Application Report
SWRA505A–March 2016–Revised April 2016

CC1310 Long-Range Module

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ABSTRACT

In internet-of-things (IOT) products, the combination of power consumption and range must be selected carefully. There are applications that have nonrechargeable coin cell batteries as the only power source and are limited to only using the TX power of SoC. Many applications use mains supply as the power source and require a long range. This solution is designed to address applications that require a long range. Some popular applications that require a long range are automatic meter reading (AMR), security and surveillance, solar farm monitoring, and street light control.

Different countries have defined the maximum output power limit for transmission and different frequency bands like industrial, scientific, and medical (ISM), or license free. The solution in this application report is designed for 865- to 867-MHz band for India and has a maximum TX power of 29.5 dBm (1 W), which is the license-free band. This solution was tested for 868 MHz and performed similarly.

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1 Introduction

Market research agencies report that there will be approximately 50 billion connected devices by 2020. The CC13xx and CC26xx family of devices from TI are the perfect platform for most low-power radio frequency (LPRF)-based IOT applications. Many applications require a higher range of communication. The CC13xx family of devices is configurable up to 14 dBm of TX power, which is 25 mW, and can provide a clear line of sight of 100 to 150 meters. When the product is installed in dense urban areas without a clear line of sight or with obstacles, a front-end module or power amplifier to generate more TX power is required. This solution effectively addresses application that require long range.

Typically, TI recommends using the CC1190 as an FEM, which allows a total of 27 dbm of TX power at 3.6 V. For applications where there is both a limitation on power supply current-sourcing capability, and which requires long range for wireless communication, the CC1190 is the ideal choice.

This design is based on CC1310 from TI and the SE2435L front-end module (FEM) from Skyworks® Inc. The SE2435L device is a power amplifier that boosts the total TX power from the module to 29.5 dBm at 3.6 V. CC1310 and SE2435L devices operate at up to 3.8 V; TI recommends operating the devices at 3.6 V. The design uses helical PCB antenna as described in *DN038 -- Miniature Helical PCB Antenna for 868 MHz or 915/920 MHz* (SWRA416).

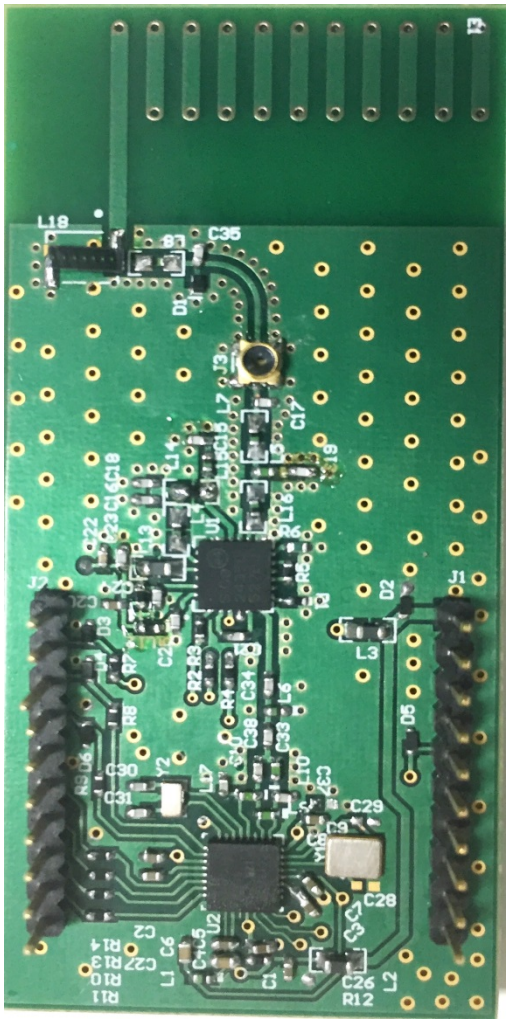

Figure 1. CC1310 and SE2435L Long-Range Module

2 Design

In addition to the range of communication, other important parameters are effective radiated power (ERP) and RX sensitivity. In high-noise environments, blocking and rejection performance is critical. For these parameters, the design performs better than expected.

