EFR32xG24 2.4 GHz 10 dBm Radio Board BRD4186C Reference Manual

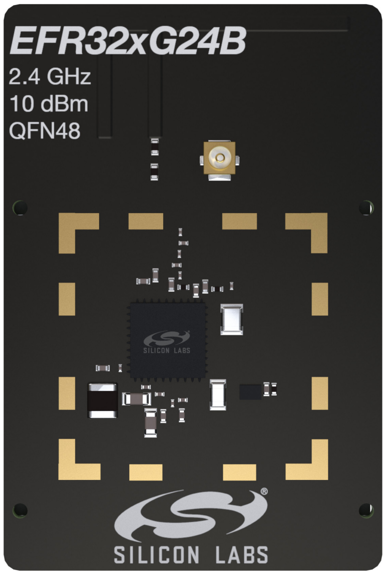
The BRD4186C Radio Board is an excellent starting point to get familiar with the EFR32™ Wireless Gecko Wireless System-on-Chip. The board enables developers to develop smart home, lighting, building automation, and AI/ML applications. It is optimized for operating in the 2.4 GHz band at 10 dBm output power. Radiated and conducted testing is supported with the on-board printed antenna and UFL connector.

The BRD4186C Radio Board is a plug-in board for the Wireless Starter Kit Mainboard (BRD4001A) and the Wireless Gecko Pro Kit Mainboard (BRD4002A) that gives access to debug interface, Virtual COM port, packet trace, display, buttons, LEDs, and additional features from expansion boards. With the supporting Simplicity Studio suite of tools, developers can take advantage of graphical wireless application development and visual energy profiling and optimization. The board also serves as a reference design for the EFR32xG24 Wireless SoC with matching network and a PCB antenna optimized for operating at 10 dBm output power in the 2.4 GHz band.

This document contains a brief introduction and description of the BRD4186C Radio Board features, focusing on the RF sections and performance.

RADIO BOARD FEATURES

- Wireless SoC: EFR32MG24B210F1536IM48
  - CPU core: ARM® Cortex®-M33
  - Flash memory: 1536 kB
  - RAM: 256 kB
- Operation frequency: 2.4 GHz
- Transmit power: 10 dBm
- Integrated PCB antenna, UFL connector (optional)
- Crystals for LFXO and HFXO: 32.768 kHz and 39 MHz
- 8 Mbit low-power serial flash for over-the-air updates



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1. Introduction

The BRD4186C Radio Boards provide a development platform (together with the Wireless Starter Kit Mainboard or the Wireless Pro Kit Mainboard) for the Silicon Labs EFR32MG24 Wireless System-on-Chips and serve as reference designs for the matching network of the RF interface.

The BRD4186C Radio Board is designed to operate in the 2400-2483.5 MHz band with the RF matching network optimized for operating at 10 dBm output power.

To develop and/or evaluate the EFR32 Wireless Gecko, the BRD4186C Radio Board can be connected to the Wireless Starter Kit Mainboard or the Wireless Pro Kit Mainboard to get access to debug interface, Virtual COM port, packet trace, display, buttons, LEDs, and additional features from expansion boards, and also to evaluate the performance of the RF interface.

2. Radio Board Connector

2.1 Introduction

The board-to-board connector scheme allows access to all EFR32MG24 GPIO pins as well as the RESETn signal. For more information on the functions of the available pins, see the EFR32MG24 data sheet.

2.2 Radio Board Connector Pin Associations

The figure below shows the mapping between the connector and the EFR32MG24 pins and their function on the Wireless Starter Kit Mainboard.

