IP CREW

Cognitive Radio Experimentation World

A Set of Methodologies for Heterogeneous Spectrum Sensing

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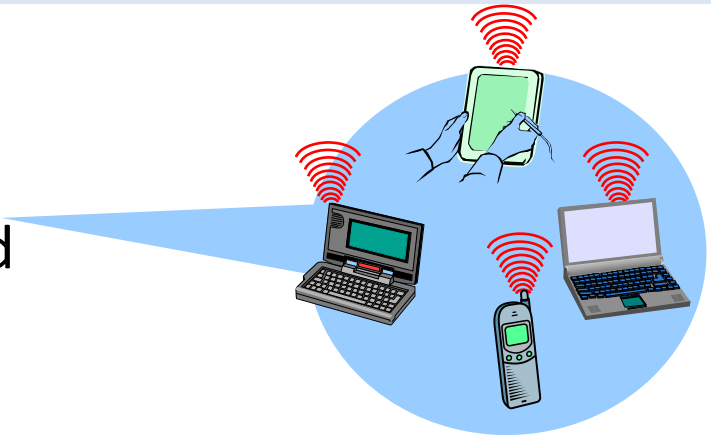
Introduction

Why heterogeneous sensing?



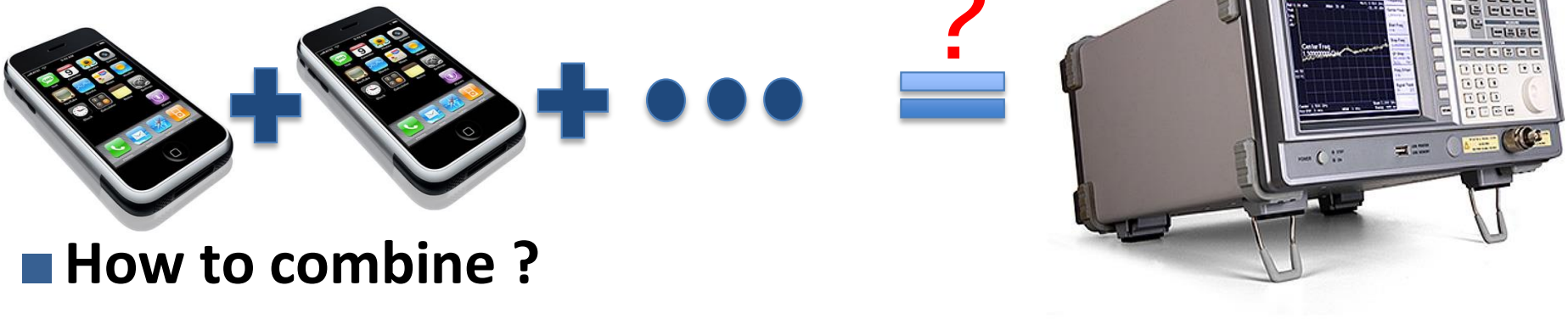
- Cognitive radio
  - ISM band is getting overcrowded
  - Cognitive Radio demands spectrum sensing

first  and then talk

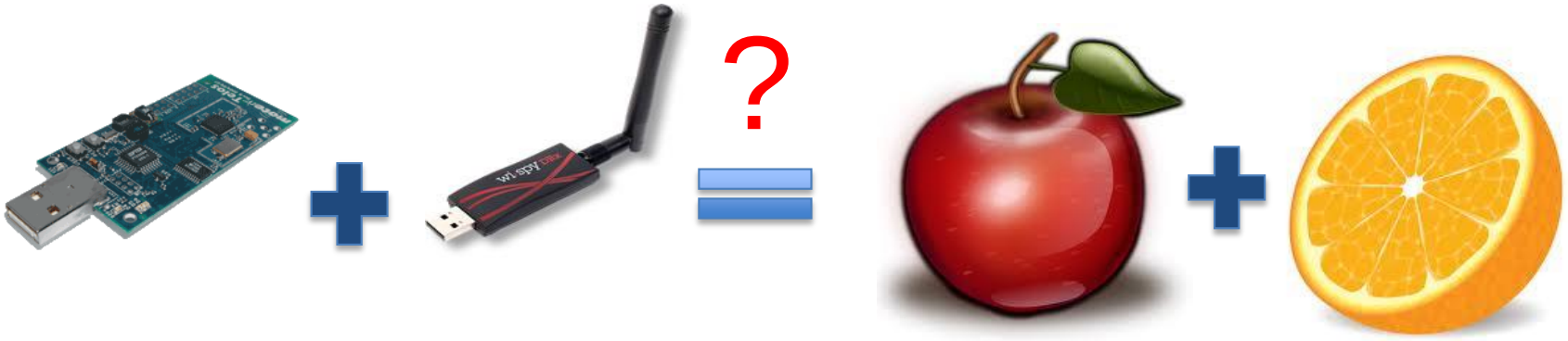
- Cost vs Performance -- Cooperative sensing with portable and small devices is desired

Challenges

- **Goal :** spectrum sensing achieved by small, portable and heterogeneous devices, in a distributed manner
- **How many ?**



- **How to combine ?**

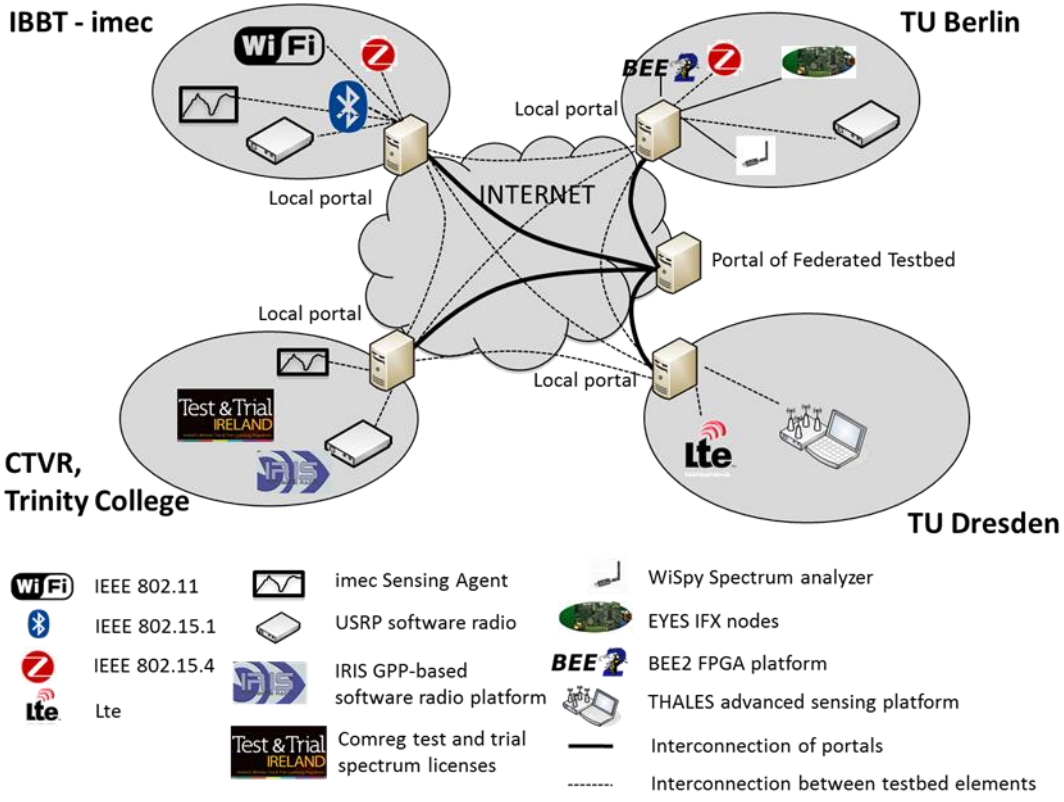


Outline

- **The FP7 Project CREW**
- **Heterogeneous Sensing Equipments in CREW**
  - Overview of devices
  - Heterogeneity of devices
- **Proposed Methodologies and Related Experiments**
  - Determine power offset among heterogeneous devices
  - Common Data Format
  - Experiment specific methodologies
- **Conclusions**

