

GDR RSD Journées LPWAN 2025

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Mesures de performances des communications IoT
avec la modulation FLRC sur la bande ISM 2.4 GHz

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Semtech transceiver portfolio

La modulation FLRC

Performances (datasheet) RX sensibility + Débit

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Conclusion et perspectives

Motivation

Lot of studies / datasets on LoRa CSS @ SubGHz

Less on LoRa CSS @ 2.4 GHz

Less on LR-FHSS @ SubGHz / 2.4 GHz

“None” on FLRC despite available since 2018? in SX128x transceivers

Semtech transceiver portfolio



Transceiver	SX127x	SX126x	SX128x	LR112x	LR2021
Generation	1 (2013)	2	1 (2018?)	3	4 (Q3 2025)
Rx sensibility (dBm)	-137 dBm	-137 dBm	-132 dBm	-141 dBm	-142 dBm
LoRa CSS	SubGHz	SubGHz	2.4 GHz	SubGHz / 2.4 GHz	SubGHz / 2.4 GHz
(G)FSK	SubGHz	SubGHz	2.4 GHz	SubGHz / 2.4 GHz	SubGHz / 2.4 GHz
GMSK		SubGHz		SubGHz / 2.4 GHz	SubGHz / 2.4 GHz
BLE PHY			2.4 GHz		2.4 GHz
FLRC			2.4 GHz		SubGHz / 2.4 GHz
Two Way Ranging			yes		yes
Positioning Wifi/GNSS				LR1120	na
LoRa Basic Modem				LR1121	na

+ WiSun, ZWave ...

NB1: LR-FHSS and Mioty rely on GMSK modulation

NB2: STM32WL product line includes SX126x transceiver

FLRC (Fast Long-Range Communication)

Proprietary Modulation by Semtech. Initially for 2.4GHz but now for SubGHz

Coherent demodulation of GMSK combined with forward error correction and interleaving techniques

Parameters @ 2.4 GHz

- Bandwidth and DataRate are linked : 260kb/s (300 kHz) -> 1.3 Mb/s (1.2 MHz)
- FEC coding rate + Gaussian Filtering
- AGC Preamble length
- Sync Word
- CRC Length

Frequency drift for a single radio

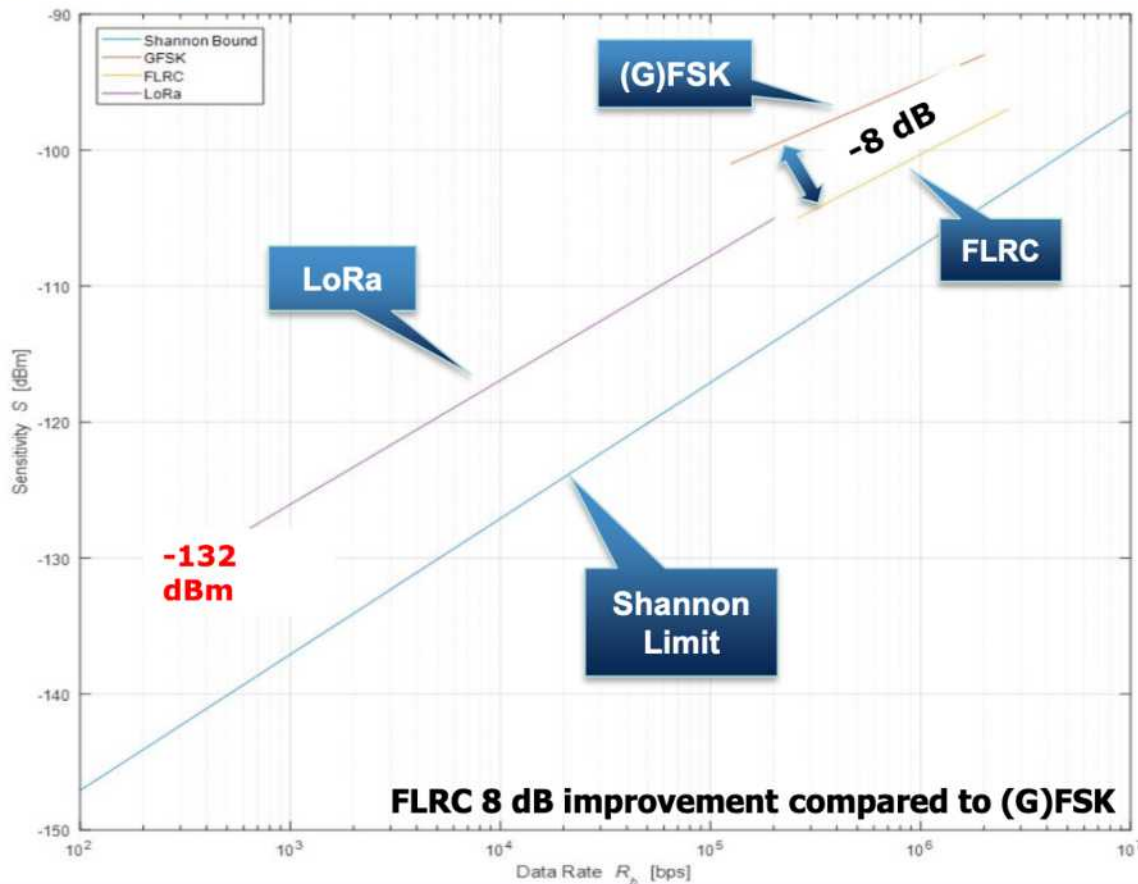
$\geq 1.04\text{Mb/s}$: max +/- 30ppm (so +/- 60ppm for the total link).