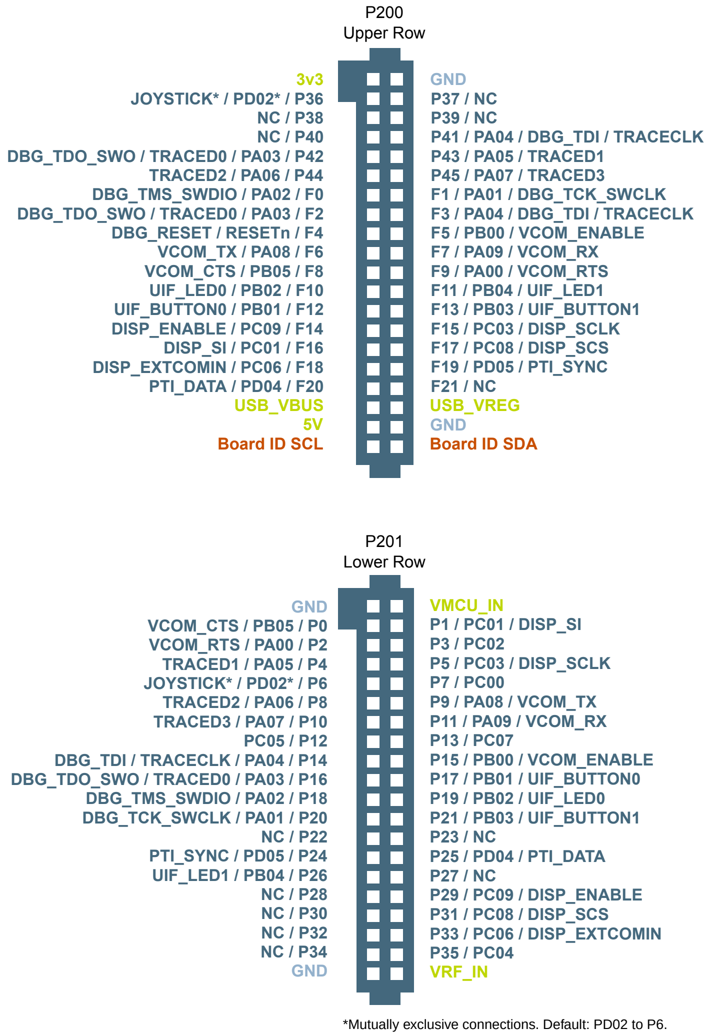

Figure 2.1. BRD4186C Radio Board Connector Pin Mapping

3. Radio Board Block Summary

3.1 Introduction

This section introduces the blocks of the BRD4186C Radio Board.

3.2 Radio Board Block Diagram

The block diagram of the BRD4186C Radio Board is shown in the figure below.

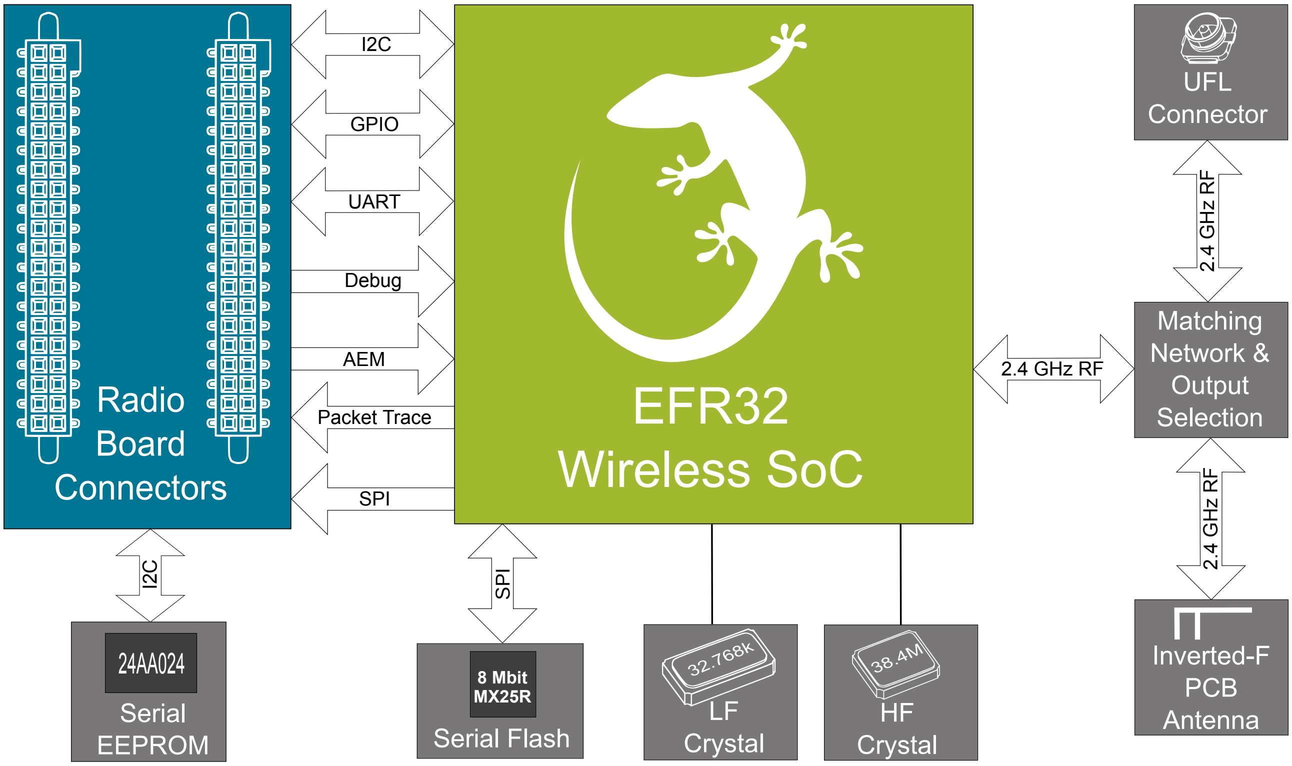

Figure 3.1. BRD4186C Block Diagram

3.3 Radio Board Block Description

3.3.1 Wireless MCU

The BRD4186C Radio Board incorporates an EFR32MG24B210F1536IM48 Wireless System-on-Chip featuring 32-bit Cortex®-M33 core, 1536 kB of flash memory, 256 kB of RAM, and a 2.4 GHz band transceiver with output power up to 10 dBm. For additional information on the EFR32MG24B210F1536IM48, refer to the EFR32MG24 data sheet.

