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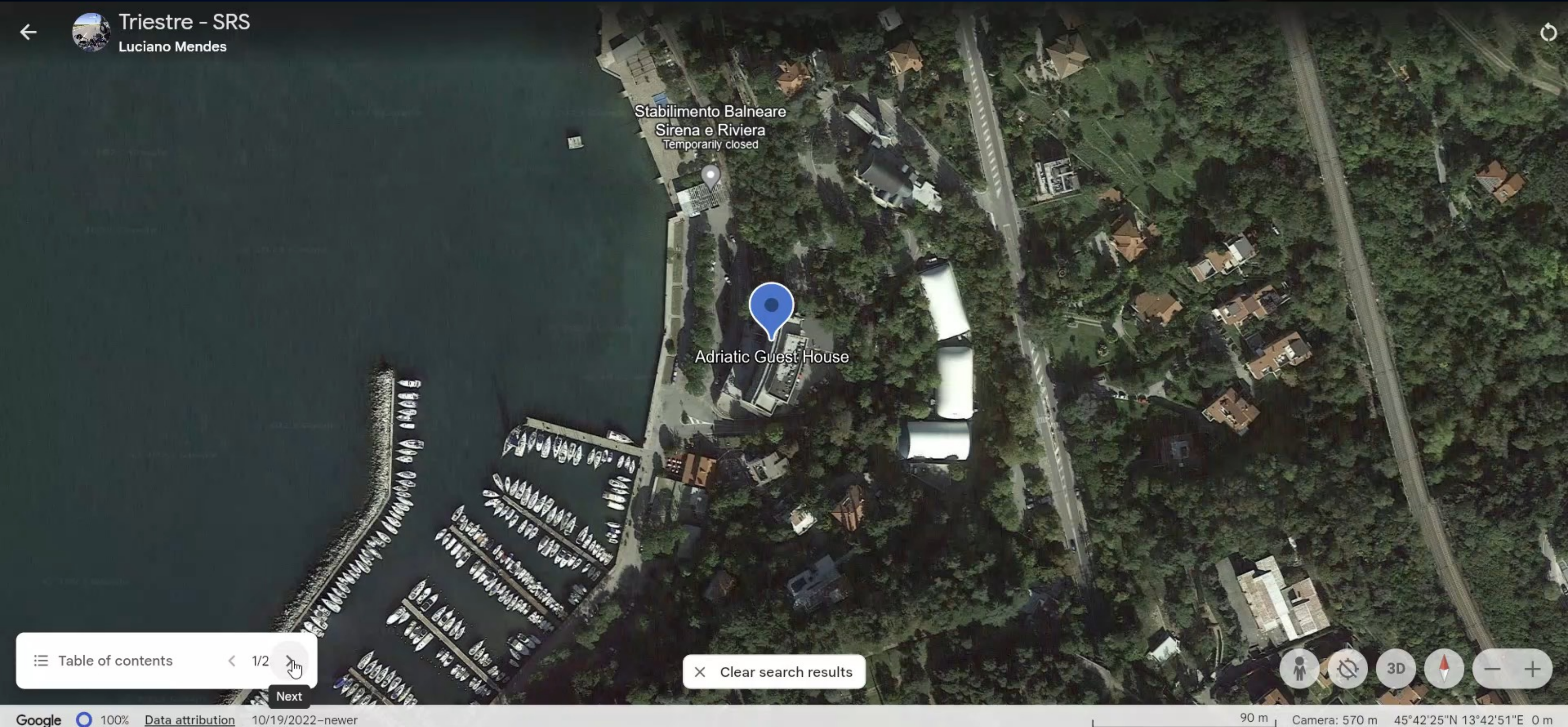
Brasil 6G

HOW 6G CAN CLOSE THE CONNECTIVITY GAP IN REMOTE AND RURAL AREAS

Prof. Dr. Luciano Mendes
www.inatel.br/brasil6g

About Inatel



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Instituto Nacional de Telecomunicações

RNP

cpqd

Universidade Federal do Ceará
VIRTVS VNITA FORTIOR

INF
Instituto de Informática
UFG
Universidade Federal de Goiás

Universidade Federal do Rio de Janeiro

Universidade Federal do Pará

Ars et Scientia
Universidade Federal de Santa Catarina
UFSC

UNISINOS

UFU
Universidade Federal de Uberlândia

Why do we need 6G?

- IMT 2020 vision was very ambitious.

- 5G-NR was a bit conservative.
  - waveform
  - Frame structure based on LTE
  - Slicing considering only three main use cases
  - Conventional spectrum allocation based on licensed spectrum

- Requirements from other verticals were not fully taken into consideration.
- Maturity comes in the even generations.

6G Networks – Beyond Communications

- Integration new features will support unprecedent services.
  - Communication
  - Sensing
  - Imaging
  - Positioning
- High throughput and low latency must be simultaneously addressed in several applications.
- Multiple Radio Access Technologies must work in harmony through a huge range of frequencies.

6G Networks – Potential solution for integration

- The 6G Network can have the features to integrate the
  - Physical world: constantly acquiring information from the real world.
  - Digital world: virtual and augmented reality connected to large scale digital twin models.
  - Biologic world: sensors collecting biomedical data and behaviors can be used to monitor health conditions and to Interact with the network.

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Extreme World Coverage

Providing access everywhere

Throughput 0.1~10 Mbps
Latency < 20 ms
Fragmented spectrum access
Satellite + Terrestrial integration

Advanced Agribusiness and Mining

Complete digitalization of smartfarms and mines

Throughput 0.1~100 Mbps
Latency < 1 ms
Cell radius > 30 km
Speed < 250 km/h
Fragmented spectrum access
Satellite + Terrestrial integration

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Large Scale Digital Twins

Representation of cities and factories in real-time

Throughput 0.1~1000 Mbps
Latency < 1 ms
Cell radius < 1 km
Speed < 100 km/h
Integrated sensing
Integrated imaging
Integrated positioning

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Haptic and Advanced Interaction

Bidirectional touch transfer and holographic representation

Throughput 10~1.000.000 Mbps
Latency < 1 ms
Speed < 100 km/h
New encoders for touch capture
New devices for touch reproduction

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Enabling Technologies - subTHz Communications

- Bandwidth above 100 GHz to provide breakthrough data rates.
- Massive MIMO – improving communication and integrating:
  - Sensing
  - Positioning
  - Imaging
- Several technological challenges for the RF chain must be overcame.
  - Amplifiers
  - Antennas
  - Oscillators

Enabling Technologies – AI for Communications

- AI beyond applications over mobile networks.
- Machine Learning can reduce PHY complexity and improve performance.

  - Signal processing for data detection – nonorthogonal MIMO
  - New modulation schemes designed by AI
  - Virtualized functions deployment and orchestration
  - Channel and parameter estimation improvement.

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Enabling Technologies – Metamaterials and RIS

- Reflective Intelligent Surfaces – reconfigurable antenna array to improve the link quality at higher frequencies.
- Considered to be a key technology for subTHz communications.
- Can improve the NLOS links and also indoor penetration.
- Effective low-cost production of metamaterials is very challenging.
- Metamaterial printing in flexible surfaces is highly important.

Enabling Technologies – Analog Radio over Fiber

- Band base processing performed at the central office.
- Low deployment and maintenance costs.
- Fiber optic infrastructure can be shared with other services
- Digital pre-distortion is mandatory to compensate the RF impairments.

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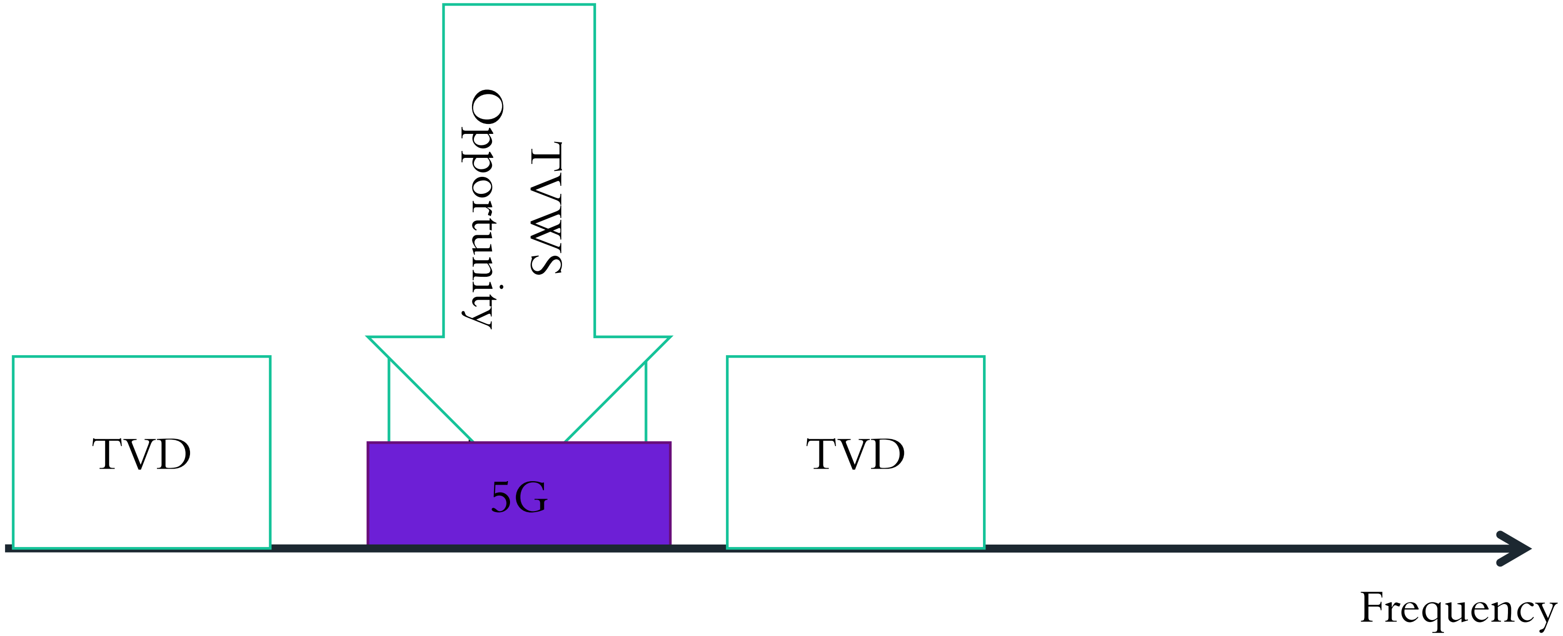
Enabling Technologies – TVWS unlicensed 6G

- Old idea, but badly executed using IEEE 802.22.
- Simple low-cost RF technology – linearization is a must.
- New waveforms, better AI and efficient spectrum sensing.
- High capacity with nonorthogonal waveforms and multiple access.
- Seamless integration with the 6G standard.

