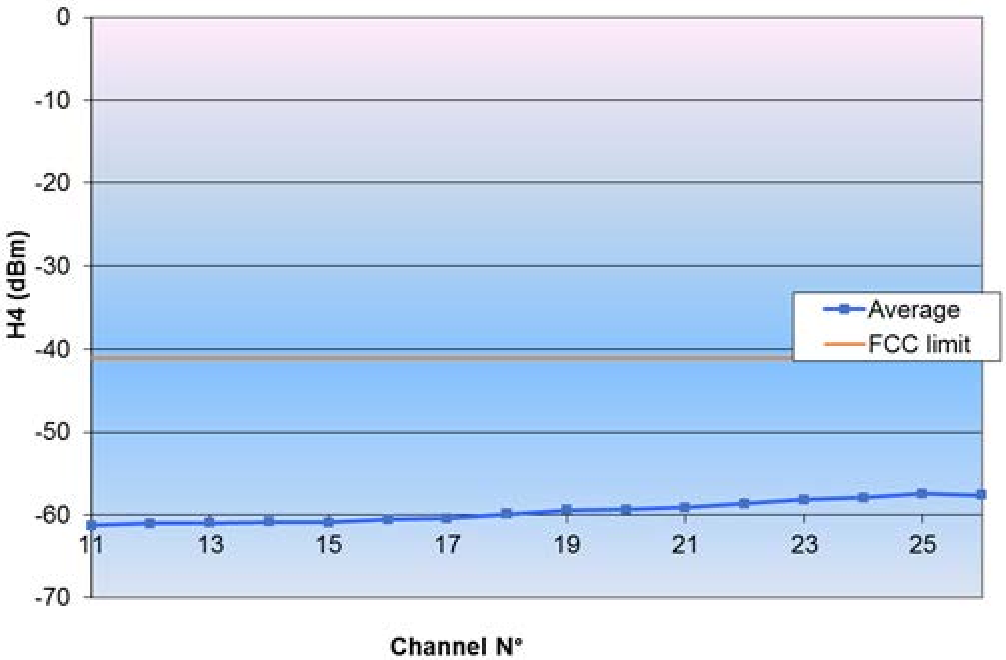

Figure 14. Conducted H4 FCC spurious

- The maximum power is at channel 25: -57.4 dBm.

Conclusion:

- Margin > 16 dB.

3.1.5.9. H5 FCC

Same method as H2, except that the spectrum analyzer frequency span is set from 12 GHz to 12.5 GHz.

Result:

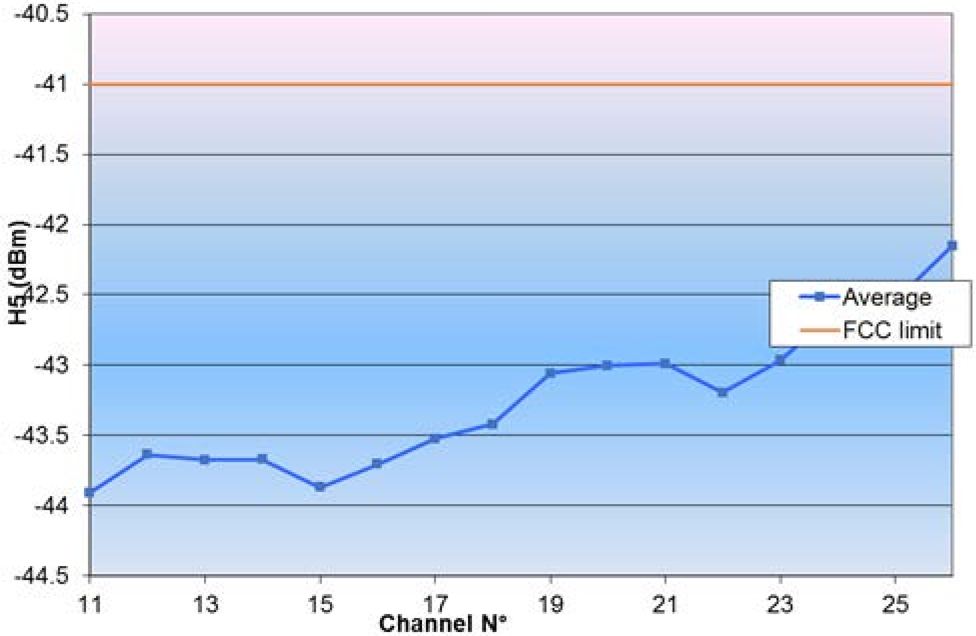

Figure 15. Conducted H5 FCC spurious

- The maximum power is at channel 26: -42.1 dBm.

Conclusion:

- Margin > 1 dB.

3.1.6. Upper Band Edge

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 = Average
  - Average mode: power
  - Number of Sweeps = 100
  - Set the channel to channel 26 (2.48 GHz)

Result:

