APPLICATION NOTE

AT04466: Wireless SoC Reference Design with RFMDs RF6575

Atmel MCU Wireless

Description

The Atmel® RFSM6575RC128A-410 reference design is a partnership between RFMD and Atmel Corporation. This design presents a complete 2.4GHz IEEE® 802.15.4-compliant radio transceiver solution that conforms to FCC CFR47 part 15 and CE.

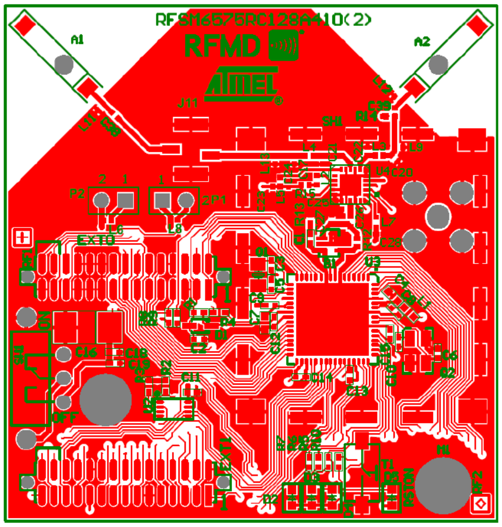
Atmel introduces the ATmega128RFA1 and ATmega256RFR2 as its ZigBee® platform which incorporates a low power 2.4GHz radio frequency transceiver and a High Performance, Low Power AVR®, 8-bit microcontroller into a single 9mm x 9mm x 0.9mm 64-pin QFN package.

RFMD presents a world class Front End Module (FEM), RF6575 for efficient extended output power above 20dBm with harmonic filtering, Antenna Diversity switch and LNA.

Features

- Output power +22dBm (>100mW)
- Industry leading 126.5dB link budget
- Sensitivity: -104.5dBm, 1% PER
- Low Harmonic Content
- Antenna Diversity
- RoHS Compliant
- Single differential bidirectional TX/RX interface

Figure 1. RFSM6575RC128A-410.



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1. Overview

1.1 RF6575

The RF6575 [2] FEM serves as a single-chip medium power >100mW (20 to 22dBm) of output power Smart Energy front end solution. The RF6575 integrates the PA with harmonic filtering, LNA, SPDT switch for TX/RX functionality, DP2T switch for antenna diversity and a 50Ω single-ended bidirectional TX/RX interface all on a single 3.5mm x 3.5mm x 0.5mm QFN 20-Pin package.

1.2 Atmel ATmega128RFA1/ATmega256RFR2

The IC integrates a powerful, AVR 8-bit RISC microcontroller, an IEEE 802.15.4-compliant transceiver, and additional peripheral features. The built-in radio transceiver supports the worldwide accessible 2.4GHz ISM band. The system is designed to demonstrate standard-based applications such as ZigBee/IEEE 802.15.4, ZigBee RF4CE, and 6LoWPAN, as well as high data rate ISM applications.

1.3 Hardware

The RFSM6575RC128A-410 reference design serves as a proven >100mWatt range extension for the ATmega128RFA1/ATmega256RFR2 with a link budget of 126.5dB. The RF6575, RF6555 [3], RFFM6201, RF6545, and RF6505 [3] also serve as range extensions for the ATmega128RFA1/ATmega256RFR2, AT86RF231, and AT86RF233 radio transceivers [1].

The RFSM6575RC128A-410 demo board can be purchased from RFMD e-store (www.rfmd.com) and RFMD support contact email SmartGrid@rfmd.com.

1.4 Software

The RFSM6575RC128A-410 demo board comes pre-flashed with the Performance test EVK application from MAC 2.8.0 stack software interface to allow for performance verification. For information about IEEE MAC Stack 2.8.0 and the user guide for the Atmel AVR2025: IEEE 802.15.4 MAC Software Package visit, www.atmel.com/tools/IEEE802_15_4MAC.aspx for details.

1.5 Applications

This application note serves to provide a developer with data, evaluation steps, and design tools to implement an IEEE 802.15.4 solution using the RF6505RC128A reference design.

- ZigBee 802.15.4 Based Systems for Remote Monitoring and Control
- Communications Hub for Smart Energy/Home Automation
- Smart metering for energy management applications
- Building Automation

2. Functional Descriptions

2.1 Connectors

The RFSM6575RC128A-410 is equipped with two 50mil, 30-pin connectors (EXT0/1), which are parallel to each other and 22mm apart. These are for interfacing with the Sensor Terminal Board [6] or RCB-Breakout Board [7].

2.2 EEPROM

- An EEPROM is provided on the RFSM6575RC128A-410 to identify the transceiver and software. It also has the production calibration and MAC address information stored.
- This EEPROM may not be required on the final product once the user's design is complete

2.3 RF Communication

- The RFSM6575RC128A-410 boards are also equipped with two PCB antennas A1 and A2 for antenna diversity over the air testing
- The reference design also supports conducted testing by use of J11 an MS-147 receptacle which is Digi-Key P/N H2800DKR-ND that mates to Digi-Key P/N H2802-ND
- It also contains SMA female connector X1, which is Digi-Key P/N J500-ND, which is also for conducted measurements

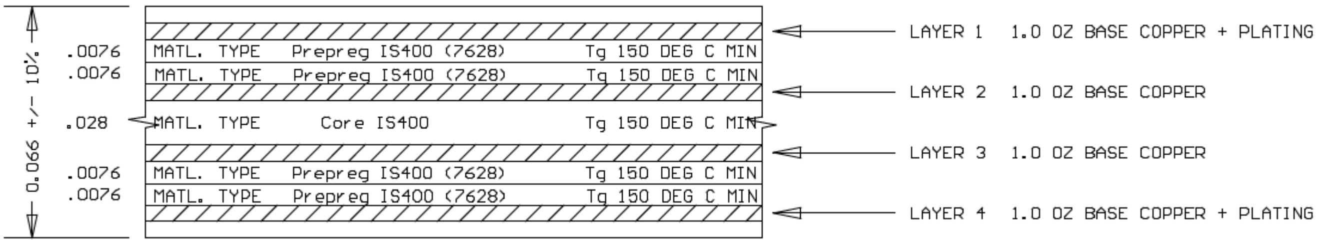
3. Mechanical Descriptions

3.1 Layer Stack-up

The RFSM6575RC128A-410 is made using a 4-layer design on standard FR4 material (IS400) with a total thickness of 66mils. It can be designed on a two layer board [4]. The top and bottom layers are large copper planes whose grounds are stitched together with through-hole vias that are in close proximity of GND pins of critical RF components [4].

- The top layer contains a solid 1oz base copper and plating for digital ground plane and is used for RF and digital signal routing. It has isolation in-between digital and RF traces.
- The filter-balun B1 requires a solid ground connection
- Middle layer 1 is a solid digital ground
- Middle layer 2 is an internal layer and a solid power plane with nets to VCC and V_RCB. The power plane should be surrounded with through-hole ground vias which connect the ground layers together.
- The bottom layer is a digital ground plane shared with RF and made with solid 1oz base copper and plating. See Figure 3-1 for layer stack-up details.

Figure 3-1. RFSM6575RC128APCBA-410 Layer Stack-Up



Note: It is highly recommended by RFMD to follow the PCB layout as closely as possible as deviations from the layout can change the reference designs performance.

3.2 Shielding

The reference design does not contain a metal shield. However, it might be necessary to protect the ICs from external noise and strong interference.

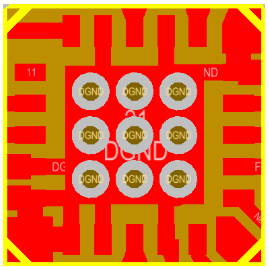
Such shields may suppress radiated harmonics from the reference design but is not necessary. The recommended size for the metal shield is 30mm x 25mm.

