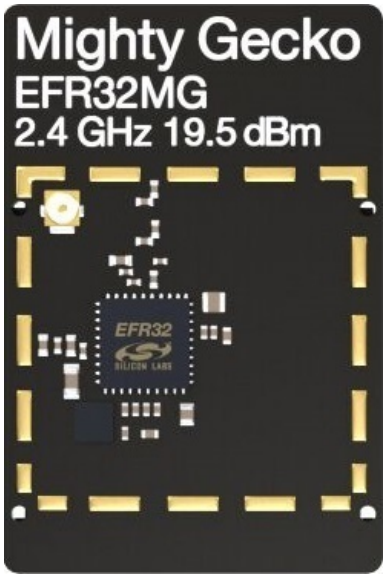
EFR32MG 2.4 GHz 19.5 dBm Radio Board BRD4151A Reference Manual

The EFR32MG family of Wireless SoCs deliver a high performance, low energy wireless solution integrated into a small form factor package.

By combining a high performance 2.4 GHz RF transceiver with an energy efficient 32-bit MCU, the family provides designers the ultimate in flexibility with a family of pin-compatible devices that scale from 128/256 kB of flash and 16/32 kB of RAM. The ultra-low power operating modes and fast wake-up times of the Silicon Labs energy friendly 32-bit MCUs, combined with the low transmit and receive power consumption of the 2.4 GHz radio, result in a solution optimized for battery powered applications.

To develop and/or evaluate the EFR32 Mighty Gecko, the EFR32MG Radio Board can be connected to the Wireless Starter Kit Mainboard to get access to display, buttons and additional features from Expansion Boards.



RADIO BOARD FEATURES

- Wireless SoC: EFR32MG1P232F256GM48
- CPU core: ARM Cortex-M4 with FPU
- Flash memory: 256 kB
- RAM: 32 kB
- Operation frequency: 2.4 GHz
- Transmit power: 19.5 dBm
- Integrated PCB antenna, UFL connector (optional).
- Crystals for LFXO and HFXO: 32.768 kHz and 38.4 MHz.

1. Introduction

The EFR32 Mighty Gecko Radio Boards provide a development platform (together with the Wireless Starter Kit Mainboard) for the Silicon Labs EFR32 Mighty Gecko Wireless System on Chips and serve as reference designs for the matching network of the RF interface.

The BRD4151A Radio Board is designed to operate in the 2400-2483.5 MHz band with the RF matching network optimized to operate with 19.5 dBm output power.

To develop and/or evaluate the EFR32 Mighty Gecko, the BRD4151A Radio Board can be connected to the Wireless Starter Kit Mainboard to get access to display, buttons 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 EFR32MG1 GPIO pins as well as the RESETn signal. For more information on the functions of the available pin functions, see the EFR32MG1 data sheet.

2.2 Radio Board Connector Pin Associations

The figure below shows the pin mapping on the connector to the radio pins and their function on the Wireless Starter Kit Mainboard.

