

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](#).

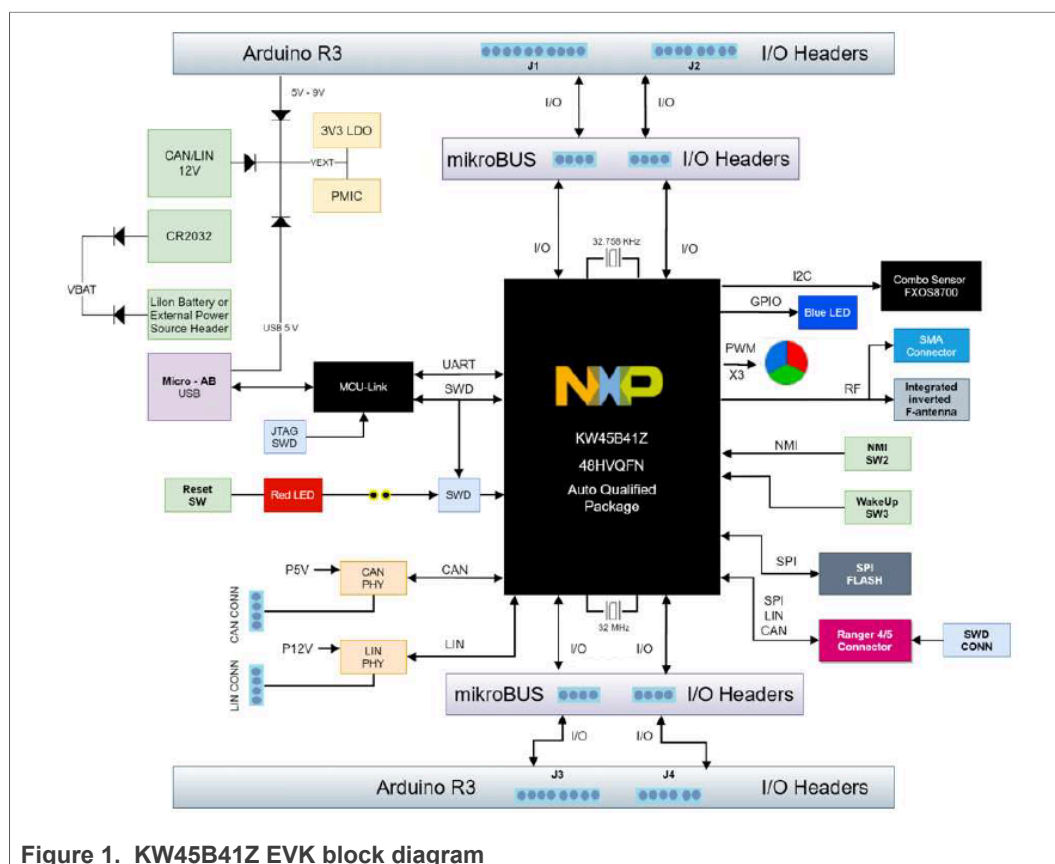


Figure 1. KW45B41Z EVK block diagram

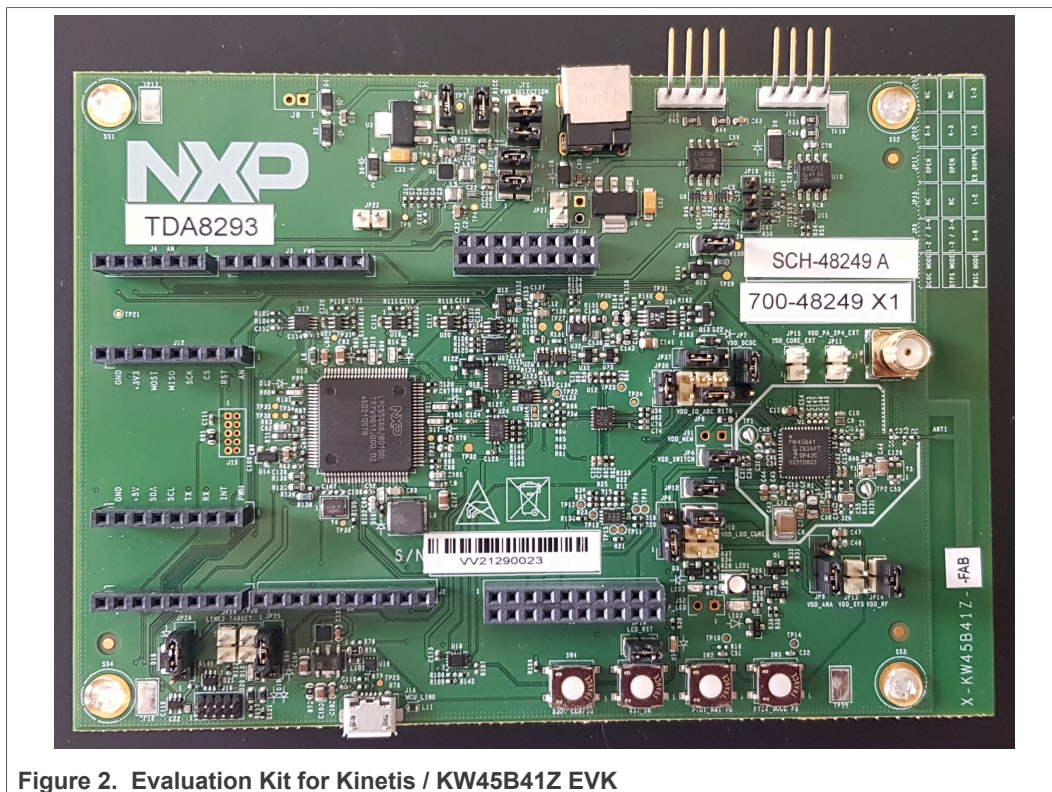


Figure 2. Evaluation Kit for Kinetis / KW45B41Z EVK

1.1 List of tests

- Noise interferer
- Packet Error Rate (PER) vs C/N¹
- 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).

