Feedback from real-time experiments

Camille MONIÈRE, PhD Student

Lab-STICC, CNRS UMR 6285
Université de Bretagne Sud, France

IMS, CNRS UMR 5218
Université de Bordeaux, France

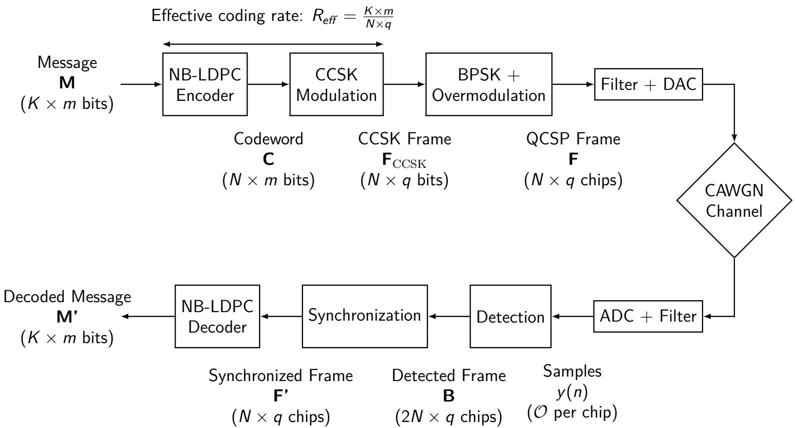
10/06/2022

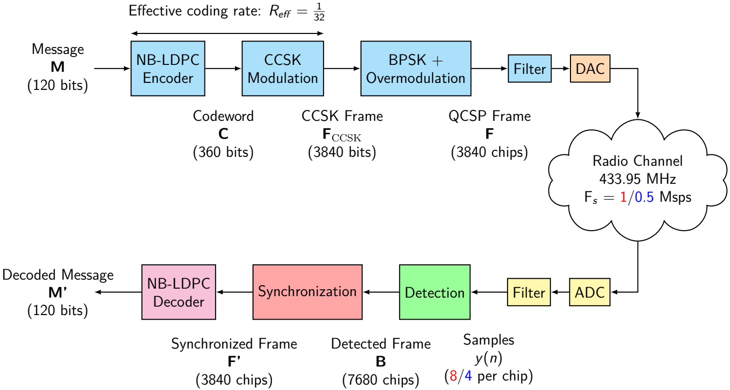
QCSP Meeting,
LETI, Grenoble, France

Sommaire

1. Context
   - QCSP System Model
   - Implementation
2. Experiments
   - Detection Critical Point: Threshold
   - Urban Area Experiments
3. Conclusion

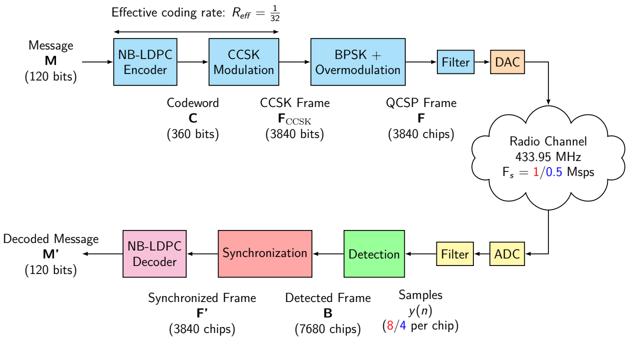
QCSP System Model





- $K = 20$
- $m = 6$
- $N = 60$
- $q = 2^m = 64$
- $R_{eff} = \frac{1}{32}$
- $\mathcal{O} = 8$ or 4

