Blind Standard Recognition Sensor Validation with Data from Measurement Campaign

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Outline

- Introduction
- Measurement setup
- Spectrum occupancy results
- Blind standard recognition sensor
- Conclusions

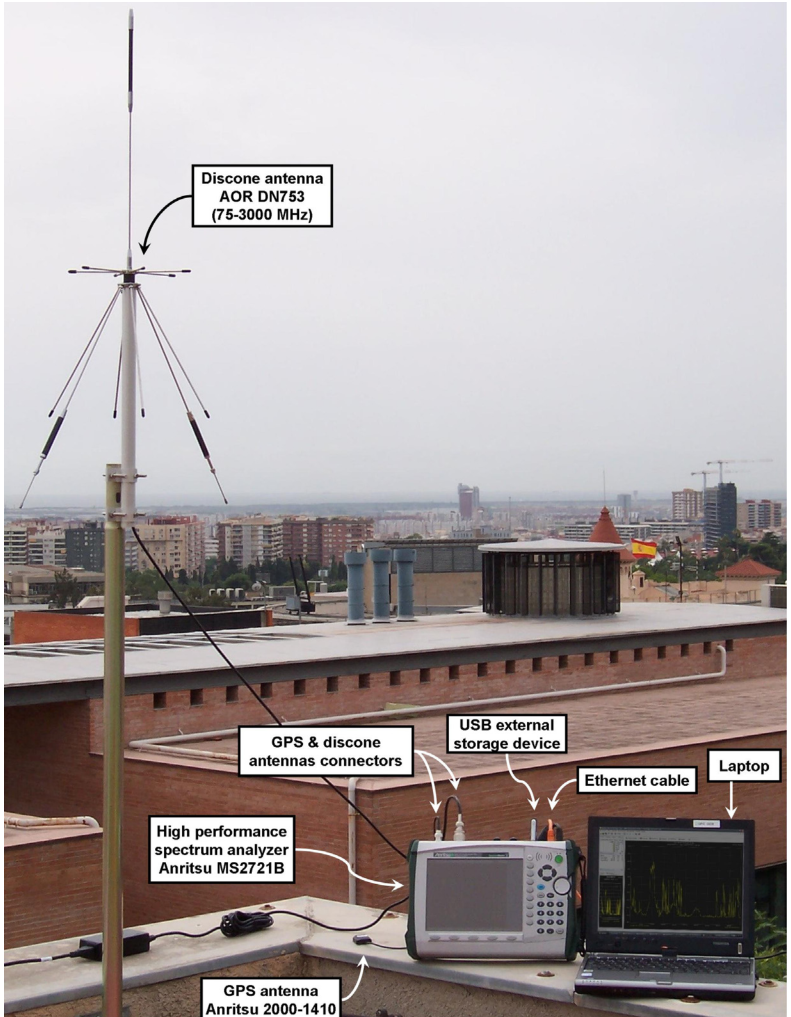
Introduction

- Dynamic Spectrum Access (DSA) / Cognitive Radio (CR):
  - Promising solution to the conflicts between:
    - Spectrum demand growth.
    - Spectrum underutilisation.
- Basic underlying idea:
  - Opportunistic and non-interfering “secondary” access to temporarily unoccupied “primary” licensed bands.
- Main premise: Spectrum is underutilized.
  - Necessary to determine the degree to which allocated bands are used.
  - Previous spectrum campaigns, but mostly in the USA.
  - Spectrum use in Europe is a rather unexplored issue. Only a few studies:
    - Dublin, Ireland, 2007 (Shared Spectrum Company).
    - Aachen, Germany, 2007 (RWTH Aachen University).
    - Locations in Germany during FIFA world cup, 2006 (University of Karlsruhe).

Introduction

- Measurement of real network activities:
  - Can provide valuable insights into current spectrum use.
  - Important step towards realistic understanding of dynamic spectrum use.
  - Useful for policy makers to define adequate DSA policies.
  - Useful for the research community to *identify suitable bands for DSA/CR*.
  - *Evaluation and validation of novel techniques*:
    - *Blind standard recognition sensor (BSRS)*.
      - Sensor embedded in a CR equipment to identify wireless standards without the need to connect to any network.
- This presentation reports the joint UPC-Supélec work in these areas.

Measurement setup

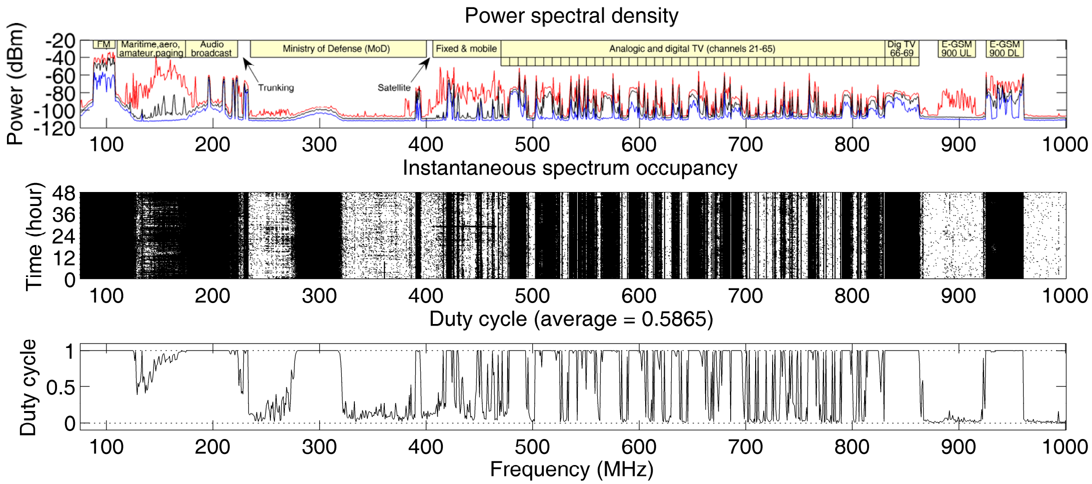


- Discone antenna (75 – 3000 MHz).
  - AOR DN-753.
  - Vertical polarization.
  - Omni-directional horizontal plane.
- High performance spectrum analyser.
  - Anritsu MS2721B.
- Controlling laptop.
- Location in building roof with LOS to:
  - TV and FM broadcast stations.
  - Cellular mobile comms base stations.
  - Military headquarter.
  - Aeronautical transmitters (airport).
  - Maritime transmitters (harbour).
  - Etc.