3.3 RF Layout Optimization

The RF6575 ground pad via pattern is a 3x3 pattern (see Figure 3-2), with through-hole vias that route from the top layer to the bottom layer. Via hole size is 12mils and the diameter is 24mils. This is for thermal dissipation and to provide a short return path for the signal.

The final product may include removing the solder mask or solder resist from the bottom layer beneath the ground pad for improved thermal dissipation.

Figure 3-2. RF6575 Ground Slug Via Pattern



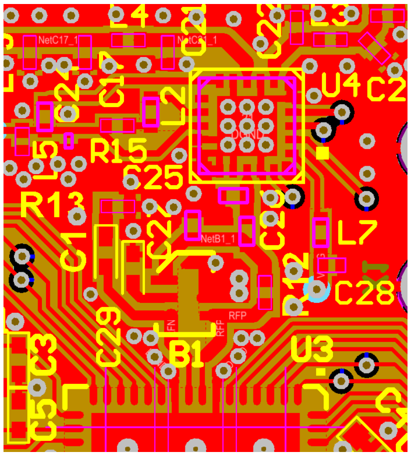
3.4 Differential (using balun) versus Single-Ended (no balun) Layout

From an RF point of view the trace coming from RFP and RFN contains an open stub at R12 (assuming C1, R12, and R13 are not mounted).

While the balun is being used this trace may cause unwanted emissions but it may be in the 7GHz to 10GHz range because of its length. Since it is at the input of the FEM and not at the output of the FEM the emissions should be at a minimum.

The end user however, should choose to either to use this trace for single-ended designing or to cut the trace if the balun B1 is used.

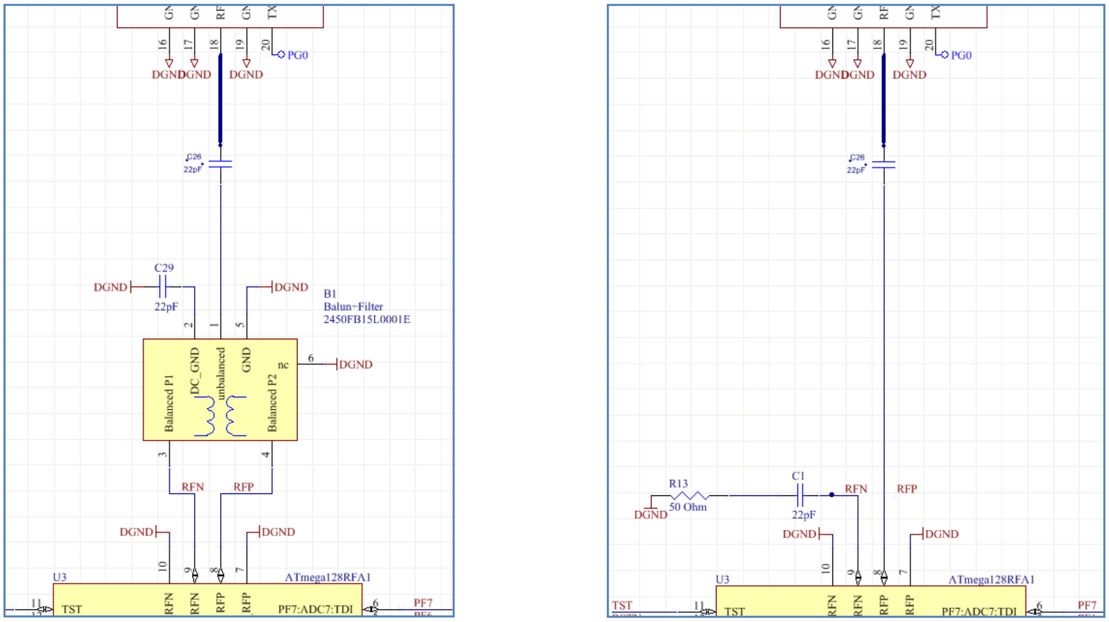
Figure 3-3. Layout From the Top Layer and How to Find the Trace Connected to R12



3.5 Differential (using balun) versus Single-Ended (no balun) Schematic

When design using the RFSM6575RC128A-410 reference design. You can choose either a differential interface or a single ended interface depending on design requirements. Figure 3-4 show how to design the schematic between the RF6575 and Atmel ATmega128RFA1/ATmega256RFR2 with the two configurations.

Figure 3-4. Differential and Single End RF6575/MEGARF Interface



4. Evaluation and Configuration

4.1 Equipments Required

- Either the RCB Sensor Terminal Board (STB) [6] or Radio Controller Board Breakout Board (RCB-BB) [7]
- Signal or Spectrum analyzer for conducted measurements
- Computer with terminal emulator application
- SMA MS-147 Cables (2 Nos)
- RCB Breakout Board RS232 Cable (if using RCB-BB)
- USB cable (if using STB)
- 3V – 4V DC Supply (if using RCB-BB)
- Power meter

4.2 Evaluation Boards

RFSM6575RC128A-410 demo board is evaluated on the Atmel RCB Sensor Terminal Board (Figure 4-1) or the Atmel Radio Controller Board Breakout Board (Figure 4-2). The Sensor Terminal Board (STB) is intended to establish a USB-based UART connection, programming interfaces, and to provide an RCB power supply using the USB cable. The Radio Controller Board Breakout Board (RCB-BB) is intended for connection with an RS-232 serial port, JTAG programming interface, and remote power supply.

Ordering information for the STB and RCB-BB, as well as descriptions, technical data, documentation, and drivers can be found at www.dresden-elektronik.de/funktechnik/products/boards-and-kits/development-boards/. These drivers support Windows® XP and Windows 7 environments.

Figure 4-1. Sensor Terminal Board

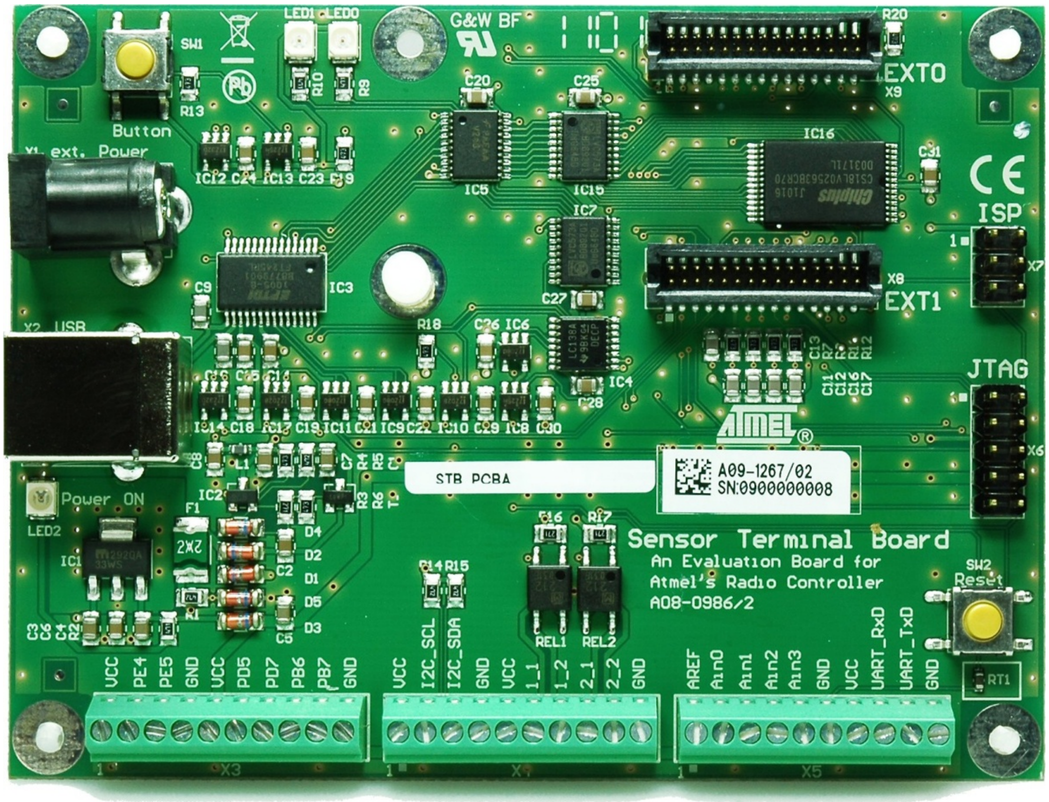
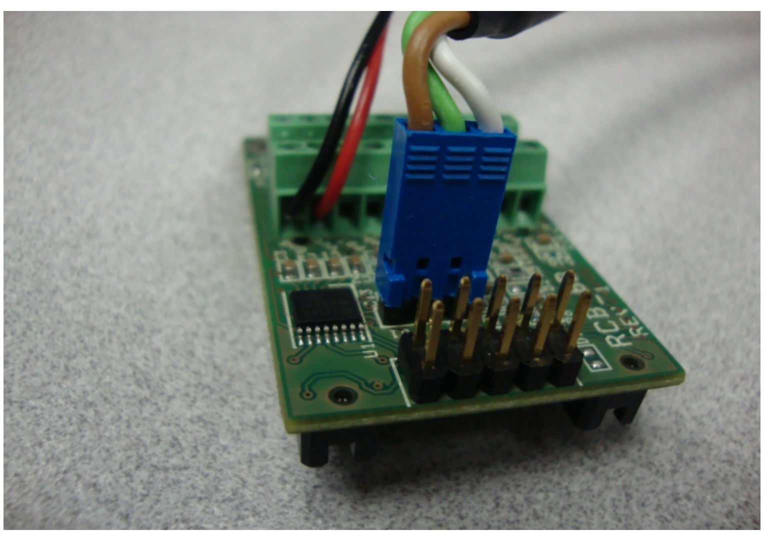


