Using RF6505 Front End Module with CC2530 under FCC 15.247

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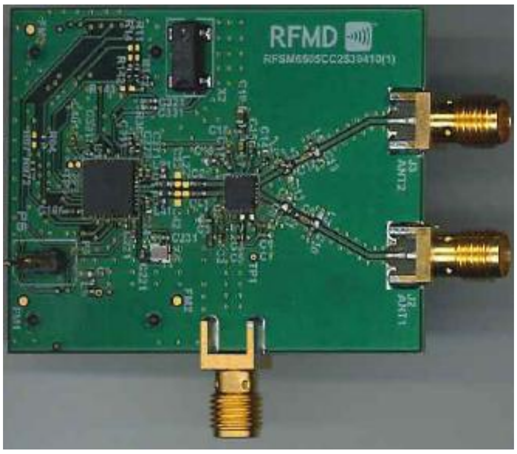

Features

- *Low PA Harmonic Content*
- *27 dBm of Output Power*
- *Excellent Sensitivity*
- *Antenna Diversity*
- *Flexible Design*

Applications

- *802.15.4 Based Systems for Remote Monitoring and Control*
- *2.4-2.5 GHz ISM Band Applications*

Keywords

- *Range Extender*
- *FCC Section 15.247*
- *External PA*
- *External LNA*
- *CC2530*
- *CC2531*
- *RF6505*

1 Introduction

The RF6505 [1] integrates a complete solution in a single Front End Module (FEM) for WLAN and ZigBee applications in the 2.4 GHz unlicensed ISM band. This FEM integrates the PA plus the harmonic filter in the transmit path and the LNA with Bypass mode in the receive side. It provides a single balanced TDD access for RX and TX paths along with two ports on the output for connecting a diversity solution or a test port.

The CC2530 [2] is TI's second generation ZigBee/IEEE 802.15.4 RF system-on-chip (SoC) for the 2.4 GHz unlicensed ISM band. This chip enables industrial grade applications by offering state-of-the-art selectivity/co-existence, excellent link budget, and low voltage operation.

The RF6505-CC2530 reference design [3] is a range extender design for the CC253x, CC2540-1 and CC85xx in the 2.4GHz ISM Bands. It increases the link budget by providing a power amplifier (PA) for increased output power, and a low-noise amplifier (LNA) with low noise figure for improved receiver sensitivity. In addition to these features it provides switches and integrated RF matching for design and high performance wireless systems.

This application note outlines the expected performance when using a RF6505-CC2530 design under FCC [4] Section 15.247 in the 2400-2483.5 MHz frequency band. This application note assumes the reader is familiar with the CC2530 and FCC 15.247 regulatory limits.

For additional information or further questions please contact, RFMD Technical Support at smartgrid@rfmd.com

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2 Abbreviations

EB	Evaluation Board
EM	Evaluation Module
FCC	Federal Communications Commission
FEM	Front End Module
LNA	Low Noise Amplifier
PA	Power Amplifier
PCB	Printed Circuit Board
PER	Packet Error Rate
RX	Receive, Receive Mode
TX	Transmit, Transmit Mode

3 Absolute Maximum Ratings

The absolute maximum ratings and operating conditions listed in the CC2530 datasheet [2] and the RF6505 datasheet [1] must be followed at all times. Stress exceeding one or more of these limiting values may cause permanent damage to any of the devices.

4 Electrical Specifications

4.1 Operating Conditions

Parameter	Min.	Typ.	Max.	Unit
Operating Frequency	2394		2507	MHz
Operating Supply Voltage for 6505CC2530(1)	3.0	3.6	4.2	V
Operating Temperature	-40	25	+85	°C

(1) The recommended maximum operational voltage level of CC2530 is 3.6V on the RF6505-CC2530 design the voltage level is regulated with a voltage regulator.

Table 4-1 Operating Conditions

4.2 Current Consumption

T_C = 25°C and frequency = 2445 MHz. All parameters measured on the RF6505-CC2530 reference design [3][2] with a 50 Ω load.

