# AN13229

## KW45B41Z-EVK Co-existence with RF System Evaluation Report for Bluetooth Low Energy Application

Rev. 0 — 31 January 2022 Application note

**Document information**

| Information | Content |
|---|---|
| Keywords | KW45, MCU, RF, Bluetooth, BLE, Kinetis |
| Abstract | This document provides the RF evaluation test results of the KW45B41Z EVK for Bluetooth LE applications (2FSK modulation). |

# 1 Introduction

This document provides the RF evaluation test results of the KW45B41Z EVK for Bluetooth LE applications (2FSK modulation). It includes the test setup description and the tools used to perform the tests on your own. To get the KW45 radio parameters, see the *KW45B41Z Data Sheet* (document KW45B41Z).

For more information about the KW45B41Z EVK EValuation Kit board, see *Hardware Design Considerations for KW455656B41Z and K32W148 Bluetooth LE Devices* (document AN13227). Find the schematic and design files at this link.

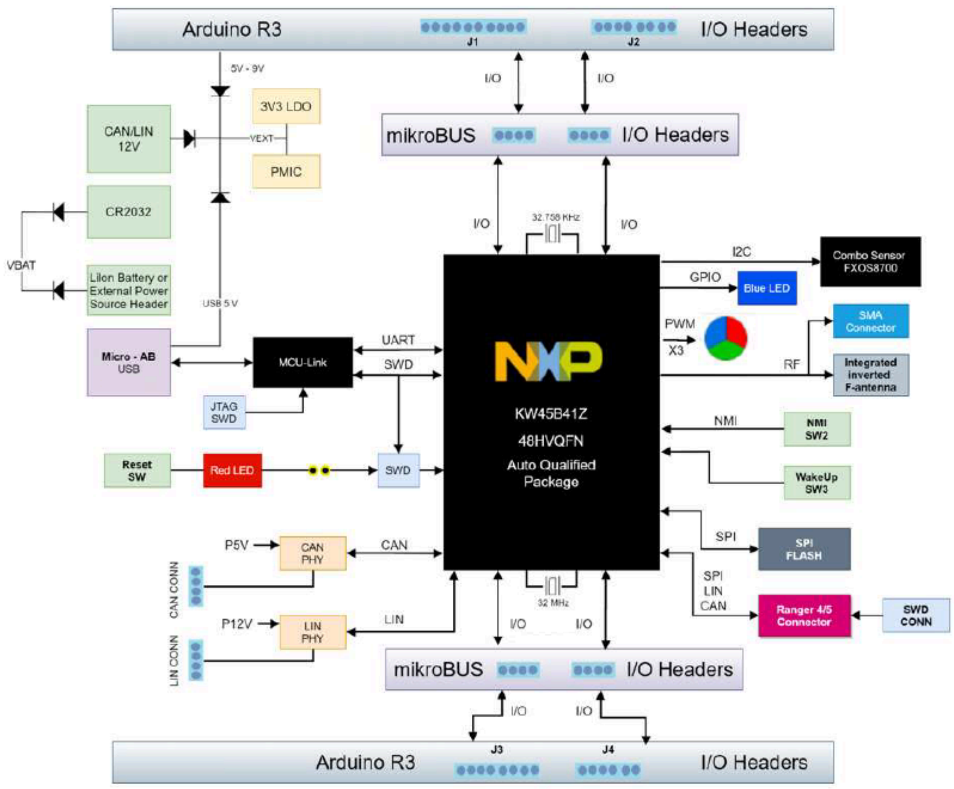


**Figure 1. KW45B41Z EVK block diagram**

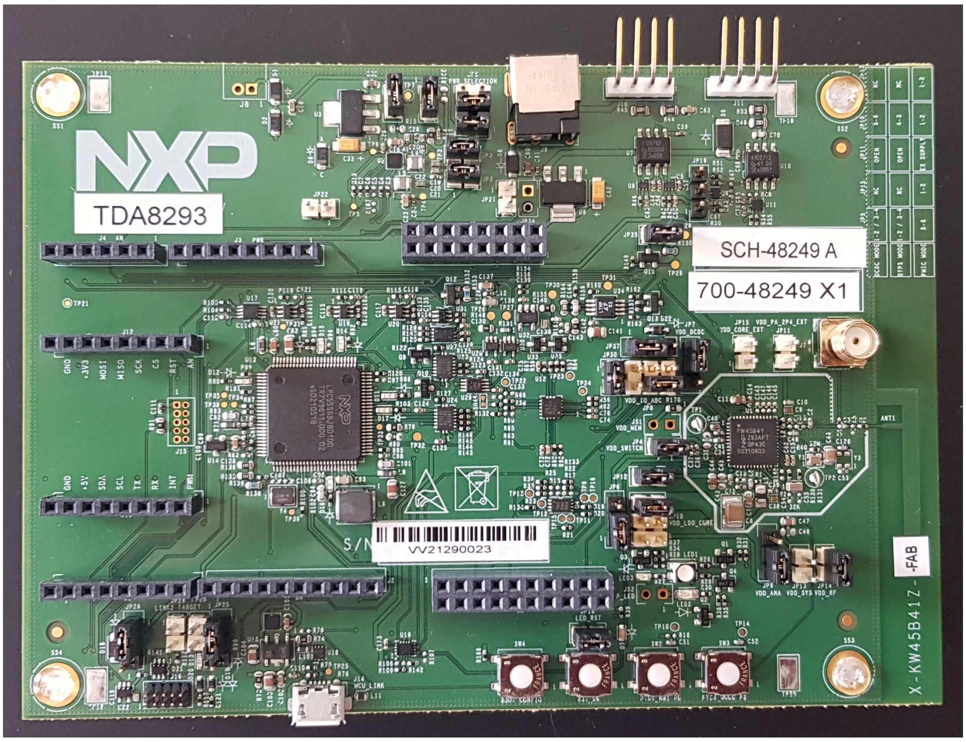


Figure 2. Evaluation Kit for Kinetis / KW45B41Z EVK

## 1.1 List of tests

- Noise interferer
- Packet Error Rate (PER) vs C/N[1]
- C/N vs frequency
- C/N vs level
- CW interferer
- Adjacent Channel Interferer (ACIs)
- Co-channel
- Bluetooth LE interferer
- Bluetooth LE ACIs
- Bluetooth LE co-channel
- Wi-Fi interferer
- Wi-Fi ACIs
- Wi-Fi co-channel

