SEMTECH

WIRELESS & SENSING PRODUCTS

Corecell reference design for LBT Spectral Scan gateway

USB / EU868 Performances report

Abstract

This document presents the results of compliance measurements to the tests required by European regulation as well as the performance and robustness measurements for a LoRa gateway. This document focus on validating the CoreCell V3 EU USB performance and perform some non-regression tests.

History

Rev.	Ref.	Change	Author	Date
1.0	-	Doc creation	L. Champion	Dec. 2020

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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 SX1250/55/57 for the radio. It prepares for the next wave of gateway 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 (SX1302 + radios + FEM + supply).

1.2 Scope

1.2.1 Version 1.0: Initial version

This document presents the measurement performed on the Corecell based on the SX1250 radio transceiver 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. **Part 15 of Title 47 of the Code of Federal Regulations** Official FCC rules that shall be fulfil by any RF device designed for the US market.
3. **ARIB STD-T108 Version 1.0**: Japan regulation for the 920 MHz band
4. **LoRaWAN v1.1 specification** describes the LoRaWAN™ network protocol.
5. **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 +20°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 validate the Corecell gateway reference design is shown in following chapters. This testbench check its compliance to the regulation limits as well as evaluates its performances.

2.2 Tx measurements

The setup presented in the figure 2.1 is used for the Tx measurements.

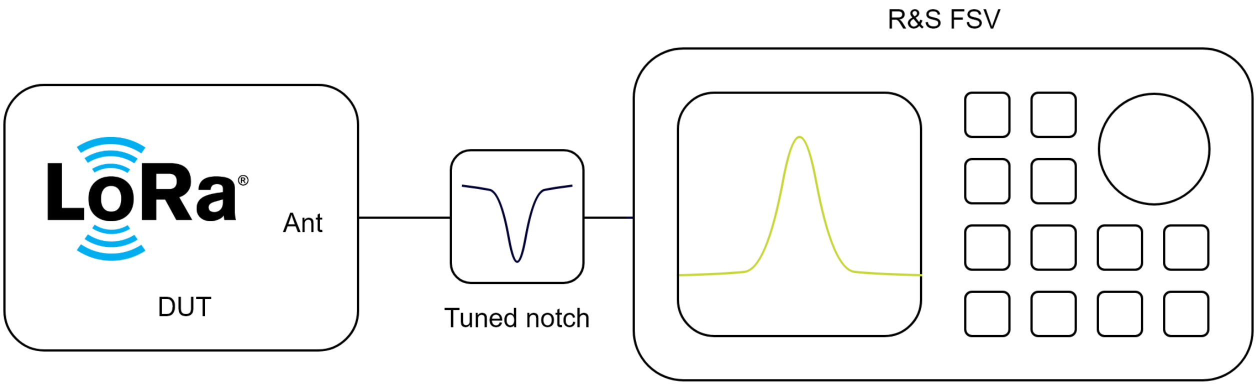


Figure 2.1: Configuration of the test bench for Tx measurements

The Tune Notch Filter is only used for some specific test, otherwise it is removed.

2.3 Rx measurements

All the Rx measurements are performed using the setup of the figure 2.2
For simple Rx measurements (Sensitivity level, RSSI and SNR, Frequency error 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.

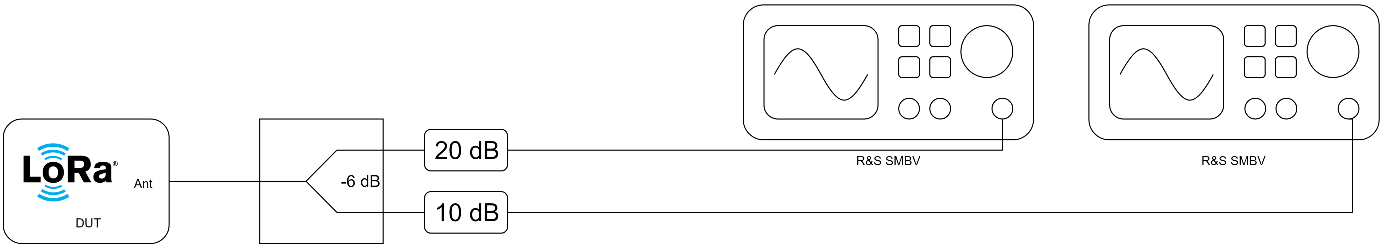
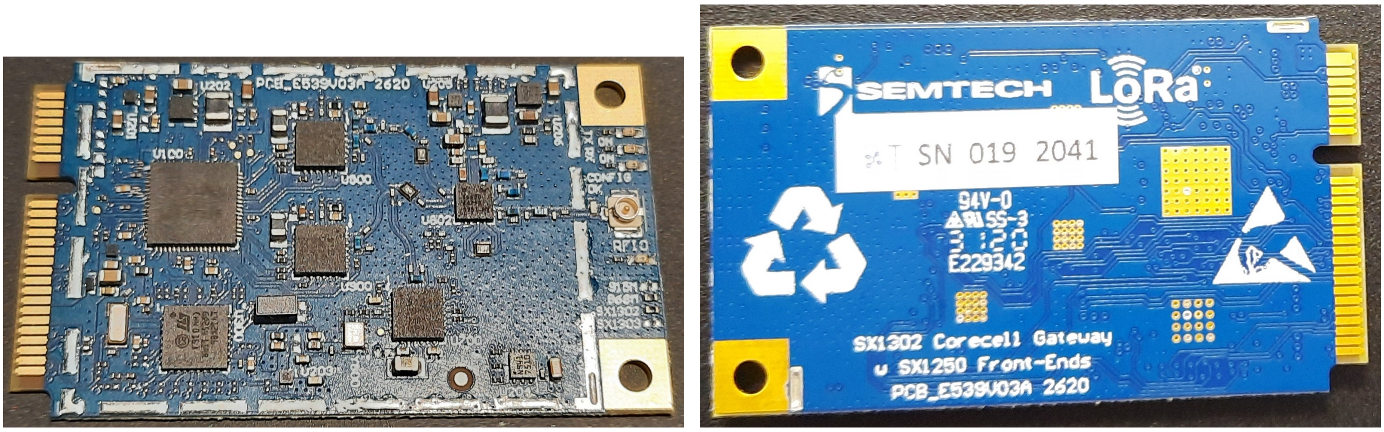


Figure 2.2: Test bench configuration for the Rx measurements

3 Devices under test

3.1 Presentation

The device used for the measurements of this report is the Corecell gateway V3 (PCB e539v03a) populated for EU region; The serial number is SN 019 2041. Along the document, it is referred as **Board EU19**.



(a) Top (b) Bottom

Figure 3.1: The Corecell gateway V3 (PCB e539v03a) EU19 validated along this document

The board is connected on the mini-pcie connector on the interface board (PCB e525v03a) allowing the connection with the host (RPI3) through a USB cable, providing the 3.3V power supply voltage to the Corecell and the PPS signal from the GPS module.

- The ferrite bead **FB207** is not populated: The power supply voltage **VCCIO33** is provided by the VCC3V3_IN input voltage and not from the on-board 3.3V regulator output.
- The ferrite bead **FB206** is removed; the component is placed on **FB204**: The power supply voltage **VCC_FEM** is provided by the VCC3V3_IN input voltage and not from the on-board 3.3V regulator output.

3.2 Software versions

The following softwares are used in the next measurements:

- **HAL**: v2.0.0
- **Packet forwarder**: v2.0.0
- **Firmware**: v2.0.6

4 Results summary

4.1 Transmitter

Items	Results
Output power	Provides up to +27 dBm.
Modulation bandwidth	Complies with the 99% of OBW within the 200kHz OCW for 125 kHz Tx
Out-of-band / Spurious emissions	Complies with the chapter 8.8 (d) of the ETSI regulation EN300 220 v3.1.1
Beacon emission time accuracy	Complies with the LoRaWan class B requirement of 1500 ± 1µs

4.2 Receiver

Items	Results
Sensitivity level and PER	The sensitivity level and the PER for higher signal input levels comply with the expected performances
RSSI	The RSSI channel and signal provide an accurate estimation of the signal input level over a wide dynamic range
SNR	The LoRa modem provides an accurate SNR value over a wide dynamic range
Blocking and Immunity to interferer	Provides at least 50 dB of interferers rejection
Frequency error tolerance	Tolerant to the end-device Xtal frequency error
Frequency drift tolerance	Robust to the end-device oscillator frequency drift

Part II

Transmitter

5 Occupied bandwidth (ETSI)

5.1 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 5.1 explains the definition of OBW, OCW and OFB.

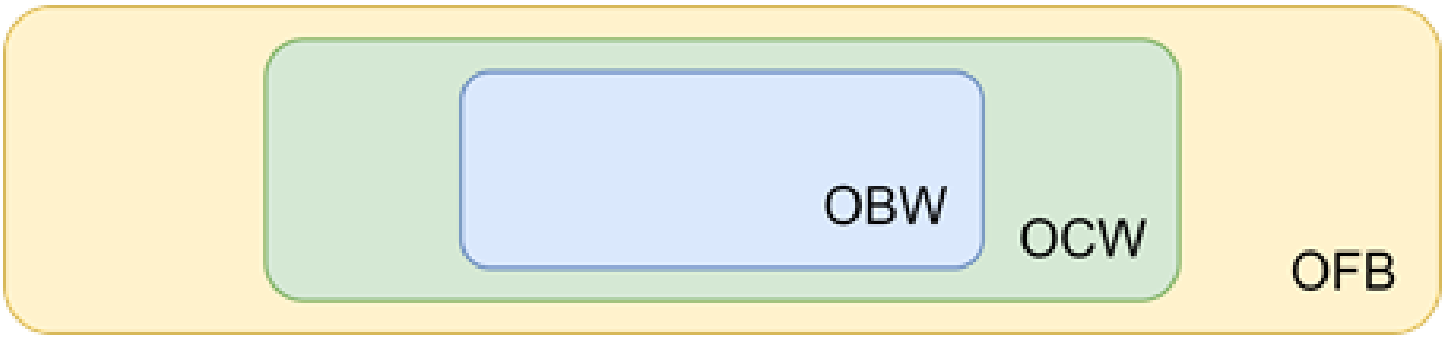


Figure 5.1: EN 300 220 OBW/OCW/OFB definition

The LoRa system defines the operating channel width (OCW) as 200 kHz for the LoRa bandwidth of 125 kHz.

5.2 Setup

The setup used to measure the occupied bandwidth is show in figure 2.1. Only the direct path is used for this measurement, the notch or the high pass filter is used to measure spurious level far from the carrier frequency.

5.3 Ambient temperature

5.3.1 LoRa 125 kHz

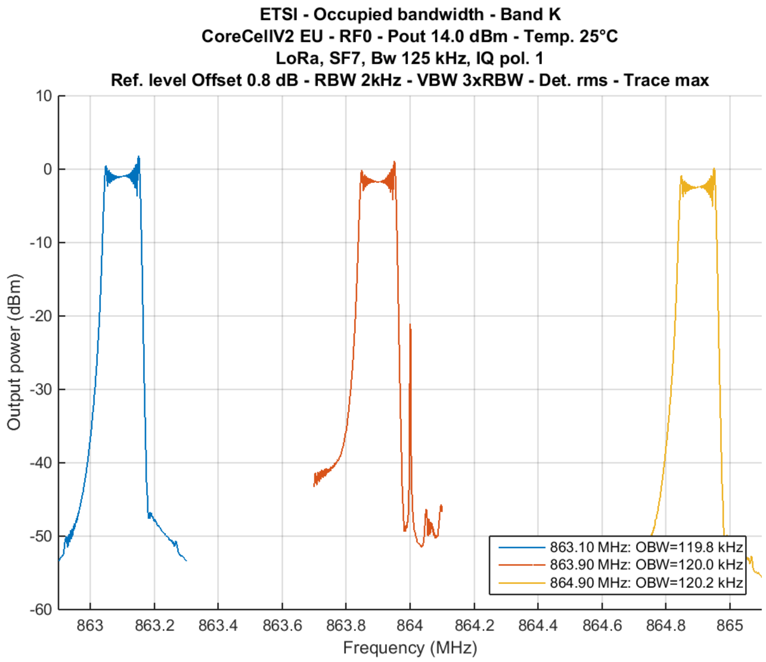


Figure 5.2: Occupied bandwidth, Band K, 14 dBm, LoRa SF7 125 kHz

In the figure 5.2, the spurious present at 864 MHz while transmitting at 863.9 MHz is an harmonic of the 32 MHz clock. Its level sufficiently low does not disturb the occupied bandwidth measurement performed using the dedicated instrument function (OBW measured at 99%).

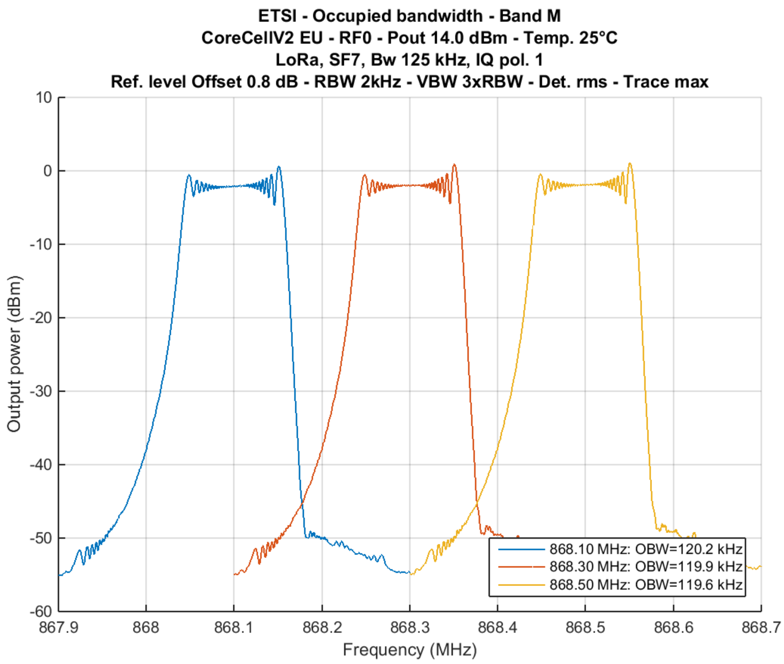


Figure 5.3: Occupied bandwidth, Band M, 14 dBm, LoRa SF7 125 kHz

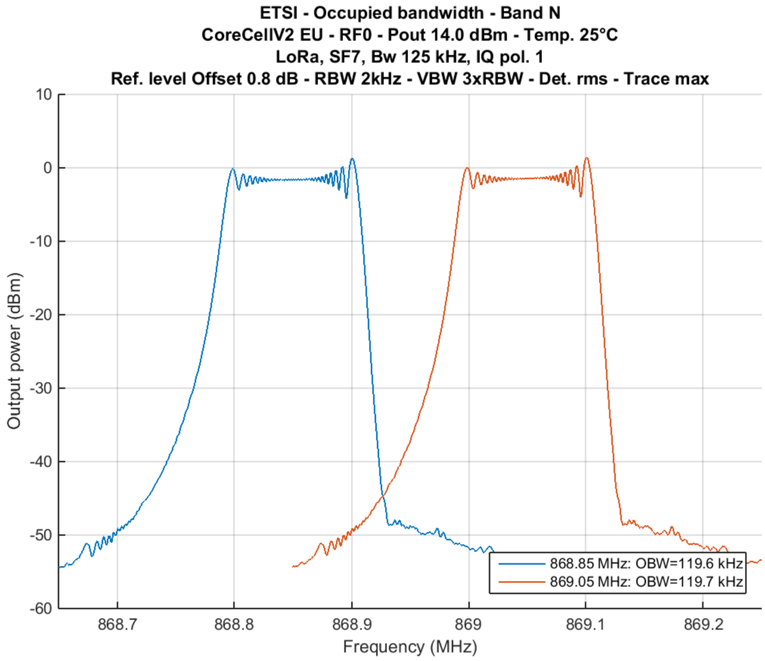


Figure 5.4: Occupied bandwidth, Band N, 14 dBm, LoRa SF7 125 kHz

In the figure 5.5, the output power is lower than 27 dBm due to the low RBW used to perform the measurement (RBW = 2 kHz).

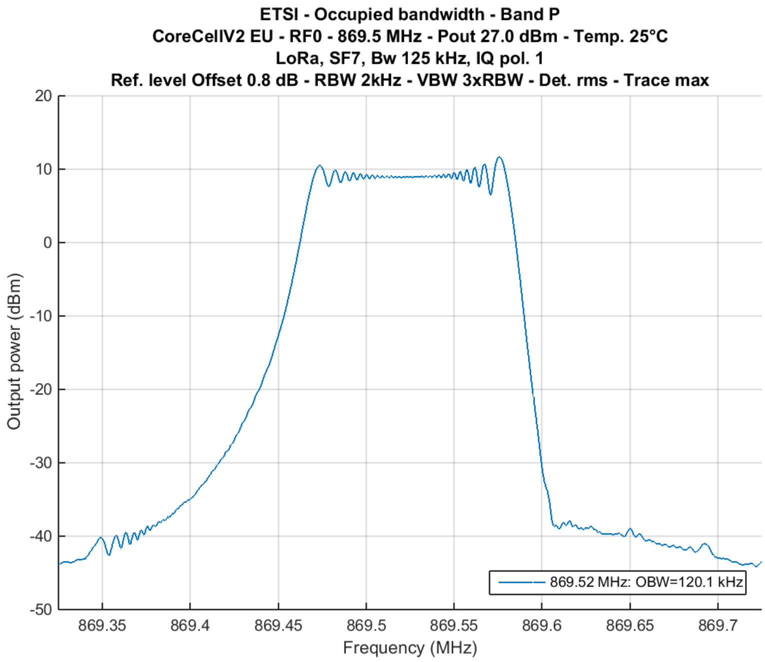


Figure 5.5: Occupied bandwidth, Band P, 27 dBm, LoRa SF7 125 kHz

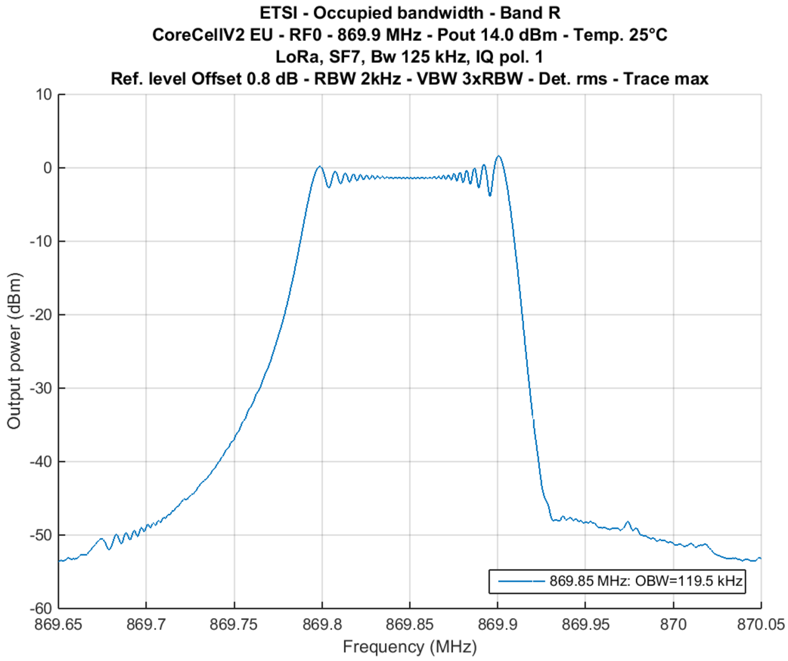


Figure 5.6: Occupied bandwidth, Band R, 14 dBm, LoRa SF7 125 kHz

5.3.2 LoRa 250 kHz

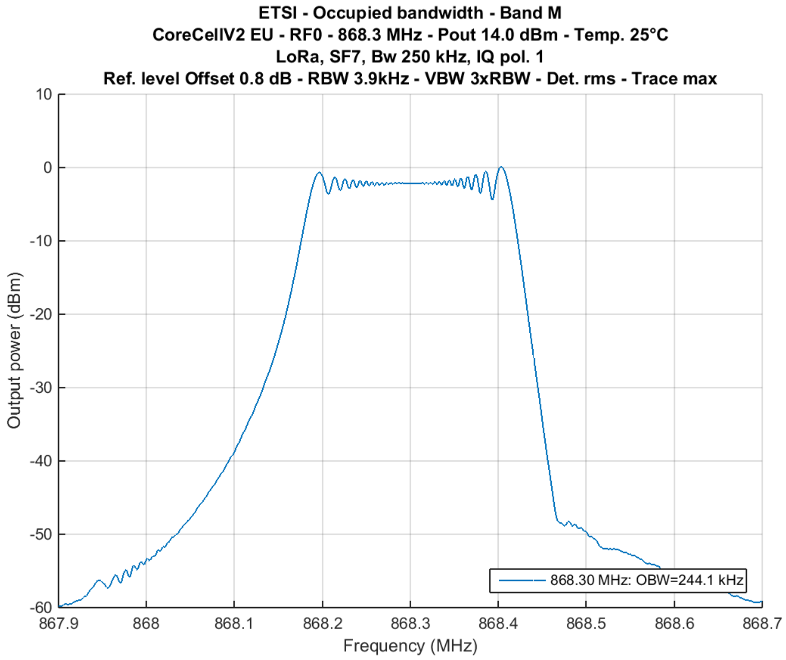


Figure 5.7: Occupied bandwidth, Band M, 14 dBm, LoRa SF7 250kHz, Ambient temperature

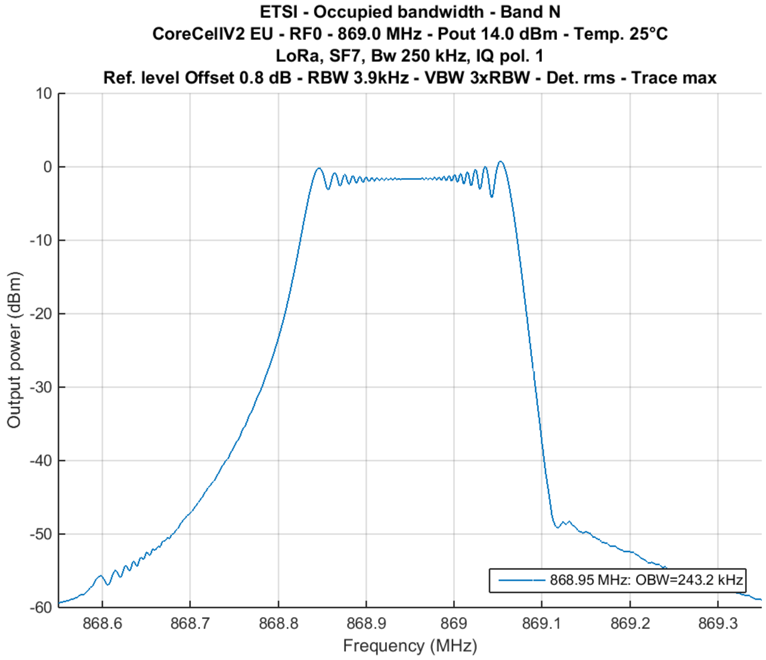


Figure 5.8: Occupied bandwidth, Band N, 14 dBm, LoRa SF7 250kHz, Ambient temperature

5.3.3 FSK 50 kbits

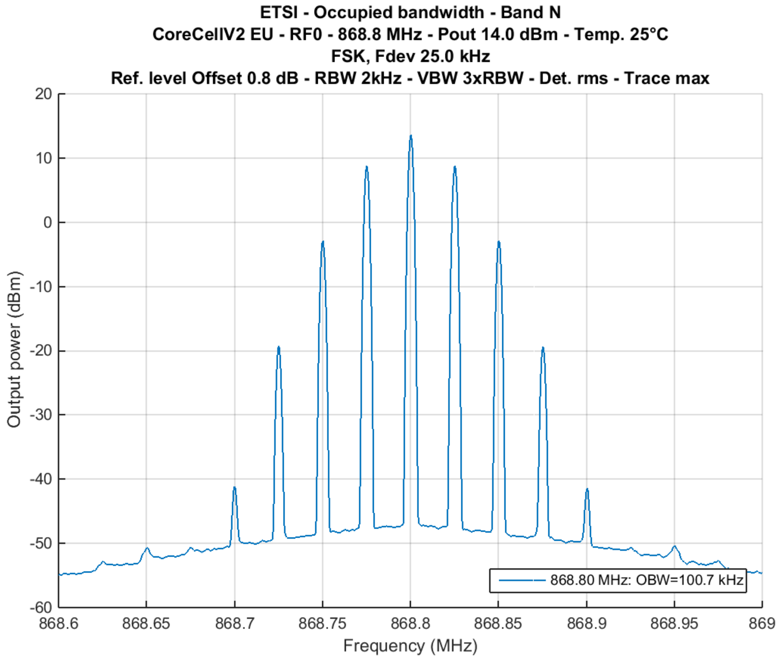


Figure 5.9: Occupied bandwidth, Band N, 14 dBm, FSK 50kbps Fdev 25 kHz

6 Tx Out Of Band Emissions (ETSI)

6.1 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.

