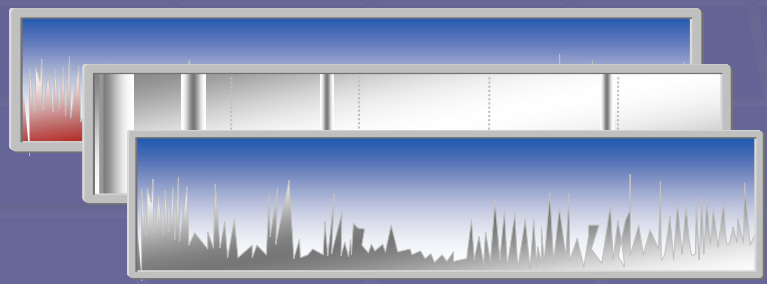
SHARED SPECTRUM COMPANY

Multi-Band, Multi-Location Spectrum Occupancy Measurements



Presentation to:
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The Future of Multimedia Communications
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Outline

- Introduction
  - Support development of dynamic spectrum sharing radio technology
- Measurement locations
- Measurement equipment
- Sample spectrum occupancy data
- Summary data
- Next steps
- Conclusions

SHARED SPECTRUM COMPANY

Introduction

- Shared Spectrum Company conducted a series of spectrum occupancy measurements
  - Initially supported by DARPA, later by NSF
  - Started 2002, latest measurements in Nov 2005
- Goals
  - Prove that there are bands with low occupancy
  - Estimate “whitespace”
  - Determine characteristics of spectrum holes (time and frequency)
- Approach
  - Fixed locations, most with excellent line-of-sight
  - Long-term (hours-days) data collections at most locations
  - Optimized for best sensitivity (vs. revisit rate)
    - Spectrum analyzer with high dynamic range, “band-by-band optimized” pre-selector

Spectrum Measurement Locations

Location	Dates	Purpose
Inside Shared Spectrum Company offices	2/4/2004 2/9/2004 10/28/2004	Test equipment
Outside in Shared Spectrum parking lot	4/6/2004	Urban location
Riverbend Park in Northern Virginia	4/7/2004	Rural location
Tysons Corner shopping center parking lot in Vienna, Virginia	4/9/2004	Urban location
National Science Foundation (NSF) building roof in Arlington, Virginia	4/16/2004	Elevated, urban location
New York City	8/5/2004 8/30/2004	Elevated, urban location
National Radio Astronomy Observatory, Green Bank, West Virginia	10/4/2004	Very quiet, rural location
Shared Spectrum office roof in Vienna, VA	12/15/2004-6/9/2005	Elevated, urban location
IIT Building Roof in Chicago, IL	11/2005	Elevated, urban location

Note 1: Reports available on SSC website (except for Chicago report, which will be on website soon)

Measurement Location Photos (1 of 2)

Tysons Corner shopping center parking lot in Vienna, Virginia


National Science Foundation (NSF) building roof in Arlington, Virginia


Riverbend Park in Northern Virginia

Measurement Locations (2 of 2)

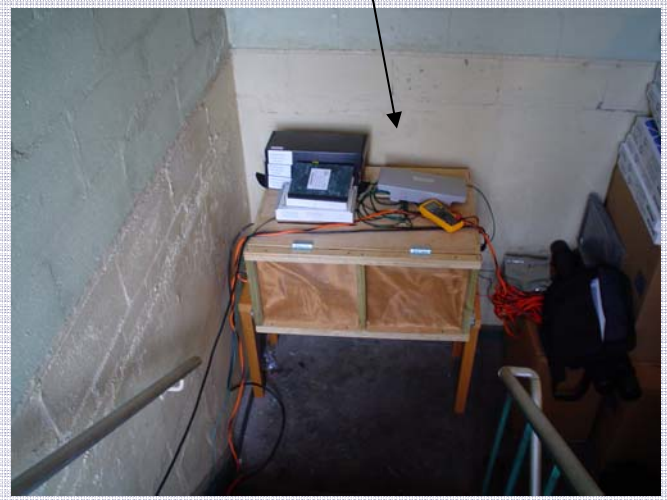
National Radio Astronomy Observatory, Green Bank, West Virginia

