AN13887

K32W148 RF System Evaluation for IEEE 802.15.4 Applications with Interferer Coexistence

Rev. 1 — 27 October 2023 Application note

Document information

Information	Content
Keywords	AN13887, K32W148, IEEE 802.15.4, noise interference, sinewave interference, Bluetooth audio interference, Wi-Fi interference, carrier-to-noise ratio, packet error rate, adjacent-channel interference
Abstract	This document provides the RF system evaluation test results of NXP K32W148 MCU for IEEE 802.15.4 applications with coexistence of these interferers: noise, sinewave, Bluetooth audio, and Wi-Fi.

1 Introduction

This document provides the RF system evaluation test results of NXP K32W148 MCU for IEEE 802.15.4 applications with coexistence of these interferers: noise, sinewave, Bluetooth audio, and Wi-Fi. The tests are based on offset quadrature phase-shift keying (OQPSK) modulation.

The document also describes test setup and provides steps to perform the tests.

Note: *To get the K32W148 radio parameters, see the K32W14x Product Family Data Sheet (K32W1480).*

1.1 K32W148 evaluation kit

For evaluating K32W148 performance, NXP K32W148 evaluation kit (K32W148-EVK board) is used (shown in Figure 1).

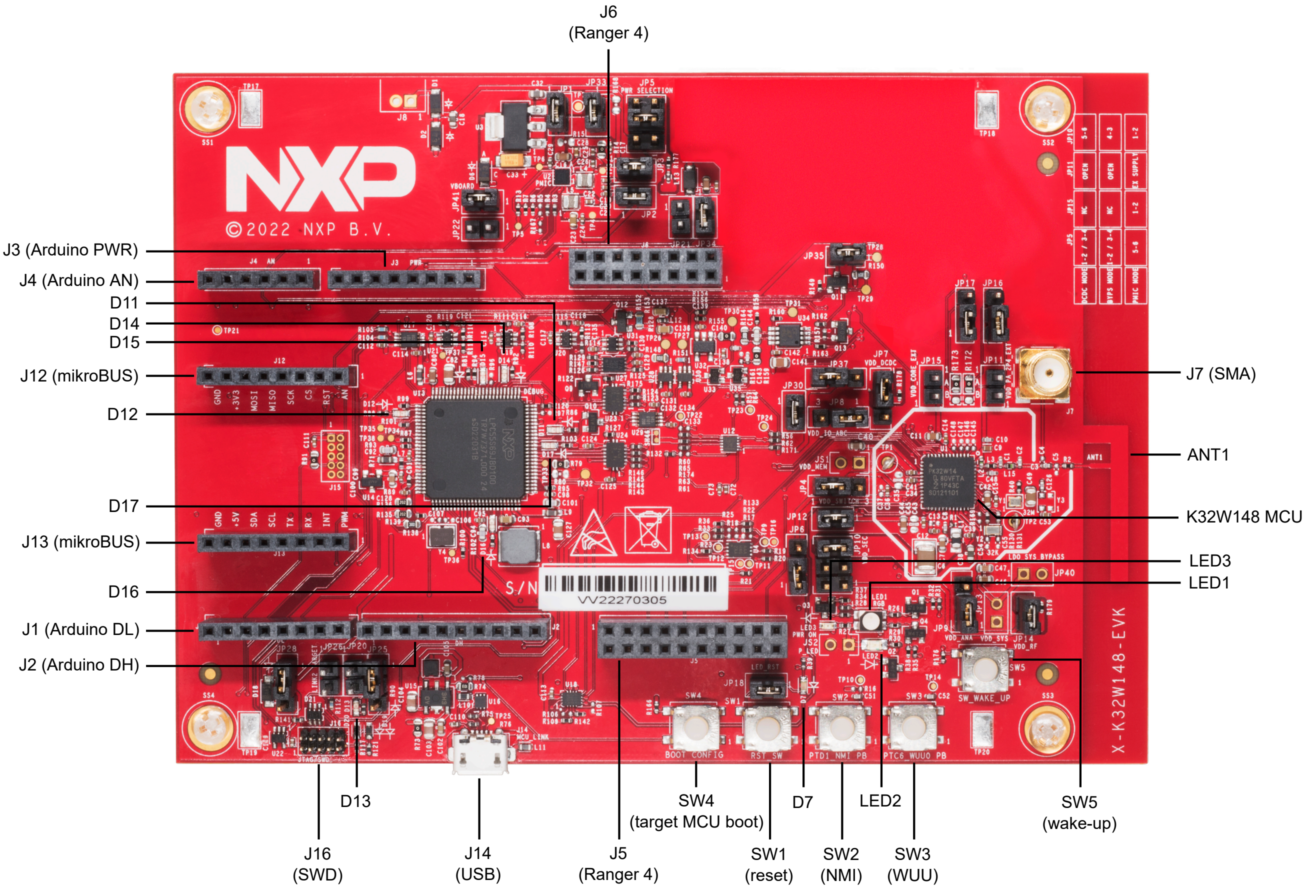

Figure 1. K32W148-EVK board

For more information on the K32W148-EVK board, see *K32W148-EVK Board User Manual* (K32W148-EVKUM).