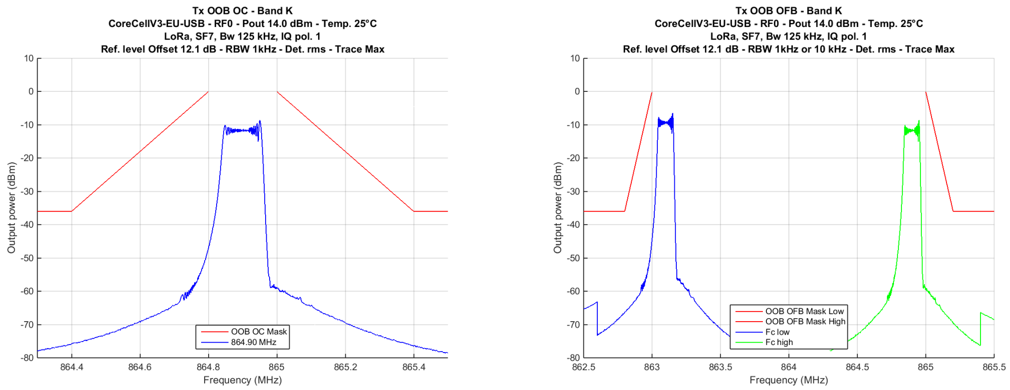
6.2 Setup

The setup used to measure the out of band emission is show in Figure 2.1. Only the direct path is used for this measurement, the notch or the high pass filter is used to measure spurious level far from the carrier frequency.

6.3 Ambient temperature

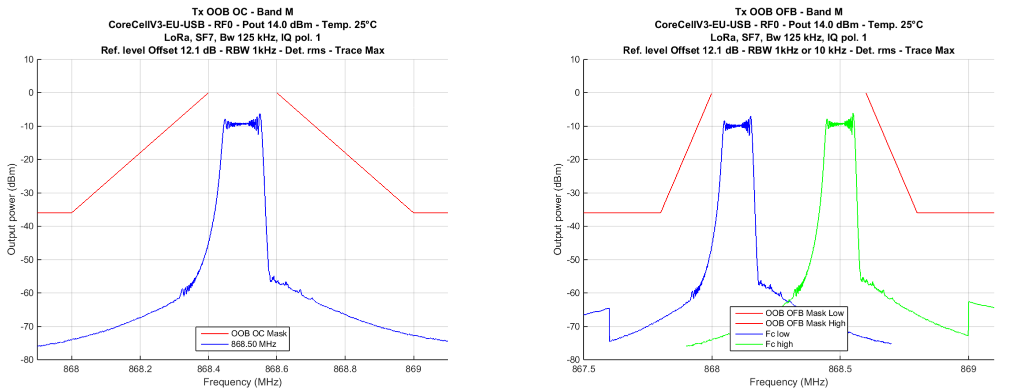
In the following measurements, a step appears in the spectrum. It is due to a change of the spectrum analyzer resolution bandwidth from 1 to 10 kHz as required by the measurement procedure described in document [1].

6.3.1 LoRa 125 kHz



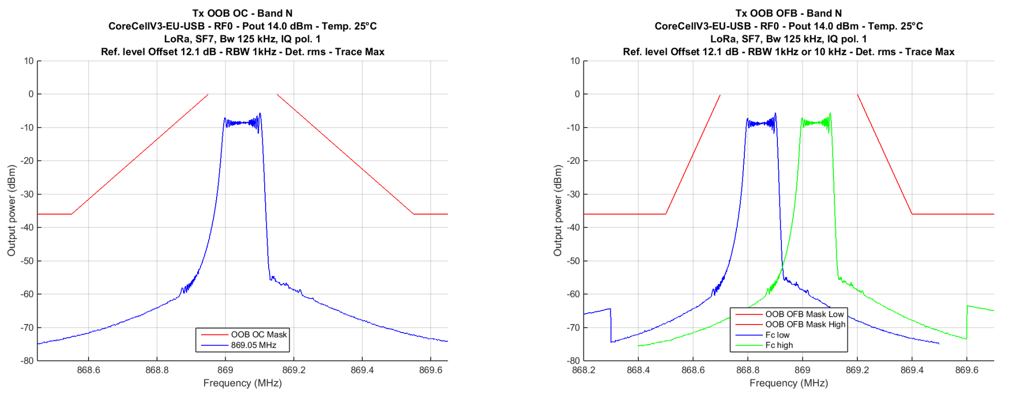
(a) Operating channel (b) Operational Frequency band

Figure 6.1: Tx Out Of Band Emissions, Band K, 14 dBm, LoRa 125 kHz



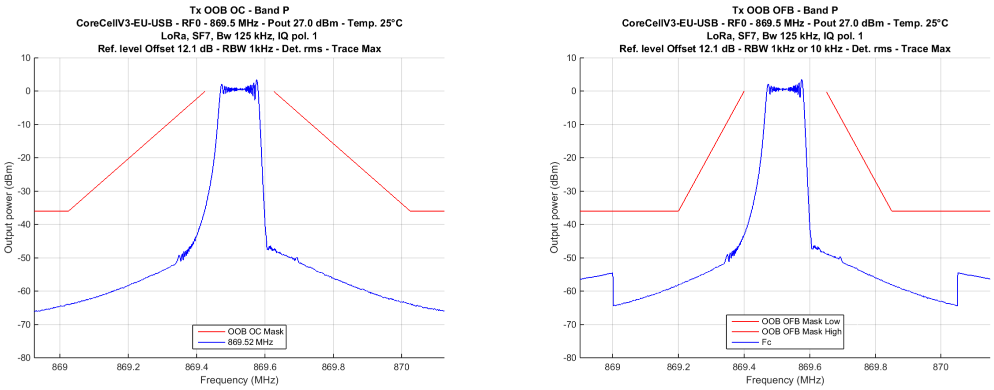
(a) Operating channel (b) Operational Frequency band

Figure 6.2: Tx Out Of Band Emissions, Band M, 14 dBm, LoRa 125 kHz



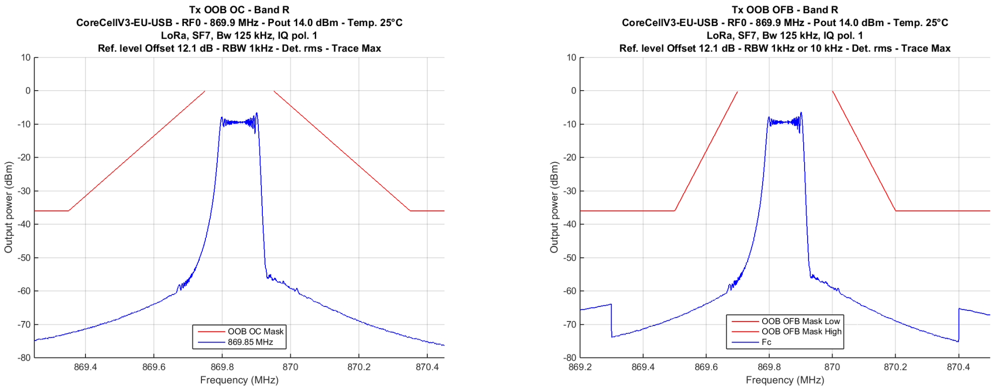
(a) Operating channel (b) Operational Frequency band

Figure 6.3: Tx Out Of Band Emissions, Band N, 14 dBm, LoRa 125 kHz



(a) Operating channel (b) Operational Frequency band

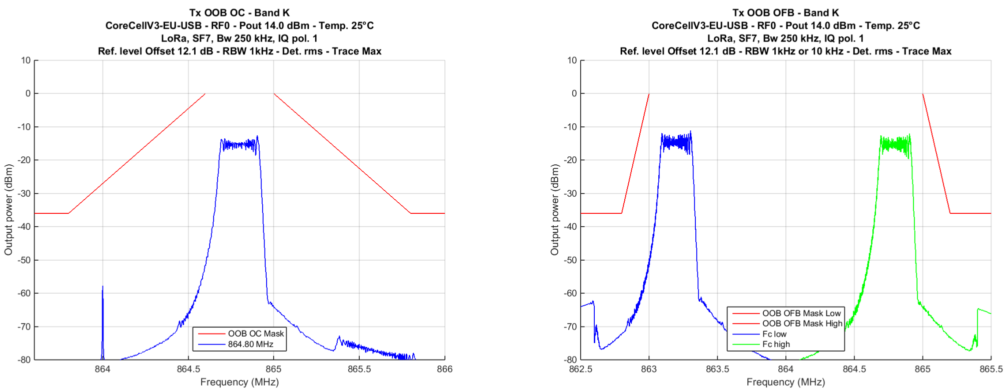
Figure 6.4: Tx Out Of Band Emissions, Band P, 27 dBm, LoRa 125 kHz



(a) Operating channe (b) Operational Frequency band

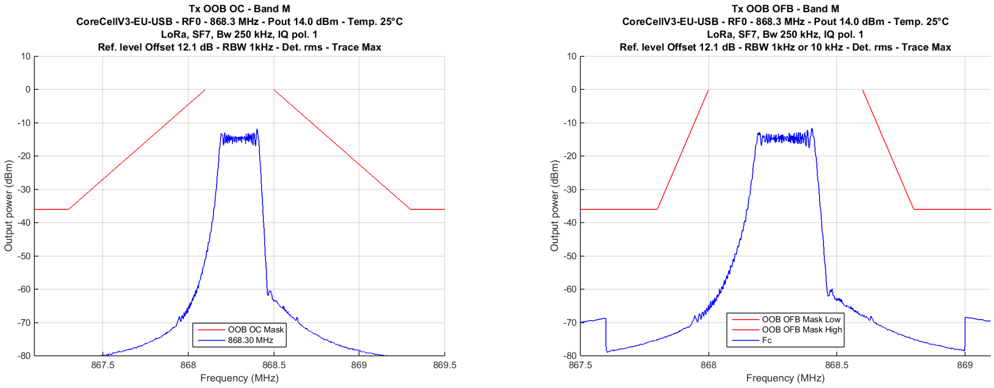
Figure 6.5: Tx Out Of Band Emissions, Band R, 14 dBm, LoRa 125 kHz

6.3.2 LoRa 250 kHz



(a) Operating channel (b) Operational Frequency band

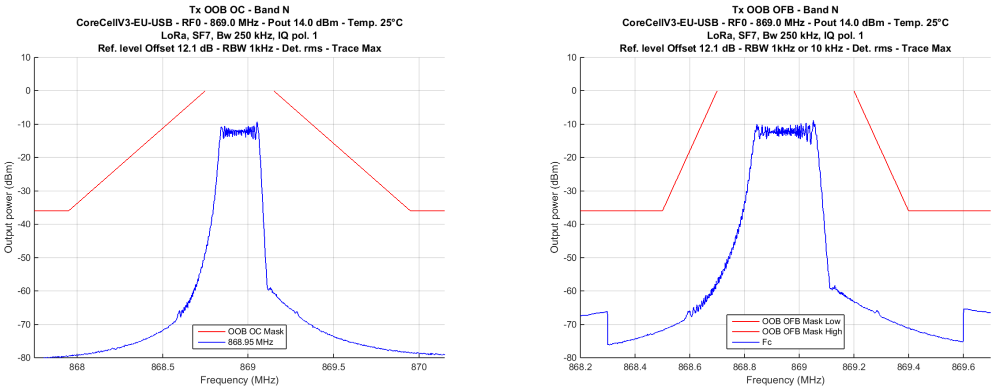
Figure 6.6: Tx Out Of Band Emissions, Band K, 14 dBm, LoRa 250 kHz



(a) Operating channel

(b) Operational Frequency band

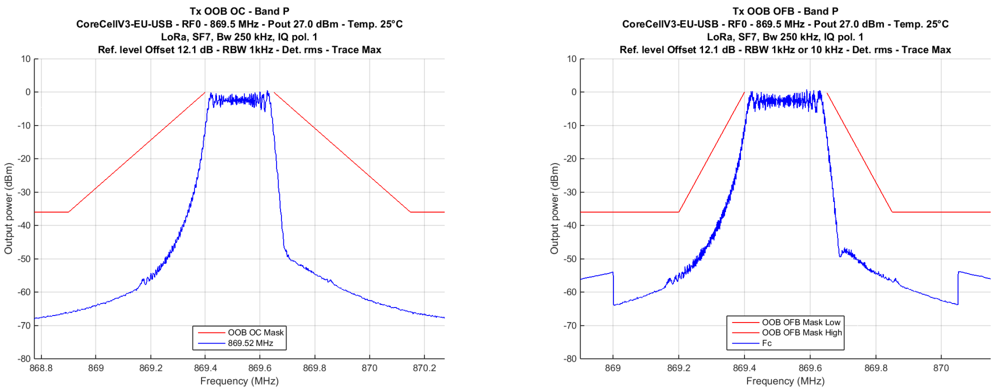
Figure 6.7: Tx Out Of Band Emissions, Band M, 14 dBm, LoRa 250 kHz



(a) Operating channel

(b) Operational Frequency band

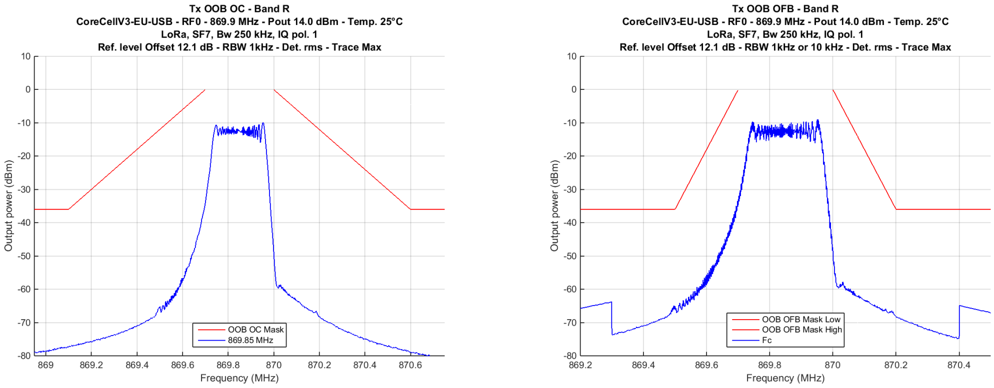
Figure 6.8: Tx Out Of Band Emissions, Band N, 14 dBm, LoRa 250 kHz



(a) Operating channel

(b) Operational Frequency band

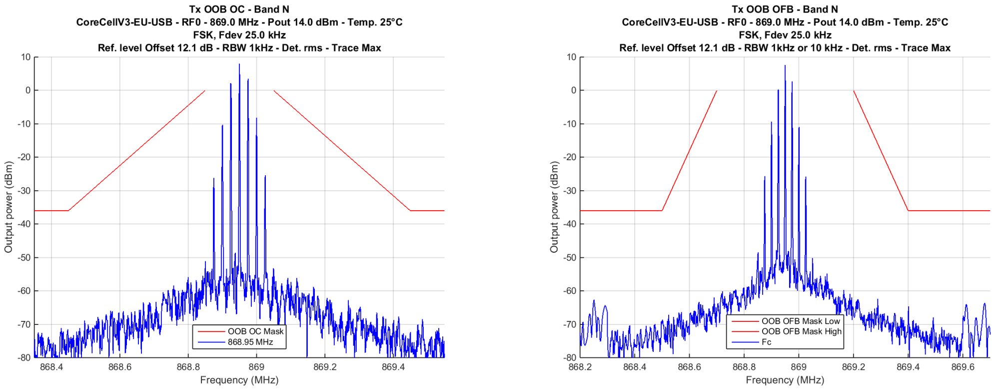
Figure 6.9: Tx Out Of Band Emissions, Band P, 27 dBm, LoRa 250 kHz



(a) Operating channel (b) Operational Frequency band

Figure 6.10: Tx Out Of Band Emissions, Band R, 14 dBm, LoRa 250 kHz

6.3.3 FSK 50 kbits



(a) Operating channel (b) Operational Frequency band

Figure 6.11: Tx Out Of Band Emissions, Band R, 14 dBm, FSK 50kbps Fdev 25 kHz

7 Transient power (ETSI)

7.1 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 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.

7.2 LoRa 125 kHz

7.2.1 Band M

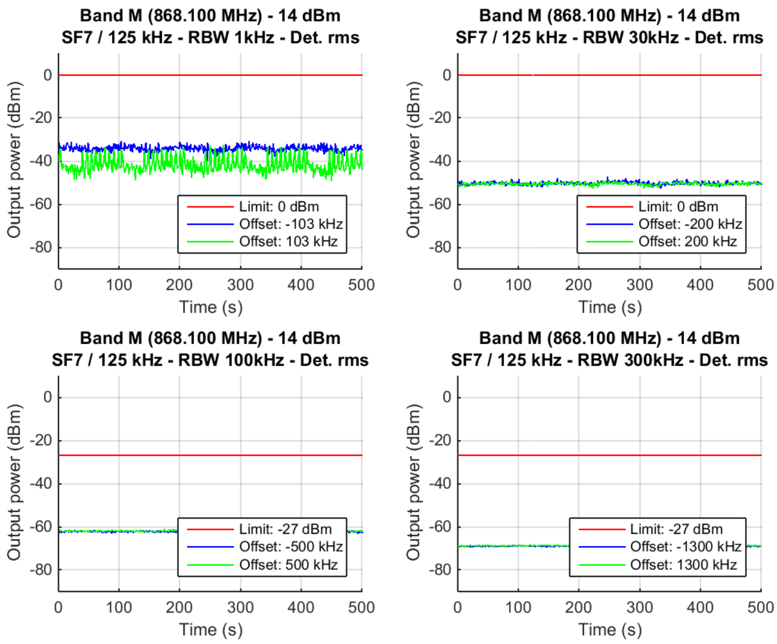


Figure 7.1: Transient power (ETSI), Band M, 868.1 MHz, 14 dBm, SF7, Bw 125 kHz

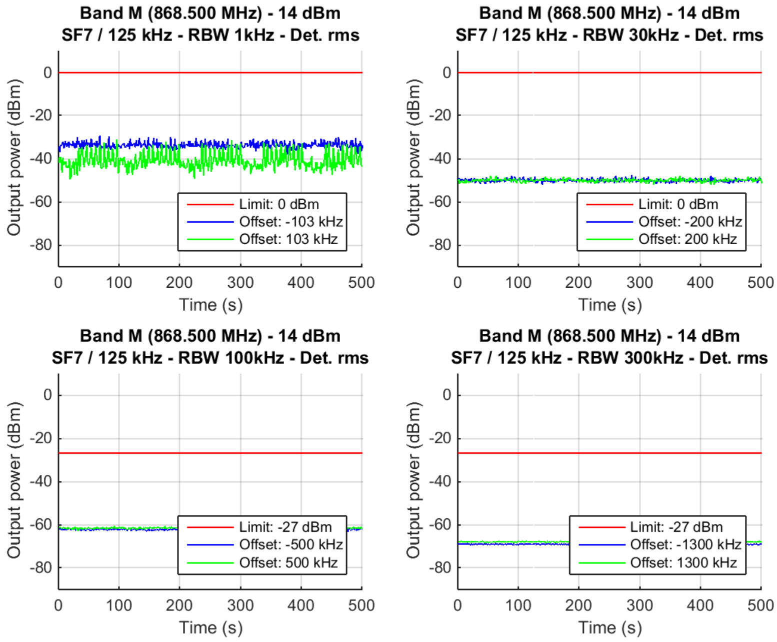


Figure 7.2: Transient power (ETSI), Band M, 868.5 MHz, 14 dBm, SF7, Bw 125 kHz

7.2.2 Band P

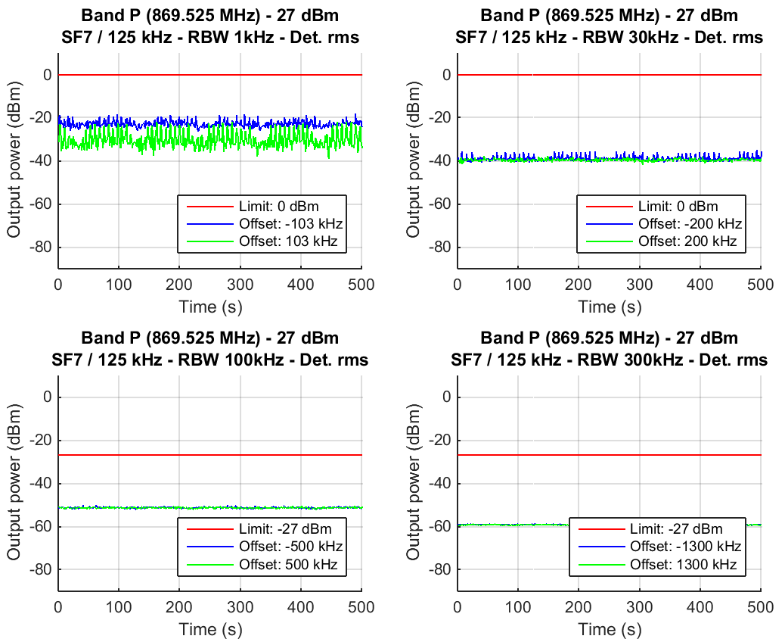


Figure 7.3: Transient power (ETSI), Band P, 869.525 MHz, 27 dBm, SF7, Bw 125 kHz

7.3 LoRa 250 kHz

7.3.1 Band M

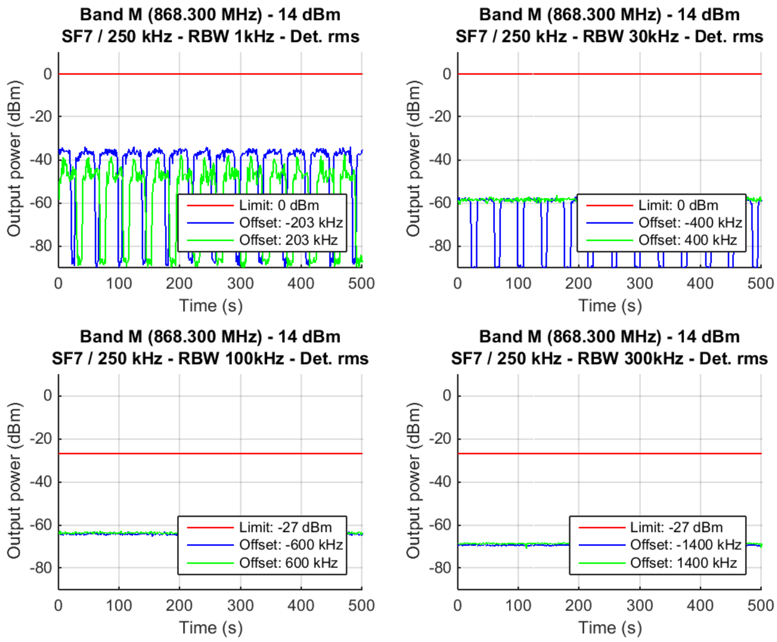


Figure 7.4: Transient power (ETSI), Band M, 868.3 MHz, 14 dBm, SF7, Bw 250 kHz

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

8.1 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 6.1). The relevant spurious domain is shown in the figure 8.1.