Implementation

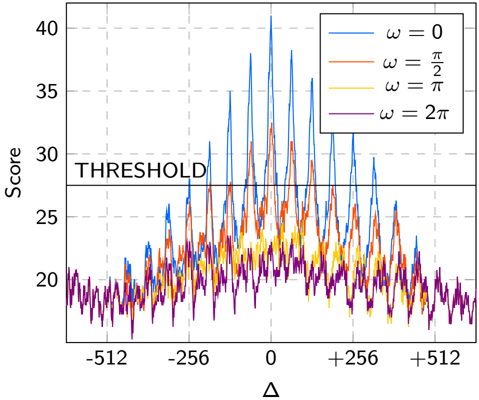


Legend	
Transmitter	Receiver
C/C++	VHDL and C++ HLS
VHDL	C/C++
	MATLAB
	C/C++ called from MATLAB

$F_s = 1$ Msps but only half of the samples are used in detection resulting in $F_s' = .5$ Msps

Issue

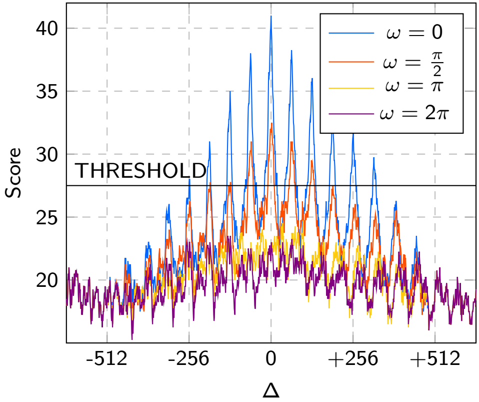
Score (function of Δ and ω)



Threshold can be calculated from synthetic values but . . .

Issue

Score (function of Δ and ω)

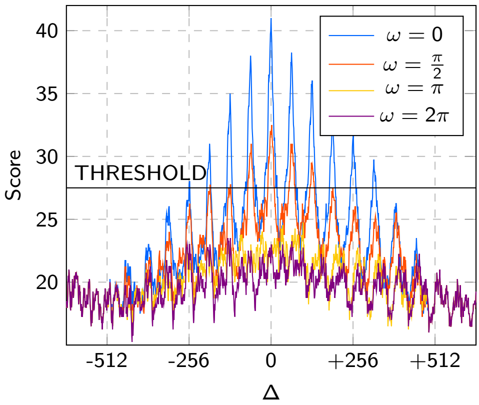


Threshold can be calculated from synthetic values but ...

- Radio channel in urban area is not Gaussian,

Issue

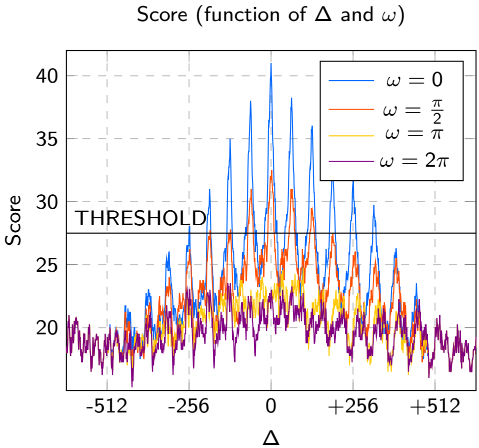
Score (function of Δ and ω)



Threshold can be calculated from synthetic values but ...

- Radio channel in urban area is not Gaussian,
- oversampling was not considered.

Issue



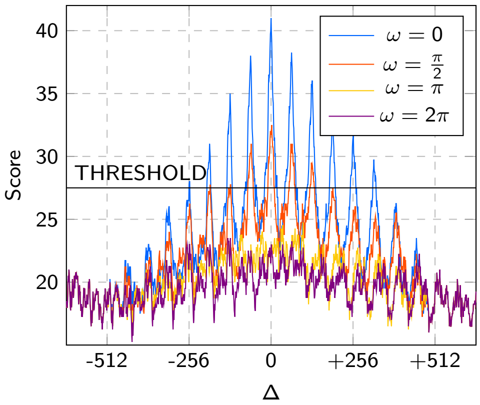
Threshold can be calculated from synthetic values but . . .

- Radio channel in urban area is not Gaussian,
- oversampling was not considered.