Shared Spectrum office roof in Vienna, VA

IIT Building Roof in Chicago, IL

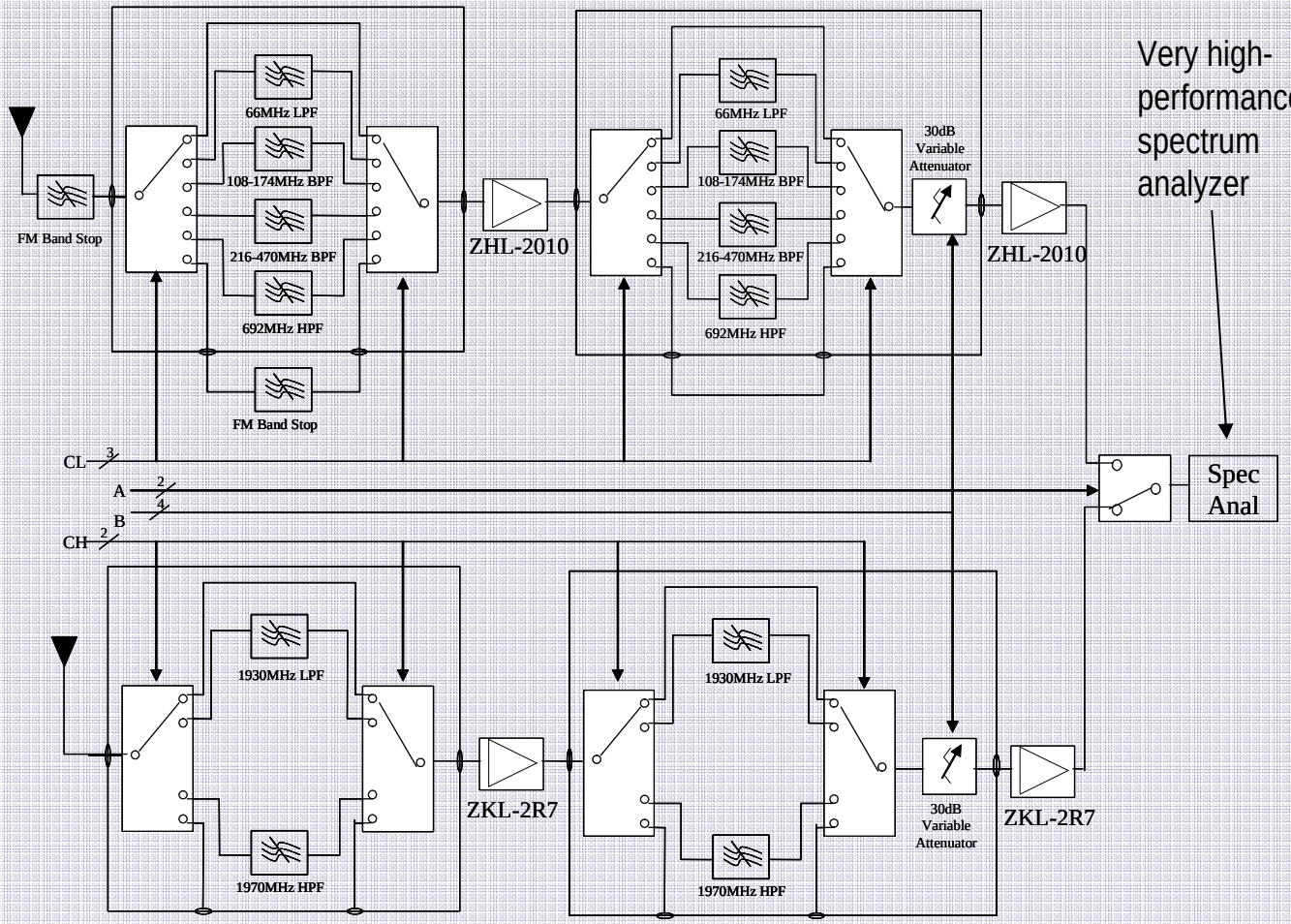
Measurement Equipment

Faraday cage used to reduce undesired collection equipment RF noise

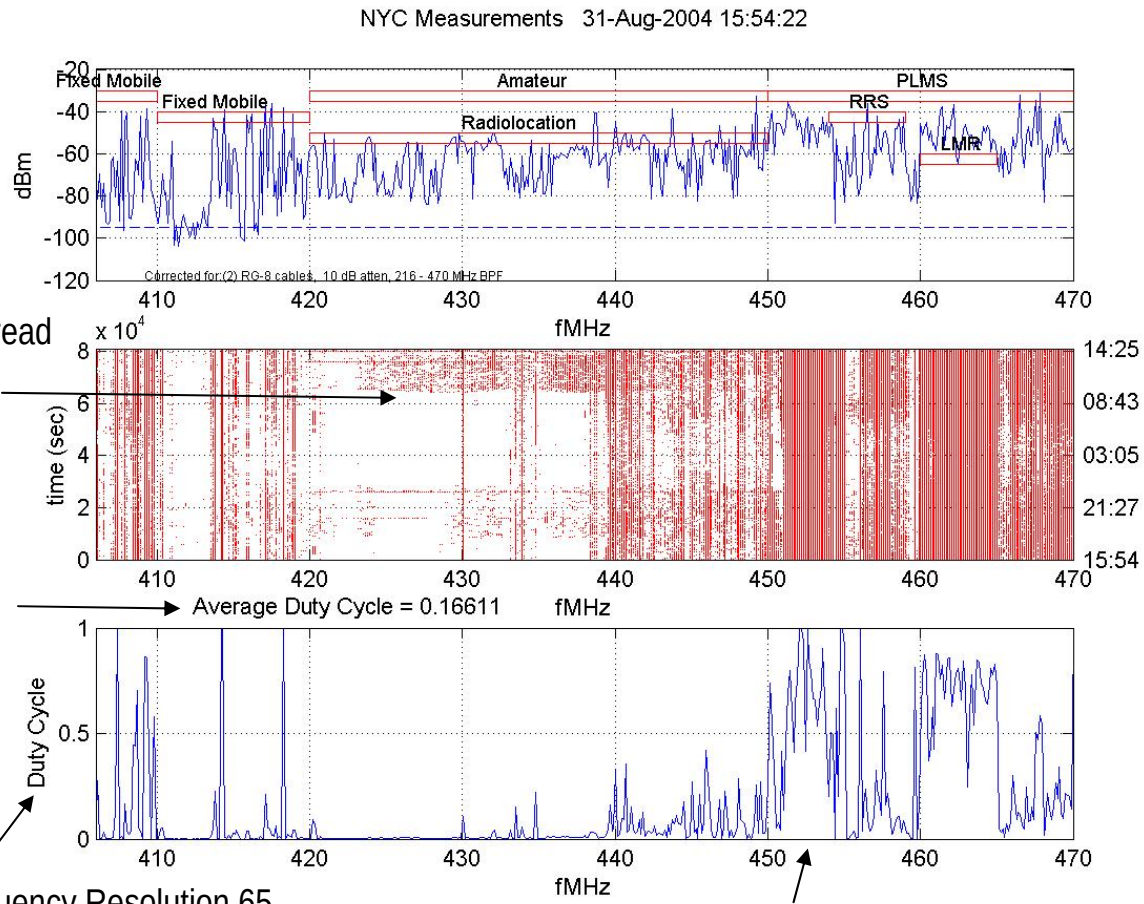


Pre-Selector Provides High Dynamic Range

- Antennas
  - Discone 30-1000 MHz
  - LPA: 1000-3000 MHz
- Filtering and gain used to reject strong signals
  - Computer controlled for each band
- NF ~ 12 dB



High Utilization (Public Safety Band)



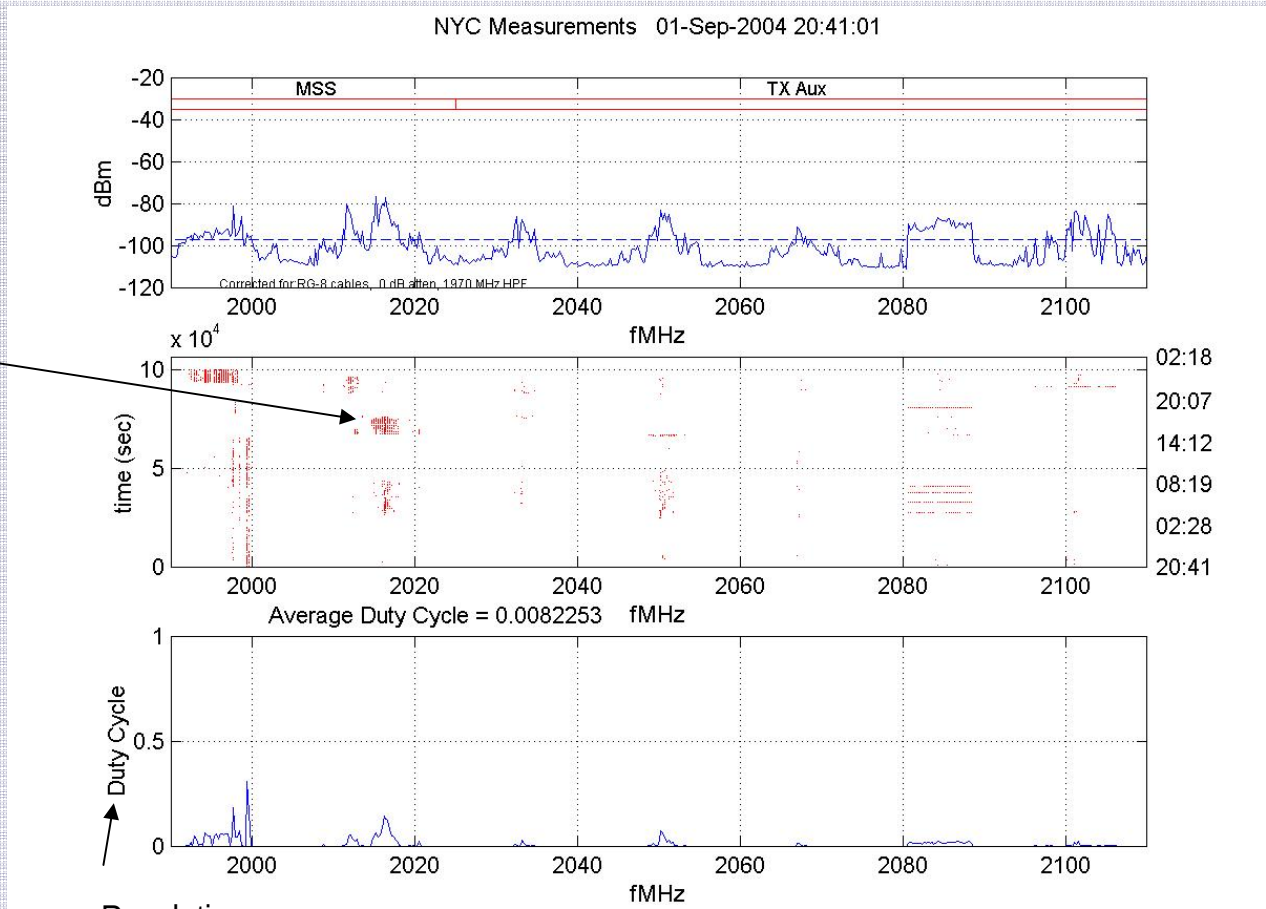
High Bandwidth, Spread Spectrum Signal

17% Duty Cycle

Upper Bound (Frequency Resolution 65 MHz/501=130 kHz/bin)

50% Duty Cycle is too High, 19% Utilization Measured Using Small Frequency Bins (450-455 MHz)

