AN12256

FRDM-KW36 Co-existence with RF System Evaluation Report for Bluetooth® Low Energy Application

Rev. 1 — 02/2020 Application Note

Contents

1 Introduction

This document provides the RF evaluation test results of the FRDM-KW36 for Bluetooth LE applications (2FSK modulation) co-existence with different interferers, such as white noise, Adjacent Channel Interferers (ACIs), Bluetooth LE, Wi-Fi, and so on. It includes the test setup description and the tools used to perform the tests on your own. For KW36 radio parameters, see the *MKW36Z/35Z Data Sheet* (document MKW36Z512).

For more information about the FRDM-KW36Z Freedom Development Board, see the *FRDM-KW36 Freedom Development Board User's Guide* (document FRDMKW36UG). Find the schematic and design files at the FRDM-KW36: Freedom Development Kit for Kinetis® KW36/35/34 MCUs web page.

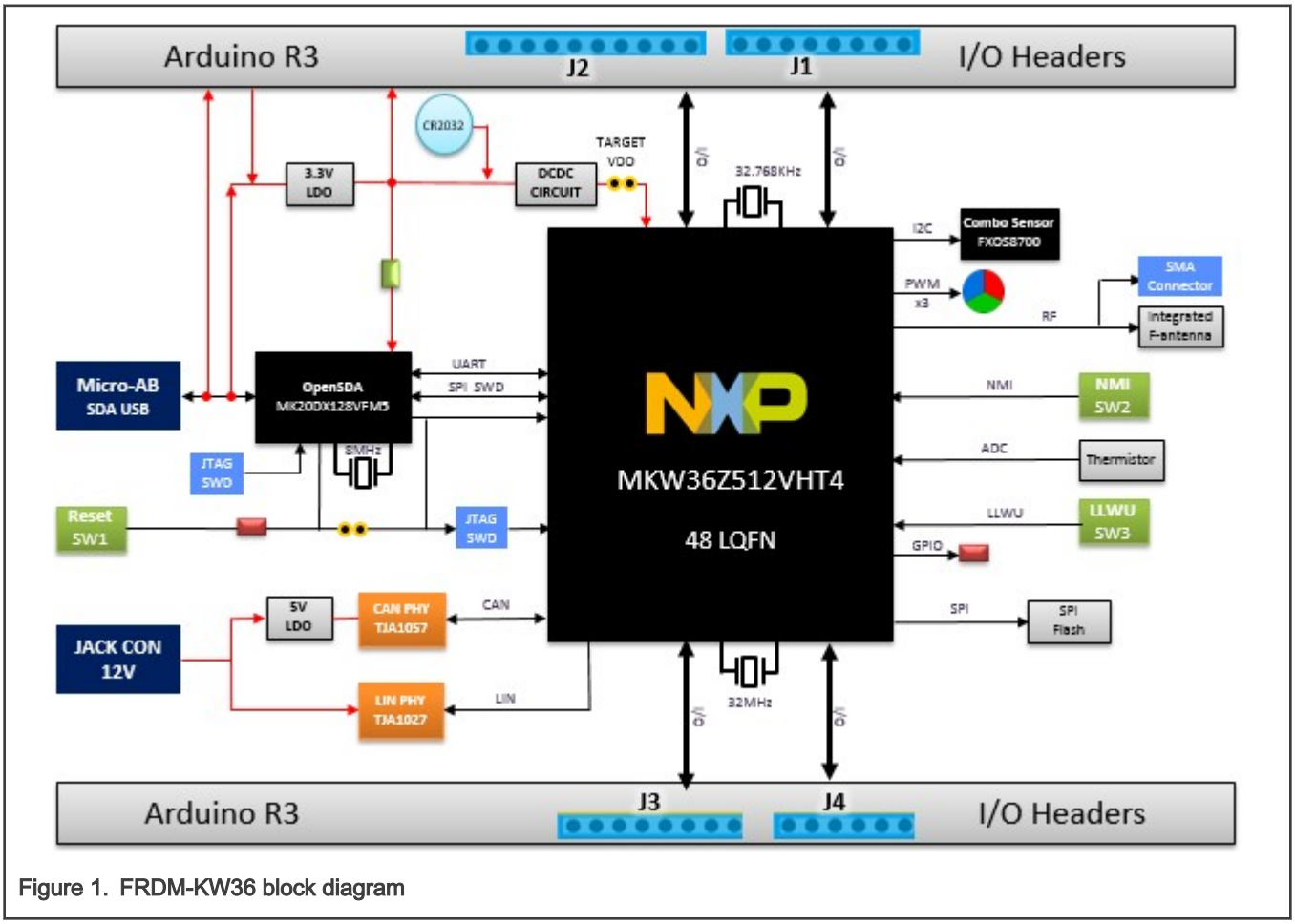

Figure 1. FRDM-KW36 block diagram

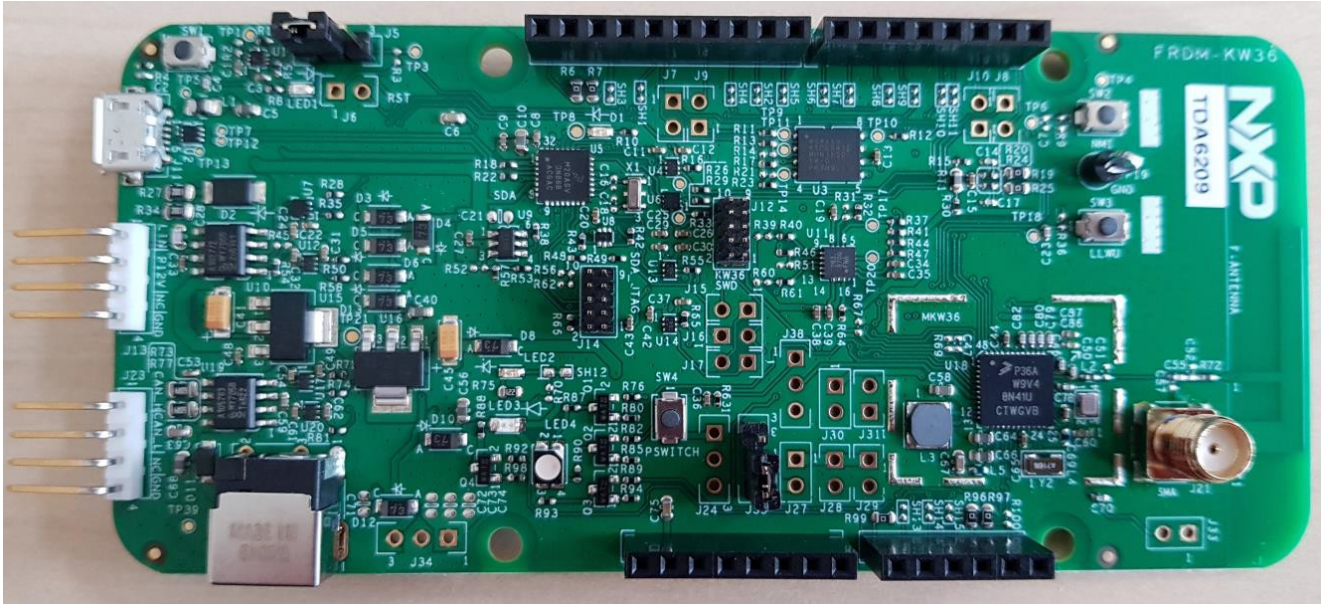

Figure 2. Freedom development kit for Kinetis/FRDM-KW36

1.1 List of tests

- Noise interferer
  - Packet Error Rate (PER) vs Carrier-to-Noise ratio (C/N)
  - C/N vsfrequency
  - C/N vslevel
- CW interferer
  - Adjacent Channel Interferers (ACIs)
  - Co-channel
- Bluetooth LE interferer
  - Bluetooth LE ACIs
  - Bluetooth LE co-channel
- Wi-Fiinterferer
  - Wi-FiACIs
  - Wi-Fico-channel

NOTE

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

1.2 Software

Before the measurements, load a binary code (connectivity software) into the board's flash memory.