Some ideas for unlicensed 6G

TVWS main idea



We cannot use RF filter: spectrum mobility.
The waveform must have very low out-of-band emission.
Fragmented spectrum allocation is necessary to improve efficiency.
Robustness against interference from TVD transmitters leakage.

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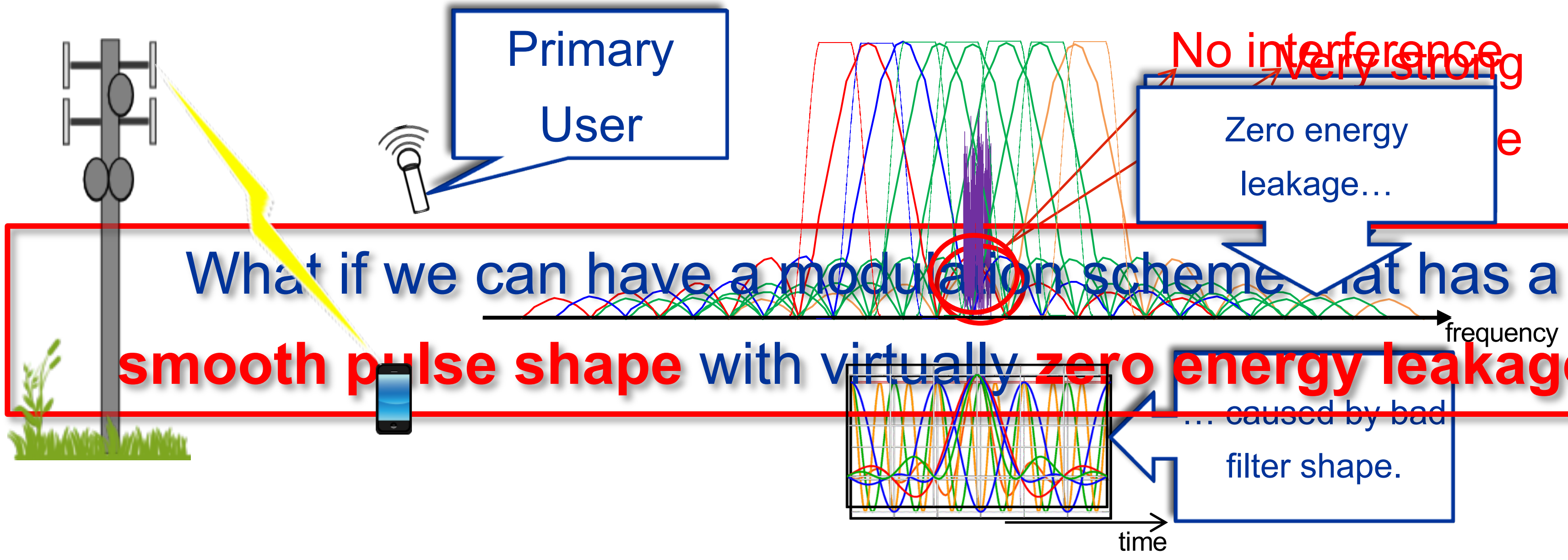
Spectrum Flexibility: low OOBE waveforms without RF filter

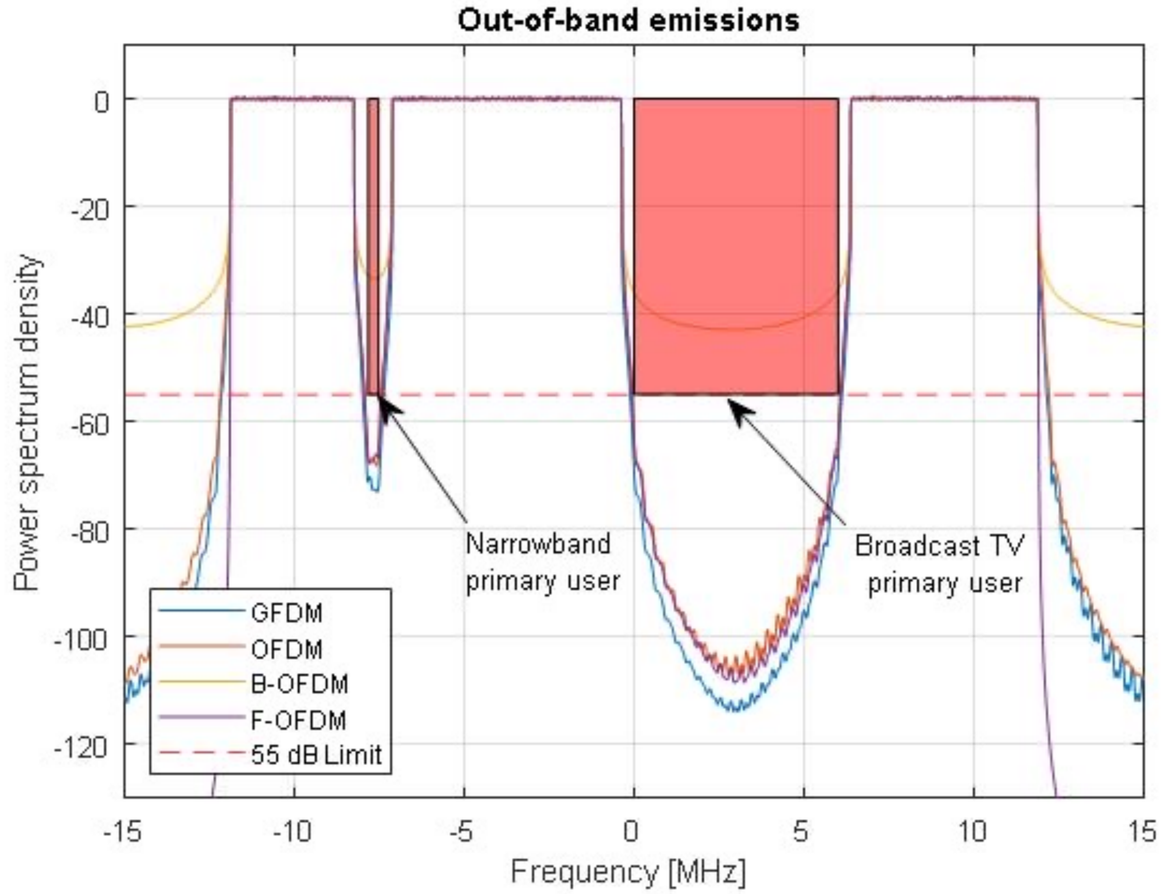


What if we can have a modulation scheme that has a **smooth pulse shape** with virtually **zero energy leakage**?