4.2.1 Supply current = 4.2 V

Parameter	Typ.	Max.	Unit
DC supply Current, TX Mode	780		mA
Quiescent current (Idle)	140		mA
RX Mode Supply Current			mA

Parameter	Typical Conditions	Typical	Unit
Transmit current, VDD = 4.2V	TXPOWER 0= 0xF5	780	mA
	TXPOWER 0= 0xE5	735	mA
	TXPOWER 0= 0xD5	665	mA
	TXPOWER 0= 0xC5	610	mA
	TXPOWER 0= 0xB5	540	mA
	TXPOWER 0= 0xA5	480	mA
	TXPOWER 0= 0x95	412	mA
	TXPOWER 0= 0x85	375	mA
	TXPOWER 0= 0x75	330	mA
	TXPOWER 0= 0x65	290	mA
	TXPOWER 0= 0x55	250	mA
	TXPOWER 0= 0x45	220	mA

Table 4-2 Current Consumption at 4.2V Supply

4.2.2 Supply current = 3.6 V

Parameter	Typ.	Max.	Unit
DC supply Current, TX Mode	730		mA
Quiescent current (Idle)	130		mA
RX Mode Supply Current (CW input signal at -20dBm)	32		mA

Parameter	Typical Conditions	Typical	Unit
Transmit current, VDD = 3.6V	TXPOWER 0= 0xF5	750	mA
	TXPOWER 0= 0xE5	685	mA
	TXPOWER 0= 0xD5	630	mA
	TXPOWER 0= 0xC5	595	mA
	TXPOWER 0= 0xB5	530	mA
	TXPOWER 0= 0xA5	475	mA
	TXPOWER 0= 0x95	410	mA
	TXPOWER 0= 0x85	375	mA
	TXPOWER 0= 0x75	330	mA
	TXPOWER 0= 0x65	285	mA
	TXPOWER 0= 0x55	240	mA
	TXPOWER 0= 0x45	205	mA

Table 4-3 Current Consumption at 3.6V Supply

4.2.3 Supply current = 3.0 V

Parameter	Typ.	Max.	Unit
DC supply Current, TX Mode	645		mA
Quiescent current (Idle)	95		mA
RX Mode Supply Current (CW input signal at -20dBm)	30		mA

Parameter	Typical Conditions	Typical	Unit
Transmit current, VDD = 3.0V	TXPOWER 0= 0xF5	645	mA
	TXPOWER 0= 0xE5	600	mA
	TXPOWER 0= 0xD5	535	mA
	TXPOWER 0= 0xC5	505	mA
	TXPOWER 0= 0xB5	450	mA
	TXPOWER 0= 0xA5	395	mA
	TXPOWER 0= 0x95	333	mA
	TXPOWER 0= 0x85	300	mA
	TXPOWER 0= 0x75	260	mA
	TXPOWER 0= 0x65	226	mA
	TXPOWER 0= 0x55	190	mA
	TXPOWER 0= 0x45	160	mA

Table 4-4 Current Consumption at 3.0V Supply

4.3 Transmit Parameters

T_C = 25°C and frequency = 2445 MHz. All parameters measured on the RF6505-CC2530 reference design [3][2] with a 50 Ω load.

4.3.1 Supply current = 4.2 V

Parameter	Typical Conditions	Typical	Unit
Output power	TXPOWER 0= 0xF5 TXPOWER 0= 0xE5 TXPOWER 0= 0xD5 TXPOWER 0= 0xC5 TXPOWER 0= 0xB5 TXPOWER 0= 0xA5 TXPOWER 0= 0x95 TXPOWER 0= 0x85 TXPOWER 0= 0x75 TXPOWER 0= 0x65 TXPOWER 0= 0x55 TXPOWER 0= 0x45	28.5 28.2 27.6 26.9 26.0 24.9 23.3 22.4 21.0 19.4 17.4 15.1	dBm
Conducted 2nd Harmonic Level TXPOWER = 0xF5		-46	dBm/MHz
Conducted 3rd Harmonic Level TXPOWER = 0xF5		-48	dBm/MHz
Stability, Output VSWR	TXPOWER = 0xF5 All phase angles	>10:1	

Table 4-5 Transmit Parameters at 4.2V Supply

4.3.2 Supply current = 3.6 V

Parameter	Typical Conditions	Typical	Unit
Output power	TXPOWER 0= 0xF5 TXPOWER 0= 0xE5 TXPOWER 0= 0xD5 TXPOWER 0= 0xC5 TXPOWER 0= 0xB5 TXPOWER 0= 0xA5 TXPOWER 0= 0x95 TXPOWER 0= 0x85 TXPOWER 0= 0x75 TXPOWER 0= 0x65 TXPOWER 0= 0x55 TXPOWER 0= 0x45	27.5 27.3 27.1 26.6 25.9 24.9 23.5 22.6 21.2 19.5 17.5 15.2	dBm
Conducted 2nd Harmonic Level TXPOWER = 0xF5		-45	dBm/MHz
Conducted 3rd Harmonic Level TXPOWER = 0xF5		-49	dBm/MHz
Stability, Output VSWR	TXPOWER = 0xF5 All phase angles	>10:1	

