Software Defined Radio Implementation for Maritime Cognitive Radio Communications

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8th Congress of the Portuguese Committee of URSI - "Drones and autonomous vehicles: present and future challenges"

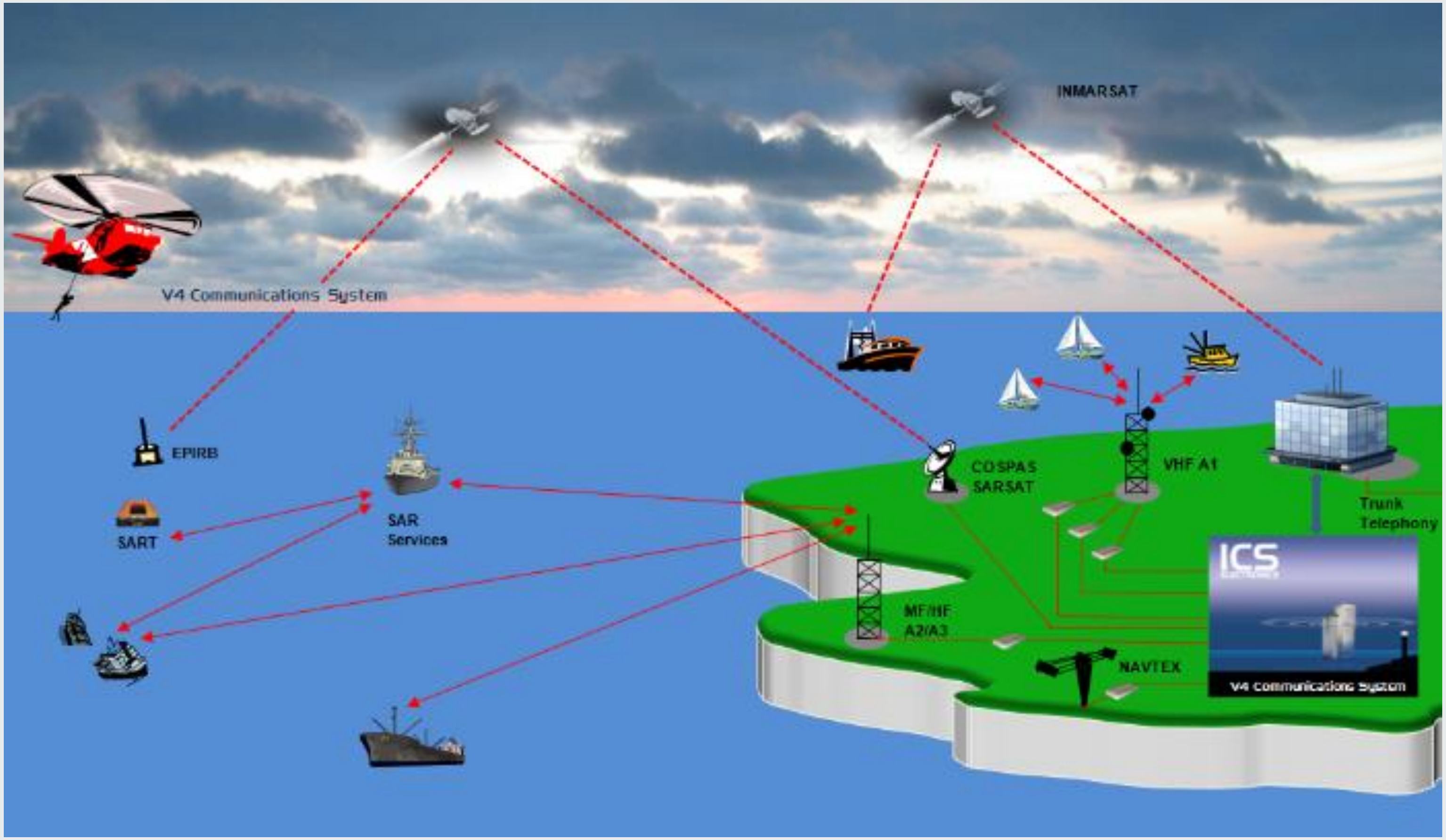
November 28th, 2014

Outline

- Introduction and Motivation
- Objectives / Contributions
- Background
- Proposed Solution
- Tests and Results
- Conclusions
- Future work
- Q&A

Introduction and Motivation

- Maritime Communications Overview



Source: ICS Electronics

Introduction and Motivation

- Maritime Communications Overview

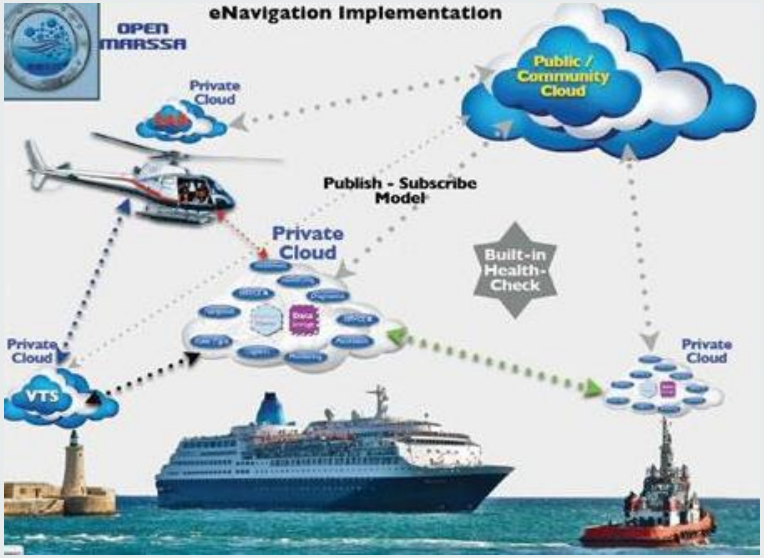
System	Band	Throughput	Application
NAVTEX	HF, MF	100 b/s	Information / Distress
DSC	VHF MF/HF	1.2 kb/s 100 b/s	Short messaging / Distress
AIS	VHF	9,6 kb/s - 2 ch.	Automatic vessel tracking
SATCOM	SHF	< 4 Mb/s	IP data / Telephony

Terrestrial networks: GSM, UMTS, LTE…

Introduction and Motivation

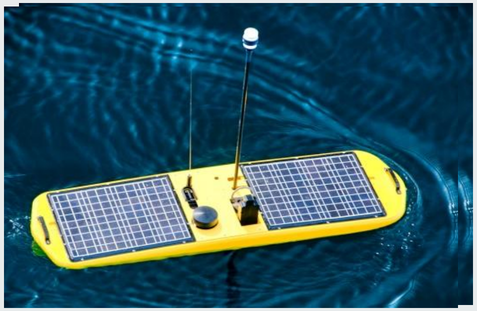
- New Demands

e-Navigation



Source: Times of Malta

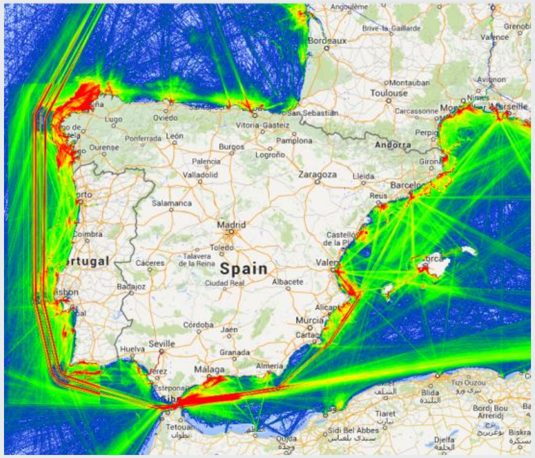
Sensor Networks

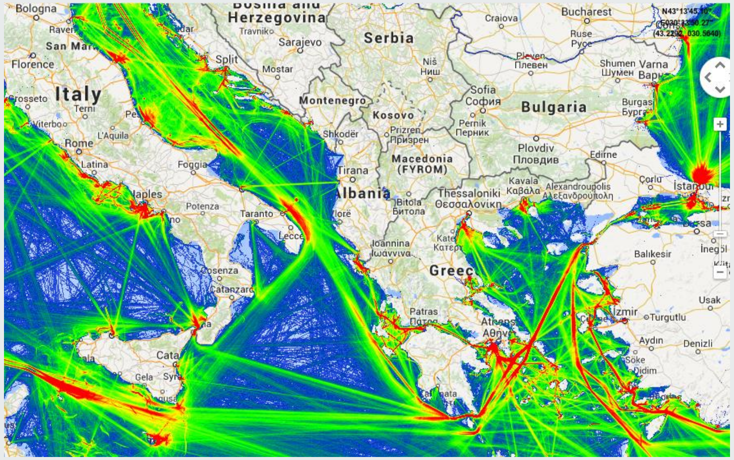


Personal Communications

Introduction and Motivation

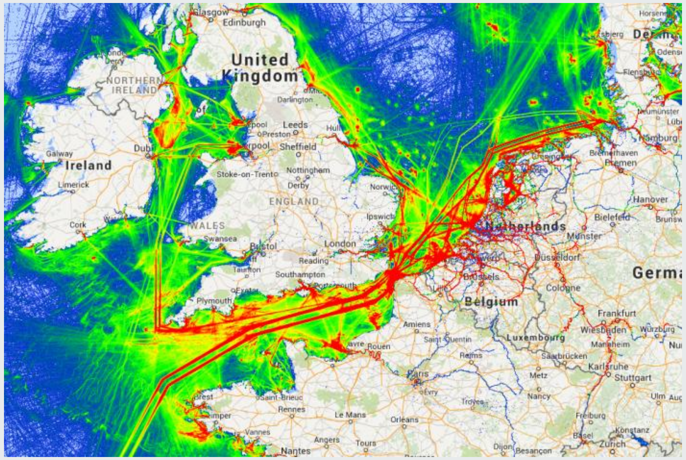
- What about coverage?