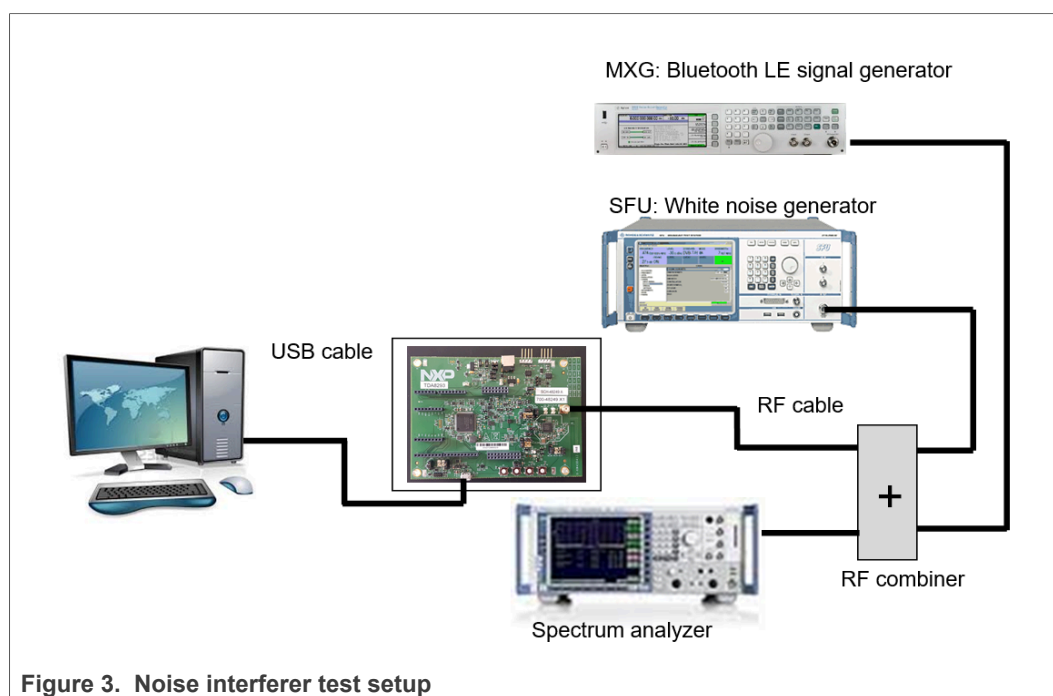
GenFSK protocol (2FSK modulation) and the HCI_blackbox. The TERATERM terminal emulator is used to communicate with the KW45 MCU.

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



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.