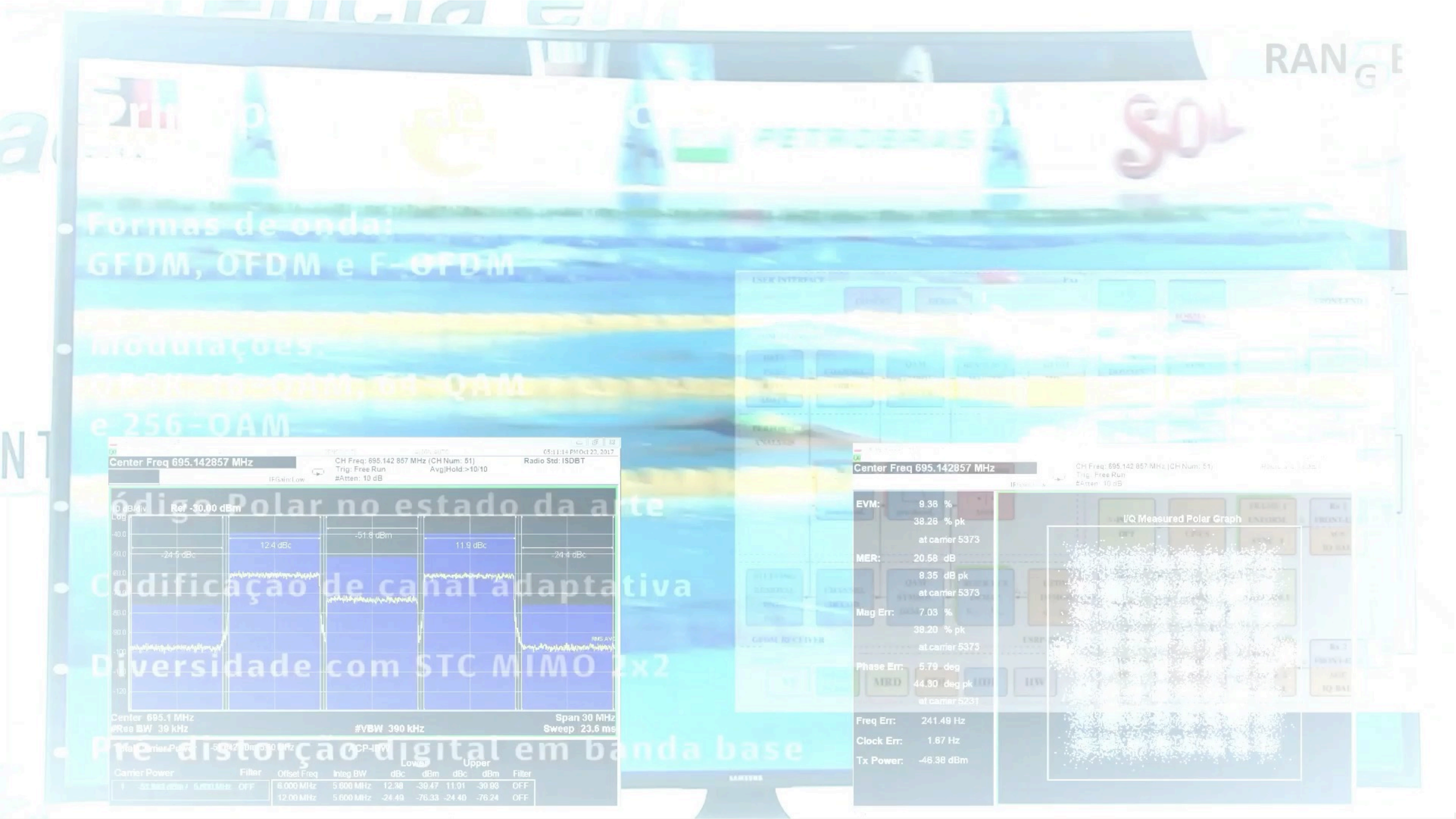
The ability to **control the pulse-shape** allows the co-existence with other technologies.

Several waveforms have been proposed in the last 10 years:

- UFDM, FBMC, GFDM, B-OFDM and F-OFDM



- Does it work?


Formas de onda:
GFDM, OFDM e F-OFDM
e 256-QAM
ódigo Polar no estado da arte
Codificação de canal adaptativa
Diversidade com STC MIMO 2x2
Pré-distorção digital em banda base
Center Freq 695.142857 MHz
Ref -30.00 dBm
12.4 dBc
11.9 dBc
Center 695.1 MHz
Span 30 MHz
#VBW 390 kHz
Center Freq 695.142857 MHz
EVM:
MER:
Mag Err:
Phase Err:
Freq Err:
Clock Err:
Tx Power:
I/Q Measured Polar Graph

TVWS Exploitation

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Spectrum Sensing is a must: geolocation data base is not enough!

TVWS Exploitation

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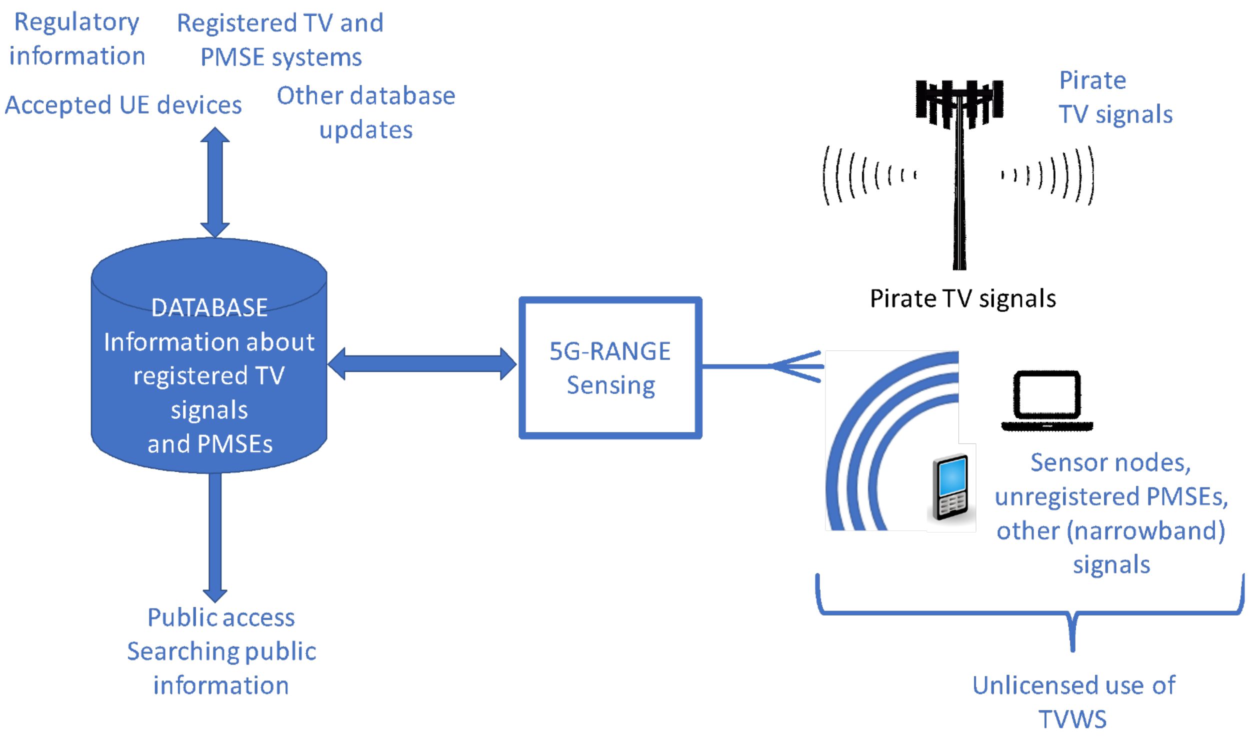
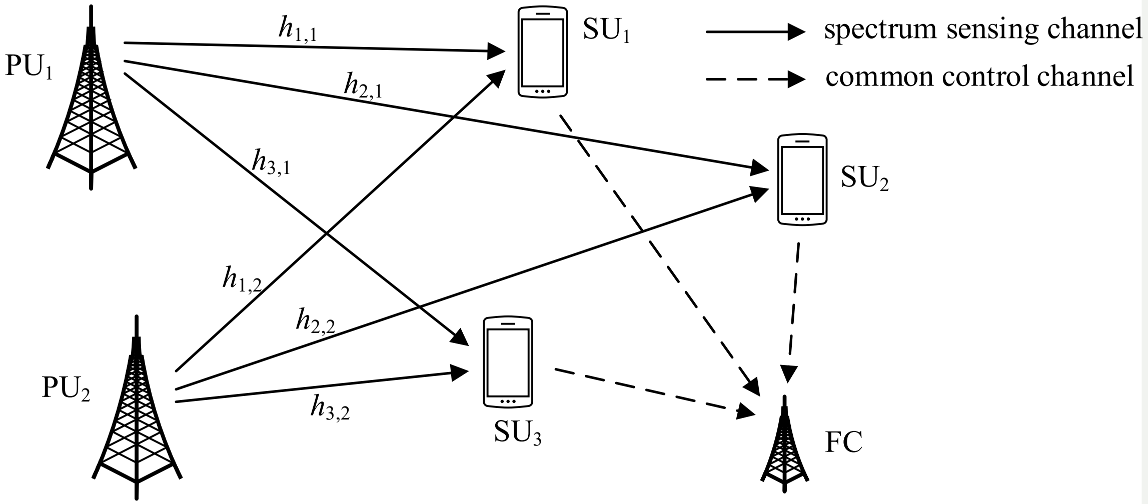
Spectrum Sensing can be integrated with data base for best evaluation spectrum.





Collaborative Sensing can improve the performance of the spectrum sensing technique.