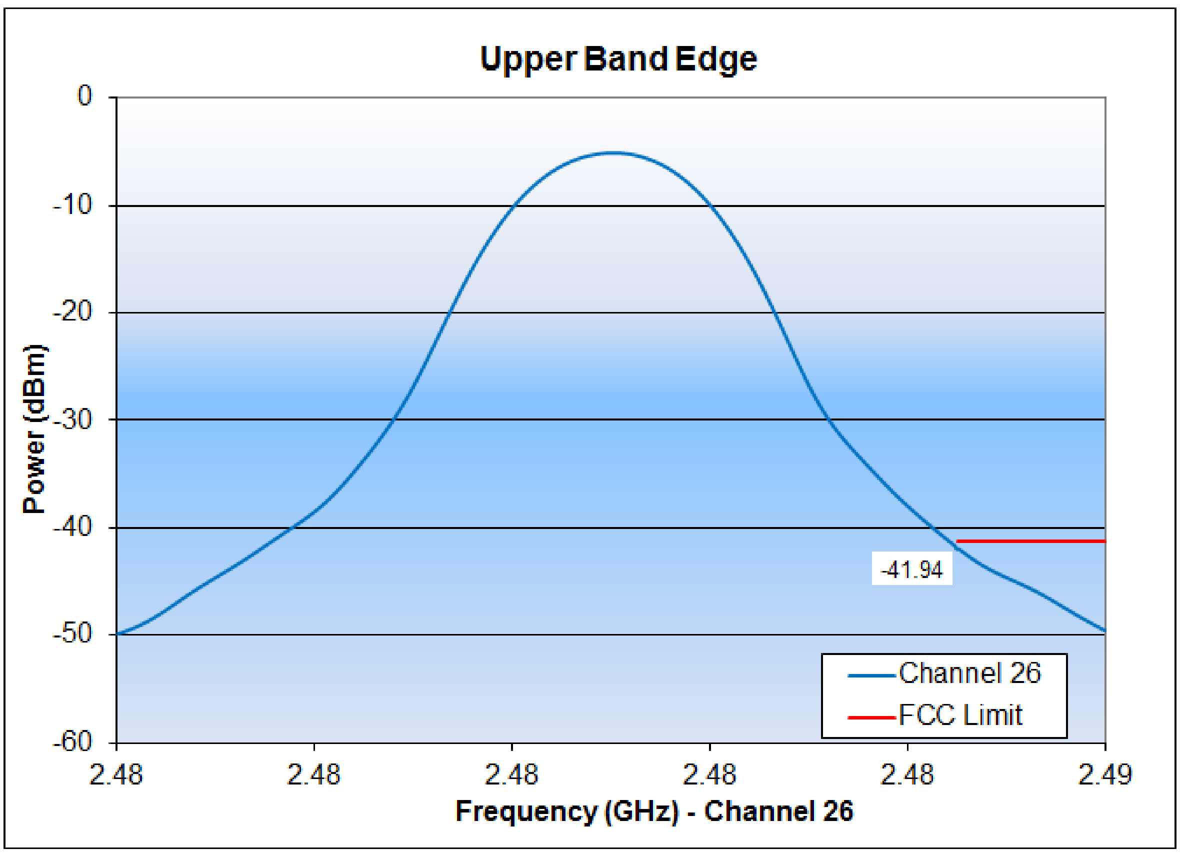

Figure 16. Upper Band Edge – Channel 26

Conclusion:

The maximum RF output power is clamp to 0x14h to be able to reach the FCC limit.

3.1.7. Error vector magnitude

Result:

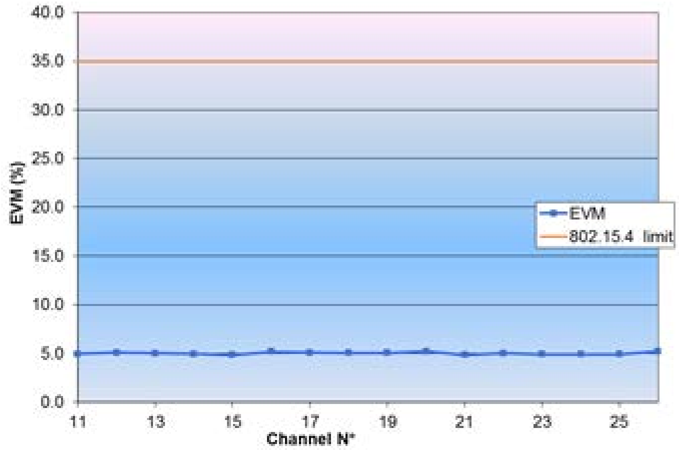

Figure 17. Conducted EVM (%)

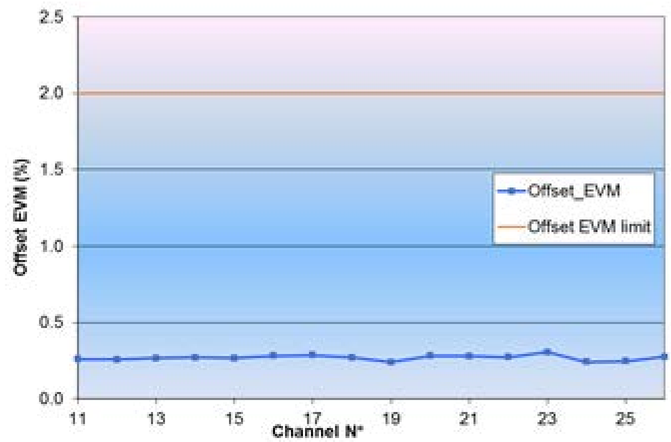

Figure 18. Conducted offset EVM (%)

Conclusion:

- EVM = 5.1 % that gives more than 29 % margin compared to the 802.15.4 limit (<35 %).
- Offset EVM = 0.24 % that gives more than 1.1 % margin compared to the KW41Z datasheet specification (<2 %).