A criterion to set the threshold is needed:

Issue

Score (function of Δ and ω)



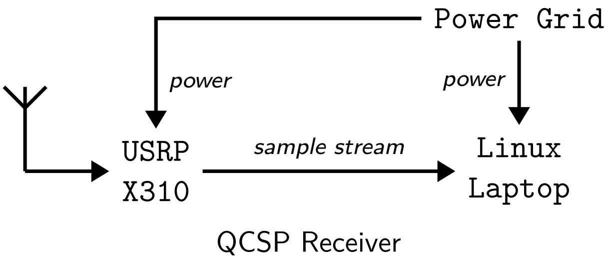
Threshold can be calculated from synthetic values but . . .

- Radio channel in urban area is not Gaussian,
- oversampling was not considered.

A criterion to set the threshold is needed:

MTBFA:
Mean Time Between False Alarms

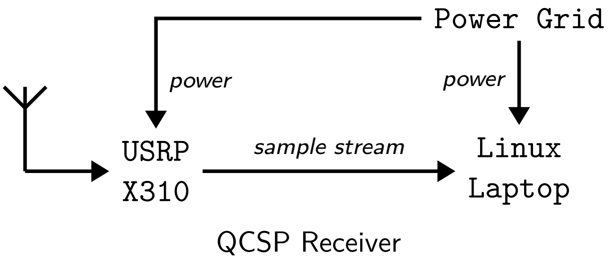
Protocol: Measuring the MTBFA



- No QCSP transmission,
- uncontrolled environment (office),
- free running detector.

Detections (*thus, false alarms*) are counted. After 100 false alarms or 5 hours elapsed, a new threshold is tested.

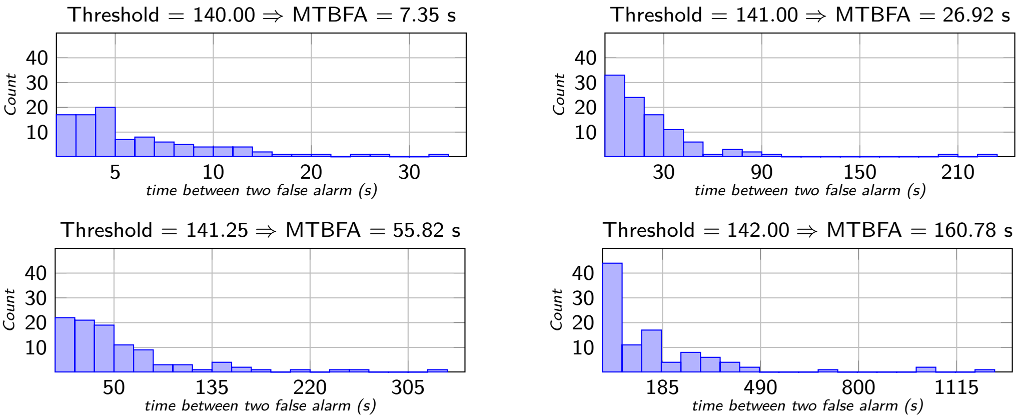
Protocol: Measuring the MTBFA



- No QCSP transmission,
- uncontrolled environment (office),
- free running detector.

Detections (*thus, false alarms*) are counted. After 100 false alarms or 5 hours elapsed, a new threshold is tested.

Results for four different thresholds, receiver gain maxed-out



How does the QCSP communication system perform in an urban area?

How does the QCSP communication system perform in an urban area?

- Does it work?

How does the QCSP communication system perform in an urban area?

- Does it work?
- Is it resilient to the channel evolution?

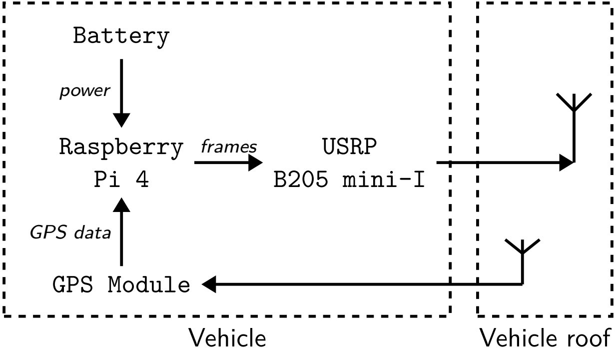
How does the QCSP communication system perform in an urban area?