## 1.2 Software

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

The KW45B41Z page describes how to use KW45B41Z EVK to load the code. The binary code that is used for the following tests are the Connectivity Software package

1 Carrier-to-noise ratio (C/N) is also called Signal-to-noise Ratio (SNR).

GenFSK protocol (2FSK modulation) and the HCI_blackbox. The TERATERM terminal emulator is used to communicate with the KW45 MCU.

## 1.3 List of equipment

The equipment used to perform the Tx and Rx measurements is listed here:

- Spectrum Analyzer
- Rohde & Schwarz (R&S) SFU - used as an interferer source for Bluetooth LE – it can be any generator with ARBitrary signal
- MXG (Agilent N5182A)
- Agilent SML03
- Agilent 33250A
- DC power supply
- PC equipped with an IEEE-488 (GPIB) card
- Noise interference

## 1.4 Test bench setup

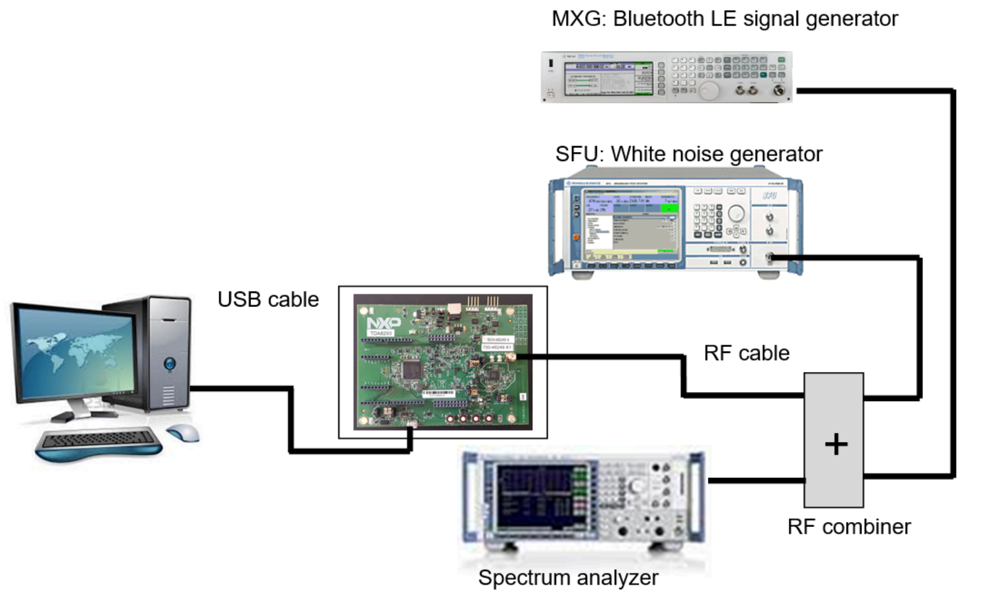


**Figure 3. Noise interferer test setup**

## 1.5 White noise interferer setup

Carrier to noise measurement highlights the demodulator (base-band) section performance.

A white noise is added into the wanted channel. The noise power is increased until the criteria PER<30.8 % is reached. The C/N is calculated on 1.02 MHz bandwidth.

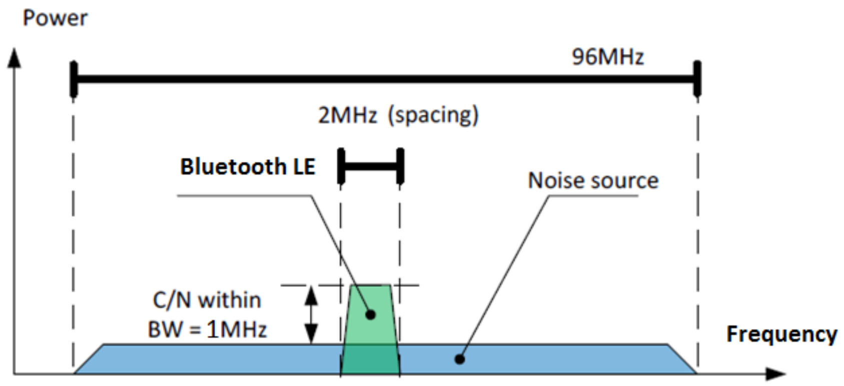


Figure 4. White noise interferer setup

## 1.6 C/N vs frequency

This section describes the test methods and results to Carrier to Noise ratio from 2.402 GHz to 2.48 GHz.

