Corecell gateway Reference design China version Performance Report

Contents

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 optimized, 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 **China**.

1.3 References documents

The following documents are cited in the present one:

1. Technical requirements for micro power short distance radio transmitting equipment (draft for comment) (微功率短距离无线电发射设备技术要求（征求意见稿））

1.4 Document convention

Excepted if it is explicitly mention, all measurements are perform 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 SX1302 prototype performances and its compliance to the regulation limits shown in figure 1.

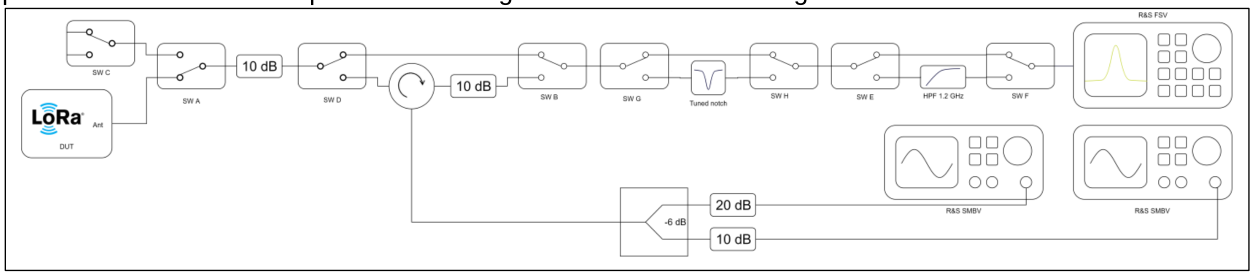


figure 1 Overall test bench setup - Default configuration

According to the specificities of each measurement, the various switches commuted to select or not some filters. The switch C is used in case of a gateway with two separated RF chains. It is not used in the measurements of this report.

2.2 Tx measurements

The setup presented in the figure 2 is used for the Tx measurements.

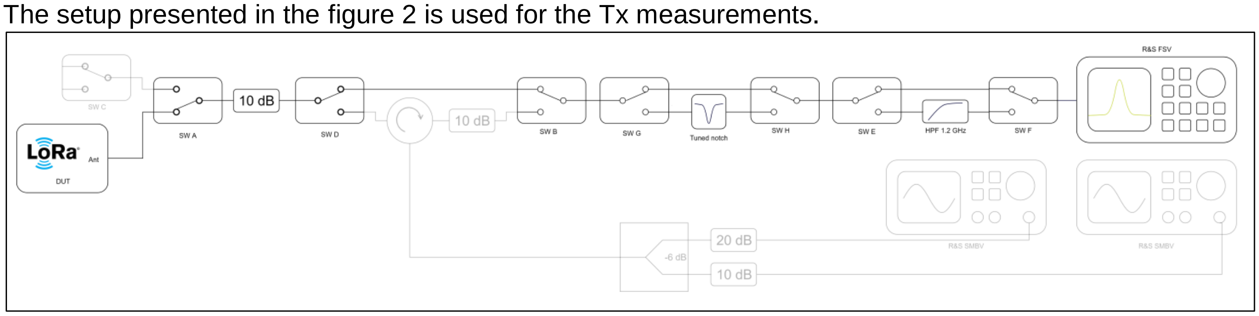


figure 2 Configuration of the test bench for Tx measurements

The 10 dB attenuator after the switch A allows mitigating effect of impedance mismatch as well as protecting the output power amplifier from reflected power due to the notch or the HPF. Except for full duplex measurements, the circulator is never used. The notch and the HPF 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 defined for each individual test.

2.3 Rx measurements

All the Rx measurements performed using the setup of the figure 3.

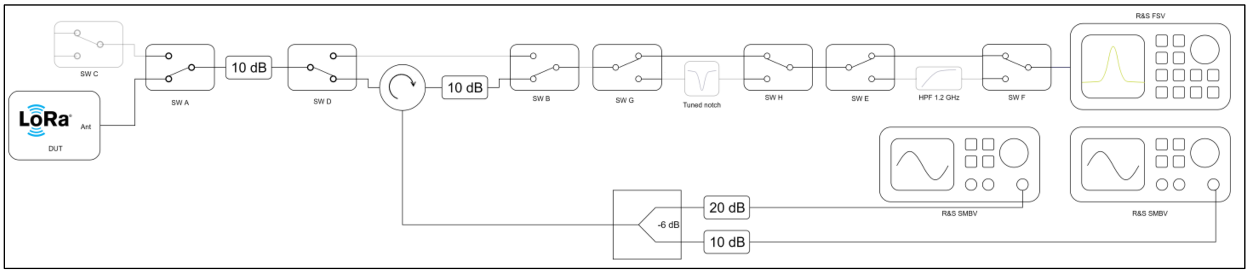


figure 3 Test bench configuration for the Rx measurements

The circulator allows simultaneously injecting a signal into the DUT and measuring the emission from it. 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 tolerance), only one signal generator is used, the output of the second one is OFF. The other generator 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 mitigating the effect of impedance mismatch on its characteristics as well as protecting each signal generator output from the power from the other one or the DUT.

3 Device under test (DUT)

3.1 Description

The board used along this document is a Corecell reference design batch #1, populated for Chinese Band (See figure 4). Excepted if it is explicitly mentioned, the board referenced ”CN” is used in the design validation.

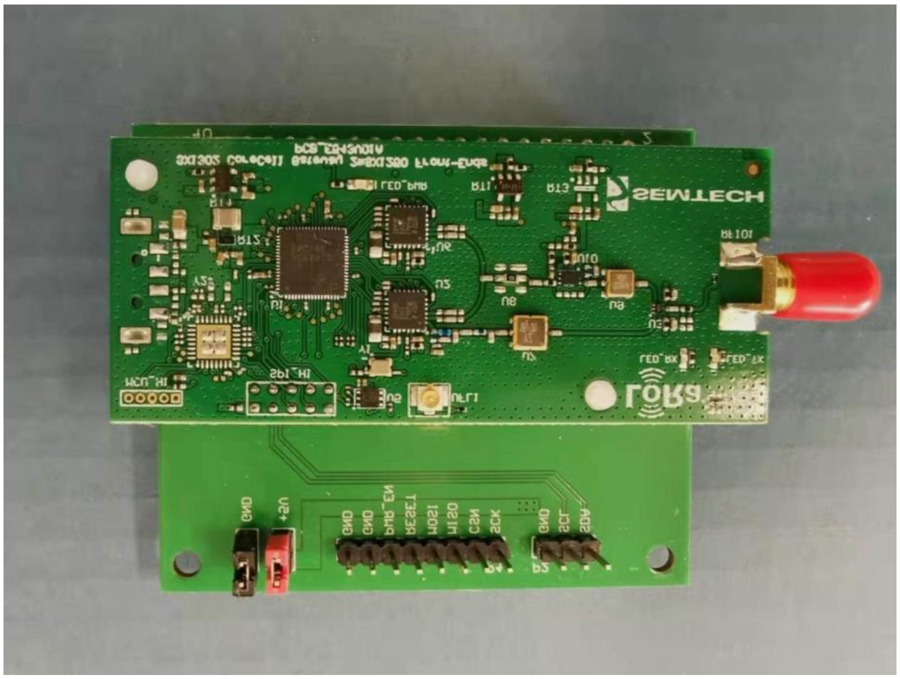


figure 4 The Corecell Ref. design mounted on the interface board with the RPI3

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

3.2 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

4 Transmitter

4.1 Sweep power

4.1.1 Description

Check the maximum output power from 500MHz-510MHz.

4.1.2 Setup

The setup used to measure the maximum power is show in figure 2. Only the direct path is used for this measurement.

4.1.3 Sweep power(max)

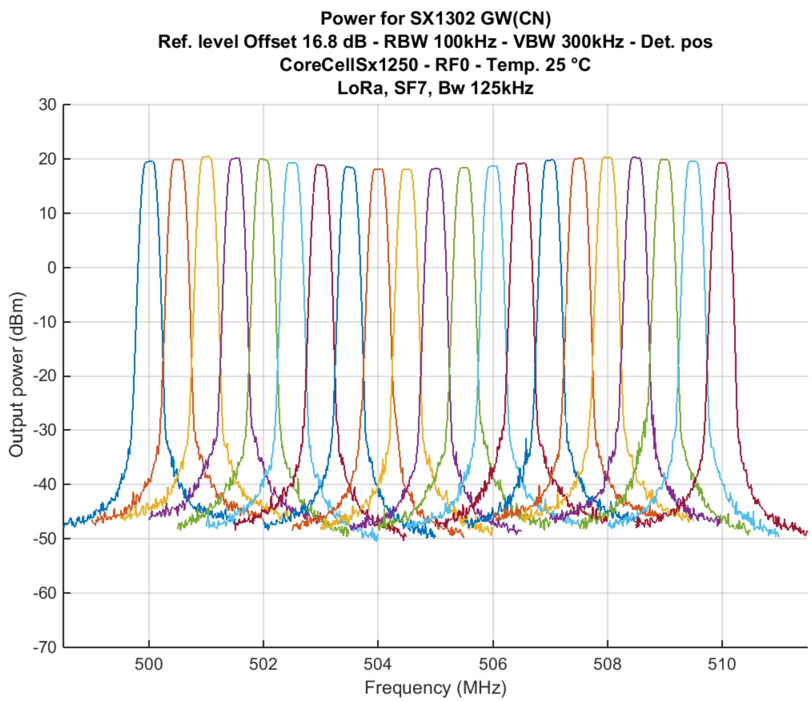


figure 5 Power sweep from 500MHz-510Hz,LoRa,125 kHz,SF7

4.2 Spurious emission

4.2.1 Description

Spurious emissions are unwanted emissions in the spurious domain at frequencies other than those of the Operating Channel and its Out Of Band Domain. Requirement for unwanted emissions list in the documents from chapter 1.3.

4.2.2 Setup

The setup used to measure the out of band emission is show in figure 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.

