
IoT field trials – Grenoble– France - 2018


TVWS field trials – Orkney – Scotland - 2017

FAST EVALUATION OF NEW RADIO TECHNOLOGIES : FROM THEORY TO FIELD TRIALS

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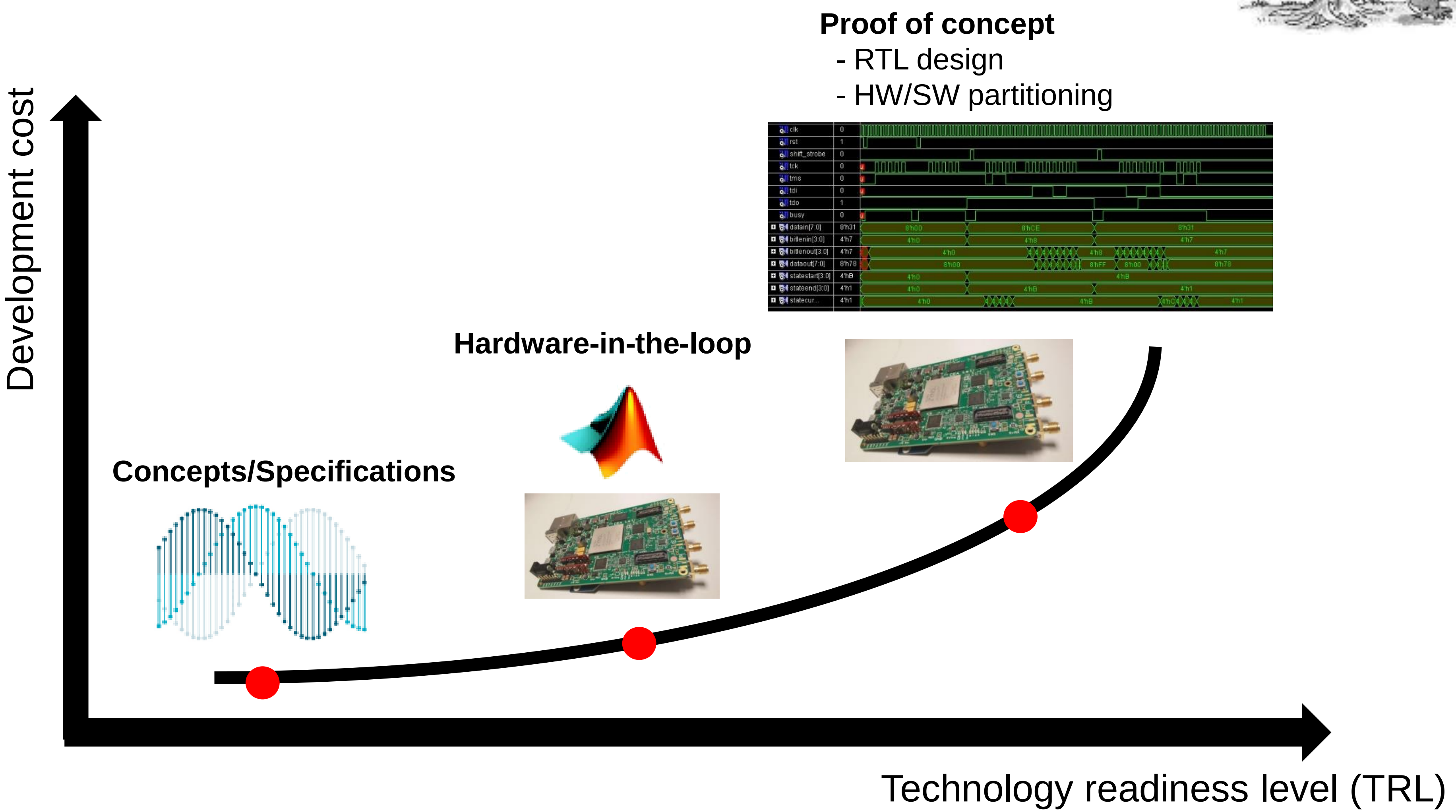
OUTLINE

- **Leti FLeX platform**
  - Methodologies
  - Platform description

- **Some examples…**
  - 5G NR, waveform definition and test @ 3,5GHz
  - TVWS modem development and test
  - Full duplex @3,5GHz
  - IoT Terrestrial and SatCom
  - Others …

- **Conclusion**

METHODOLOGY



LETI FLEX PLATFORM

- **HW architecture (Zynq + RFSoc) [2014]**
  - Large FPGA for intensive computations
  - Flexible embedded microprocessor (ARM)
  - Digital / Analog Interfaces
    - Agile RF Transceiver IC with ability to provide 2x2 MIMO and flexible carrier frequency (from 70MHz up to 6GHz) – AD9361
    - High end DAC/ADC

- **SW architecture**
  - Embedded Linux / RT / Bare Metal

- **On going development for the next generation**

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5G FOR SUB-6GHZ

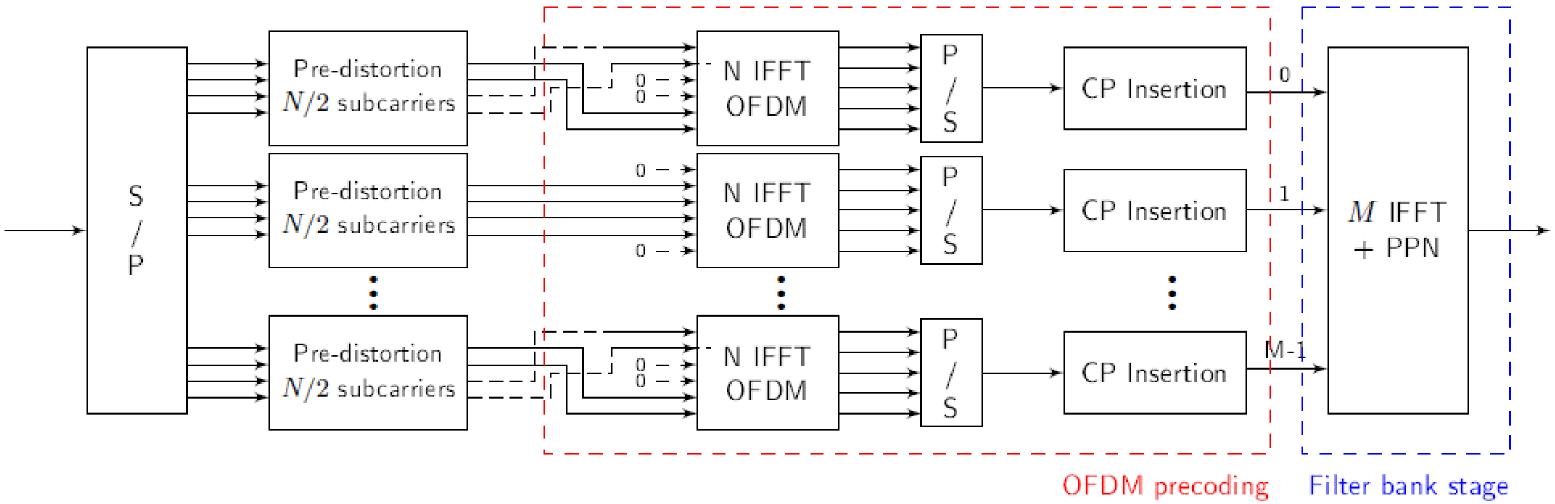
- **Since 2010, many works on waveform design,**
  - Cognitive radio, PMR, TVWS and 5GNR

- **Strong background,**
  - Main contributor of IEEE P1900.7, TVWS standard
  - Many scientific contributions:
    - e.g “Block Filtered -OFDM : A new Promising Waveform for Multi-service Scenarios”, R. Gerzaguet, D. Demmer, JB. Doré and D. Kténas, IEEE International Conference on Communication, ICC 2017, Best Paper Award

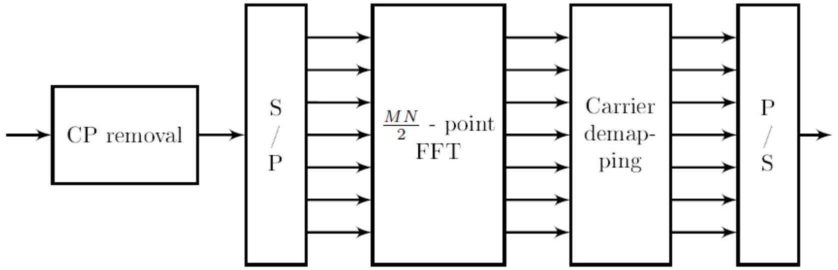
- **In 5G context, BF-OFDM waveform fulfills requirements**
  - Filtered waveform with OOB emission reduction,
  - Allows coexistence of “true” multi service within the same bandwidth,
  - Compatible with 4G/LTE/OFDM framework,
  - Receiver is fully compatible with OFDM Rx…

BF-OFDM FOR 5G

- **BF-OFDM principle**
  - TX: Combination of a filter bank and OFDM signaling

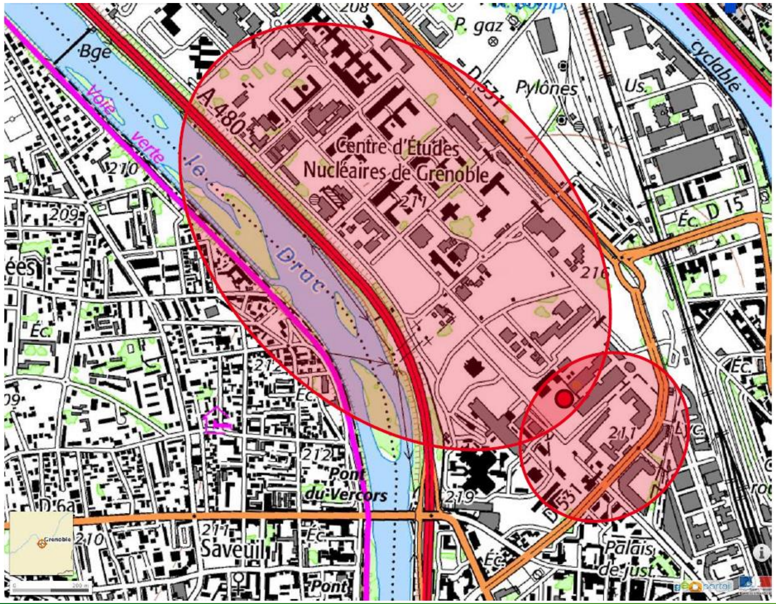


  - RX : a simple OFDM receiver…



FROM THEORY TO PRACTICE: 5G FIELD TRIALS

- **Field trials at 3,5GHz TDD band started in 04/2017**
  - License granted by French regulator ARCEP for 5G experimentation on Minatec campus at CEA-Leti, Grenoble
    - 40MHz BW
    - Indoor/outdoor
  - Use case:
    - 5G multiservice transmission (eMBB + IoT + URLLC)