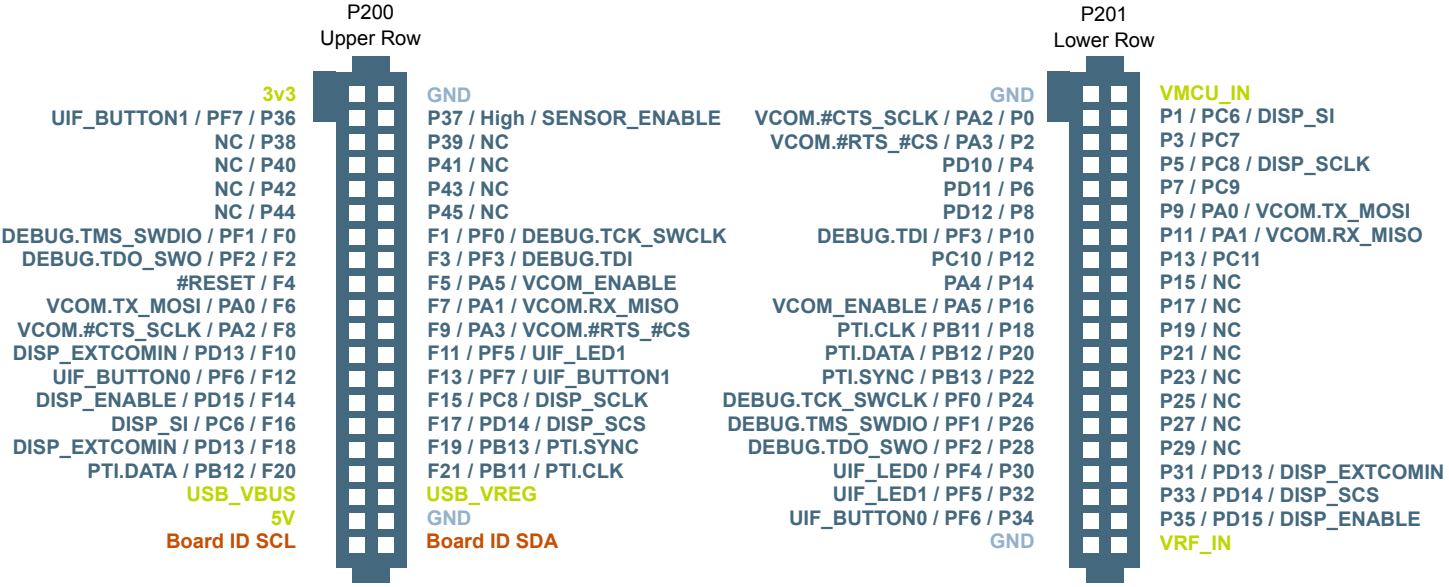


Figure 2.1. BRD4151A Radio Board Connector Pin Mapping

3. Radio Board Block Summary

3.1 Introduction

This section gives a short introduction to the blocks of the BRD4151A Radio Board.

3.2 Radio Board Block Diagram

The block diagram of the EFR32MG Radio Board is shown in the figure below.

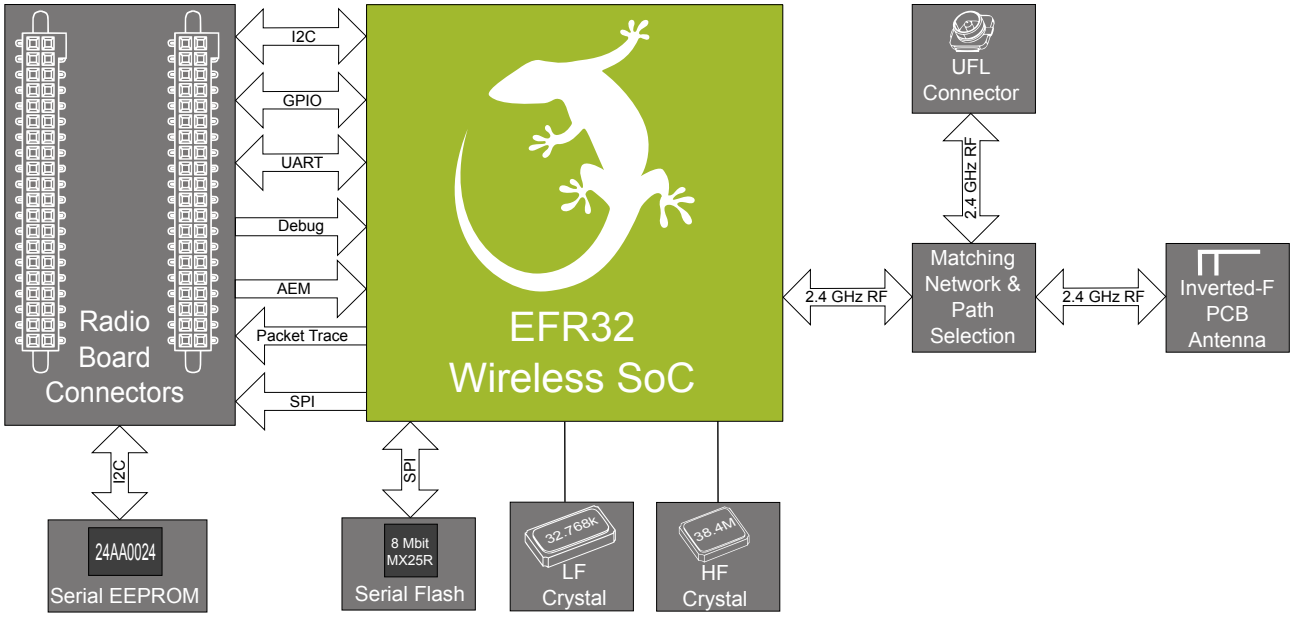


Figure 3.1. BRD4151A Block Diagram

3.3 Radio Board Block Description

3.3.1 Wireless MCU

The BRD4151A EFR32 Mighty Gecko Radio Board incorporates an EFR32MG1P232F256GM48 Wireless System on Chip featuring 32-bit Cortex-M4 with FPU core, 256 kB of flash memory and 32 kB of RAM and a 2.4 GHz band transceiver with output power up to 19.5 dBm. For additional information on the EFR32MG1P232F256GM48, refer to the EFR32MG1 Data Sheet.

3.3.2 LF Crystal Oscillator (LFXO)

The BRD4151A Radio Board has a 32.768 kHz crystal mounted.