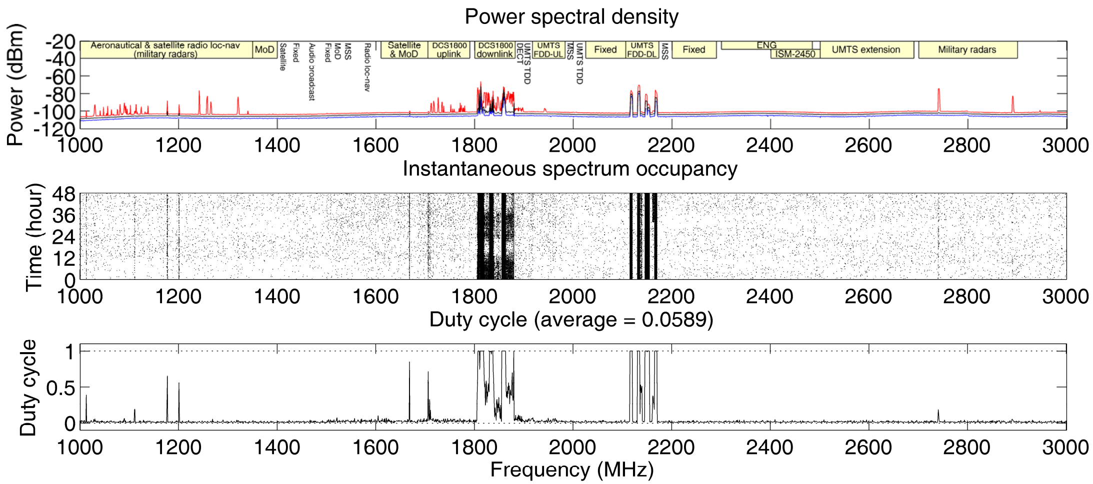
Measurement setup

Parameter	Value
Center frequency	Block 1: 250 MHz Block 4: 1750 MHz Block 2: 750 MHz Block 5: 2250 MHz Block 3: 1250 MHz Block 6: 2750 MHz
Frequency span	**6 blocks of 500 MHz**
Resolution/video bandwidth (RBW/VBW)	10 kHz / 10 kHz
Sweep time	Automatically selected
Reference level	– 20 dBm
Scale	10 dB/div
Detection type	RMS detector
Measurement period	**48 hours**

Spectrum occupancy results



- Relatively high use below 1 GHz.

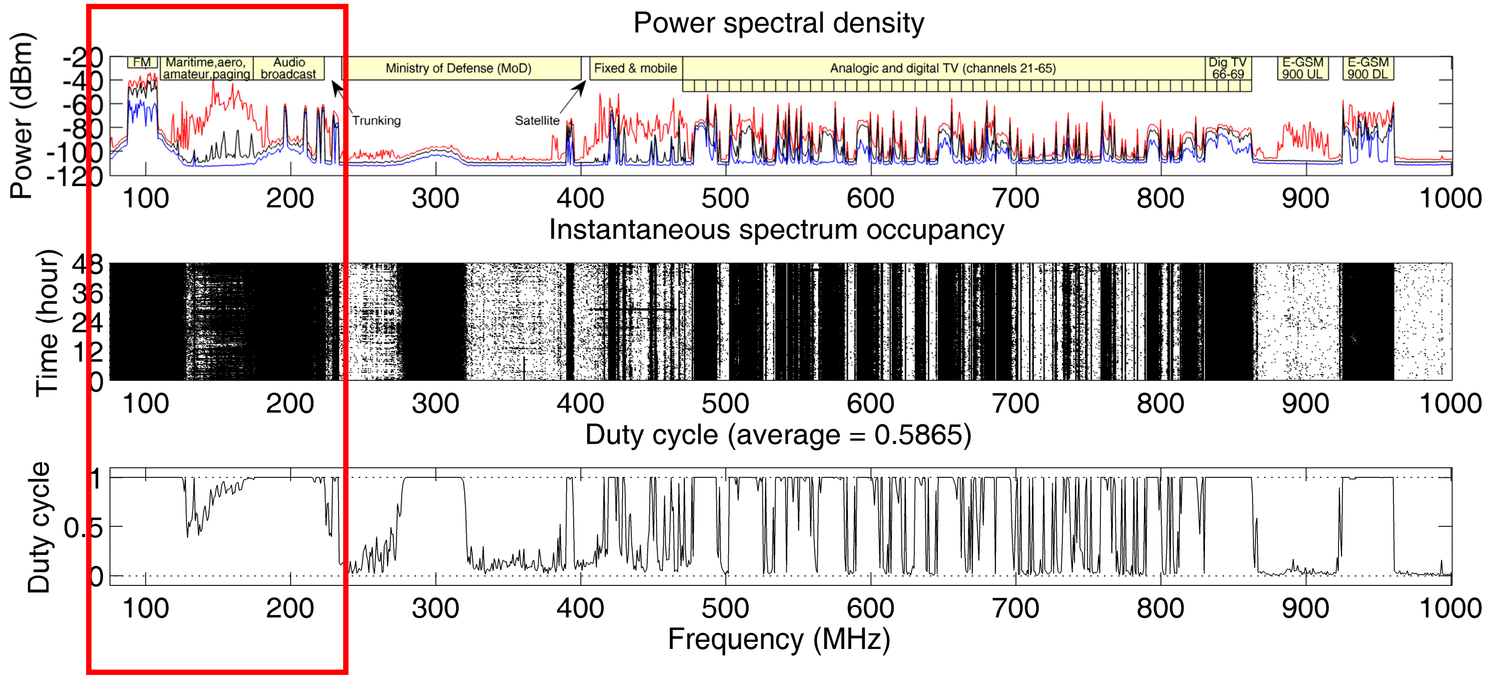


- Sparse use between 1 and 3 GHz, with some exceptions:
  - DCS 1800 system.
  - UMTS system.