Mid-Level Utilization – TX Aux Band

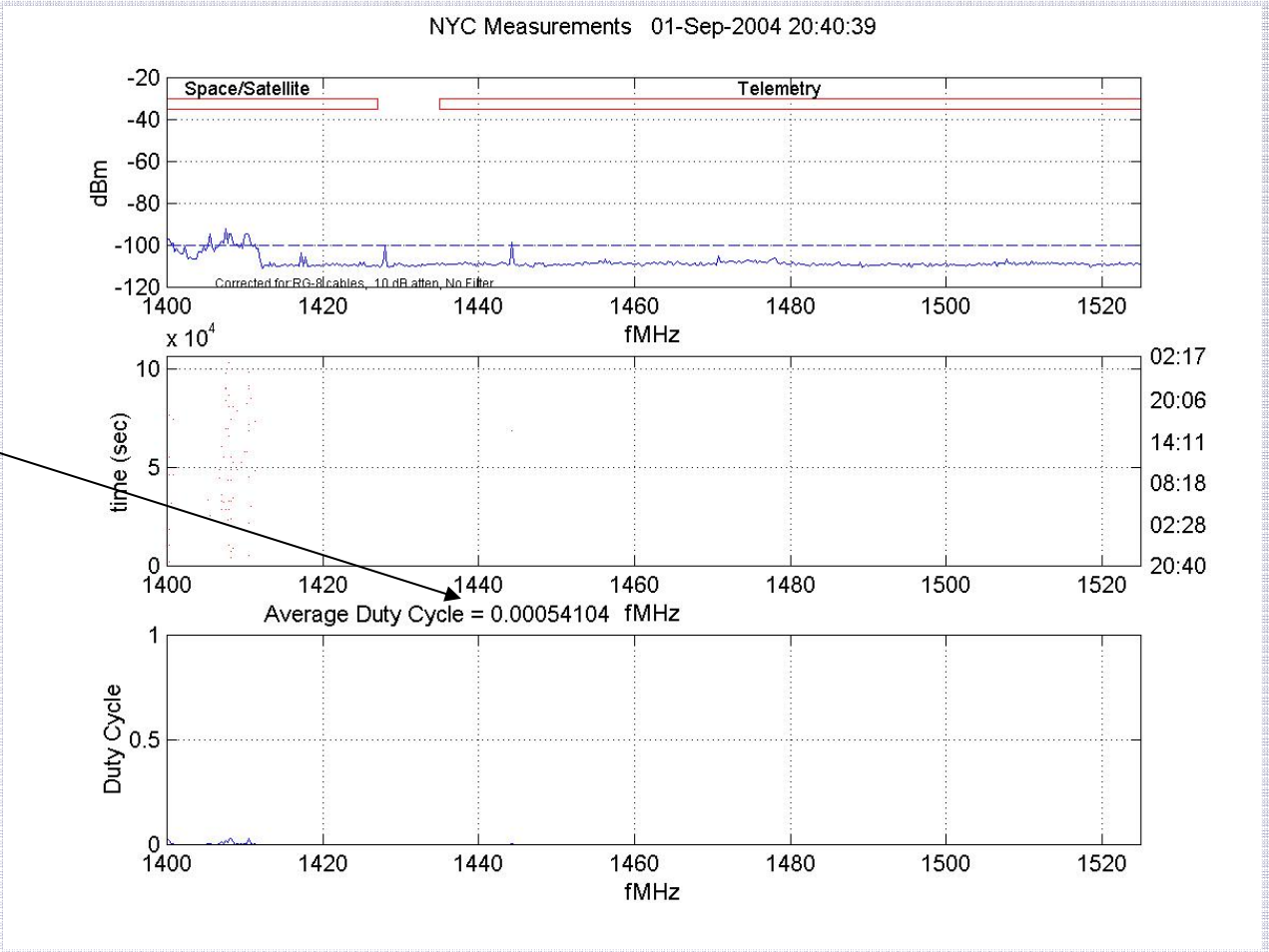


Mobile Video Links

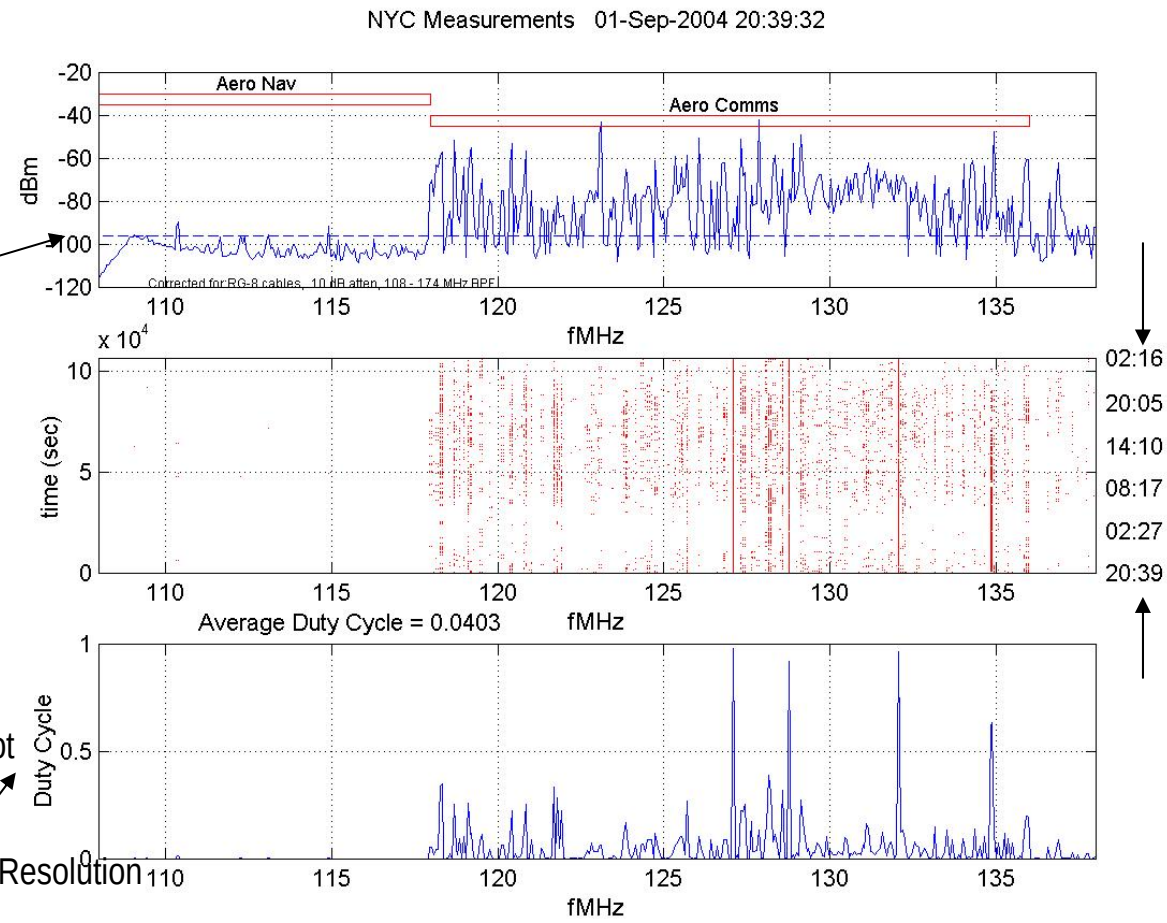
Upper Bound (Frequency Resolution
120 MHz/501=240 kHz/bin)