$\leq 650\text{Kb/s}$: max +/- 10ppm (so +/- 20ppm for the total link).

Source: [Semtech, SX1280/SX1281 Long Range, Low Power, 2.4GHz Transceiver with Ranging Capability, Data Sheet Rev 3.3, DS.SX1280-1.W.APP Sept 2023](#)

LoRa CSS, FLRC, (G)FSK

High Sensitivity Modems



**High Link
Budget**

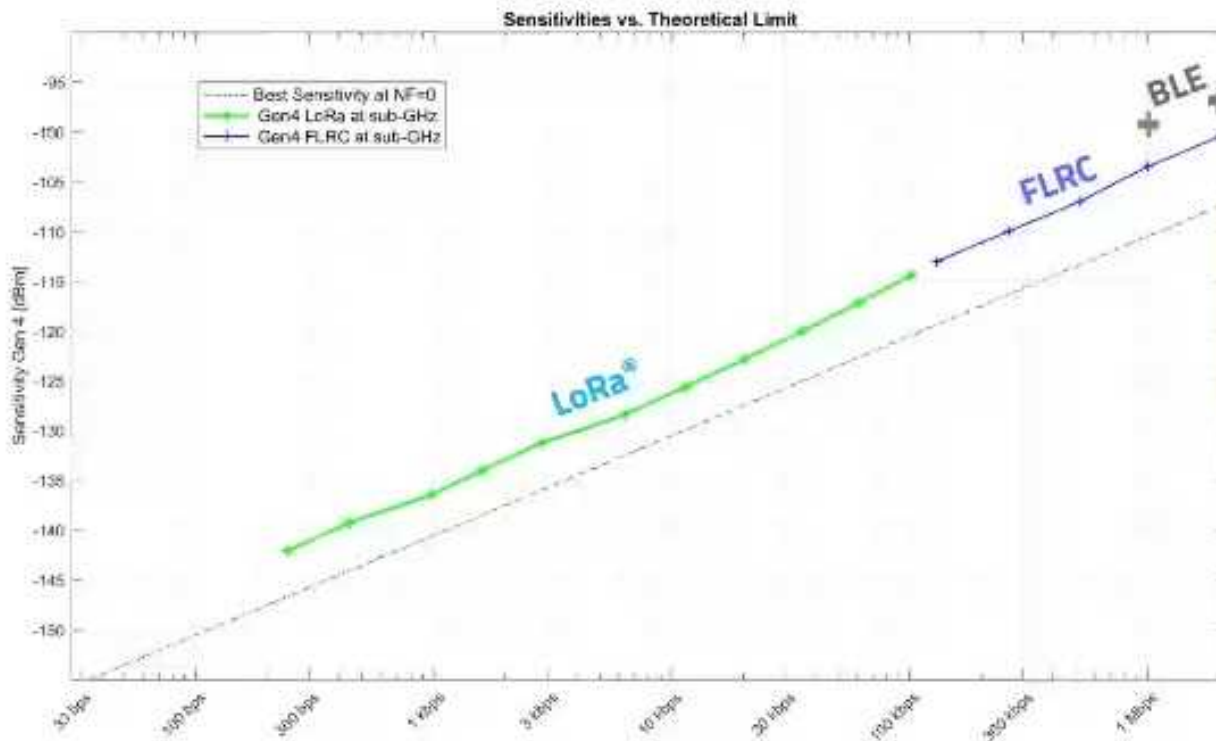
**In the 2.4 GHz
Band**



LoRa CSS, FLRC, (G)FSK, BLE PHY

Introducing Sub-GHz and 2.4GHz FLRC in LR2021

FLRC (Fast Long-Range Communication), a high-speed PHY technology offering 130kbps – 2.6 Mbps with high spectral efficiency and best theoretical sensitivity



Leading Bluetooth® LE SOC

FLRC, used at sub-GHz, will offer 8-10 dB* advantage in range, better penetration, and support 130kbps – 2.6 Mbps

* 8-10dB is a combination of sub-GHz path loss advantage and better receiver performance

Performance from the datasheet

LoRa CSS @2.4 GHz (2400-2483 MHz)

Bandwidth [kHz]	Raw Data Rates [kb/s]							
	SF5	SF6	SF7	SF8	SF9	SF10	SF11	SF12
203	31.72	19.03	11.1	6.34	3.57	1.98	1.09	0.595
406	63.44	38.06	22.2	12.69	7.14	3.96	2.18	1.19
812	126.88	76.13	44.41	25.38	14.27	7.93	4.36	2.38
1625	253.91	152.34	88.87	50.78	28.56	15.87	8.73	4.76

