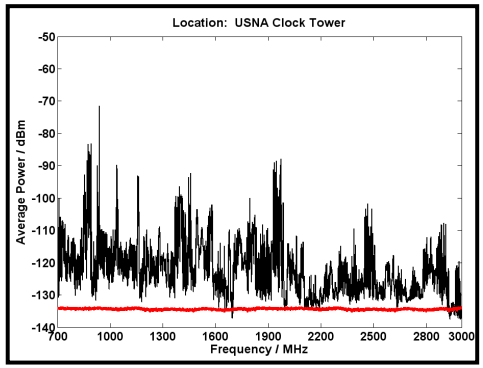
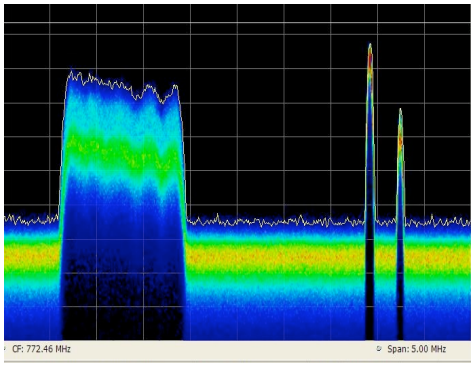
Cognitive Radio Testbed: Real-World Electromagnetic Spectrum Surveys, Modeling, and Simulation





SDR 2010 Conference - December 2010

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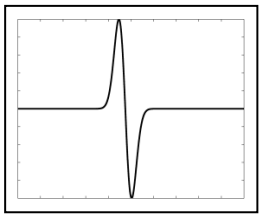
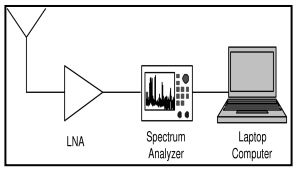
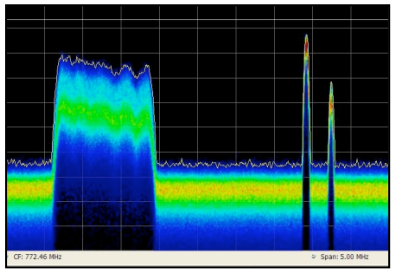
Presentation Overview



Overview and Background

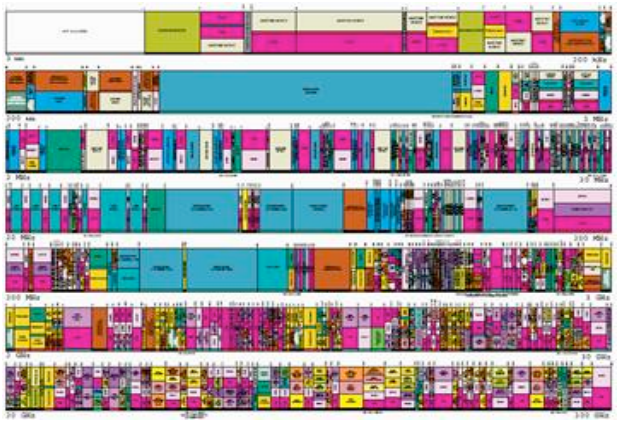


Measurement Systems and Results



Spectrum Modeling and Playback

Background, Motivation and Objectives



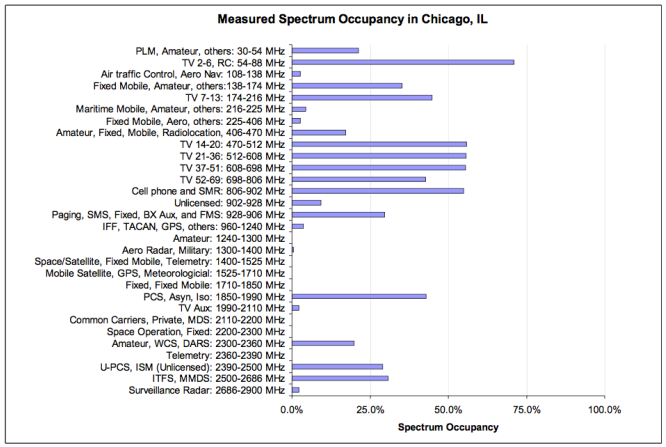
- Statically allocated to licensed users
- Entire 6 kHz – 300 GHz allocated
- Study results:
  - At a given point in space and time, most licensed spectrum is unused
  - 94% of spectrum is unused worldwide
  - 18% per year growth rate for spectrum demand in the future