2.1 Radio: CC1310

The CC1310 device is designed for long-range, city-wide, low-power networks. This device is used in home automation, building automation, and outdoor wide-area networks. The advantages of the CC1310 device are its high sensitivity (–124 dBm at 0.625 kbps), strong co-existence (up to 80-dB blocking), and low-power consumption (61 µA/MHz ARM® Cortex®-M3).

CC1310 has the following four low-power sections:

- A main CPU with a Cortex-M3
- An RF core with radio controller (The RF core is a flexible radio system that interfaces the analog RF circuitry and baseband circuitry, handles data to and from the system, and assembles the information bits in a packet structure.)
- General peripherals
- A sensor controller

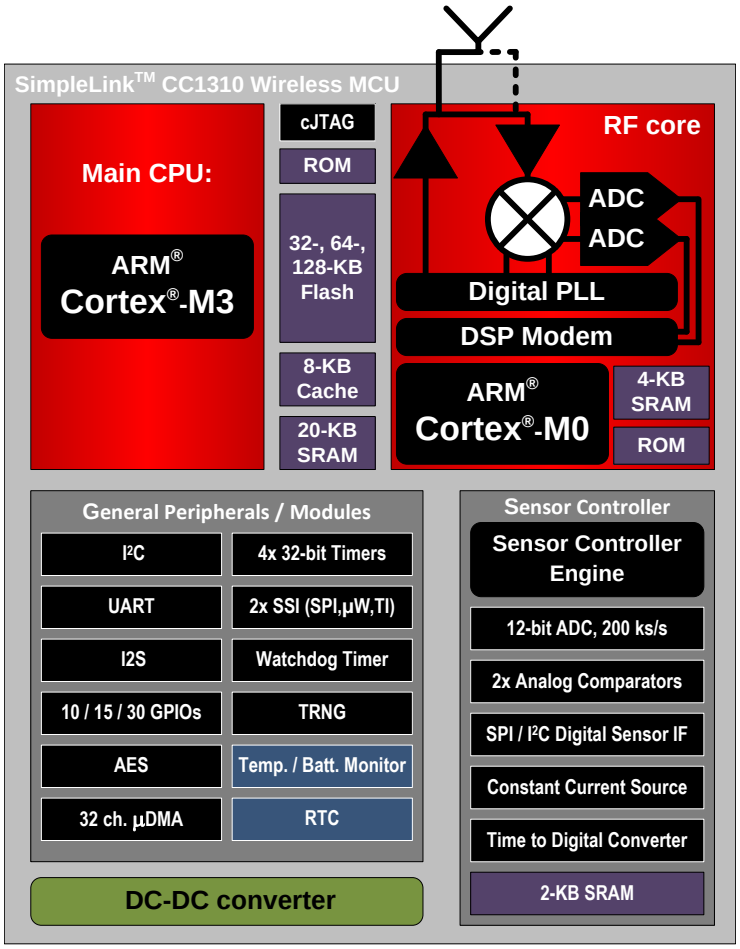

Figure 2. CC1310 Block Diagram

2.2 FEM/PA: Skyworks SE2435L

The SE2435L device is a high-performance, highly integrated, RF front-end module designed for ISM band applications operating in the 860- to 930-MHz frequency band.

The SE2435L device is designed for maximum flexibility with fully matched 50-Ω TX and RX inputs and antenna outputs and includes digital controls compatible with CMOS levels of 1.6 to 3.6 V.

