WIRELESS & SENSING PRODUCTS

Corecell gateway Reference design EU version

Performance Report

Abstract

The Corecell gateway reference design is the first plateform which implement the new baseband processor SX1302. This document presents the compliance measurements results to the tests required by European regulation as well as the performance and robustness measurements required for a LoRa gateway.

History

Rev.	Ref.	Change	Author	Date
1.0	-	Doc creation	P. Calvet	September 2019

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Part I

General

1 Introduction

1.1 Presentation

The Corecell gateway is a new reference design based on the SX1302 baseband processor and the new radio transceiver SX1250. It prepares for the next wave of gateways infrastructure deployments in both indoor and outdoor scenarios.

It addresses market needs for cost optimised, low power, low touch development and accelerates gateway design by providing a new reference design.

1.2 Scope

This document presents the measurement performed on the Corecell gateway reference design for the **European region**.

1.3 References documents

The following documents are cited in the present one:

1. **ETSI EN 300 220 v3.1.1** European Regulation for Short Range Devices in the 25 MHz to 1 000 MHz frequency range.
2. **LoRaWAN v1.1 specification** describes the LoRaWAN™ network protocol.
3. **AN1200.37 - Application Note: Recommendations for Best Performance** provides recommendations on PCB design to fight against crystal heating.

1.4 Document convention

Excepted if it is explicitly mentioned, all measurements are performed at ambient temperature i.e +25°C.

→ **Any text inside a framed box means a conclusion of the current section.**

2 Test bench

2.1 General description

The general test bench used along this document to measure and validate the Corecell reference design performances and its compliance to the regulation limits is shown in figure 2.1.

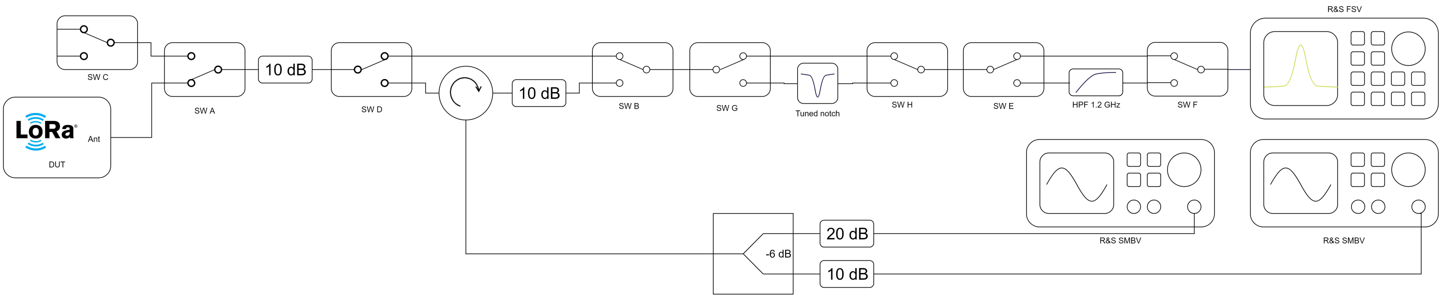


Figure 2.1: Overall test bench setup - Default configuration

According to the specificities of each measurement, the various switches are commuted to select or deselect each functional block. The switch C is used in case of a gateway with two separated RF chains (two antennas or full duplex configuration). It is not used in the measurements of this report.

2.2 Tx measurements

The setup presented in figure 2.2 is used for the Tx measurements.

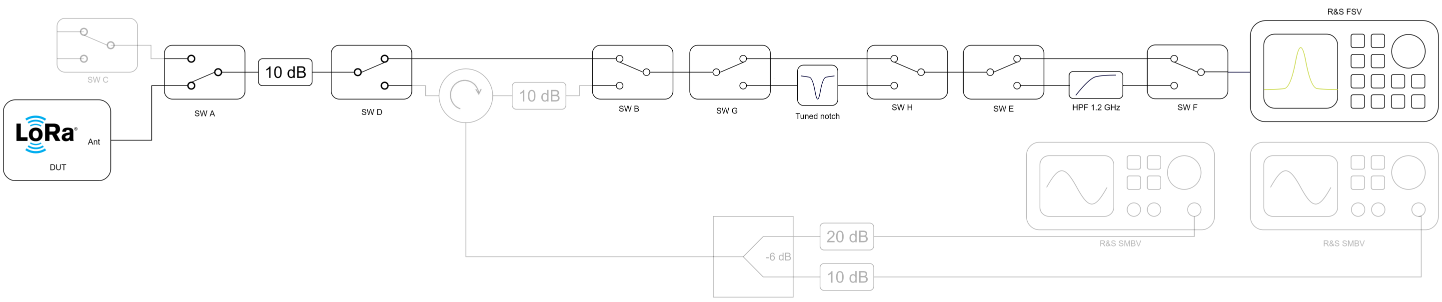


Figure 2.2: Configuration of the test bench for Tx measurements

The 10 dB attenuator after the switch A allows to mitigate effect of impedance mismatch as well as protect the power amplifier of the DUT from reflected power due to the notch or the HPF. Except in case of full duplex measurements, the circulator is never used. The notch and the HPF are only enabled for spurious and LTE bands emission measurements to decrease the carrier level. Finally, loss of attenuator, switch and cables have been previously measured and compensated in the spectrum analyzer (Ref. Level Offset). Other instrument settings are defined for each individual test.

2.3 Rx measurements

All the Rx measurements are performed using the setup of figure 2.3

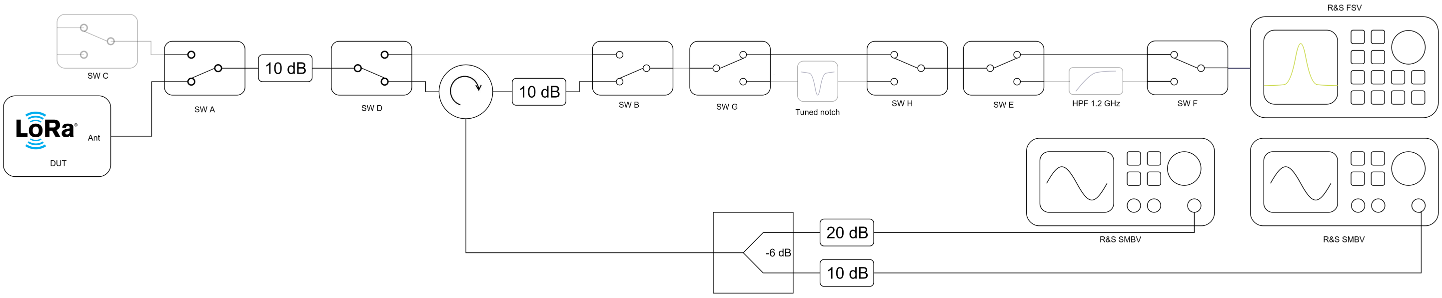


Figure 2.3: Test bench configuration for the Rx measurements

The circulator allows to simultaneously inject a signal into the DUT and measure the emission from it (full duplex configuration). The 10 dB attenuator between the circulator and the switch B mitigates effect of impedance mismatch in order to provided stable and quasi-constant loss over the circulator operating frequency range.

For simple Rx measurements (Sensitivity level, RSSI and SNR, Frequency error or Frequency drift tolerance), only one signal generator is used, the output of the second one is OFF. The other generator is used for the blocking measurement to inject an interferer at various frequencies. The attenuators of 20 and 10 dB at the right of the power splitter allow to mitigate the effect of impedance mismatch on its characteristics as well as protect each signal generator output from the power from the other one or the DUT.

2.4 Over temperature measurements

All the temperature measurements are performed by placing the DUT in a climatic room (see figure 2.4). The probe of an additional thermometer is placed in the climatic room to check the temperature inside.

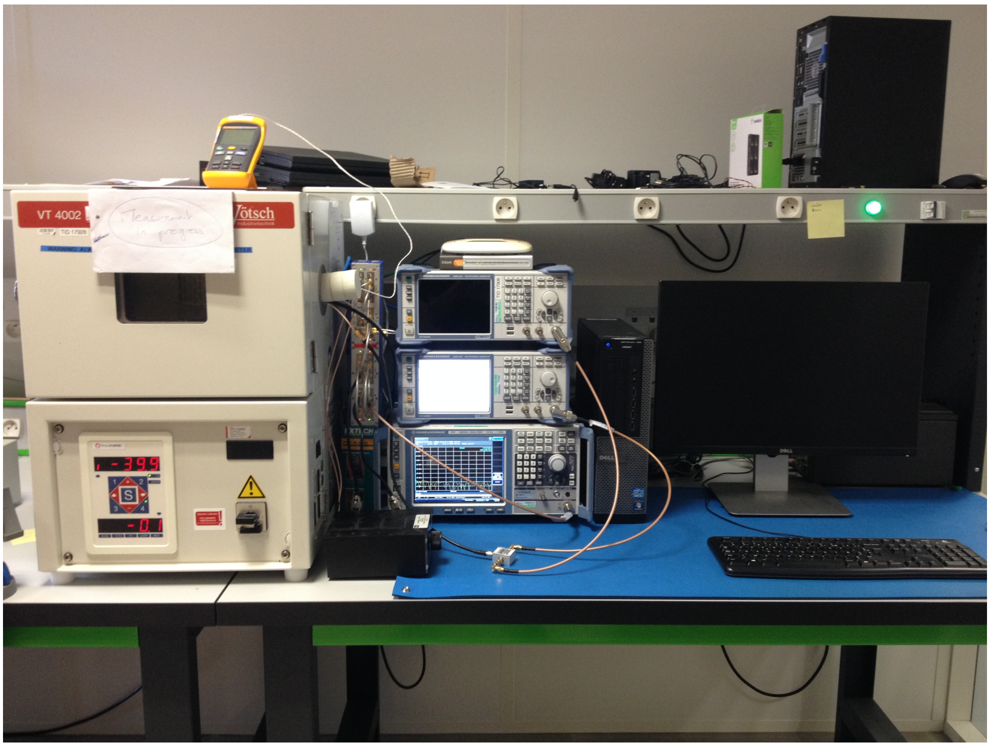


Figure 2.4: Temperatures measurements are performed in climatic room.

Only the DUT is placed in the climatic oven; the rest of the testbench is placed outside.

3 Device under test (DUT)

3.1 Description

The board used along this document is a Corecell reference design batch #1, populated for Europe Band (See figure 3.1). Excepted if it is explicitly mentioned, the board referenced "EU2" is used in the design validation.

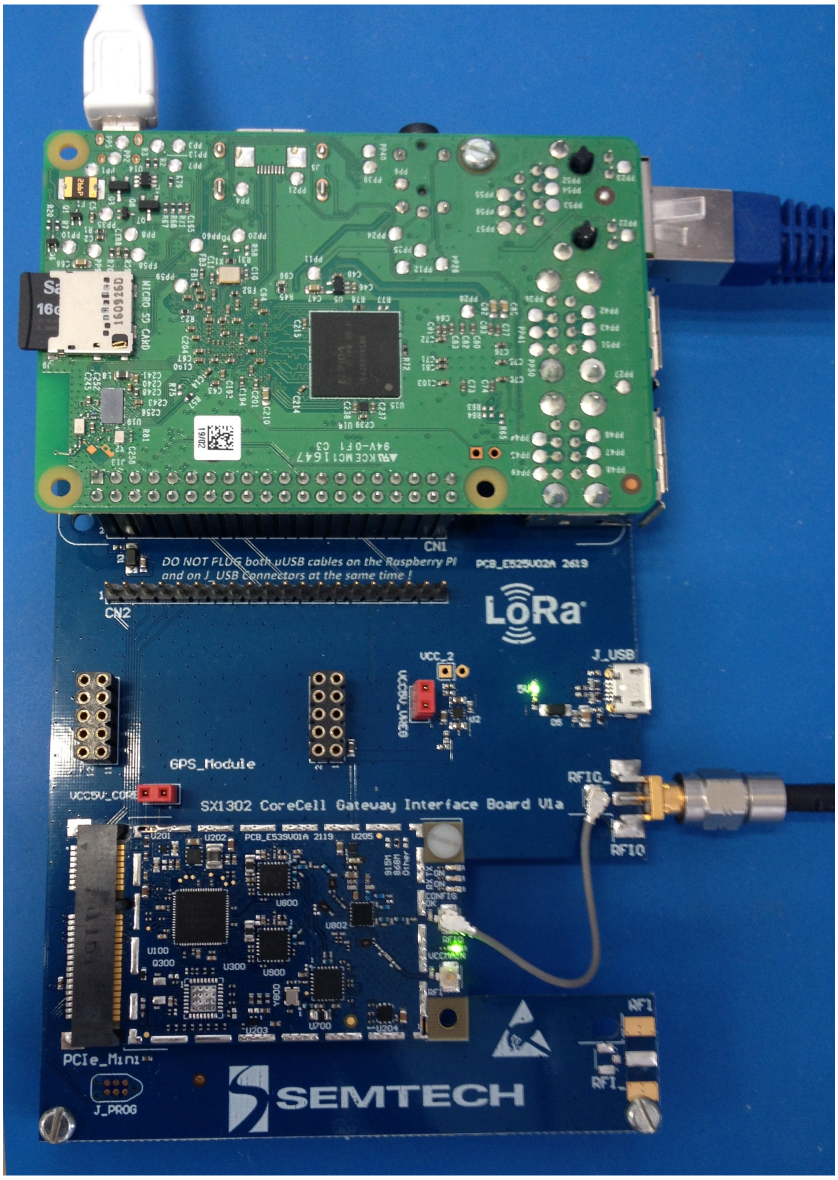


Figure 3.1: The Corecell Ref. design mounted on the interface board with the RPI3

The Corecell ref. design is mounted on the interface board with a RPI3 hosting the HAL and the packet forwarder.

3.2 Board updates

The following updates have been performed on the Corecell reference design:

- The VCC_FEM regulator output capacitor **C206** has been replaced by a bigger one (from 1 to 4.7µF). The component reference is the one of capacitors C204, C207 and C822.

3.3 Firmware

The following repository contains the HAL and the packet forwarder which are used for the corecell reference design validation:
`https://github.com/Lora-net/sx1302_hal`

Part II

Transmitter

4 Occupied bandwidth (ETSI)

4.1 Description

This test refers to the chapter 5.6 of the EN 300 220 v3.1.1 [1]. It checks that 99% of the total mean power (OBW) falls entirely inside the Operating Channel bandwidth (OCW) declared in the Operational Frequency band (OFB). The figure 4.1 explains the definition of OBW, OCW and OFB.

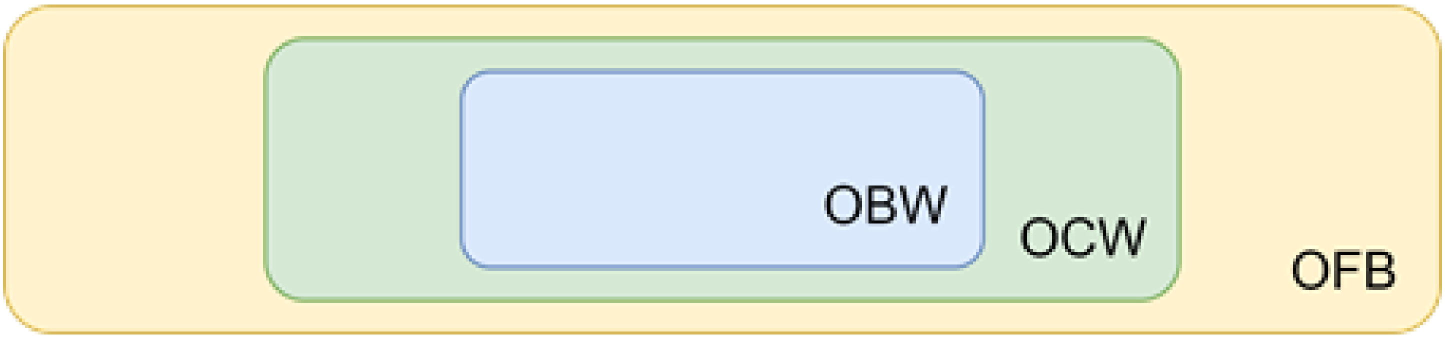


Figure 4.1: EN 300 220 OBW/OCW/OFB definition

The LoRa system defines the operating channel width (OCW) as 200 kHz for the LoRa bandwidth of 125 kHz. The reference oscillator frequency drift influences the result of this test so it shall be performed in temperature i.e -40°C and +85°C.

4.2 Setup

The setup used to measure the occupied bandwidth is shown in figure 2.2. Only the direct path is used for this measurement, the notch or the high pass filter are used to measure spurious level far from the carrier frequency.

4.3 Ambient temperature

4.3.1 LoRa 125 kHz

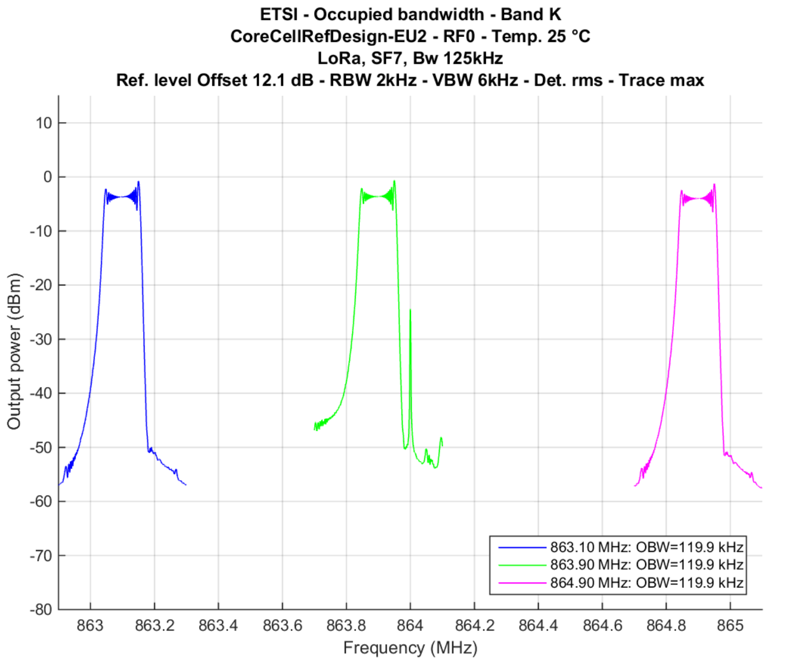


Figure 4.2: Occupied bandwidth, Band K, 14 dBm, LoRa SF7, Bw 125 kHz

In the figure 4.2, the spurious presents at 864 MHz is an harmonic of the 32 MHz reference clock. Its level sufficiently low does not disturb the occupied bandwidth measurement performed using the dedicated instrument function (OBW measured at 99%).

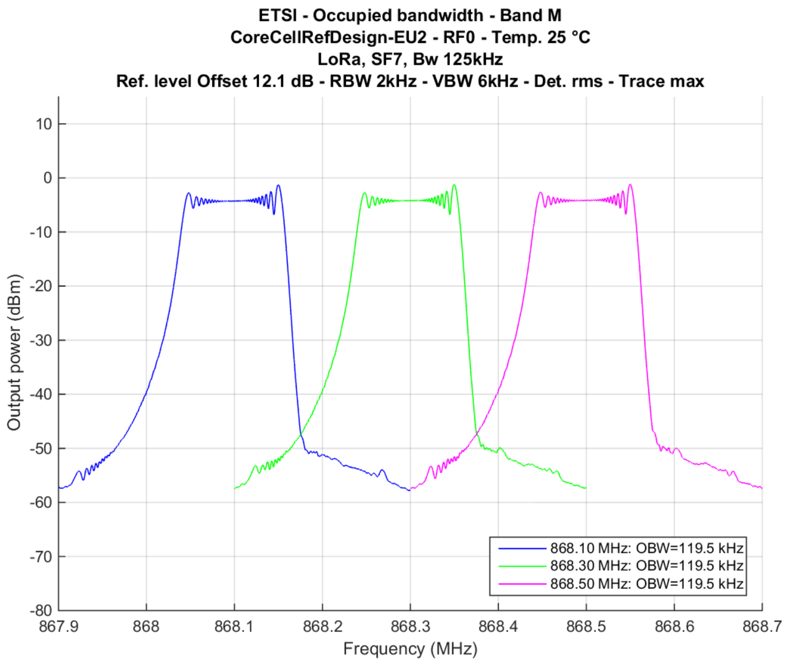


Figure 4.3: Occupied bandwidth, Band M, 14 dBm, LoRa SF7, Bw 125 kHz

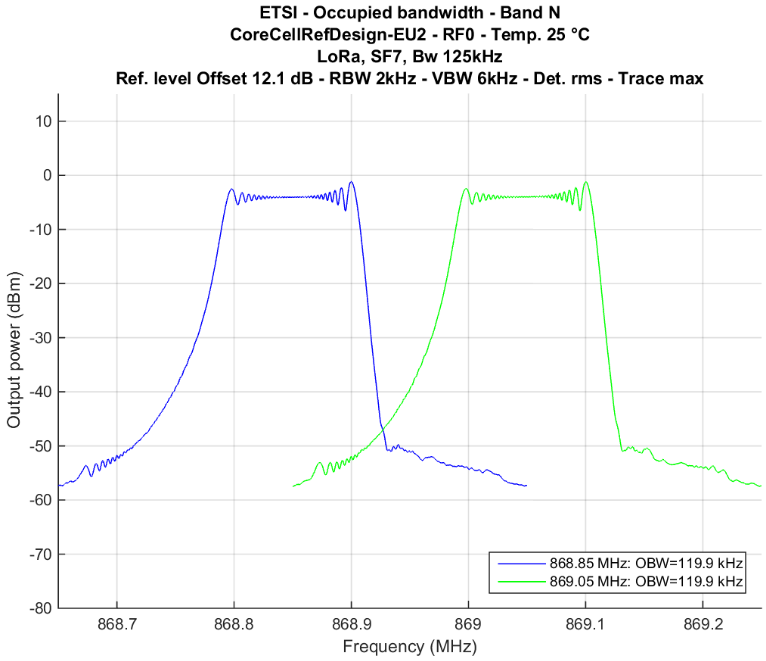


Figure 4.4: Occupied bandwidth, Band N, 14 dBm, LoRa SF7, Bw 125 kHz

In the figure 4.5, the output power is lower than 27 dBm due to the low resolution bandwidth used to perform the measurement (RBW = 2 kHz).