Bandwidth [kHz]	Receiver Sensitivity [dBm]							
	SF5	SF6	SF7	SF8	SF9	SF10	SF11	SF12
203	-109	-111	-115	-118	-121	-124	-127	-130
406	-107	-110	-113	-116	-119	-122	-125	-128
812	-105	-108	-112	-115	-117	-120	-123	-126
1625	-99	-103	-106	-109	-111	-114	-117	-120

FSPL

887 m

3950 m

8850 m

31500 m

Packer Error Rate (PER) of 1%. Packet with 10 bytes of payload, 25°C, 3.3V, CR = 4/5

Performance from the datasheet LoRa CSS versus FLRC (@2.4 GHz)

Bandwidth [kHz]	Raw Data Rates [kb/s]							
	SF5	SF6	SF7	SF8	SF9	SF10	SF11	SF12
203	31.72	19.03	11.1	6.34	3.57	1.98	1.09	0.595
406	63.44	38.06	22.2	12.69	7.14	3.96	2.18	1.19
812	126.88	76.13	44.41	25.38	14.27	7.93	4.36	2.38
1625	253.91	152.34	88.87	50.78	28.56	15.87	8.73	4.76

Symbol	Raw Bit Rate R _b [Mb/s]	Bandwidth BW [MHz DSB]
FLRC_BR_1_300_BW_1_2	1.3	1.2
FLRC_BR_1_040_BW_1_2	1.04	1.2
FLRC_BR_0_650_BW_0_6	0.65	0.6
FLRC_BR_0_520_BW_0_6	0.52	0.6
FLRC_BR_0_325_BW_0_3	0.325	0.3
FLRC_BR_0_260_BW_0_3	0.26	0.3

Performance from the datasheet
FLRC @2.4 GHz (2400-2483 MHz)

Symbol	Raw Programmed Data Rate Rb [Mb/s]	Programmed Coding Rate CR	Effective Data Rate Rbeff [Mb/s]	Sensitivity [dBm] at PER 1%
FLRC_BR_1_300_BW_1_2	1.3	1	1.3	-96
	1.3	3/4	0.975	-100
	1.3	1/2	0.65	-99
FLRC_BR_1_040_BW_1_2	1.04	1	1.04	-97
	1.04	3/4	0.78	-100
	1.04	1/2	0.52	-101
FLRC_BR_0_650_BW_0_6	0.65	1	0.65	-99
	0.65	3/4	0.488	-103
	0.65	1/2	0.325	-104
FLRC_BR_0_520_BW_0_6	0.52	1	0.52	-100
	0.52	3/4	0.39	-104
	0.52	1/2	0.26	-104
FLRC_BR_0_325_BW_0_3	0.325	1	0.325	-101
	0.325	3/4	0.244	-106
	0.325	1/2	0.163	-106
FLRC_BR_0_260_BW_0_3	0.26	1	0.26	-103
	0.26	3/4	0.195	-105
	0.26	1/2	0.130	-106

FSPL

606-628 m

1920-1980 m

In-vivo Point-to-Point Experiments

- Short Range NLOS

- Duration 27 days, 4.6 millions of messages
- Multiple parameters @ Low power (as possible)
 - + LoRa High speed (for reference)
- Preliminary tests: multiple parameter combinations
- Main test run: 32 configurations
 - <bitrate, CR, BT > x Tx power (0, -5, -10, -15 dBm)

- Long Range LOS

- Duration 3 days, ~300000 messages
- Only most influencing parameters
 - Bitrate/BW + CR
 - + LoRa High speed (for reference)
- Fix Tx power (10 dBm)