Spectrum occupancy results

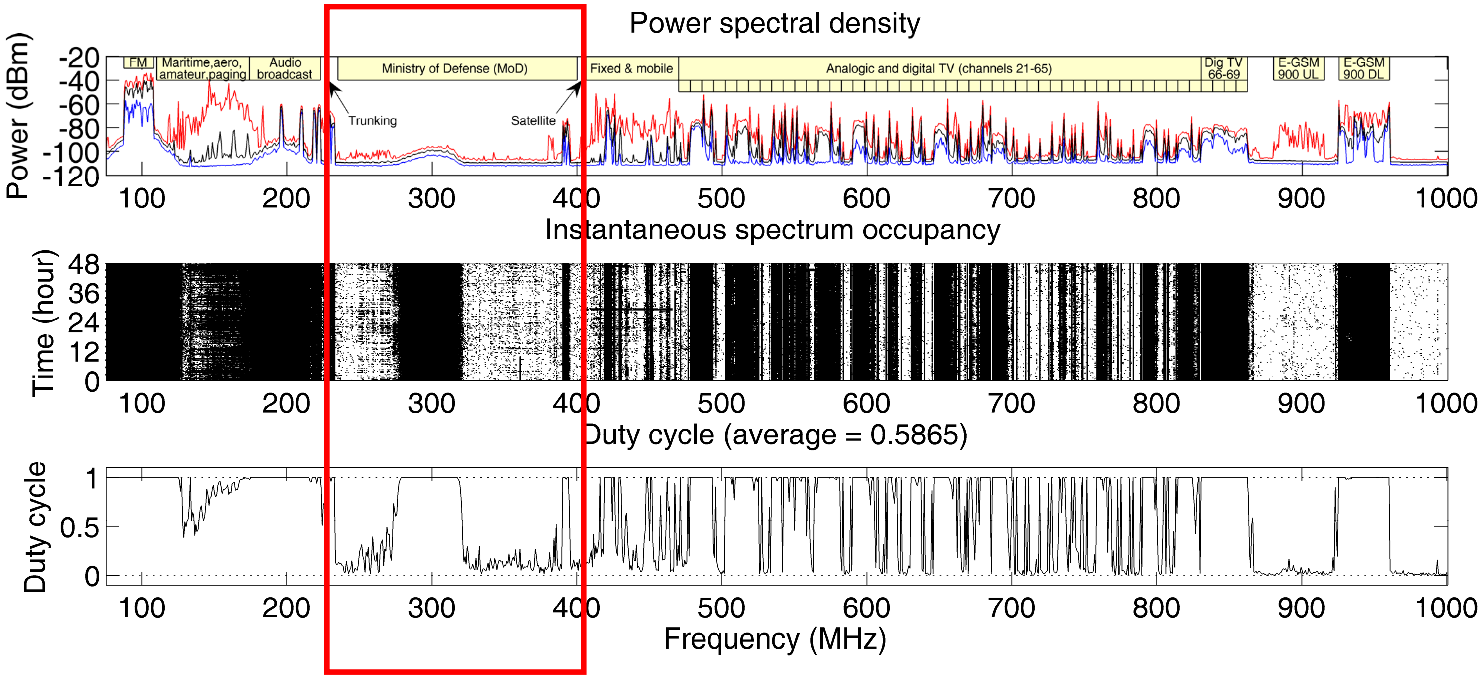
<table>
<tr><th>Block</th><th>Frequency range (MHz)</th><th colspan="3">Average duty cycle</th></tr>
<tr><td>1</td><td>75 – 500</td><td>60.98 %</td><td rowspan="2">58.65 %</td><td rowspan="6">22.57 %</td></tr>
<tr><td>2</td><td>500 – 1000</td><td>56.67 %</td></tr>
<tr><td>3</td><td>1000 – 1500</td><td>2.07 %</td><td rowspan="4">5.89 %</td></tr>
<tr><td>4</td><td>1500 – 2000</td><td>12.08 %</td></tr>
<tr><td>5</td><td>2000 – 2500</td><td>7.57 %</td></tr>
<tr><td>6</td><td>2500 – 3000</td><td>1.85 %</td></tr>
</table>

Spectrum occupancy results



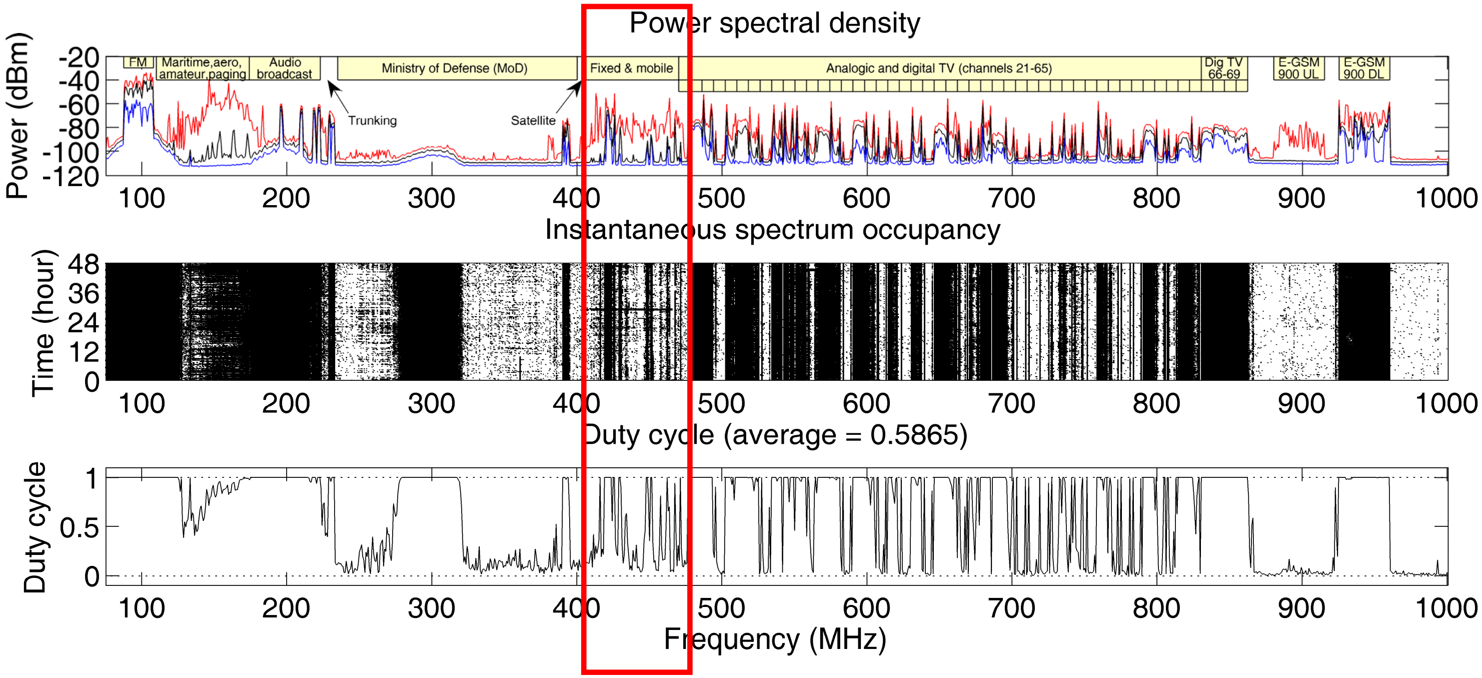
- Below 235 MHz: Duty cycles between 90% and 100%.
  - FM broadcasting (87.5-108 MHz).
  - Maritime and aeronautical radio navigation (108-174 MHz).
  - Audio broadcasting (174-223 MHz).
  - Private/Professional Mobile Radio (PMR) systems (223-235 MHz)