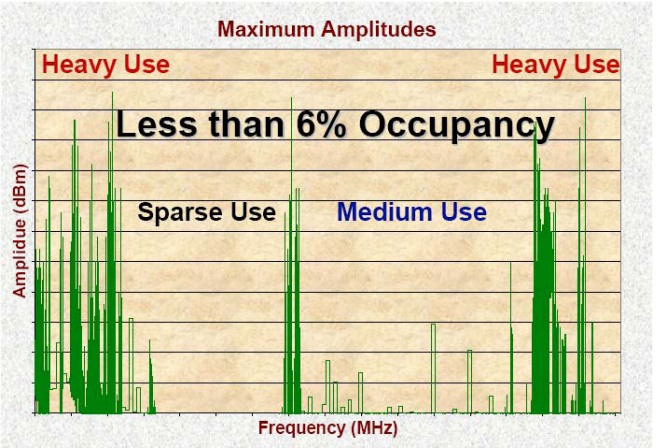
Current Status: Current allocation model resulting insufficient usage of spectrum -> Does not have enough spectrum to meet wireless communications growing demands

Source of problem: Not availability of the spectrum but accessibility to the spectrum

Solution: Cognitive Radio/Dynamic Spectrum Access technologies

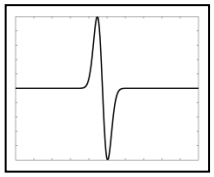
Typical Spectrum Occupancies





400 MHz – 7.2 GHz Spectral Usage (Atlanta, GA)		
	Urban	Rural
Usage in time & space	6.5%	0.8%
Amount of “white space”	5.3 GHz	6.6 GHz

http://www.sharedspectrum.com/measurements/download/NSF_Chicago_2005-11_measurements_v12.pdf
The XG Vision Request for Comment Version 2.0 – BBN technologies
System Consideration for Autonomous Dynamic Spectrum Utilization, Randall Janka & Vlad Dorfman



