DISTRIBUTED SPECTRUM SENSING USING LOW COST HARDWARE

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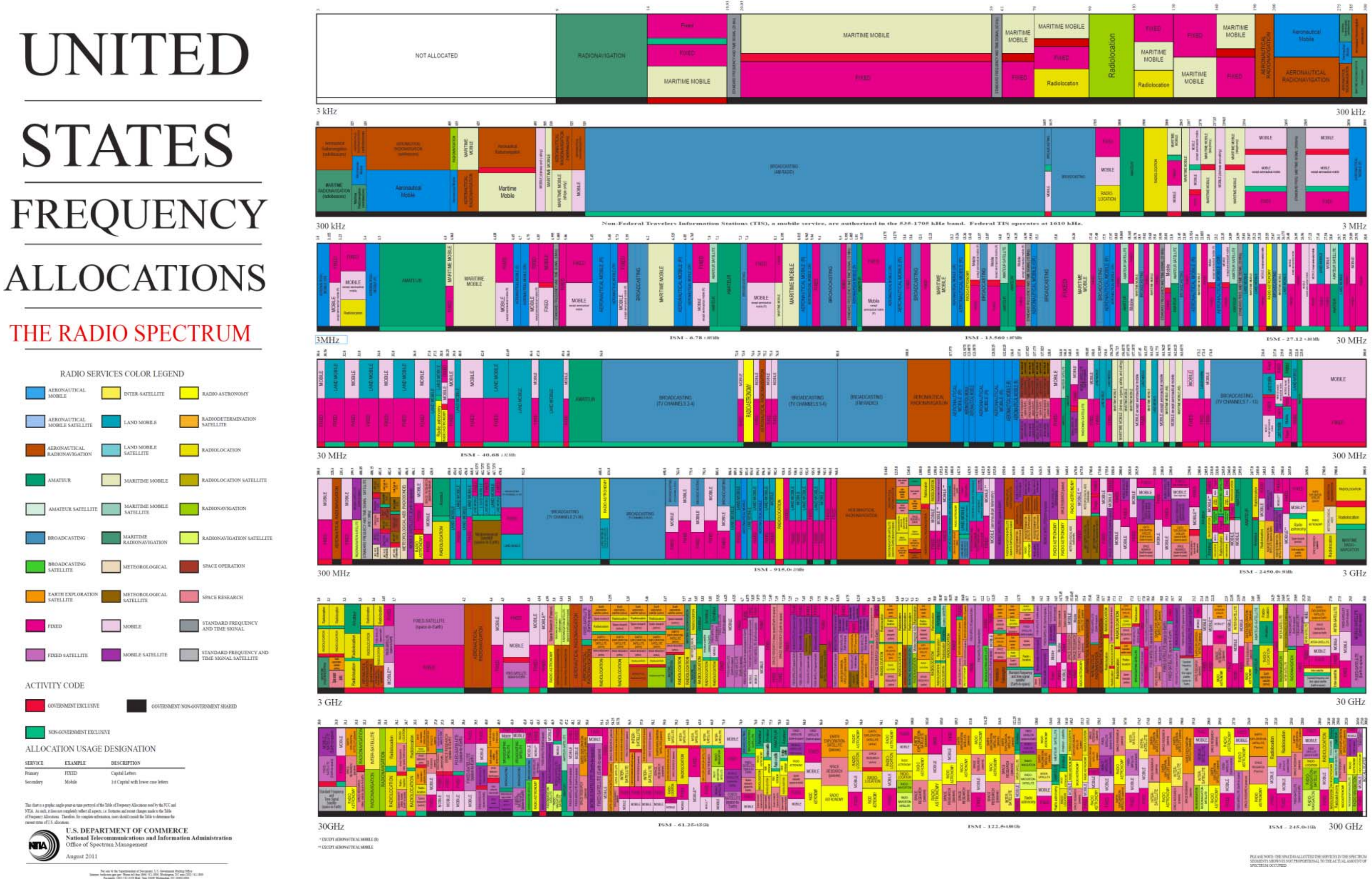
Background – spectrum sensing



Cognitive radio

- Use unused (but possible allocated) spectrum for communication
  - We need information on the actual spectrum occupation
    - Spectrum databases
      - A way to share and reserve spectrum usage based on geolocation
    - Spectrum sensing
      - Find available spectrum by sensing
      - Possibility to send feedback to database

Spectrum sensing

Spectrum sensing,
binary hypothesis

$$y(t) = \begin{cases} n(t), & H_0 \\ s(t) + n(t), & H_1 \end{cases}$$

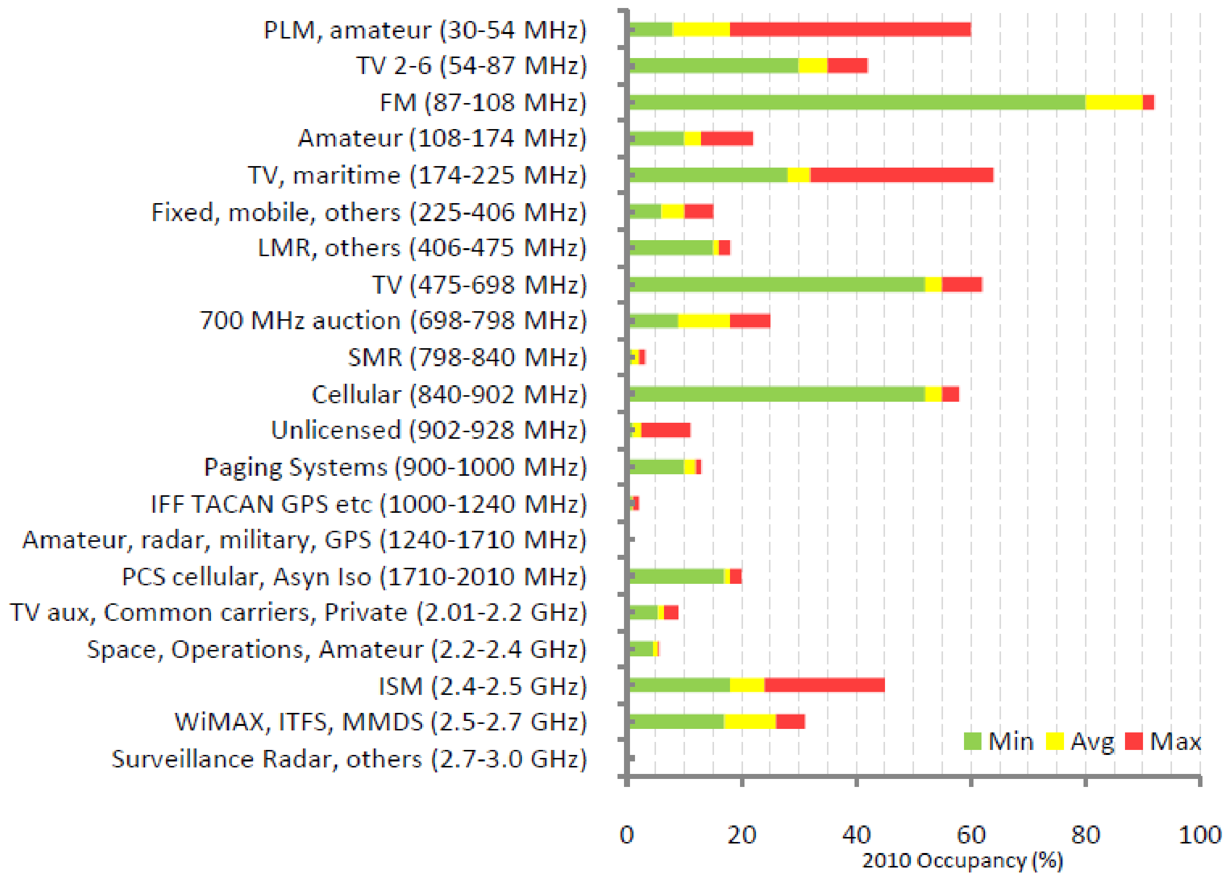
Spectrum sensing,
Detection / false detection