TVWS Exploitation

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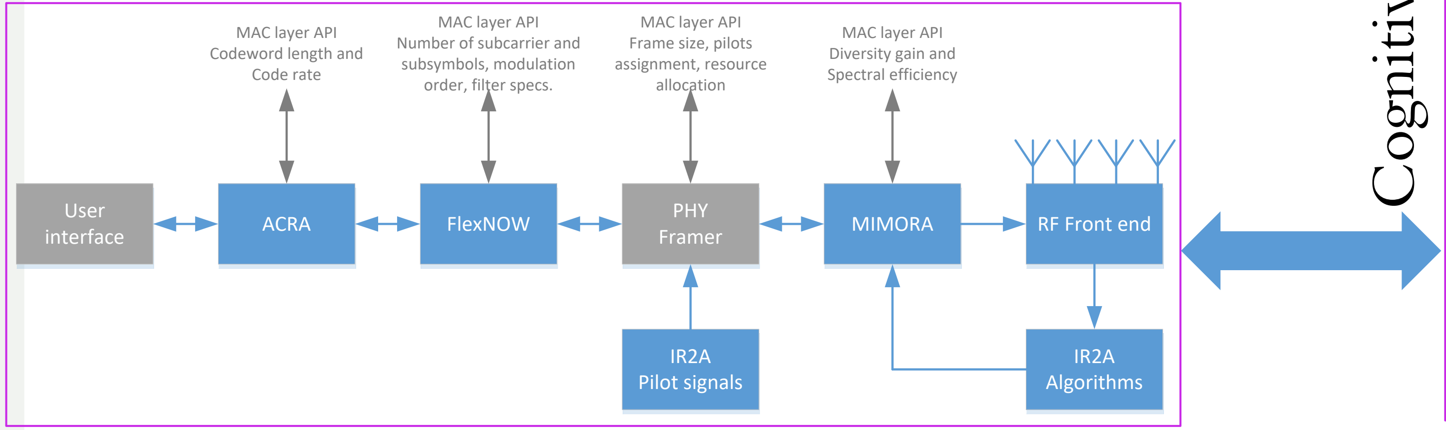
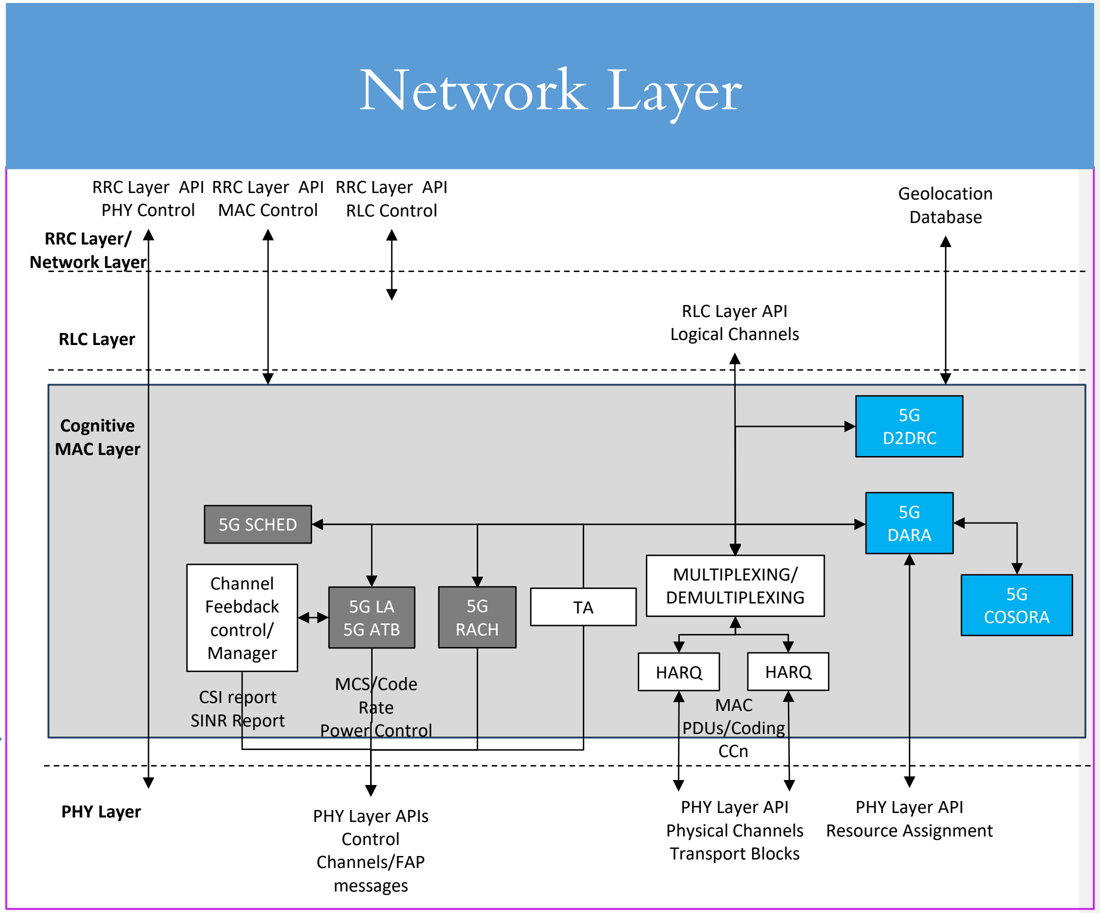
- ***Propose Radio Access Network***
  - Powerful coding scheme
  - MIMO for diversity and multiplexing
  - Narrow subcarriers – robustness against multipath

Flexible PHY

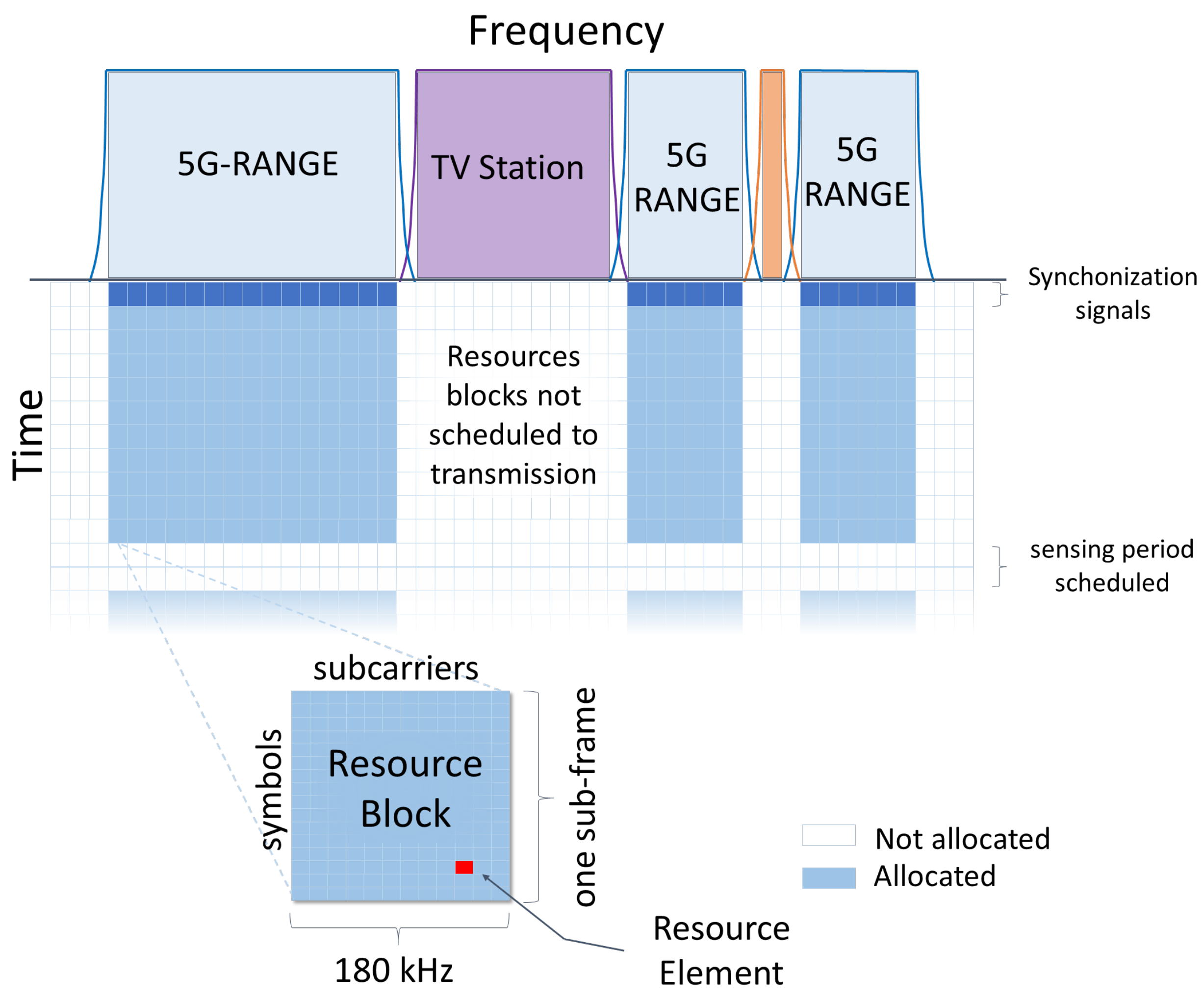


Cognitive MAC



TVWS Exploitation

- ***Flexible frame structure & Numerology***
  - Idea
    - Use low OOB waveform to allow coexistence in TVWS bands.
    - Use different numerology address conflicting requirements.
  - Approach
    - TVWS primary user protection implemented using blank resources on the grid.
    - Silence period to allow spectrum sensing.
    - Resource grid designed to allow multiple numerology to coexist in different subframes.
    - Dynamic selection of the numerology, on a subframe basis, according to user mobility and actual channel state.