3.3.3 HF Crystal Oscillator (HFXO)

The BRD4151A Radio Board has a 38.4 MHz crystal mounted.

3.3.4 Matching Network for 2.4 GHz

The BRD4151A Radio Board incorporates a 2.4 GHz matching network which connects the 2.4 GHz TRX pin of the EFR32MG1 to the one on-board printed Inverted-F antenna. The component values were optimized for the 2.4 GHz band RF performace and current consumption with 19.5 dBm output power.

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

3.3.5 Inverted-F Antenna

The BRD4151A Radio Board includes a printed Inverted-F antenna (IFA) tuned to have close to 50 Ohm impedance at the 2.4 GHz band.

For detailed description of the antenna see Chapter 4.5 Inverted-F Antenna.

3.3.6 UFL Connector

To be able to perform conducted measurements, Silicon Labs added an 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 component. It can be connected to the UFL connector as well through a series 0 Ohm resistor which is not mounted by default. For conducted measurements through the UFL connector the series component to the antenna should be removed and the 0 Ohm resistor should be mounted (see Chapter 4.2 Schematic of the RF Matching Network for further details).

3.3.7 Radio Board Connectors

Two dual-row, 0.05” pitch polarized connectors make up the EFR32MG Radio Board interface to the Wireless Starter Kit Mainboard.

For more information on the pin mapping between the EFR32MG1P232F256GM48 and the Radio Board Connector, refer to Chapter 2.2 Radio Board Connector Pin Associations.

4. RF Section

4.1 Introduction

This section gives a short introduction to the RF section of the BRD4151A.

4.2 Schematic of the RF Matching Network

The schematic of the RF section of the BRD4151A Radio Board is shown in the following figure.

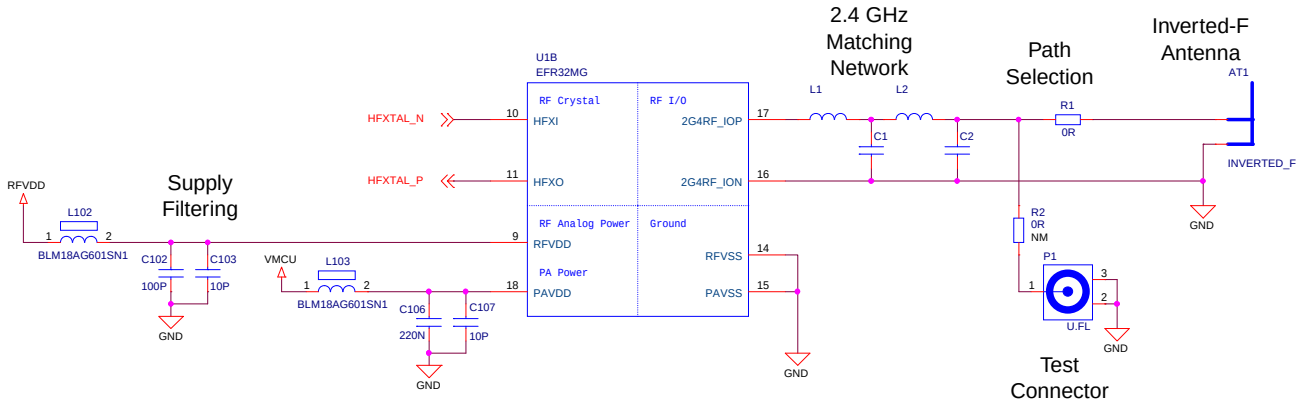


Figure 4.1. Schematic of the RF Section of the BRD4151A

4.2.1 Description of the 2.4 GHz RF Matching

The 2.4 GHz matching connects the 2G4RF_IOP pin to the on-board printed Inverted-F Antenna. The 2G4RF_ION pin is connected to ground. For higher output powers (13 dBm and above) beside the impedance matching circuitry it is recommended to use additional harmonic filtering as well at the RF output. The targeted output power of the BRD4151A board is 19.5 dBm. As a result, the RF output of the IC is connected to the antenna through a four-element impedance matching and harmonic filter circuitry.

For conducted measurements the output of the matching network can also be connected to the UFL connector by relocating the series R1 resistor (0 Ohm) to the R2 resistor position between the output of the matching and the UFL connector.

4.3 RF Section Power Supply

On the BRD4151A Radio Board the supply pin of the RF Analog Power (RFVDD) is connected directly ot the output of the on-chip DC-DC converter while the supply for the 2.4 GHz PA (PAVDD) is provided directly by the mainboard. This way, by default, the DC-DC converter provides 1.8 V for the RF analog section, the mainboard provides 3.3 V for the PA (for details, see the schematic of the BRD4151A).