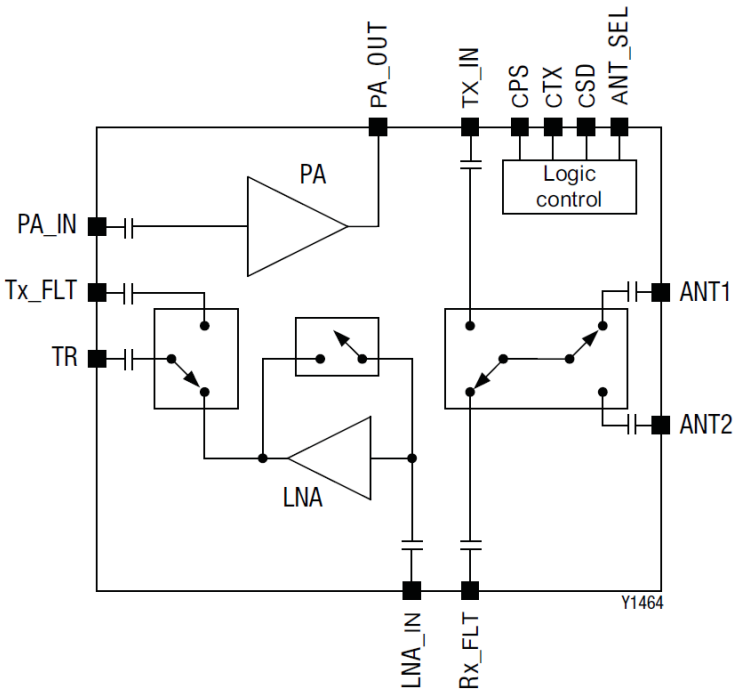

Figure 3. SE2435L Block Diagram

2.3 Schematic

The RF core is configurable up to 14 dBm of TX output power with a typical RX sensitivity of approximately –110 dBm. With the SE2435L device, the maximum TX output power increases to 29.5 dBm at a 3.6-V operating voltage. The SE2435L device also offers a RX sensitivity gain of about 5 dBm, making the total link budget greater than 140 dBm for IEEE 802.15.4g mode at a 50-kbps data rate. The CC1310 device is connected in differential mode with external bias configuration connected to the SE2435L device. The CC1310 device controls the operating mode of the SE2435L device through the DIO_5, DIO_6, and DIO_7 GPIOs, which are connected to CPS, CSD, and CTX, respectively. Table 1 is the truth table for mode control.

Table 1. Mode Control Logic for SE2435L

Mode	CPS	CSD	CTX	ANT_SEL
Sleep (all off)	0	0	0	X
Receive or transmit bypass	0	1	0	X
Receive LNA mode	1	1	0	X
Transmit	X	1	1	X
ANT1 port enabled	X	X	X	0
ANT2 port enabled	X	X	X	1

In addition to a feed and filter section, the design is equipped with protection circuitry that protects the board from damage from high ESD from touch or through the antenna.

L13 (6n8) is for optimizing the load with the existing PCB stack up. L11 and L12 are for filtering from possible feedback coming out of VCC2. C23 (100 pF) is for better decoupling to ground at 900 MHz with C11 and C25 (47 pF). C15 (3p9) and C19 (3p3) are for tuning the notches. Protection circuitry is included in this design because there are many products that are installed close to high-voltage areas or operate on high voltage lines and have strict high-ESD immunity requirements. This protection circuitry protects the board from any damages and enables the product to comply with those requirements.

Both devices have a 4-mm × 4-mm package that makes the design compact and easy to integrate.

Figure 4 shows the CC1310 schematic.

