AN14515

FRDM-MCXW71 RF System Evaluation Report for Bluetooth Low Energy Applications with Interferer Coexistence

Rev. 1.0 — 13 January 2025 Application note

Document information

Information	Content
Keywords	MCX W71, MCU, RF, Bluetooth, Bluetooth LE, FRDM-MCXW71, AN14515
Abstract	The document describes test setup and provides steps to perform the RF system evaluation test of FRDM-MCXW71 for Bluetooth LE applications (2FSK modulation) with coexistence of the following interferers: noise, Sinewave, Bluetooth audio, and Wi-Fi.

1 Introduction

The document describes test setup and provides steps to perform the RF system evaluation test of FRDM-MCXW71 for Bluetooth LE applications (2FSK modulation) with coexistence of the following interferers: noise, Sinewave, Bluetooth audio, and Wi-Fi.

To get the MCX W71 radio parameters, see the *MCX W71 Data Sheet* (document MCX W71).

For more information about the FRDM-MCXW71 board, see *Hardware Design Considerations for MCX W71 Bluetooth LE Devices* (document UG10146). Find the schematic and design files at this link.

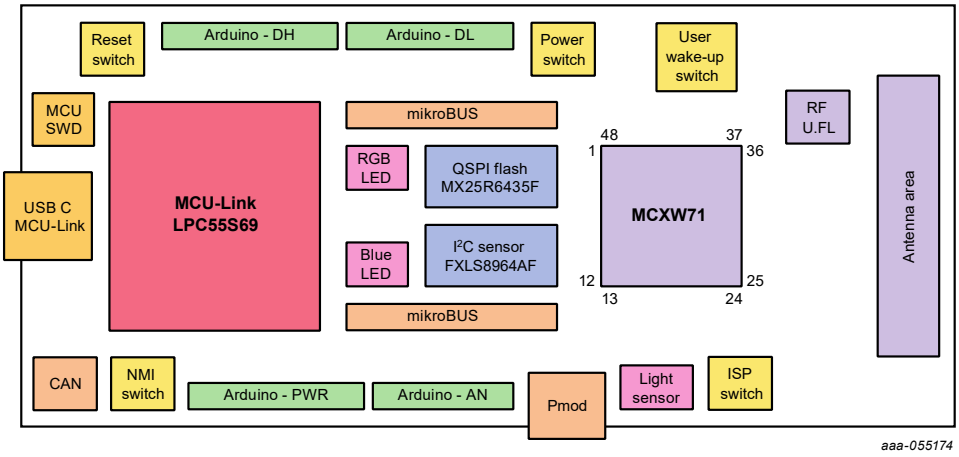

Figure 1. FRDM-MCXW71 block diagram

Figure 2 shows the top-view of the FRDM-MCXW71 board.

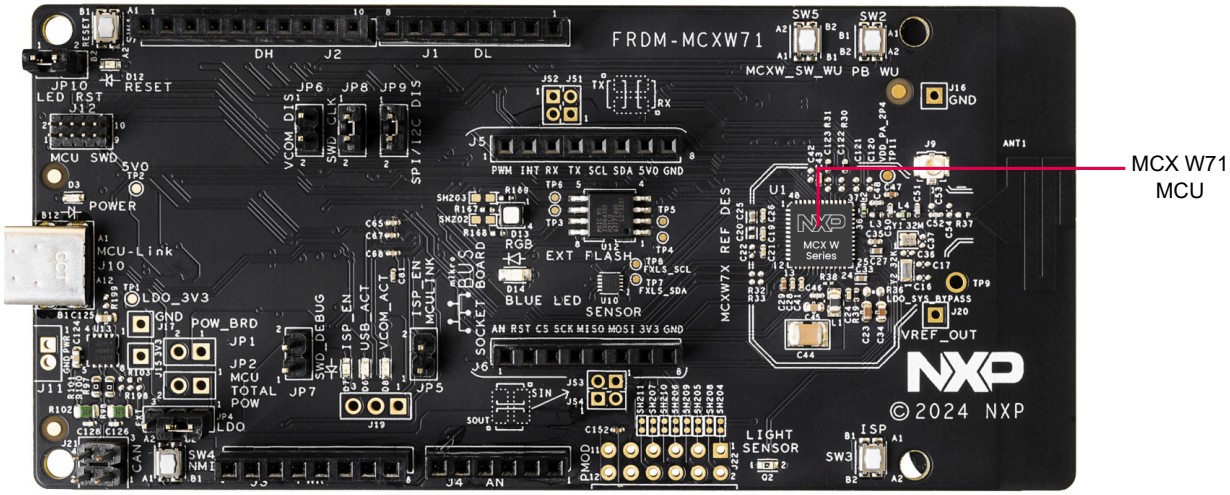

Figure 2. Evaluation kit for FRDM-MCXW71

1.1 List of tests

The list of RF system evaluation tests is as follows:

- Noise interferer
- Packet error rate (PER) versus C/N[1]

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

- C/N versus frequency
- C/N versus level
- CW interferer
- Adjacent-channel interference (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 MCX W71 page describes how to use the FRDM-MCXW71 board to load the code. The binary code that is used for the evaluation tests are the Connectivity Software package GenFSK protocol (2FSK modulation) and the HCI_blackbox. The Teraterm terminal emulator is used to communicate with the MCX W71 MCU.