FROM THEORY TO FIELD TRIALS

- **Multi service transmission**

Broadband

- ► PRB 180 KHz
- ► BF-OFDM
- ► MIMO up to 12b/s/Hz
- ►TTI 1ms

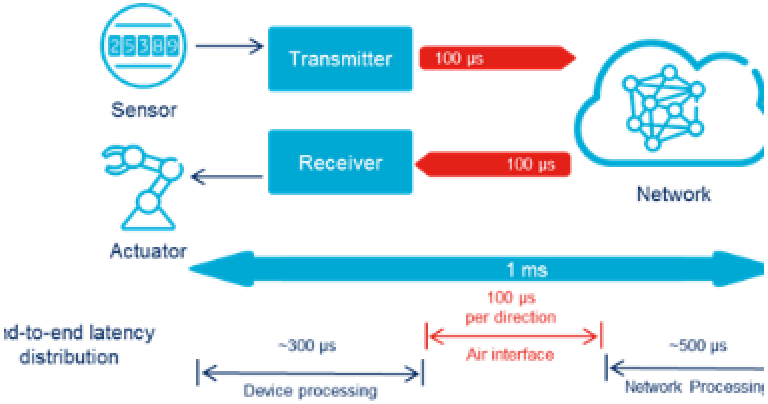
5G eIoT

- ► B=180 KHz
- ► SC-BF-OFDM + QPSK + TC R=1/3
- ► T-OLM-BF-OFDM (ultra low PAPR)
- ► 128 bytes payload

Wikipedia

URLLC

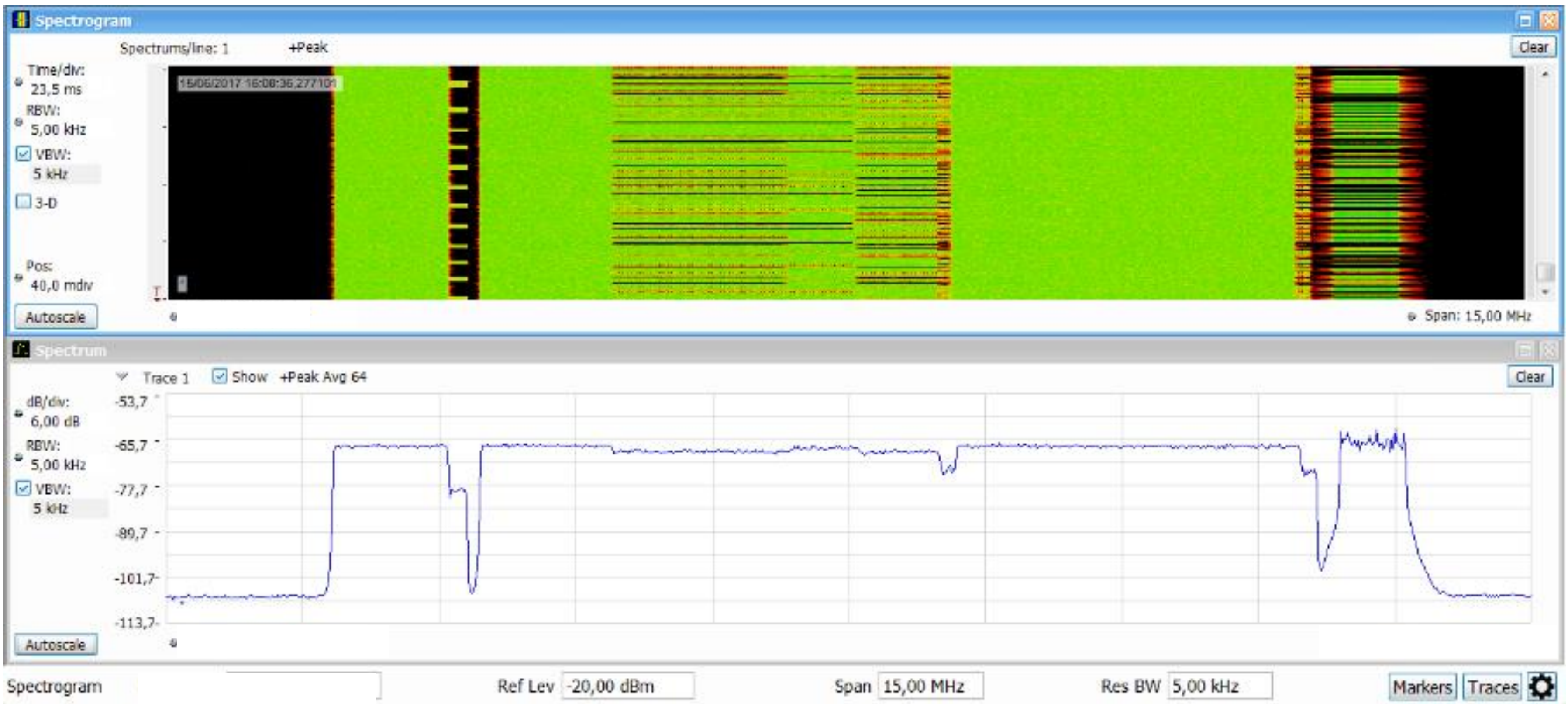
- ► B=720 KHz
- ► BF-OFDM
- ► 10 bytes payload
- ► QPSK + Polar Code R=1/3
- ► TTI 0.25 ms



https://www.linkedin.com/pulse/what-urllc-nutshell-denise-pau

FROM THEORY TO FIELD TRIALS

- **… A real multi-service experiment**



FROM THEORY TO FIELD TRIALS

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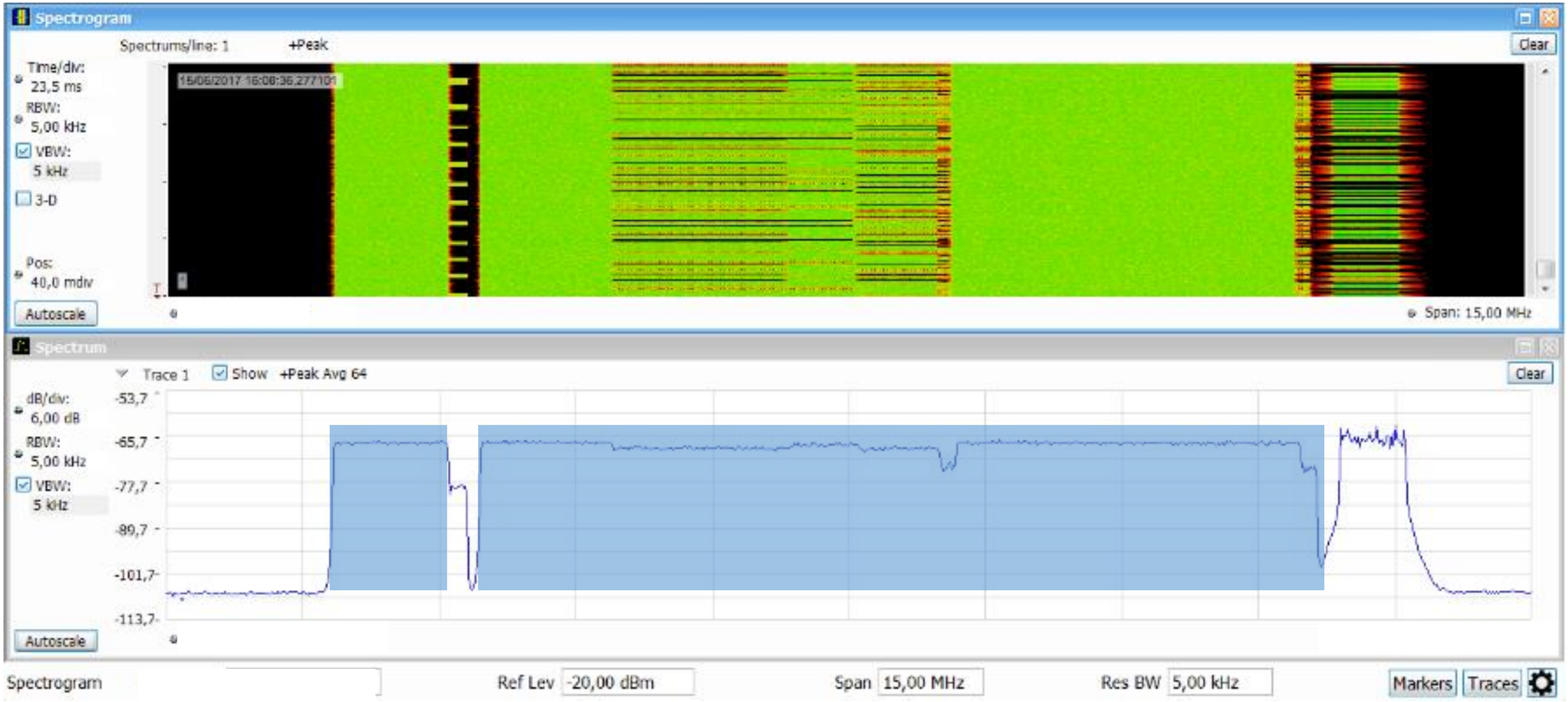