- Does it work?
- Is it resilient to the channel evolution?

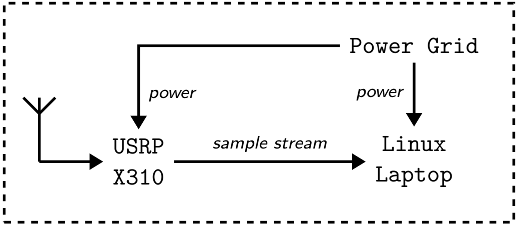
Best way to know is to test it in real conditions!

Transmitter

Standalone, embedded in a car moving through the town.

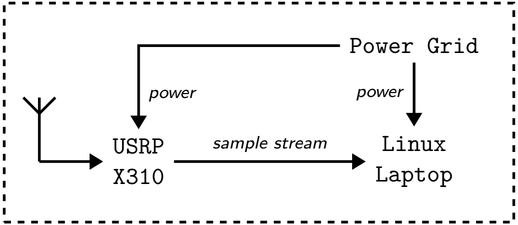


Receiver



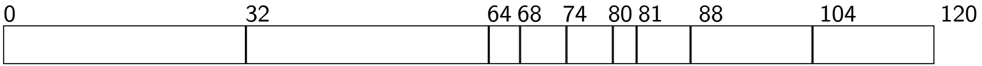
Building (*ENSIBS*) roof

Receiver

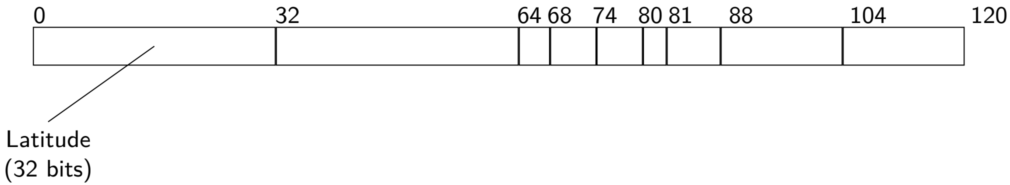


Building (*ENSIBS*) roof

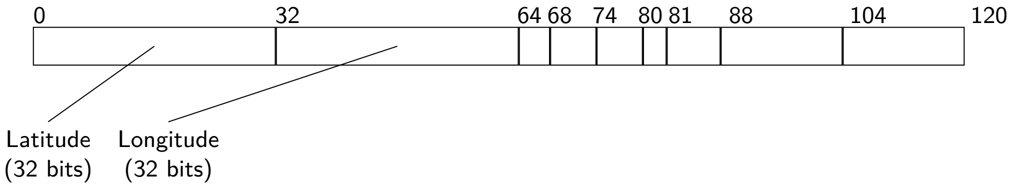
Sent Data



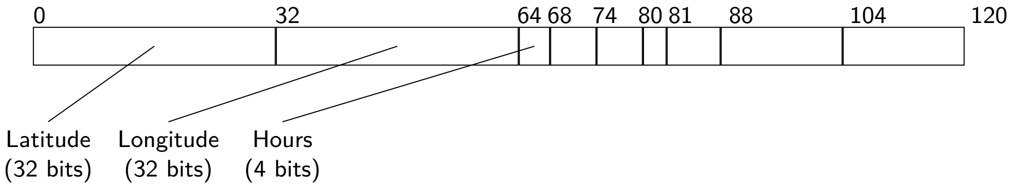
Sent Data



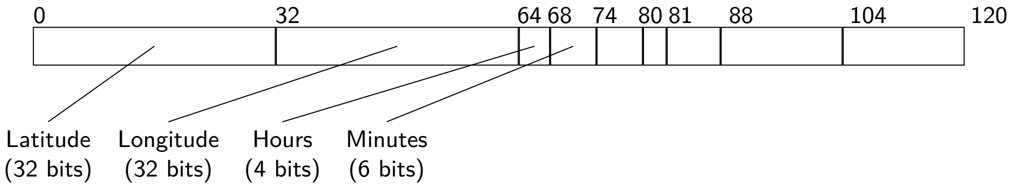
Sent Data


0
32
64
68
74
80
81
88
104
120
Latitude
(32 bits)
Longitude
(32 bits)