1.3 List of equipment

The equipments used to perform the TX and RX measurements are listed as follows:

- 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 shows the noise interferer test setup.

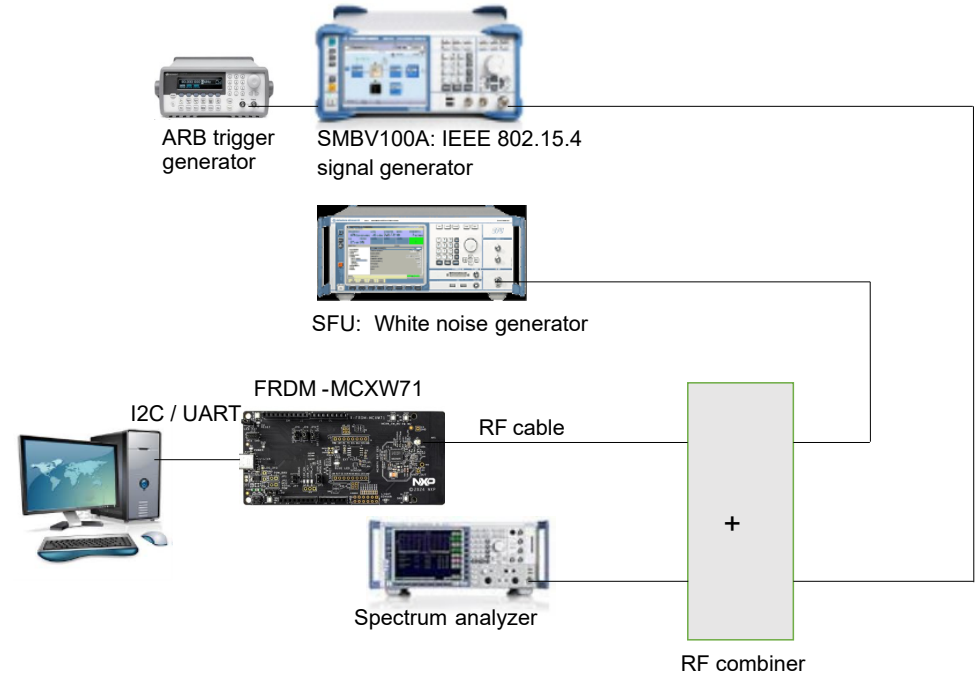

Figure 3. Noise interferer test setup

1.5 White noise interferer setup

Carrier-to-noise (C/N) 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.

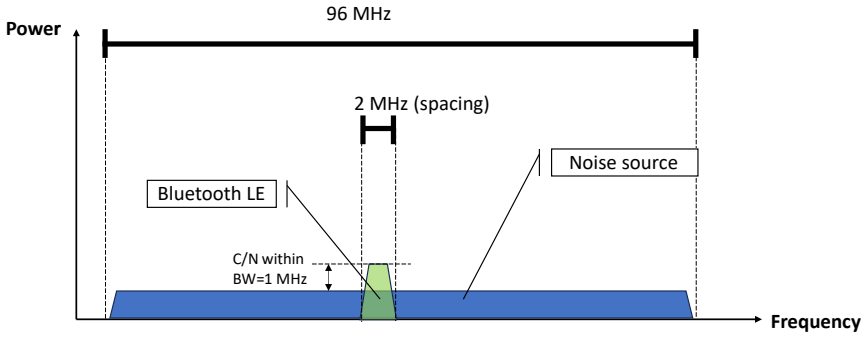

Figure 4. White noise interferer setup

1.6 C/N versus frequency

This section describes the test methods and results to carrier-to-noise ratio (C/N) from 2.402 GHz to 2.48 GHz.

1.6.1 Test method

- Set the MCX W71 radio to: RX mode, modulated, continuous mode, frequency: from channel 0 (2.402 MHz) to channel 39 (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 channel 39 (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 shows the test result for C/N versus frequency ranging from 2.402 GHz to 2.48 GHz.