Table 4-6 Transmit Parameters at 3.6V Supply

4.3.3 Supply current = 3.0 V

Parameter	Typical Conditions	Typical	Unit
Output power	TXPOWER 0= 0xF5 TXPOWER 0= 0xE5 TXPOWER 0= 0xD5 TXPOWER 0= 0xC5 TXPOWER 0= 0xB5 TXPOWER 0= 0xA5 TXPOWER 0= 0x95 TXPOWER 0= 0x85 TXPOWER 0= 0x75 TXPOWER 0= 0x65	25.9 25.8 25.4 25.1 24.5 23.4 21.9 20.9 19.4 17.7	dBm
Conducted 2nd Harmonic Level TXPOWER = 0xF5		-47	dBm/MHz
Conducted 3rd Harmonic Level TXPOWER = 0xF5		-48	dBm/MHz
Stability, Output VSWR	TXPOWER = 0xF5 All phase angles	>10:1	

Table 4-7 Transmit Parameters at 3.0V Supply

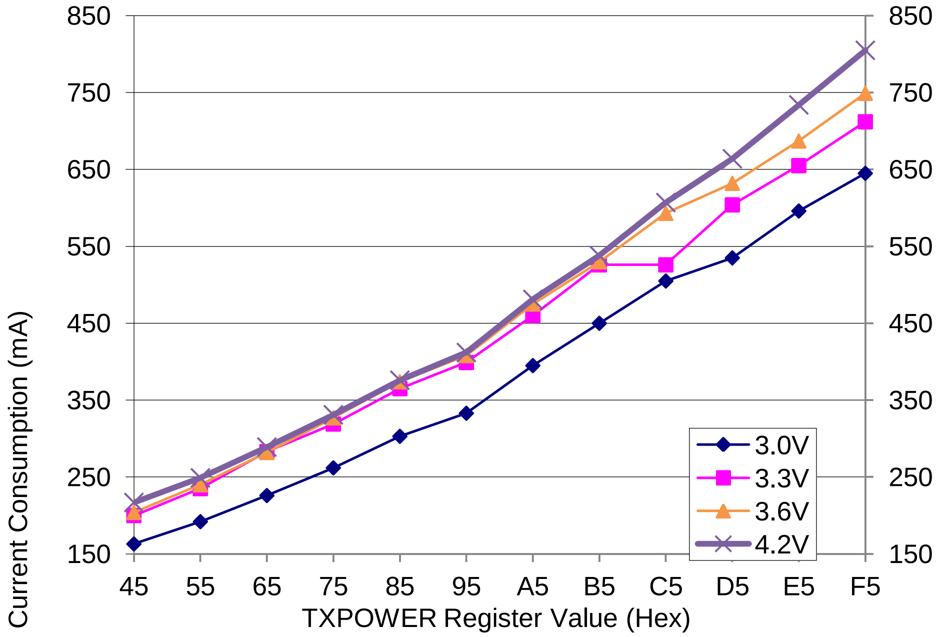

Figure 4-1 Typical Current TX Consumption vs. CC2530 TXPOWER Setting over Voltage