Electromagnetic Environment for Testbed

- **Cognitive Radio (IEEE 1900.1):** A type of radio in which communication systems are aware of their environment and internal state and can make decisions about their radio operating behavior based on that information and predefined objectives.
- **Cognitive Radio Workshop (The Technical Cooperation Program) -** ***May 2008:***
  A Cognitive Military Radio is a device using awareness, knowledge and understanding of its environment to improve communications capability to support net-centric mission effectiveness.
- **Dynamic Spectrum Access (DSA) (IEEE 1900.1):** The real-time adjustment of spectrum utilization in response to changing circumstances and objectives.
- **Opportunistic Spectrum Access (IEEE 1900.1):** Dynamic spectrum access by secondary spectrum users that exploits local and instantaneous spectrum availability in a non-interfering manner and without primary user negotiation.
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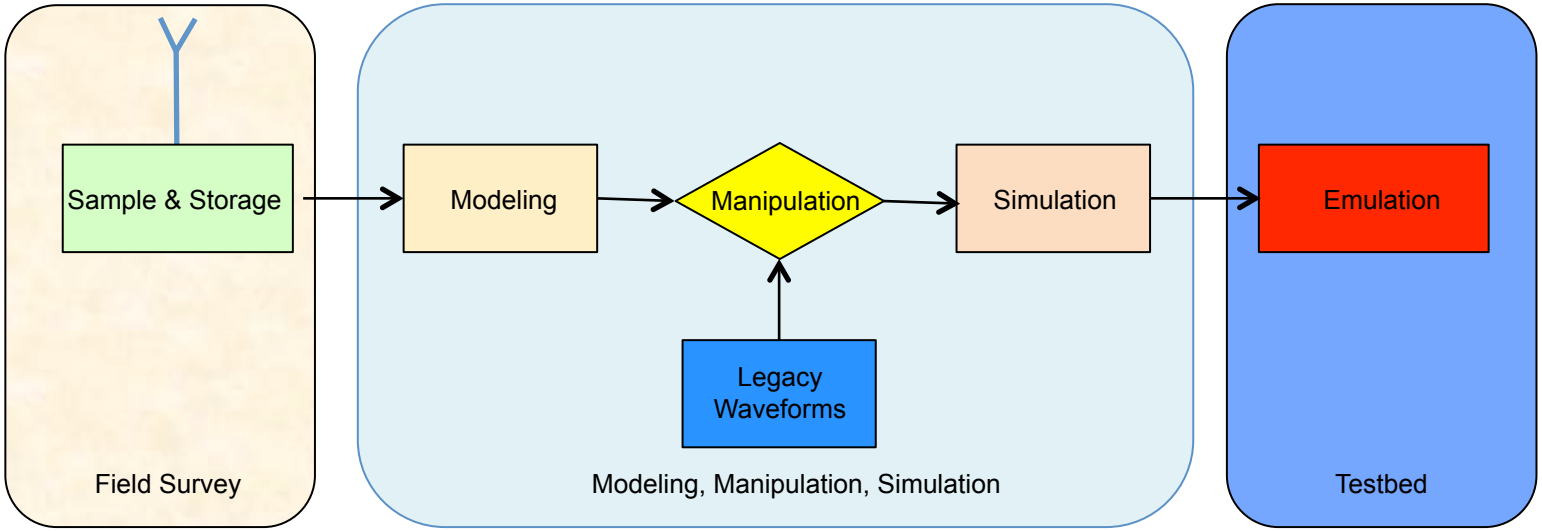
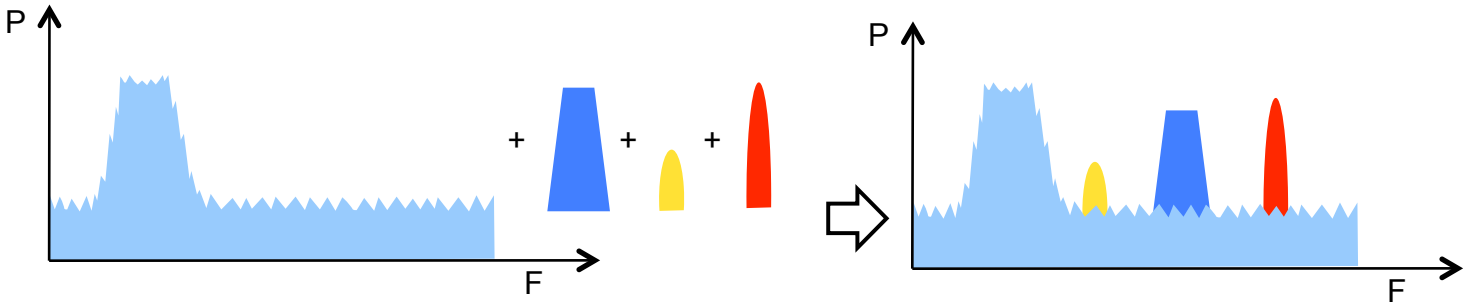
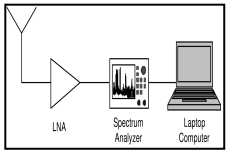
Electromagnetic environment conditions are crucial to operations of CR/ DSA radios => Realistic electromagnetic environment is needed for CR/ DSA radio testbed

Real-World Electromagnetic Environment Survey, Model and Emulation/Simulation System