4.2.3 Spurious emission below 1GHz

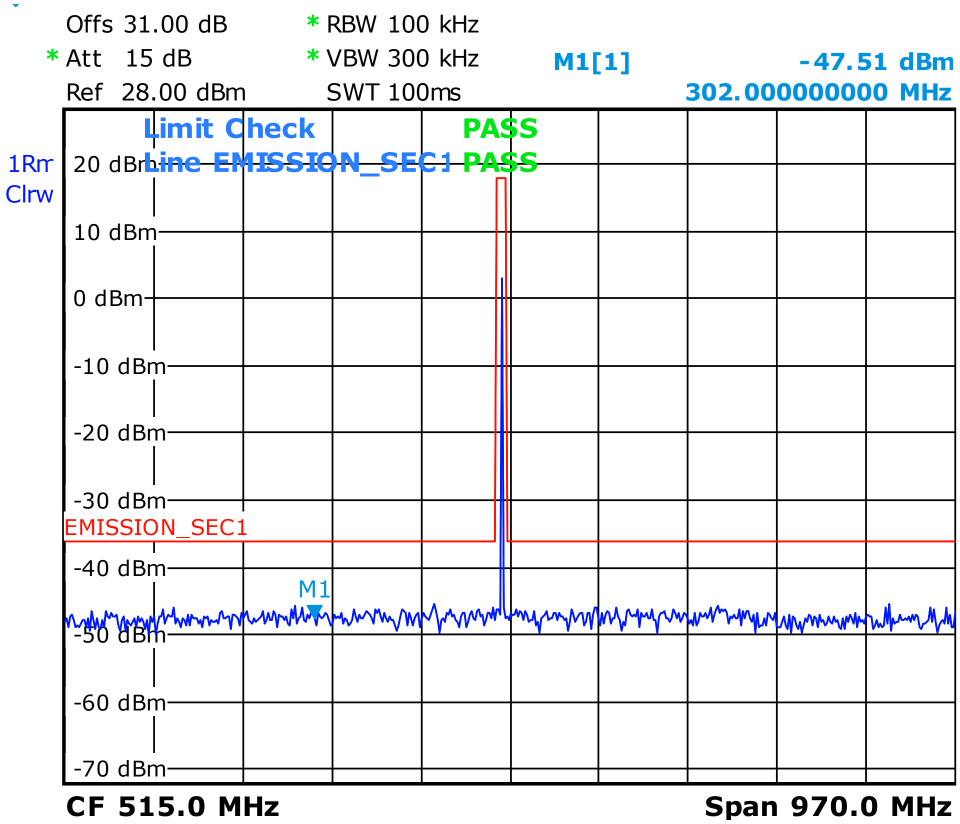


figure 6 Spurious emission, scan from 30MHz-1GHz,Tx at 505.5MHz,Bw125KHz

4.2.4 Spurious emission above 1GHz

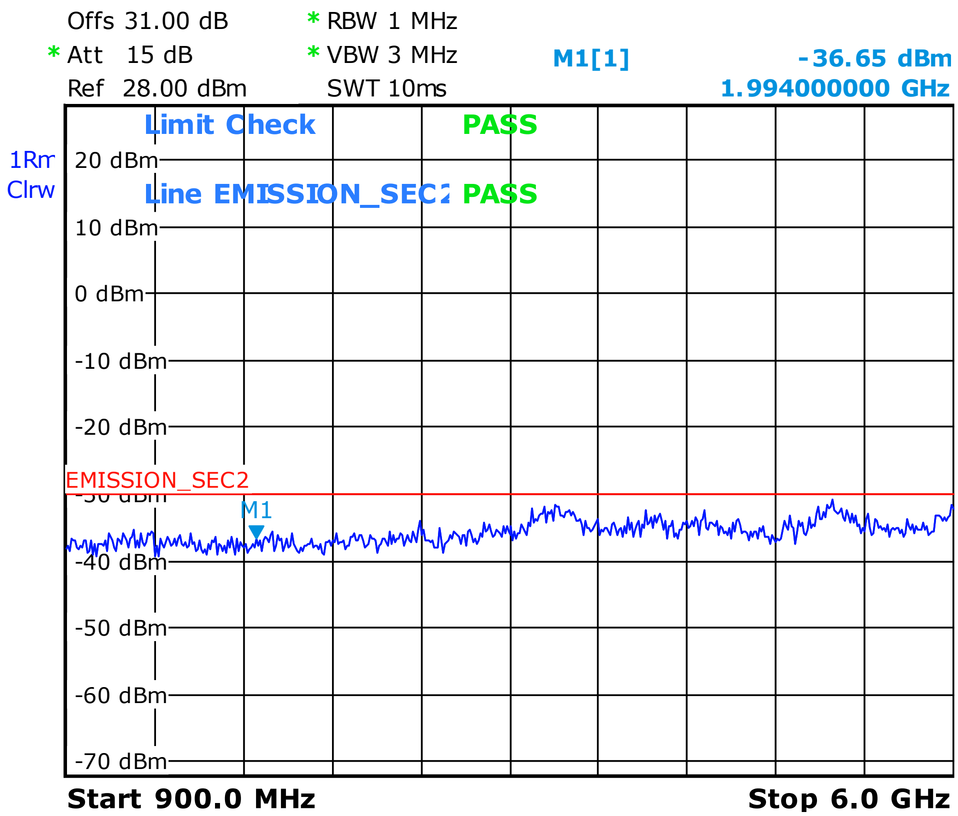


figure 7 Spurious emission, scan from 900MHz-6GHz,Tx at 505.5MHz,Bw125KHz

5 Receiver

5.1 *Sensitivity level and PER*

5.1.1 Description

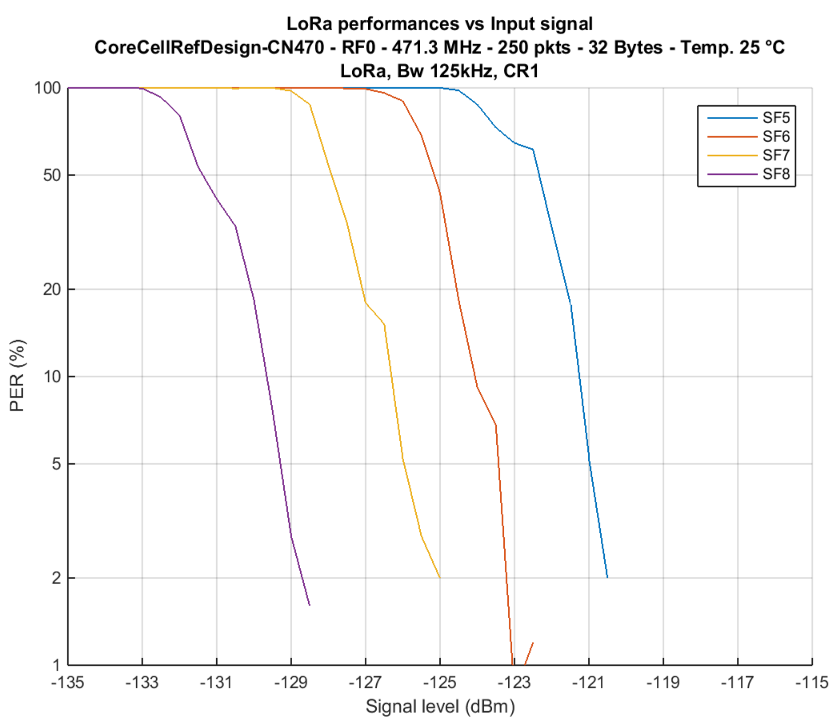
This test determines the sensitivity level i.e. the minimum RF input power needed to demodulate the received packet. It is determined for a PER of 10%. It also verifies the PER remains null for input power above the sensitivity level i.e. no saturation occurs.

5.1.2 Setup

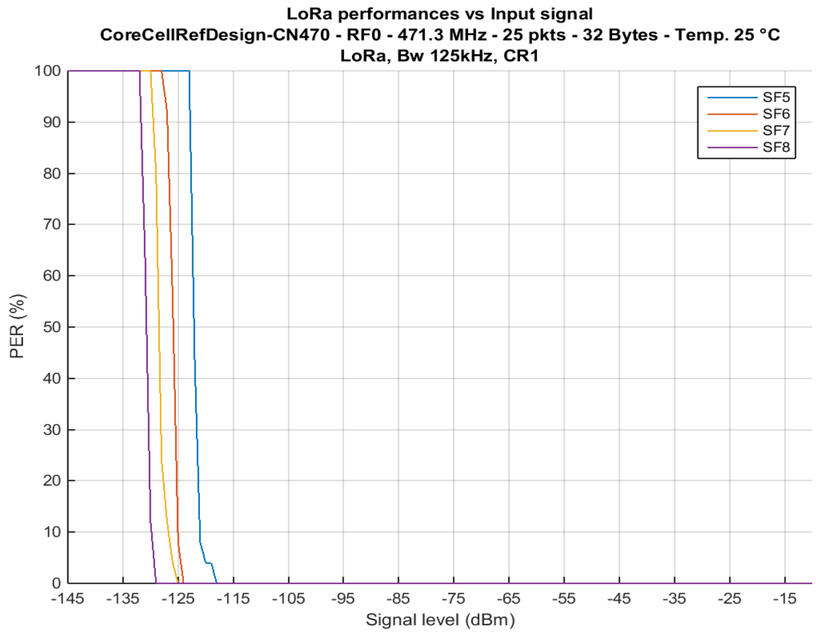
The sensitivity measurement setup shown in figure 3. Only one signal generator used here, the output of the second one is OFF. It generates LoRa packets toward the DUT for several output powers and frequencies. The effect of impedance mismatch mitigated by the use of attenuators at the power splitter 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.

5.1.3 MultiSF modem versus Spreading Factor

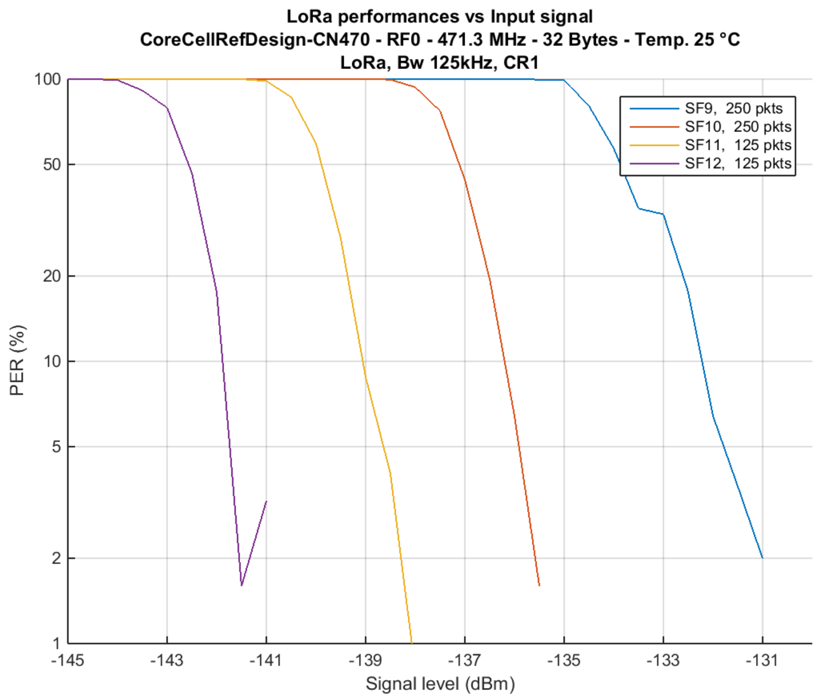


(a) Sensitivity level

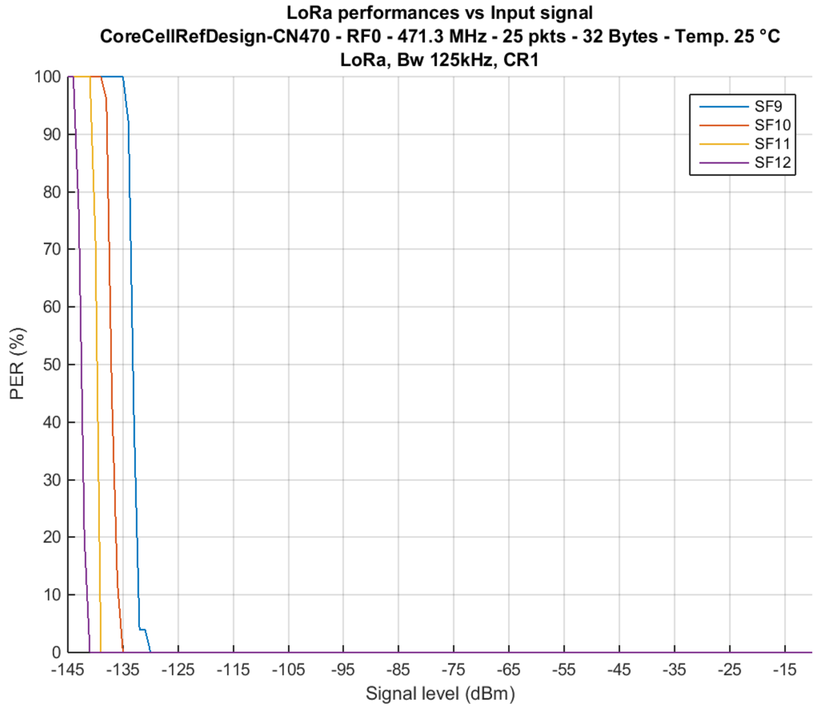


(b) High level

figure 8 Sensitivity level and PER, MultiSF 125 kHz modem vs SF (5 to 8), 471.3 MHz



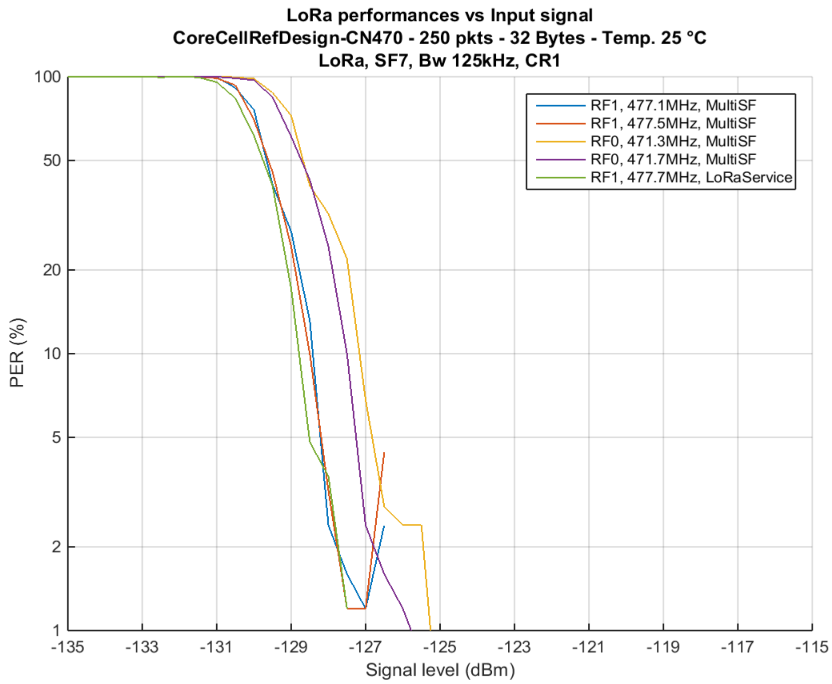
(a) Sensitivity level



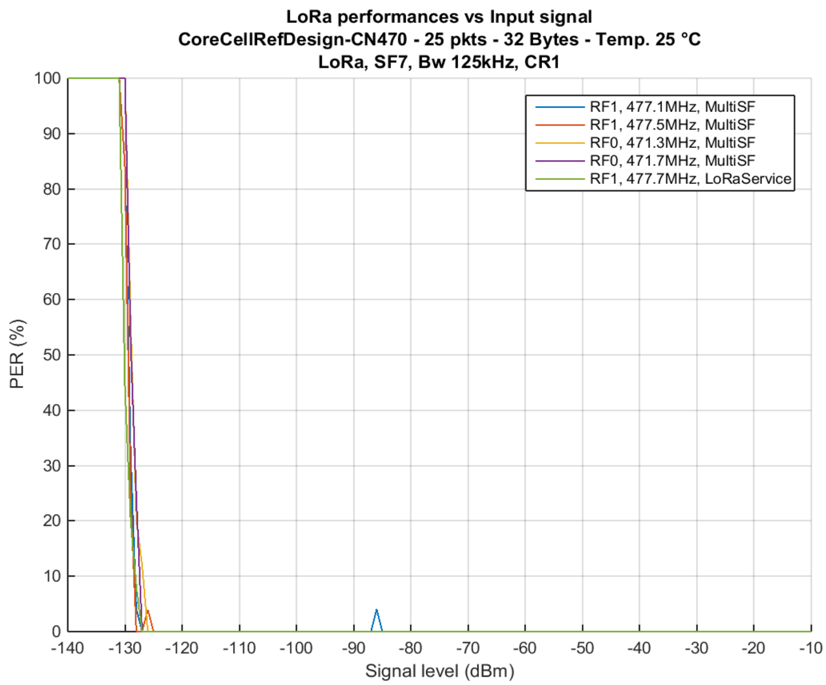
(b) High level

figure 9 Sensitivity level and PER, MultiSF 125 kHz modem vs SF (9 to 12), 471.3 MHz