Spectrum occupancy results



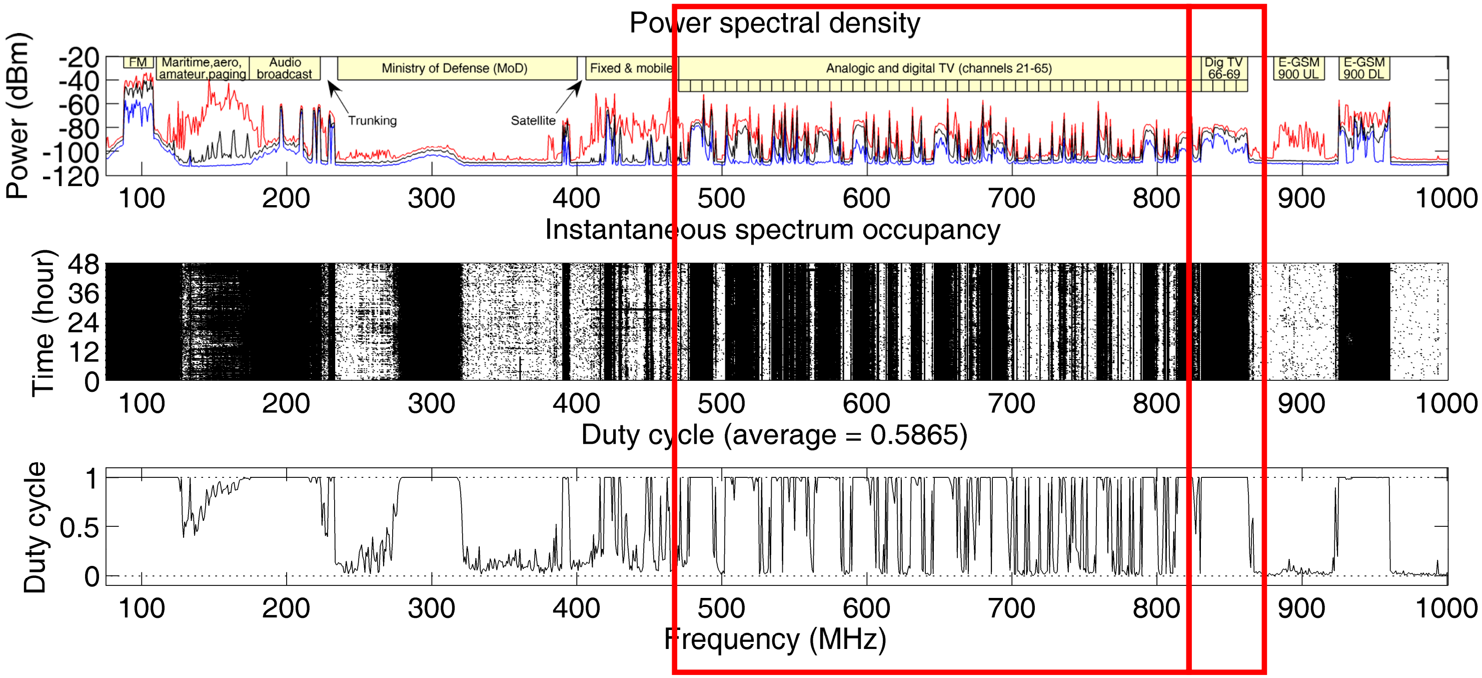
- 235 – 400 MHz:
  - Some potential opportunities / white spaces.
  - But exclusively reserved for government's security services and systems.

Spectrum occupancy results



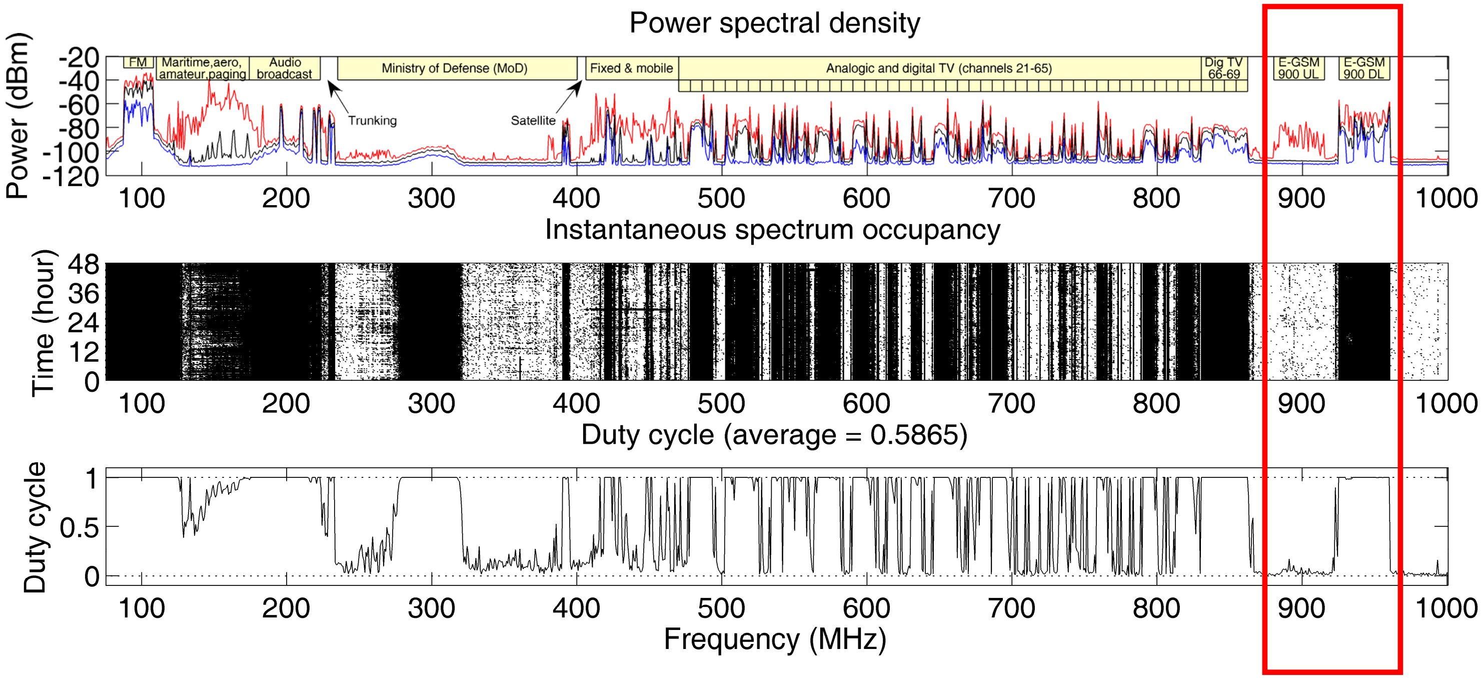
- 400 – 470 MHz:
  - Allocated to PMR/PAMR, SRD, amateur and paging.
  - Available white spaces, but narrower available free bandwidths.