Figure 4-2. RCB Breakout Board RS232 Cable Connected to RCB-BB

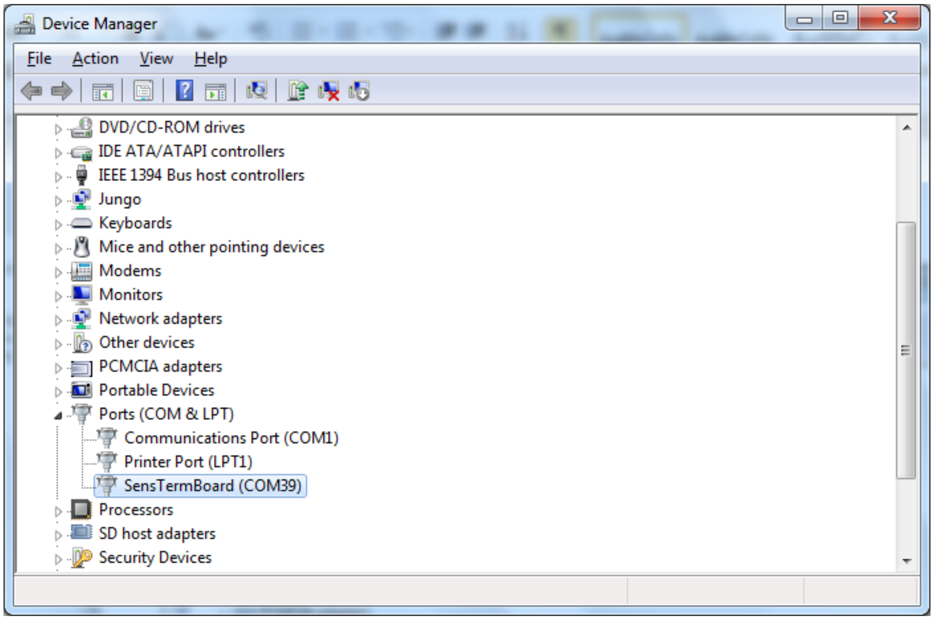


4.3 Steps for Installing and Configuring the Demo Board

1. To control the RFSM6575RC128A-410 that is mounted on the STB, a USB connection between the STB and a host PC is required.
2. Connect USB **X2** connector of the STB with a host-PC USB interface. This causes a driver installation procedure to install a basic device driver in the first run, and a serial driver on top of the basic USB STB driver in the second run. If the STB is connected the first time, the "Found New Hardware Wizard" dialogue displays.

3. If the installation does not start automatically, download the necessary driver from www.ftdichip.com/Products/ICs/FT245R.htm. Select the path where the driver was downloaded before.
4. Perform both installation procedures in a similar way. After completion, the Windows Device Manager (Start>Settings>Control Panel>System>Hardware>Device Manager) displays the assigned COM port number under Ports (COM&LPT).

Figure 4-3. Device Manager after Driver Installation



5. Note this COM port number to configure the terminal application controlling the RCB.
6. To establish a connection to the RFSM6575RC128A-410 reference design board and enable the test menu options the following information must be stored in the terminal emulator application.

Note: PuTTY was used for the purposes of this document.

7. Choose the following settings in the relevant COM port:

Baud (Bits per second):	9600
Parity:	None
Data Bits:	8
Stop Bits:	1
Flow Control:	None

8. Press any key to establish communication with the RFSM6575RC128A-410 reference board.

The images below display once the RFSM6575RC128A-410 board is connected properly. Images of the various menu options that configure the reference board accordingly for transmit and receive testing are also shown below.

Note: After establishing a connection with the computer terminal, the RFSM6575RC128A-410 board searches for a peer device. This feature allows the remote RFSM6575RC128A-410 board to operate without a computer terminal. For transmission performance testing (single node) mode, press the Enter key on the computer to skip this search. The main menu for the Transmission Performance Evaluation section is displayed as shown in Figure 4-4.

Figure 4-4. Starting the Terminal Emulator (main screen)