FROM THEORY TO FIELD TRIALS

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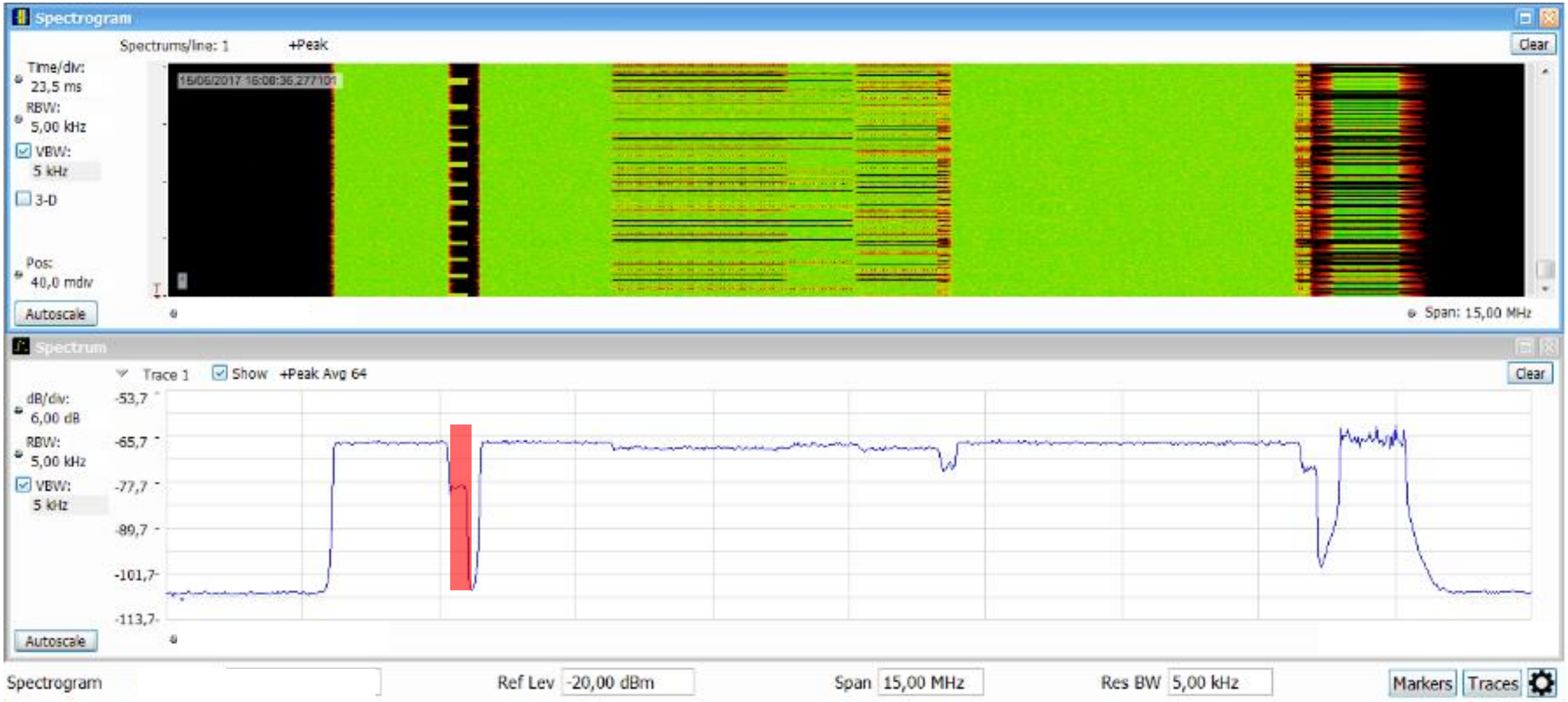
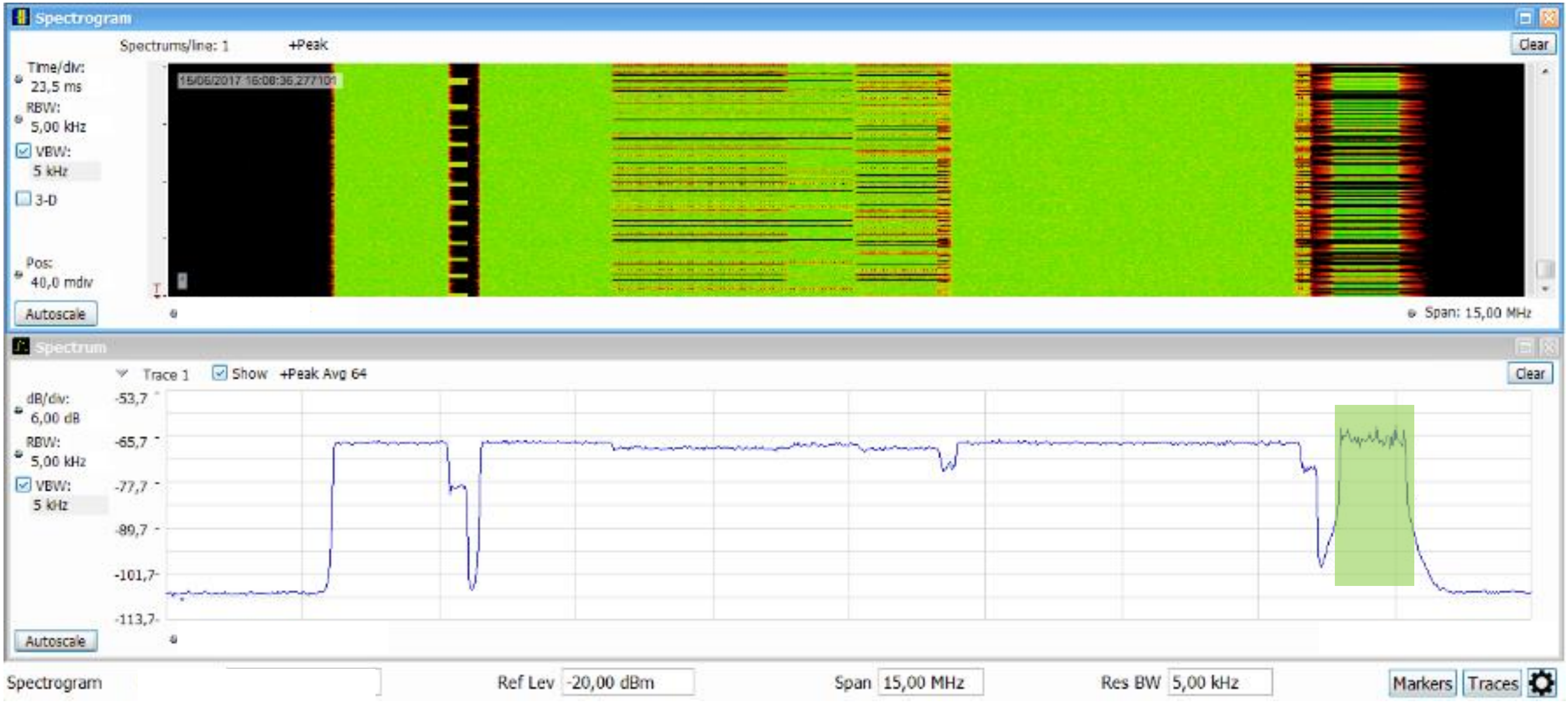


