

# Evaluation of Energy-based Spectrum Sensing Algorithm for Vehicular Networks

Catalin Lacatus, Rama Vuyyuru, Onur Altintas  
Toyota InfoTechnology Center

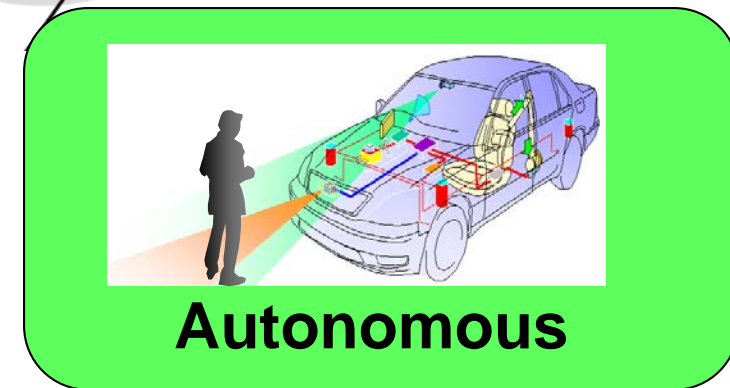
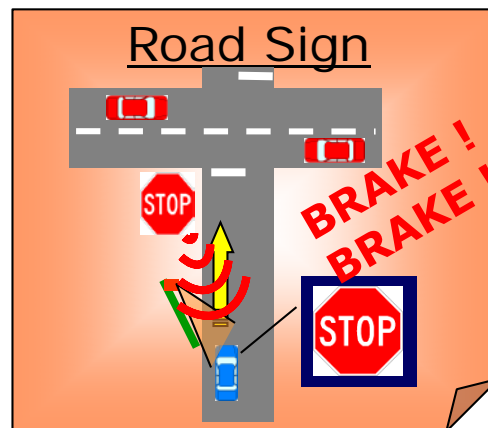
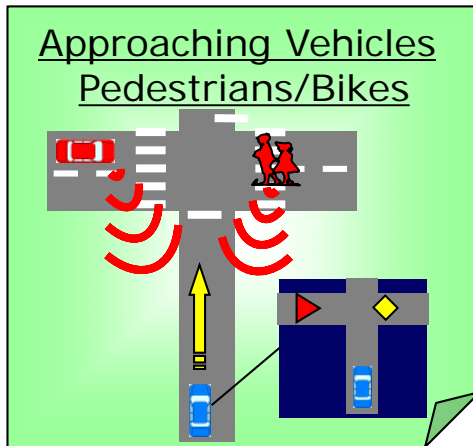
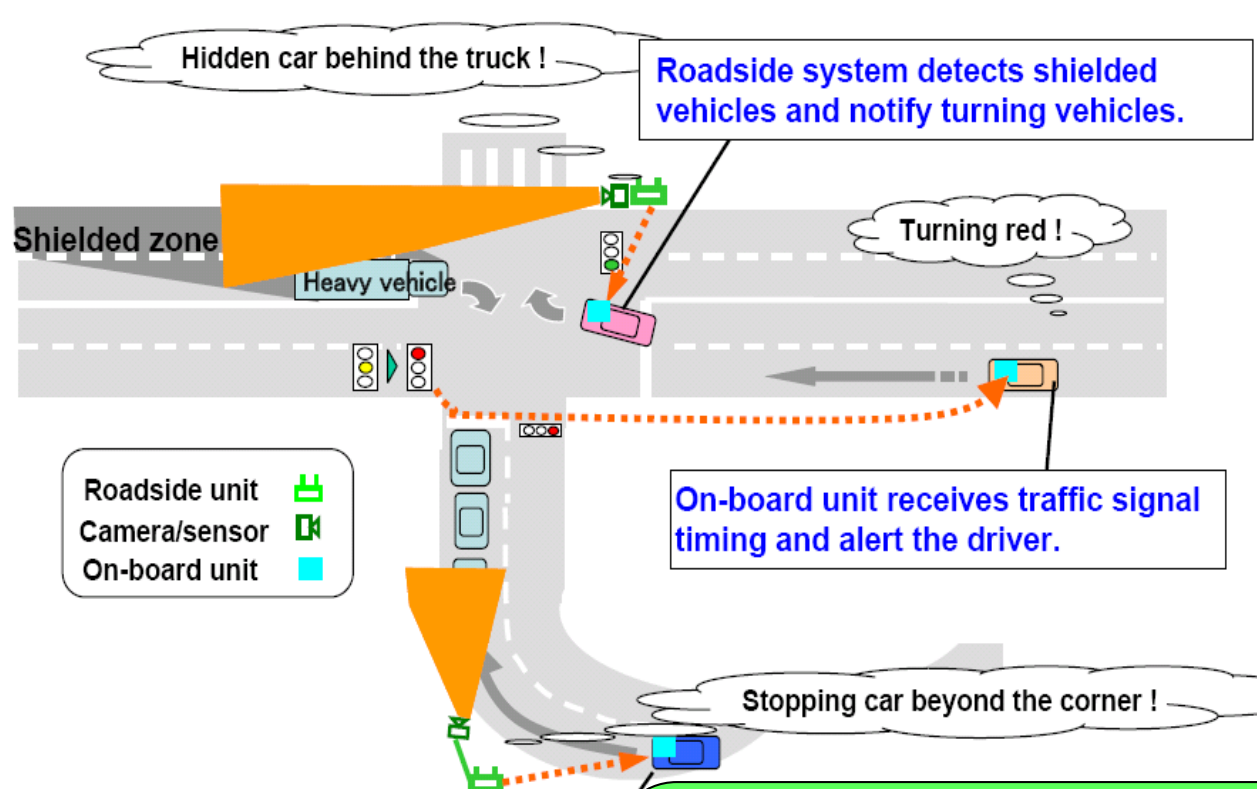
Dusan Borota, Ivan Seskar  
WINLAB, Rutgers University