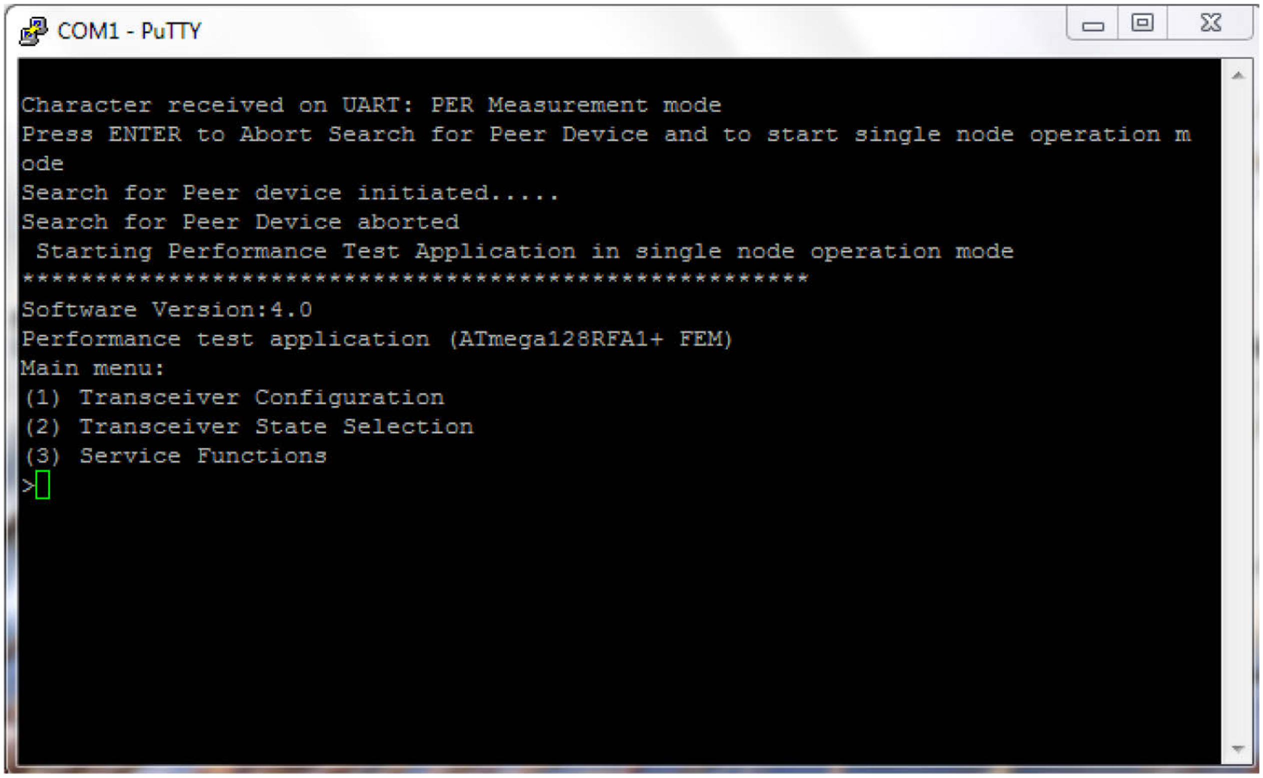
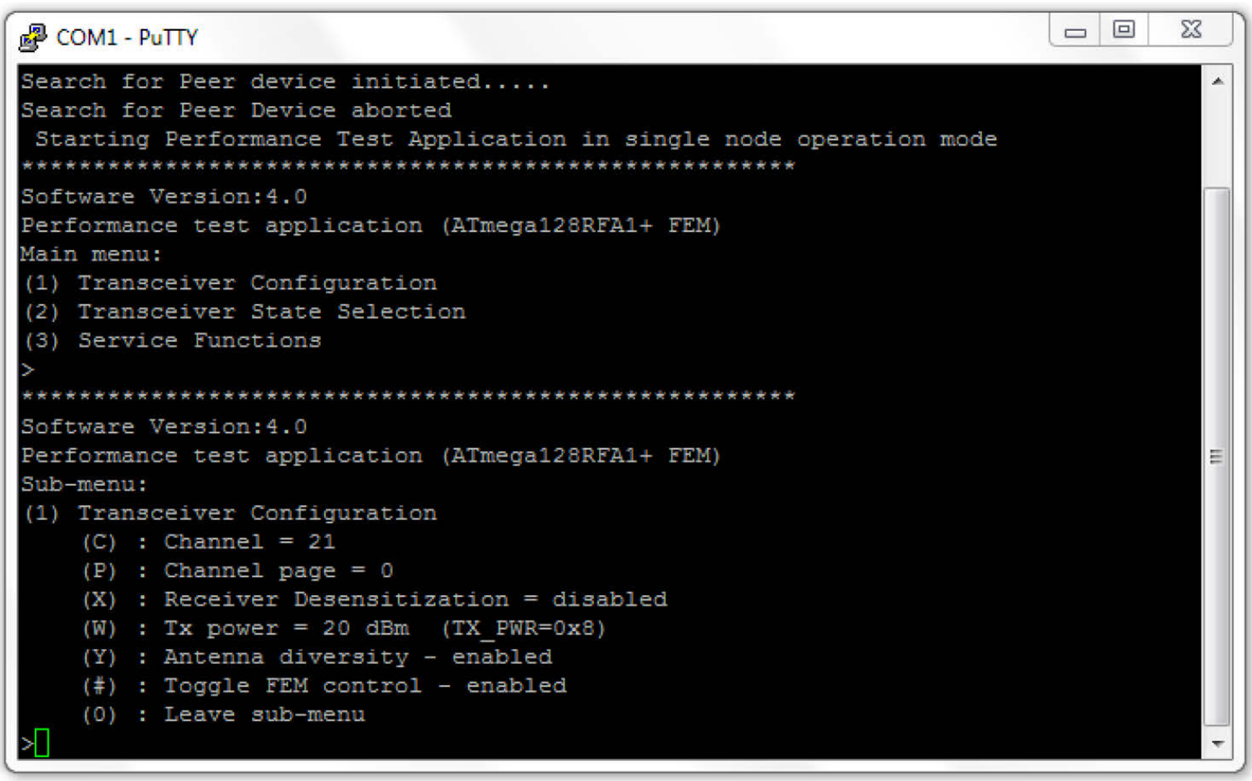


Figure 4-5. Transceiver Configuration Menu Screen



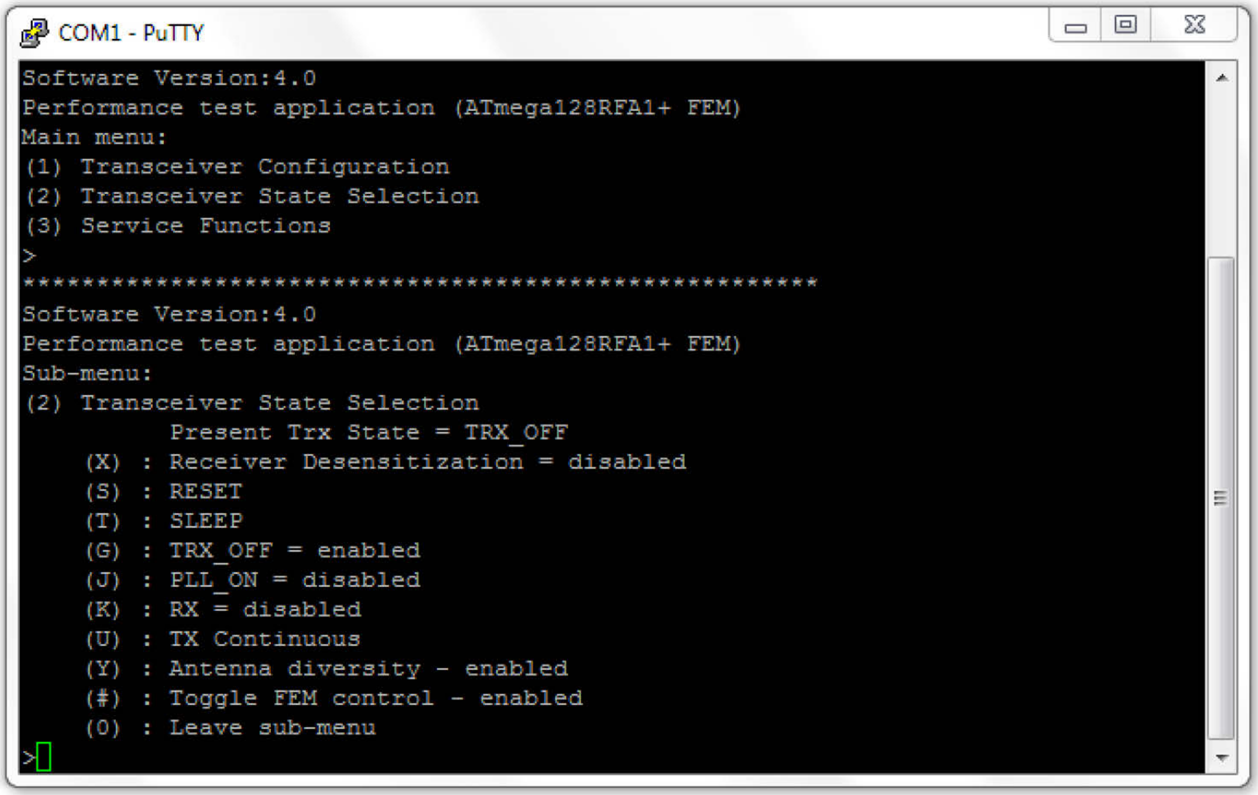
4.4 Transmission Performance Evaluation

1. From the single-node main menu, press **1** to enter the **Transceiver Configuration** menu (Figure 4-5).
2. Set the Channel to the channel to test. The default is Channel 21. To change the channel press **C**, type channel number (11…26) and press **Enter**.
3. Set the TX power level, the default is 20dBm.
   - Press **W** to change the power level
   - Press **A** for absolute and type the power level in dBm (or)
   - Press **R** for register value; type a two digit hexadecimal value (00…0F) and press **Enter**
4. Press **Y** to select antenna and enter **1** or **2**. Press **Y** again to re-enable **Antenna diversity** wherein both antennas are used.