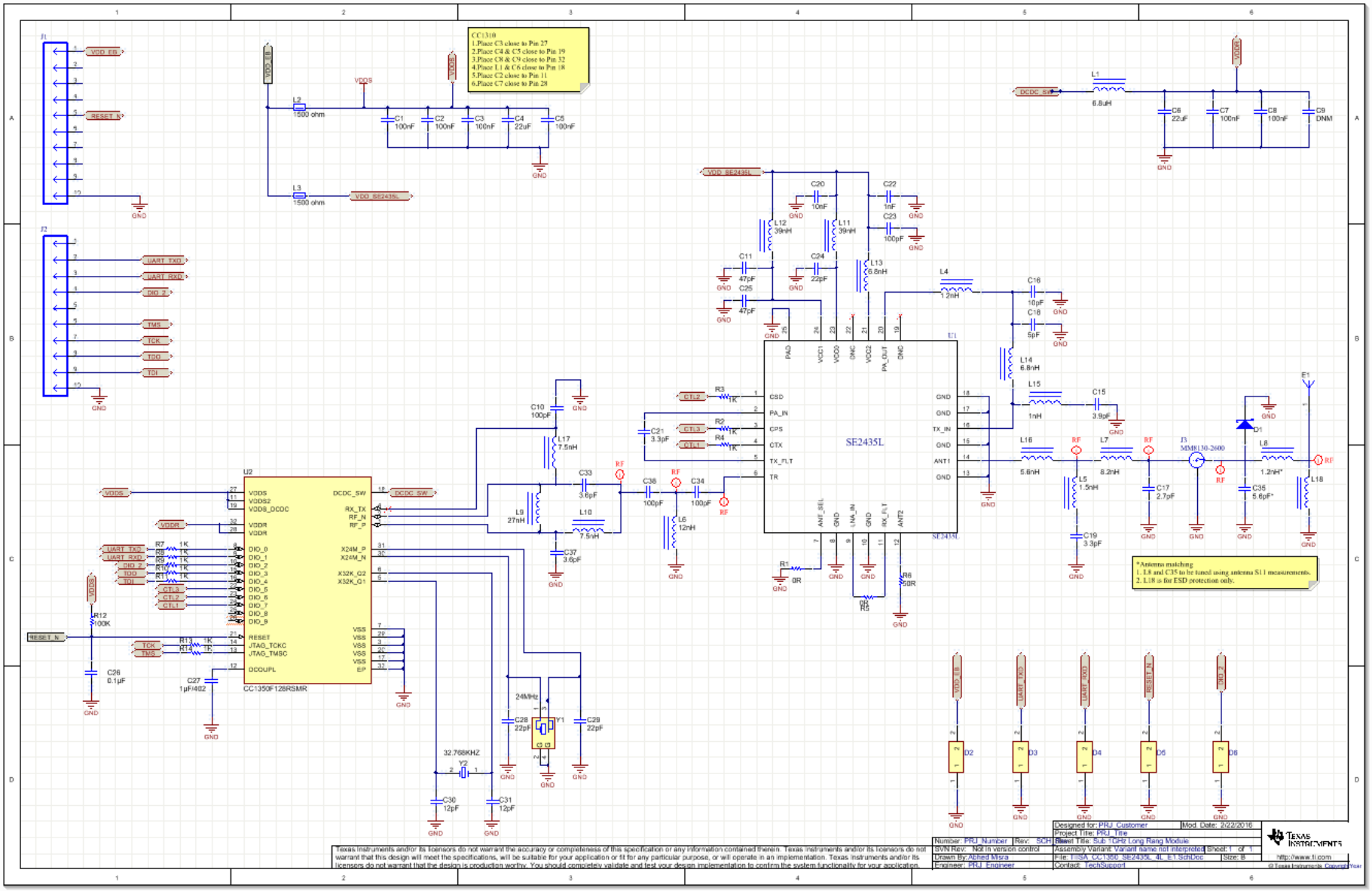

Figure 4. Schematic of CC1310 Long-Range Module

Figure 5 shows the layout of the CC1310.

