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

Table 1. List of tests

EUROPE

<table>
<thead>
<tr>
<th>Reference</th>
<th>Limit</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX Maximum Power</td>
<td>ETSI EN 300 328</td>
<td>PASS</td>
</tr>
<tr>
<td>Eirp Tx spectral density</td>
<td>ETSI EN 300 328</td>
<td>PASS</td>
</tr>
<tr>
<td>TX spectral density</td>
<td>802.15.4_2011</td>
<td>PASS</td>
</tr>
<tr>
<td>Spurious 30 MHz – 1 GHz</td>
<td>ETSI EN 300 328</td>
<td>PASS</td>
</tr>
<tr>
<td>Spurious 1 GHz – 12.5 GHz</td>
<td>ETSI EN 300 328</td>
<td>PASS</td>
</tr>
<tr>
<td>EVM</td>
<td>802.15.4_2011</td>
<td>PASS</td>
</tr>
<tr>
<td>TX Frequency Tolerance</td>
<td>802.15.4_2011</td>
<td>PASS</td>
</tr>
<tr>
<td>Reachable Low limit of max power</td>
<td>802.15.4_2011</td>
<td>PASS</td>
</tr>
<tr>
<td>Phase noise (unspread)</td>
<td>802.15.4_2003</td>
<td>For information</td>
</tr>
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</table>
Conducted tests

<table>
<thead>
<tr>
<th>EUROPE</th>
<th>Reference</th>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receiver</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RX emissions 30 MHz – 1 GHz</td>
<td>ETSI EN 300 328</td>
<td>-57 dBm (100 KHz)</td>
</tr>
<tr>
<td>RX emissions 1 GHz – 12.5 GHz</td>
<td>ETSI EN 300 328</td>
<td>-47 dBm (1 MHz)</td>
</tr>
<tr>
<td>RX sensitivity</td>
<td>802.15.4</td>
<td>-85 dBm</td>
</tr>
<tr>
<td>Adjacent channel interference rejection N +/-1</td>
<td>802.15.4_2011</td>
<td>0 dB</td>
</tr>
<tr>
<td>Alternate channel interference rejection N +/-2</td>
<td>802.15.4_2011</td>
<td>30 dB</td>
</tr>
<tr>
<td>Receiver blocking</td>
<td>ETSI EN 300 328</td>
<td>-57 dBm / -47 dBm</td>
</tr>
<tr>
<td>RX Maximum input level</td>
<td>802.15.4_2011</td>
<td>-20 dBm</td>
</tr>
<tr>
<td>Misc.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return loss (S11)</td>
<td>Return loss in Tx mode</td>
<td>For information</td>
</tr>
<tr>
<td></td>
<td>Return loss in Rx mode</td>
<td>For information</td>
</tr>
</tbody>
</table>
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:

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

<table>
<thead>
<tr>
<th>Result</th>
<th>Target</th>
<th>802.15.4 limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.6 ppm</td>
<td>+/-25 ppm</td>
<td>+/-40 ppm</td>
</tr>
</tbody>
</table>

**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:

![Phase noise measurement graph](image)

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:

- 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.

![Conducted Tx spurious (30 MHz to 1 GHz)](image)

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:

- 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:

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

Conclusion:
- Margin > 26 dB.

Figure 9. Conducted H3 spurious
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:

- 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:

- 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:

![Conducted H2 FCC spurious](image)

- 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](image)

- 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:

- 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:

- 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:

![Upper Band Edge](image)

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:

![Conducted EVM (%)](image1)

![Conducted offset EVM (%)](image2)

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](image1)

![Figure 20. Conducted Rx test setup for interference rejection](image2)
Figure 21. Conducted Rx test setup for spurious

Conducted tests
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.

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:

- 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 $\text{PER} = 1\%$.

Results:

![Figure 24. Maximum input power](image)

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.

![Conducted Rx spurious 30 MHz – 12.5 GHz](image)