The FRDM-KW36: Freedom Development Kit for Kinetis® KW36/35/34 MCUs web page describes how to use FRDM-KW36 to load the code. The binary code used for the following tests is the Connectivity Software package General Frequency Shift Keying (GenFSK) protocol (2FSK modulation). The TERATERM terminal emulator is used to communicate with the KW36 MCU.

1.3 List of equipments

Those equipment are used to perform the Rx and Tx measurements:

- 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
- Power supply
- PC equipped with a IEEE-488 General Purpose Interface Bus (GPIB) card
- Noise interference

1.4 Test bench setup

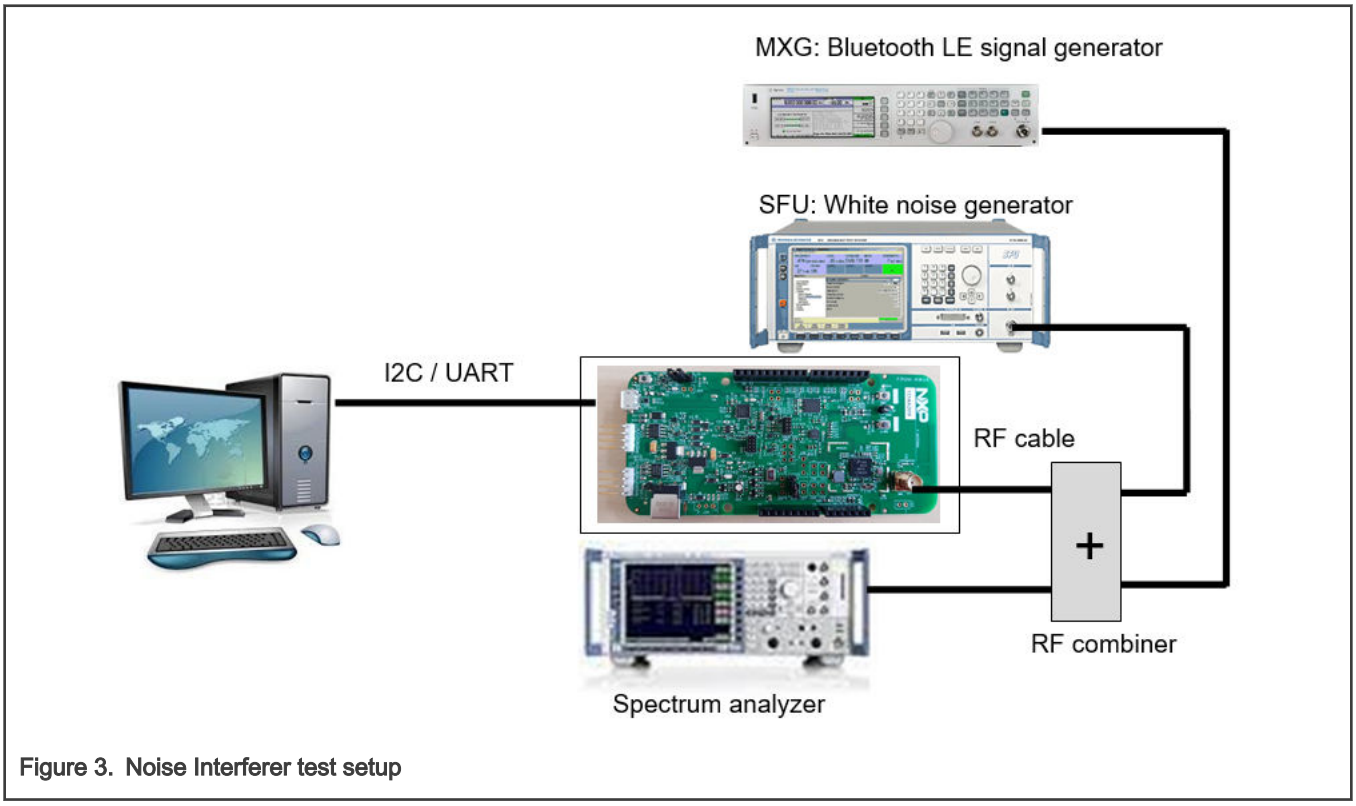

Figure 3. Noise Interferer test setup

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 till the criteria PER < 30.8 % is reached. The C/N is calculated on 1.02 MHz bandwidth.

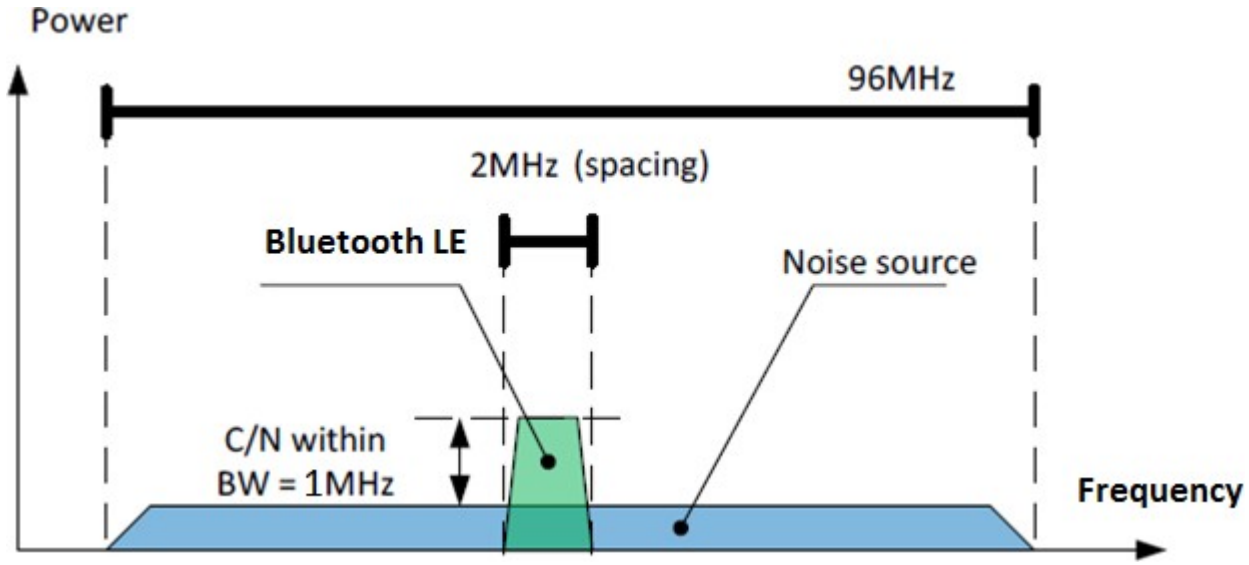

Figure 4. White noise Interferer setup

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 KW36 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 20 bytes)
  - 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 +5 dB and decreased by step of 0.1 dB till the criteria PER < 30.8 % is reached for all channels.