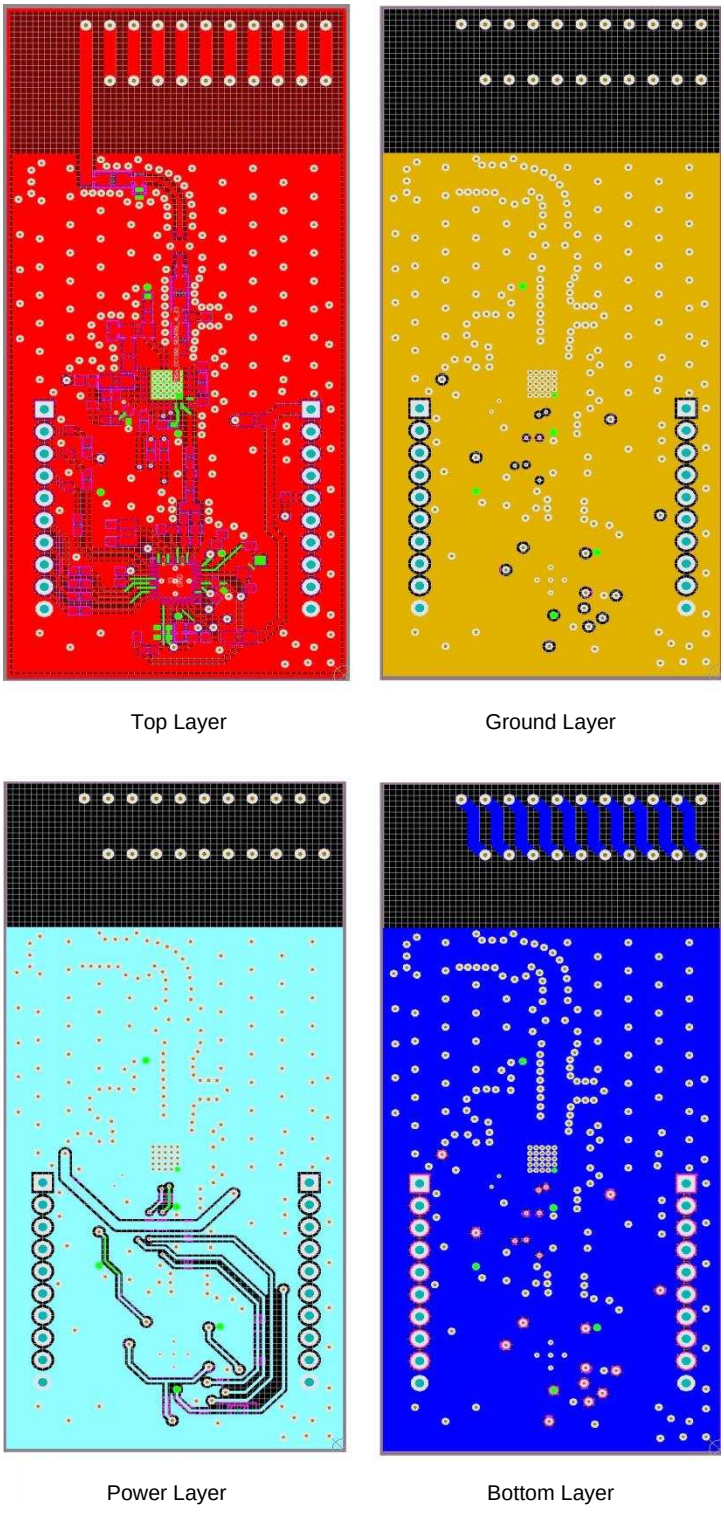

Figure 5. CC1310 Long-Range Module Layout

The design is a 4-layer board with the following stackup:

- TOP
- Ground
- Power
- Bottom layer

The fine-tuning components are also based on this stackup. The board is 1.6 mm thick. The antenna from *DN038 -- Miniature Helical PCB Antenna for 868 MHz or 915/920 MHz* (SWRA416) is modified with another turn to tune it with a shunt capacitor for a frequency of 865 MHz. Use a solid ground plane on the second layer to avoid using a VCC plane on other layers.

2.4 SmartRF™ Studio Software

To evaluate the design, TI recommends using the EM on the SmartRF06EB with SmartRF studio software. The supported functions of this software are continuously updated. Download the software from www.ti.com.

The DIOs (DIO5, DIO6, and DIO7) must be configured in a manner other than the standard radio setup that controls the PA/FEM SE2435L device.