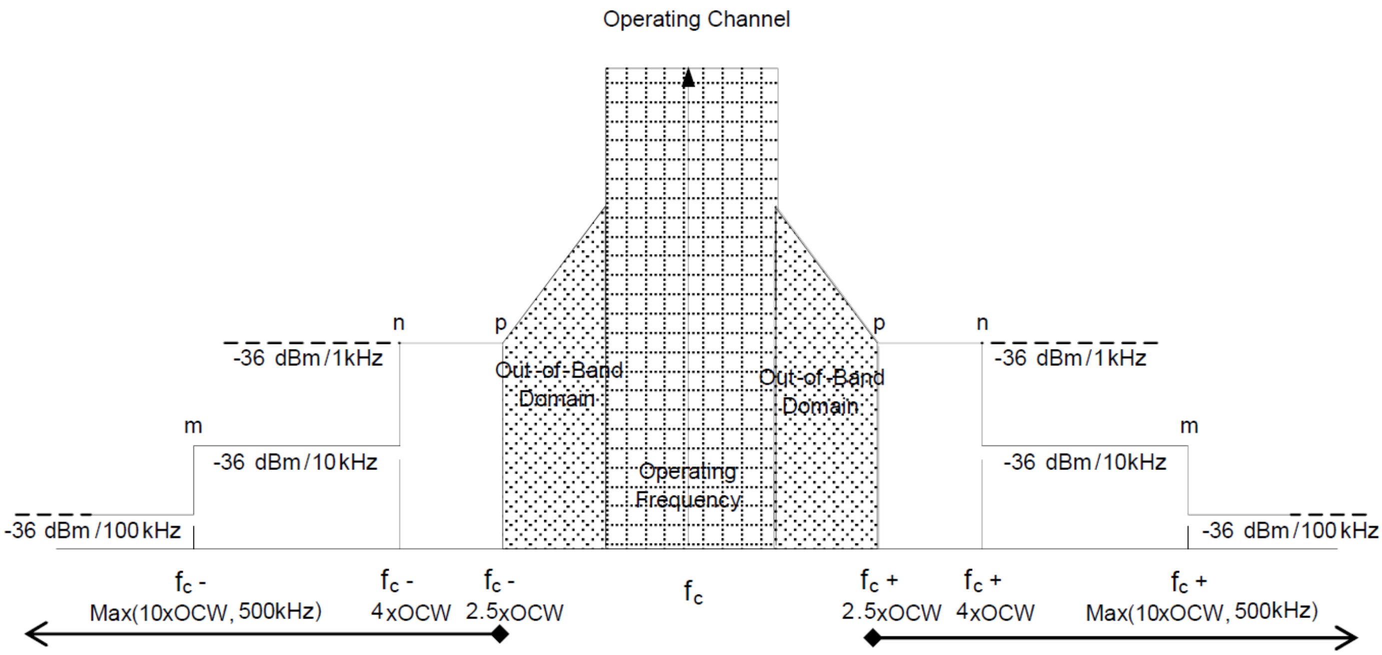
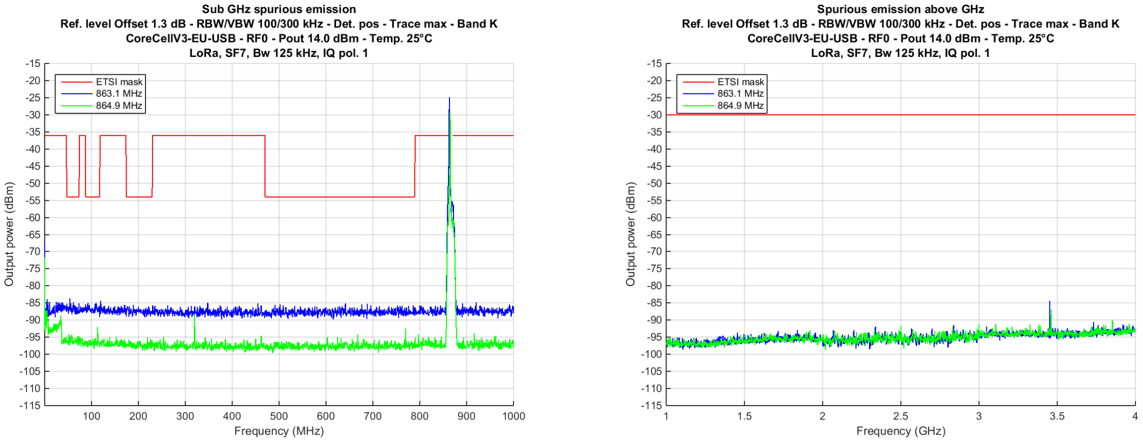


Figure 8.1: Spectrum Mask for Unwanted Emissions in the Spurious Domain

8.2 LoRa 125 kHz

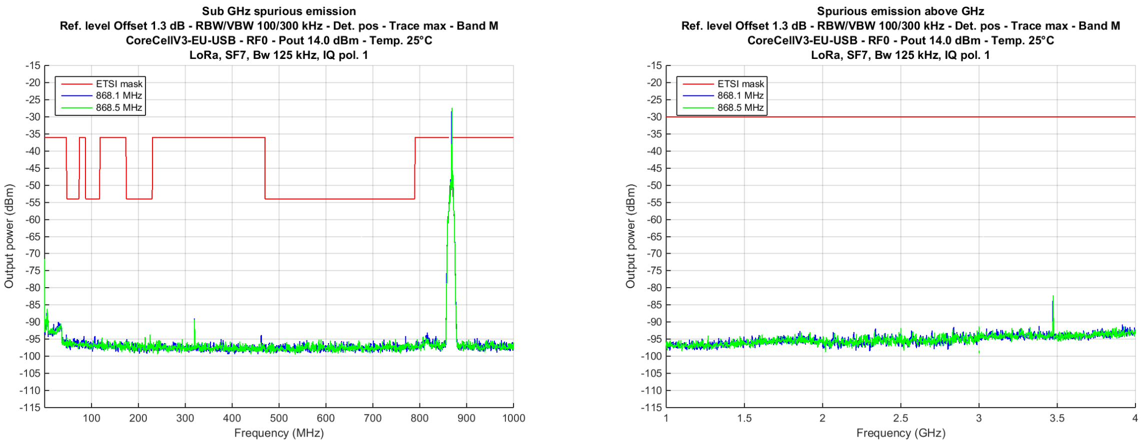
8.2.1 Band K



(a) Sub GHz (b) Above GHz

Figure 8.2: Spurious measurement, Band K, 14 dBm, LoRa 125 kHz, SF7

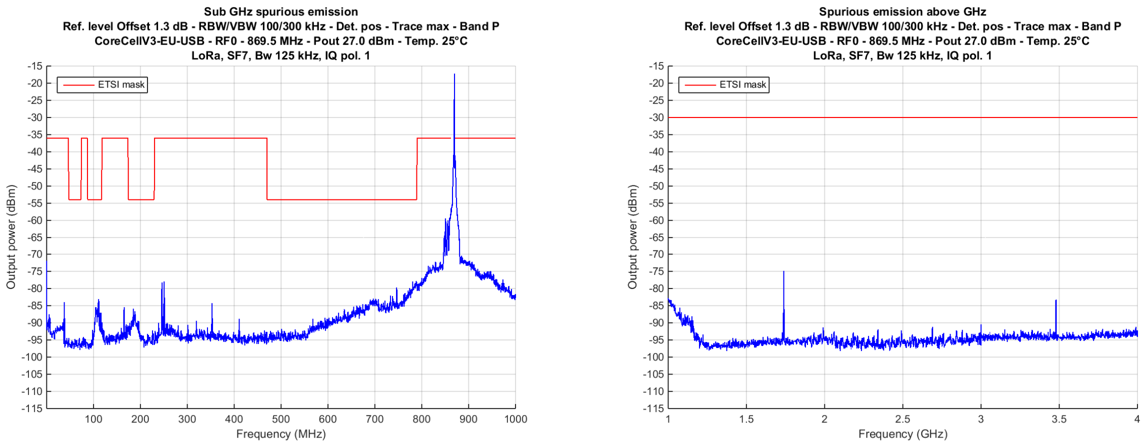
8.2.2 Band M



(a) Sub GHz (b) Above GHz

Figure 8.3: Spurious measurement, Band M, 14 dBm, LoRa 125 kHz, SF7

8.2.3 Band P



(a) Sub GHz (b) Above GHz

Figure 8.4: Spurious measurement, Band P, 27 dBm, LoRa 125 kHz, SF7

9 Beacon emission time accuracy

9.1 Description

In addition to the Class A random receive windows, Class B devices open extra receive windows at scheduled times. Class B is achieved by having the gateway sending a beacon on a regular basis to synchronize all the end-devices in the network so that the end-device can open a short extra reception window (called ping slot) at a predictable time during a periodic time slot.

From chapter 15.4 of the document [4], the beacon is sent every 128 seconds plus **TBeaconDelay**, whereby TBeaconDelay is 1.5 ms $\pm 1 \mu s$ delay. The beacon emission is synchronized to the PPS signal coming from the GPS module.

→ **This test evaluates the system performances and the compliance to the LoRaWan specification regarding the Class B requirements. The beacon emission time accuracy shall be better than $1.5ms \pm 1\mu s$ after the PPS signal rising edge.**

9.2 Setup

The setup shown in the figure 9.1 allows to evaluate the beacon emission time accuracy. The packet emission is synchronized with the rising edge of PPS signal.

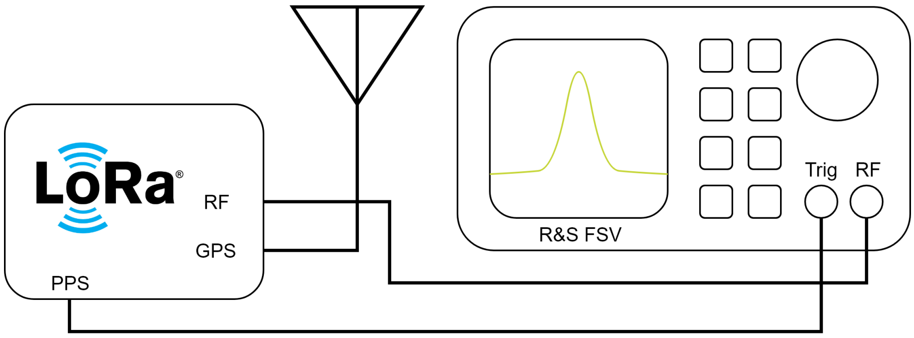


Figure 9.1: Setup used to measure the beacon emission time accuracy.

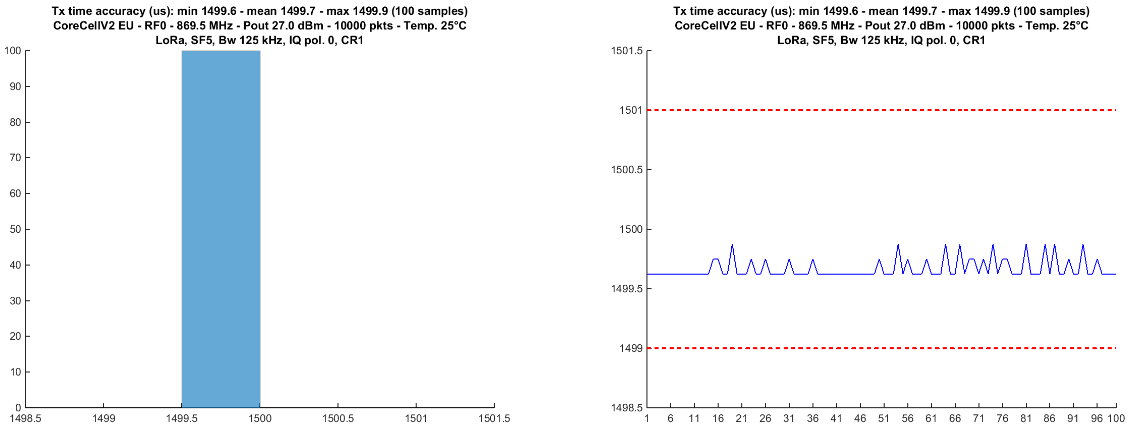
The PPS signal is also used to trigger the capture of IQ data by the spectrum analyzer at a sampling frequency of 8 MHz. This sampling frequency reduces the error on the emission time to 125 ns. The data are download to the computer and correlated with a reference LoRa preamble in order to measure accurately the start of the LoRa packets.

The beacon emission is launched with the command:

```
./test_loragw_hal_tx -u -d/dev/ttyACM0 -k0 -c0 -r1250 -f868 -mLORA -s10 -b125 -l8 -n1000 -z32 -t0
--pwid 10 --pa 1
```