3.2. RX tests

3.2.1. Test setup

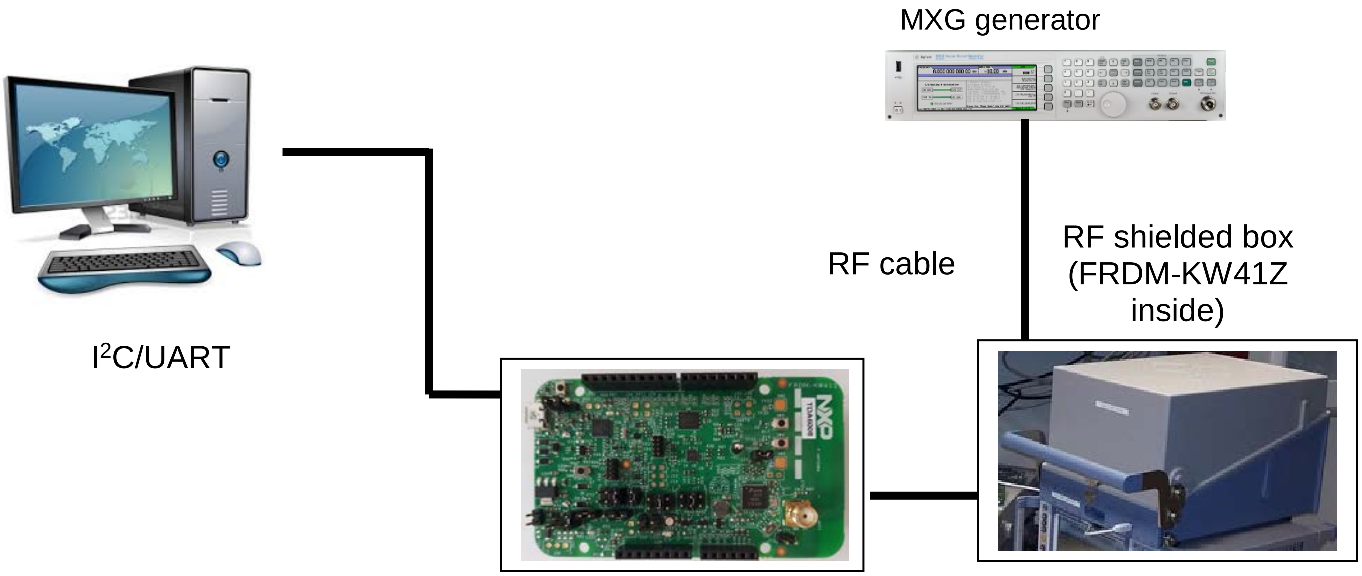

Figure 19. Conducted Rx test setup for sensitivity with RF generator and faraday box

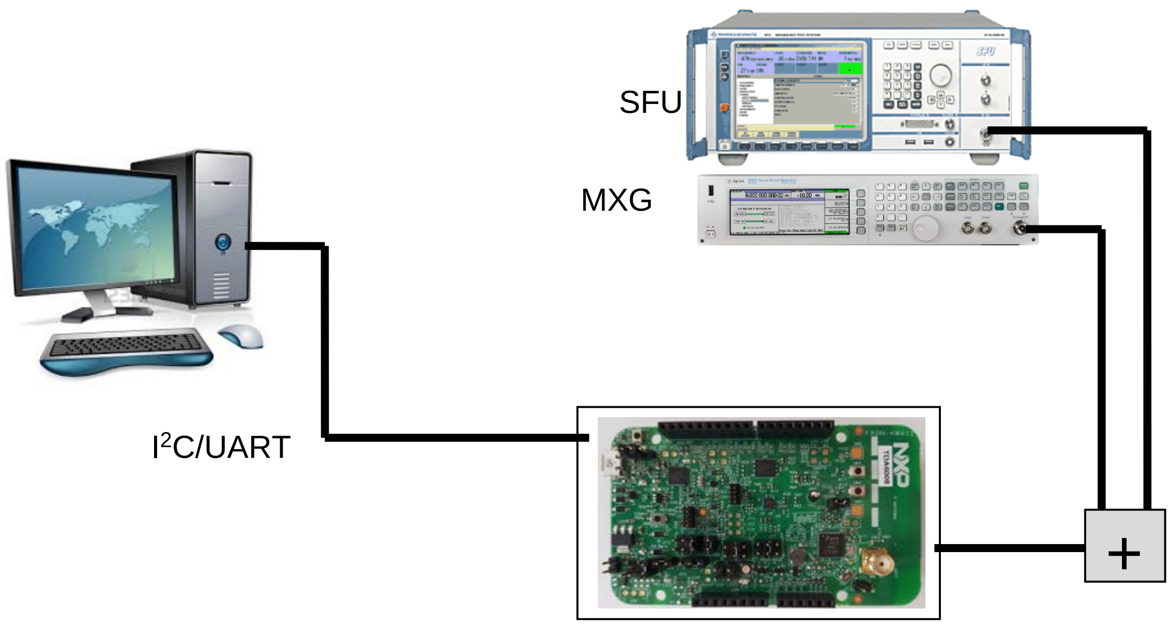

Figure 20. Conducted Rx test setup for interference rejection

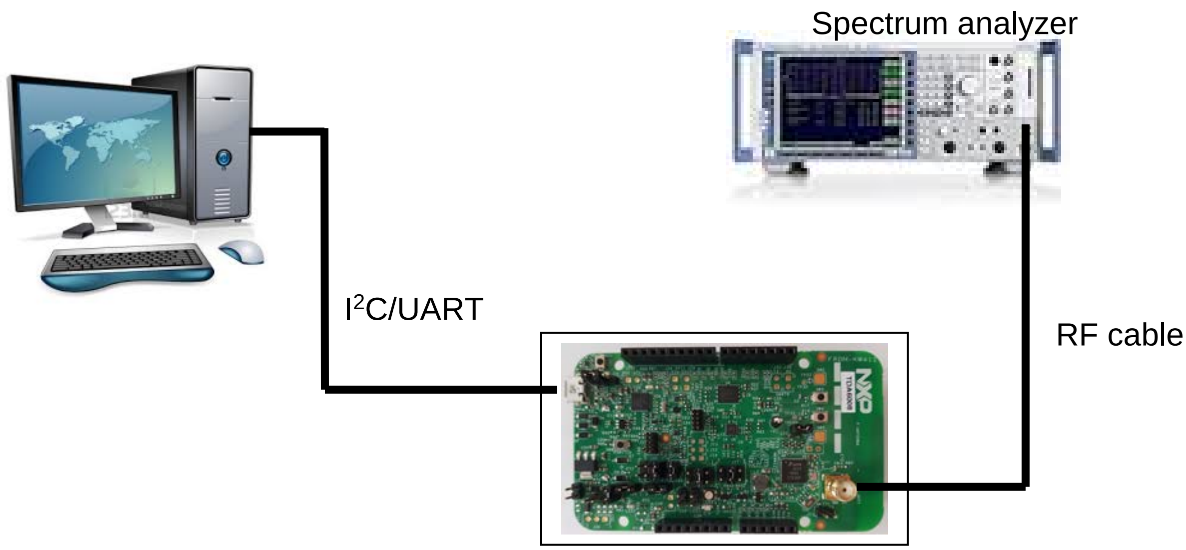

Figure 21. Conducted Rx test setup for spurious

3.2.2. Sensitivity

3.2.2.1. Using the ARB generator

Test method:

- To be immune to external parasitic signals, FRDM-KW41Z is put into an RF shielded box.