TVWS Exploitation

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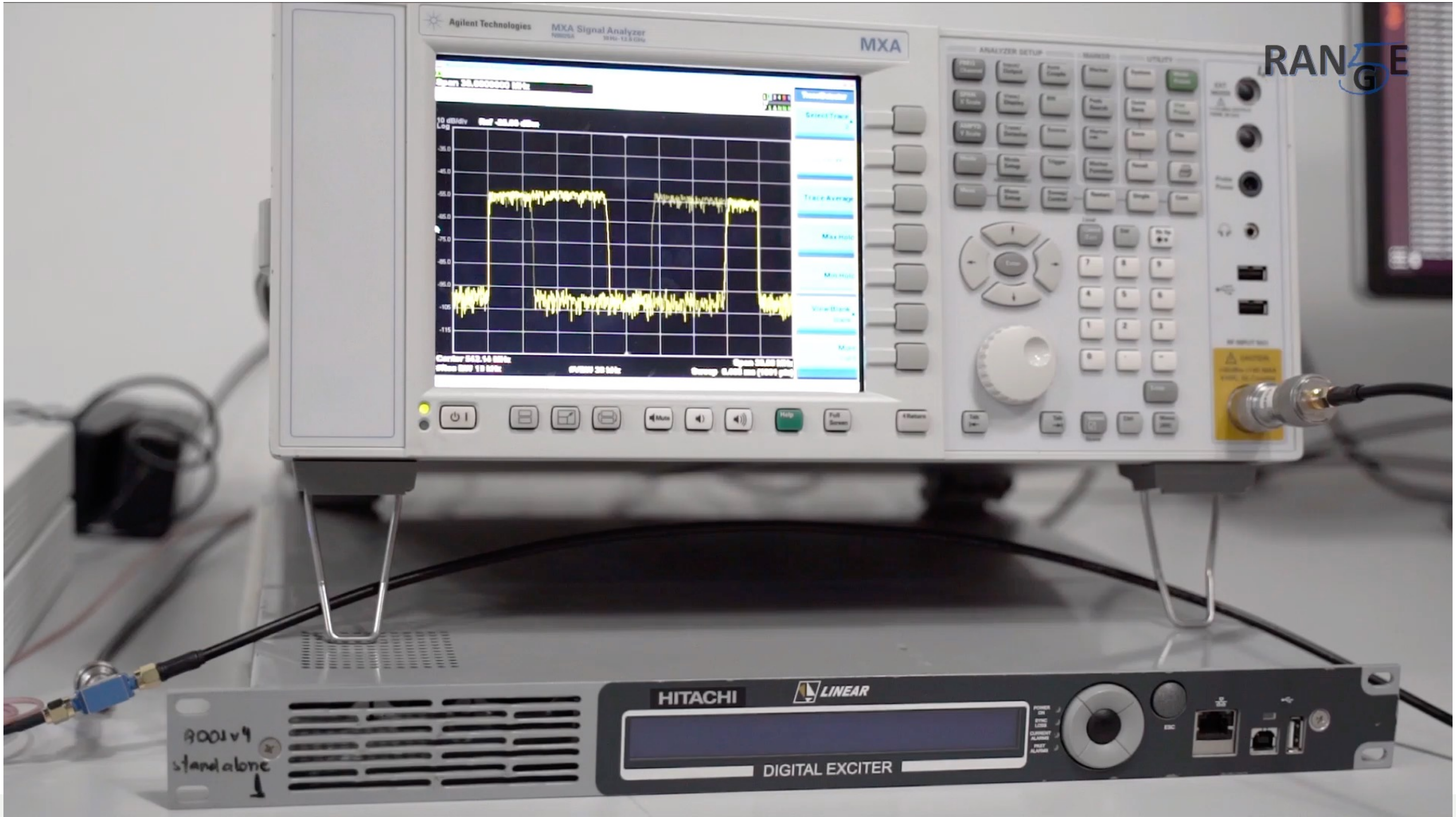
- Does it work?



TVWS Exploitation

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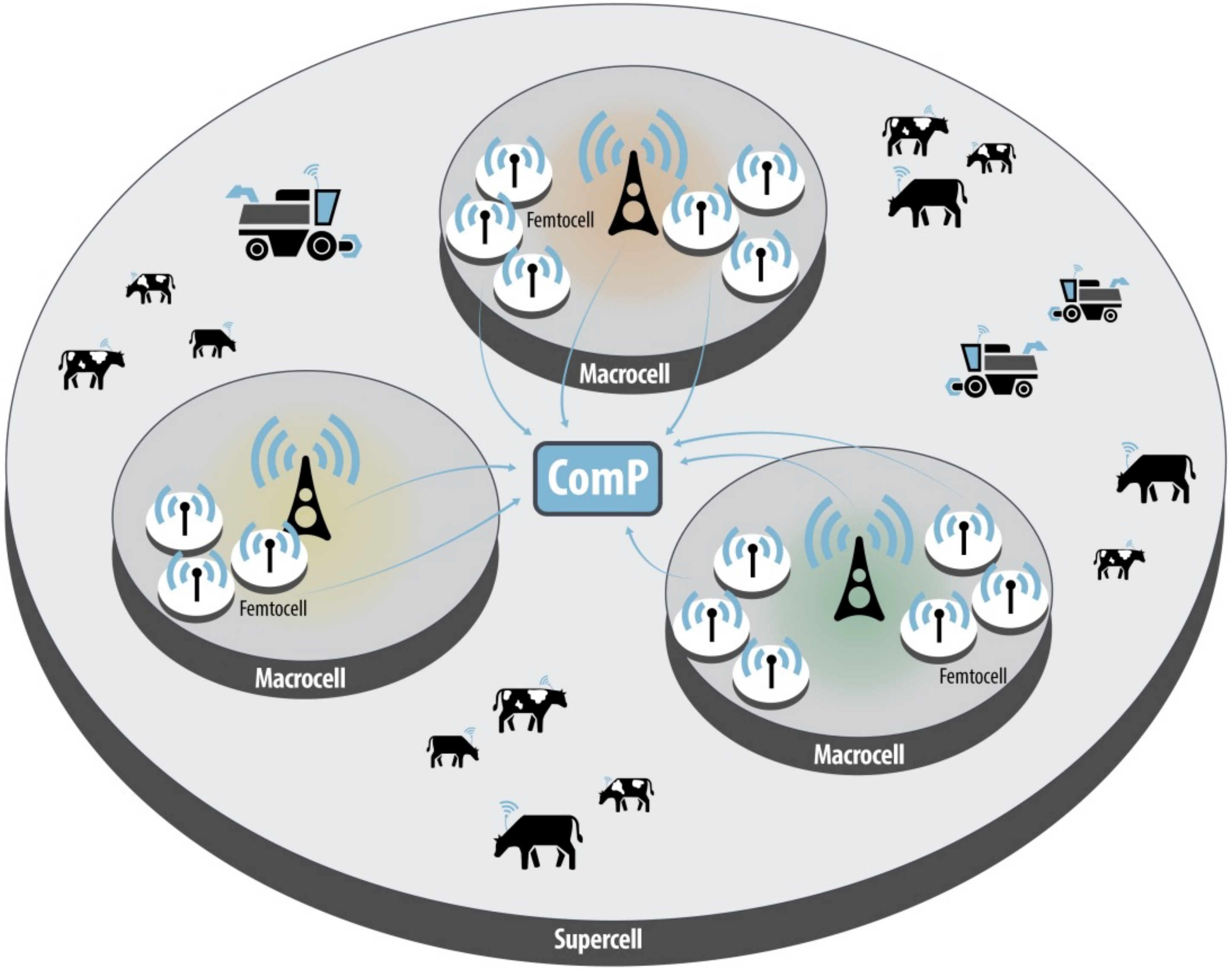
- Proposed architecture:
  - Multiple frequencies, same PHY!
  - Integrated RANs
  - Single Core
  - Seamless connection for the user



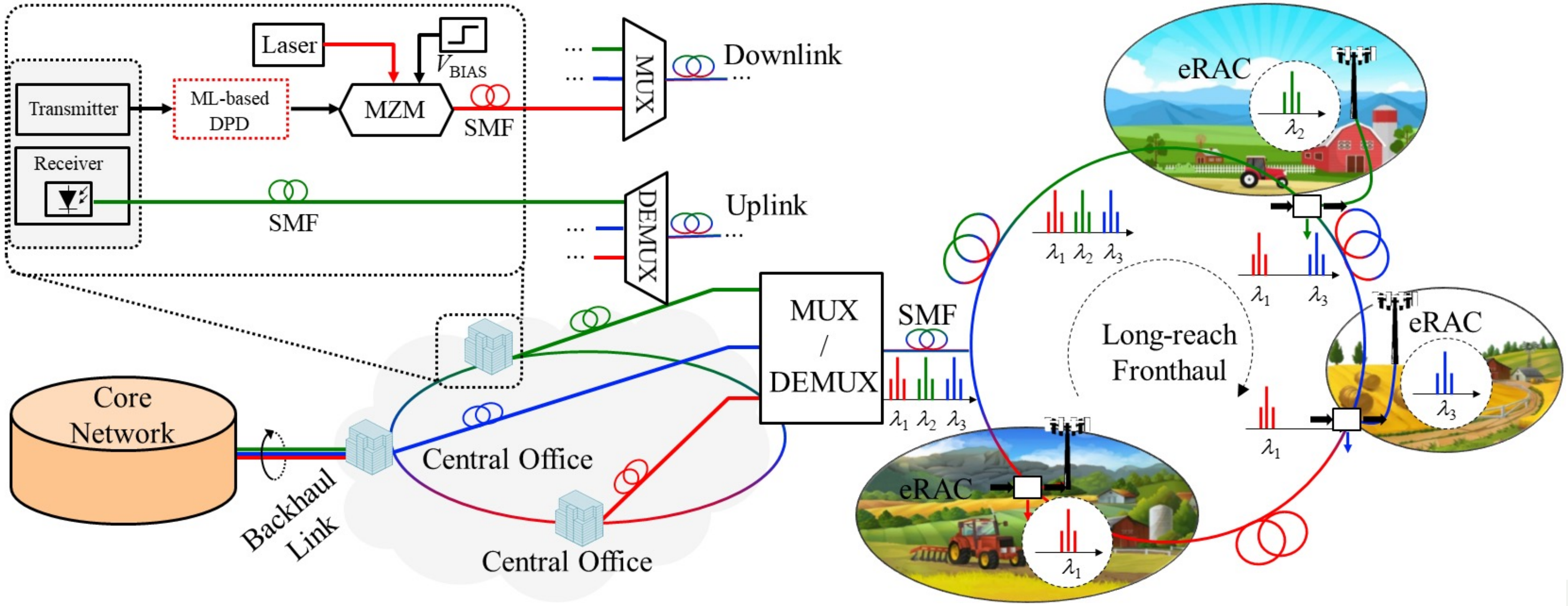
AI applied to Analog RoF for Remote Area

Expensive equipment in remote areas must be avoided.

All band-base processing can be performed at the Central Office

Only a simple Remote Radio Head unit is necessary at the deployment site.