5.1.4 MultiSF/SingleSF modem versus channels



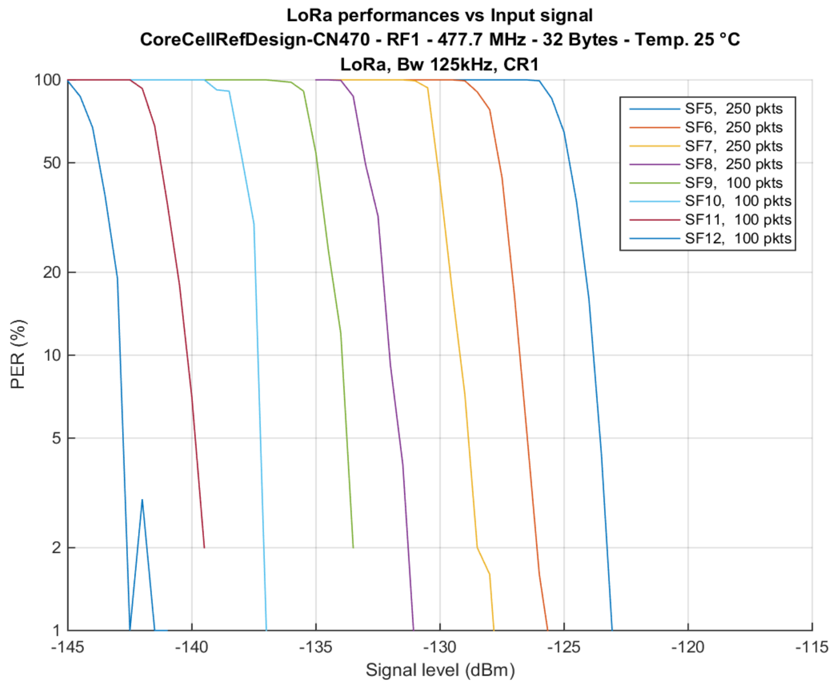
(a) Sensitivity level



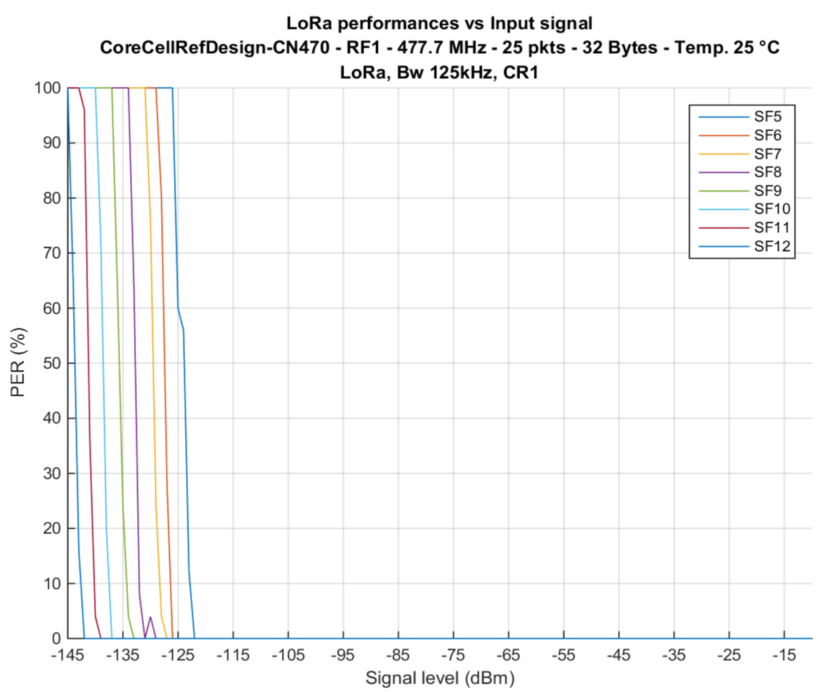
(b) High level

figure 10 Sensitivity level and PER, MultiSF / SingleSF modems versus channels, SF7, Bw 125 kHz

5.1.5 SingleSF modem versus Spreading Factor



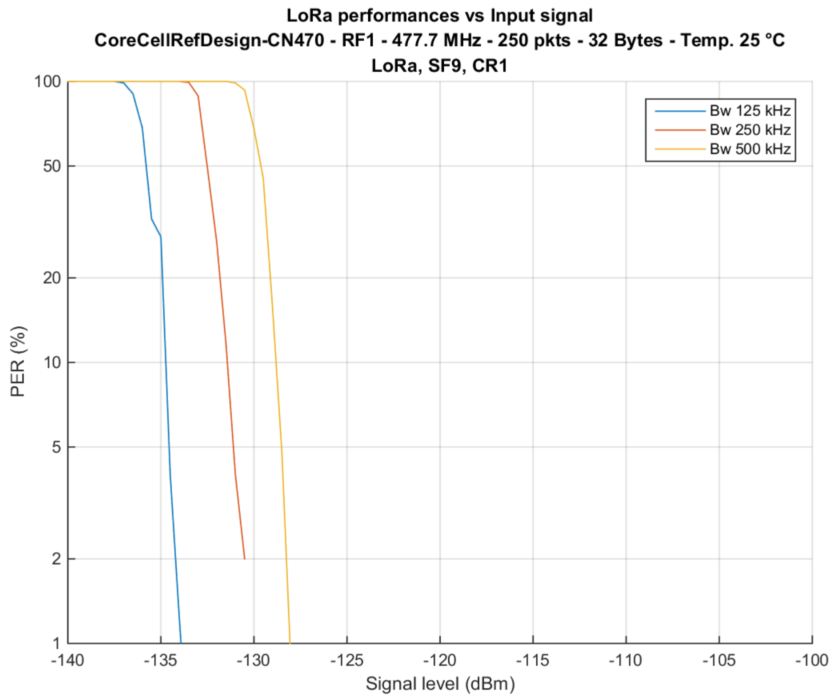
(b) Sensitivity level



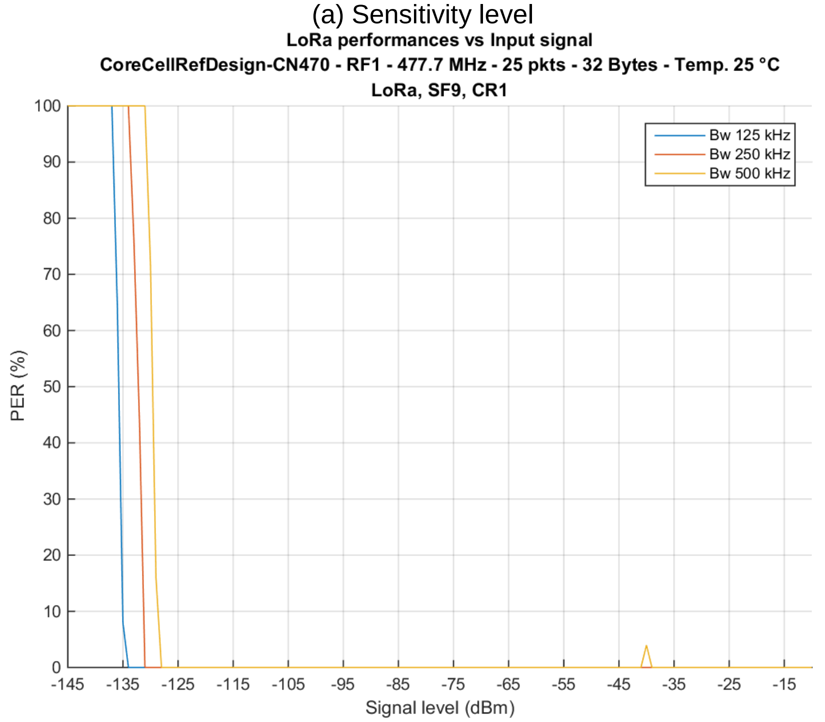
(b) High level

figure 11 Sensitivity level and PER, SingleSF modem vs SF, 477.7 MHz, Bw 125 kHz

5.1.6 SingleSF modem versus Bandwidth



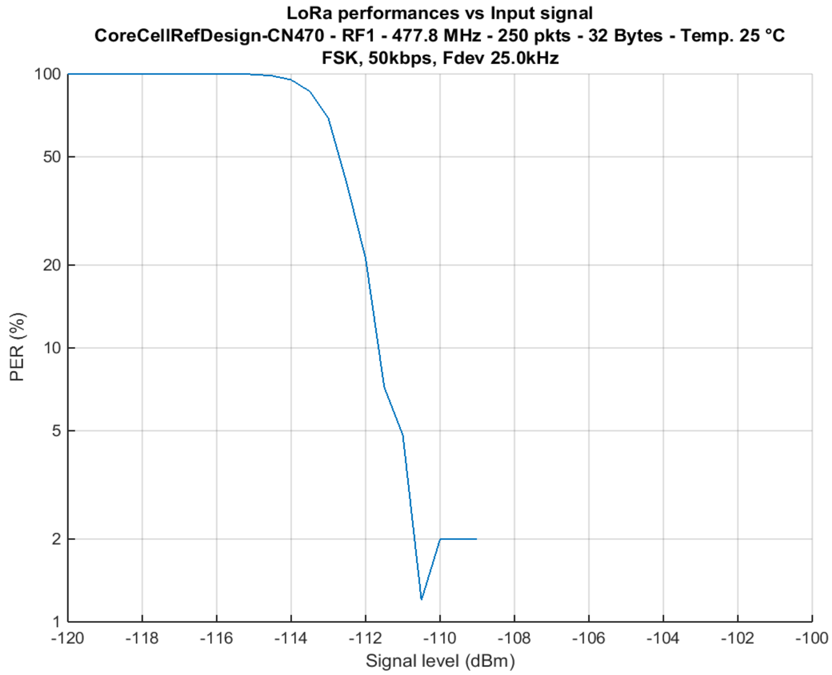
(a) Sensitivity level



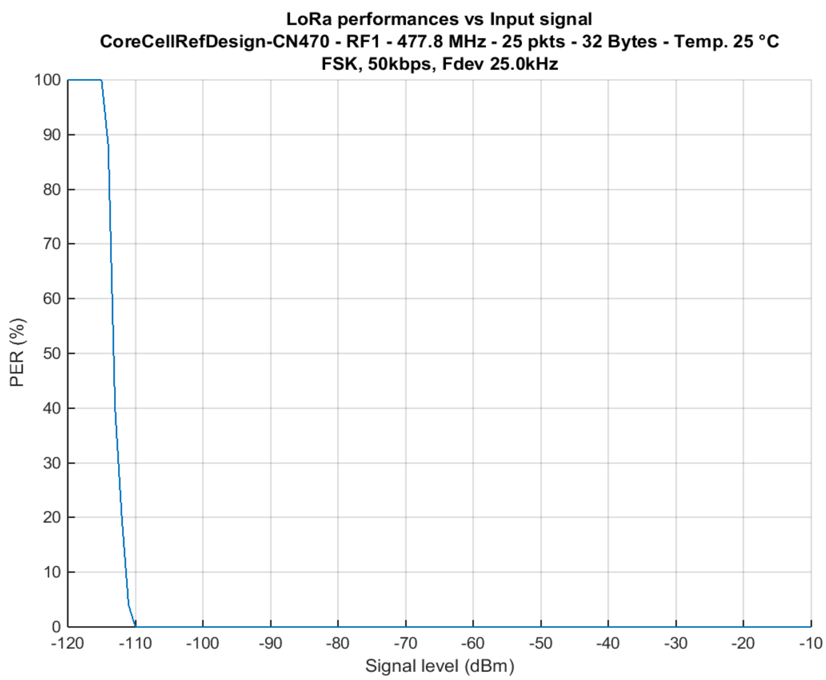
(b) High level

figure 12 Sensitivity level and PER, SingleSF modem vs bandwidth, 477.7 MHz,SF9

5.1.7 FSK modem



(a) Sensitivity level



(b) High level

figure 13 Sensitivity level and PER, FSK modem, RF1, 477.8 MHz

5.2 *RSSI*

5.2.1 Description

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

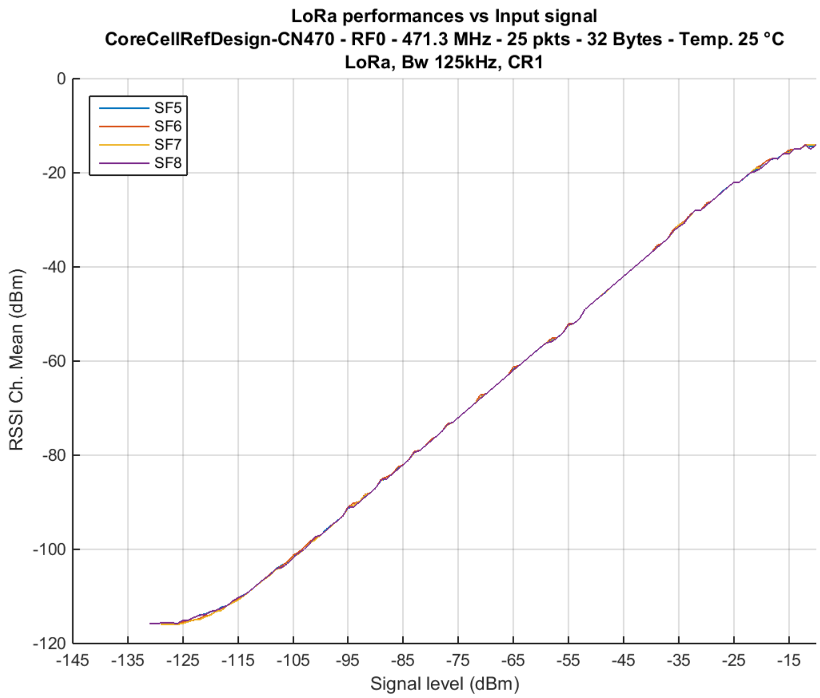
- RSSI Channel: This indicator represents the power in the channel bandwidth, taken care the power of signal and the thermal noise. It concerns LoRa and FSK modulation.
- RSSI Signal: This indicator represents the LoRa signal only, without taken care the thermal noise power. It only concerns the LoRa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

5.2.2 Setup

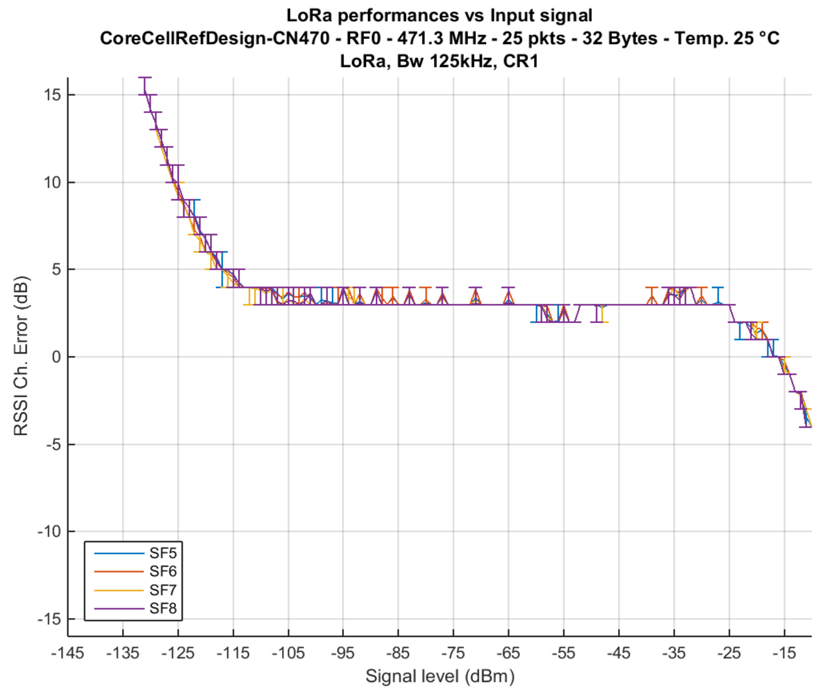
The sensitivity measurement setup shown in figure 3. Only one signal generator used here, the output of the second one is OFF. It generates LoRa packets toward the DUT for several output powers and frequencies. The effect of impedance mismatch mitigated by the use of attenuators at the power splitter 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.