1.6.2 Result

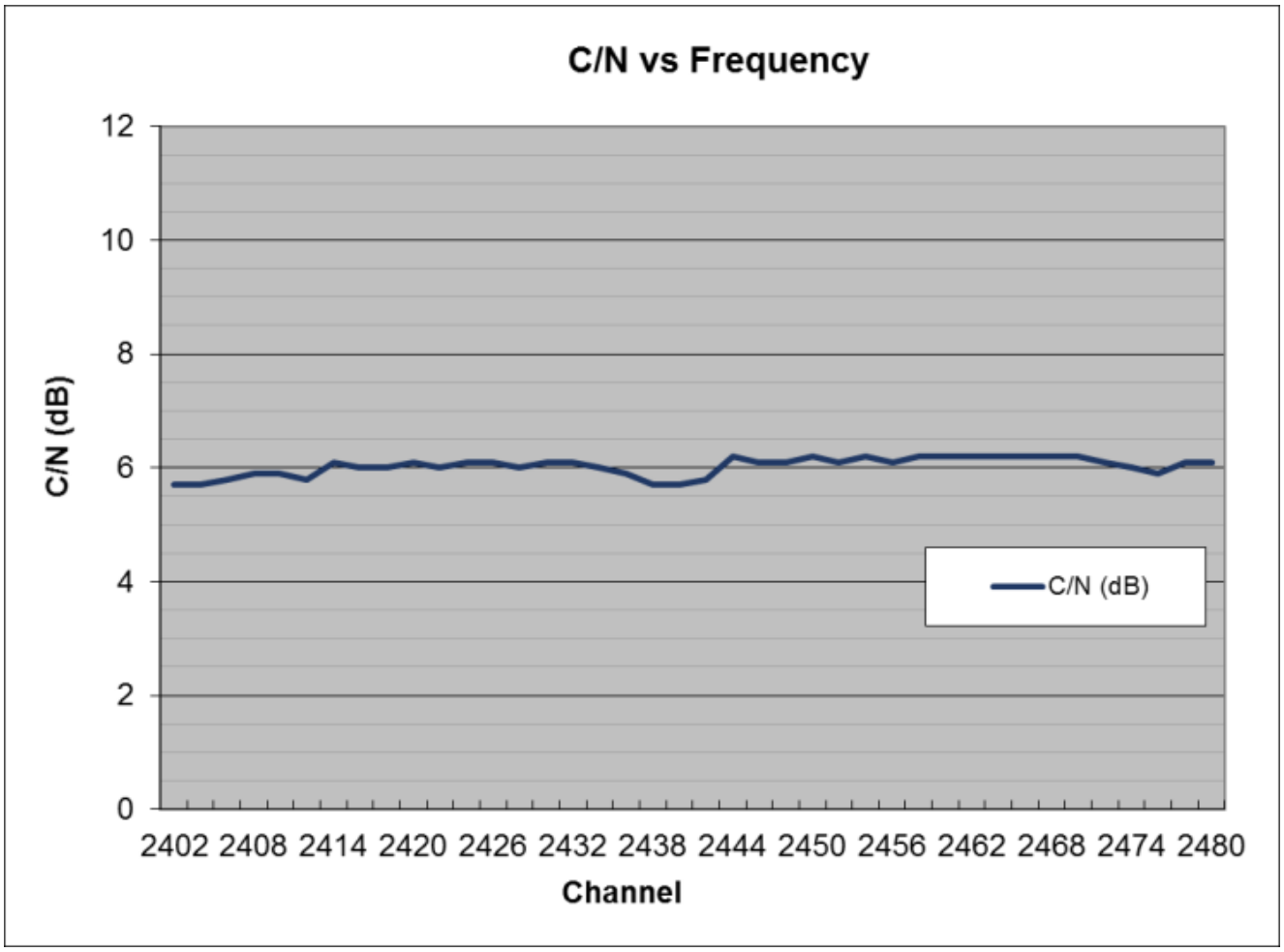

Figure 5. C/N vs frequency

1.6.3 Conclusion

C/N performance is independent from the channel (purely base-band performance). C/N is 6 dB.

1.7 PER vs C/N

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

1.7.1 Test method

- Set the KW36 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 20 bytes)

- Continuous mode
- Frequency: Channel 19 (2.44 MHz)
- Constant RF output level = -40 dBm.

- Set the analyzer for power calibration @2.44 GHz, -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

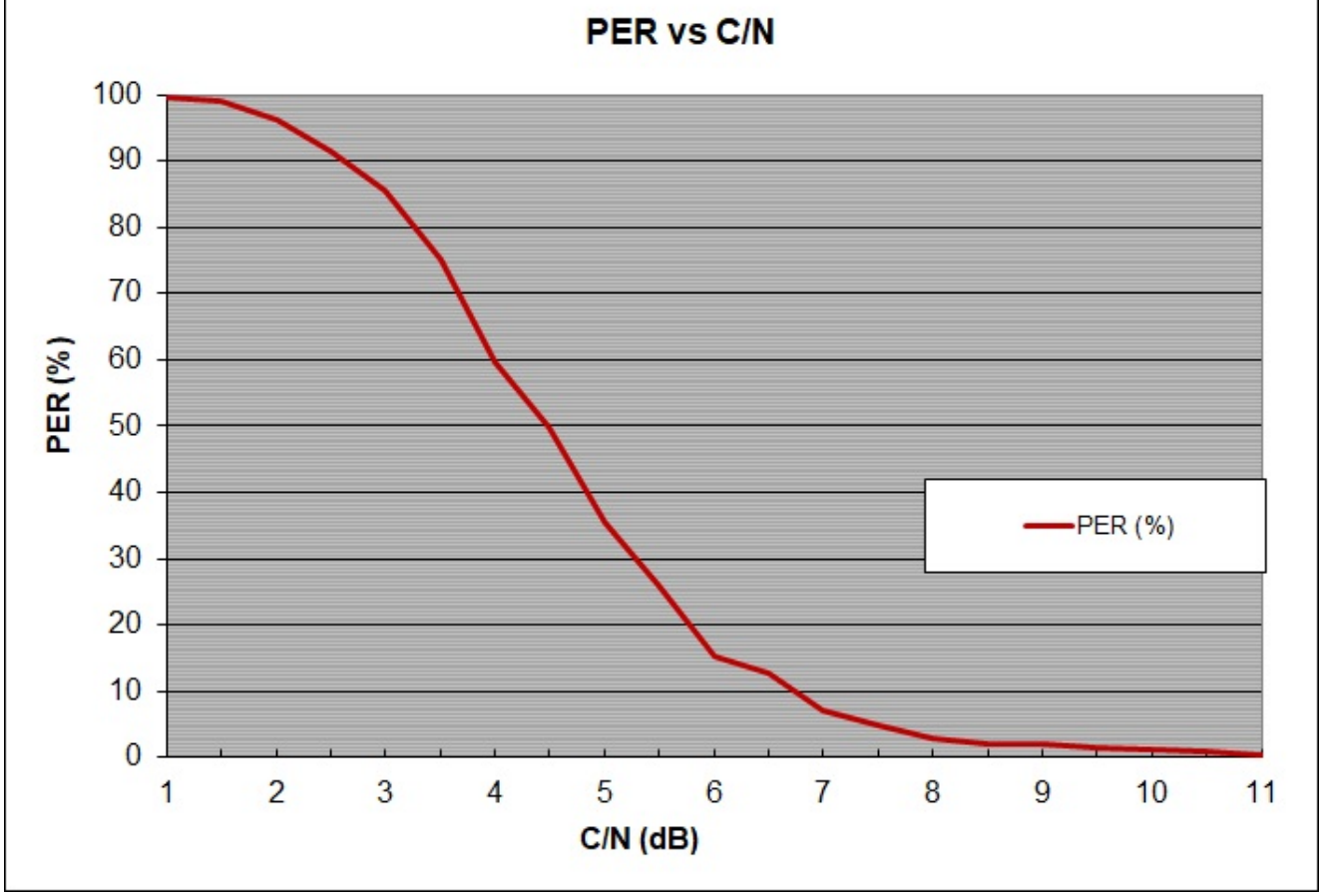

Figure 6. PER vs C/N

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 KW36 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 20 bytes)
  - 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 till the PER criteria (< 30.8 %) is reached.

