Measurement Results for Combined CC2530 and CC2590 Solution

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Keywords

- *CC2530*
- *CC2531*
- *CC2590*
- *Range Extender*
- *External LNA*
- *External PA*
- *2.4 GHz IEEE 802.15.4 systems*

1 Introduction

CC2530 [1] is TI's second generation ZigBee® / IEEE 802.15.4 RF System-on-Chip (SoC) for the 2.4 GHz unlicensed SRD/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 CC2531 is identical to the CC2530 with the addition of an USB interface

CC2590 [2] is a range extender for 2.4-GHz RF transceivers, transmitters and SoC products from Texas Instruments. CC2590 increases the link budget by providing a Power Amplifier (PA) for higher output power and a Low Noise Amplifier (LNA) for improved receiver sensitivity. CC2590 further contains RF switches, RF matching, and a balun.

This design note gives measurement results for the combined CC2530-CC2590 solution at 3 V operation, -40°C, +25°C, and +85°C. The following parameters were measured:

- Sensitivity
- RX current
- Output power and harmonics
- TX current
- Error Vector Magnitude (EVM)
- Stability vs load impedance

The results presented are the average numbers from measurements on 11 PCB's. The results presented are specified by test and should only be used as an indication of expected performance.

The combined CC2530-CC2590 schematic is shown in Appendix – CC2530 and CC2590 Schematic.

The RF front end of CC2530 is the same as in CC2531. The presented results in this application note are therefore also valid for CC2531.

Table of Contents

2 Abbreviations

EVM	Error Vector Magnitude
ISM	Industrial, Scientific, Medical
MHz	Mega Hertz
RF	Radio Frequency
RX	Receive
SRD	Short Range Devices
TX	Transmit

3 RX Measurements

3.1 Sensitivity (1% PER)

2405 MHz			2440 MHz			2480 MHz		
-40C	+25C	+85C	-40C	+25C	+85C	-40C	+25C	+85C
-99.6	-98.0	-95.7	-98.9	-97.4	-94.8	-99.8	-98.2	-95.8

Table 3.1. Sensitivity [dBm]. 3 V Supply Voltage

3.2 RX Current vs Input Power Level

RX current is measured with CC2530 waiting for sync and CPU idle.

	-40C	+25C	+85C
-100	26.5	28.2	29.9
-90	26.5	28.2	29.8
-80	26.2	28.2	28.1
-70	24.7	25.9	27.5
-60	24.1	25.3	26.1
-50	23.7	24.6	25.4
-40	23.6	24.4	25.4
-30	23.6	24.4	25.4
-20	24.3	24.7	25.6
-10	28.1	27.1	27.2

Table 3.2. RX Current [mA] vs Input Power Level [dBm]. 3 V Supply Voltage

4 TX Measurements

4.1 Output Power and Harmonics

	2405 MHz			2440 MHz			2480 MHz		
	-40C	+25C	+85C	-40C	+25C	+85C	-40C	+25C	+85C
0xF5	13.2	11.4	8.3	13.0	11.1	7.8	12.1	10.1	6.8
0xE5	12.1	9.7	6.2	11.8	9.3	5.6	10.8	8.2	4.4
0xD5	11.1	8.2	4.3	10.7	7.7	3.7	9.7	6.5	2.4
0xC5	10.2	6.9	2.8	9.8	6.4	2.1	8.8	5.1	0.9
0xB5	9.5	5.8	1.5	9.1	5.2	0.9	7.9	3.9	-0.4
0xA5	8.5	4.2	-0.2	7.9	3.6	-0.8	6.6	2.2	-2.2
0x95	6.7	2.2	-2.1	6.0	1.6	-2.7	4.6	0.2	-4.1
0x85	5.6	1.0	-3.4	4.9	0.4	-4.1	3.5	-1.0	-5.4
0x75	3.8	-0.5	-5.0	3.1	-1.1	-5.6	1.7	-2.6	-6.9
0x65	2.0	-2.2	-6.6	1.3	-2.9	-7.2	-0.2	-4.3	-8.5
0x55	-0.2	-4.3	-8.6	-0.9	-5.0	-9.2	-2.4	-6.3	-10.5
0x45	-2.6	-6.7	-10.8	-3.3	-7.3	-11.4	-4.8	-8.7	-12.7
0x35	-5.1	-9.1	-13.1	-5.8	-9.7	-13.7	-7.3	-11.0	-14.9
0x35	-6.8	-10.7	-14.6	-7.4	-11.3	-15.2	-8.9	-12.6	-16.4
0x15	-8.9	-12.8	-16.6	-9.6	-13.3	-17.1	-11.0	-14.6	-18.3
0x05	-11.0	-14.9	-18.7	-11.7	-15.4	-19.2	-13.0	-16.7	-20.5