The FP7 Project CREW

- Project Partners:
  IBBT, imec, CTVR, TU Berlin, TU Dresden, Thales, EADS, JSI
- Project Start: October 2010
- Project Goal: Development of a Federated Testbed for Cognitive Radio Experimentation http://www.crew-project.eu/

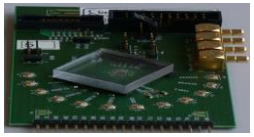
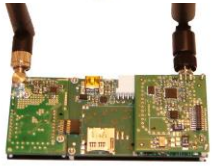


Heterogeneous Sensing in CREW

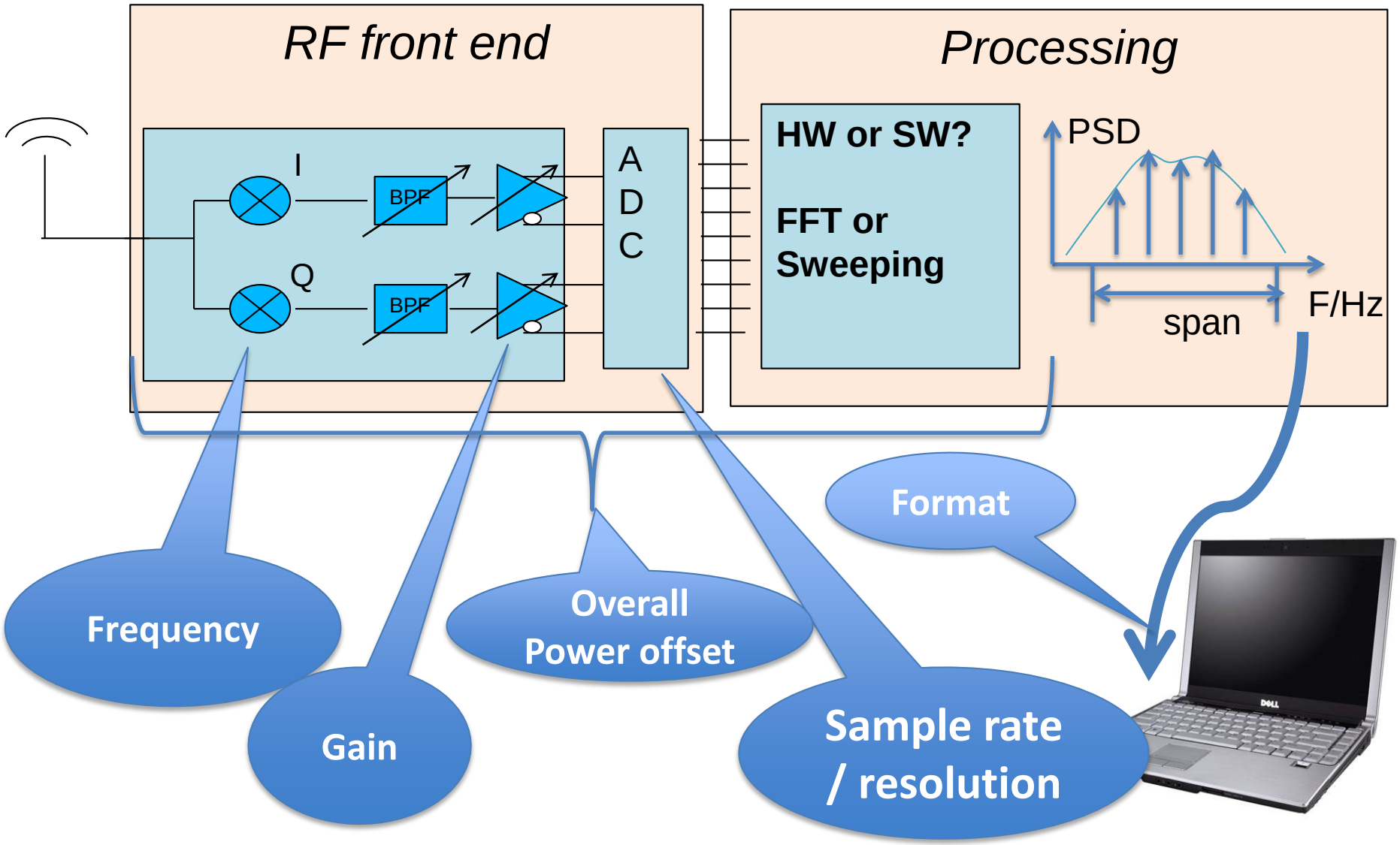
- The CREW Project offers the unique chance to compare a great number of sensing solutions from different project partners

- **Cross-Platform Study**
  - Comparison of inexpensive off-the-shelf to customized sophisticated solutions
  - Comparison of different processing approaches
  - Methodologies dealing with
    - Heterogeneity in hardware
    - Heterogeneity in software

Sensing Equipments

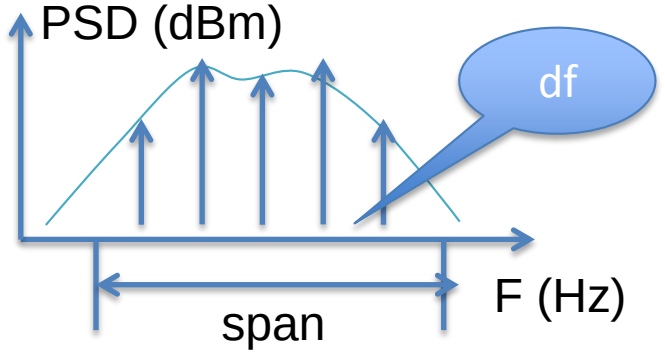
	Device	Signal processing	Customization
imec		 Fixed-point FFT on Embedded uP	HW + SW
USRP		 Configurable periodogram on GPP	SW only
Airmagnet		Fixed-point FFT hardware processing	None
Wispy		RSSI measurement	None, open source SW
Telos B		RSSI measurement	SW only
JSI		RSSI measurement	HW + SW

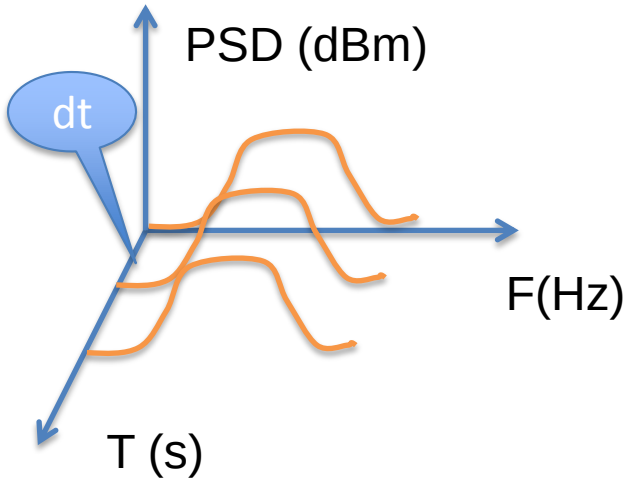
Heterogeneity of sensing equipments



Heterogeneity of sensing equipments

- Power Spectrum Density (PSD) in dBm is the common output for all devices
- **Heterogeneity**
  - Spectrum matrices
    - Resolution bandwidth (df)
    - Span
    - Time resolution (dt) : Time to collect sample + processing time
  - Output format:
    - Binary ? CSV? XML ?.....