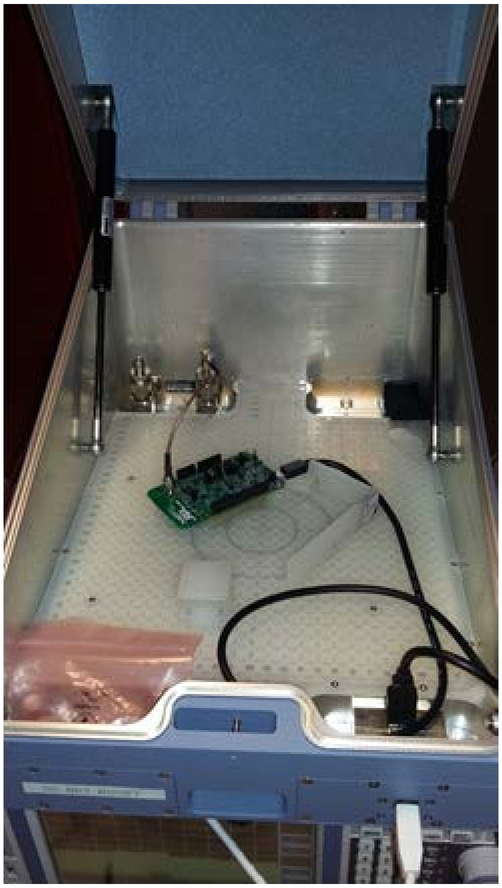

Figure 22. Sensitivity test

The generator (Agilent NX5181 MXG) is used in the ARB mode to generate a pattern of 1000 packets. The TERATERM window is used to control the module.

- Set it to channel 11.
- The connection is automatically established and the PER (Packet Error Rate) is measured.
- Decrease the level of the SFU at the RF input of the module until PER = 1 %.
- Repeat it up to channel 26.

Result:

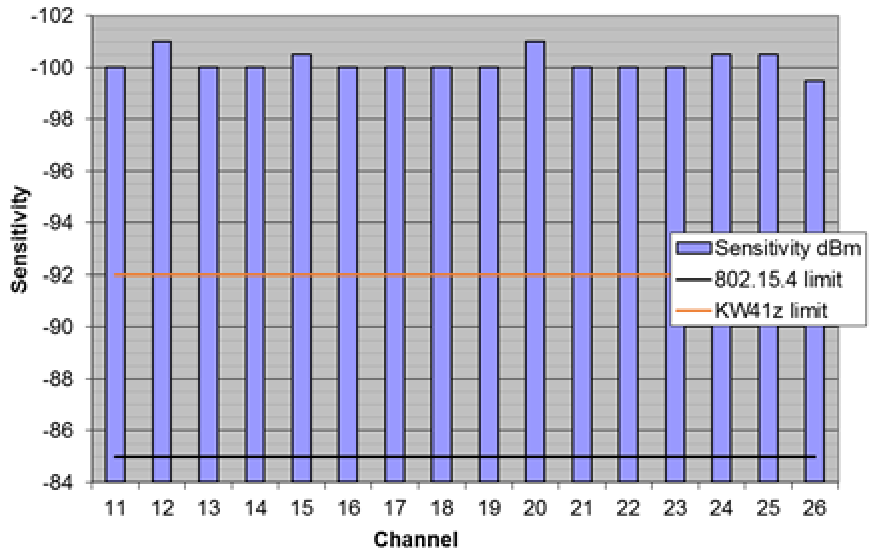

Figure 23. Sensitivity result

- The best sensitivity is on channels 12 and 20: -101 dBm.
- The lowest sensitivity is on channel 26: -99.5 dBm.
- Delta over channels: 1.5 dB.

Conclusion:

- FRDM-KW41Z shows an average value of -100 dBm.

3.2.3. Receiver maximum input level

Test method:

- The same test setup as with the sensitivity test is used.
- The signal level is increased up to PER = 1 %.

Results:

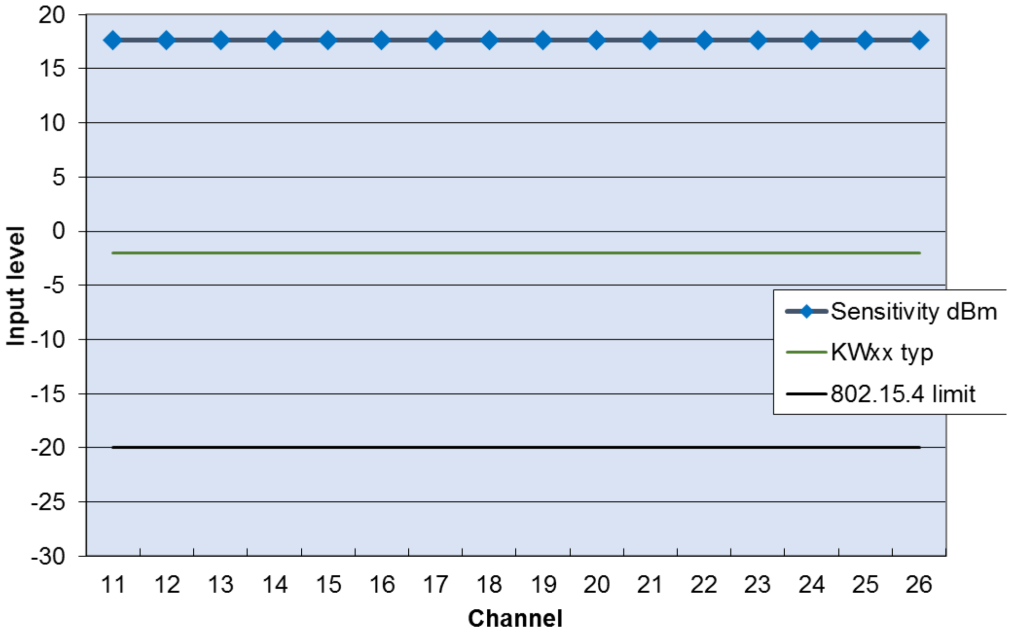

Figure 24. Maximum input power

Conclusion:

- The results are in line with the expected values.

