GHz Spectrum Acquisition in Realtime

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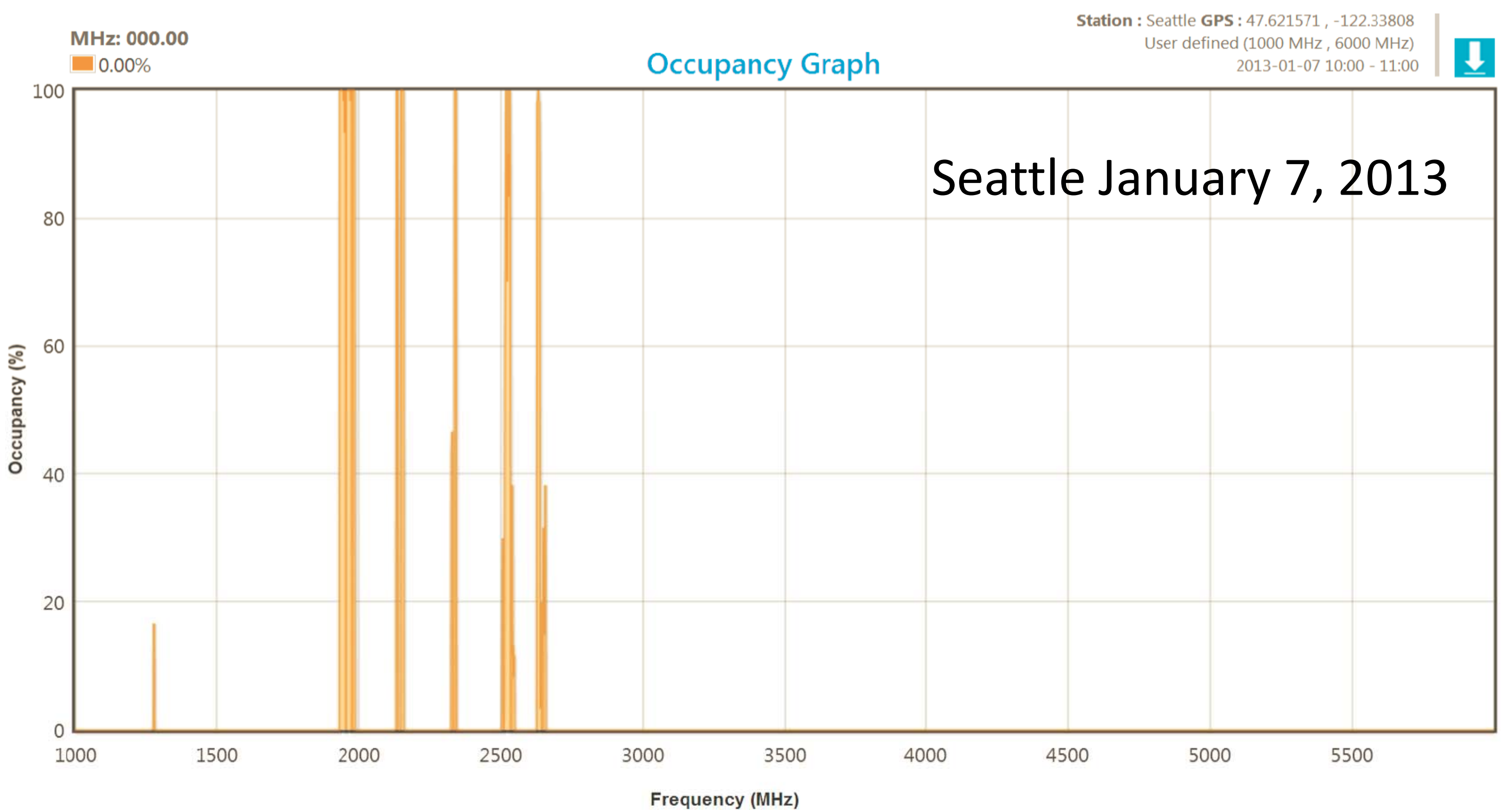
Spectrum Crisis