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  - Experiments Related Methodologies
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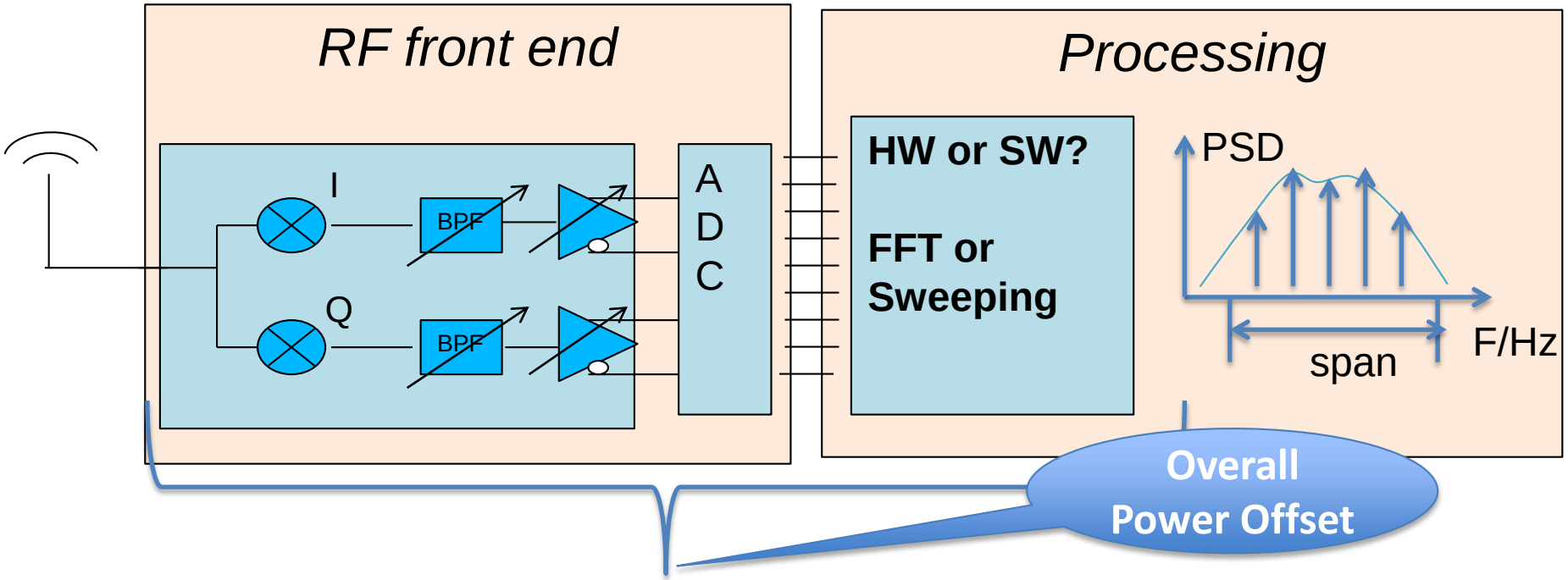
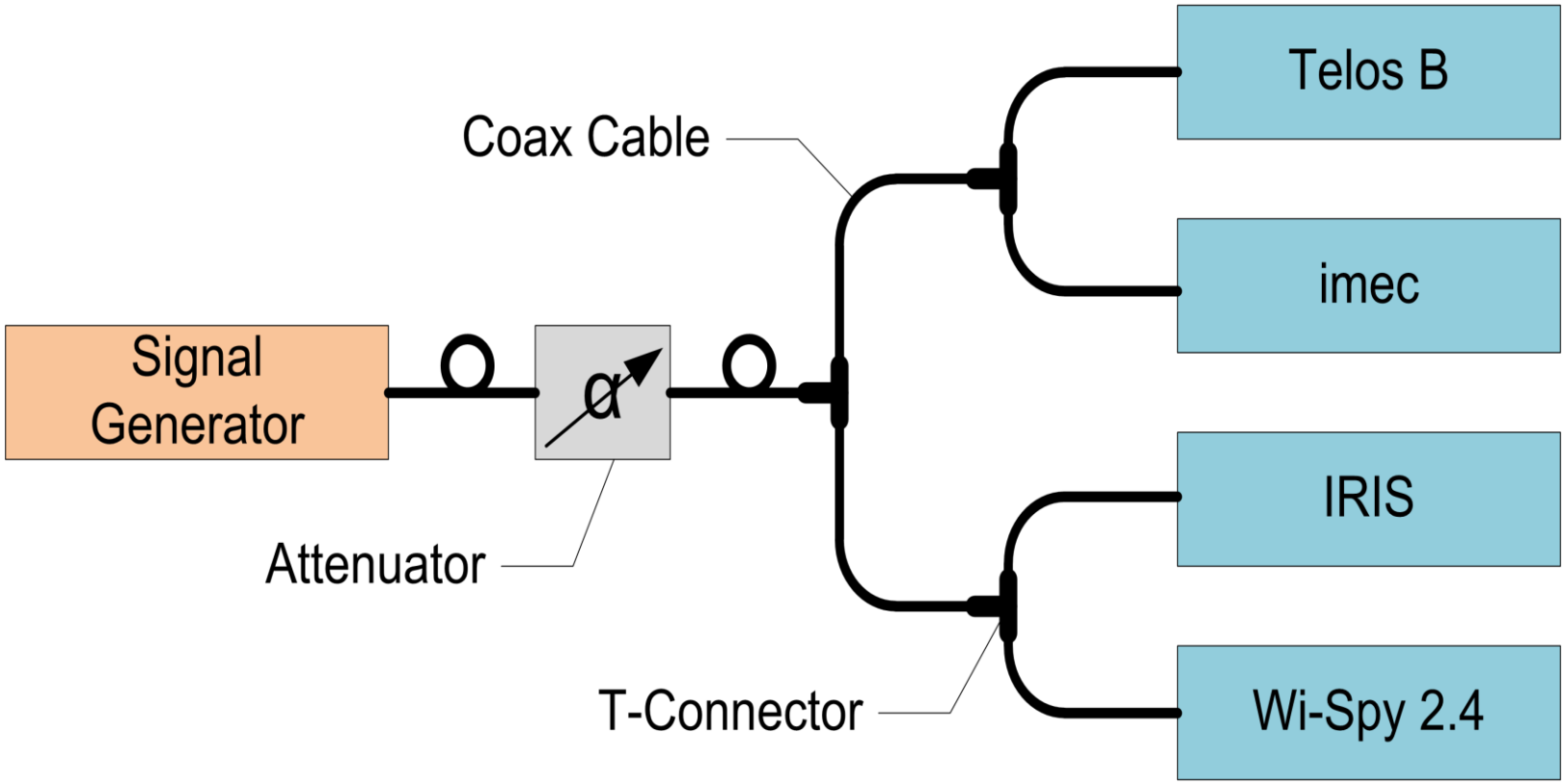
Power offset of Heterogeneous Devices



- Distortion at each amplification stage
- Limited ADC resolution
- Processing : e.g., FFT windowing function, overlapping..
- Power offset refers to the difference in measured power by heterogeneous devices given the same input signal