3.3.2 LF Crystal Oscillator (LFXO)

The BRD4186C Radio Board has a 32.768 kHz crystal mounted. For details regarding the crystal configuration, refer to application note AN0016.2: Oscillator Design Considerations.

3.3.3 HF Crystal Oscillator (HFXO)

The BRD4186C Radio Board has a 39 MHz crystal mounted. For details regarding the crystal configuration, refer to application note AN0016.2: Oscillator Design Considerations.

3.3.4 Matching Network for 2.4 GHz

The BRD4186C Radio Board incorporates a 2.4 GHz matching network which connects the 2.4 GHz RF input/output of the EFR32MG24 to the one on-board printed Inverted-F antenna. The component values were optimized for the 2.4 GHz band RF performance and current consumption with 10 dBm output power.

For a detailed description of the matching network, see section 4.2.1 2.4 GHz RF Matching Description.

3.3.5 UFL Connector

To be able to perform conducted measurements, Silicon Labs added a UFL connector to the Radio Board. The connector allows an external 50 Ohm cable or antenna to be connected during design verification or testing.

Note: By default, the output of the matching network is connected to the printed inverted-F antenna by a series 0 Ohm resistor. To support conducted measurements, or the connection of an external antenna, the option to connect the output to the UFL connector is available. If using this option, move the series 0 Ohm resistor to the antenna to the series resistor to the UFL connector (see section 4.2.1 2.4 GHz RF Matching Description for further details). On the layout, the footprints of these two resistors have overlapping pads to prevent simultaneous connection of the antenna and the UFL connector.

3.3.6 Radio Board Connectors

Two dual-row, 0.05” pitch polarized connectors make up the BRD4186C Radio Board interface to the Wireless Starter Kit Mainboard.

For more information on the pin mapping between the EFR32MG24B210F1536IM48 and the connectors, refer to section 2.2 Radio Board Connector Pin Associations.

3.3.7 Inverted-F Antenna

The BRD4186C Radio Board includes a printed inverted-F antenna (IFA) tuned to have close to 50 Ohm impedance at the 2.4 GHz band.

For a detailed description of the antenna, see section 4.4 Inverted-F Antenna.

3.3.8 Serial Flash

The BRD4186C Radio Board is equipped with an 8 Mbit Macronix MX25R SPI flash that is connected directly to the EFR32MG24 to support over-the-air (OTA) updates. For additional information on the pin mapping, see the BRD4186C schematic.

3.3.9 Serial EEPROM

The BRD4186C Radio Board is equipped with a serial I^2C EEPROM for board identification and to store additional board-related information.

4. RF Section

4.1 Introduction

This section gives a short introduction to the RF section of the BRD4186C Radio Board.

4.2 RF Section Schematic

BRD4186C Radio Board RF section schematic is shown in the following figure.

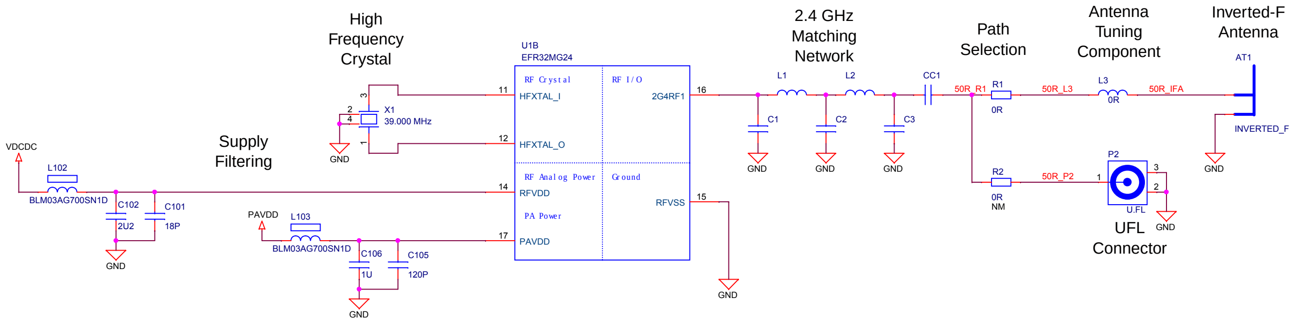

Figure 4.1. BRD4186C RF Section Schematic

4.2.1 2.4 GHz RF Matching Description

The 2.4 GHz RF matching connects the 2G4RF1 pin to the on-board printed IFA. The component values were optimized for the 2.4 GHz band RF performance and current consumption with the targeted 10 dBm output power.

