



# Measuring Spectrum Occupancy

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Mark McHenry  
Shared Spectrum Company  
[www.sharespectrum.com](http://www.sharespectrum.com)



# Agenda

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- Shared Spectrum Company (SSC) overview
- Spectrum occupancy measurement applications
- SSC measurement systems
  - Spectrum analyzer system
  - Man-made noise system
  - Sentinel system
- Summary



# About Shared Spectrum Company

- Innovator in Dynamic Spectrum Access software
- Pioneer in TV Whitespace since 1999
- DARPA XG, WNAN, EPLRS-XF, MAINGATE
- Industry leader - Commerce Spectrum Management Advisory Committee, Wireless Innovation Forum, IEEE P1900
- Multiple partners are implementing SSC technology [Non-Exclusive]



**COBHAM**



**HARRIS**

**THALES**

**Raytheon**

Booz | Allen | Hamilton



communications

**BBN**  
TECHNOLOGIES





# Spectrum Occupancy Measurement Applications

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- Determine spectrum hole width and duration statistics
  - Analysis used to determine secondary user's transmit power and bandwidth limitations based on legacy equipment parameters
- Determine legacy signal characteristics
  - Bandwidth, duty cycle, frequency assignments, guard bands, etc
  - Impact on DSA classifier design and system analysis
- Determine legacy transmitter mobility and number of transmitters
  - Impact on DSA detection rates
- Obtain test datasets for spectrum detection, classification and other applications
- Determine anomalous propagation effects such as ducting
  - Cause brief periods of interference from/to distant transceivers
- Managing and analysis of DSA field demonstrations



# Spectrum Measurements Has Many Advantages Compared to Databases

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- Many parameters are easier, less expensive and more accurately obtained via measurements than by requiring each user to submit the data
  - What frequencies are built out and in use
  - Where and when actual transmissions occur
  - Transmit duty cycles
  - Temporal transmit variations
  - Signal bandwidths
  - Use of frequency guard bands
  - Scenario information (mobile, fixed, number of users via the signal amplitude statistics).
- Usage in unlicensed bands where many user parameters are not directly known to regulators
- Parameters that are not known by the users or contained in the frequency assignment
  - Users don't know their temporal usage and their mobility and would have to measure this information
  - Spectrum management decisions have been delegated down to regional authorities and in some cases delegated further to local authorities. There is no centralized knowledge of what equipment is deployed, what spectrum is being used, etc. To "undo" this distributed set of assignments would take significant effort and would be expensive.
- There are signals that are not known or controlled by regulators
  - Man-made noise, "rogue" illegal or accidental signals, anomalous propagation loss events involving licensed signals that create unexpected signal levels, signals coming from across the US borders that are not well known and spurious transmissions.



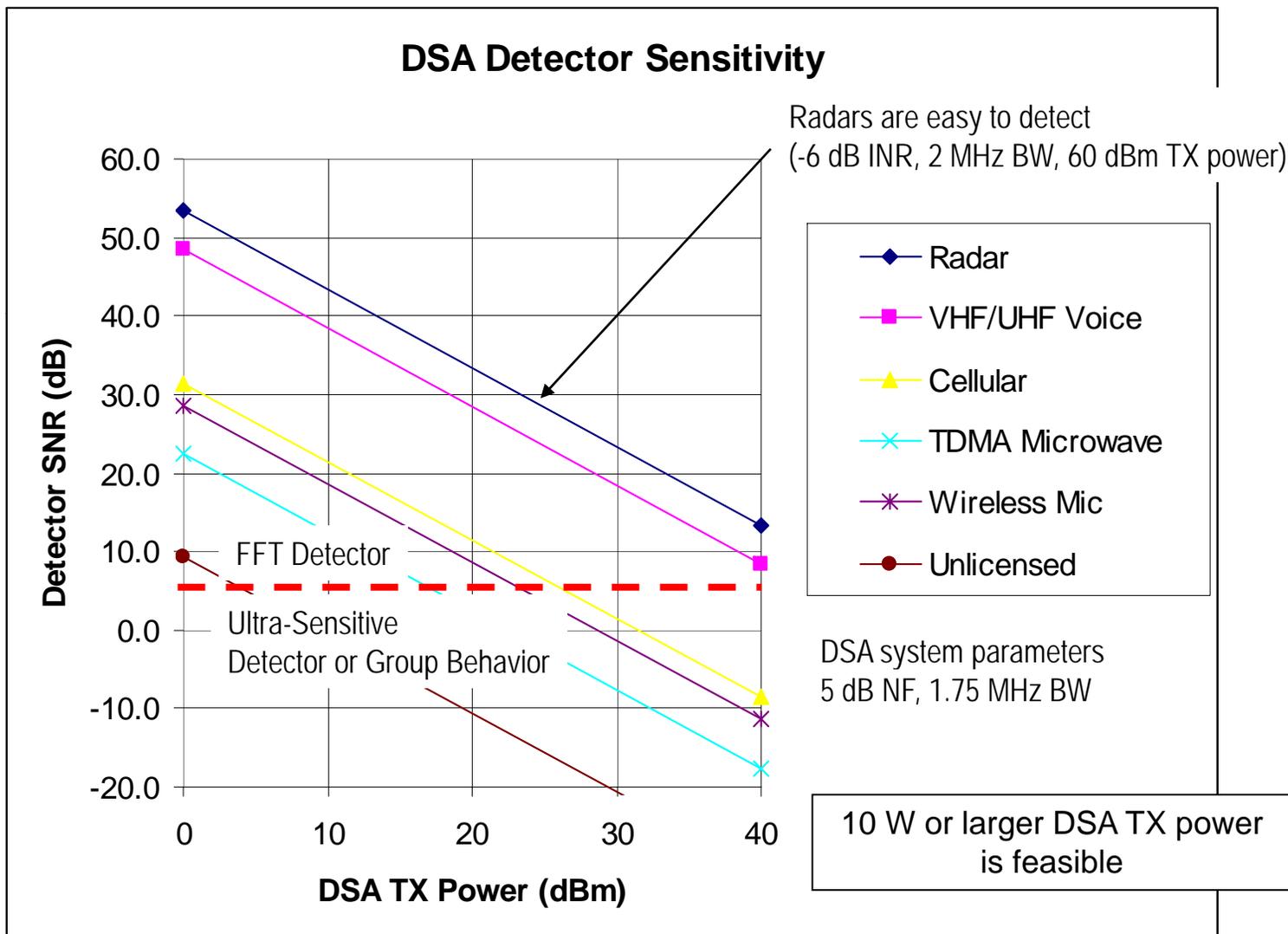
# Measurements and Analysis Used Together