$$P_D = \mathbf{Pr}(Y > \lambda | H_1)$$

$$P_F = \mathbf{Pr}(Y > \lambda | H_0)$$

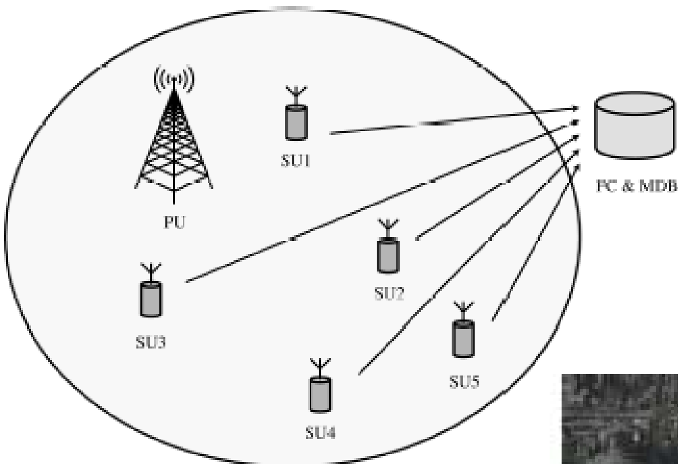
- General issues
  - do we have a priory information on signals?
  - narrowband / wideband detection

Real spectrum occupancy, Chicago 2010



Source: *Tanim M. Taher, Roger B. Bacchus, Kenneth J. Zdunek, Dennis A. Roberson. Long-term Spectral Occupancy Findings in Chicago. 2011 IEEE International Symposium on Dynamic Spectrum Access Networks*

Distributed sensing using low cost hardware



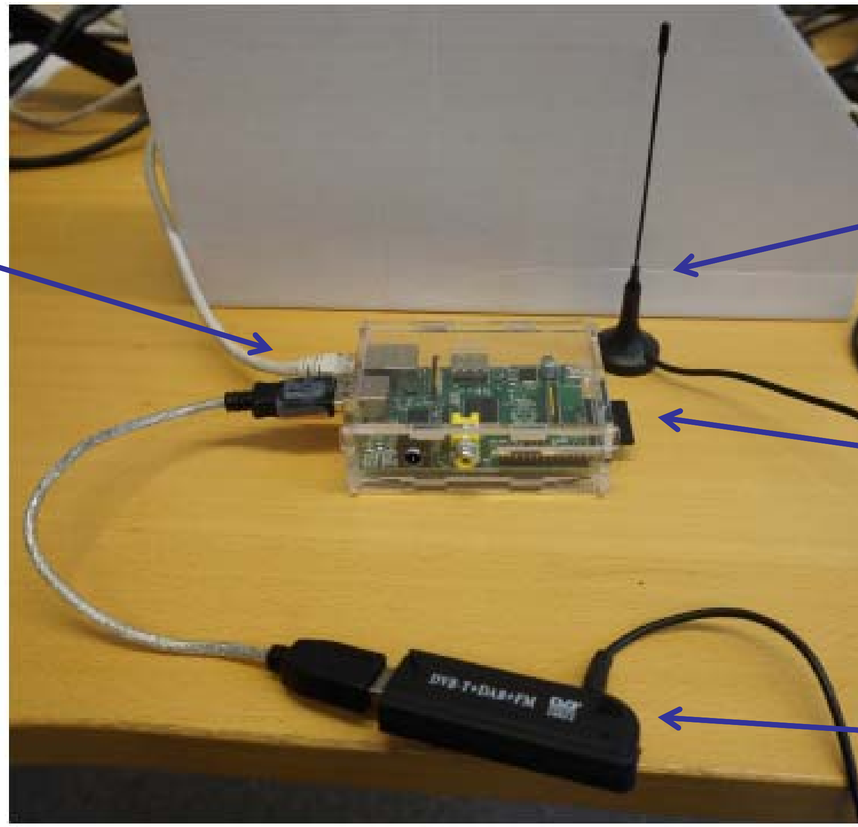
Research questions:

Can we achieve reliable spectrum sensing using distributed, low cost sensing equipment?
Can inferior hardware be replaced by software and redundancy?

Basic equipment list

Ethernet / IP
link to server

Antenna



RaspberryPi

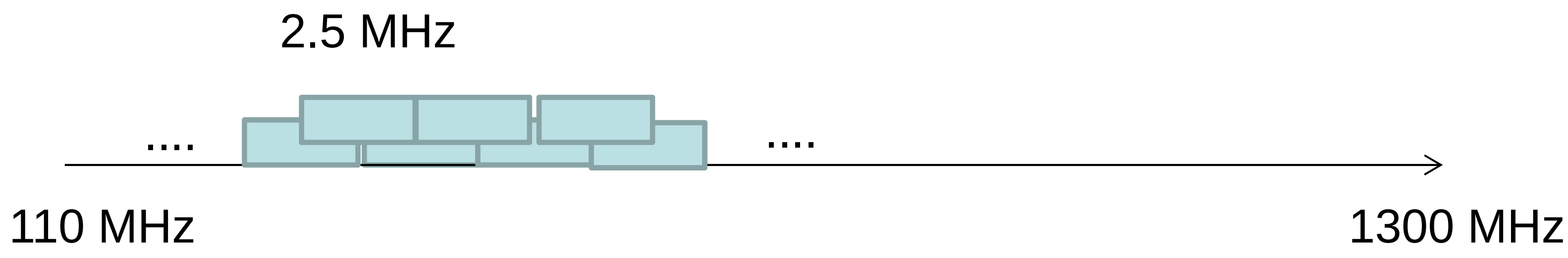
DVB-T Dongle

Technical details of used setup

Raspberry Pi / DVB-T dongle	
RPi CPU	700 MHz ARM11
RPi RAM	512 MB
RPi / Dongle communication	USB2.0
Communication to database	Ethernet / TCP/IP
Demodulator chip	Realtek RTL2832U
Tuner chip	Rafael Micro R820T
I/Q sample resolution	8 bit
Maxium sample rate over USB	2.5 MS/s
Frequency range	24-1766 MHz
Price (RPi / Dongle)	35 $ / 15 $

Basic spectrum sensing setup

- Using modified version of `rtl_power` software
- Bandwidth 2.5 MHz, effecting bandwidth 1.25 MHz
- Sweep time 70 s for total 1190 MHz → approx. 70 ms / frequency (including tuner
- FFT analysis of energy with a Resolution BandWidth (RBW) of 39.0625 MHz



Antenna configurations

Node	Antenna	Placement
RPi 1	Wideband double discone	On balcony
RPi 2	Small TV whip	Window sill
RPi 3	Wideband antenna	Roof of office bldg.
RFeye	Wideband double discone	5-th floor terrace