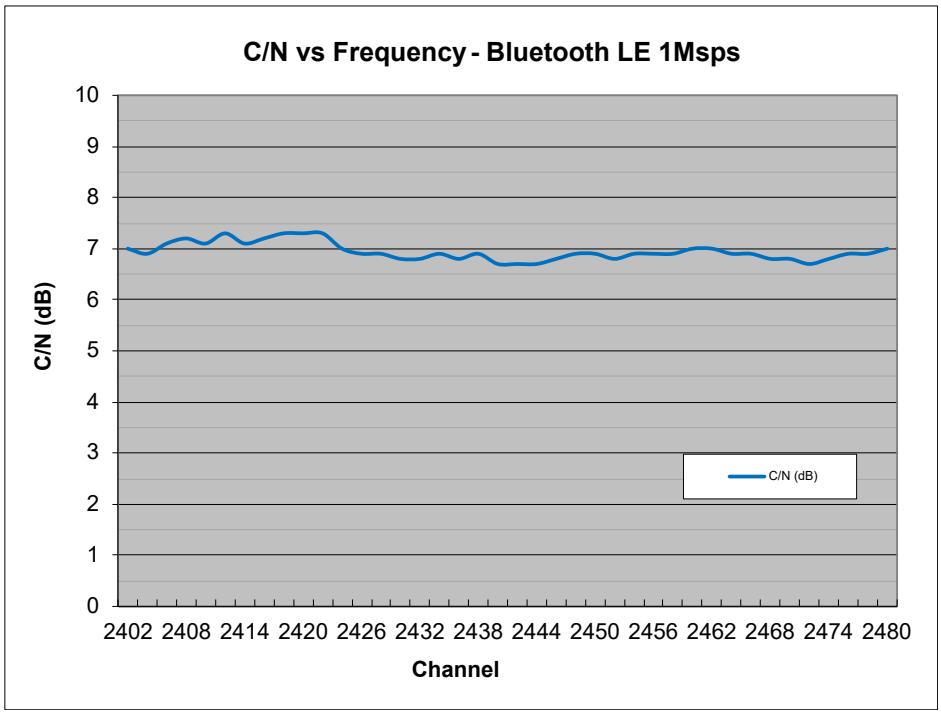

Figure 5. C/N versus frequency

1.6.3 Conclusion

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

C/N is 7 dB.

1.7 PER versus 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 MCX W71 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 a step of 0.5 dB.

1.7.2 Result

Figure 6 shows the test result for PER versus C/N.

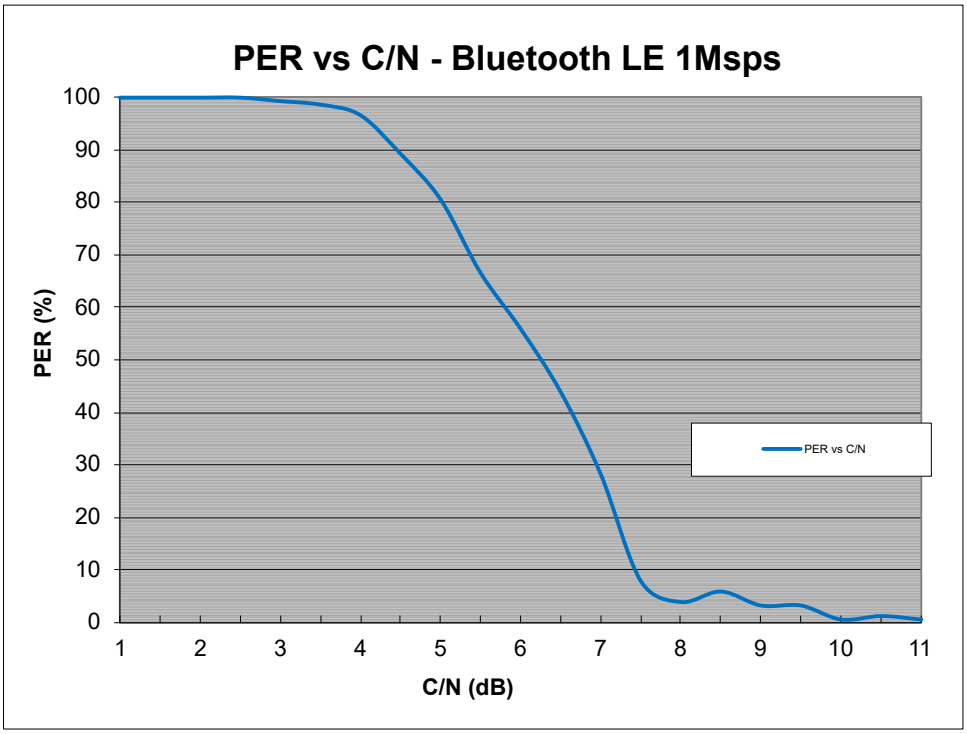

Figure 6. PER versus C/N

1.7.3 Conclusion

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

1.8 C/N versus 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 MCX W71 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 shows the test result for C/N versus Input level.