FROM THEORY TO FIELD TRIALS

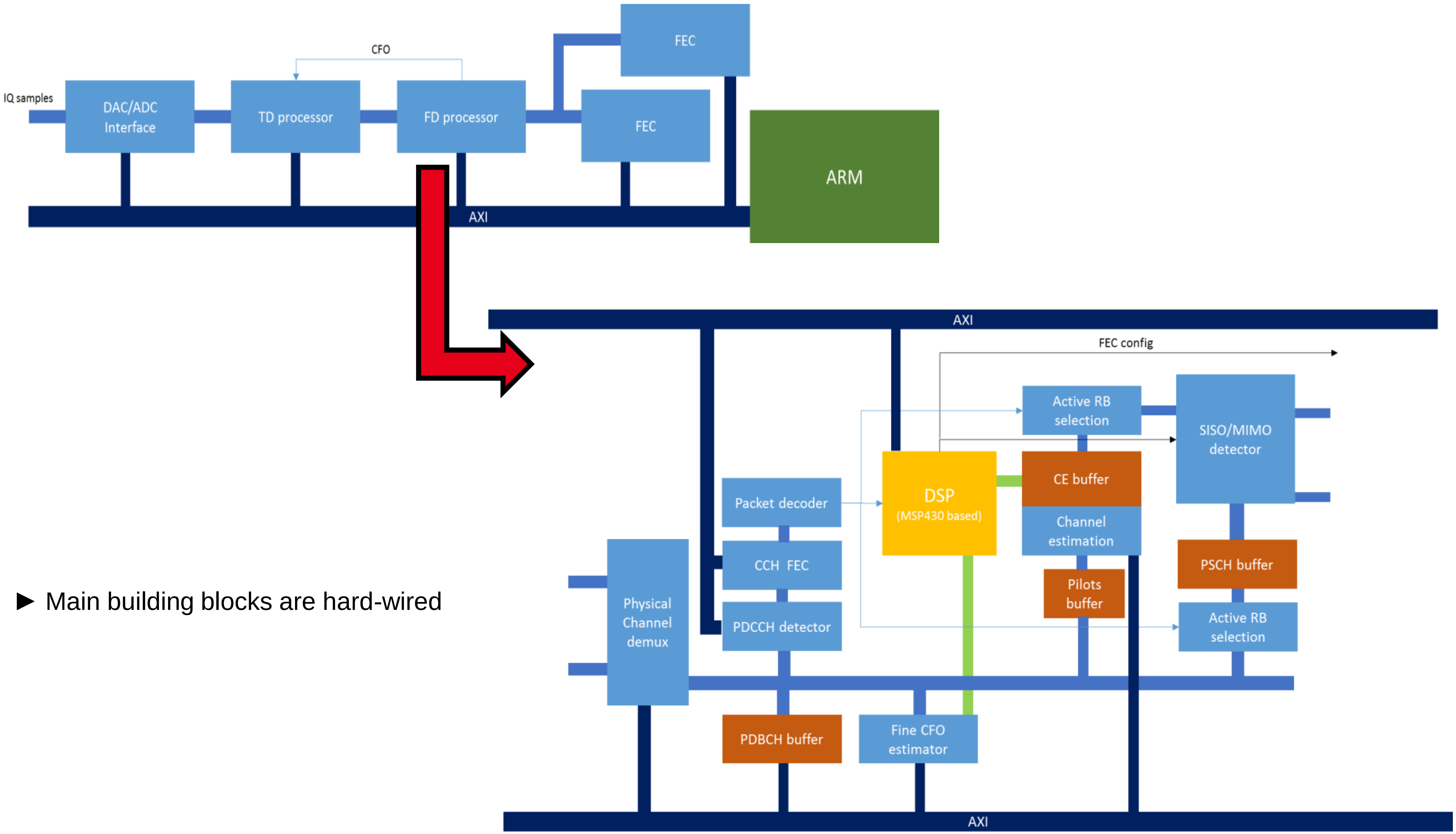
URLLC

- … A real multi-service experiment



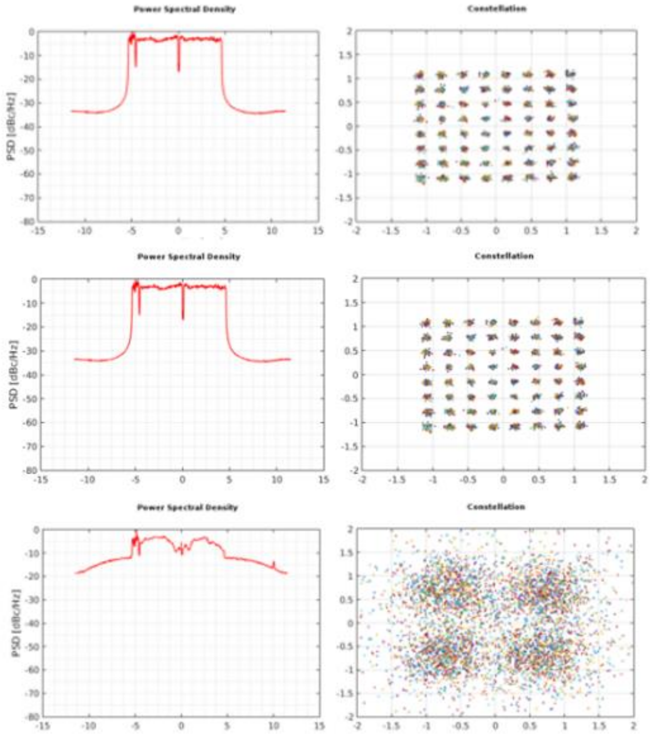
5G MIMO BASE STATION

DIGITAL BASEBAND ARCHITECTURE



► Main building blocks are hard-wired

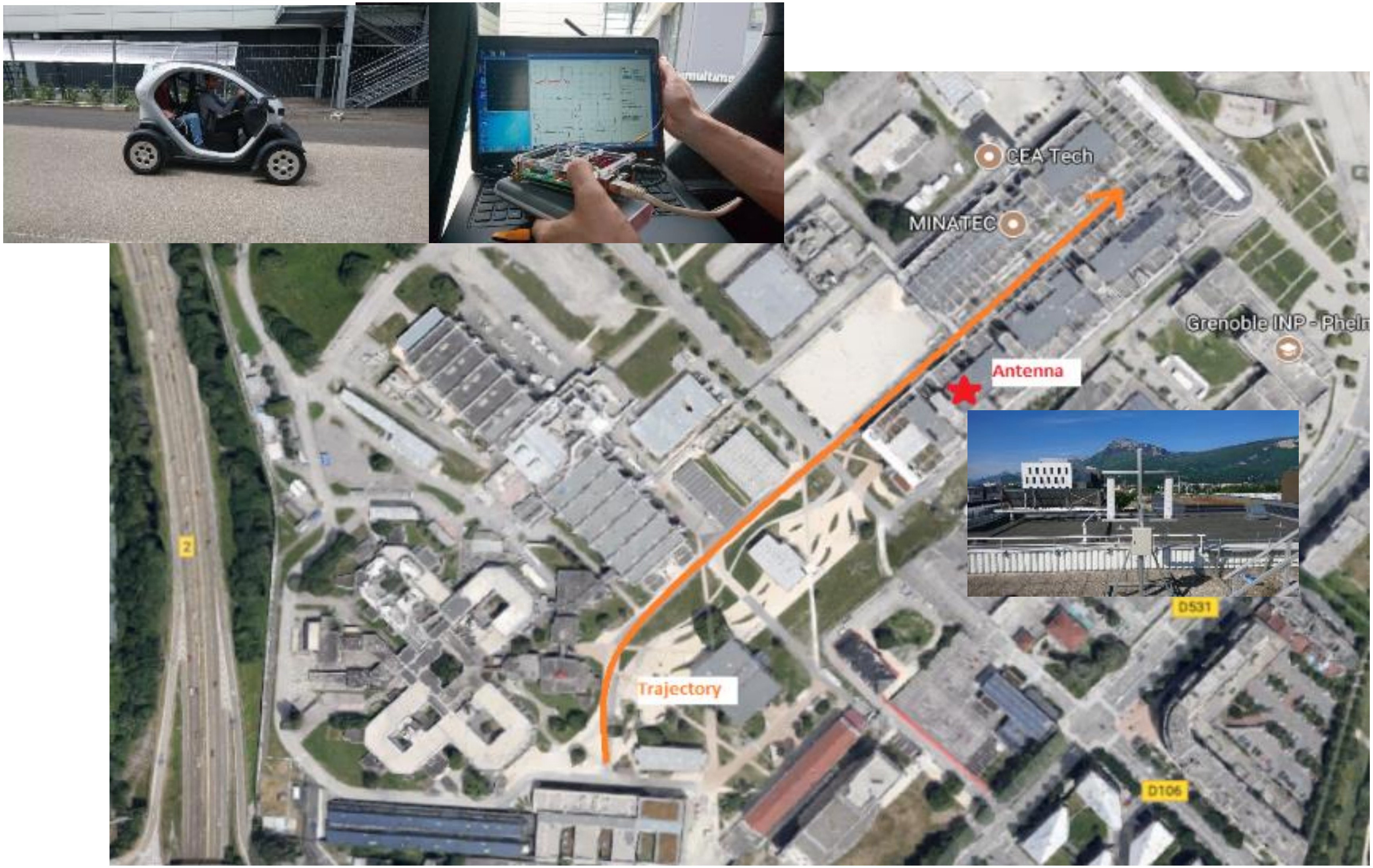
INVESTIGATED SCENARIOS



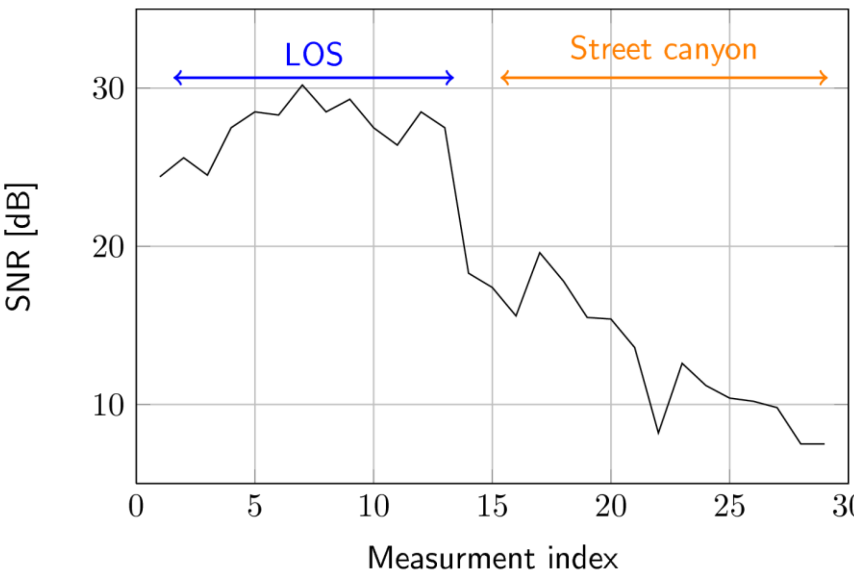
- **P1** is the pure **LOS** configuration and offers the best performance (Tx to Rx distance **200m**).
- **P2** is in **NLOS** as the measurement point is located behind a building (Tx to Rx distance **225m**).
- **P3** (**230m**) and **P5** (**340m**) are in **NLOS** but some **reflections** from other buildings offer a better performance w.r.t. P2.
- **P4** (**320m**) is in **LOS** with **shadowing** due to the trees.
- **P6** (**390m**) and **P7** (**360m**) are in **NLOS** and are located at the **maximum reachable distance**.

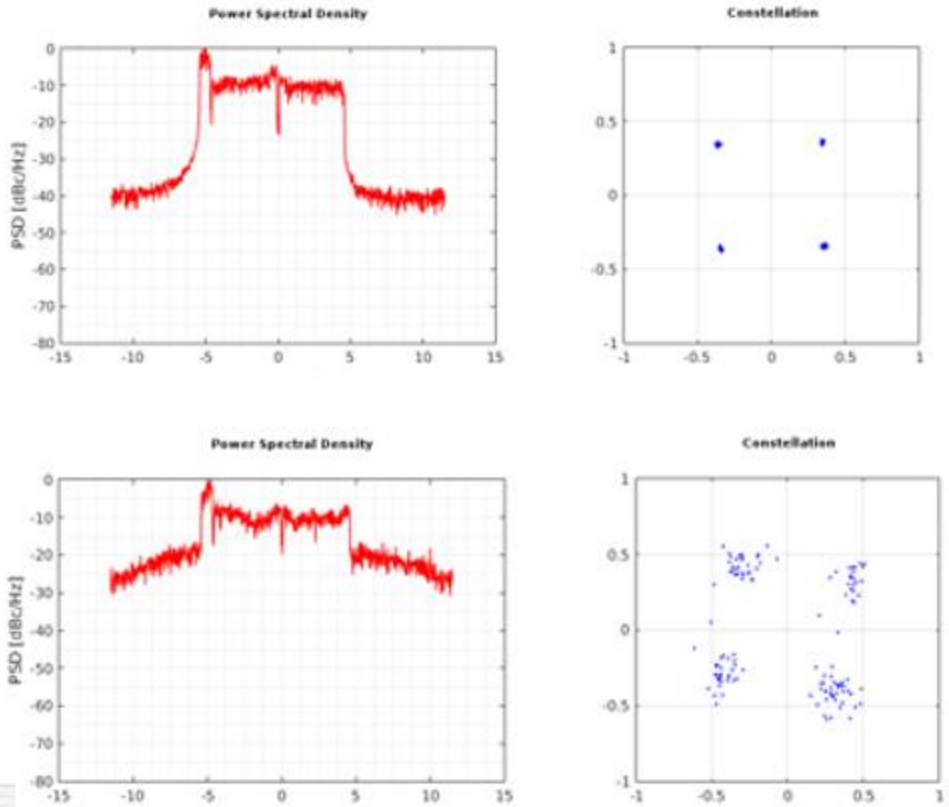
=> Limited TX power (100mW – 20dBm + 17,5dBi Antenna Gain – cable Loss ~ 1,5dB)

MOBILITY SCENARIO



URLLC PERFORMANCE





URLLC performance, LOS (top) vs NLOS (bottom)