# Outline

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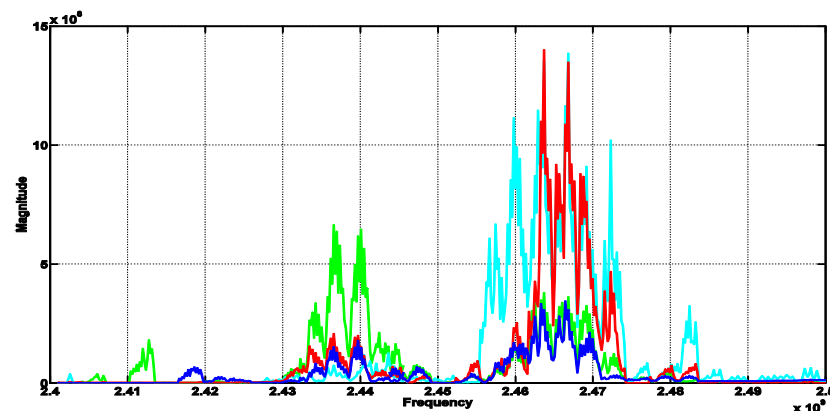
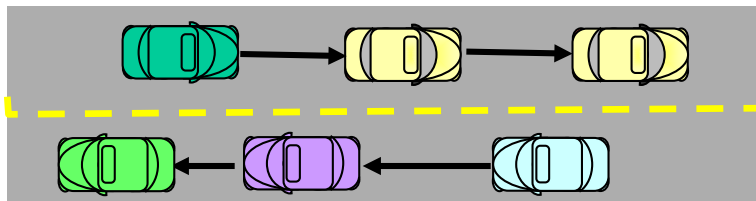
- Introduction
- System configuration
  - ORBIT testbed
- Energy detection algorithm
- Sensing performance evaluation
  - Experimental results
- Conclusion

# Vehicular communication networks



# Spectrum sensing for vehicular communications

- Why spectrum sensing for vehicles
  - Spectrum scarcity may be reality due to proliferation of future vehicular applications
  - Spectrum management in real time to enable reliable communications
- Mobility factor in spectrum sensing
  - Short sensing and detection time
  - Highly mobile environment
  - Channel variance in outdoor environment
  - Need for collaboration
    - All nodes need to understand which channel to transmit or listen when necessary

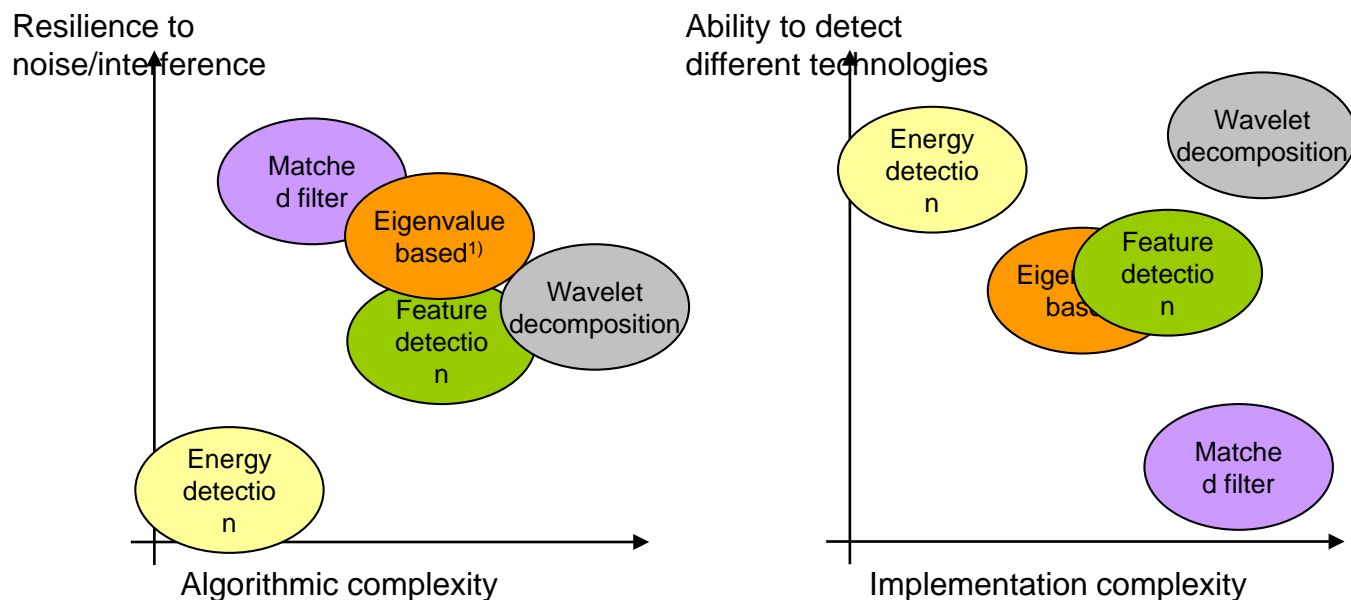


# Evaluation of energy based spectrum sensing algorithm

- Contribution in this paper
  - Simple multi-resolution spectrum sensing algorithm for detecting wide-band signals.
    - The wideband energy detector essentially computes a running average of the signal power over a window of pre-specified band.
  - Experimental validation of proposed spectrum sensing algorithm by using USRP-1 and GNU radio software
    - Experiments using multiple sensors and transmitters to identify significance of location in energy detection algorithm
    - Compare experimentally measured results with spectrum analyzer to further validate results.

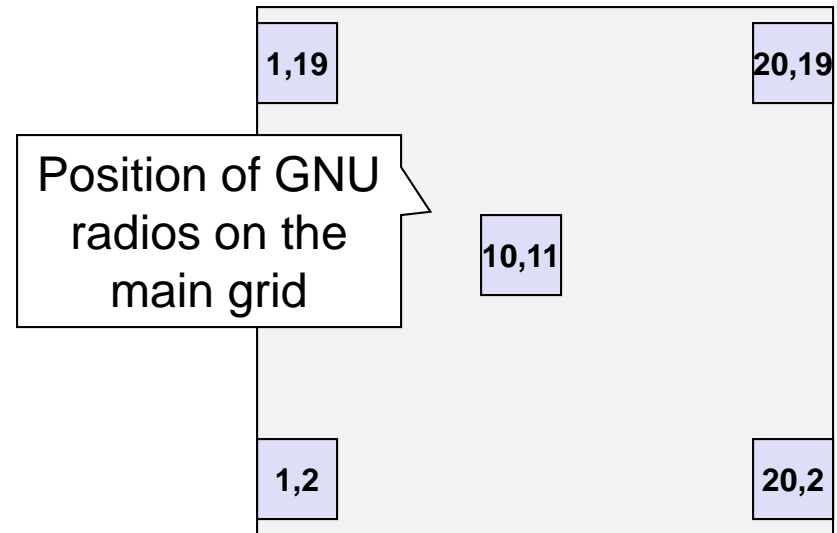
# Energy based spectrum sensing technology