Spectrum occupancy results



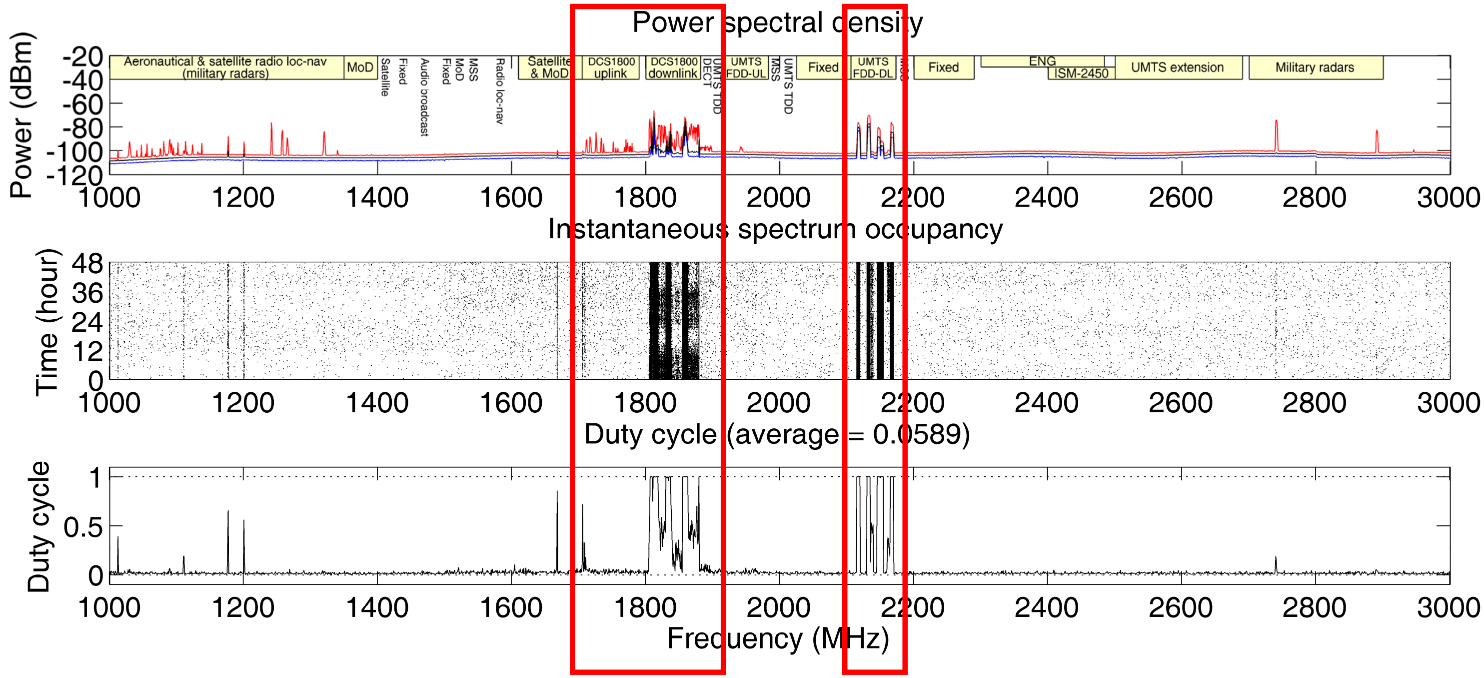
- 470 – 862 MHz:
  - 470 – 830 MHz: An/Dig TV → 66.58% of the band (~130 MHz) is usable.
  - 830 – 862 MHz: Dig TV → Intensive usage (~100%).

Spectrum occupancy results



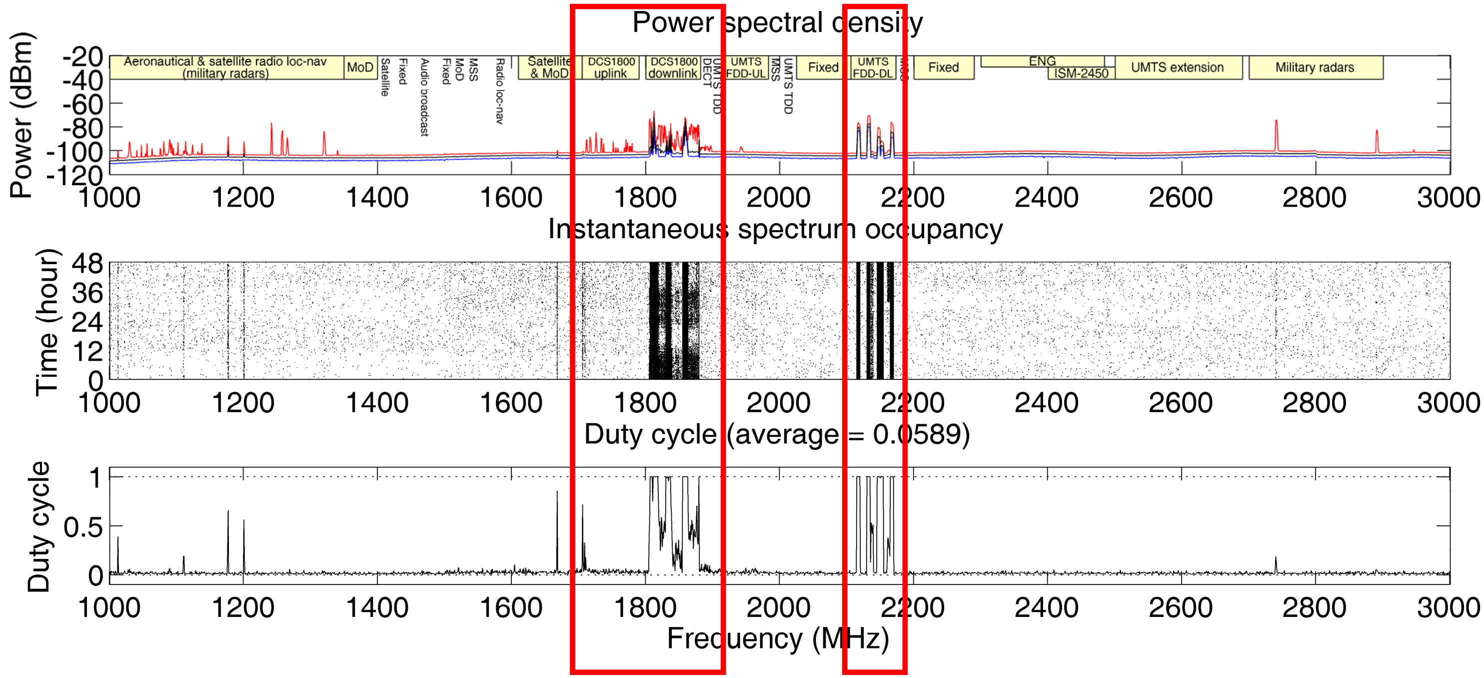
- 880 – 915 MHz / 925 – 960 MHz:
  - Allocated to E-GSM 900.
  - Unbalanced occupancy patterns: 4.03% in uplink, 96.20% in downlink.
  - Similar trends were observed in previous studies (e.g., Islam et al., CrownCom 2008).