9.3 Bandwidth 125 kHz

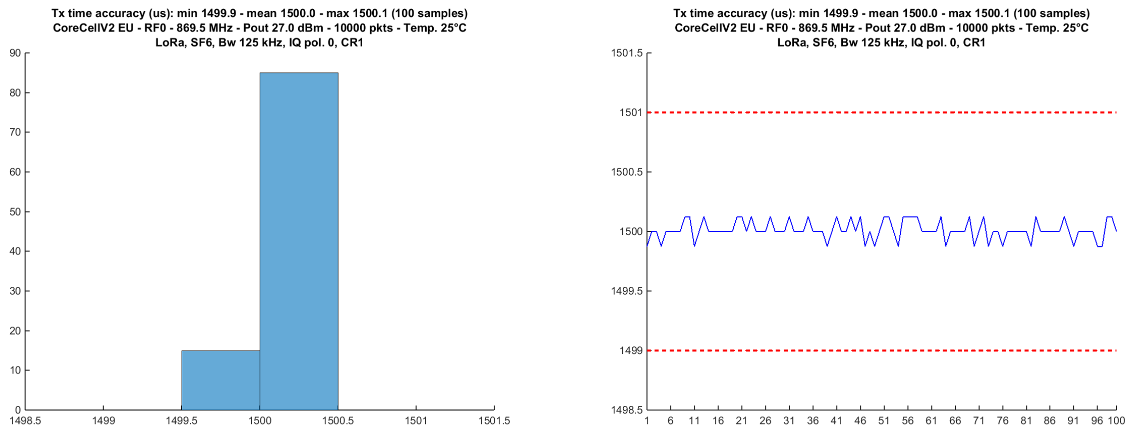
9.3.1 SF5



(a) Histogram (b) Samples

Figure 9.2: Beacon emission time accuracy, BW 125 kHz, SF5, Ambient temperature

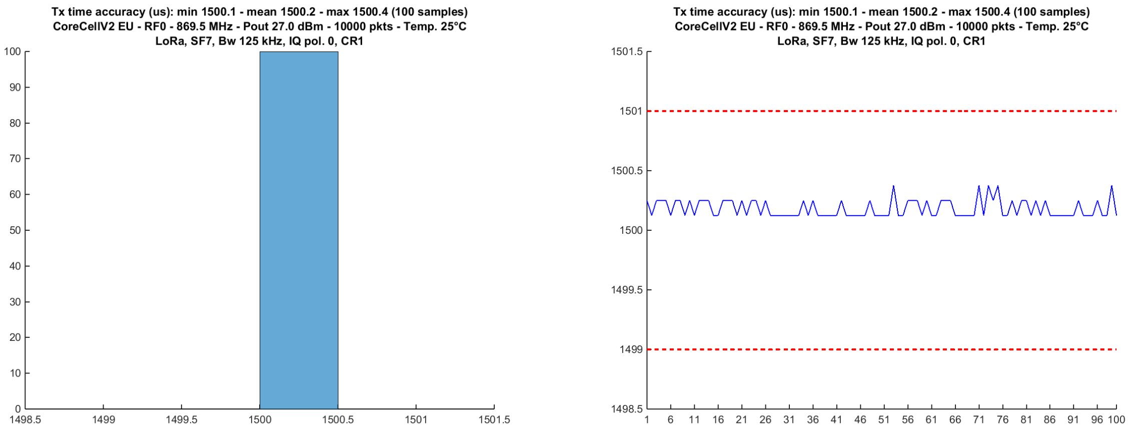
9.3.2 SF6



(a) Histogram (b) Samples

Figure 9.3: Beacon emission time accuracy, BW 125 kHz, SF6, Ambient temperature

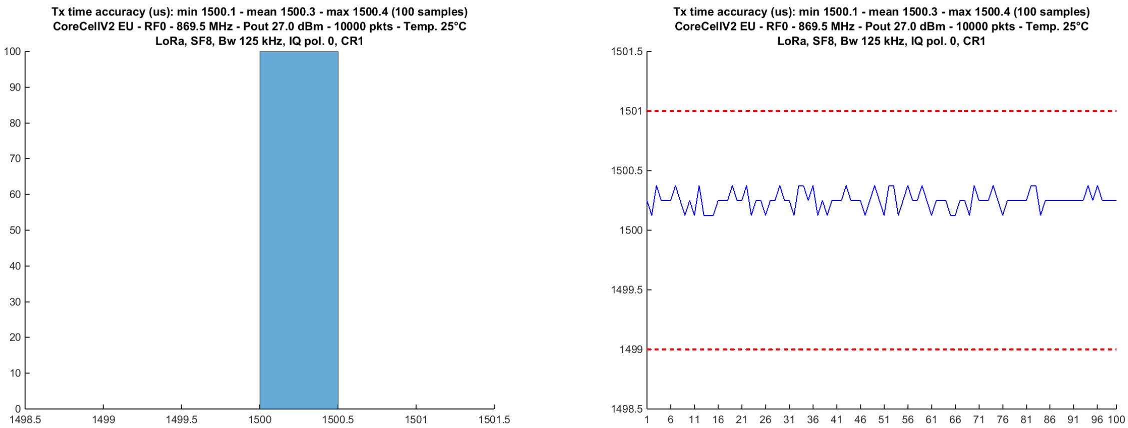
9.3.3 SF7



(a) Histogram (b) Samples

Figure 9.4: Beacon emission time accuracy, BW 125 kHz, SF7, Ambient temperature

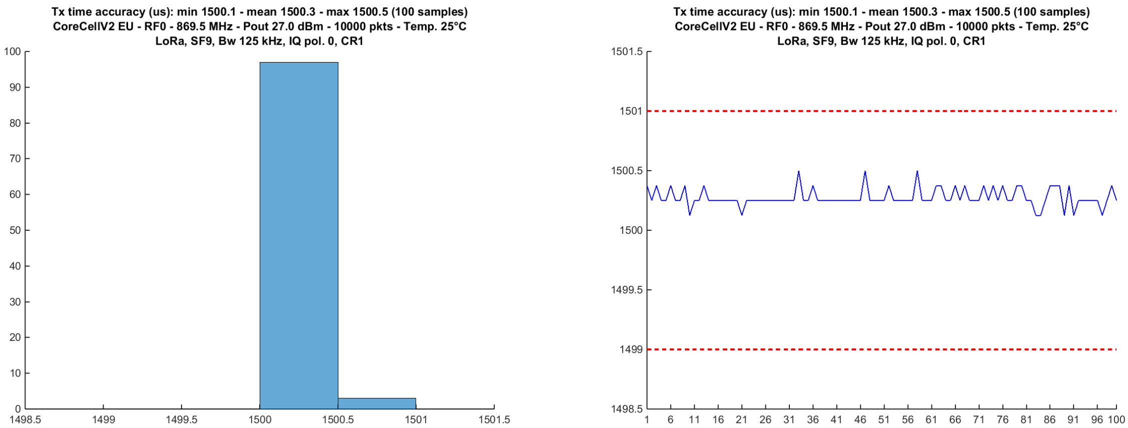
9.3.4 SF8



(a) Histogram (b) Samples

Figure 9.5: Beacon emission time accuracy, BW 125 kHz, SF8, Ambient temperature

9.3.5 SF9

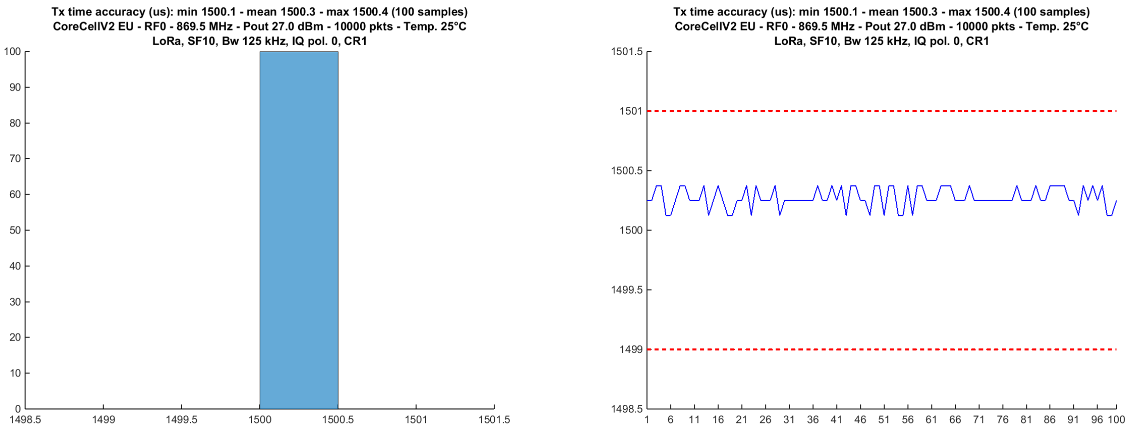


(a) Histogram

(b) Samples

Figure 9.6: Beacon emission time accuracy, BW 125 kHz, SF9, Ambient temperature

9.3.6 SF10

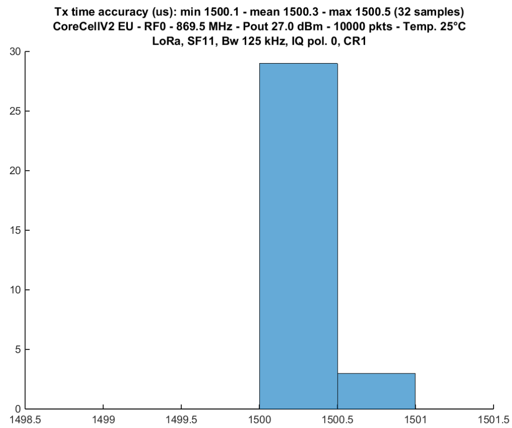


(a) Histogram

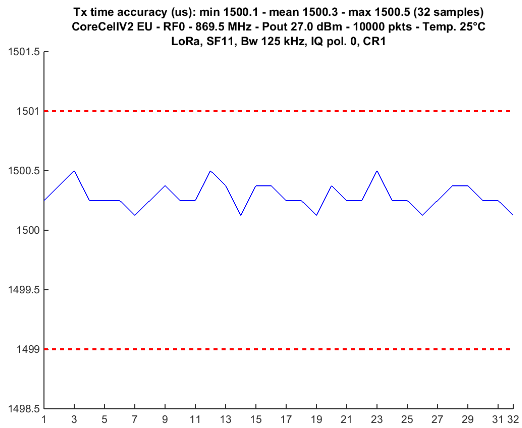
(b) Samples

Figure 9.7: Beacon emission time accuracy, BW 125 kHz, SF10, Ambient temperature

9.3.7 SF11



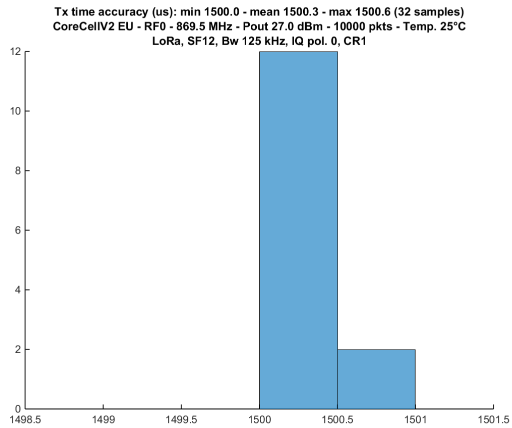
(a) Histogram



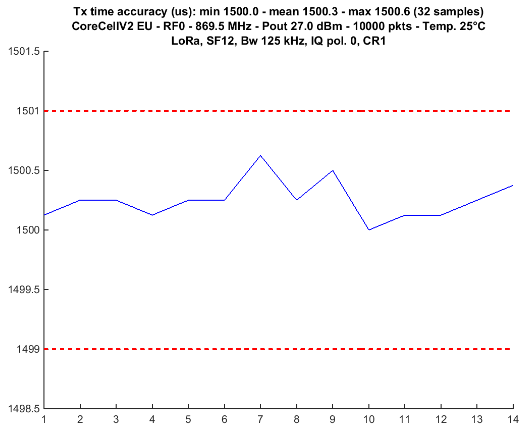
(b) Samples

Figure 9.8: Beacon emission time accuracy, BW 125 kHz, SF11, Ambient temperature

9.3.8 SF12



(a) Histogram

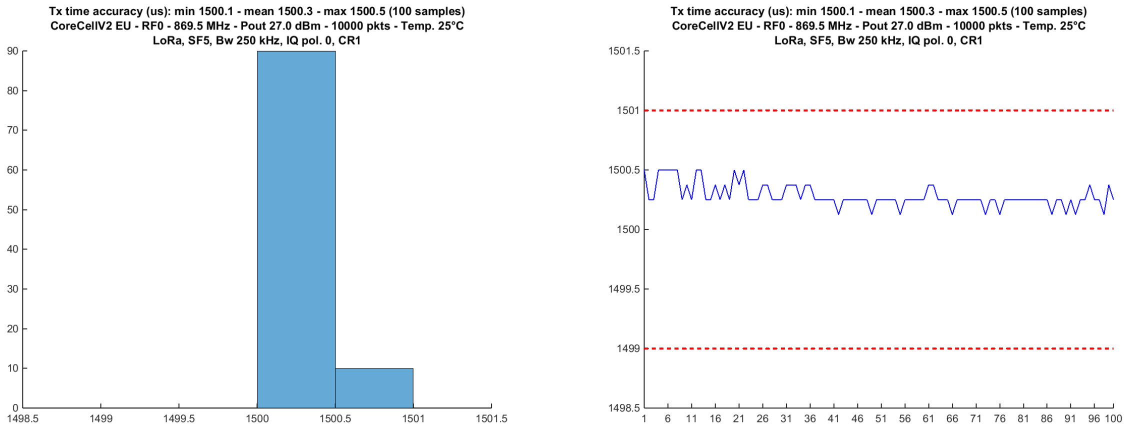


(b) Samples

Figure 9.9: Beacon emission time accuracy, BW 125 kHz, SF12, Ambient temperature

9.4 Bandwidth 250 kHz

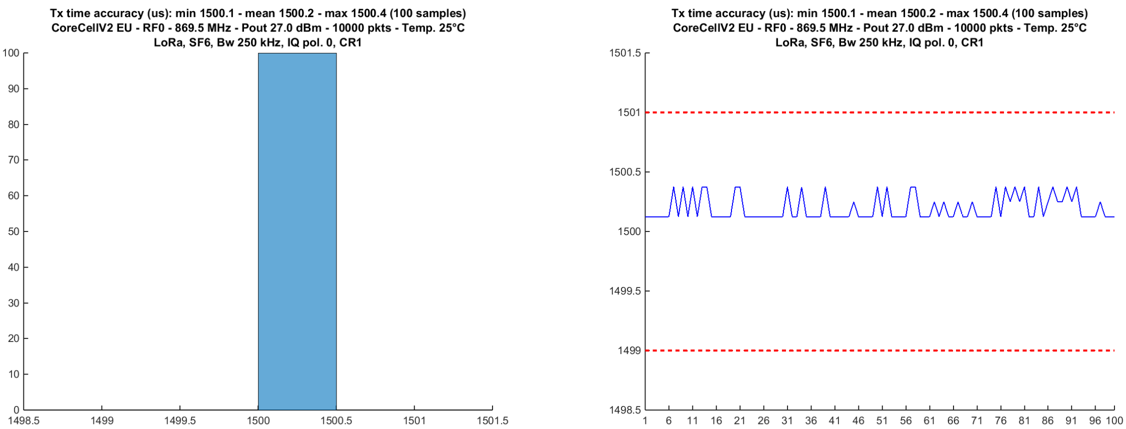
9.4.1 SF5



(a) Histogram (b) Samples

Figure 9.10: Beacon emission time accuracy, BW 250 kHz, SF5, Ambient temperature

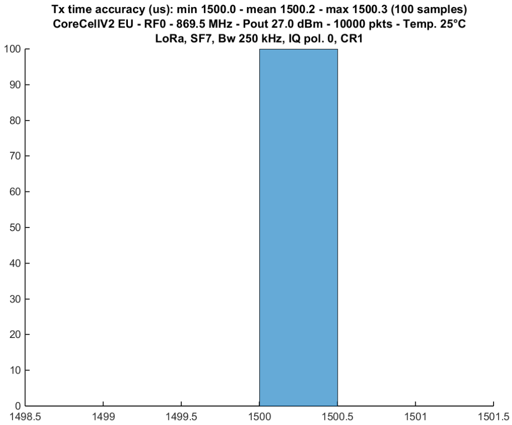
9.4.2 SF6



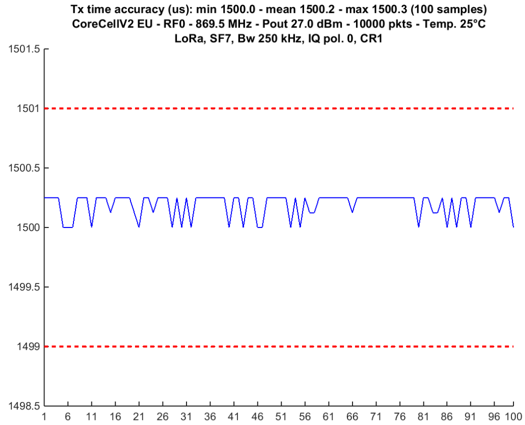
(a) Histogram (b) Samples

Figure 9.11: Beacon emission time accuracy, BW 250 kHz, SF6, Ambient temperature

9.4.3 SF7



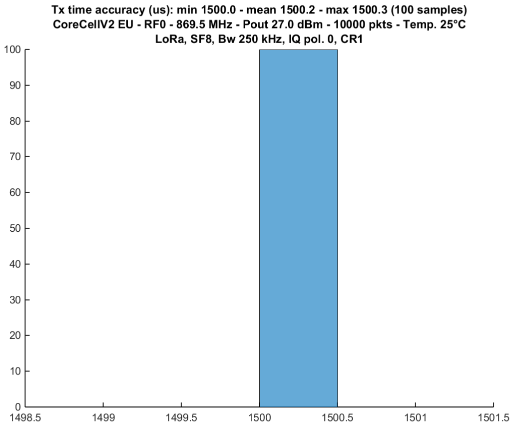
(a) Histogram



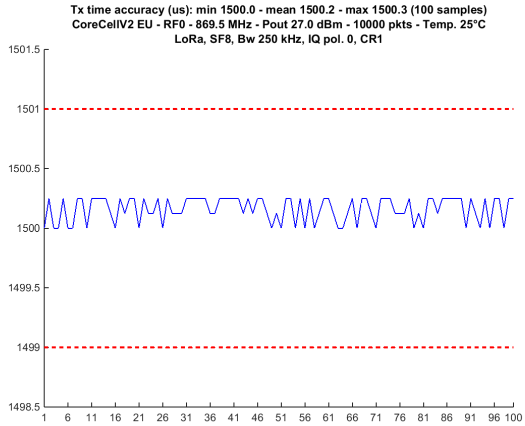
(b) Samples

Figure 9.12: Beacon emission time accuracy, BW 250 kHz, SF7, Ambient temperature

9.4.4 SF8



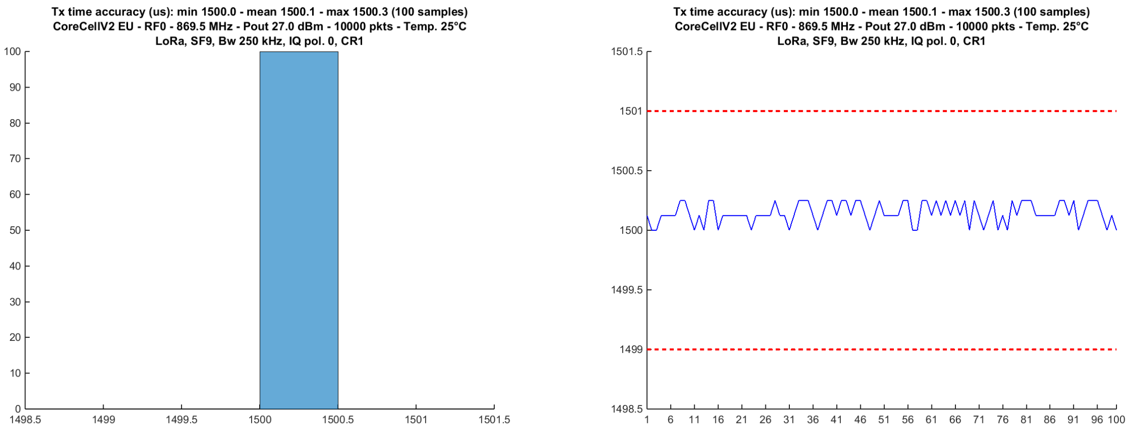
(a) Histogram



(b) Samples

Figure 9.13: Beacon emission time accuracy, BW 250 kHz, SF8, Ambient temperature

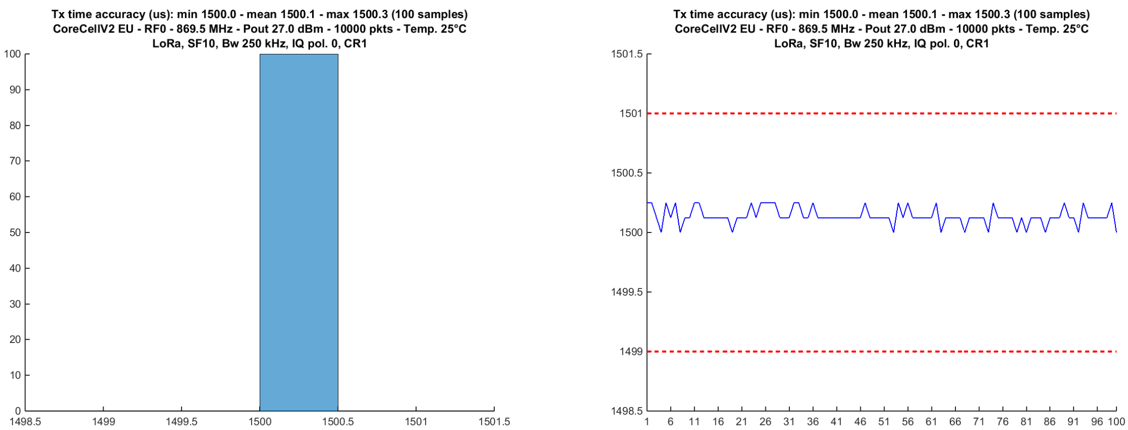
9.4.5 SF9



(a) Histogram (b) Samples

Figure 9.14: Beacon emission time accuracy, BW 250 kHz, SF9, Ambient temperature

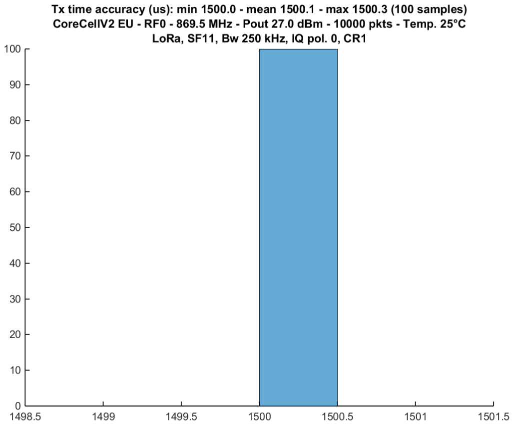
9.4.6 SF10



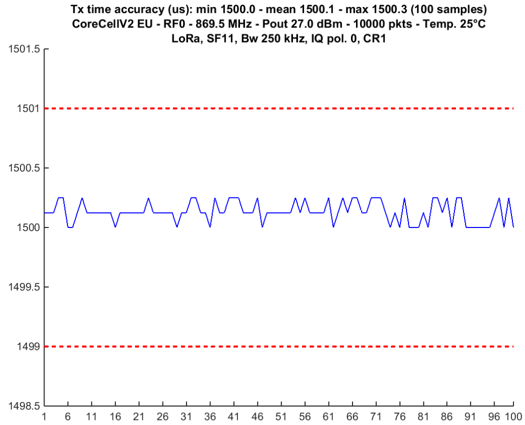
(a) Histogram (b) Samples

Figure 9.15: Beacon emission time accuracy, BW 250 kHz, SF10, Ambient temperature

9.4.7 SF11



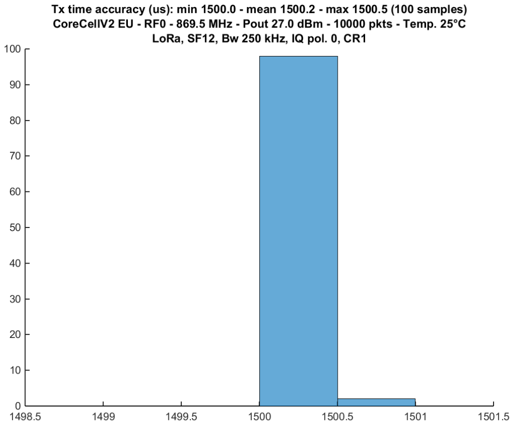
(a) Histogram



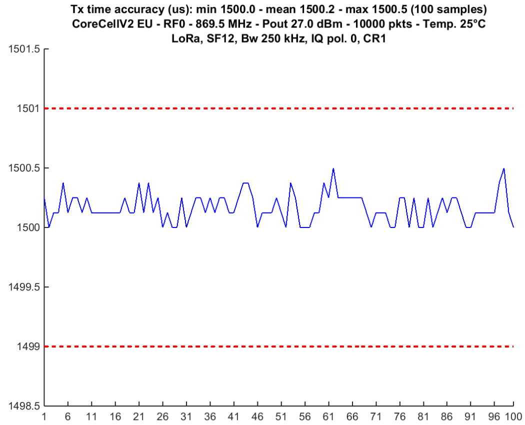
(b) Samples

Figure 9.16: Beacon emission time accuracy, BW 250 kHz, SF11, Ambient temperature

9.4.8 SF12



(a) Histogram

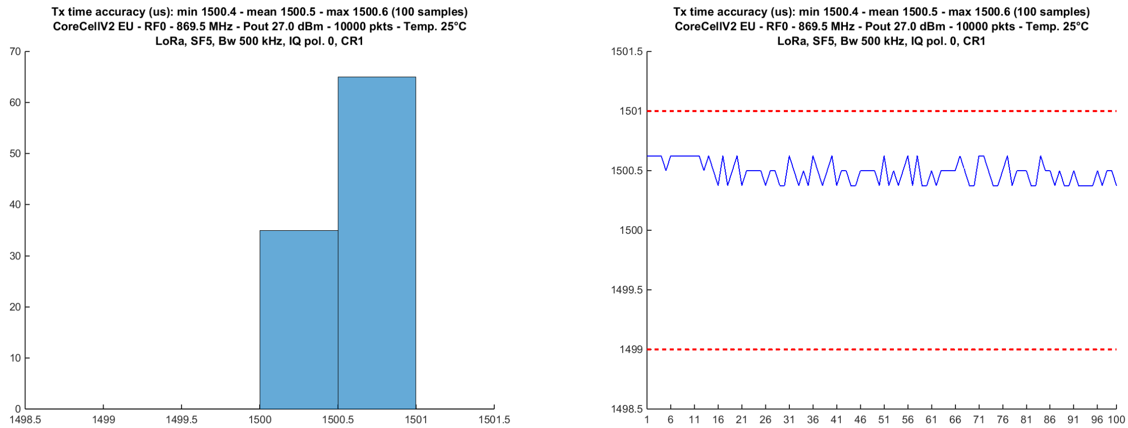


(b) Samples

Figure 9.17: Beacon emission time accuracy, BW 250 kHz, SF12, Ambient temperature