1.8.2 Result

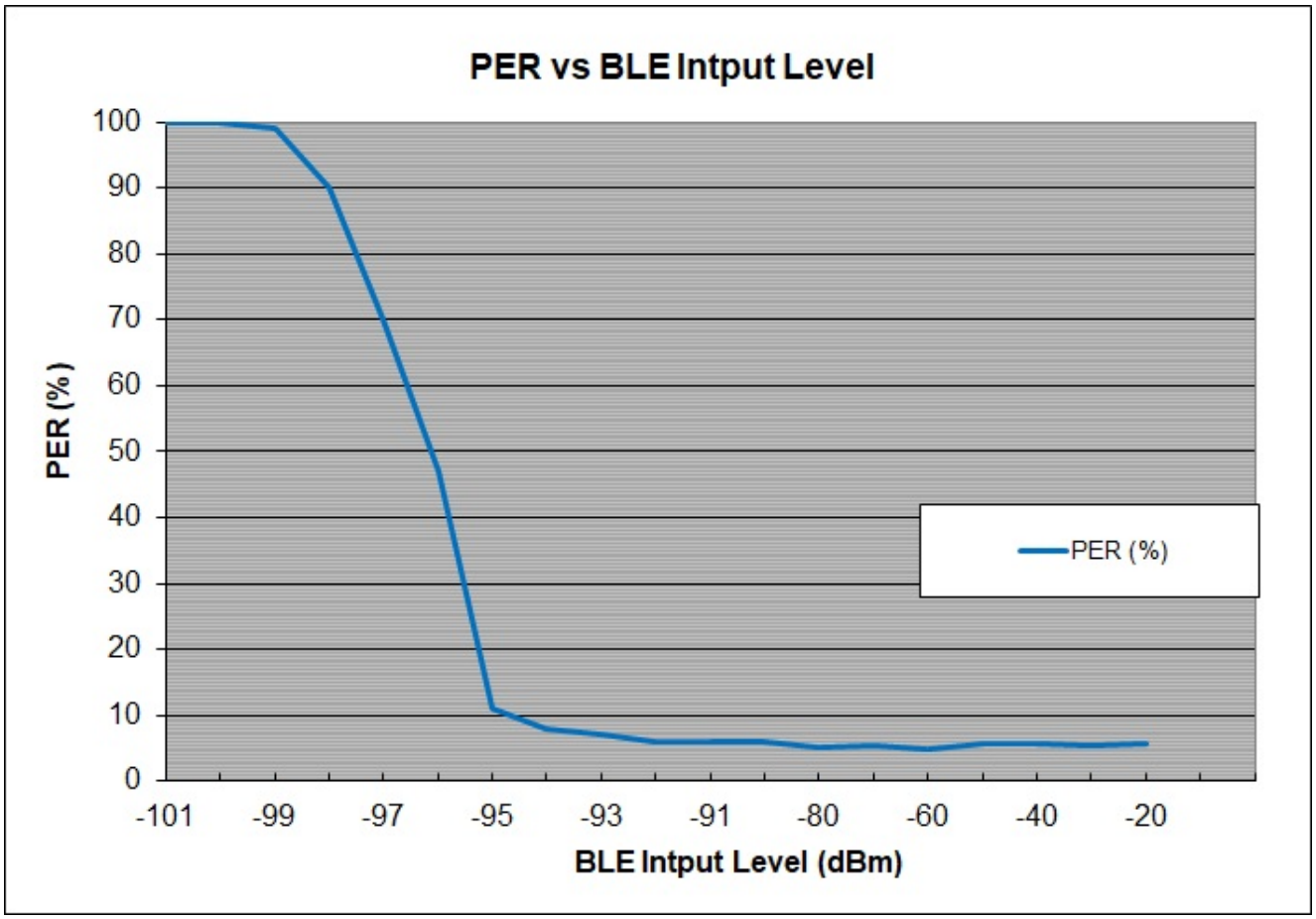

Figure 7. C/N vs Bluetooth LE RF input level

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 of the Sinewave interferer.

2.1 Test setup

2.1.1 Test bench

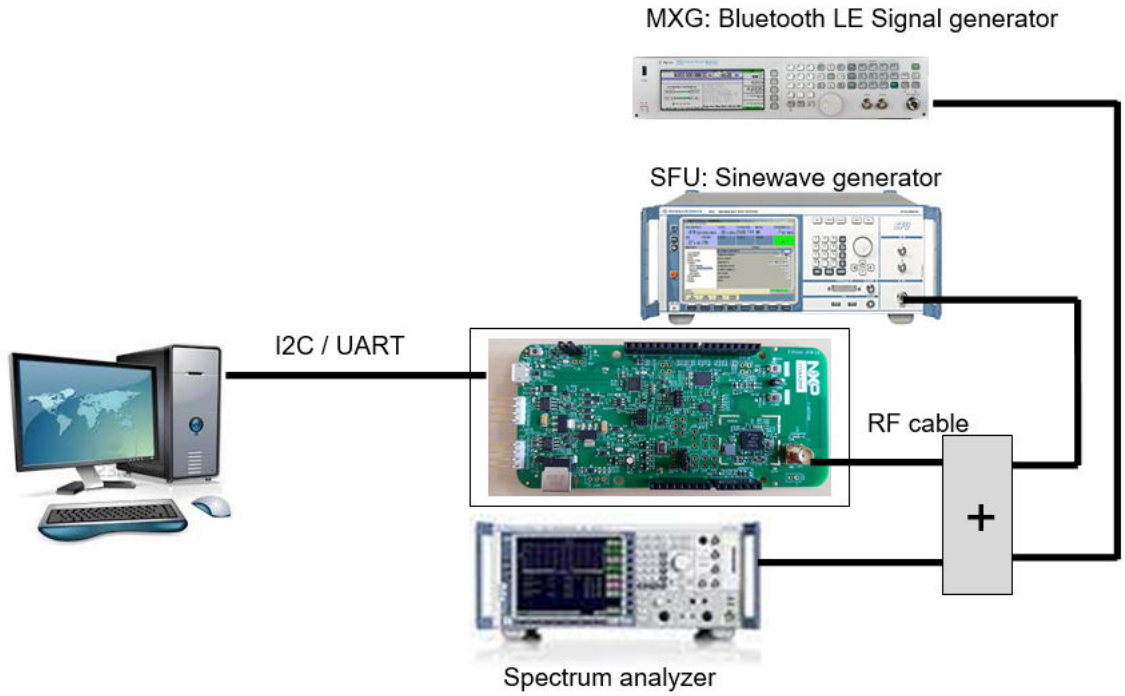

Figure 8. Sinewave Interferer test setup

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 till the criteria PER<30.8 % is reached.