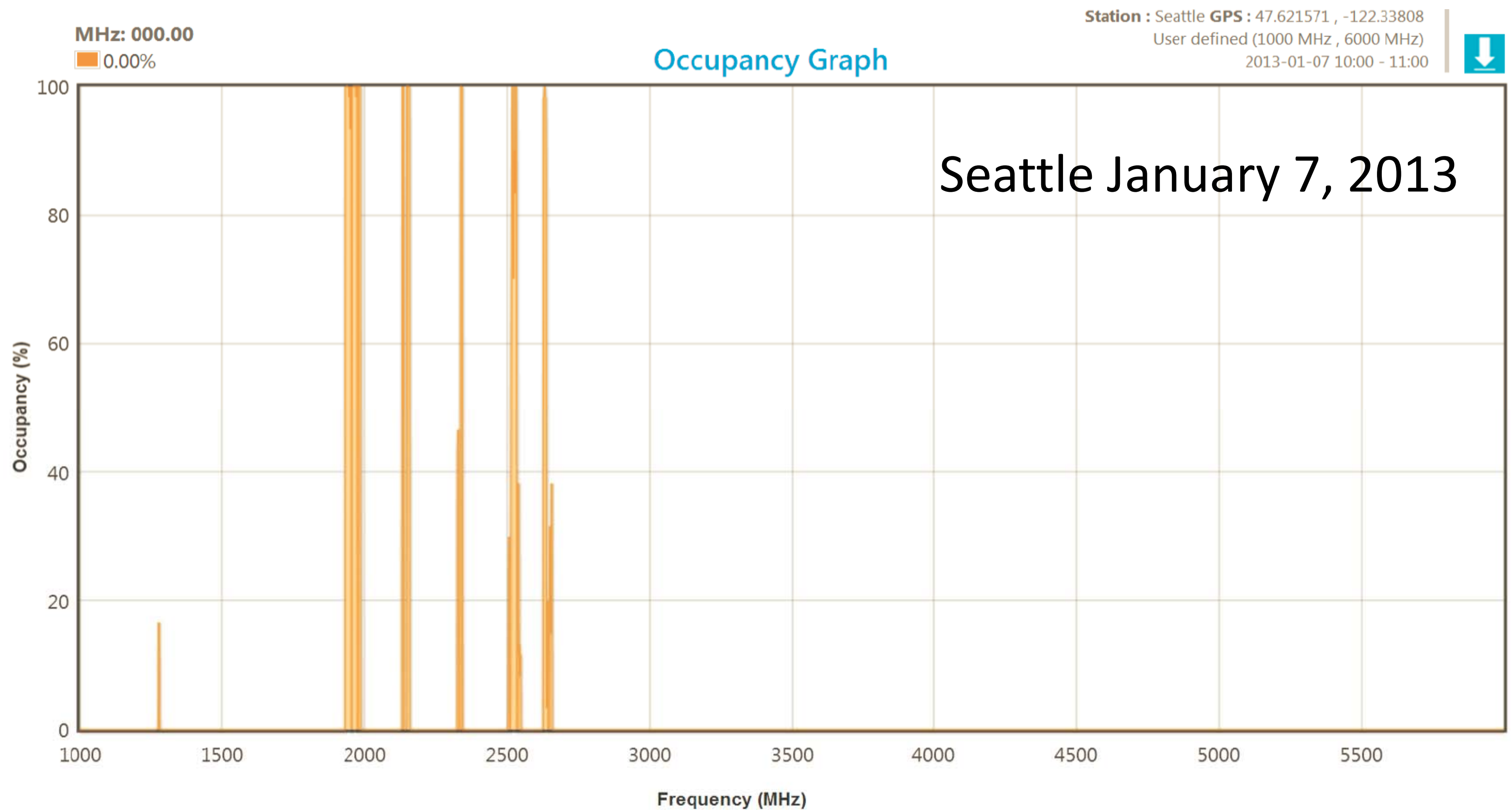
- The FCC predicted a spectrum crunch starting 2013
- But at any time, most of the spectrum is unused



Dynamic Spectrum Access

Sense to find unused bands; Use them!

How do you capture GHz of spectrum?