Most ship-to-ship and ship-to-shore communications use the VHF Band

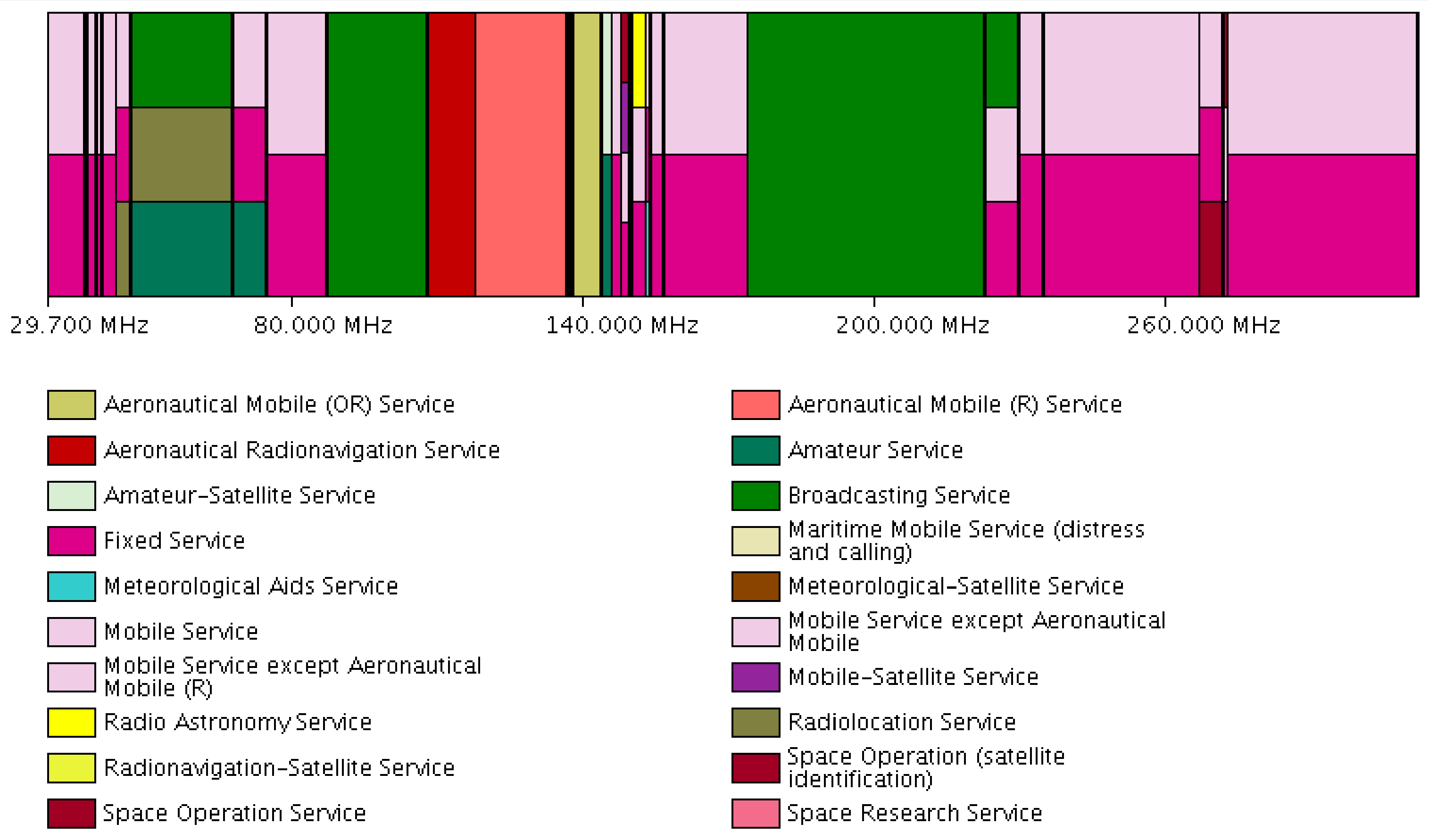
~ 30 nautical miles



“Traffic Density”. Source: Marine Traffic

Introduction and Motivation

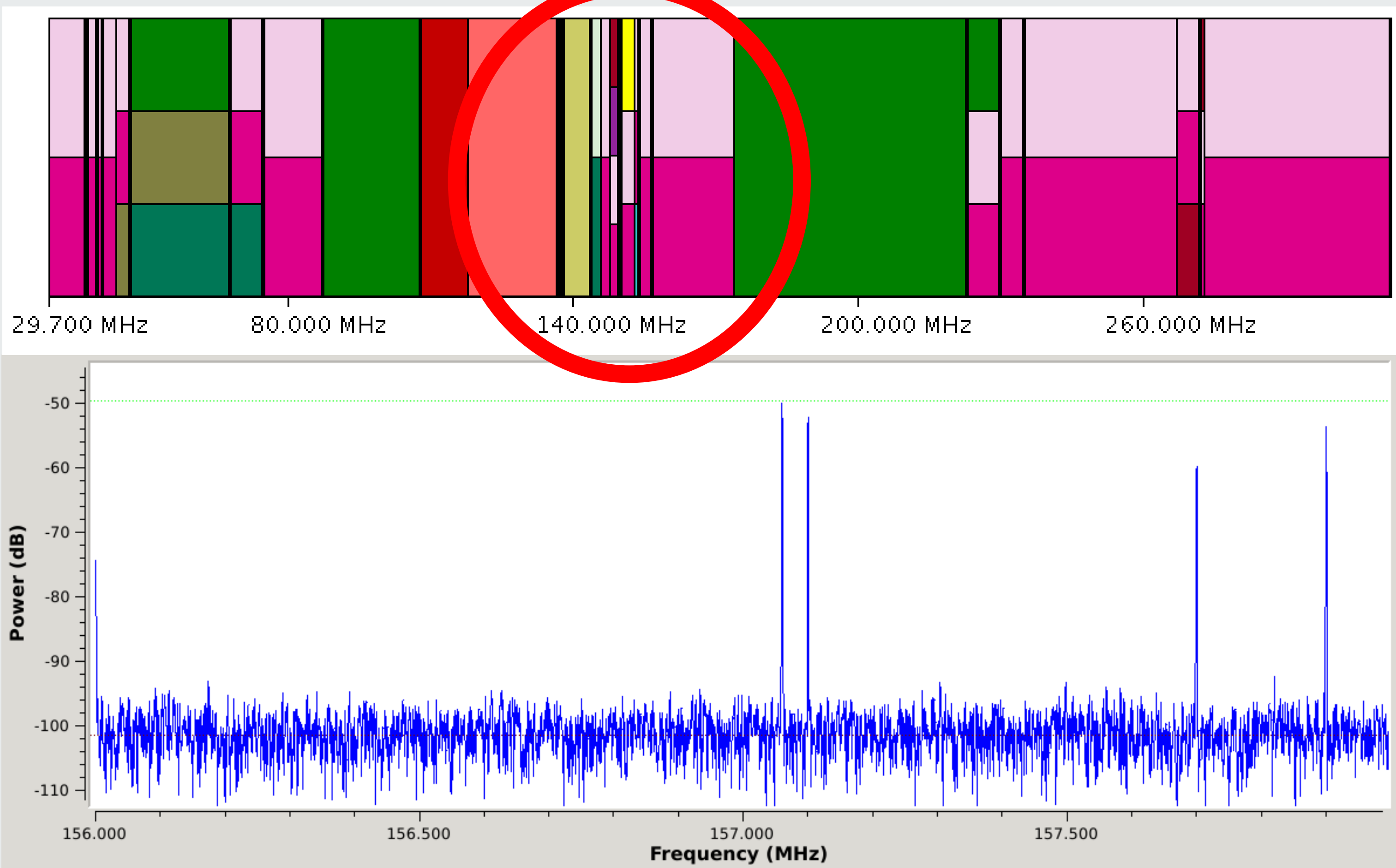
- Radio Resources Overview – The VHF Band



Source: ANACOM

Introduction and Motivation

- Radio Resources Overview – The VHF Band



Introduction and Motivation

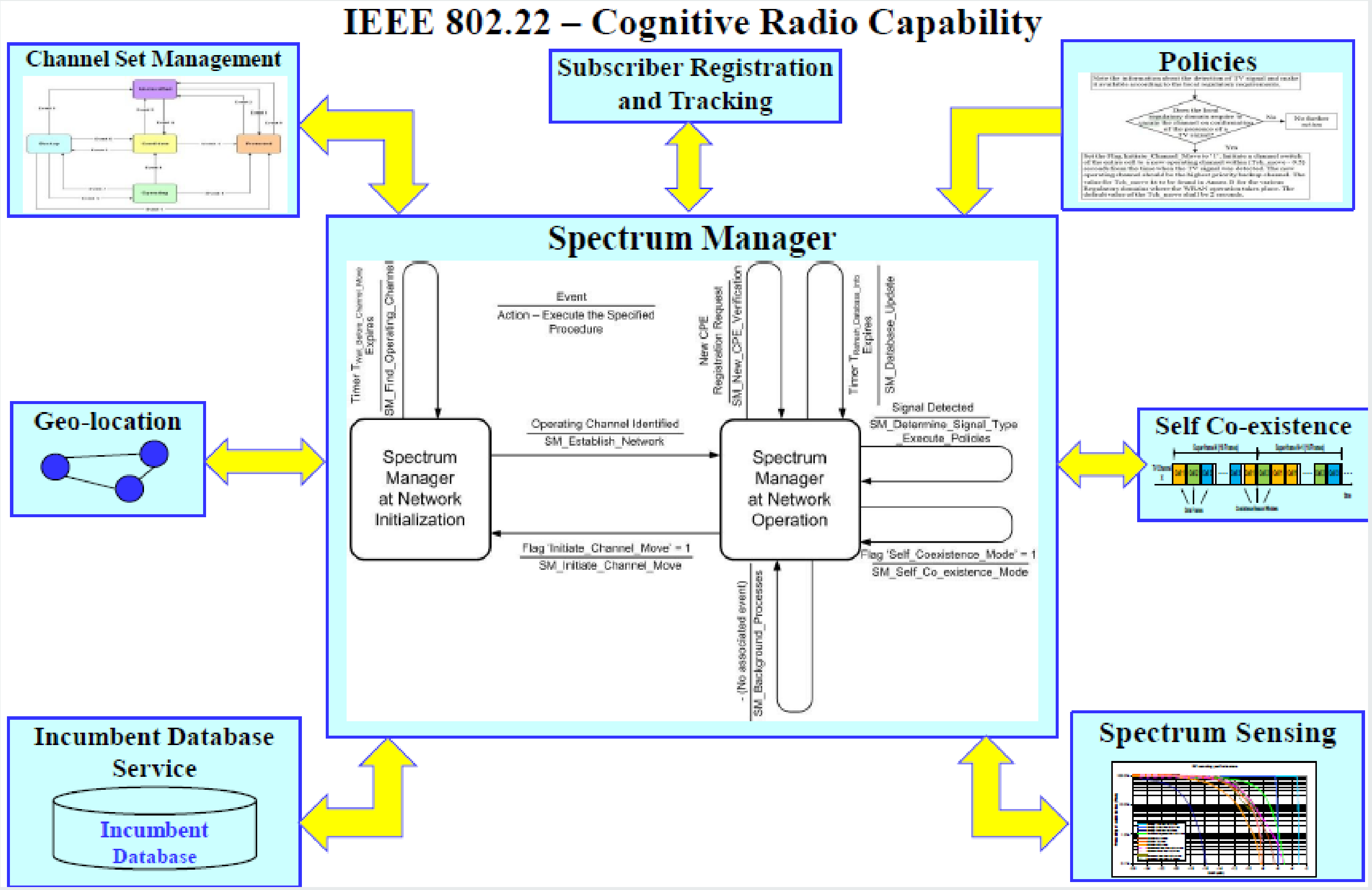
- Solutions

Spectrum refarming?

New spectrum allocations?

Introduction and Motivation

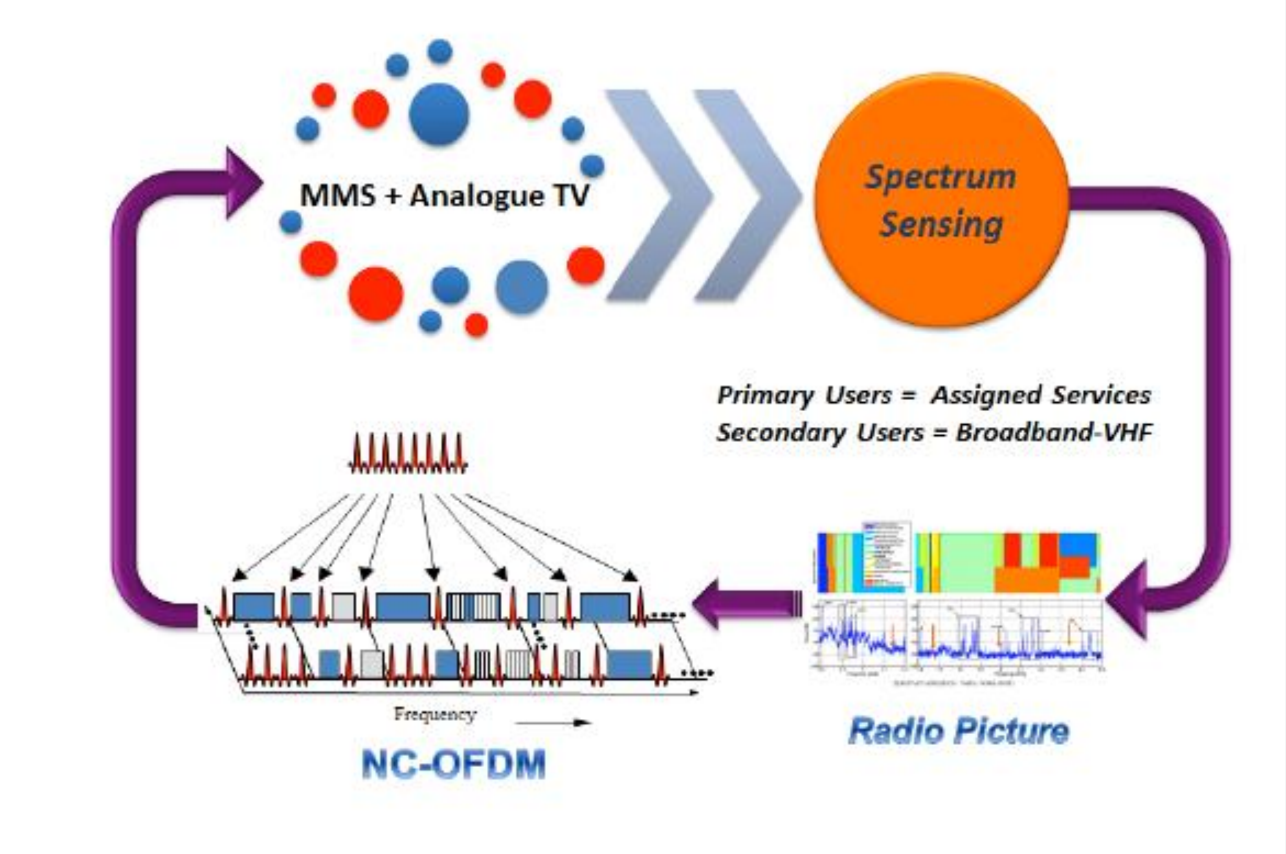
- Opportunistic Systems (Smart Solutions)