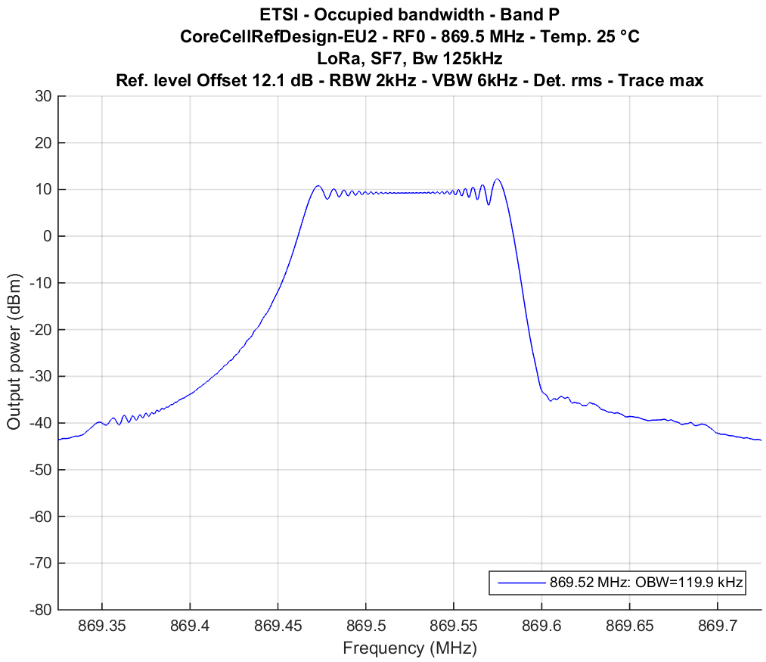


Figure 4.5: Occupied bandwidth, Band P, 27 dBm, LoRa SF7, Bw 125 kHz

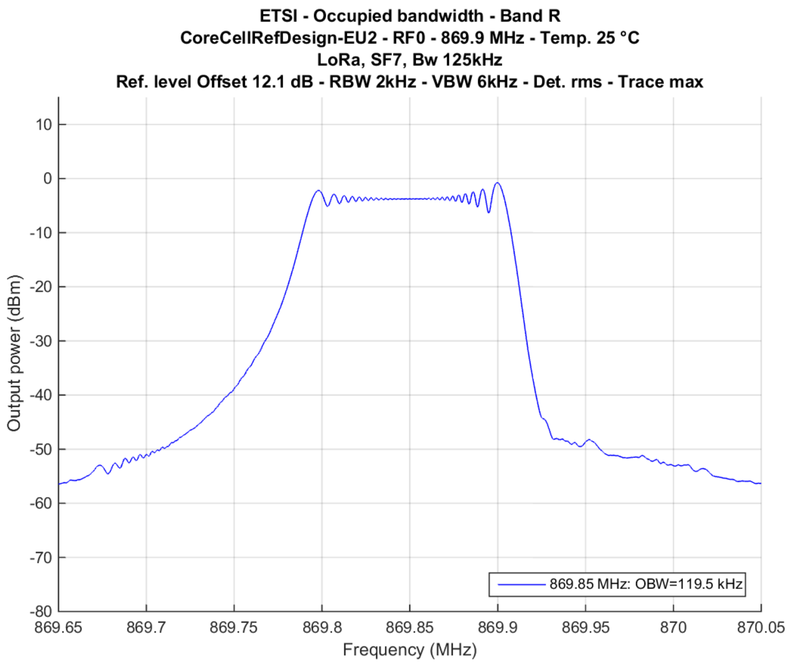


Figure 4.6: Occupied bandwidth, Band R, 14 dBm, LoRa SF7, Bw 125 kHz

4.3.2 LoRa 250 kHz

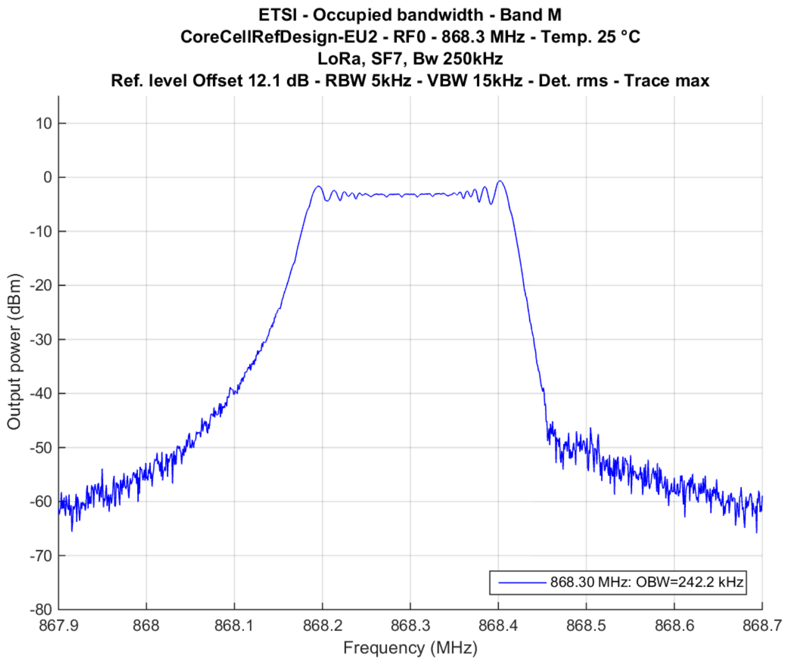


Figure 4.7: Occupied bandwidth, Band M, 14 dBm, LoRa SF7, Bw 250kHz

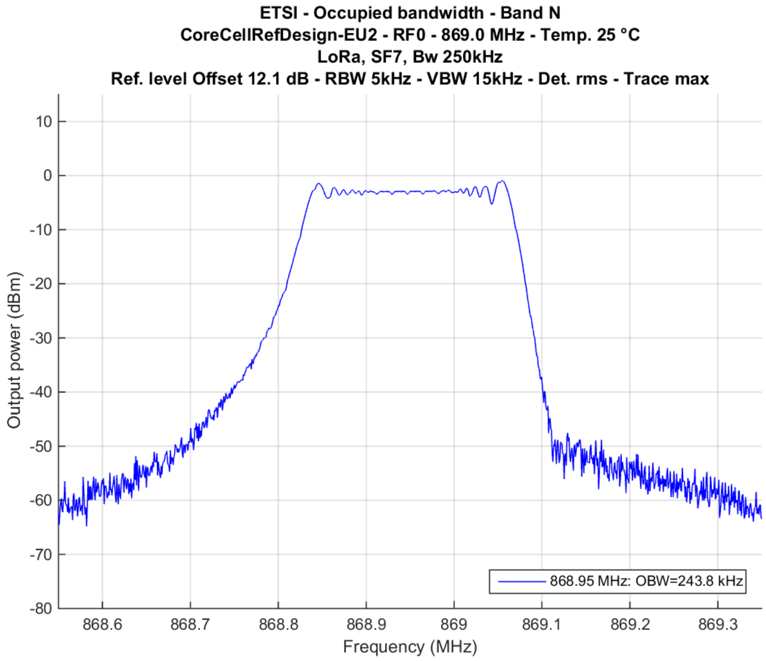


Figure 4.8: Occupied bandwidth, Band N, 14 dBm, LoRa SF7, Bw 250kHz

4.3.3 FSK 50 kbits

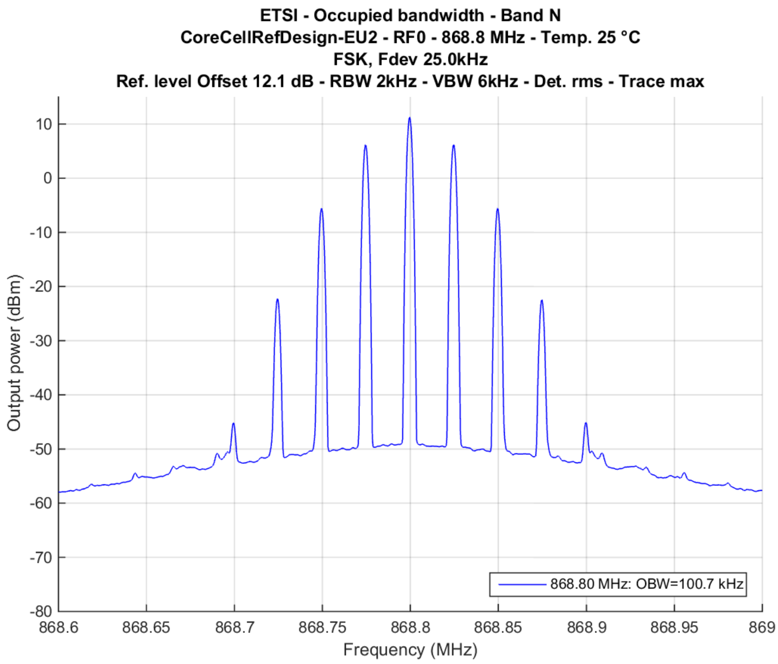
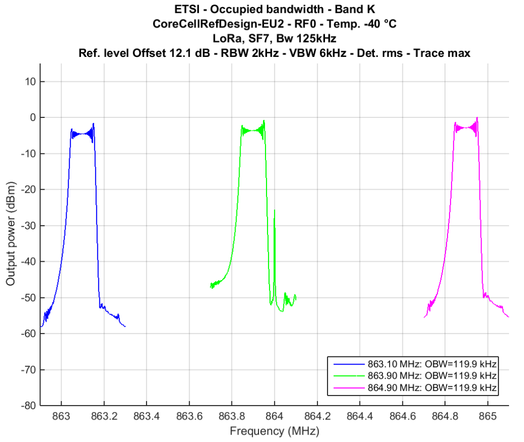


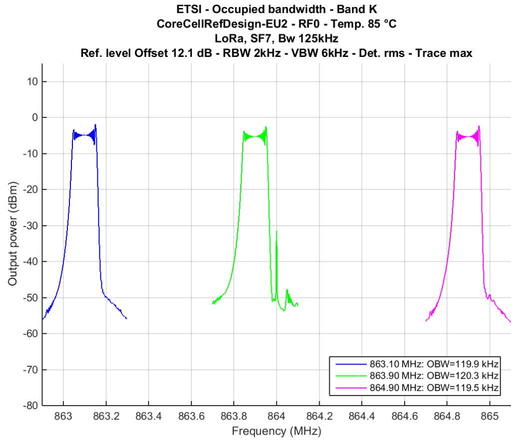
Figure 4.9: Occupied bandwidth, Band N, 14 dBm, FSK 50 kbps, Fdev 25 kHz

4.4 Extremes temperatures

4.4.1 LoRa 125 kHz

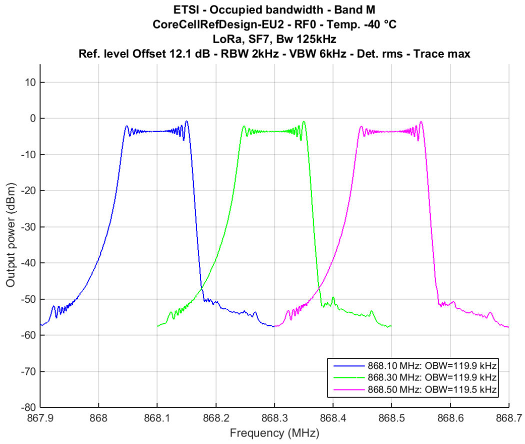


(a) -40°C

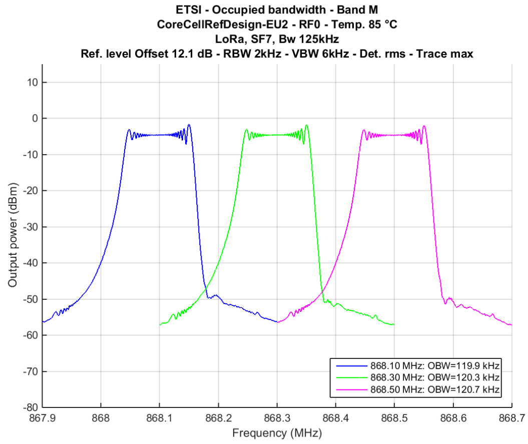


(b) +85°C

Figure 4.10: Occupied bandwidth, Band K, 14 dBm, LoRa SF7, Bw 125 kHz, Extremes temperatures

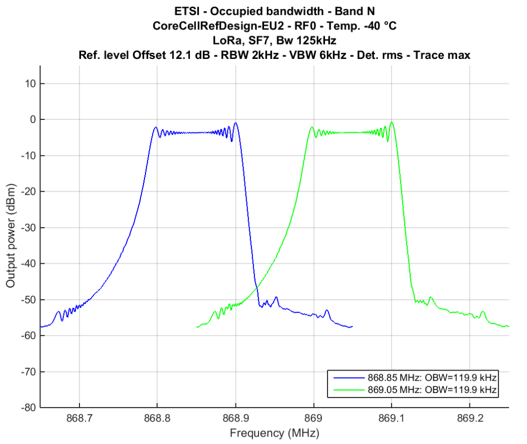


(a) -40°C

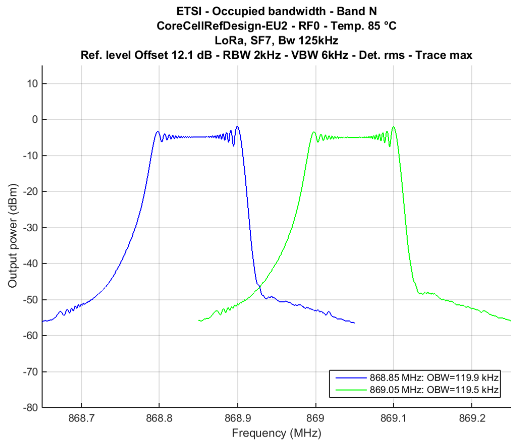


(b) +85°C

Figure 4.11: Occupied bandwidth, Band M, 14 dBm, LoRa SF7, Bw 125 kHz, Extremes temperatures

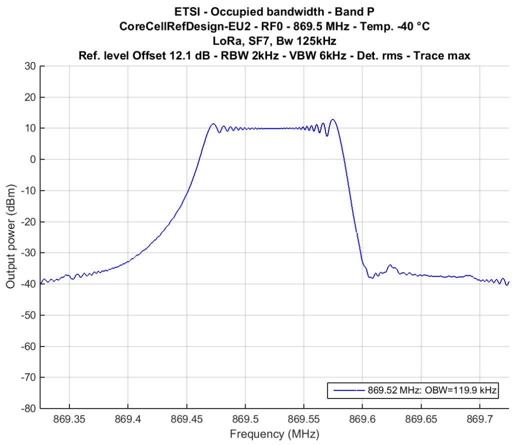


(a) -40°C

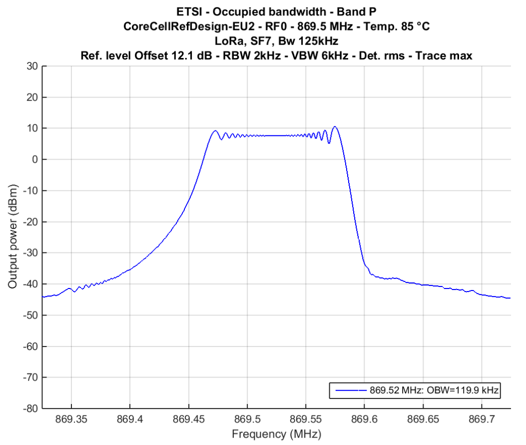


(b) +85°C

Figure 4.12: Occupied bandwidth, Band N, 14 dBm, LoRa SF7, Bw 125 kHz, Extremes temperatures

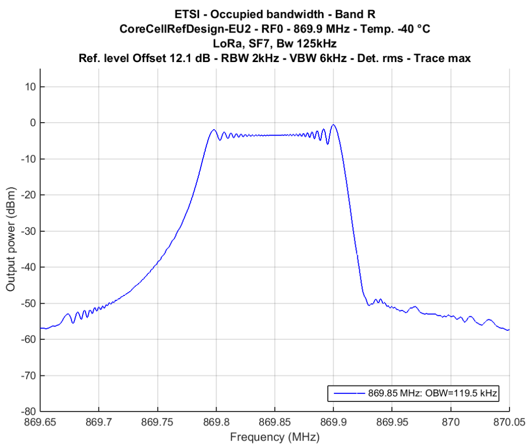


(a) -40°C

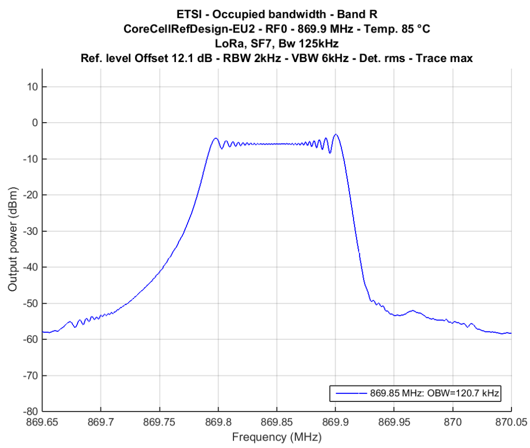


(b) +85°C

Figure 4.13: Occupied bandwidth, Band P, 27 dBm, LoRa SF7, Bw 125 kHz, Extremes temperatures



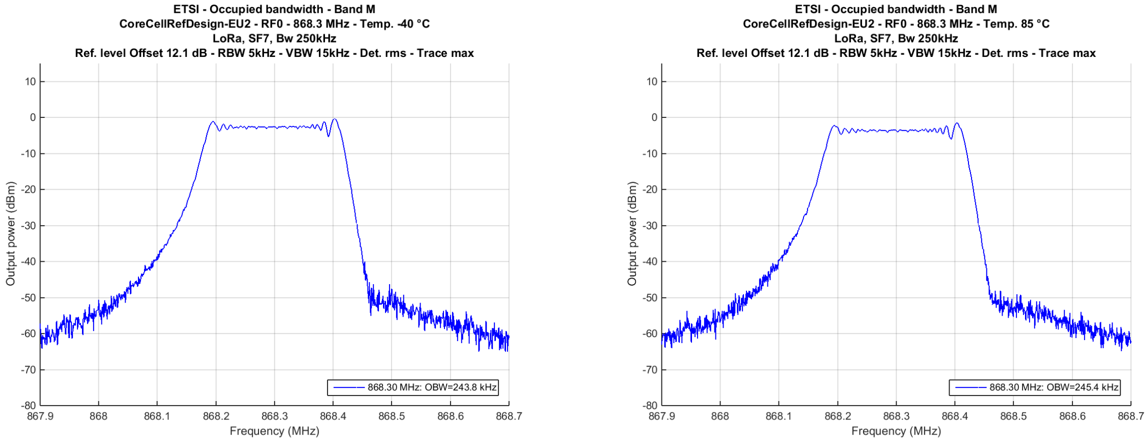
(a) -40°C



(b) +85°C

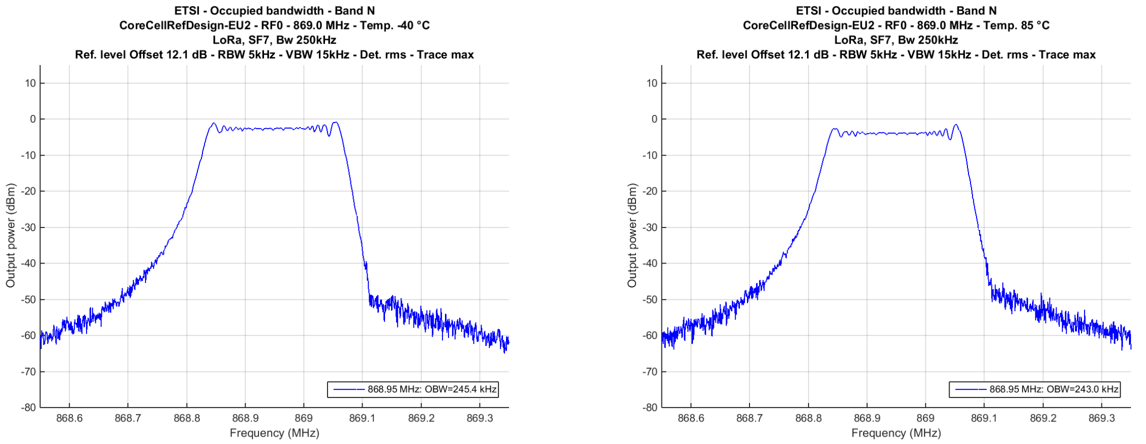
Figure 4.14: Occupied bandwidth, Band R, 14 dBm, LoRa SF7, Bw 125 kHz, Extremes temperatures

4.4.2 LoRa 250 kHz



(a) -40°C (b) +85°C

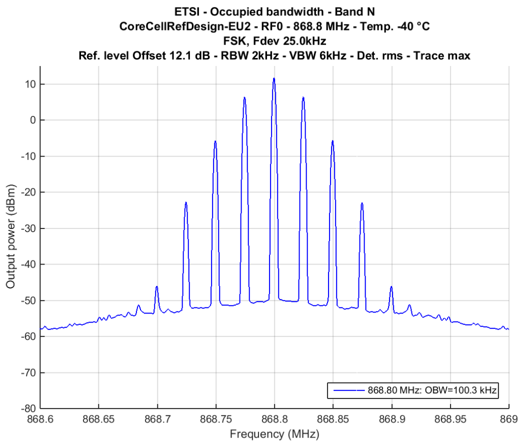
Figure 4.15: Occupied bandwidth, Band M, 14 dBm, LoRa SF7, Bw 250kHz, Extremes temperatures



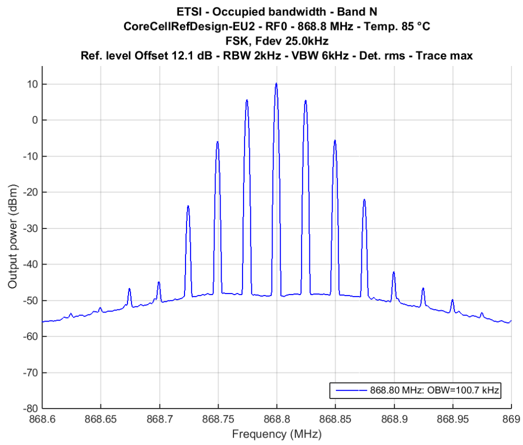
(a) -40°C (b) +85°C

Figure 4.16: Occupied bandwidth, Band N, 14 dBm, LoRa SF7, Bw 250kHz, Extremes temperatures

4.4.3 FSK 50 kbits



(a) -40°C



(b) +85°C

Figure 4.17: Occupied bandwidth, Band N, 14 dBm, FSK 50 kbps, Fdev 25 kHz, Extremes temperatures

5 Tx Out Of Band Emissions (ETSI)

5.1 Description

This test refers to the chapter 5.8 of the European regulation EN 300 220 v3.1.1 (document [1]). Unwanted emissions in the Out Of Band domain are those falling in the frequency range immediately below the lower and above the upper frequency of the Operating Channel.

The OOB domain includes both frequencies outside the Operating Channel within and outside the Operational Frequency Band. See document [1] for more information about this test.

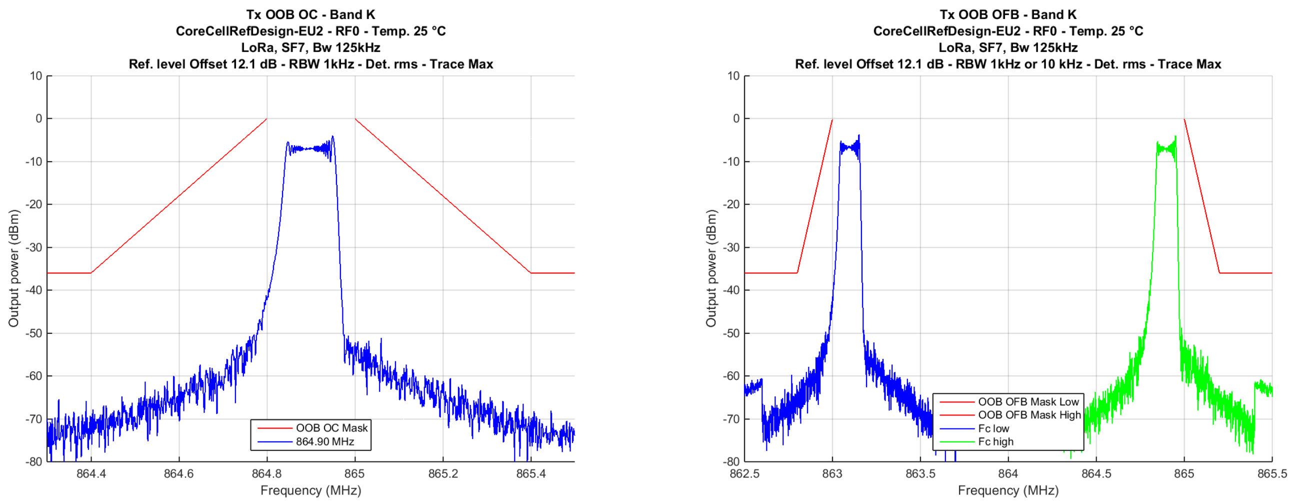
5.2 Setup

The setup used to measure the out of band emission is show in figure 2.2. Only the direct path is used for this measurement, the notch or the high pass filter are used to measure spurious level far from the carrier frequency.

5.3 Ambient temperature

In the following measurements, a step appears in the spectrum. It is due to a change of the spectrum analyzer resolution bandwidth from 1 to 10 kHz as required by the measurement procedure described in document [1].

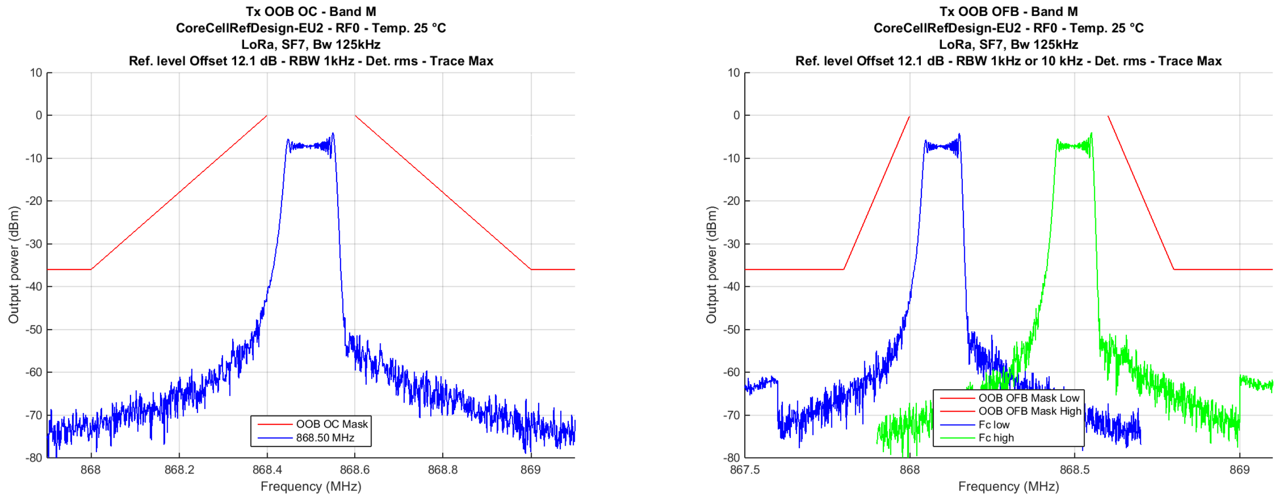
5.3.1 LoRa 125 kHz



(a) Operating channel

(b) Operational Frequency band

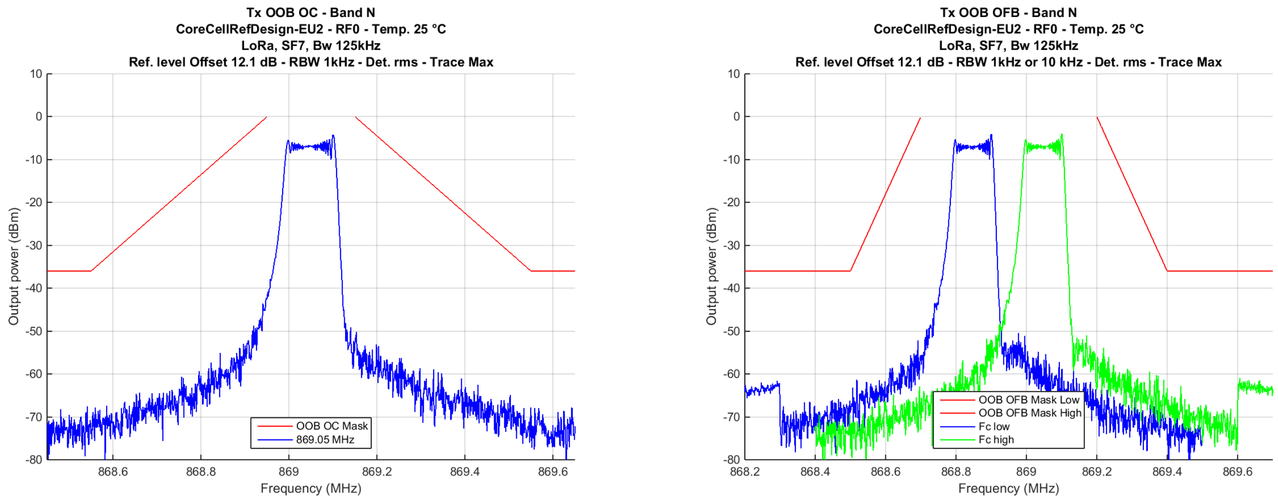
Figure 5.1: Tx Out Of Band Emissions, Band K, 14 dBm, LoRa SF7, Bw 125 kHz



(a) Operating channel

(b) Operational Frequency band

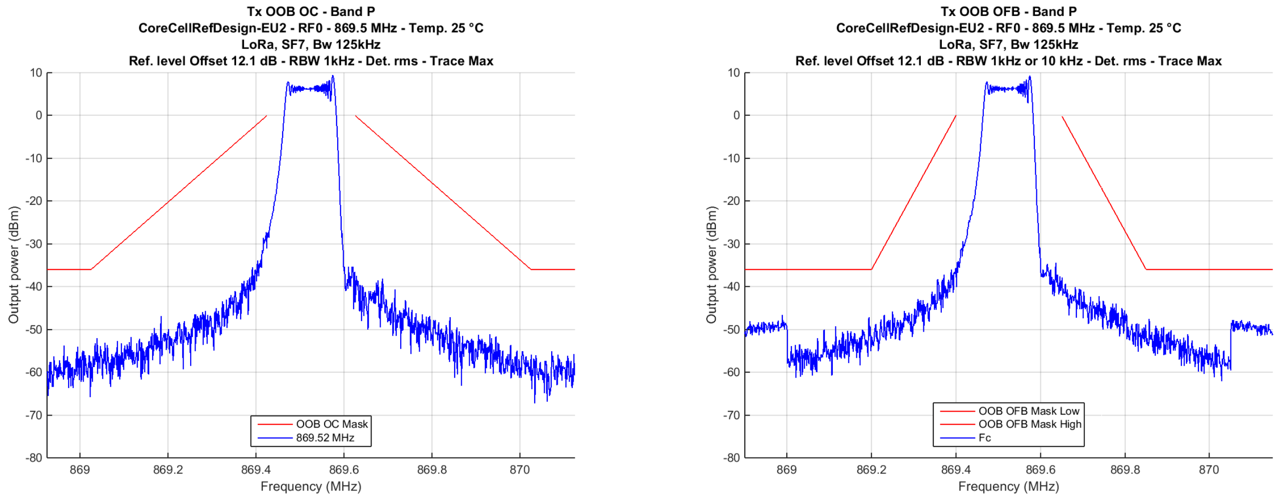
Figure 5.2: Tx Out Of Band Emissions, Band M, 14 dBm, LoRa SF7, Bw 125 kHz