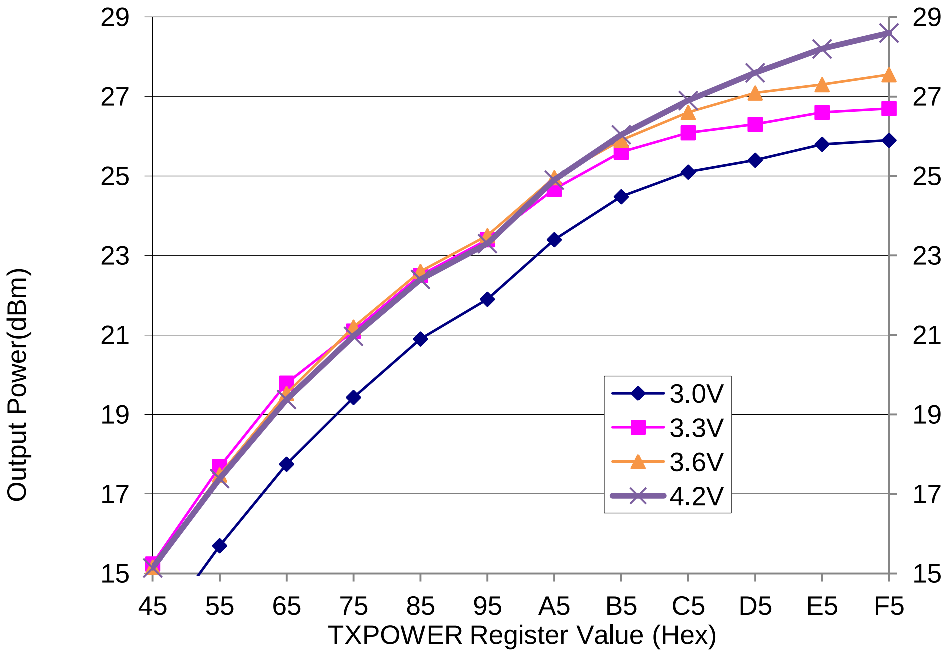

Figure 4-2 Typical Output Power vs. CC2530 TXPOWER Setting over Voltage

4.4 Receive Parameters

T_C = 25°C, VDD = 3.3V and frequency = 2445 MHz. All parameters measured on the RF6505-CC2530 reference design [3] with a 50 Ω load.

Parameter	Typical Conditions	Typical	Unit
Receive Sensitivity	1 % PER, IEEE 802.15.4 [6] requires -85 dBm	-101	dBm
Saturation	IEEE 802.15.4 [6] requires -20 dBm	26	dBm
RSSI Offset(1)		81	

(1) Due to in the external LNA and the offset in CC2530 the RSSI readouts from RF6505-CC2530 is different from RSSI offset values for a standalone CC2530 design.

Table 4-8 Receive Parameters at 3.3V Operation

5 SmartRF Studio and SmartRF05EB

The RF6505-CC2530 together with SmartRF™ Studio 7 software [5] and SmartRFEB can be used to evaluate performance and functionality. See Appendix – Performance Verification for details on how to evaluate performance and functionality. The RF6505-CC2530 can be configured using the SmartRF Studio 7 software. The SmartRF Studio software is highly recommended for obtaining optimum register settings.

6 Reference Design Considerations

The RF6505-CC2530 reference design includes schematic, gerber files and bill of materials [3]. It is highly recommended to follow the reference design for optimum performance. **Error! eference source not found.**shows the RF6505-CC2530 schematic.

6.1 Power Decoupling

Proper power supply decoupling must be used for optimum performance. The capacitor C19 must be optimized to prevent RF leakage into the control lines of the RF6505 which may cause oscillations.

6.2 Filtering

The values of L5, L6, C11, C12 and C13 are for harmonics filtering purposes only. These components assist in the required filtering of harmonics to pass regulatory requirements.

6.3 PCB Layout Considerations

The top layer is used for components and signal routing, and the open areas are filled with metallization connected to ground using several vias. The areas under the two chips are used for grounding and must be well connected to the ground plane with multiple vias. Footprint recommendation for the RF6505 is given in the RF6505 datasheet [1].

Layer two is a complete ground plane and is not used for any routing. This is done to ensure short return current paths. The low impedance of the ground plane prevents any unwanted signal coupling between any of the nodes that are decoupled to it.

Layer three is a power plane. The power plane ensures low impedance traces at radio frequencies and prevents unwanted radiation from power traces.

Layer four is used for routing, and as for layer one, open areas are filled with metallization connected to ground using several vias.

6.4 Shielding

RF shielding may be necessary to keep the radiated harmonics below the regulatory limits.