### 1.6.1 Test method

- Set the KW45 radio to: RX mode, modulated, continuous mode, frequency: from channel 0 (2.402 MHz) to channel39 (2.48 GHz).
- Set the generator to: Bluetooth LE modulated signal (typical 1500 packets of 37 bytes payload), continuous mode, frequency: from channel 0 (2.402 MHz) to channel39 (2.48 GHz), constant RF output level = -40 dBm.
- Set the analyzer for power calibration, -40 dBm on Bluetooth LE signal and white noise (BW=96 MHz on SFU). Center frequency = 2.435 GHz, span = 10 MHz, BW=2 MHz.
- C/N is set to +10 dB and decreased by step of 0.1 dB until the criteria PER<30.8 % is reached for all channels.

### 1.6.2 Result

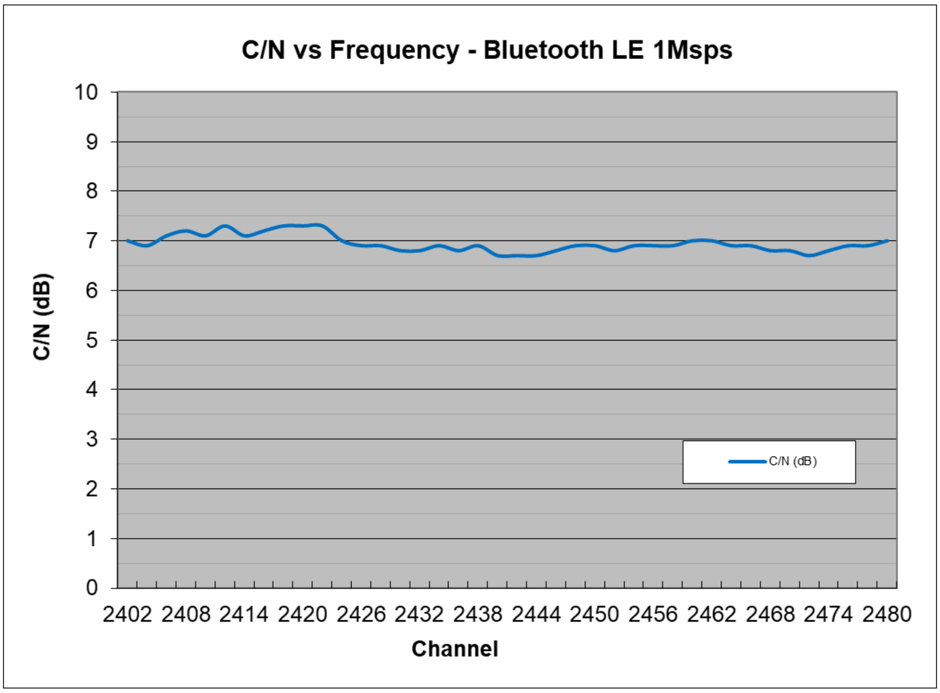


**Figure 5. C/N vs frequency**

### 1.6.3 Conclusion

C/N performance is independent from the channel (purely base-band performance).

C/N is 7 dB.

## 1.7 PER vs C/N

This section describes the test methods and results to Packet Error Rate (PER) depending on the Carrier to Noise Ratio (C/N).

### 1.7.1 Test method

- Set the KW45 radio to: RX mode, modulated, continuous mode, frequency: channel 19 (2.44 MHz).
- Set the generator to: Bluetooth LE modulated signal (typical 1500 packets of 37 bytes payload), continuous mode, frequency: channel 19 (2.44 MHz), constant RF output level = -40 dBm.
- Set the analyzer for power calibration @2.44GHz, - 40 dBm on Bluetooth LE signal and White Noise (BW=96 MHz on SFU). Center frequency = 2.435 GHz, span = 10 MHz, BW = 2 MHz.
- PER is measured for various C/N values from 1 to 11 by step of 0.5 dB.

### 1.7.2 Result

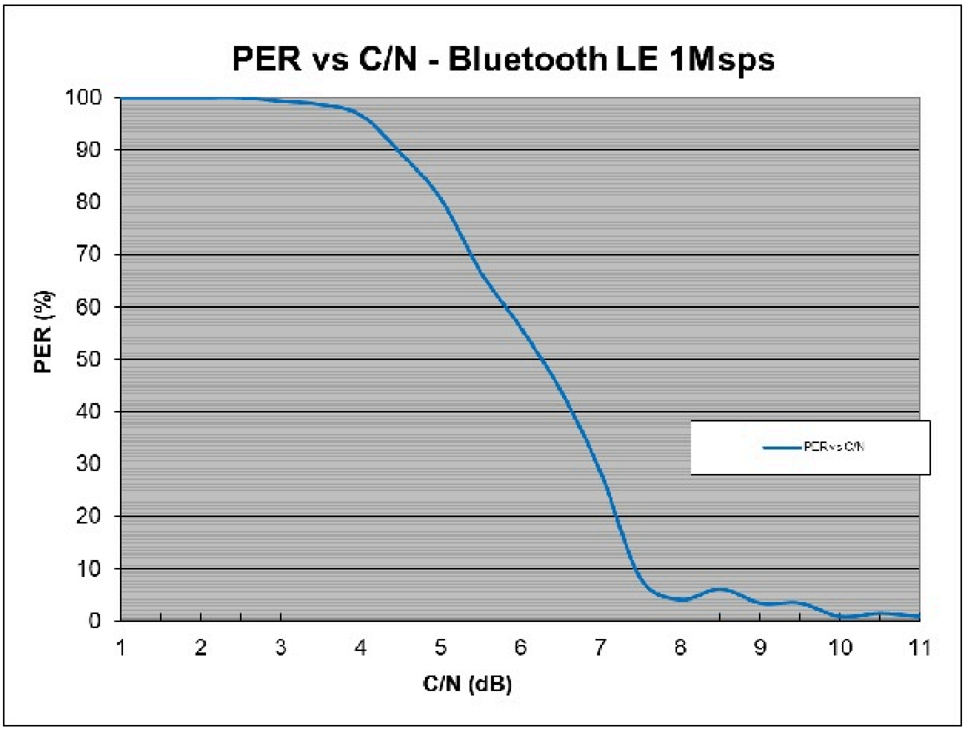


Figure 6. PER vs C/N

### 1.7.3 Conclusion

PER degrades smoothly when the noise increases. There is no abrupt degradation.