3 Test Results

3.1 Spur Emission

Figure 6 and Figure 7 show that the module passes the ETSI specifications of a margin of –36 dBm.

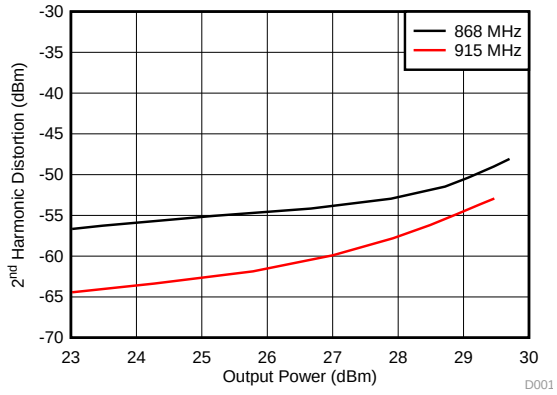

Figure 6. Second Harmonic vs Pout, CW

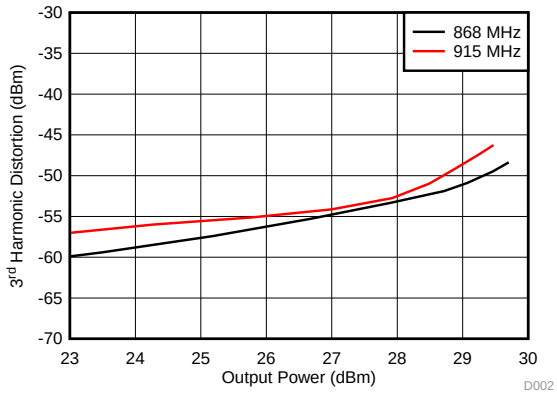

Figure 7. Third Harmonic vs Pout, CW

3.2 Test for TX Performance

The module has been tested at a supply voltage of 3.6 V with the CC1310 device configured for 10-dBm TX power and the SE2435L device configured for TX mode. Figure 8, Figure 9, and Figure 10 show the TX power versus current consumption and gain curve.

TI recommends using the external DC-DC convertor for extended battery life usage and to boost the power amplifier supply to higher voltage, for an additional 0.5 to 1 dbm of TX power. The SE2435L, when operated between 3.8 V to 4.0 V, can be configured and expected to deliver 30 dbm of TX power.