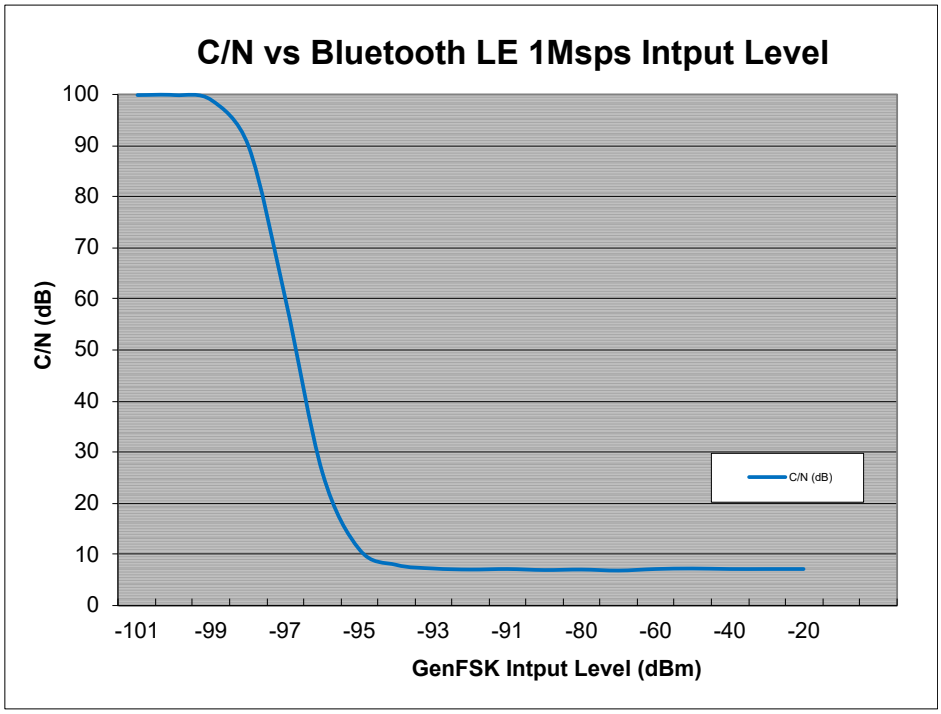

Figure 7. C/N versus Bluetooth LE RF input level

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

This section describes the Sinewave signal and Sinewave interferer test setup.

2.1.1 Test bench

Figure 8 shows the Sinewave interferer test setup.

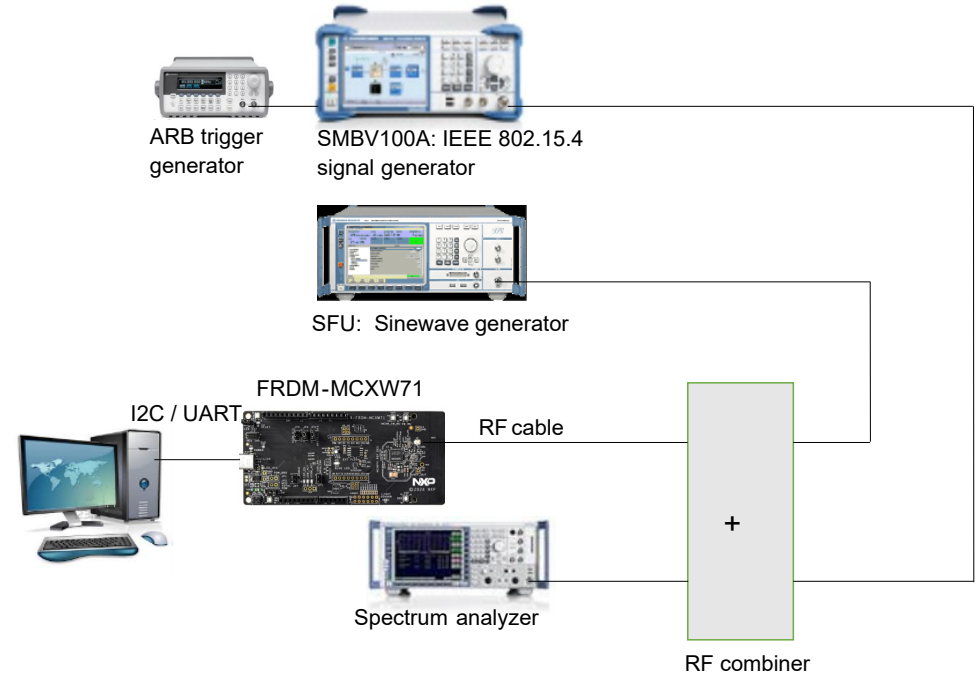

Figure 8. Sinewave interferer test setup

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.

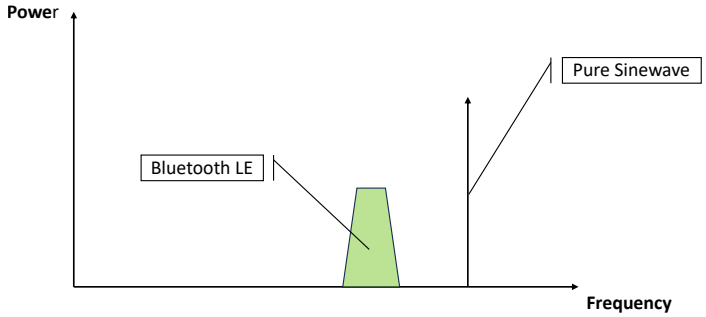

Figure 9. Pure Sinewave interferer

2.2 Sinewave interference test

This section describes the test methods and results to packet error rate (PER) depending on the Sinewave interferer.

2.2.1 Test method

- Set the MCX W71 radio to: RX mode (Bluetooth LE 1 Msps, 2 Msps, 500 ksps or 125 ksps), 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 shows the test result.