Source: IEEE 802.22 Working Group

Introduction and Motivation

- Opportunistic Systems (Smart Solutions)



Source: Bolas et. al. 2012

Objectives

Broadband VHF Communication System

Opportunistic Use of Maritime VHF Spectrum

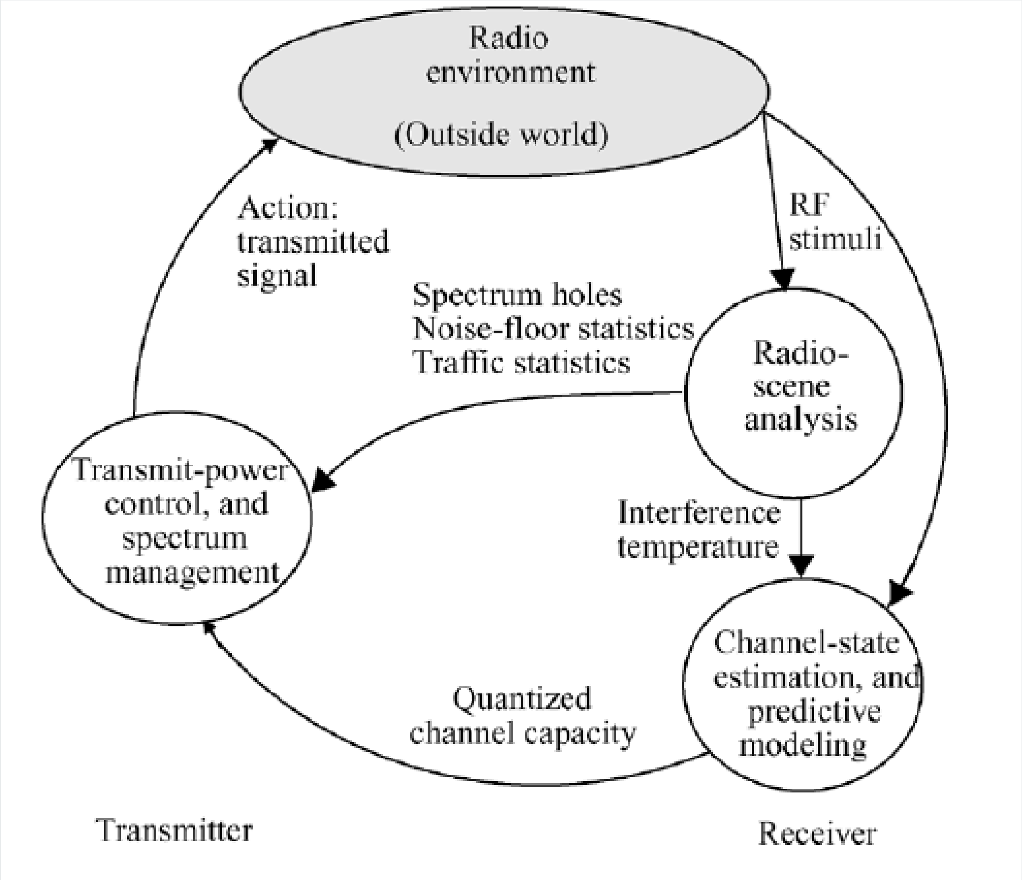
Spectrum Sensing, Transceiver Techniques, Network Synchronization → Cognitive Radio

Contributions

- Implementation of a custom system for the VHF maritime band;
- Implementation and integration of the major components of a cognitive radio;
- Development and implementation of a cognitive engine, as well as a network synchronization protocol;
- Coexistence evaluation between opportunistic and primary users.

Background

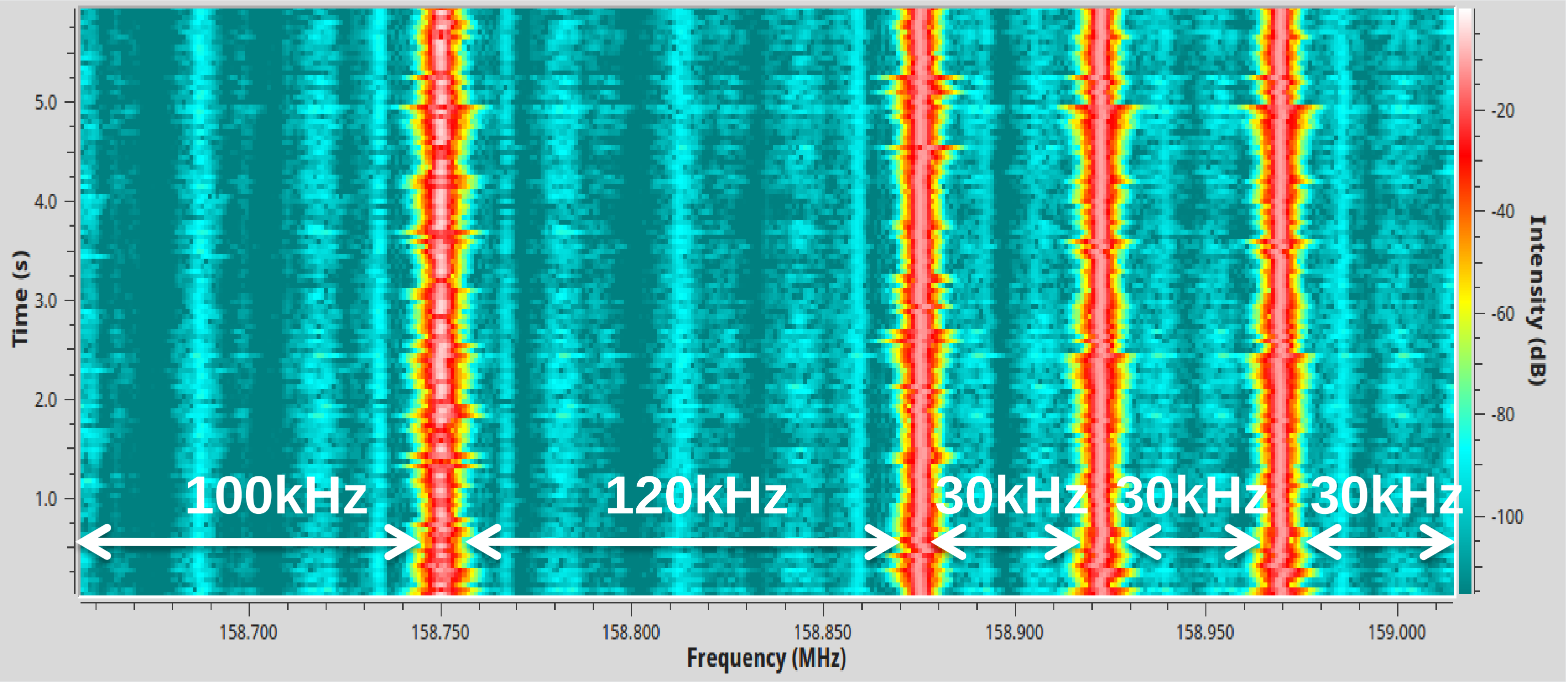
- Cognitive Radios



Source: Haykin 2005

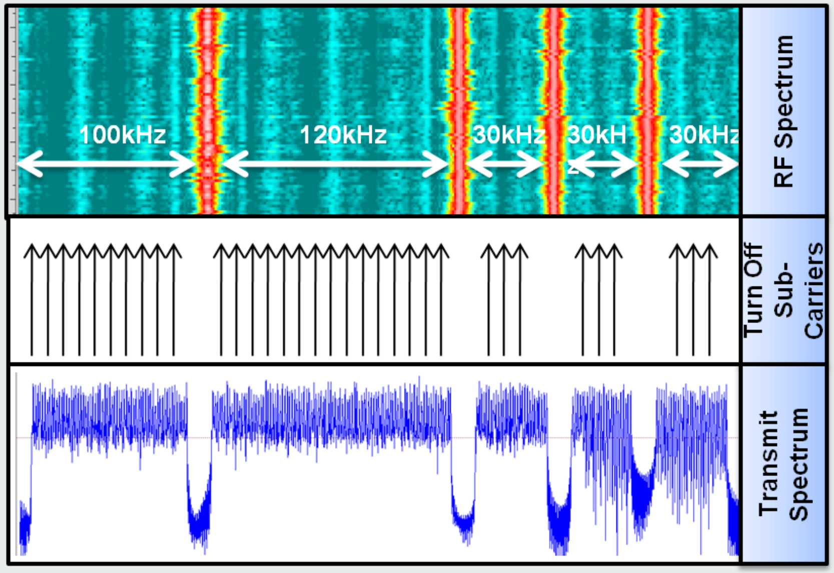
Background

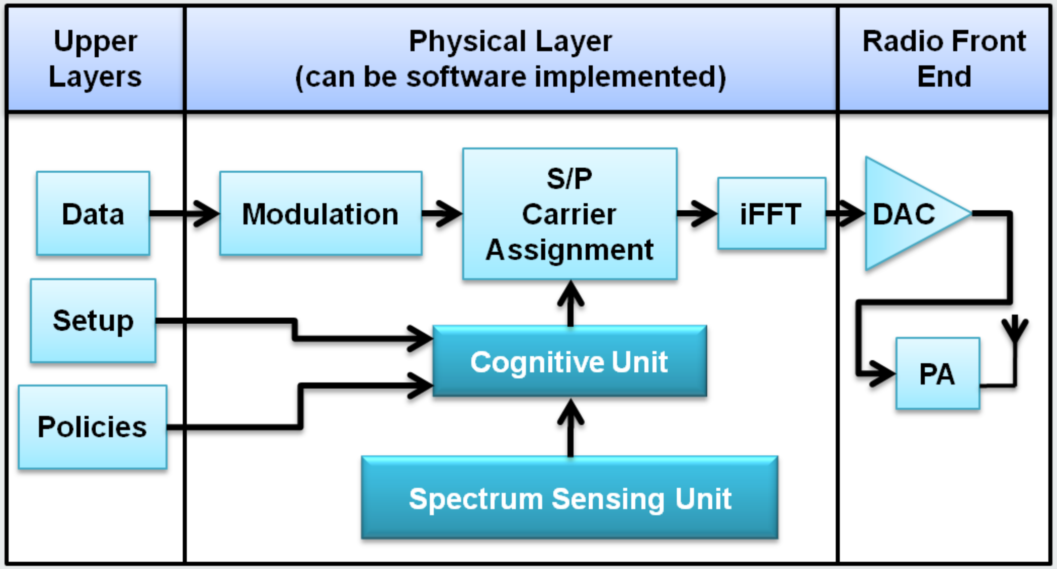
- Spectrum Sensing
  - Detection of Primary User Activity in a Multichannel Scenario