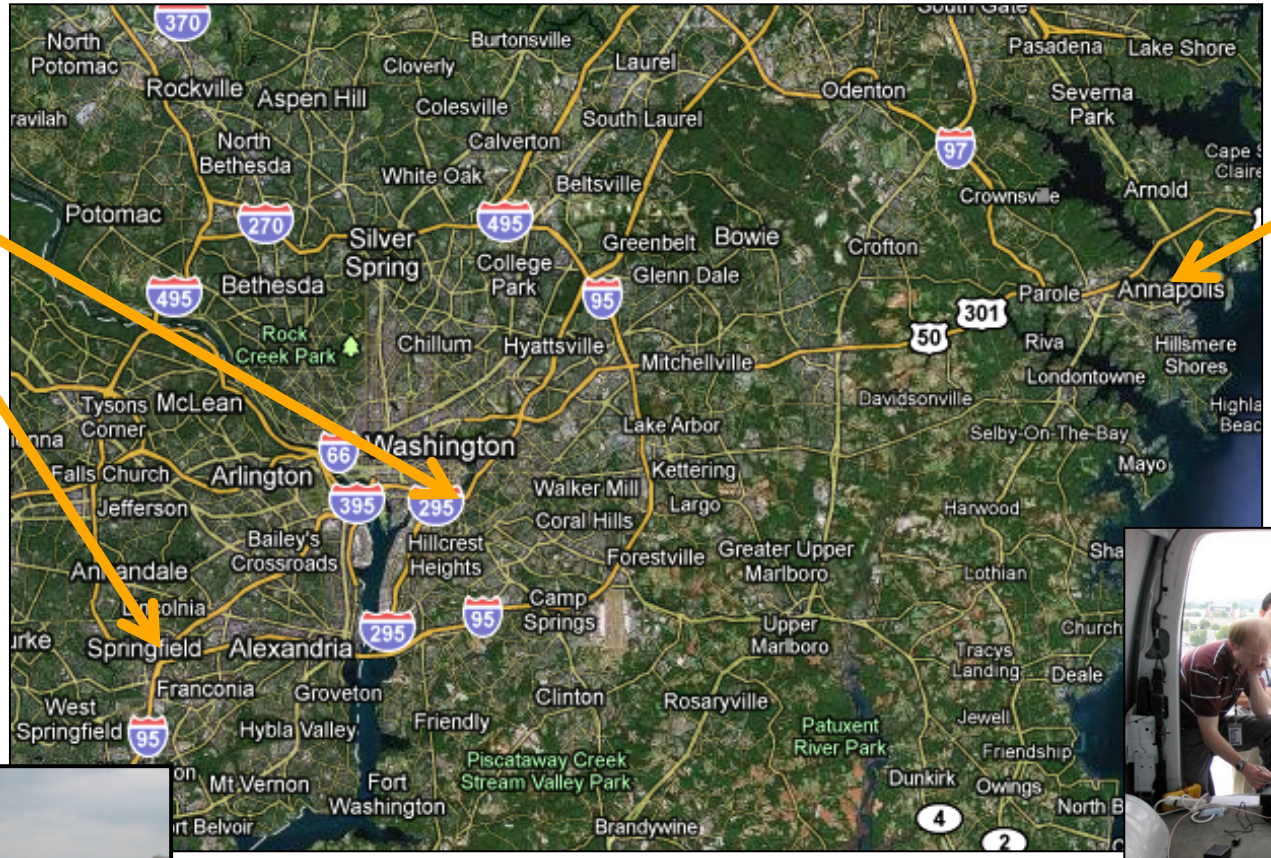
Measurement Locations

Measurements performed in both Urban and Suburban areas.