## 1.8 C/N vs level

This section describes the test methods and results to the Carrier to Noise Ratio (C/N) versus Input level from -10 dBm to -101 dBm.

### 1.8.1 Test method

- Set the KW45 radio to: RX mode, modulated, continuous mode, frequency: channel 19 (2.44 MHz).
- Set the generator to: Bluetooth LE modulated signal (typical 1500 packets of 37 bytes payload), continuous mode, frequency: from channel 19 (2.44 MHz), various RF output level from -20 dBm to the sensitivity level +1 dBm.
- Set the analyzer for power calibration on Bluetooth LE signal and white noise (BW=96 MHz on SFU). Center frequency = 2.435 GHz, span = 10 MHz, BW=2 MHz.
- A pure sinewave is swept from channel 0 (2.402 GHz) to channel 39 (2.48 GHz) with a constant level set to -20 dBm.
- PER is measured for various constant RF input level and decreasing the C/N values until the PER criteria (<30.8 %) is reached.

### 1.8.2 Result

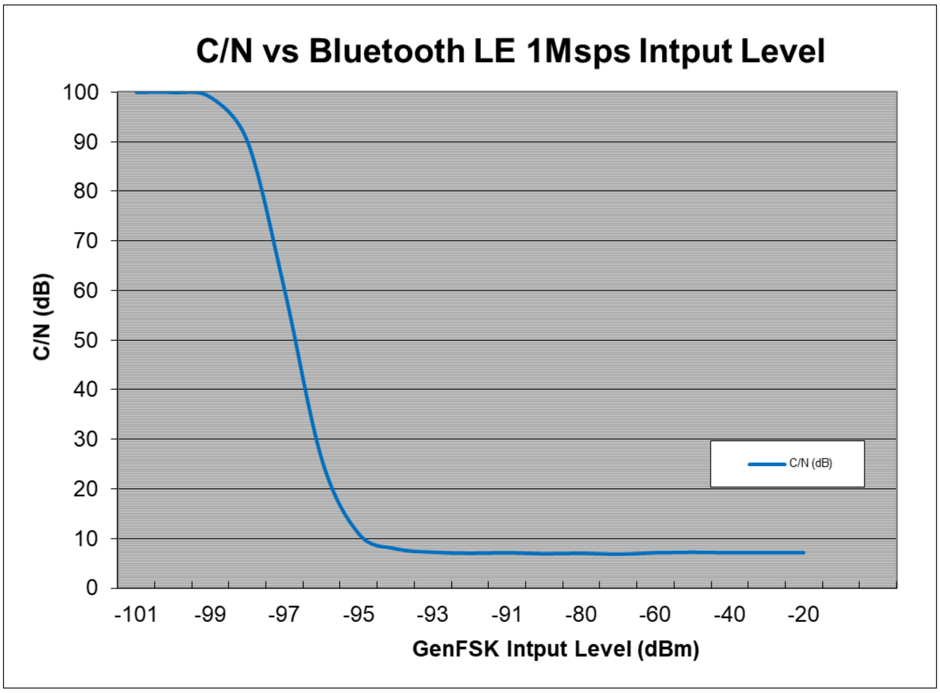


Figure 7. C/N vs Bluetooth LE RF input level

### 1.8.3 Conclusion

- For very low levels, both receiver noise (noise figure) and demodulator performance contribute to overall C/N performance.
- For higher level, the C/N is constant (independent from the receiver section).

## 2 Sinewave interference

This section describes the test bench setup, test methods, and results to Packet Error Rate (PER) depending on the Sinewave interferer.

### 2.1 Test setup

### 2.1.1 Test bench

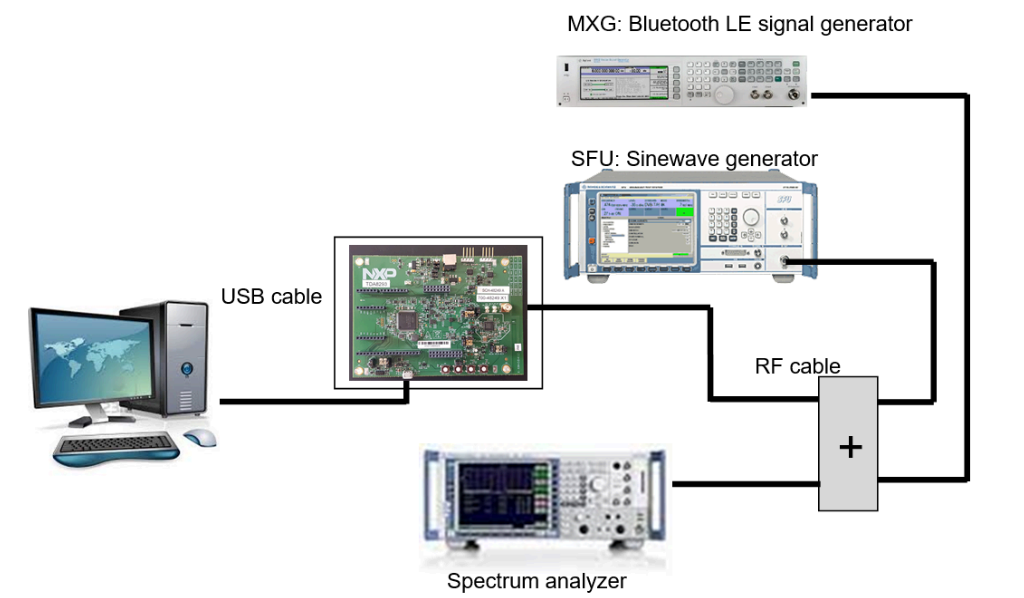


**Figure 8. Sinewave interferer test setup**

### 2.1.2 Signal definition

A pure sinewave is used in this test case to measure the ACIs (N+/-8) and co-channel immunity.