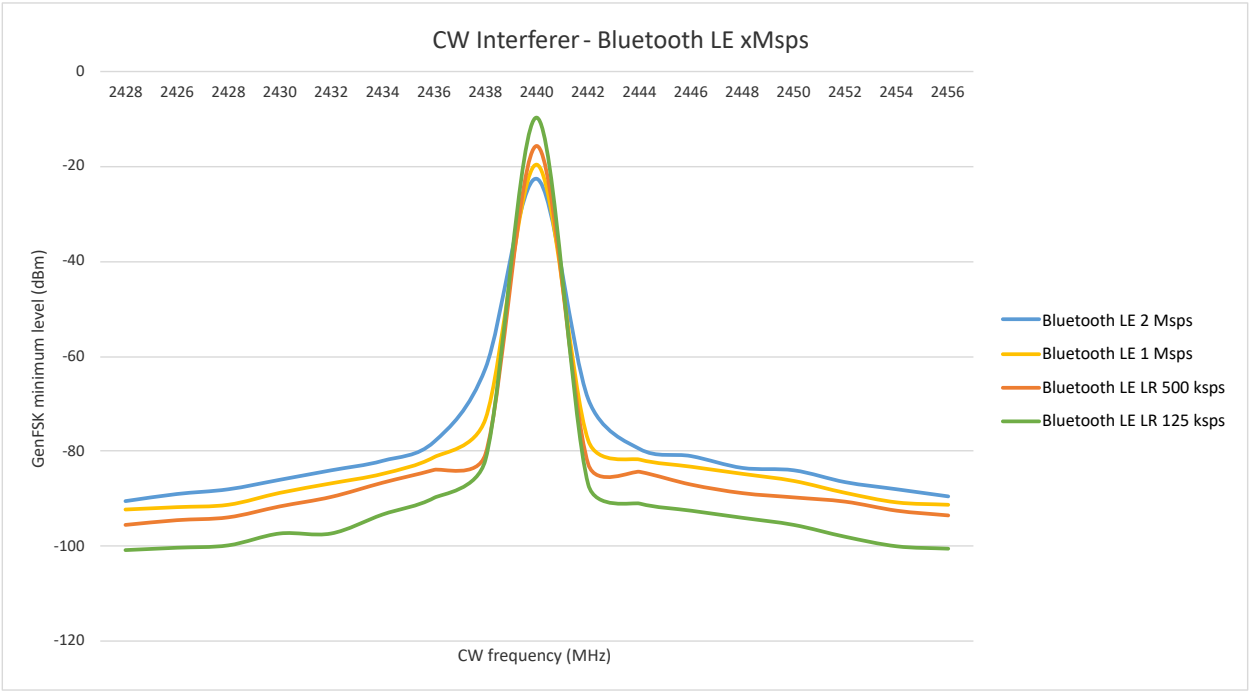

Figure 10. RF input level versus CW frequency

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 PER depending on the Bluetooth audio interferer.

3.1 Test setup

This section describes the Bluetooth interferer signal and Bluetooth LE interferer test setup.

3.1.1 Test bench

Figure 11 shows the Bluetooth LE interferer test setup.

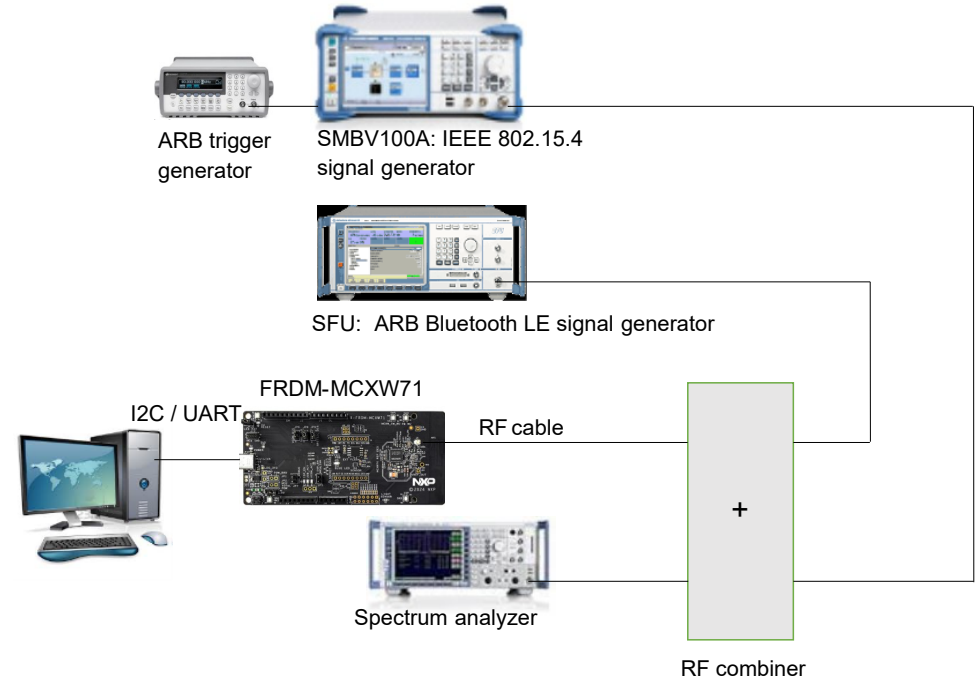

Figure 11. Bluetooth LE interferer test setup

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.

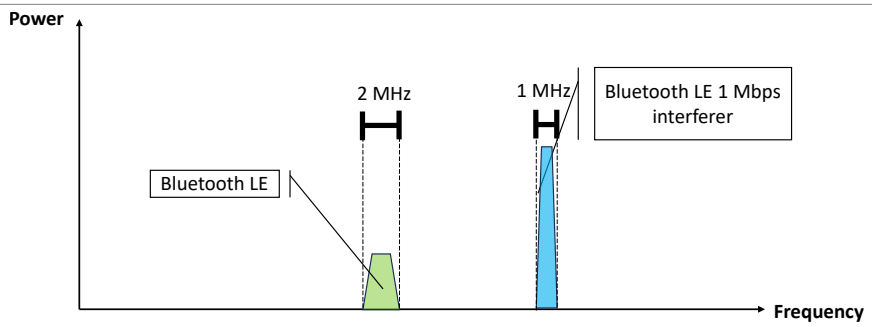

Figure 12. Bluetooth LE interferer – ACIs

3.2 Bluetooth audio interference test

This section describes the test methods and results to PER depending on the Bluetooth audio interferer.