(a) Operating channel

(b) Operational Frequency band

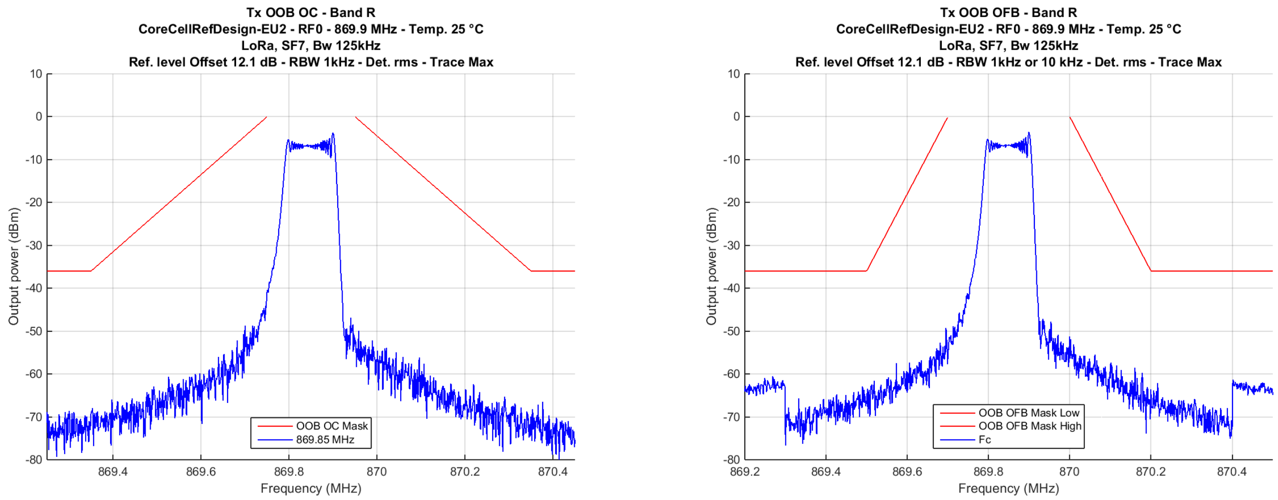
Figure 5.3: Tx Out Of Band Emissions, Band N, 14 dBm, LoRa SF7, Bw 125 kHz



(a) Operating channel

(b) Operational Frequency band

Figure 5.4: Tx Out Of Band Emissions, Band P, 27 dBm, LoRa SF7, Bw 125 kHz

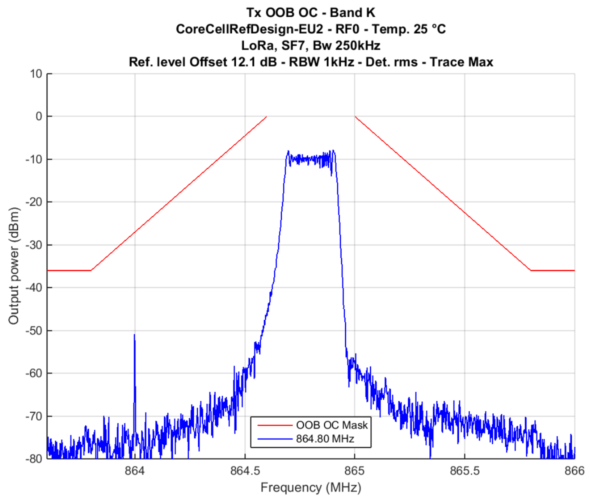


(a) Operating channel

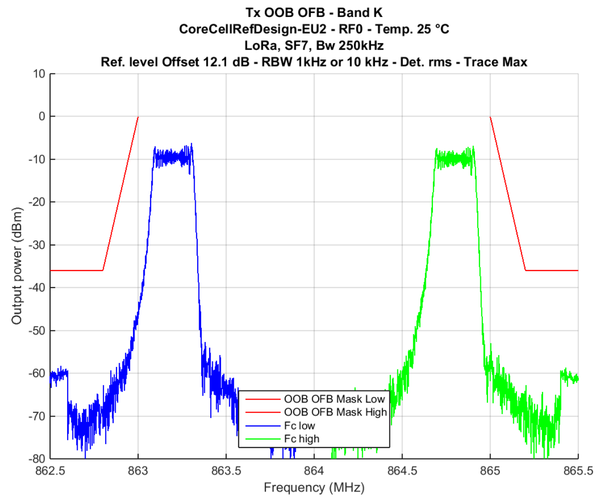
(b) Operational Frequency band

Figure 5.5: Tx Out Of Band Emissions, Band R, 14 dBm, LoRa SF7, Bw 125 kHz

5.3.2 LoRa 250 kHz

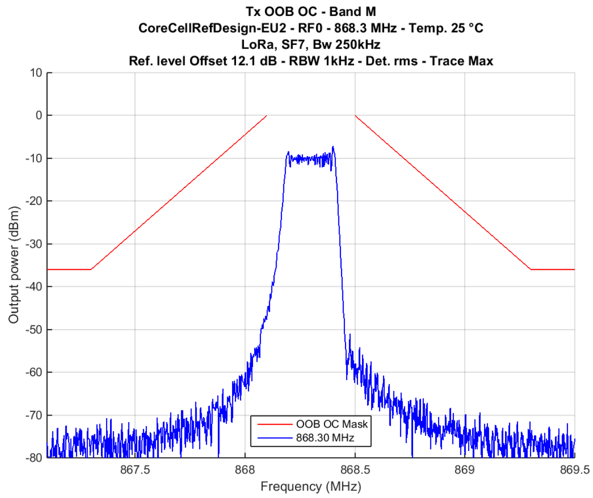


(a) Operating channel

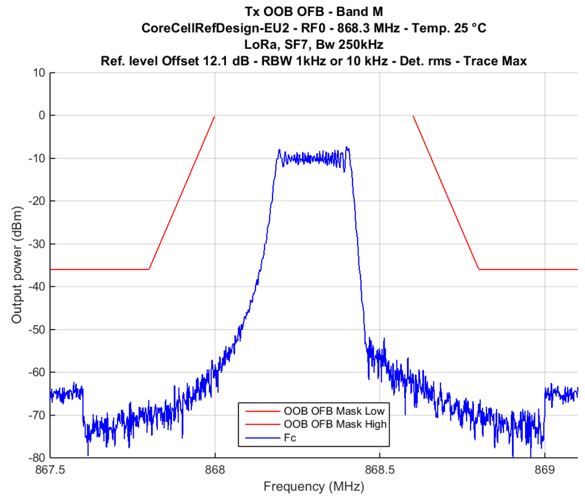


(b) Operational Frequency band

Figure 5.6: Tx Out Of Band Emissions, Band K, 14 dBm, LoRa SF7, Bw 250 kHz

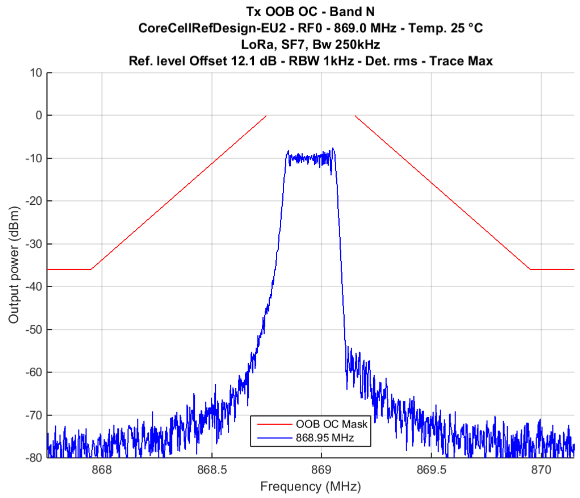


(a) Operating channel

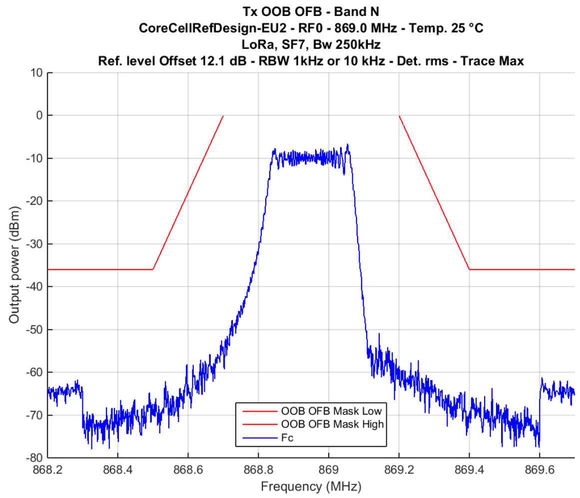


(b) Operational Frequency band

Figure 5.7: Tx Out Of Band Emissions, Band M, 14 dBm, LoRa SF7, Bw 250 kHz

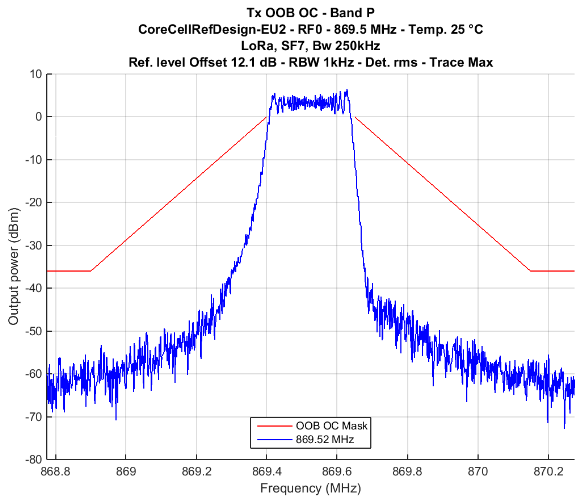


(a) Operating channel

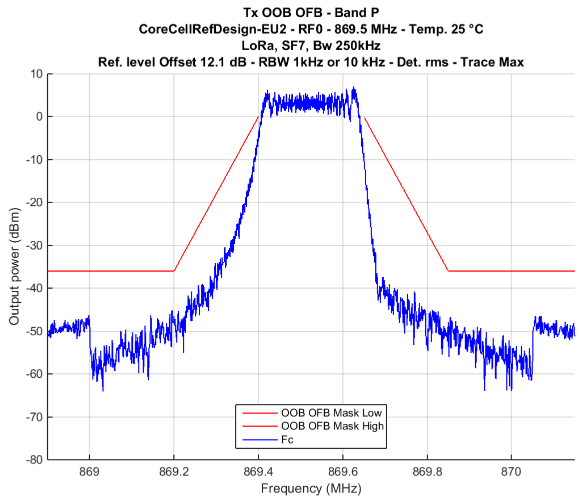


(b) Operational Frequency band

Figure 5.8: Tx Out Of Band Emissions, Band N, 14 dBm, LoRa SF7, Bw 250 kHz

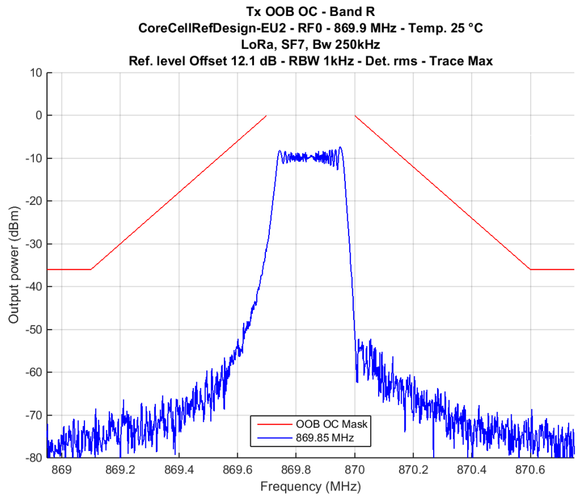


(a) Operating channel

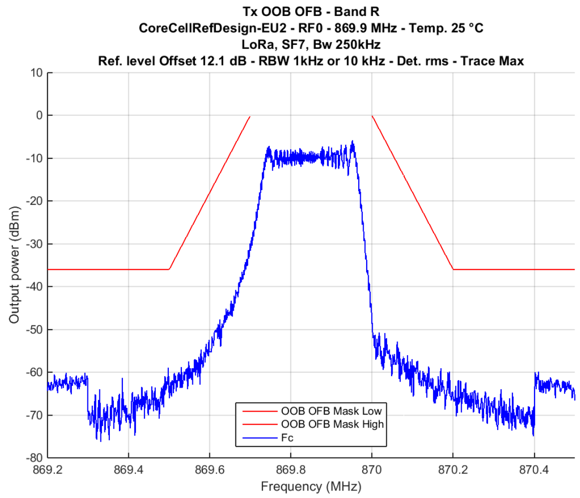


(b) Operational Frequency band

Figure 5.9: Tx Out Of Band Emissions, Band P, 27 dBm, LoRa SF7, Bw 125 kHz



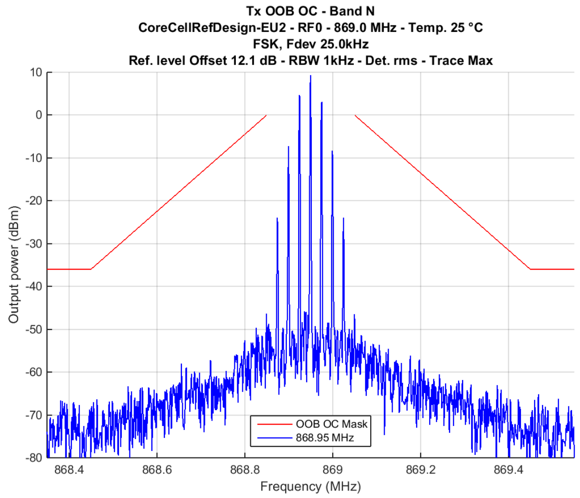
(a) Operating channel



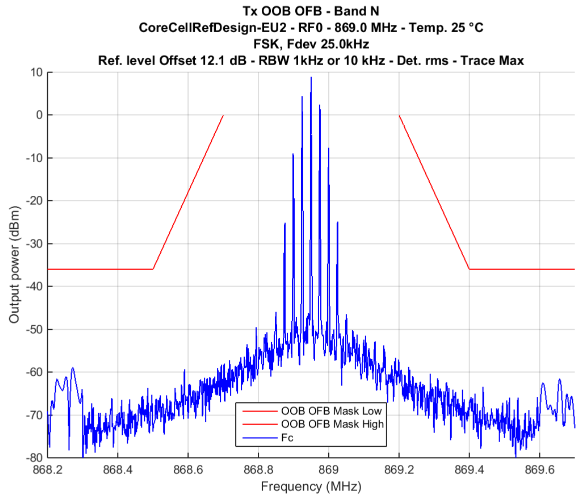
(b) Operational Frequency band

Figure 5.10: Tx Out Of Band Emissions, Band R, 14 dBm, LoRa SF7, Bw 250 kHz

5.3.3 FSK 50 kbits



(a) Operating channel

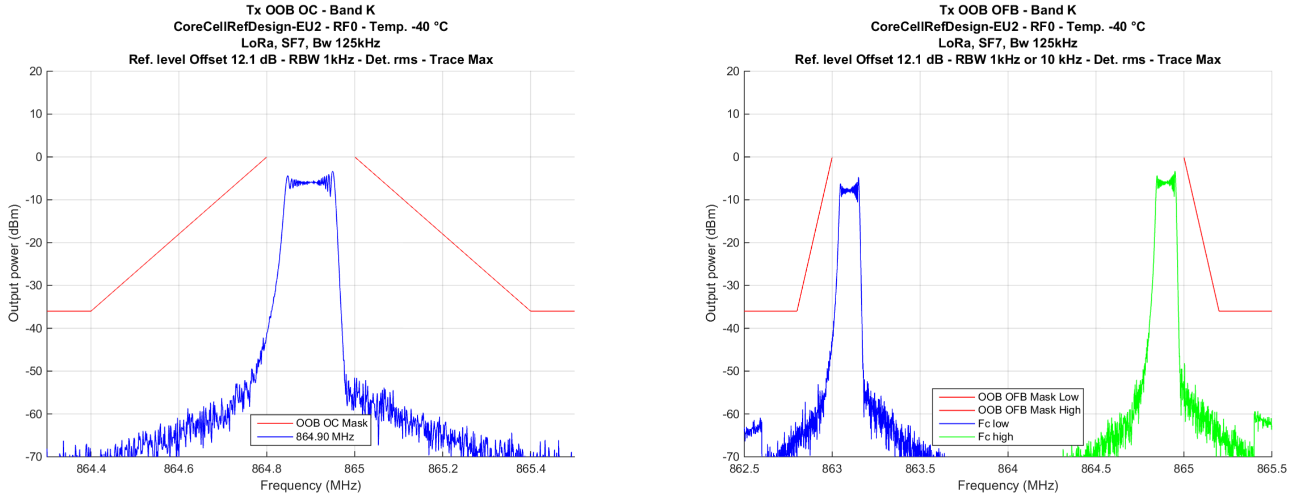


(b) Operational Frequency band

Figure 5.11: Tx Out Of Band Emissions, Band R, 14 dBm, FSK 50 kbps, Fdev 25 kHz

5.4 Low temperature: -40°C

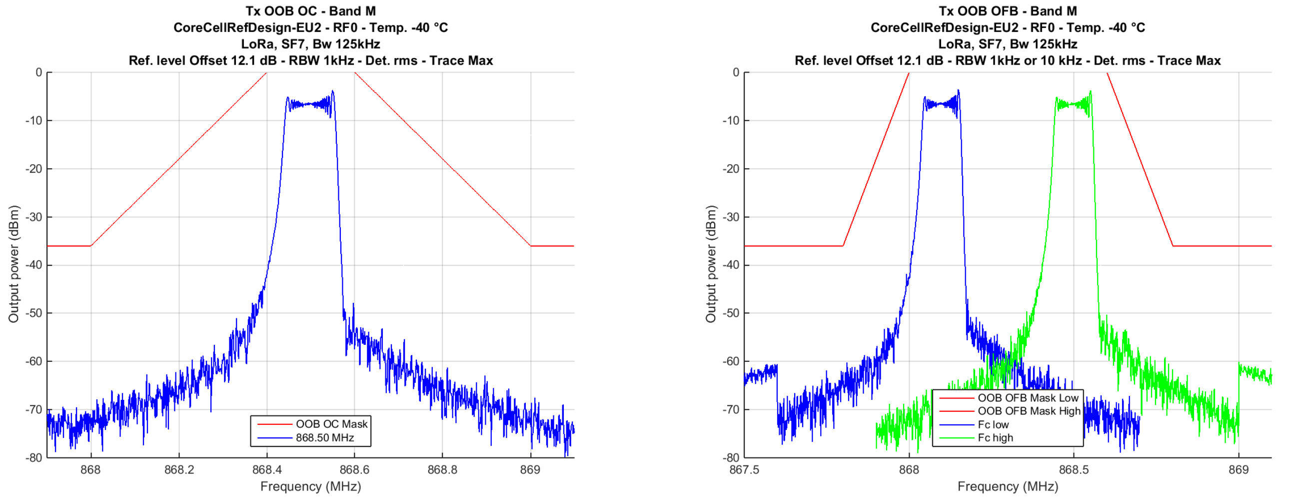
5.4.1 LoRa 125 kHz



(a) Operating channel

(b) Operational Frequency band

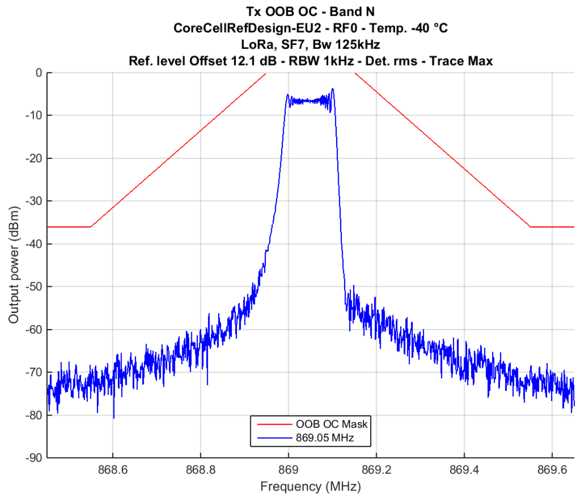
Figure 5.12: Tx Out Of Band Emissions, Band K, 14 dBm, LoRa SF7, Bw 125 kHz