Background

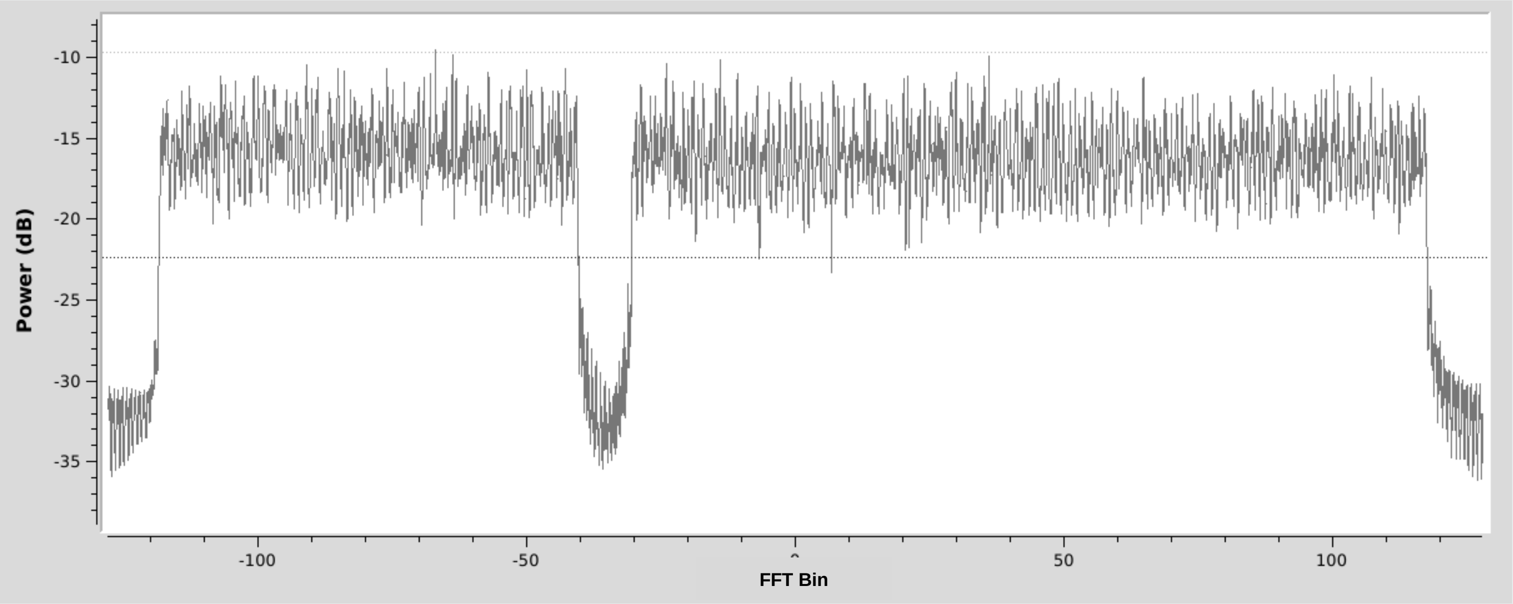
- Spectrum Shaping with a Multicarrier Modulation:
  - Orthogonal Frequency Division Multiplexing (OFDM)





Background

- OFDM
  - It's awesome, but…



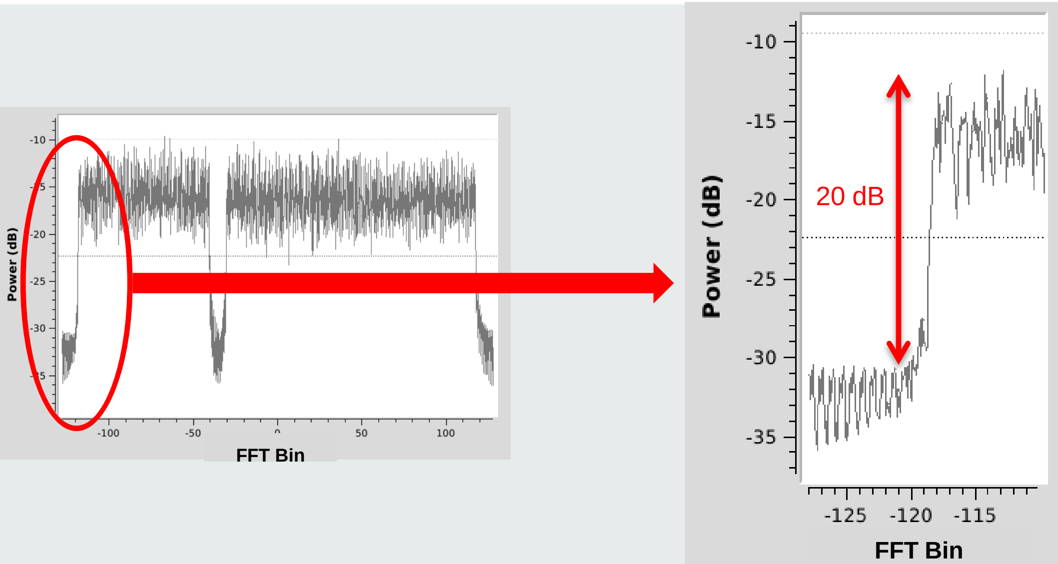
256 bin OFDM Signal

10 + 10 OOB disabled sub-carriers

10 NC disabled sub-carriers

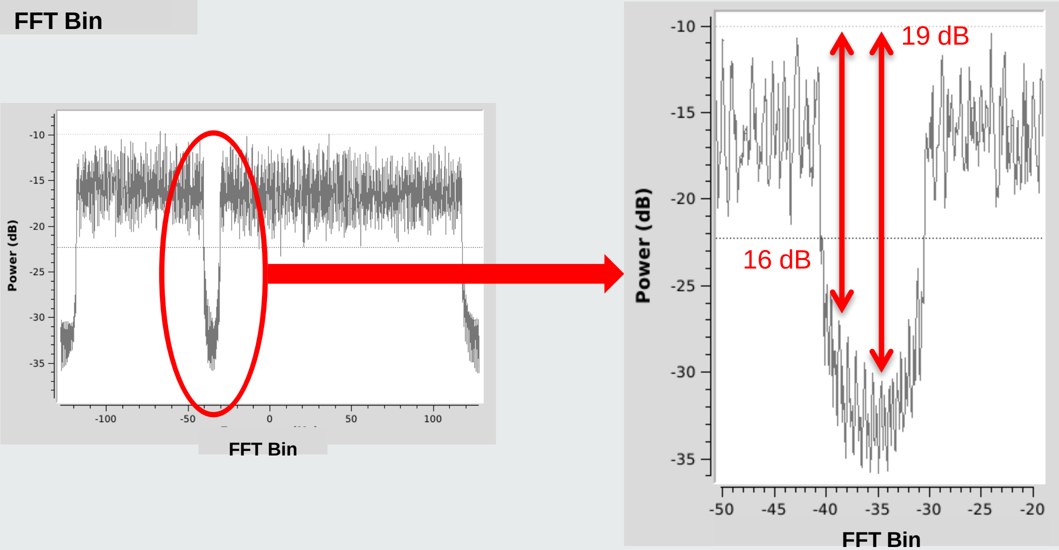
•Radiation leakage
•Relatively high Peak-to-Average Power Ratio (PAPR)

Background



Out Of Band (OOB) Radiation

Non Contiguous (NC) Radiation



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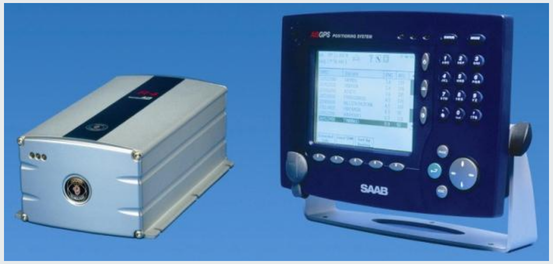
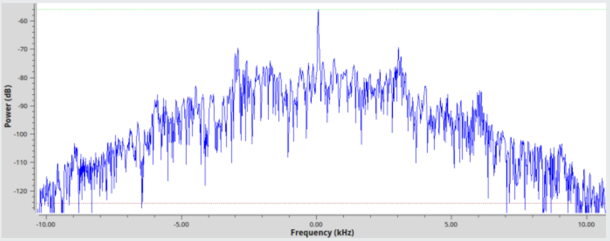
Proposed Solution

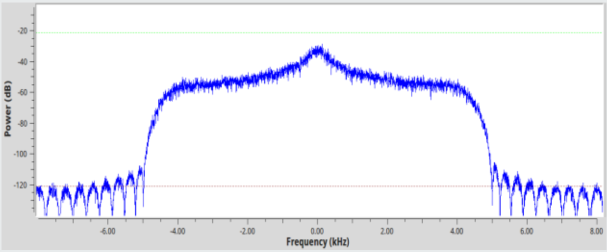
- Opportunist Use of Radio Spectrum in the Maritime context