Realtime GHz Spectrum Sensing is Difficult

- Today, sequential scanning of tens of MHz

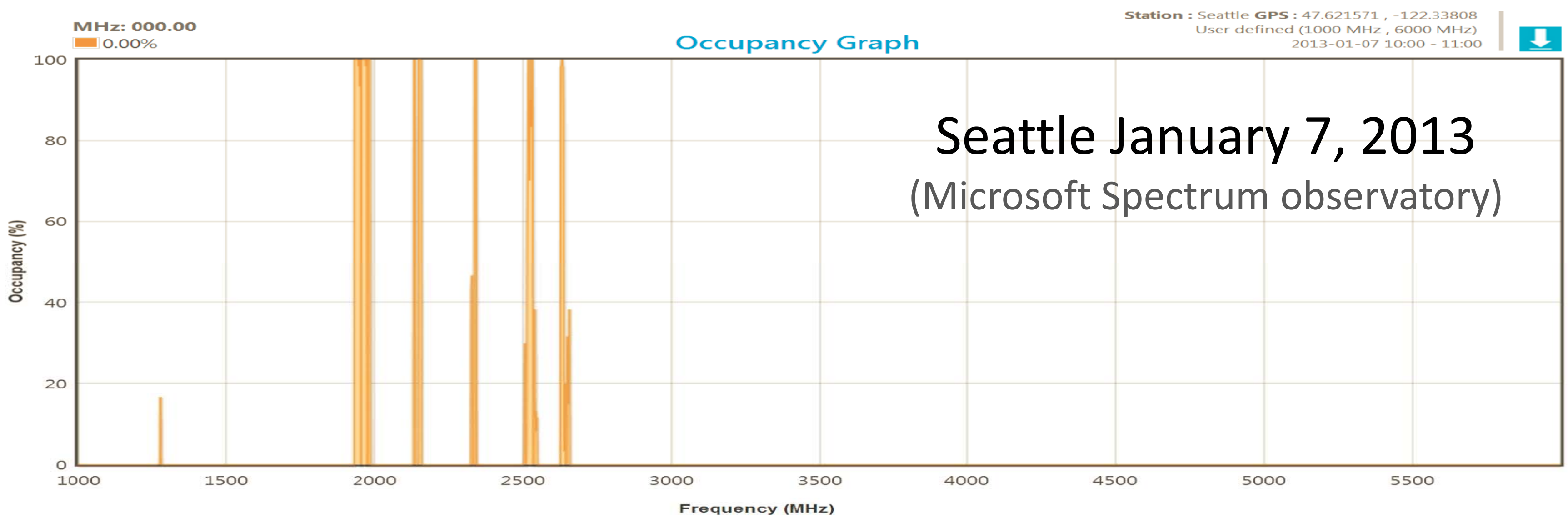
  ➔ Can easily miss radar signals

- Key Challenge: high-speed ADCs

Tens of MHz ADC
Low-power
High resolution
Cheap

A Few GHz ADC
10x more power
Poor resolution
Expensive

<u>Idea:</u> Leverage Sparsity

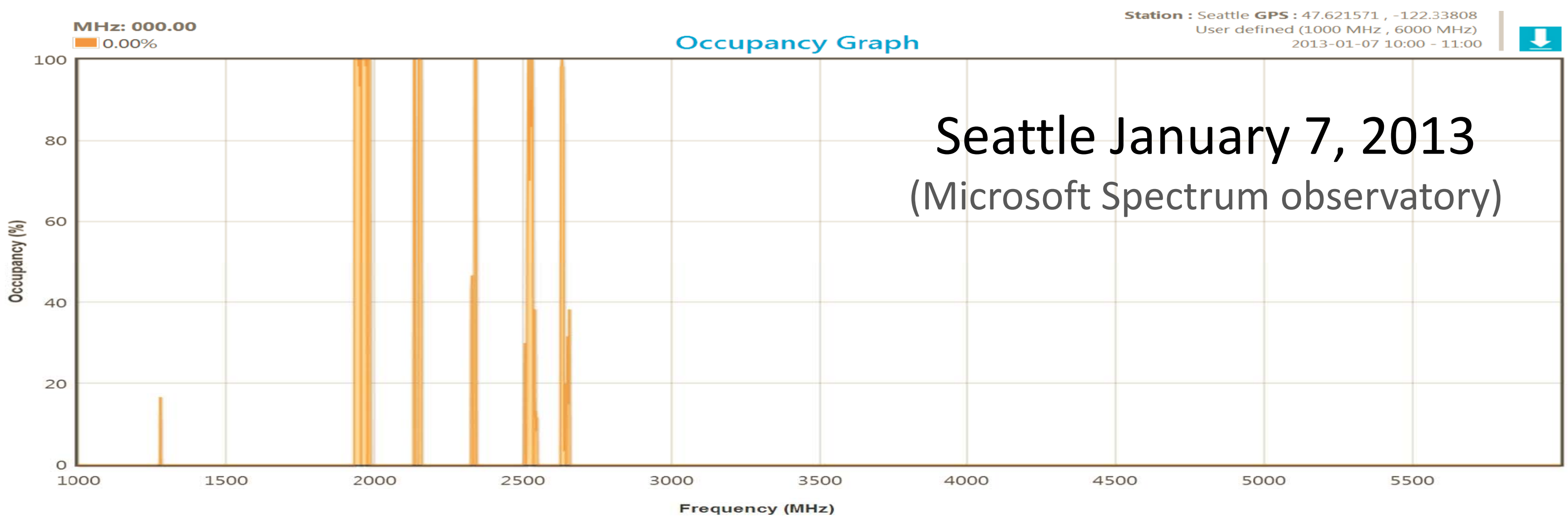


Sparse recovery show that one can acquire sparse signals using sub-Nyquist sampling

Compressive Sensing however is difficulty

- Random sampling → Can't use low-speed ADCs
- Compute million-point FFT → High power

Idea: Leverage Sparsity



Sparse FFT

No random sampling → Use a few low-speed ADCs

Sub-linear algorithm → Computes large FFT cheaply

How Does Sparse FFT Work?