3.2.4. 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: 10 MHz/1 GHz.
      - RBW = 100 kHz.
    - Then set the start/stop frequency: 1 GHz/30 GHz.
      - RBW = 1 MHz.

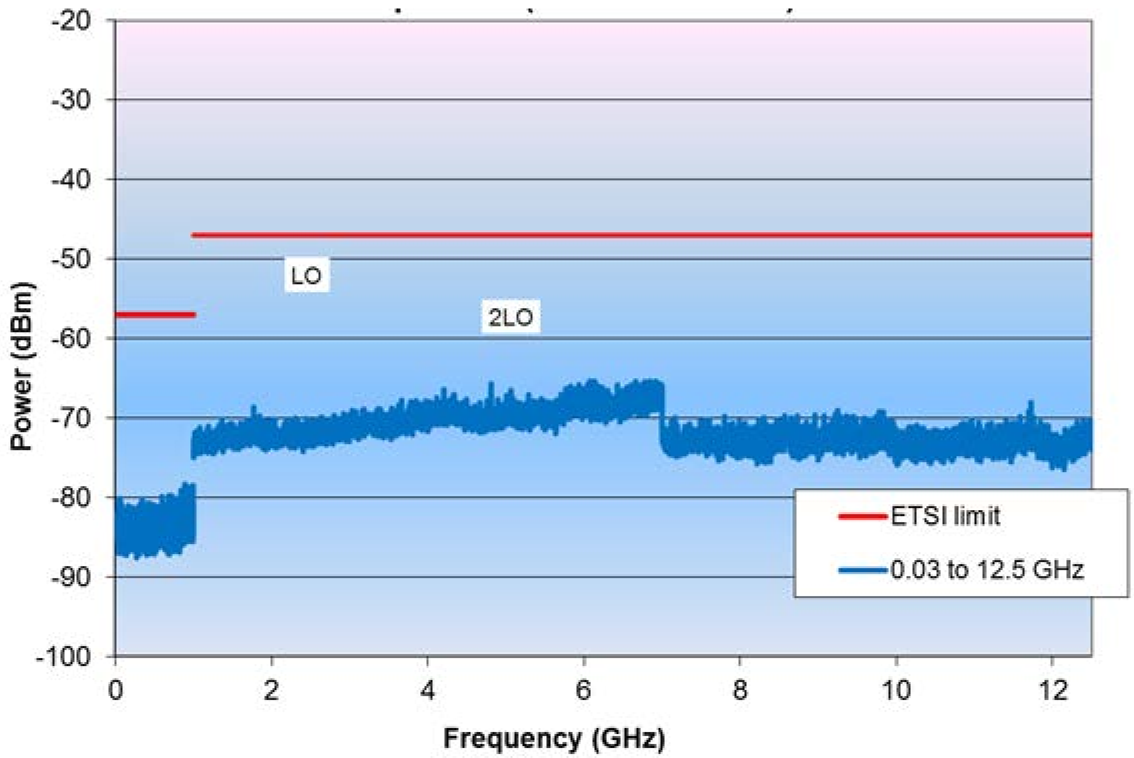

Figure 25. Conducted Rx spurious 30 MHz – 12.5 GHz

Conclusion:

- There are no spurs above the spectrum analyzer noise floor, except for 2xLO.
- More than 15-dB margin.

3.2.5. Receiver interference rejection

3.2.5.1. Adjacent and alternate channels

The interferers are located at 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 the desired signal: Aeroflex IFR3416.
- Generator for interferers: R&S SFU.
- Criterion: PER < 1 %.
- The wanted signal is set to -82 dBm; the interferer is increased until the PER threshold is reached.
- Channels under test: 11, 18, and 26 (although n - 1 and n - 2 are not system-relevant for channel 11 and n + 1 and n + 2 are not relevant for channel 26).
- Set the analyzer to:
  - Ref amp = -20 dBm, Trace = max hold, detector = max peak.
  - Start/stop frequency: 10 MHz/1 GHz.
    - RBW = 100 kHz.
  - Then set the start/stop frequency: 1 GHz/30 GHz.
    - RBW = 1 MHz.

Result:

	ch11				ch18				ch26			
	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
Interferer level (dBc)	35.2	34.2	33.2	35.2	37.2	31.7	34.2	34.2	34.2	31.7	31.7	33.2
802.15.4 limit (dB)	30	0	0	30	30	0	0	30	30	0	0	30
Margin (dB)	5.2	34.2	33.2	5.2	7.2	31.7	34.2	4.2	4.2	31.7	31.7	3.2

Figure 26. Adjacent and alternate rejection

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

NOTE

Adjacent (n + 1 / n - 1) and alternate (n - 2 / n + 2) are related to 802.15.4. The n -/+ 3 data are not required, they serve for informational purposes only.

3.2.5.2. N - 3 and n + 3 channels

Test method:

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

Result:

	ch11		**ch18**		**ch26**	
	2405		2440		2480	
	n-3	**n+3**	**n-3**	**n+3**	**n-3**	**n+3**
	2390	2420	2425	2455	2465	2495
Interferer level (dBc)	**55.2**	**55.2**	**53.7**	**54.7**	**54.7**	**55.2**
Datasheet typical value (dB)	48	48	48	48	48	48
Margin (dB)	7.2	7.2	5.7	6.7	6.7	7.2

Figure 27. Other in-band rejection

Conclusion: In line with the expected values.