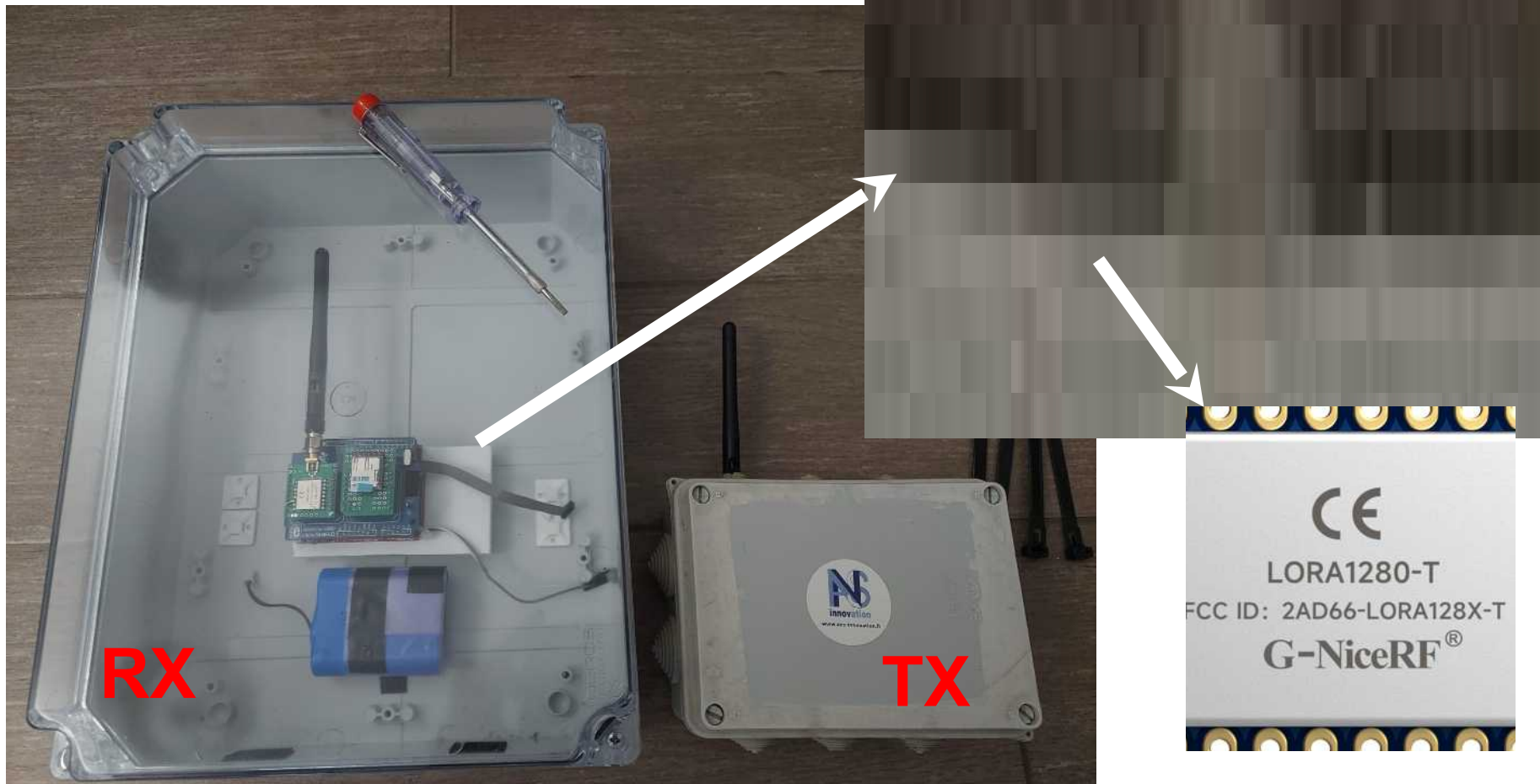
NB: fixed payload size 30 bytes

NB: the firmware is not optimized for low power consumption TCXO always on

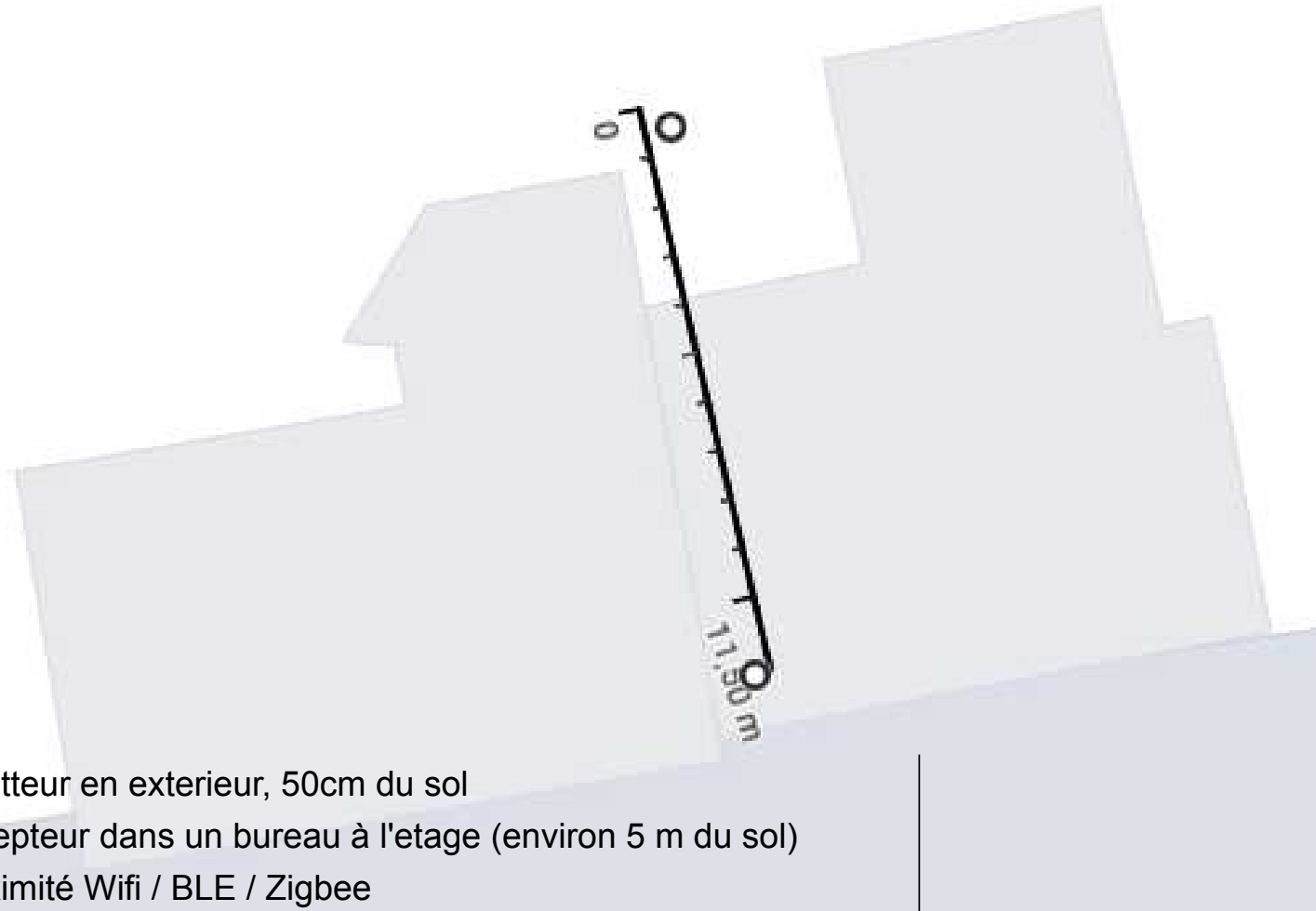
FLRC endpoints

[Olimexino STM32](#) + [OpenLog](#) +

[NiceRF SX1280 with TCXO](#) + 3 dBi antenna



Short Range NLOS (duration 27 days)



Long Range LOS (duration 3 days)