Note: Antenna diversity should be disabled while validating only one antenna.

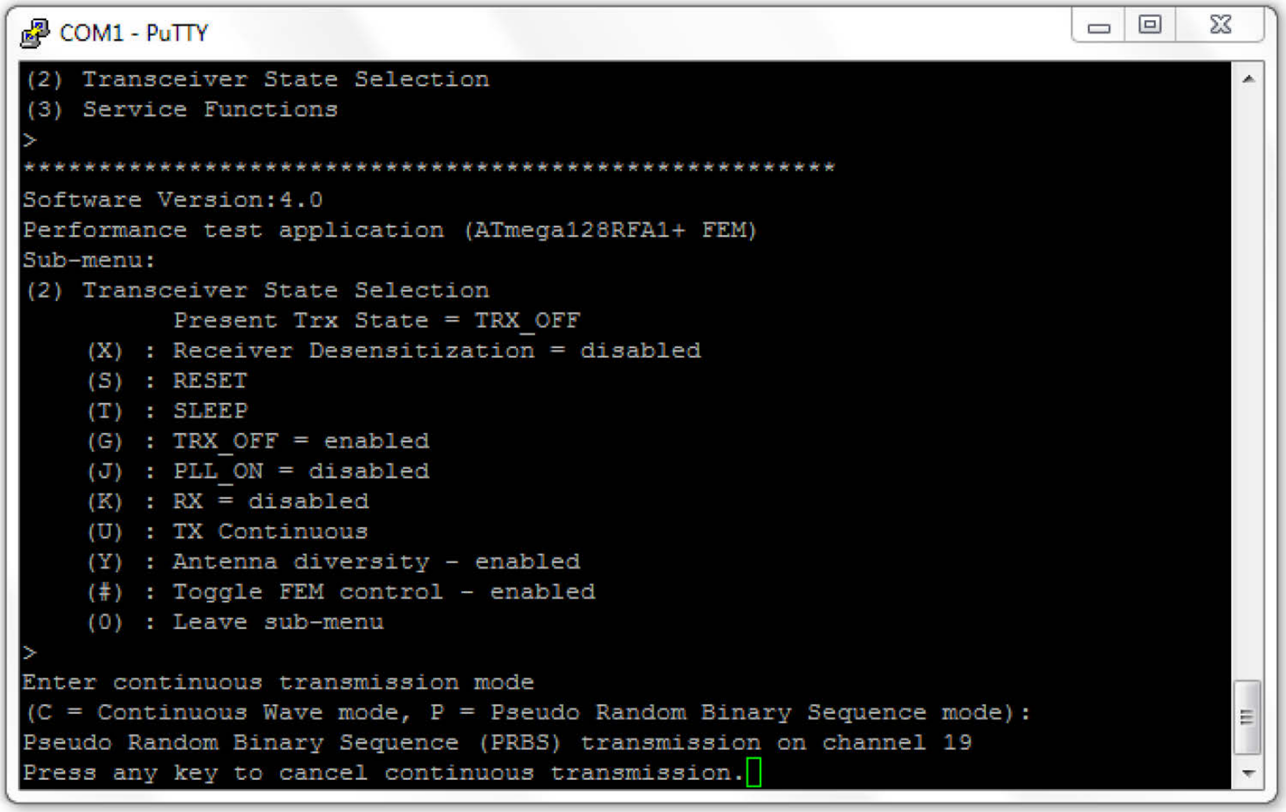
5. Press **O** to leave **Transceiver Configuration** menu.

Figure 4-6. Transceiver State Selection Menu Screen



6. From the Main Menu, press **2** to enter **Transceiver State Selection** menu (see Figure 4-6).
7. Set **Antenna diversity** if it has not been configured earlier. This setting can be configured similar to **Transceiver Configuration** menu.
8. Press **U** to start transmission.
   - Select **C** for continuous waveform
   - Select **P** for modulated (Pseudo Random Binary Sequence) waveform (see Figure 4-7). At this point the demo board is transmitting a signal
9. Spectrum analyzer or Power meter connected to the antenna feed point displays the output power level.
10. Press any key to terminate transmission.

Figure 4-7. Starting Continuous Transmission



4.5 Packet Error Test Rate

Two RFSM6575RC128A-410 boards are required to perform PER testing and the setup is show in Figure 4-8. One board acts as a transmitter and it requires a computer terminal. Another board acts as receiver for which a computer terminal is optional.

Apply power to transmitter board. With terminal emulator window active, press any key to begin search for peer device (receiver) as shown in Figure 4-9. While the transmitter is searching (approximately 12 seconds), apply power to Receiver board. When the receiver is detected, the transmitter and receiver will display a script reading **Peer device found**.