Spectrum occupancy results



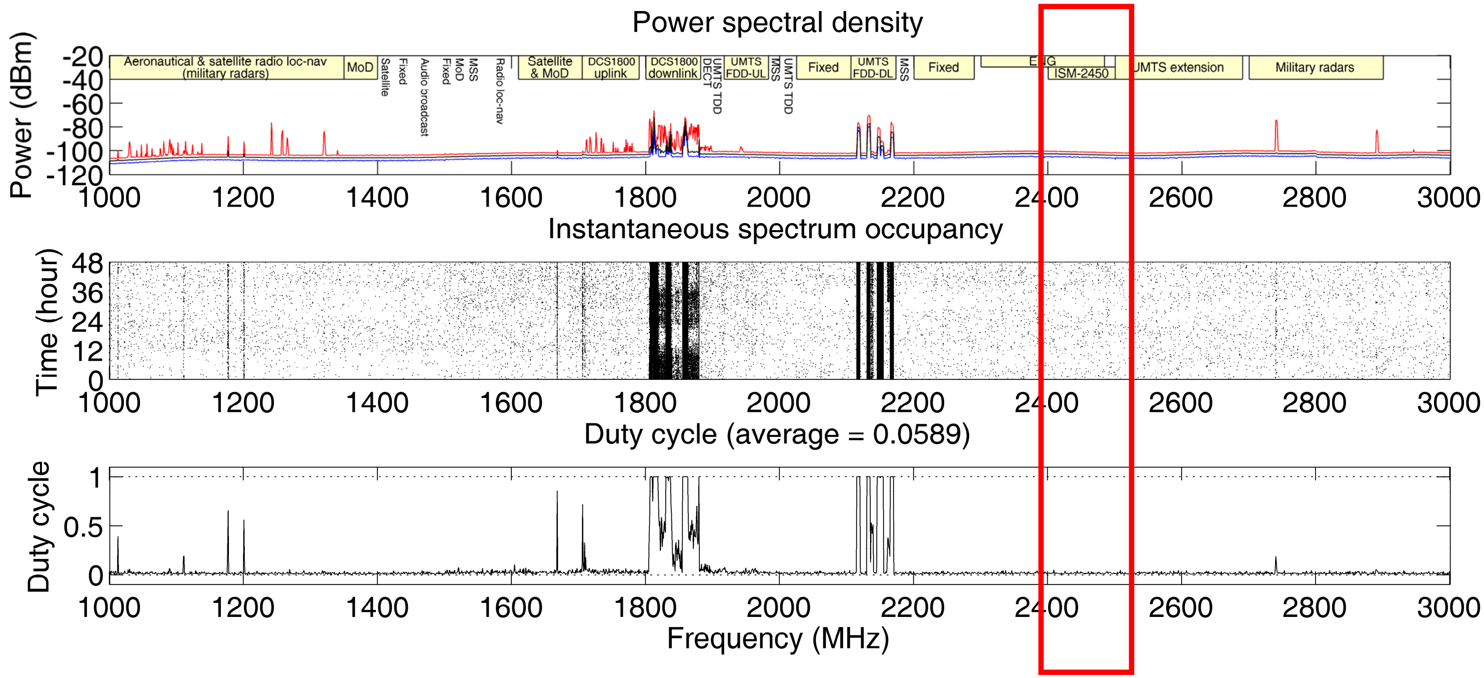
- Above 1 GHz:
  - The highest use is observed for mobile cellular communication systems:
    - Same unbalanced patterns:
      - DCS 1800: 3.52% uplink / 59.75% downlink.
      - UMTS: 2.86% uplink / 48.38% downlink.

Spectrum occupancy results



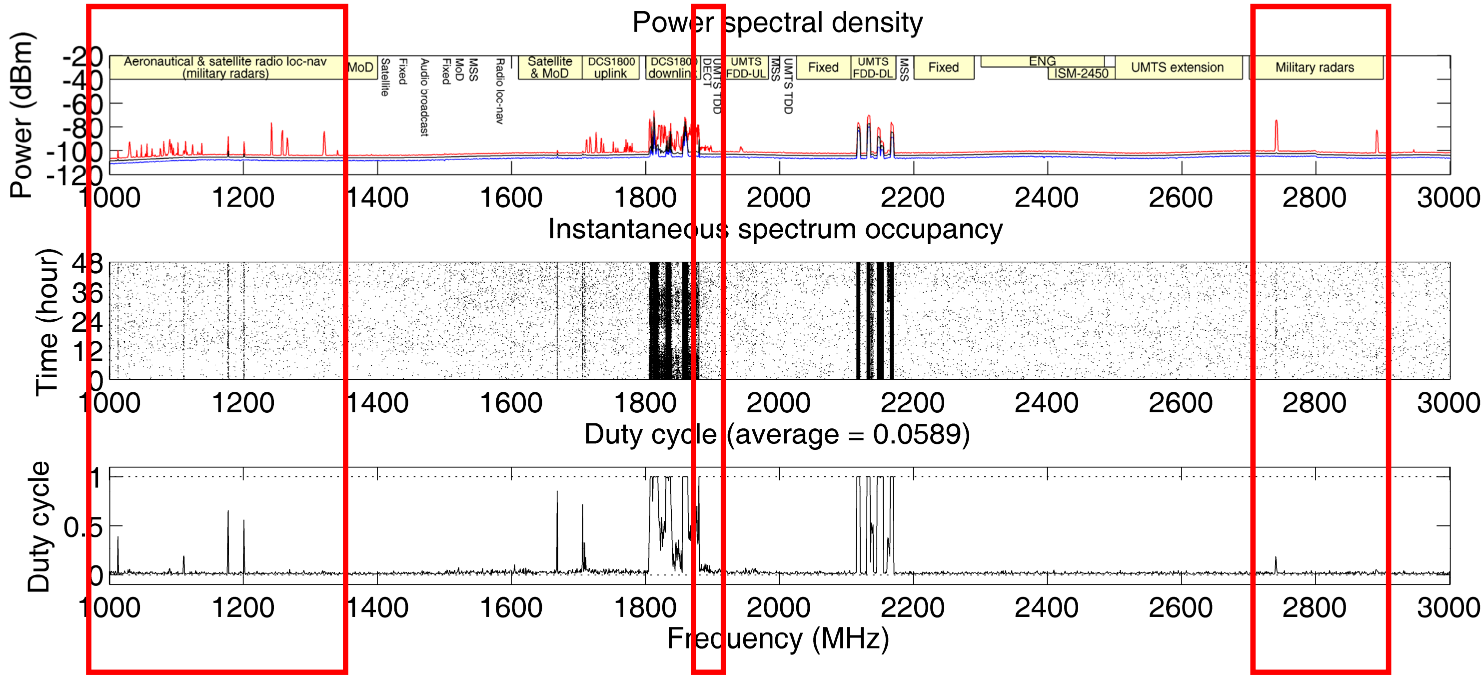
- Above 1 GHz:
  - The highest use is observed for mobile cellular communication systems:
    - These bands also provide some opportunities for secondary use:
      - DCS 1800: Temporal patterns day/night.
      - UMTS: Some “unoccupied” 5-MHz channels. UMTS TDD / extension → free.

Spectrum occupancy results



- Above 1 GHz:
  - The ISM-2450 band appears to be unused:
    - Our measurement location is a building roof!
    - Severe indoor-to-outdoor attenuation by walls.