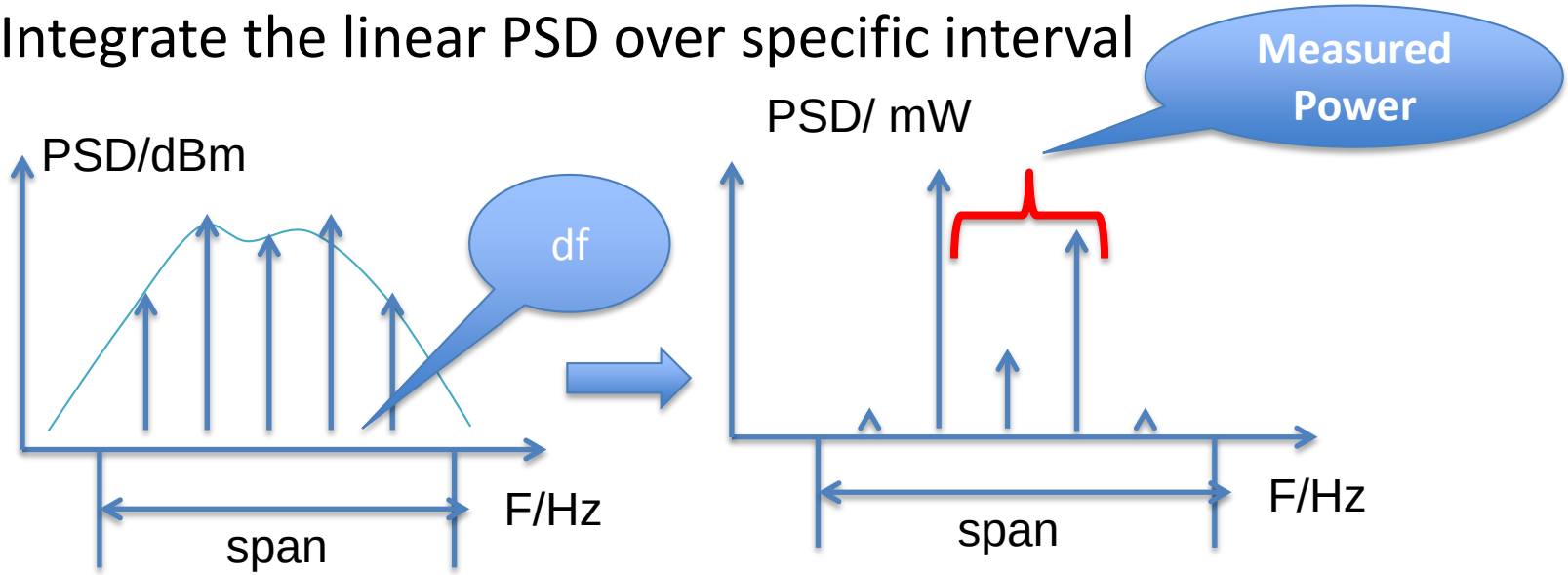
Measure the Power Offset

- **Experiment setup**
  - Measurements with coaxial cable connection
  - Perform measurement for various input signal types and strength



Measure the Power Offset

- Desired metric : The power measured in a certain band
- Difficulties：No common frequency resolution and span
- Methodology
  - Integrate the linear PSD over specific interval

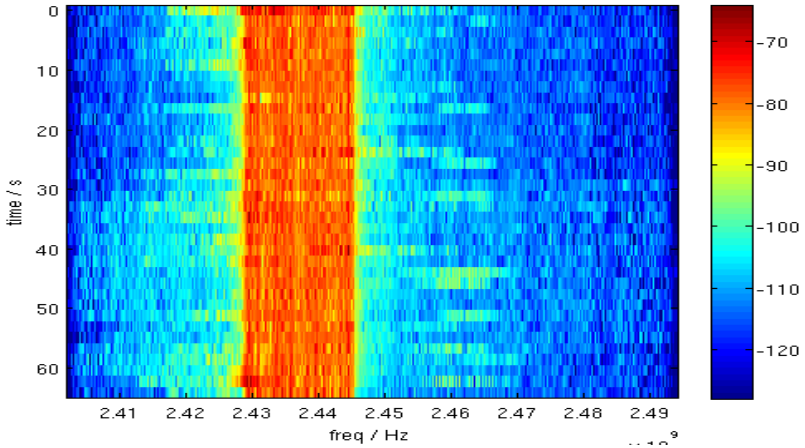


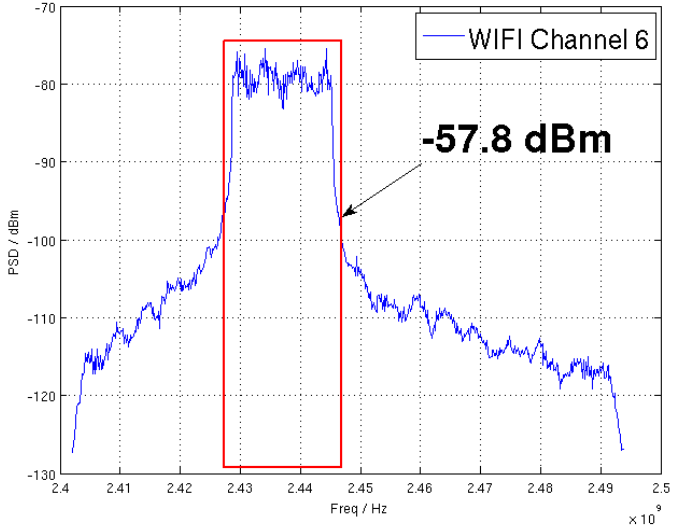
  - Power Offset = TxPower – Attenuation – Measured Power
  - Calibrated Power = Measured Power – Power Offset

Measure Offset Airmagnet Example

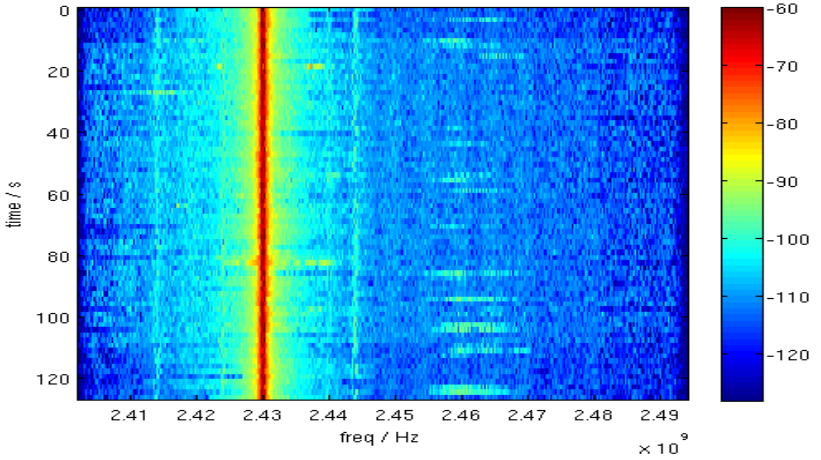
Input signal 60 dBm => offset is 2.6 dBm