Low Utilization Band

Less Than 1% Apparent Duty Cycle



Aviation Band



Max-Hold Plot

Threshold Value

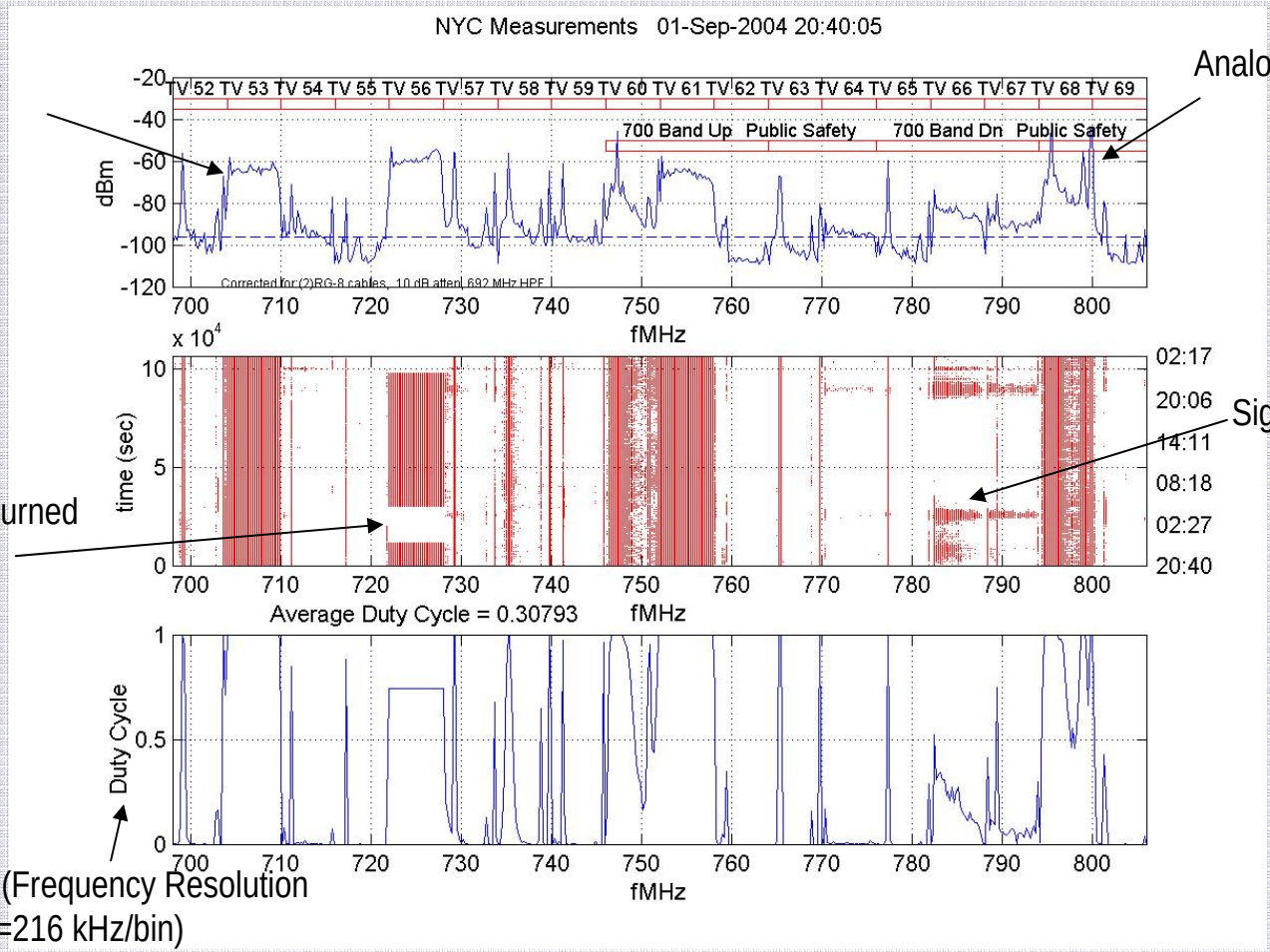
Waterfall Plot

Duty Cycle Plot

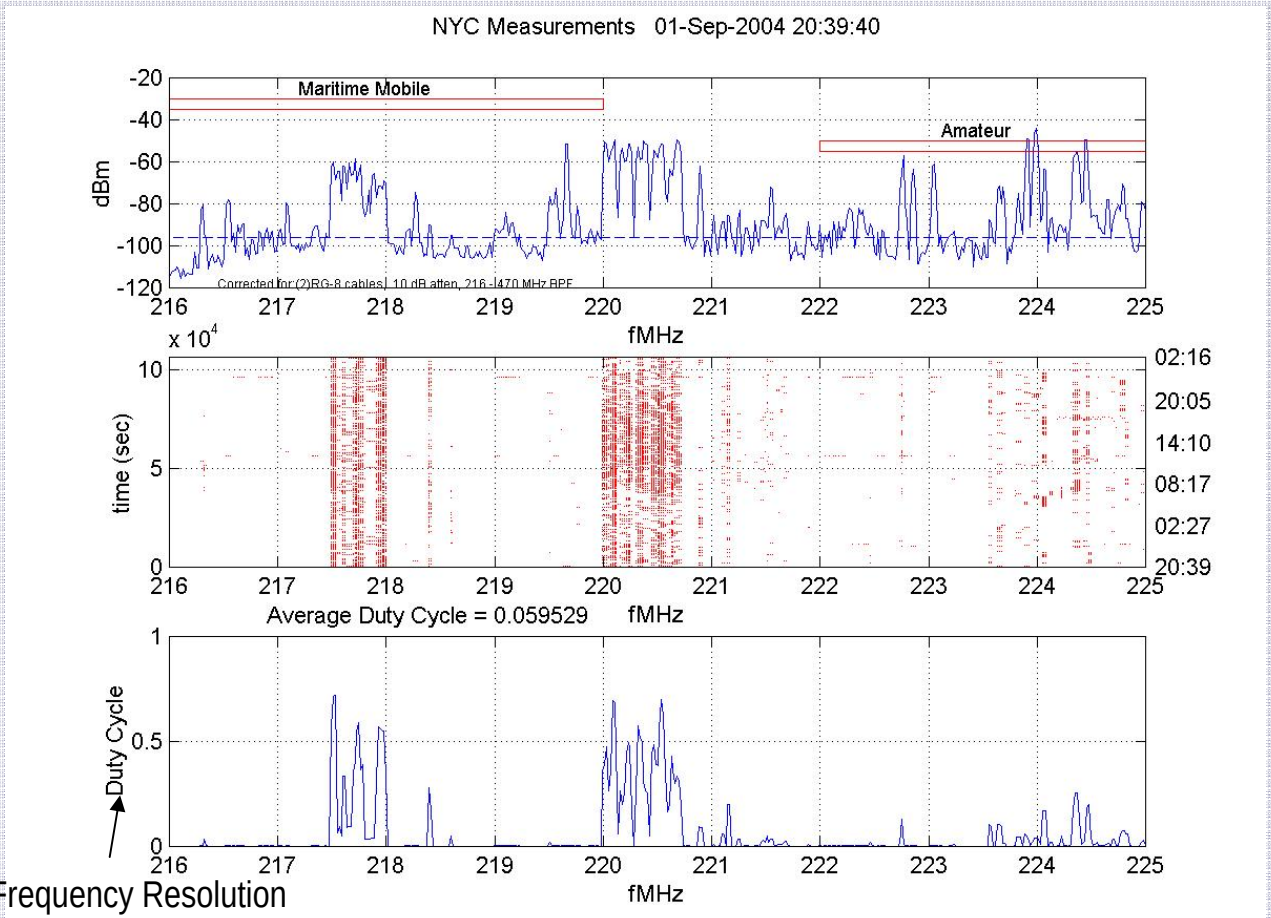
Upper Bound (Frequency Resolution 20 MHz/501=40 kHz/bin)

26 hour collection period

UHF TV Band

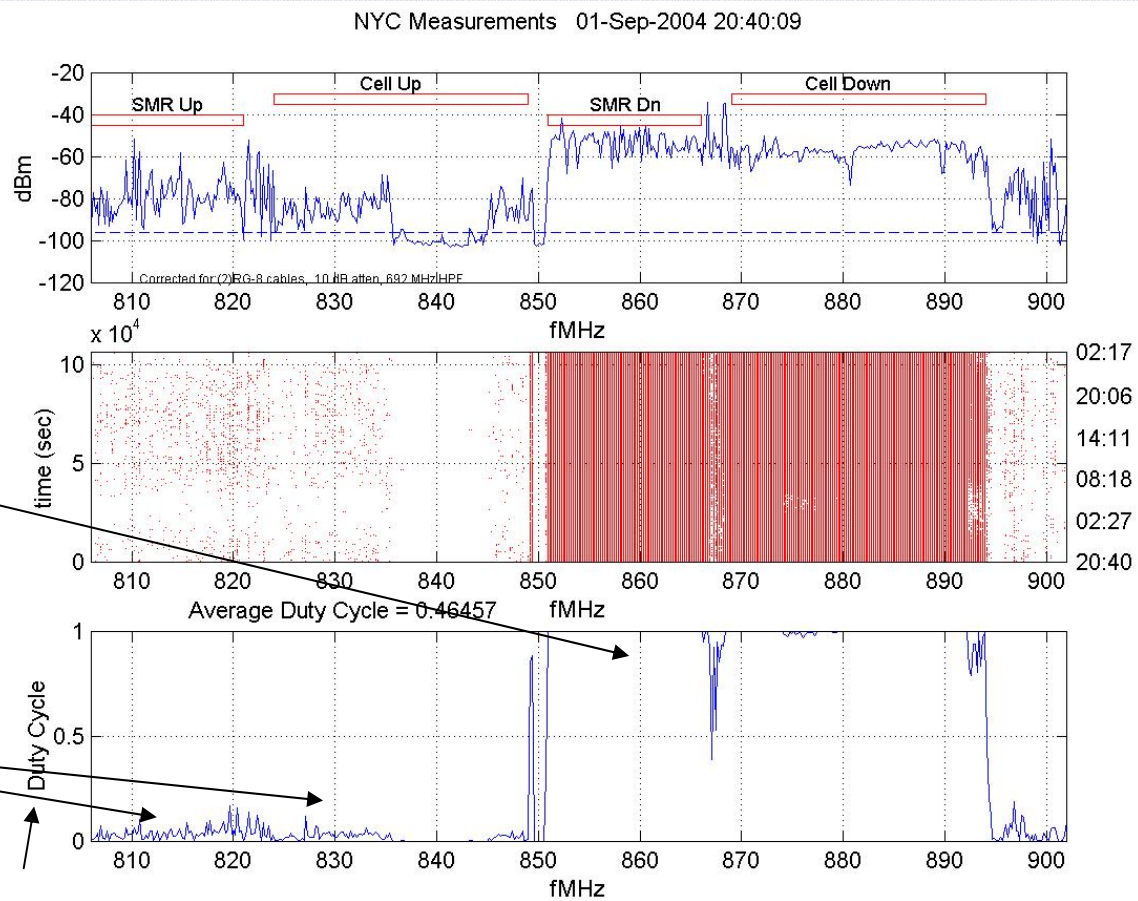


Maritime Mobile and Amateur Band



Upper Bound (Frequency Resolution 20 MHz/501=40 kHz/bin)