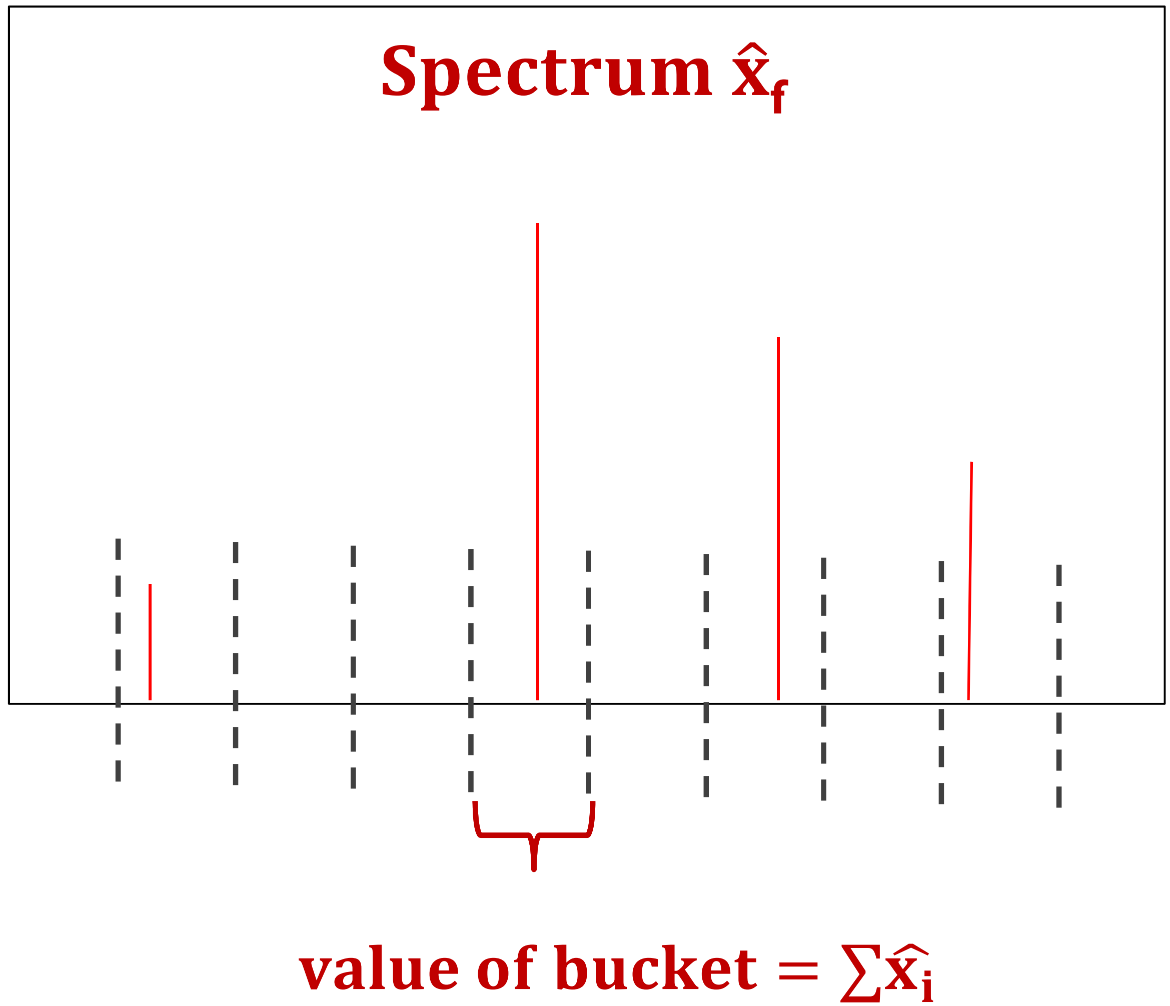
1- Bucketize

Divide spectrum into a few buckets

→ Can ignore empty bucket

2- Estimate

Estimate the large coefficient in each non-empty bucket



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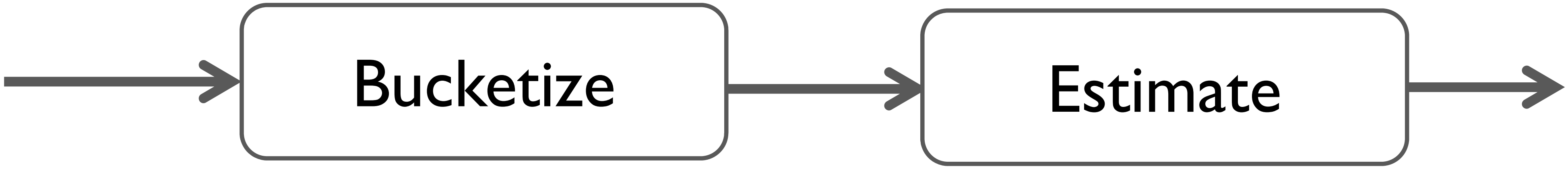