9.5 Bandwidth 500 kHz

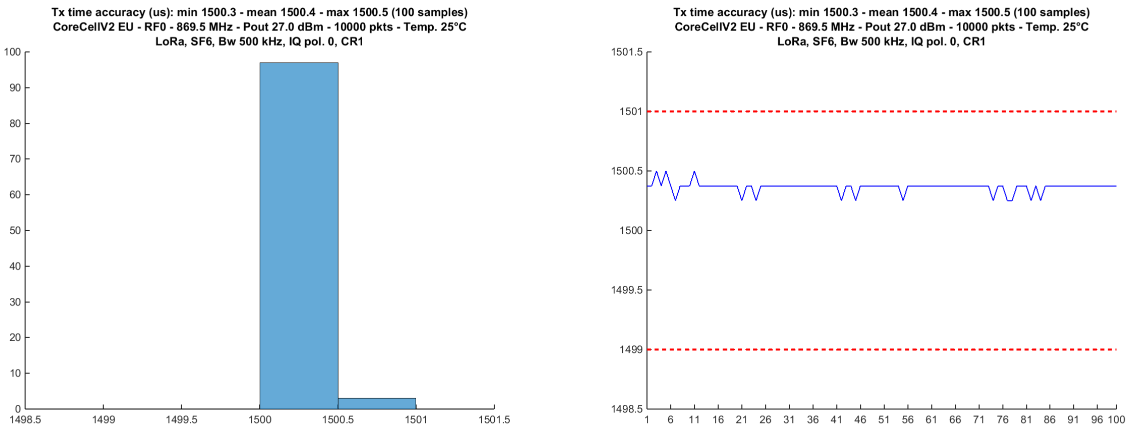
9.5.1 SF5



(a) Histogram (b) Samples

Figure 9.18: Beacon emission time accuracy, BW 500 kHz, SF5, Ambient temperature

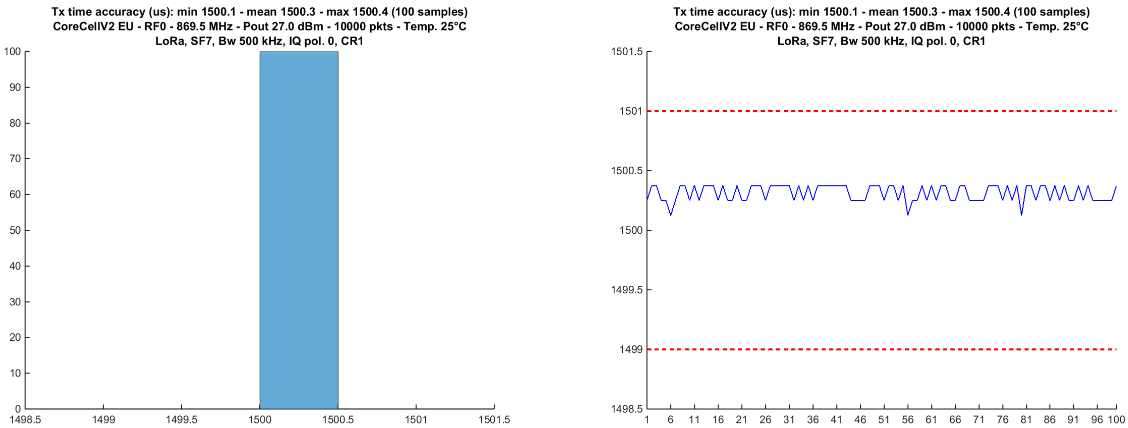
9.5.2 SF6



(a) Histogram (b) Samples

Figure 9.19: Beacon emission time accuracy, BW 500 kHz, SF6, Ambient temperature

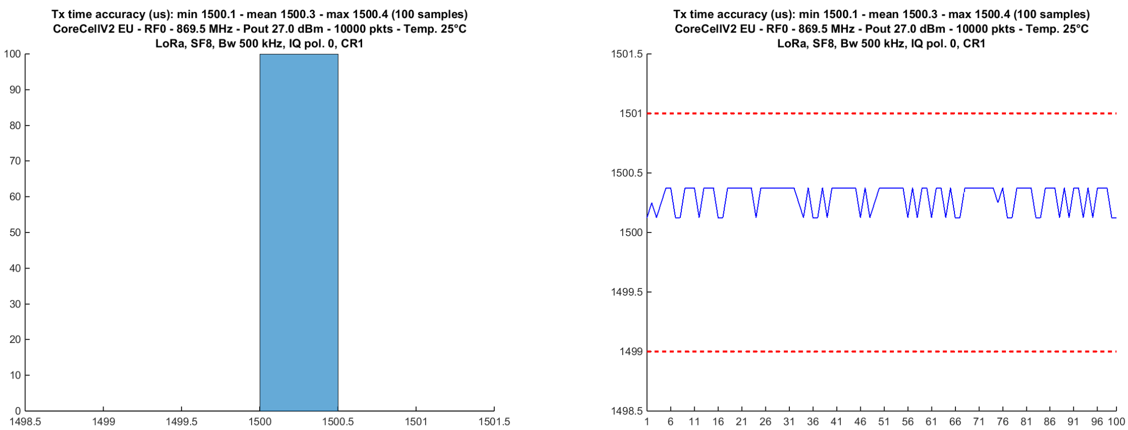
9.5.3 SF7



(a) Histogram (b) Samples

Figure 9.20: Beacon emission time accuracy, BW 500 kHz, SF7, Ambient temperature

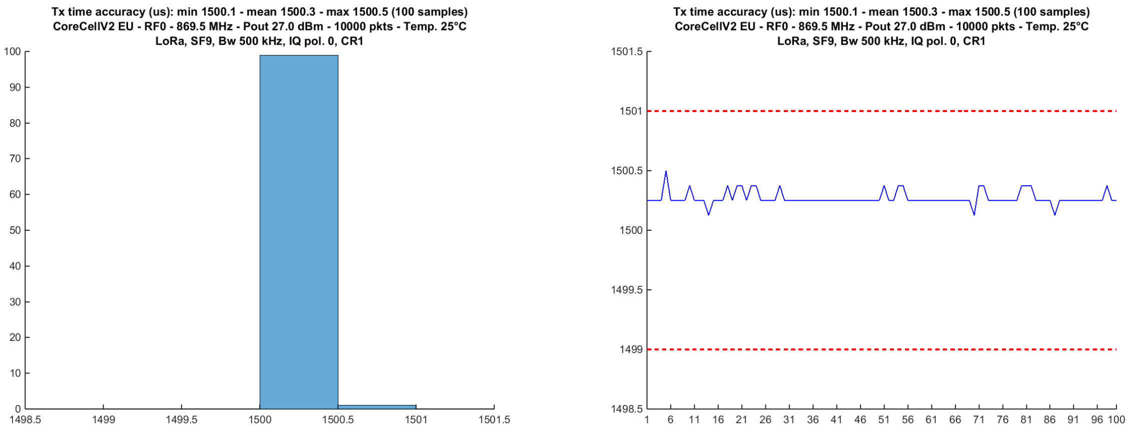
9.5.4 SF8



(a) Histogram (b) Samples

Figure 9.21: Beacon emission time accuracy, BW 500 kHz, SF8, Ambient temperature

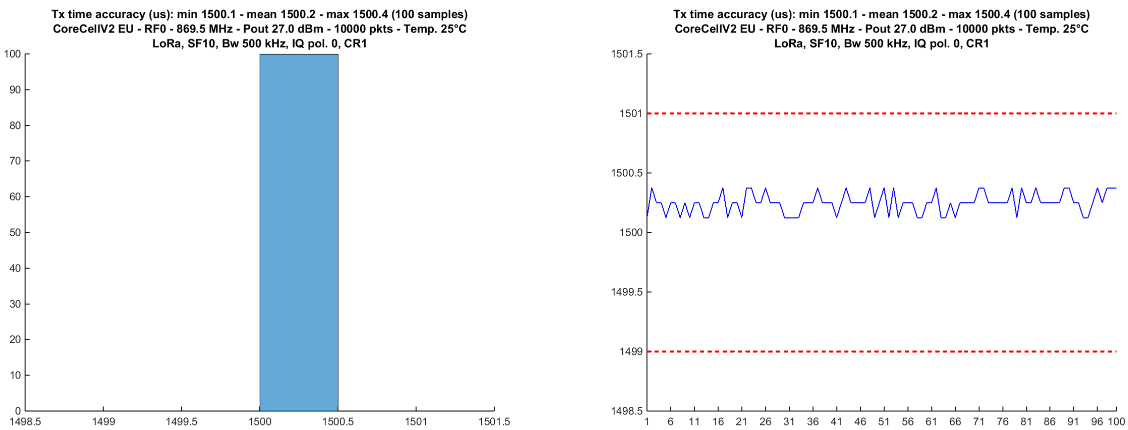
9.5.5 SF9



(a) Histogram (b) Samples

Figure 9.22: Beacon emission time accuracy, BW 500 kHz, SF9, Ambient temperature

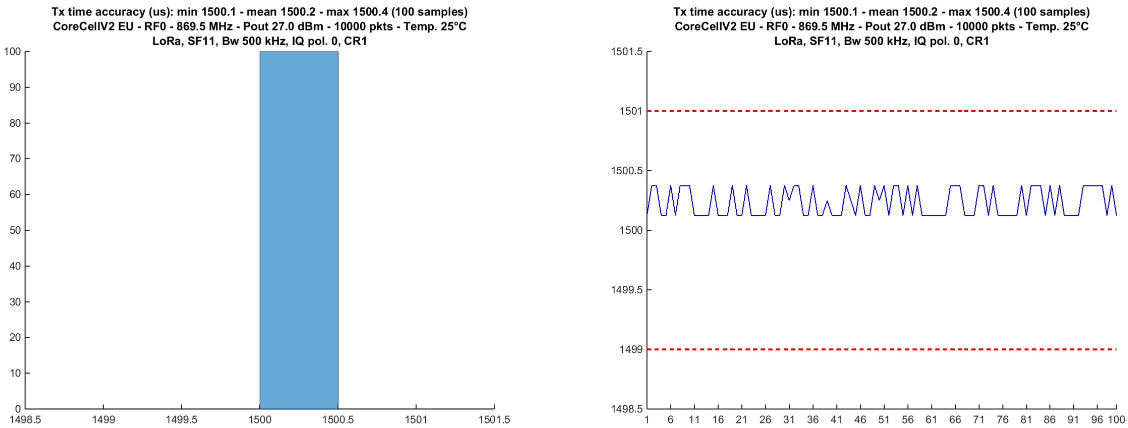
9.5.6 SF10



(a) Histogram (b) Samples

Figure 9.23: Beacon emission time accuracy, BW 500 kHz, SF10, Ambient temperature

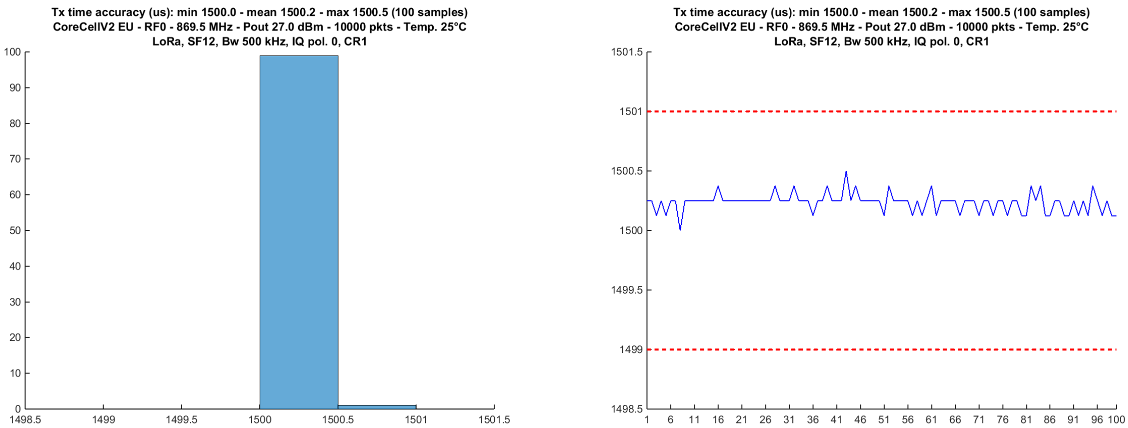
9.5.7 SF11



(a) Histogram (b) Samples

Figure 9.24: Beacon emission time accuracy, BW 500 kHz, SF11, Ambient temperature

9.5.8 SF12



(a) Histogram (b) Samples

Figure 9.25: Beacon emission time accuracy, BW 500 kHz, SF12, Ambient temperature

Part III

Receiver

10 Sensitivity level and PER

10.1 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 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.

In case of full duplexing, the sensitivity level shall be determined while transmitting simultaneously packets with the highest output power in order to evaluate the impact of any transient caused by the ramp up/down of the power amplifier on the packets reception. So, the sensitivity level and the PER are observed while transmitting thousands LoRa packets with a short delay between them

10.2 Setup

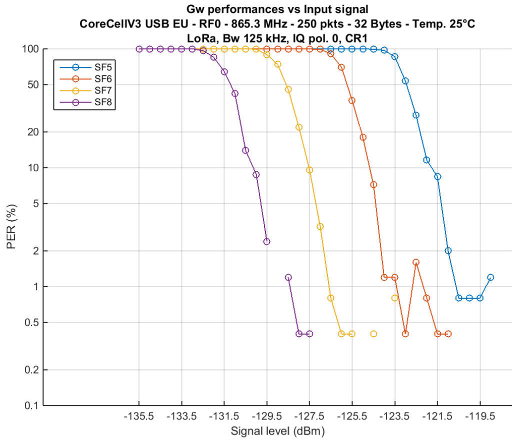
The sensitivity measurement setup is shown in figure 2.2. Only one signal generator is used here, the output of the second one is OFF. It generates LoRa packets toward the DUT for several output powers and frequencies. The effect of impedance mismatch is mitigated by the use of attenuators at the power splitter inputs.

The **packet forwarder** software running on the RPI3 pulls data from the SX1302 by SPI bus and send them to the computer through UDP protocol.

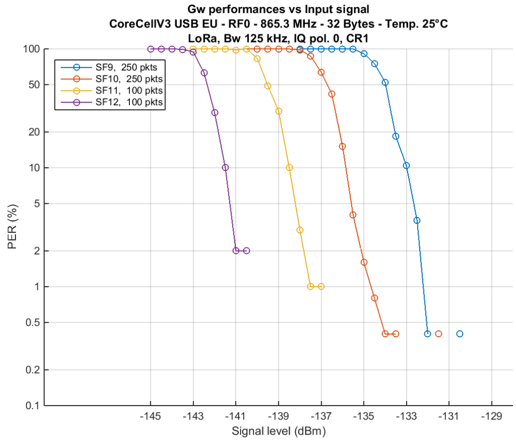
10.3 MultiSF modem versus Spreading Factor

Note: Sync word is set to 0x12 for SF5 and SF6 and 0x34 for all others SF. Furthermore, the number of preamble symbols is set to 8 whatever the SF.

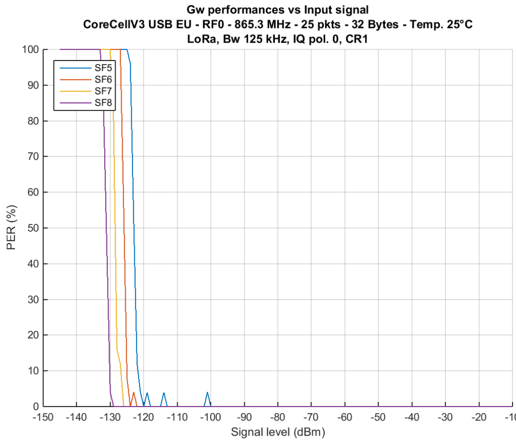
10.3.1 Ambient temperature



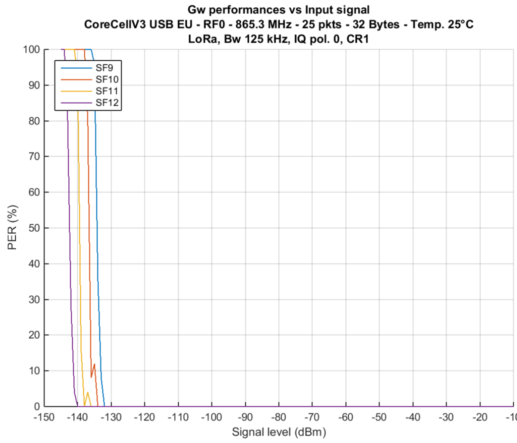
(a) Sensitivity level



(b) Sensitivity level



(c) High level

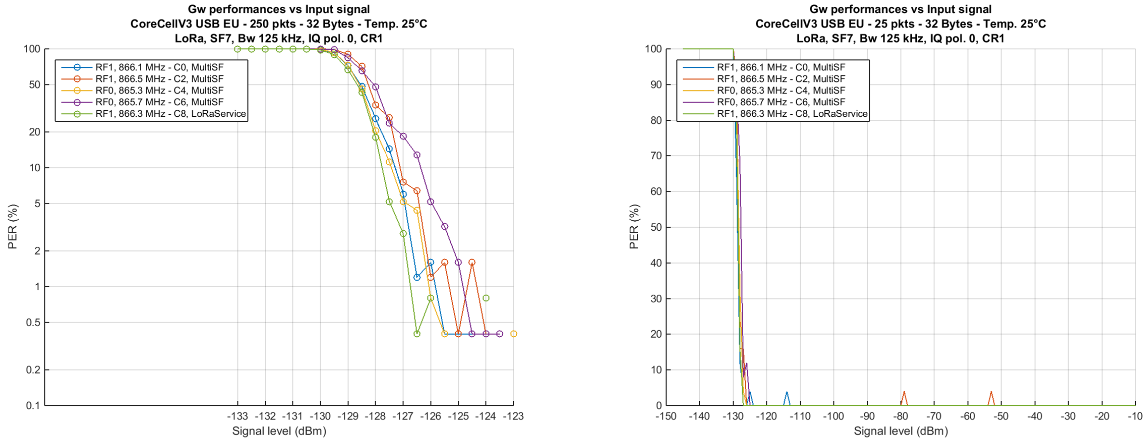


(d) High level

Figure 10.1: Sensitivity level and PER, MultiSF 125 kHz modem vs SF, 865.3 MHz, Ambient temperature

10.4 MultiSF and SingleSF modems versus channels

10.4.1 Ambient temperature

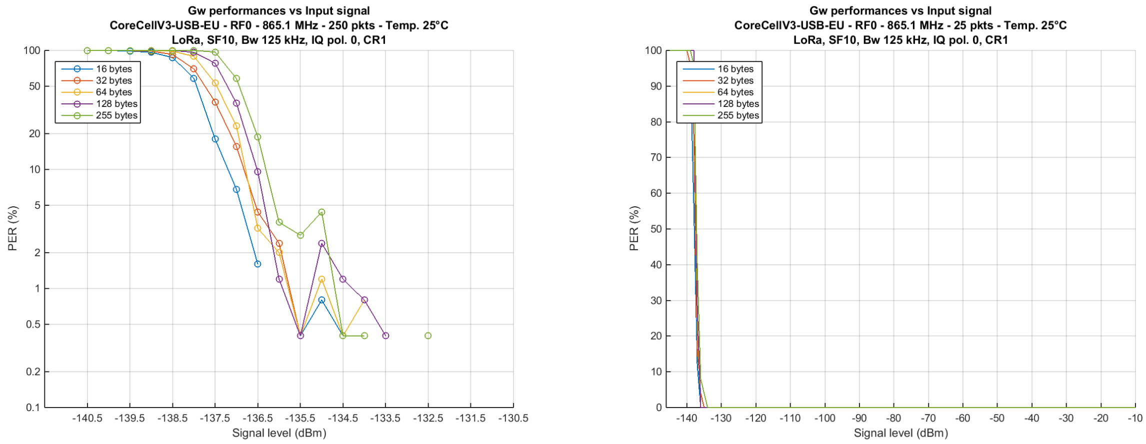


(a) Sensitivity level

(b) High level

Figure 10.2: Sensitivity level and PER, MultiSF and SingleSF modems versus channels, SF7, Bw 125 kHz

10.5 MultiSF modem versus payload size

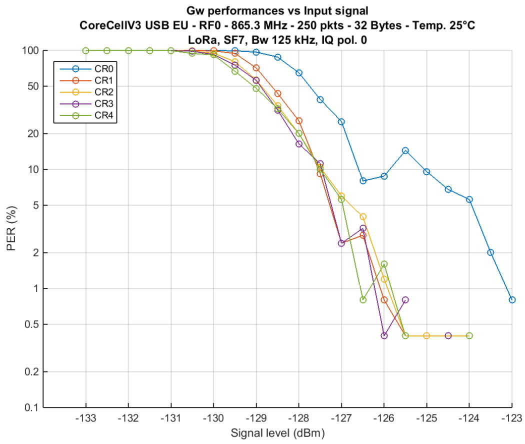


(a) Sensitivity level

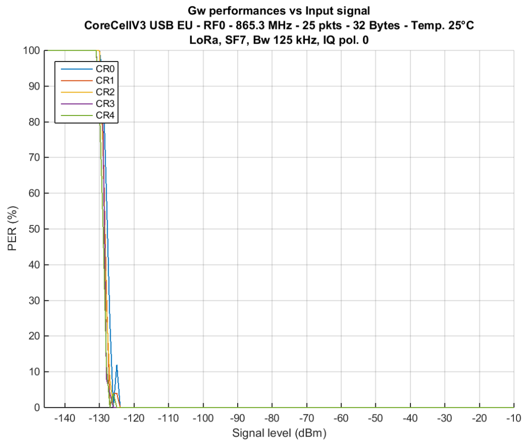
(b) High level

Figure 10.3: Sensitivity level and PER, MultiSF modems vs Payload size, 865.1 MHz, SF10

10.6 MultiSF modem versus coding rate



(a) Sensitivity level

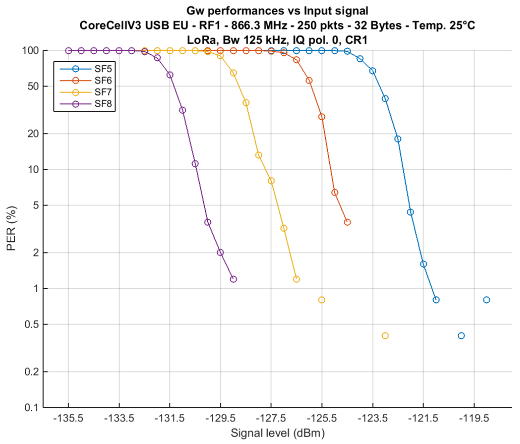


(b) High level

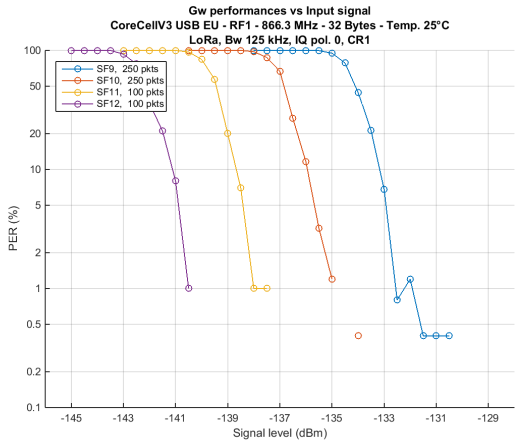
Figure 10.4: Sensitivity level and PER, MultiSF modem versus coding rate, 865.3 MHz, SF7

→ **Not using Coding Rate in LoRa frame is not recommended and will not anymore be supported in future version of HAL**

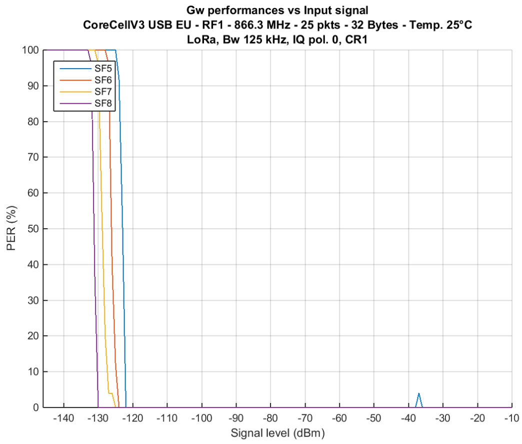
10.7 SingleSF modem vs Spreading factor BW 125kHz



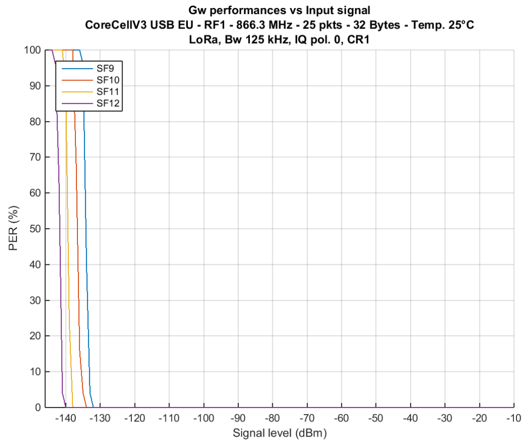
(a) Sensitivity level



(b) Sensitivity level



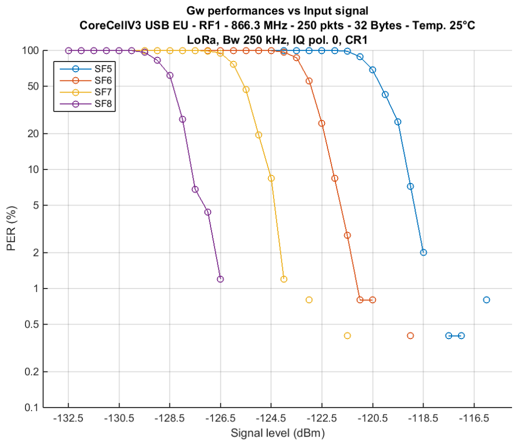
(c) High level



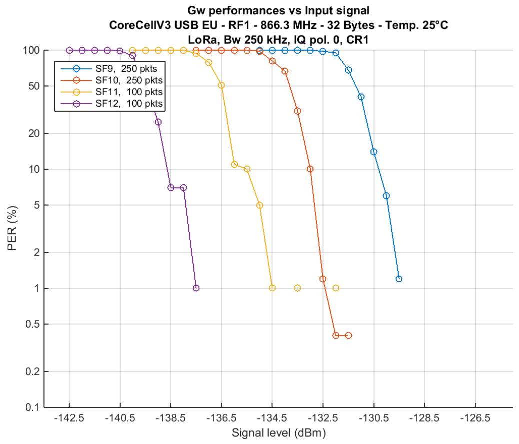
(d) High level

Figure 10.5: Sensitivity level and PER, SingleSF modems vs SF BW 125kHz, 866.3 MHz

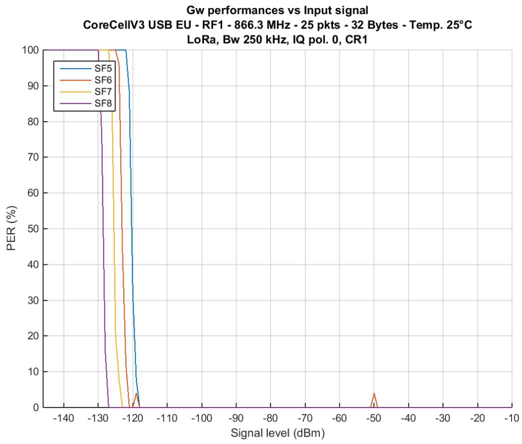
10.8 SingleSF modem vs Spreading factor BW 250kHz