The matching network consists of a five-element impedance matching and harmonic filter circuitry and a DC blocking capacitor (not required for the 20 dBm part).

For conducted measurements, the matching network output can also be connected to the UFL connector by removing the series R1 resistor (0 Ohm) between the antenna and the matching network and mounting it to the R2 resistor position between the matching network and the UFL connector.

4.3 Bill of Materials for the 2.4 GHz Matching Network

The bill of materials for the BRD4186C Radio Board 2.4 GHz matching network is shown in the following table.

Table 4.1. Bill of Materials for the BRD4186C 2.4 GHz RF Matching Network

Component Name	Value	Manufacturer	Part Number
L1	2.5 nH	Murata	LQP03HQ2N5B02D
L2	1.7 nH	Murata	LQP03HQ1N7B02D
C1	2.3 pF	Murata	GRM0335C1H2R3WA01D
C2	1.6 pF	Murata	GRM0335C1H1R6WA01D
C3	Not Mounted	—	—
CC1	18 pF	Murata	GJM0335C1E180GB01D

4.4 Inverted-F Antenna

The BRD4186C Radio Board includes an on-board, printed inverted-F antenna, tuned for the 2.4 GHz band. Due to the design restrictions of the radio board, the input of the antenna and the output of the matching network can't be placed directly next to each other. Therefore, a 50 Ohm transmission line was necessary to connect them.

The resulting impedance that is presented to the matching network output is shown in the following figure. During the measurement, the BRD4186C Radio Board was attached to a Wireless Starter Kit Mainboard.

As shown in the figure, the antenna impedace (blue curve) is close to 50 Ohm in the entire 2.4 GHz band, and the reflection (red curve) is under -10 dB.

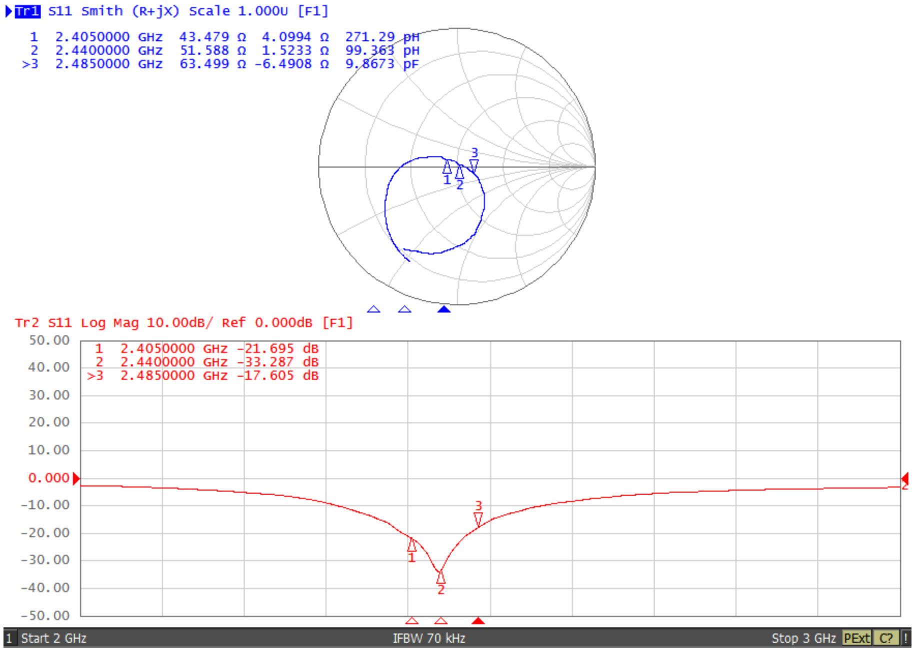

Figure 4.2. Impedance and Reflection of the Inverted-F Antenna of the BRD4186C Board Measured from the Matching Output

5. Mechanical Details

The BRD4186C Radio Board is illustrated in the figures below.