The sinewave power is increased until the criteria PER < 30.8 % is reached.

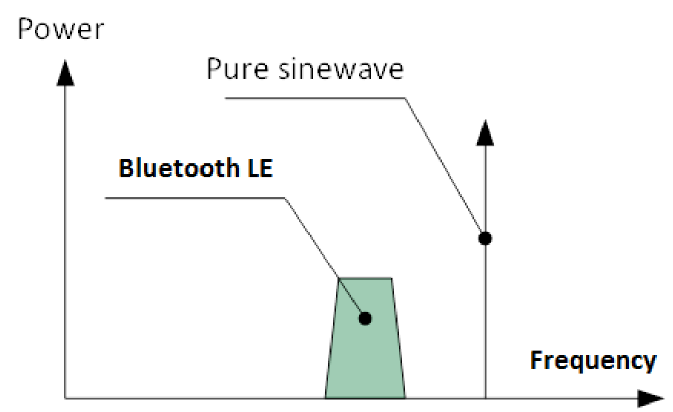


**Figure 9. Pure sinewave interferer**

## 2.2 Sinewave interference test

This section describes the test methods and results to Packet Error Rate (PER) depending on the Sine wave interferer.

### 2.2.1 Test method

- Set the KW45 radio to: RX mode(Bluetooth LE 1 Msps, 2 Msps, 500Ksps or 125Ksps), modulated, continuous mode, frequency: channel 19 (2.44 MHz).
- Set the generator to: Bluetooth LE modulated signal (typical 1500 packets of 37 bytes payload), continuous mode, frequency: channel 19 (2.44 MHz).
- Set the analyzer for power calibration on Bluetooth LE signal and Sinewave (-20 dBm).
- A pure sinewave is swept from channel 0 (2.402 GHz) to channel 39 (2.48 GHz) with a constant level set to -20 dBm.
- Bluetooth LE power is decreased until PER criteria (<30.8 %) is reached.

### 2.2.2 Result

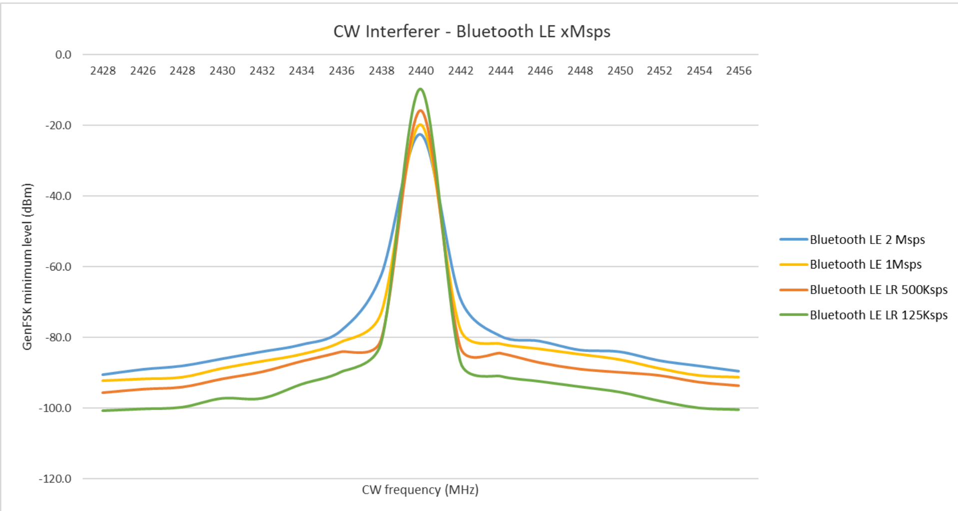


**Figure 10. RF input level vs CW frequency**

## 2.3 Conclusion

A sinewave at a slight high level (-20 dBm) acts as a blocker. The receiver regulates its gain; therefore, the noise figure increases.

# 3 Bluetooth Audio interference

This section describes the test bench setup, test methods, and results to Packet Error Rate (PER) depending on the Bluetooth audio interferer.