Figure 4-8. Packet Error Rate (PER) Testing Setup

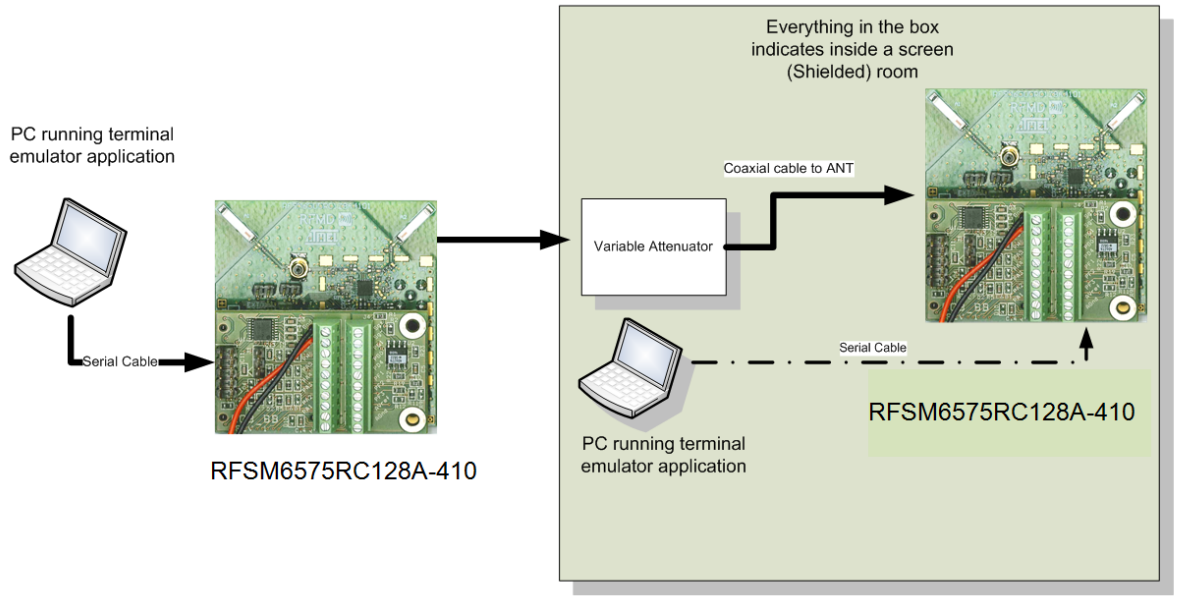
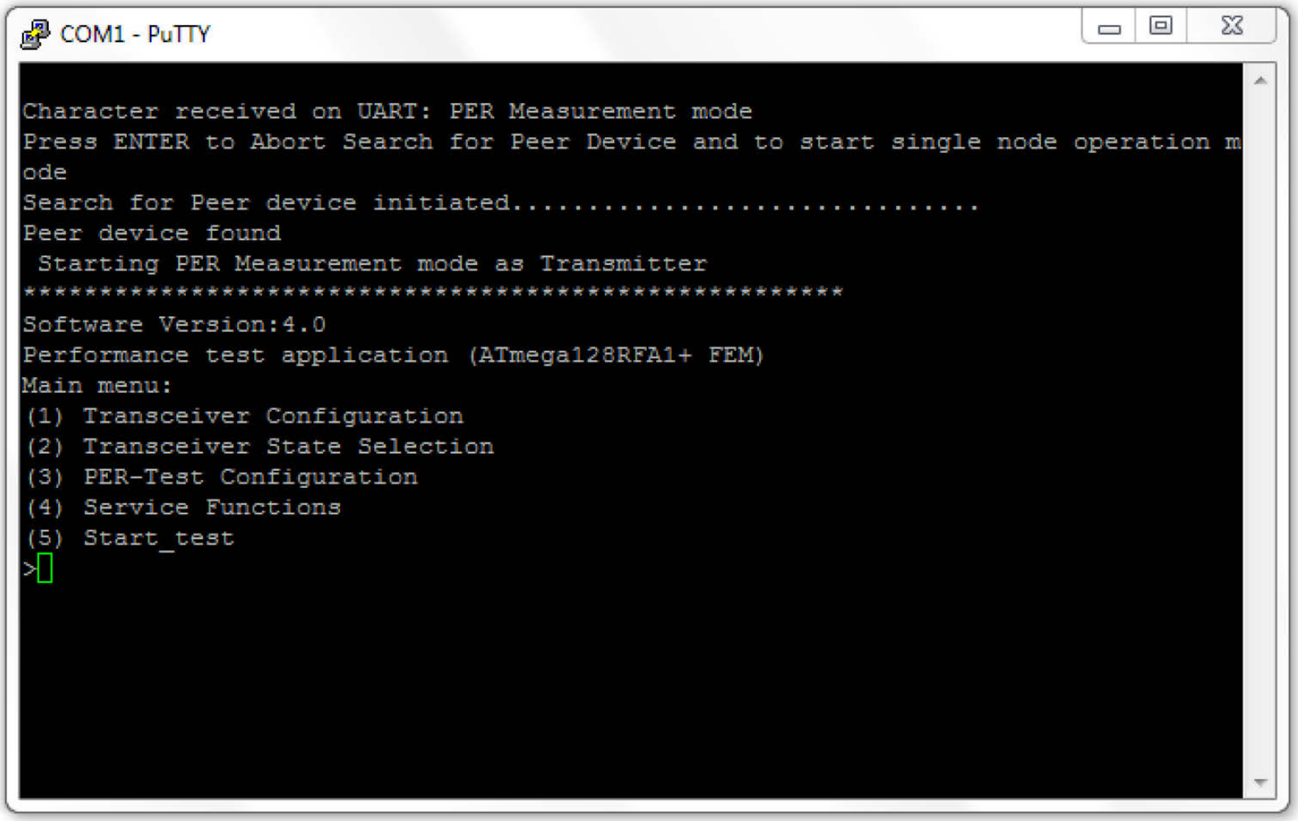


Figure 4-9. Successful Detection of Peer Node



1. Set the Channel number to the channel to test. The default channel is 21.
2. To change the Channel press **C**.

3. Type the two digit channel number (11…26) and press **Enter**.
4. Set the transmit power level. The default power level is 20dBm.
   - Press **W** to change the power level
   - Press **A** for absolute and type the power level in dBm (or)
   - Press **R** for register value; type a two digit hexadecimal value (00…0F) and press **Enter**
5. Press **A** to Toggle ACK request until it reads no **ACK requested**.
6. Press **F** to Toggle Frame Retry until it reads **False**.
7. Press **M** to Toggle CSMA enabled until it reads **False**.
8. Select the antenna for transmission. Toggle the antenna by pressing **Y**.

Note: For validating one Receiving antenna it is required to disable antenna diversity and choose that particular antenna.

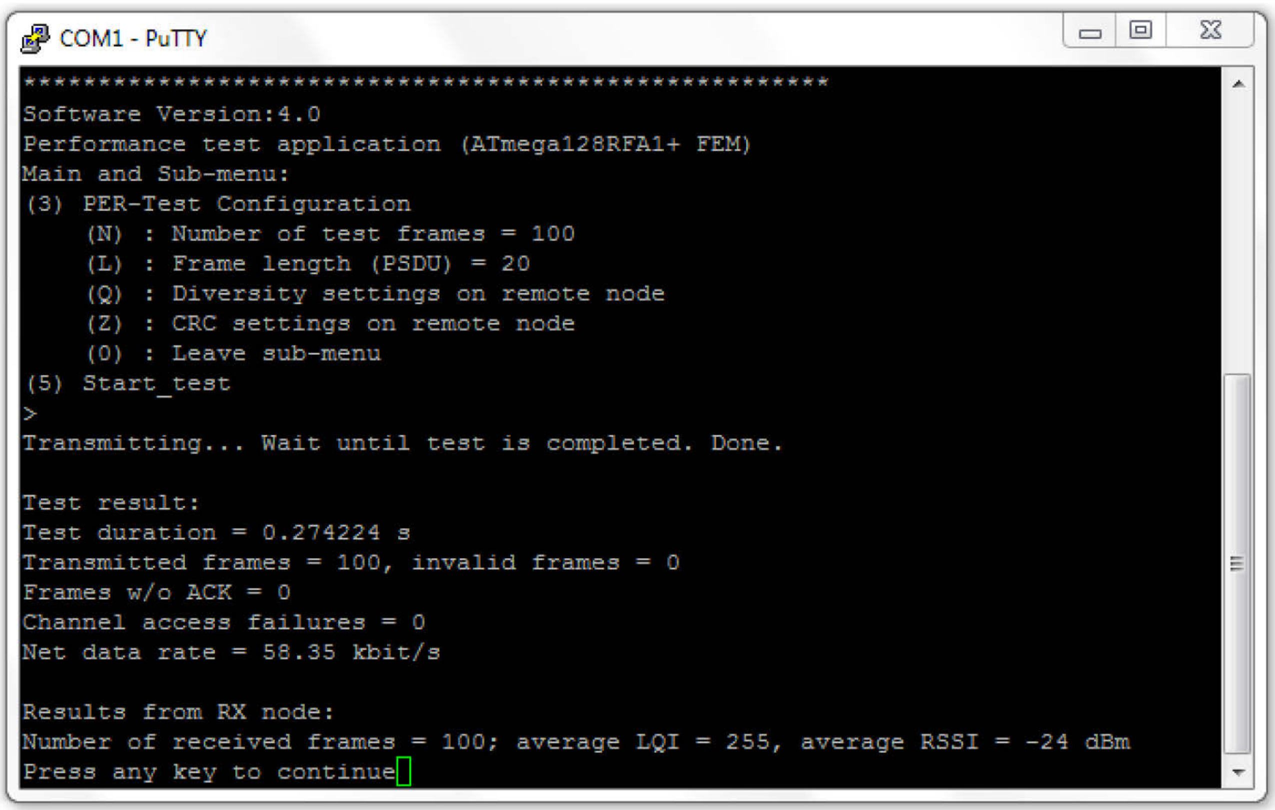
9. Press **Z** to toggle RF Front End control until it reads enabled.
10. Press **O** to return to Main menu. Then Press **3** to enter the **PER-Test Configuration** menu.
11. Set the number of packets for transmission. The default number is 100. To change the number of packets, press **N**, specify the number of frames and press **Enter**.
12. Select the antenna for reception by pressing **Q**, followed by **C** and then **2** or **3**.