1.2 System requirements

The following equipments are used to perform RX and TX measurements:

- R&S SFU as the interferer source for noise, sinewave, Bluetooth audio, and Wi-Fi interference tests. Any generator with ARB can be used as interference source.

- R&S SMBV100A for generating the desired IEEE 802.15.4 signal. Any generator with ARB can be used as IEEE 802.15.4 signal generator.
- PC equipped with a general-purpose interface bus (GPIB) card

To communicate with the K32W148 MCU, the PC should have Tera Term installed.

Before performing any measurement, a binary code must be loaded into the flash memory of the board using the In-System Programming (ISP) utility. For details, see the *KW45B41Z and K32W148 In-System Programming Utility* application note (AN13859).

Figure 2 shows an example binary code from Connectivity Test Tool that used by NXP for tests described in this document.

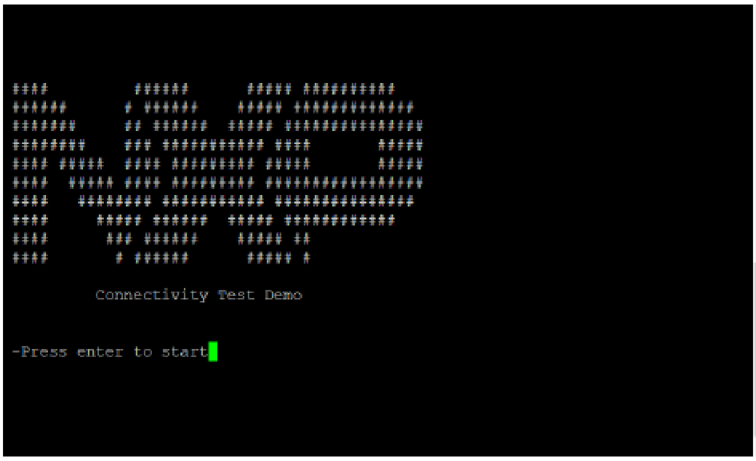

Figure 2. Binary code loaded

1.3 List of tests

Following are the tests conducted on the K32W148 MCU:

- Noise interference:
  - Carrier-to-noise ratio (C/N) vs frequency

    Note: *Carrier-to-noise ratio (C/N) is also known as signal-to-noise ratio (SNR).*
  - Packet error rate (PER) vs C/N
- Sinewave (continuous wave) interference
- Bluetooth audio interference
- Wi-Fi interference:
  - Adjacent-channel interference (ACI)
  - Co-channel

2 Noise interference

This section is divided into the following subsections:

- Noise interference test setup
- Noise interference tests

2.1 Noise interference test setup

Setup diagram

Figure 3 shows the setup diagram of the noise interference test.

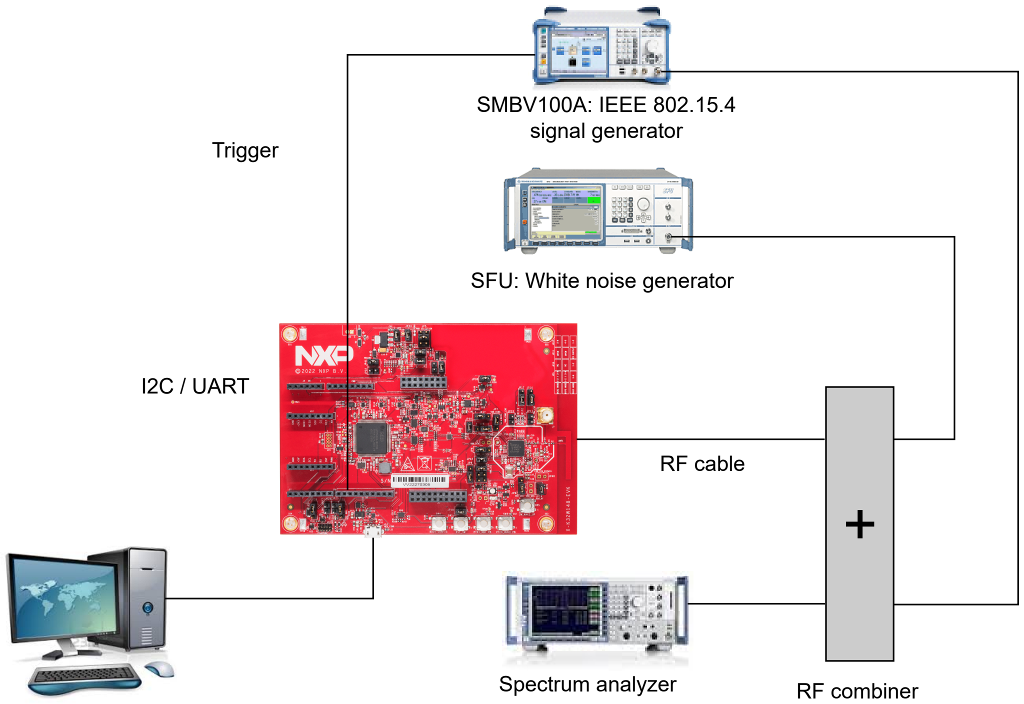

Figure 3. Noise interference test setup

Signal definition

Carrier-to-noise (C/N) measurement highlights the demodulator (baseband) section performance.