4.4 Bill of Materials for the 2.4 GHz Matching

The Bill of Materials of the 2.4 GHz matching network of the BRD4151A Radio Board is shown in the following table.

Table 4.1. Bill of Materials for the BRD4151A 2.4 GHz 19.5 dBm RF Matching Network

Component name	Value	Manufacturer	Part Number
C1	2.0 pF	Murata	GRM1555C1H2R0WA01
C2	1.0 pF	Murata	GRM1555C1H1R0WA01
L1	1.8 nH	Murata	LQP15MN1N8W02
L2	3.0 nH	Murata	LQP15MN3N0W00

4.5 Inverted-F Antenna

The BRD4151A 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 and reflection measured at the output of the matcing network are shown in the following figure. As it can be observed the impedance is close to 50 Ohm (the reflection is better than -10 dB) for the entire 2.4 GHz band.

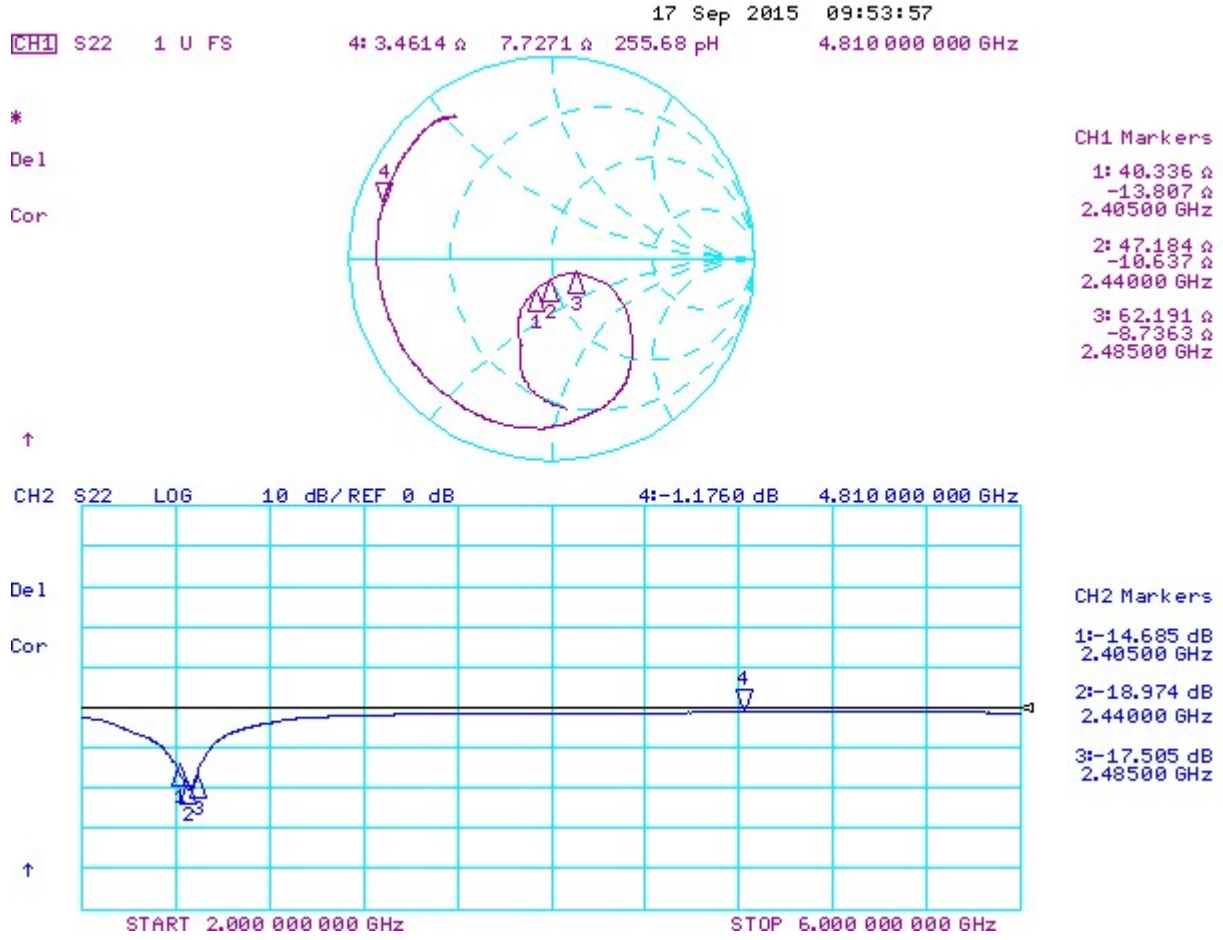


Figure 4.2. Impedance and Reflection of the Inverted-F Antenna of the BRD4151A

5. Mechanical Details

The BRD4151A EFR32 Mighty Gecko Radio Board is illustrated in the figures below.