3.2.1 Test method

- Set the MCX W71 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 shows the test result.

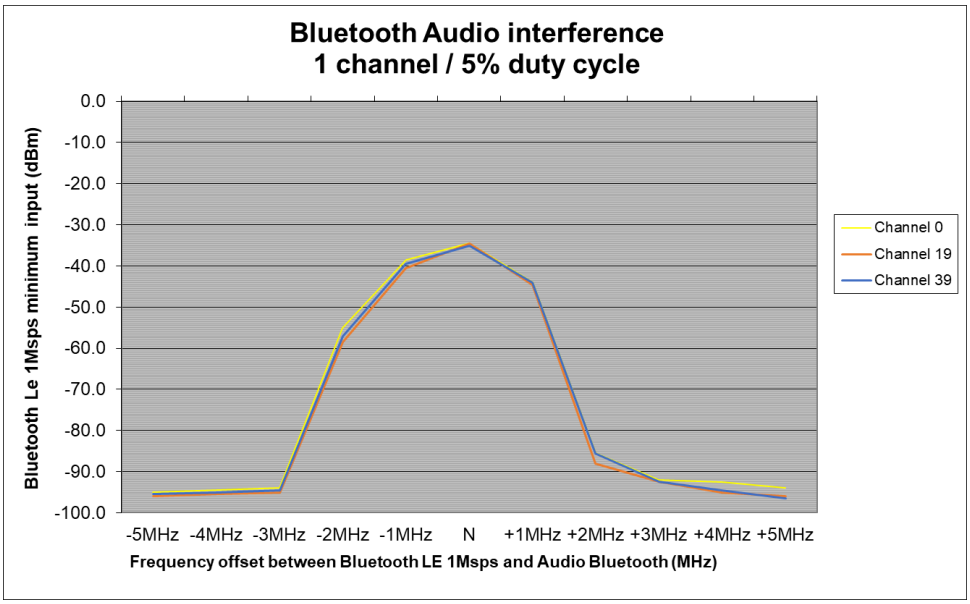

Figure 13. Bluetooth LE minimum input level versus Bluetooth audio stream interferer

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

This section describes the Wi-Fi interferer signal and Wi-Fi interferer test setup.

4.1.1 Test bench

Figure 14 shows the Wi-Fi interferer test setup.

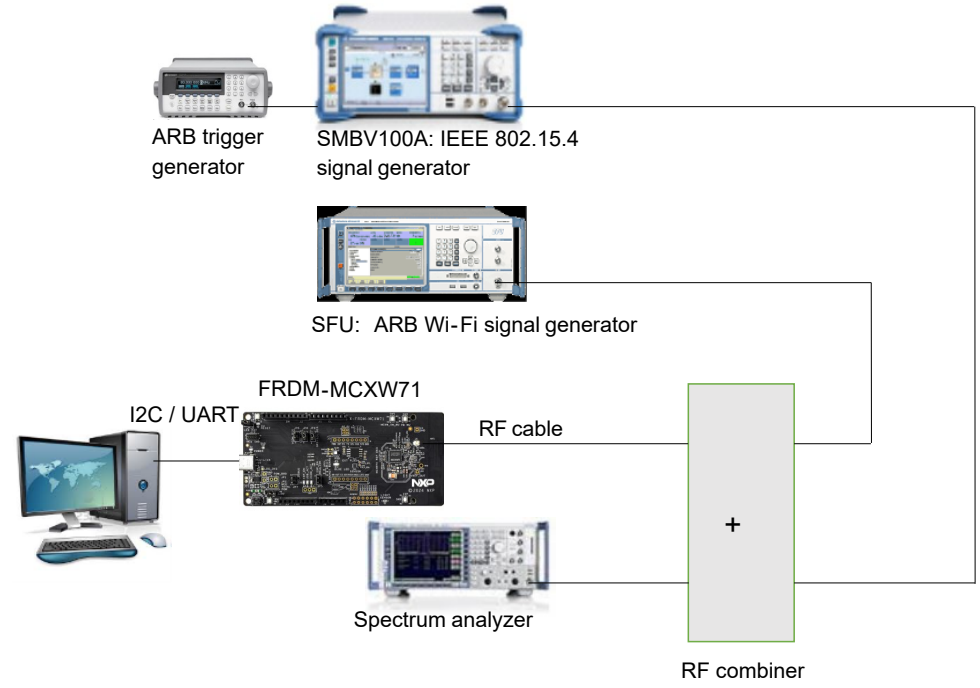

Figure 14. Wi-Fi interferer test setup

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 Mbit/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.