5.2.3 MultiSF modem versus Spreading Factor

5.2.3.1 RSSI channel

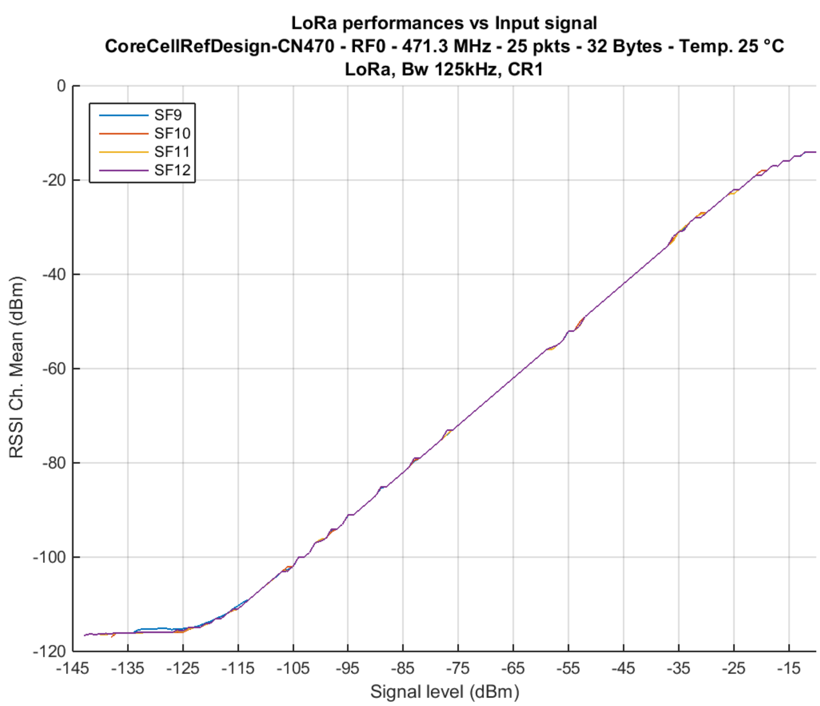


(a) RSSI Channel mean

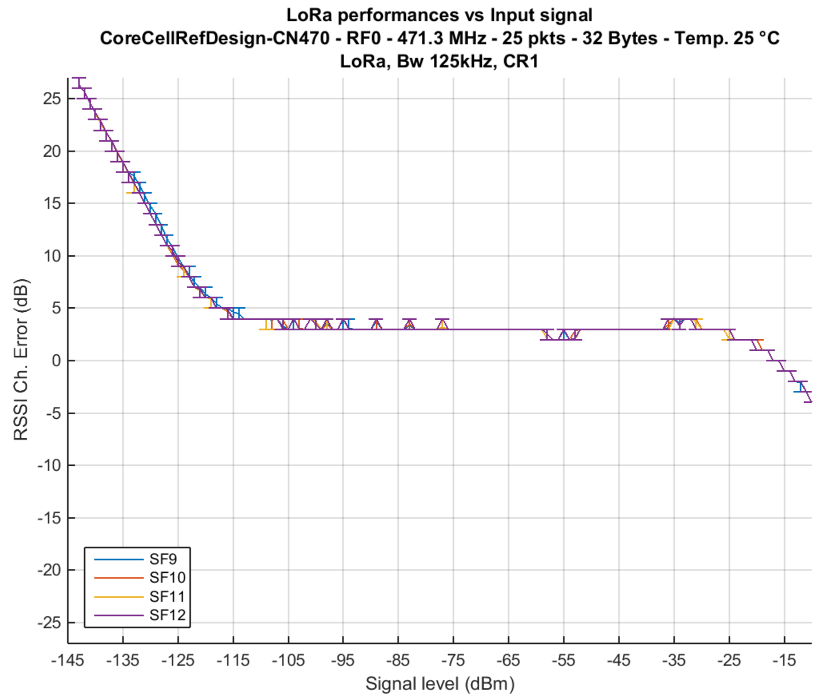


(b) RSSI Channel error

figure 14 RSSI Channel, MultiSF modems vs Spreading factors (5 to 8), 471.3 MHz



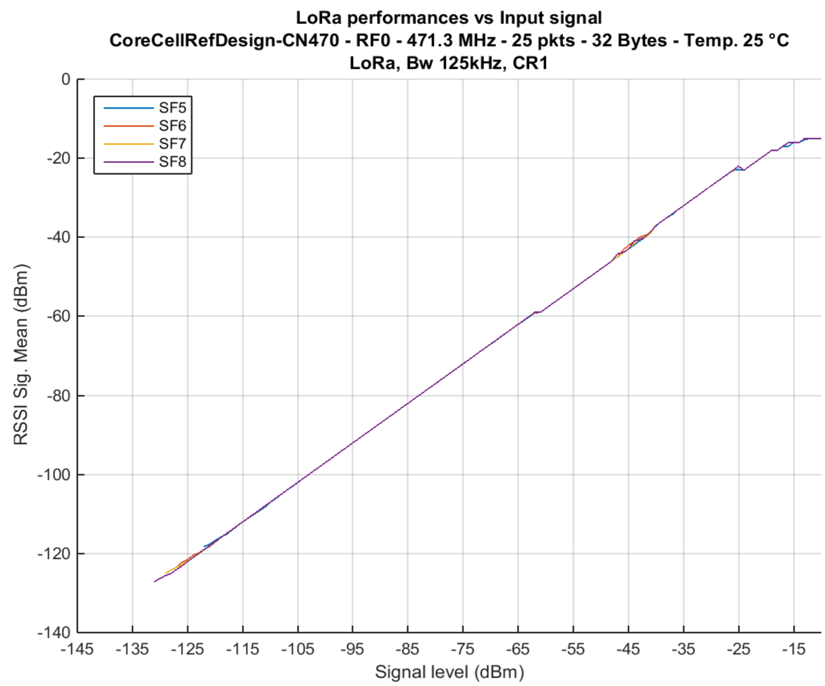
(a) RSSI Channel mean



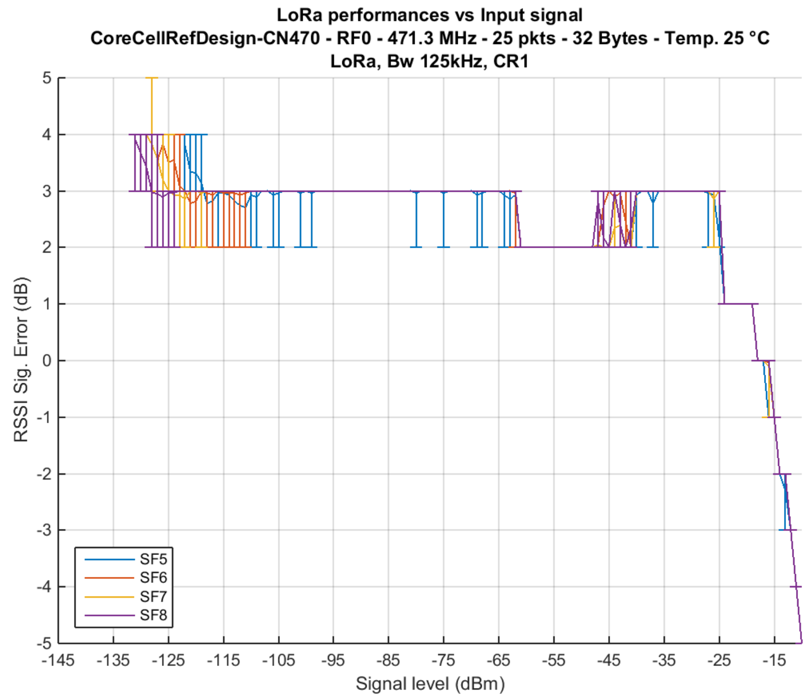
(b) RSSI Channel error

figure 15 RSSI Channel, MultiSF modems vs Spreading factors (9 to 12), 471.3 MHz

5.2.3.2 RSSI signal

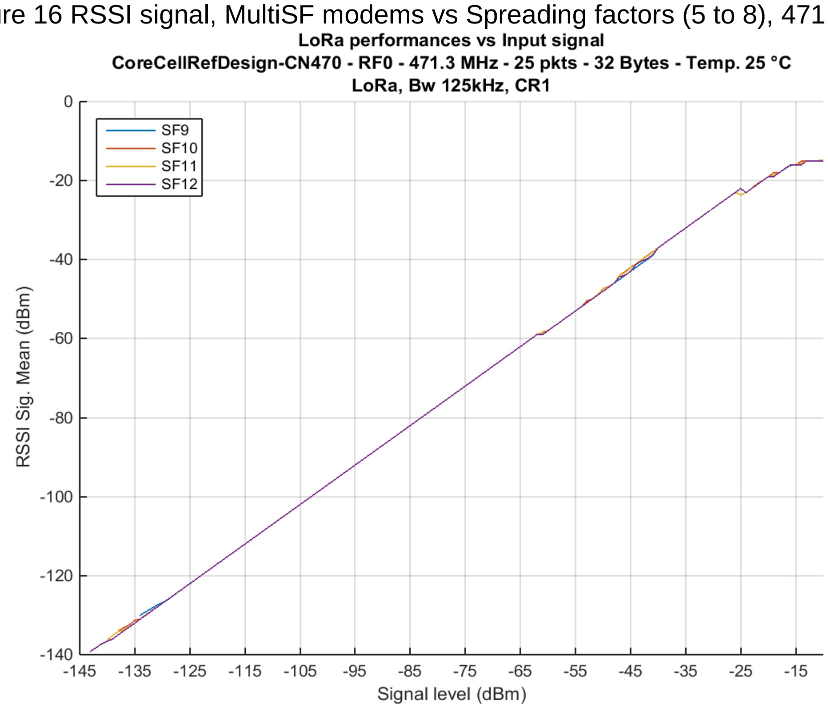


(a) RSSI signal mean

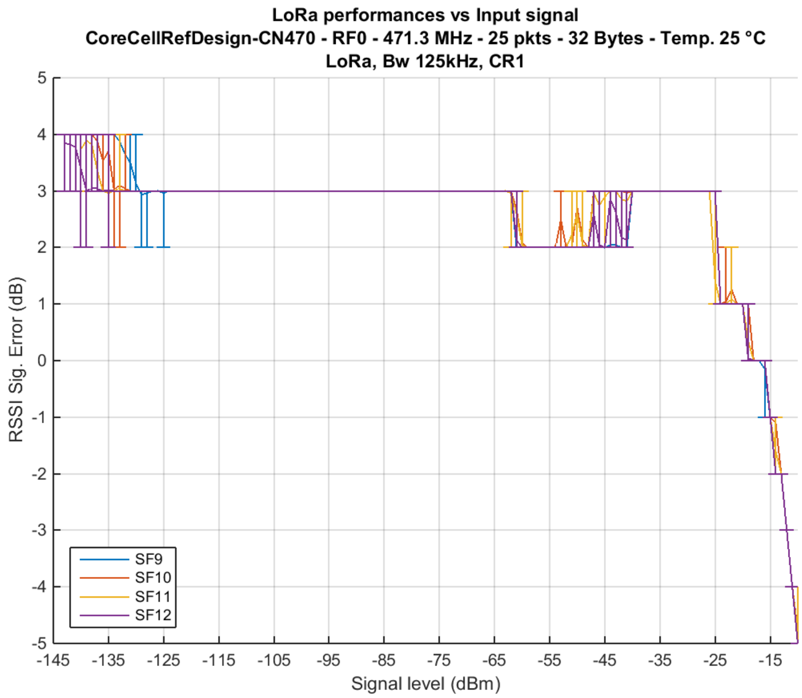


(b) RSSI signal error

figure 16 RSSI signal, MultiSF modems vs Spreading factors (5 to 8), 471.3 MHz



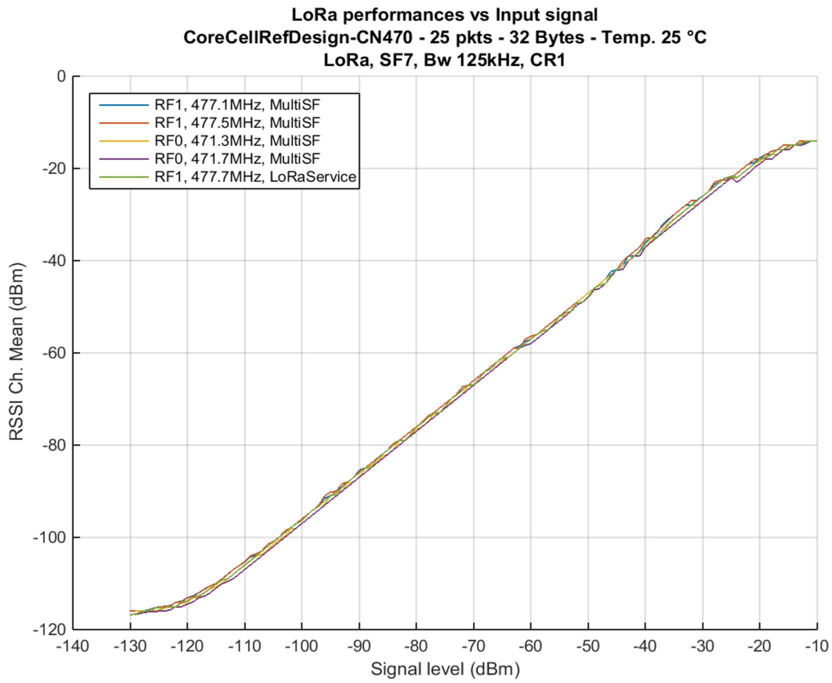
(a) RSSI signal mean



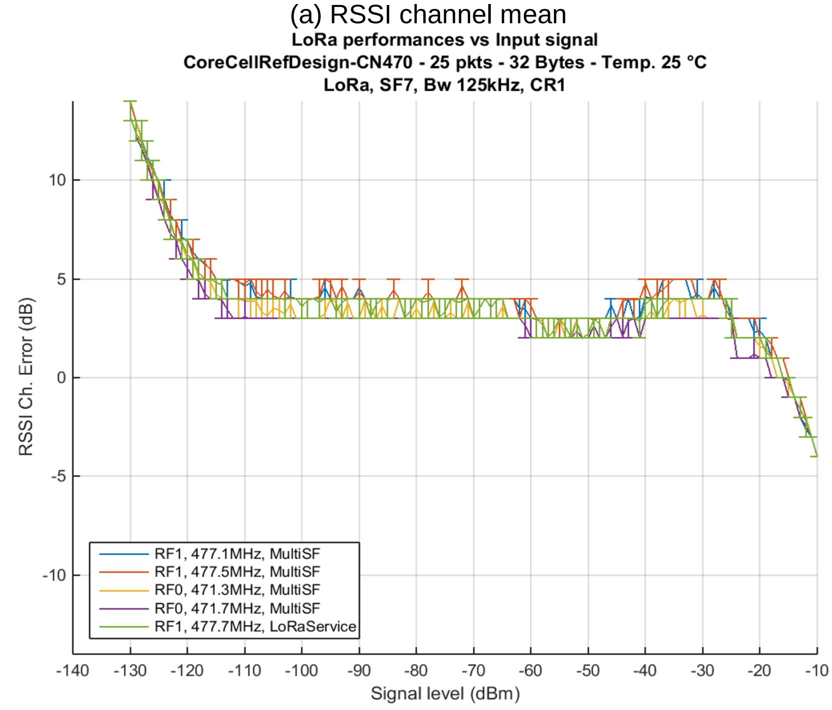