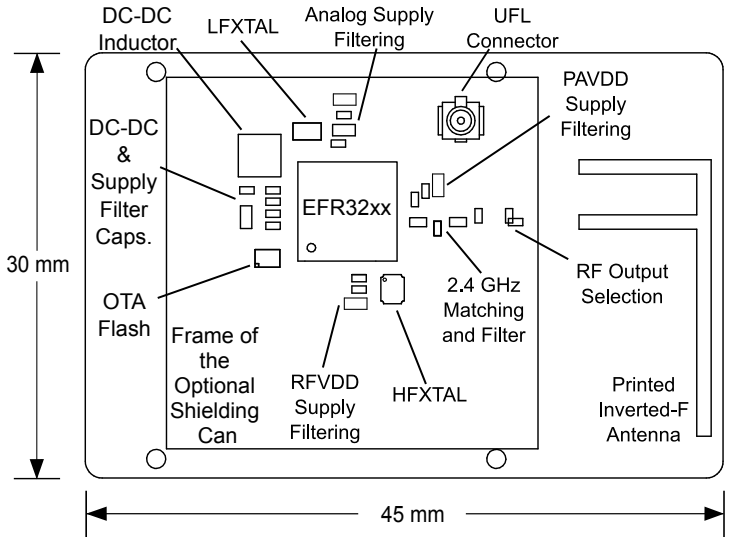


Figure 5.1. BRD4151A Top View

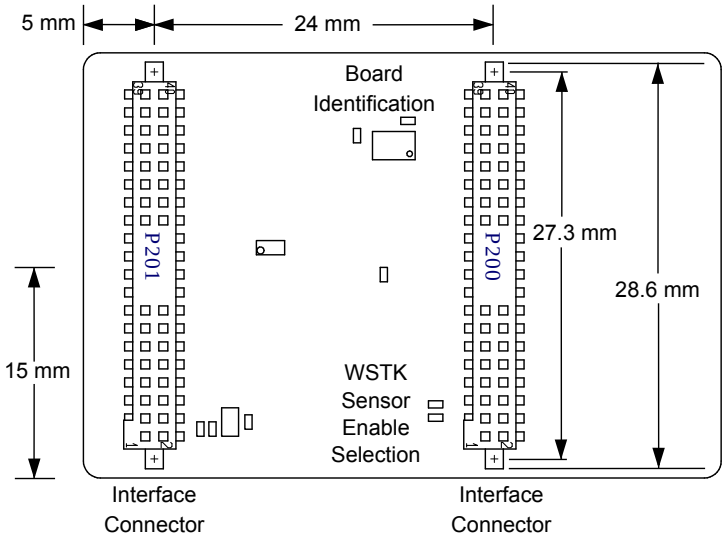


Figure 5.2. BRD4151A Bottom View

6. EMC Compliance

6.1 Introduction

Compliance of the fundamental and harmonic levels 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 specified 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 Watt (30 dBm) in the 2400-2483.5 MHz band. For spurious emmissions 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 (equals to -41.2 dBm in EIRP).

Additionally, for spurious frequencies above 1 GHz, FCC 15.35 allows duty-cycle relaxation to the regulatory limits. For the EmberZNet PRO the relaxation is 3.6 dB. Therefore, the -41.2 dBm limit can be modified to -37.6 dBm.

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 the -37.6 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. Besides that, Silicon Labs applies those to the conducted spectrum i.e., it is assumed that, in case of a custom board, an antenna is used which has 0 dB gain at the fundamental and the harmonic frequencies. In that theoretical case, based on the conducted measurement, the compliance with the radiated limits can be estimated.

The overall applied limits are shown in the table below.

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

Harmonic	Frequency	Limit
2nd	4800~4967 MHz	-37.6 dBm
3rd	7200~7450.5 MHz	-37.6 dBm
4th	9600~9934 MHz	-30 dBm
5th	12000~12417.5 MHz	-37.6 dBm

7. RF Performance

7.1 Conducted Power Measurements

During measurements, the EFR32MG 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.

7.1.1 Conducted Measurements in the 2.4 GHz band

The BRD4151A board was connected directly to a Spectrum Analyzer through its UFL connector (the R1 resistor (0 Ohm) was removed and a 0 Ohm resistor was soldered to the R2 resistor position). During measurements, the voltage supply for the board was 3.3 V provided by the mainboard. The supply for the radio (RFVDD) was 1.8 V provided by the on-chip DC-DC converter, the supply for the power amplifier (PAVDD) was 3.3 V (for details, see the schematic of the BRD4151A). The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to the maximum level.

The typical output spectrum is shown in the following figure.