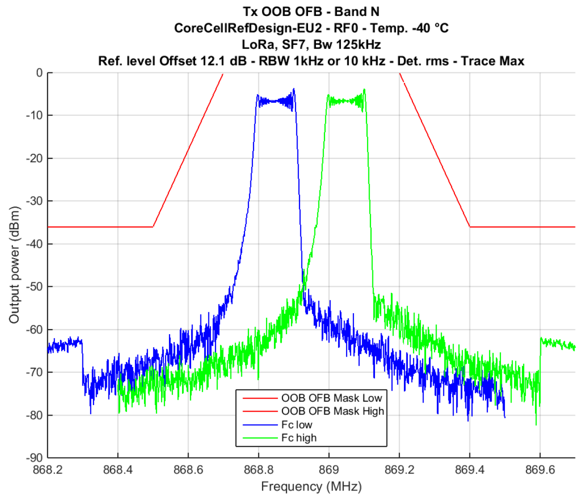
(a) Operating channel

(b) Operational Frequency band

Figure 5.13: Tx Out Of Band Emissions, Band M, 14 dBm, LoRa SF7, Bw 125 kHz

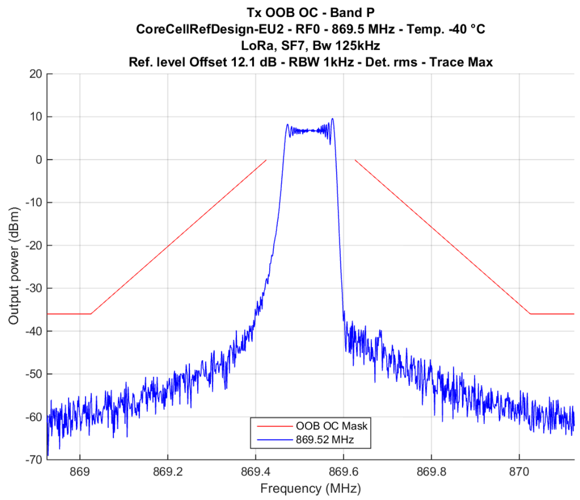


(a) Operating channel

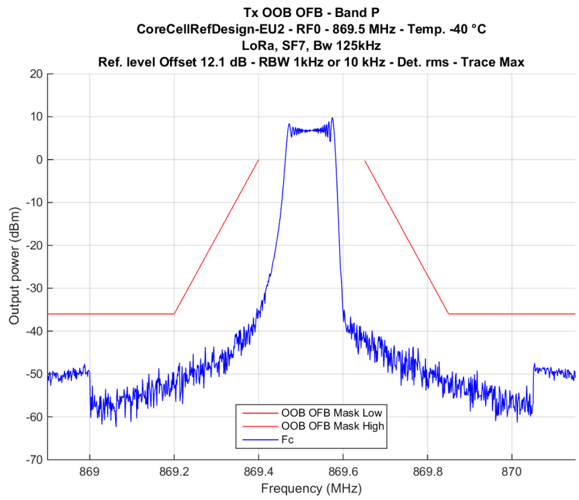


(b) Operational Frequency band

Figure 5.14: Tx Out Of Band Emissions, Band N, 14 dBm, LoRa SF7, Bw 125 kHz

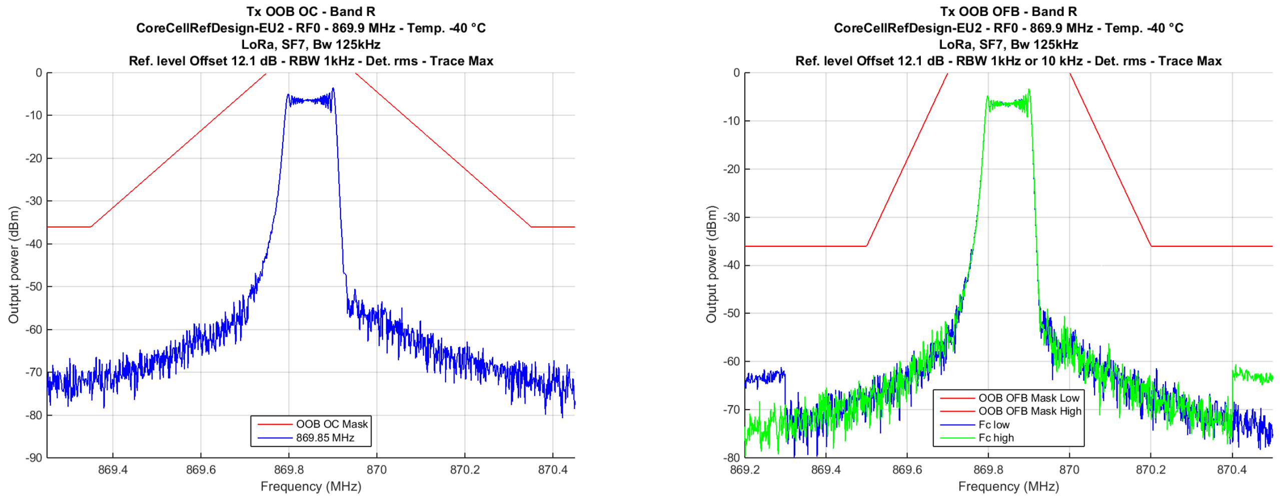


(a) Operating channel



(b) Operational Frequency band

Figure 5.15: Tx Out Of Band Emissions, Band P, 27 dBm, LoRa SF7, Bw 125 kHz

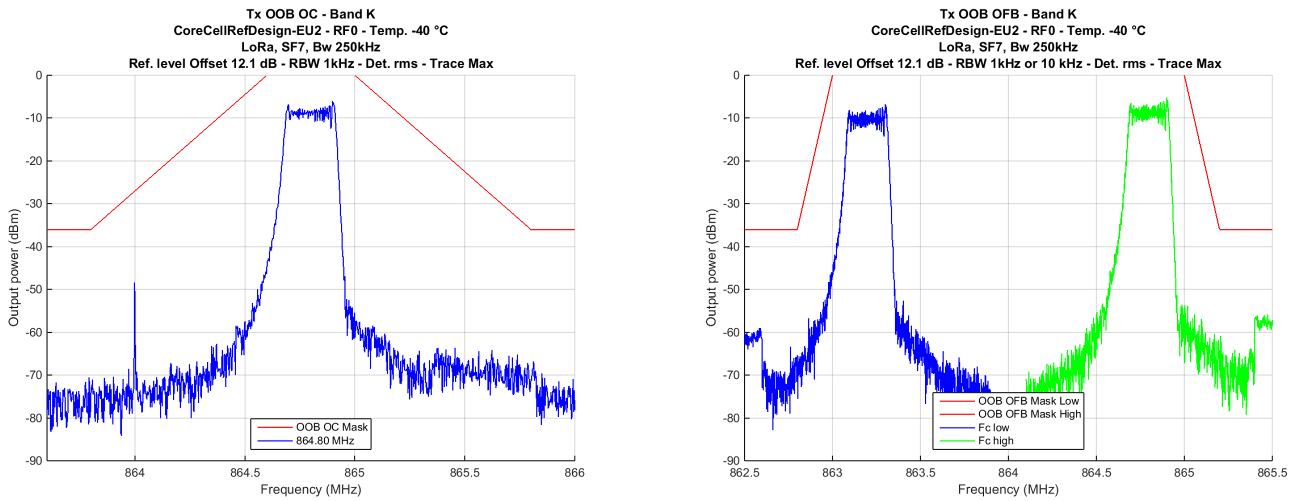


(a) Operating channel

(b) Operational Frequency band

Figure 5.16: Tx Out Of Band Emissions, Band R, 14 dBm, LoRa SF7, Bw 125 kHz

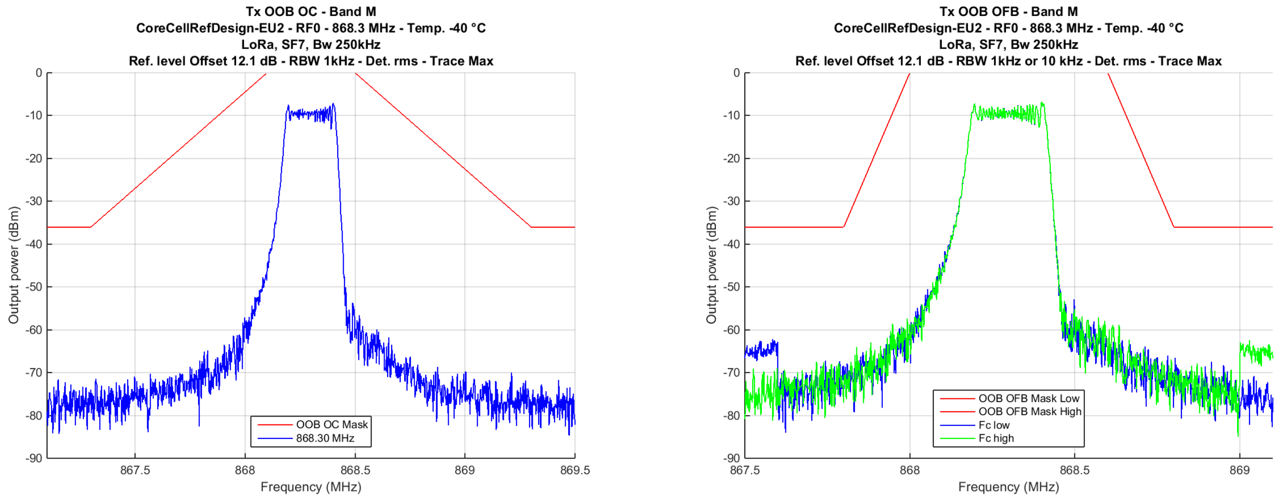
5.4.2 LoRa 250 kHz



(a) Operating channel

(b) Operational Frequency band

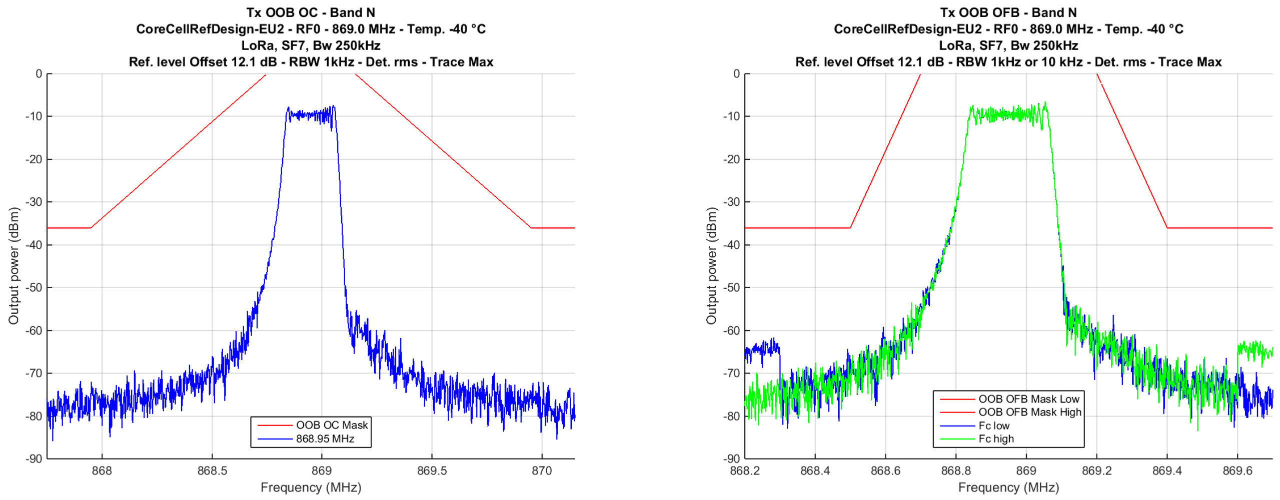
Figure 5.17: Tx Out Of Band Emissions, Band K, 14 dBm, LoRa SF7, Bw 250 kHz



(a) Operating channel

(b) Operational Frequency band

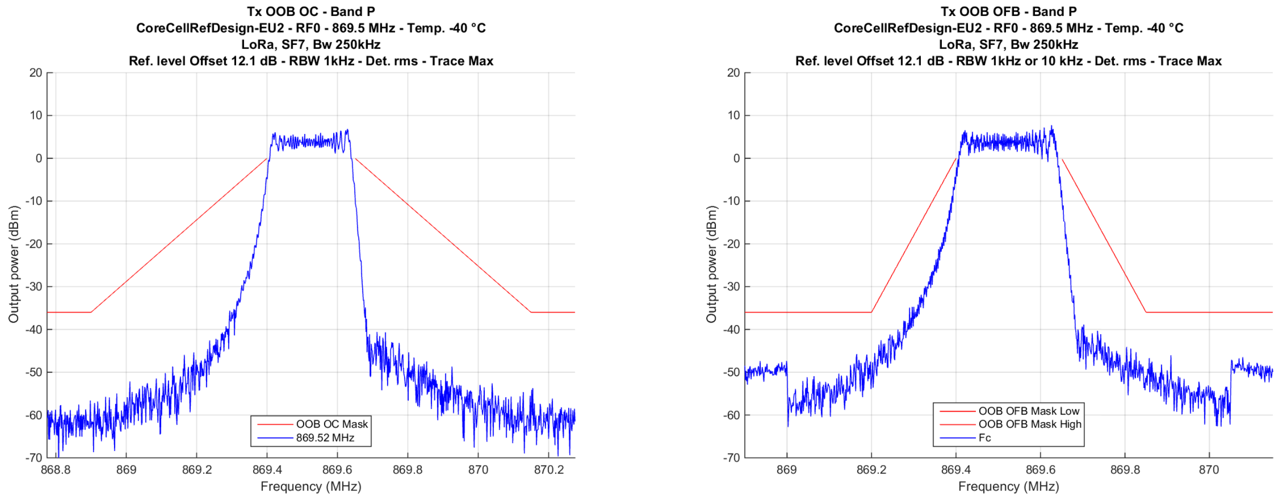
Figure 5.18: Tx Out Of Band Emissions, Band M, 14 dBm, LoRa SF7, Bw 250 kHz



(a) Operating channel

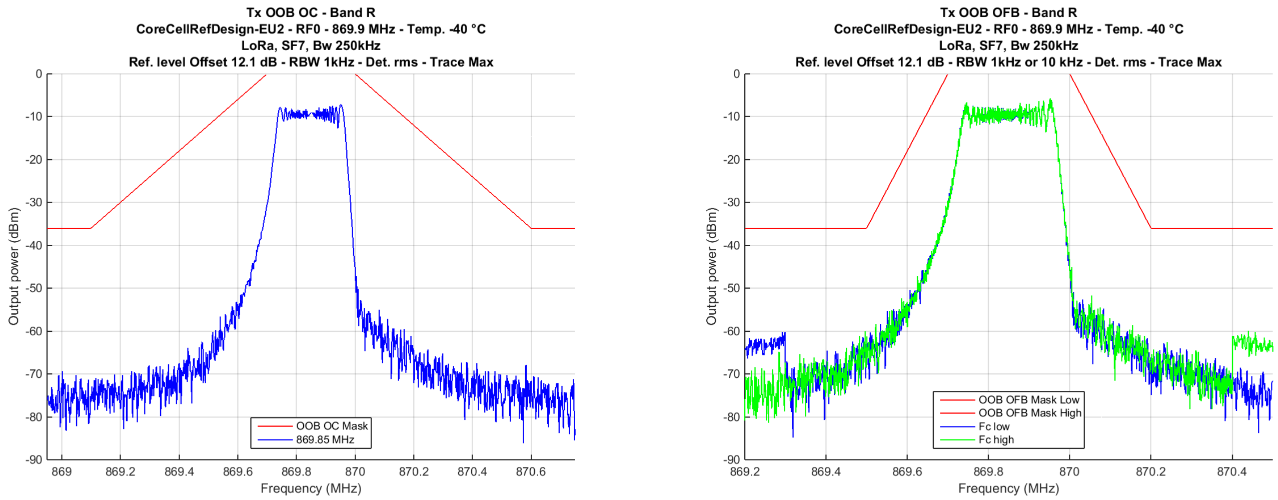
(b) Operational Frequency band

Figure 5.19: Tx Out Of Band Emissions, Band N, 14 dBm, LoRa SF7, Bw 250 kHz



(a) Operating channel (b) Operational Frequency band

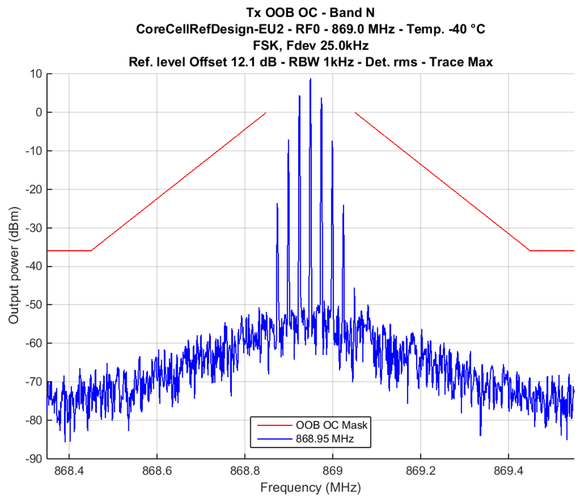
Figure 5.20: Tx Out Of Band Emissions, Band P, 27 dBm, LoRa SF7, Bw 250 kHz



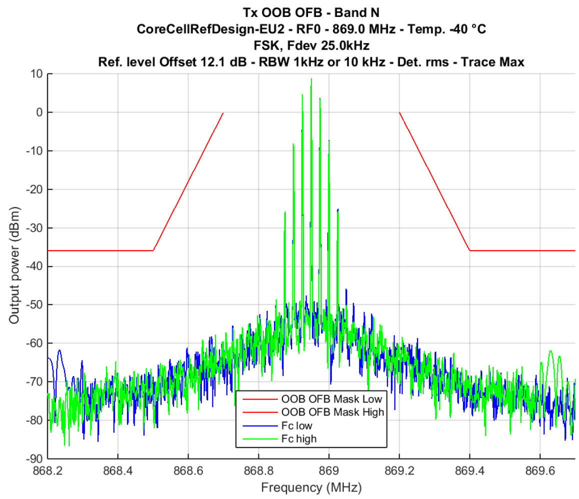
(a) Operating channel (b) Operational Frequency band

Figure 5.21: Tx Out Of Band Emissions, Band R, 14 dBm, LoRa SF7, Bw 250 kHz

5.4.3 FSK 50 kbits



(a) Operating channel

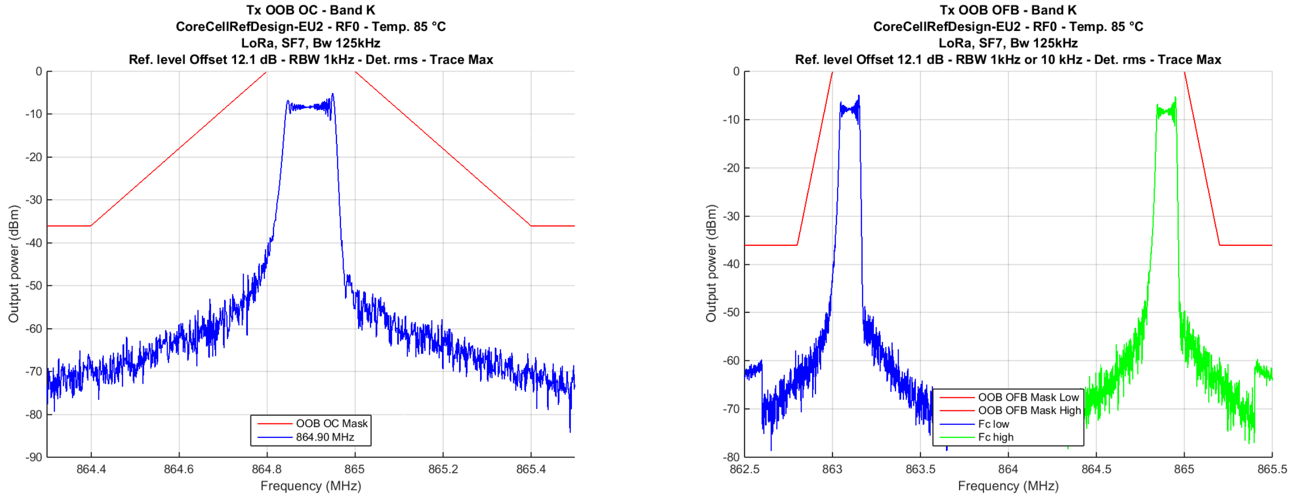


(b) Operational Frequency band

Figure 5.22: Tx Out Of Band Emissions, Band R, 14 dBm, FSK 50 kbps, Fdev 25 kHz

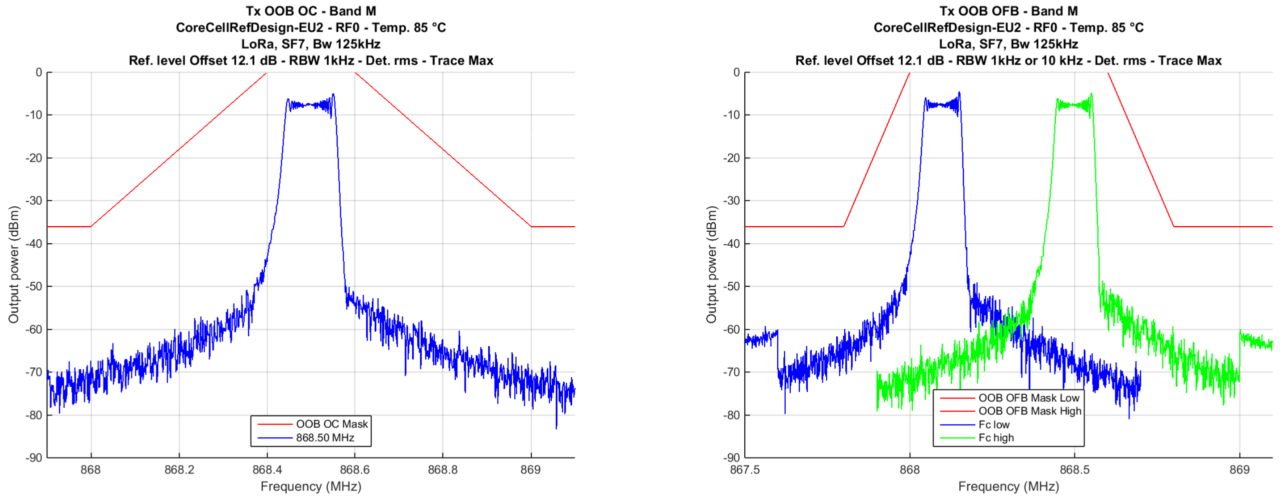
5.5 High temperature: +85°C

5.5.1 LoRa 125 kHz



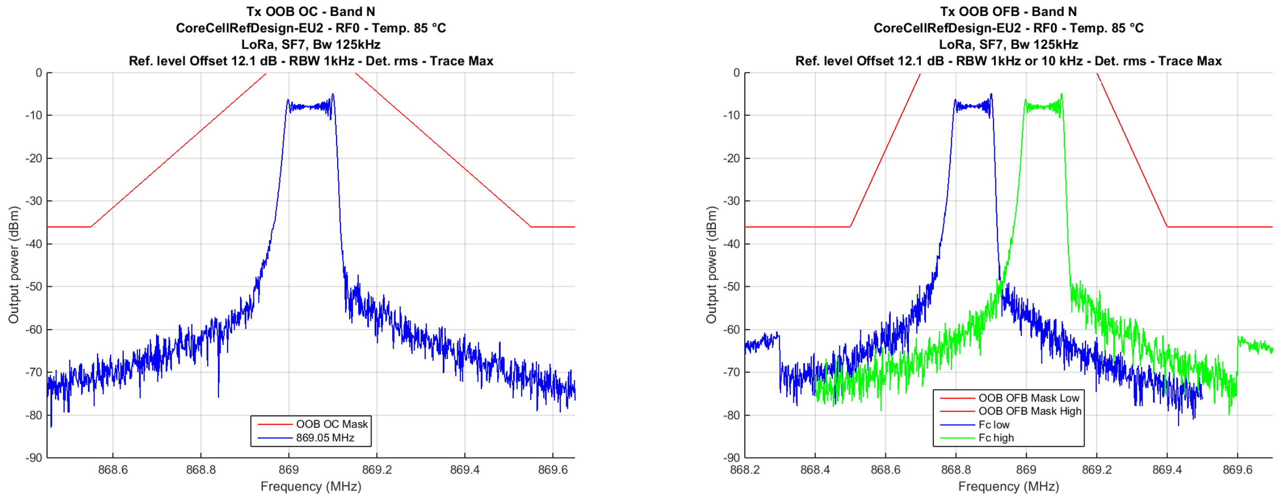
(a) Operating channel (b) Operational Frequency band

Figure 5.23: Tx Out Of Band Emissions, Band K, 14 dBm, LoRa SF7, Bw 125 kHz



(a) Operating channel (b) Operational Frequency band

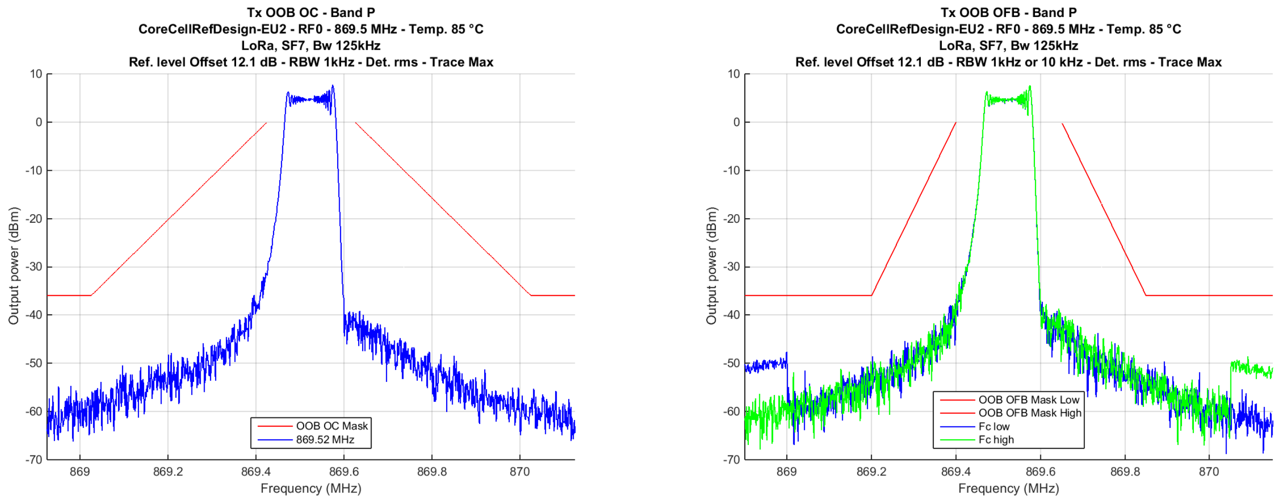
Figure 5.24: Tx Out Of Band Emissions, Band M, 14 dBm, LoRa SF7, Bw 125 kHz



(a) Operating channel

(b) Operational Frequency band

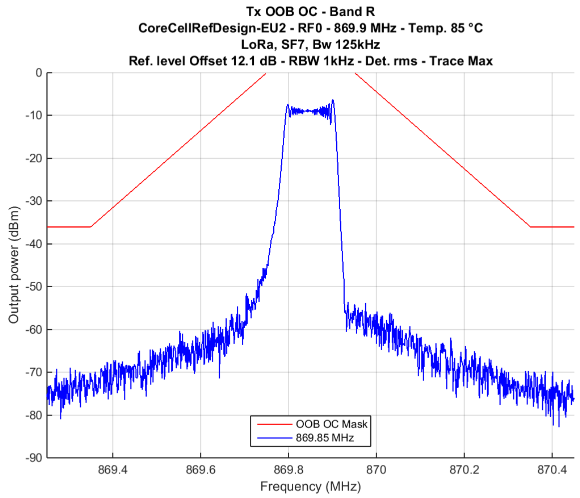
Figure 5.25: Tx Out Of Band Emissions, Band N, 14 dBm, LoRa SF7, Bw 125 kHz