chez le
Per'GRAS
de père en fils depuis 1896

FSPL -107.3 dB

Tx

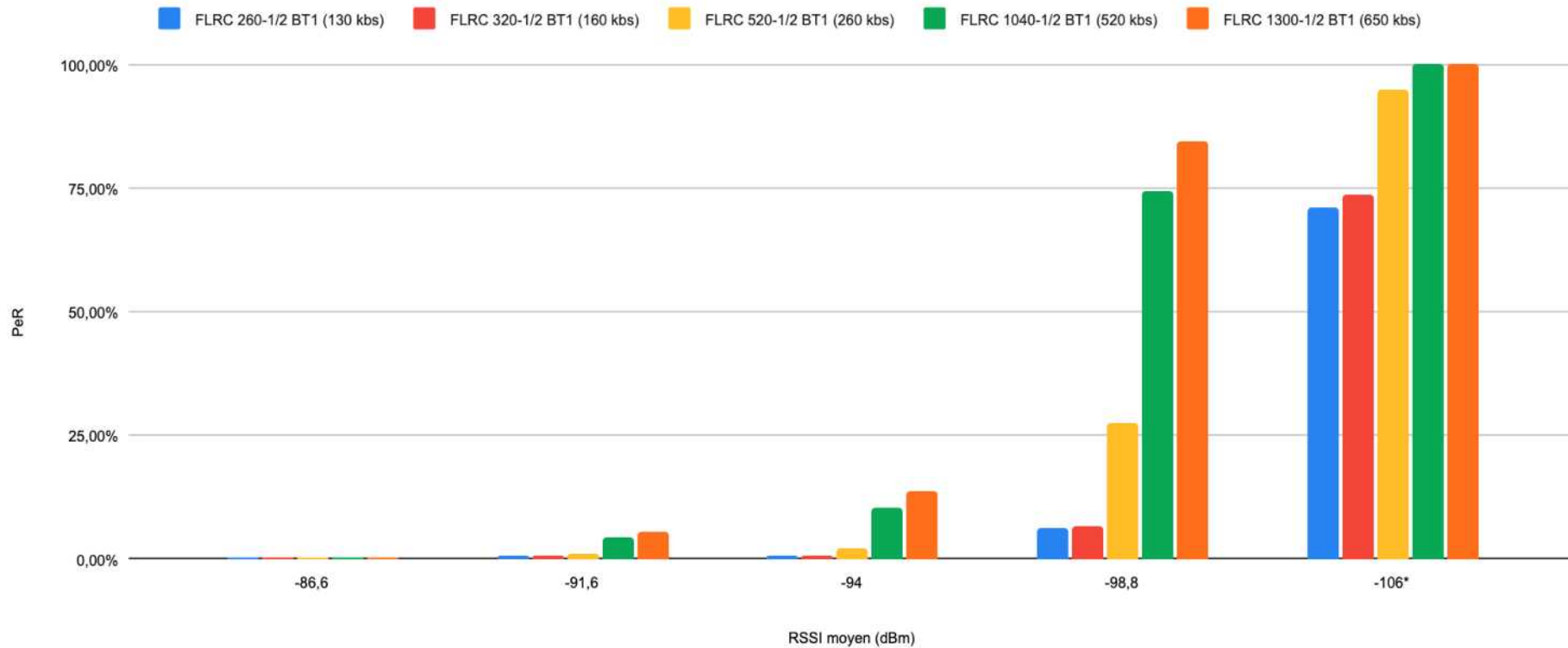
~2300m LOS

Rx

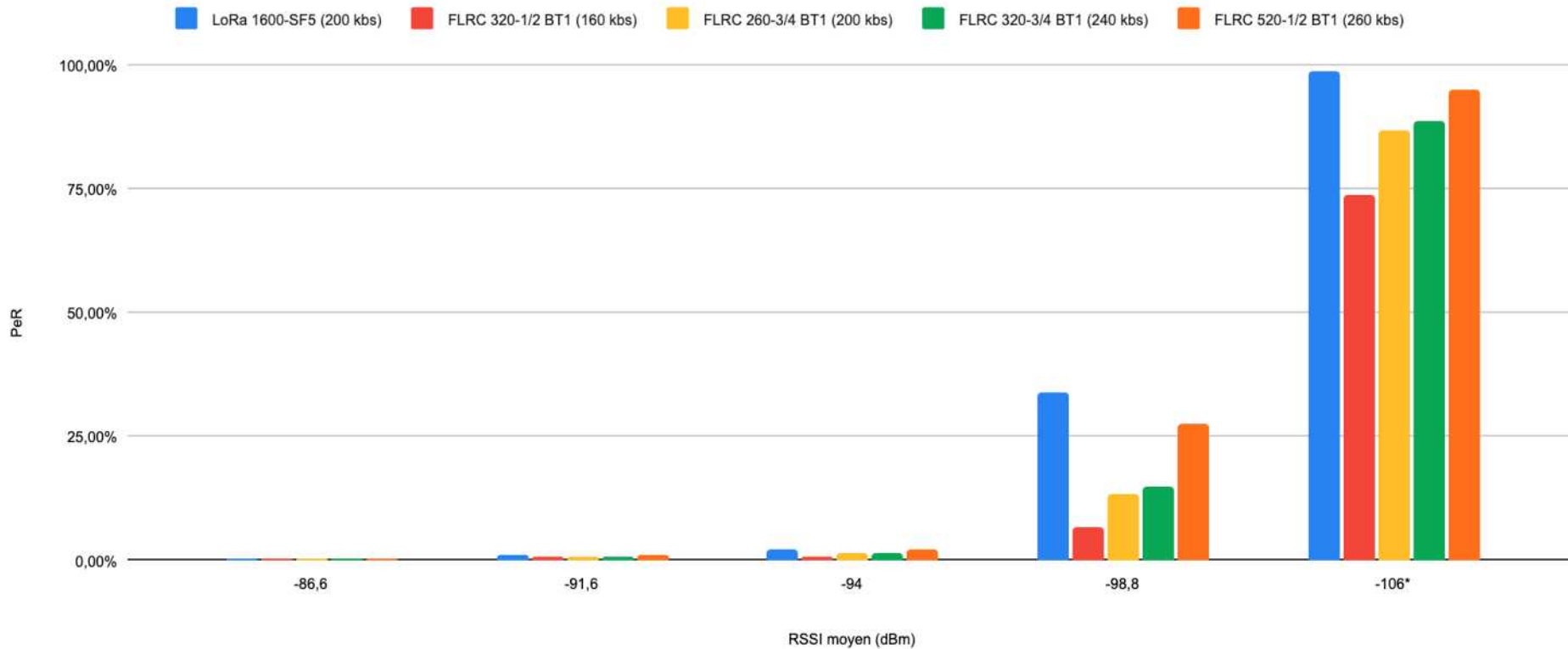