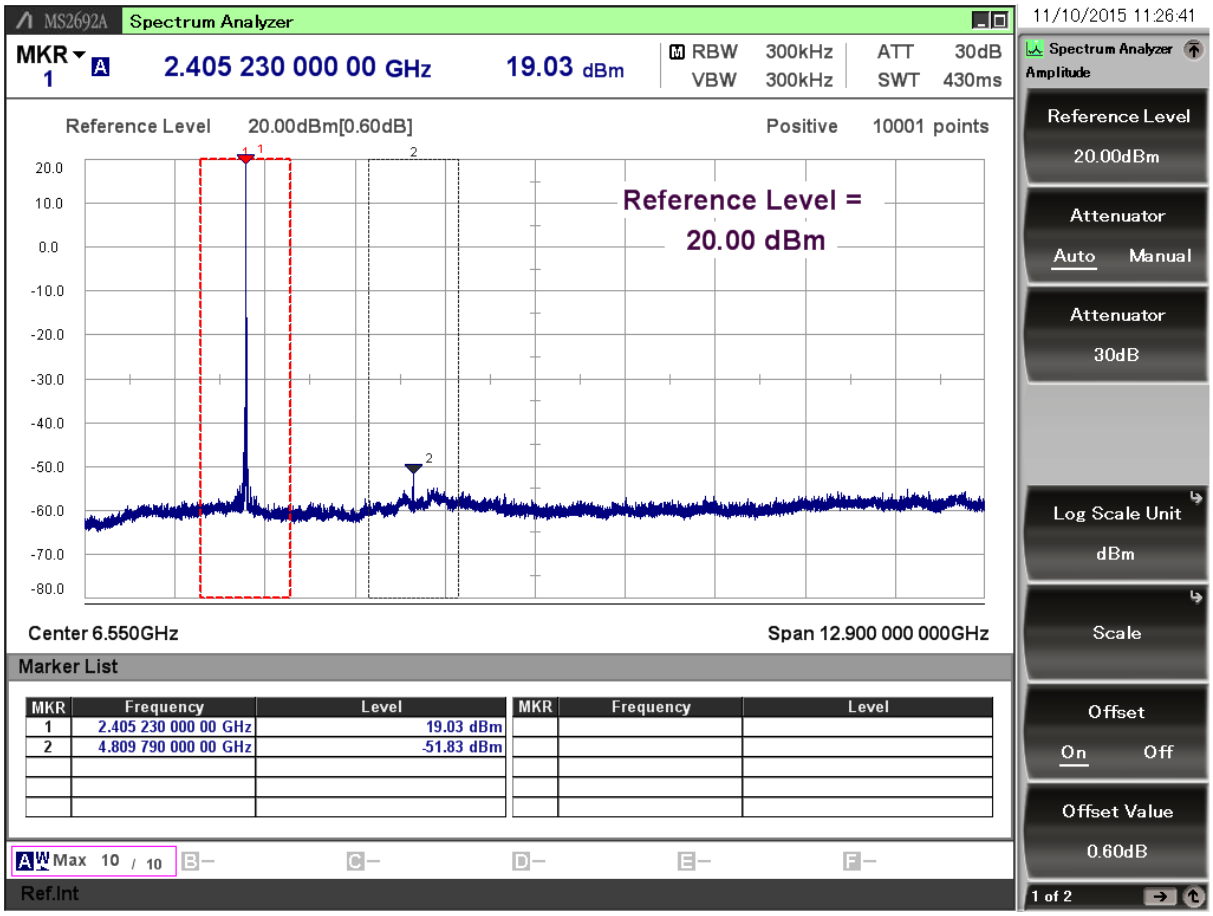


Figure 7.1. Typical Output Spectrum of the BRD4151A

As it can be observed, the fundamental is slightly lower than 19.5 dBm and the strongest unwanted emission is the double-frequency harmonic and it is under the -37.6 dBm applied 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 a 0.3 dB insertion loss.

7.2 Radiated Power Measurements

During measurements, the EFR32MG 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. The radiated power was measured in an antenna chamber by rotating the DUT 360 degrees with horizontal and vertical reference antenna polarizations in the XY, XZ and YZ cuts. The measurement axes are shown in the figure below.