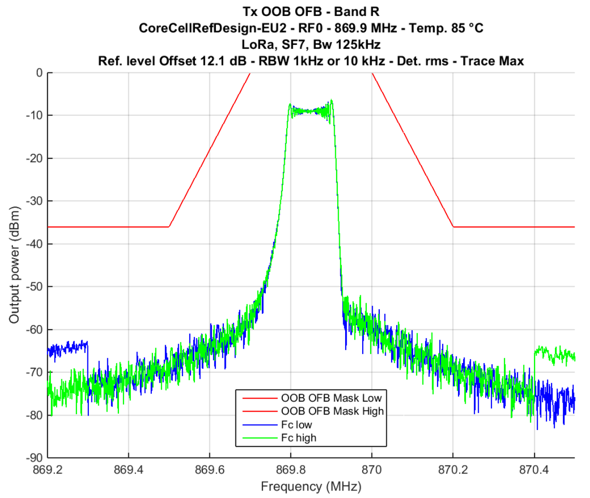
(a) Operating channel

(b) Operational Frequency band

Figure 5.26: Tx Out Of Band Emissions, Band P, 27 dBm, LoRa SF7, Bw 125 kHz



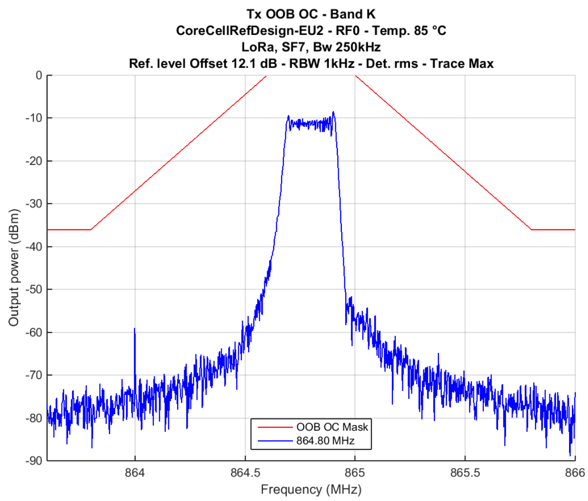
(a) Operating channel



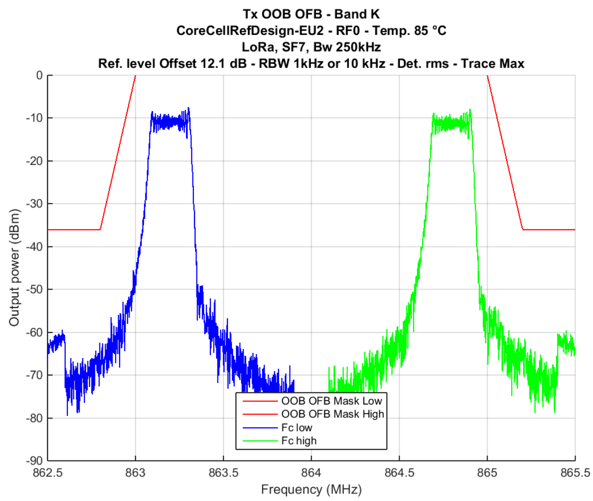
(b) Operational Frequency band

Figure 5.27: Tx Out Of Band Emissions, Band R, 14 dBm, LoRa SF7, Bw 125 kHz

5.5.2 LoRa 250 kHz

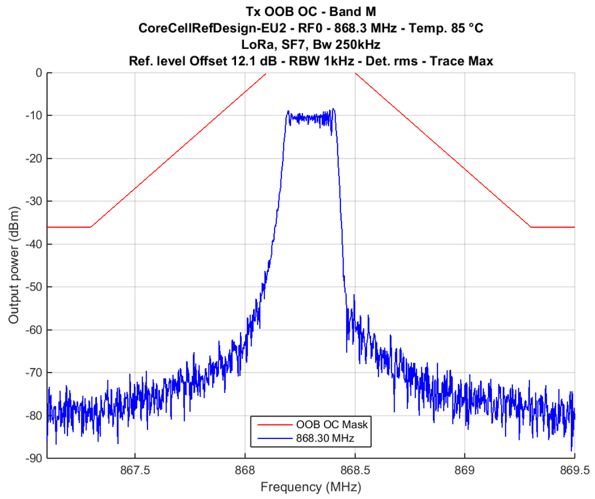


(a) Operating channel

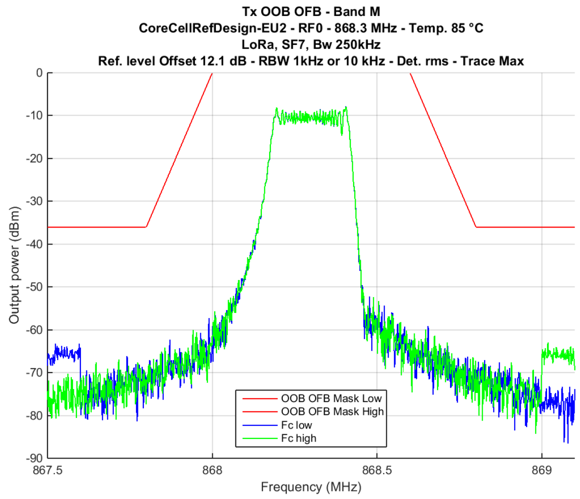


(b) Operational Frequency band

Figure 5.28: Tx Out Of Band Emissions, Band K, 14 dBm, LoRa SF7, Bw 250 kHz

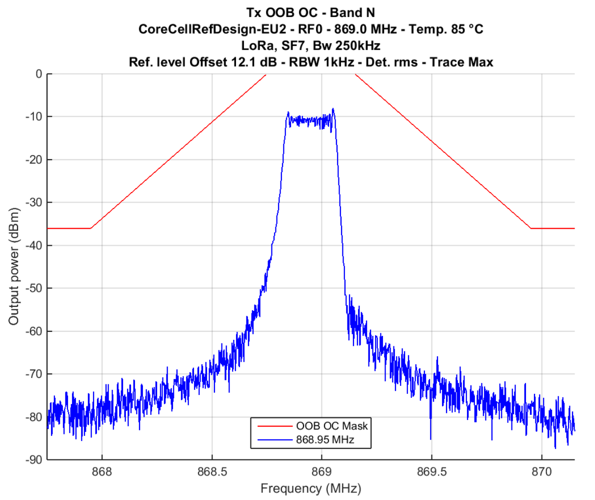


(a) Operating channel

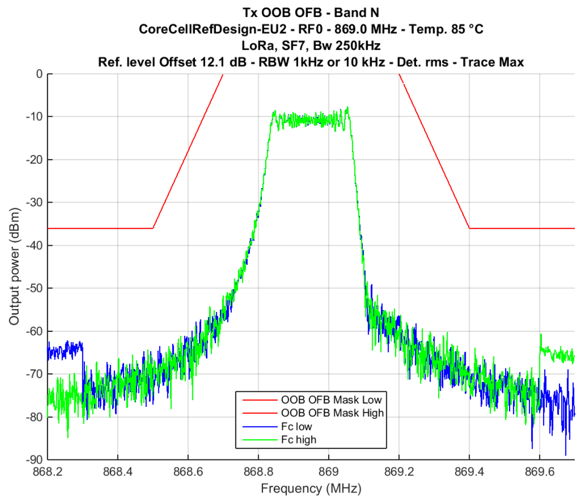


(b) Operational Frequency band

Figure 5.29: Tx Out Of Band Emissions, Band M, 14 dBm, LoRa SF7, Bw 250 kHz

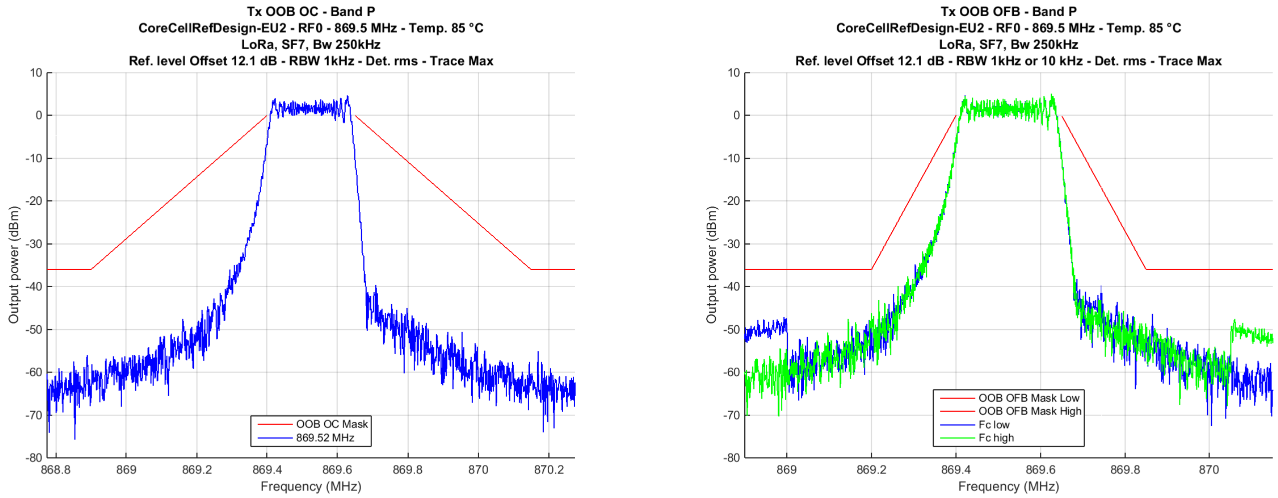


(a) Operating channel



(b) Operational Frequency band

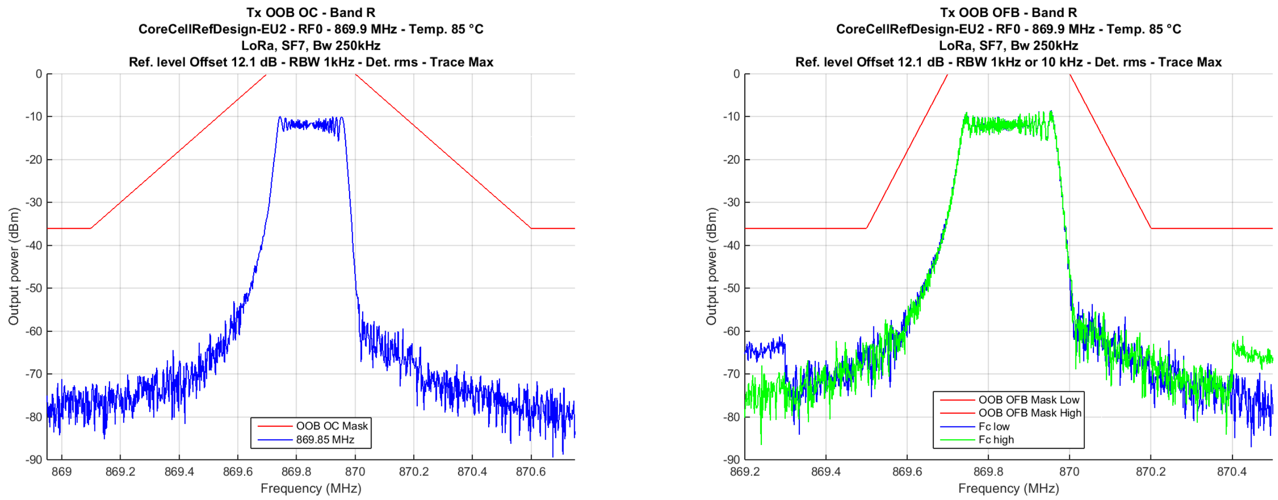
Figure 5.30: Tx Out Of Band Emissions, Band N, 14 dBm, LoRa SF7, Bw 250 kHz



(a) Operating channel

(b) Operational Frequency band

Figure 5.31: Tx Out Of Band Emissions, Band P, 27 dBm, LoRa SF7, Bw 250 kHz

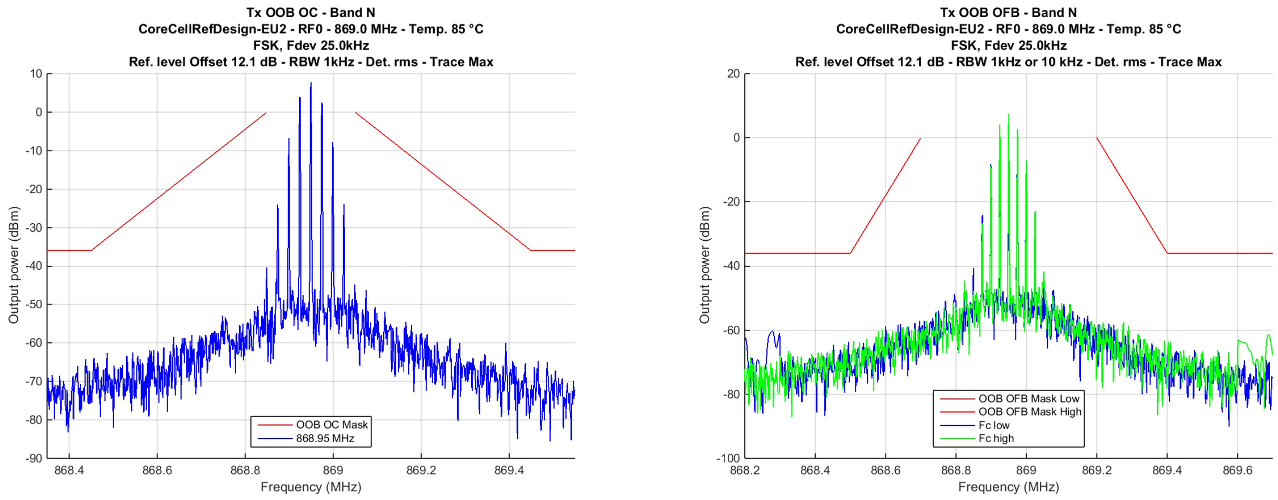


(a) Operating channel

(b) Operational Frequency band

Figure 5.32: Tx Out Of Band Emissions, Band R, 14 dBm, LoRa SF7, Bw 250 kHz

5.5.3 FSK 50 kbits



(a) Operating channel (b) Operational Frequency band

Figure 5.33: Tx Out Of Band Emissions, Band R, 14 dBm, FSK 50 kbps, Fdev 25 kHz

6 Transient power (ETSI)

6.1 Description

This test refers to the chapter 5.10 of the European regulation EN 300 220 v3.1.1 (document [1]). Transmitter transient power is power falling into frequencies other than the operating channel as a result of the transmitter being switched on and off.

This test evaluates the power amplifier ramp up / down man-aged by the AGC running on the MCU present in the SX1302.

6.2 LoRa 125 kHz

6.2.1 Band M

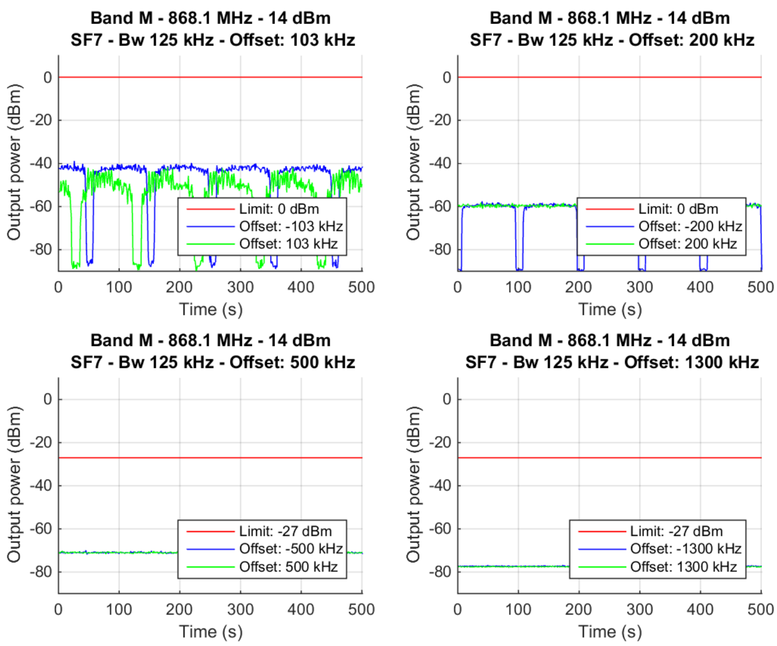


Figure 6.1: Transient power (ETSI), Band M, 868.1 MHz, 14 dBm, LoRa SF7, Bw 125 kHz

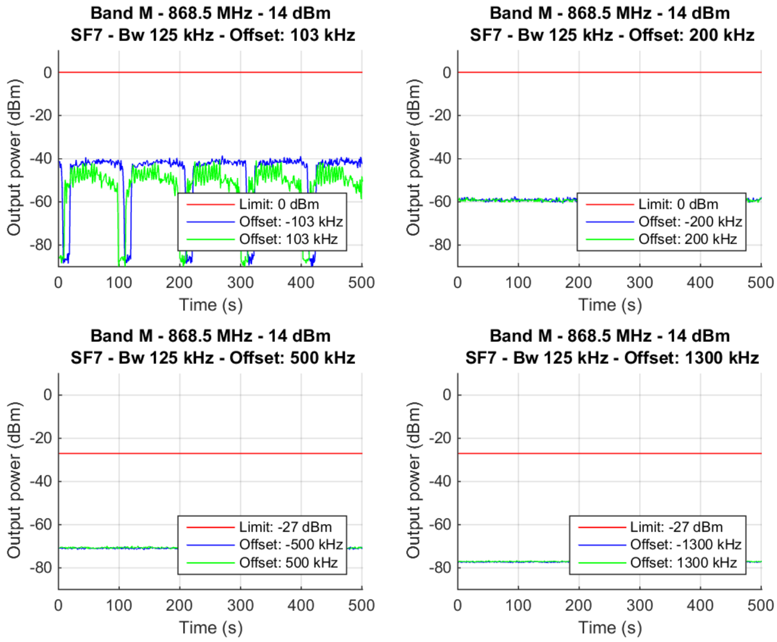


Figure 6.2: Transient power (ETSI), Band M, 868.5 MHz, 14 dBm, LoRa SF7, Bw 125 kHz

6.2.2 Band P

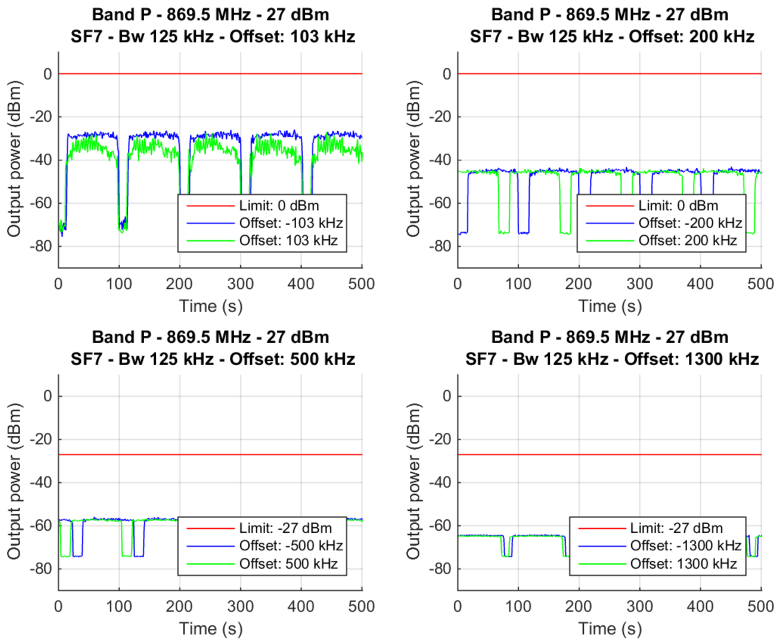


Figure 6.3: Transient power (ETSI), Band P, 869.525 MHz, 27 dBm, LoRa SF7, Bw 125 kHz

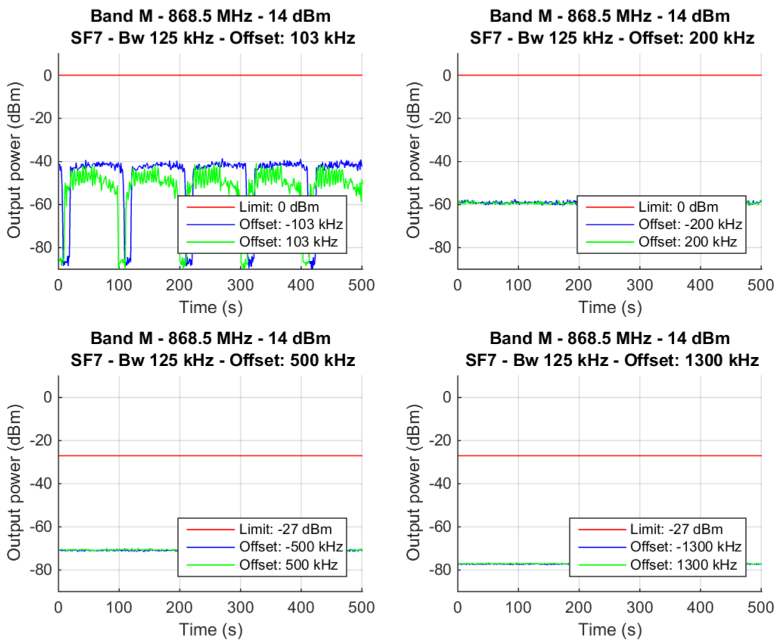


Figure 6.4: Transient power (ETSI), Band P, 869.525 MHz, 27 dBm, LoRa SF12, Bw 125 kHz

6.3 LoRa 250 kHz

6.3.1 Band M

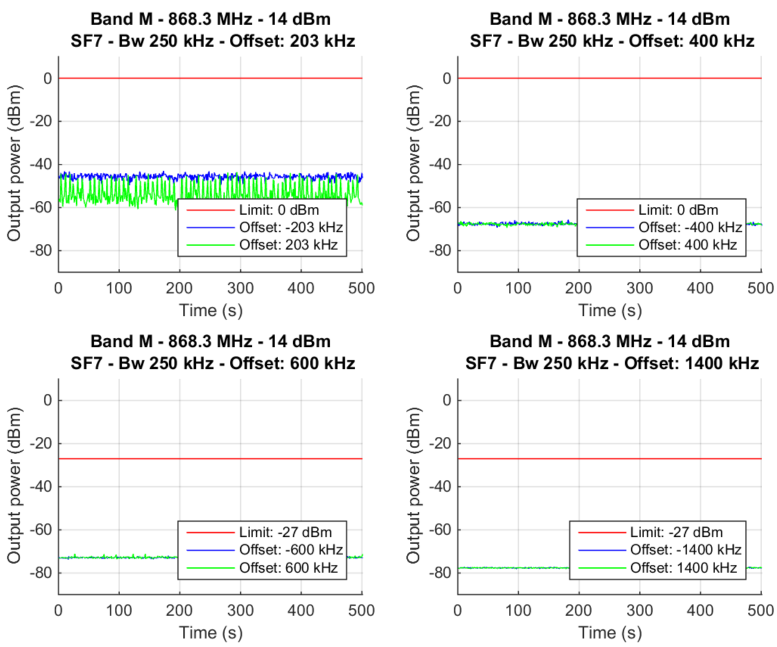


Figure 6.5: Transient power (ETSI), Band M, 868.3 MHz, 14 dBm, LoRa SF7, Bw 250 kHz

7 Spurious emission: Unwanted emissions in the spurious domain (ETSI)

7.1 Description

This measurement refers to the chapter **Unwanted emissions in the spurious domain** of the ETSI regulation (see document [1]). Spurious emissions are unwanted emissions in the spurious domain at frequencies other than those of the Operating Channel and its Out Of Band Domain (see section 5.1). The relevant spurious domain is shown in figure 7.1.

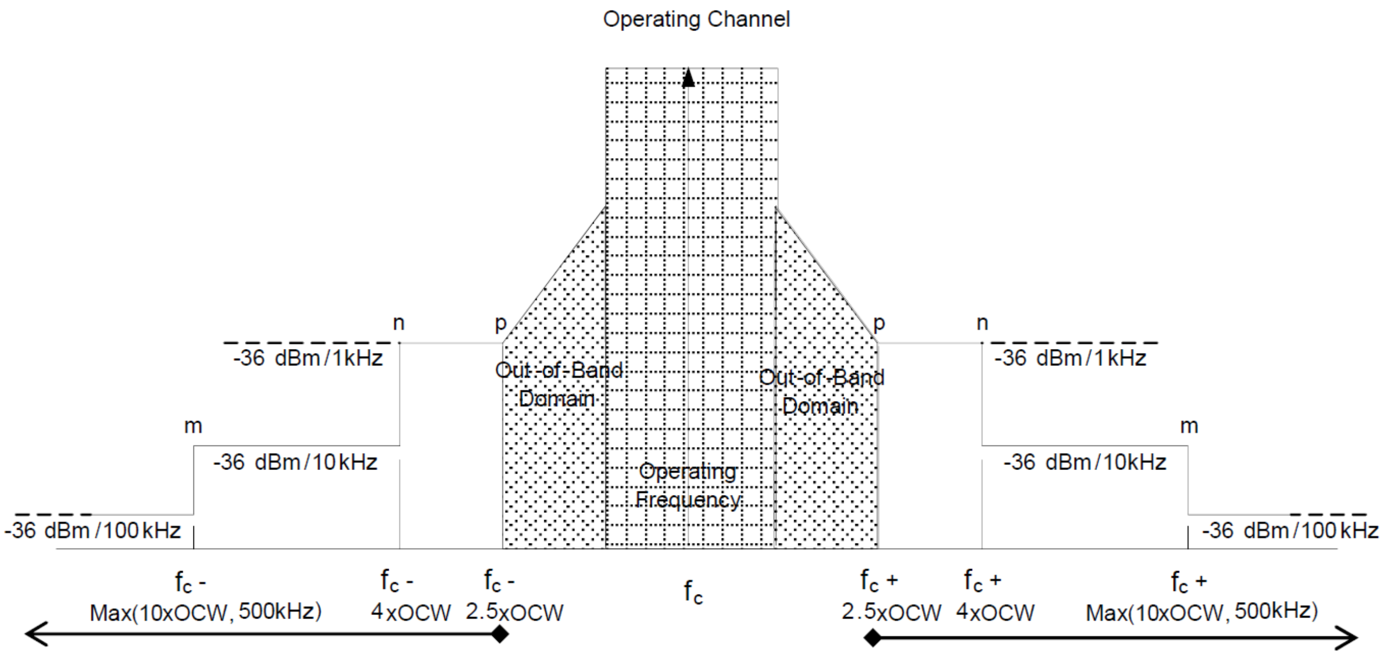


Figure 7.1: Spectrum Mask for Unwanted Emissions in the Spurious Domain

The power of any unwanted emission in the spurious domain shall not exceed the values given in the table 7.1.

State	Frequency		
	47 MHz to 74 MHz 87.5 MHz to 118 MHz 174 MHz to 230 MHz 470 MHz to 790 MHz	Other frequencies below 1 000 MHz	Frequencies above 1 000 MHz
TX mode	-54 dBm	-36 dBm	-30 dBm
RX and all other modes	-57 dBm	-57 dBm	-47 dBm

Table 7.1: Spurious domain emission limits

7.2 LoRa 125 kHz

7.2.1 Band K

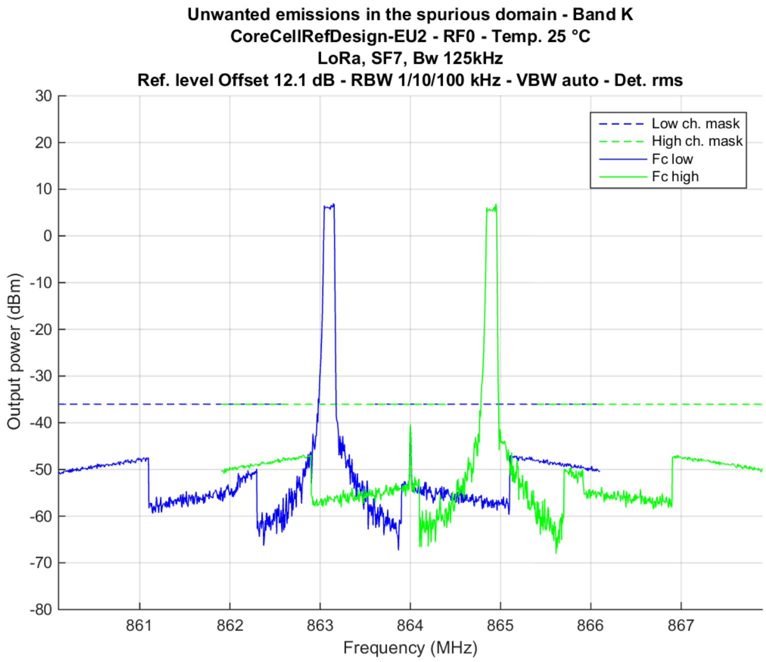
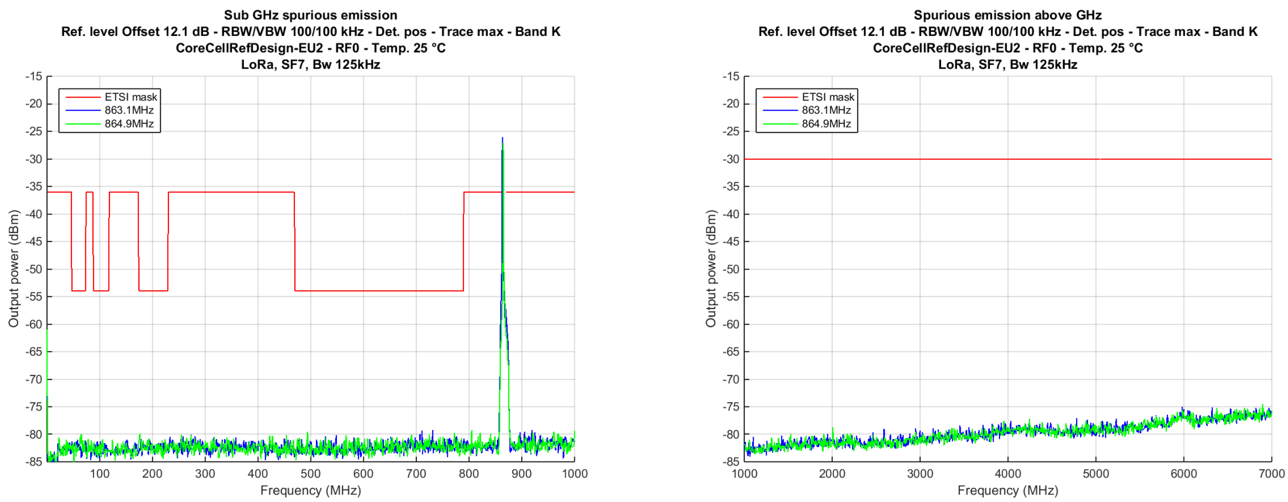


Figure 7.2: Unwanted emissions in the spurious domain, Band K, 14 dBm, LoRa SF7, Bw 125 kHz