## 3.1 Test setup

### 3.1.1 Test bench

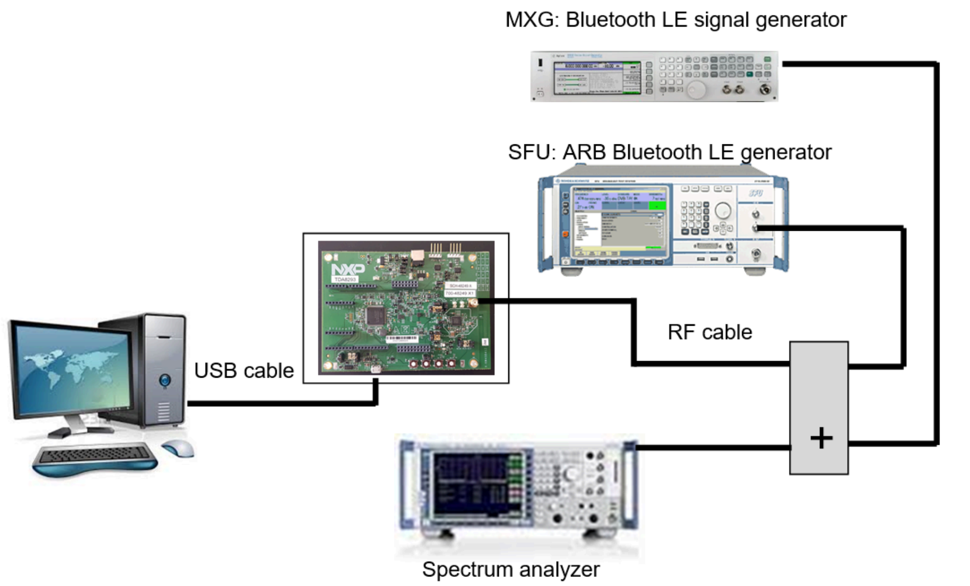


Figure 11. Bluetooth LE Interferer test setup

### 3.1.2 Signal definition

The following measurements have been made by capturing 1 channel (case 1) from a smartphone Bluetooth Audio Stream.

The Bluetooth interferer is set to a constant level at -40 dBm. Its frequency is swept from -5 MHz to +5 MHz around Bluetooth LE channel. Duty cycle is forced to 5 %.

Bluetooth LE RR level is decreased until the criteria PER<30.8 % is reached.

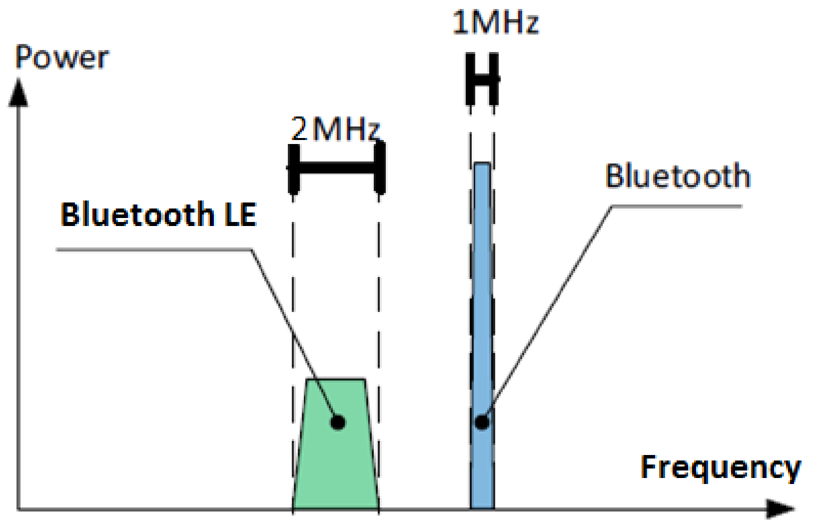


Figure 12. Bluetooth LE interferer – ACIs

## 3.2 Bluetooth Audio interference test

This section describes the test methods and results to Packet Error Rate (PER) depending on the Bluetooth audio interferer.

### 3.2.1 Test method

- Set the KW45 radio to: RX mode, modulated, continuous mode, frequency: channel 19 (2.44 MHz).
- Set the generator to: Bluetooth LE modulated signal (typical 1500 packets of 37 bytes payload), continuous mode, frequency: channel 0 (2.402 GHz), 19 (2.44 MHz), and 39 (2.48 GHz).
- Set the analyzer for power calibration on Bluetooth LE signal and Bluetooth Audio signal.
- Bluetooth Audio stream is set to a level = -40 dBm and frequency from -5 MHz to +5 MHz by step of 1 MHz around the wanted channel frequency. Duty cycle is forced to 5 %.
- Bluetooth LE power is decreased until PER criteria (<30.8 %) is reached.

### 3.2.2 Result

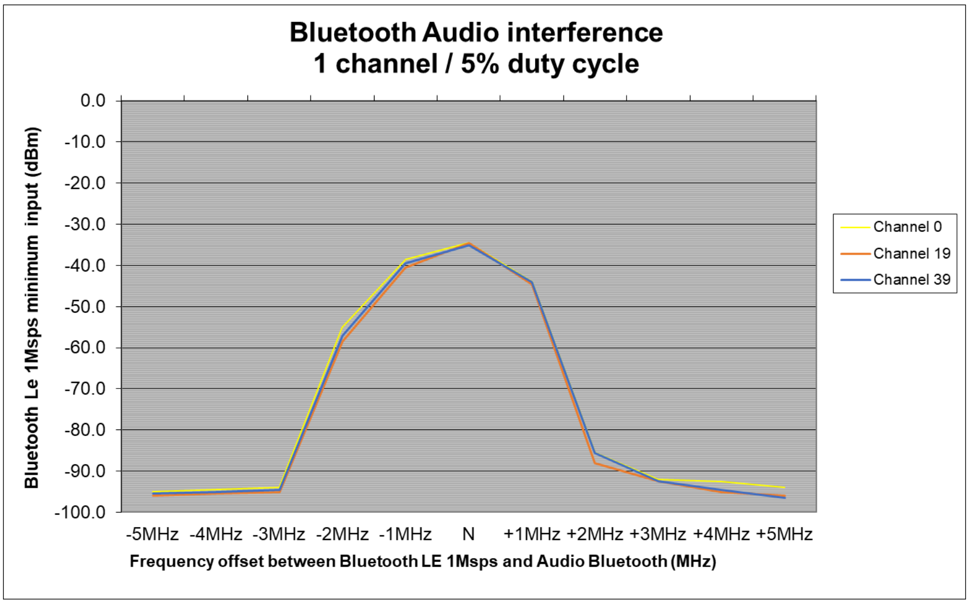


Figure 13. Bluetooth LE minimum input level vs Bluetooth audio stream interferer

### 3.2.3 Conclusion

- For co-channel, the carrier to interference ratio (C/I) is +4.5 dB (Bluetooth LE ch0, 19 or 39).
- For a Bluetooth channel outside the receiver bandwidth, the immunity performance increases rapidly.