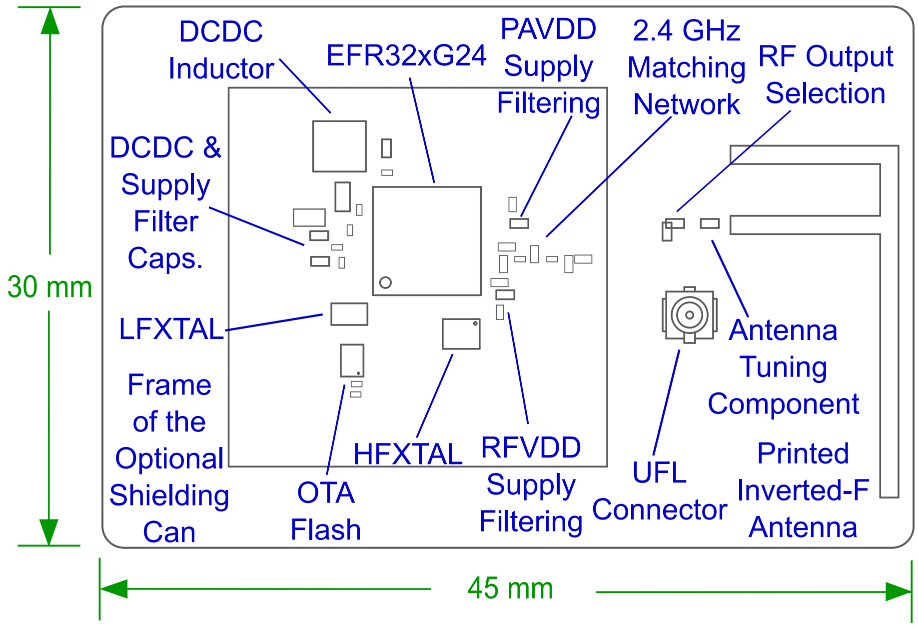

Figure 5.1. BRD4186C Top View

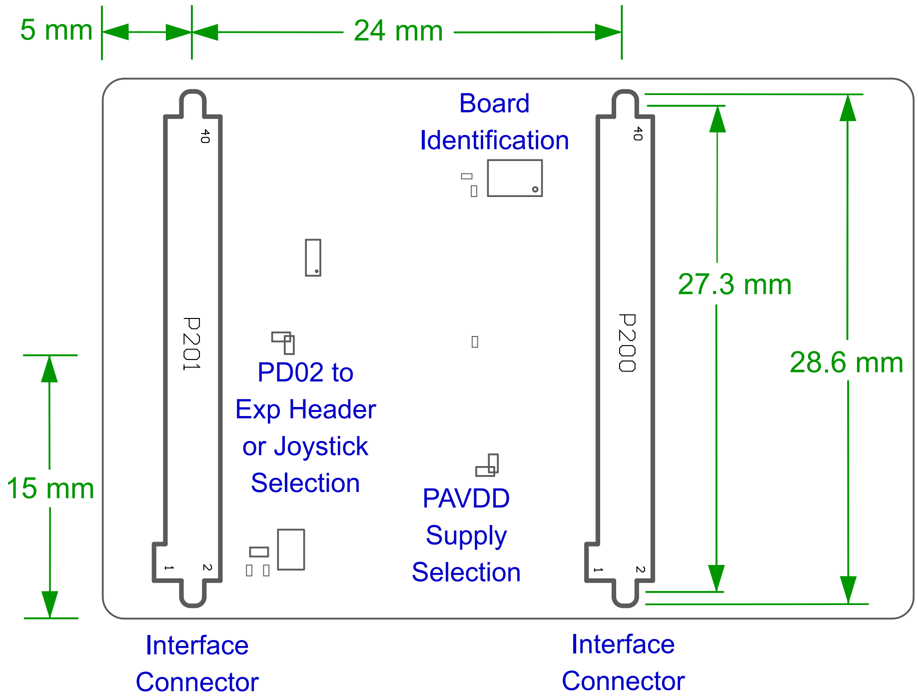

Figure 5.2. BRD4186C Bottom View

6. EMC Compliance

6.1 Introduction

BRD4186C Radio Board fundamental and harmonic levels compliance is tested against the following standards:

- 2.4 GHz:
  - ETSI EN 300-328
  - FCC 15.247

6.2 EMC Regulations for 2.4 GHz

6.2.1 ETSI EN 300-328 Emission Limits for the 2400-2483.5 MHz Band

Based on ETSI EN 300-328, the allowed maximum fundamental power for the 2400-2483.5 MHz band is 20 dBm EIRP. For the unwanted emissions in the 1 GHz to 12.75 GHz domain, the specific limit is -30 dBm EIRP.

6.2.2 FCC15.247 Emission Limits for the 2400-2483.5 MHz Band

FCC 15.247 allows conducted output power up to 1 W (30 dBm) in the 2400-2483.5 MHz band. For spurious emissions, the limit is -20 dBc based on either conducted or radiated measurement, if the emission is not in a restricted band. The restricted bands are specified in FCC 15.205. In these bands, the spurious emission levels must meet the levels set out in FCC 15.209. In the range from 960 MHz to the frequency of the 5th harmonic, it is defined as 0.5 mV/m at 3 m distance, which equals to -41.2 dBm in EIRP.

If operating in the 2400-2483.5 MHz band, the 2nd, 3rd, and 5th harmonics can fall into restricted bands. As a result, for those harmonics the -41.2 dBm limit should be applied. For the 4th harmonic, the -20 dBc limit should be applied.

6.2.3 Applied Emission Limits for the 2.4 GHz Band

The above ETSI limits are applied both for conducted and radiated measurements.

The FCC restricted band limits are radiated limits only. In addition, Silicon Labs applies the same restrictions to the conducted spectrum. By doing so, compliance with the radiated limits can be estimated based on the conducted measurement by assuming the use of an antenna with 0 dB gain at the fundamental and the harmonic frequencies.