Cell Phone Band

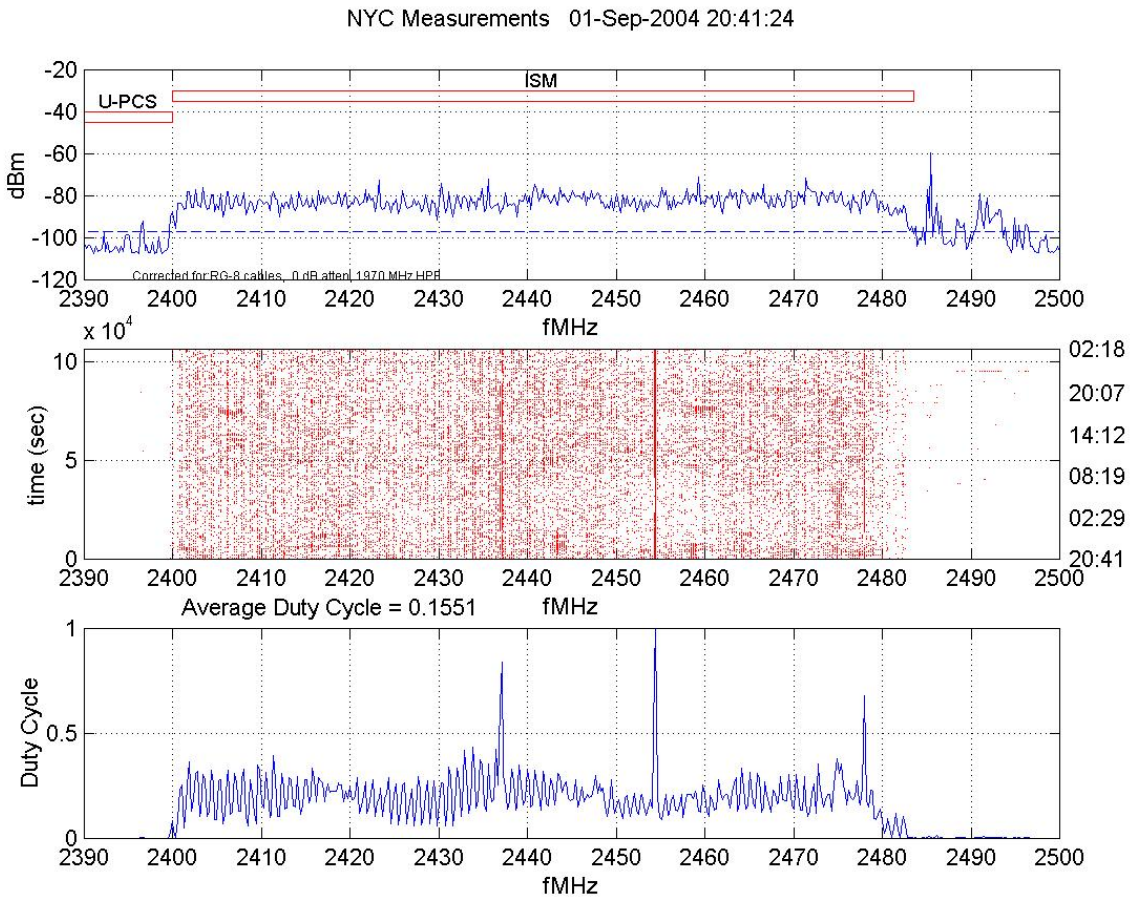


Base Stations Easy to Detect and Have High Apparent Duty Cycle

SMR Provide Has Higher Usage Than Cell Provider

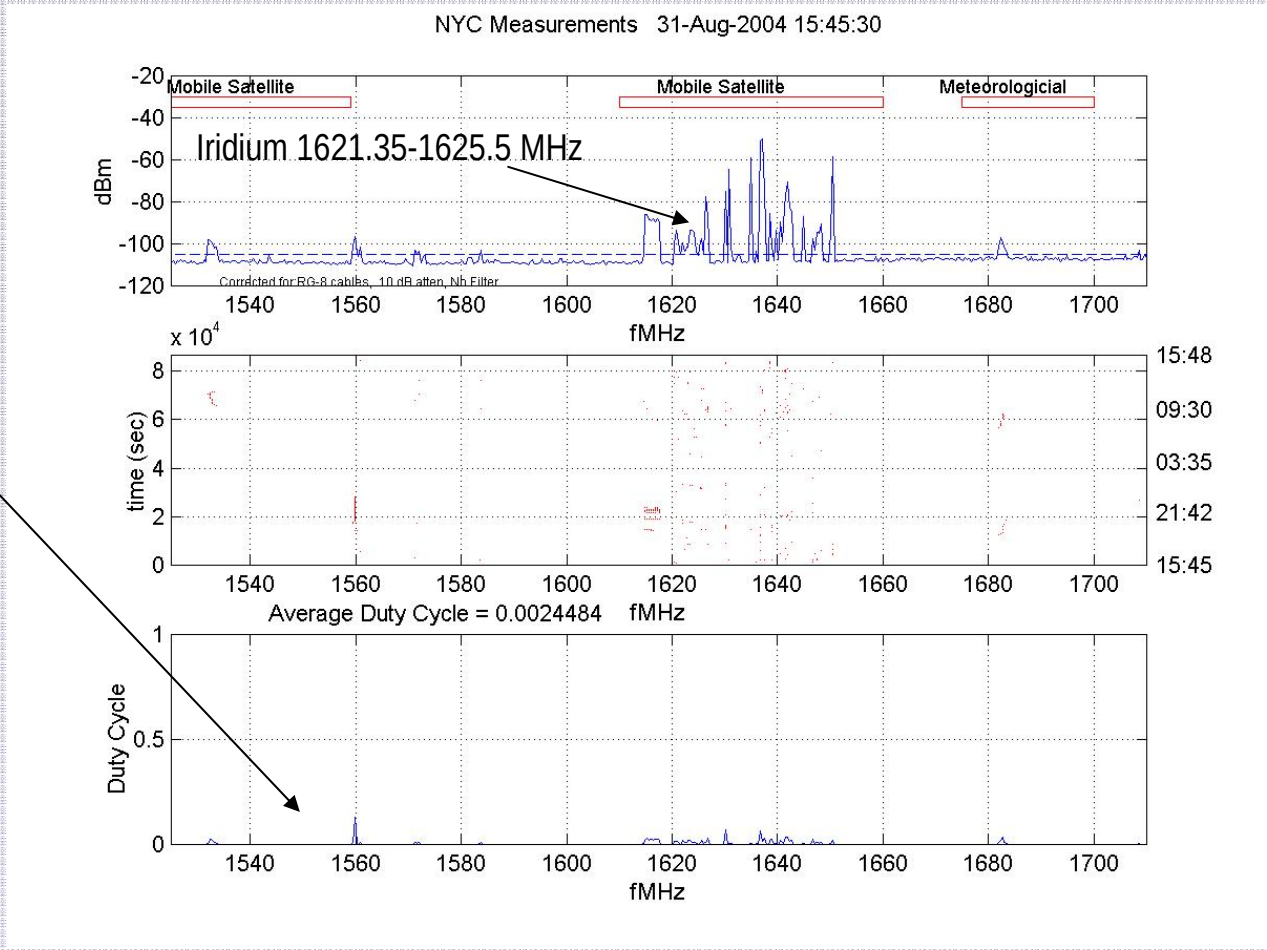
Upper Bound (Frequency Resolution 96 MHz/501=192 kHz/bin)