Noise floor estimation

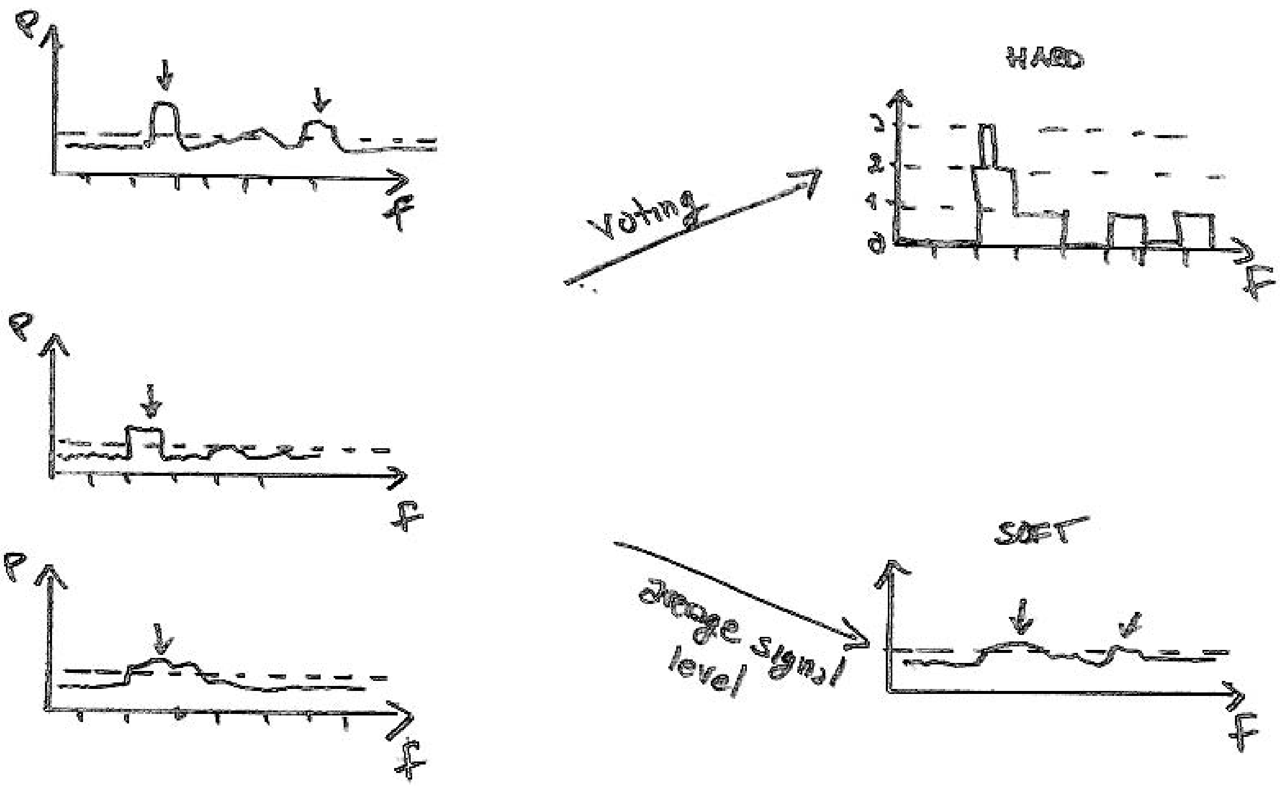
- Noise floor varies
  - a) in time, b) in frequency, c) in receiver location /setup
- Three alternatives considered
  - **Rank-order filtering**
  - Akaike information criterion
  - Minimum description length

Database used in setup

- MongoDB document database
  - NoSQL database
- Each document consist of measurement from one 1.25 MHz band
  - Time
  - SensorID
  - Start / Stop of frequency interval
  - RBW
  - Number of bins
  - Gains
  - dBm values for each bin

Distributed sensing – alternatives used

- Data fusion from different receivers
- Hard decision vs. soft decision



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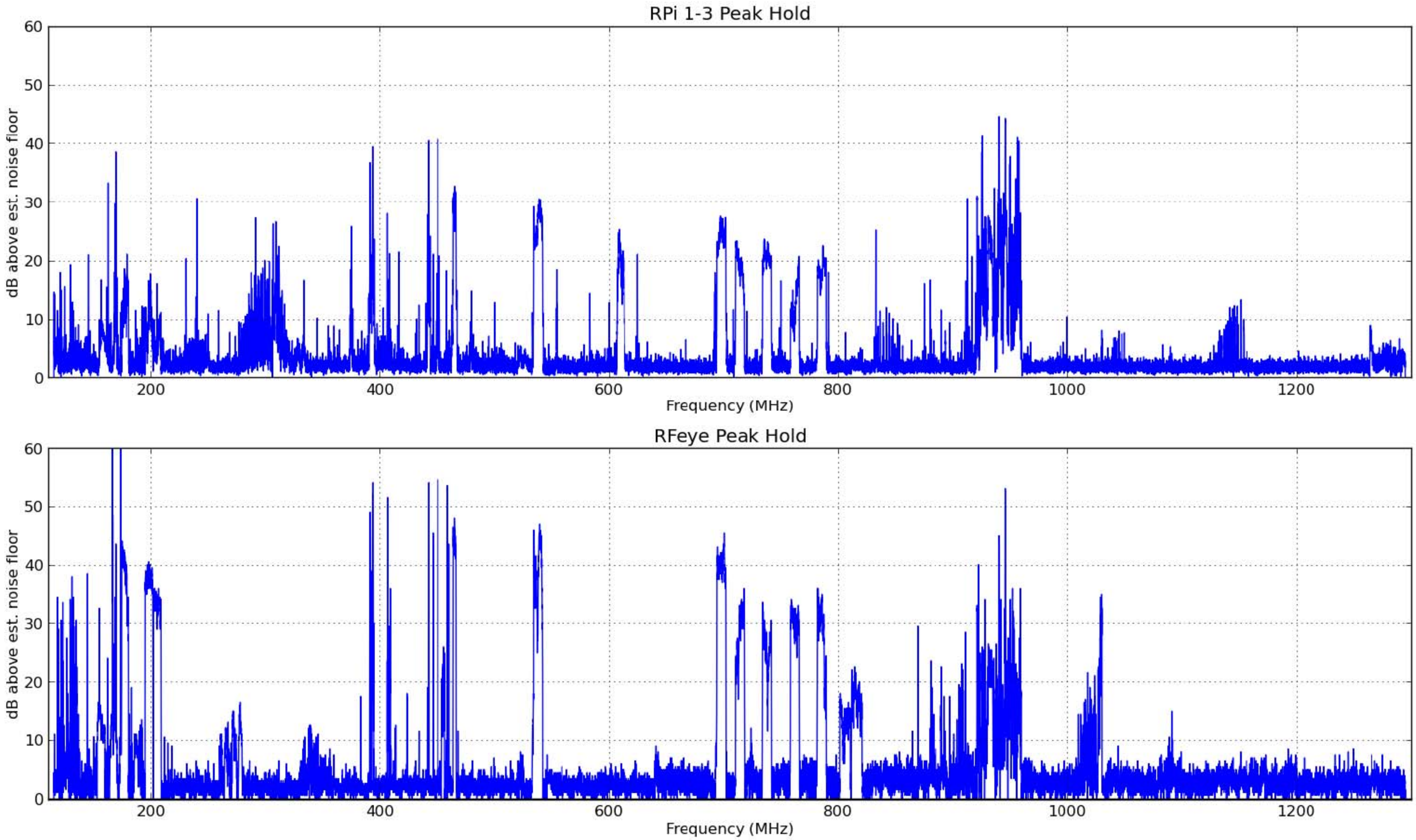
Reference equipment