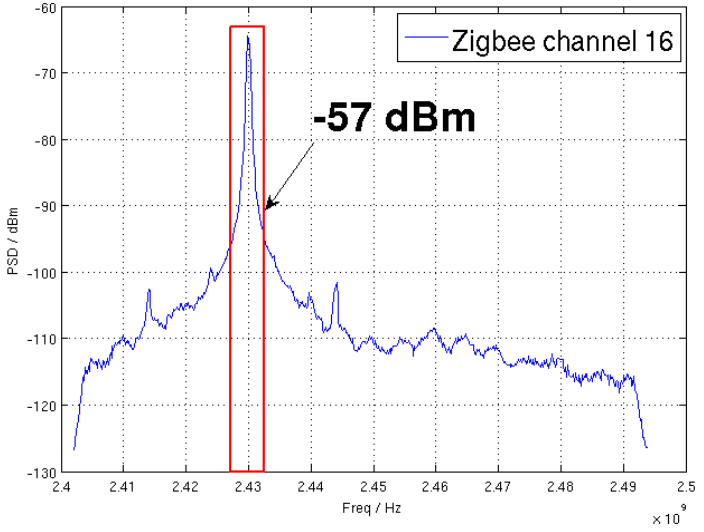
WIFI channel 6



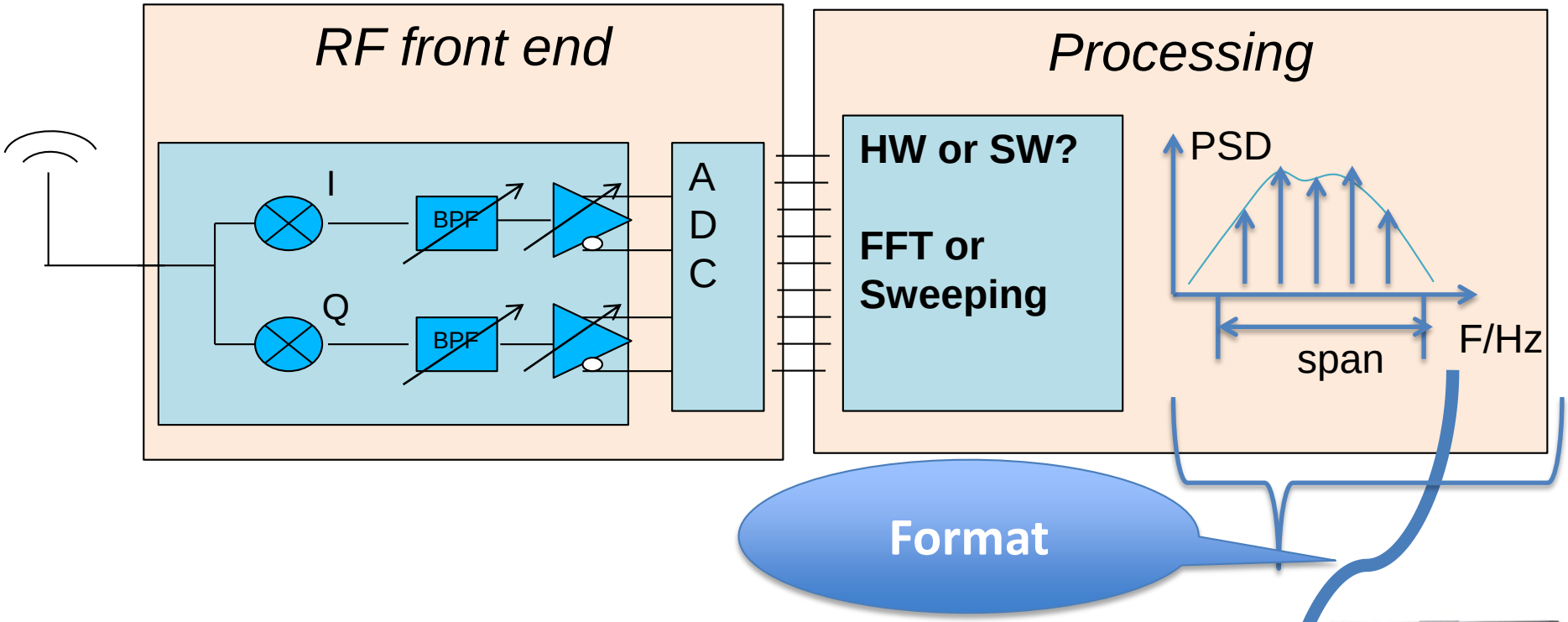


Zigbee channel 16





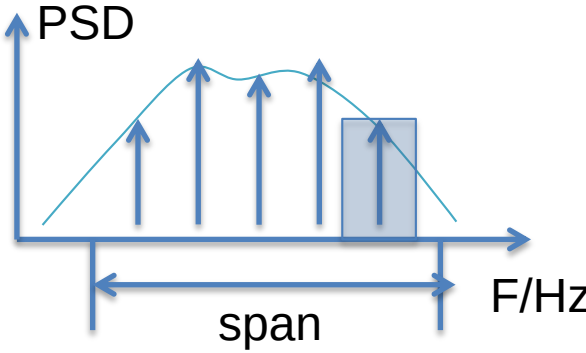
Heterogeneity in sensing equipments



Common data format is desired to achieve fair comparison among devices

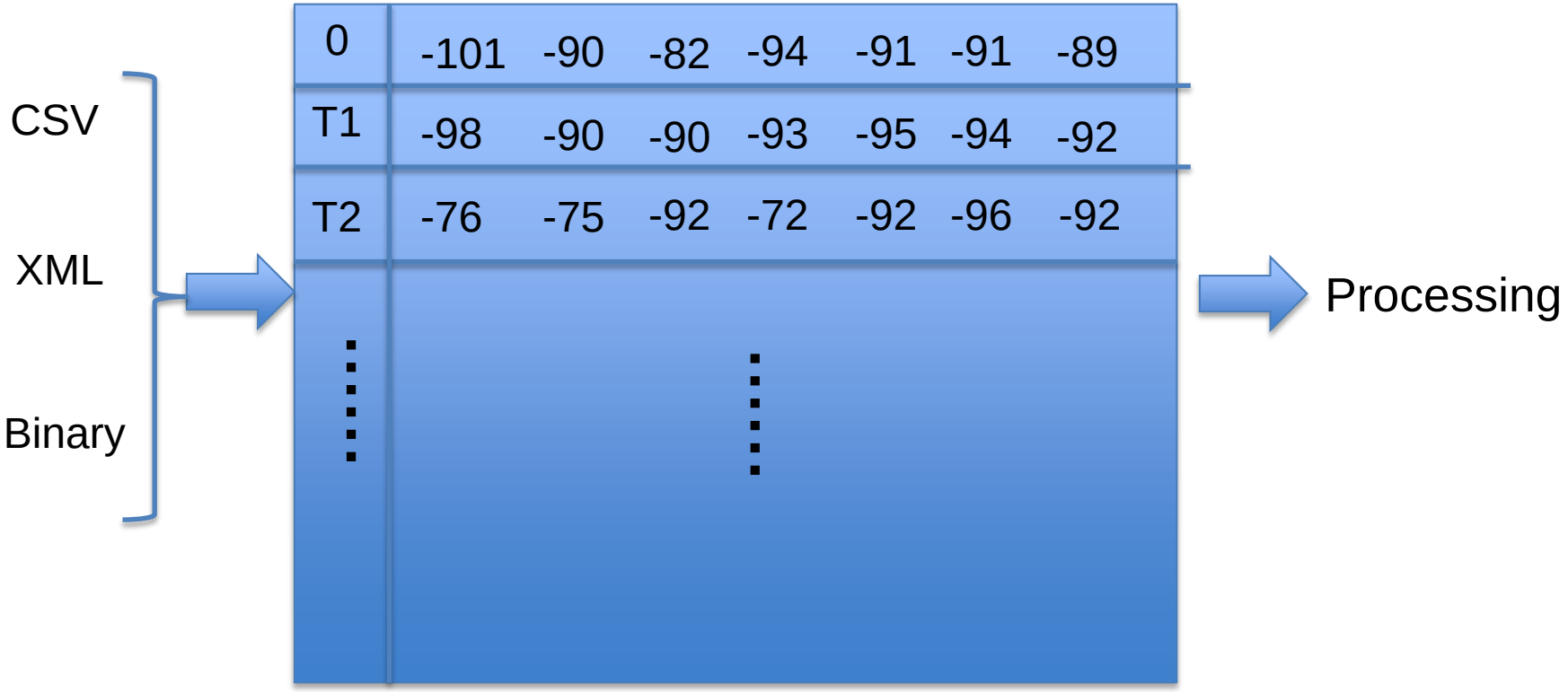
Metadata

- Metadata of the experiment
  - Tx signal pattern, Tx power level, background environment
- Metadata of each trace
  - Device name
  - Location of the device
  - Calibration offset (obtained by pre-calibration)
  - Frequency bins
    - Array defining center frequencies of the rows of the power matrix
  - Resolution bandwidth
    - Band width around each center frequency
  - Starting time
    - The starting time of the experiment
  - Relative time
    - The time stamp of each sweep relative to the start time