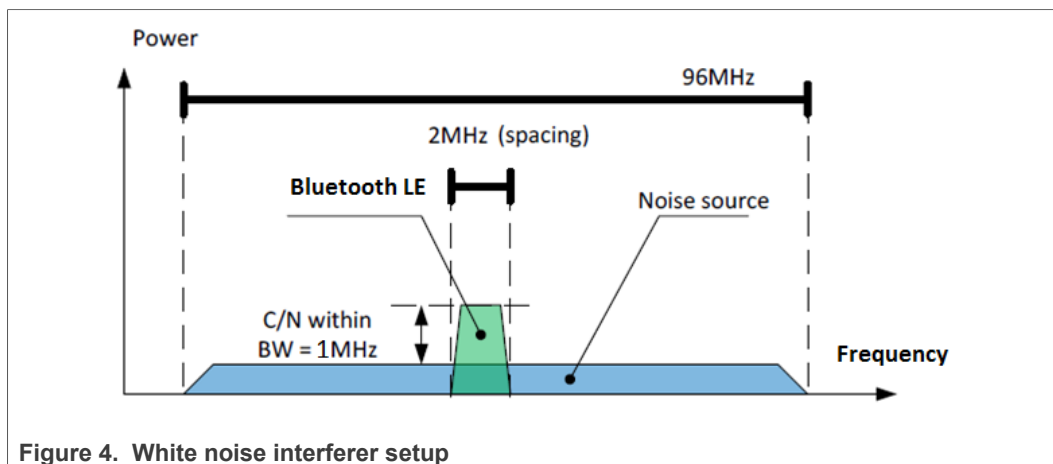


Figure 4. White noise interferer setup

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

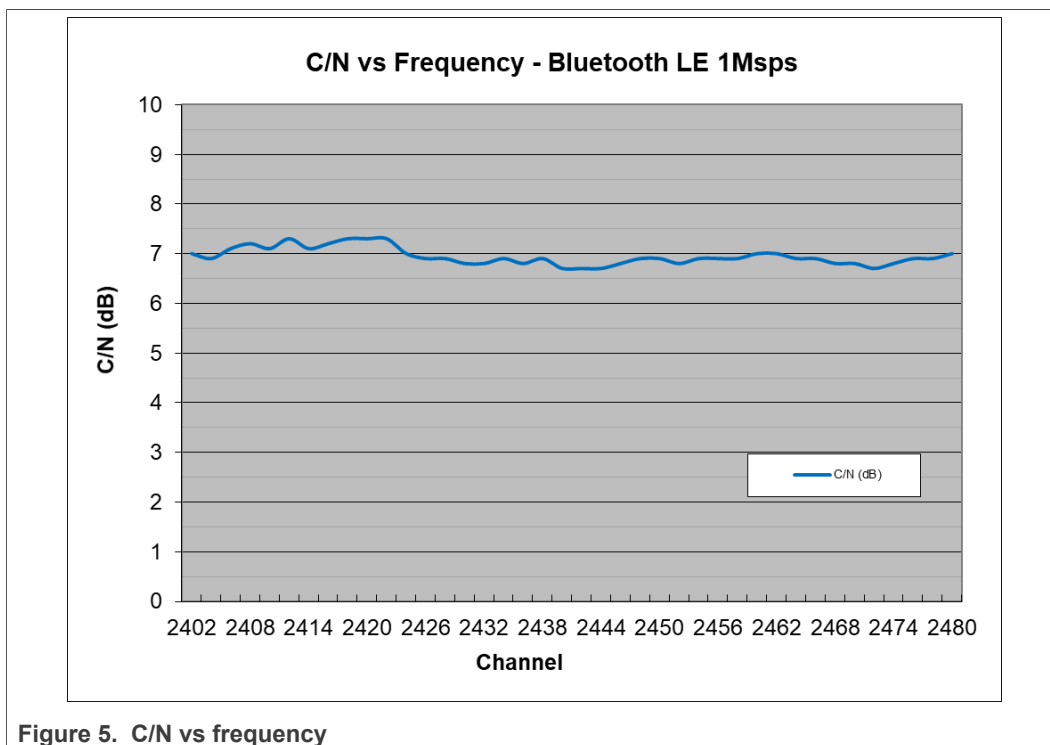


Figure 5. C/N vs frequency

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

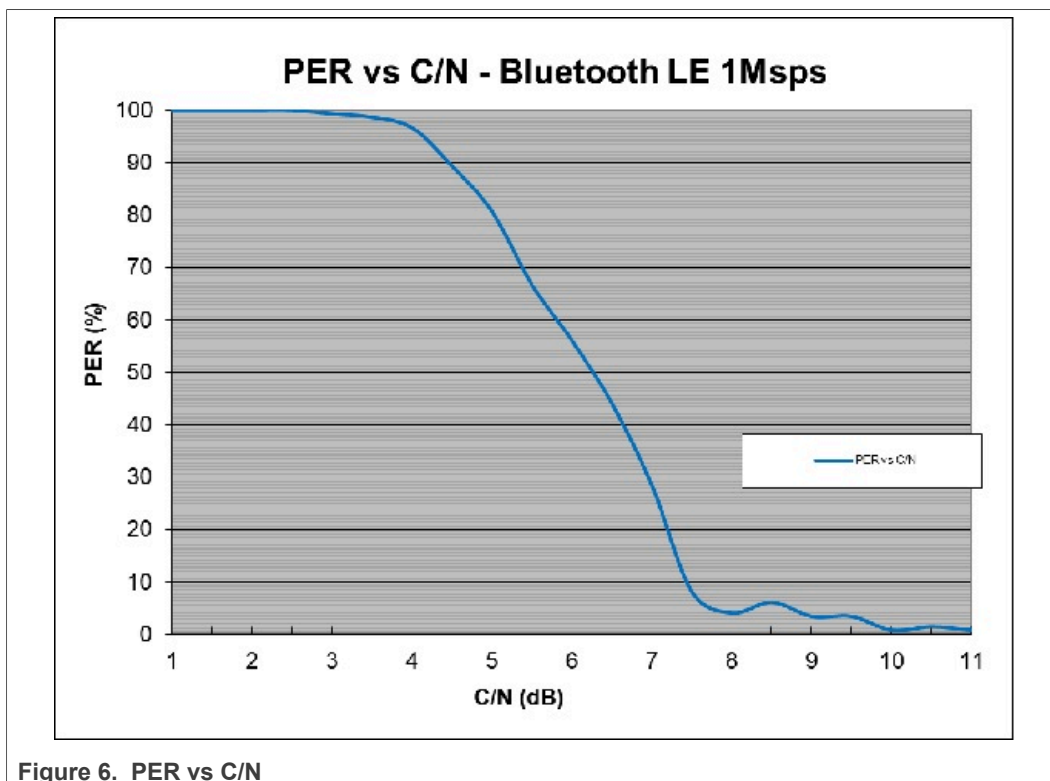


Figure 6. PER vs C/N

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

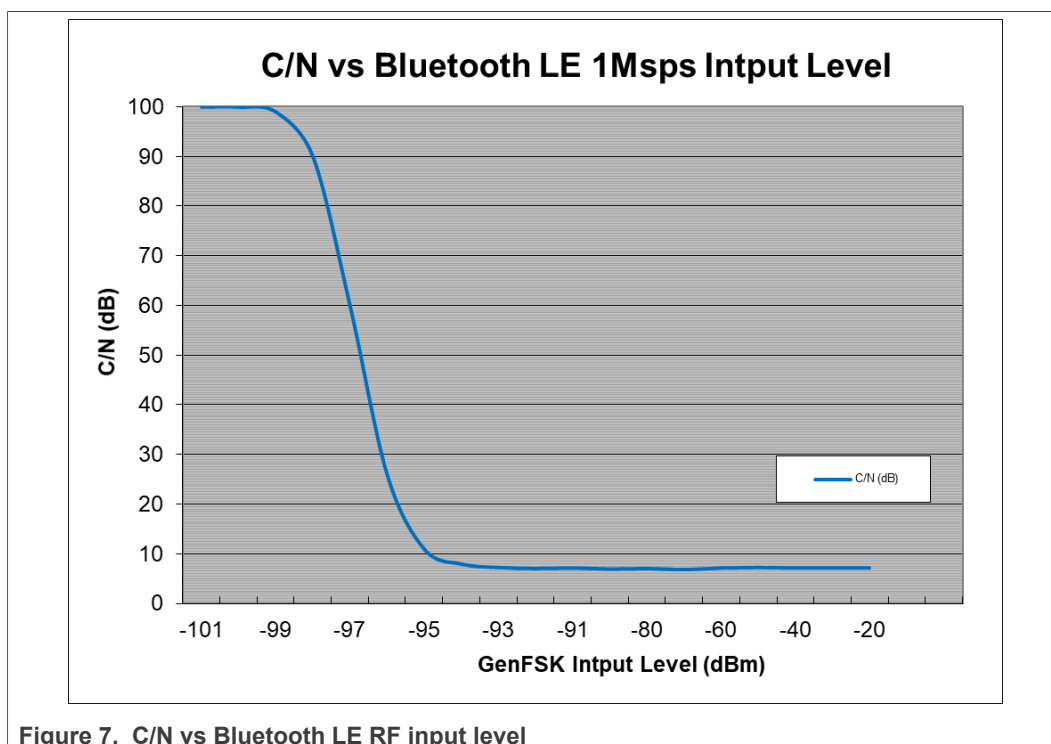


Figure 7. C/N vs Bluetooth LE RF input level