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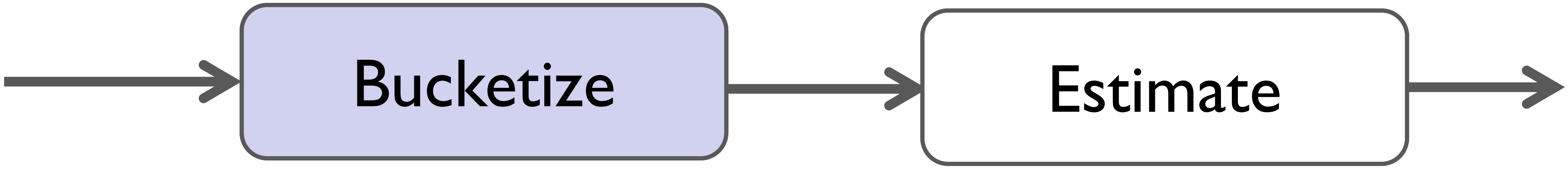
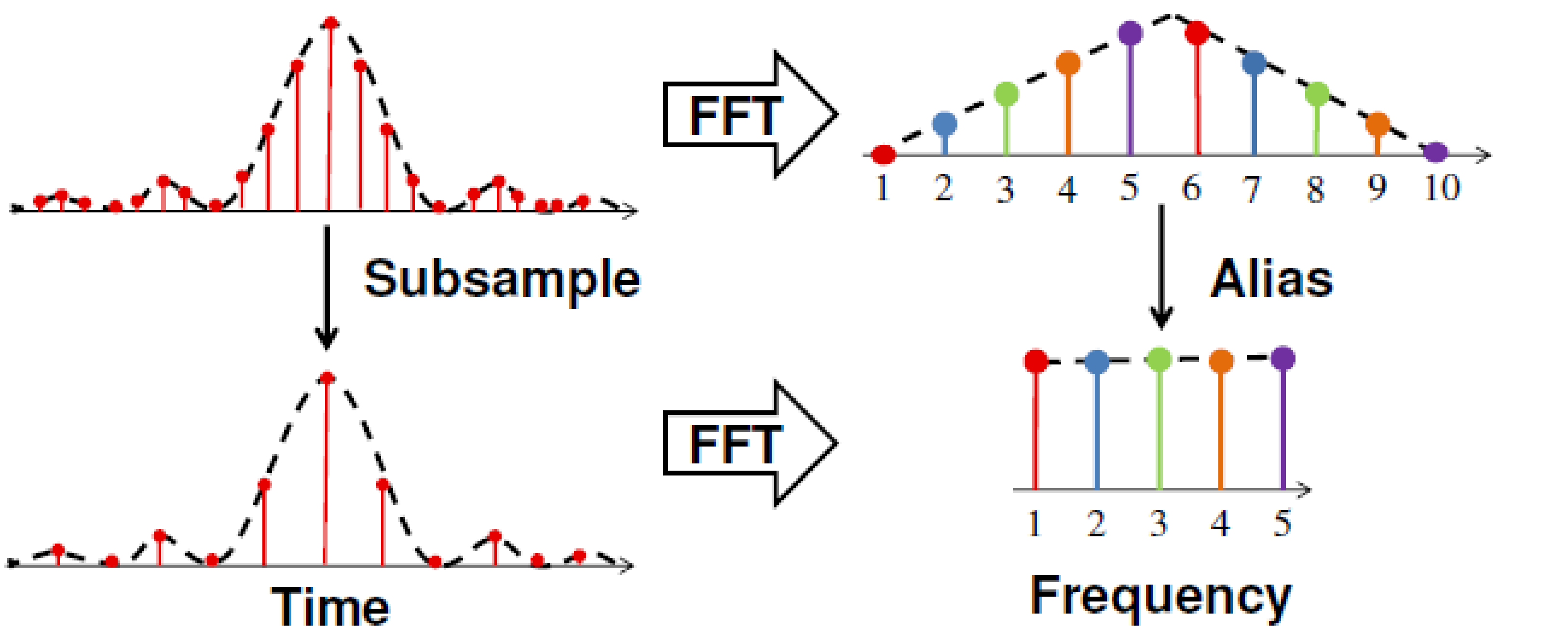


Sub-sampling time ➔ Aliasing the frequencies



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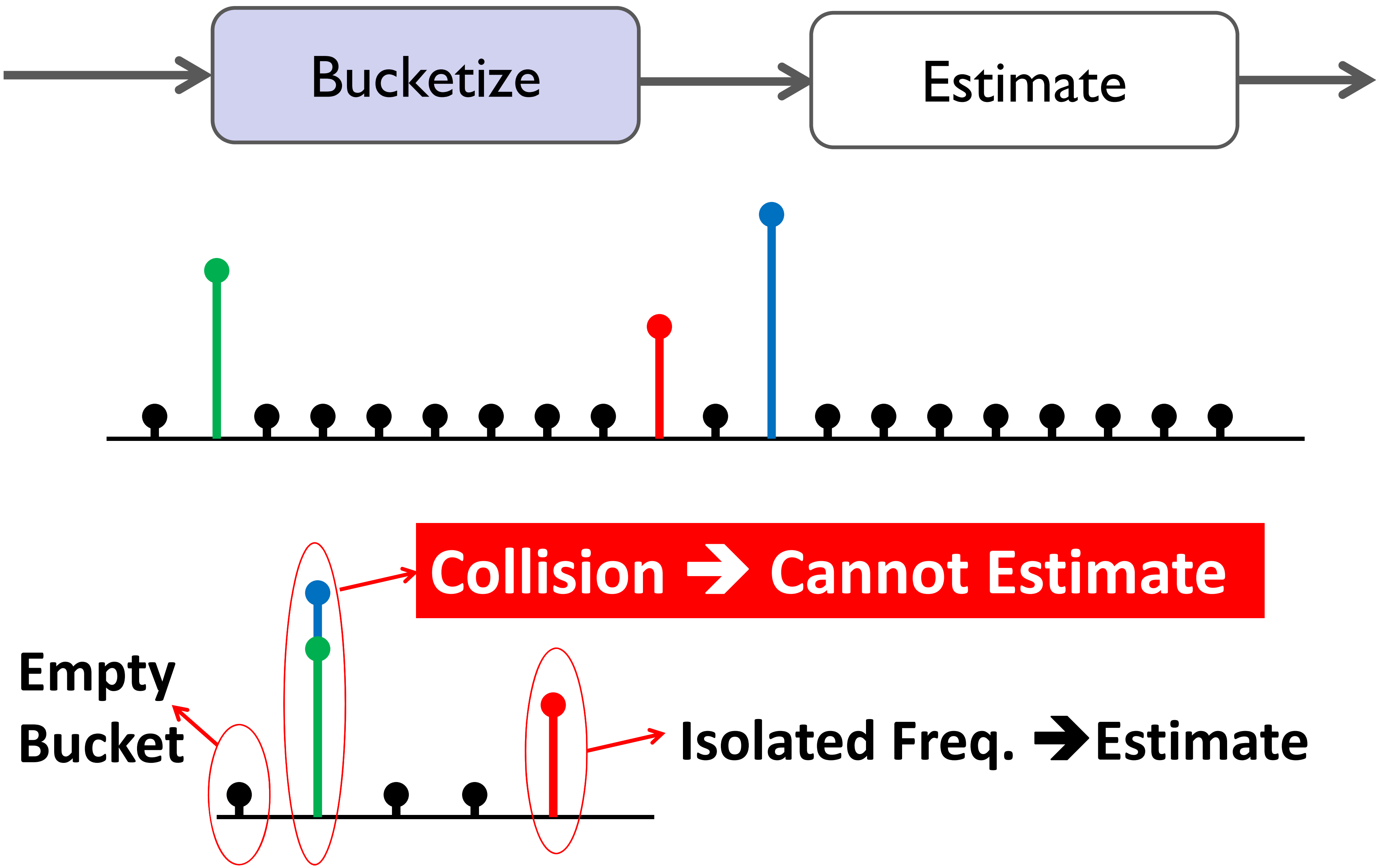