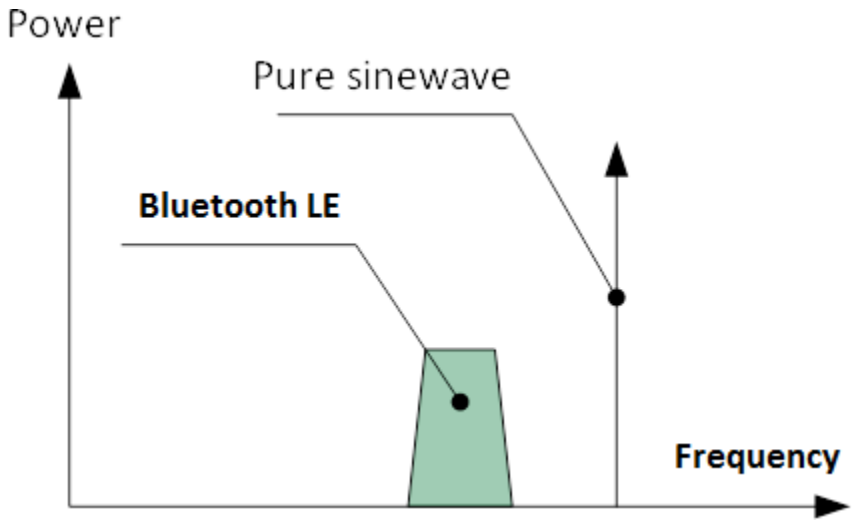

Figure 9. ure sinewave interferer

2.2 Sinewave interference test

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

2.2.1 Test method

- Set the KW36 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 20 bytes)
  - 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 till PER criteria (< 30.8 %) is reached.

2.2.2 Result

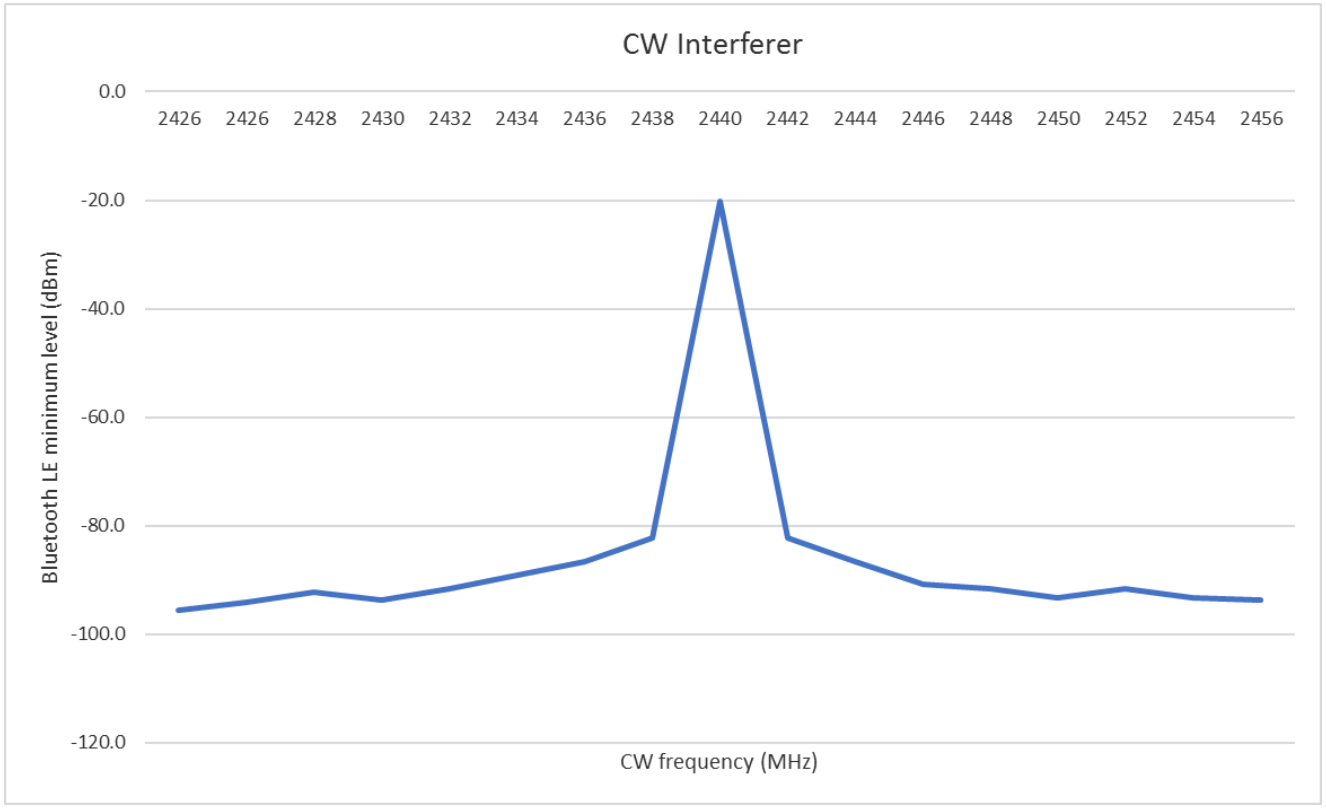

Figure 10. RF intput level vs CW frequency

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 of the Bluetooth audio interferer.

3.1 Test setup

3.1.1 Test bench

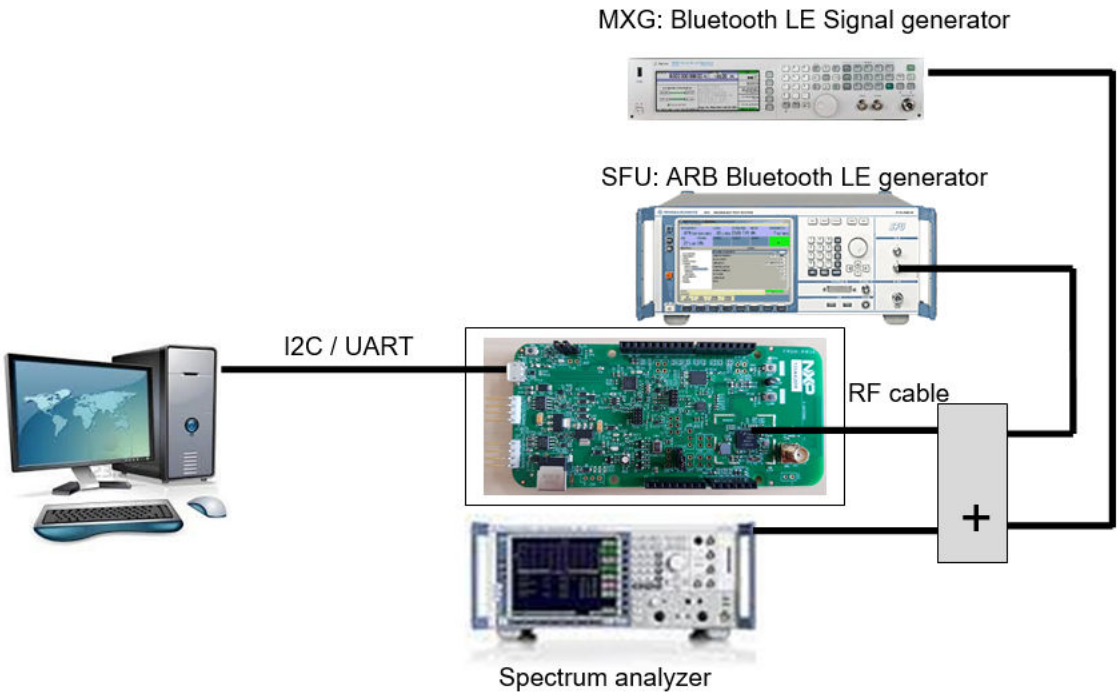

Figure 11. Bluetooth LE Interferer test setup

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 till the criteria PER < 30.8% is reached.