- CRFS RFEye Node installed in Turku / Finland (Turku University of Applied Sciences)
- Used in a spectrum observatory, lead by Illinois Institute of Technology
- Covers same spectrum width, with same RBW (39.0625 MHz)
- Sweep time only 3 s (compared to RPi 70 s)

Results from measurements

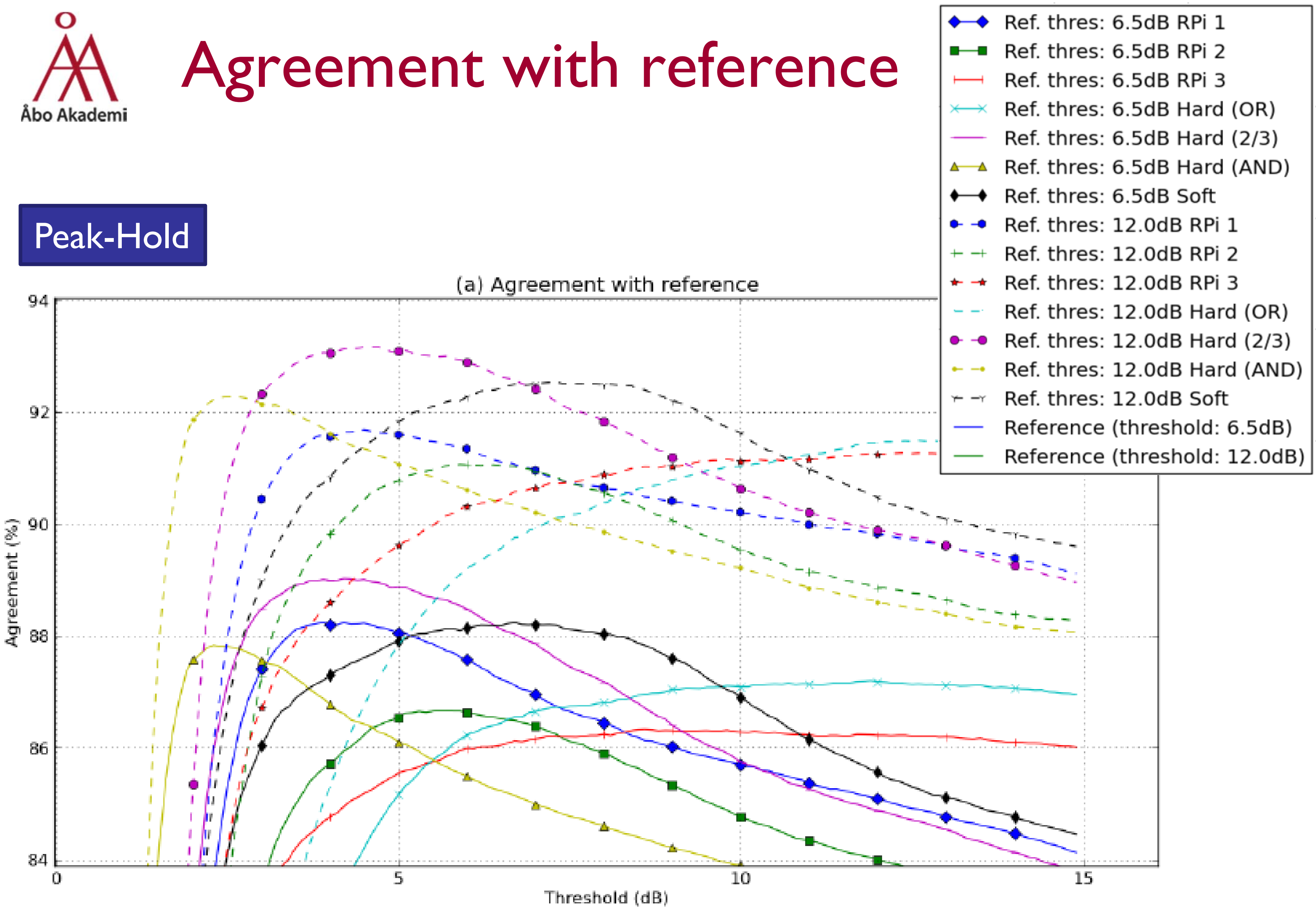
- Measurement campaign
  - RPi 6th June, 2014, RF Eye 12 June
    - (even if different dates, both were workday afternoons)
- Thresholds 6.5 dB and 12 dB over noise floor for RFEye
- RPI various 0-15 dB for detection
- Various data fusion techniques
  - Hard decision
  - Soft combining on signal levels