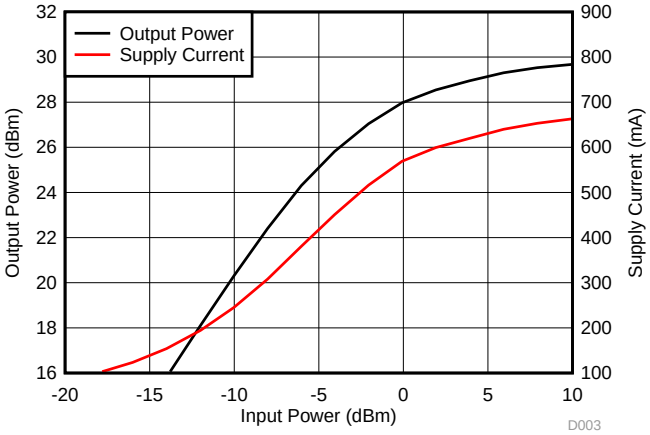

Figure 8. Pout and ICC vs Pin, CW

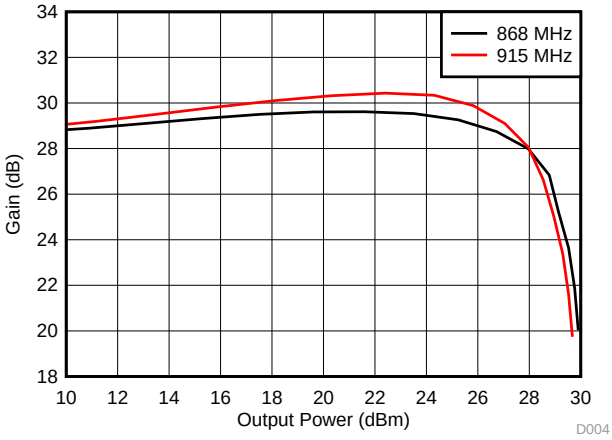

Figure 9. Gain vs Pout, CW

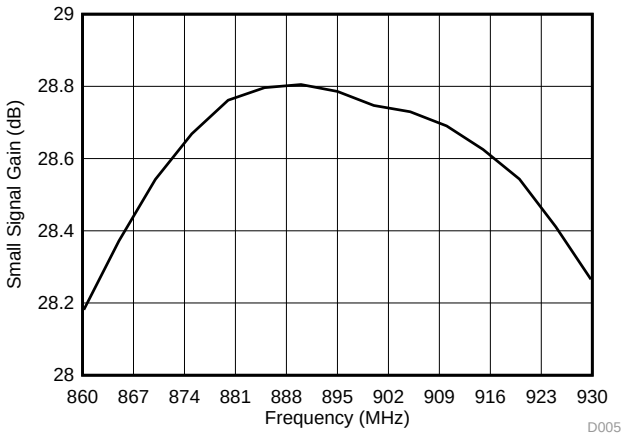

Figure 10. Small Signal Gain vs Frequency, CW

3.3 Test for RX Performance

The RX sensitivity of the CC1310 device is approximately –109 dBm for the IEEE 802.15.4g PHY settings with a 50-kpbs configuration. The SE2435L provides a gain of 15 to 16 dbm in RX mode, which makes the total link budget greater than 145 dbm. Figure 11 shows the RX sensitivity measurement of the CC1310 device in continuous RX mode logged in SmartRF studio. The signal generator generates a signal, which is fed into the module. Figure 11 shows that when an input signal of –40 dbm from a signal generator is input to a board the received signal measured on the CC1310 device is –24 dbm, which confirms the gain of 16 dbm in RX sensitivity.