- Most Common Primary Users

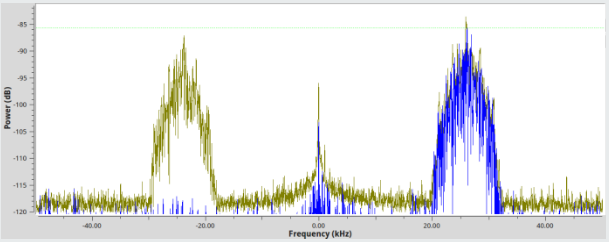




Analogue Telephony



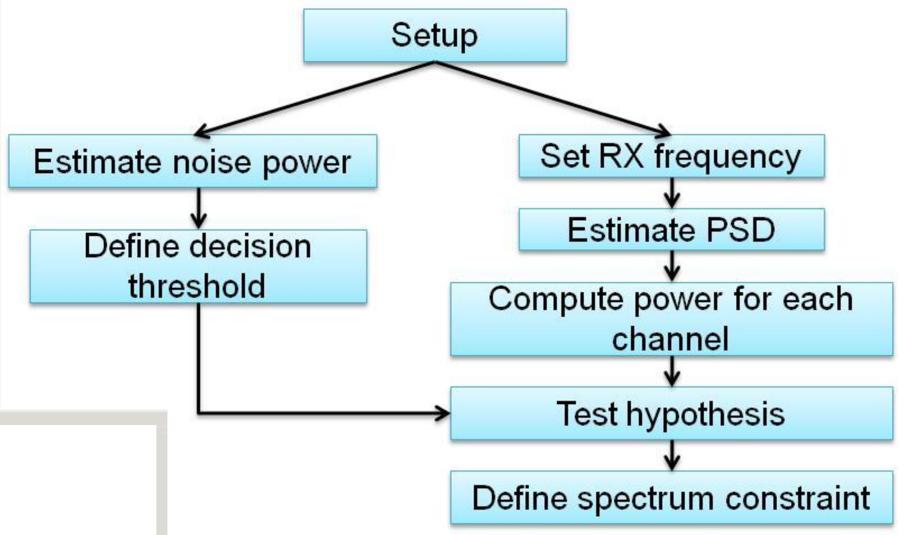
DSC

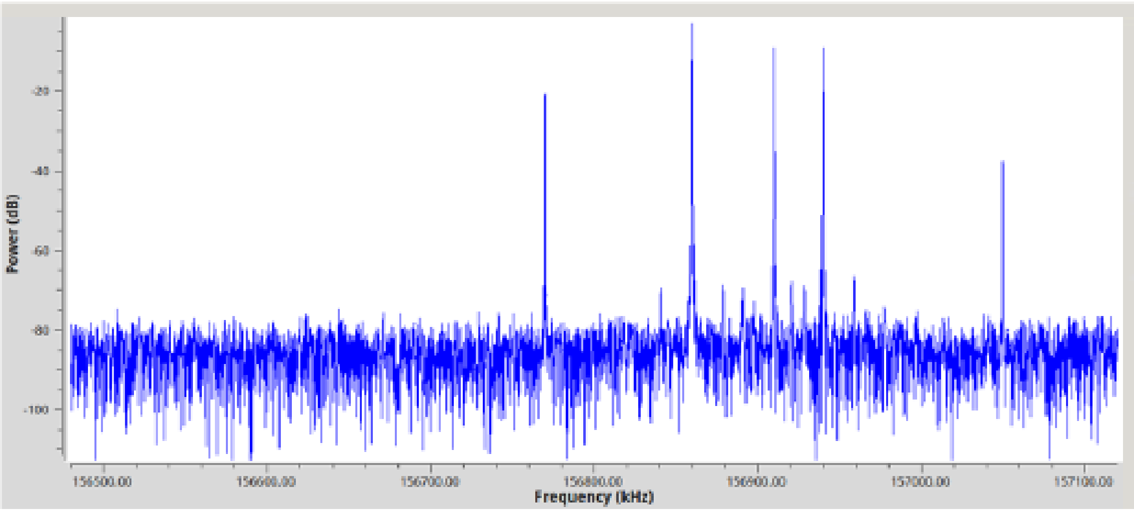


AIS

Proposed Solution

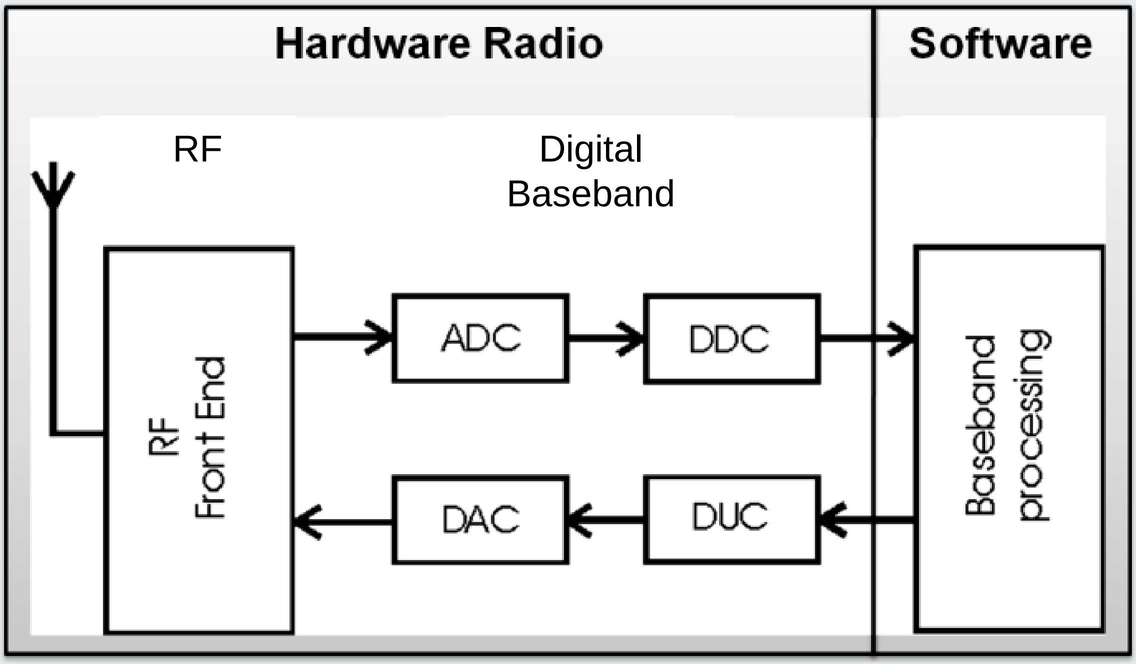
- Multiuser Scenario – Multichannel Detector