- Why energy detection based algorithm
  - Simple non-coherent processing technique
  - It requires minimum amount of information
  - No prior information about type of sensing signal is required
  - Efficient sensing method for narrowband signals



# System configuration – ORBIT test bed

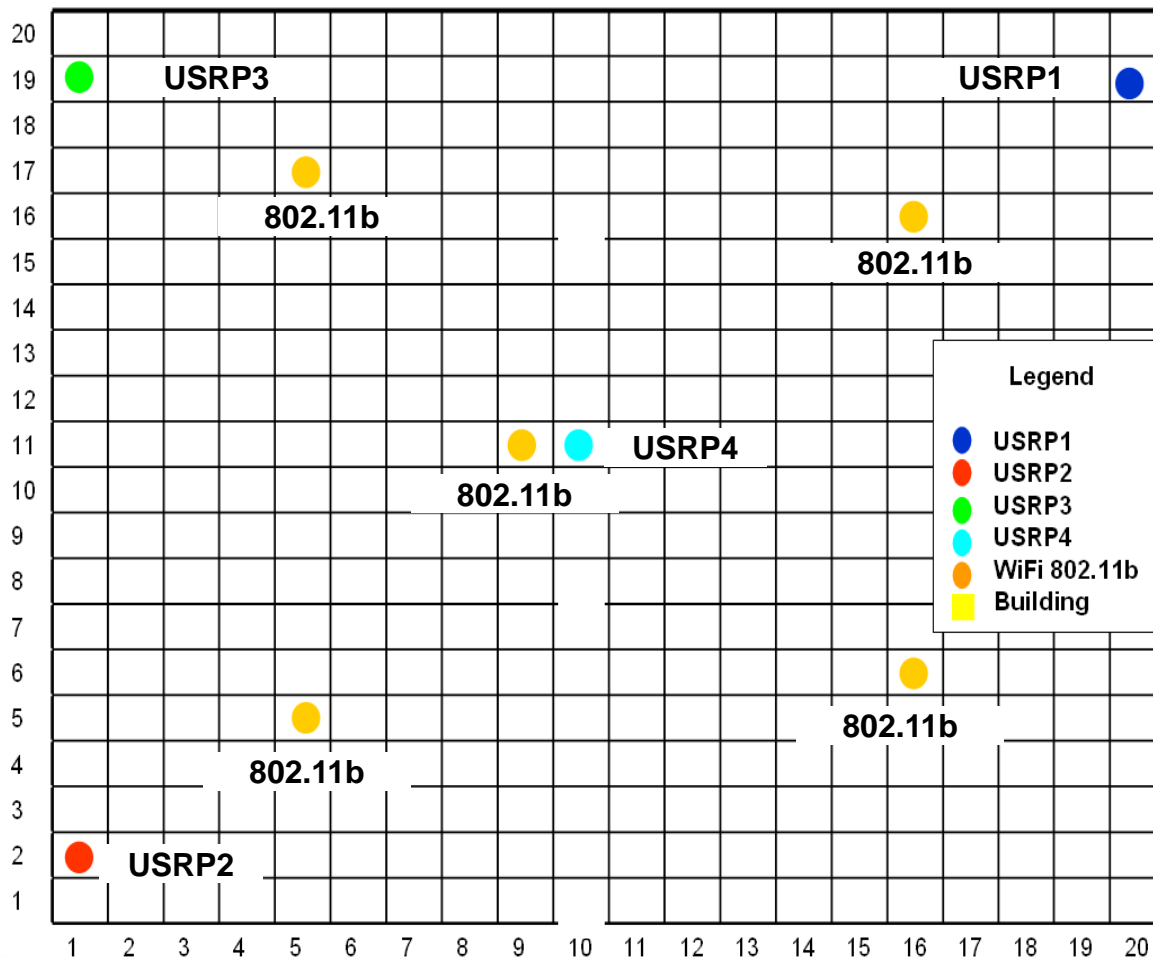
1. Indoor testbed at WINLAB, Rutgers University has 20x20 nodes grid
  - Each node is a PC with two 802.11a/b/g interfaces
  - Recently added few nodes of this grid with USRP-1 nodes.



2. Indoor grid enables experimental evaluation of coexistence of different communication systems and protocols.
3. In the future is planned to add more software defined radios for large scale cognitive networks experiments.

# System configuration –USRP nodes

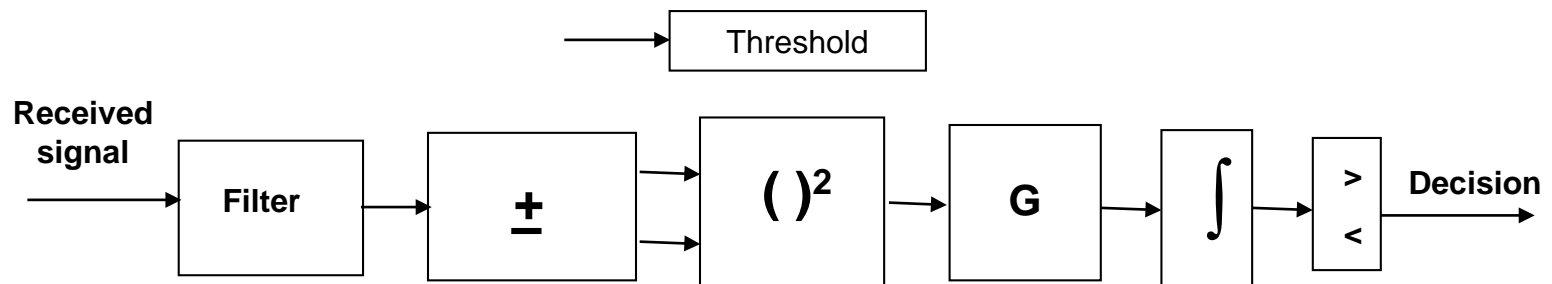
- USRP on ORBIT
  - 4 USRP-1 nodes and 5 802.11b transmitters used in this experiment.