In the main menu, press **5** and the text **Transmitting… Wait until test is completed** is displayed on the screen. The main screen displays the number of packets received and this defines the PER value (Figure 4-10).

For example,

```
1000/1000 equates to 0% PER
990/1000 equates to 1% PER
Average PER < 1% at -100dBm
```

Figure 4-10. Terminal Screen after PER Test



5. Transmission Performance

5.1 Transmit Output Power Performance

Table 5-1. Measured Transmit Output Power Across Channels

Channel/MHz	P_{OUT}[dBm] @ -30°C	P_{OUT}[dBm] @ 25°C	P_{OUT}[dBm] @ 85°C
Channel 11 (2405)	22	22	20.9
Channel 12 (2410)	22	21.9	20.8
Channel 13 (2415)	22	21.8	20.8
Channel 14 (2420)	21.9	21.7	20.7
Channel 15 (2425)	21.8	21.6	20.6
Channel 16 (2430)	21.7	21.4	20.4
Channel 17 (2435)	21.5	21.4	20.4
Channel 18 (2440)	21.5	21.4	20.4
Channel 19 (2445)	21.4	21.4	20.3
Channel 20 (2450)	21.3	21.3	20.3
Channel 21 (2455)	21.3	21.3	20.2
Channel 22 (2460)	21.2	21.2	20.2
Channel 23 (2465)	21.1	21.1	20.1
Channel 24 (2470)	21.0	21.0	20.1
Channel 25 (2475)	21.0	21.0	20.1
Channel 26 (2480)	21.0	21.0	20.1

Table 5-2. Measured 2nd Harmonic over Temperature

Channel/MHz	H2[dBm/MHz] @ -30°C	H2[dBm/MHz] @ 25°C	H2[dBm/MHz] @ 85°C
Channel 11 (2405)	-66	-55.3	-52.4
Channel 19 (2450)	-52.9	-50.3	-51.2
Channel 26 (2480)	-48.8	-45.6	-47.1

Table 5-3. Measured 3rd Harmonic over Temperature

Channel/MHz	H3[dBm/MHz] @ -30°C	H3[dBm/MHz] @ 25°C	H3[dBm/MHz] @ 85°C
Channel 11 (2405)	-45.5	-51.8	-51.2
Channel 19 (2450)	-45.3	-52.1	-51.2
Channel 26 (2480)	-48.8	-53.5	-51.5

5.2 RX Sensitivity Performance

Table 5-4. Measured RX Sensitivity Across Channels

Rx sensitive data (250kbps)	1% (PER)	20% (PER)
Channel 11	-104.5	-105.5
Channel 19	-104.5	-105.5
Channel 26	-104.5	-105.5

The output power from the Transmit RFSM6575RC128A-410 board should be measured separately as done on section. This power level is needed as a baseline for calculating the attenuation level between the Transmit RFSM6575RC128A-410 board and Receive RFSM6575RC128A-410 board.

5.2.1 Simple Sensitivity Calculation

A very simple way to determine the expected sensitivity of a radio system is that the external LNA should improve the radio by approximately the noise figure of the transceiver minus the noise figure of the external LNA.

I.e. = Sensitivity – (TXVR N.F. – FEM N.F. – Filter Loss).

5.2.2 Single-ended versus Differential Sensitivity

- The RF6575 improves the sensitivity of the Atmel ATmega128RFA1 by 3.5dB in the Single-ended design and 4dB in the Differential design

5.2.3 Additional Harmonic Filtering versus No Filter

- The RFSM6575RC128A-410 does not need any additional harmonic filtering components (C17, L4, and C21 on antenna1 and C22, L3, and C20 on antenna2) to satisfy FCC emissions requirements when operating at an EIRP of ≤+20dBm
- However, the RFSM6575RC128A-410 does need the additional harmonic filtering for an EIRP of >+20dBm in order to satisfy FCC emissions requirements
- The harmonic filter on the RFSM6575RC128A-410 allows the reference design to achieve an output power of up to +23dBm single-ended and +22dBm differential while still complying with FCC regulations at 3.3V operation

5.2.4 Harmonic Filter Affect on Sensitivity

- The harmonic filter (C17, L4, and C21 on antenna1 and C22, L3, and C20 on antenna2) reduces the overall sensitivity by ~1dB. The RFSM6575RC128A-410 can achieve a sensitivity of up to -106dBm at ≤1% PER without the harmonic filter.

6. FCC Compliance Measurements

This section provides the harmonics performance and FCC pre-compliance test results of RFSM6575RC128A-410 board.

Figure 6-1. Channel 19 Second Harmonic Conducted (P_{OUT} = 20.6dBm)

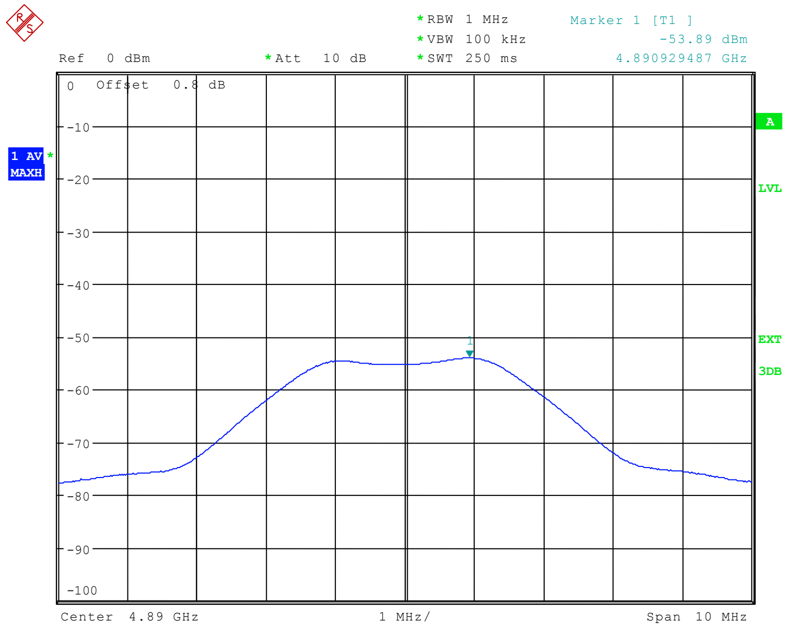


Figure 6-2. Channel 19 Third Harmonic Conducted (P_{OUT} = 20.6dBm)

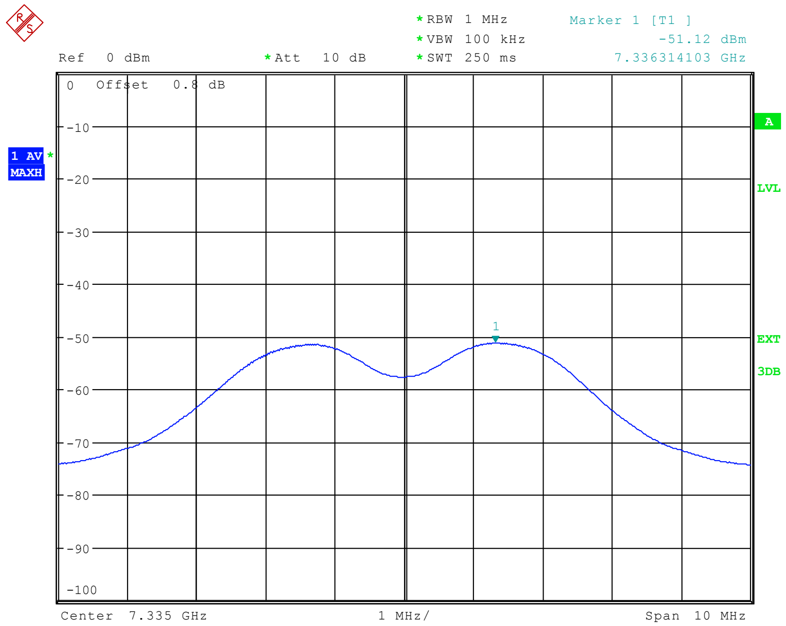


Figure 6-3. Channel 11 Power Spectral Density (P_{OUT} = 21.1dBm)