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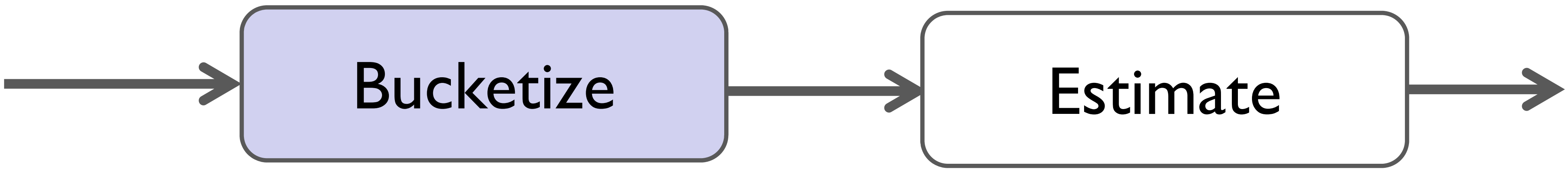
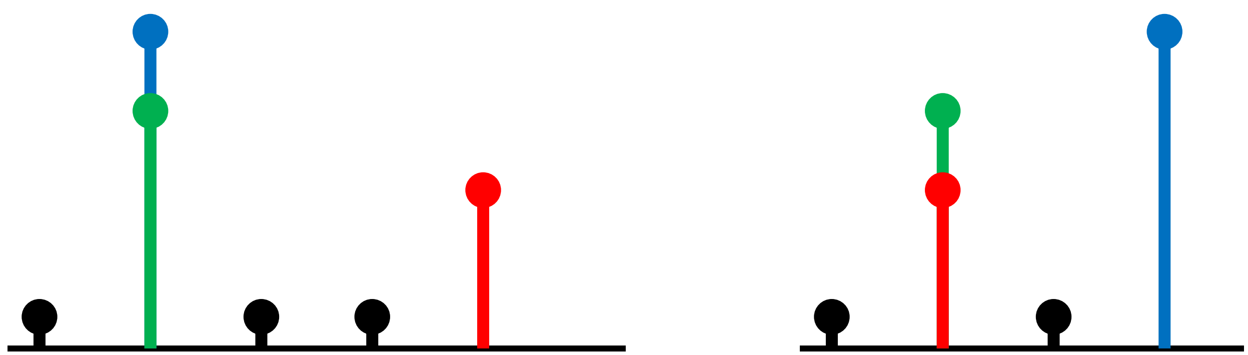


- Bucketize using multiple co-prime aliasing filters
  - Same frequencies don't collide in two filters
- Identify isolated freq. in one filter and subtract them from the other; and iterate …



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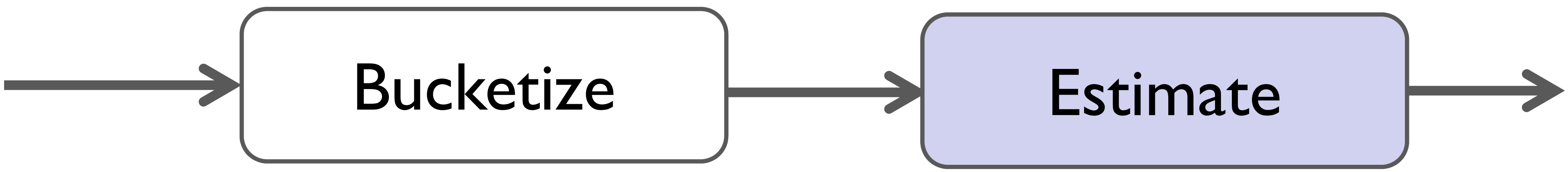