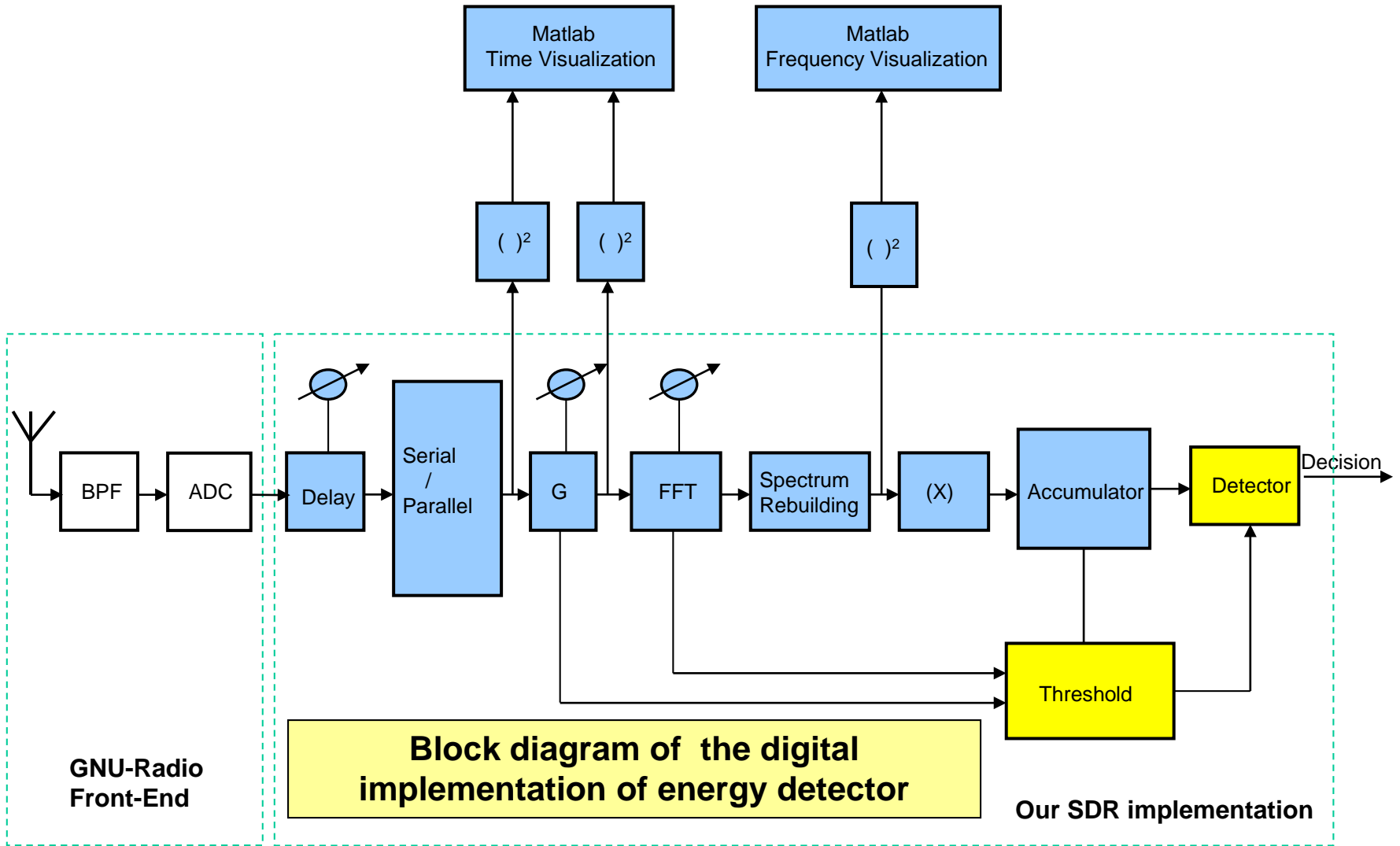
# Energy detection algorithm

- The energy detector essentially computes a running average of the signal power over a window of pre-specified band.
- Spectrum band (2.4-2.5 GHz) will be scanned with steps of 3 MHz to limit the amount of information (< 100Mbps) between USRP-1 and host computer.
- The frequency domain transform will be used as a zooming technique for finding spectrum holes with a small granularity.