3.2.5.3. Receiver blocking

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

Receiver category 1 (See 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.

Test method:

- Generator for the desired signal: Aeroflex IFR3416.
- Generator for the interferers: R&S SFU.
- Criterion: PER < 10 %.
- The wanted signal is set to Pmin + 6 dB (-94 dBm); the interferer is increased until the PER threshold is reached.
- Channels under test: 11 and 26.

Results:

	ch11	ch11	ch26	ch26
	2405	2405	2480	2480
	Low	**High**	**Low**	**High**
	2380	2503.5	2380	2503.5
Interferer level (dBm)	**-18.6**	**-14.6**	**-17.6**	**-14.6**
802.15.4 limit (dBm)	-53	-53	-53	-53
Margin (dB)	34.4	38.4	35.4	38.4

	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)	**-17.6**	**-17.6**	**-16.6**	**-17.6**	**-17.6**	**-17.6**
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	29.4	29.4	30.4	29.4	29.4	29.4

	ch11	ch11	ch11	ch11	ch11	ch11
	2405	2405	2405	2405	2405	2405
	High	**High**	**High**	**High**	**High**	**High**
	2523.5	2553.5	2583.5	2613.5	2643.5	2673.5
Interferer level (dBm)	**-14.6**	**-14.6**	**-14.6**	**-13.6**	**-13.6**	**-13.6**
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	32.4	32.4	32.4	33.4	33.4	33.4

	ch26	ch26	ch26	ch26	ch26	ch26
	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)	**-16.6**	**-16.6**	**-16.6**	**-14.6**	**-13.6**	**-13.6**
802.15.4 limit (dBm)	-47	-47	-47	-47	-47	-47
Margin (dB)	30.4	30.4	30.4	32.4	33.4	33.4

Figure 28. Receiver blocking (out-of-band) rejection

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

Receiver category 2 (See 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.

Test method:

- Generator for the desired signal: Aeroflex IFR3416
- Generator for the interferers: R&S SFU
- Criterion: PER < 10 %
- The wanted signal is set to Pmin + 6 dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 11 and 26

Result:

	ch11	**ch11**	**ch26**	**ch26**
	2405	2405	2480	2480
	Low	**High**	**Low**	**High**
	2380	2503.5	2380	2503.5
Interferer level (dBm)	**-18.5**	**-14.7**	**-17.7**	**-14.5**
802.15.4 limit (dBm)	-57	-57	-57	-57
Margin (dB)	38.5	42.3	39.3	42.5

	ch11	**ch11**	**ch26**	**ch26**
	2405	2405	2480	2480
	Low	**Low**	**Low**	**Low**
	2300	2583.5	2300	2583.5
Interferer level (dBm)	**-17.6**	**-16.6**	**-17.6**	**-17.6**
802.15.4 limit (dBm)	-47	-47	-47	-47
Margin (dB)	29.4	30.4	29.4	29.4

Figure 29. Receiver blocking (out-of-band) rejection

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

3.2.5.4. 3G blocker

A CW is used as the 3G interferer. It is set to 2100 MHz.

Test method:

- Generator for the desired signal: Aeroflex IFR3416.
- Generator for the blocker: R&S SFU.
- Criterion: PER < 1 %.
- The wanted signal is set to -82 dBm; the interferer level is increased until the PER threshold is reached.
- Channels under test: 11.
- Set the analyzer to:
    - Ref amp = -20 dBm, Trace = max hold, detector = max peak.
    - Start/stop frequency: 10 MHz/1 GHz.
        - RBW = 100 kHz.
    - Then set the start/stop frequency: 1 GHz/30 GHz.
        - RBW = 1 MHz.

	ch11
	2405
	3G
	2100
Interferer level (dBm)	**-16.8**
Interferer level (dBc)	65.2

Figure 30. 3G immunity

Conclusion:

- This measurement does not make references to any standards.
- It provides information about the robustness of the KW41Z to the 3G blocker.

3.2.5.5. LTE blocker (2500 MHz band)

A CW is used as the LTE interferer. It is set to 2500 MHz.

Test method:

- Generator for the desired signal: Aeroflex IFR3416.
- Generator for the blocker: R&S SFU.
- Criterion: PER < 1 %.
- The wanted signal is set to -82 dBm; the interferer level is increased until the PER threshold is reached.
- Channels under test: 26.

Result:

- Set the radio to:
  - Receiver mode, frequency: channel 26.
- Generator wanted level: -82 dBm.
- Set the analyzer to:
  - Ref amp = -20 dBm, Trace = max hold, detector = max peak.
    - Start/stop frequency: 10 MHz/1 GHz.
      - RBW = 100 kHz.
    - Then set the start/stop frequency: 1 GHz/30 GHz.
      - RBW = 1 MHz.

	ch26
	2480
	LTE
	2500
Interferer level (dBm)	-11.8
Interferer level (dBc)	70.2

Figure 31. LTE immunity

Conclusion:

- This measurement doesn’t make references to any standards.
- It provides information about the KW41Z robustness to the LTE blocker in the 2100 MHz band.