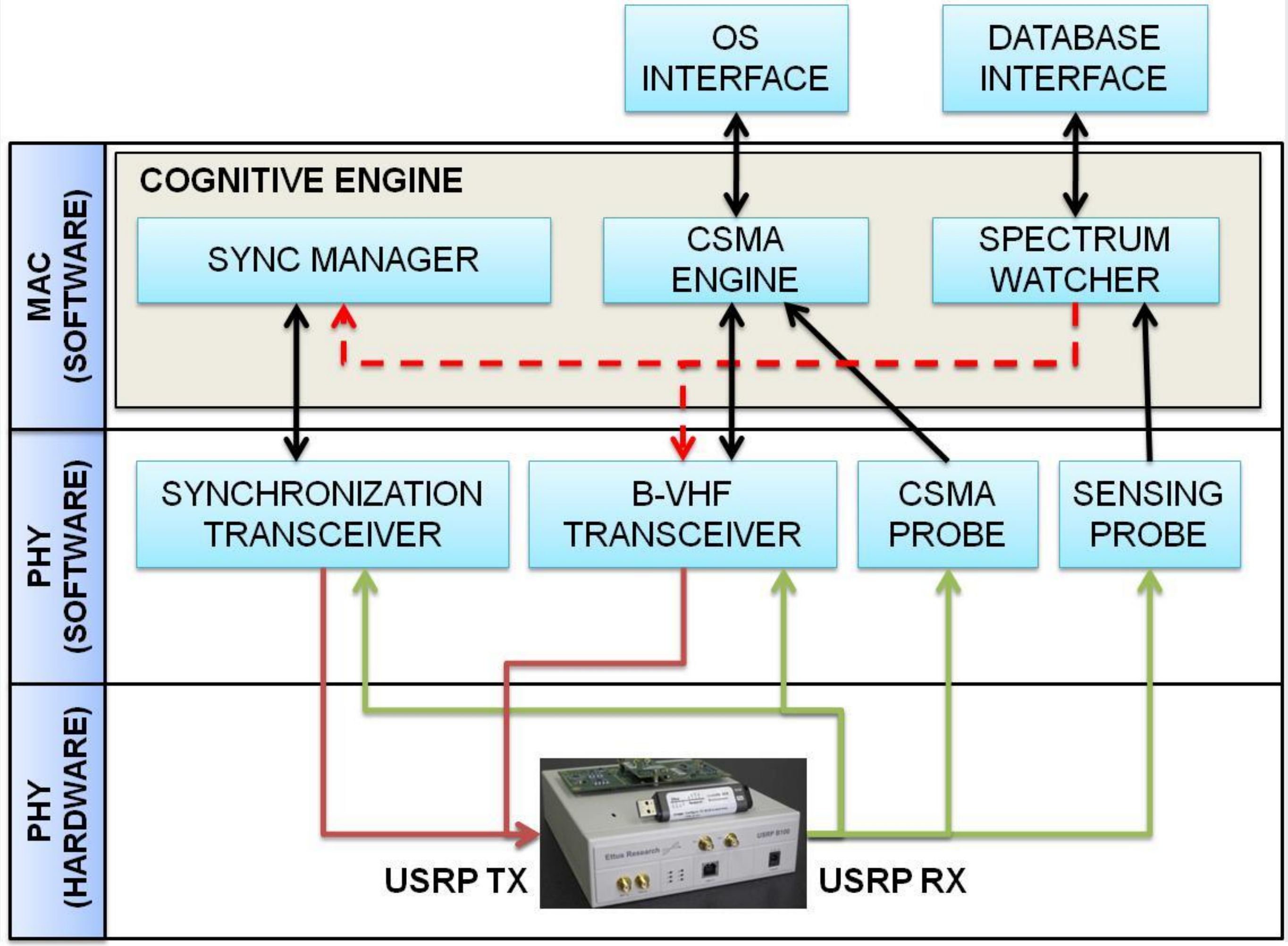
Proposed Solution

- Reconfigurable radio transceiver
  - Software Defined Radio



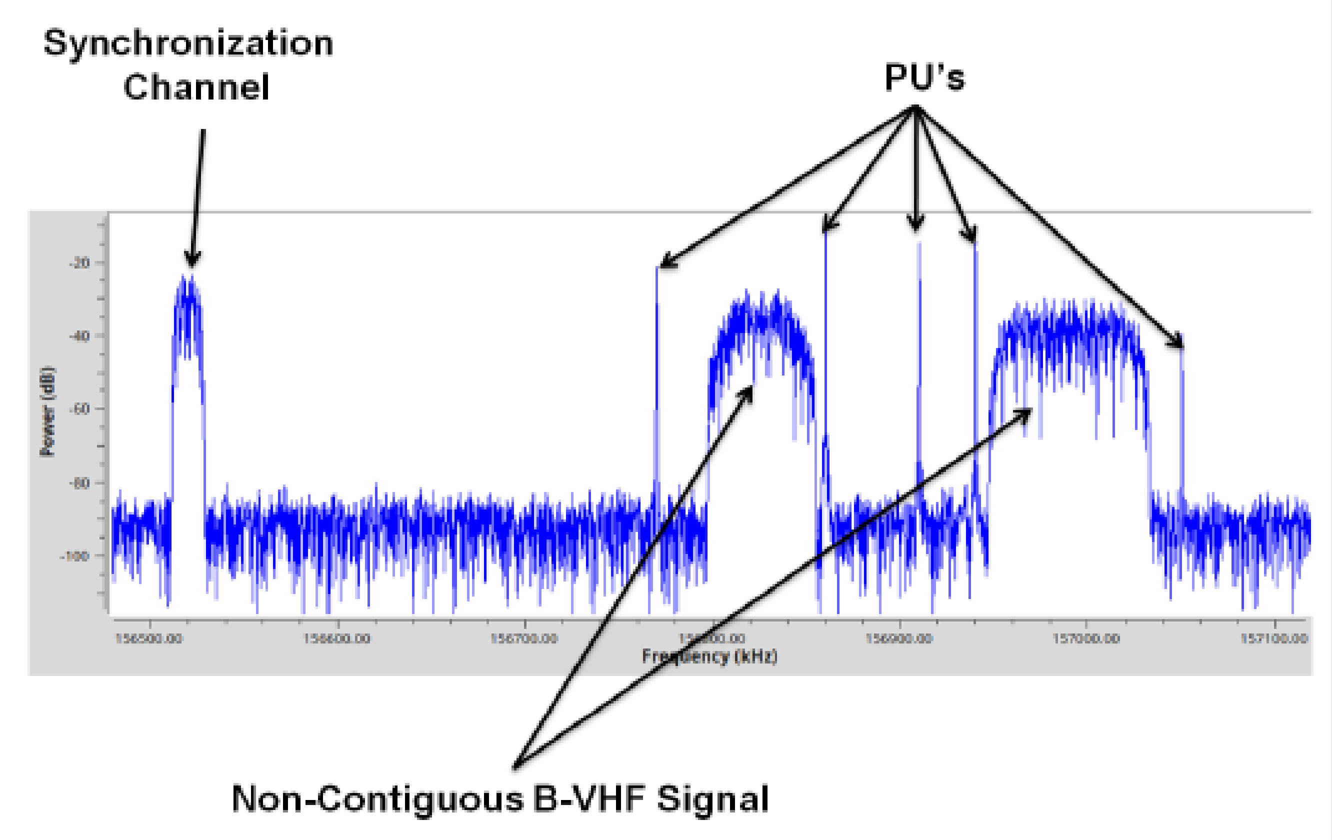
Proposed Solution

- Radio Architecture – Master Station



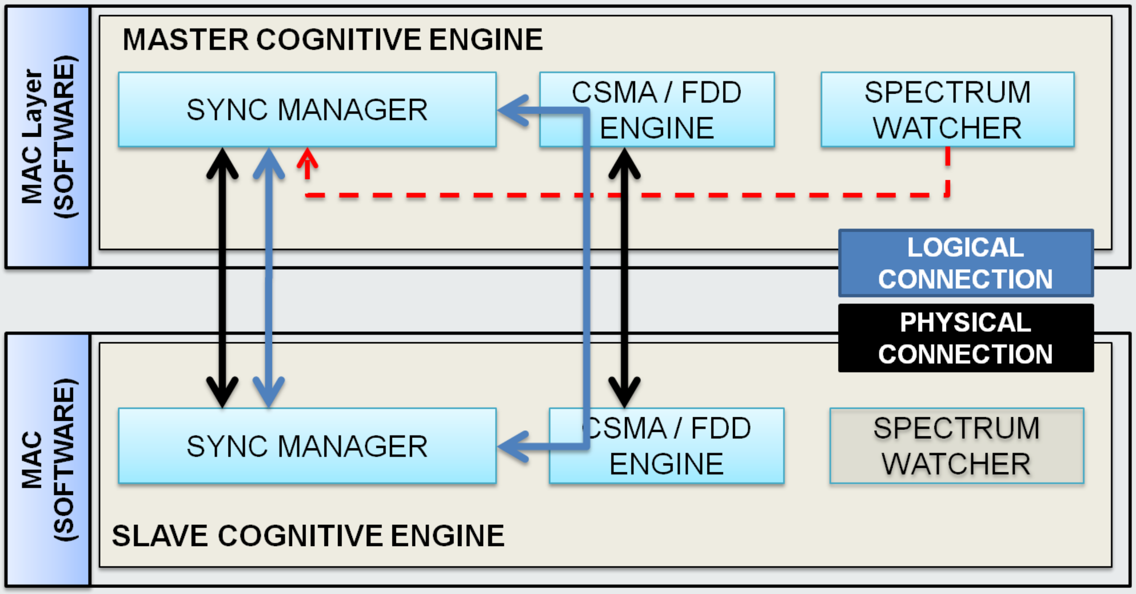
Proposed Solution

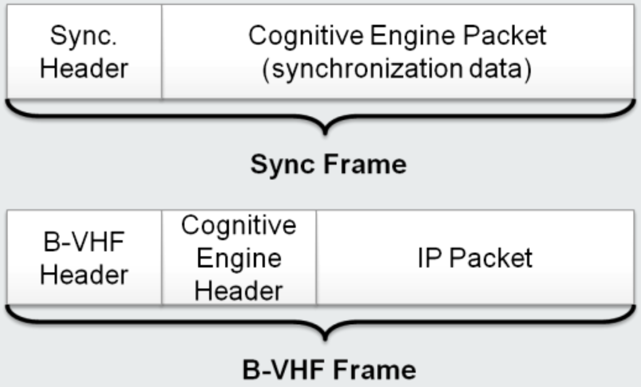
- Network Synchronization



Proposed Solution

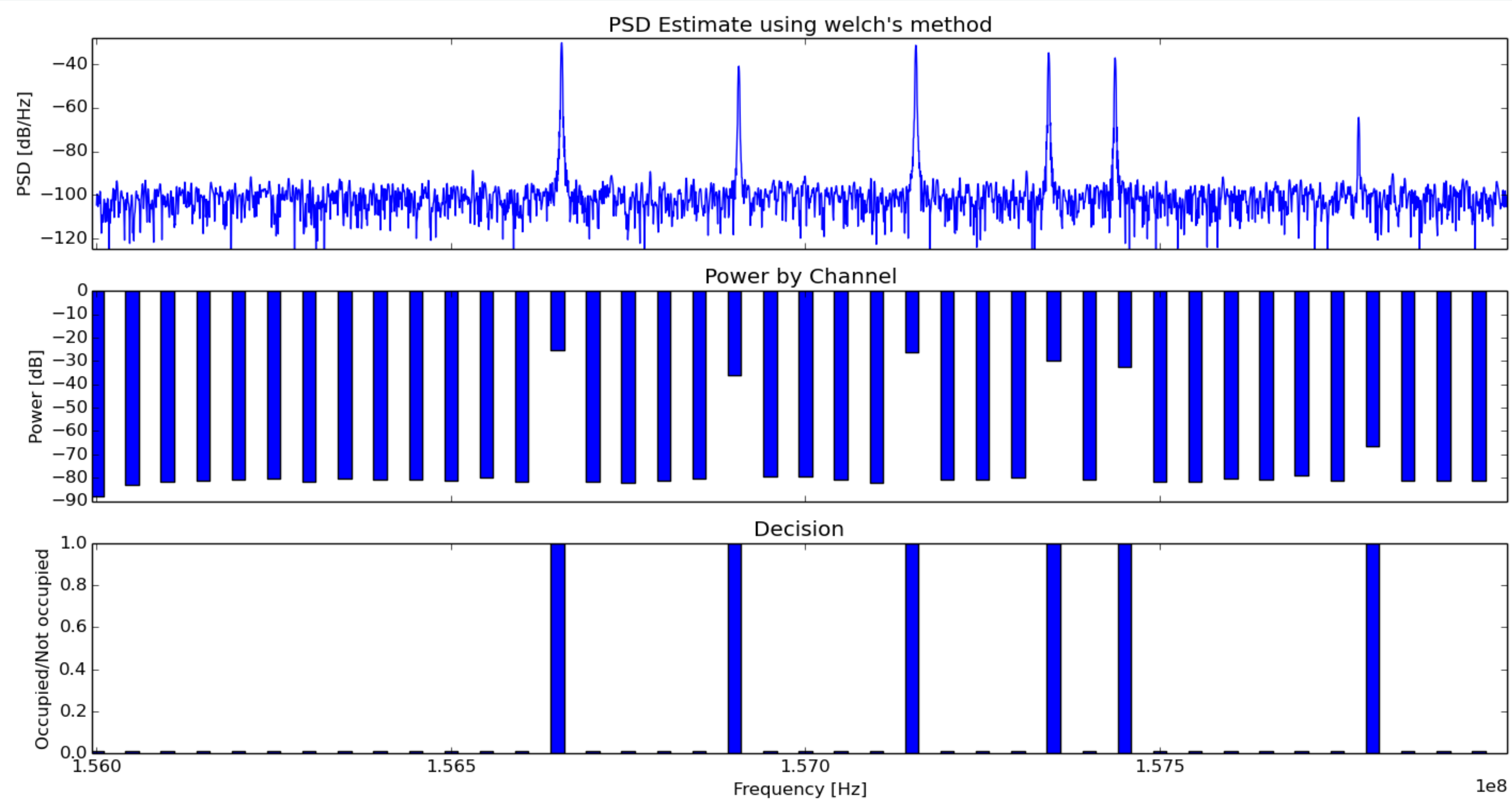
- Cognitive Engine and Network Synchronization





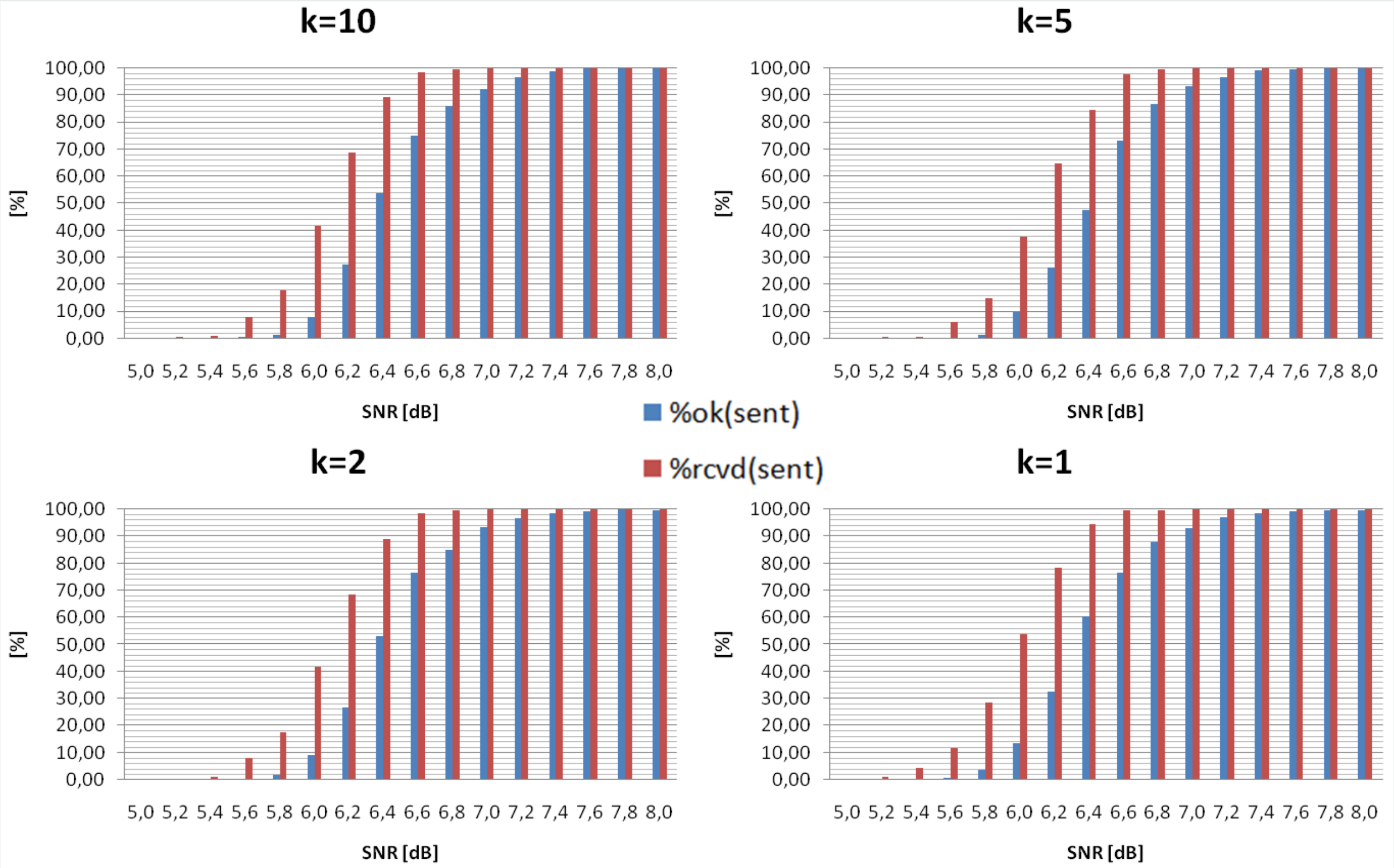
Tests And Results

- Spectrum Sensing - Results



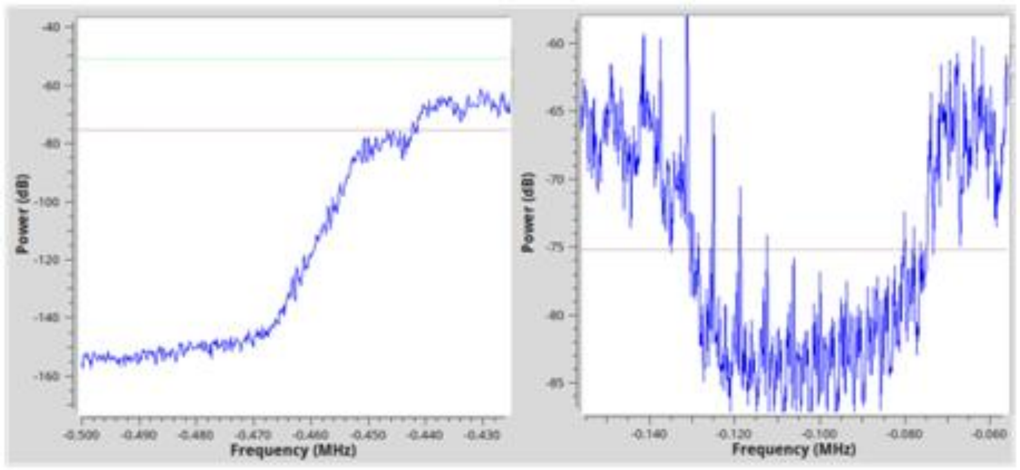
Tests And Results

- Transceiver Analysis – Simulation Results (k – Rice Factor)