White noise is added into the desired channel. The noise power is increased until the criteria PER = 1% is met. The C/N is calculated on 2.3 MHz bandwidth.

Figure 4 shows the settings required for the noise interference test.

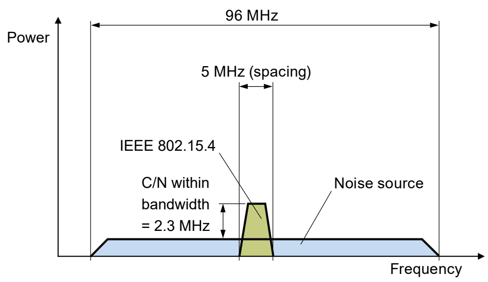

Figure 4. White noise interference test settings

2.2 Noise interference tests

This section is divided into the following subsections:

- C/N vs frequency test
- PER vs C/N test

2.2.1 C/N vs frequency test

Test method

Follow these steps to perform the C/N vs frequency test:

1. Configure the K32W148 radio as follows:
   - RX mode
   - Modulated
   - Continuous mode
   - Frequency: From channel 11 (2405 MHz) to channel 26 (2480 MHz)
2. Configure the desired signal on the signal generator as follows:
   - IEEE 802.15.4 modulated signal (typically 1000 packets of 20 bytes)
   - Continuous mode
   - Frequency: From channel 11 (2405 MHz) to channel 26 (2480 MHz)
   - RF output power level (fixed): -78.5 dBm
3. Configure the noise generator (SFU) as follows:
   - Center frequency: Channel 18 (2440 MHz)
   - Bandwidth: 2 MHz
4. Check the power levels of the desired IEEE 802.15.4 signal and noise signal on the spectrum analyzer, which performs power calibration on these signals:
   - Span is 10 MHz.
   - C/N function is enabled with a channel bandwidth at 2 MHz.
5. For each channel of the desired signal, start from a C/N where PER is at 0%, then decrease it until the criteria PER = 1% is met, and then, record and plot the C/N value, as shown in Figure 5.

Test results

Figure 5 shows the results of the C/N vs frequency test.

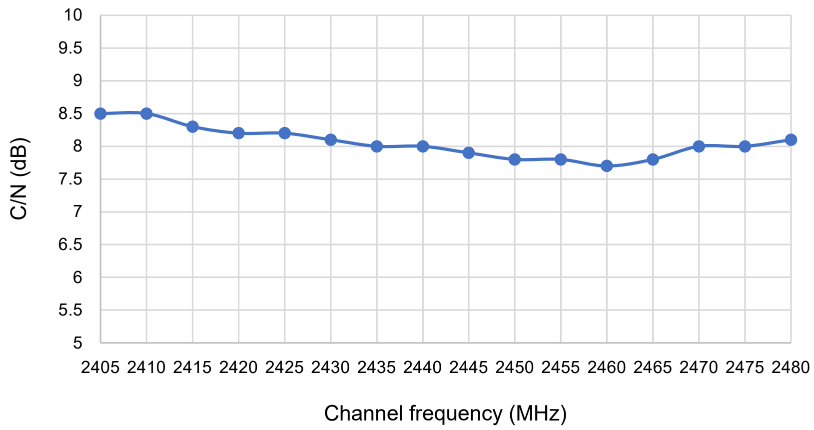

Figure 5. C/N vs frequency test results

Conclusion

C/N performance is independent from the channel (purely baseband performance). Typically, the measured C/N is 8 dB.

2.2.2 PER vs C/N test

Test method

Follow these steps to perform the PER vs C/N test:

1. Configure the K32W148 radio as follows:
   - RX mode
   - Modulated
   - Continuous mode
   - Frequency: From channel 11 (2405 MHz) to channel 26 (2480 MHz)
2. Configure the desired signal on the signal generator as follows:
   - IEEE 802.15.4 modulated signal (typically 1000 packets of 20 bytes)
   - Continuous mode
   - Frequency: From channel 11 (2405 MHz) to channel 26 (2480 MHz)
   - RF output power level (fixed): -78.5 dBm

- Configure the noise generator (SFU) as follows:
  – Center frequency: 2440 MHz
  – Bandwidth: 2 MHz
- Check the power levels of the desired IEEE 802.15.4 signal and noise signal on the spectrum analyzer, which performs power calibration on these signals:
  – Span is 10 MHz.
  – C/N function is enabled with a channel bandwidth at 2 MHz.
- For each channel of the desired signal, start from a C/N where PER is at 0%, then decrease it and plot the C/N and PER values, as shown in Figure 6.