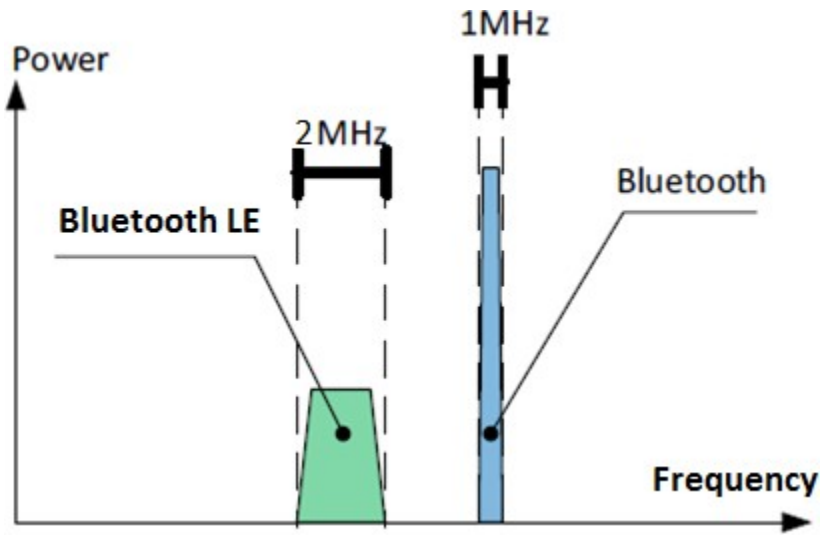

Figure 12. Bluetooth LE interferer – ACIs

3.2 Bluetooth Audio interference test

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

3.2.1 Test method

- Set the KW36 radio to:
  - RX mode
  - Modulated
  - Continuous mode
  - Frequency: Channel 19 (2.44 MHz)
- Set the generatorto:
  - Bluetooth LE modulated signal (typical 1500 packets of 20 bytes)
  - Continuous mode
  - Frequency: Channel 0 (2.405 GHz), Channel 19 (2.44 MHz), and Channel 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 2.435 GHz to 2.445 GHz by step of 1 MHz. Duty cycle is forced to 5 %.
- Bluetooth LE power is decreased till PER criteria (< 30.8 %) is reached.

3.2.2 Result

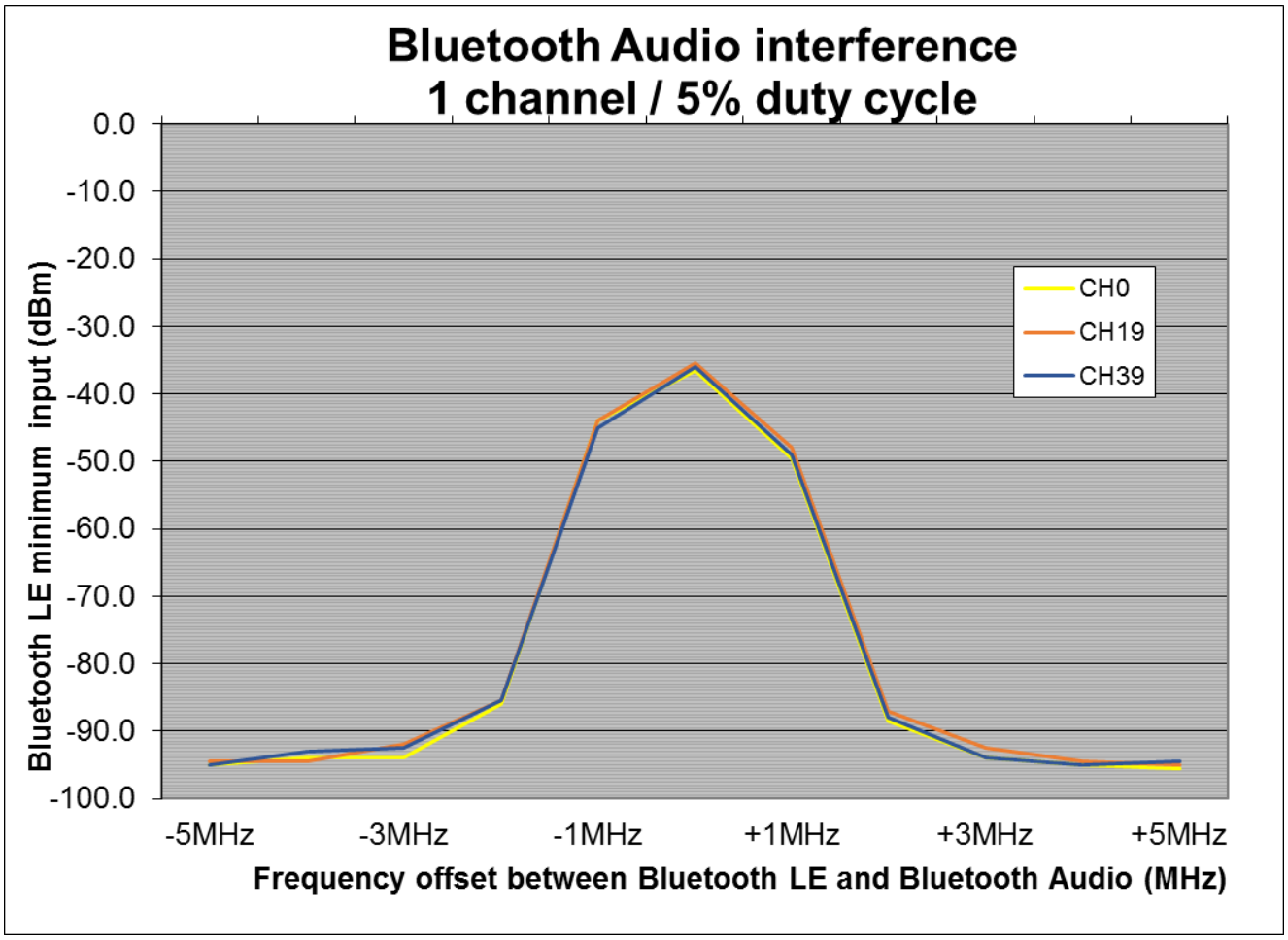

Figure 13. Bluetooth LE minimum input level vs Bluetooth audio stream interferer

3.2.3 Conclusion

- For co-channel, the carrier to interference ratio (C/I) is +3dB (Bluetooth LE Chaneel 0, Channel 19 or Channel 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 of the Wi-Fi interferer.