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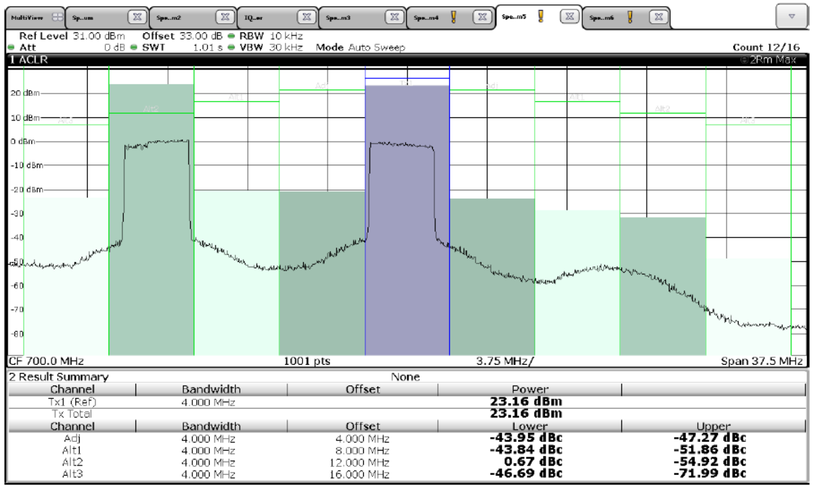
TVWS IN ORKNEY ISLAND

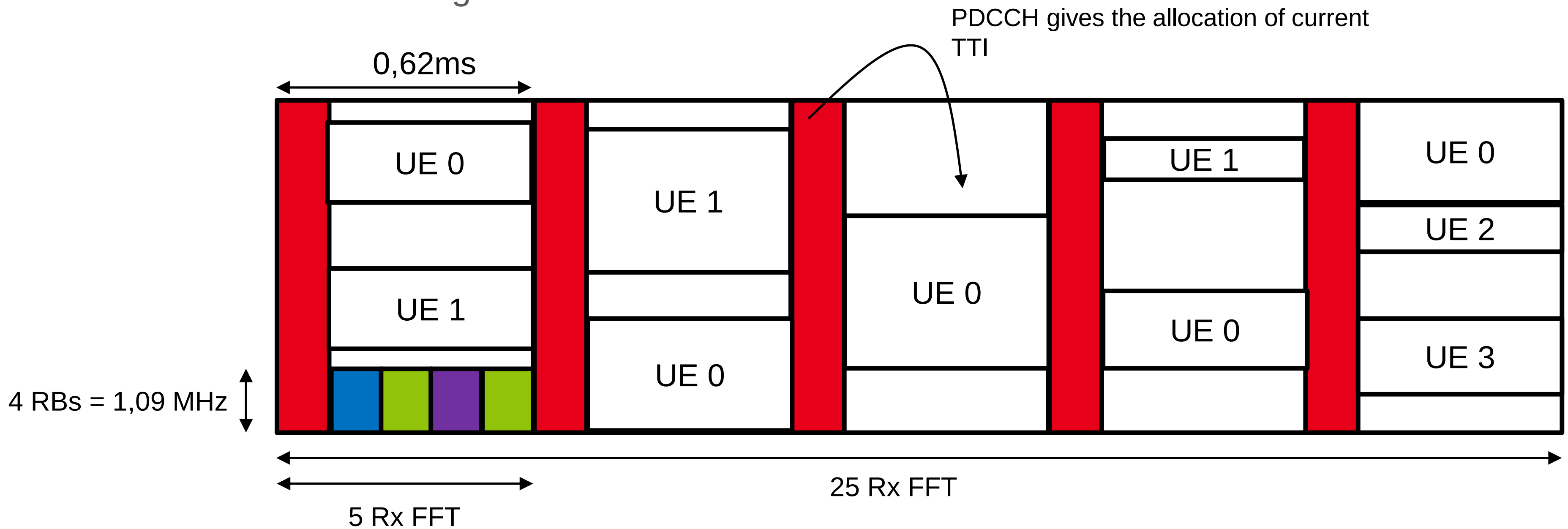
- **Objectives**
  - Maritime network in Scotland
  - Flexible access in TV band
  - Fragmented Spectrum

- **Proposed System**
  - BF-OFDM PHY(Low ACL)
  - TDD/FDD access



MODEM - BASEBAND

- **Frame format**
  - OFDMA
  - Physical channel
    - PDSCH: Shared Channel (Payload)
    - PDCCH: Control Channel (RB allocation)
    - PSCH: Primary Synchronization Channel
    - SSCH: Secondary Synchronization Channel
    - PBCH: Broadcast Channel (Cell specific information)
    - Reference Signal: Pilot



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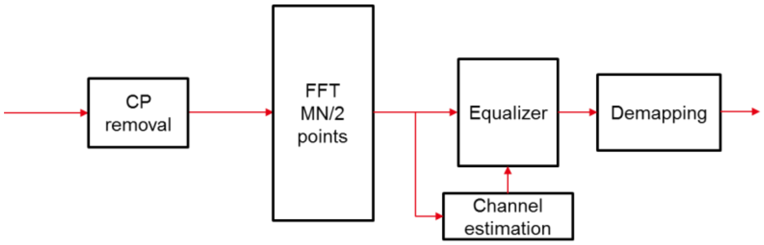
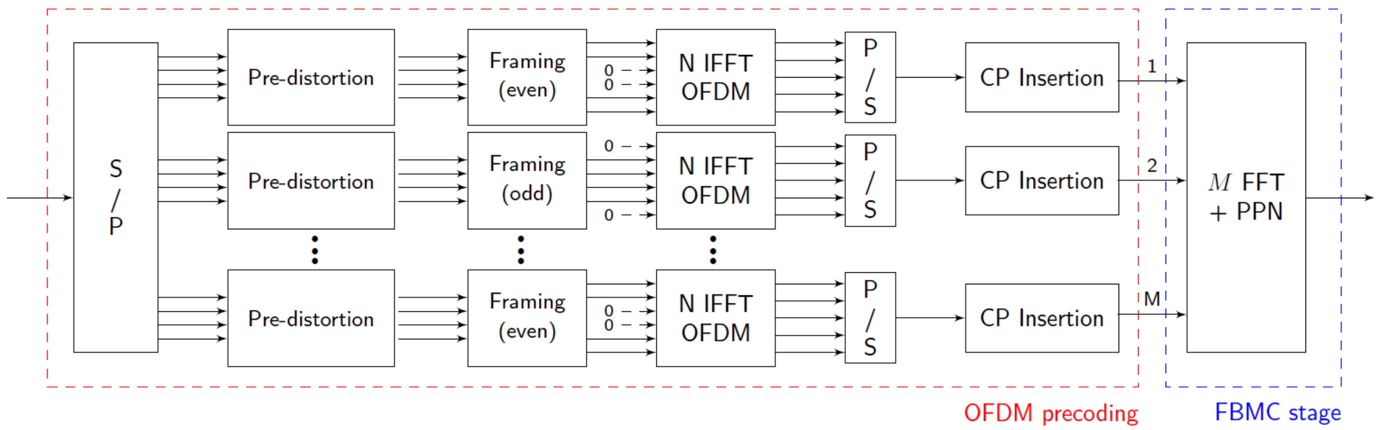
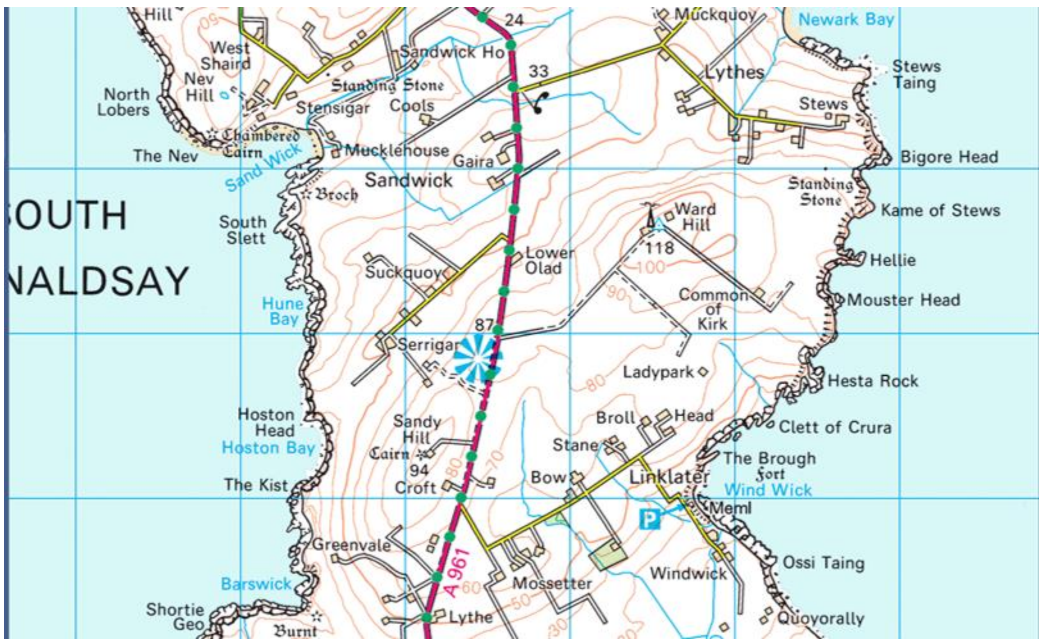


- **Waveform configuration**
  - Sampling frequency := 35 MHz
  - Inter Carrier Spacing := 8.54 kHz
  - FFT size (Rx) := 4096
  - M := 128
  - N/2 (Resource Block) := 32
  - K (Filter) := 4 (Gaussian)
  - Cyclic Prefix Duration := 7,3us (6,25%)
  - Symbol Duration := (117 +7,3)us