Test results

Figure 6 shows the results of the PER vs C/N test where center frequency is at 2440 MHz.

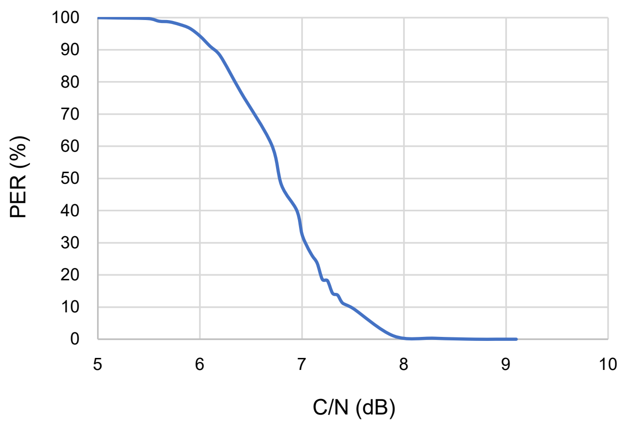

Figure 6. PER vs C/N test results

Conclusion

When the noise increases, PER degrades smoothly – no abrupt degradation.

3 Sinewave interference

This section is divided into the following subsections:

- Sinewave interference test setup
- Sinewave interference test

3.1 Sinewave interference test setup

Setup diagram

Figure 7 shows the setup diagram of the sinewave interference test.

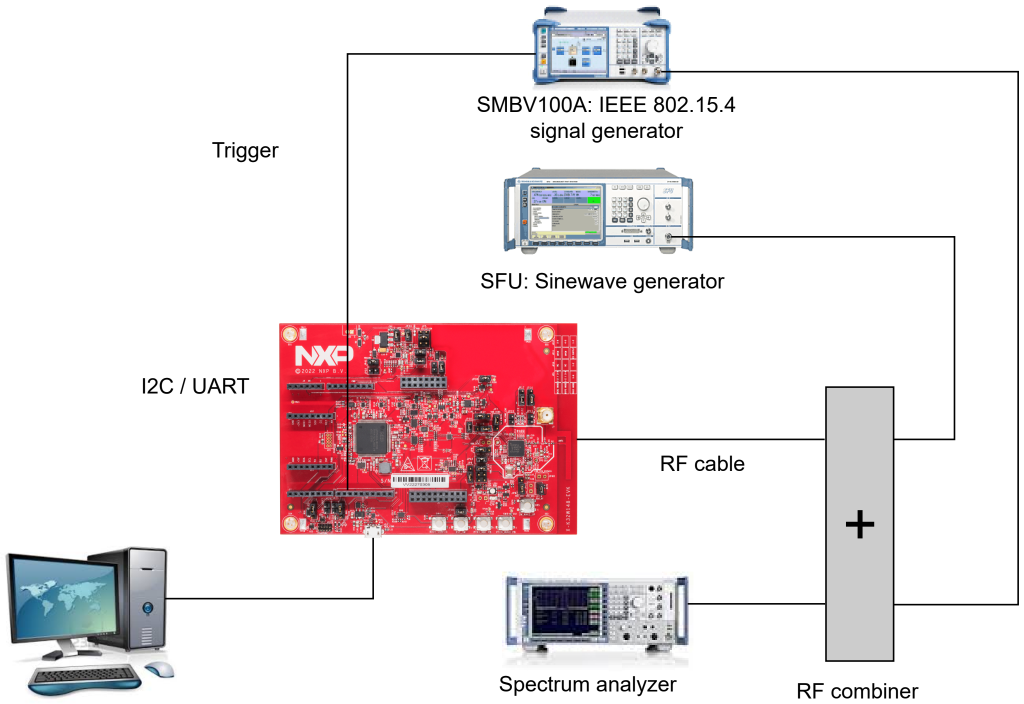

Figure 7. Sinewave interference test setup

Signal definition

In this test case, a pure sinewave is used to measure the adjacent-channel interference (ACI) (N±8) and co-channel immunity.

The sinewave power is increased until the criteria PER = 1% is met.

Figure 8 shows the settings required for the sinewave interference test.