$$FSPL \text{ (with txpower + antenna gains)} = 10 + 3 - 107.3 + 3 = -91.3 \text{ dBm}$$

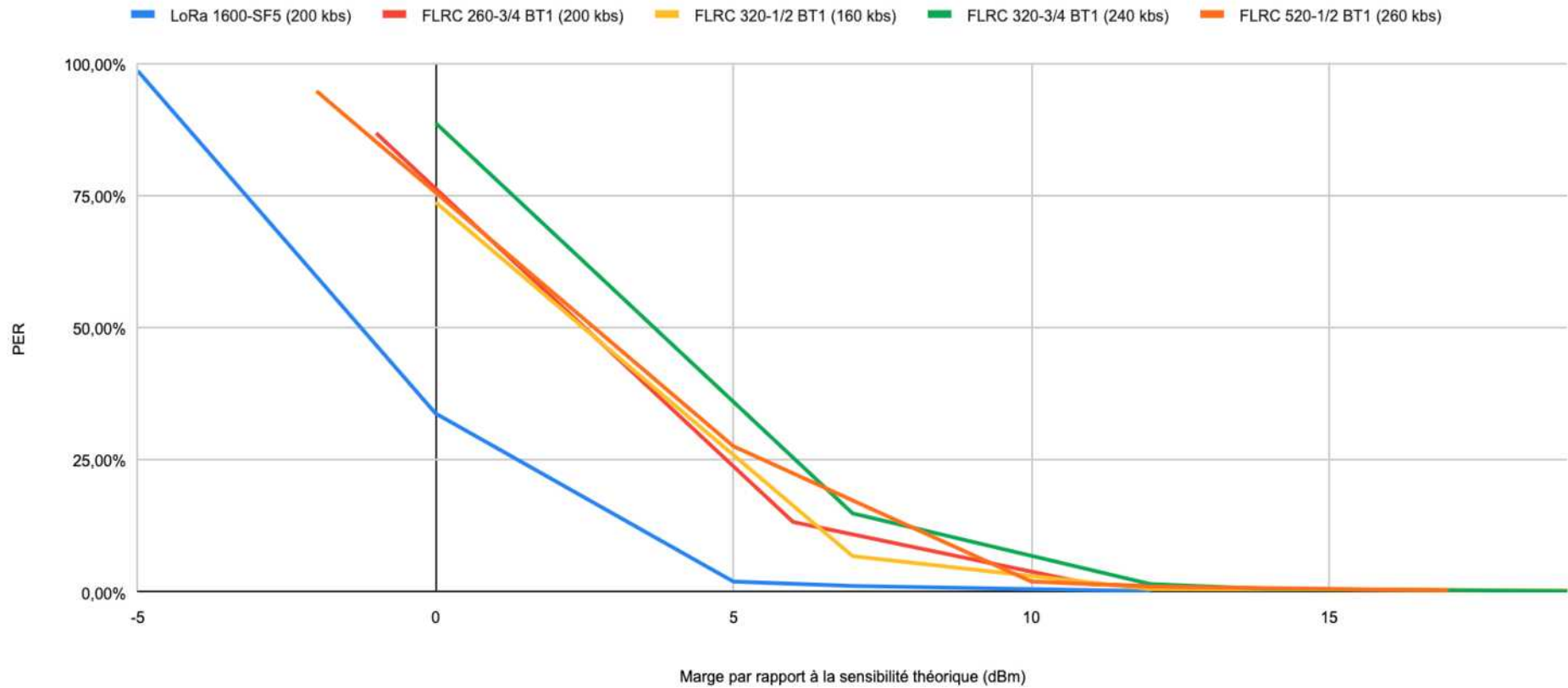
PER for Short Range NLOS (duration 27 days)