The block diagram of the Energy Detector

## Energy detection algorithm Detailed implementation



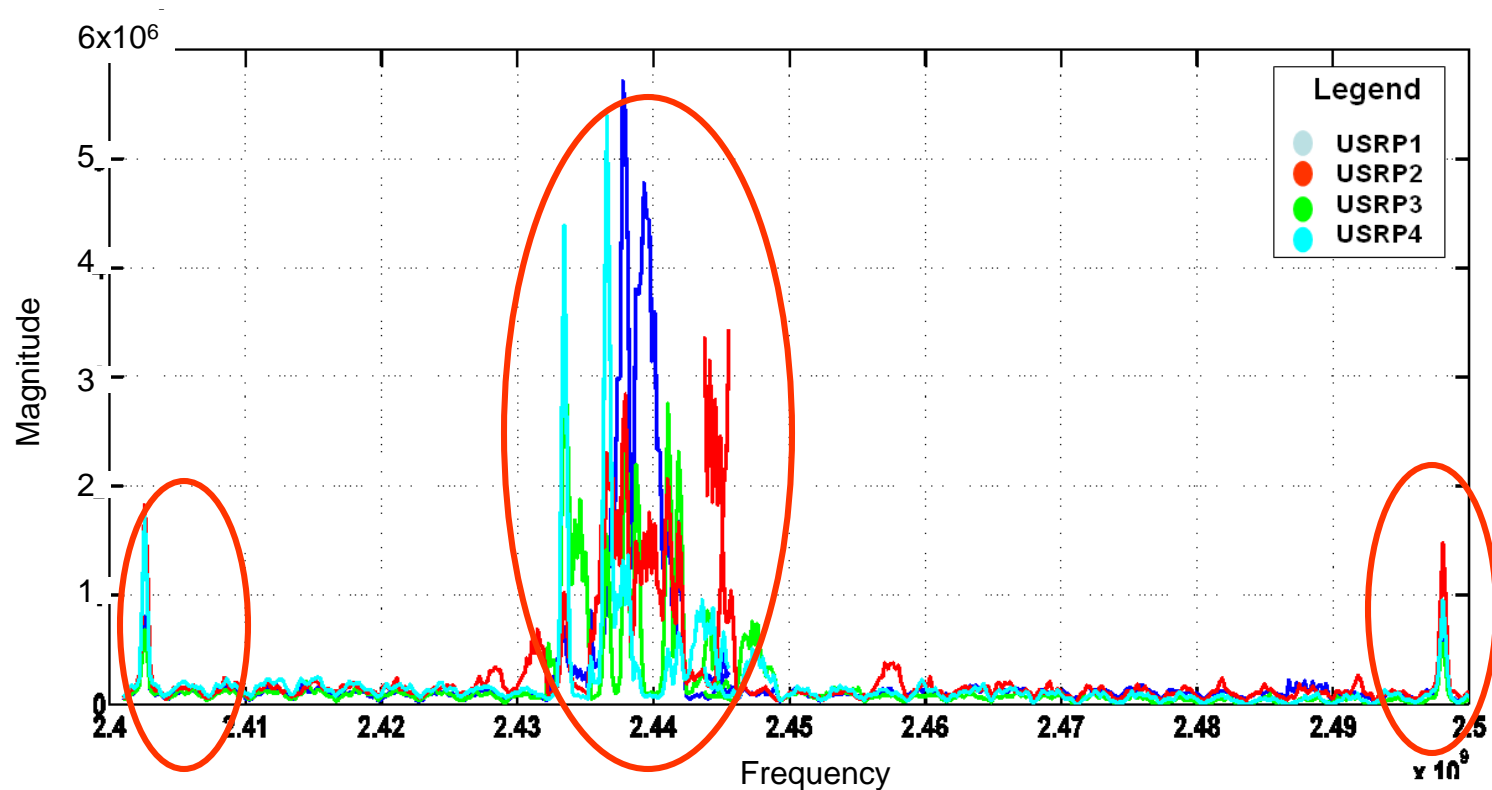
# Energy detection algorithm

- Algorithm

1. The time samples are passed through a delay block for compensating the receiver block delays;
2. The serial samples from output of delay block are passed through a serial/parallel converter that provide blocks of samples that matches with the FFT dimension;
3. The sample data is passed through the FFT block for frequency analyze; FFT is used as a zooming technique with the granularity of band over FFT dimension;
4. The spectrum rebuilding block is needed for removing the mirror effect introduced by FFT block;
5. The complex data from spectrum rebuilding block is passed in real domain by using a dot product operation;
6. The real information is averaged over multiple FFT blocks in order to remove some short period interference;
7. Finally the real data is compared with the optimal threshold for tacking the decision of spectrum availability.

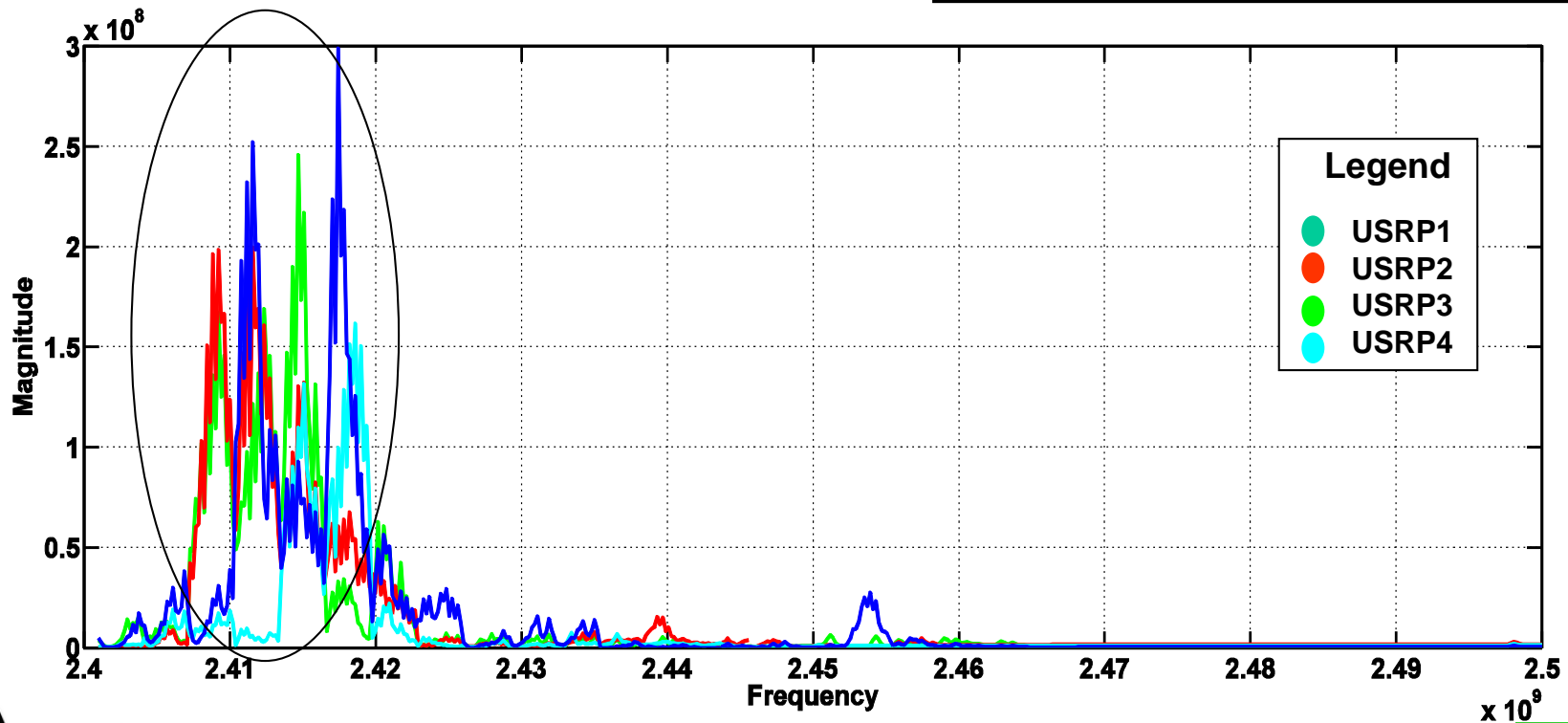
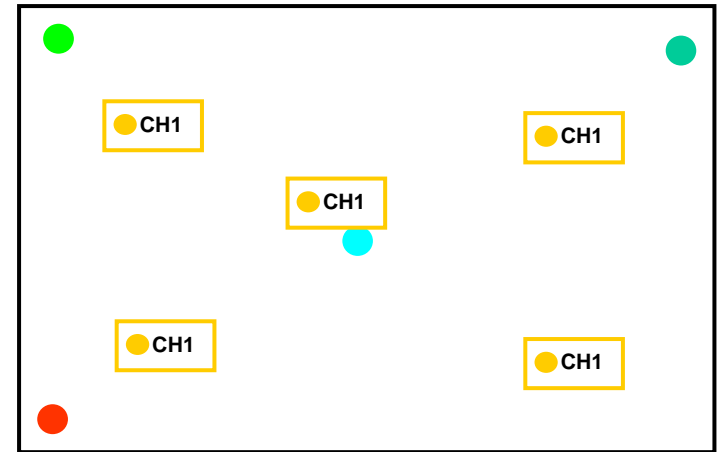
# Sensing performance evaluation