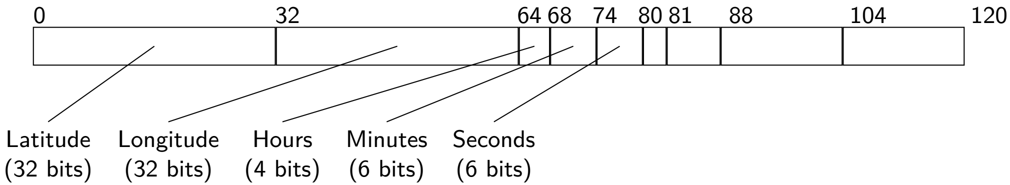
Sent Data


0
32
64 68
74
80 81
88
104
120
Latitude (32 bits)
Longitude (32 bits)
Hours (4 bits)

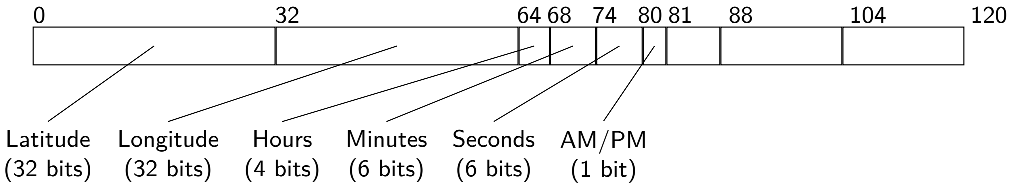
Sent Data


0
32
64
68
74
80
81
88
104
120
Latitude (32 bits)
Longitude (32 bits)
Hours (4 bits)
Minutes (6 bits)

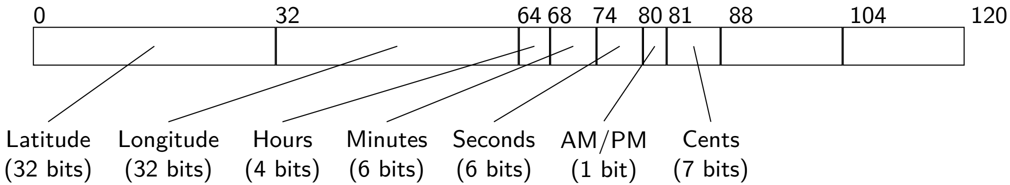
Sent Data


0
32
64
68
74
80
81
88
104
120
Latitude
(32 bits)
Longitude
(32 bits)
Hours
(4 bits)
Minutes
(6 bits)
Seconds
(6 bits)

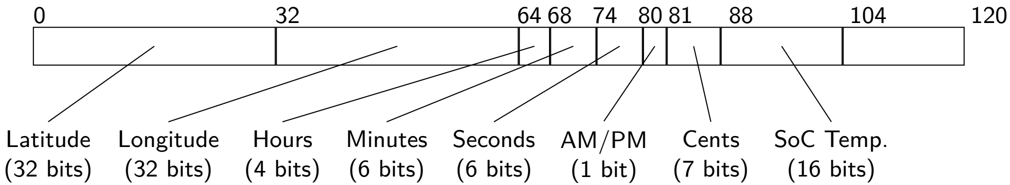
Sent Data


0
32
64 68
74
80 81
88
104
120
Latitude (32 bits)
Longitude (32 bits)
Hours (4 bits)
Minutes (6 bits)
Seconds (6 bits)
AM/PM (1 bit)