1.8.3 Conclusion

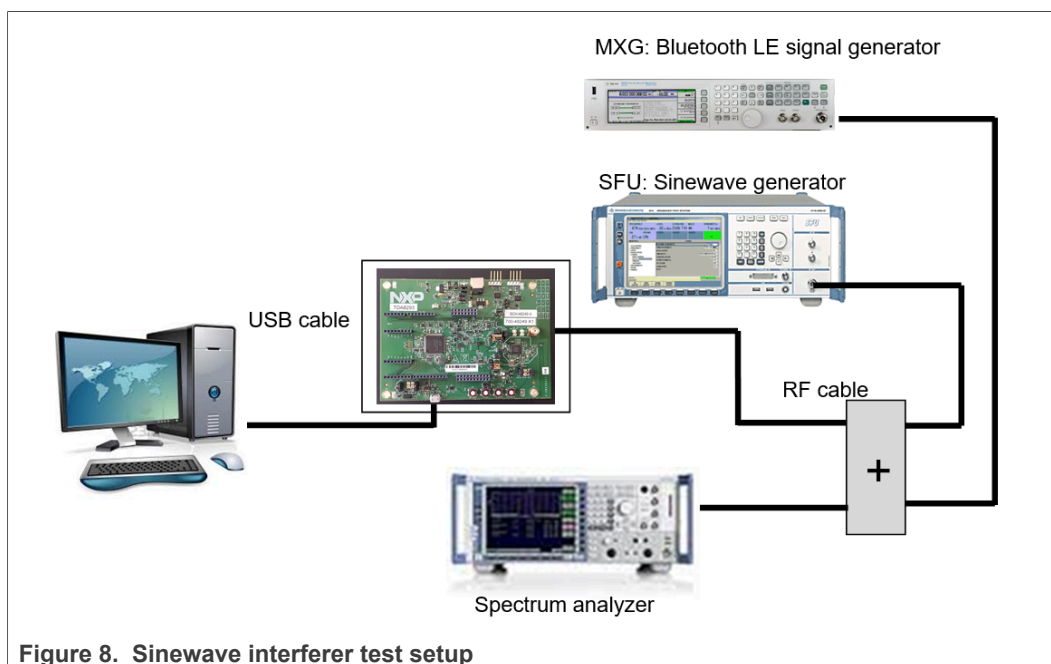
- For very low levels, both receiver noise (noise figure) and demodulator performance contribute to overall C/N performance.
- For higher level, the C/N is constant (independent from the receiver section).

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

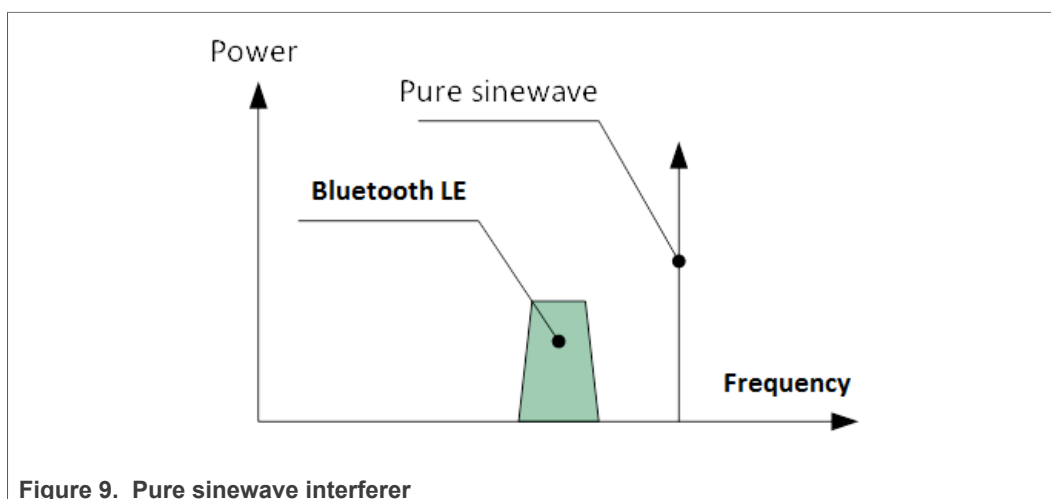
2.1.1 Test bench



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.