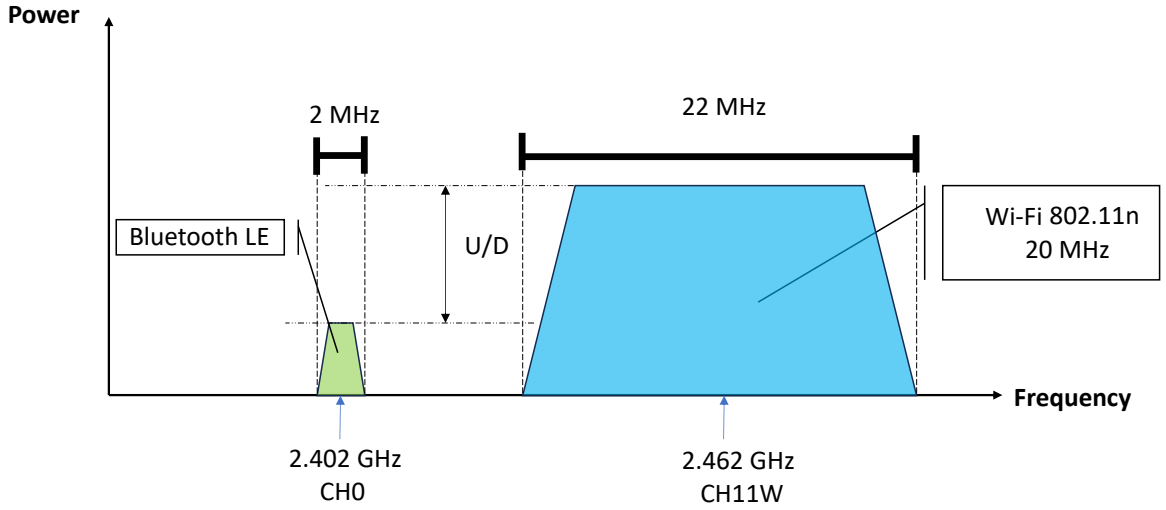

Figure 15. Wi-Fi interferer – ACIs

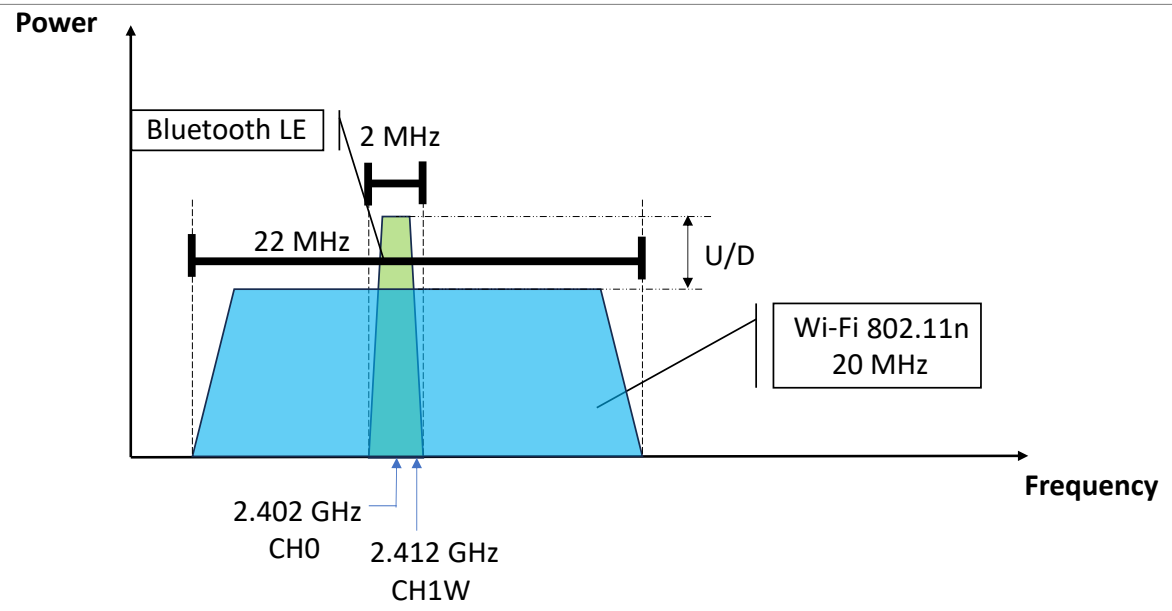

Figure 16. Wi-Fi interferer – co-channel

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 MCX W71 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 shows the ACIs result.