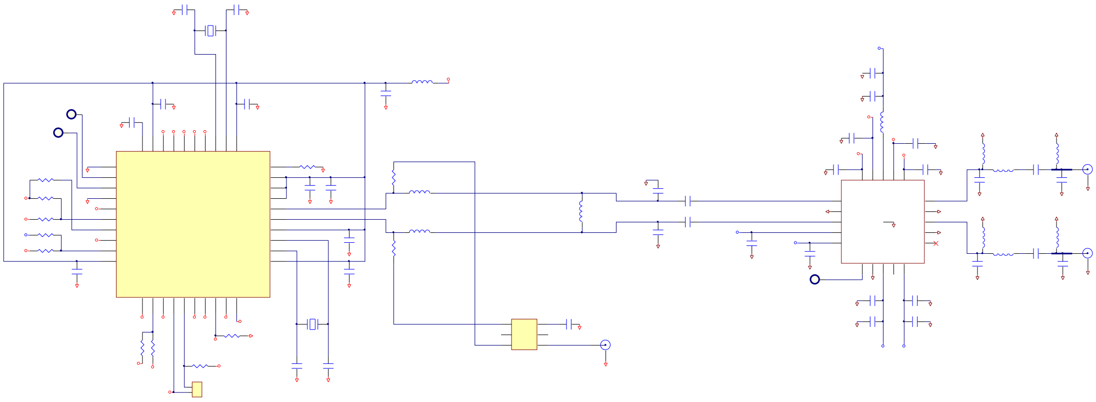

Figure 6-1 RF6505-CC2530 Schematic

7 Disclaimer

The RF6505-CC2530 reference design board purpose and use is for ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY and is not considered by TI or RFMD to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing –related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board has been tested against FCC regulations, but there has been no formal compliance testing at an external test house. It is the end user's responsibility to ensure that their system complies with applicable regulations. For additional information or further questions please contact, RFMD Technical Support at smartgrid@rfmd.com.

8 Reference

[1] RF6505 Datasheet (RF6505DS)

[2] CC2530 Data Sheet (SWRS081)

[3] RF6505-CC2530 reference design (SWRR090)

[4] FCC rules (www.fcc.gov)

[5] SmartRF™ Studio 7 (SWRR085)

[6] DN002 Practical Sensitivity Testing (SWRA097)

9 General Information

9.1 Document History

Revision	Date	Description/Changes
SWRA385	2011.11.14	Initial release

10 Appendix – Performance Verification

10.1 Equipment

(1) SmartRF Studio 7 installed on each PC used, which can be downloaded at [5].
(2) An RF generator with packet option, or a CC253x, or RF6505-CC2530 connected to a SmartRFEB for packet transmission. Using the CC253xEM or RF6505-CC2530 as an RF generator will require a PC.
(1) A RF6505-CC2530 connected to a SmartRFEB and a PC for packet reception
(2) Attenuators and cable
(3) A 4.2V DC supply and a USB cable

10.2 General Setup

1) The firmware revision of the SmartRF Studio must be downloaded to the SmartRFEB
2) Place the RF6505-CC2530 board onto the SmartRFEB via the evaluation module connectors
3) Connect the USB cable from the PC to the SmartRFEB. Note: If the SmartRFEB is connected to a USB socket on a PC, it will draw power from the USB. The on board voltage regulator supplies 3.3V to the board, but has limited current source capability and cannot supply the RF6505-CC2530 with the optimum supply of 4.0V to 4.2V. An external supply is therefore needed and shall be connected as shown in Connecting 4.2V Supply to the RF6505-CC2530Figure 10-1.
4) Supply 4.2V DC to the SmartRFEB
5) The chip type will appear in the test box labeled “List of Connected Devices” at the bottom of the SmartRF Studio Interface. This should read “USB device ID = 0xxx, Firmware (revision = 00xx), CC2530”.
6) Double click on the chip type in the device list to open up the SmartRF Studio7 device control panel for user interface.
7) Once the user interface is open find the “Range Extender” option, click on the arrow and select CC2591. Now you’re ready to evaluate the RF6505-CC2530.

- To use an external power supply remove the jumper from Pins 2 & 3 in the Power Source Sections of the SmartRF05EB.
- Then place the supply lead to pin 2 and ground to a common ground plane on the SmartRF05EB board

Figure 10-1 Connecting 4.2V Supply to the RF6505-CC2530

10.3 Transmission

10.3.1 Continuous Transmission

1) Complete steps 1 through 7 of the General Setup procedure.
2) Find the Continuous TX mode tab
3) Adjust your desired TX power setting for CC253 using “TX Power” box in the RF Parameters section or by modifying the TXPOWER register value in the Register view.
4) Select the center frequency, either by using the “Frequency” box or using the “IEEE 802.15.4 channel” box.
5) Select between modulated and un-modulated in the Continuous T tab.
6) Select the correct antenna path, the two antenna paths are controlled thorough GPIO P1.0 and P1.1, so to change the antenna path from ANT1 to ANT2 the following registers needs to be changed; PODIR=0x82 and PO=0x7D, see Figure 10-2.