Digital Radio over Fiber uses CPRII and eCPRII with expensive DACs and ADCs



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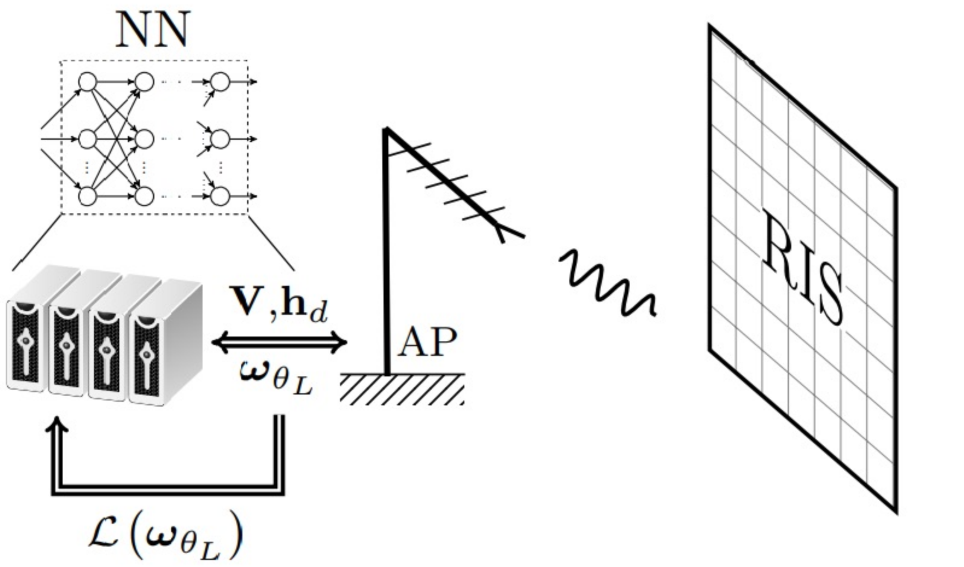
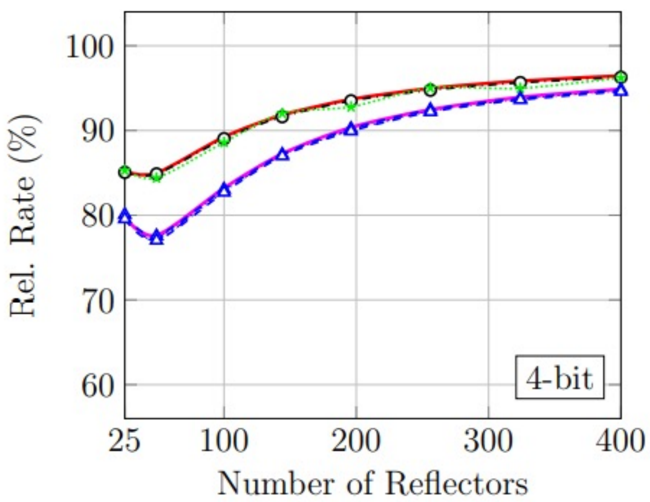
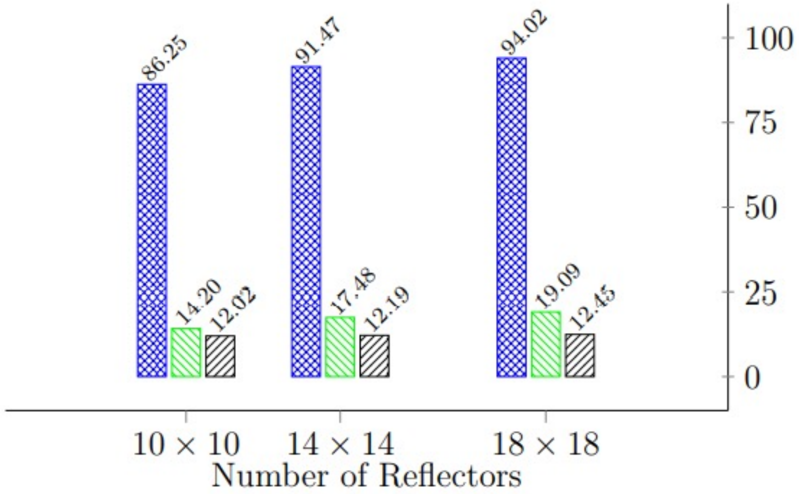
RIS is considered an enabling technology for future high-frequency networks.

Adjusting each antenna element in the RIS can introduce severe overhead.

AI can reduce the impact in the spectrum efficiency by reducing the number of updated for each antenna element.





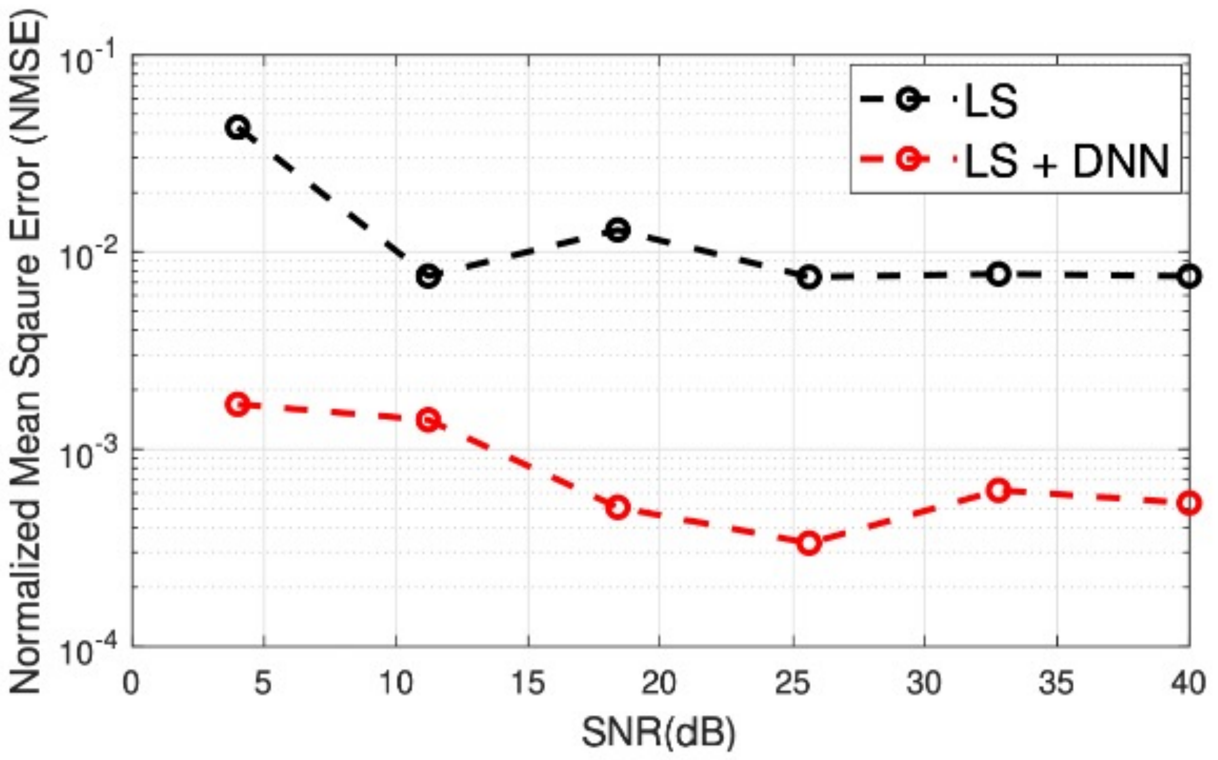


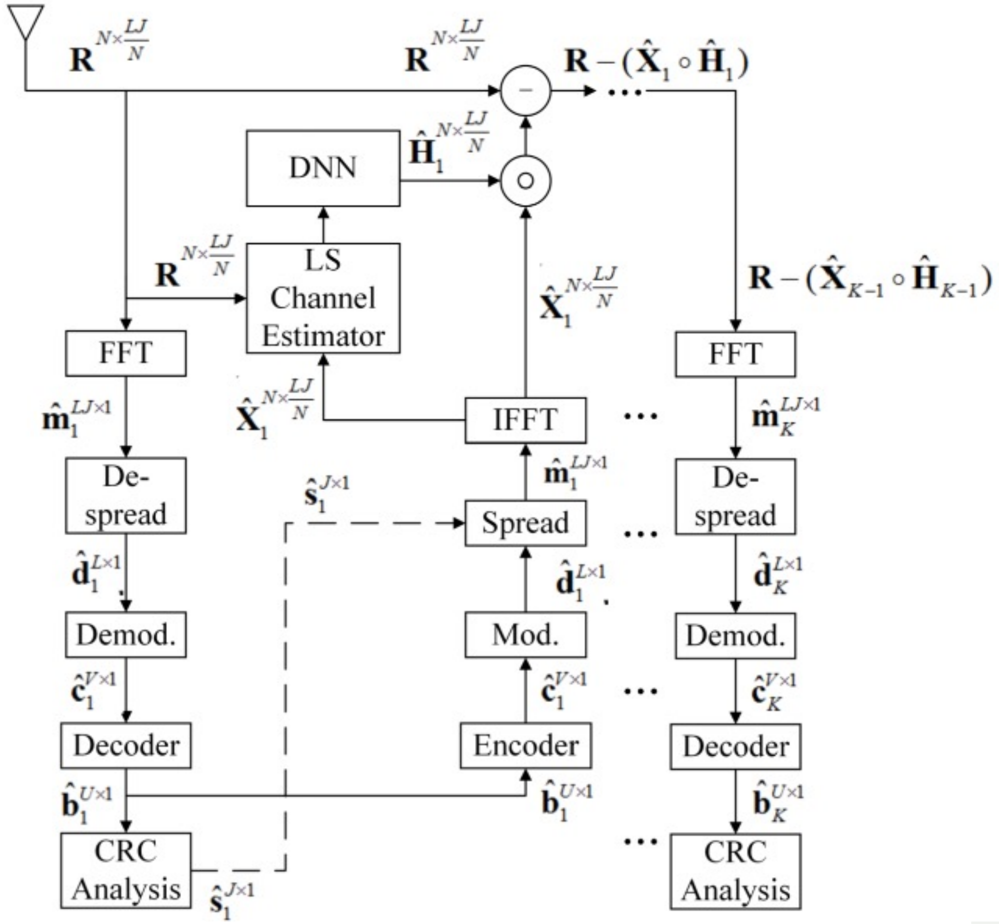
AI applied for improving channel estimation

Channel estimation is key for mobile networks.