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- Comparing measurements to predictions is essential to have an accurate understanding of spectrum use
- Relying on analysis alone will result in disagreements on assumptions, propagation models and other factors.
- Measurements force an agreement between analysis and truth that is critical if the analysis is to be believed

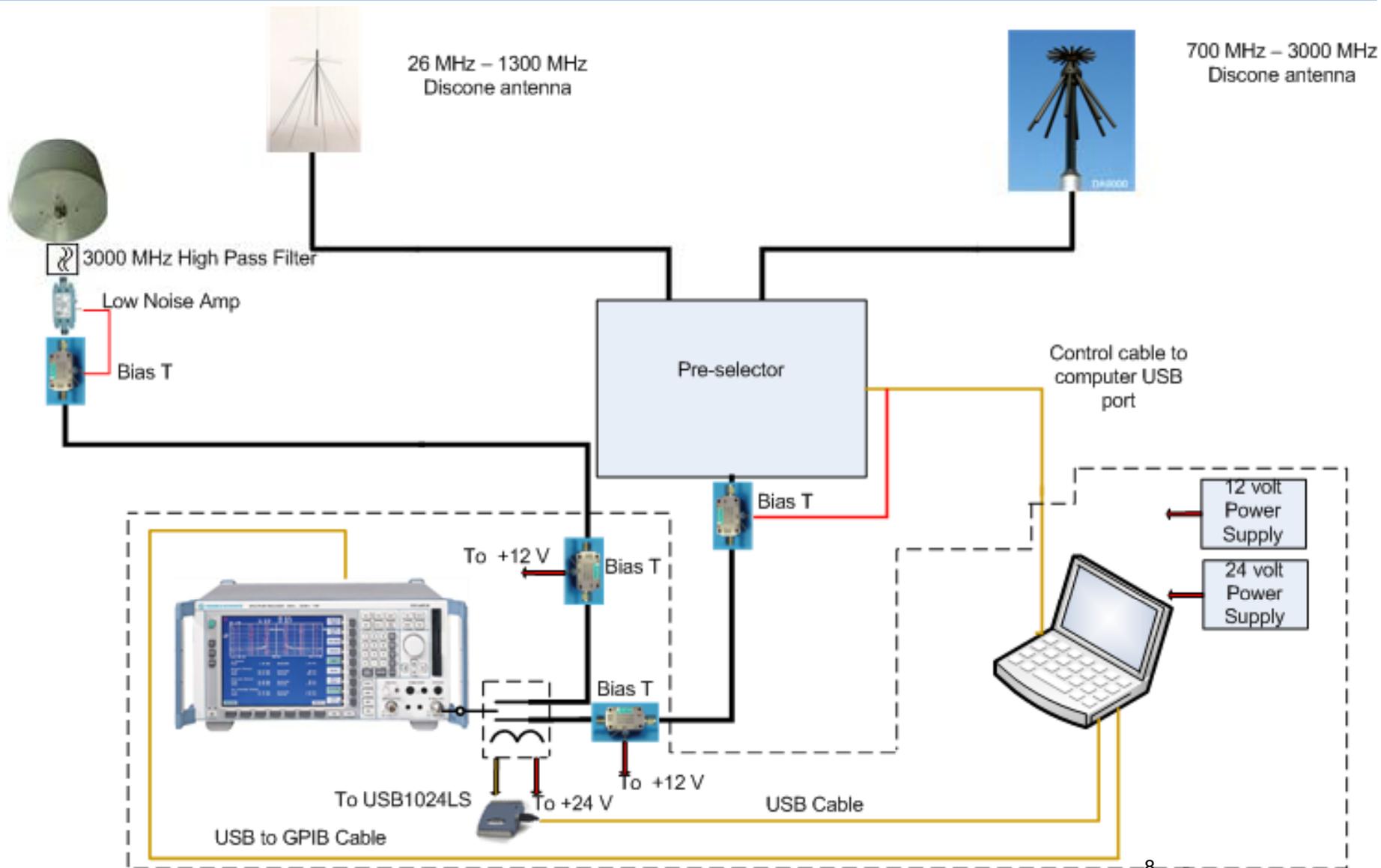


# Spectrum Occupancy Sensitivity is Related to Spectrum Sharing System TX Power





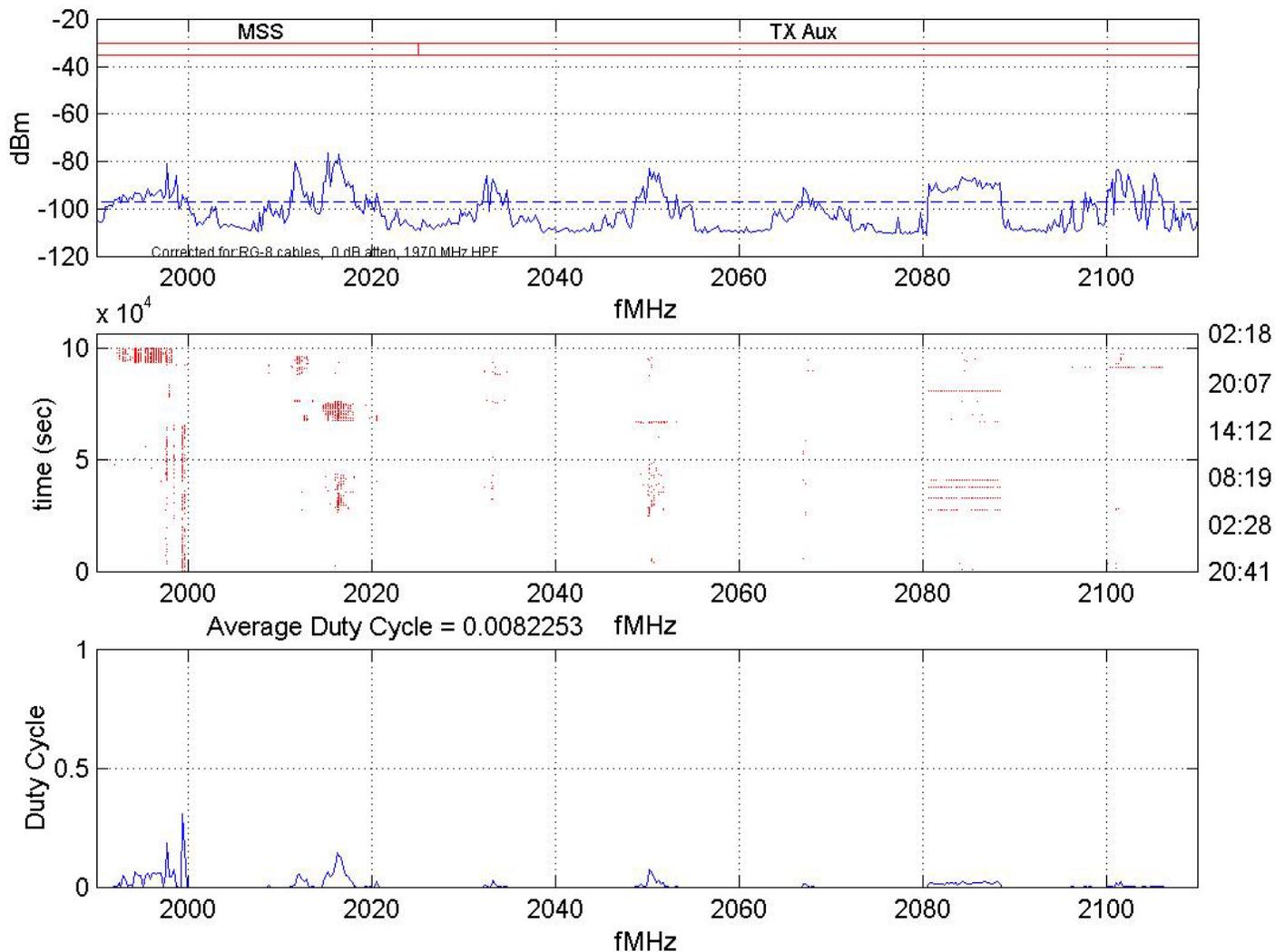
# SSC Spectrum Analyzer Spectrum Occupancy Measurement System