**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:

<table>
<thead>
<tr>
<th>n-2</th>
<th>n-1</th>
<th>n+1</th>
<th>n+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2395</td>
<td>2400</td>
<td>2410</td>
<td>2415</td>
</tr>
<tr>
<td>Interferer level (dBc)</td>
<td>35.2</td>
<td>34.2</td>
<td>33.2</td>
</tr>
<tr>
<td>802.15.4 limit (dB)</td>
<td>30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Margin (dB)</td>
<td>5.2</td>
<td>34.2</td>
<td>33.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ch18</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-2</td>
</tr>
<tr>
<td>2430</td>
</tr>
<tr>
<td>Interferer level (dBc)</td>
</tr>
<tr>
<td>802.15.4 limit (dB)</td>
</tr>
<tr>
<td>Margin (dB)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ch26</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-2</td>
</tr>
<tr>
<td>2470</td>
</tr>
<tr>
<td>Interferer level (dBc)</td>
</tr>
<tr>
<td>802.15.4 limit (dB)</td>
</tr>
<tr>
<td>Margin (dB)</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th></th>
<th>ch11</th>
<th></th>
<th>ch18</th>
<th></th>
<th>ch26</th>
</tr>
</thead>
<tbody>
<tr>
<td>ch</td>
<td>2405</td>
<td>n-3</td>
<td>2440</td>
<td>n-3</td>
<td>2480</td>
</tr>
<tr>
<td></td>
<td>2495</td>
<td></td>
<td>2425</td>
<td></td>
<td>2465</td>
</tr>
<tr>
<td>Interferer level (dBc)</td>
<td>55.2</td>
<td>53.7</td>
<td>54.7</td>
<td>54.7</td>
<td>55.2</td>
</tr>
<tr>
<td>Datasheet typical value (dB)</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Margin (dB)</td>
<td>7.2</td>
<td></td>
<td>5.7</td>
<td>6.7</td>
<td>6.7</td>
</tr>
</tbody>
</table>

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:

<table>
<thead>
<tr>
<th></th>
<th>ch11</th>
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<th>ch26</th>
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<tbody>
<tr>
<td></td>
<td>2405</td>
<td>2405</td>
<td>2480</td>
<td>2480</td>
</tr>
<tr>
<td>Low</td>
<td>2380</td>
<td>2503.5</td>
<td>2380</td>
<td>2503.5</td>
</tr>
<tr>
<td>Interferer level (dBm)</td>
<td>-18.6</td>
<td>-14.6</td>
<td>-17.6</td>
<td>-14.6</td>
</tr>
<tr>
<td>802.15.4 limit (dBm)</td>
<td>-53</td>
<td>-53</td>
<td>-53</td>
<td>-53</td>
</tr>
<tr>
<td>Margin (dB)</td>
<td>34.4</td>
<td>38.4</td>
<td>35.4</td>
<td>38.4</td>
</tr>
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</table>

<table>
<thead>
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<td>2405</td>
<td>2405</td>
<td>2405</td>
<td>2480</td>
<td>2480</td>
</tr>
<tr>
<td>Low</td>
<td>2300</td>
<td>2330</td>
<td>2360</td>
<td>2300</td>
<td>2330</td>
</tr>
<tr>
<td>Interferer level (dBm)</td>
<td>-17.6</td>
<td>-17.6</td>
<td>-16.6</td>
<td>-17.6</td>
<td>-17.6</td>
</tr>
<tr>
<td>802.15.4 limit (dBm)</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
</tr>
<tr>
<td>Margin (dB)</td>
<td>29.4</td>
<td>29.4</td>
<td>30.4</td>
<td>29.4</td>
<td>29.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<tr>
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<td>2405</td>
<td>2405</td>
<td>2405</td>
<td>2405</td>
<td>2405</td>
<td>2405</td>
</tr>
<tr>
<td>High</td>
<td>2523.5</td>
<td>2553.5</td>
<td>2583.5</td>
<td>2613.5</td>
<td>2643.5</td>
<td>2673.5</td>
</tr>
<tr>
<td>Interferer level (dBm)</td>
<td>-14.6</td>
<td>-14.6</td>
<td>-14.6</td>
<td>-13.6</td>
<td>-13.6</td>
<td>-13.6</td>
</tr>
<tr>
<td>802.15.4 limit (dBm)</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
</tr>
<tr>
<td>Margin (dB)</td>
<td>32.4</td>
<td>32.4</td>
<td>32.4</td>
<td>33.4</td>
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<tr>
<td>High</td>
<td>2523.5</td>
<td>2553.5</td>
<td>2583.5</td>
<td>2613.5</td>
<td>2643.5</td>
<td>2673.5</td>
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<tr>
<td>Interferer level (dBm)</td>
<td>-16.6</td>
<td>-16.6</td>
<td>-16.6</td>
<td>-14.6</td>
<td>-13.6</td>
<td>-13.6</td>
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<tr>
<td>802.15.4 limit (dBm)</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
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<td>-47</td>
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<tr>
<td>Margin (dB)</td>
<td>30.4</td>
<td>30.4</td>
<td>30.4</td>
<td>32.4</td>
<td>33.4</td>
<td>33.4</td>
</tr>
</tbody>
</table>