Table 4.1. Output Power [dBm] vs CC2530 TXPOWER. 3 V Supply Voltage

	2405 MHz			2440 MHz			2480 MHz		
	-40C	+25C	+85C	-40C	+25C	+85C	-40C	+25C	+85C
0xF5	-37.6	-47.2	-66.7	-43.5	-54.1	-67.5	-46.3	-59.2	-65.2
0xE5	-42.7	-59.8	-62.7	-49.2	-66.4	-63.3	-53.0	-64.3	-63.2
0xD5	-48.4	-61.1	-62.9	-56.7	-60.8	-64.5	-60.8	-59.5	-65.3
0xC5	-55.4	-58.3	-64.5	-62.5	-59.4	-66.5	-63.1	-59.8	-67.6
0xB5	-60.5	-58.3	-66.4	-62.1	-60.2	-68.6	-59.2	-61.0	-69.7
0xA5	-57.9	-59.8	-69.0	-58.1	-62.2	-71.4	-57.4	-63.2	-72.9
0x95	-55.2	-62.6	-72.2	-57.9	-65.0	-74.7	-58.9	-66.3	-76.4
0x85	-55.9	-64.4	-74.2	-59.0	-67.0	-77.1	-60.2	-68.3	-78.9
0x75	-58.0	-67.1	-77.0	-61.3	-69.7	-79.6	-62.5	-71.1	-81.6
0x65	-60.7	-70.2	-79.7	-64.0	-72.6	-82.2	-65.3	-74.2	-84.7
0x55	-64.3	-74.0	-82.8	-67.7	-76.4	-85.4	-68.9	-77.9	-88.4
0x45	-68.8	-78.4	-86.2	-72.0	-80.3	-88.2	-73.0	-81.7	-91.9
0x35	-73.7	-82.6	-88.7	-76.6	-83.9	-90.3	-76.8	-85.3	-95.5
0x35	-76.8	-85.6	-90.3	-79.5	-85.7	-91.7	-79.3	-87.1	-97.1
0x15	-81.1	-88.9	-91.9	-83.1	-87.7	-93.0	-82.0	-88.9	-98.4
0x05	-85.2	-91.5	-92.7	-86.0	-89.5	-93.7	-84.3	-90.4	-100.0

Table 4.2. Conducted 2nd Harmonic [dBm] vs CC2530 TXPOWER. 3 V Supply Voltage

Radiated 2nd harmonic at maximum output power is typically below -39 dBm at 25^{o}C. A Titanis 2.4 GHz swivel antenna from Antenova [3] was used in the measurement.