RPi nodes vs. RFEye



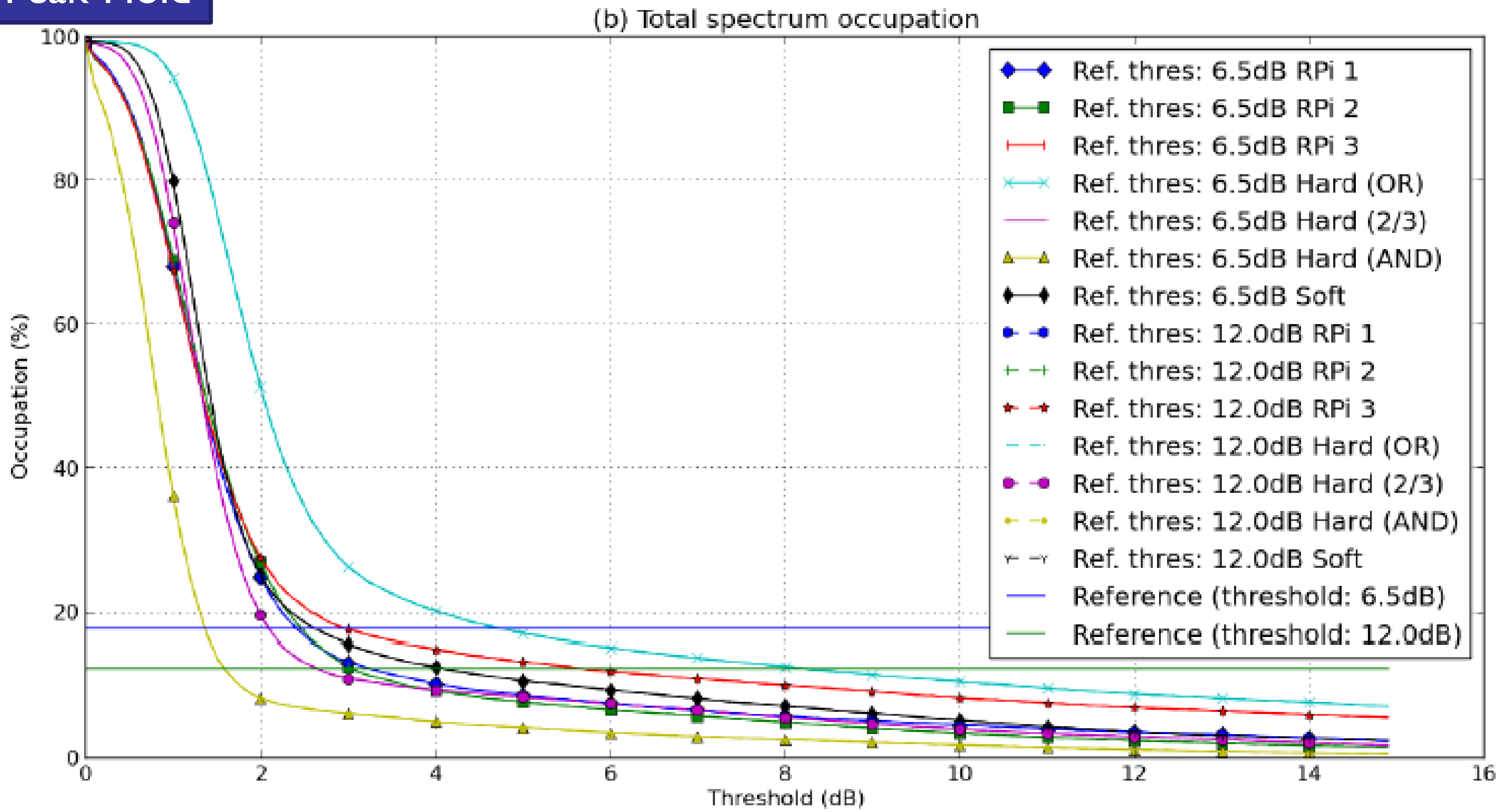
Agreement with reference

Peak-Hold



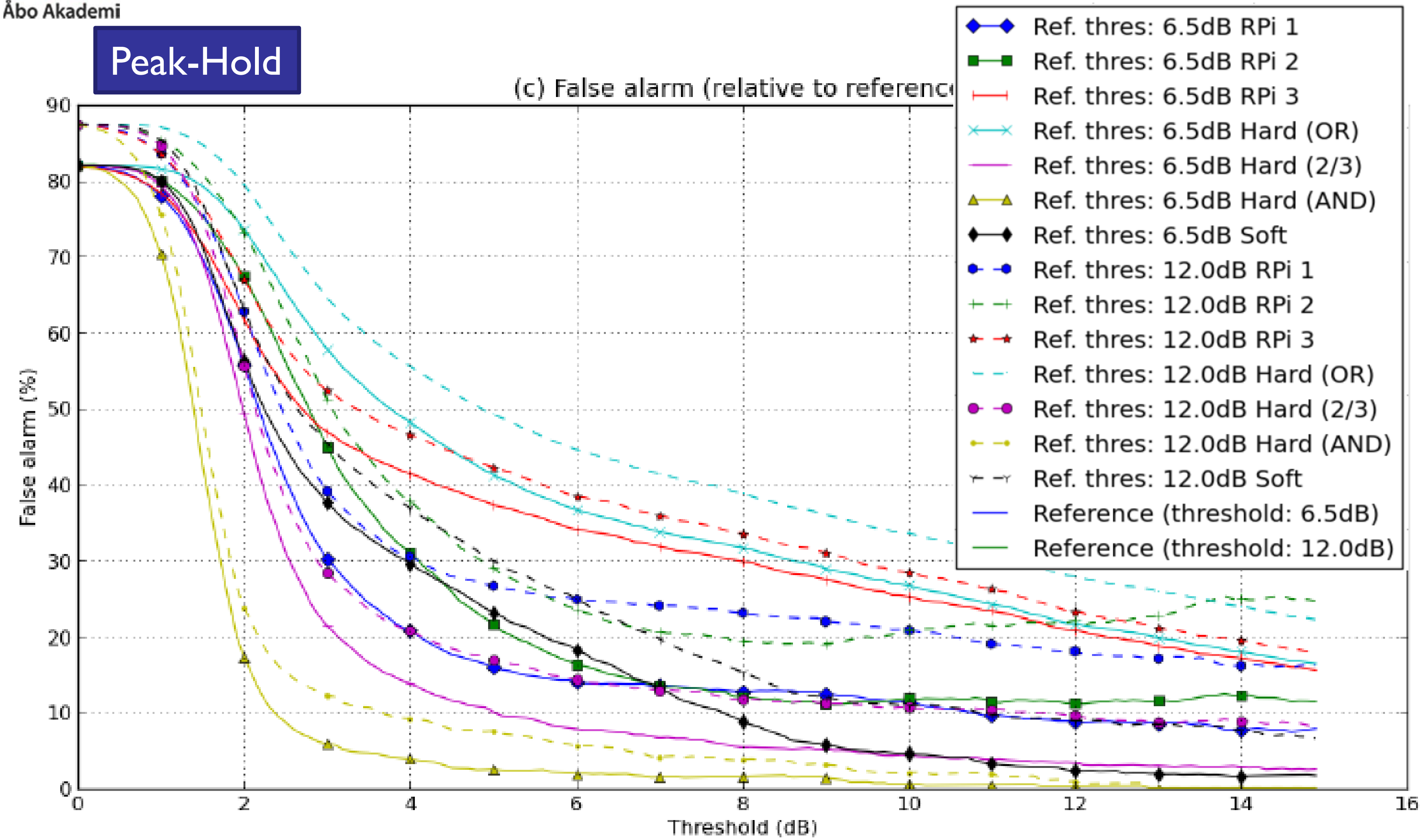
Spectrum occupation

Peak-Hold



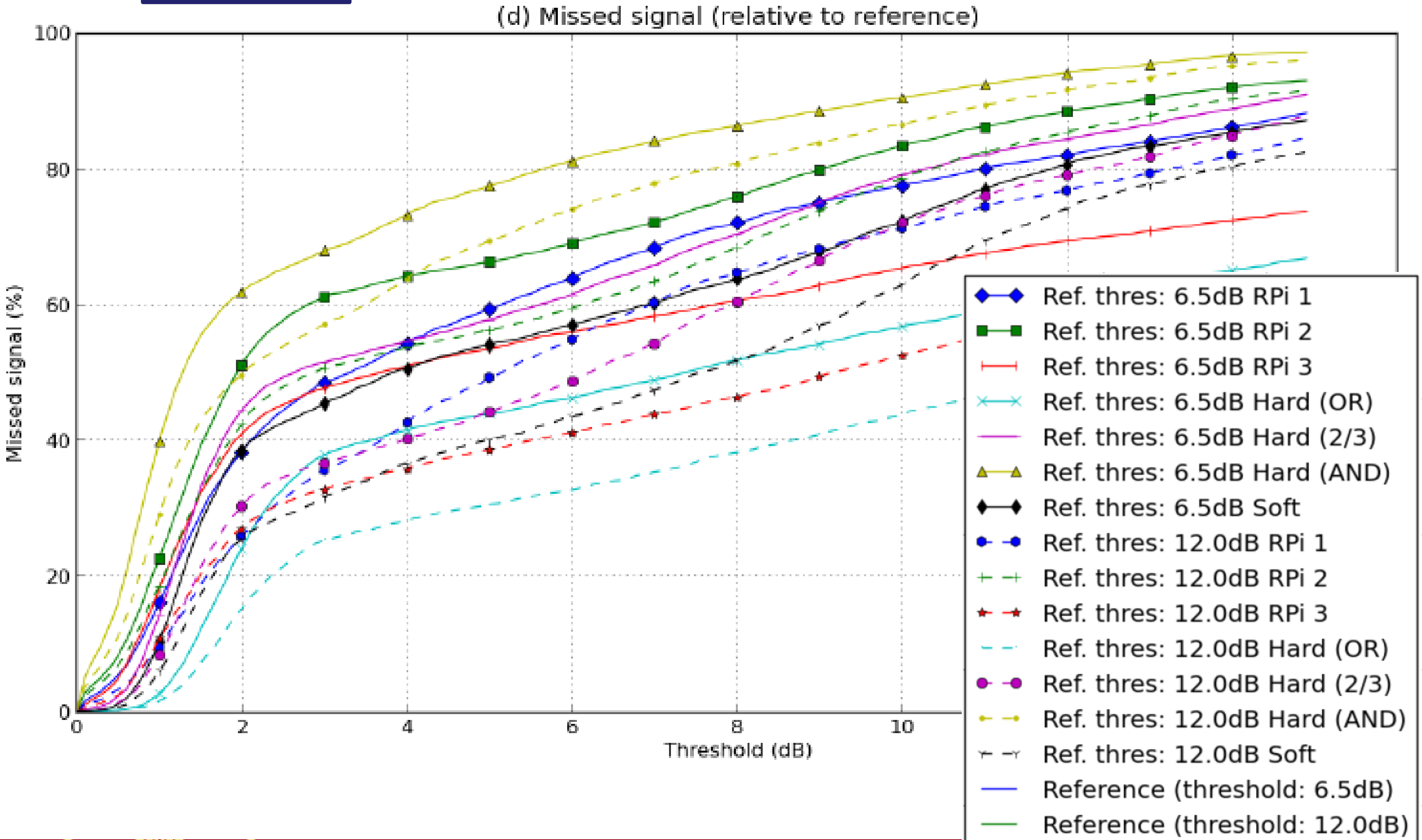
False alarms (relative to reference)