The overall applied limits are shown in the table below. For the harmonics that fall into the FCC restricted bands, the FCC 15.209 limit is applied. ETSI EN 300-328 limit is applied for the rest.

Table 6.1. Applied Limits for Spurious Emissions for the 2.4 GHz Band

Harmonic	Frequency	Limit
2nd	4800~4967 MHz	-41.2 dBm
3rd	7200~7450.5 MHz	-41.2 dBm
4th	9600~9934 MHz	-30.0 dBm
5th	12000~12417.5 MHz	-41.2 dBm

7. RF Performance

7.1 Conducted Power Measurements

During measurements, the BRD4186C Radio Board was attached to a Wireless Starter Kit Mainboard which was supplied by USB. The voltage supply for the radio board (VMCU) was 3.3 V and for the power amlifier (PAVDD), it was 1.8 V.

7.1.1 Conducted Power Measurements with Unmodulated Carrier

The transceiver was operated in unmodulated carrier transmission mode. The output power of the radio was set to 10 dBm. The typical output spectrum is shown in the following figure.

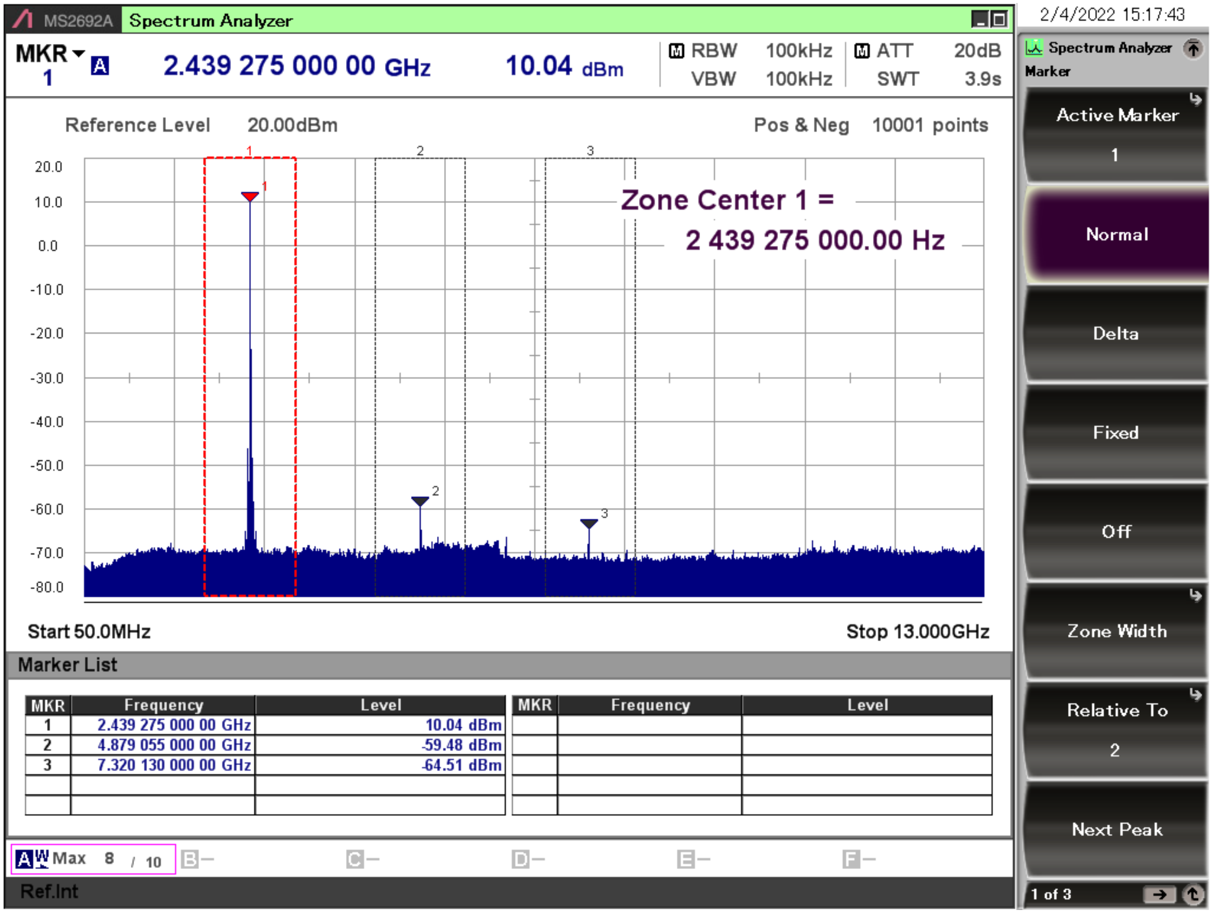

Figure 7.1. Typical Output Spectrum of the BRD4186C; PAVDD = 1.8 V

As shown in the figure, the fundamental is 10 dBm and all of the unwanted emissions are under the -41.2 dBm limit.