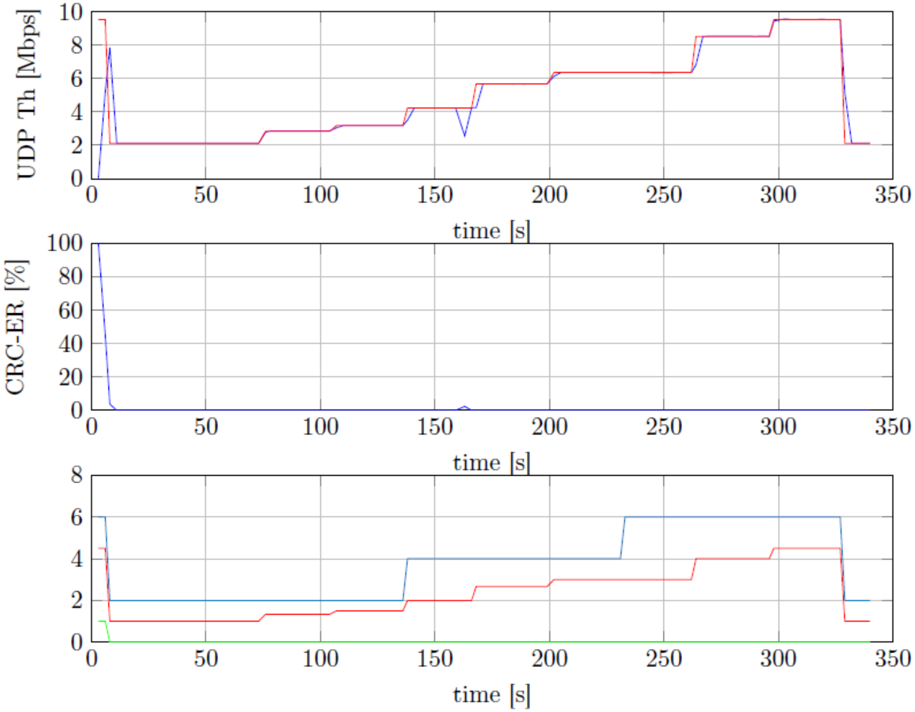
FIELD TRIALS IN ORKNEY

- **Setup 1 – Sandy Hill - Omni Tx 11dBi**
  - Sandy Hill : 94 m (height)

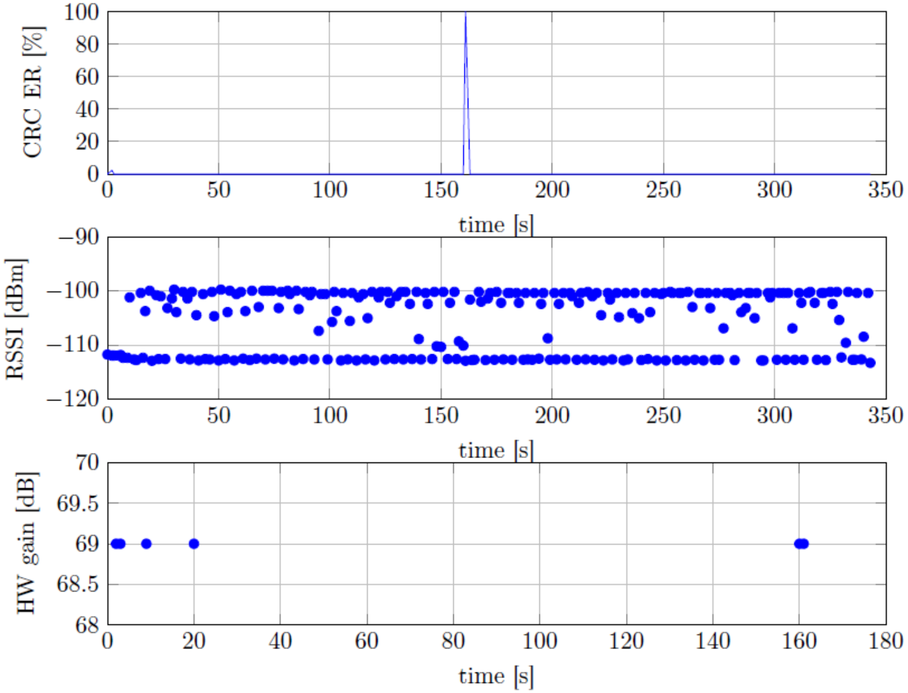


FIELD TRIALS IN ORKNEY

8MHz Bw TDD - TX: Yagi (14dBi) RX: Yagi (8 dBi) LNA Off - PDSCH



8MHz Bw TDD - TX: Yagi (14dBi) RX: Yagi (8 dBi) LNA Off - PDCCH



P11: 15,64 km (height 40m)

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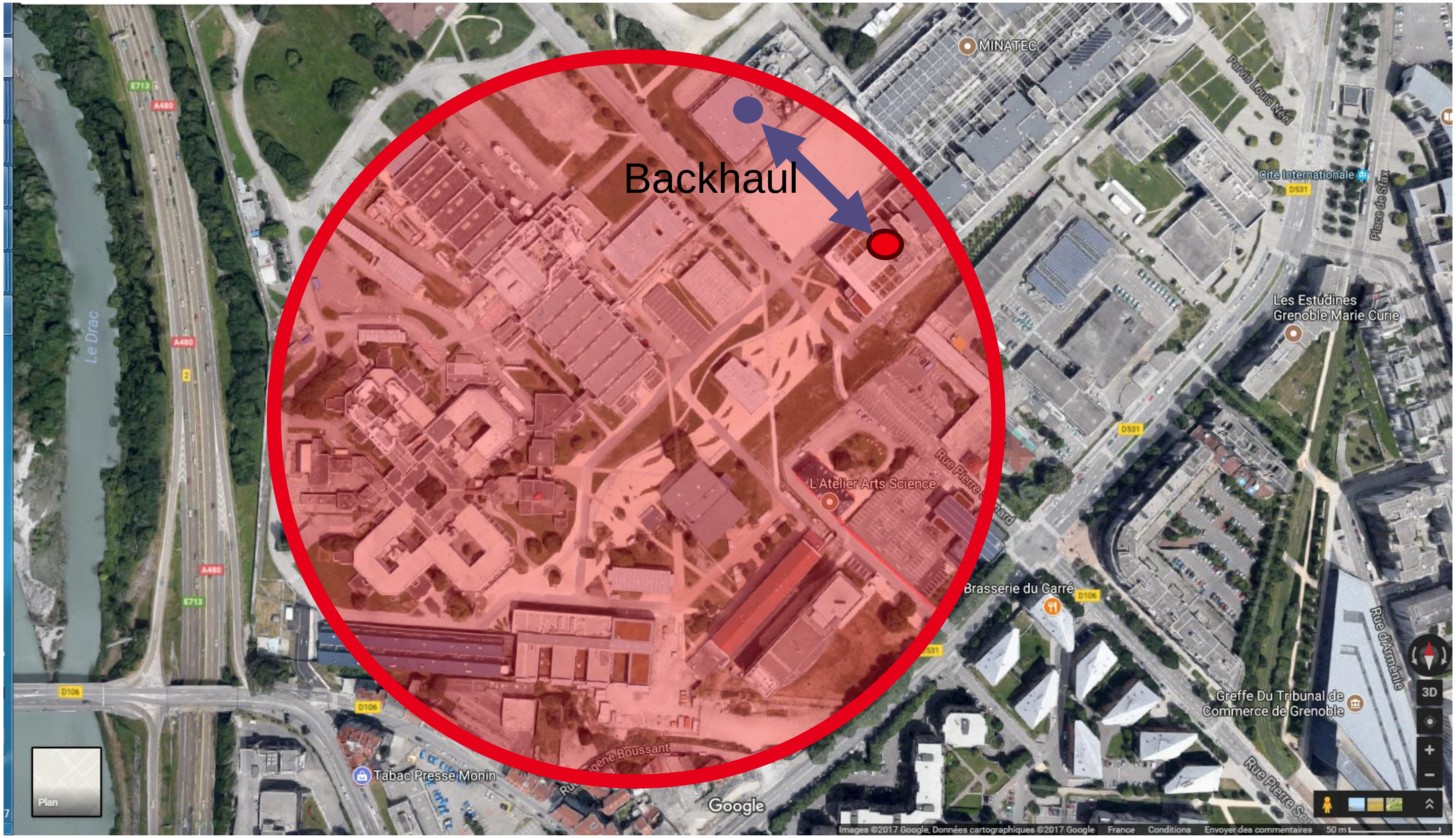
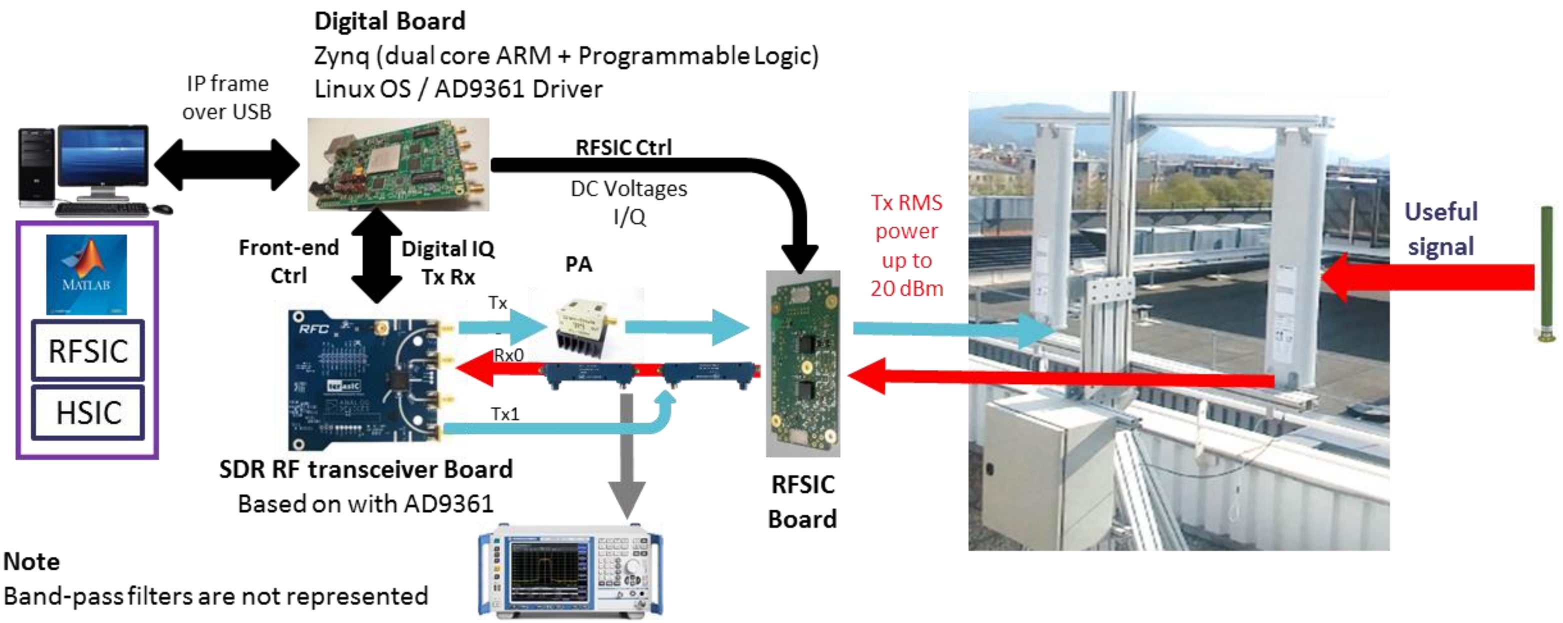
FULL DUPLEX