(a) Sub GHz

(b) Above GHz

Figure 7.3: Spurious measurement, Band K, 14 dBm, LoRa SF7, 125 kHz

7.2.2 Band M

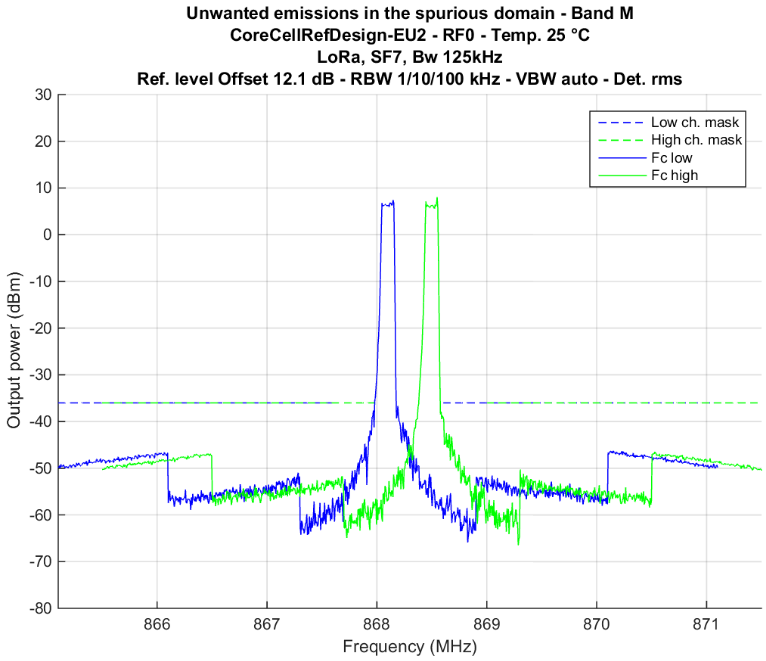
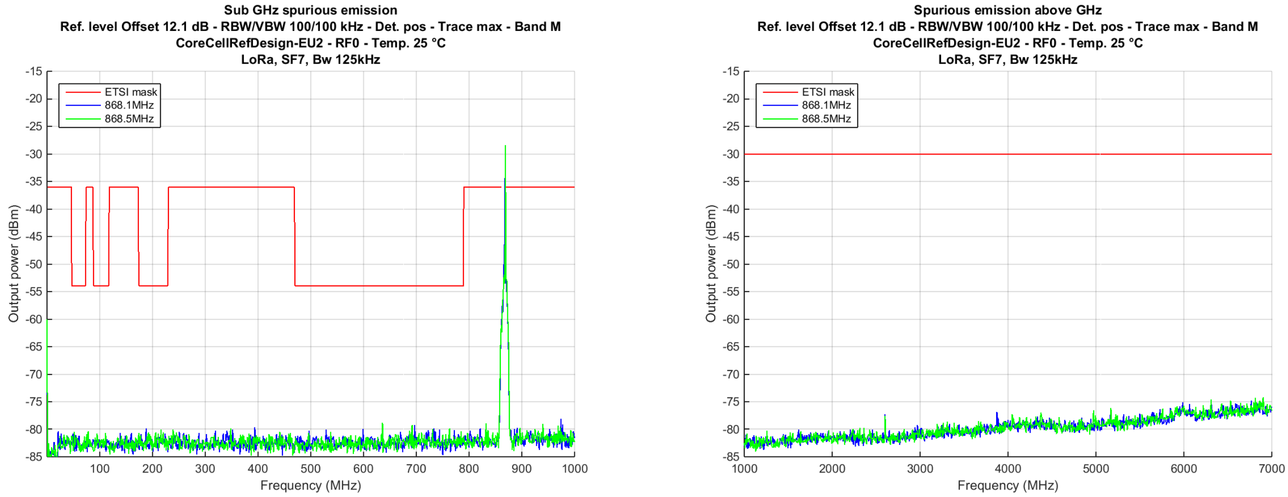


Figure 7.4: Unwanted emissions in the spurious domain, Band M, 14 dBm, LoRa SF7, 125 kHz



(a) Sub GHz

(b) Above GHz

Figure 7.5: Spurious measurement, Band M, 14 dBm, LoRa SF7, 125 kHz

7.2.3 Band P

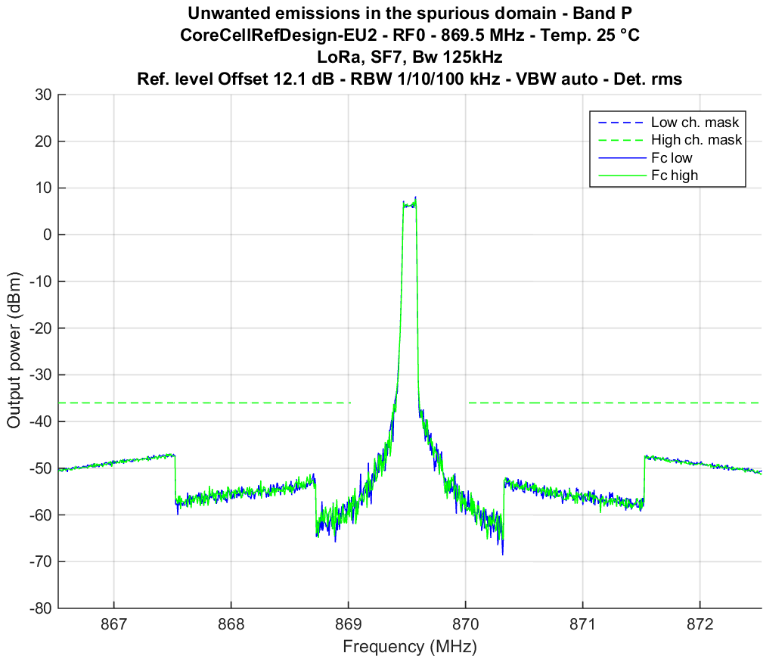
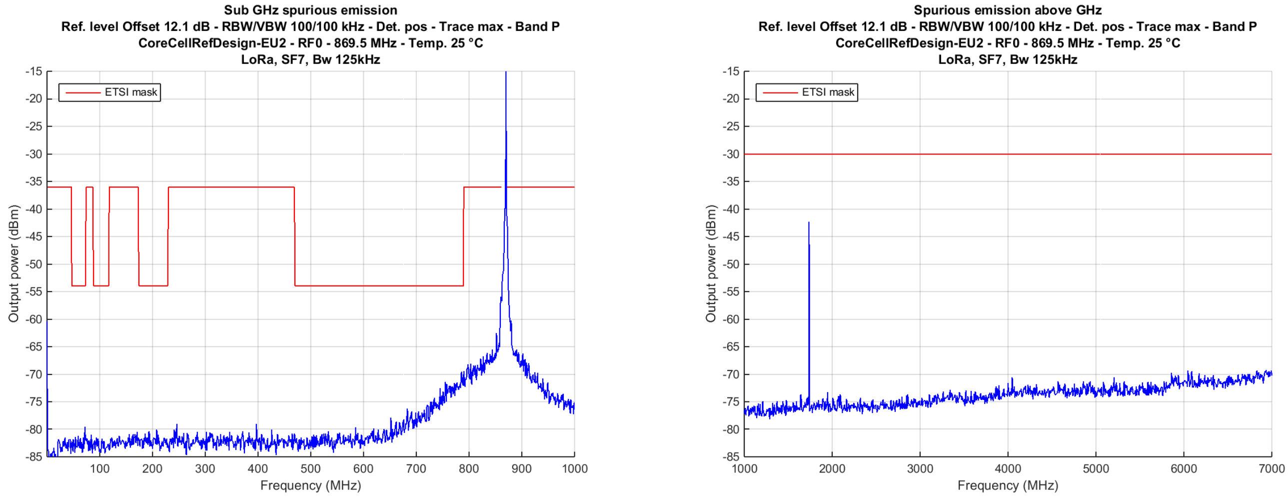


Figure 7.6: Unwanted emissions in the spurious domain, Band P, 27 dBm, LoRa SF7, 125 kHz



(a) Sub GHz

(b) Above GHz

Figure 7.7: Spurious measurement, Band P, 27 dBm, LoRa SF7, 125 kHz

7.2.4 Band R

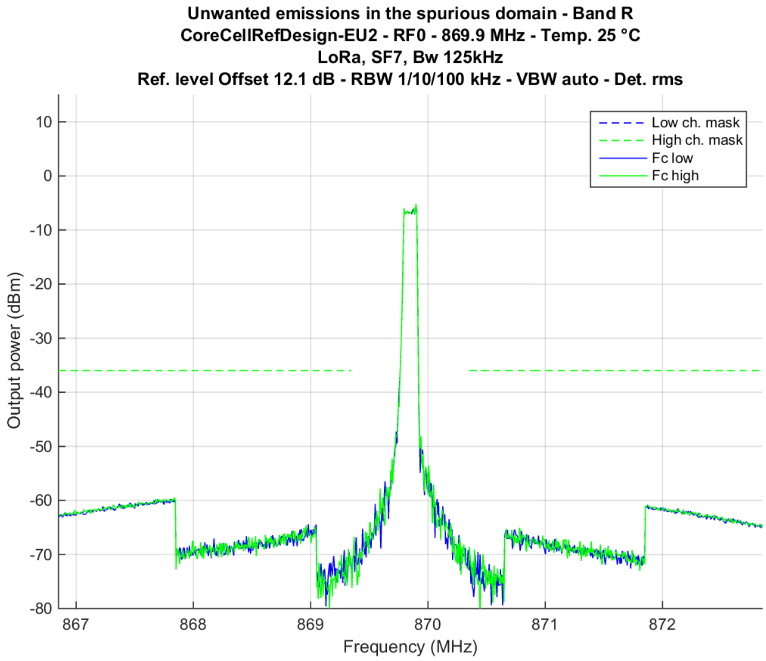


Figure 7.8: Unwanted emissions in the spurious domain, Band R, 14 dBm, LoRa SF7, 125 kHz

7.3 LoRa 250 kHz

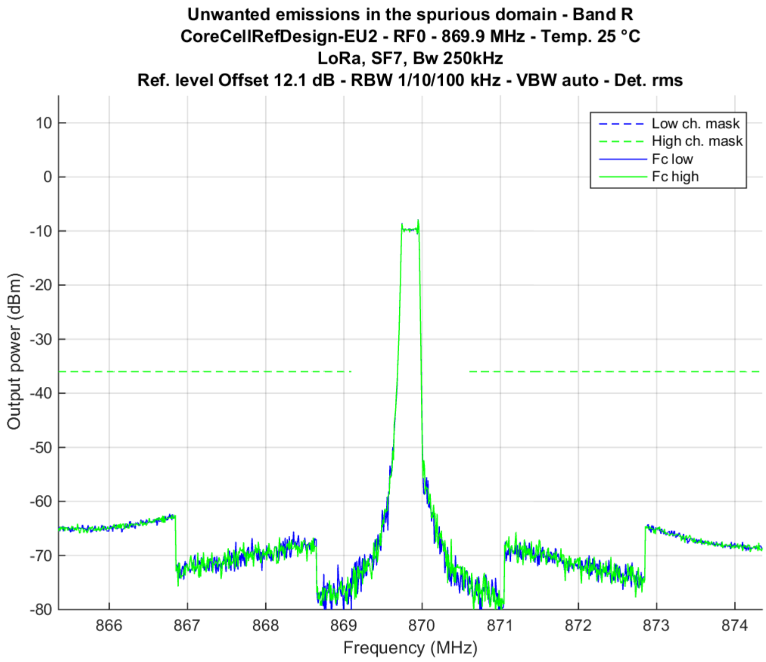


Figure 7.9: Unwanted emissions in the spurious domain, Band R, 14 dBm, LoRa SF7, 250 kHz

7.4 FSK 50 kbits

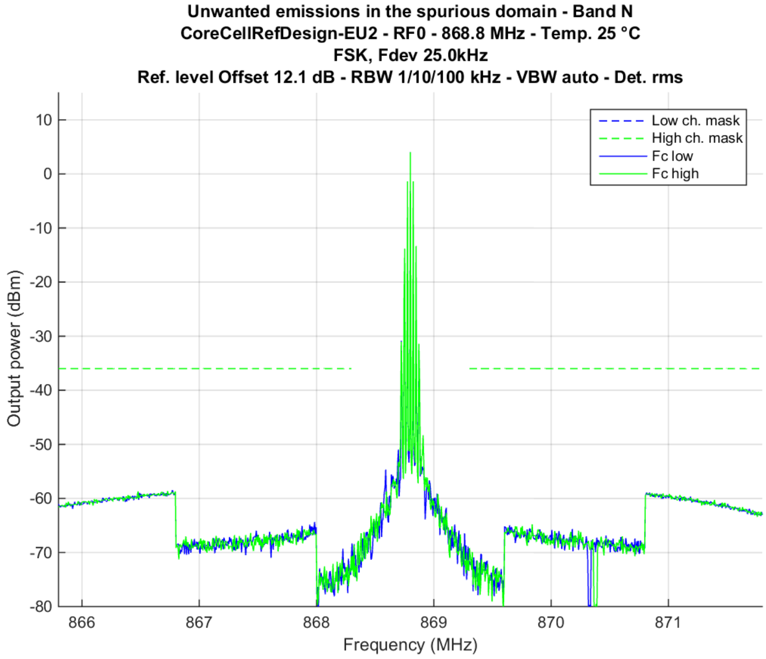


Figure 7.10: Unwanted emissions in the spurious domain, Band N, 14 dBm, FSK 50 kbits, Fdev 25 kHz

Part III

Receiver

8 Sensitivity level and PER

8.1 Description

This test determines the sensitivity level i.e. the minimum RF input power needed to demodulate the received packet. It is determined for a PER of 10%. It also verifies the PER remains null for input power above the sensitivity level i.e. no saturation occurs.

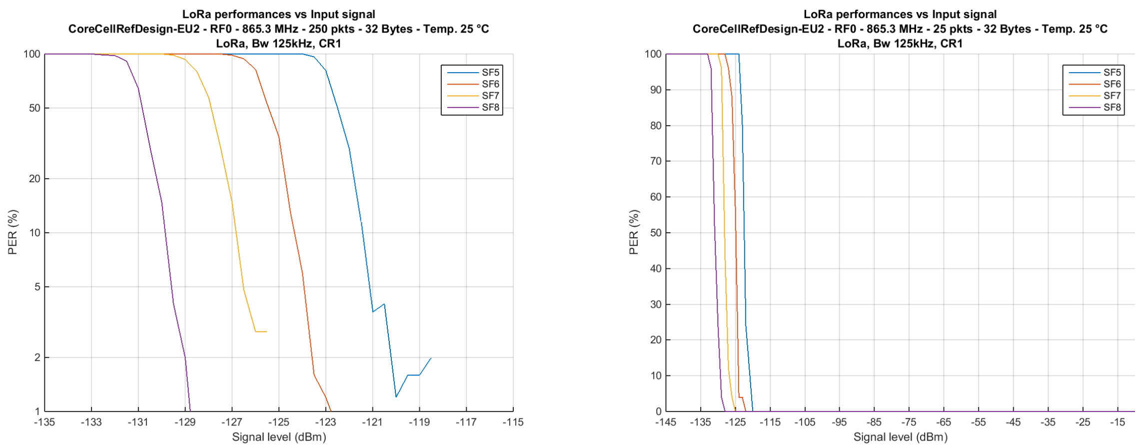
Note: The requirement on the minimum LoRa sensitivity allows to comply every time the Rx sensitivity level requirement of the European regulation describes in the section 5.14 of the document [1]. Indeed, the formula mentioned in the table 32 of document [1] gives a sensitivity level of 10.log10(RxBw) – 117 dBm i.e. -96 dBm. This is about 30 dB worse than the LoRa sensitivity level for a spreading factor of 7.

8.2 Setup

The sensitivity measurement setup is shown in figure 2.3. Only one signal generator is used here, the output of the second one is OFF. It generates LoRa packets toward the DUT for several output powers and frequencies. The effect of impedance mismatch is mitigated by the use of attenuators at the power splitter inputs and along the switch matrix.

The **packet forwarder** software running on the RPI3 pulls data from the Corecell ref. design by SPI bus and send them to the computer through UDP protocol.

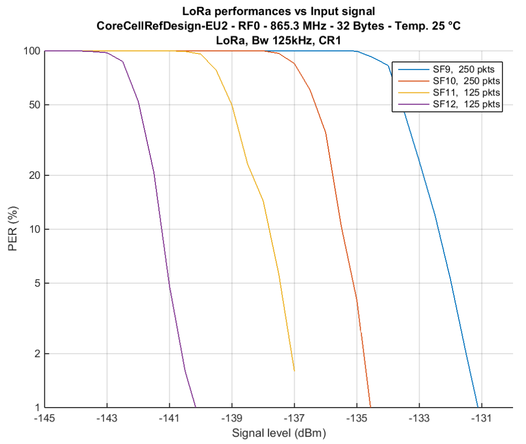
8.3 MultiSF modem versus Spreading Factor



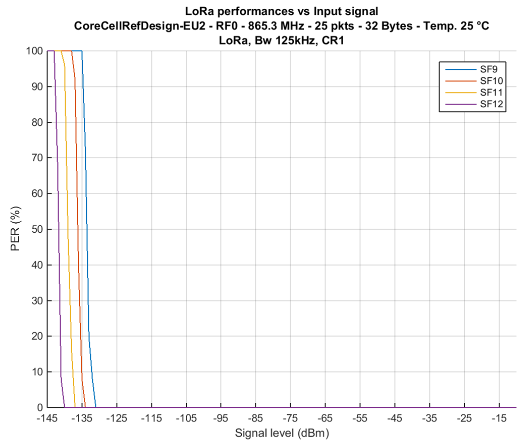
(a) Sensitivity level

(b) High level

Figure 8.1: Sensitivity level and PER, MultiSF 125 kHz modem vs SF (5 to 8), 865.3 MHz



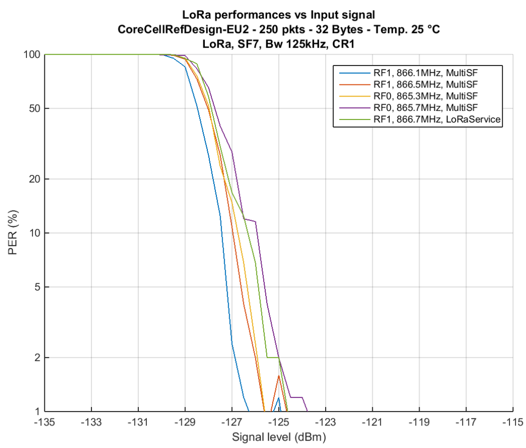
(a) Sensitivity level



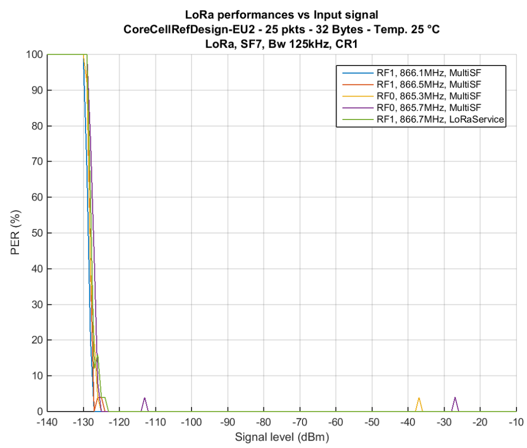
(b) High level

Figure 8.2: Sensitivity level and PER, MultiSF 125 kHz modem vs SF (9 to 12), 865.3 MHz

8.4 MultiSF / SingleSF modems versus channels



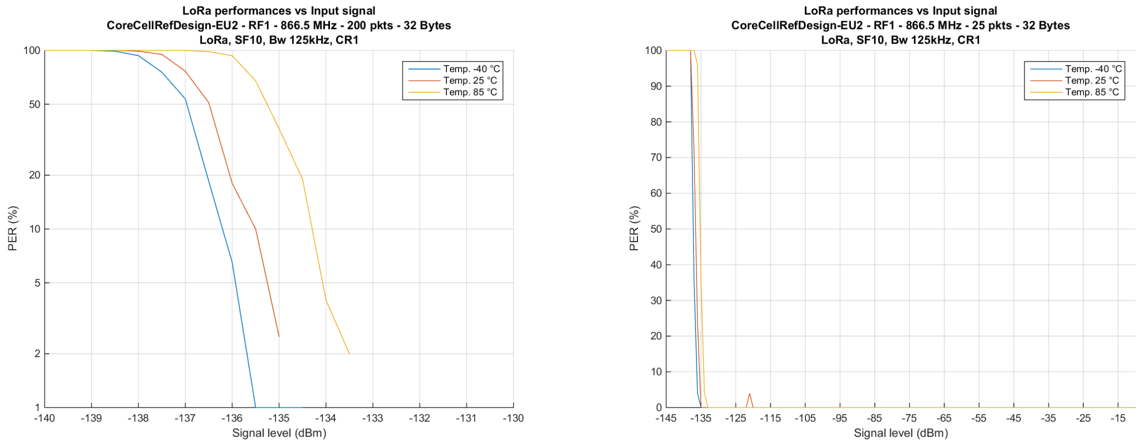
(a) Sensitivity level



(b) High level

Figure 8.3: Sensitivity level and PER, MultiSF / SingleSF modems versus channels, SF7, Bw 125 kHz

8.5 MultiSF modem versus temperature

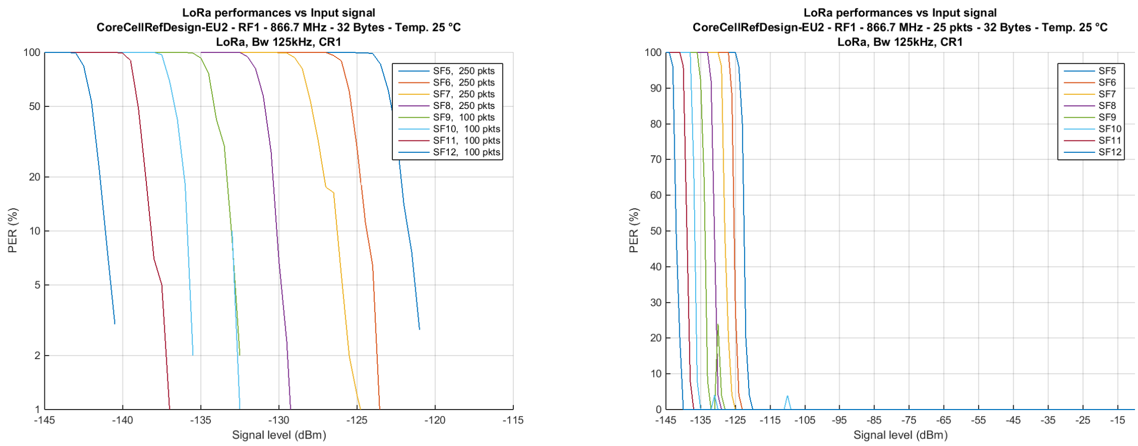


(a) Sensitivity level

(b) High level

Figure 8.4: Sensitivity level and PER, MultiSF modem versus temperature, SF10, Bw 125 kHz

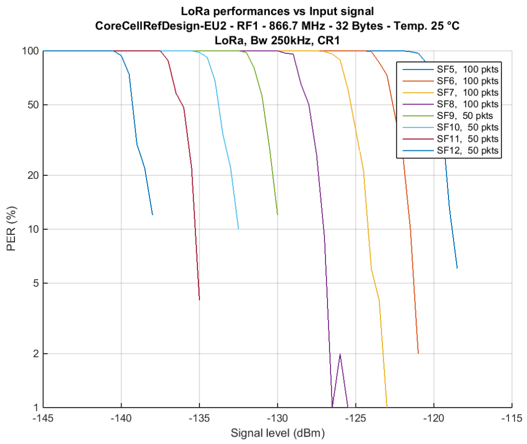
8.6 SingleSF modem vs Spreading factor



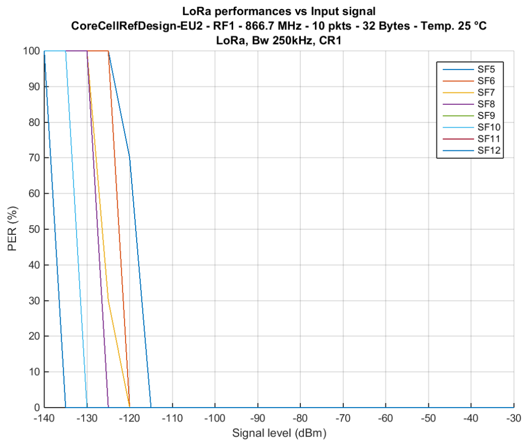
(a) Sensitivity level

(b) High level

Figure 8.5: Sensitivity level and PER, SingleSF modem vs SF, 866.7 MHz, Bw 125 kHz



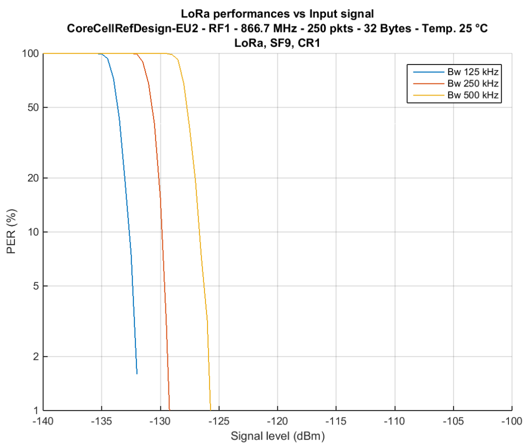
(a) Sensitivity level



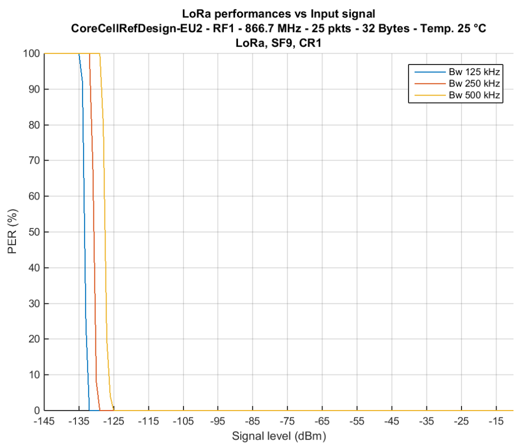
(b) High level

Figure 8.6: Sensitivity level and PER, SingleSF modem vs SF, 866.7 MHz, Bw 250 kHz

8.7 SingleSF modem vs Bandwidth



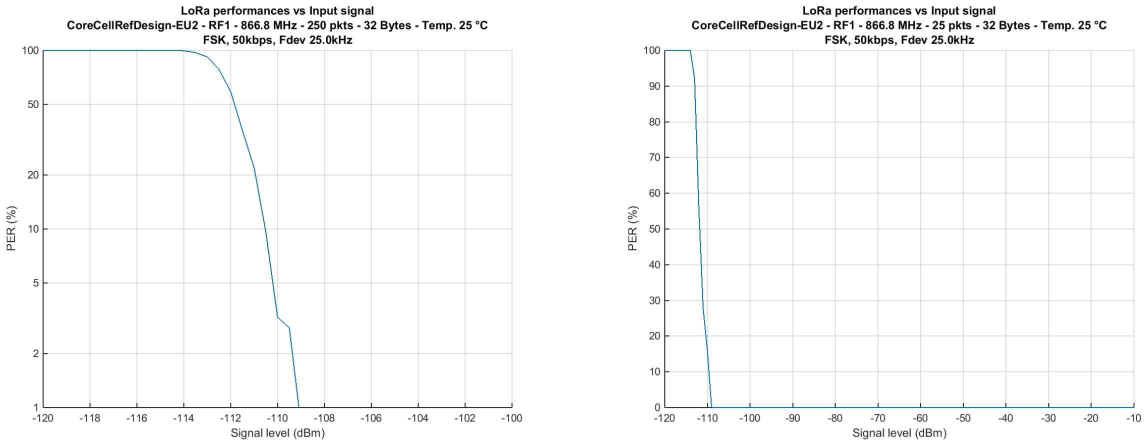
(a) Sensitivity level



(b) High level

Figure 8.7: Sensitivity level and PER, SingleSF modem vs bandwidth, 866.7 MHz, SF9

8.8 FSK modem



(a) Sensitivity level

(b) High level

Figure 8.8: Sensitivity level and PER, FSK modem, RF1, 866.8 MHz

9 RSSI

9.1 Description

The LoRa modems returns two indicators of the received signal level: RSSI Channel and Signal:

- RSSI Channel: This indicator represents the power in the channel bandwidth, taken care the power of signal and the thermal noise. It concerns LoRa and FSK modulations.
- RSSI Signal: This indicator represents the LoRa signal only without taken care the thermal noise power. It only concerns the LoRa modulation; this indicator is not available for the FSK modulation.