Site 3

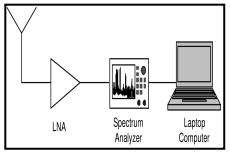
Site 2

Site 1

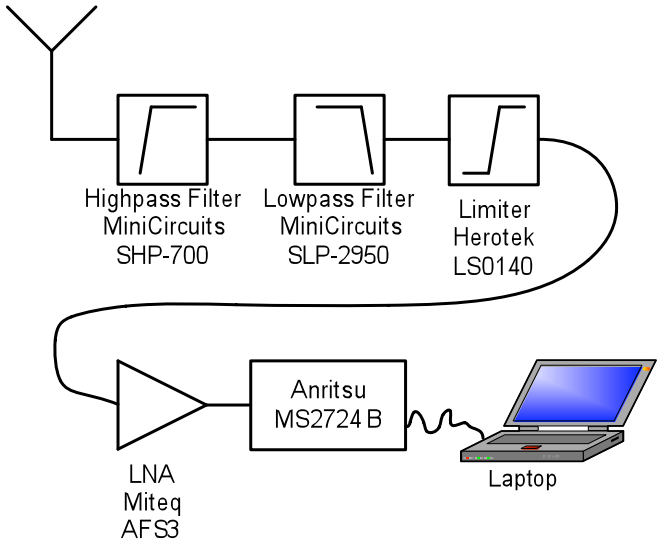


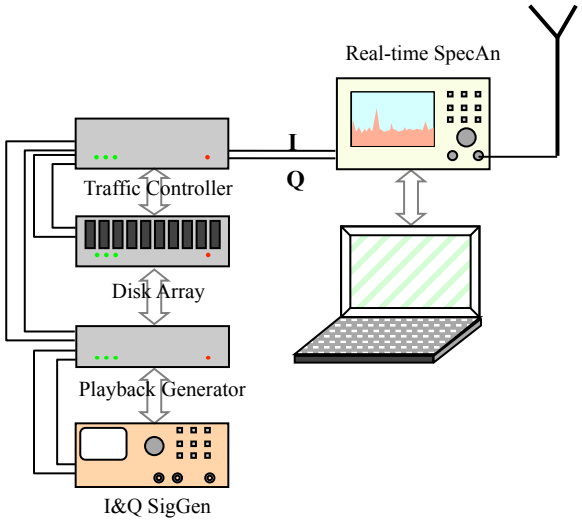
Measurement Locations

1. USNA Clock Tower, Annapolis, MD
2. Springfield Mall, Springfield VA
3. NRL pier, Washington, DC



Experimental Setups



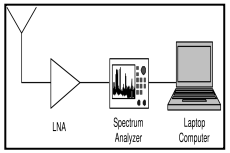


USNA Swept Spectrum

Miteq Broadband LNA
Anritsu MS2724B
Freq. Range: 690-810 MHz
Res. BW: 3.0 kHz
Noise Figure: 3.1 dB
551 points / 500 MHz
15 min. sweep time

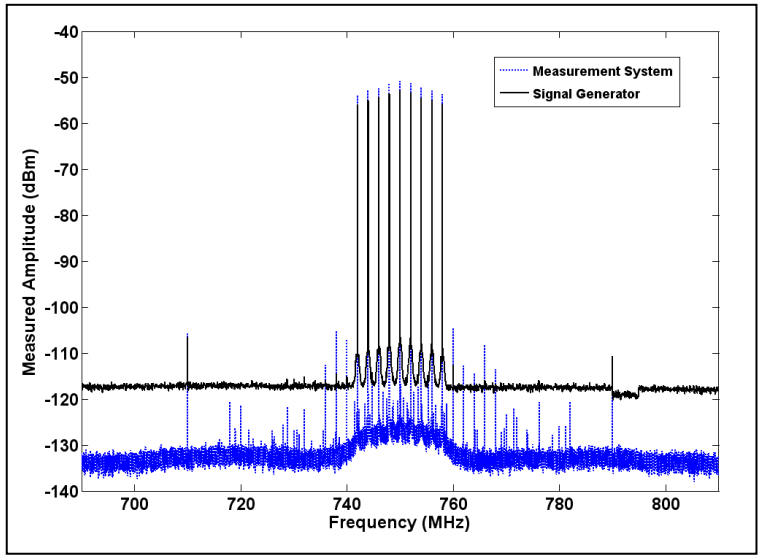
NRL Real Time

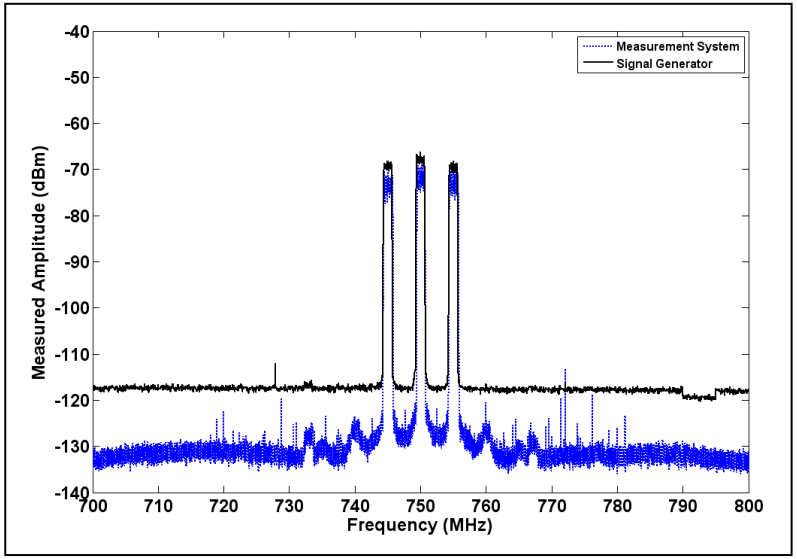
Rohde&Schwarz vertical dipole HE 309
    20 MHz – 1,300 MHz
Tektronix RSA 6114A
    40 MHz real-time acquisition BW
    100 Ms/s
    14 bits/ea I&Q
X-COM Systems
    Storage disk array: 2 TB



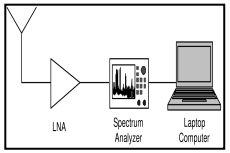
Measurement system performance evaluation and characterization

System evaluated in an RF Isolation Chamber.
Measured Noise Figure, Spurious Response, IP_2/IP_3.