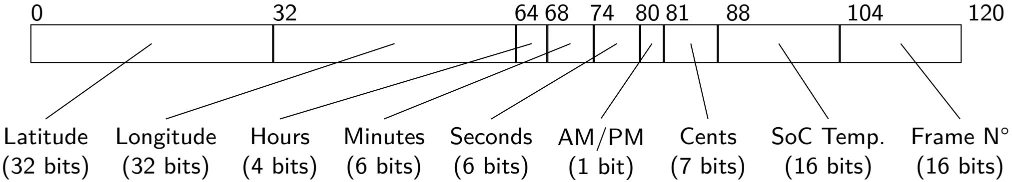
Sent Data


0
32
64
68
74
80
81
88
104
120
Latitude (32 bits)
Longitude (32 bits)
Hours (4 bits)
Minutes (6 bits)
Seconds (6 bits)
AM/PM (1 bit)
Cents (7 bits)

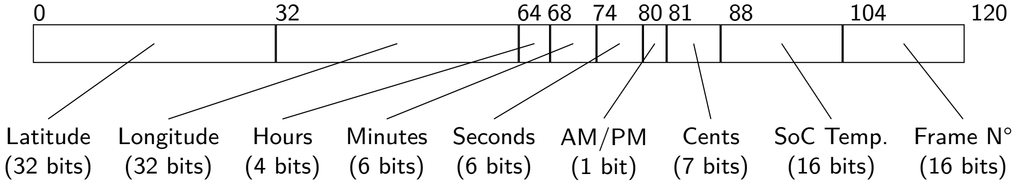
Sent Data


0
32
64
68
74
80
81
88
104
120
Latitude (32 bits)
Longitude (32 bits)
Hours (4 bits)
Minutes (6 bits)
Seconds (6 bits)
AM/PM (1 bit)
Cents (7 bits)
SoC Temp. (16 bits)

Sent Data


0
32
64
68
74
80
81
88
104
120
Latitude (32 bits)
Longitude (32 bits)
Hours (4 bits)
Minutes (6 bits)
Seconds (6 bits)
AM/PM (1 bit)
Cents (7 bits)
SoC Temp. (16 bits)
Frame N° (16 bits)

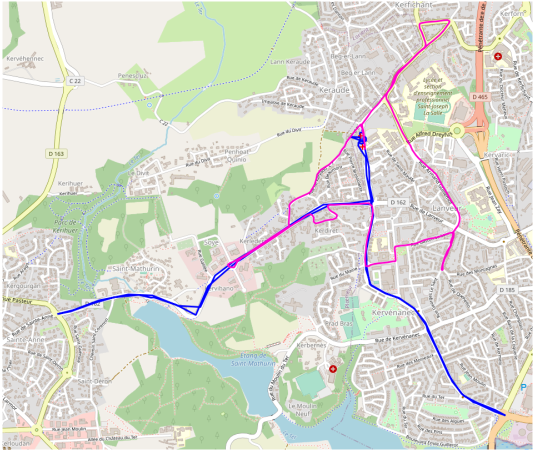
Sent Data



GPS module is used to fetch latitude and longitude, while other information are given by the RPi4 SoC.

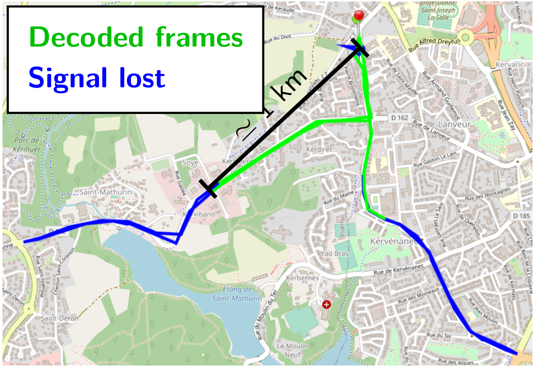
Note: The track is also recorded by an independent smartphone in the car, as redundancy.