(b) RSSI signal error

figure 17 RSSI signal, MultiSF modems vs Spreading factors (9 to 12), 471.3 MHz

5.2.4 MultiSF/SingleSF modem versus channels

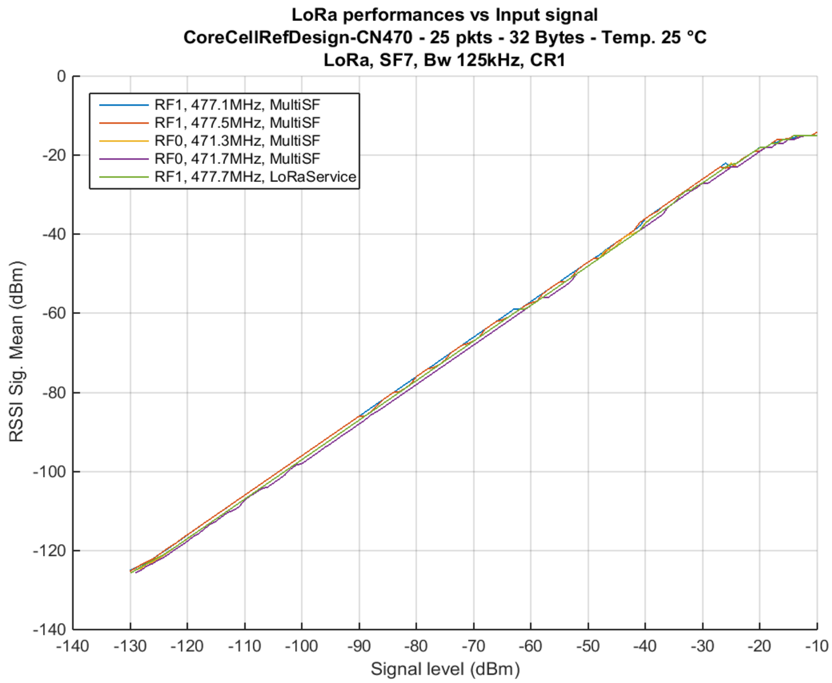


(a) RSSI channel mean

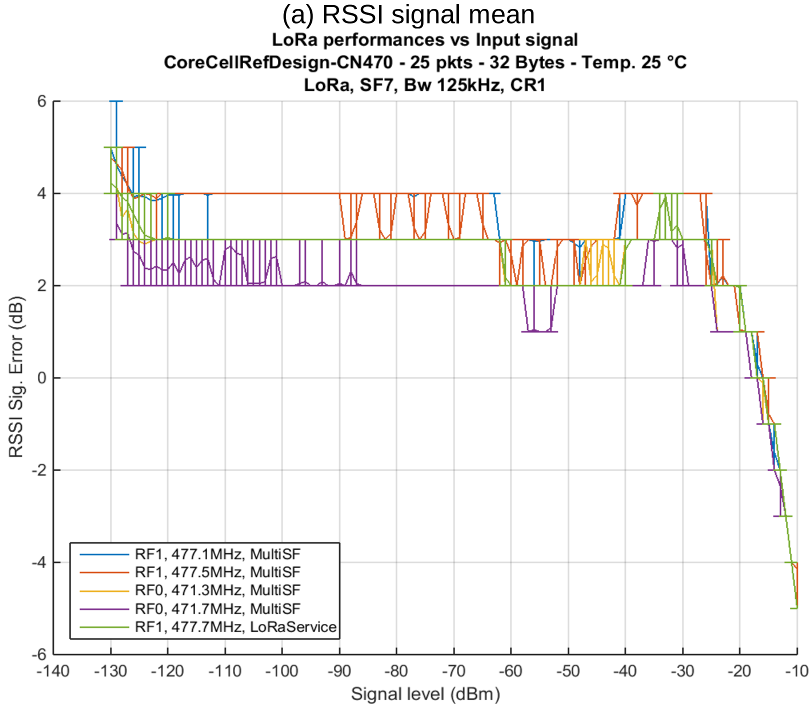


(b) RSSI channel error

figure 18 RSSI channel, MultiSF and SingleSF vs channels,SF7



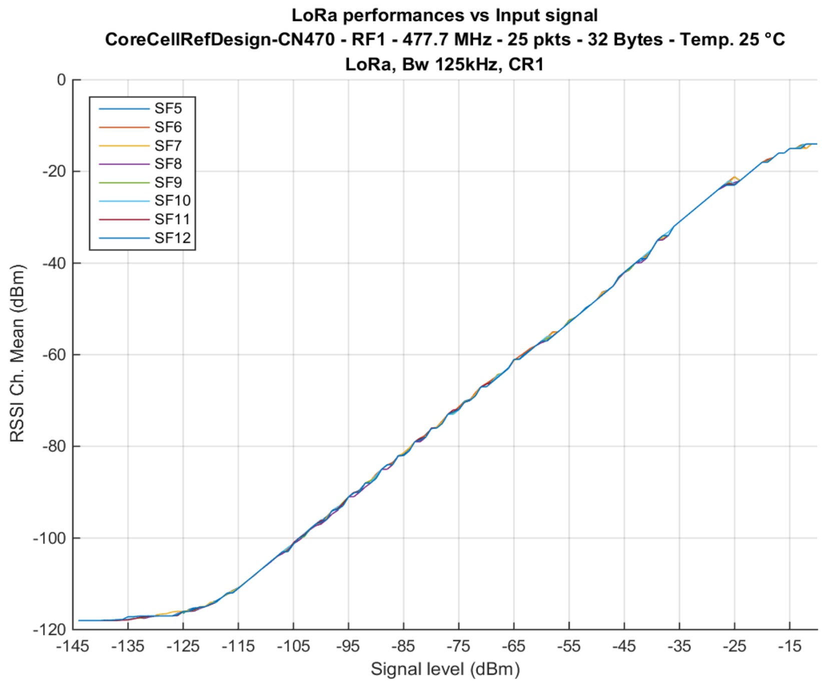
(a) RSSI signal mean



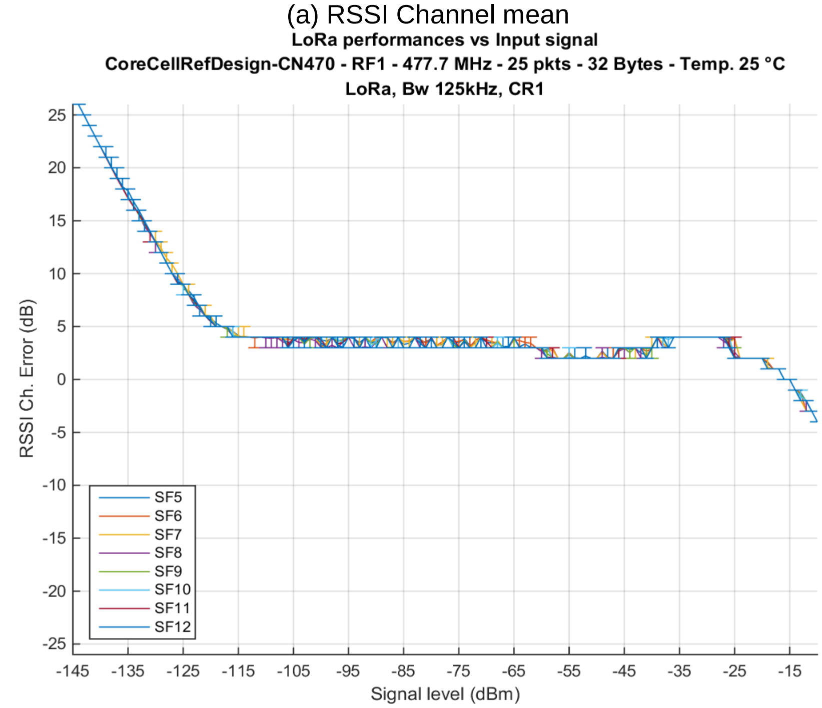
(b) RSSI signal error

figure 19 RSSI signal, MultiSF and SingleSF vs channels,SF7

5.2.5 SingleSF modem versus Spreading Factor

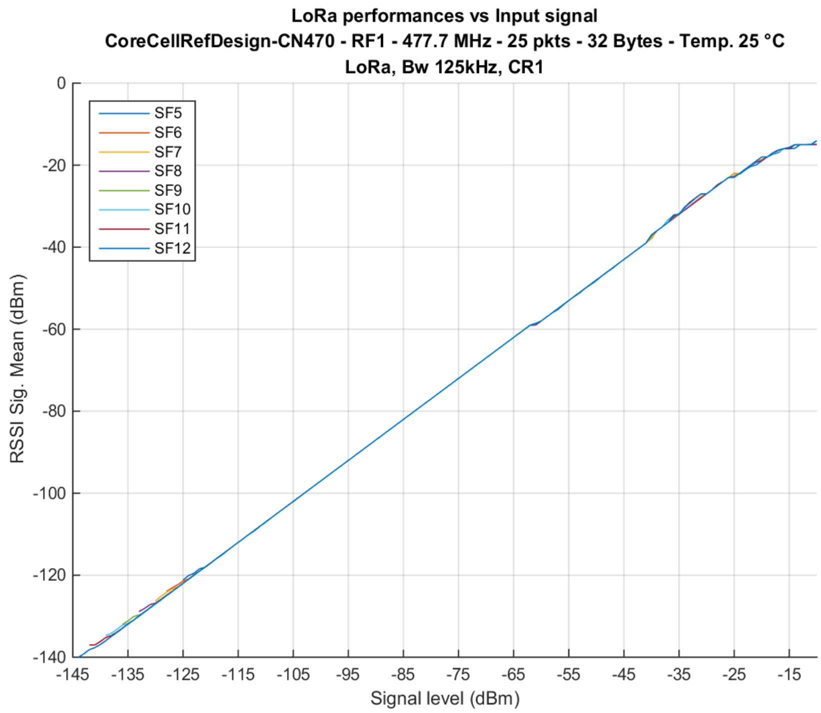


(a) RSSI Channel mean

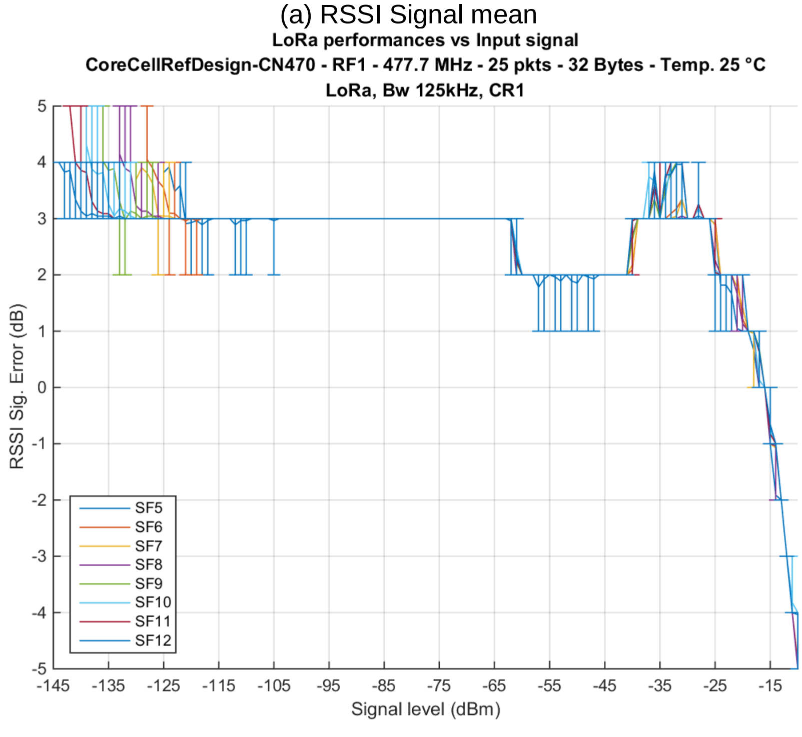


(b) RSSI Channel error

figure 20 RSSI Channel, SingleSF modem vs Spreading factors, 477.7 MHz, Bw 125 kHz