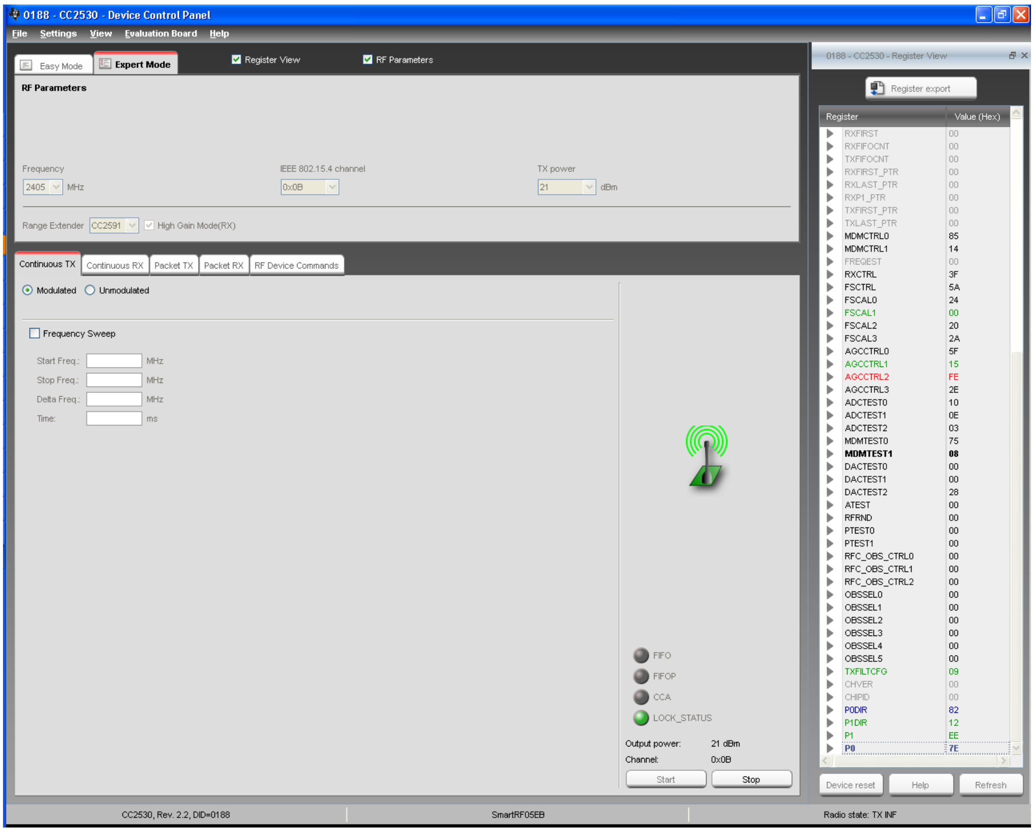

Figure 10-2 Continuous Transmission Tab, ANT2

10.3.2 Packet Transmission

1) Complete steps 1 through 7 of the General Setup procedure.
2) Select the Packet TX mode tab
3) Adjust your desired TX power setting for CC253 using “TX Power” box in the RF Parameters section or by modifying the TXPOWER register value in the Register view.
4) Select the center frequency, either by using the “Frequency” box or using the “IEEE 802.15.4 channel” box.
5) Select the number of packets you want to send and the packet payload size.

6) Select the correct antenna path, the two antenna paths are controlled thorough GPIO P1.0 and P1.1, so to change the antenna path from ANT1 to ANT2 the following registers needs to be changed; PODIR=0x82 and PO=0x7D, see Figure 10-3.