	2405 MHz			2440 MHz			2480 MHz		
	-40C	+25C	+85C	-40C	+25C	+85C	-40C	+25C	+85C
0xF5	-47.6	-52.6	-59.9	-50.7	-52.9	-60.2	-48.6	-51.6	-61.9
0xE5	-48.9	-56.2	-66.6	-51.7	-56.8	-67.0	-49.8	-55.7	-68.8
0xD5	-50.3	-60.5	-72.6	-53.6	-61.4	-72.7	-51.9	-60.6	-74.7
0xC5	-52.0	-64.4	-76.8	-55.7	-65.3	-76.2	-54.3	-64.6	-78.7
0xB5	-54.0	-68.0	-80.0	-58.0	-68.8	-80.1	-57.2	-67.5	-81.8
0xA5	-57.7	-72.2	-84.7	-62.3	-72.6	-84.7	-61.1	-71.3	-86.1
0x95	-63.8	-77.0	-88.7	-67.4	-77.1	-87.8	-65.7	-76.6	-90.3
0x85	-66.8	-80.0	-90.0	-69.8	-80.5	-91.2	-67.8	-79.7	-93.1
0x75	-71.0	-84.3	-93.6	-73.6	-84.0	-93.6	-71.5	-83.1	-94.5
0x65	-74.7	-87.8	-95.0	-77.0	-87.9	-94.8	-75.9	-88.0	-96.5
0x55	-80.2	-91.7	-96.3	-82.5	-92.7	-97.6	-81.2	-91.9	-99.1
0x45	-86.1	-95.3	-100.0	-88.3	-94.9	-100.2	-87.1	-95.6	-100.3
0x35	-91.9	-97.9	-100.2	-93.1	-97.8	-101.7	-92.2	-99.5	-103.2
0x35	-94.2	-100.1	-103.1	-94.5	-99.2	-103.9	-96.7	-100.7	-105.8
0x15	-97.3	-100.4	-105.4	-97.9	-100.0	-105.1	-99.0	-103.2	-105.1
0x05	-99.9	-103.5	-106.3	-99.9	-104.7	-107.8	-100.5	-105.4	-109.8

Table 4.3. Conducted 3rd Harmonic [dBm] vs CC2530 TXPOWER. 3 V Supply Voltage

Radiated 3rd harmonic at maximum output power is typically below -35 dBm at 25^{o}C. A Titanis 2.4 GHz swivel antenna from Antenova [3] was used in the measurement.

4.2 TX Current

	2405 MHz			2440 MHz			2480 MHz		
	-40C	+25C	+85C	-40C	+25C	+85C	-40C	+25C	+85C
0xF5	67.5	59.4	52.5	67.0	59.0	52.2	67.2	59.0	52.0
0xE5	57.9	50.9	45.8	57.5	50.6	45.5	57.7	50.4	45.4
0xD5	52.4	46.2	42.4	52.0	45.9	42.1	52.0	45.7	42.0
0xC5	49.0	43.5	40.7	48.7	43.2	40.4	48.6	43.0	40.3
0xB5	46.1	41.1	39.1	45.6	40.7	38.9	45.5	40.6	38.8
0xA5	43.2	39.0	38.0	42.8	38.7	37.8	42.5	38.6	37.7
0x95	39.3	36.5	36.4	38.9	36.3	36.3	38.7	36.2	36.3
0x85	37.8	35.6	36.0	37.4	35.4	35.8	37.2	35.3	35.8
0x75	35.7	34.6	35.4	35.3	34.4	35.3	35.2	34.4	35.3
0x65	34.0	33.8	35.0	33.7	33.6	34.9	33.6	33.6	34.9
0x55	32.6	33.2	34.7	32.4	33.0	34.6	32.3	33.1	34.6
0x45	31.6	32.7	34.5	31.5	32.6	34.4	31.5	32.7	34.4
0x35	31.0	32.5	34.3	30.9	32.4	34.2	30.9	32.4	34.3
0x35	30.8	32.3	34.2	30.7	32.3	34.1	30.7	32.3	34.2
0x15	30.6	32.2	34.2	30.5	32.1	34.1	30.5	32.2	34.1
0x05	29.3	31.0	33.0	29.2	30.9	32.9	29.2	31.0	32.9