Two experiments made:



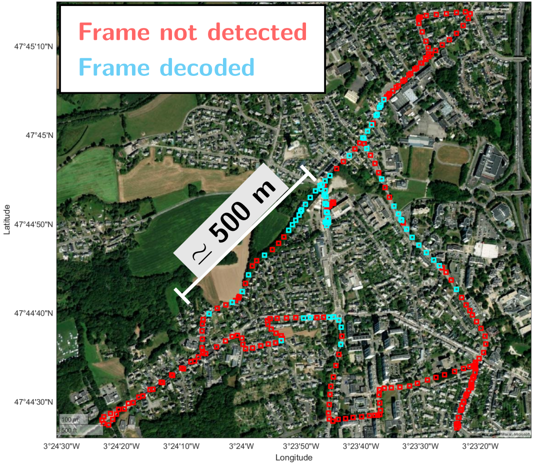
1. Blue track:
   - 15/04/2022,
   - receiver's antenna is disposed on a ground plane,
   - GPS module failed ...
2. Magenta track:
   - 30/05/2022,
   - receiver's antenna is plugged directly on the radio device,
   - transmitter antenna was damaged,
   - everything else was fine.

First Experiment



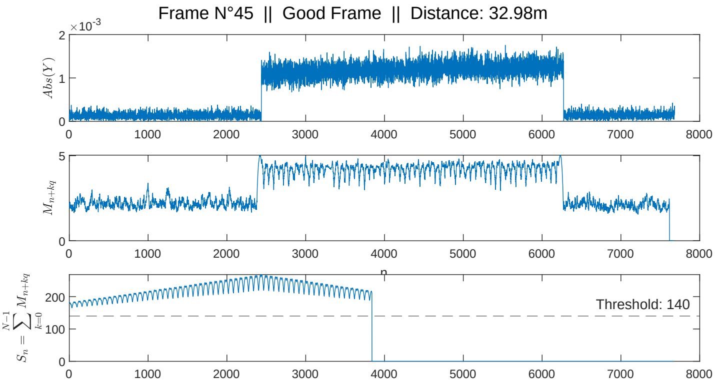
- Locations retrieved from the time extracted from the frames crossed with the time-stamps of the smartphone GPS data,
- locations are coherent with the live tracking done by phone during the experiment,
- a maximum range of up to 1 km has been achieved.

Second Experiment

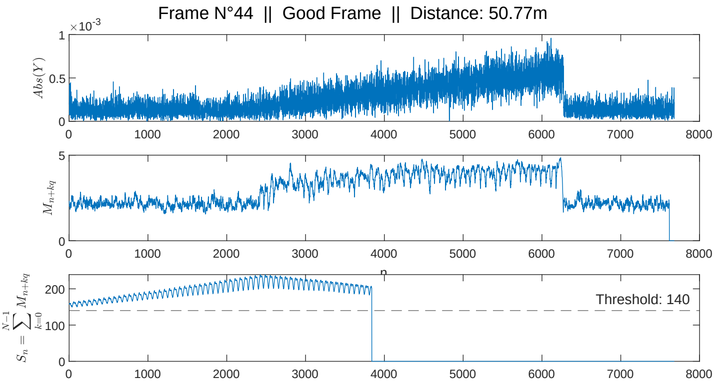


- Locations directly extracted from frames and frames logged by the transmitter,
- detection data are also logged,
- a maximum range of up to 500 m, expected due too antennas poorer quality.