# TX Aux Band

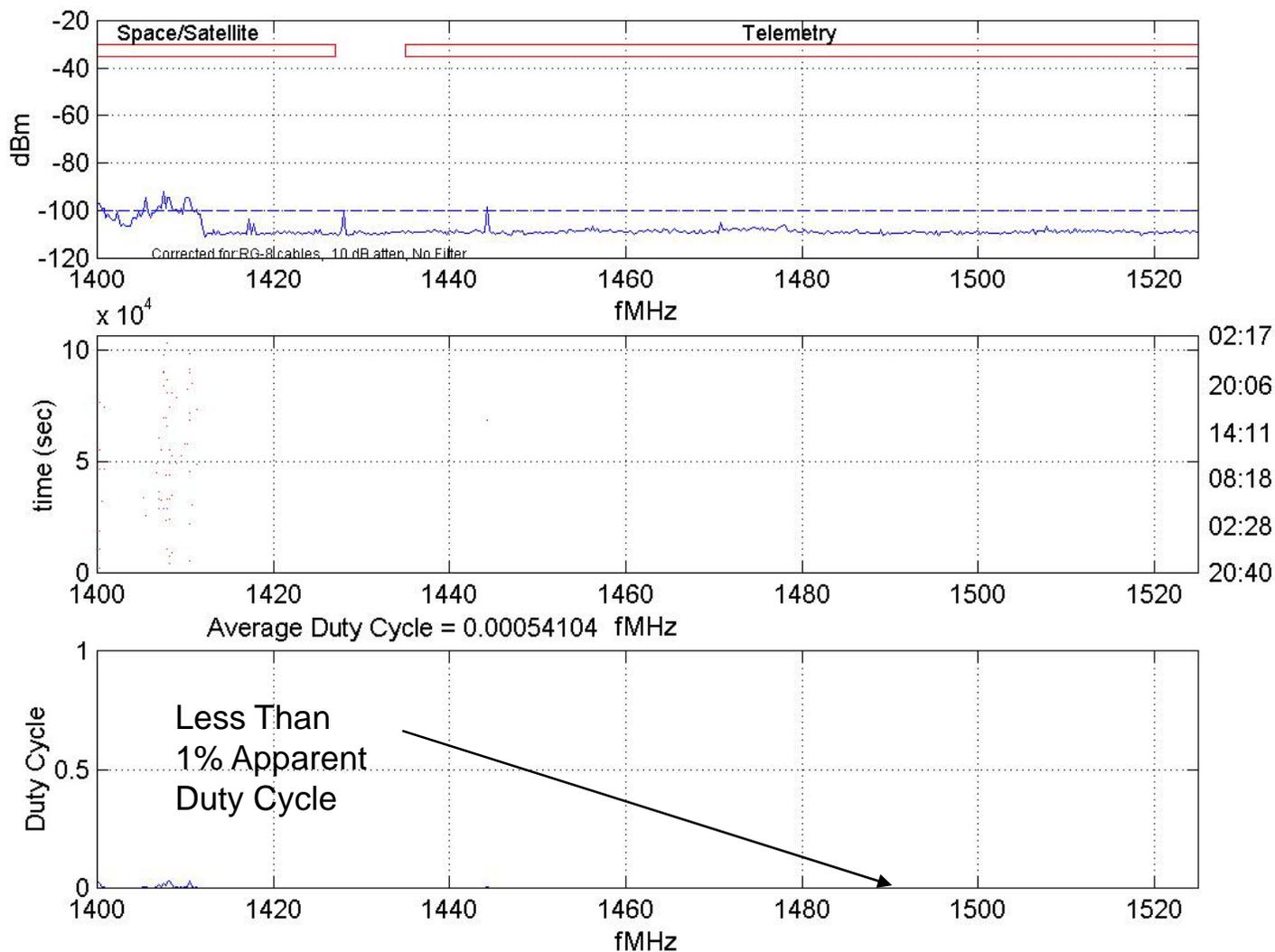
NYC Measurements 01-Sep-2004 20:41:01





# Telemetry Band

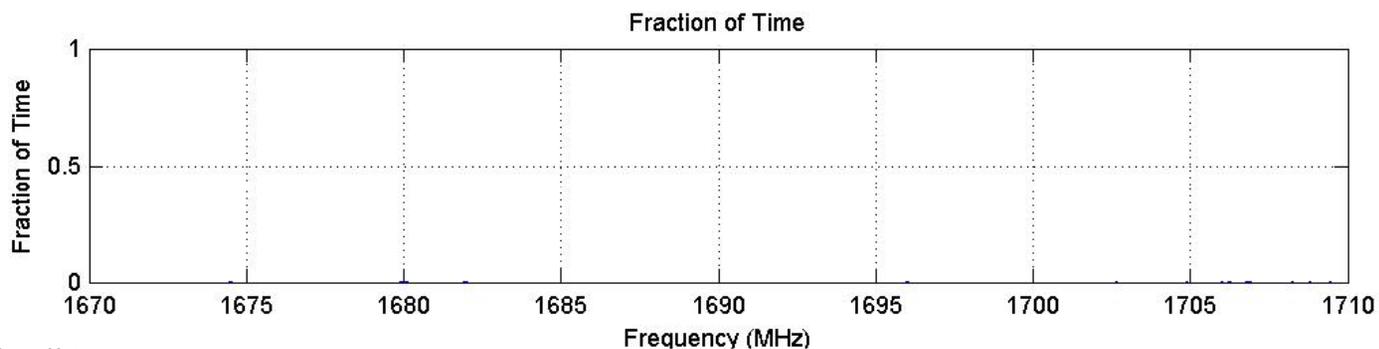