Table 4.4. TX Current [mA] vs CC2530 TXPOWER. 3 V Supply Voltage

4.3 Error Vector Magnitude (EVM)

	2405 MHz			2440 MHz			2480 MHz		
	-40C	+25C	+85C	-40C	+25C	+85C	-40C	+25C	+85C
0xF5	14.0	5.6	3.1	8.5	3.7	2.6	4.0	3.6	2.7
0xE5	6.5	2.6	2.1	3.6	2.2	2.1	2.4	2.3	2.1
0xD5	3.9	2.1	2.1	2.5	2.0	2.1	2.3	2.2	2.1
0xC5	2.6	2.0	2.2	2.1	2.1	2.1	2.1	2.1	2.1
0xB5	2.3	2.0	2.1	2.0	2.0	2.1	2.2	2.0	2.1
0xA5	2.1	2.1	2.1	2.1	2.1	2.1	2.3	2.1	2.1
0x95	2.1	2.0	2.1	2.2	2.0	2.1	2.2	2.0	2.1
0x85	2.2	2.1	2.1	2.3	2.1	2.1	2.3	2.1	2.1
0x75	2.1	1.9	2.0	2.1	1.9	2.0	2.1	2.0	2.0
0x65	1.9	1.8	1.9	2.0	1.8	1.9	2.0	1.9	2.0
0x55	1.8	1.8	1.9	1.9	1.8	1.9	2.1	1.9	2.0
0x45	2.0	1.8	1.9	2.0	1.9	2.0	2.3	2.1	2.1
0x35	2.2	2.0	2.0	2.4	2.2	2.1	2.7	2.4	2.3
0x35	2.5	2.3	2.2	2.7	2.4	2.3	3.2	2.7	2.5
0x15	3.0	2.7	2.5	3.3	2.9	2.6	3.9	3.3	3.0
0x05	3.7	3.3	3.0	4.0	3.5	3.2	4.8	4.1	3.6

Table 4.5. EVM [%] vs CC2530 TXPOWER. 3 V Supply Voltage

	2405 MHz			2440 MHz			2480 MHz		
	-40C	+25C	+85C	-40C	+25C	+85C	-40C	+25C	+85C
0xF5	24.1	8.8	3.7	14.1	6.0	3.3	6.2	5.2	3.5
0xE5	10.8	3.7	2.6	5.7	3.3	2.6	3.5	3.2	2.6
0xD5	6.3	2.6	2.7	3.5	2.5	2.7	3.4	2.7	2.7

Table 4.6. Maximum EVM [%] vs CC2530 TXPOWER. 3 V Supply Voltage

4.4 Typical TX Parameters vs. Load Impedance

The load impedance presented to the CC2590 PA output is critical to the TX performance. The load impedance is selected as a compromise between several criteria, such as output power, efficiency and the level of the harmonics. The matching components between the PA output and the antenna should transform 50 ohm antenna impedance to the selected impedance which the CC2590 PA should see. This is taken care of by the reference design (see Appendix) and the user should provide a well matched antenna to get the required performance.

In order to measure the performance under different mismatch conditions the CC2530-CC2590 design is loaded with different impedances at the SMA connector reference plane. A well matched antenna will have impedance inside the black circle in the Smith chart, which illustrates the limit for 10 dB return loss. At each load the output power, current and spurious frequency components are measured. These measurements are known as load-pull measurements.

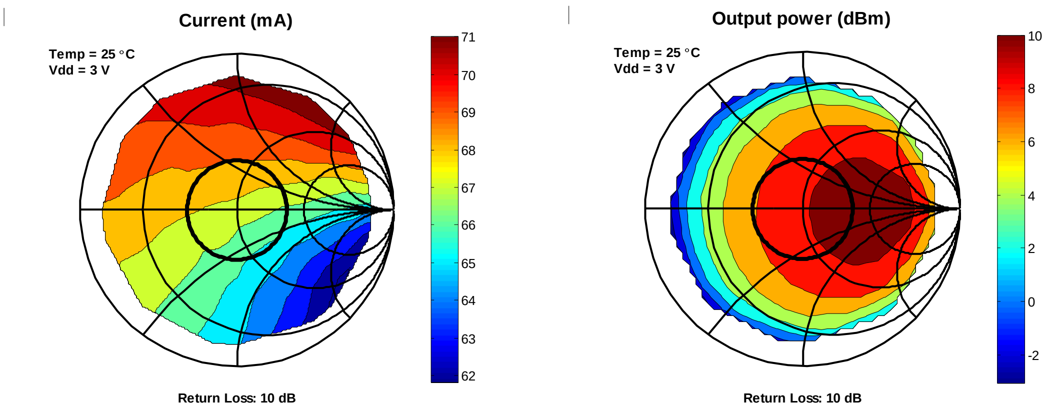

Figure 4.1. Current (left) and Output Power (right) vs. Load Impedance at SMA Connector at 25°C, 3 V. TXPOWER = 0xFE.