Estimate frequency by repeating the bucketization with a time shift ΔT

$$\Delta Phase = 2\pi f\ \Delta T$$

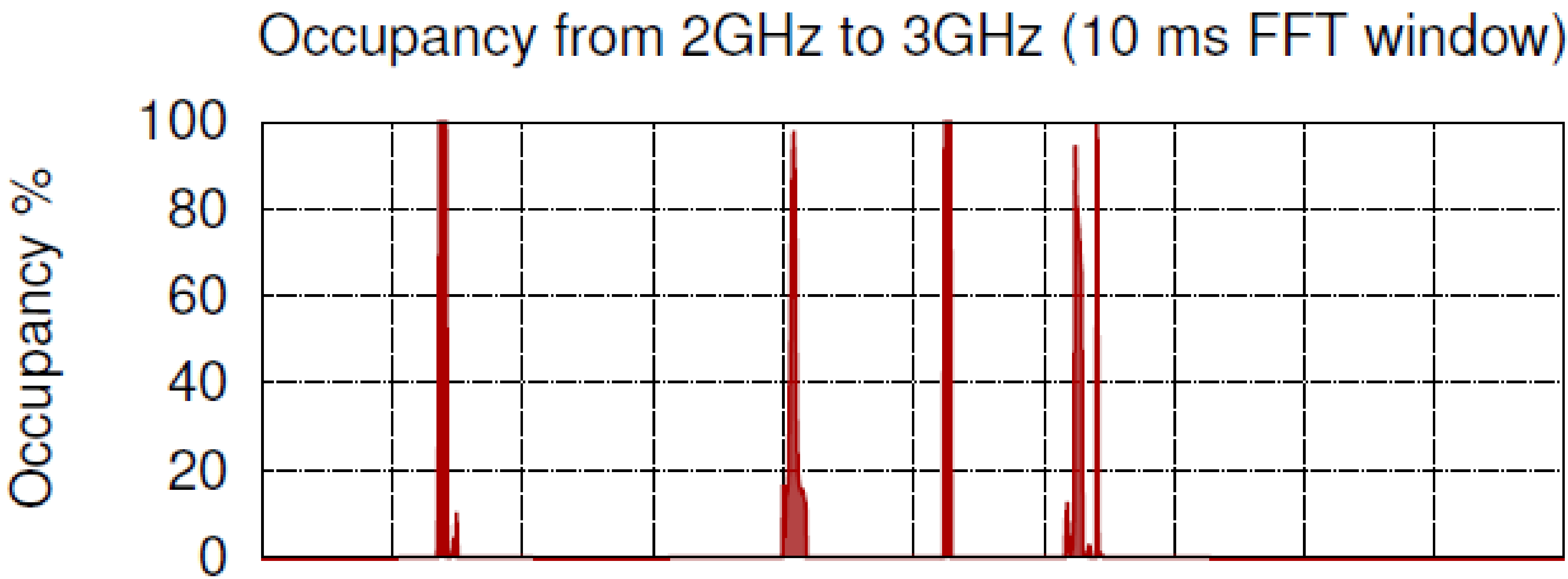
BigBand: GHz Receiver for Sparse Signals

- Sub-sample the data → Can use low-speed ADCs
- Very fast algorithm → Lower-power consumption

- Used sparse FFT to build a GHz receiver from three tens of MHz ADCs
- Both senses and decodes the spectrum