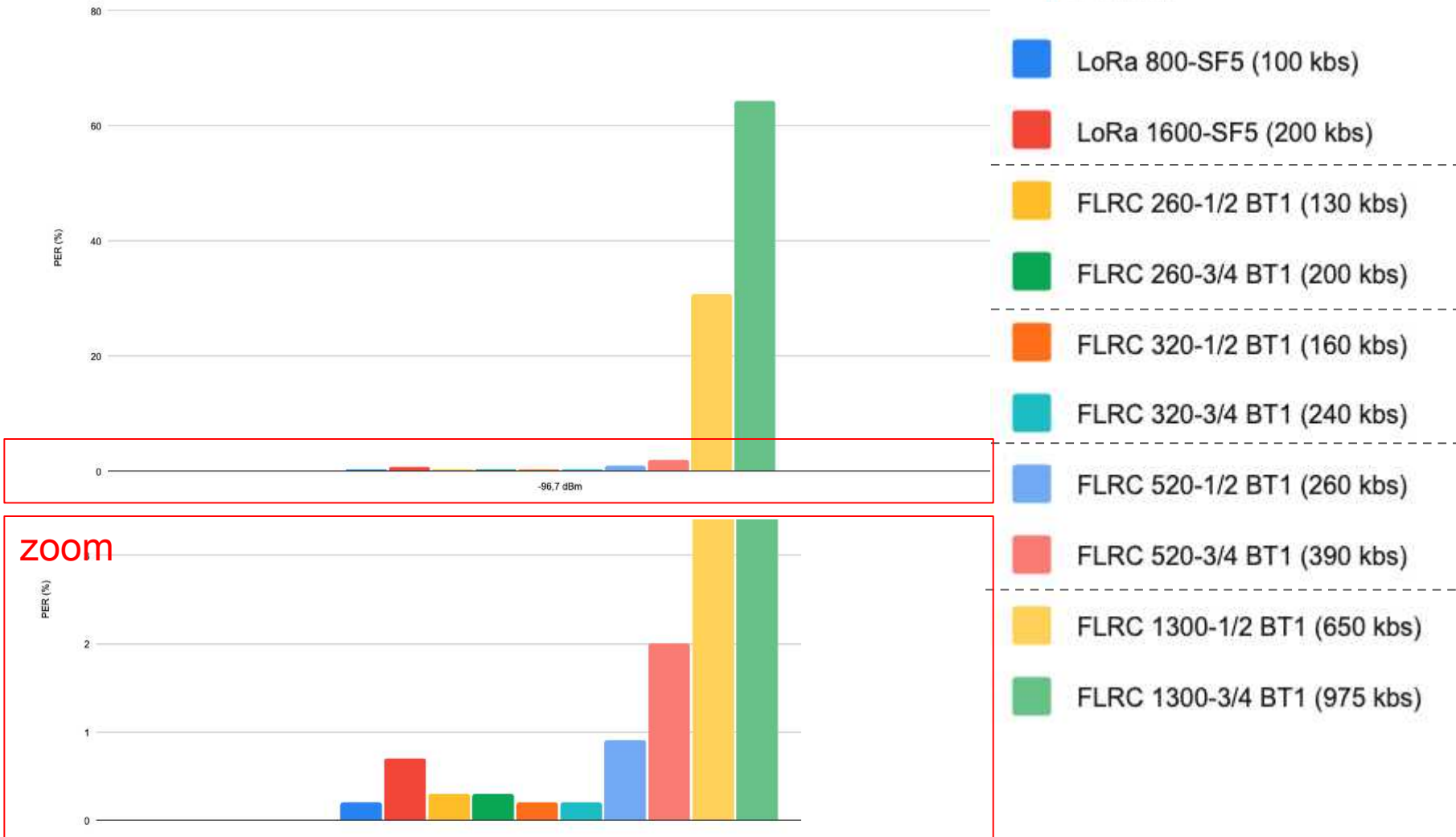
PER for Short Range NLOS (duration 27 days)