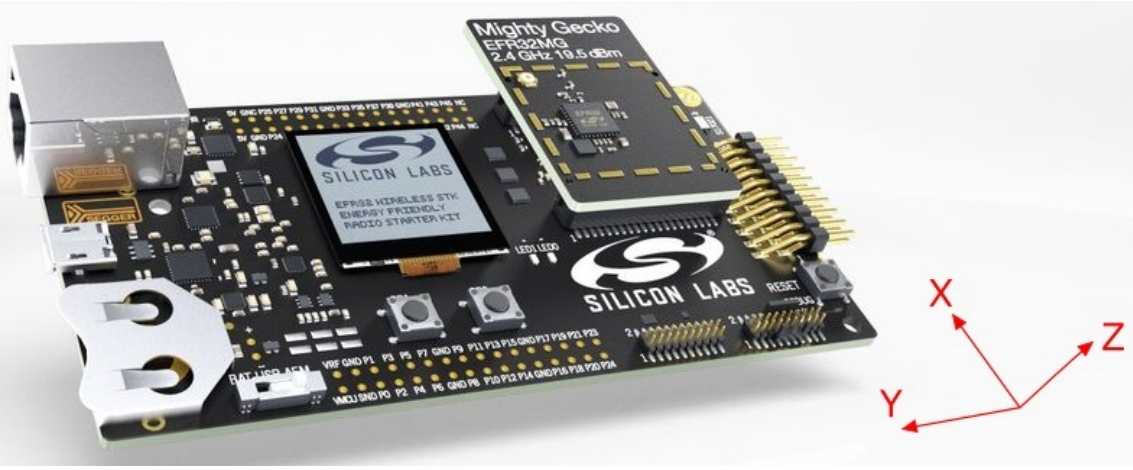


Figure 7.2. DUT: Radio Board with the Wireless Starter Kit Mainboard (Illustration)

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 Radiated Measurements in the 2.4 GHz band

For the transmitter antenna, the on-board printed Inverted-F antenna of the BRD4151A board was used (the R1 resistor (0 Ohm) was mounted). During the measurements the board was attached to a Wireless Starter Kit Mainboard (BRD4001 (Rev. A02)) which was supplied through USB. During measurements, the voltage supply for the board was 3.3 V provided by the mainboard. The supply for the radio (RFVDD) was 1.8 V provided by the on-chip DC-DC converter, the supply for the power amplifier (PAVDD) was 3.3 V (for details, see the schematic of the BRD4151A). The transceiver was operated in continuous carrier transmission mode. The output power of the radio was set to the maximum level.

The results are shown in the table below.

Table 7.1. Maximums of the Measured Radiated Powers of BRD4151A

2.4 GHz	EIRP [dBm]	Orientation	Margin [dB]	Limit in EIRP [dBm]
Fund	21.9	XZ/H	8.1	30
2nd	-47.8	XY/V	10.2	-37.6
3rd	-52.2	YZ/H	14.6	-37.6
4th	-50.4	YZ/V	20.4	-30
5th	Noise*	-/-	>10	-37.6
* Signal level is below the Spectrum Analyzer noise floor.				

As it can be observed, thanks to the high gain of the Inverted-F antenna, the level of the fundamental is higher than 19.5 dBm. The strongest harmonic is the double-frequency one but its level is under -45 dBm.

8. EMC Compliance Recommendations

8.1 Recommendations for 2.4 GHz ETSI EN 300-328 compliance

As it was shown in the previous chapter, the radiated power of the fundamental of the BRD4151A EFR32 Mighty Gecko Radio Board complies with the 20 dBm limit of the ETSI EN 300-328 in case of the conducted measurement but due to the high antenna gain the radiated power is higher than the limit by 2 dB. In order to comply, the output power should be reduced (with different antennas, depending on the gain of the used antenna, the necessary reduction can be different). The harmonic emissions are under the -30 dBm limit. Although the BRD4151A Radio Board has an option for mounting a shielding can, that is not required for the compliance.

8.2 Recommendations for 2.4 GHz FCC 15.247 compliance

As it was shown in the previous chapter, the radiated power of the fundamental of the BRD4151A EFR32 Mighty Gecko Radio Board complies with the 30 dBm limit of the FCC 15.247. The harmonic emissions are under the -37.6 dBm applied limit both in case of the conducted and the radiated measurements. Although the BRD4151A Radio Board has an option for mounting a shielding can, that is not required for the compliance.

9. Board Revisions

Table 9.1. BRD4151A Radio Board Revisions

Radio Board Revision	Description
B01	Initial release
B02	Series component between the antenna and the matching output has been replaced with 0 Ohm resistor. Corrected silkscreen marking for the output power.
B03	Updated EFR32 to revision C0.

Note: The silkscreen marking on the board (e.g., PCBxxxx A00) denotes the revision of the PCB. The revision of the actual Radio Board can be read from the on-board EEPROM.

10. Errata

Table 10.1. BRD4151A Radio Board Errata

Radio Board Revision	Problem	Description
B01	Incorrect silkscreen marking.	Output power marked as "20 dBm" instead of "19.5 dBm."
	Unnecessary component mounted.	Power Amplifier settings have been optimized so the C3 capacitor is not necessary any more, 0 Ohm resistor can be used instead.