- No external transmissions from our experiment
  - Determine noise level in current environment



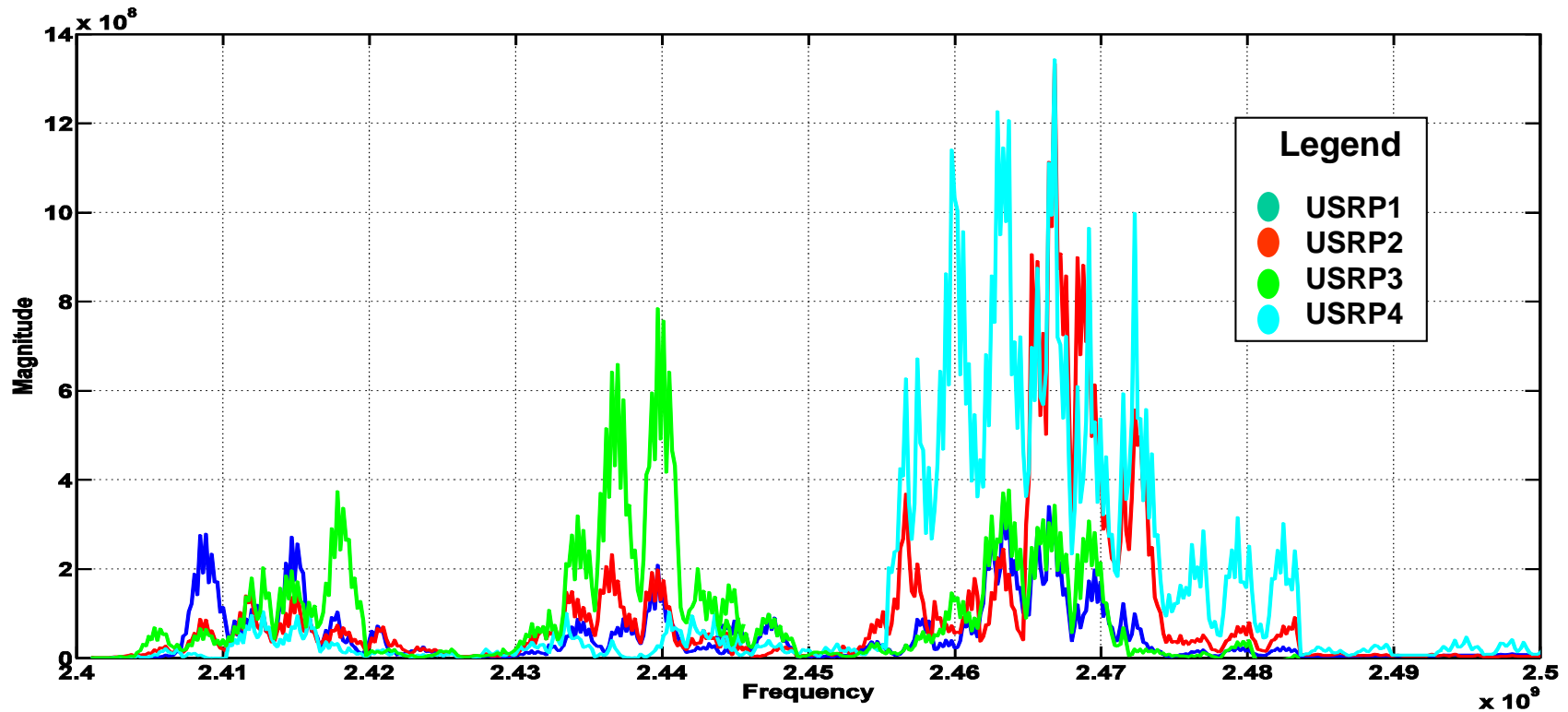
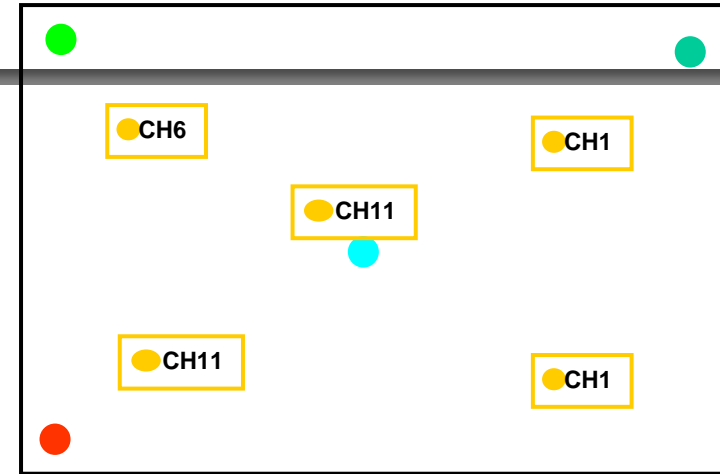
# Sensing performance evaluation