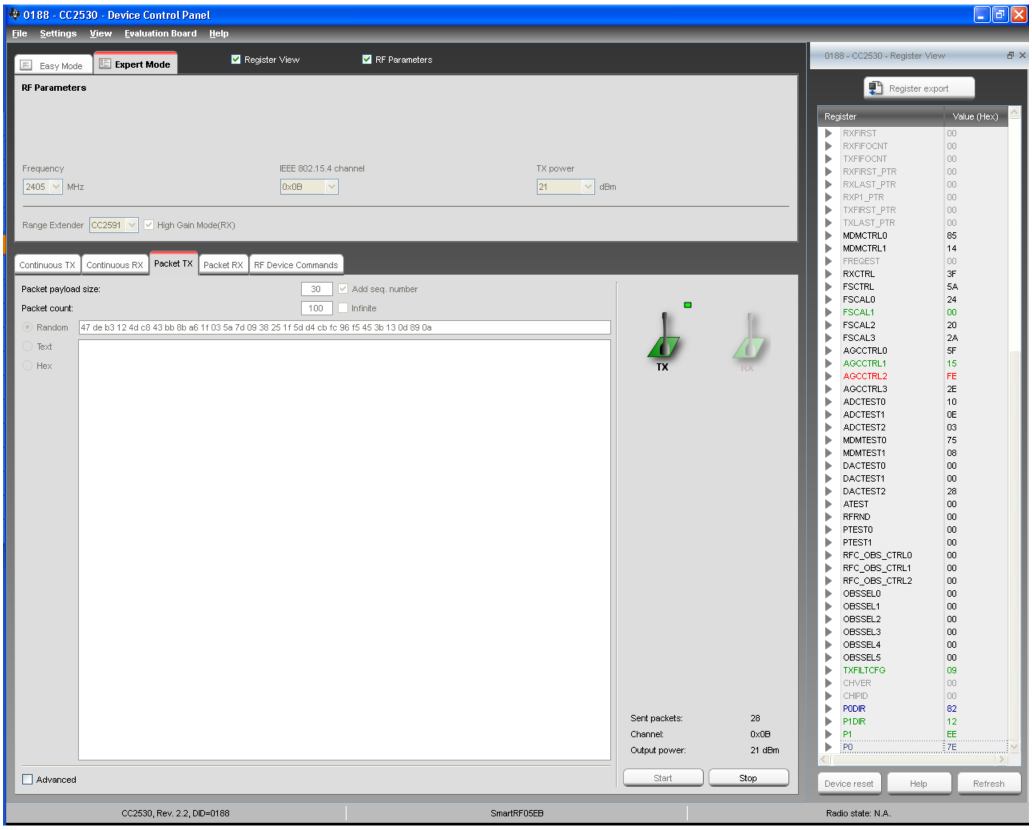

Figure 10-3 Packet TX Transmission Tab, ANT2

10.4 Reception

10.4.1 Practical Sensitivity testing

To properly evaluate the receiver performance of the RF3858-CC1101 reference design, it is necessary to be able to find the sensitivity threshold, i.e. the lowest input signal the receiver can decode with acceptable signal quality. This Application Note describes how to test the sensitivity using a PER (Packet Error Rate) test. For questions on testing sensitivity with SmartRF Studio please refer to [6].