Most PAs have the ability to oscillate at unwanted frequencies under certain conditions. The worst conditions are usually high output power, low temperatures, and high VDD. This is also the case for CC2590. The spurious frequency components are measured under different mismatch conditions as illustrated in Figure 4.2 and Figure 4.3 from DC to f0 (fundamental) and from f0 to 2f0 (2^{nd} harmonic). The plots show that the spurious level is low and there are no oscillations. The CC2530-CC2590 solution is a very robust design which tolerates high mismatch ratios at high output power, low temperatures at 3 V supply voltage.

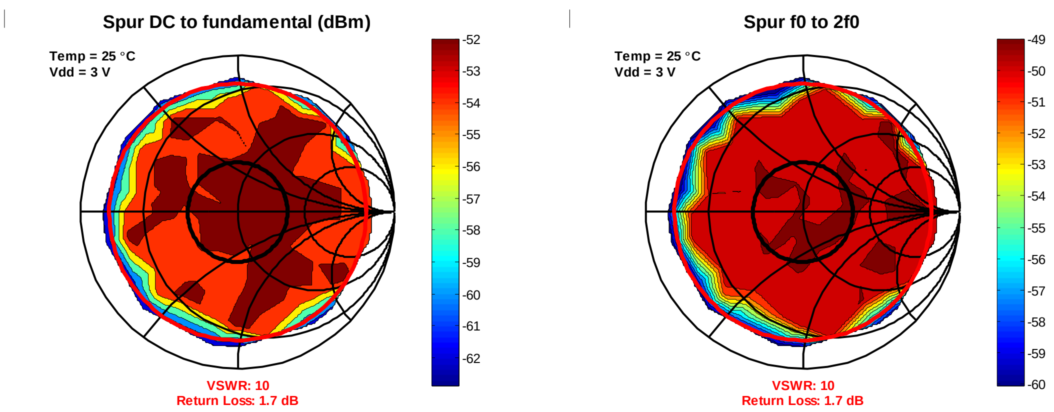

Figure 4.2. Spurious Frequency Components vs. Load Impedance at SMA Connector at 25°C, 3 V. TXPOWER = 0xFE.

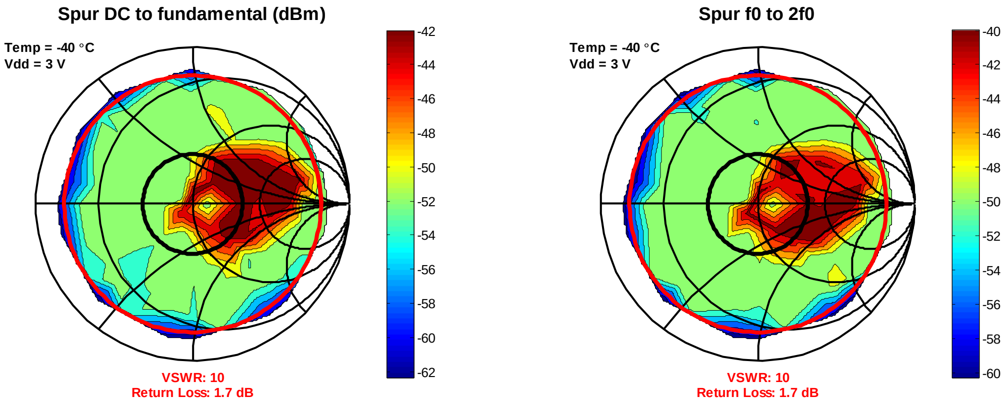

Figure 4.3. Spurious Frequency Components vs. Load Impedance at SMA Connector at -40°C, 3 V. TXPOWER = 0xFE.

5 References

[1] CC2530 Data sheet

[2] CC2590 Data sheet

[3] Antenova Titan 2.4 GHz swivel antenna

6 General Information

6.1 Document History

Revision	Date	Description/Changes
SWRA375	2011.07.28	Initial release

Appendix – CC2530 and CC2590 Schematic