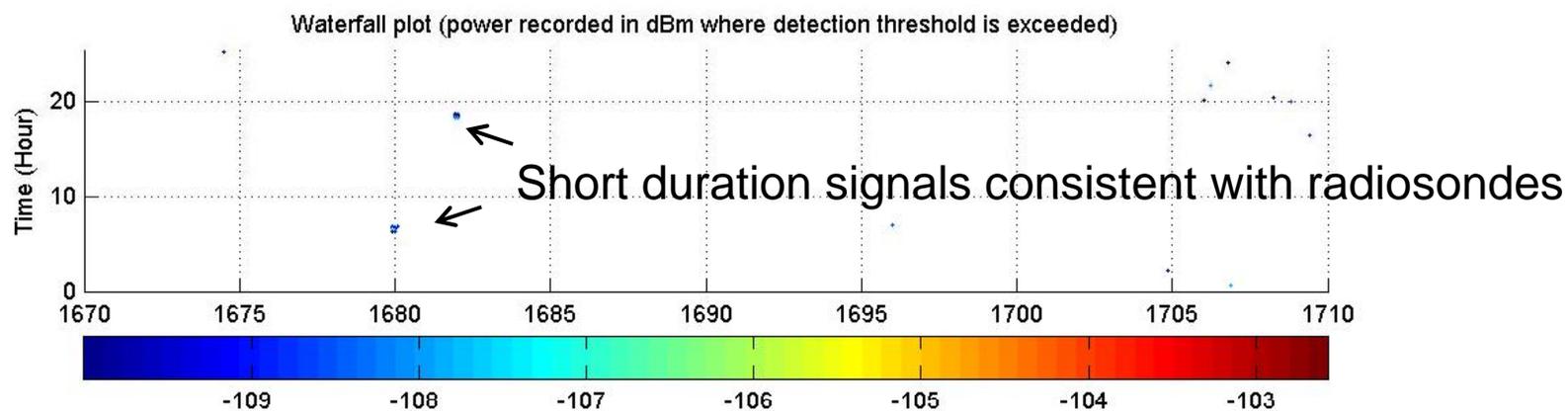
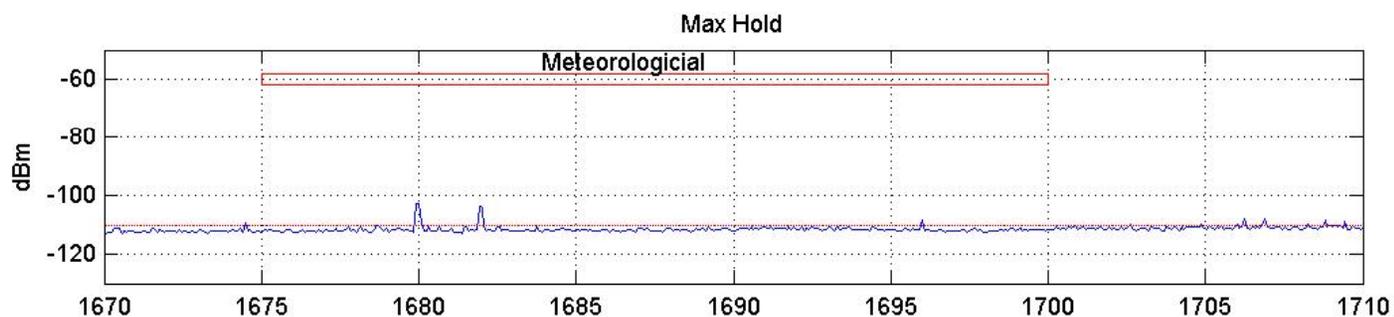
NYC Measurements 01-Sep-2004 20:40:39