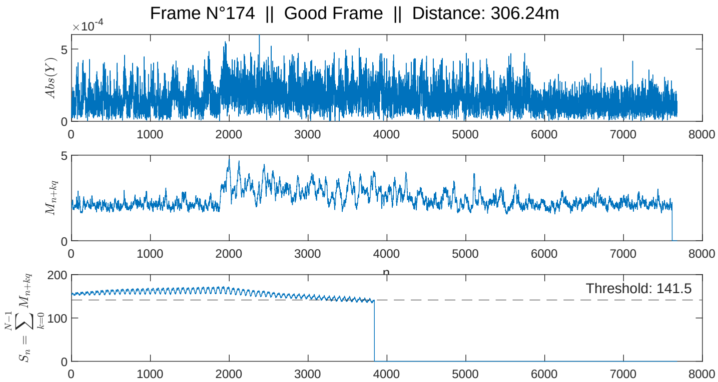
Second Experiment: Frame examples



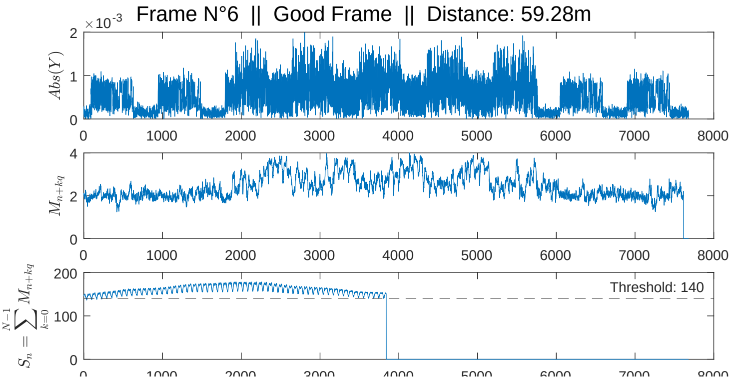
Second Experiment: Frame examples



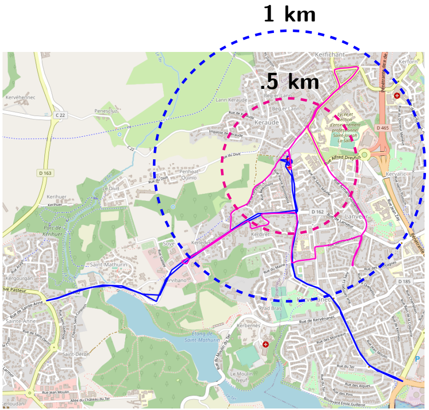
Second Experiment: Frame examples



Second Experiment: Frame examples



Overall ranges



Range difference are related to the antennas.

Thus, a lower bound for the range of 500 m can be defined.
For a consumption lower than 1 μJ per information bit, it is promising.

Transmitter power have been measured to 4 dBm when transmitting a QCSP frame for the chosen settings, and for the given data rate, a frame takes 30 ms to be emitted.

Conclusion

It Just Works™

Conclusion

- A full real time prototype is ready,
- not the sexiest (hybrid, not fully embedded, MATLAB)
- but already good enough to draw attention.
- Bonus: logged data already allow further explorations.

Conclusion

- A full real time prototype is ready,
- not the sexiest (hybrid, not fully embedded, MATLAB)
- but already good enough to draw attention.
- Bonus: logged data already allow further explorations.

Yay!

Futur Points of Interest

→ A retro-engineered LoRa-like communication stack will be tested following the same protocol, to make comparisons.

→ The hardware detector is nearly there (and can theoretically achieve throughput up to 200MChip/s, with the resources).

→ TO CHECK: QCSP reception seems to be more resilient to saturation than (for example) LoRa-*like* transmissions.

References

[1] Michael Fingeroff. *High-Level Synthesis Blue Book*. New Jersey: Xlibris Corporation, 2010. ISBN: 978-1-4500-9724-6 978-1-4500-9723-9.

[2] "IEEE Std 802.15.4-2020, IEEE Standard for Low-Rate Wireless Networks". In: (May 2020), p. 799.

[3] Camille Monière et al. "Time Sliding Window for the Detection of CCSK Frames". In: *IEEE Workshop on Signal Processing Systems (SiPS'2021)*. Combria, Portugal, Oct. 2021.

[4] *OpenStreetMap*. https://www.openstreetmap.org/copyright.

[5] Kassem Saied. "Quasi-Cyclic Short Packet (QCSP) Transmission for IoT". Theses. Université Bretagne Sud, Mar. 2022.

[6] Xilinx. *Vivado Design Suite User Guide: High-Level Synthesis (UG902)*. 2019.

Thank you, have you any question?