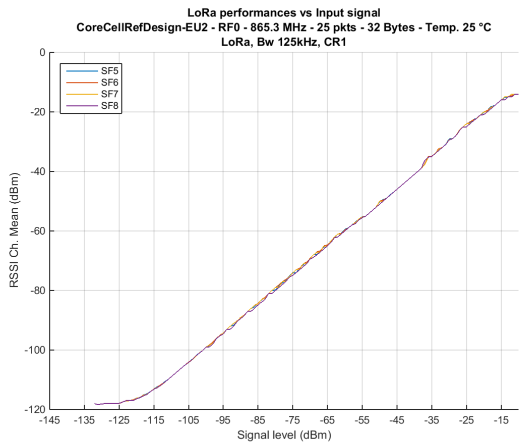
9.2 Setup

The RSSI measurement is performed simultaneously of the PER one. The setup is shown in figure 2.3. Only one signal generator is used here, the output of the second one is OFF. It generates LoRa packets toward the DUT for several output powers and frequencies. The effect of impedance mismatch is mitigated by the use of attenuators at the power splitter inputs and along the switch matrix.

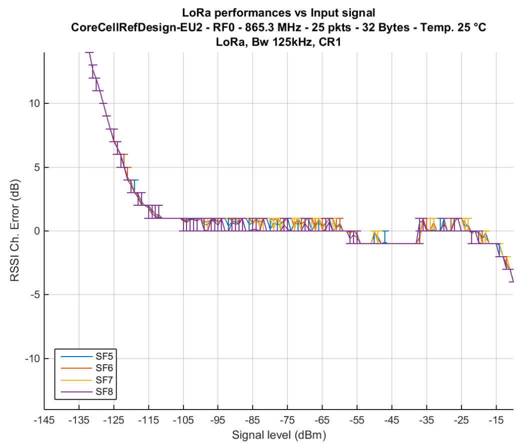
The **packet forwarder** software running on the RPI3 pulls data from the Corecell reference design by the SPI bus and send them to the computer through UDP protocol.

9.3 MultiSF modem versus Spreading Factor

9.3.1 RSSI channel

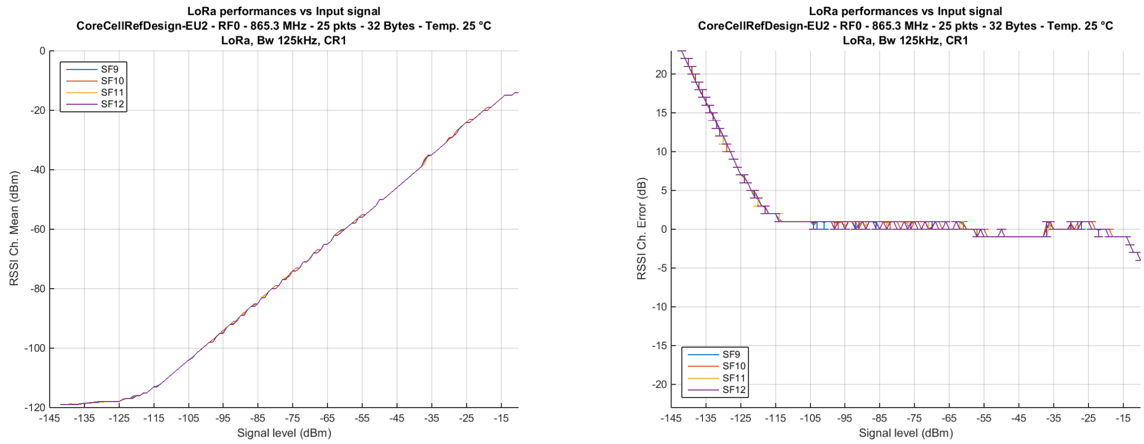


(a) RSSI Channel mean



(b) RSSI Channel error

Figure 9.1: RSSI Channel, MultiSF modems vs Spreading factors (5 to 8), 865.3 MHz

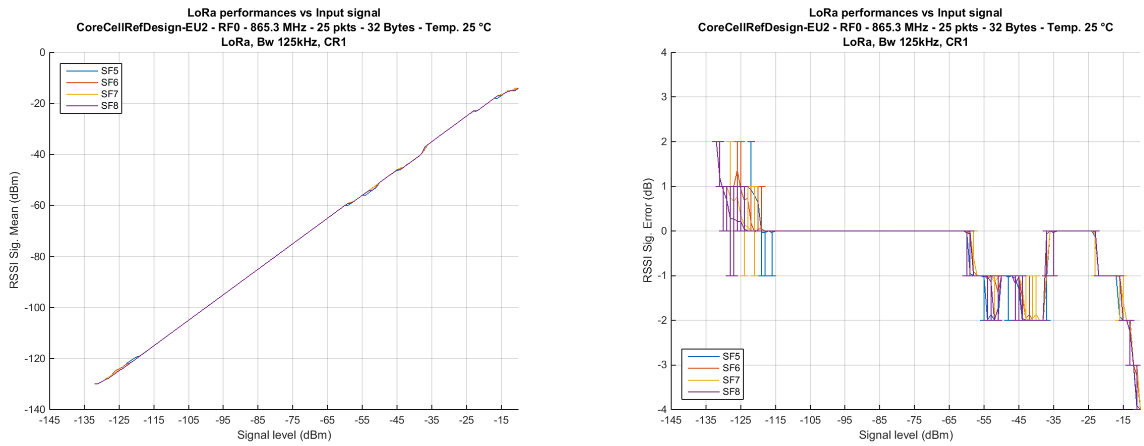


(a) RSSI Channel mean

(b) RSSI Channel error

Figure 9.2: RSSI Channel, MultiSF modems vs Spreading factors (9 to 12), 865.3 MHz

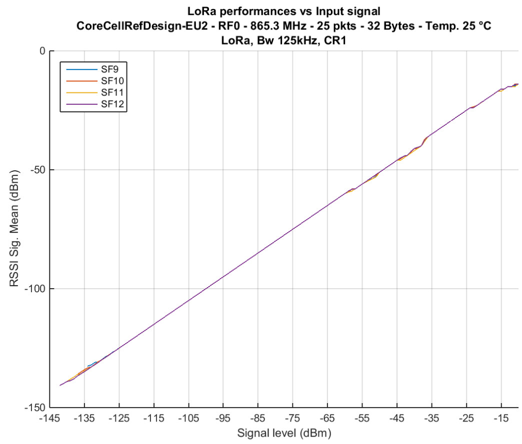
9.3.2 RSSI signal



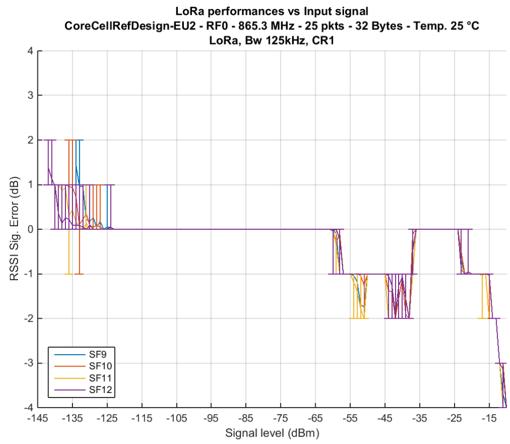
(a) RSSI Signal mean

(b) RSSI Signal error

Figure 9.3: RSSI Signal, MultiSF modem vs Spreading factors (5 to 8), 865.3 MHz



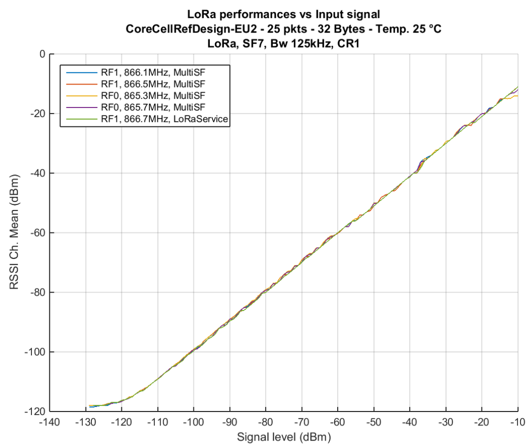
(a) RSSI Signal mean



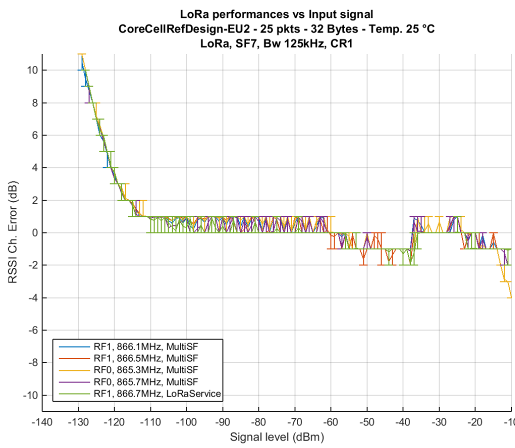
(b) RSSI Signal error

Figure 9.4: RSSI Signal, MultiSF modem vs Spreading factors (9 to 12), 865.3 MHz

9.4 MultiSF / SingleSF modems versus channels

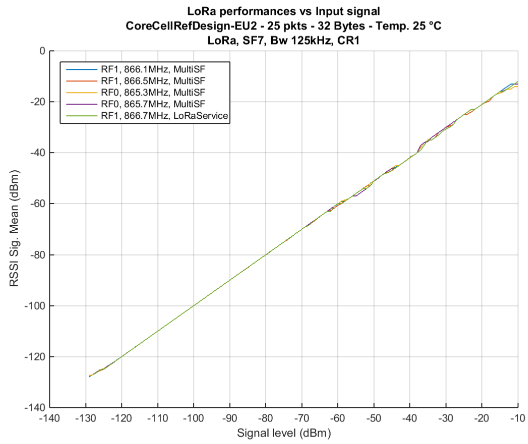


(a) RSSI Channel mean

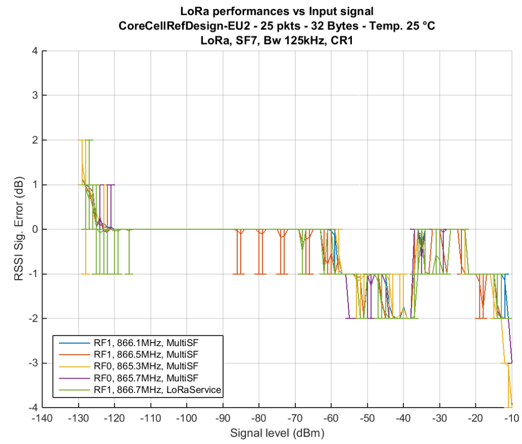


(b) RSSI Channel error

Figure 9.5: RSSI Channel, MultiSF and SingleSF modems versus channels, SF7



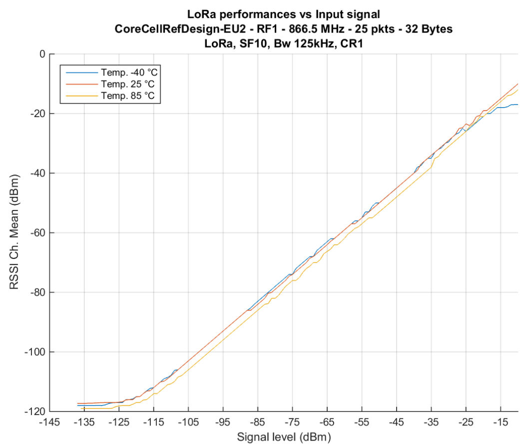
(a) RSSI Signal mean



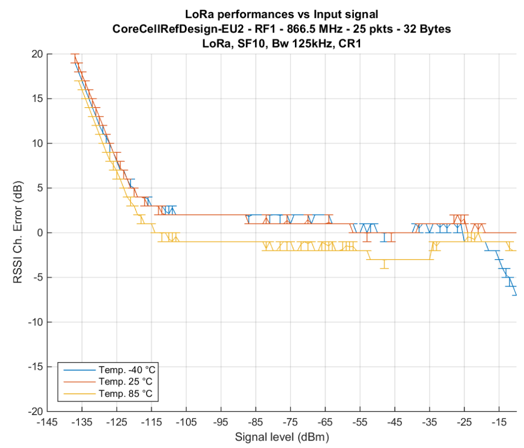
(b) RSSI Signal error

Figure 9.6: RSSI Signal, MultiSF and SingleSF modems versus channels, SF7

9.5 MultiSF modem versus temperature

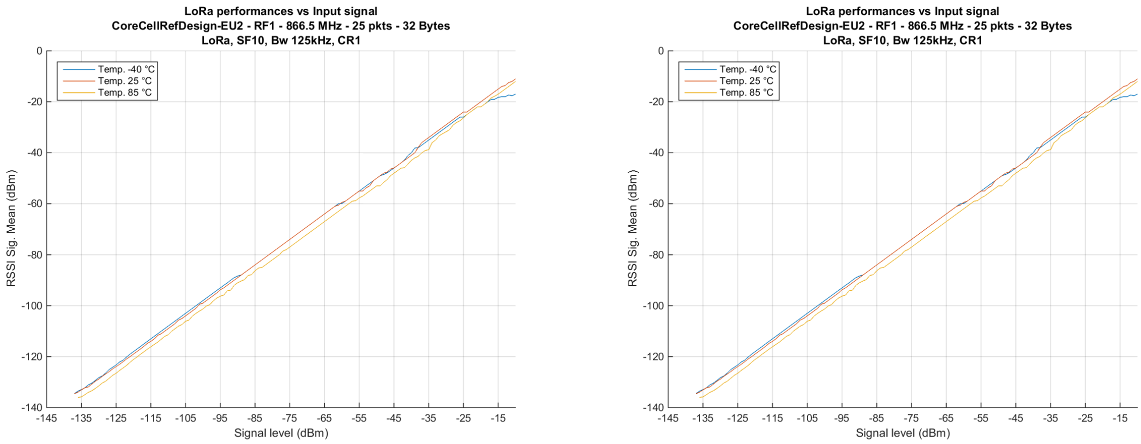


(a) RSSI Channel mean



(b) RSSI Channel error

Figure 9.7: RSSI Channel, MultiSF modem versus temperature, 866.5MHz, SF10, Bw 125 kHz



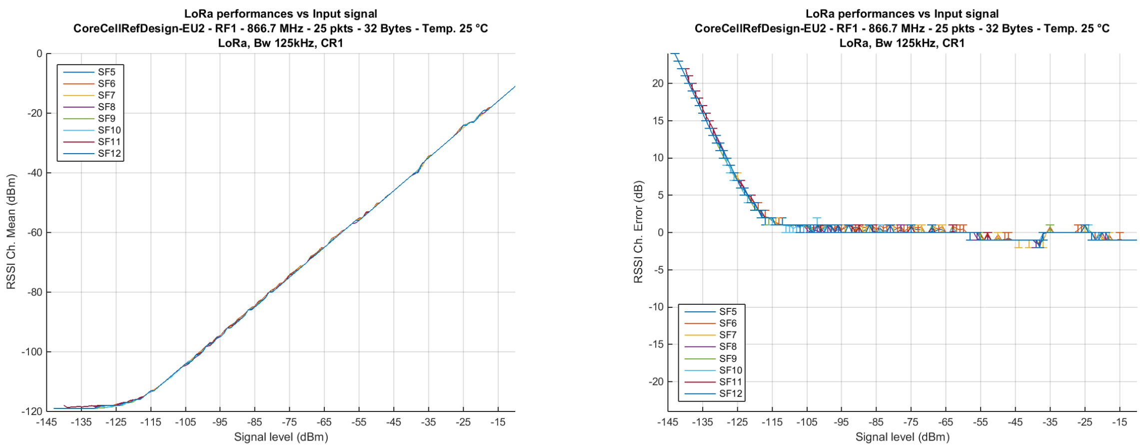
(a) RSSI Signal mean

(b) RSSI Signal error

Figure 9.8: RSSI Signal, MultiSF modem versus temperature, 866.5MHz, SF10, Bw 125 kHz

9.6 SingleSF modem versus Spreading Factor

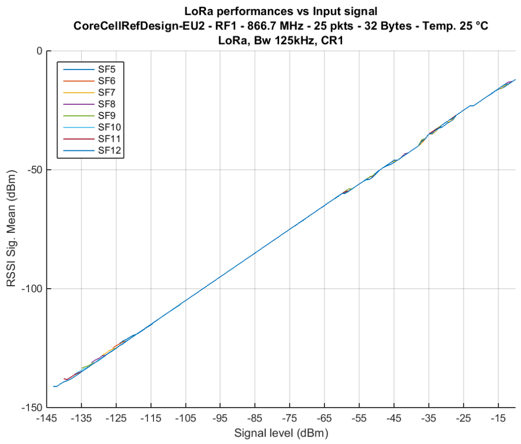
9.6.1 Bandwidth 125 kHz



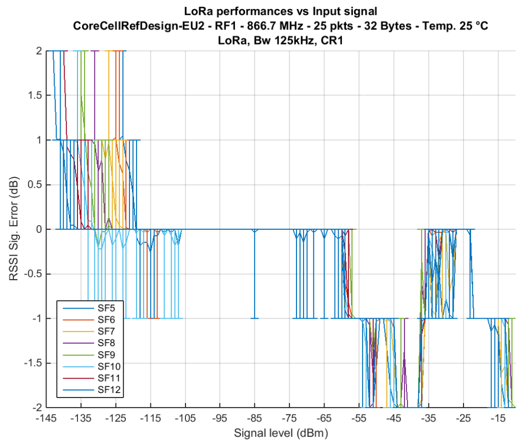
(a) RSSI Channel mean

(b) RSSI Channel error

Figure 9.9: RSSI Channel, SingleSF modem vs Spreading factors, 866.7 MHz, Bw 125 kHz



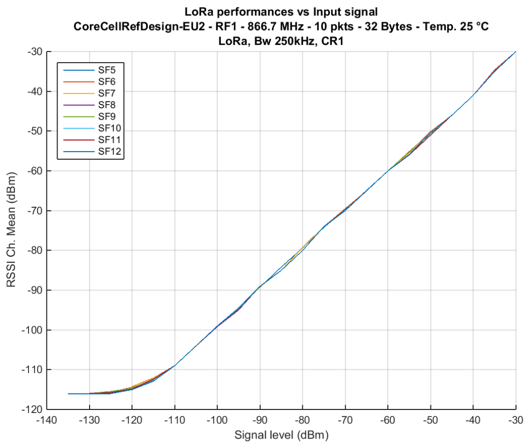
(a) RSSI Signal mean



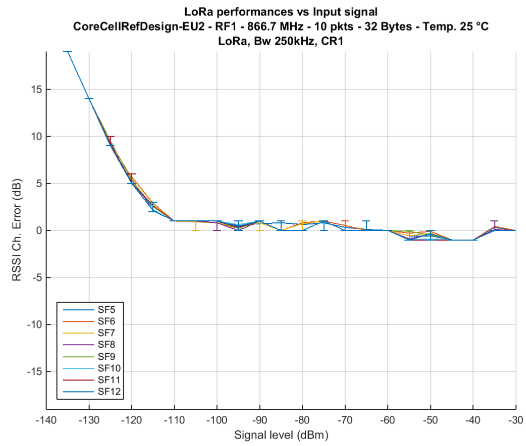
(b) RSSI Signal error

Figure 9.10: RSSI Signal, SingleSF modem vs Spreading factors, 866.7 MHz, Bw 125 kHz

9.6.2 Bandwidth 250 kHz

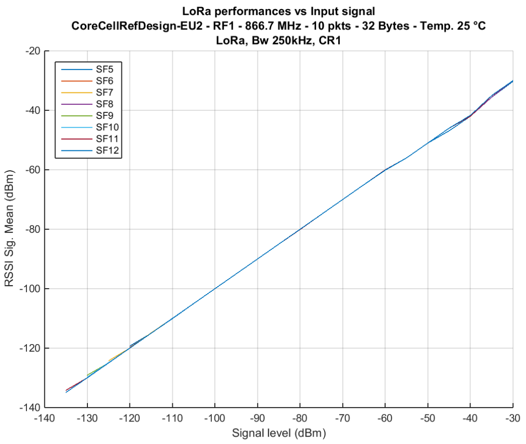


(a) RSSI Channel mean

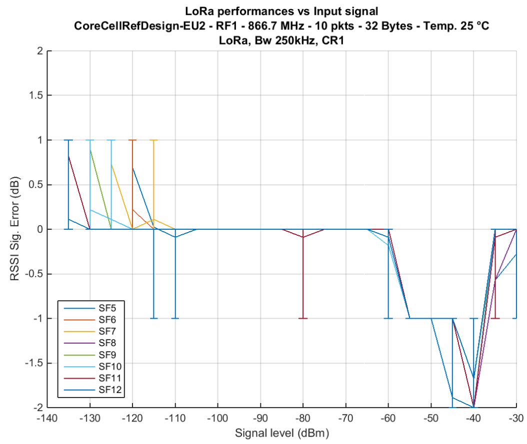


(b) RSSI Channel error

Figure 9.11: RSSI Channel, SingleSF modem vs Spreading factors, 866.7 MHz, Bw 250 kHz



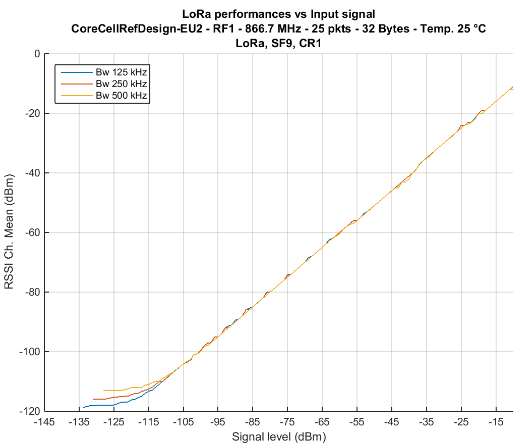
(a) RSSI Signal mean



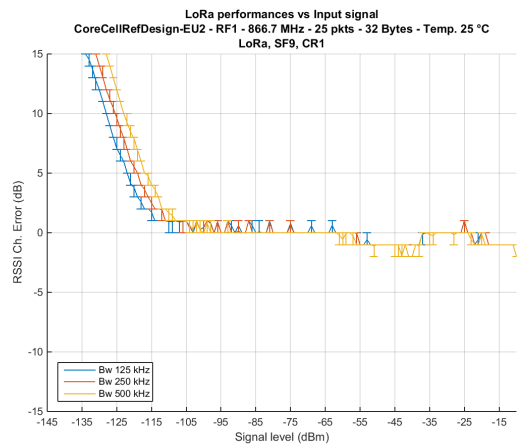
(b) RSSI Signal error

Figure 9.12: RSSI Signal, SingleSF modem vs Spreading factors, 866.7 MHz, Bw 250 kHz

9.7 SingleSF modem versus Bandwidth

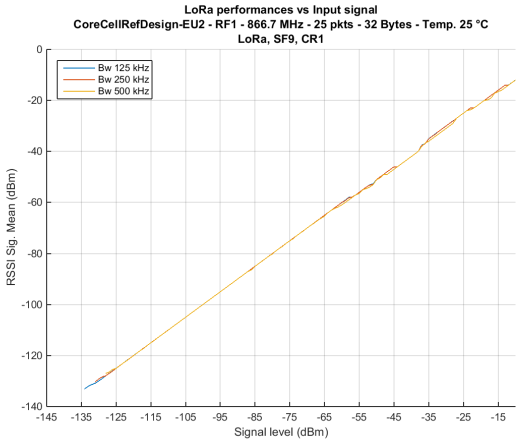


(a) RSSI Channel mean

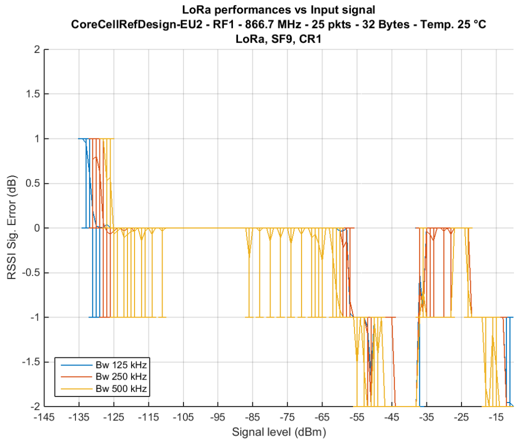


(b) RSSI Channel error

Figure 9.13: RSSI Channel, SingleSF modem vs Spreading factors, 866.7 MHz, Bw 125 kHz



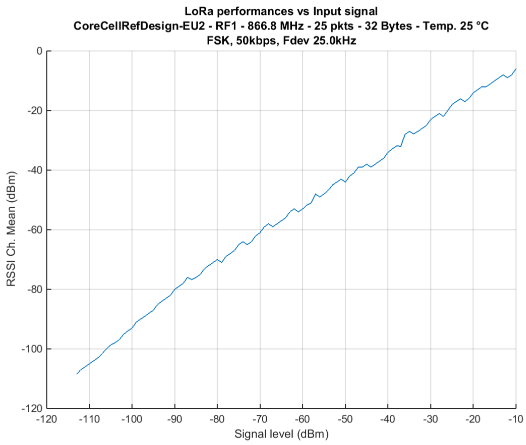
(a) RSSI Signal mean



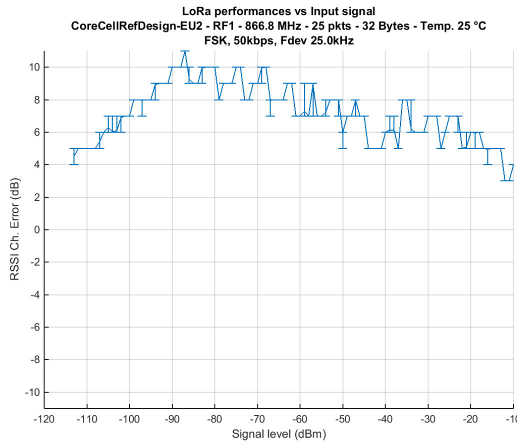
(b) RSSI Signal error

Figure 9.14: RSSI Signal, SingleSF modem vs Bandwidth, 866.7 MHz, SF9

9.8 FSK modem



(a) RSSI Channel mean



(b) RSSI Channel error

Figure 9.15: RSSI Channel, FSK modem, RF1, 866.8 MHz

→ **The linearization of the RSSI response will be improved in the next version of the HAL.**

10 SNR

10.1 Presentation

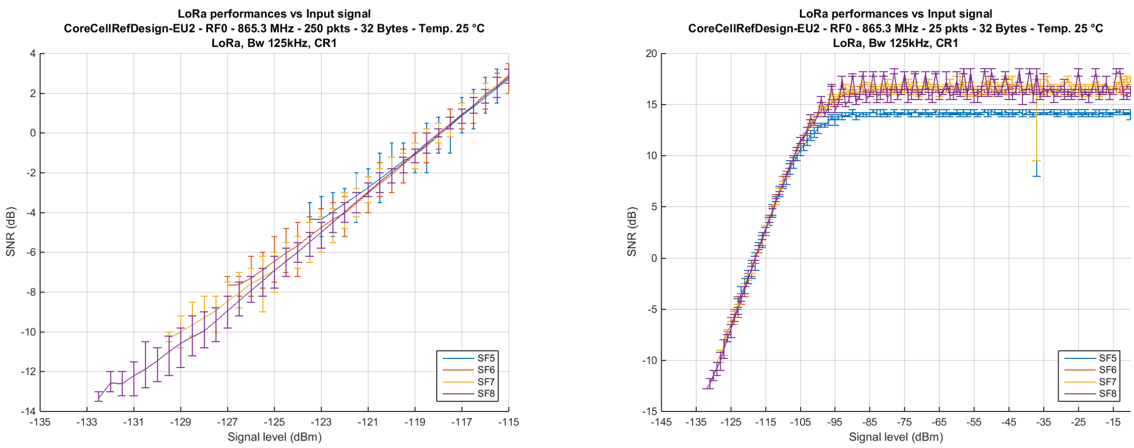
In conjunction with the RSSI value, the LoRa modem determines the Signal-To-Noise Ratio while receiving packets. This test verifies the accuracy of this indicators according the packet parameters (Spreading Factor, bandwidth, modem kind, payload length, ...)