11. Document Revision History

Revision 1.7

2016-11-20

Minor editorial updates.

Revision 1.6

2016-10-31

Corrected error in radio board connector pinout diagram.

Revision 1.5

2016-05-24

Updating Board Revisions content. Fixing Errata description.

Revision 1.4

2016-05-05

Adding Introduction chapter; moving SoC Description chapter (short ver.) to Block Description chapter. Minor improvements.

Revision 1.3

2016-02-11

Addign RF Section Power Supply chapter. Minor improvements.

Revision 1.2

2016-01-28

Fixing image render problem.

Revision 1.1

2015-25-25

Updating Inverted-F Antenna Chapter and radiated measurement results based on board revision B02.

Revision 1.0

2015-11-27

Initial release.

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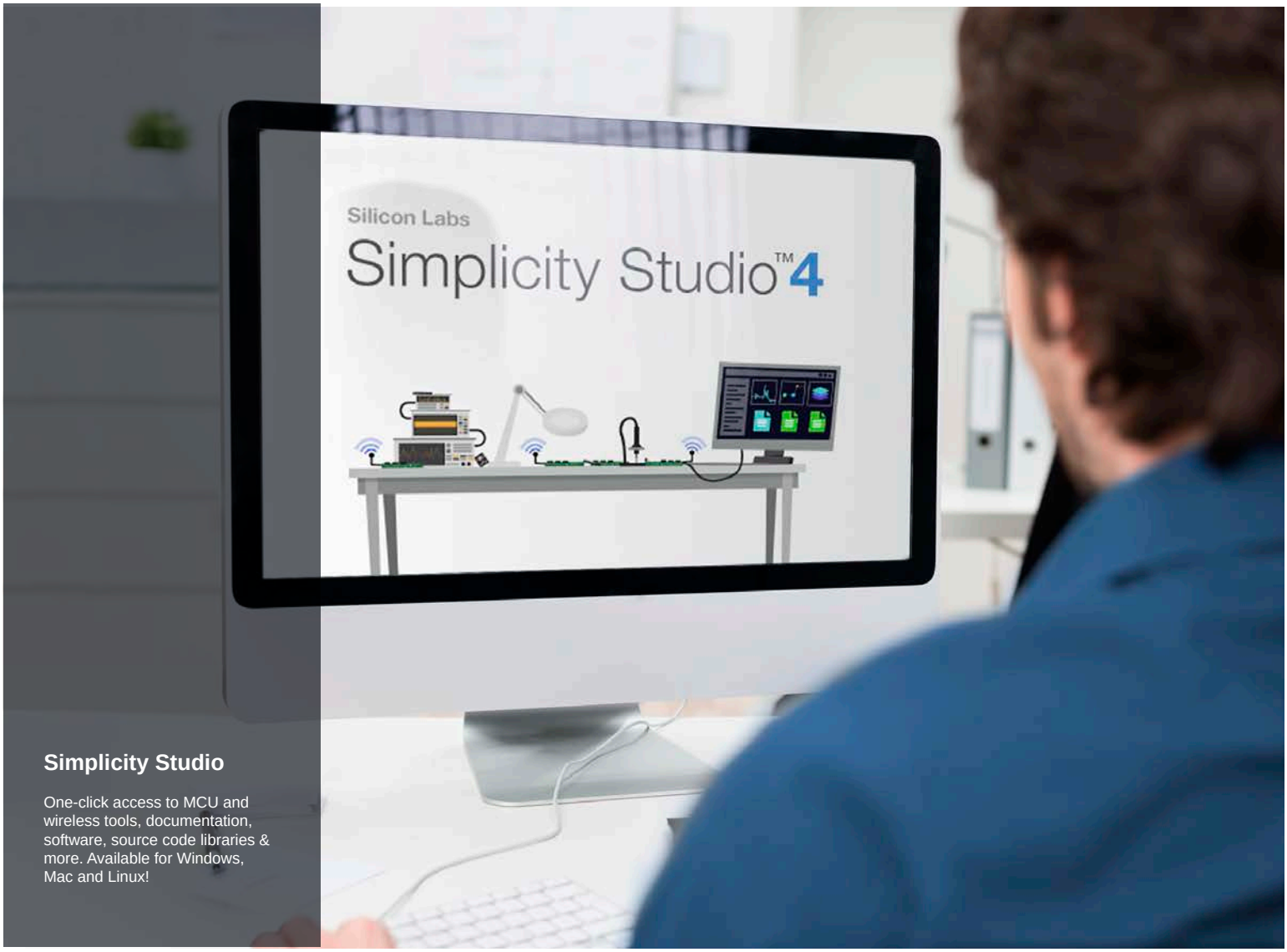
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