Unlicensed Band

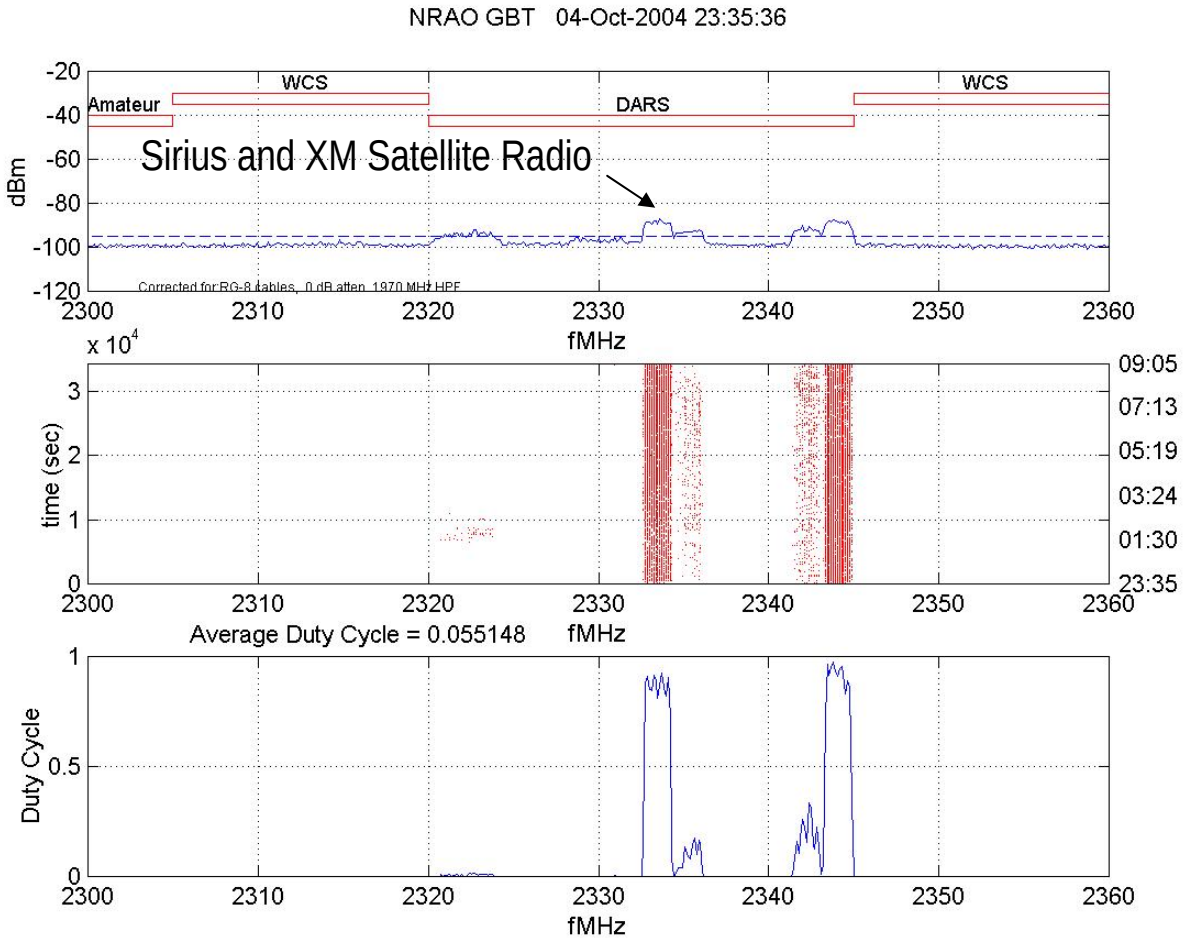


Satellite Band

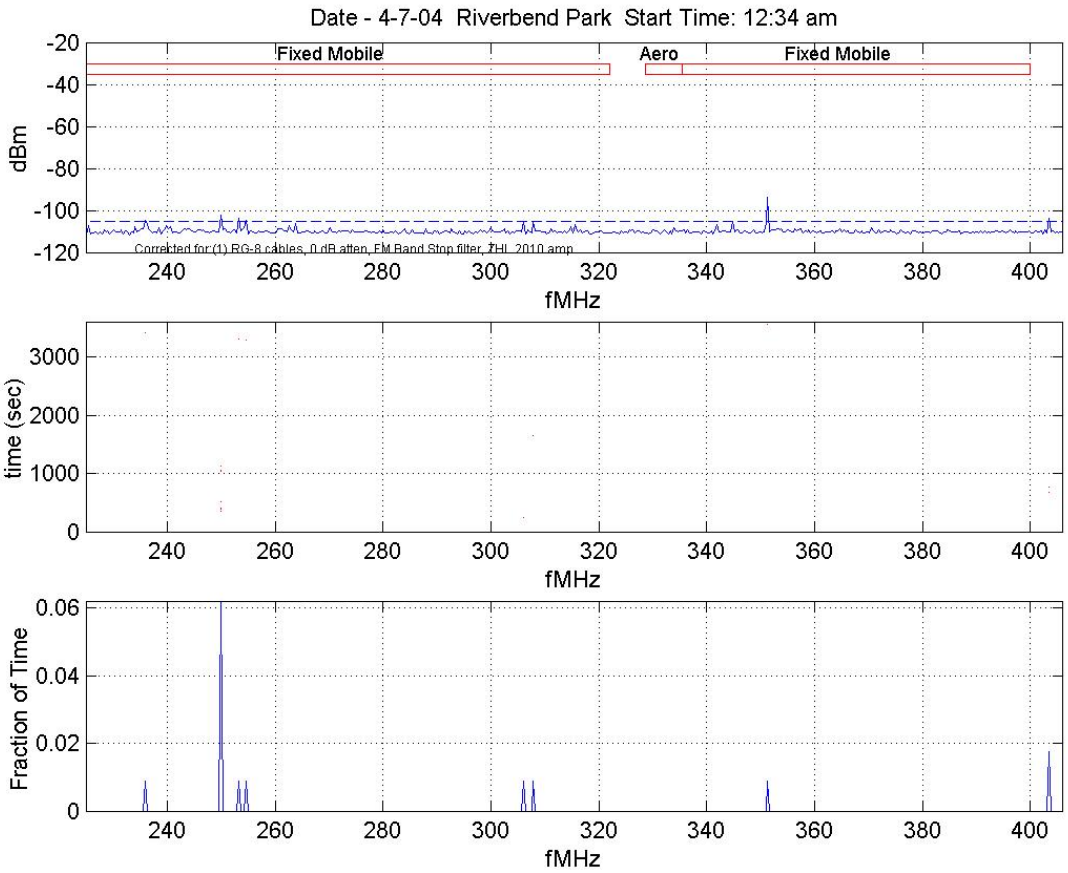
Signals are not detected because
- Not there, or
- Too weak