# 4 Wi-Fi interference

This section describes the test bench setup, test methods, and results to Packet Error Rate (PER) depending on the Wi-Fi interferer.

## 4.1 Test setup

### 4.1.1 Test bench

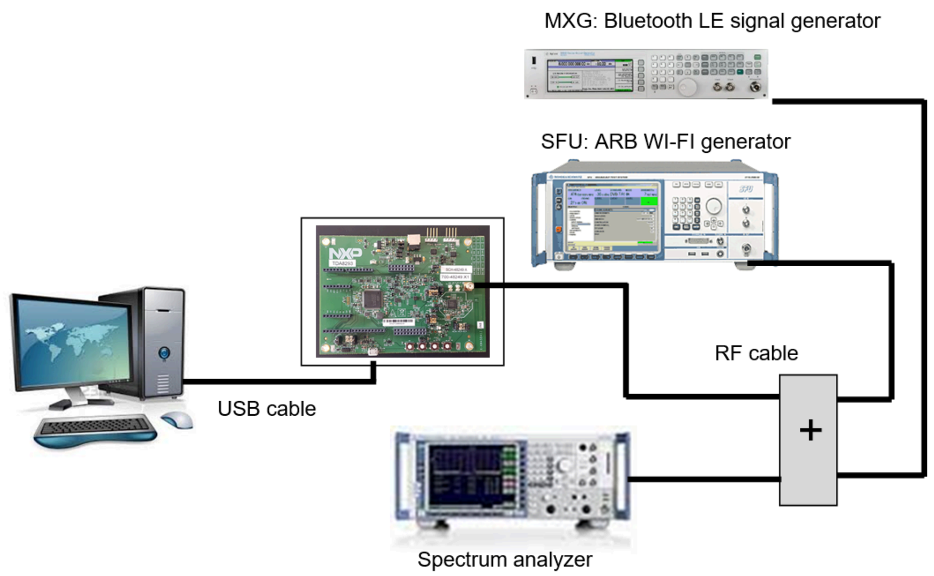


**Figure 14. Wi-Fi Interferer test setup**

### 4.1.2 Signal definition

A real Wi-Fi signal has been sampled and used for this test series:

- 802.11n mode, 20 MHz bandwidth (signal antenna).
- Access point (client) is sending datagrams to station (server).
- The theoretical data rate set on the AP is 100 Mbits/s (full load).
- A report is sent back by the station every second to show the practical measured throughput (typically 58 Mbit/s).

The streaming has been sampled with a Signal analyzer (sample frequency 40 MHz, length 1 s).

IQ samples are played with an RF arbitrary generator to simulate a Controlled Wi-Fi adjacent signal.

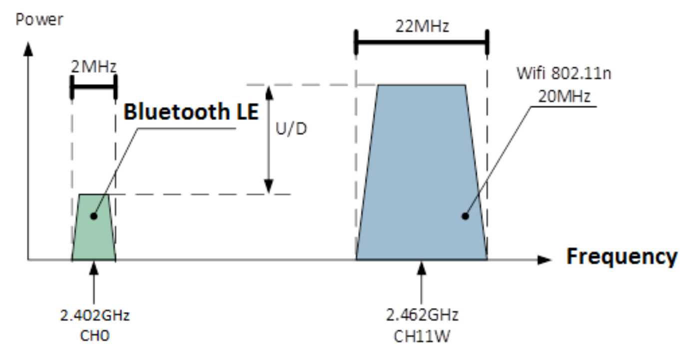


Figure 15. Wi-Fi interferer – ACIs

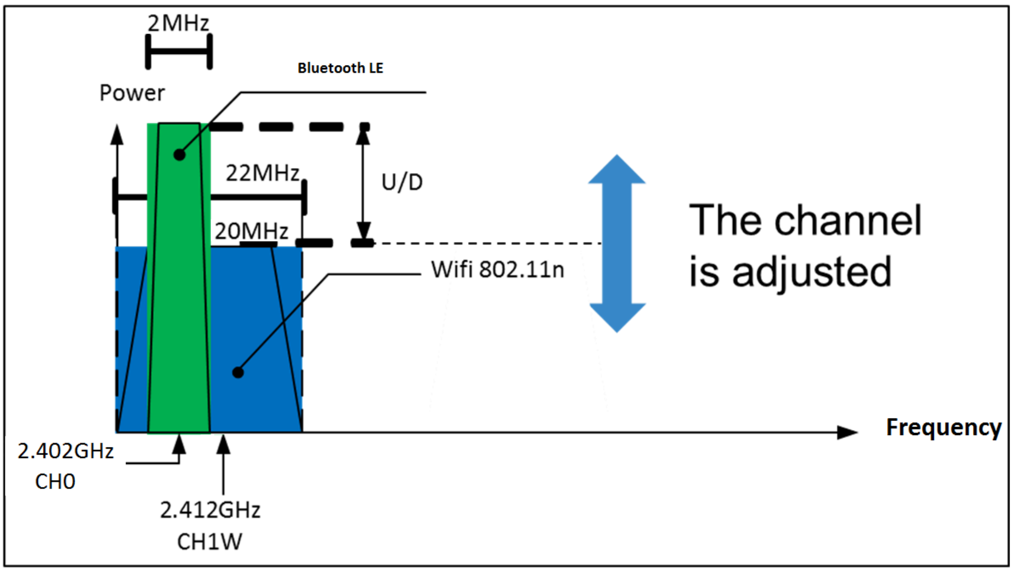


Figure 16. Wi-Fi interferer – co-channel

## 4.2 Wi-Fi interference tests

This section describes the test methods and results to Packet Error Rate (PER) depending on the Wi-Fi interferer.