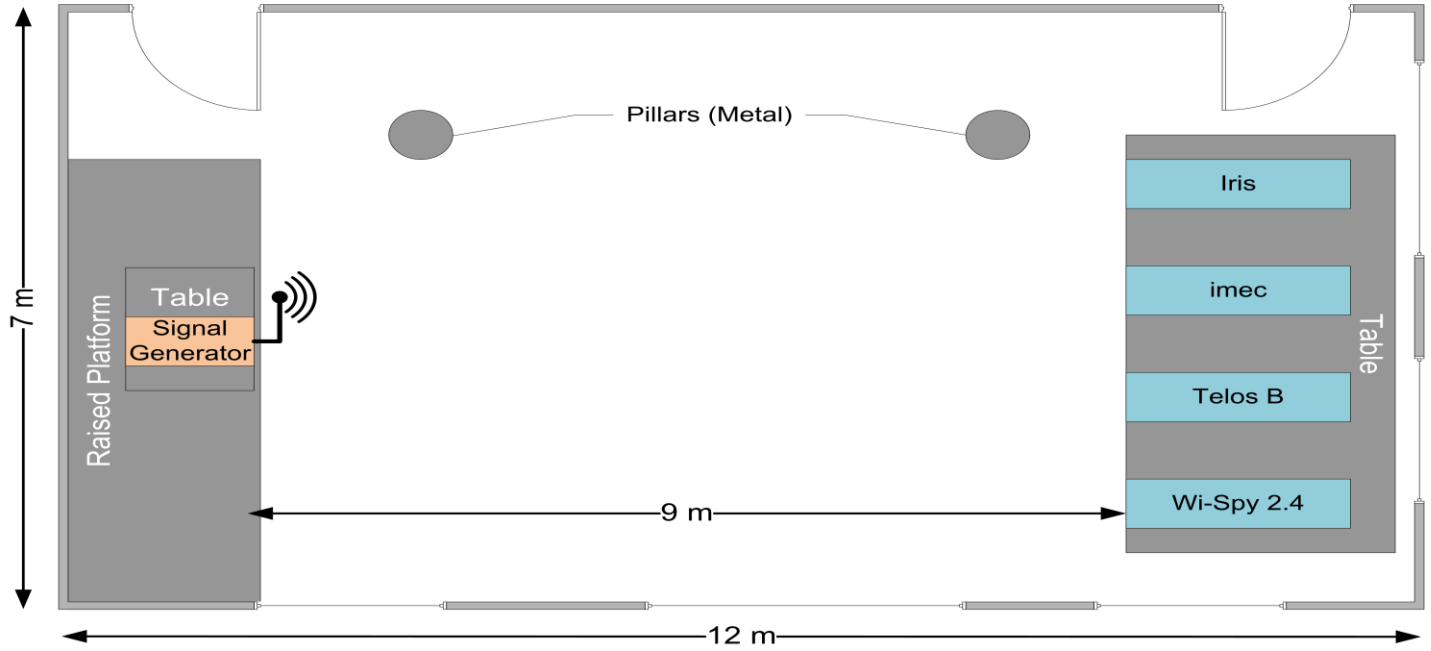
CREW Common Data Format

- Data -- Power matrix
  - The matrix containing PSD and relative time stamp.
  - Obtained by a dedicated script for each device



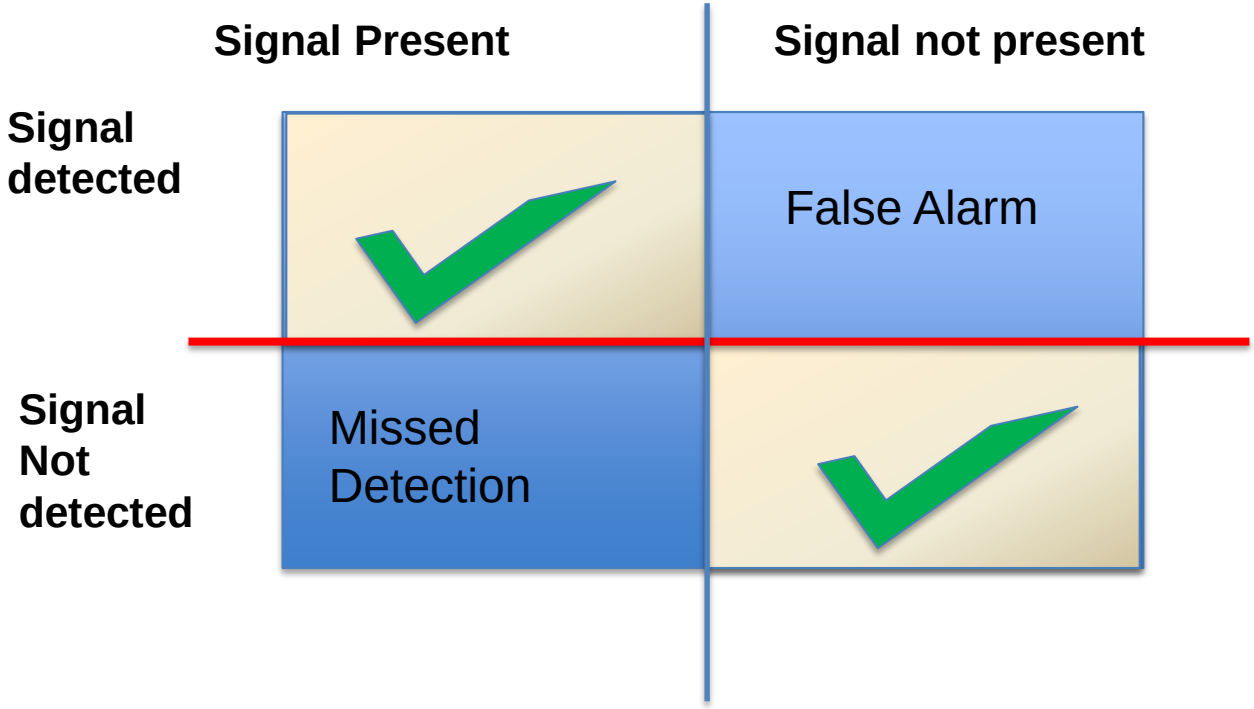
Dublin Experiment

- Focus : Temporal accuracy
- Scenarios
  - Tx signal Slow On/Off Pattern (60 s On / 60 s Off)
  - Tx signal Fast On/Off Pattern (10 ms On / 100 ms Off)
- Channel Characteristics
  - Static (no people in room) and Dynamic (10…15 people moving randomly around between TX and sensing nodes)