Peak-Hold



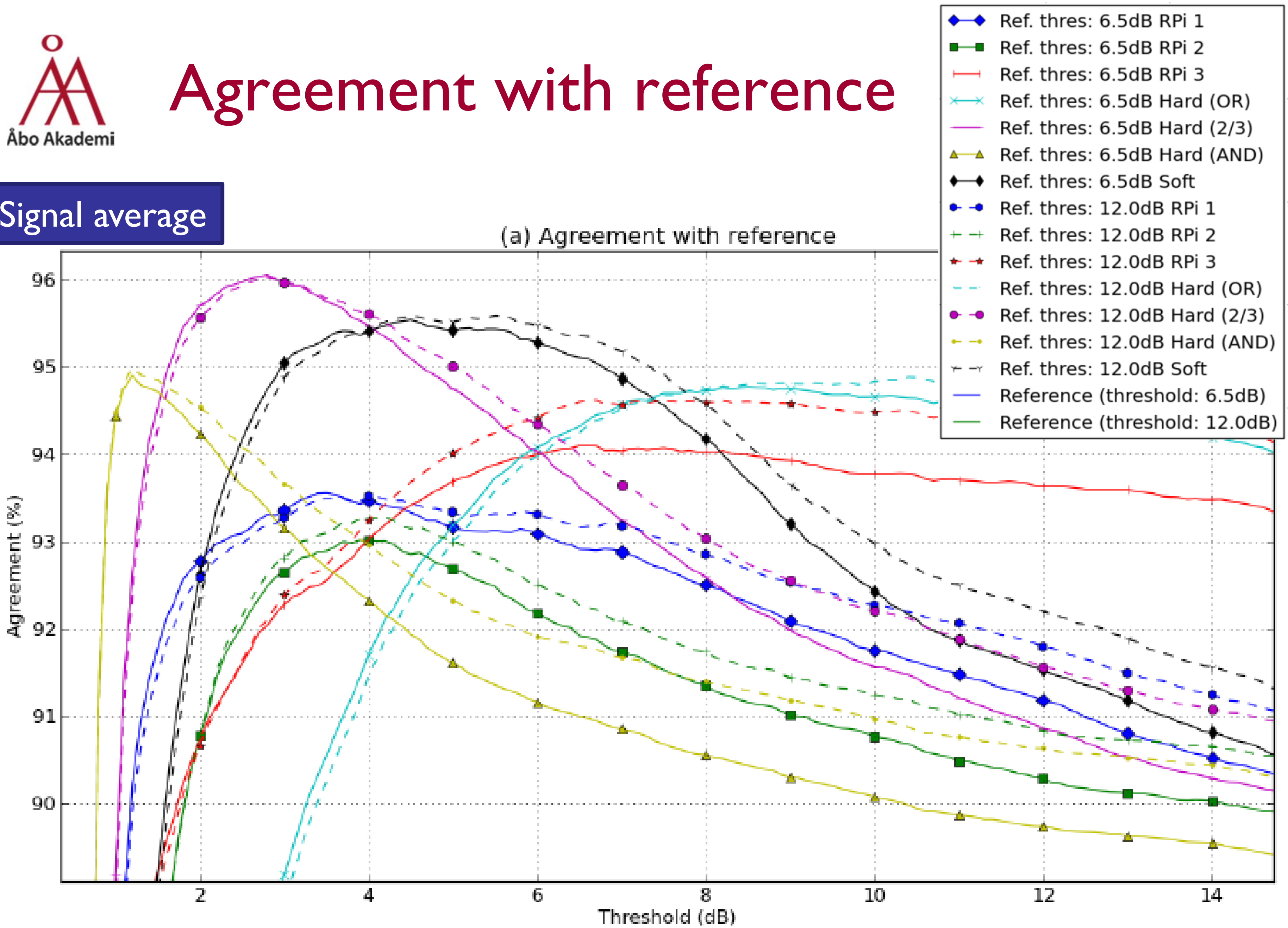
Missed signals

Peak-Hold



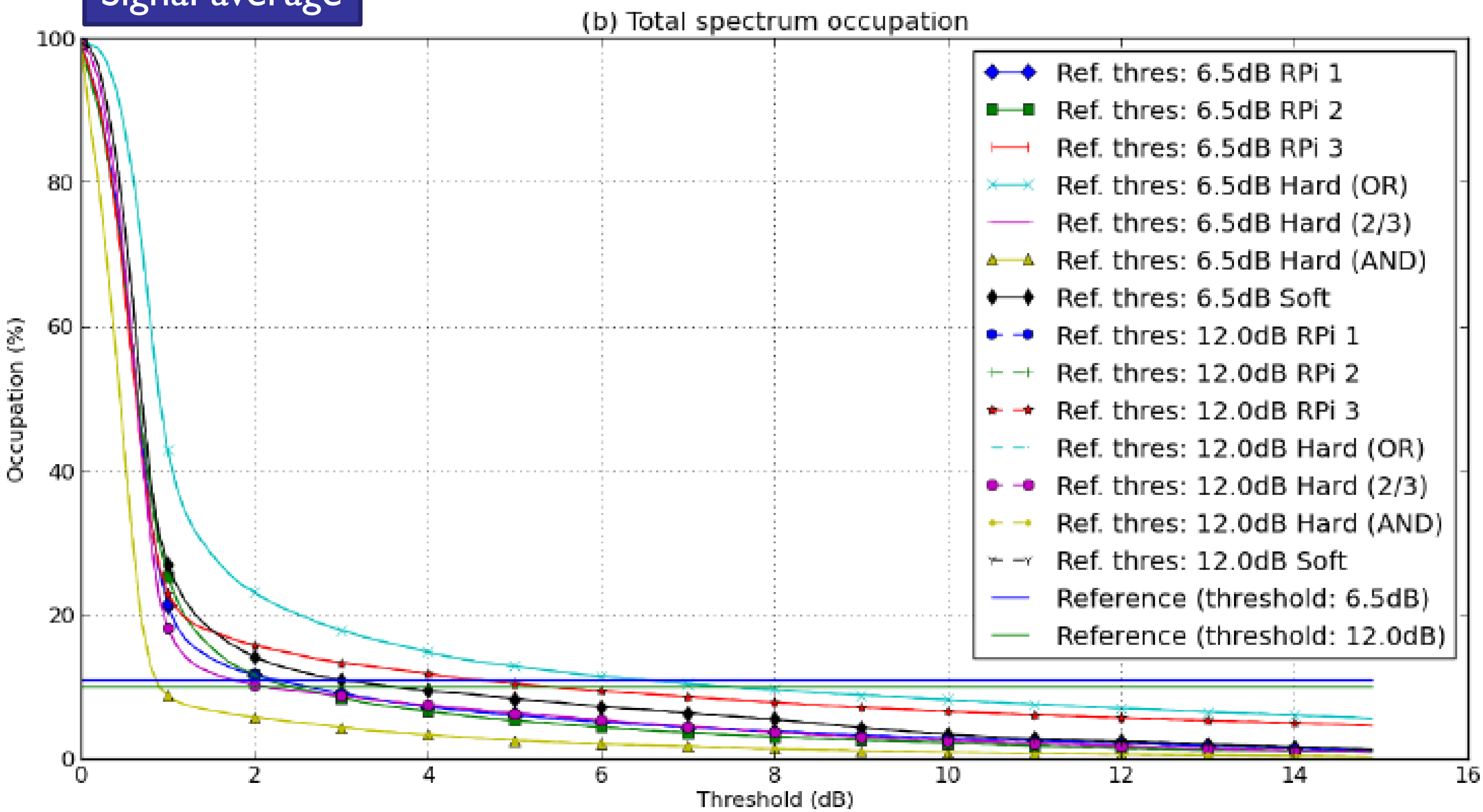
Agreement with reference

Signal average



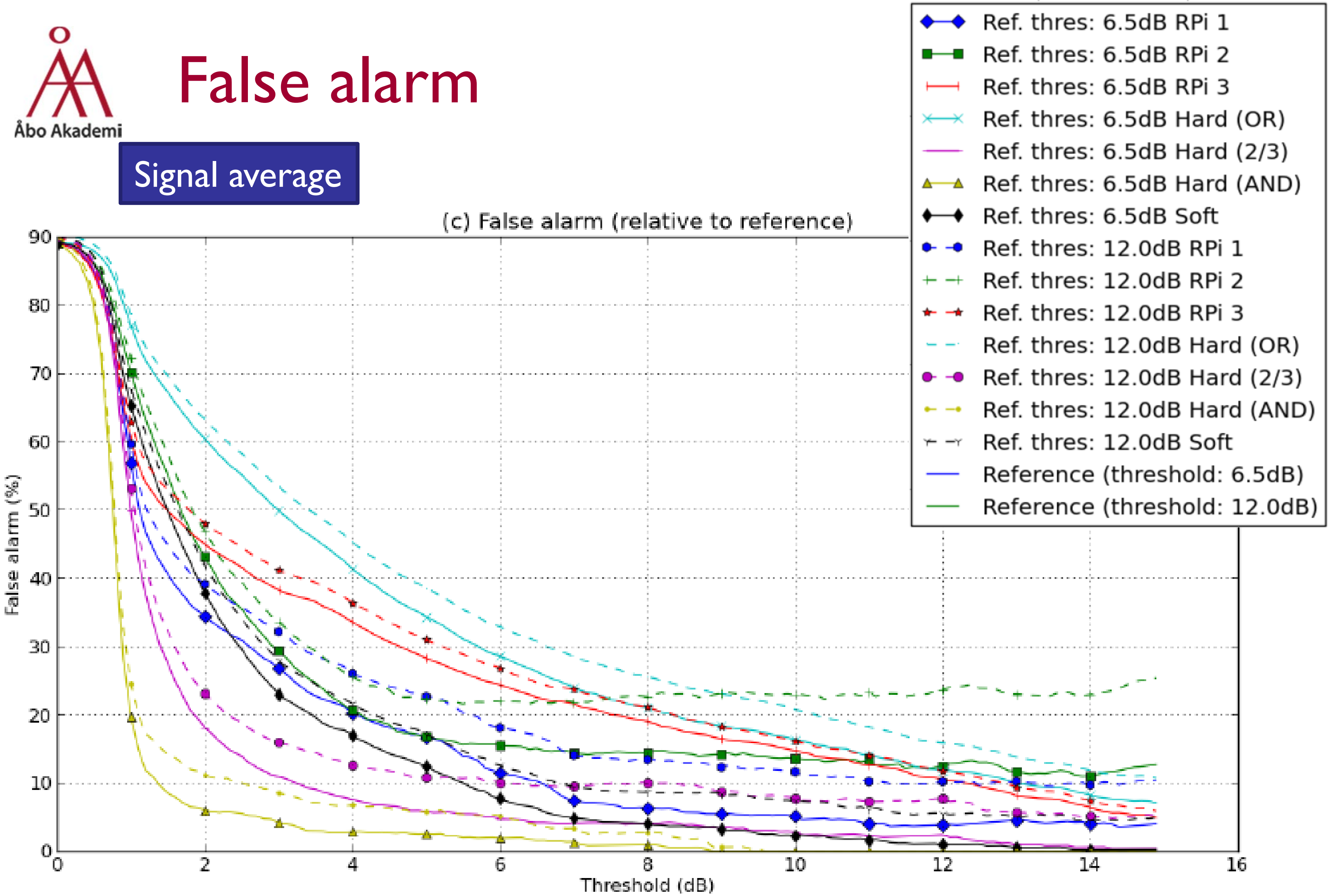
Spectrum occupation

Signal average



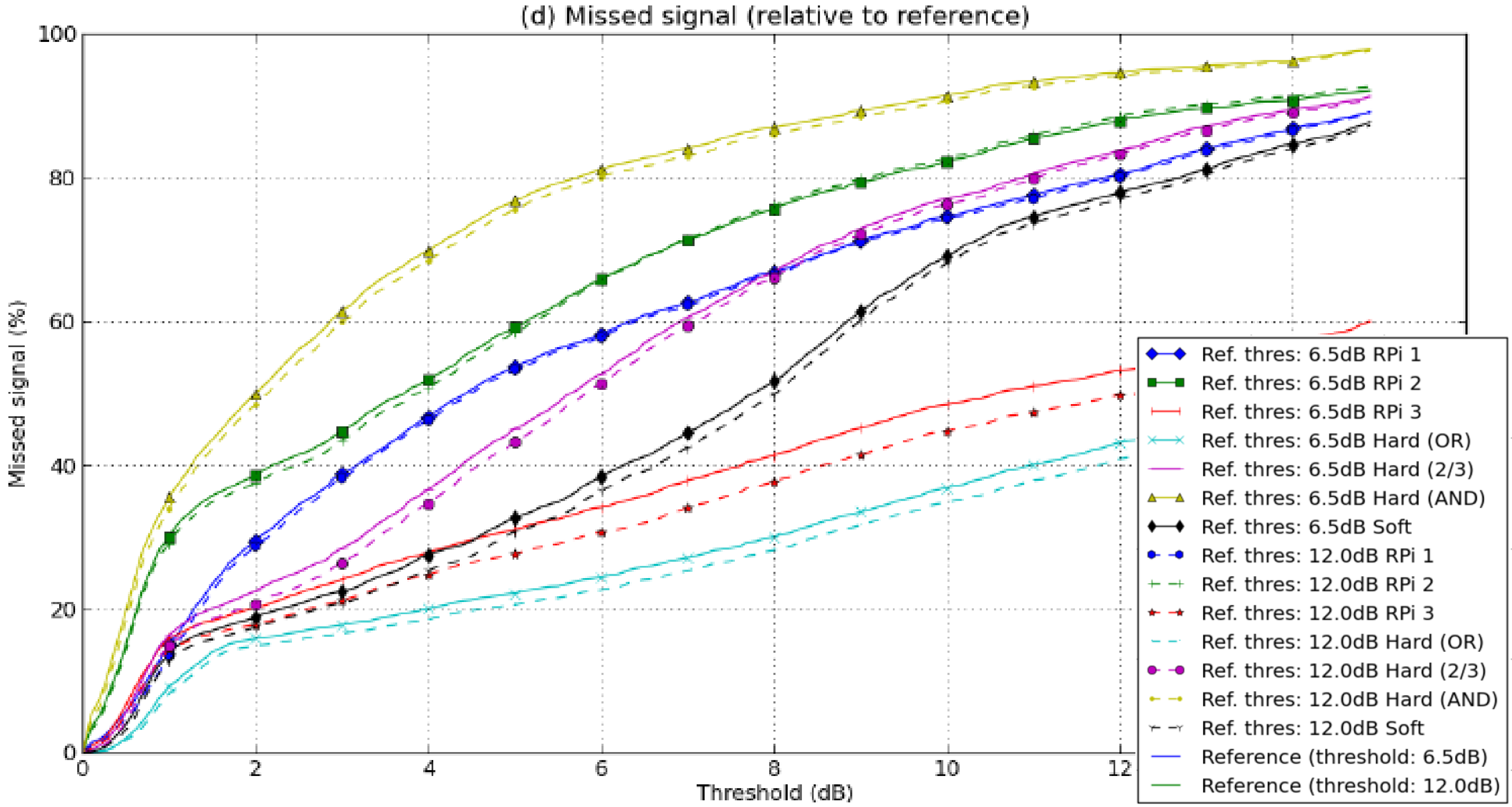
False alarm

Signal average



Missed signals