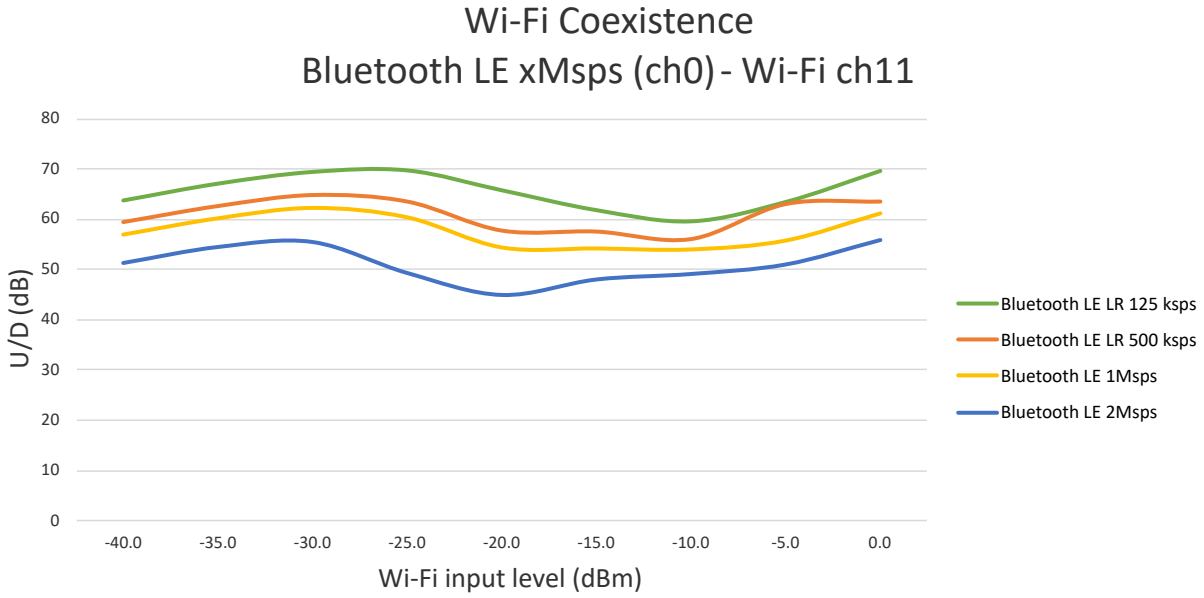

Figure 17. Bluetooth LE and Wi-Fi coexistence (ACIs)

4.2.3 Co-channel test method

- Set the MCX W71 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 1 (2.412 GHz).
- Bluetooth LE power is decreased until PER criteria (< 30.8 %) is reached.

4.2.4 Co-channel result

Figure 18 shows the Bluetooth LE and Wi-Fi co-channel test result.

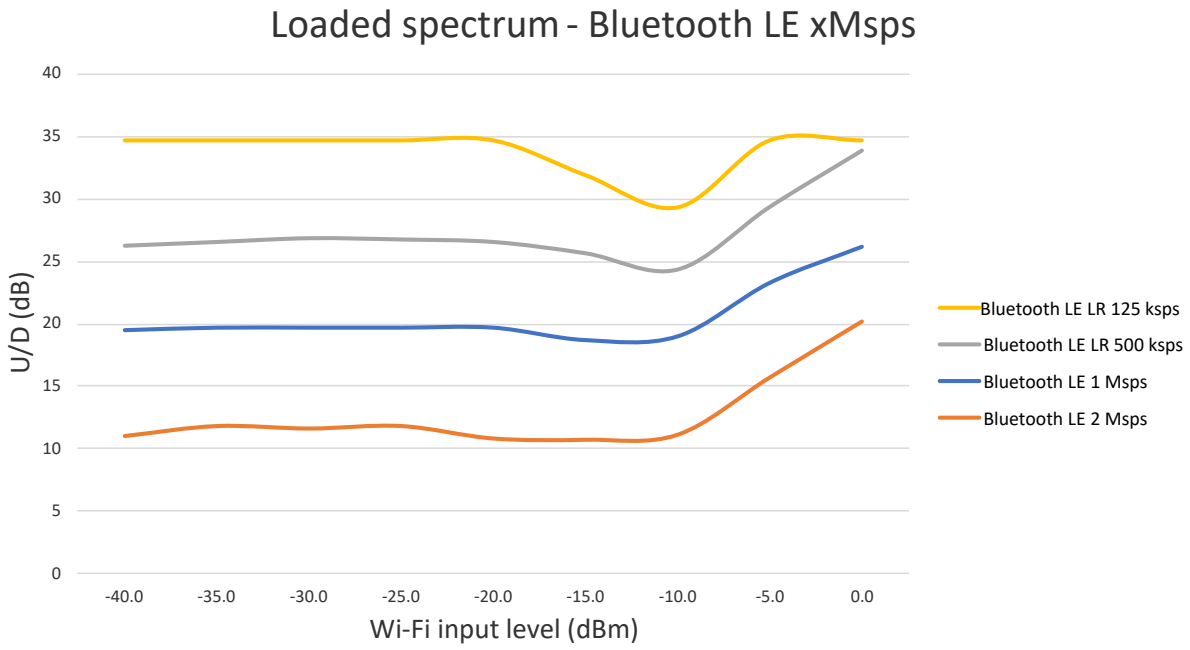

Figure 18. Bluetooth LE and Wi-Fi co-channel

4.3 Conclusion

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

5 Revision history

Table 1 summarizes the revisions to this document.

Table 1. Revision history

Document ID	Release date	Description
AN14515 v.1.0	13 January 2025	Initial public release

Legal information

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.

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 https://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 document 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.

HTML publications — An HTML version, if available, of this document is provided as a courtesy. Definitive information is contained in the applicable document in PDF format. If there is a discrepancy between the HTML document and the PDF document, the PDF document has priority.

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.

NXP B.V. — NXP B.V. is not an operating company and it does not distribute or sell products.

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.

FRDM-MCXW71 RF System Evaluation Report for Bluetooth Low Energy Applications with Interferer Coexistence

Contents