AI can improve the quality of classic estimators.

Improvement can make new NOMA feasible.





AI applied for improving SNR estimation

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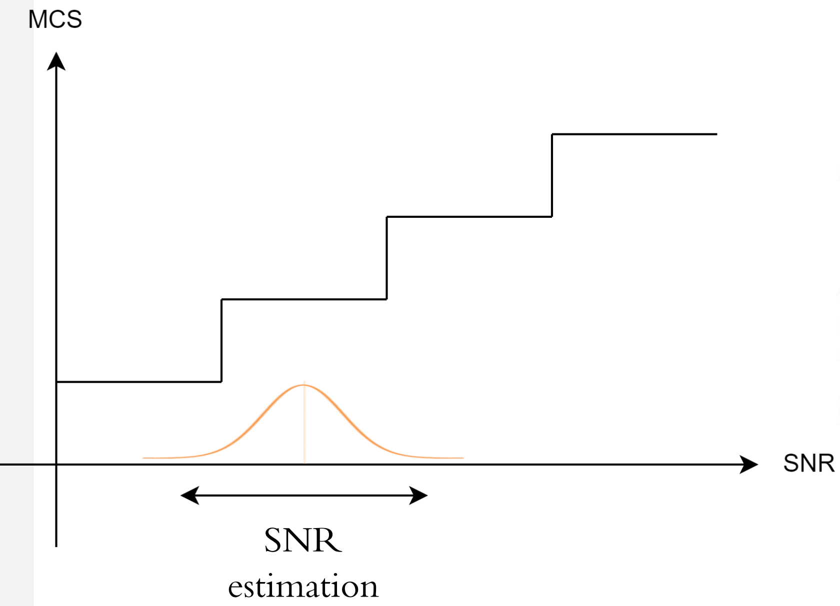
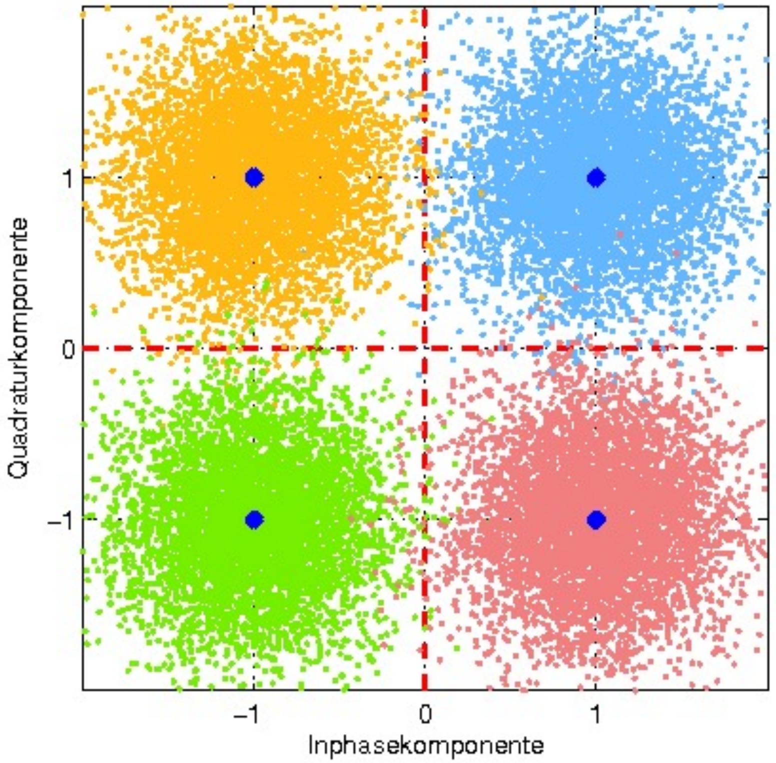
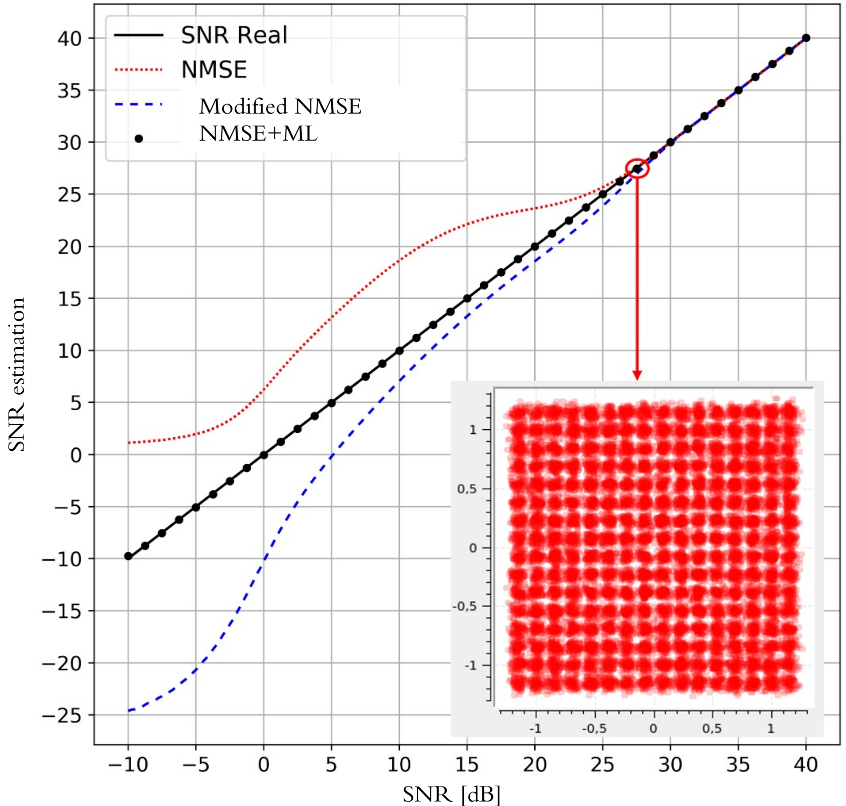
SNR estimation is essential for defining proper MCS selection.

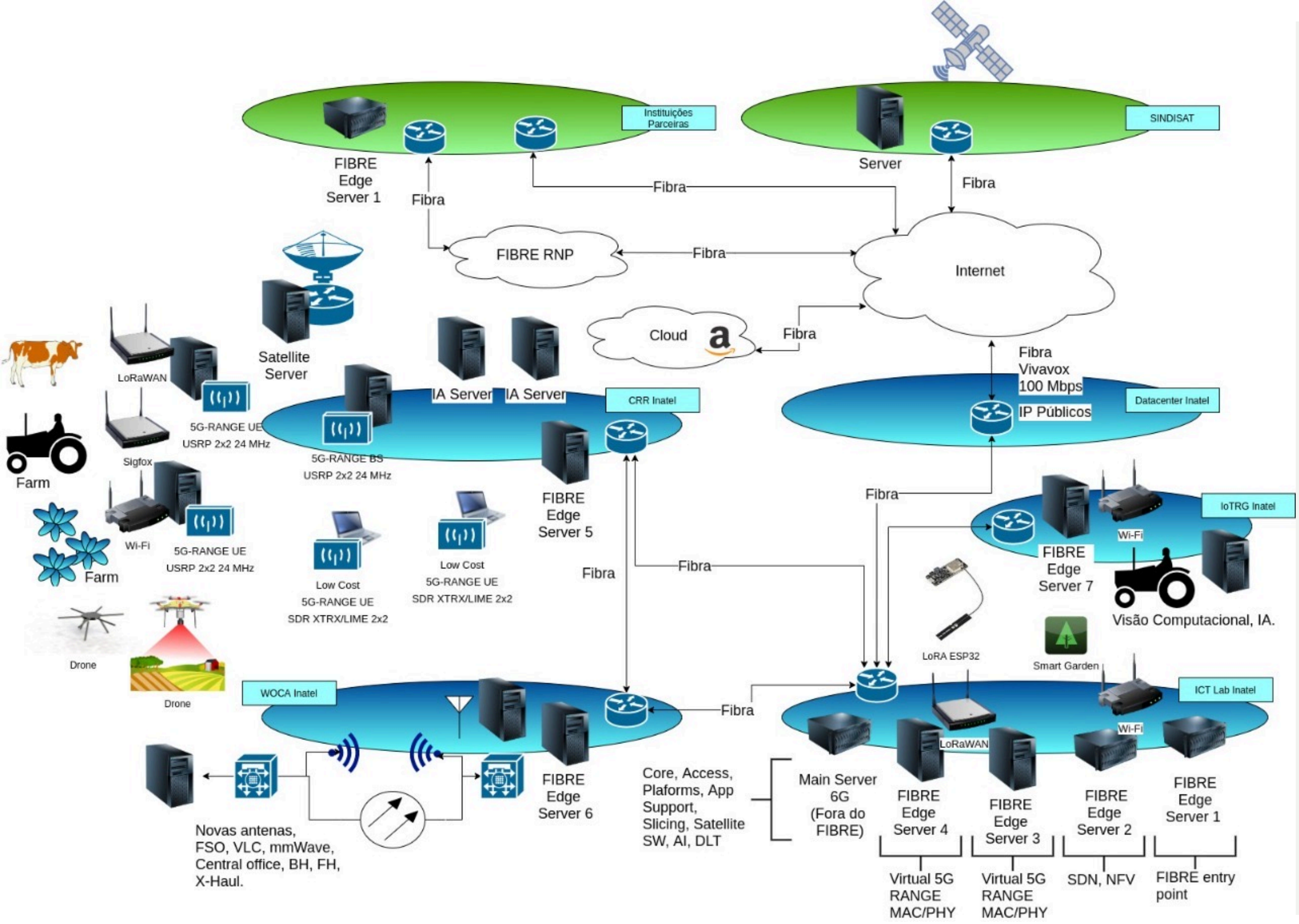
Conventional estimators provide erroneous SNRs, leading poor BER or poor SE.