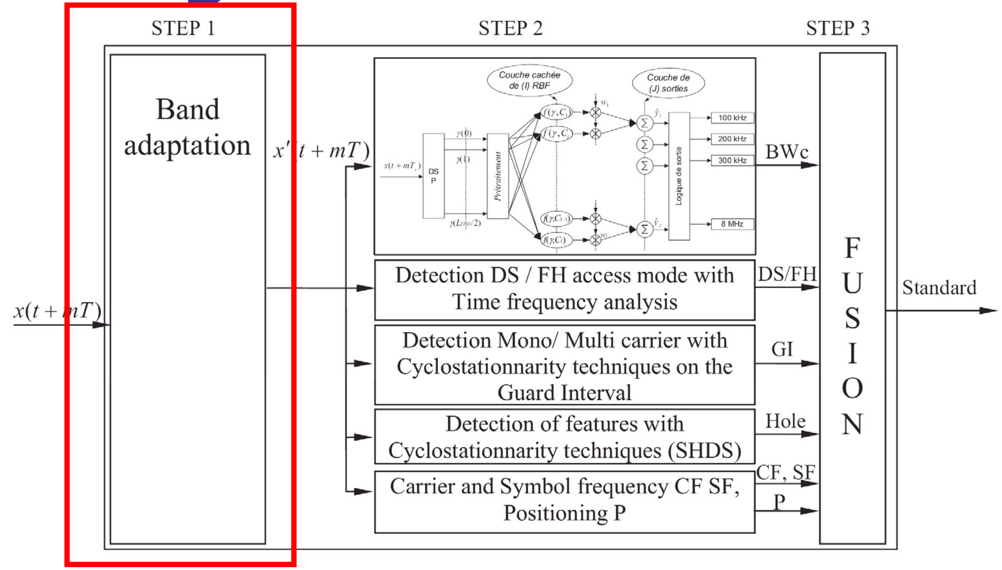
Spectrum occupancy results



- Above 1 GHz:
  - The rest of spectrum seems not to be used at all, with some exceptions:
    - 960 – 1350 MHz: Aeronautical radio navigation.
    - 1880 – 1900 MHz: DECT cordless phones.
    - 2700 – 2900 MHz: Military radars.

Blind standard recognition sensor

- Sensor embedded in a CR equipment to identify wireless standards without the need to connect to any network.
- The received signal is analyzed in 3 steps:



- STEP 1: Reduction of the bandwidth to be analyzed to non-zero regions.
  - Ratio between global and smallest recognizable bandwidths may be very high.
  - Solution: Iterative adaptation of the bandwidth to be analyzed:
    - Conventional periodogram to analyse signal energy.
    - Filtering.
    - Decimation around the detected peak of energy.

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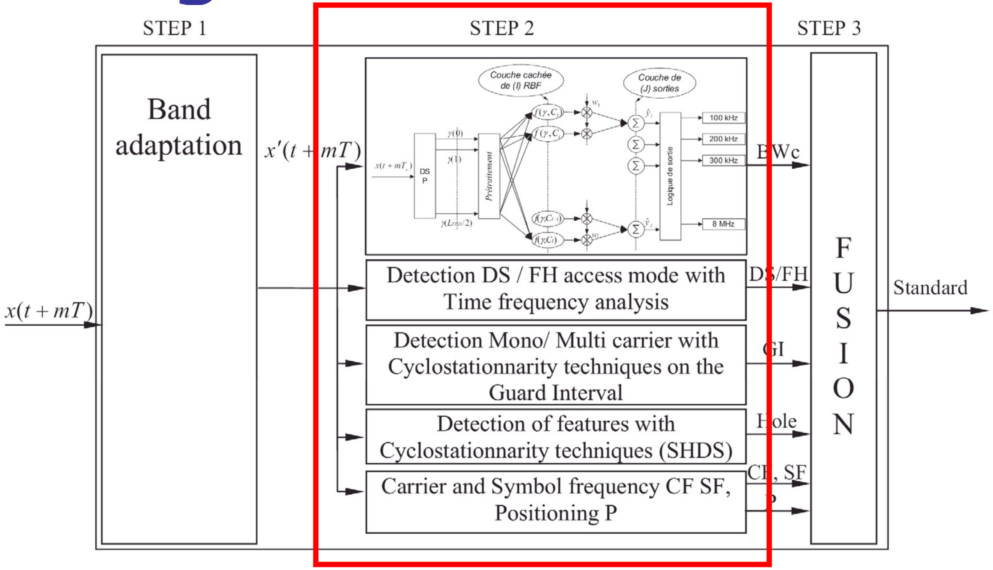

- STEP 2: Analysis of signal characteristics with sensors.
  - Bandwidth recognition sensor.
  - Single/multi-carrier detection sensor.
  - Frequency hopping / direct sequence detection sensor.

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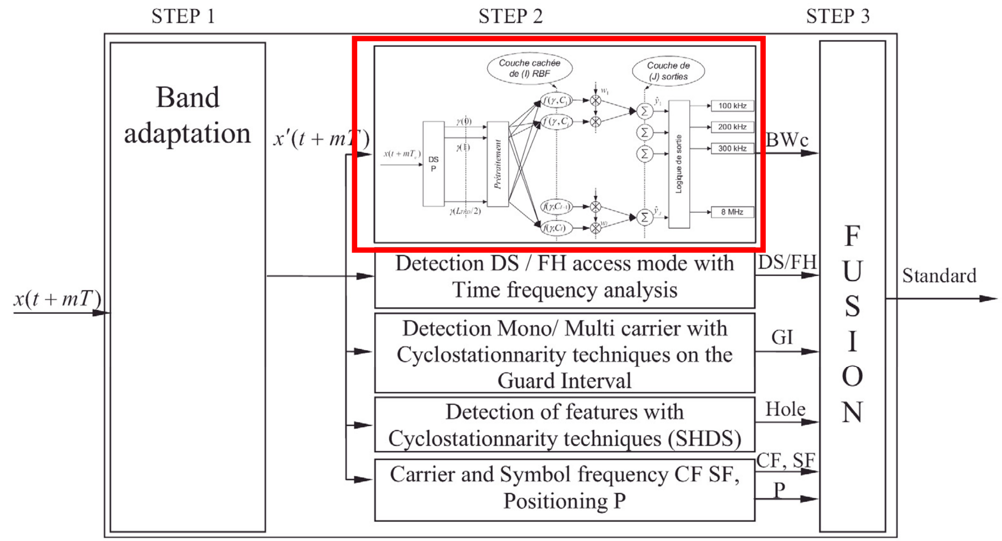

- STEP 2: Analysis of signal characteristics with sensors.
  - Bandwidth recognition sensor.
    - Bandwidth and spectral shape of the received signal is obtained.
    - Empirical spectrum shape is compared with a reference shape.
    - Radial Basis Functional Neural Network (RBF NN) identifies matching patterns.