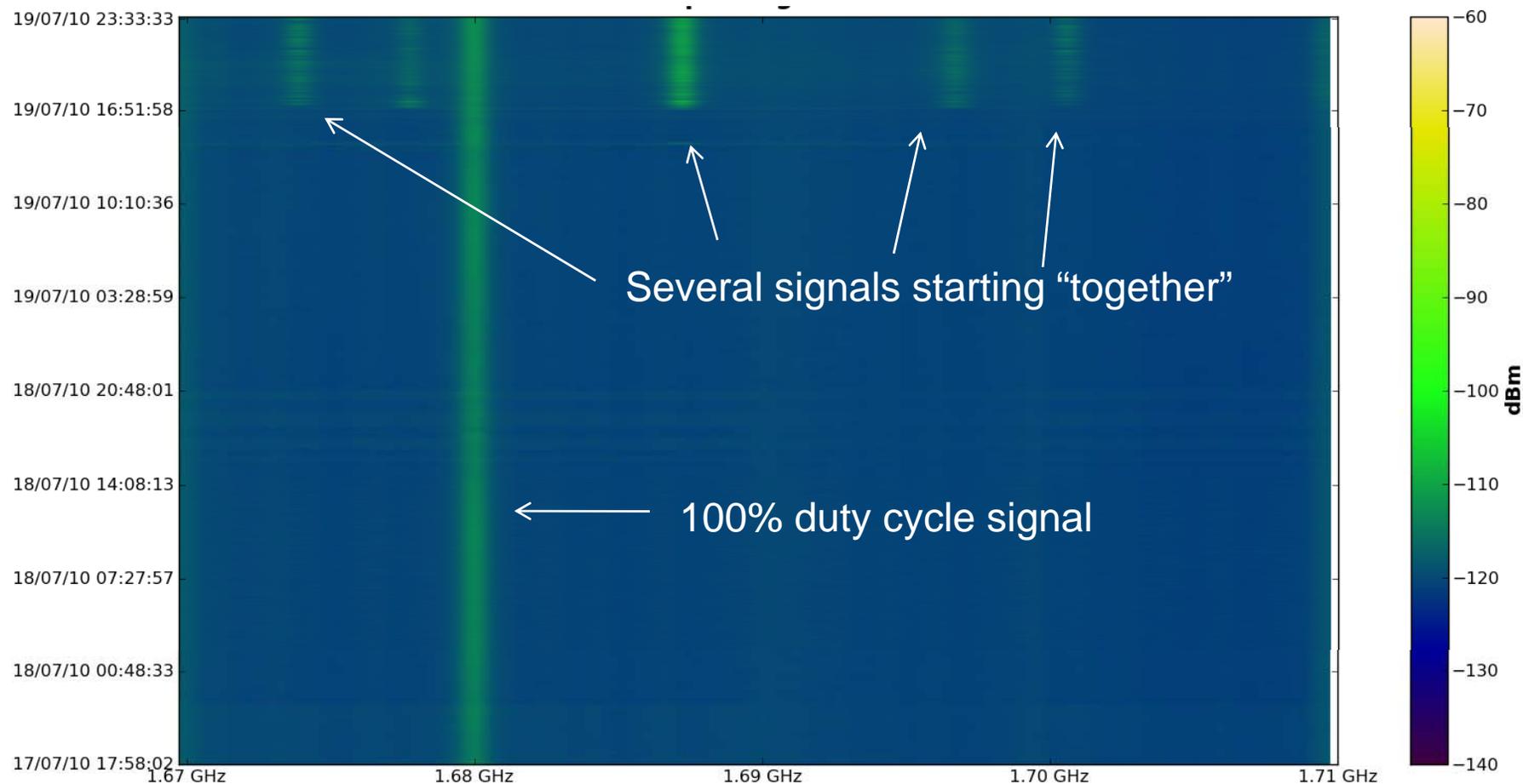
# 1670 MHz to 1710 MHz Meteorological Band

SSC Rooftop Collection- Start: 02/Jul/2010, 00:53:48. Stop: 03/Jul/2010, 02:18:41.