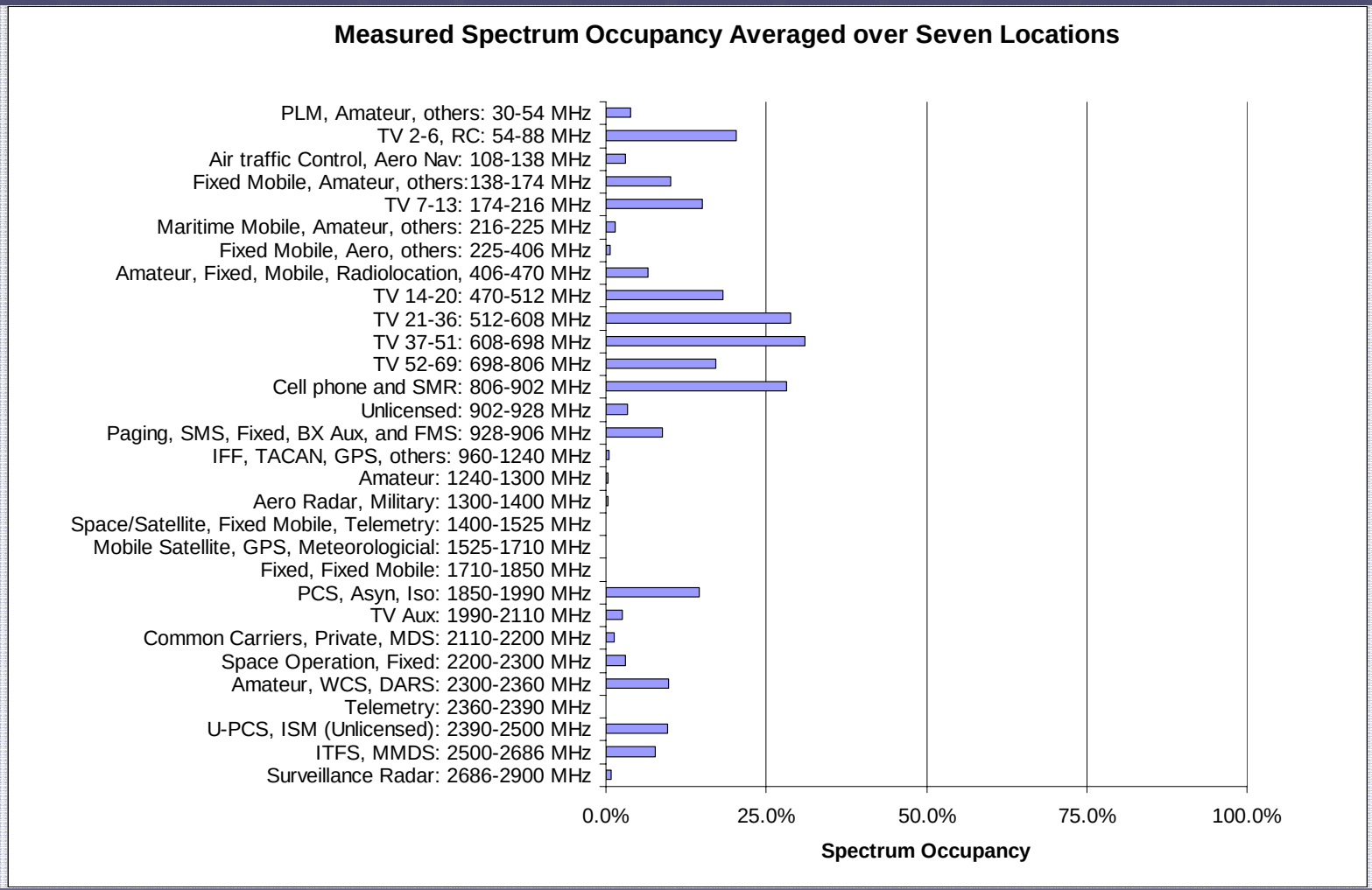
Signals At Radio Quiet Zone



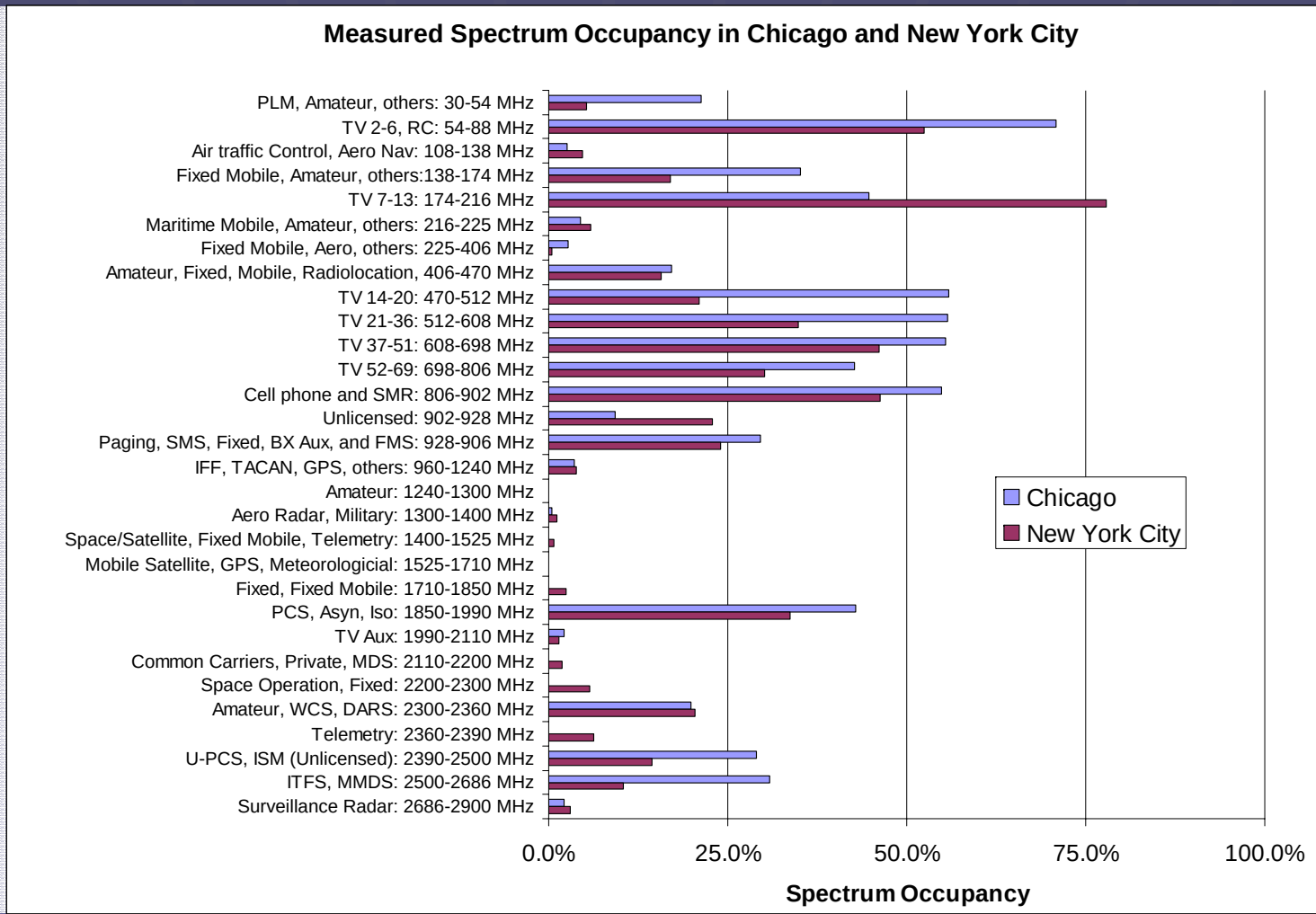
Low Utilization in a Rural Environment



Average Occupancy In Each Band

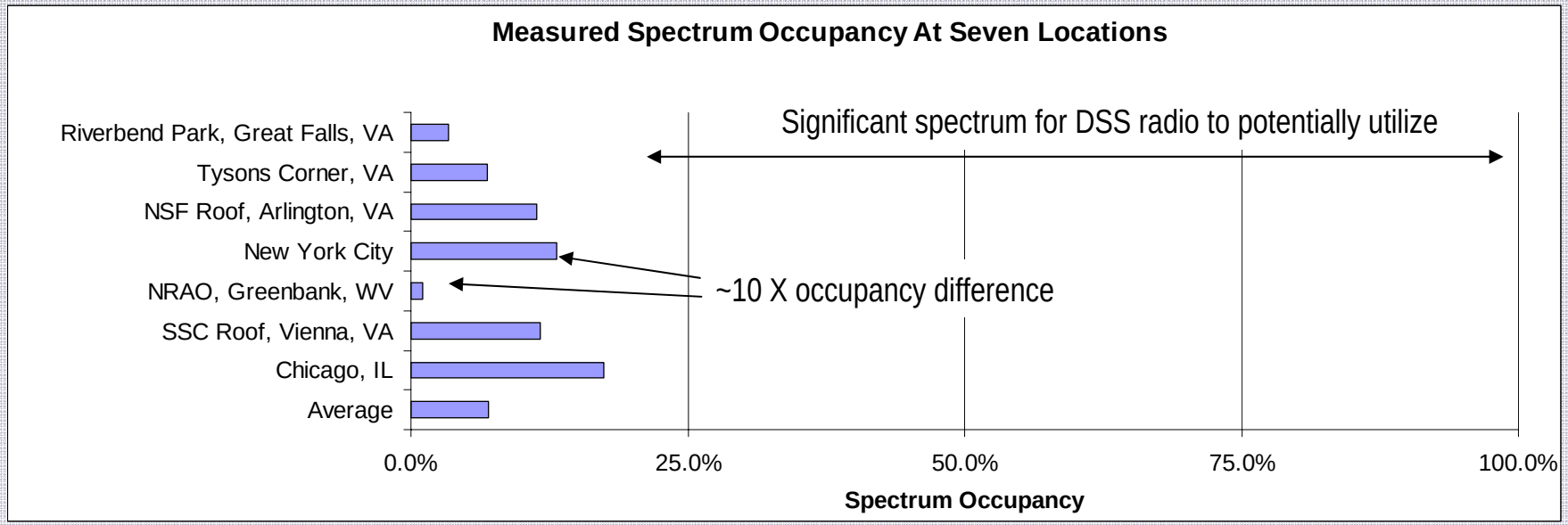


Significant Occupancy Differences Between Similar Locations



Average Occupancy at Different Locations

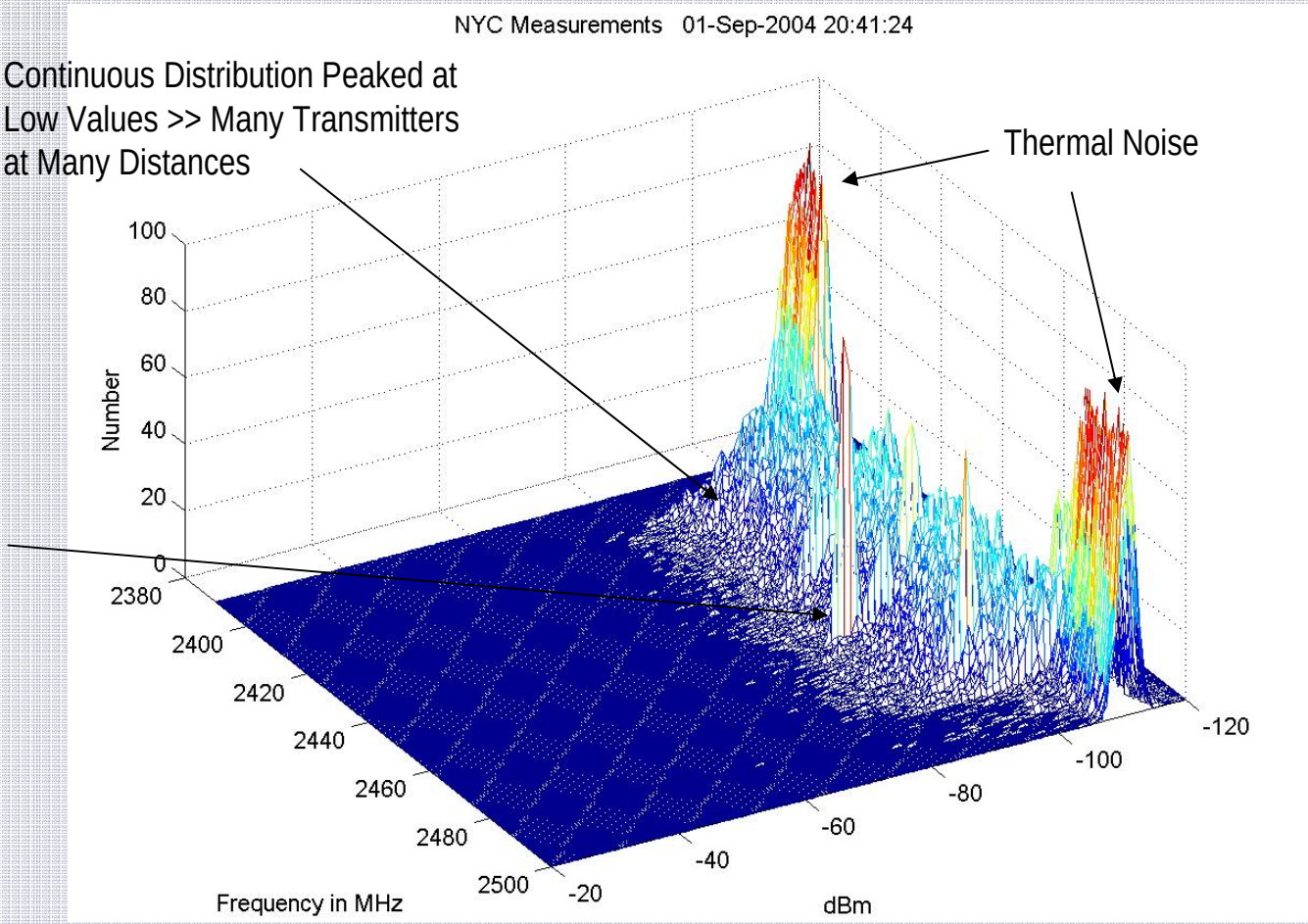
- ~ 10 X higher occupancy difference



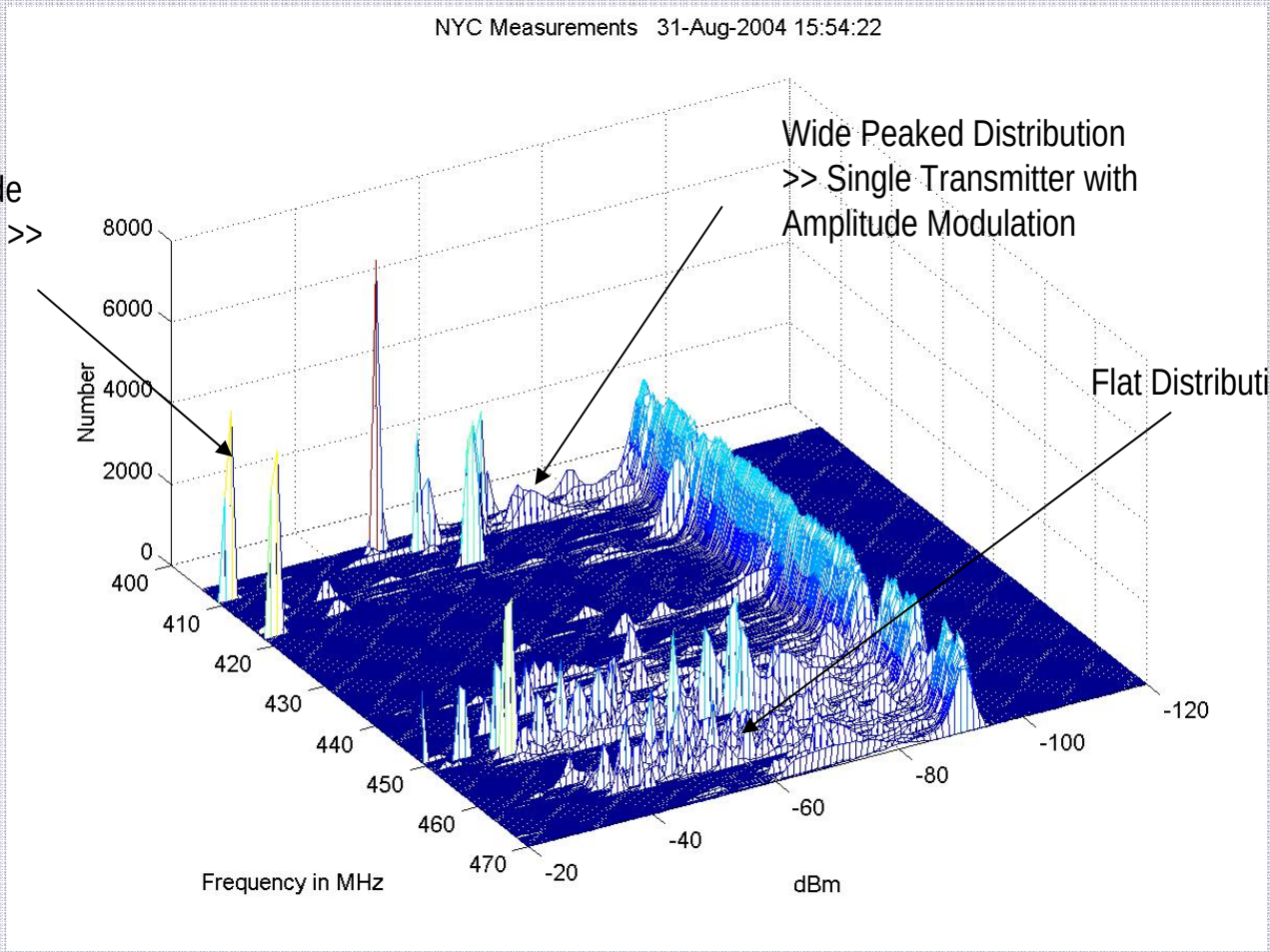
Needed Follow-on Work

- Establish a general and comprehensive estimate of spectrum occupancy
  - 10 urban locations
  - 10 suburban locations
  - 3 international urban locations
- Determine the size of spectrum holes
  - Simultaneous fixed and nomadic measurements
  - Synchronized spectrum analyzer trace triggering
- Determine the cause of low spectrum occupancy
  - Research the FCC/NTIA regulations and assignment databases
  - Who are the “owners”? Why they are not using the bands?
- Obtain long-term trends of spectrum usage and background noise levels
  - Collect data over a continuous, two year period
  - Determine seasonality variations
  - Long-term peak-to average occupancy ratios
- Determine the operating characteristics of the legacy users in bands with low occupancy
  - Enable dynamic spectrum sharing systems to be better designed
  - Signal parameters (transmission gaps statistics, transmitter mobility, number of transmitters, the signal bandwidths, and other parameters)

Amplitude Histogram of 2.4 GHz Band



Amplitude Histogram of Public Safety Band



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Conclusions

- Measurements show there is significant spectrum “whitespace”
  - 13% in NYC – peak period
  - Many bands have minimal use
  - A low agility, contiguous waveform DSS radio provides high utility
- Large occupancy differences with location
- Significant band-to-band variations in “similar” locations
  - NYC vs Chicago
- Summarized needed follow-on work