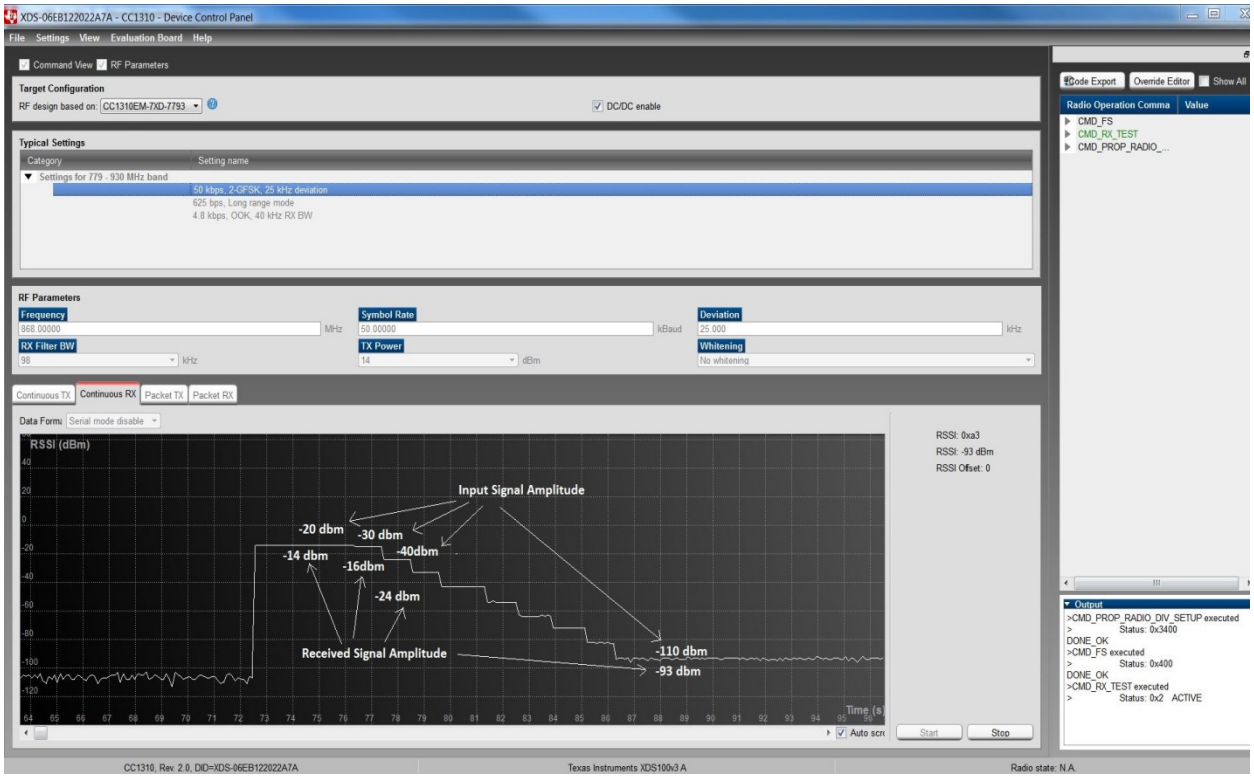

Figure 11. RX Sensitivity of CC1310 LRM

3.4 Power Consumption Analysis

Figure 12 shows the power consumption curve verses TX power configuration. The CC1310 device adds another 11 mA in case of a peak power output of 30 dBm. For the detailed power consumption or operating mode consumption of the part, see the *CC1310 SimpleLink Ultralow Power Sub-1-GHz Wireless MCU* data sheet (SWRS181).

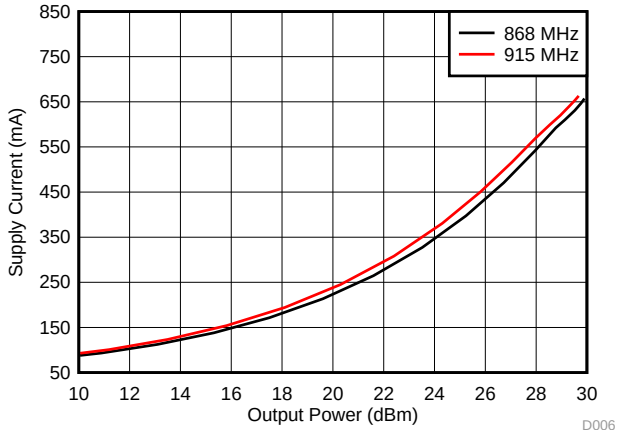

Figure 12. Power Consumption Analysis (PA Only)

4 Summary

This application report targets applications with long-range requirements. This design is compact and is highly efficient with a maximum output TX power of 30 dBm. The PCB antenna keeps the cost low and provides effective radiated performance. Using simple register configurations, the design can be scaled down to a lower output power. The small form factor of the design makes it readily usable in compact designs like energy meters, load switches, street lights, home automation, solar farms, and so forth.

5 References

- *CC1310 TI Product Page*, SimpleLink™ Sub-1 GHz Ultralow-Power Wireless Microcontroller
- *CC1190 TI Product Page*, http://www.ti.com/product/CC1190
- *SE2435L: 860 to 930 MHz High-Power RF Front-End Module* data sheet, http://www.skyworksinc.com/uploads/documents/SE2435L_202412G.pdf
- *DN038 -- Miniature Helical PCB Antenna for 868 MHz or 915/920 MHz*, (SWRA416)
- *Antenna Selection Quick Guide* (SWRA351)
- *SmartRF Studio Download Page*, http://www.ti.com/tool/SMARTRFTM-STUDIO

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (March 2016) to A Revision	Page
• Changed maximum TX power from 30 dBm to 29.5 dBm.	1
• Updated Introduction section.	2
• Updated Test for TX Performance section.	9
• Added CC1190 TI Product Page reference.	11
• Added *SE2435L: 860 to 930 MHz High-Power RF Front-End Module* reference.	11

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