PER for Short Range NLOS (duration 27 days)



PER for Long Range LOS (duration 3 days)



Conclusion

Promising low power modulation for audio/video/seismograph streaming

FLRC up to 2.6 Mbps with LR2021

But

No FLRC concentrators (like SX130x) → multiple bitrate, multiple frequencies

No FLRC datarates in LoRaWAN specifications

(Our) Perspectives

Immunity/Collision tests FLRC @ 2.4 GHz (Wifi, BLE, LoRa CSS, FLRC)

Very long range tests FLRC @ 2.4 GHz (distance 50 and 150 kms) balloons/UAV

New tests FLRC @ 868 MHz (LR2021)

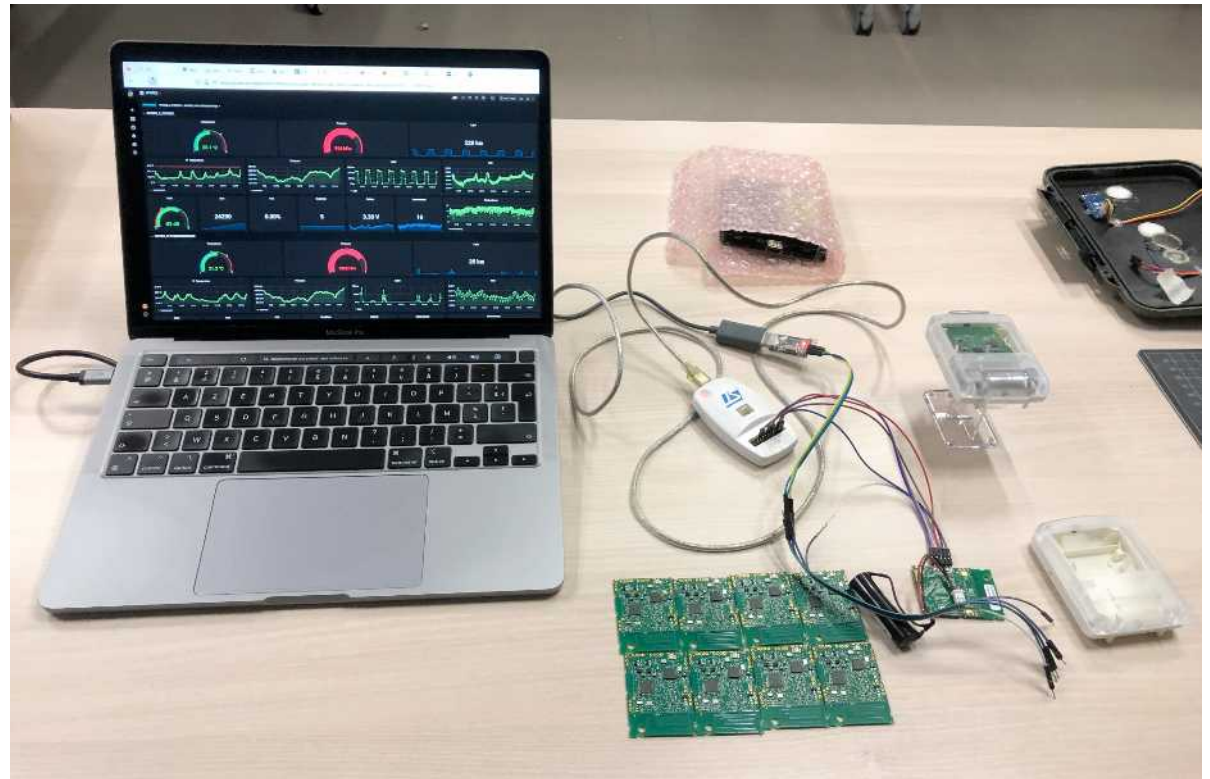
Immunity/Collision tests FLRC @ SubGHz (LoRa CSS, FLRC)

Dataset is coming : <https://github.com/CampusIoT/datasets>

Special thanks to Laurent Gras



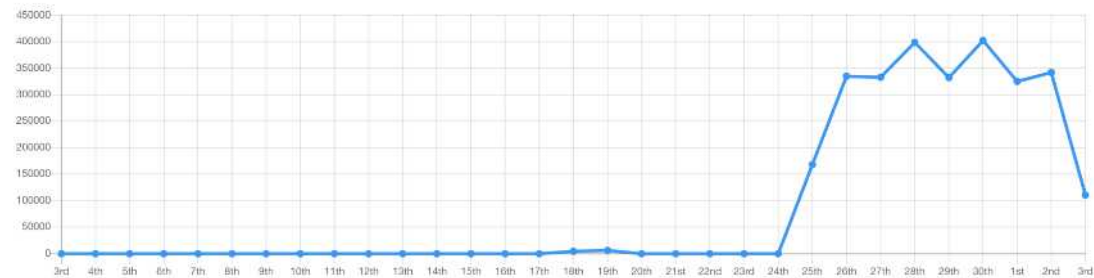
Annonce : piles 3.6V et cartes SX1272 à donner



Announce : Test LoRa/LoRaWAN très longue distance Pic à 725000 messages / jour (depuis le Mont Aigoual)



Frames received



Frames received