- **Self backhaul scenario @3,5GHz**



FULL DUPLEX

- Strong transmission toward Backhaul link while receiving low power signal from mobile network



- Experimental results
  - **90+ dB** cancellation reach overs the air at 3.5 GHz

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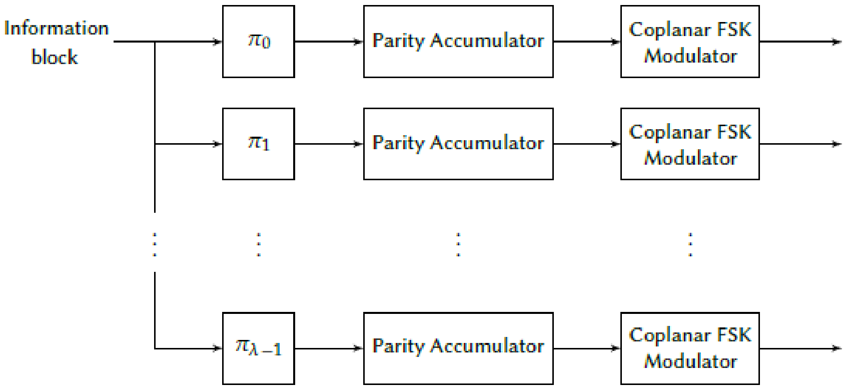
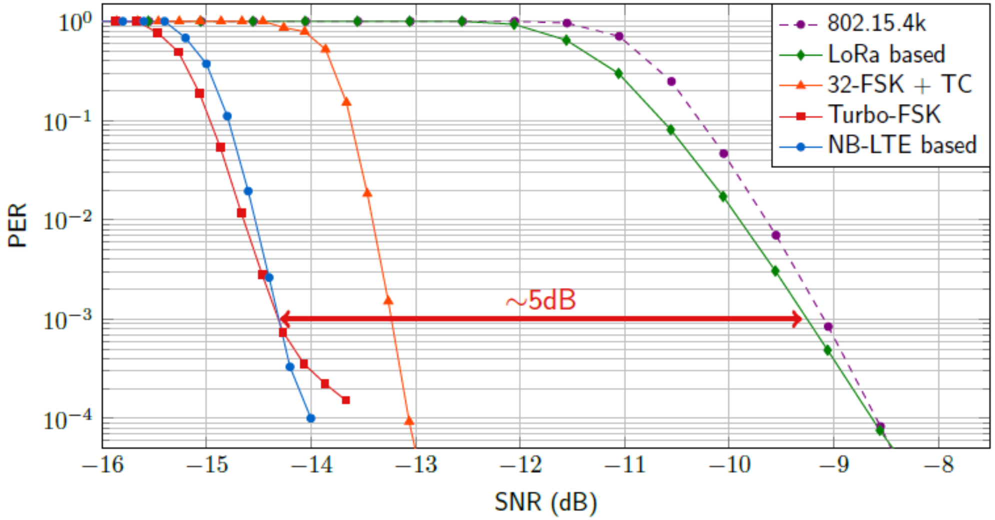
WAVEFORM FOR IOT - TURBO-FSK

- **Coplanar Turbo-FSK waveform [Roth15]**
  - Information bits are encoded and transmitted λ times
    - interleaver
    - Parity Accumulator
    - PSK + FSK modulator (NB-IOT compatible)

  → low PAPR for a low power consumption

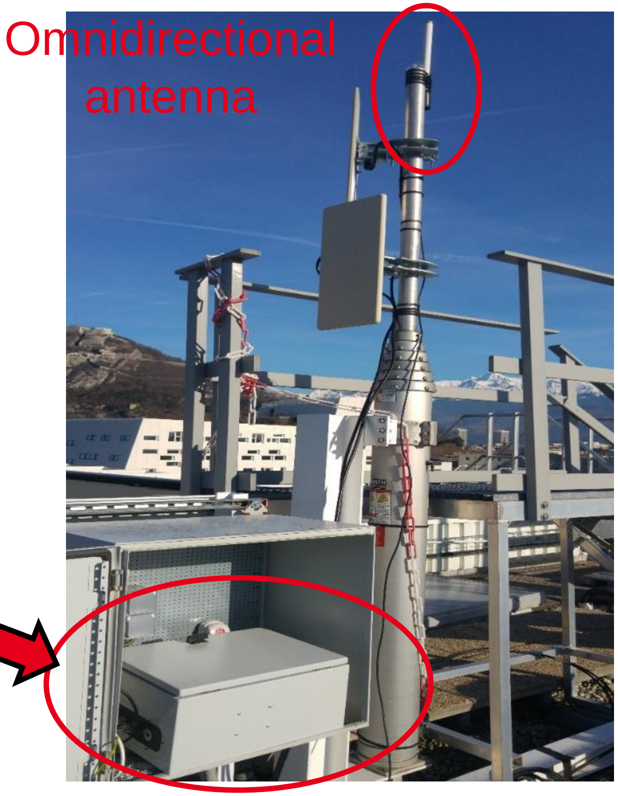
  → low SNR





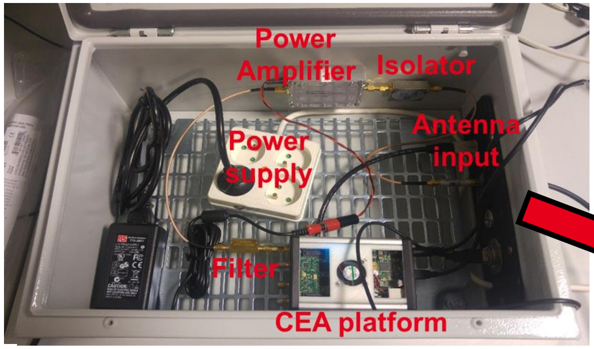
[Roth15]: Y. Roth, J. B. Doré, L. Ros, and V. Berg, “Turbo-FSK: A new uplink scheme for low power wide area networks,” SPAWC, 2015

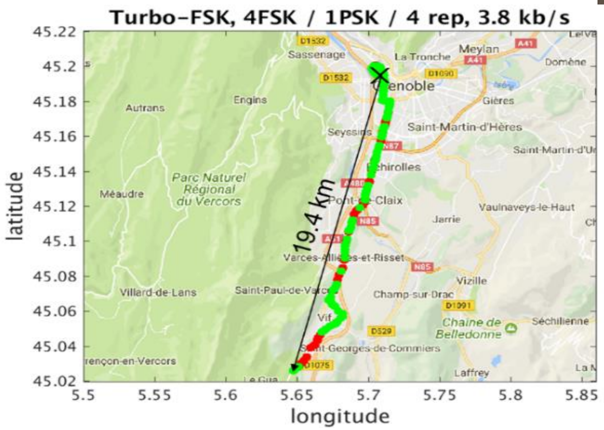
IOT DEMONSTRATOR



- **Objectives:**
  - Field trials in Grenoble using ISM 868 MHz band
  - Point-to-point demonstration

- **Demonstrator:**
  - P = 14 dBm



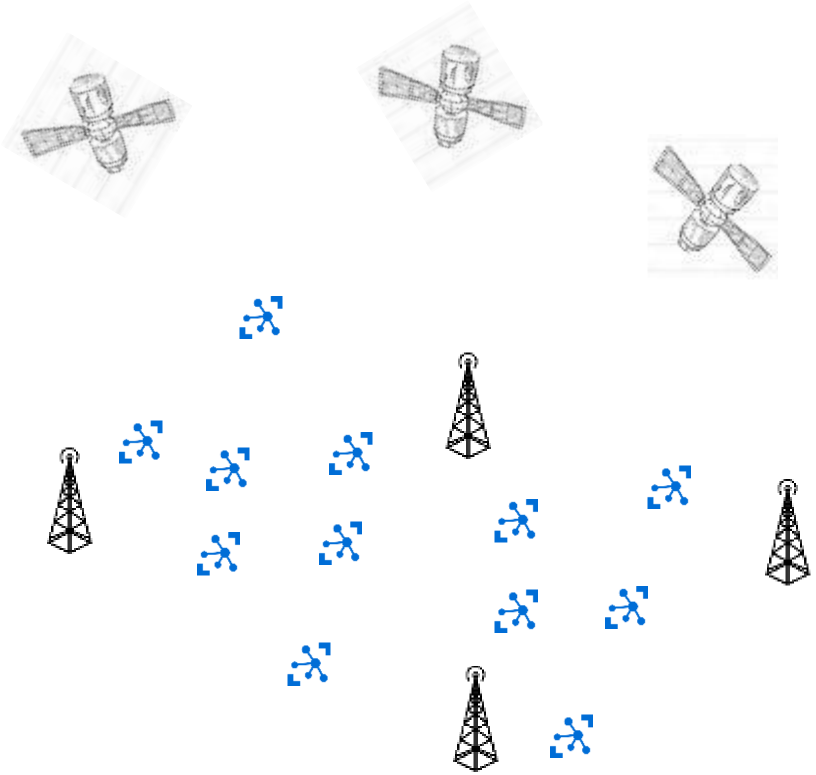


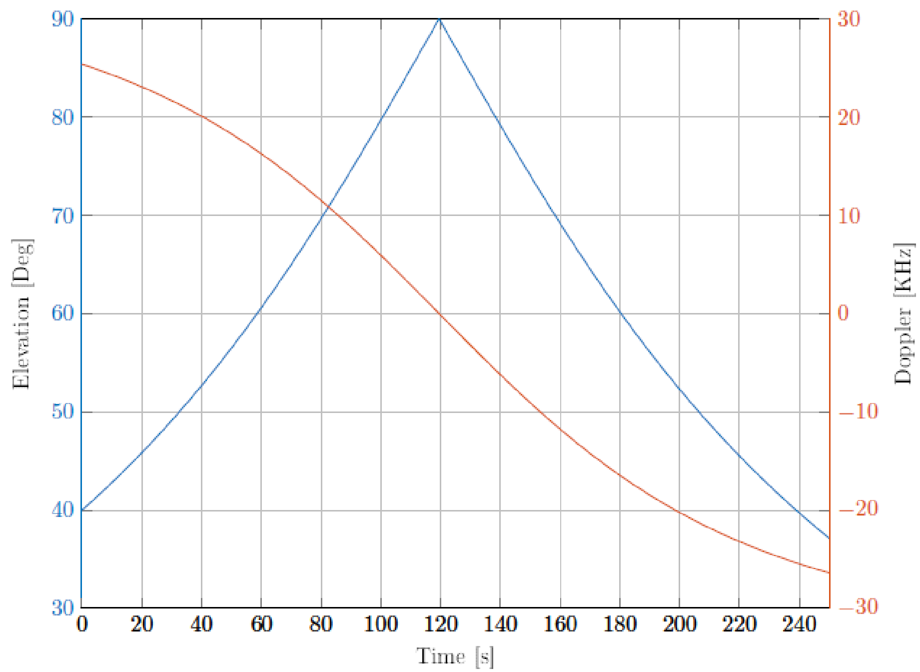
- “Leti Developing Low-power Network for IoT”, 27/06/2018