Note: The conducted measurement is performed by connecting the on-board UFL connector to a spectrum analyzer through an SMA conversion adapter (P/N: HRMJ-U.FLP(40)). This connection itself introduces approximately 0.3 dB insertion loss.

7.1.2 Conducted Power Measurements with Modulated Carrier

Depending on the applied modulation scheme and the spectrum analyzer settings specified by the relevant EMC regulations, the measured power levels are usually lower compared to the results with unmodulated carrier. These differences are measured and used as relaxation factors on the results of the radiated measurement performed with unmodulated carrier. This way, the radiated compliance with modulated transmission can be evaluated.

In this case, both the ETSI EN 300-328 and the FCC 15.247 regulations define the following spectrum analyzer settings for measuring the unwanted emissions above 1 GHz:

- Detector: Average
- RBW: 1 MHz

The table below shows the measured differences for the supported modulation schemes.

Table 7.1. Measured Relaxation Factors for the Supported Modulation Schemes

Applied Modulation (Packet Length: 255 bytes)	BLE Coded PHY: 125 Kb/s (PRBS9) [dB]	BLE Coded PHY: 500 Kb/s (PRBS9) [dB]	BLE 1M PHY: 1 Mb/s (PRBS9) [dB]	BLE 2M PHY: 2 Mb/s (PRBS9) [dB]
2nd harmonic	-2.7	-3.1	-3.3	-9.1
3rd harmonic	-4.8	-5.2	-5.2	-10.7
4th harmonic	-5.5	-6.5	-6.7	-11.9
5th harmonic	-6.3	-6.5	-6.7	-11.4

As shown, the BLE 125 Kb/s coded modulation scheme has the lowest relaxation factors. These values will be used as the worst case relaxarion factors for the radiated measurements.

7.2 Radiated Power Measurements

During measurements, the BRD4186C Radio Board was attached to a Wireless Starter Kit Mainboard which was supplied by USB. The voltage supply for the radio board was 3.3 V, for the power amlifier (PAVDD) it was 1.8 V. The radiated power was measured in an antenna chamber by rotating the board 360 degrees with horizontal and vertical reference antenna polarizations in the XY, XZ, and YZ cuts. The measurement planes are illustrated in the figure below.

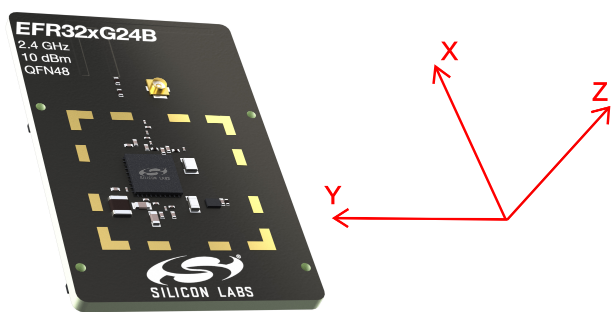

Figure 7.2. Illustration of Reference Planes with a Radio Board

Note: The radiated measurement results presented in this document were recorded in an unlicensed antenna chamber. Also, the radiated power levels may change depending on the actual application (PCB size, used antenna, and so on). Therefore, the absolute levels and margins of the final application are recommended to be verified in a licensed EMC testhouse.

7.2.1 Maximum Radiated Power Measurements

For the transmitter antenna, the on-board printed inverted-F antenna of the BRD4186C Radio Board was used (the R1 resistor was mounted). The supply for the RF section (RFVDD) and the 2.4 GHz power amplifier (PAVDD) was 1.8 V provided by the on-chip DC-DC converter; for details, see the BRD4186C schematic. The transceiver was operated in unmodulated carrier transmission mode. The output power of the radio was set to 10 dBm based on the conducted measurement.

The results are shown in the tables below. The correction factors are applied based on the BLE 125 Kb/s coded modulation, shown in section 7.1.2 Conducted Power Measurements with Modulated Carrier. For the rest of the supported modulation schemes, the correction factors are larger, thus the related calculated margins would be higher compared to the ones shown in the table below. Thus, the margins below can be considered as worst case margins.

Table 7.2. Maximums of the Measured Radiated Powers in EIRP [dBm] and the Calculated Modulated Margins in [dB] with the Wireless Starter Kit Mainboard; PAVDD = 1.8 V

Frequency (2440 MHz)	Measured Un-modulated EIRP [dBm]	Orientation	BLE 125 Kb/s Coded Modulation			Limit in EIRP [dBm]
			Correction Fac-tor [dB]	Calculated Modulated EIRP [dBm]	Modulated Mar-gin [dB]	
Fund	13.4	XZ/H	NA (0 is used)	13.4	16.6	30.0
2nd	-56.9	XZ/H	-2.7	-59.6	18.3	-41.2
3rd	-41.5	YZ/H	-4.8	-46.3	5.1	-41.2
4th	<-50*	-/-	-5.5	<-50	>20.0	-30.0
5th	-50.1	YZ/H	-6.3	-56.4	15.2	-41.2
* Signal level is below the Spectrum Analyzer noise floor.						