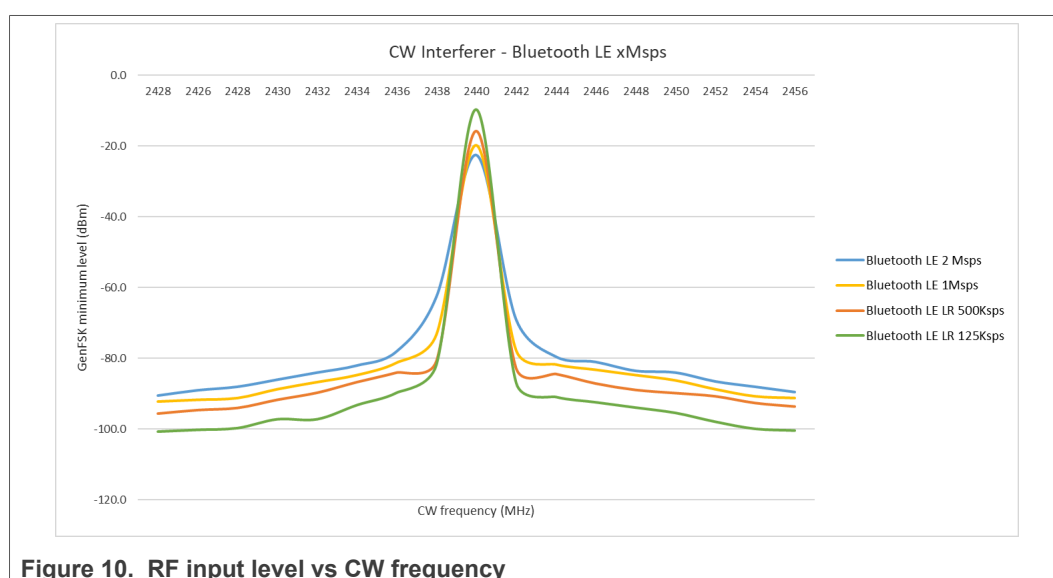
2.2 Sinewave interference test

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



2.3 Conclusion

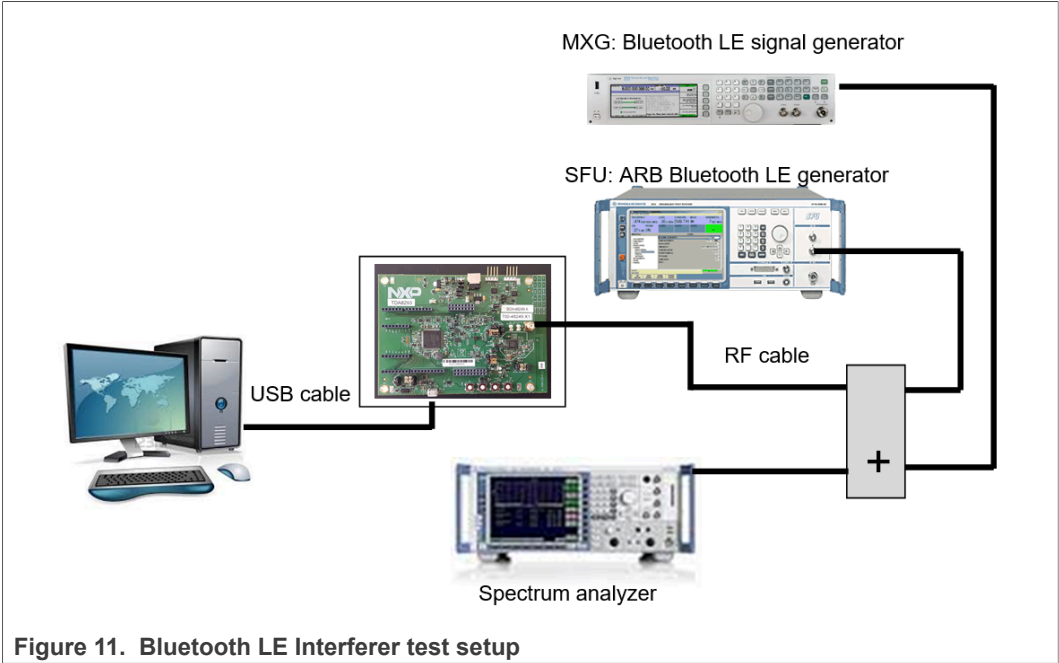
A sinewave at a slight high level (-20 dBm) acts as a blocker. The receiver regulates its gain; therefore, the noise figure increases.

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

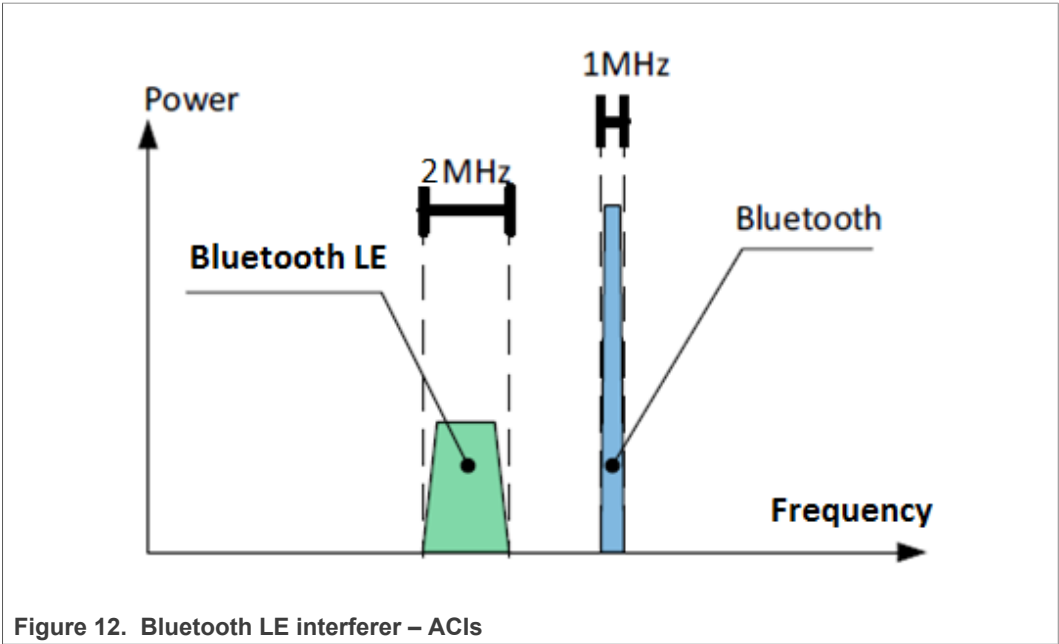


3.1.2 Signal definition

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.