EE Times Connecting the Global Electronics Community

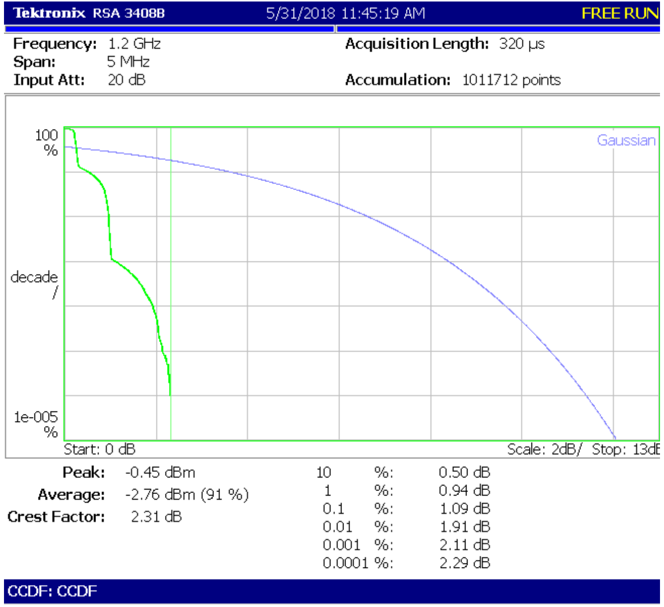
SATCOM AND IOT

- **Seamless connectivity for IoT**
  - Terrestrial and Satellite network (HAPS, LEO..)
    - Provide seamless connectivity
  - Baseband should be the same !
    - Proposed PHY: Coplanar Turbo-FSK





SATCOM AND IOT



- **Seamless connectivity for IoT**
  - Terrestrial and Satellite network (HAPS, LEO..)
    - Provide seamless connectivity
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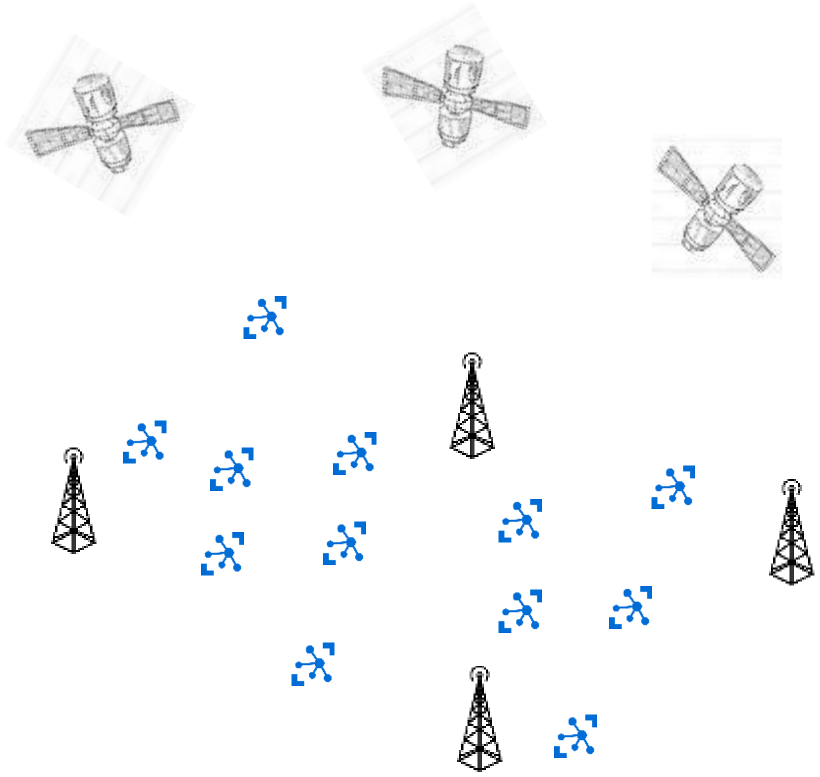

- **Measurements**
  - LEO @L-Band
  - Channel emulation through a channel emulator

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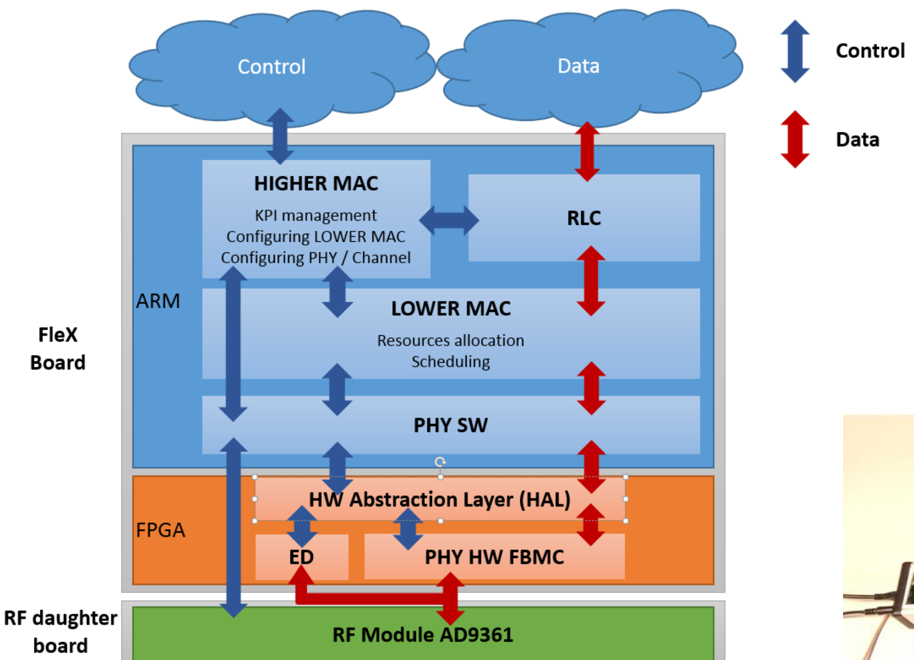
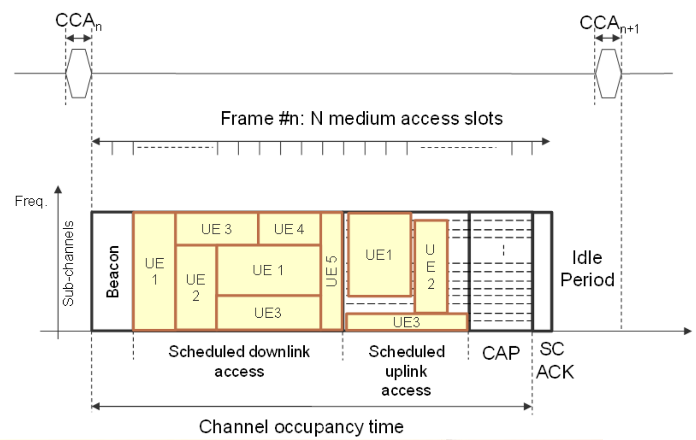
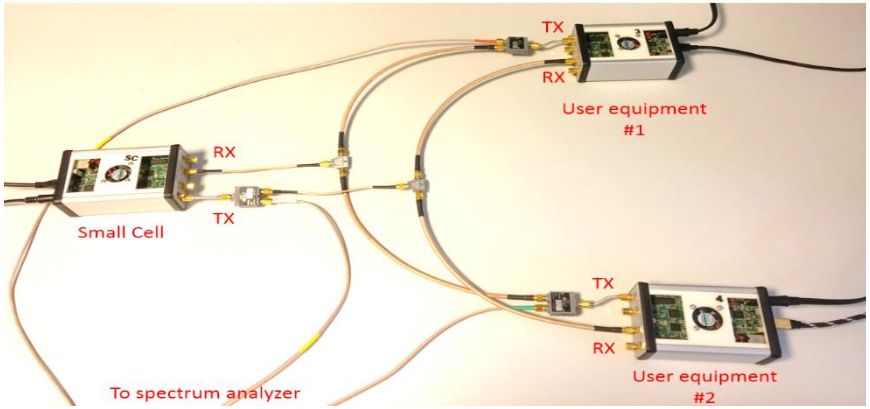
MAC DESIGN FOR DYNAMIC CHANNEL ACCESS @ 5GHZ

- **Implementation of LBT-based MAC design for 5 GHz operation**
  - Dynamic channel assessments are used to feed a machine-learning algorithm for dynamic channel selection (per-channel reward)
- **Implementation shows fair coexistence with off-the-shelf WiFi devices**







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CONCLUSION

Field Trials

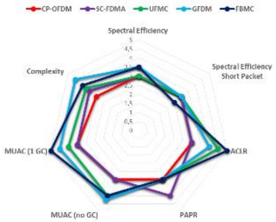
Channel propagation, smart antennas

RF Design & ASIC

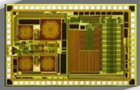
DEMONSTRATORS

Theoretical Research

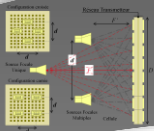
Waveforms
Phy / MAC / RRM
Channel coding



Discrete components
Demonstrations
PoC



Critical functions design,
new technologies



Channel emulator
Antennas design
Anechoic chamber

ARCEP
www.arcep.fr
Autorité de régulation des communications électroniques et des postes

5G License for field trials 2017 (6 months+)
Cooperative networks
Applications
Localization

THANK YOU!

BF-OFDM field trials in Orkney (Scotland), TVWS – 11/2017 ©CEA-Leti