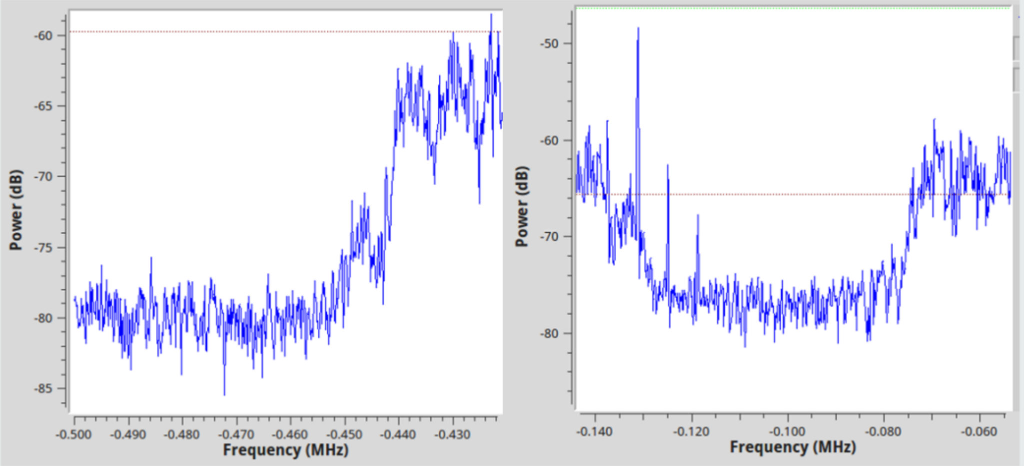
Tests And Results

- Transceiver Analysis – OOB and NC Radiation



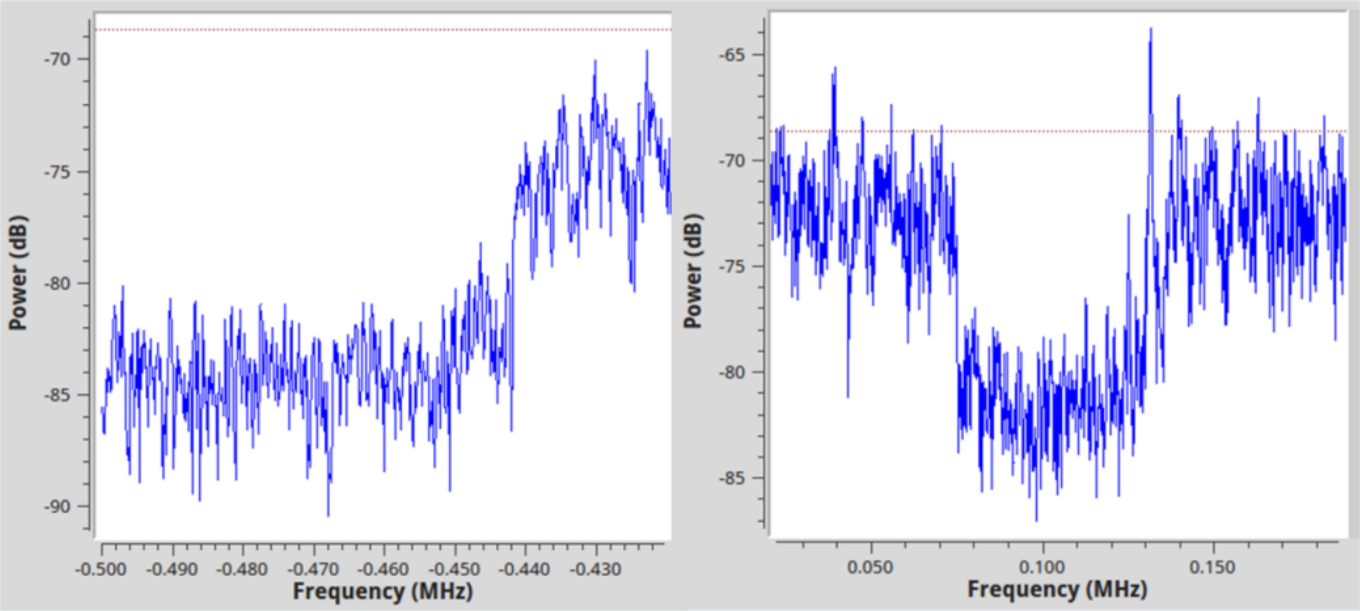
Transmitted

Received
w/ AWGN
(simulation)



Tests And Results

- Transceiver Analysis – OOB and NC Radiation

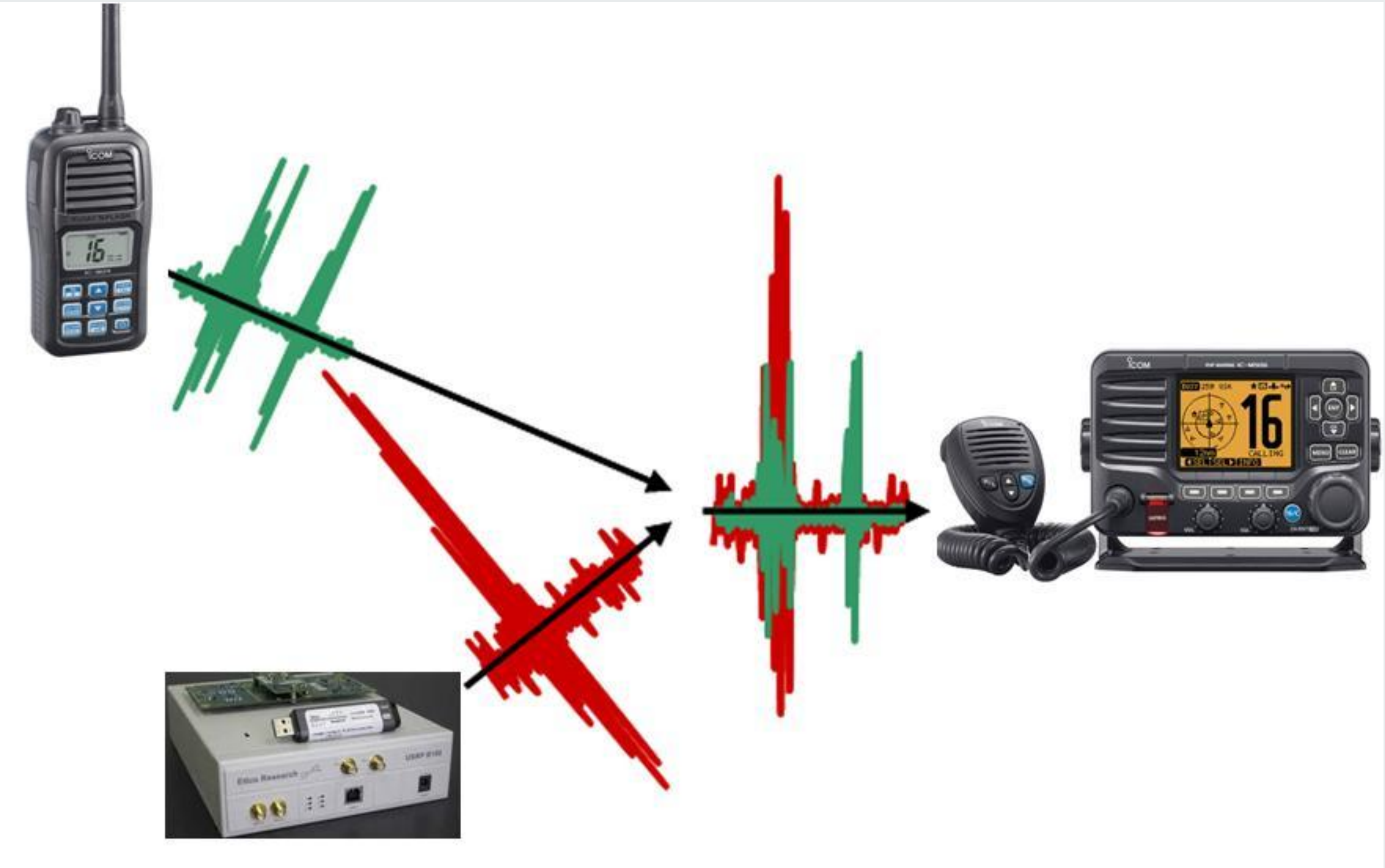


Received by the USRP

(over the air)

Tests And Results

- Subjective Coexistence Analysis



Tests And Results

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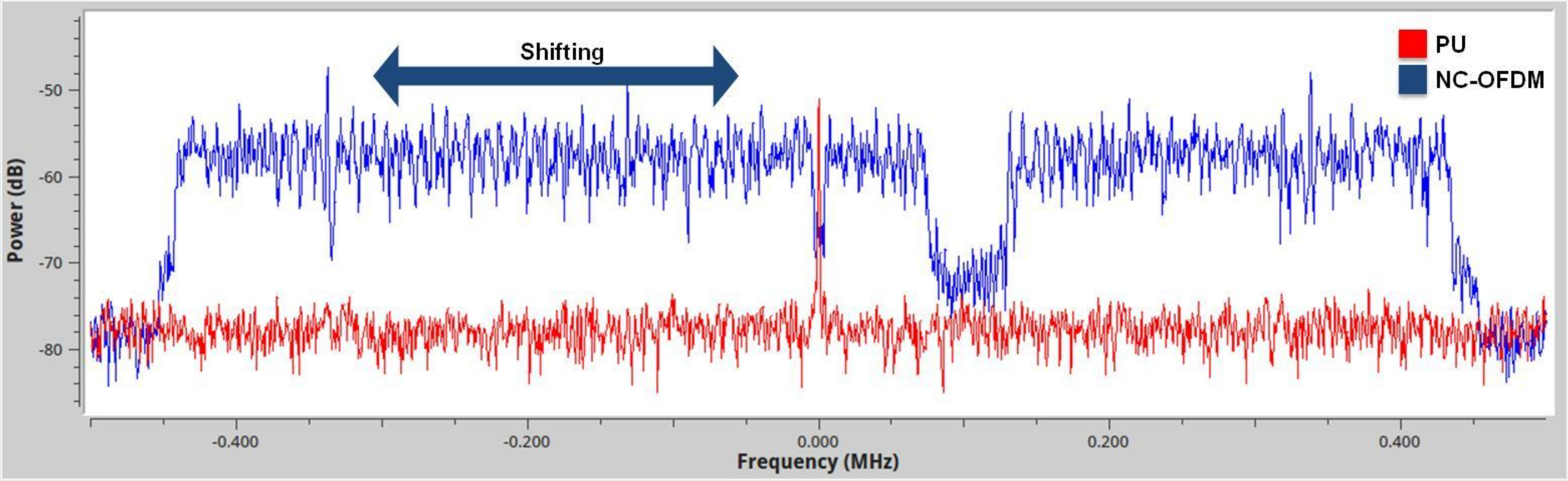
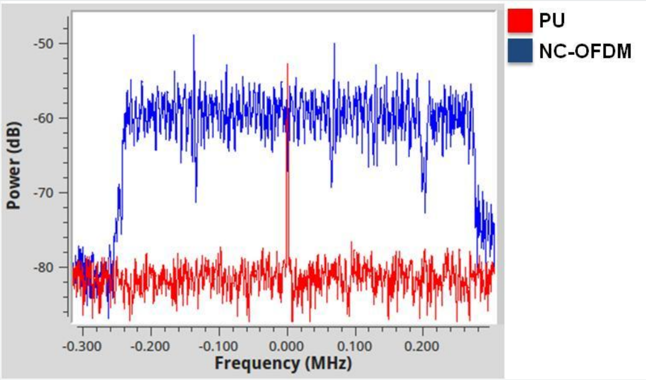