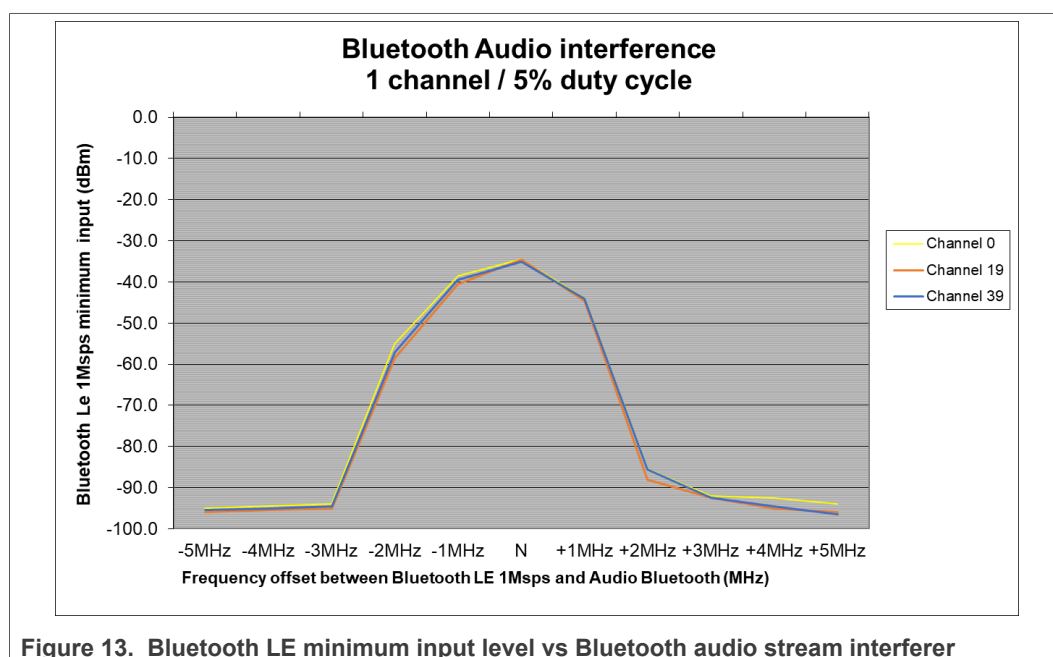
3.2 Bluetooth Audio interference test

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



3.2.3 Conclusion

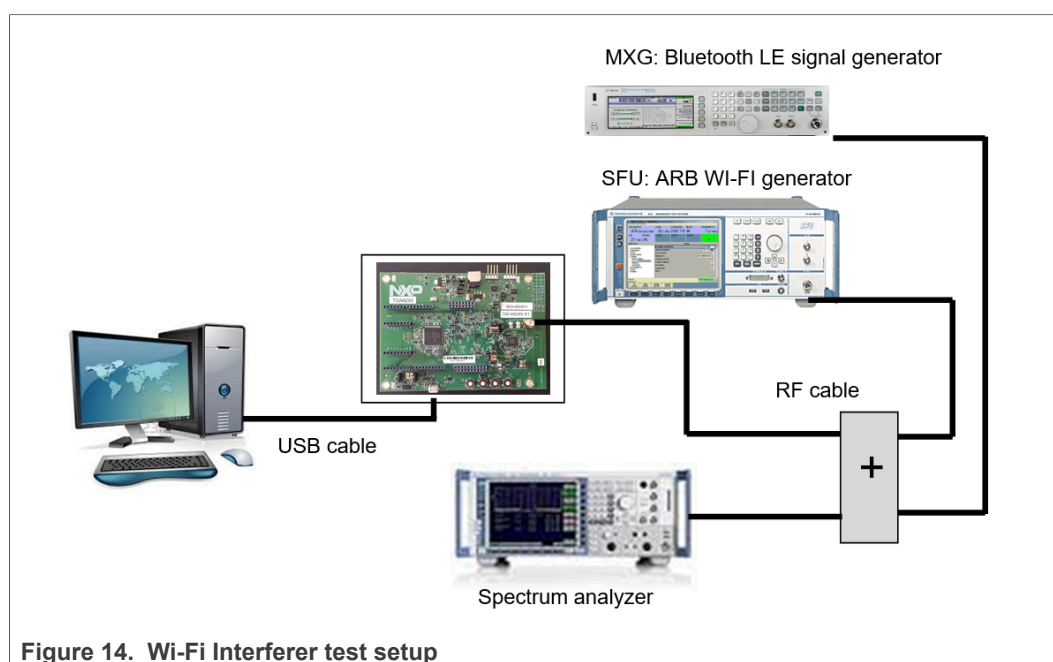
- For co-channel, the carrier to interference ratio (C/I) is +4.5 dB (Bluetooth LE ch0, 19 or 39).
- For a Bluetooth channel outside the receiver bandwidth, the immunity performance increases rapidly.

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



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.