# Comparison with Other Measurements Provides Insights

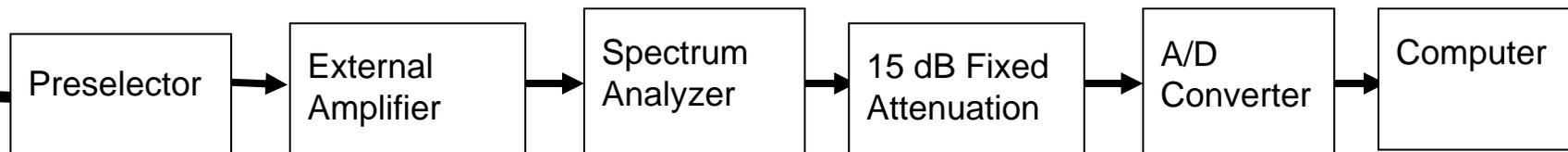


Data from Illinois Institute of Technology, Dennis Roberson



# Man-Made Noise Measurement System

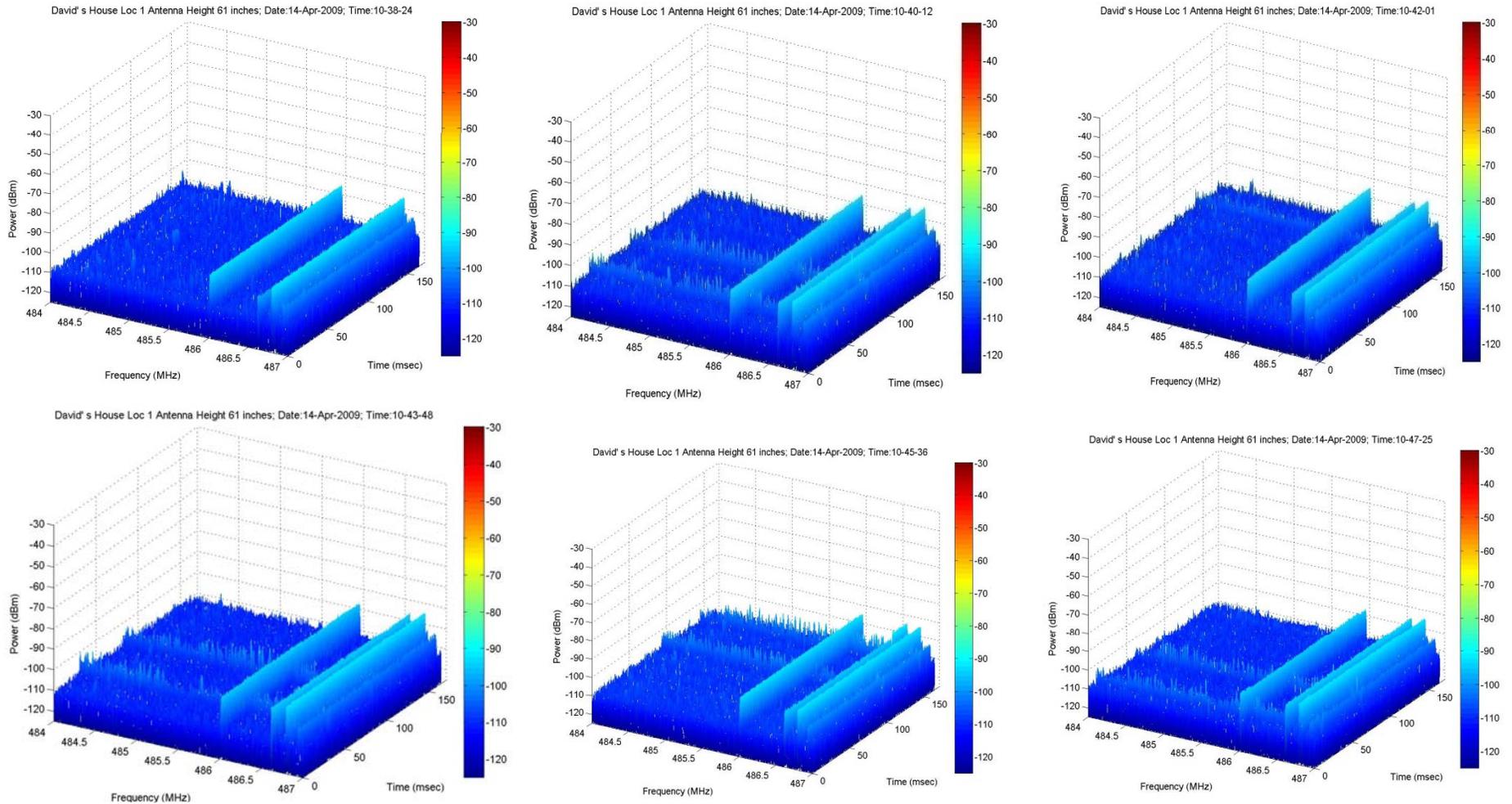
- Wideband discone antenna (25-1300 MHz)
- SSC designed pre-selector module
  - Custom designed switched filter/gain stage
  - Receiver front end to provide for low noise, gain (+17 dB) and rejection of outside band interferers
- External amplifier
  - 3.7 dB noise figure and 23 dB gain
  - Decreases the noise figure of the system.
- The signal is down-converted to 20.4 MHz in the spectrum analyzer
- Time series data is saved in the computer after A/D conversion
- 48 Hz resolution bandwidth



- Measurements in Non-Occupied Channels only
- Measurements for <5 minutes per channels