AI can improve better estimation and correct MCS selection.









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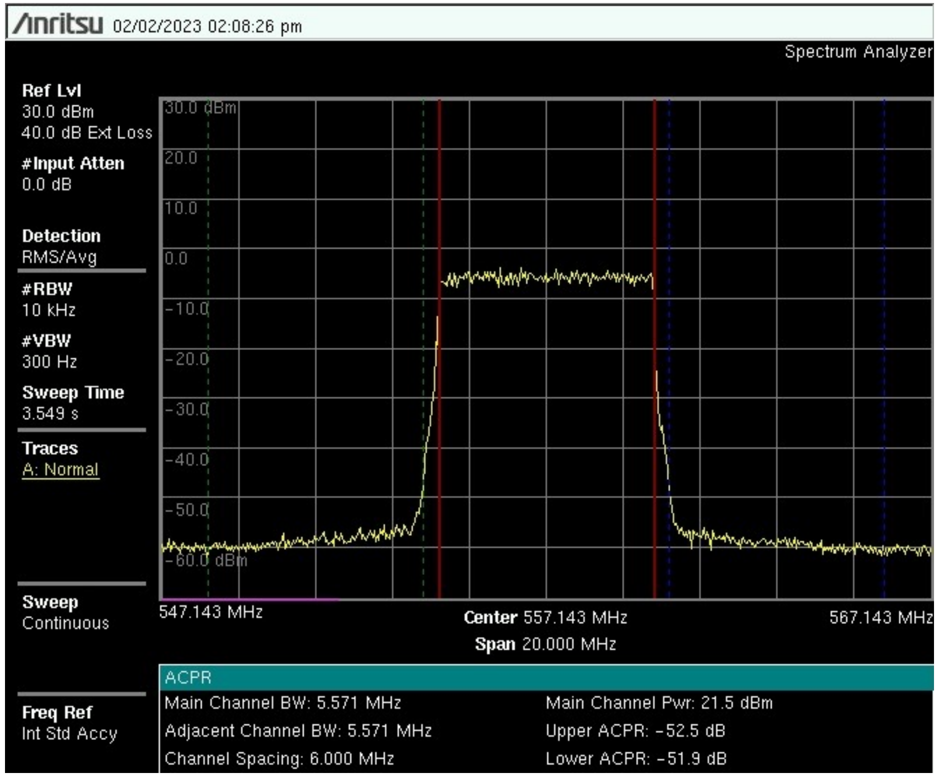
Platform for training and evaluating the AI algorithms for mobile networks

Field Tests

- Setup for the Base Station

5G-RANGE IDU and ODU

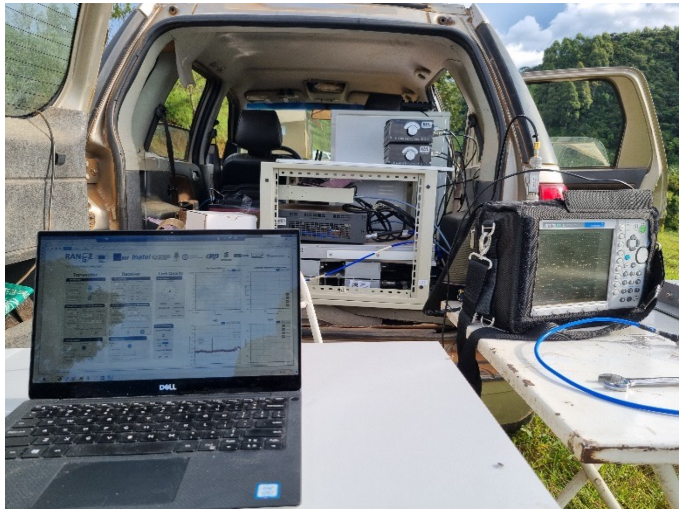
5G-RANGE Antennas



Transmit Signal delivered to the Antenna

Field Tests

- Setup for the mobile unit assembled in a car used for field measurements.



Filed Tests

TVWS signal can be up to 28.8 dB stronger than TV signal in adjacent channels without causing interference.

Coverage with 1 W peak power per channel – 15 km with throughput of 24 Mbps @ 6 MHz / 96 Mbps @ 24 MHz.

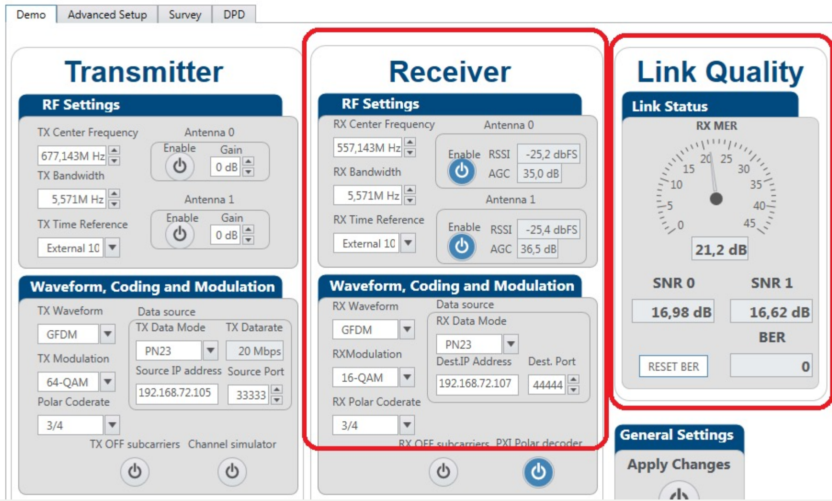
Coverage with 1 W peak power per channel – 38 km with throughput of 4 Mbps @ 6 MHz / 16 Mbps @ 24 MHz.

Coverage with 2 W peak power per channel – 38 km with throughput of 7 Mbps @ 6 MHz / 28 Mbps @ 24 MHz.

Coverage with 8 W peak power per channel – 38 km with throughput of 13 Mbps @ 6 MHz / 52 Mbps @ 24 MHz.

No interference observed in DTV signals caused by TVWS signals with transmitting power up to 10 W peak power.

Instead of restricting in channel power, ACLR or OOBE should be the limiting factor.



Conclusions

- 6G is much more than communications.
- Integration of several networks – a network of networks
- Must be designed considering current and future demands of the global society.
- Key services and applications must be early developed to trigger monetization as soon as possible.
- Regulation and policies must be developed to allow the integration of all digital services.

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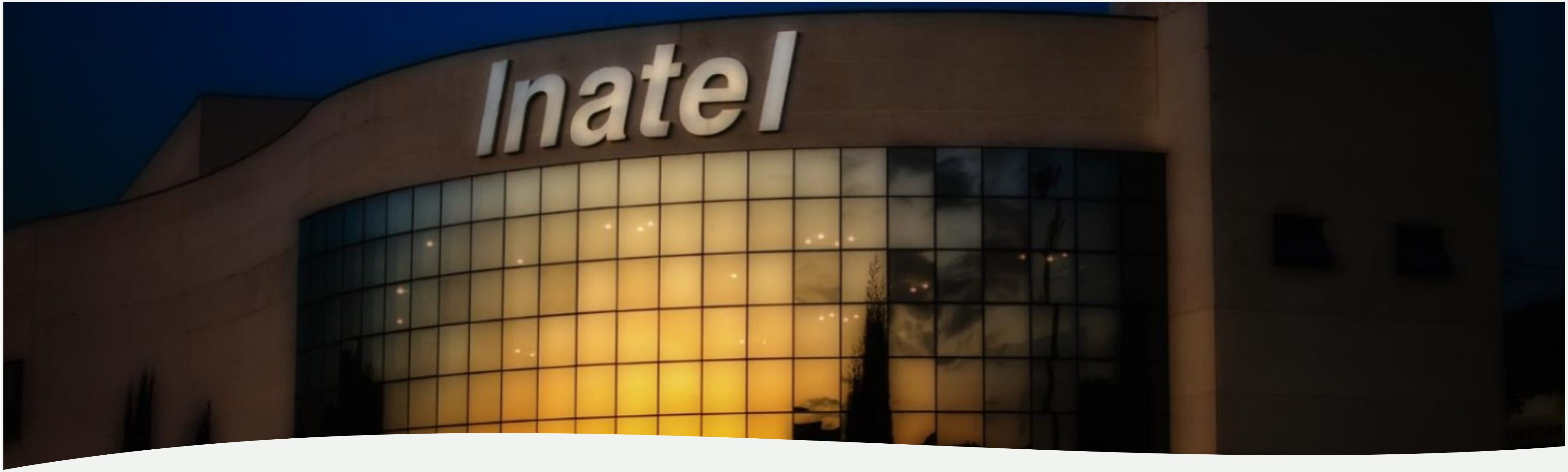

Grazie Mille!

Luciano Leonel Mendes
luciano@inatel.br