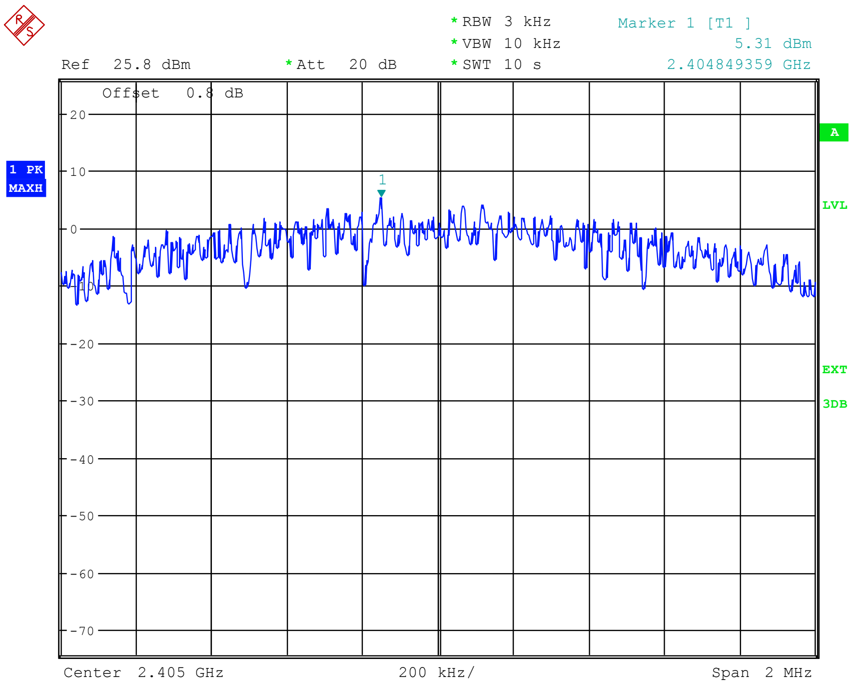


Figure 6-4. Channel 19 Power Spectral Density (P_{OUT} = 20.6dBm)

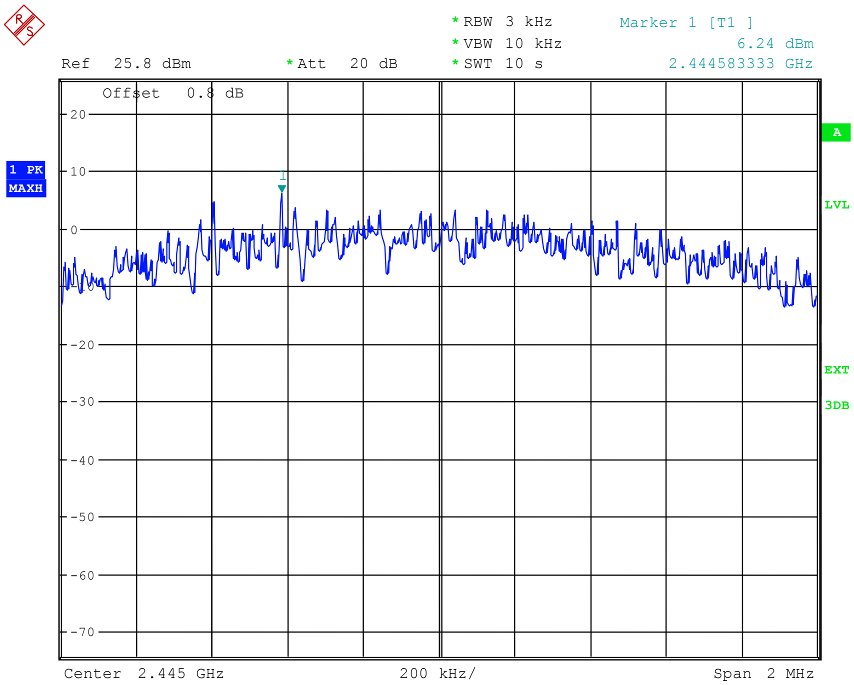
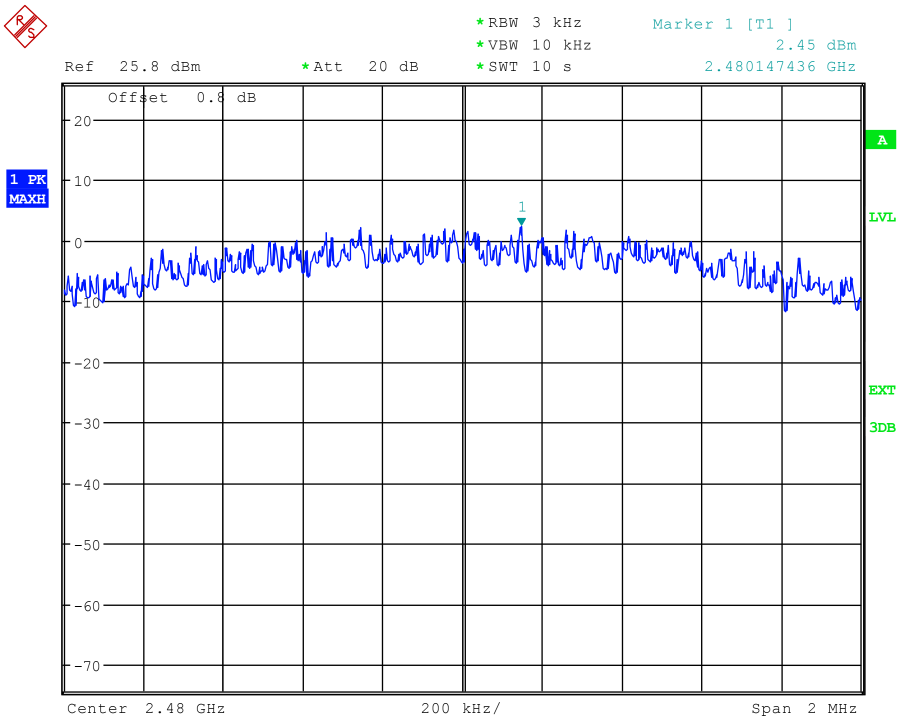


Figure 6-5. Channel 26 Power Spectral Density (P_{OUT} = 19.5dBm)



7. References

[1] Atmel ATmega256RFR2 Datasheet, http://www.atmel.com/products/wireless/802154-microcontrollers/default.aspx.

[2] RF6575 Datasheet, http://www.rfmd.com/CS/Documents/RF6575DS.pdf.

[3] RF6555+ATmega256RFR2 reference design, http://www.rfmd.com/atmel/zigbeerf.aspx.

[4] Atmel AVR10004 RCB256RF2-Hardware User Manual, http://www.atmel.com/Images/Atmel-42081-RCB256RFR2-Hardware-User-Manual_Application-Note_AVR10004.pdf.

[5] FCC Code of Federal Register (CFR); Part 47; Section 15.35, Section 15.205, Section 15.209, Section 15.231.

[6] Sensor terminal board: www.dresden-elektronik.de/funktechnik/service/download/documentation/?L=1#c3646.

[7] RCB Breakout board: www.dresden-elektronik.de/funktechnik/produkte/boards-und-kits/development-boards/rcb-breakout-board

8. Revision History

Doc. Rev.	Date	Comments
42277A	04/2014	Initial document release

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