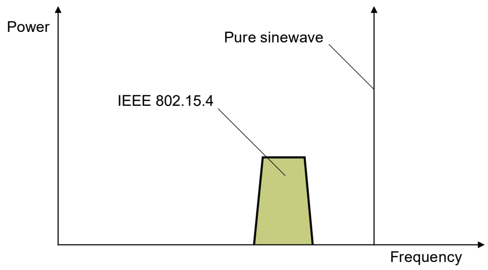

Figure 8. Pure sinewave interference – test settings

3.2 Sinewave interference test

Test method

Follow these steps to perform the sinewave interference test:

1. Configure the K32W148 radio as follows:
   - RX mode
   - Modulated
   - Continuous mode
   - Frequency: Channel 18 (2440 MHz)
2. Configure the desired signal on the signal generator as follows:
   - IEEE 802.15.4 modulated signal (typically 1000 packets of 20 bytes)
   - Continuous mode
   - Frequency: On one channel, channel 18 (2440 MHz)
3. Check the power levels of the desired signal and the sinewave (-20 dBm) on the spectrum analyzer.
4. For a pure sinewave interferer swept from channel 11 (2405 MHz) to channel 18 (2440 MHz) with a constant power level set at -20 dBm, decrease the power level until the criteria PER = 1% is met. Then, note the required power level and the frequency of the sinewave.

Test results

Figure 9 shows the results of the sinewave interference test where sinewave interferer is at 2440 MHz / 20 dBm and PER (sensitivity) is at 1%.

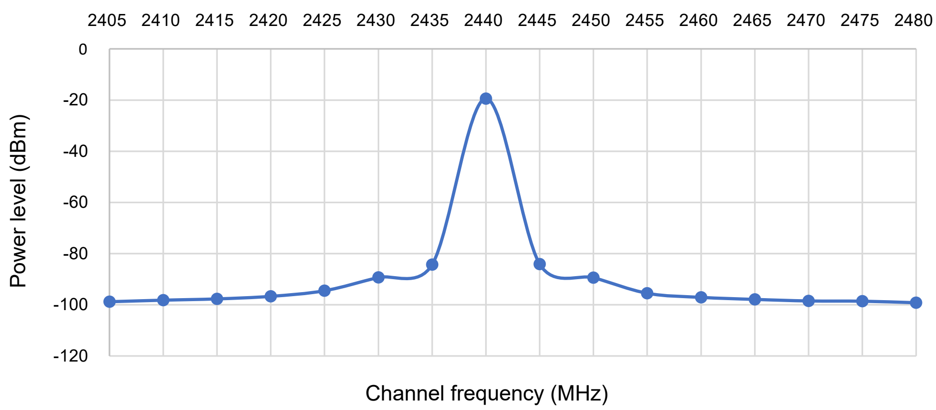

Figure 9. RF input power level vs continuous wave interferer test results

Conclusion

A sinewave signal at a slightly higher power level (-20 dBm) acts as a blocker; therefore, the K32W148 receiver regulates its receiver gain.

4 Bluetooth audio interference

This section is divided into the following subsections:

- Bluetooth audio interference test setup
- Bluetooth audio interference test

4.1 Bluetooth audio interference test setup

Setup diagram

Figure 10 shows the setup diagram of the Bluetooth audio interference test.

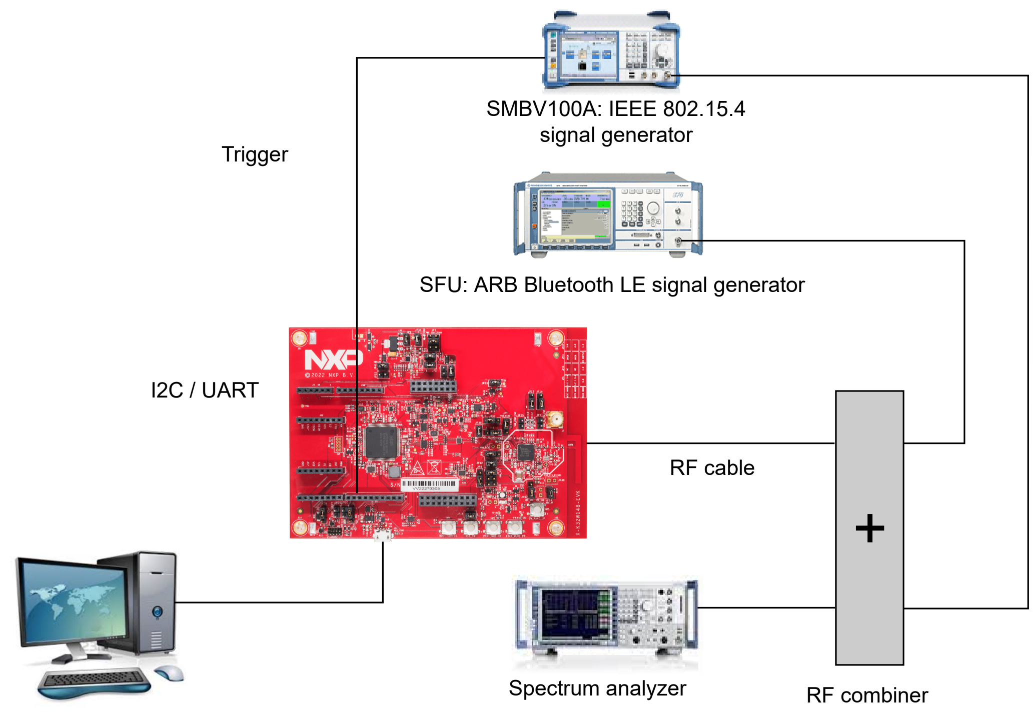

Figure 10. Bluetooth audio interference test setup

Signal definition

The following measurements can be made by capturing 1 channel (case 1) from a smartphone Bluetooth audio stream:

- The Bluetooth interferer is set at a constant power level of -51.5 dBm. Its frequency is varied from -5 MHz to +5 MHz on the IEEE 802.15.4 channel by step of 1 MHz. Duty cycle is forced to 5%.
- The IEEE 802.15.4 signal power is decreased until the criteria PER = 1% is met.