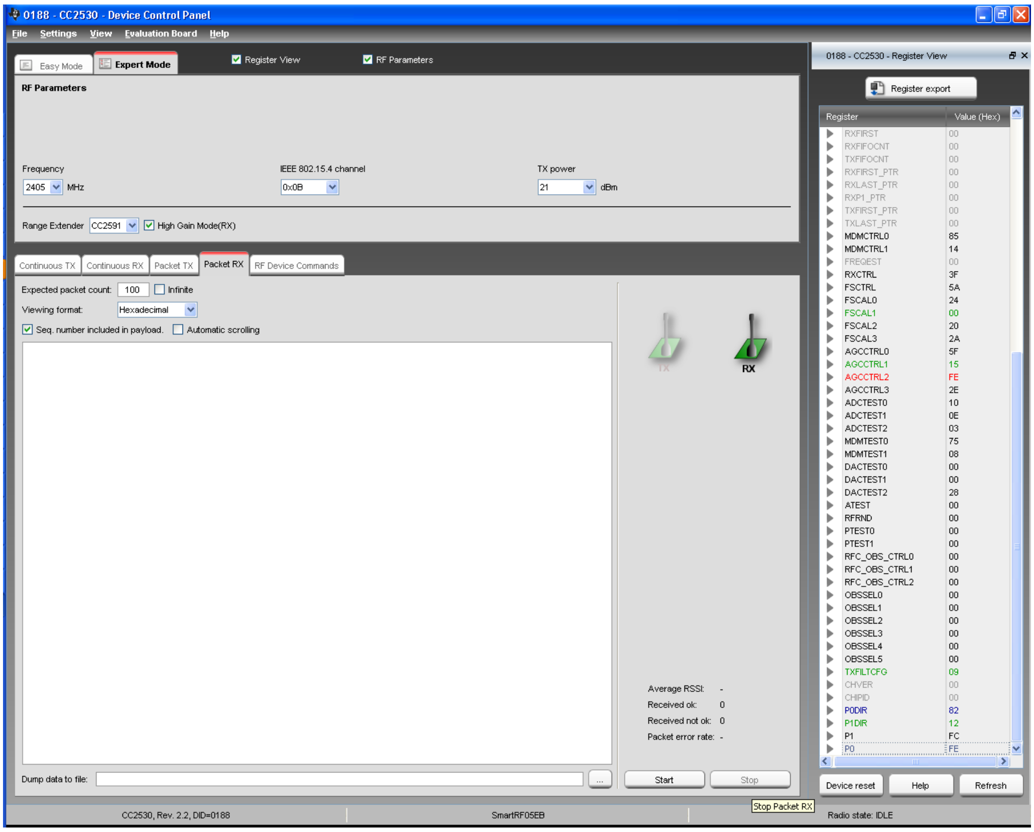

Figure 10-4 Packet Reception Tab

10.4.2 PER Test Setup

1) Setup the equipment as shown in the block diagram in Figure 10-5.
2) Complete steps 1 through 7 of the General Setup procedure.
3) If using a CC2530 or the RF6505-CC2530 as the packet transmitter, use the Packet transmission section in this application note to setup the module that will transmit packets. Otherwise, setup the RF generator to send 802.15.4 packets and configure it for the selected RF frequency.
4) Select the Packet TX mode tab as shown in Figure 10-4.
5) Set the number of packets expected to receive.
6) Verify the antenna is correct on the interface and the base frequency matches the frequency of the board or RF generator that will be transmitting the packets.
7) Set attenuation level near the expected result.
8) Press Start to begin listening for packets before beginning to transmit packets.
9) Adjust the attenuation level until a 1% PER is achieved.
10) The Packet RX will continue until the number of packets programmed has been reached, or until 100 consecutive packets have been lost.

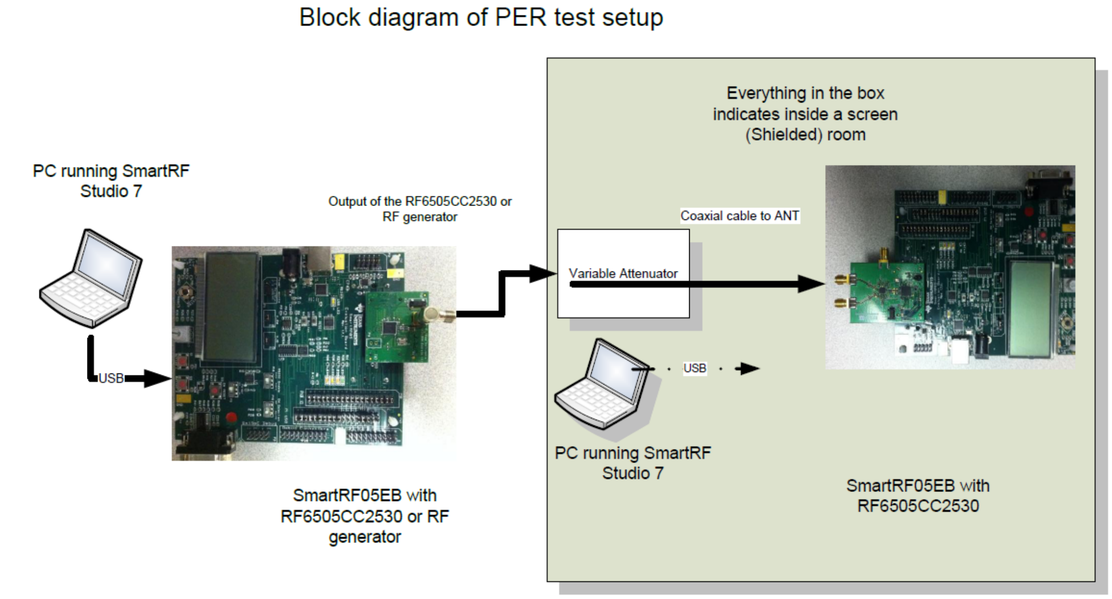

Figure 10-5 Block Diagram of PER Test Setup