10.2 Setup

The SNR is measured using the setup presented in figure 2.3 (Sensitivity, RSSI, ...). The DUT is connected to the SPDT A "common path".

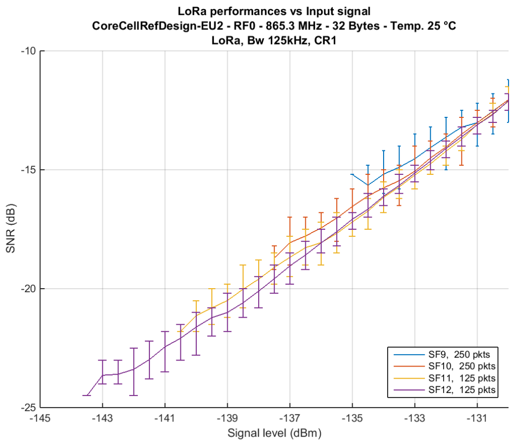
The SNR measurement presents the mean value computed with the linear values of measured samples then expressed in a logarithm way. For each measurement step, the top and bottom horizontal bars represent the maximum and the minimum SNR value. They should be close to the mean value.

10.3 MultiSF modems versus Spreading Factor

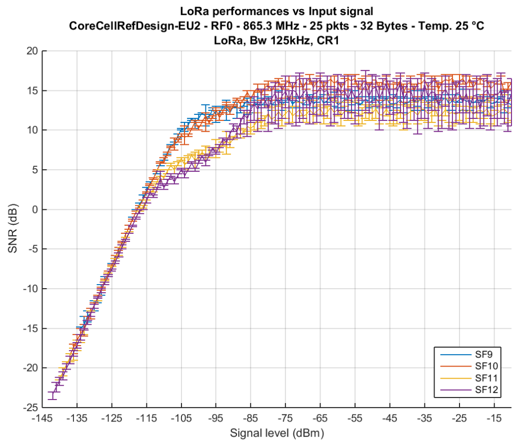


(a) Sensitivity level (b) High level

Figure 10.1: SNR, MultiSF modems versus Spreading Factor (5 to 8), 865.3 MHz



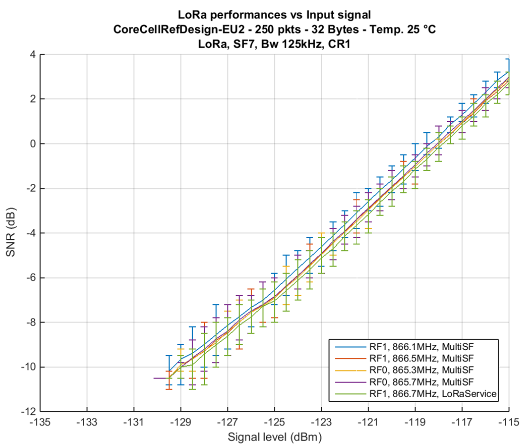
(a) Sensitivity level



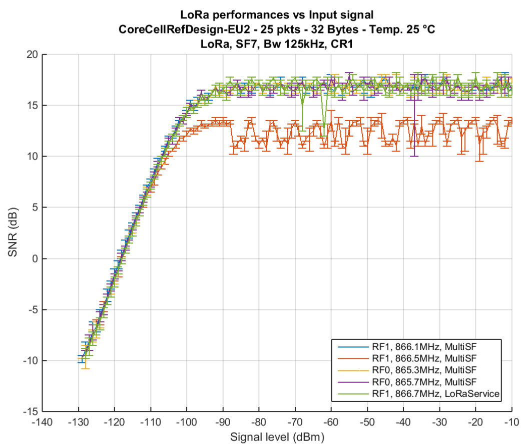
(b) High level

Figure 10.2: SNR, MultiSF modems versus Spreading Factor (9 to 12), 865.3 MHz

10.4 MultiSF / SingleSF modems versus channels



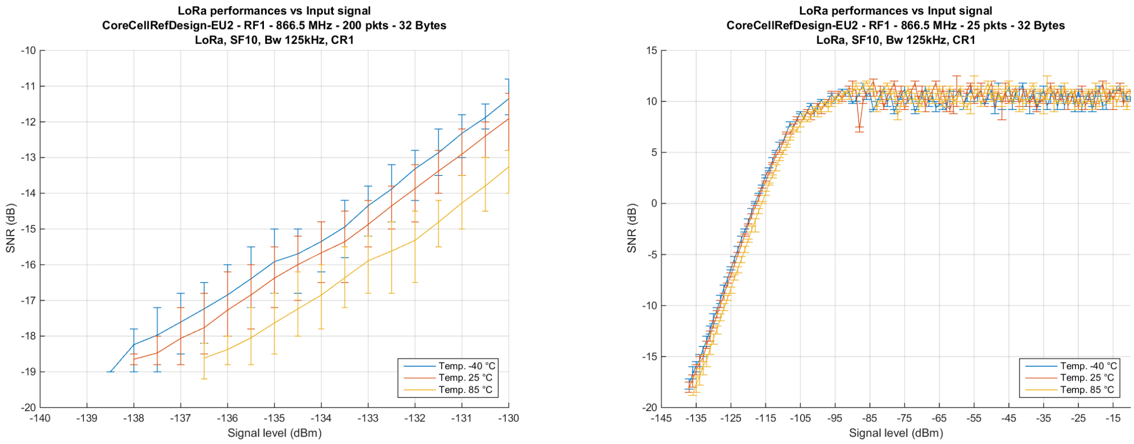
(a) Sensitivity level



(b) High level

Figure 10.3: SNR, MultiSF / SingleSF modems versus channels, SF77, Bw 125 kHz

10.5 MultiSF modem versus temperature

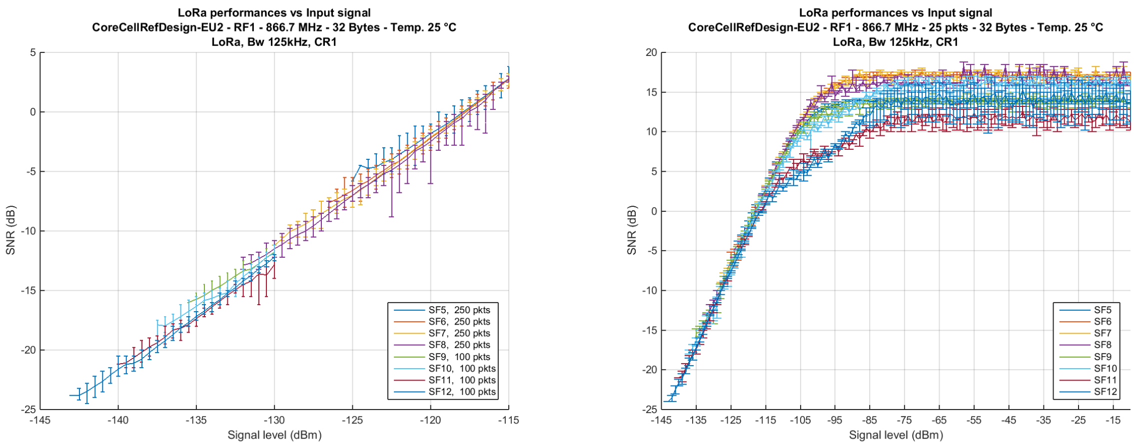


(a) Sensitivity level

(b) High level

Figure 10.4: SNR, MultiSF modem versus temperature, 866.5 MHz, SF10, Bw 125 kHz

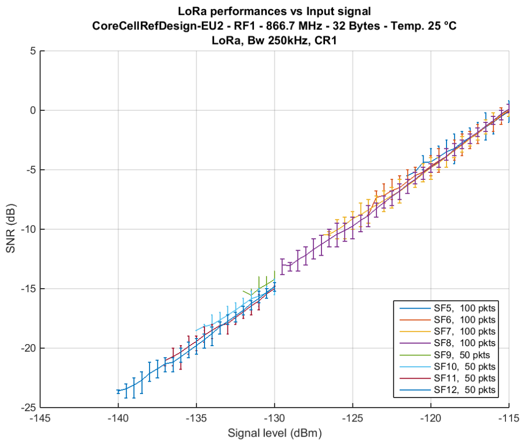
10.6 SingleSF modem vs Spreading factor



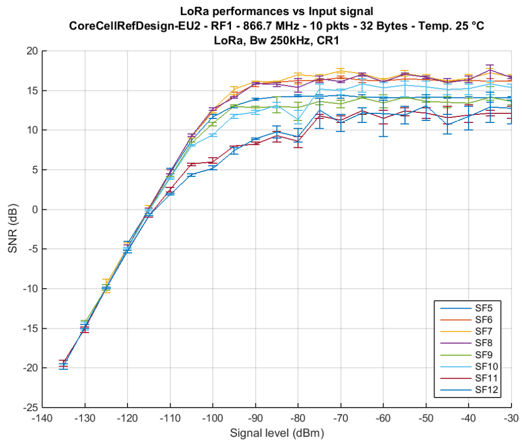
(a) Sensitivity level

(b) High level

Figure 10.5: SNR, SingleSF modem versus Spreading factors, 866.7 MHz, Bw 125 kHz



(a) Sensitivity level



(b) High level

Figure 10.6: SNR, SingleSF modem versus Spreading factors, 866.7 MHz, Bw 250 kHz

11 Blocking and Immunity to interferer

11.1 Description

A blocking measurement is performed to evaluate the system robustness to interferer in the vicinity of the gateway.

11.2 Setup

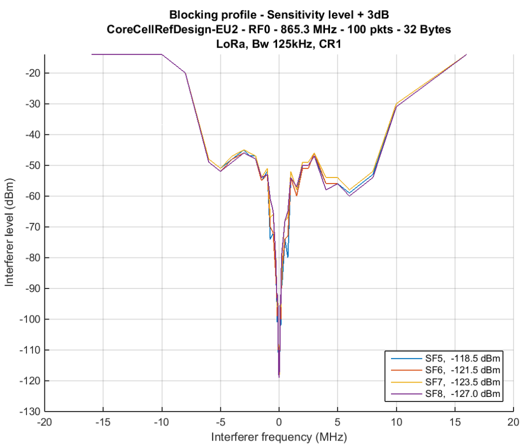
The test bench allowing to assess the coexistence robustness is shown in figure 2.3. Useful signal and interferer are combined in the power splitter/combiner. The attenuators allow to reduce the mutual interference between both signal generators.

The interferer is a continuous carrier wave swept from -16 to +16 MHz in comparison with the carrier frequency, with a variable step in order to find sensitive frequencies.

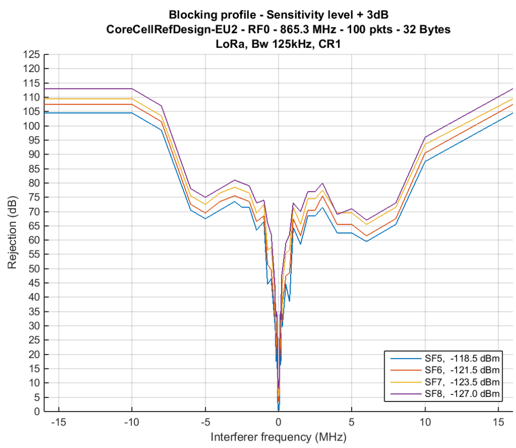
→ It is planned to increase the severity of this measurements using a two tones interferer. Results will be presented in a next version of the present document.

For each interferer step, the output power of the useful signal is set to the sensitivity level + 3 dB. The PER measurement is done on 25 packets. The interferer level is adjusted automatically to cause a PER of 10%.

11.3 MultiSF modem versus Spreading Factor

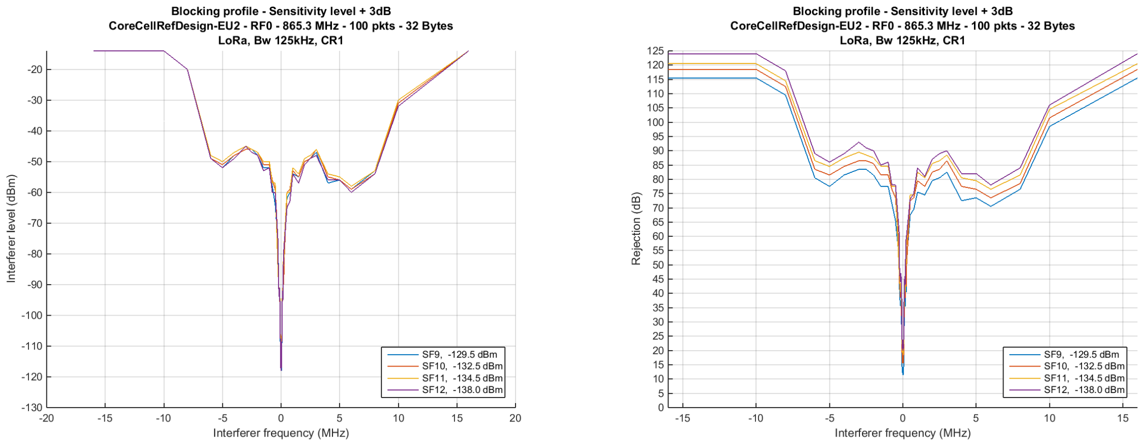


(a) Interferer level (dBm)



(b) Rejection (dB)

Figure 11.1: Blocking profile, MultiSF modem versus Spreading Factor (5 to 8), 865.3 MHz

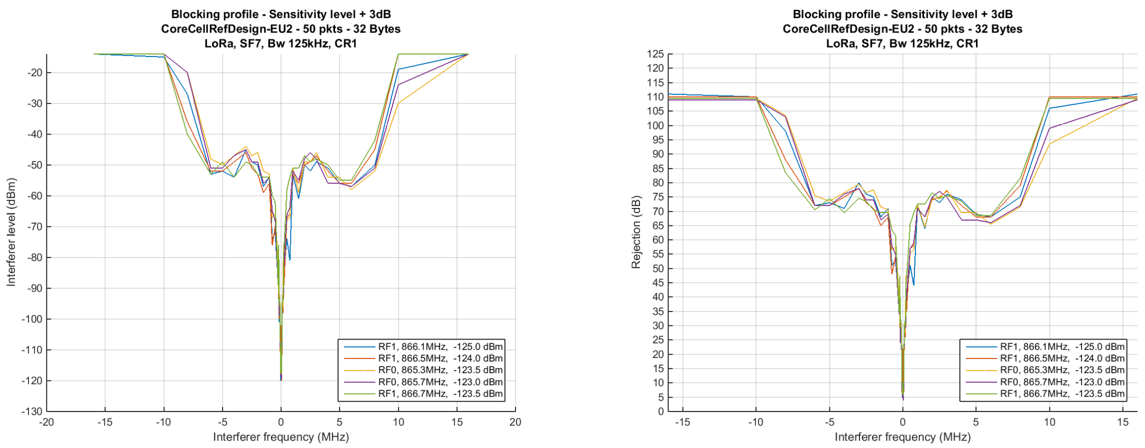


(a) Interferer level (dBm)

(b) Rejection (dB)

Figure 11.2: Blocking profile, MultiSF modem versus Spreading Factor (9 to 12), 865.3 MHz

11.4 MultiSF modem versus channels



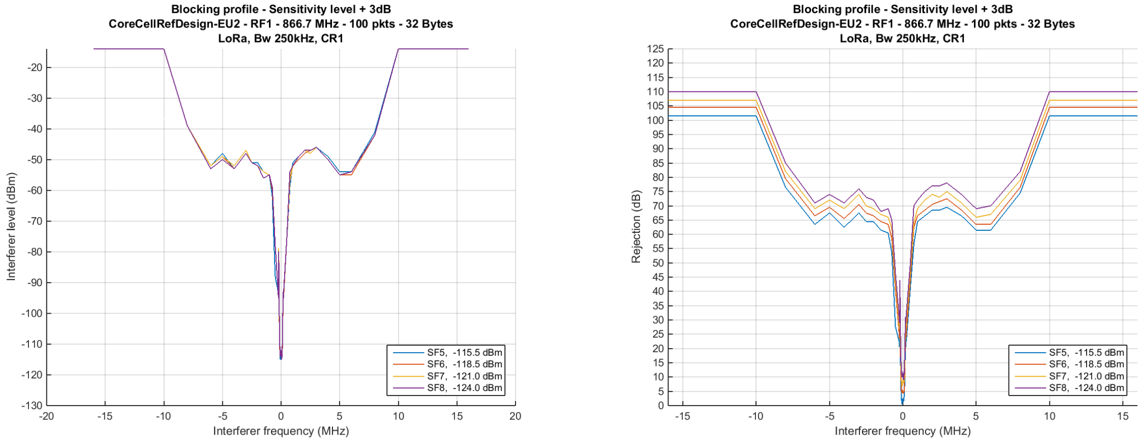
(a) Interferer level (dBm)

(b) Rejection (dB)

Figure 11.3: Blocking profile, MultiSF modem versus channels, SF7, Sensitivity level + 3dB

11.5 SingleSF modem versus spreading factor

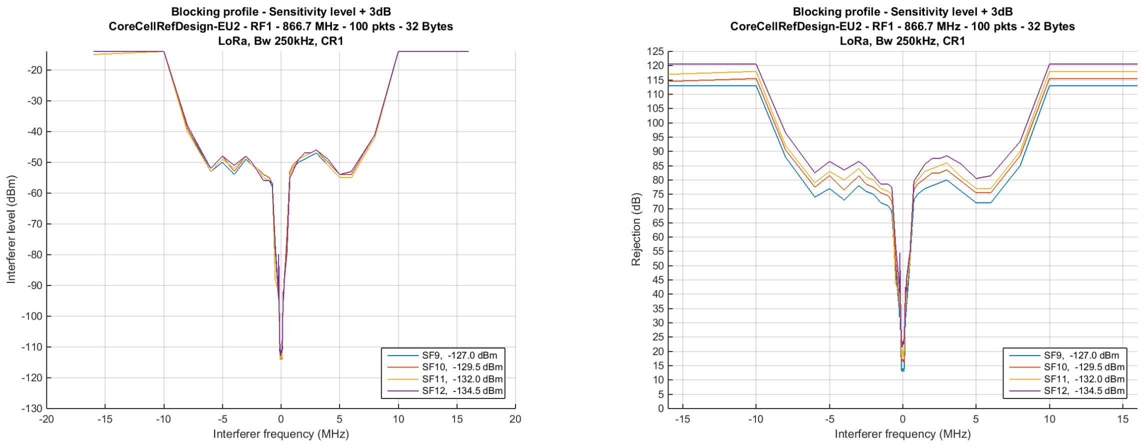
11.5.1 Bandwidth 250 kHz



(a) Interferer level (dBm)

(b) Rejection (dB)

Figure 11.4: Blocking profile, MultiSF modem versus Spreading Factor (5 to 8), 866.7 MHz, Bandwidth 250 kHz

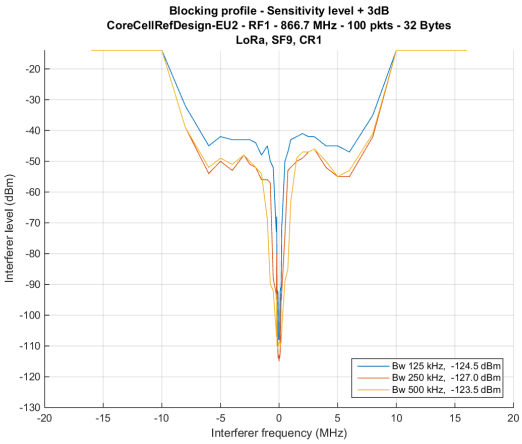


(a) Interferer level (dBm)

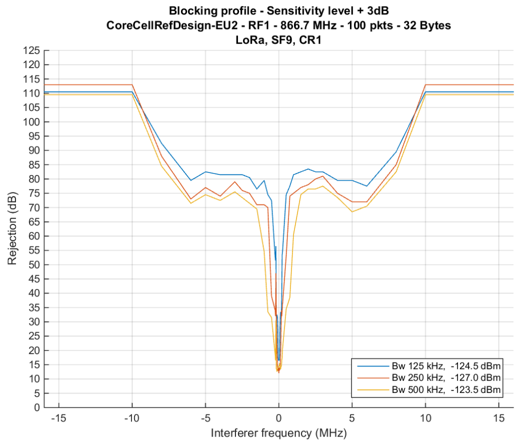
(b) Rejection (dB)

Figure 11.5: Blocking profile, MultiSF modem versus Spreading Factor (9 to 12), 866.7 MHz, Bandwidth 250 kHz

11.6 SingleSF modem versus bandwidth



(a) Interferer level (dBm)



(b) Rejection (dB)

Figure 11.6: Blocking profile, SingleSF modem versus bandwidth, SF9, 866.7 MHz, Sensitivity level + 3dB (-123.5dBm)

A Acronyms and Glossary

ADC chipset function, analog digital converter

ARIB Association of Radio Industries and Businesses

ATE automatic test equipment used to test the integrated chipset

AWGN Additive White Gaussian Noise

BOM bill of material for a given printed board circuit

BS base station of a radio system

CCAS Clear Channel assessment. This process is intended to be used for allocating or reserving the correct channel for the RF transmission

CDMA code division multiple access. In order to have several communication on the same medium, we can separate them by code projection means

CW carrier wave, used in radio frequency transmission

CPW coplanar waveguide for a transmission line

CPWG coplanar grounded waveguide for a transmission line

CPU central processing unit

DAC Digital Analog Converter

dBc unit description, decibel relative to the carrier maximum power

dBd dB towards dipole antenna (2.14 dBi)

dBi dB isotropic, used to define antenna gain

dBm unit description, decibel relative to milliwatt

DRC Design Rules Check

DPI Design Public Interface, define the interface of a design in terms of mechanics, materials, constraint.

DUT Device Under Test during measurement

EIRP Emitted Isotropic Radiated Power

EMC electromagnetic compliance

ERC Electrical Rules Check

ETSI European Telecommunications Standard Institute

FCC Federal Communications Commission

FEC Forward Error Correction, algorithm used by combining received data and redundancy codes to recover from false data

FER Frame Error Rate

FHSS Frequency Hopping Spread Spectrum used in radio frequency transmission

FM Frequency Modulation used in radio frequency transmission

FTS Fine TimeStamps identifying when a packet is received

HAL Hardware Abstraction Layer

IEC International Electrotechnical Commission

IF radio frequency term as intermediate frequency, used to describe the frequency used in up or down conversion system

IFA inverted F antenna : an antenna that looks like and inverted F letter

IL Insertion Loss

ISA industry standard architecture

ISM industrial, scientific and medical frequency band as described in the ERC70-3

JIT Just In Time TX scheduling

LBT Listen Before Talk. Process that oblige a device to listen a RF channel before using it, in order to ensure that this channel is not occupied

LIC Least Interferer Channel. A type of LBT process

LOS Line Of Sight. This term describe how the wave are propagated between a transmitter and a receiver, in a direct manner

LPF Low Pass Filter. Electronic function where high frequencies are attenuated whereas low frequencies stay unchanged

MIPS million instruction per second

MMIC Monolithic Microwave Integrated Circuit used to describe the integrated circuit in microwave technologies

MOSI Master Output Slave Input, Synchronous Serial Link

MISO Master Input Slave Output, Synchronous Serial Link

MS mobile station

N/A not applicable or not available

NLOS Non Line Of Sight. This term describe how the wave are propagated between a transmitter and a receiver, in a non direct manner. only reflection are taken into account

NRI National Radio Interface

OCW Occupied Channel Bandwidth

OOB out of band, describe the spurious that do not belong to the wanted emission spectrum, and outside the authorized band in usage

OSR Over Sampling Ratio, uses to determine a sampling frequency

p.d.f. probability density function

PA Power Amplifier

PIFA plate inverted F antenna describe an antenna that looks like a plate that has a F letter shape seen from the side

PPS Pulse Per Second. Electrical signal uses for precise timekeeping and time measurement

PSD Power Spectral Density

PSU Power Supply Unit

RBW resolution bandwidth, spectrum analyzer setting

RF Radio Frequency

RFU Reserved for Future Use

RPI Raspberry Pi, development board

RSSI receiving signal strength indicator used in radio frequency system

RAM random access memory

Rx Receiver

SF Spreading Factor, a LoRa modulation parameter

SNR Ratio of signal power to the noise power

SPDT single path dual through, describe the type of switch only a single is connected at a given time

SPI serial peripheral interface used to connect different chip with a reduced number of signals

SRD Short Range Devices

SWR Standing Wave Ratio, a measurement to express the impedance matching efficiency

UFL U.FL miniature microwave connector

VBW video bandwidth, spectrum analyzer setting

VLT Victim Link transmitter

VNA Vector Network Analyzer

XO crystal oscillator