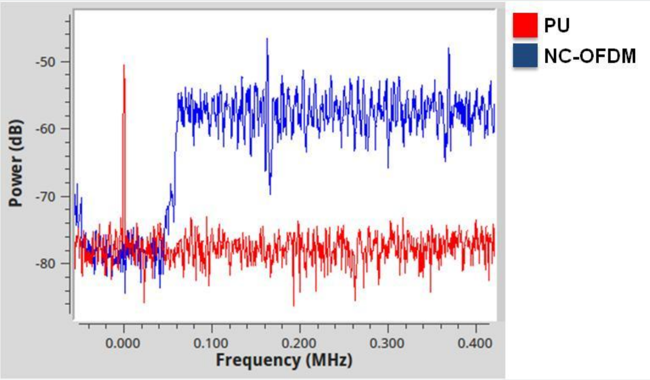
Tests And Results

- Subjective Coexistence Analysis

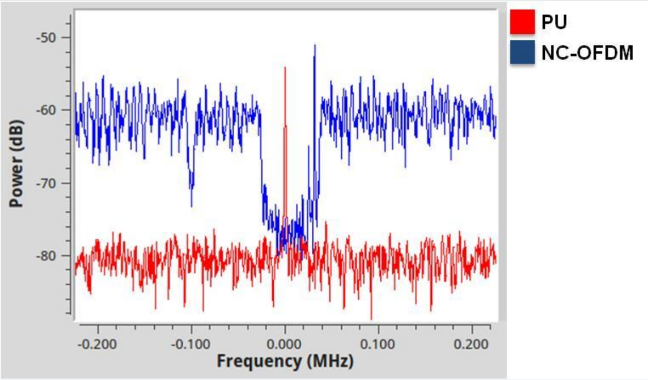
In Band



OOB



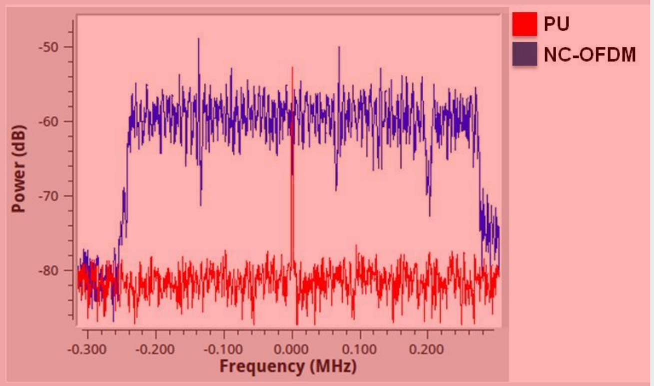
NC



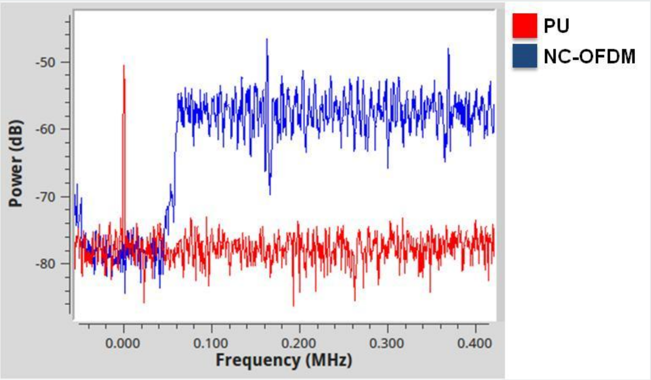
Tests And Results

- Subjective Coexistence Analysis

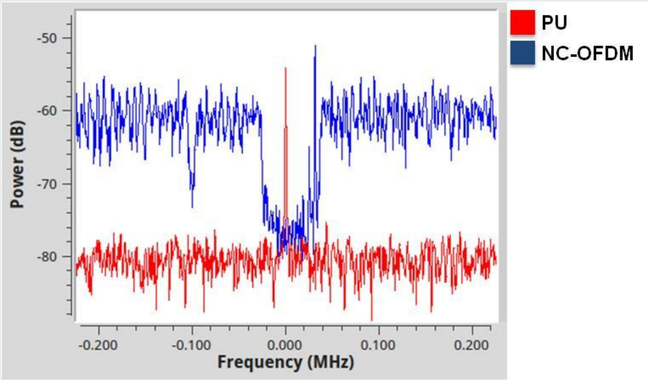
In Band



OOB



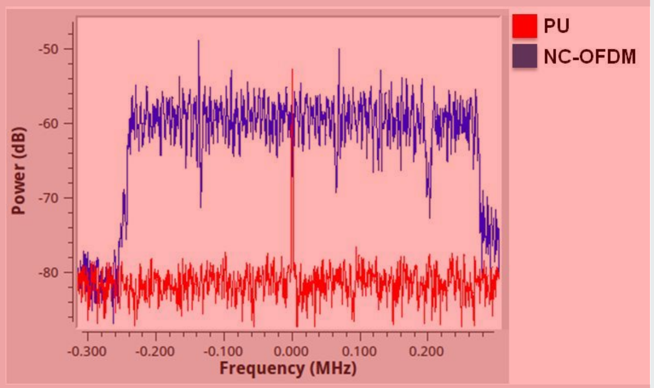
NC



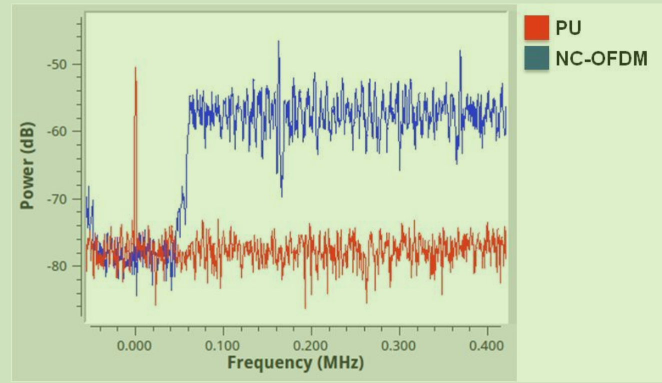
Tests And Results

- Subjective Coexistence Analysis

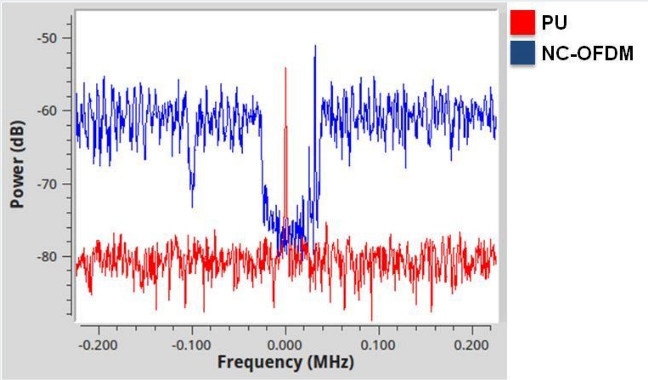
In Band



OOB



NC



Tests And Results

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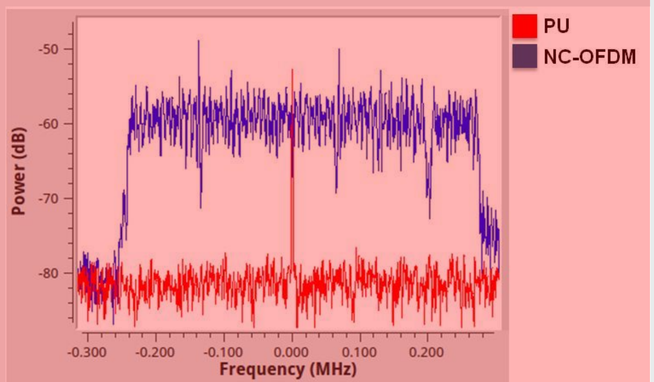
In Band



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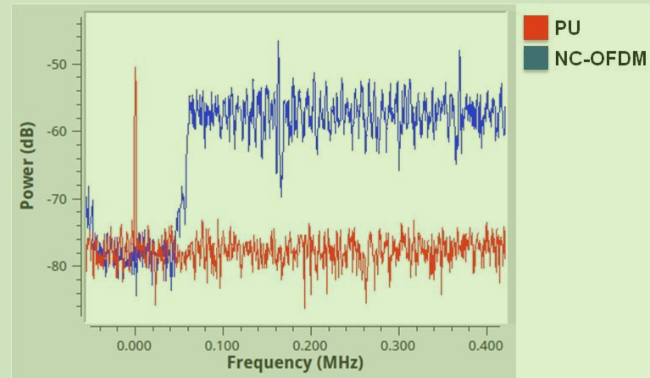
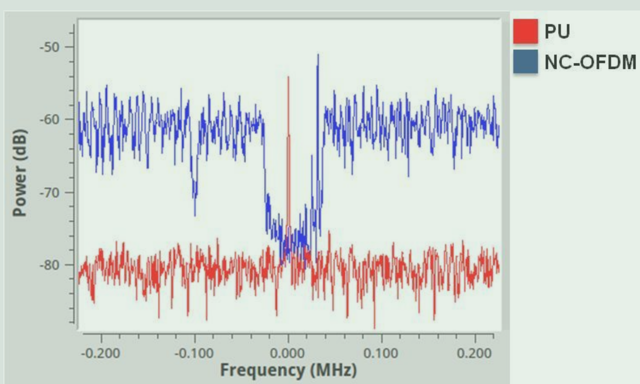
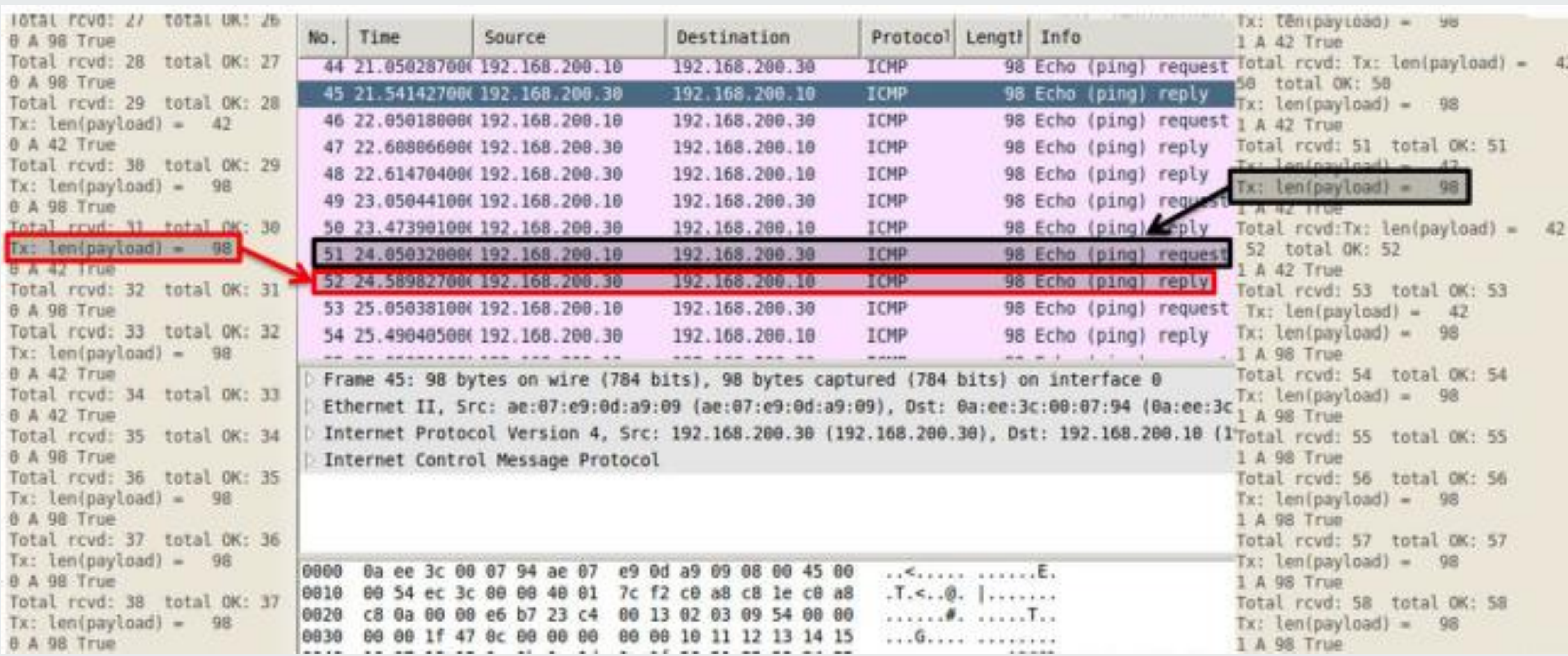


NC



Tests And Results

- Tunneling IP Data – Packet Analysis



Conclusions

- Prototype, fully functional broadband cognitive radio system;
- Innovative aspects concerning cognitive radio implementations;
- Results demonstrate the ability to detect multiple primary users
- Acceptable behavior for a digital communication system in terms of packet performance and radiation profile;
- Regulatory and coexistence issues;
- Transport of IP data.

Future Work

- Network and Radio Architecture;
- Transceiver and Sensing Techniques
- Network Synchronization;
- Coexistence Analysis and Evaluation.

Thank you for your attention!

Q&A

Marinha

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