As shown in the table, with 10 dBm output power, the radiated power of the fundamental is higher than 10 dBm due to the high antenna gain. The 3rd harmonic is very close to the limit with the Wireless Starter Kit Mainboard in case of the unmodulated carrier transmission. But with the relaxation of the supported modulation schemes, the margin is at least 5.1 dB.

7.2.2 Antenna Pattern Measurements

The measured normalized antenna patterns are shown in the following figures.

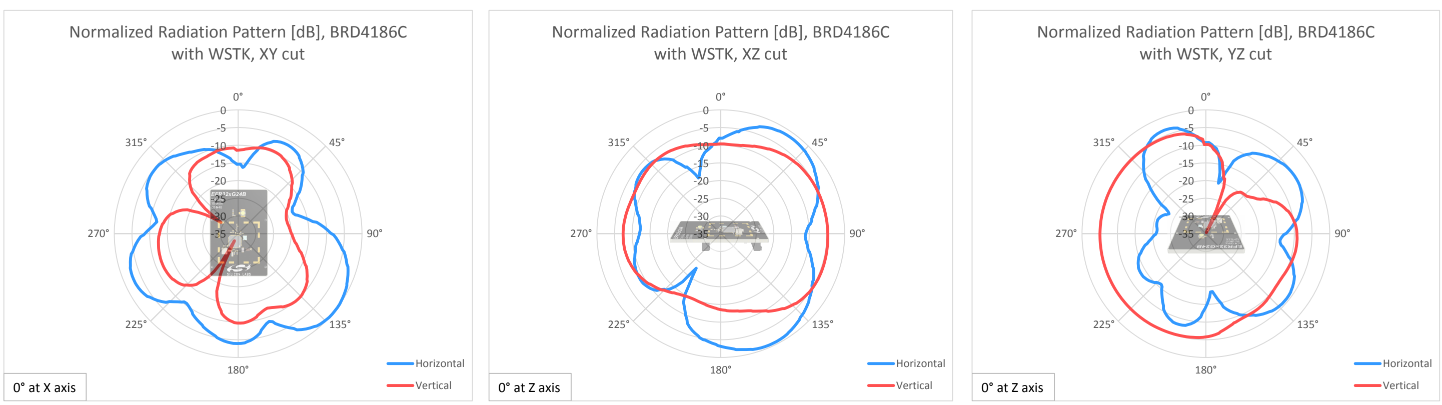

Figure 7.3. Normalized Antenna Pattern of the BRD4186C with the Wireless Starter Kit Mainboard

8. EMC Compliance Recommendations

8.1 Recommendations for 2.4 GHz ETSI EN 300-328 Compliance

As shown in section 7.2 Radiated Power Measurements, the power of the BRD4186C fundamental with 10 dBm output is compliant with the 20 dBm limit of the ETSI EN 300-328 regulation. With the supported modulation schemes, the harmonics are also compliant with the relevant limits. Although the BRD4186C Radio Board has an option for mounting a shielding can, it is not required for compliance.

8.2 Recommendations for 2.4 GHz FCC 15.247 Compliance

As shown in section 7.2 Radiated Power Measurements, the power of the BRD4186C fundamental with 10 dBm output is compliant with the 30 dBm limit of the FCC 15.247 regulation. With the supported modulation schemes, the harmonics are also compliant with the relevant limits. Although the BRD4186C Radio Board has an option for mounting a shielding can, it is not required for compliance.

9. Board Revision History

The board revision is laser engraved in the Board Info field on the bottom side of the PCB, as outlined in the figure below. The revision printed on the silkscreen is the PCB revision.

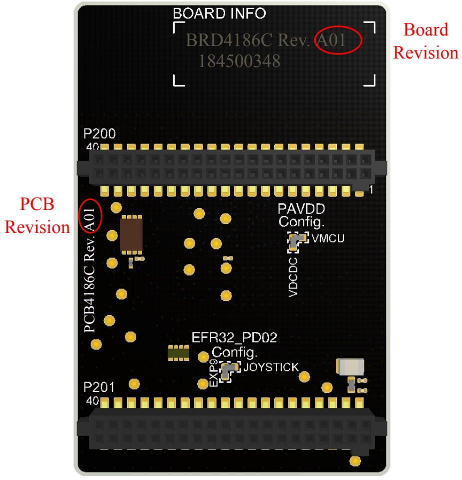

Figure 9.1. Revision Info

Table 9.1. BRD4186C Radio Board Revision History

Board Revision	Description
A01	U1 with new factory calibrations.
A00	Initial release.

10. Errata

There are no known errata at present.

11. Document Revision History

Revision 1.0

April, 2022

- Initial document release.

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