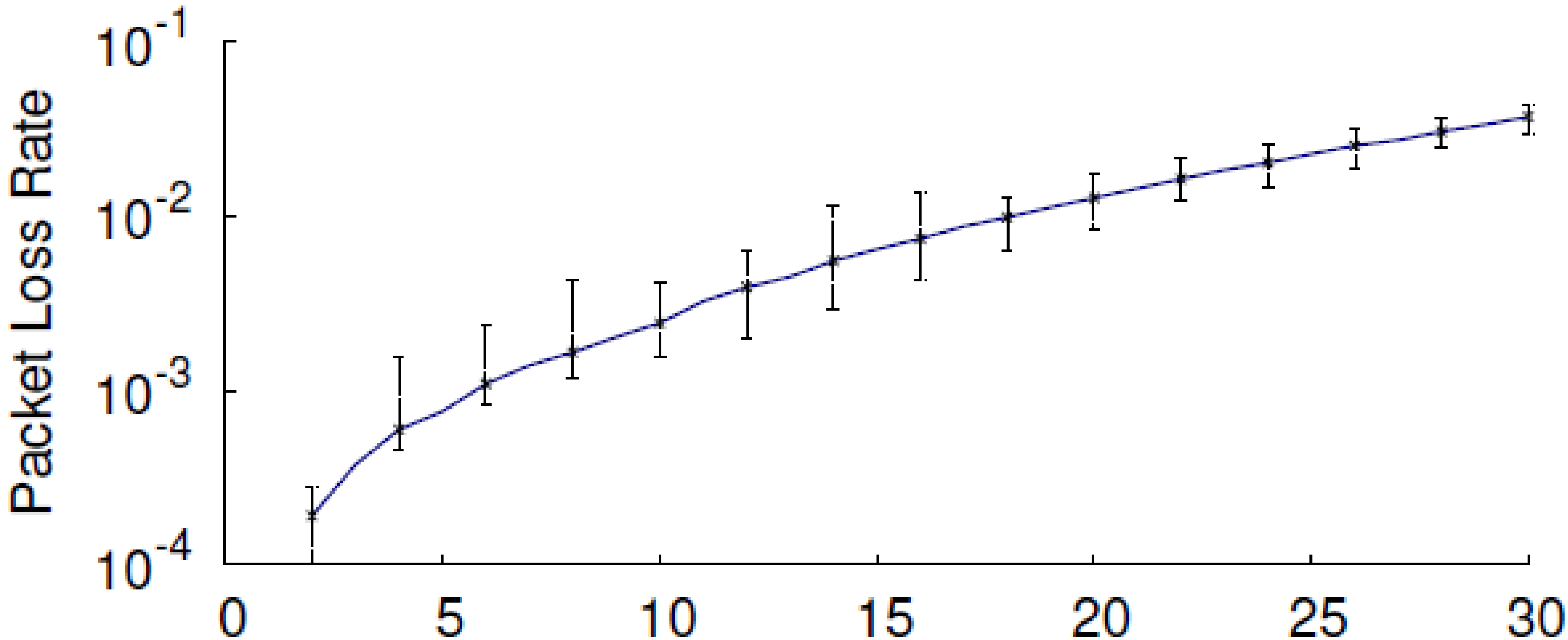
Realtime GHz Spectrum Sensing

Cambridge, MA January 15 2013



3 ADCs with a combined digital Bandwidth of 150 MHz can acquire a GHz

Decoding Senders Randomly Hopping in a GHz



sFFT enables realtime GHz sensing and decoding for low-power portable devices

But, what if the spectrum is not sparse?!

Differential BigBand

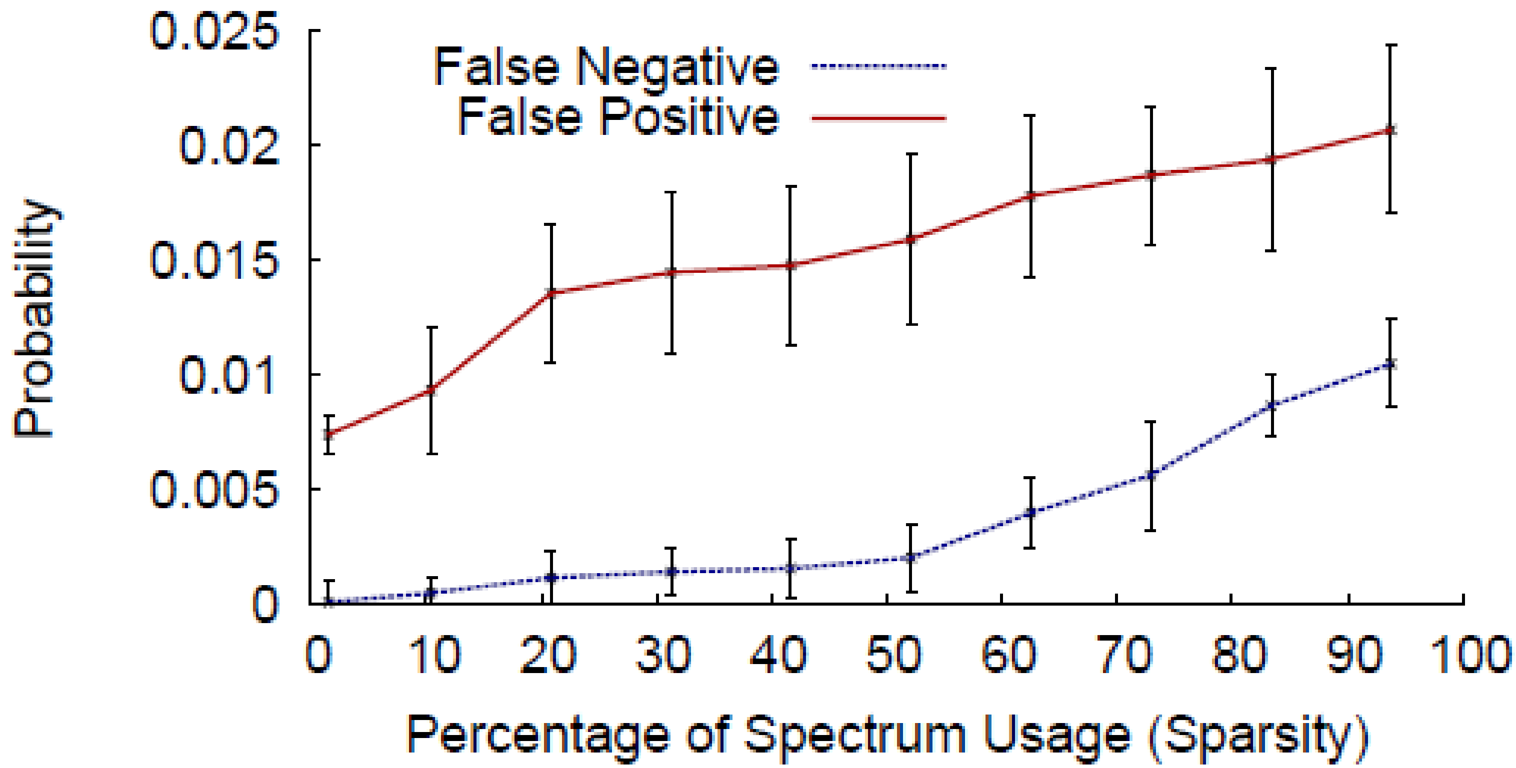
- Even if the spectrum is 100% occupied, changes in occupancy are sparse

  → Apply sFFT to Changes/Diffs

- Can’t subtract signals; operate over power

- Realtime GHz sensing; but no decoding

Sensing Accuracy with Differential BigBand



Can sense the spectrum even when occupancy is very high

Conclusion

- BigBand provides GHz-wide realtime spectrum sensing and decoding using sFFT
- Differential-BigBand provides GHz sensing using sFFT
- Imagine multi-GHz of unlicensed open spectrum operating with carrier sense (a la WiFi)