4.1 Test setup

4.1.1 Test bench

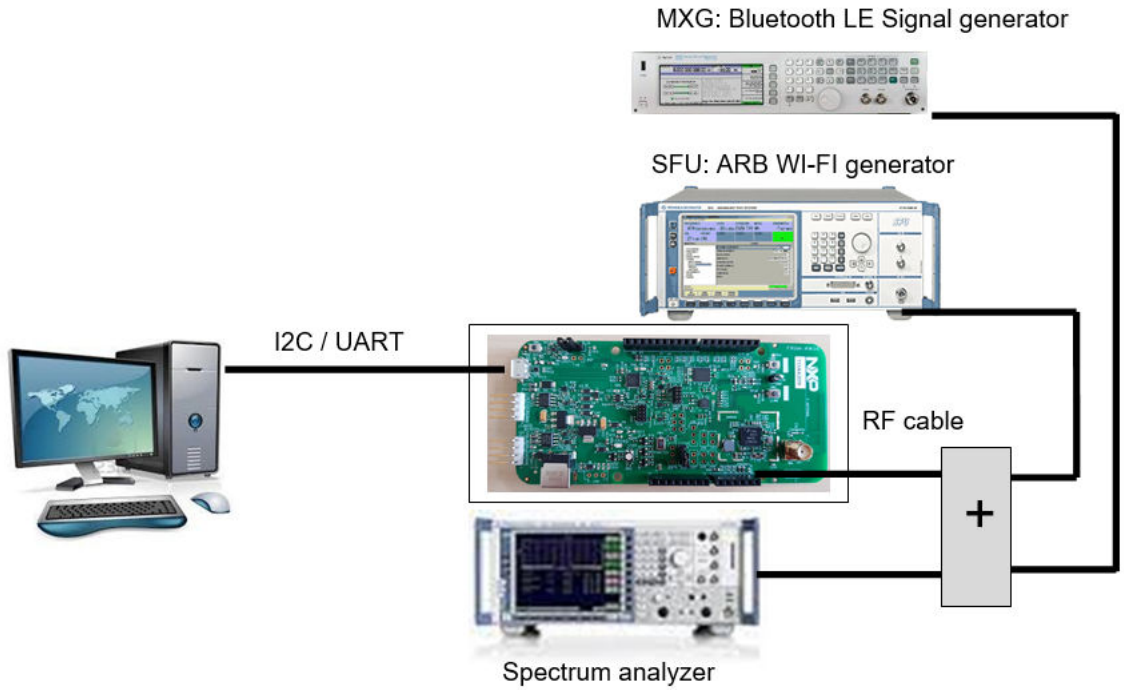

Figure 14. Wi-Fi Interferer test setup

4.1.2 Signal definition

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

- 802.11n mode, 20MHz bandwidth (signal antenna).
- Access point (client) is sending datagrams to station (server).
- The theorical 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 is played with a RF arbitrary generator to simulate a Controlled Wi-Fi adjacent signal.

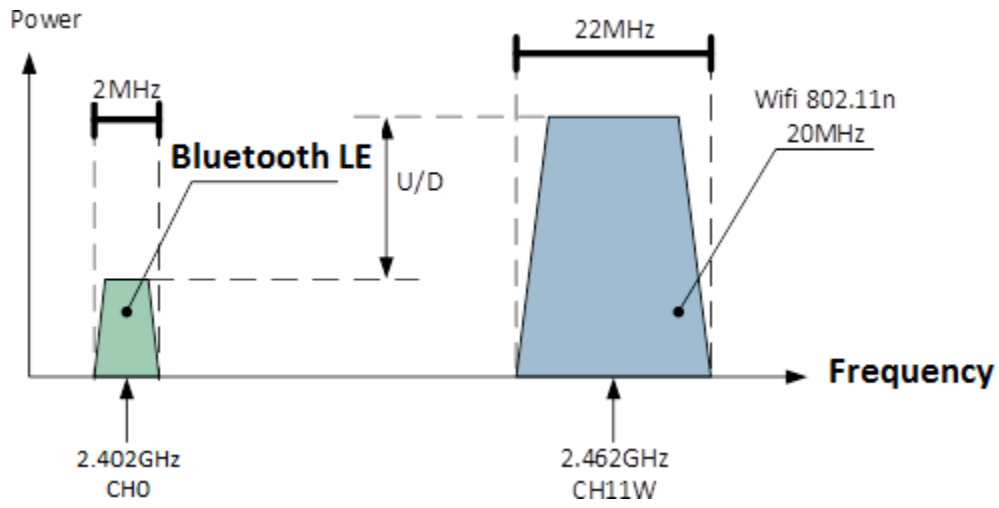

Figure 15. Wi-Fi interferer – ACIs

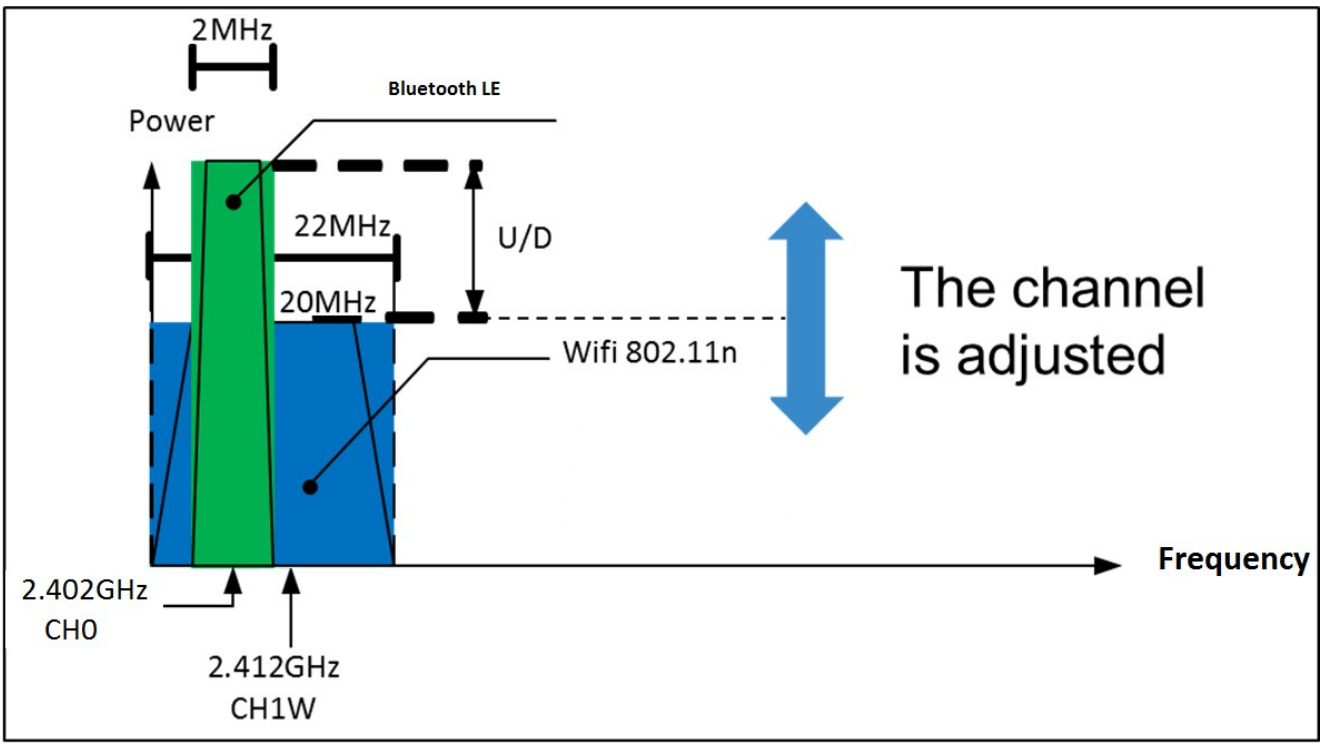

Figure 16. Wi-Fi interferer – Co-channel

4.2 Wi-Fi interference tests

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

4.2.1 ACIs test method

- Set the KW36 radio to:
  - RX mode
  - Modulated

  - Continuous mode
  - Frequency: Channel 0 (2.402 MHz)
- Set the generator to:
  - Bluetooth LE modulated signal (typical 1500 packets of 20 bytes)
  - Continuous mode
  - Frequency: Channel 0 (2.402 MHz).
- Set the analyzer for power calibration on Bluetooth LE signal and Wi-Fisignal.
- 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 till PER criteria (< 30.8 %) is reached.