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 \( P_{\text{min}} + 6 \) dB (-82 dBm); the interferer is increased until the PER threshold is reached
- Channels under test: 11 and 26

Result:

<table>
<thead>
<tr>
<th></th>
<th>ch11</th>
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<th>ch26</th>
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<td>Low</td>
<td>2405</td>
<td>High</td>
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</tr>
<tr>
<td>2380</td>
<td>2503.5</td>
<td>2380</td>
<td>2503.5</td>
<td></td>
</tr>
<tr>
<td>Interferer level (dBm)</td>
<td>-18.5</td>
<td>-14.7</td>
<td>-17.7</td>
<td>-14.5</td>
</tr>
<tr>
<td>802.15.4 limit (dBm)</td>
<td>-57</td>
<td>-57</td>
<td>-57</td>
<td>-57</td>
</tr>
<tr>
<td>Margin (dB)</td>
<td>38.5</td>
<td>42.3</td>
<td>39.3</td>
<td>42.5</td>
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</tbody>
</table>

<table>
<thead>
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<th>ch11</th>
<th></th>
<th>ch26</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>2405</td>
<td>Low</td>
<td>2480</td>
<td>Low</td>
</tr>
<tr>
<td>2300</td>
<td>2583.5</td>
<td>2300</td>
<td>2583.5</td>
<td></td>
</tr>
<tr>
<td>Interferer level (dBm)</td>
<td>-17.6</td>
<td>-16.6</td>
<td>-17.6</td>
<td>-17.6</td>
</tr>
<tr>
<td>802.15.4 limit (dBm)</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
<td>-47</td>
</tr>
<tr>
<td>Margin (dB)</td>
<td>29.4</td>
<td>30.4</td>
<td>29.4</td>
<td>29.4</td>
</tr>
</tbody>
</table>

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

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

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.

### Figure 30. 3G immunity

<table>
<thead>
<tr>
<th>Channel</th>
<th>Interferer level (dBm)</th>
<th>Interferer level (dBc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>2405</td>
<td>65.2</td>
</tr>
<tr>
<td>3G</td>
<td>2100</td>
<td>-16.8</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>ch26</th>
<th>2480</th>
<th>LTE</th>
<th>2500</th>
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</thead>
<tbody>
<tr>
<td>Interferer level (dBm)</td>
<td>-11.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interferer level (dBc)</td>
<td></td>
<td>70.2</td>
<td></td>
</tr>
</tbody>
</table>

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.

Matching components are:

- \( L_2 = 5.6 \text{ nH} \)

<table>
<thead>
<tr>
<th>Description</th>
<th>Manufacturer name</th>
<th>Manufacturer part number</th>
</tr>
</thead>
<tbody>
<tr>
<td>IND -- 0.0056 ( \mu \text{H} ) @ 500 MHz 300 mA +/-0.1 nH 0402</td>
<td>MURATA</td>
<td>LQP15MN5N6B02</td>
</tr>
</tbody>
</table>

- \( C_{50} = 0.7 \text{ pF} \)

<table>
<thead>
<tr>
<th>Description</th>
<th>Manufacturer name</th>
<th>Manufacturer part number</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAP CER 0.7 pF 50 V 0.1 pF C0G 0402</td>
<td>MURATA</td>
<td>GRM1555C1HR70BA01D</td>
</tr>
</tbody>
</table>
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.

![S11 diagram (Rx mode)](image)

**Results:**
- Return loss: $-20.7 \text{ (2.4 GHz)} < S11 < -14.6 \text{ dB (2.48 GHz)}$.

**NOTE**
There is no specification for the return loss.

**Conclusion:**
- The return loss ($S11$) is lower than $-10 \text{ dB}$.
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.

Results:
- Return loss: $-19.8 \text{ (2.4 GHz)} < S_{11} < -12.7 \text{ dB (2.48 GHz)}$.

NOTE
There is no specification for the return loss.

Conclusion:
- The return loss ($S_{11}$) is lower than $-10 \text{ dB}$.
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>
<thead>
<tr>
<th>Revision number</th>
<th>Date</th>
<th>Substantive changes</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>08/2017</td>
<td>Initial release</td>
</tr>
<tr>
<td>1</td>
<td>10/2017</td>
<td>Various smaller updates</td>
</tr>
<tr>
<td>1.1</td>
<td>12/2017</td>
<td>Section 3.1.6 added with small updates</td>
</tr>
<tr>
<td>1.2</td>
<td>03/2018</td>
<td>Small updates for 3.1.6</td>
</tr>
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</table>
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