Figure 11 shows the settings required for the Bluetooth audio interference test.

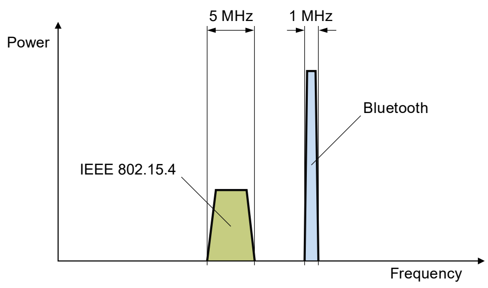

Figure 11. Bluetooth audio interference test settings

4.2 Bluetooth audio interference test

Test method

Follow these steps to perform the Bluetooth audio interference test:

1. Configure the K32W148 radio as follows:
   - RX mode

   - Modulated
   - Continuous mode
   - Frequency: Channel 11 (2405 MHz), channel 18 (2440 MHz), channel 21 (2455 MHz), and channel 26 (2480 MHz)
2. Configure the desired signal on the signal generator as follows:
   - IEEE 802.15.4 modulated signal (typically 1000 packets of 20 bytes)
   - Continuous mode
   - Frequency: Channel 11 (2405 MHz), channel 18 (2440 MHz), channel 21 (2455 MHz), and channel 26 (2480 MHz)
3. Check the power levels of the desired IEEE 802.15.4 signal and Bluetooth audio stream interference signal on the spectrum analyzer, which performs power calibration on these signals.
4. Set the Bluetooth audio stream to -51.5 dBm, and then vary the frequency from -5 MHz to +5 MHz by step of 1 MHz only on the existing Bluetooth channels (between 2402 MHz and 2480 MHz). Force duty cycle to 5%.
5. Decrease the IEEE 802.15.4 signal power until the criteria PER = 1% is met.

Test results

Figure 12 shows the results of the Bluetooth audio interference test with interferer Bluetooth audio Fs3MHz where PER (sensitivity) is at 1%.

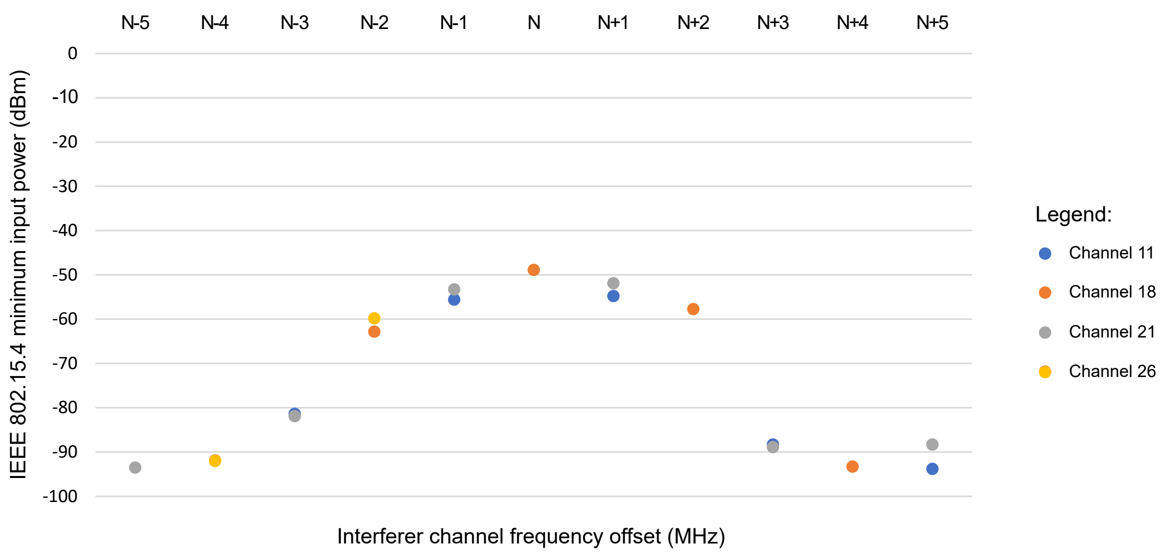

Figure 12. IEEE 802.15.4 minimum input power vs Bluetooth audio test results

Conclusion

For co-channel, the carrier-to-interferer ratio (C/I) is +3 dB (IEEE 802.15.4 channel 11, 18, or 26).