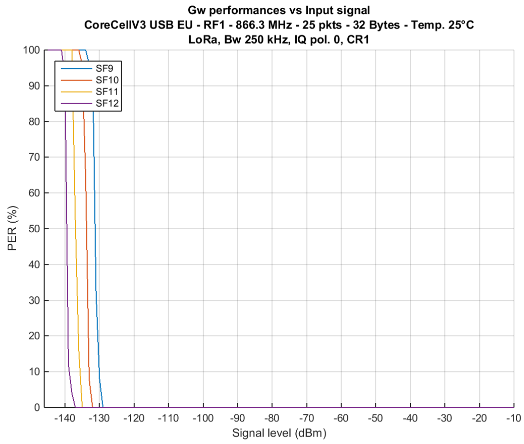
(a) Sensitivity level



(b) Sensitivity level



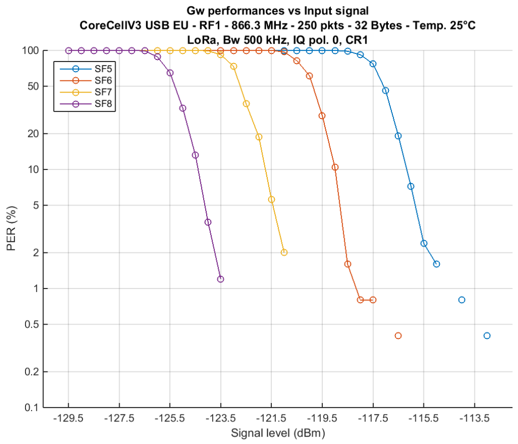
(c) High level



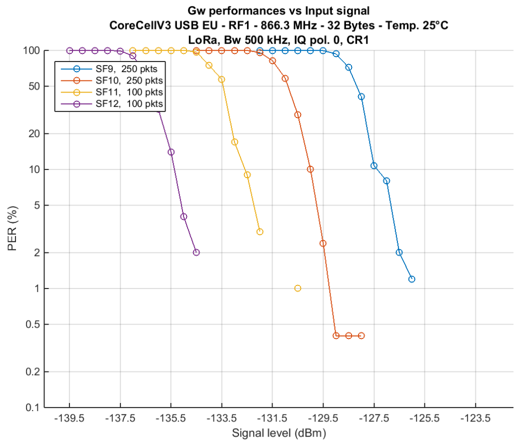
(d) High level

Figure 10.6: Sensitivity level and PER, SingleSF modems vs SF BW 250kHz, 866.3 MHz

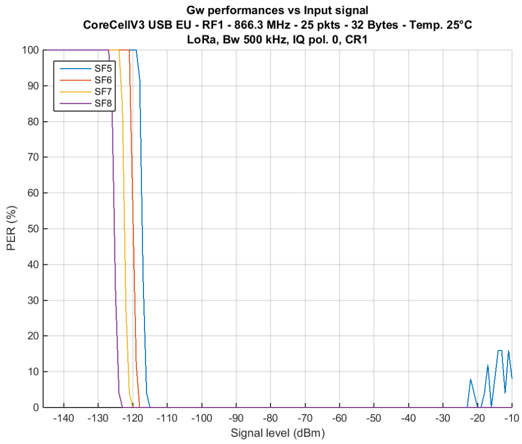
10.9 SingleSF modem vs Spreading factor BW 500kHz



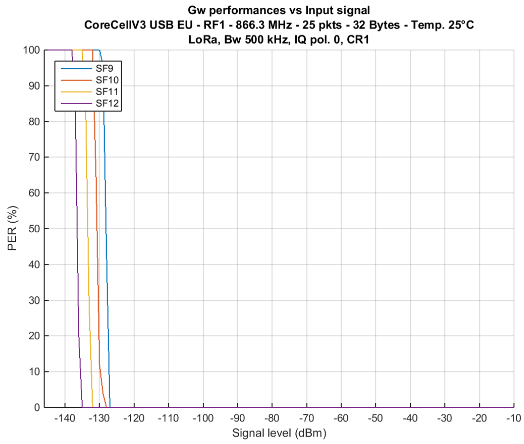
(a) Sensitivity level



(b) Sensitivity level



(c) High level

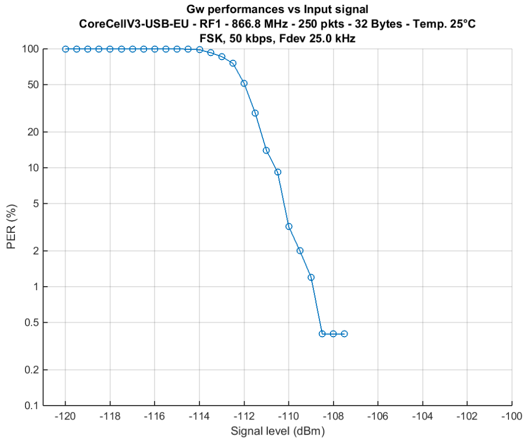


(d) High level

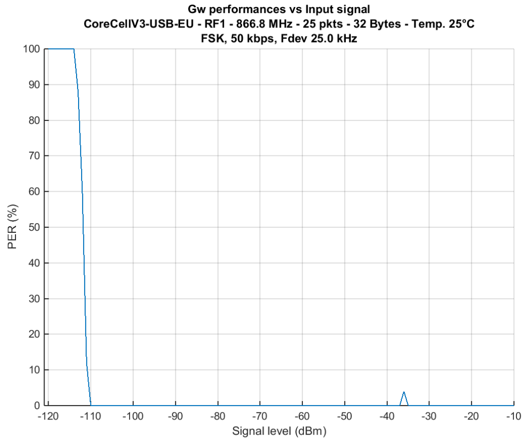
Figure 10.7: Sensitivity level and PER, SingleSF modems vs SF BW 500kHz, 866.3 MHz

10.10 FSK modem

10.10.1 Ambient temperature



(a) Sensitivity level



(b) High level

Figure 10.8: Sensitivity level and PER, FSK modem, RF1, 866.8 MHz, Ambient temperature

11 RSSI

11.1 Description

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

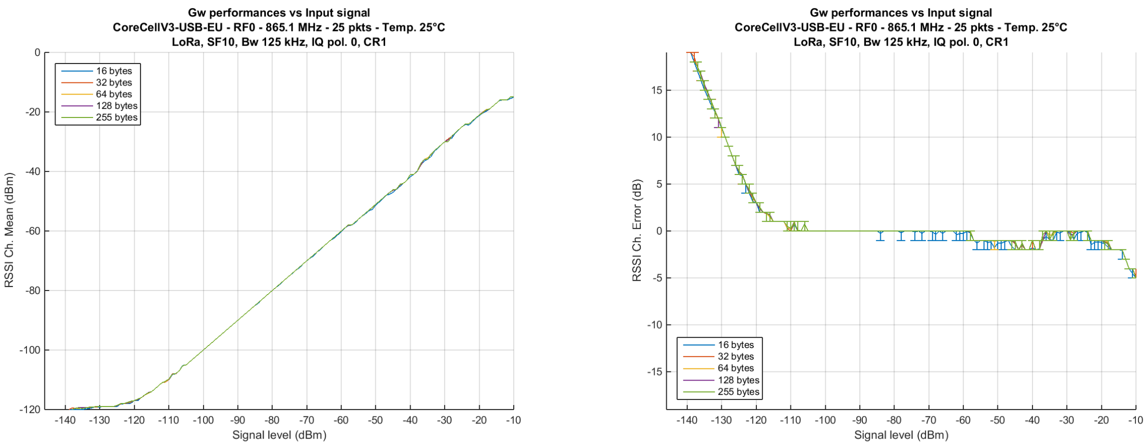
- RSSI Channel: This indicator represents the power in the channel bandwidth, taken care the power of signal and the thermal noise. It concerns LoRa and FSK modulation.
- RSSI Signal: This indicator represents the LoRa signal only without taken care the thermal noise power. It only concerns the LoRa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

11.2 Setup

The RSSI measurement is performed simultaneously of the PER one. The setup is shown in figure 2.2. 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 SX1302 prototype by SPI bus and send them to the computer through UDP protocol.

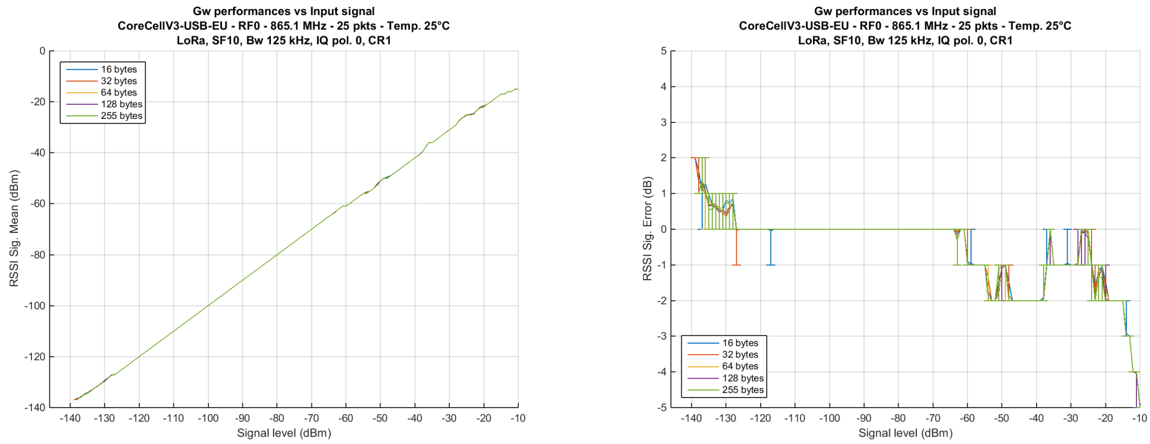
11.3 MultiSF modem versus payload size



(a) RSSI Channel mean

(b) RSSI Channel error

Figure 11.1: RSSI Channel, MultiSF modems versus payload size, SF10, Ambient temperature

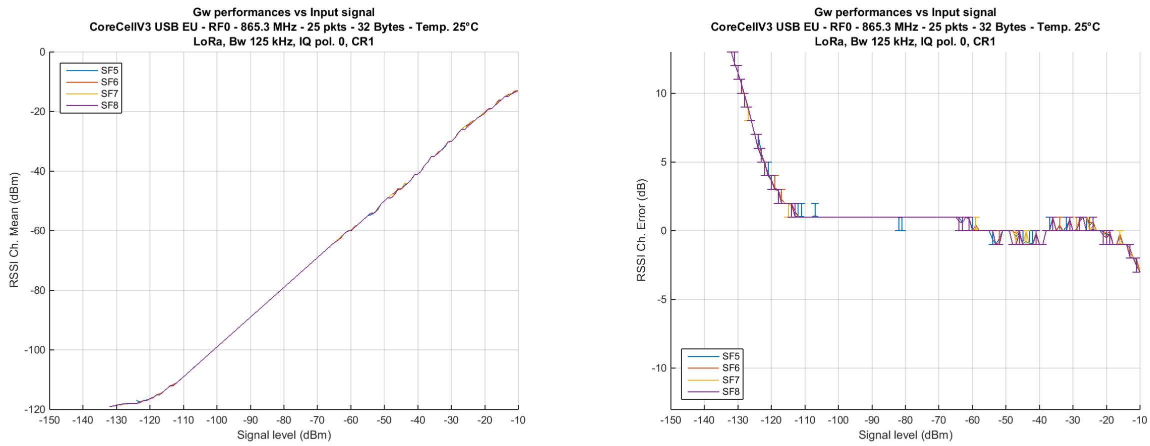


(a) RSSI Signal mean (b) RSSI Signal error

Figure 11.2: RSSI Signal, MultiSF modems versus payload size, SF10, Ambient temperature

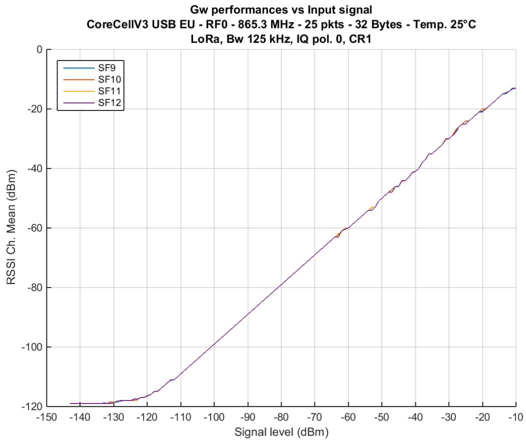
11.4 MultiSF modem versus Spreading Factor

11.4.1 Ambient temperature

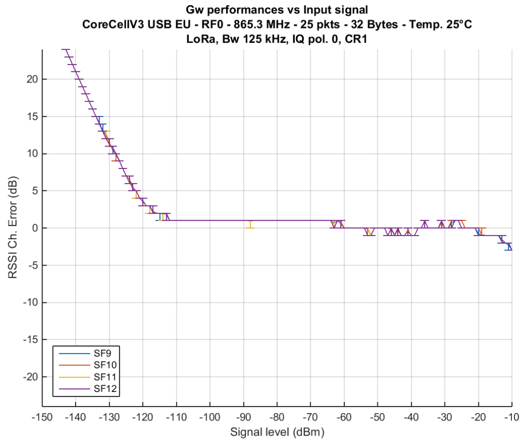


(a) RSSI Channel mean (b) RSSI Channel error

Figure 11.3: RSSI Channel, MultiSF modem vs Spreading factors, 865.3 MHz, Ambient temperature

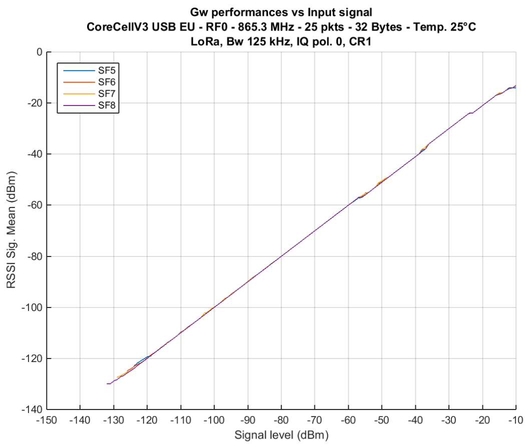


(a) RSSI Signal mean

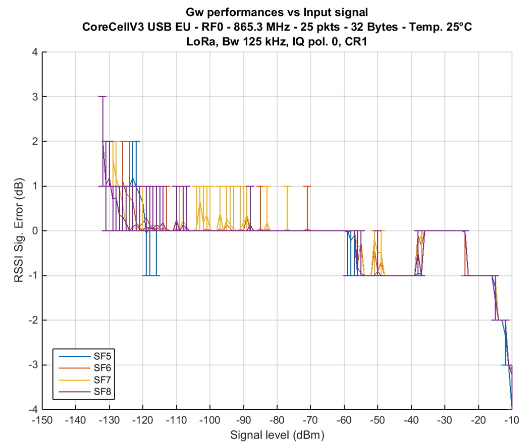


(b) RSSI Signal error

Figure 11.4: RSSI Channel, MultiSF modem vs Spreading factors, 865.3 MHz

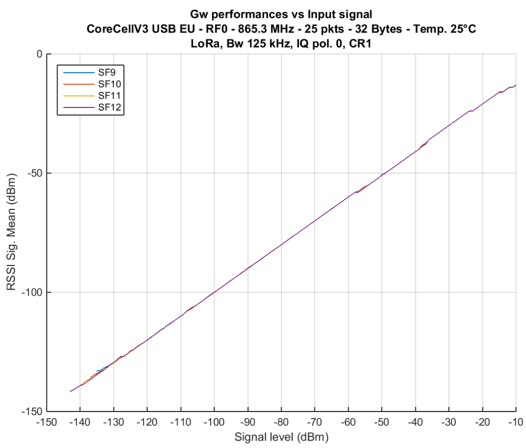


(a) RSSI Signal mean

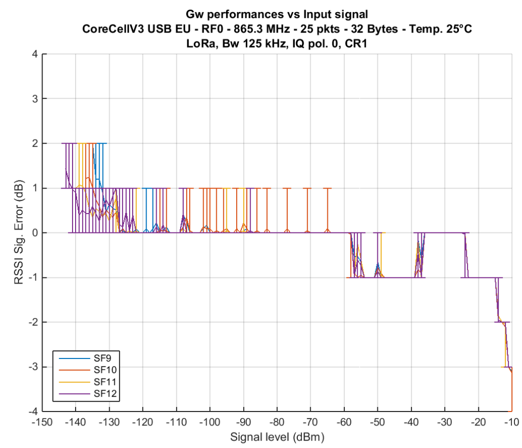


(b) RSSI Signal error

Figure 11.5: RSSI Signal, MultiSF modem vs Spreading factors, 865.3 MHz



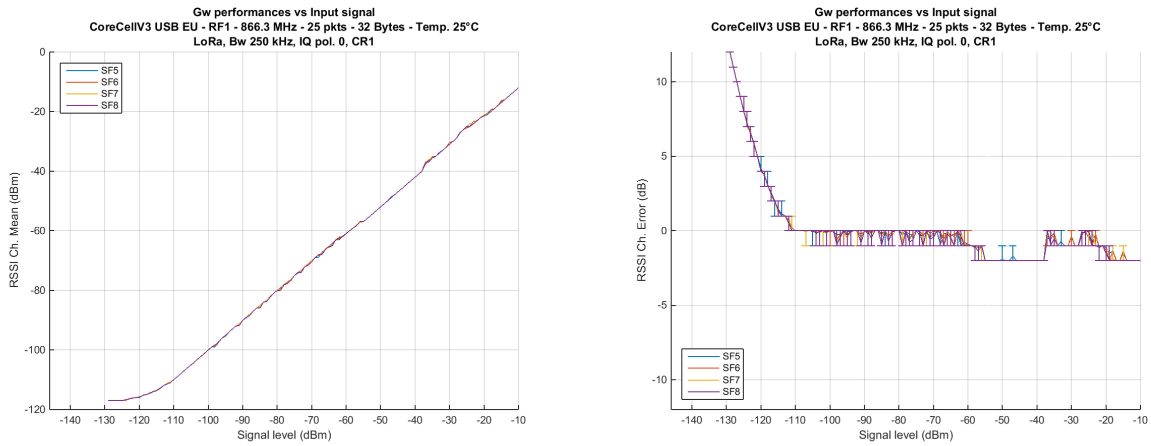
(a) RSSI Signal mean



(b) RSSI Signal error

Figure 11.6: RSSI Signal, MultiSF modem vs Spreading factors, 865.3 MHz

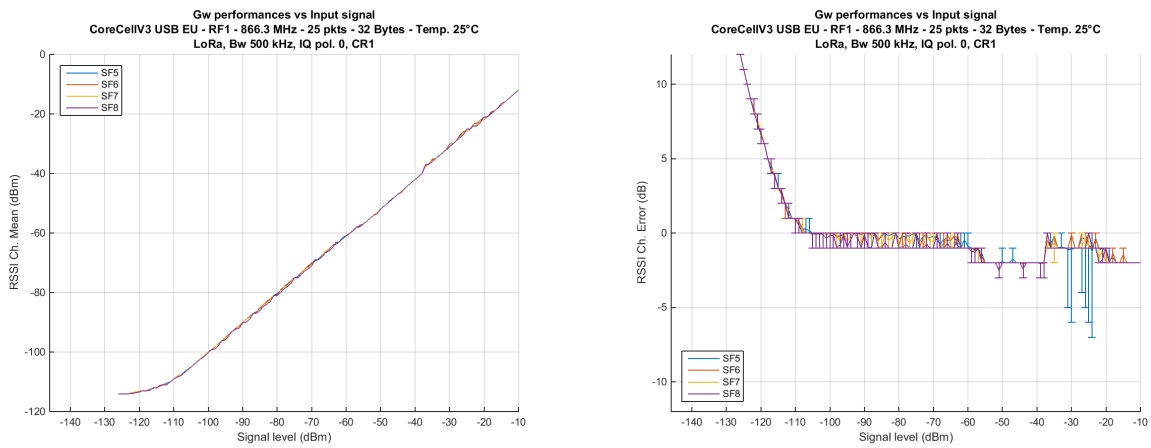
11.5 SingleSF modem BW 250 kHz



(a) RSSI Channel mean (b) RSSI Channel error

Figure 11.7: RSSI Channel, SingleSF modem, 866.3 MHz, Bw 250 kHz

11.6 SingleSF modem BW 500 kHz

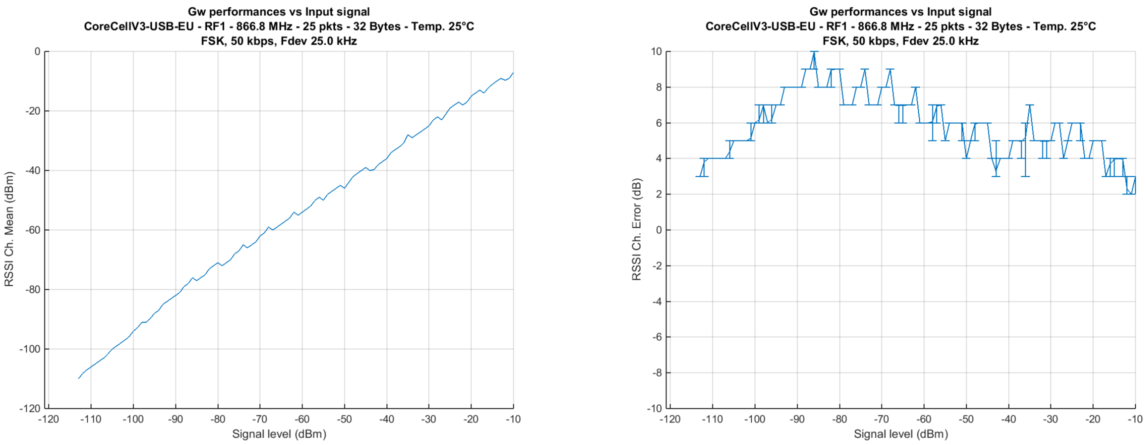


(a) RSSI Channel mean (b) RSSI Channel error

Figure 11.8: RSSI Channel, SingleSF modem, 866.3 MHz, Bw 500 kHz

11.7 FSK modem

11.7.1 Ambient temperature



(a) RSSI Channel mean (b) RSSI Channel error

Figure 11.9: RSSI Channel, FSK modem, RF1, 866.8 MHz, Ambient temperature

12 SNR

12.1 Presentation

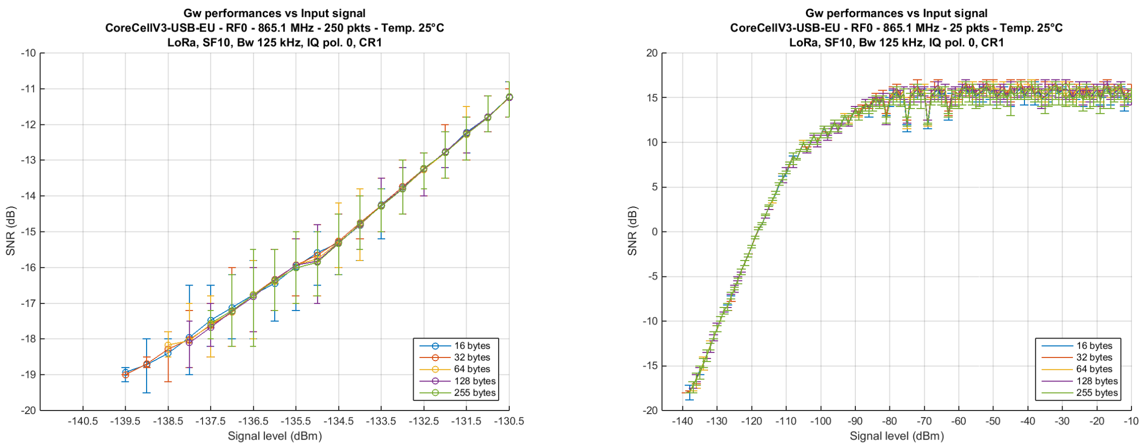
In conjunction with the RSSI value, the LoRa modem determines the Signal-To-Noise Ratio while receiving packets. This test verifies the accuracy of this indicators whatever the SF, the bandwidth, the payload length and its content.