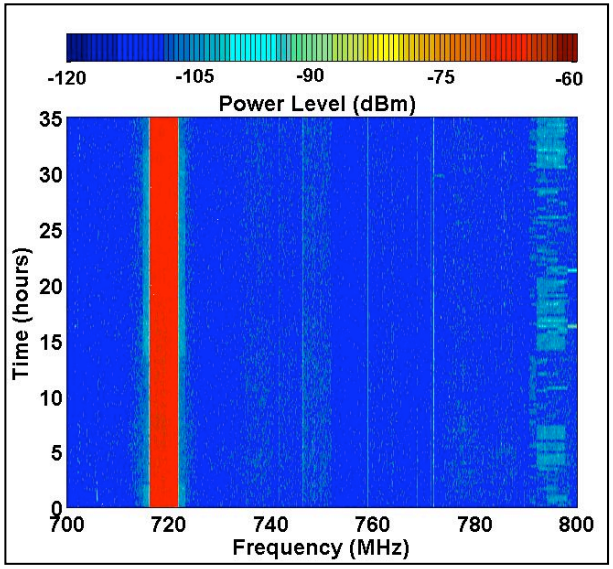


Spectrum Occupancy Measurement System Parameters	
Parameter	**Value**
Noise Figure	3.1 dB
1 dB Compression Point	+5.0 dBm
Output 3rd Order Intercept Point	+15.1 dBm
Output 2nd Order Intercept Point	+28.5 dBm
Strongest spurious signal	-110 dBm

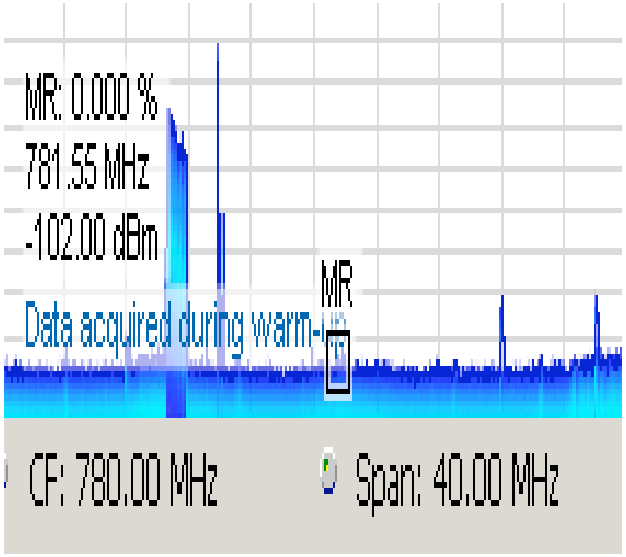


Spectrum survey measurement results from both measurement systems

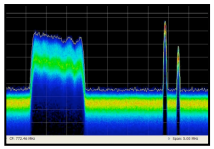
Spectrogram recorded from the USNA clock tower