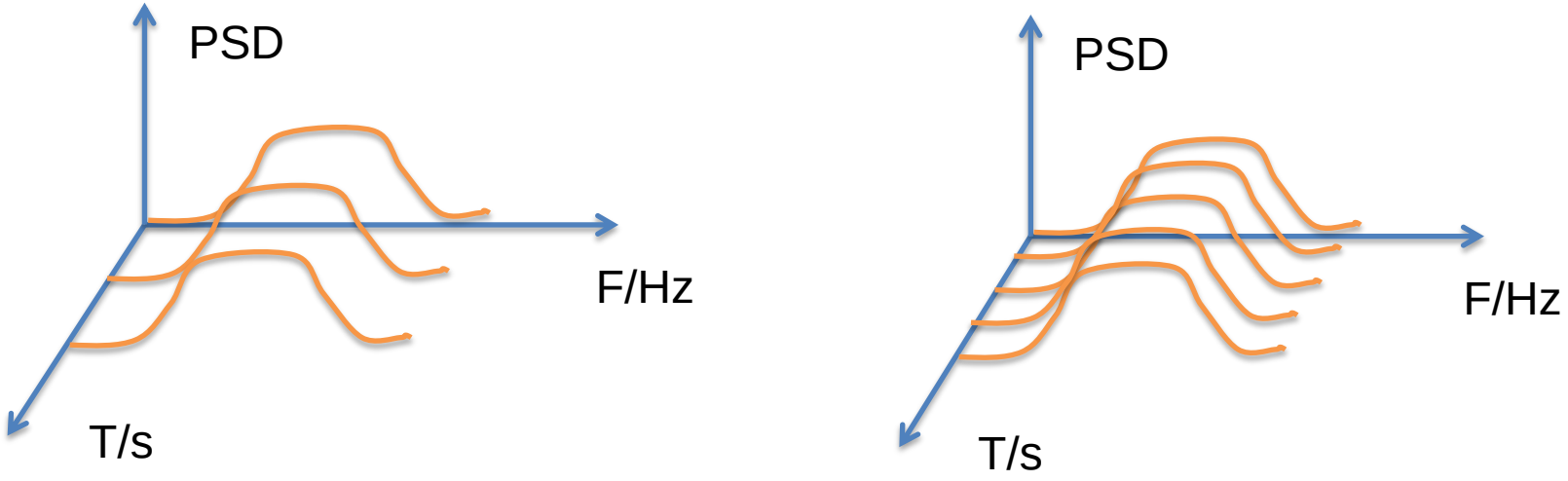
Desired Comparing metrics

- Receiver Operating Characteristic
  - Probability of False Alarm VS Probability of Missed Detection



Experiment Dublin

- **Difficulties**
  - No common data rate in time domain
  - Different frequency coverage => fairness?
- **Methodology**
  - Average / Resample the PSD matrix so all devices have the common data rate in time domain