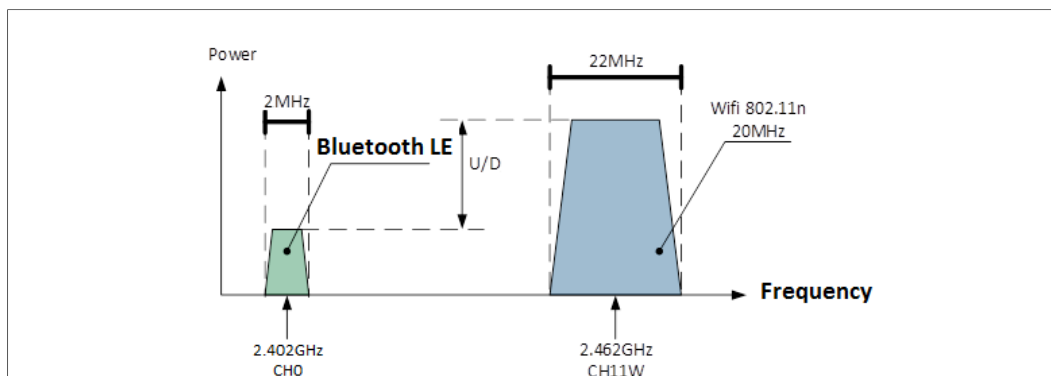


Figure 15. Wi-Fi interferer – ACIs

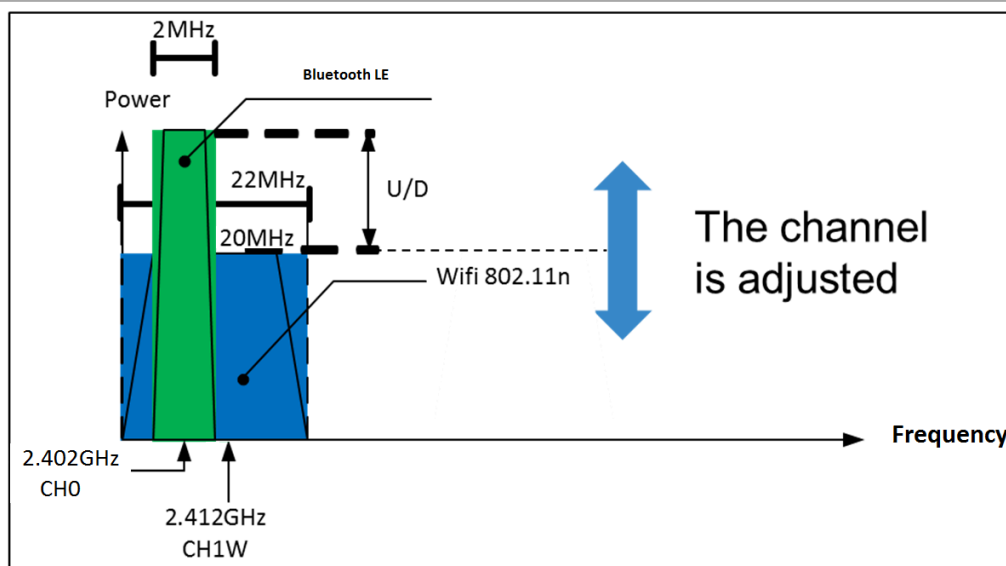


Figure 16. Wi-Fi interferer – co-channel

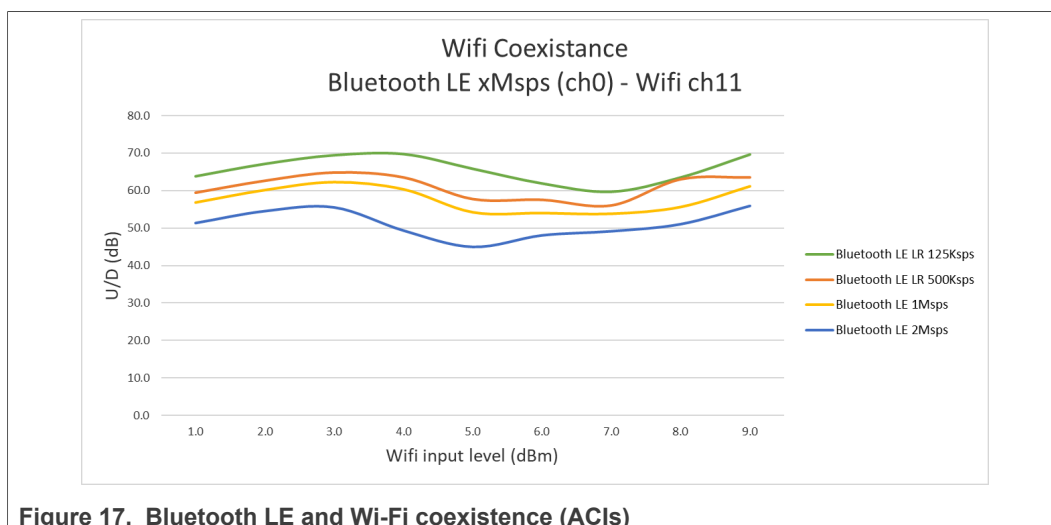
4.2 Wi-Fi interference tests

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.