3.3. Return loss

3.3.1. RF path with matching components

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

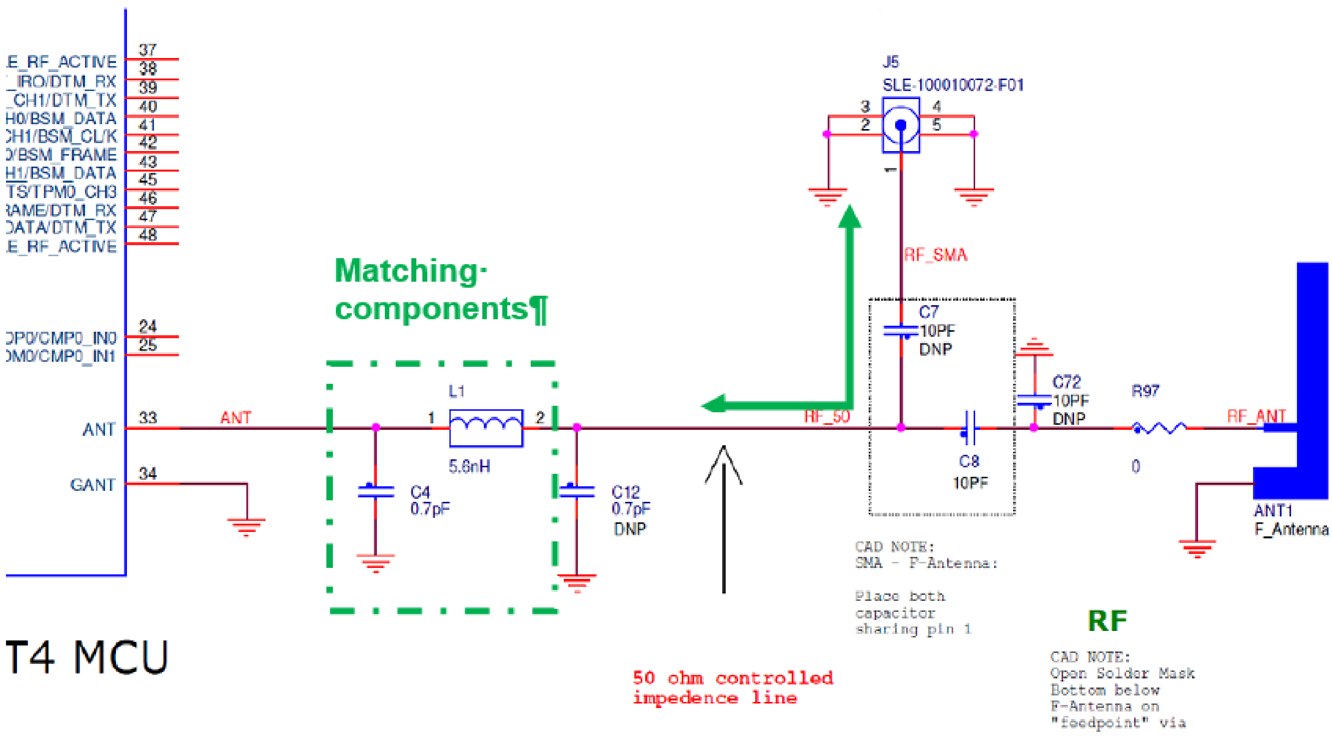

Figure 32. RF matching

Matching components are:

- L2 = 5.6 nH

Description	Manufacturer name	Manufacturer part number
IND -- 0.0056 µH @ 500 MHz 300 mA +/-0.1 nH 0402	MURATA	LQP15MN5N6B02

- C50 = 0.7 pF

Description	Manufacturer name	Manufacturer part number
CAP CER 0.7 pF 50 V 0.1 pF C0G 0402	MURATA	GRM1555C1HR70BA01D

3.3.2. Rx

NOTE

In the Rx mode, the return loss measurement is performed by setting the LNA gain of the KW41Z to the maximum.

Hardware: FRDM-KW41z rev.A.

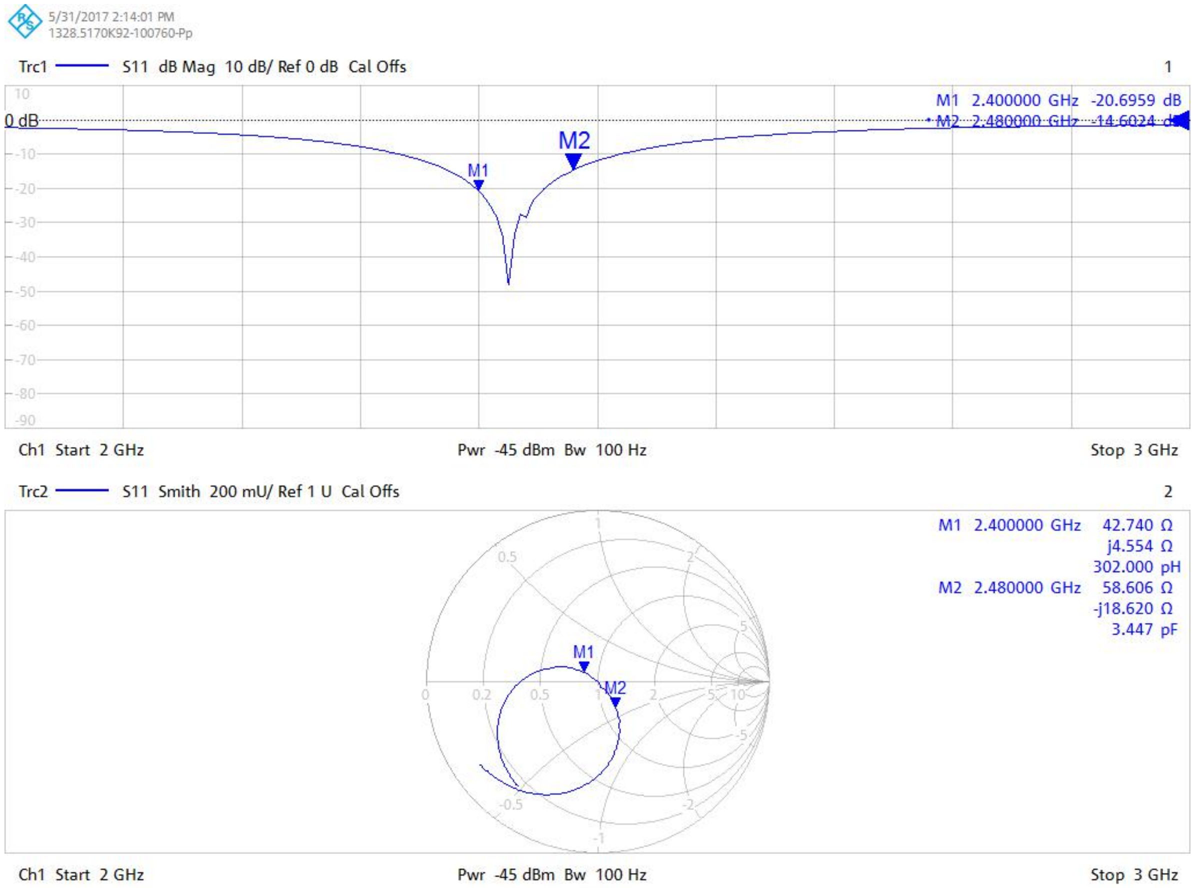

Figure 33. S11 diagram (Rx mode)