5 Wi-Fi interference

This section is divided into the following subsections:

- Wi-Fi interference test setup
- Wi-Fi interference tests

5.1 Wi-Fi interference test setup

Setup diagram

Figure 13 shows the setup diagram of the Wi-Fi interference test.

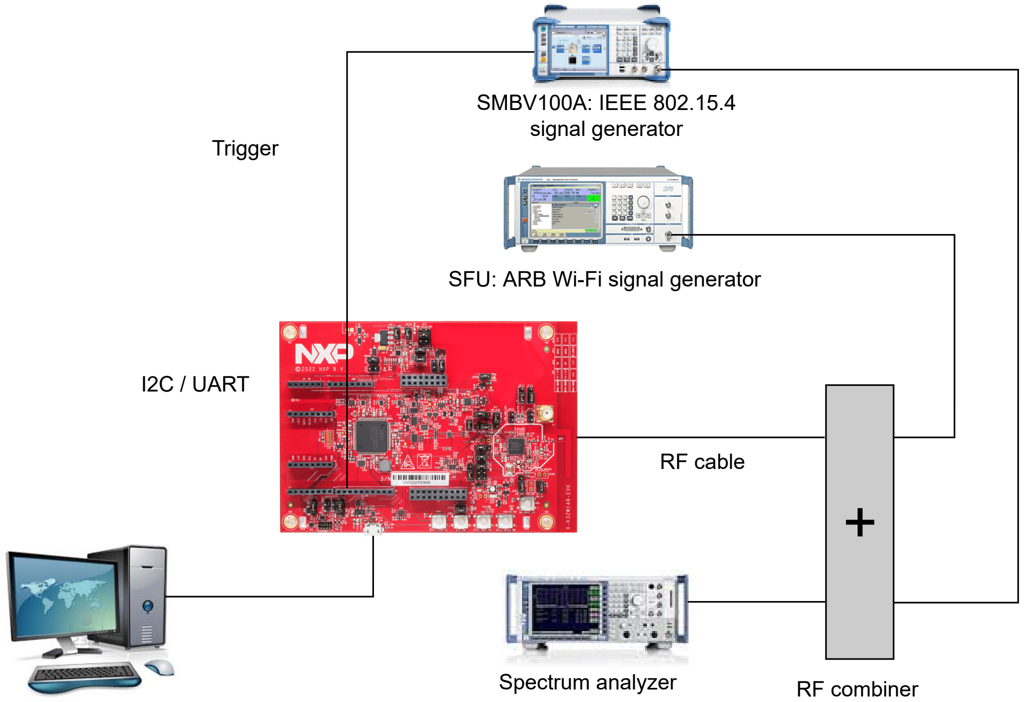

Figure 13. Wi-Fi interference test setup

Signal definition

A *real* Wi-Fi signal with the following definition is sampled and used for Wi-Fi interference tests:

- 802.11n mode, 20 MHz bandwidth (signal antenna)
- Access point (client) sends datagrams to station (server)
- The theoretical data rate set on the access point is 100 Mbits/s (full load)
- The station sends back a report every second to show the actual measured throughput (typically 58 Mbit/s)

The stream is sampled with a signal analyzer (sample frequency = 40 MHz, sampling time = 1 second).

I/Q samples are played with an RF arbitrary generator to simulate a controlled Wi-Fi adjacent signal.

Figure 14 and Figure 15 show the settings required for the two Wi-Fi interference tests: adjacent-channel interference (ACI) and co-channel.

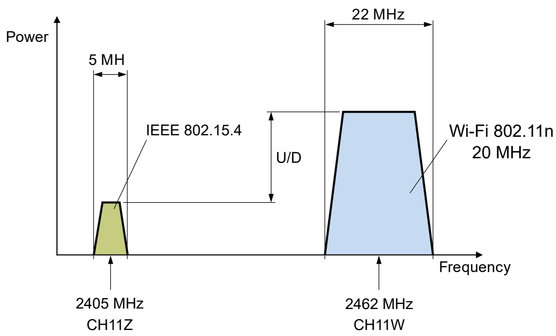

Figure 14. ACI test settings

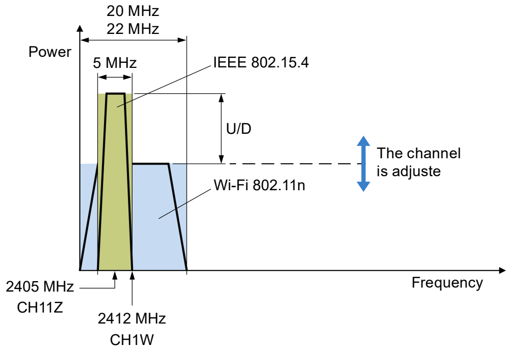

Figure 15. Co-channel test settings

5.2 Wi-Fi interference tests

This section is divided into the following subsections:

- ACI test
- Co-channel test

5.2.1 ACI test

Test method

Follow these steps to perform the ACI test:

1. Configure the K32W148 radio as follows:
   - RX mode
   - Modulated
   - Continuous mode
   - Frequency: Channel 11 (2405 MHz)
2. Configure the desired signal on the signal generator as follows:
   - IEEE 802.15.4 modulated signal (typically 1000 packets of 20 bytes)
   - Continuous mode
   - Frequency: Channel 11 (2405 MHz)
3. Check the power levels of the desired IEEE 802.15.4 signal and Wi-Fi signal on the spectrum analyzer, which performs power calibration on these signals.
4. Vary power level of the Wi-Fi signal (bandwidth = 22 MHz) from -40 dBm to 0 dBm on channel 11 (2462 MHz).