- Transmission on channel 1
  - 5 Transmitters on same channel



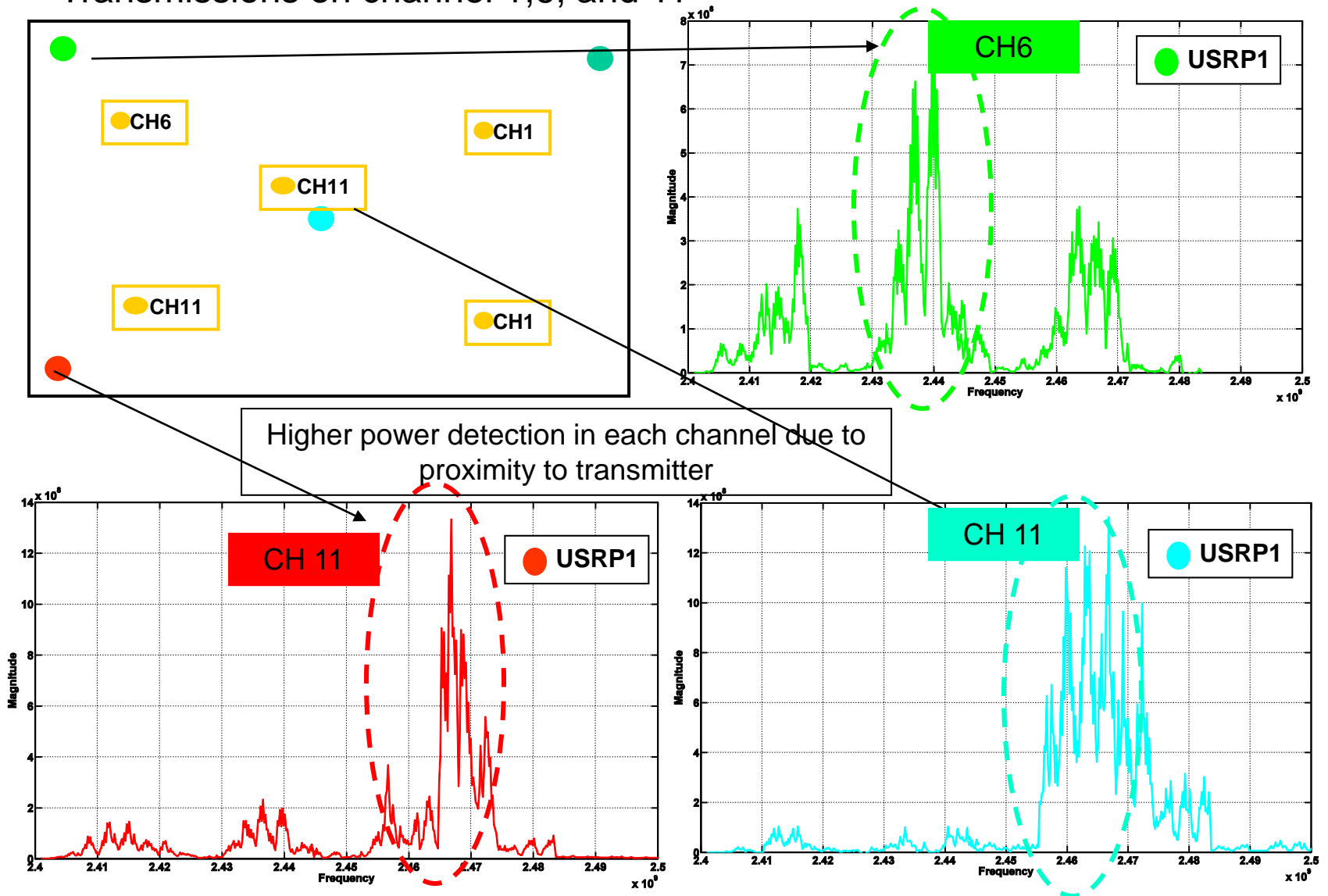
# Sensing performance evaluation

- Transmissions on channel 1,6, and 11



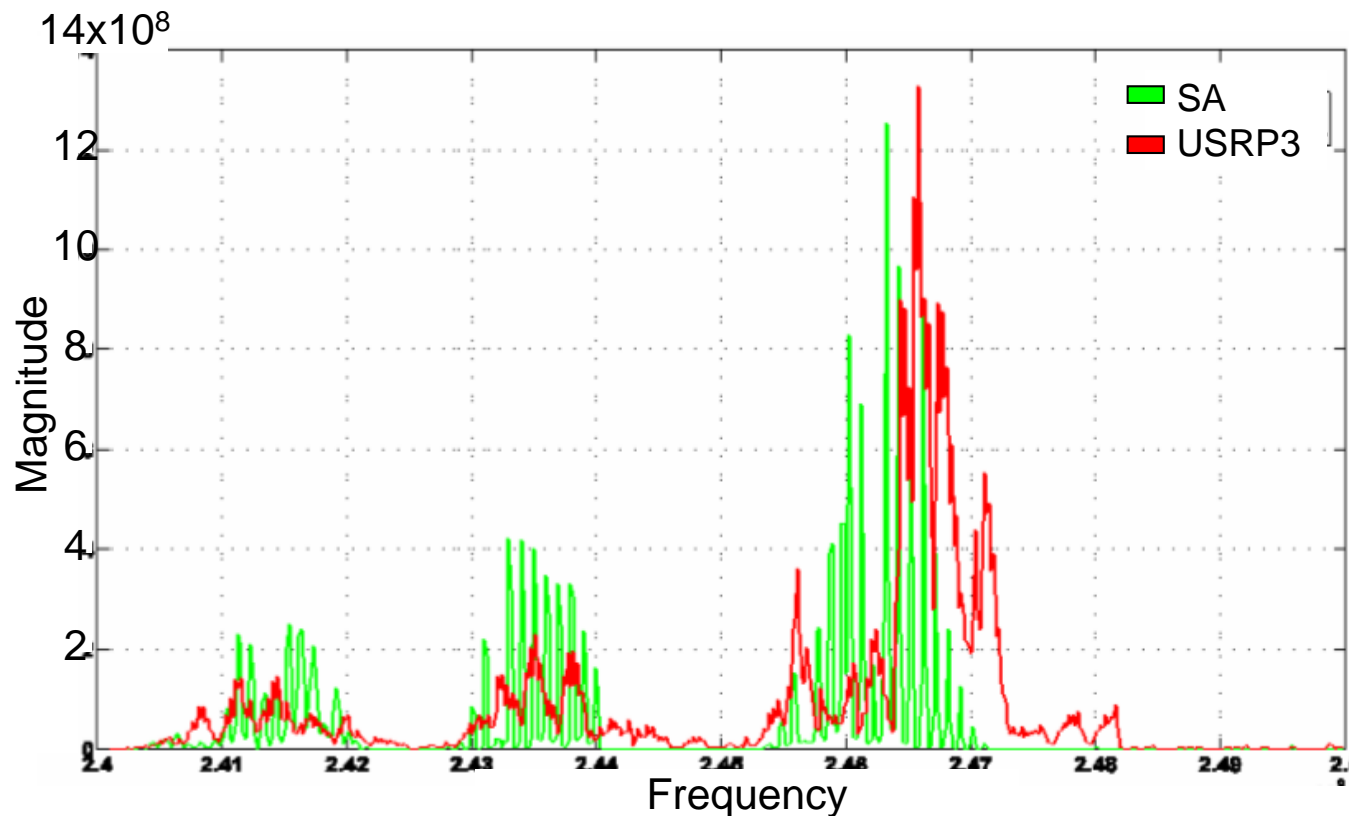
# Sensing performance evaluation

- Transmissions on channel 1, 6, and 11



# Sensing performance evaluation

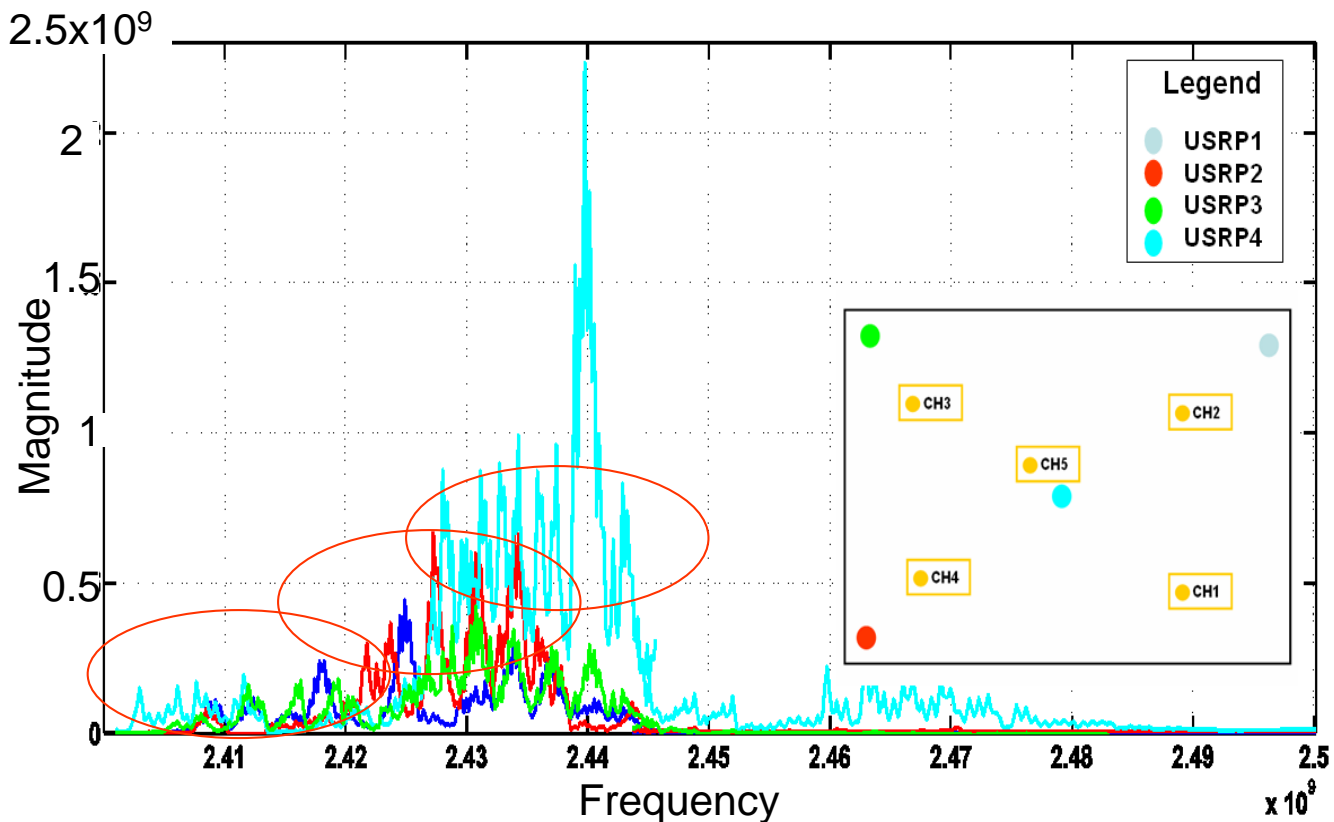
- Comparison with spectrum analyzer measurements
  - Measurements from spectrum analyzer matched with results from sensor.





# Sensing performance evaluation

- Channels 1,2,3,4 and 5 transmissions
  - All 5 channels detected but channel 4 and 5 seems to be transmitting at higher power
  - Need for sensing with different thresholds and smaller resolution required in diverse situations



# Conclusions

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- We have proposed and implemented a multi-resolution energy detection algorithm for sensing wideband channels .
  - This approach can reduce the amount of computation and sensing time significantly.
- The experiments we have performed revealed practical aspects that are essential for the development of spectrum sensing methods for vehicular dynamic spectrum access systems.
  - Different levels of energy is detected based on transmitter location
    - Transmitter and sensor location will impact performance of spectrum sensing algorithm.
  - For vehicular mobility environment it is very challenging to define detection threshold for energy detection algorithms.