Results:

- Return loss: -20.7 (2.4 GHz) < S11 < -14.6 dB (2.48 GHz).

NOTE

There is no specification for the return loss.

Conclusion:

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

3.3.3. Tx

NOTE

In the Tx mode, the return loss measurement is performed by setting the KW41Z RF output power to the minimum.

Hardware: FRDM-KW41Z rev. A.

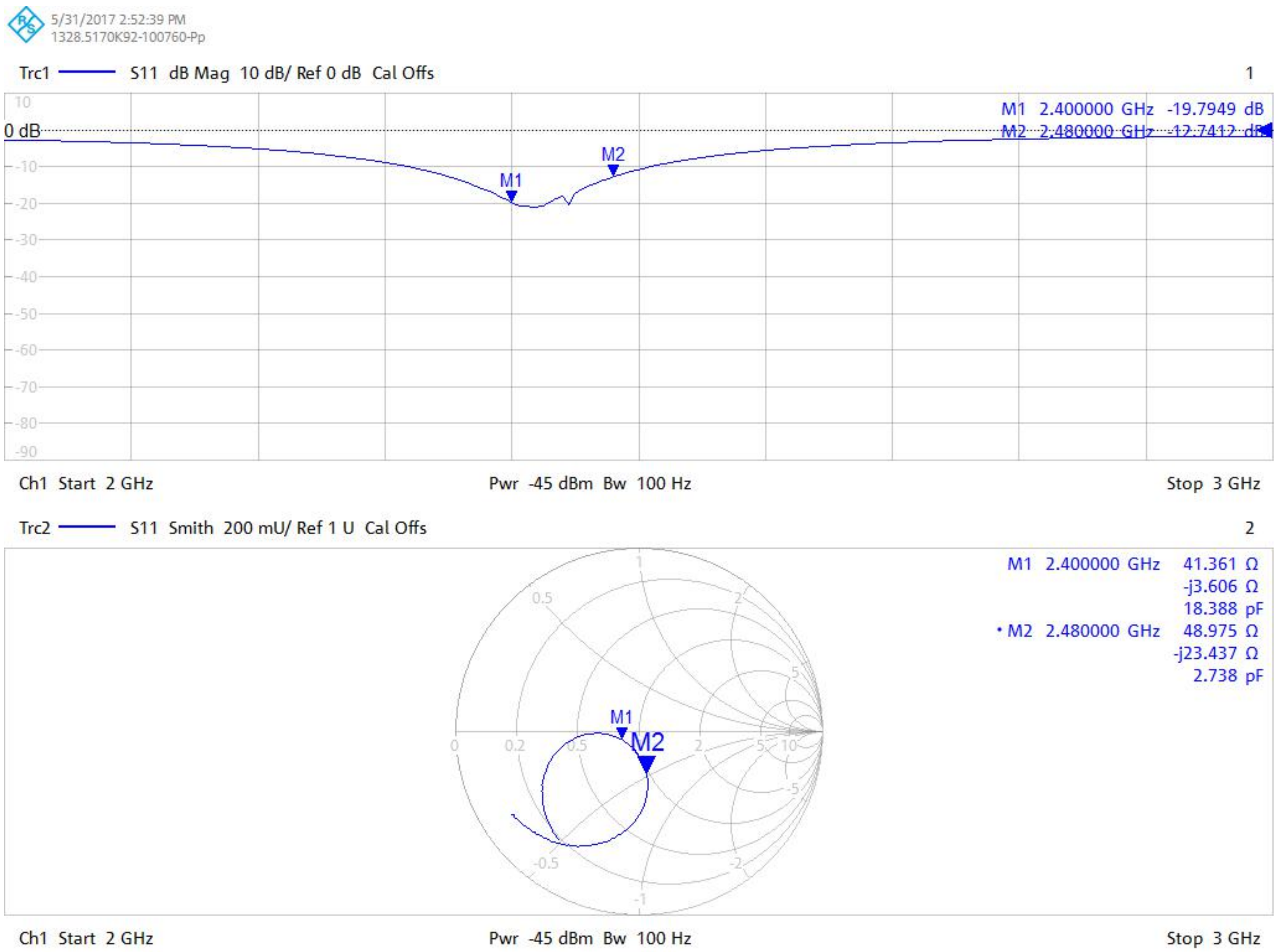

Figure 34. S11 diagram (Tx mode)

Results:

- Return loss: -19.8 (2.4 GHz) < S11 < -12.7 dB (2.48 GHz).

NOTE

There is no specification for the return loss.

Conclusion:

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

4. Conclusion

Beyond the RED and 802.15.4 compliances, these radio tests prove a good performance of the KW41Z wireless MCU.

5. References

- **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.
- **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).
- **FCC Part 15:** Operation to FCC Part 15 is subject to two conditions. Firstly, the device may not cause harmful interference and, secondly, 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.

6. Revision history

Table 3 summarizes the changes made to this document since the initial release.

Table 3. Revision history

Revision number	Date	Substantive changes
0	08/2017	Initial release.
1	10/2017	Various smaller updates.
1.1	12/2017	*Section 3.1.6* added with small updates
1.2	03/2018	Small updates for 3.1.6

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