12.2 Setup

The SNR is measured using the setup presented in the figure 2.2 (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.

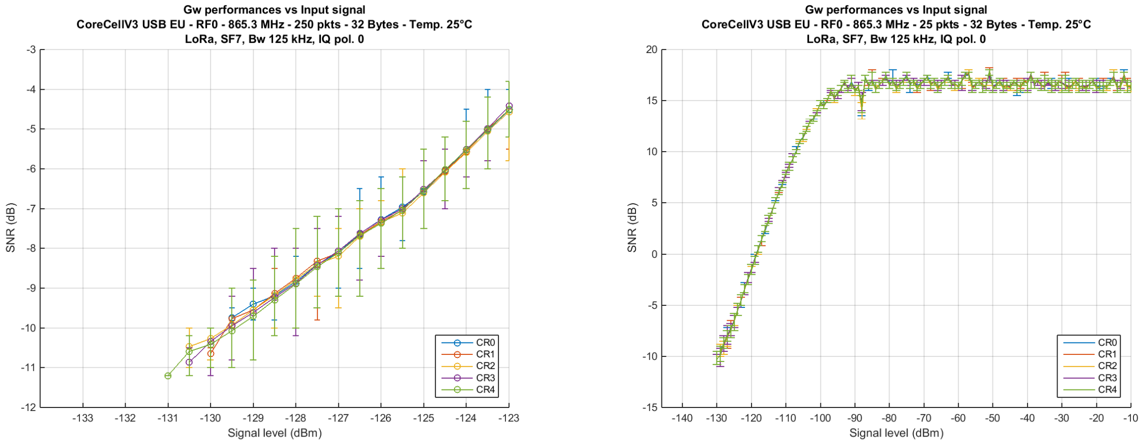
12.3 MultiSF modem versus payload size



(a) Sensitivity level (b) High level

Figure 12.1: SNR, MultiSF modems versus payload size, SF10

12.4 MultiSF modem versus coding rate

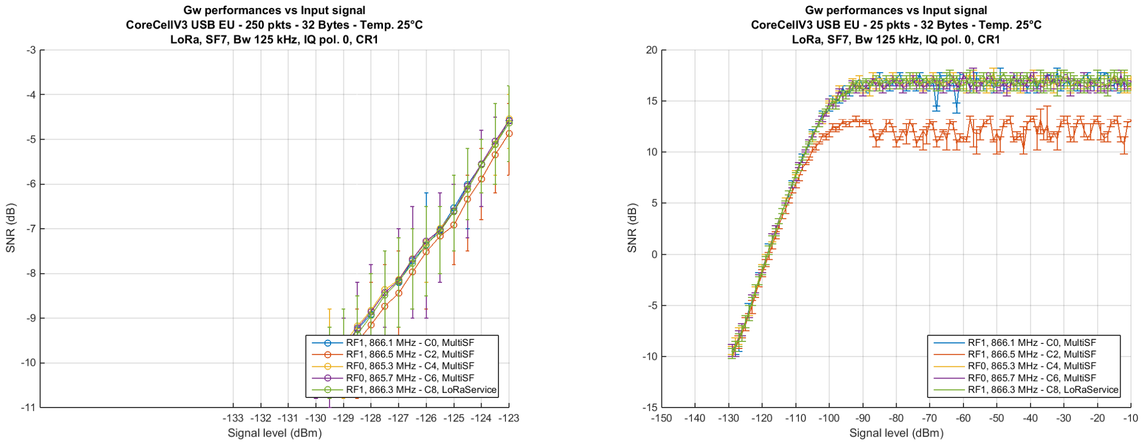


(a) Sensitivity level (b) High level

Figure 12.2: SNR, MultiSF modems versus coding rate, SF7, Ambient temperature

12.5 MultiSF and SingleSF modems versus channels

12.5.1 Ambient temperature

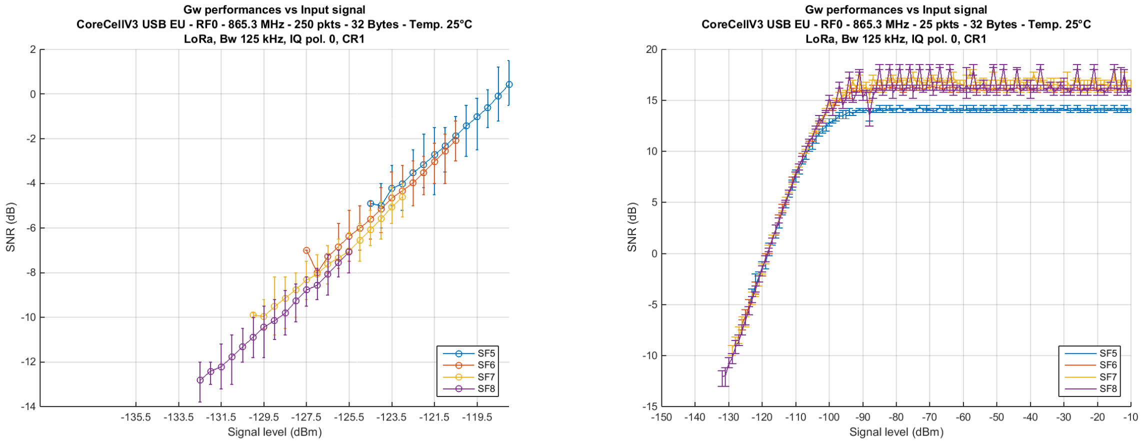


(a) Sensitivity level (b) High level

Figure 12.3: SNR, MultiSF modems versus channels, Ambient temperature

12.6 MultiSF modems versus Spreading Factor (5-8)

12.6.1 Ambient temperature

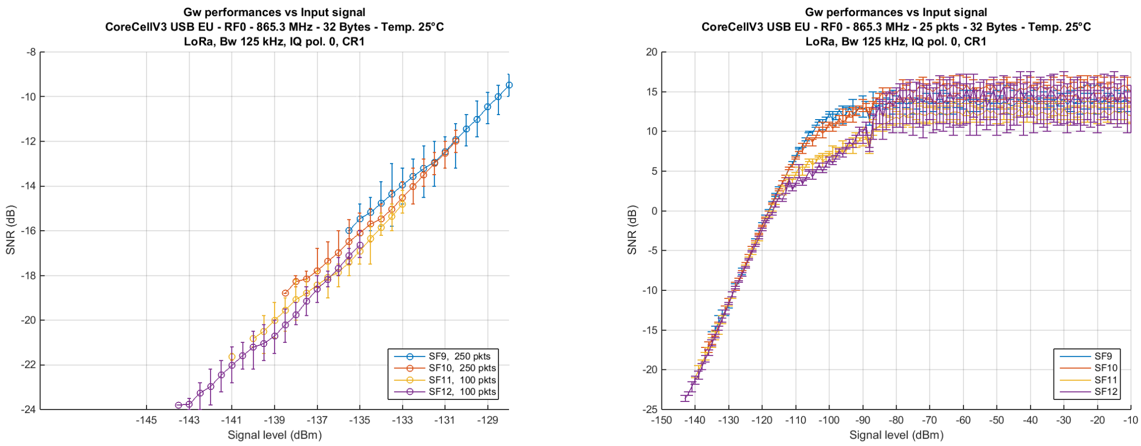


(a) Sensitivity level (b) High level

Figure 12.4: SNR, MultiSF modems versus Spreading Factor(5-8), Ambient temperature

12.7 MultiSF modems versus Spreading Factor (9-12)

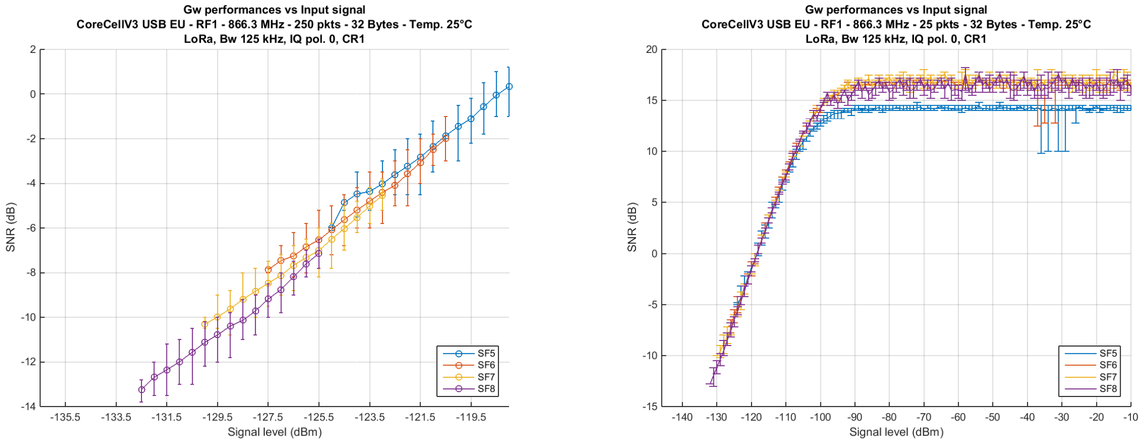
12.7.1 Ambient temperature



(a) Sensitivity level (b) High level

Figure 12.5: SNR, MultiSF modems versus Spreading Factor(9-12), Ambient temperature

12.8 SingleSF modem vs Spreading factor (5-8) 125kHz

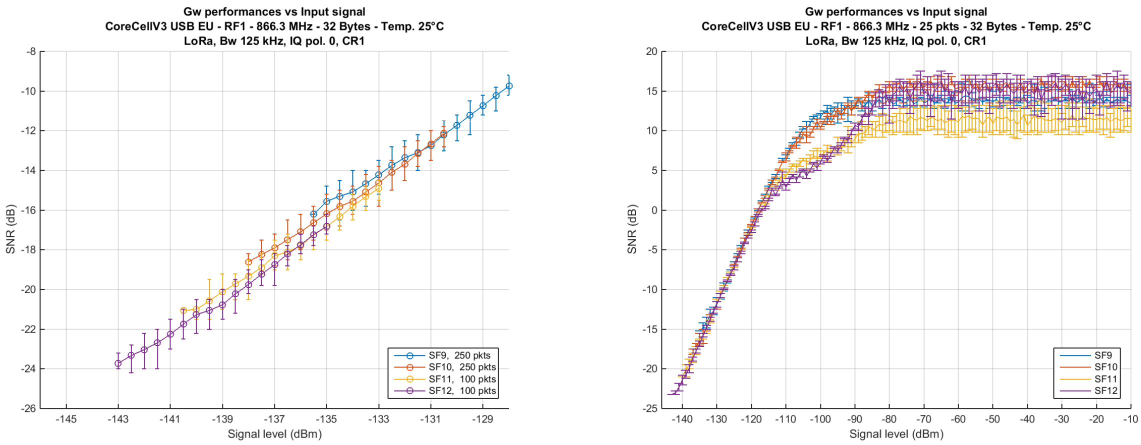


(a) Sensitivity level

(b) High level

Figure 12.6: SNR, SingleSF modem versus Spreading factors (5-8), Bw 125 kHz

12.9 SingleSF modem vs Spreading factor (9-12) 125kHz

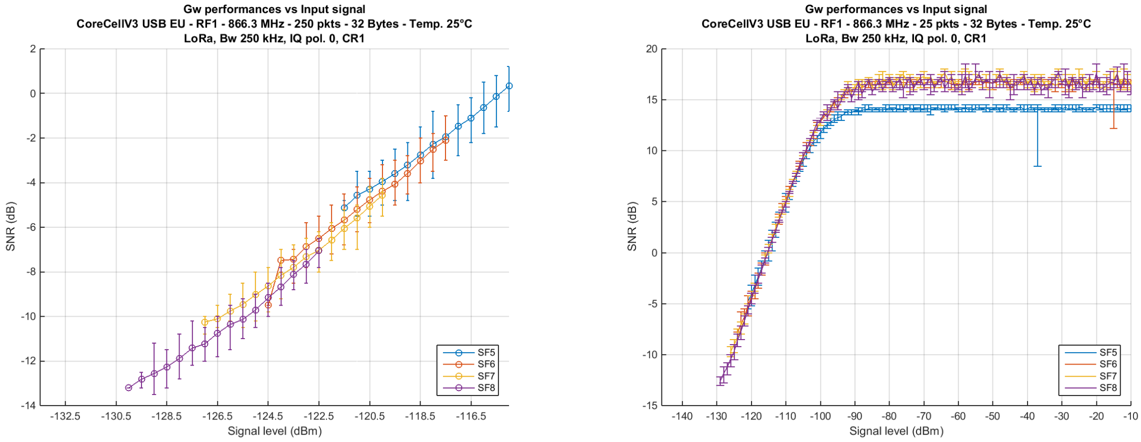


(a) Sensitivity level

(b) High level

Figure 12.7: SNR, SingleSF modem versus Spreading factors (9-12), Bw 125 kHz

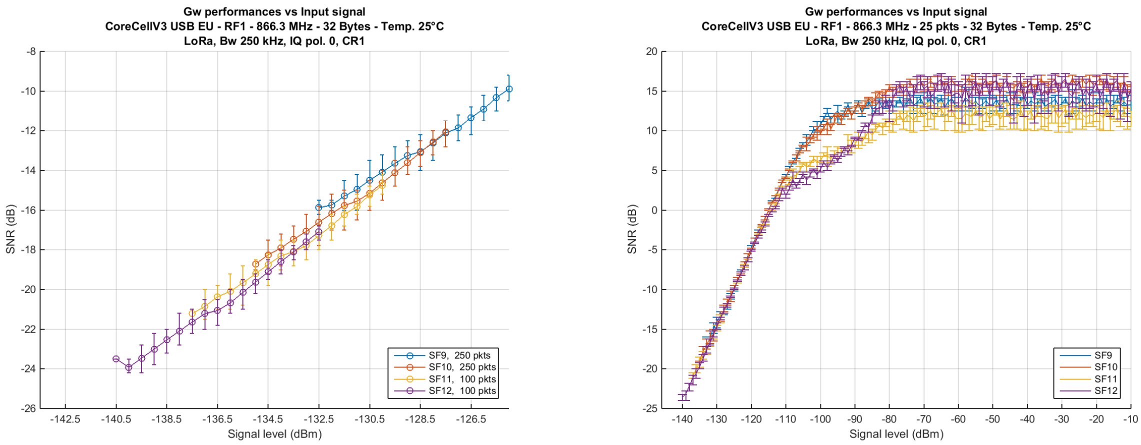
12.10 SingleSF modem vs Spreading factor (5-8) 250kHz



(a) Sensitivity level (b) High level

Figure 12.8: SNR, SingleSF modem versus Spreading factors(5-8), Bw 250 kHz

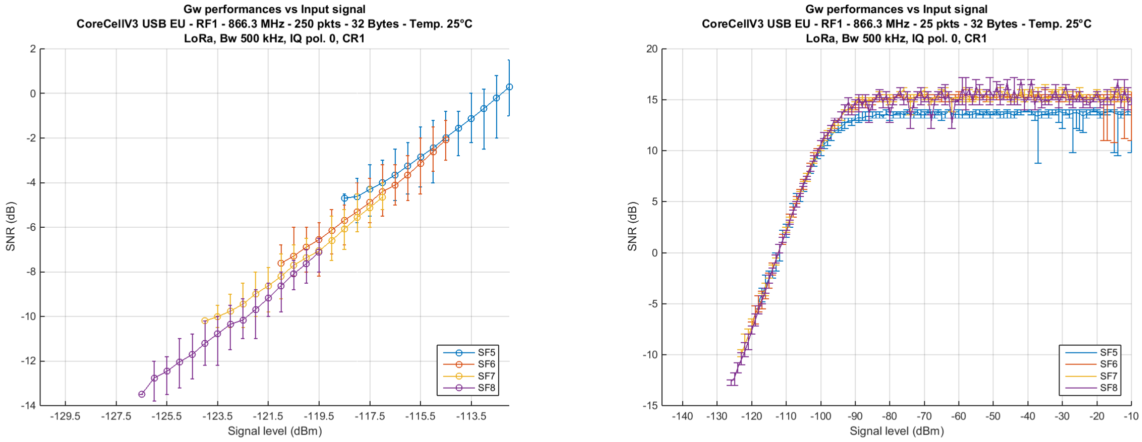
12.11 SingleSF modem vs Spreading factor (9-12) 250kHz



(a) Sensitivity level (b) High level

Figure 12.9: SNR, SingleSF modem versus Spreading factors(9-12), Bw 250 kHz

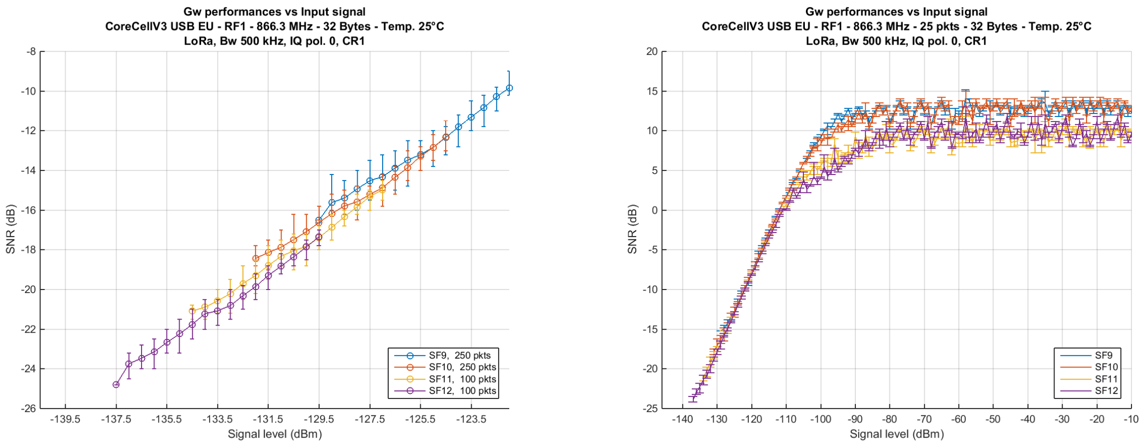
12.12 SingleSF modem vs Spreading factor (5-8) 500kHz



(a) Sensitivity level (b) High level

Figure 12.10: SNR, SingleSF modem versus Spreading factors (5-8), Bw 500 kHz

12.13 SingleSF modem vs Spreading factor (9-12) 500kHz



(a) Sensitivity level (b) High level

Figure 12.11: SNR, SingleSF modem versus Spreading factors (9-12), Bw 500 kHz

13 Blocking and Immunity to interferer

13.1 Description

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

13.2 Setup

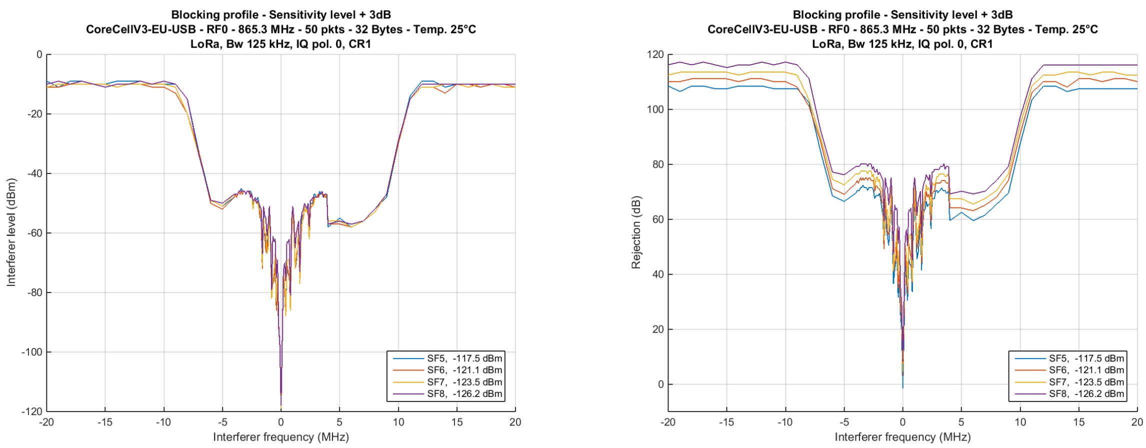
The test bench allowing to assess the coexistence robustness is shown in figure 2.2. Useful signal and interferer are combined in the power splitter/combiner. The attenuators allow to reduce the mutual interference between both signal generators.

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 i.e. -122 dBm for SF7 and -129.5 dBm for SF10. The PER measurement is done on 25 packets. The interferer level is adjusted automatically to cause a PER of 10%.