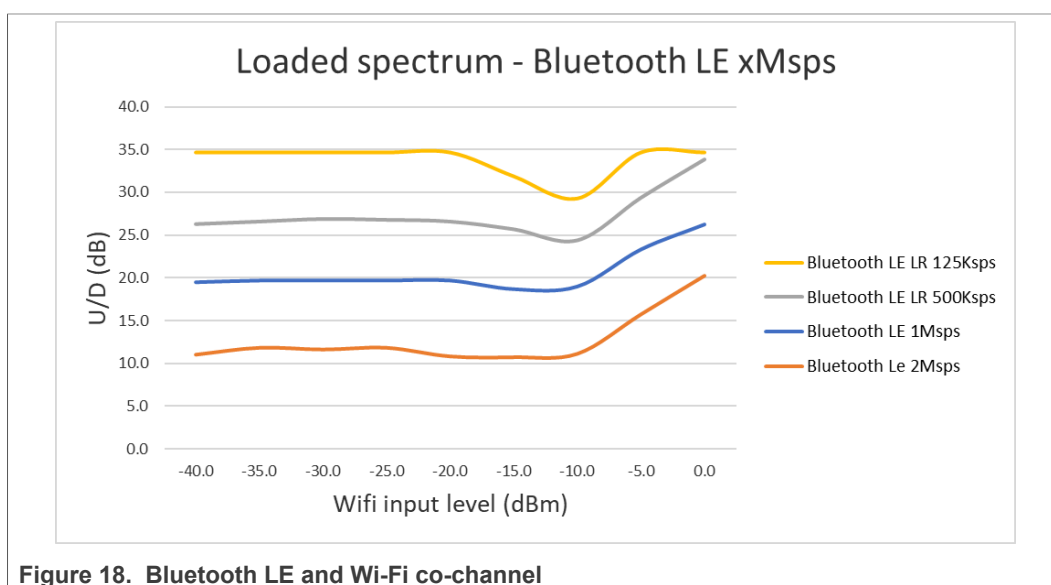
4.2.2 ACIs result



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



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 |

6 Legal information

6.1 Definitions

Draft — A draft status on a document indicates that the content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included in a draft version of a document and shall have no liability for the consequences of use of such information.

6.2 Disclaimers

Limited warranty and liability — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

Right to make changes — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

Suitability for use — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors and its suppliers accept no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

Applications — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification. Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

Terms and conditions of commercial sale — NXP Semiconductors products are sold subject to the general terms and conditions of commercial sale, as published at <http://www.nxp.com/profile/terms>, unless otherwise agreed in a valid written individual agreement. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. NXP Semiconductors hereby expressly objects to applying the customer's general terms and conditions with regard to the purchase of NXP Semiconductors products by customer.

Export control — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

Suitability for use in non-automotive qualified products — Unless this data sheet expressly states that this specific NXP Semiconductors product is automotive qualified, the product is not suitable for automotive use. It is neither qualified nor tested in accordance with automotive testing or application requirements. NXP Semiconductors accepts no liability for inclusion and/or use of non-automotive qualified products in automotive equipment or applications.

In the event that customer uses the product for design-in and use in automotive applications to automotive specifications and standards, customer (a) shall use the product without NXP Semiconductors' warranty of the product for such automotive applications, use and specifications, and (b) whenever customer uses the product for automotive applications beyond NXP Semiconductors' specifications such use shall be solely at customer's own risk, and (c) customer fully indemnifies NXP Semiconductors for any liability, damages or failed product claims resulting from customer design and use of the product for automotive applications beyond NXP Semiconductors' standard warranty and NXP Semiconductors' product specifications.

Translations — A non-English (translated) version of a document, including the legal information in that document, is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

Security — Customer understands that all NXP products may be subject to unidentified vulnerabilities or may support established security standards or specifications with known limitations. Customer is responsible for the design and operation of its applications and products throughout their lifecycles to reduce the effect of these vulnerabilities on customer's applications and products. Customer's responsibility also extends to other open and/or proprietary technologies supported by NXP products for use in customer's applications. NXP accepts no liability for any vulnerability. Customer should regularly check security updates from NXP and follow up appropriately. Customer shall select products with security features that best meet rules, regulations, and standards of the intended application and make the ultimate design decisions regarding its products and is solely responsible for compliance with all legal, regulatory, and security related requirements concerning its products, regardless of any information or support that may be provided by NXP.

NXP has a Product Security Incident Response Team (PSIRT) (reachable at PSIRT@nxp.com) that manages the investigation, reporting, and solution release to security vulnerabilities of NXP products.

6.3 Trademarks

Notice: All referenced brands, product names, service names, and trademarks are the property of their respective owners.

NXP — wordmark and logo are trademarks of NXP B.V.

Contents

| | | |
|----------|---|-----------|
| 1 | Introduction | 2 |
| 1.1 | List of tests | 3 |
| 1.2 | Software | 3 |
| 1.3 | List of equipment | 4 |
| 1.4 | Test bench setup | 4 |
| 1.5 | White noise interferer setup | 4 |
| 1.6 | C/N vs frequency | 5 |
| 1.6.1 | Test method | 5 |
| 1.6.2 | Result | 6 |
| 1.6.3 | Conclusion | 6 |
| 1.7 | PER vs C/N | 6 |
| 1.7.1 | Test method | 6 |
| 1.7.2 | Result | 7 |
| 1.7.3 | Conclusion | 7 |
| 1.8 | C/N vs level | 7 |
| 1.8.1 | Test method | 7 |
| 1.8.2 | Result | 8 |
| 1.8.3 | Conclusion | 8 |
| 2 | Sinewave interference | 8 |
| 2.1 | Test setup | 8 |
| 2.1.1 | Test bench | 9 |
| 2.1.2 | Signal definition | 9 |
| 2.2 | Sinewave interference test | 9 |
| 2.2.1 | Test method | 10 |
| 2.2.2 | Result | 10 |
| 2.3 | Conclusion | 10 |
| 3 | Bluetooth Audio interference | 10 |
| 3.1 | Test setup | 10 |
| 3.1.1 | Test bench | 11 |
| 3.1.2 | Signal definition | 11 |
| 3.2 | Bluetooth Audio interference test | 12 |
| 3.2.1 | Test method | 12 |
| 3.2.2 | Result | 12 |
| 3.2.3 | Conclusion | 12 |
| 4 | Wi-Fi interference | 13 |
| 4.1 | Test setup | 13 |
| 4.1.1 | Test bench | 13 |
| 4.1.2 | Signal definition | 13 |
| 4.2 | Wi-Fi interference tests | 14 |
| 4.2.1 | ACIs test method | 14 |
| 4.2.2 | ACIs result | 15 |
| 4.2.3 | Co-channel test method | 15 |
| 4.2.4 | Co-channel result | 15 |
| 4.3 | Conclusion | 16 |
| 5 | Revision history | 16 |
| 6 | Legal information | 17 |

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section 'Legal information'.