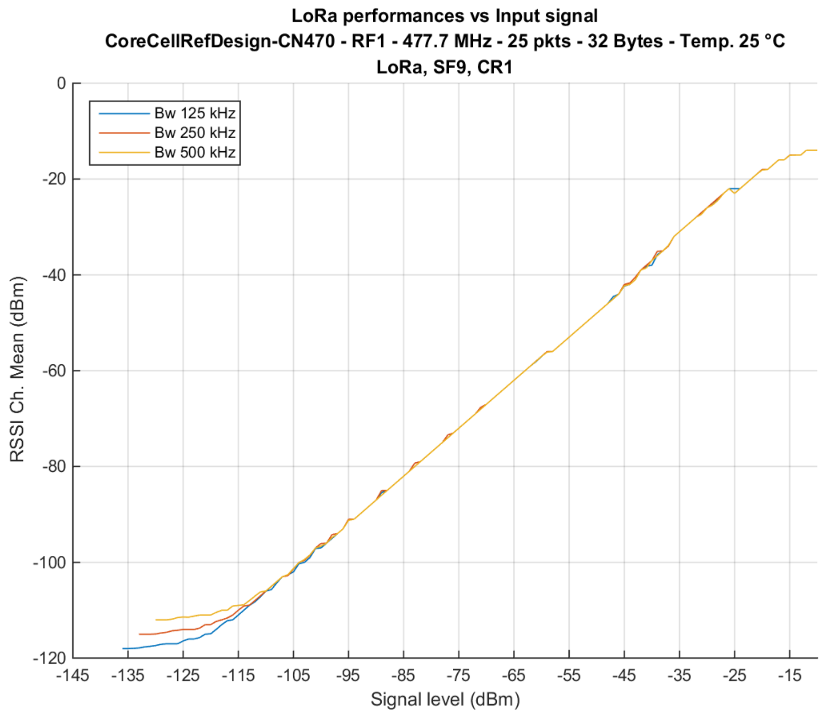
(a) RSSI Signal mean



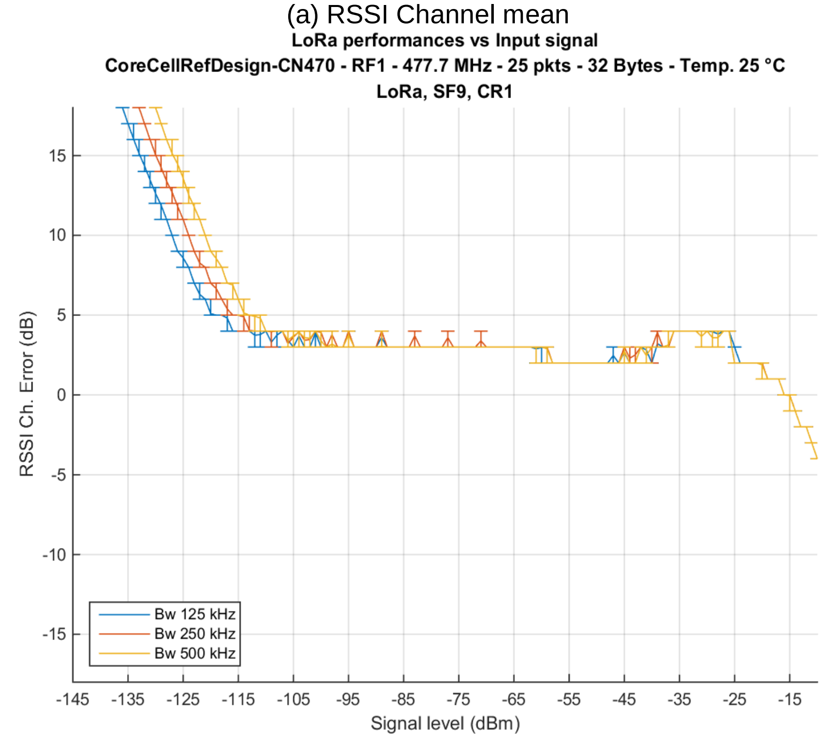
(b) RSSI Signal error

figure 21 RSSI Signal, SingleSF modem vs Spreading factors, 477.7 MHz, Bw 125 kHz

5.2.6 SingleSF modem versus Bandwidth

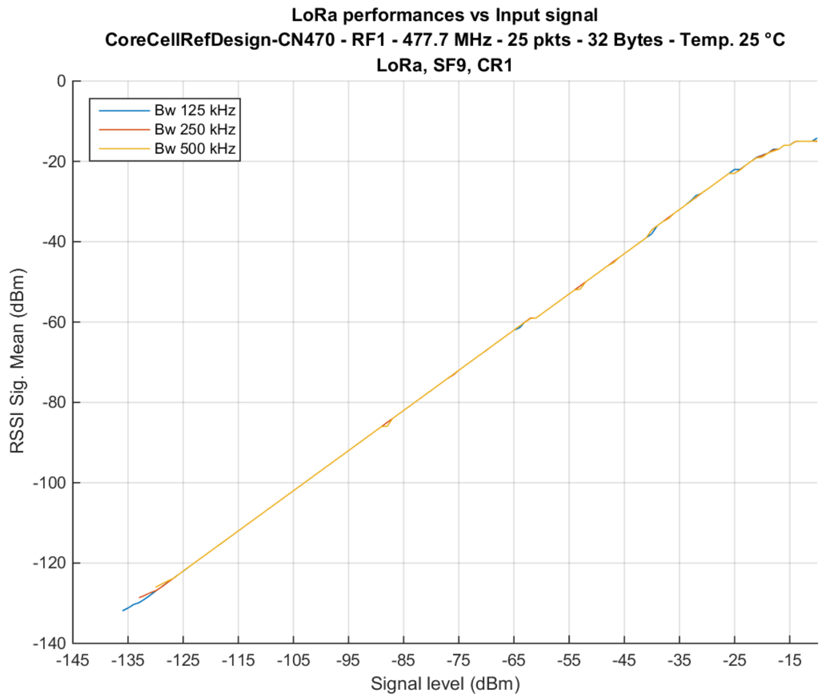


(a) RSSI Channel mean

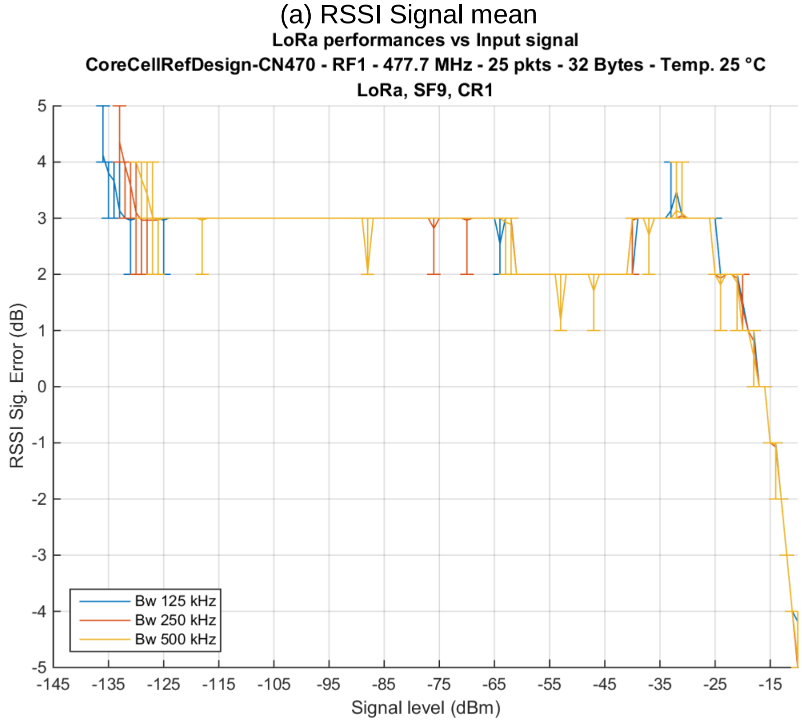


(b) RSSI Channel error

figure 22 RSSI Channel, SingleSF modem vs bandwidth, 477.7 MHz,SF9



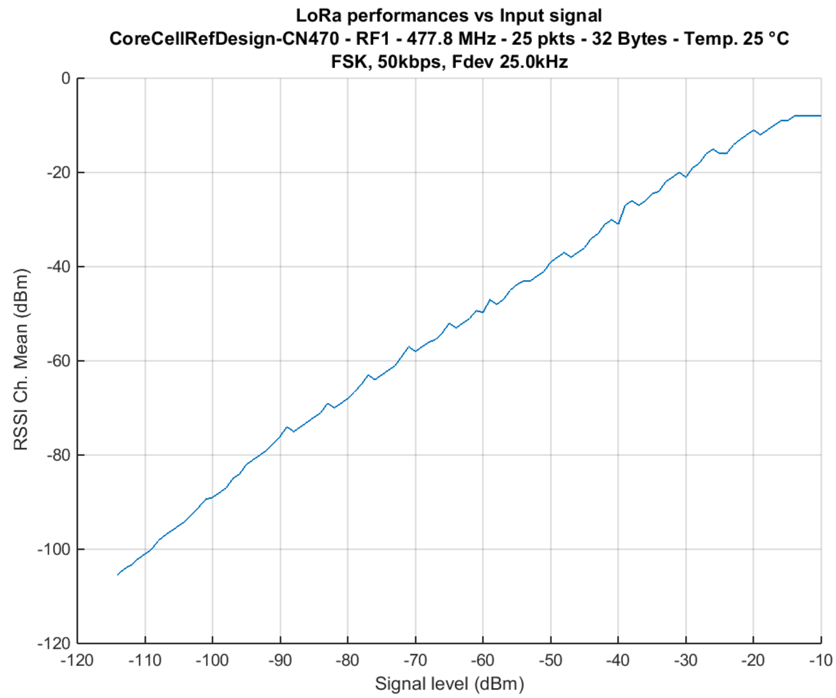
(a) RSSI Signal mean



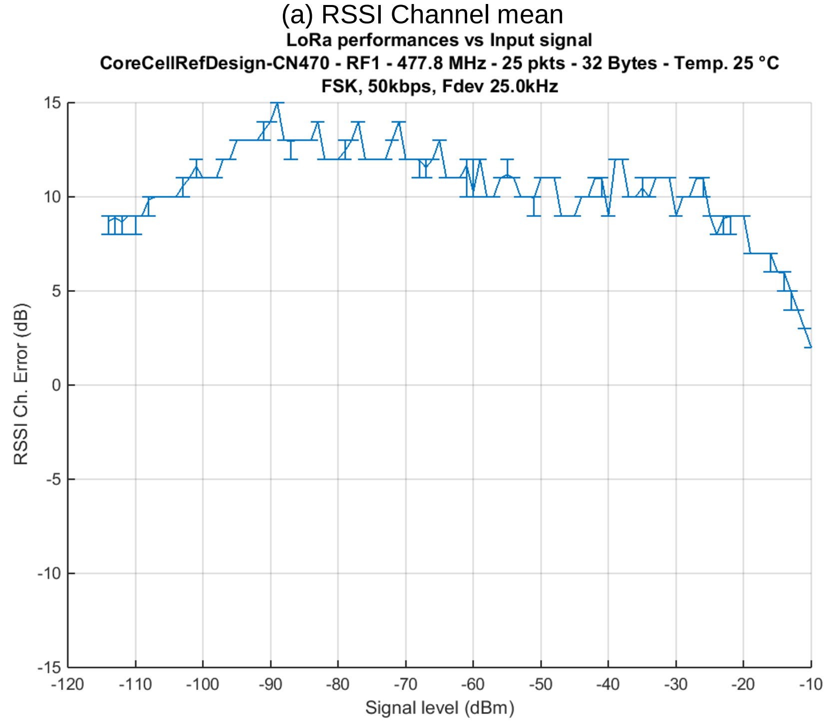
(b) RSSI Signal error

figure 23 RSSI Signal, SingleSF modem vs bandwidth, 477.7 MHz, SF9

5.2.7 FSK modem



(a) RSSI Channel mean



(b) RSSI Channel error

figure 24 RSSI Channel, FSK modem, RF1, 477.8 MHz

5.3 *SNR*

5.3.1 Description

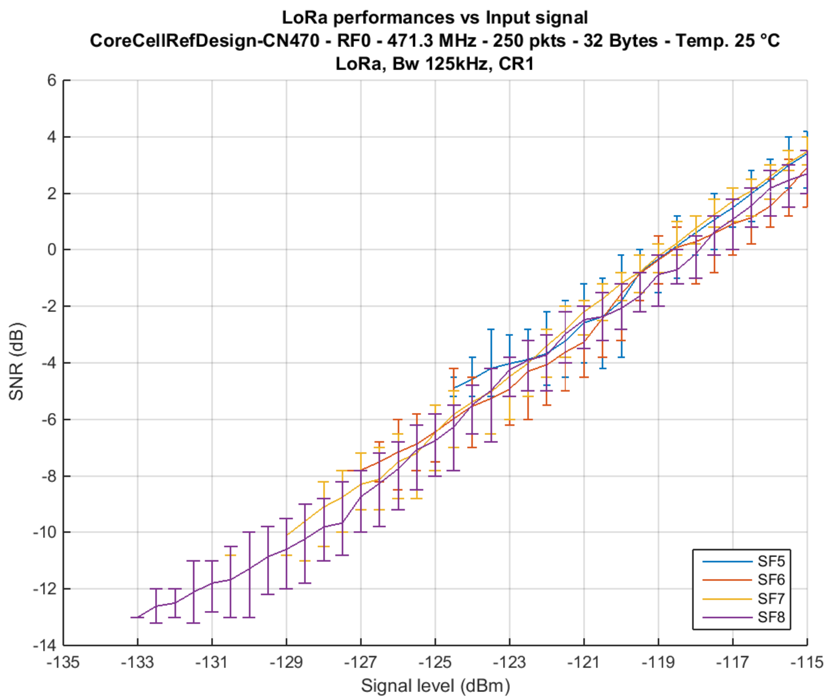
In conjunction with the RSSI value, the LoRa modem determines the Signal-To-Noise Ratio while receiving packets. This test verifies the accuracy of this indicators according the packet parameters (Spreading Factor, bandwidth, modem kind, payload length, ...).

5.3.2 Setup

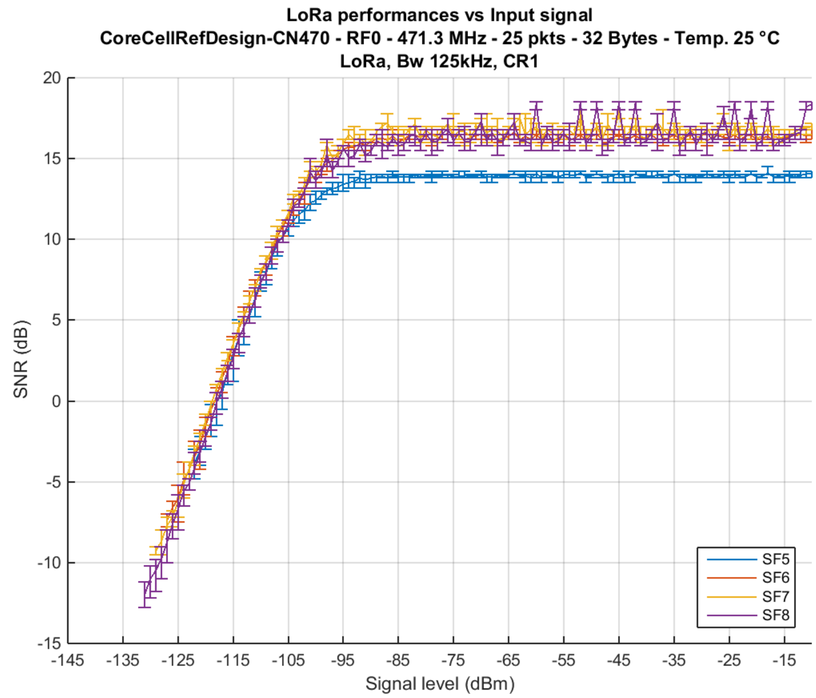
The SNR measured using the setup presented in the figure **3**(Sensitivity, RSSI). The DUT connected to the SPDT A "common path".