### 4.2.1 ACIs test method

- Set the KW45 radio to: RX mode (Bluetooth LE 1 Msps, 2 Msps, 500 Ksps or 125 Ksps), modulated, continuous mode, frequency: channel 0 (2.402 MHz).
- Set the generator to: Bluetooth LE modulated signal (typical 1500 packets of 37 bytes payload), continuous mode, frequency: channel 0 (2.402 MHz).
- Set the analyzer for power calibration on Bluetooth LE signal and Wi-Fi signal.
- Wi-Fi signal (BW=22 MHz) is set from a level of -40 dBm to 0 dBm, channel 11 (2.462 GHz), and channel 6 (2.437 GHz).
- Bluetooth LE power is decreased until PER criteria (<30.8 %) is reached.

### 4.2.2 ACIs result

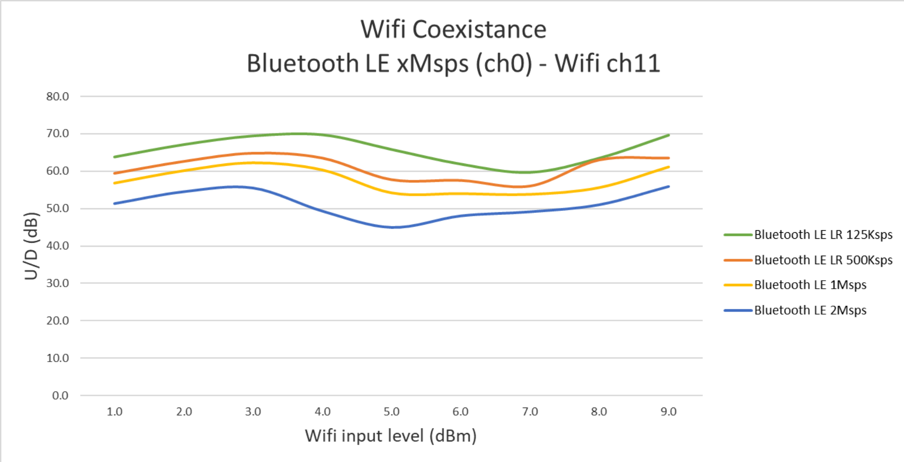


**Figure 17. Bluetooth LE and Wi-Fi coexistence (ACIs)**

### 4.2.3 Co-channel test method

- Set the KW45 radio to: RX mode (Bluetooth LE 1 Msps, 2 Msps, 500Ksps or 125Ksps), modulated, continuous mode, frequency: channel 0 (2.402 MHz).
- Set the generator to: Bluetooth LE modulated signal (typical 1500 packets of 37 bytes payload), continuous mode, frequency: channel 0 (2.402 MHz).
- Set the analyzer for power calibration on Bluetooth LE signal and Wi-Fi signal.
- Wi-Fi signal (BW=22 MHz) is set from a level of -40 dBm to 0 dBm, channel 1 (2.412 GHz).
- Bluetooth LE power is decreased until PER criteria (< 30.8 %) is reached.

### 4.2.4 Co-channel result

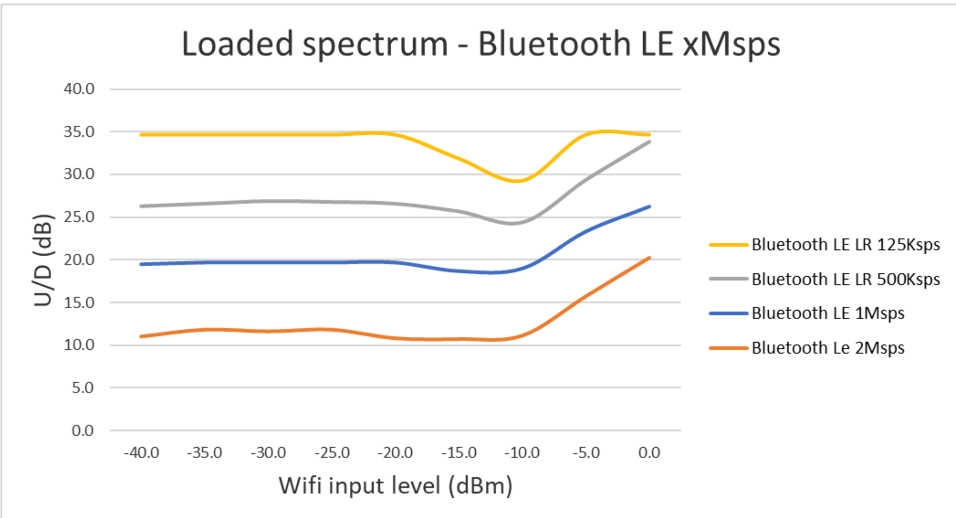


**Figure 18. Bluetooth LE and Wi-Fi co-channel**

### 4.3 Conclusion

The ratio between Unwanted and Wanted power is relatively constant whatever the Wi-Fi interferer vs Bluetooth LE rate.

## 5 Revision history

| Revision number | Date | Substantive changes |
|---|---|---|
| 0 | 31 January 2022 | Initial release |

 

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