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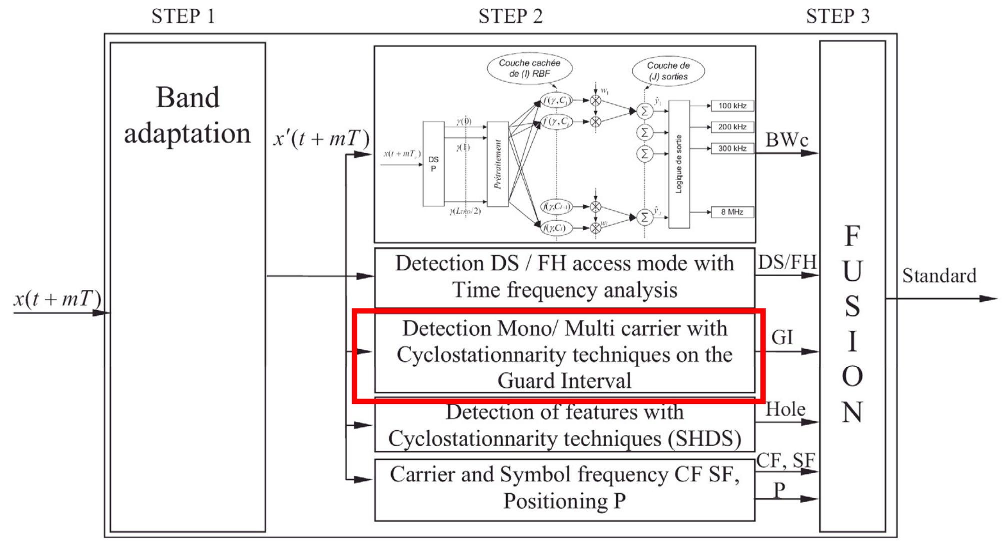

- STEP 2: Analysis of signal characteristics with sensors.
  - Single/multi-carrier detection sensor.
    - DVB-T/LMDS and DAB/DECT systems may induce confusion.
    - Distinction between both systems relies on the guard interval of multi-carrier systems.
    - Autocorrelation function is computed.
    - Cyclic frequency corresponding to the guard interval is derived.

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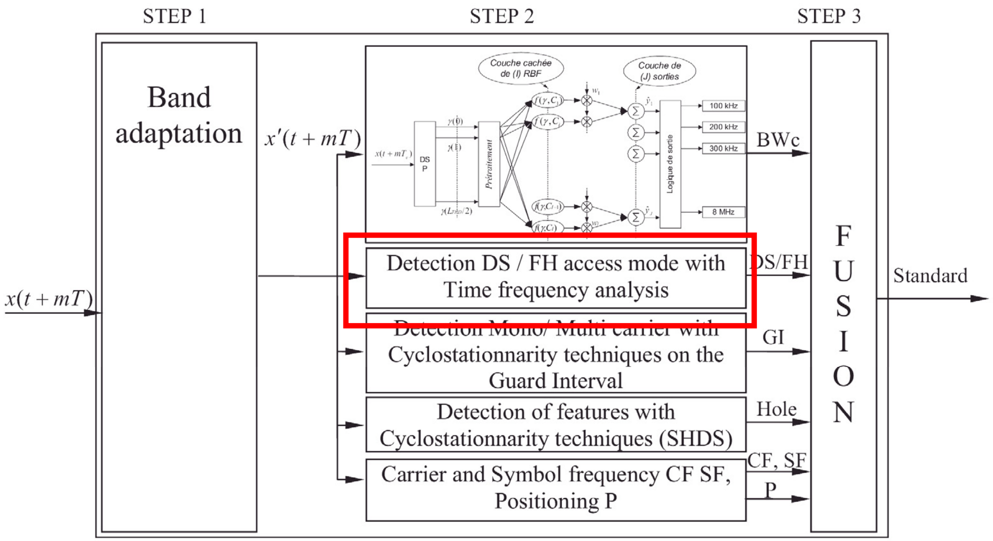

- STEP 2: Analysis of signal characteristics with sensors.
  - Frequency hopping / direct sequence detection sensor.
    - The previous analysis with 2 sensors is not enough.
    - Difficulties in discriminating between Bluetooth and IEEE 802.11b.
    - The use of the Wigner-Ville Transform (WVT) was proposed to address this problem.
    - This approach is able to distinguish between Bluetooth and IEEE 802.11b.

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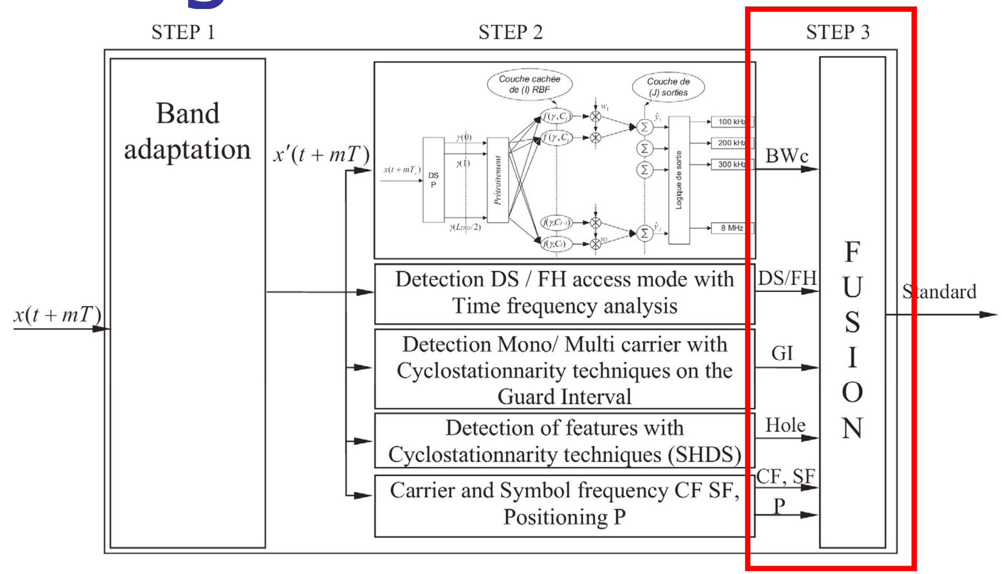

- STEP 3: Fusion of information from sensors and decision.
  - After STEP 2, three indicators are obtained.
  - Simple way to fuse information:
    - Apply some logical rules on these indicators.
    - Could be improved with neural networks, like Multilayer Perceptron.

Conclusions

- Joint work UPC-Supélec:
  - Broadband spectrum measurement campaign.
    - Future work:
      - Extension to wider frequency ranges (75 – 7075 MHz).
      - More sophisticated and accurate measurement equipment.
      - Different environments: urban, sub-urban and rural.
      - Different locations: in outdoor and indoor environments.
  - Blind standard recognition sensor.
    - Future work:
      - Evaluation and validation of BSRS with empirical data.
      - Both research lines are expected to converge in the future.

Thank you for your attention

Any questions?