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.

5.3.3 MultiSF modem versus Spreading Factor

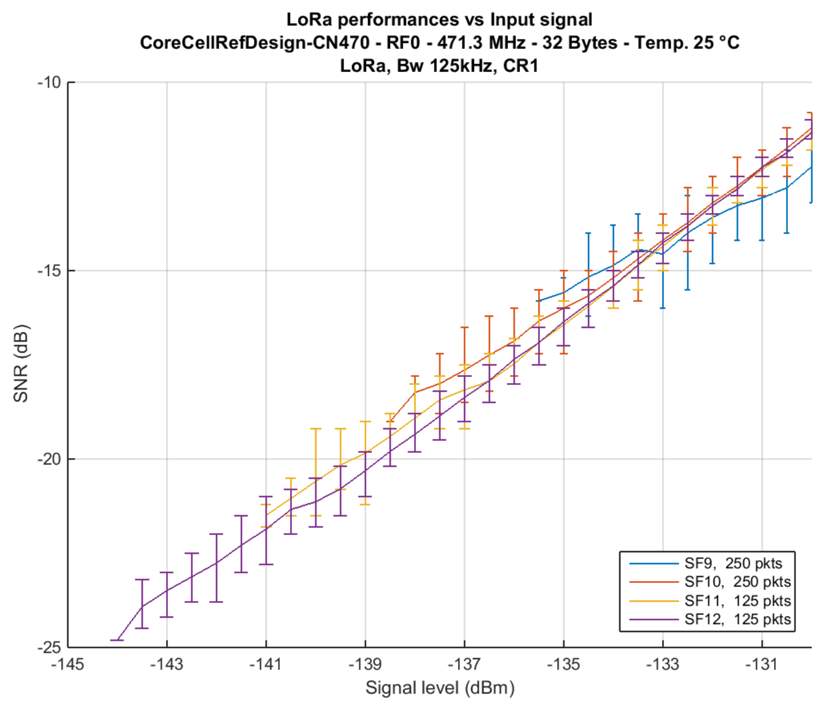


(a) Sensitivity level

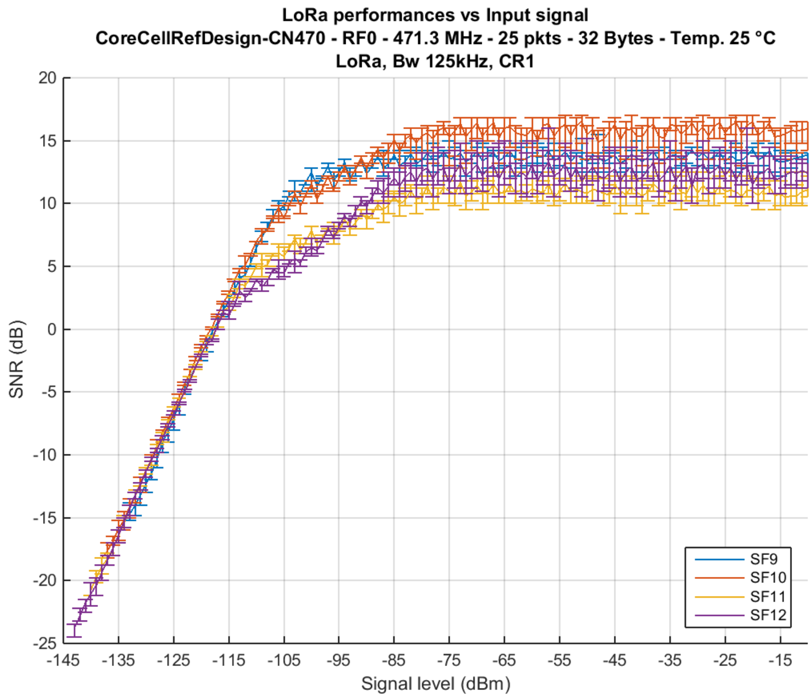


(b) High level

figure 25 SNR, MultiSF modems versus Spreading Factor (5 to 8), 471.3 MHz



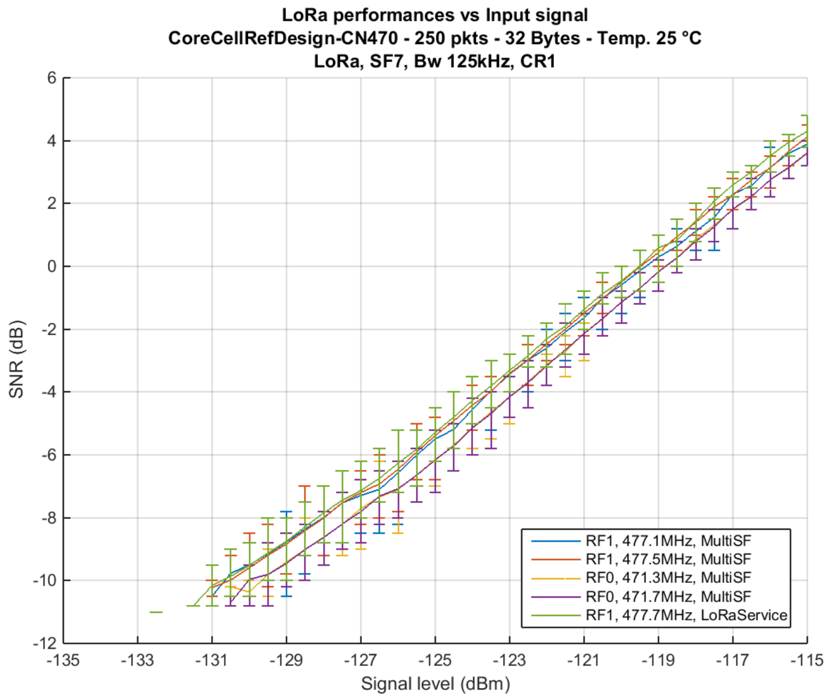
(a) Sensitivity level



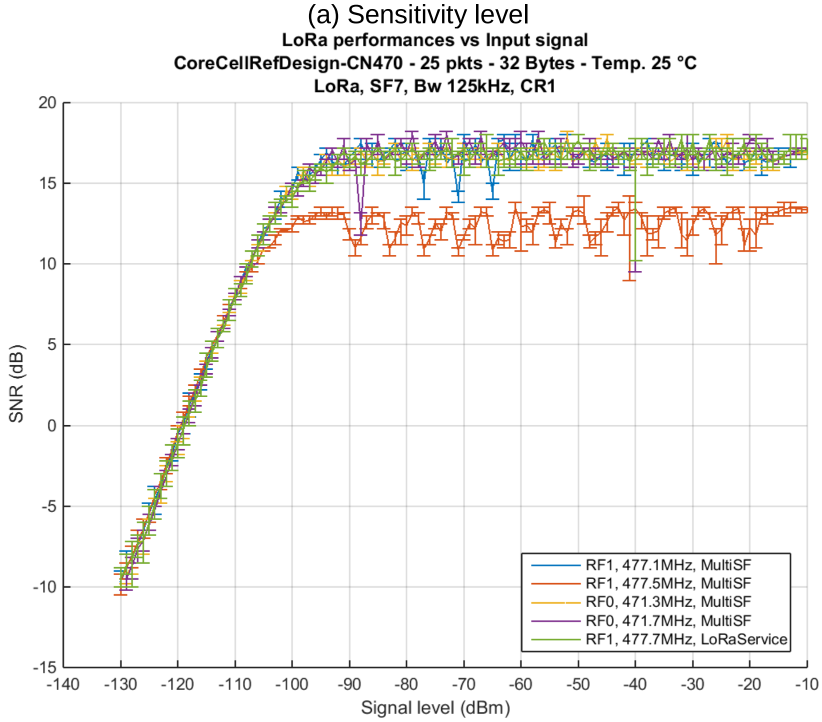
(b) High level

figure 26 SNR, MultiSF modems versus Spreading Factor (9 to 12), 471.3 MHz

5.3.4 MultiSF/SingleSF modem versus channels



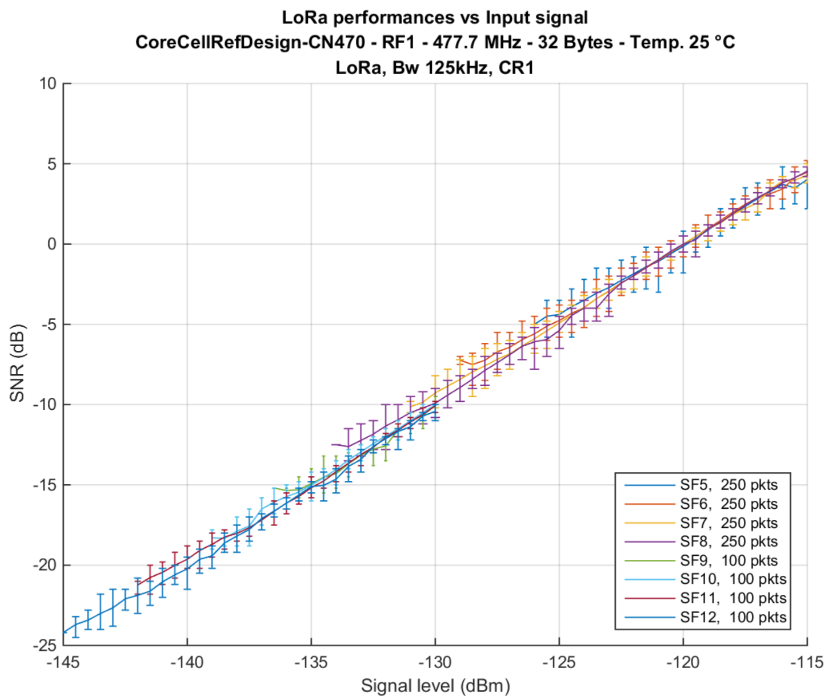
(a) Sensitivity level



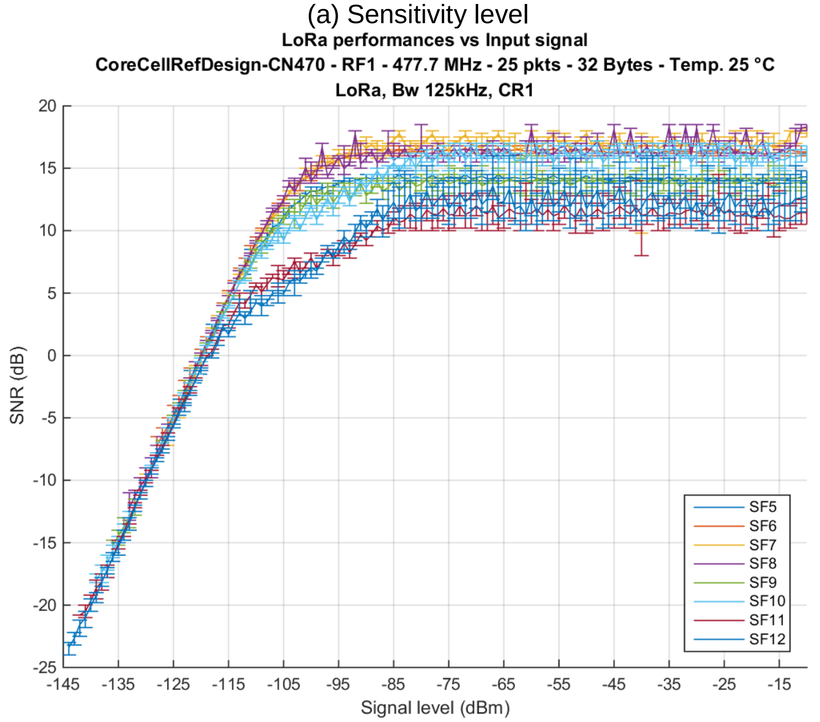
(b) High level

figure 27 SNR, MultiSF and SingleSF modems versus channels, 471.3 MHz

5.3.5 SingleSF modem versus Spreading Factor



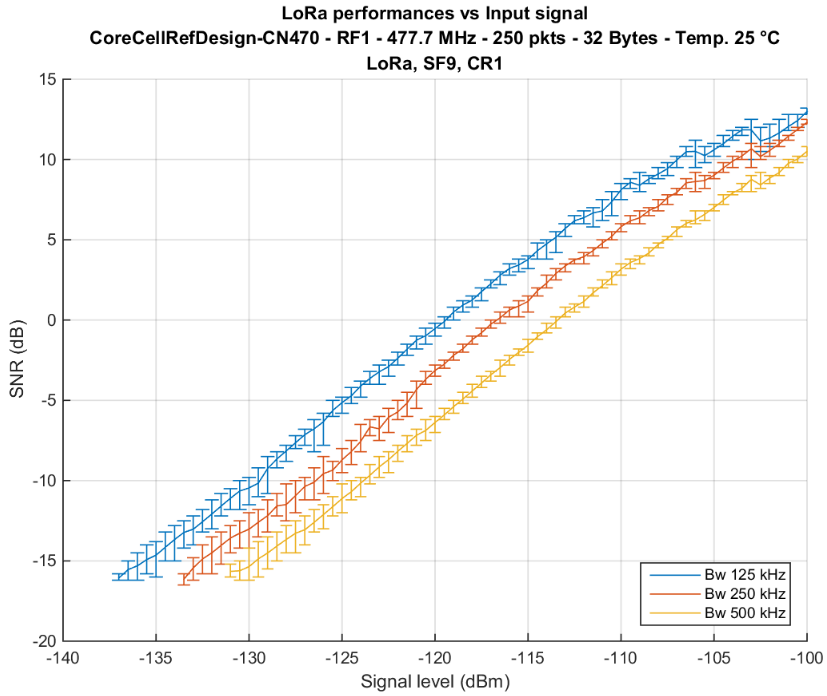
(a) Sensitivity level



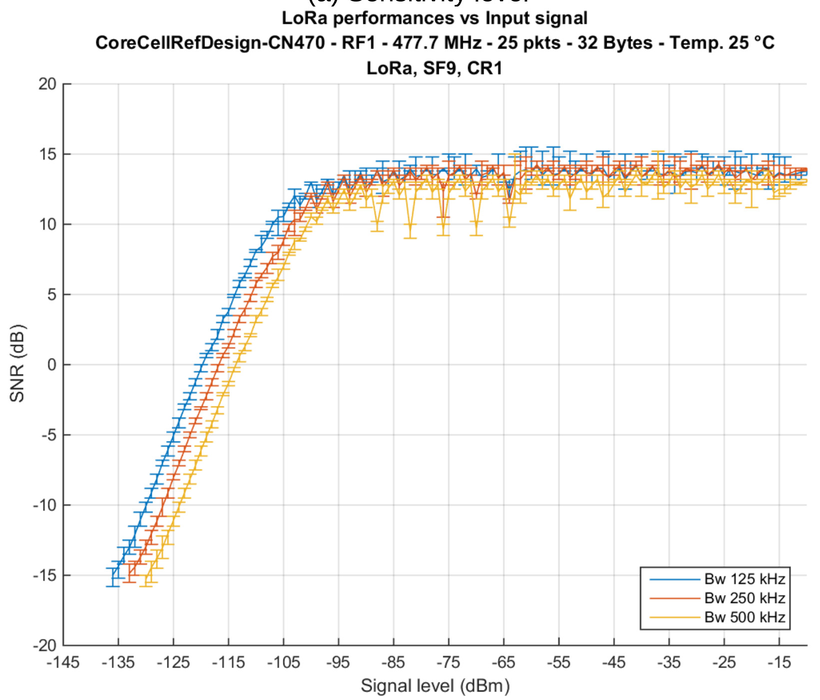
(b) High level

figure 28 SNR, SingleSF modems versus spreading factor, 477.7 MHz,BW125kHz

5.3.6 SingleSF modem versus Bandwidth



(a) Sensitivity level



(b) High level

figure 29 SNR, SingleSF modem vs bandwidth, 477.7 MHz,SF9