4.2.2 ACIs result

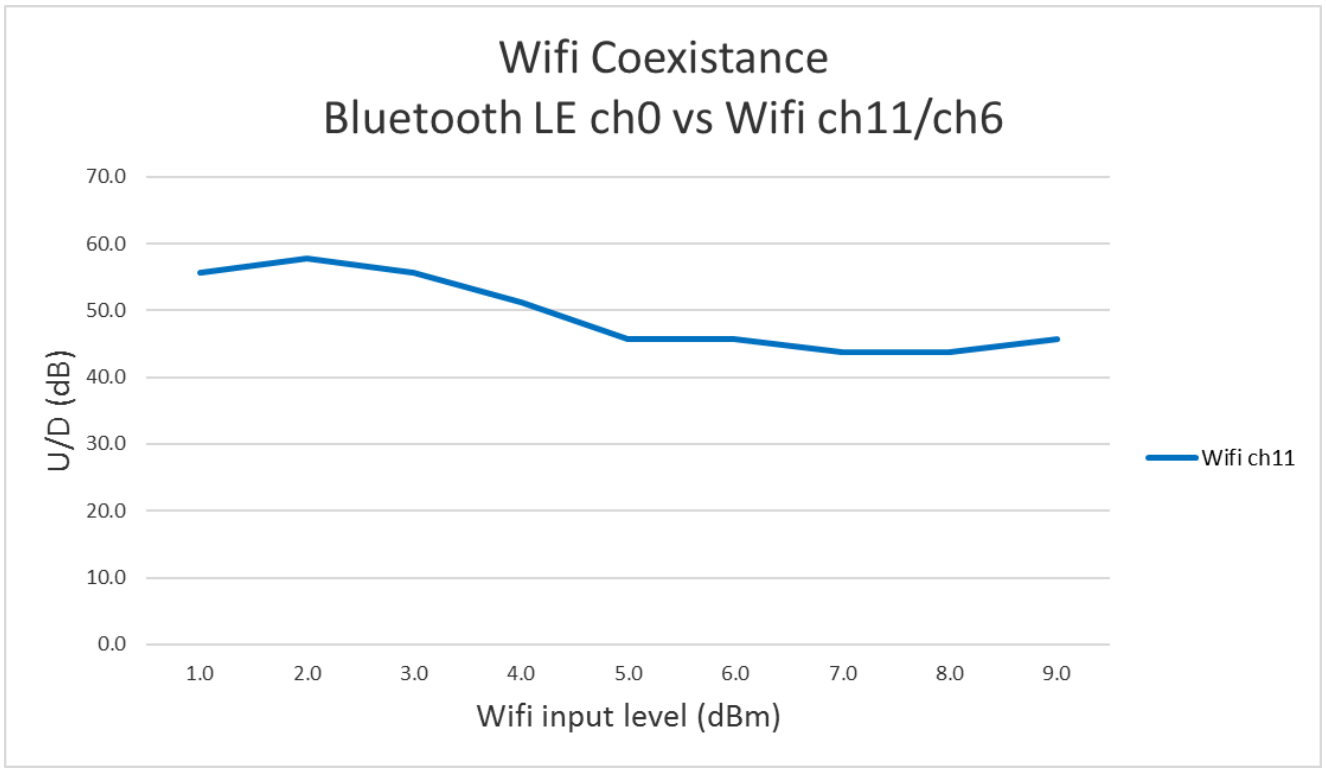

Figure 17. Bluetooth LE and Wi-Fi coexistence (ACIs)

4.2.3 Co-channel test method

- Set the KW36 radio to:
  - RX mode
  - Modulated
  - Continuous mode
  - Frequency: Channel 0 (2.402 MHz).
- Set the generator to:

— Bluetooth LE modulated signal (typical 1500 packets of 20 bytes)

— Continuous mode

— Frequency: Channel 0 (2.402 MHz).

- Set the analyzer for power calibration on Bluetooth LE signal and Wi-Fisignal.
- 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 till PER criteria (< 30.8 %) is reached.

4.2.4 Co-channel result

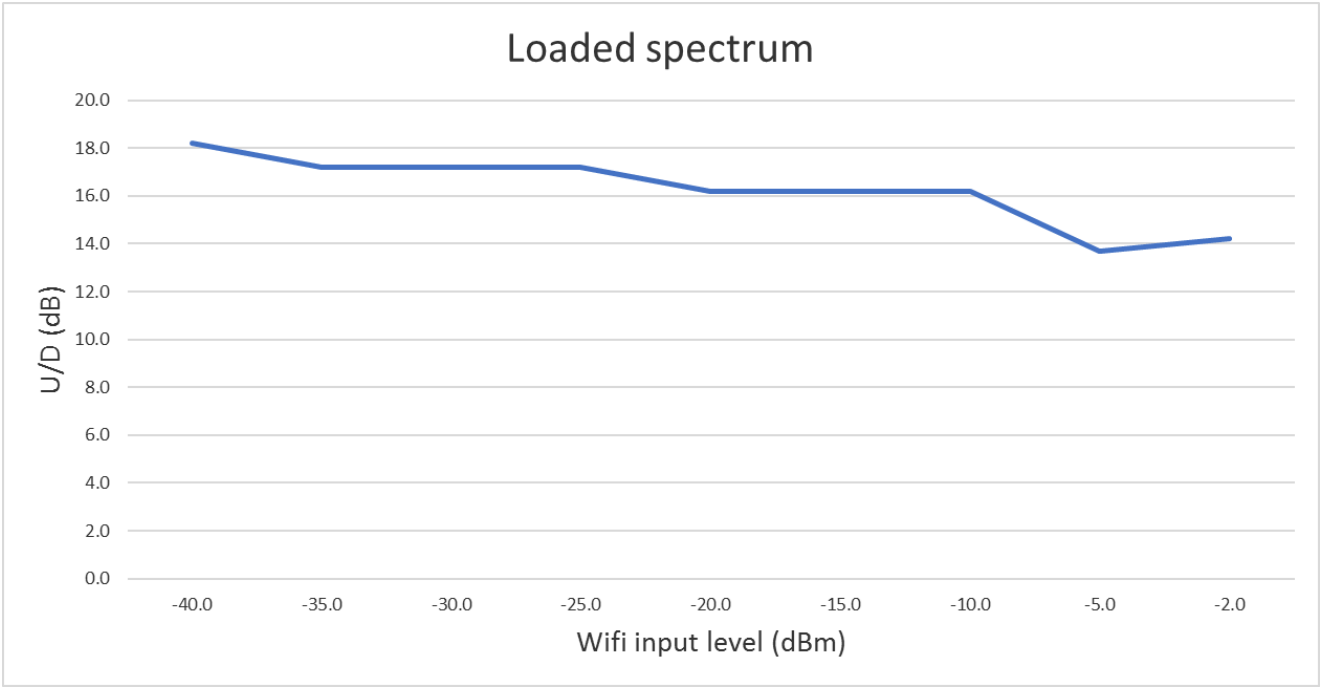

Figure 18. Bluetooth LE and Wi-Fi co-channel

4.3 Conclusion

The ratio between Unwanted and Wanted power is constant ~17 dB up to -10 dBm Wi-Fi interferer.

5 Revision history

Table 1. Revision history

Revision number	Date	Substantive changes
0	09/2018	Initial release
1	02/2020	Update Figure 6 and Figure 7

How To Reach Us

Home Page:

nxp.com

Web Support:

nxp.com/support

For more information, please visit: http://www.nxp.com

For sales office addresses, please send an email to: salesaddresses@nxp.com

Date of release: 02/2020

Document identifier: AN12256

arm