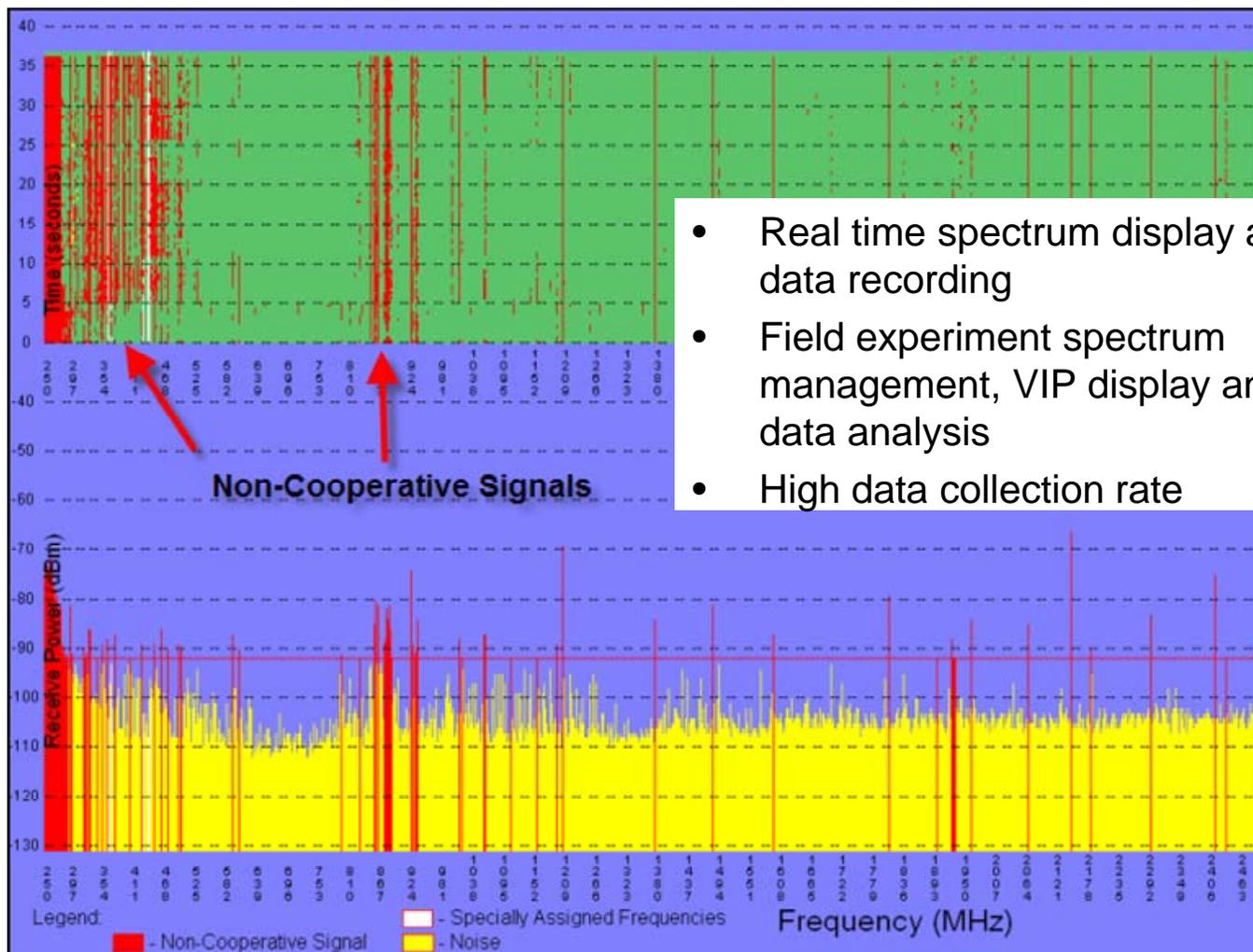
# Example Man-Made Noise Characteristics



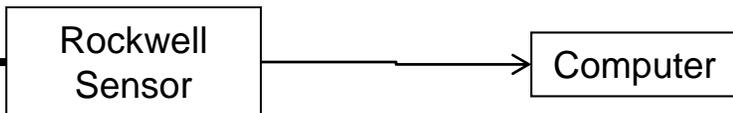
Determine temporal and spectral shape of man-made noise



# Sentinel Measurement System



- Real time spectrum display and data recording
- Field experiment spectrum management, VIP display and data analysis
- High data collection rate





## Summary

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- SSC has three different spectrum measurement systems
  - Many different applications
- Measurements and analysis used together
  - Comparing measurements to predictions is essential to have an accurate understanding of spectrum use
  - Relying on analysis alone will result in disagreements on assumptions, propagation models and other factors.
  - Measurements force an agreement between analysis and truth that is critical if the analysis is to be believed
- Spectrum measurements have many advantages compared to databases
  - Many parameters are easier, less expensive and more accurately obtained via measurements than by requiring each user to submit the data
  - Usage in unlicensed bands where many user parameters are not directly known to regulators
  - Parameters that are not known by the users or contained in the frequency assignment
  - There are signals that are not known or controlled by regulators