5. Decrease the IEEE 802.15.4 signal power level until the criteria PER = 1% is met.

Test results

Figure 16 shows the results of the ACI test where Wi-Fi is at 2462 MHz frequency and PER (sensitivity) is at 1%.

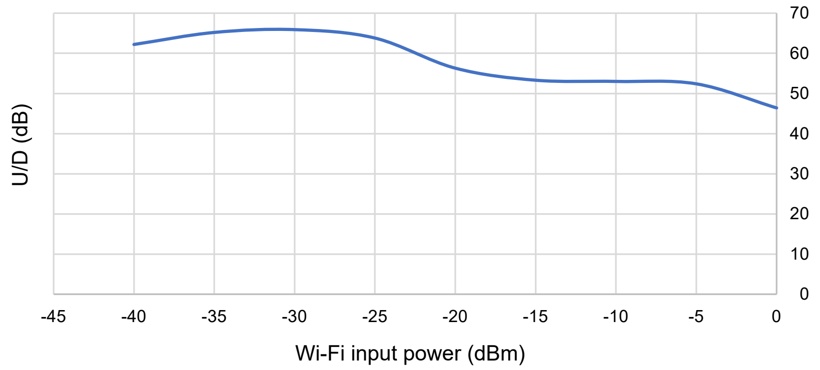

Figure 16. IEEE 802.15.4 and Wi-Fi coexistence ACI test results

Conclusion

The ratio between unwanted and wanted power is constant at around 9 dB for a Wi-Fi interferer up to 0 dBm.

5.2.2 Co-channel test

Test method

Follow these steps to perform the co-channel test:

1. Configure the K32W148 radio as follows:
   - RX mode
   - Modulated
   - Continuous mode
   - Frequency: Channel 11 (2405 MHz)
2. Configure the desired signal on the signal generator as follows:
   - IEEE 802.15.4 modulated signal (typically 1000 packets of 20 bytes)
   - Continuous mode
   - Frequency: Channel 11 (2405 MHz)
3. Check the power levels of the desired IEEE 802.15.4 signal and Wi-Fi signal on the spectrum analyzer, which performs power calibration on these signals.
4. Vary the power level of the Wi-Fi signal (bandwidth = 22 MHz) from -40 dBm to 0 dBm on channel 1 (2412 MHz).
5. Decrease the IEEE 802.15.4 signal power level until the criteria PER = 1% is met.

Test results

Figure 17 shows the results of the co-channel test where Wi-Fi is at 2412 MHz frequency and PER (sensitivity) is at 1%.

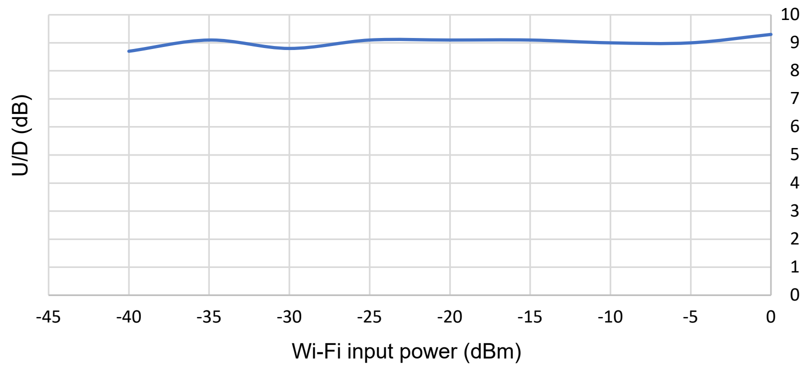

Figure 17. IEEE 802.15.4 and Wi-Fi coexistence co-channel test results

Conclusion

The ratio between unwanted and wanted power is constant at around 9 dB for a Wi-Fi interferer up to 0 dBm.

6 Acronyms

Table 1 lists the acronyms used in this document.

Table 1. Acronyms

Acronym	Description
ACI	Adjacent-channel interference
C/N	Carrier-to-noise ratio
GPIB	General-purpose interface bus
OQPSK	Offset quadrature phase-shift keying
PER	Packet error rate
SNR	Signal-to-noise ratio

7 Revision history

Table 2 summarizes the revisions to this document.

Table 2. Revision history

Revision number	Date	Substantive changes
1	27 October 2023	Initial public release

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