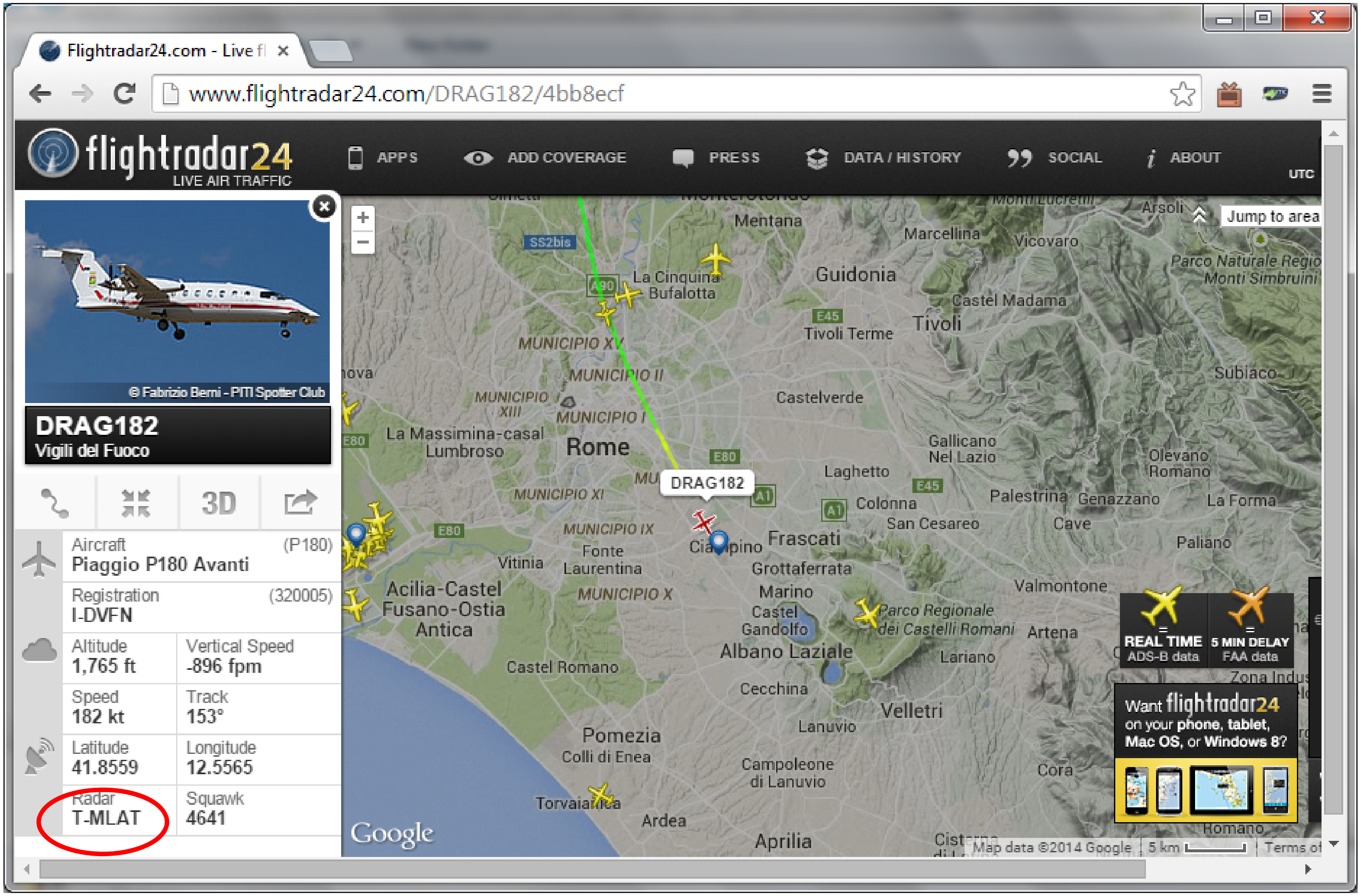
Signal average



Conclusions

- Correspondence of 85-95 % of spectrum for RPi and RFEye
- Antennas are important, a lot of information can be lost due to antenna quality and placement
  - The RPi with the best antenna corresponded best to the reference
- Selecting thresholds for detection challenging
  - Now heuristics used, not optimal
- Data fusion model should be better done, exploring time/frequency/space model better
- Technologies that could / should be explored
  - compressive singing in sensor nodes
  - data mining on generated data

Next step ;) ?



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