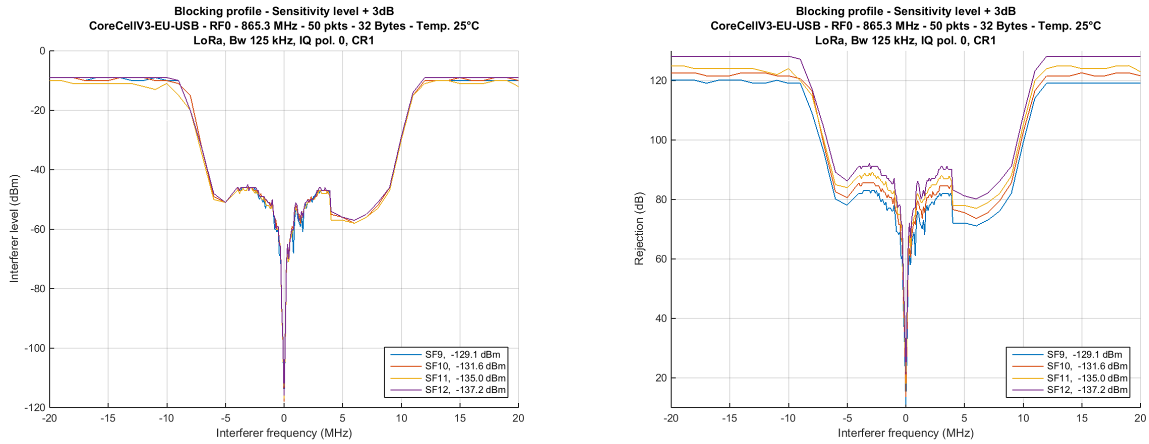
13.3 MultiSF modem versus Spreading Factor



(a) Interferer level (dBm)

(b) Rejection (dB)

Figure 13.1: Blocking profile, MultiSF modem versus Spreading Factor (5 to 8)

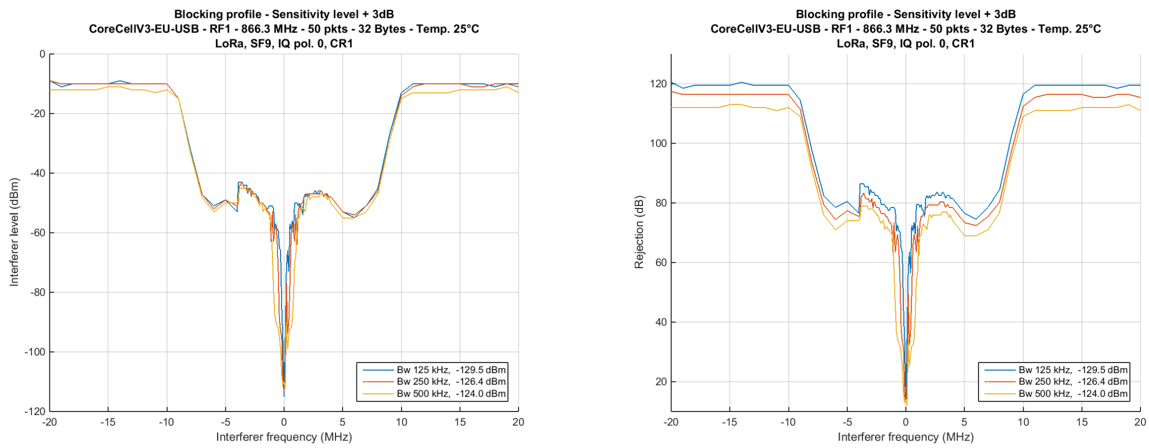


(a) Interferer level (dBm)

(b) Rejection (dB)

Figure 13.2: Blocking profile, MultiSF modem versus Spreading Factor (9 to 12)

13.4 SingleSF modem versus bandwidth



(a) Interferer level (dBm)

(b) Rejection (dB)

Figure 13.3: Blocking profile, SingleSF modem versus bandwidths, SF9, Sensitivity level + 3dB

14 Frequency error tolerance

14.1 Description

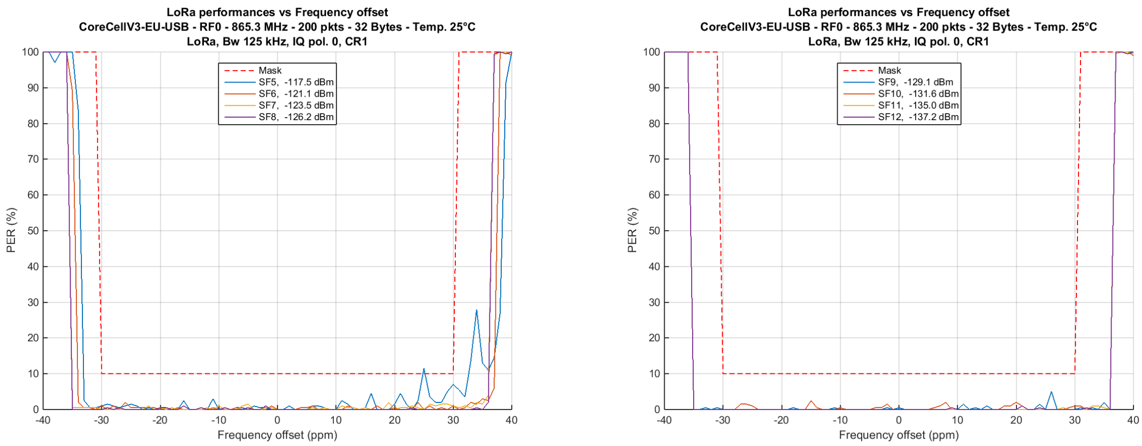
The LoRa modems present in the SX1302 base band processor are tolerant to an error on the transmitter reference clock frequency. This test evaluates the robustness of compensation mechanisms

14.2 Setup

The setup used for this measurement is shown in Figure 7.1. Only the direct path and the signal generator are used. In order to simulate the remote transmitter crystal imperfection, both the baseband and the RF frequencies shall be updated simultaneously with the evaluated error.

14.3 MultiSF modems versus Spreading Factor

14.3.1 Ambient temperature



(a) SF5 to SF8 (b) SF9 to SF12

Figure 14.1: Frequency error tolerance, MultiSF modems vs SF, RF0, 865.3 MHz, Ambient temperature

To be analyzed why mask has change b/w v1.1 report

14.4 FSK modem

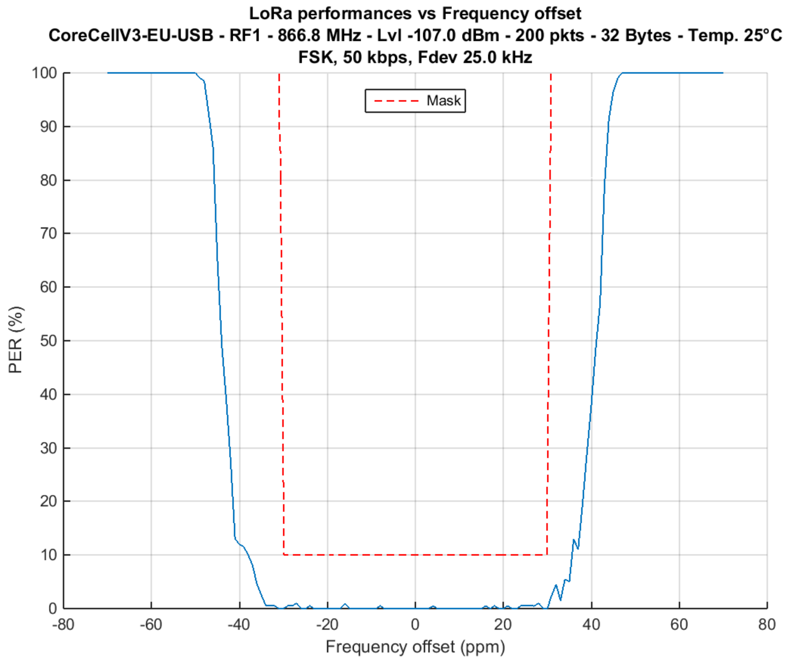


Figure 14.2: Frequency error tolerance, FSK modem, RF1, 866.8 MHz, Ambient temp.

15 Frequency drift tolerance

15.1 Description

The SX1302 shall be able to track the frequency drift of received packets due to the heating of the end-device crystal / oscillator by its PA. This issue is marked with the packet duration.

This test measures the PER in function of the frequency drift and allows to determinate the range for which the SX1302 is able to track.

15.2 Setup

The setup used for this measurement is shown in the figure 2.2. Only the direct path and the signal generator are used.

For each measurement step, a packet is generated accelerated/decelerated with the value of the frequency drift. The sampling frequency as well as the radio frequency are updated simultaneously. The measurement is performed over a minimum of 100 packets in order to average the results.

15.3 Pass / Fail criteria

The document [5] provides frequency drift measurements performed on a SX1261 and a SX1262 without thermal insulation around the crystal.

The figure 8 shows the maximum frequency drift measured at the beginning of the packet on a SX1261 without thermal insulation (blue and orange curves) is -90 Hz/s. In the figure 9 (blue curve), the maximum frequency drift at the beginning of the packet is -160 Hz/s.

$\rightarrow$ **This is the worst case which is treated in this section. The SX1302 shall be able to track at least a frequency drift of (± 160 Hz/s).**

Furthermore, the table 1 of the application note (document [5]) provides for each region, the maximum PHY Payload Length [Bytes] according to the spreading factor.

$\rightarrow$ **For Europe, the measurement shall be performed using 64 bytes of payload.**

15.4 MultiSF modem, BW125 kHz, SF5

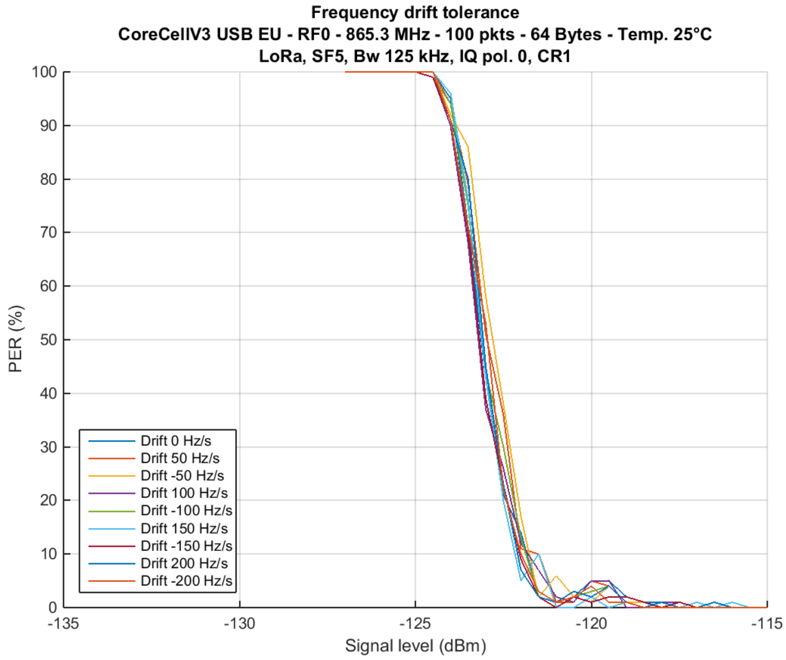


Figure 15.1: Frequency drift tolerance, MultiSF modem, 865.3 MHz, SF5, Bw 125 kHz, 64 bytes

15.5 MultiSF modem, BW125 kHz, SF6

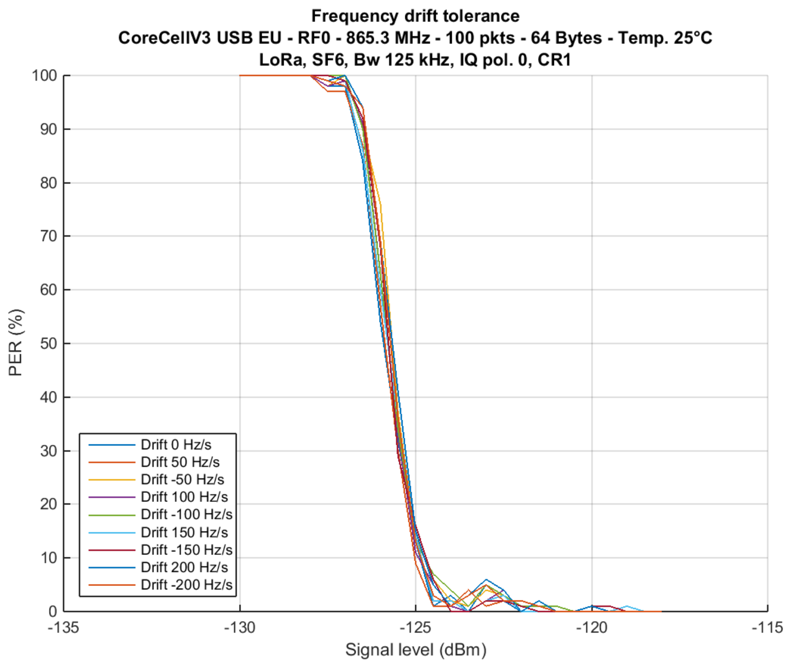


Figure 15.2: Frequency drift tolerance, MultiSF modem, 865.3 MHz, SF6, Bw 125 kHz, 64 bytes

15.6 MultiSF modem, BW125 kHz, SF7

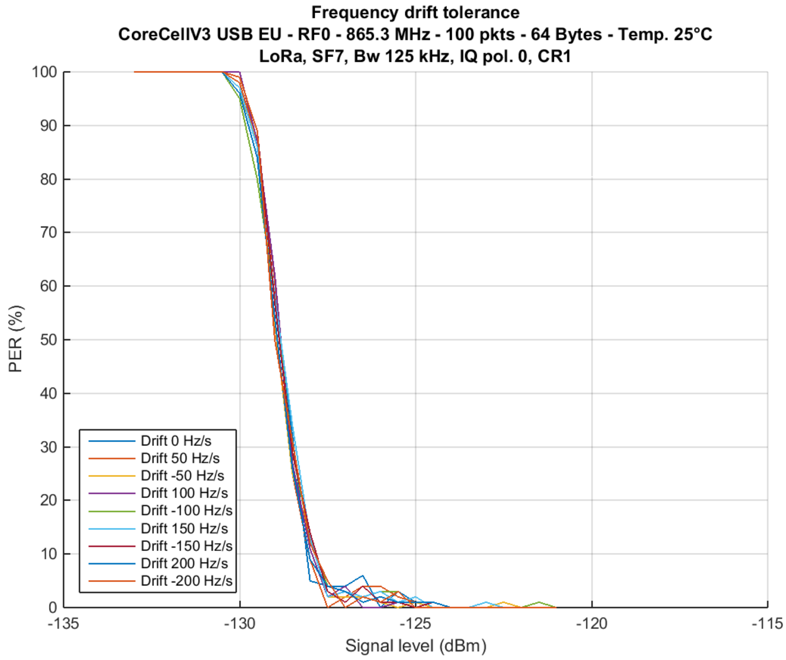


Figure 15.3: Frequency drift tolerance, MultiSF modem, 865.3 MHz, SF7, Bw 125 kHz, 64 bytes

15.7 MultiSF modem, BW125 kHz, SF8

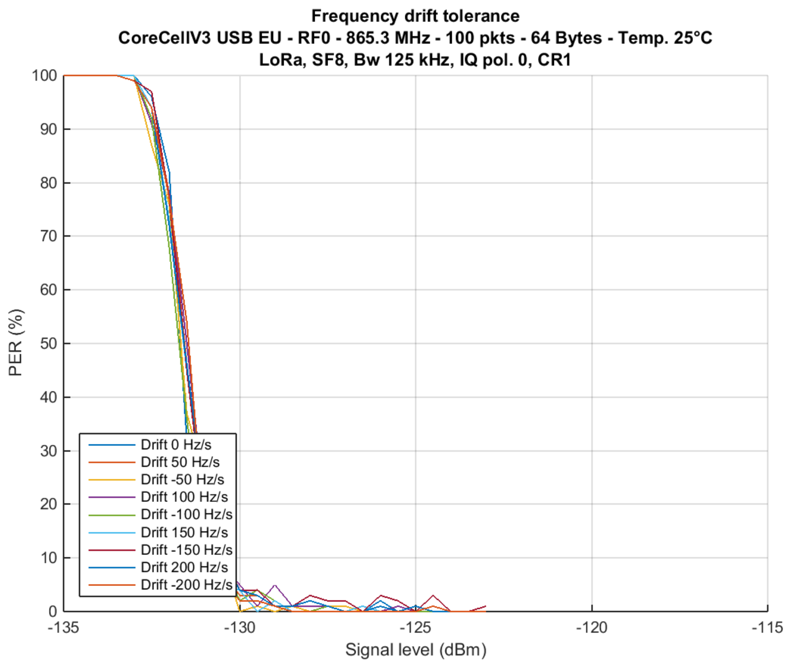


Figure 15.4: Frequency drift tolerance, MultiSF modem, 865.3 MHz, SF8, Bw 125 kHz, 64 bytes

15.8 MultiSF modem, BW125 kHz, SF9

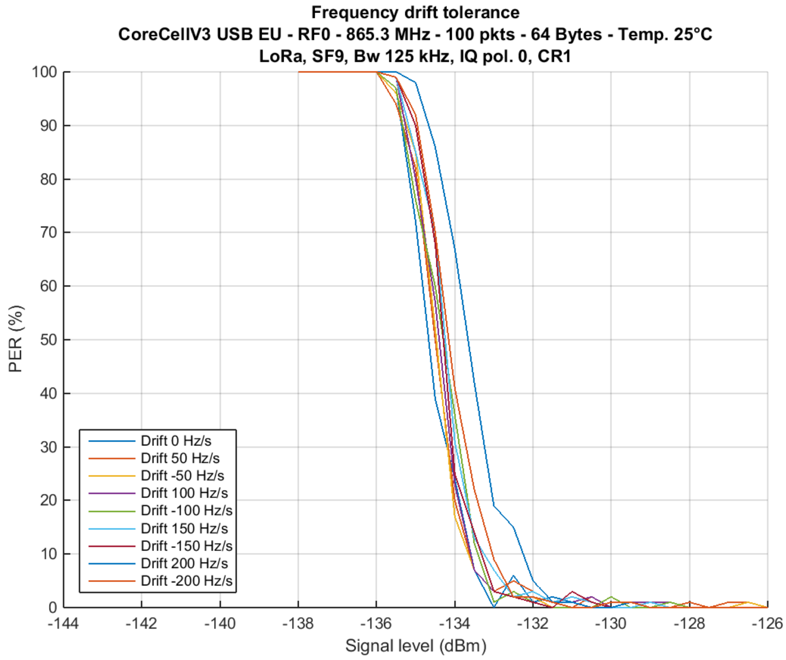


Figure 15.5: Frequency drift tolerance, MultiSF modem, 865.3 MHz, SF9, Bw 125 kHz, 64 bytes

15.9 MultiSF modem, BW125 kHz, SF10

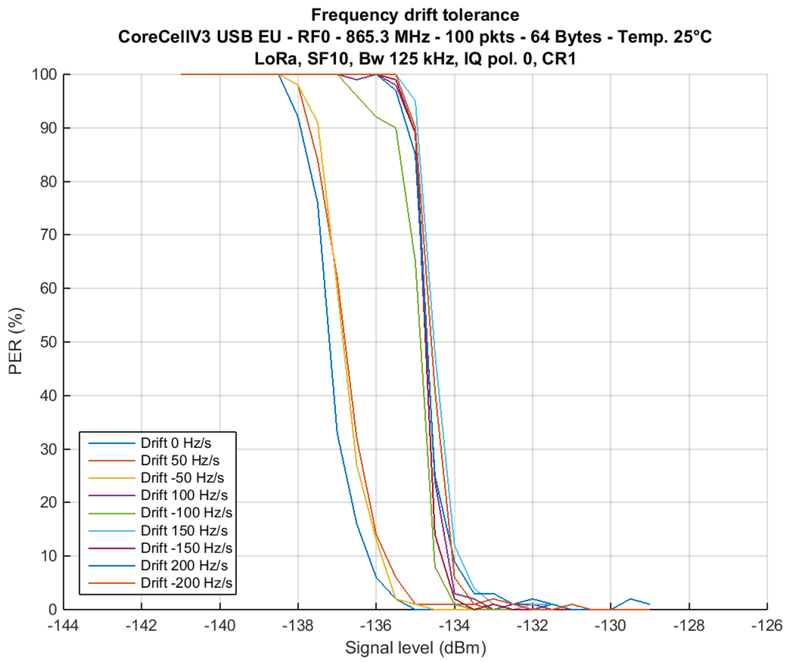


Figure 15.6: Frequency drift tolerance, MultiSF modem, 865.3 MHz, SF10, Bw 125 kHz, 64 bytes

15.10 MultiSF modem, BW125 kHz, SF11

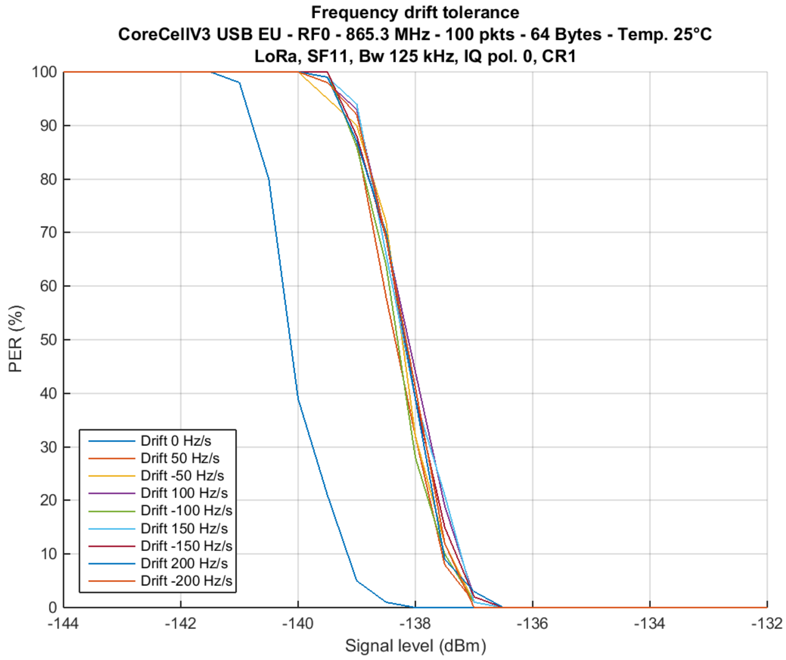


Figure 15.7: Frequency drift tolerance, MultiSF modem, 865.3 MHz, SF11, Bw 125 kHz, 64 bytes

15.11 MultiSF modem, BW125 kHz, SF12

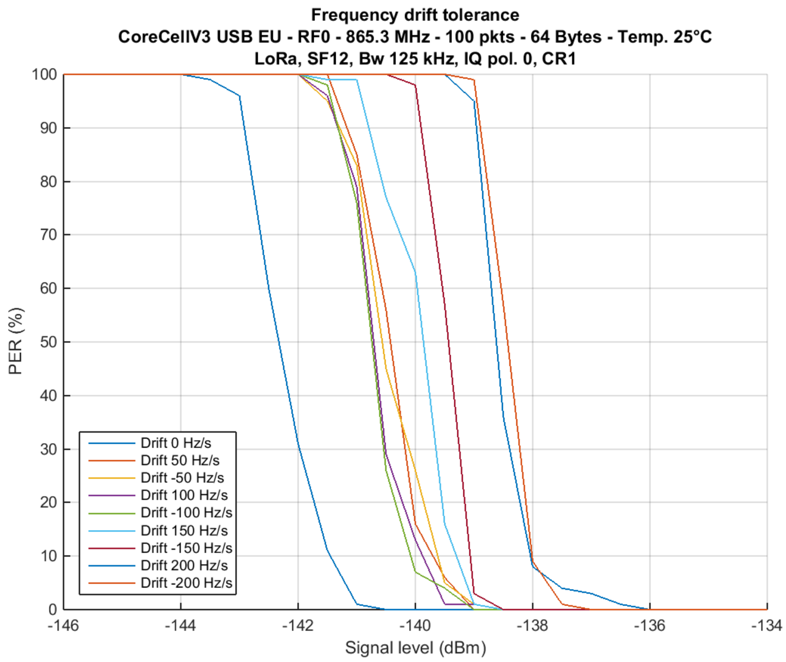


Figure 15.8: Frequency drift tolerance, MultiSF modem, 865.3 MHz, SF12, Bw 125 kHz, 64 bytes

Part IV

Annexes

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

Important Notice

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