5.4 *Blocking and Immunity to interface*

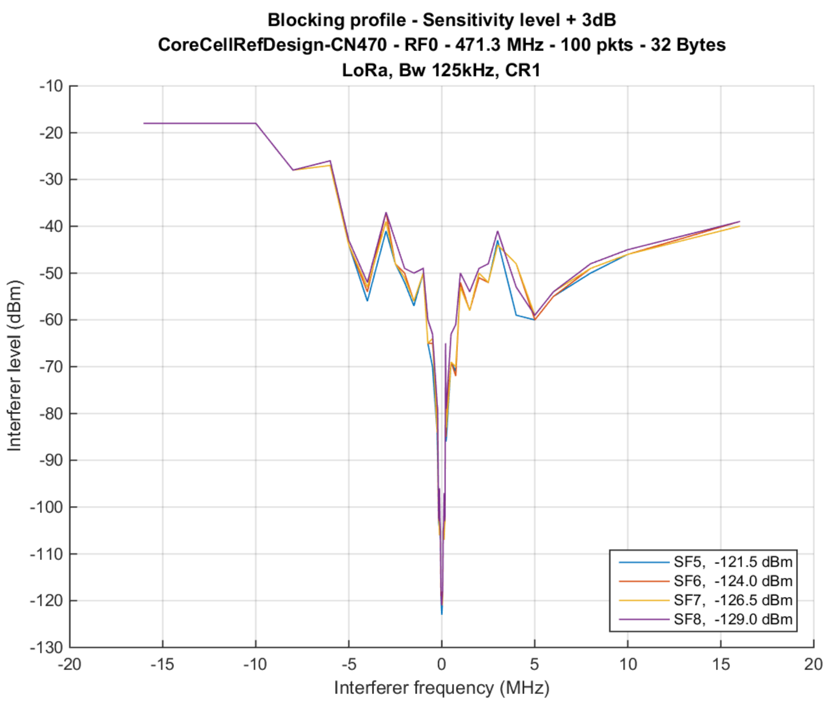
5.4.1 Description

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

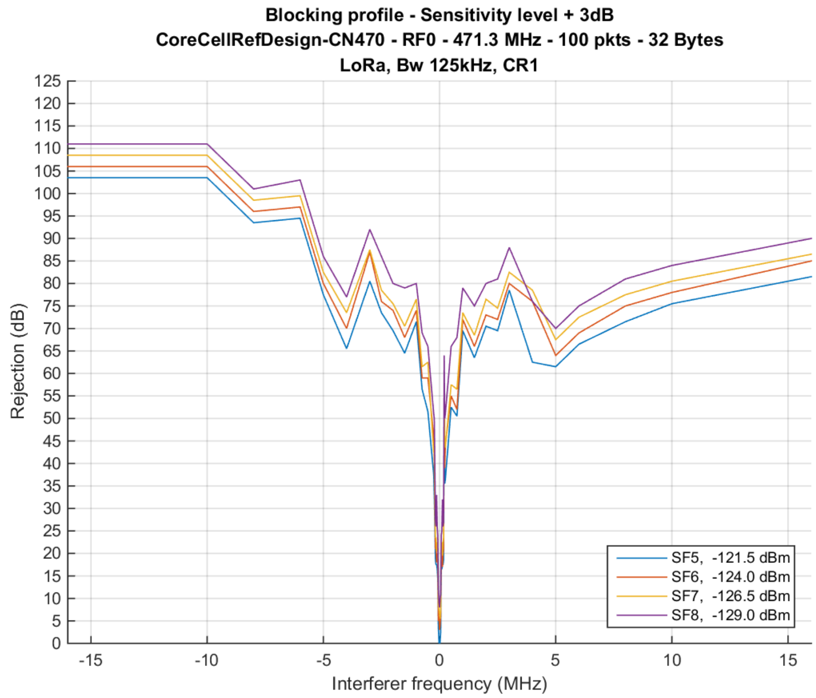
5.4.2 Setup

The test bench allowing to assess the coexistence robustness is shown in figure **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.
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%.

5.4.3 MultiSF modem versus Spreading Factor

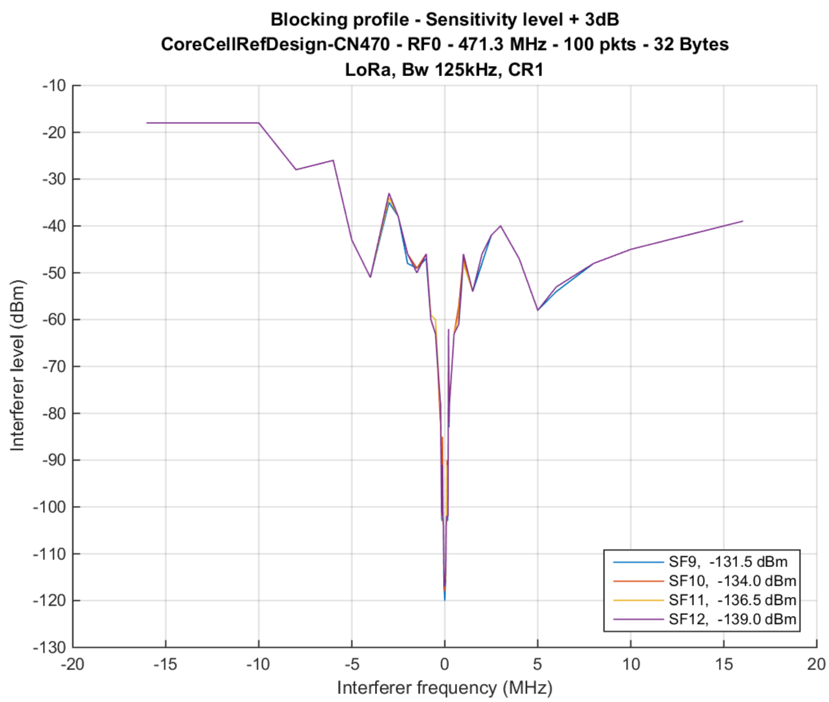


(a) Interferer level(dBm)

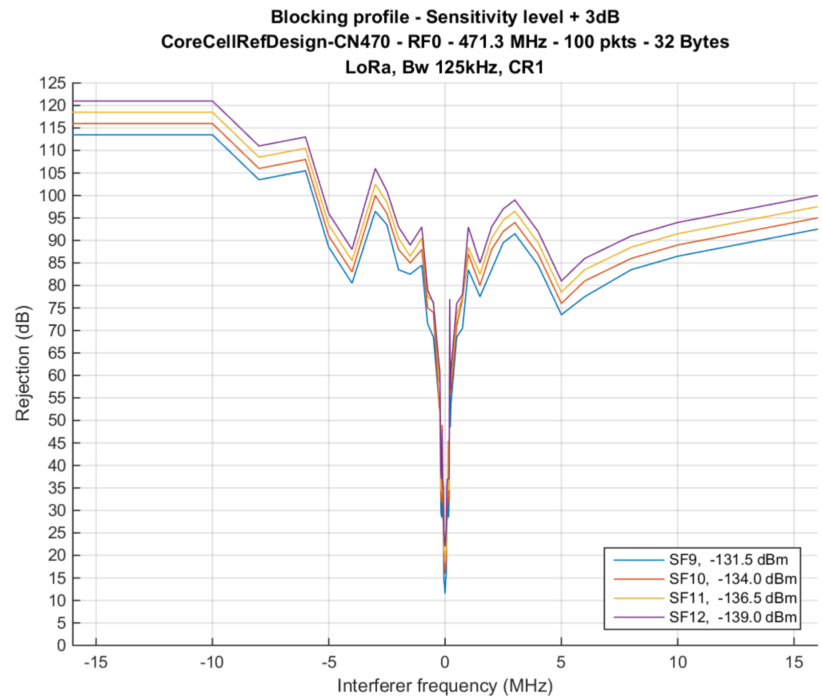


(b) Rejection(dB)

figure 30 Blocking profile, MultiSF modem versus Spreading Factor (5 to 8), 471.3 MHz



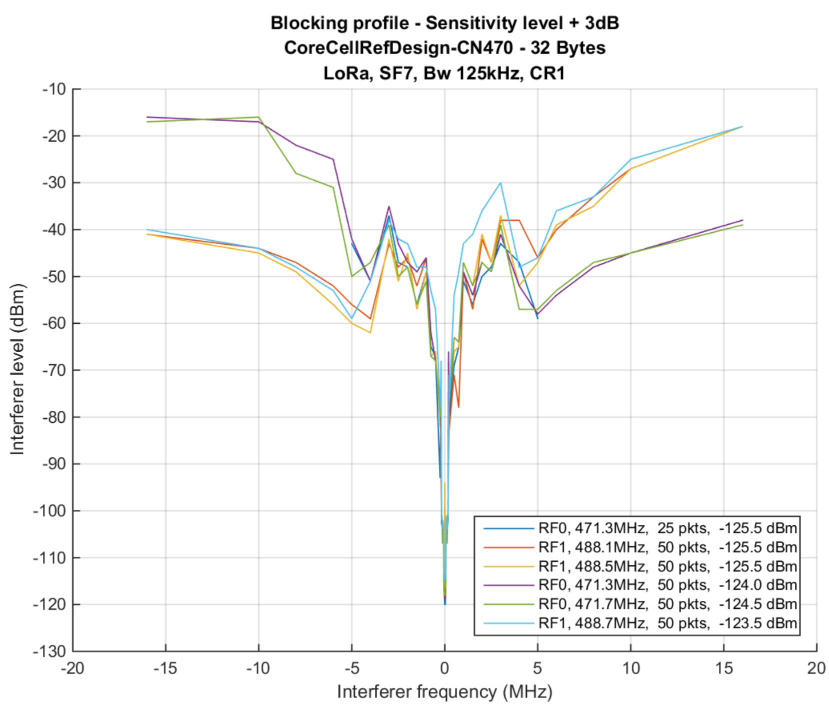
(a) Interferer level(dBm)



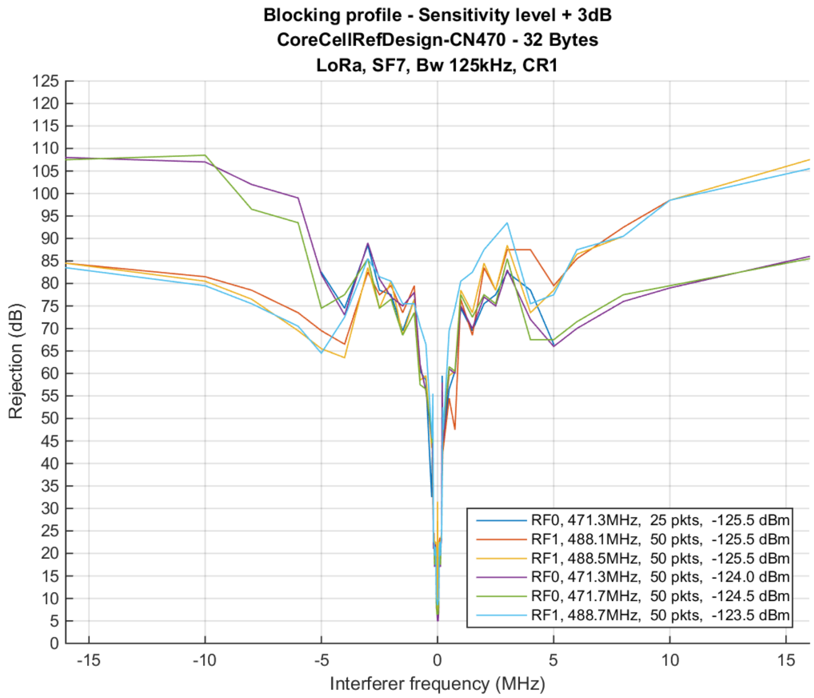
(b) Rejection(dB)

figure 31 Blocking profile, MultiSF modem versus Spreading Factor (9 to 12), 471.3 MHz

5.4.4 MultiSF modem versus channels



(a) Interferer level(dB)



(b) Rejection(dB)

figure 32 Blocking profile, MultiSF modem versus channels, SF7, Sensitivity level + 3dB

6 Appendix 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