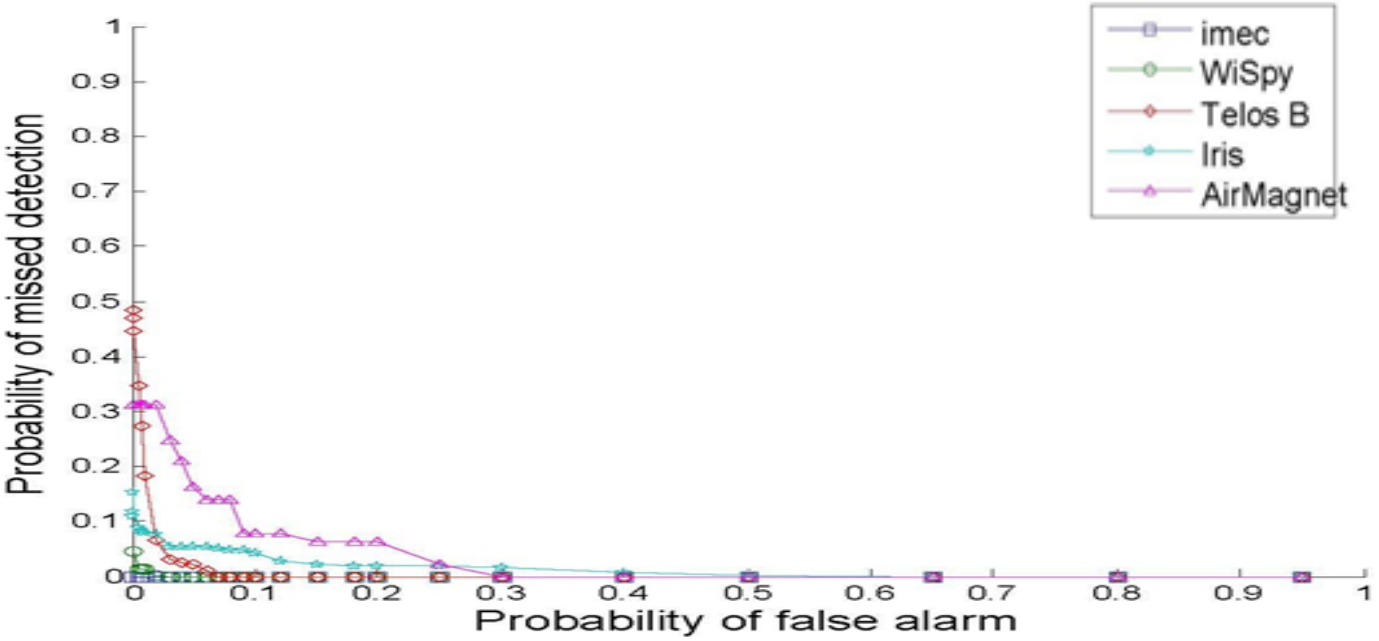


  - Determine actual sample collection for a specific band

Experiment Dublin

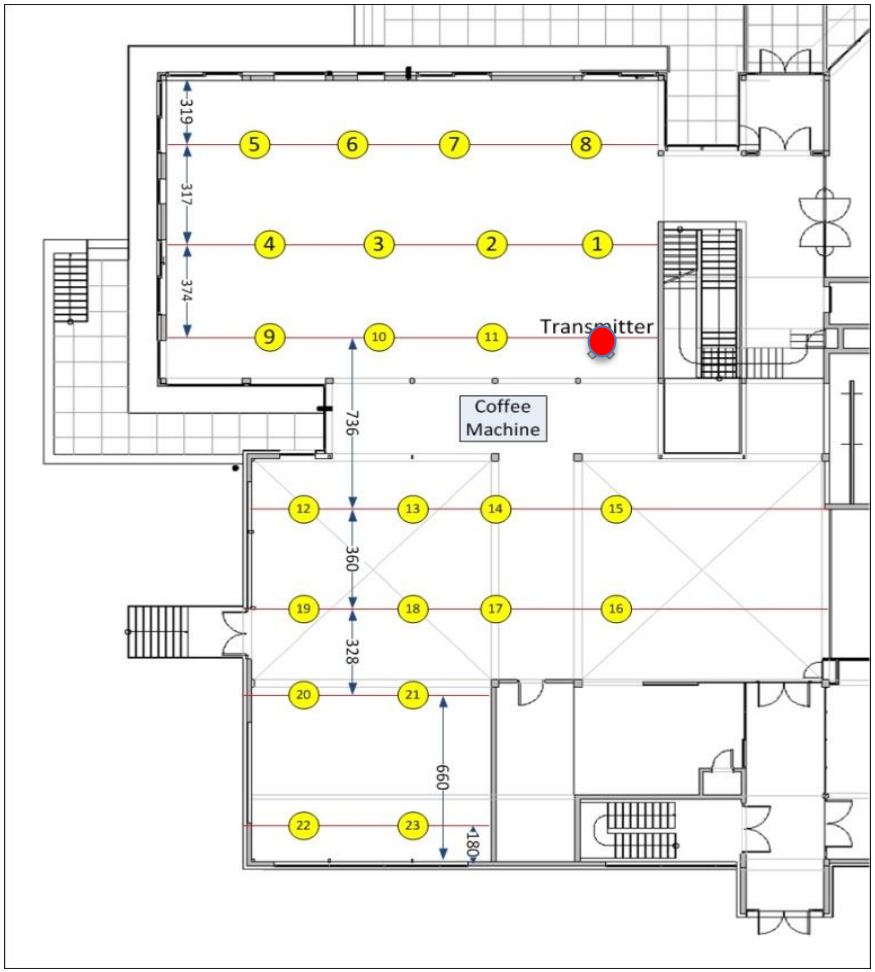
Post processing

- Vary probability of false alarm (PFA) from zero to 100%
- For each PFA, calculate the threshold of energy detection
- Use this threshold to calculate PMD
- Obtain the receiver operation characteristic (ROC) plot



Experiment Leuven

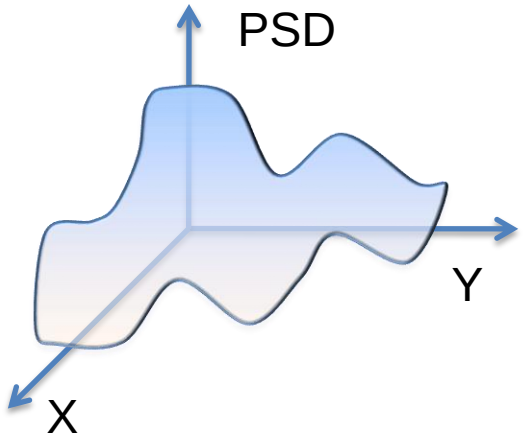
Exp .Leuven – Spatial accuracy



- Where ? imec cafeteria large indoor environment
- Transmitter at fixed location, continuous 20 Mhz OFDM signal
- Heterogeneous devices are used to measure spectrum at all locations.
- Least Squares method used to generate the pathloss model for each device.

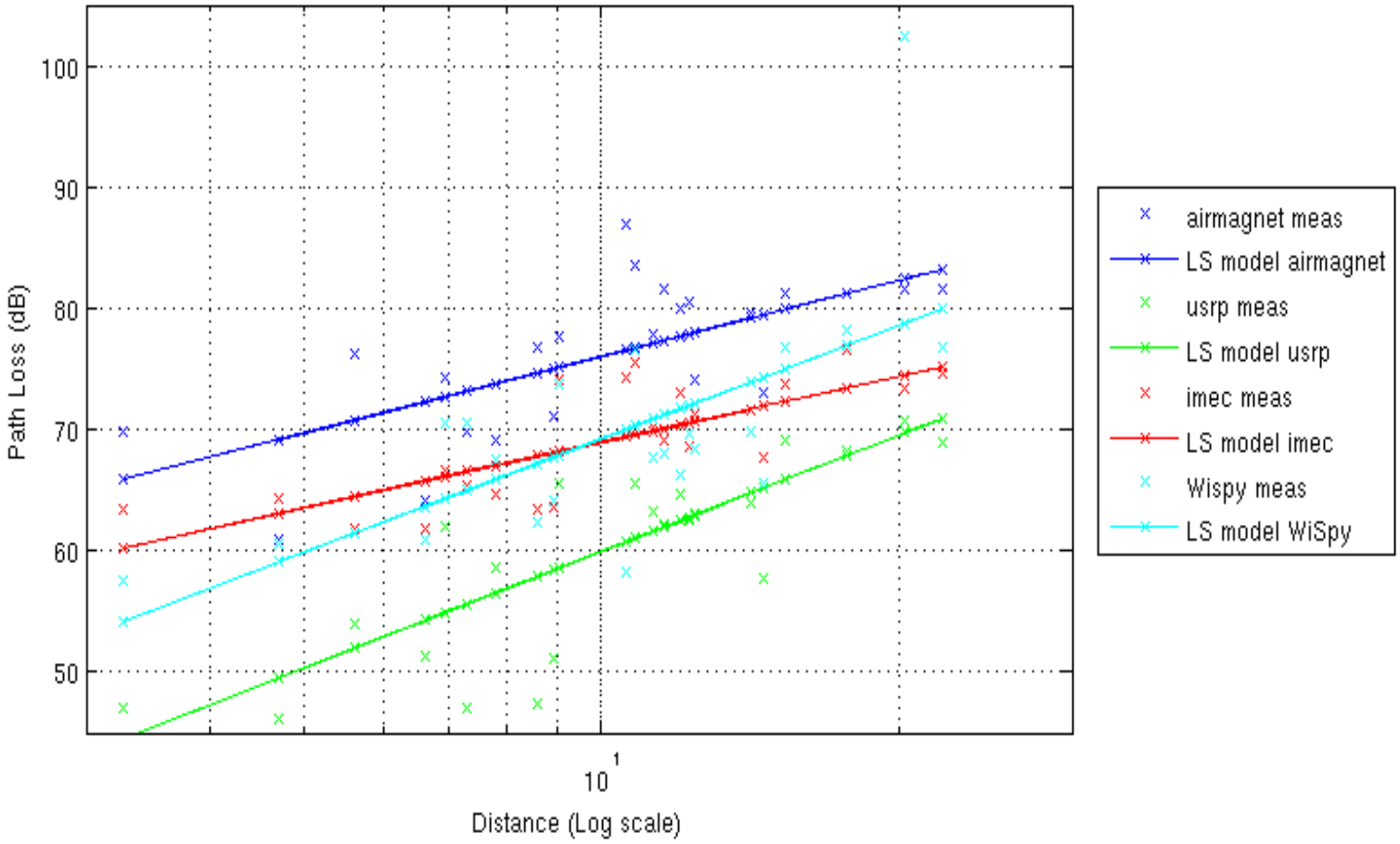
Experiment Leuven

- **Desired metrics**
  - Path loss vs distance model
    - $PL = \beta + 10x\,\alpha\,x\ \log10\,(\,d\,/\,d^*) + \Delta$
- **Difficulties:**
  - How to determine the “ground truth” ?
  - How to generate the path loss model ?
  - How to compensate for the power offset?
  - How to determine outlier of the experiment ?



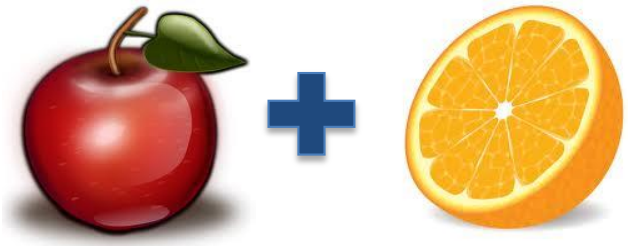
Experiment Leuven

$$PL = \beta + 10 \times \alpha \times \log10 (d / d^*) + \Delta$$



Conclusions

Heterogeneity	Methodology
Output format	Dedicated script + Common Data Format
Overall power loss in receiver chain	Power offset measured by coaxial cable experiment
Frequency Resolution	Integration over a specific band
Sweep time	Averaging and resample
Reference determination	(Weighted) mean of all devices



Thank you!

Q&A

- More info
  - http://www.crew-project.eu/
  - Contact for information:

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