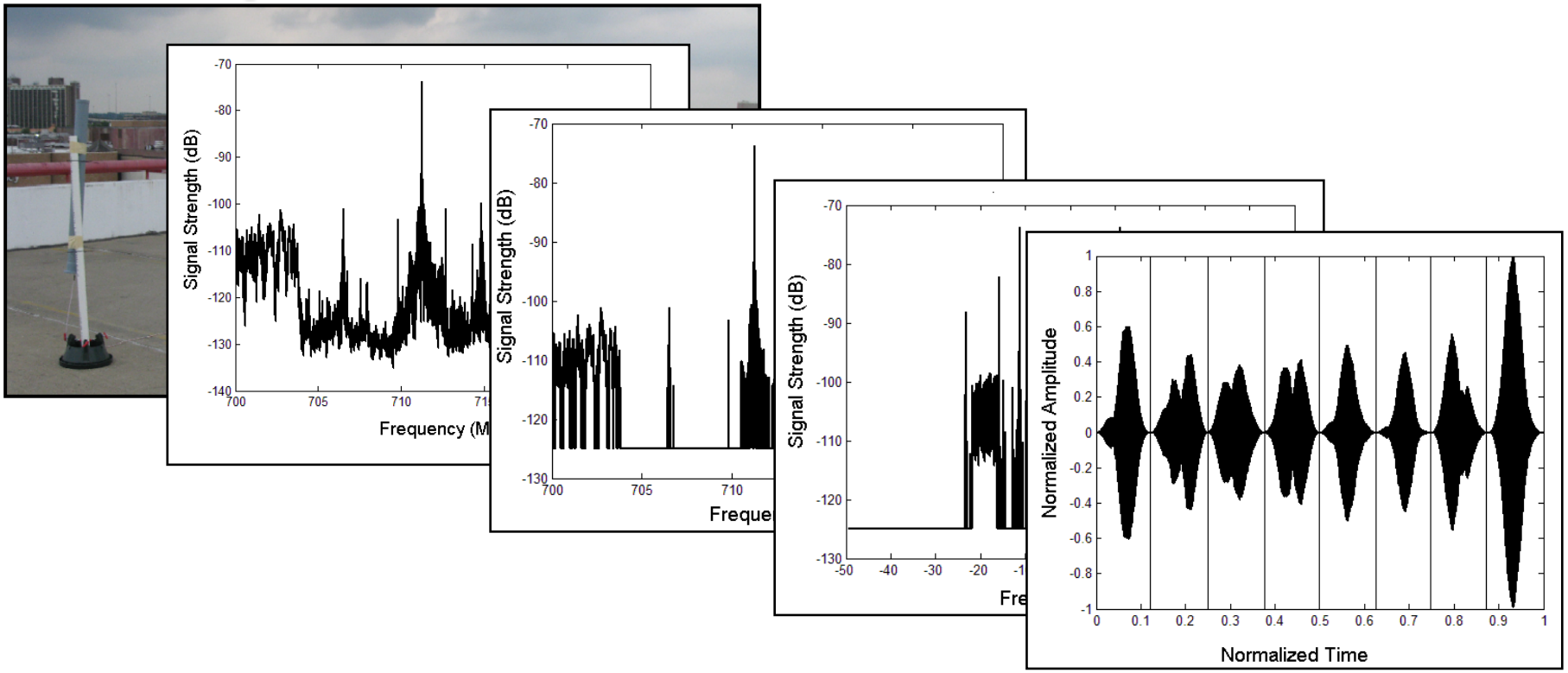
Spectrum recorded from NRL pier



Average, Minimum, and Maximum Percent Occupancy for the 700-800 MHz frequency band			
Location	**Avg.**	**Minimum**	**Maximum**
Suburban - 6/12/09	**9 %**	**6 %**	**14 %**
Urban - 6/12/09	**5 %**	**4 %**	**6 %**
Urban - 6/16/09	**8 %**	**4 %**	**12 %**

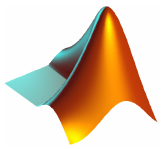


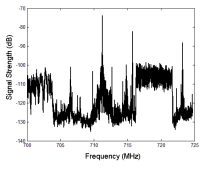
Spectrum modeling at USNA using swept-spectrum measurements

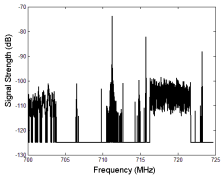


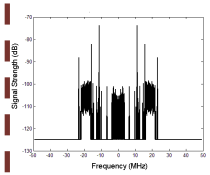
Measure | Import | Filter | Threshold | Random Phase | IFFT Window | Concatenate & Playback

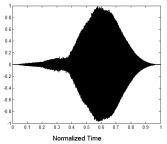
1 2 3 4 5 6 7 8











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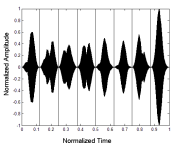
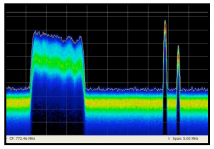
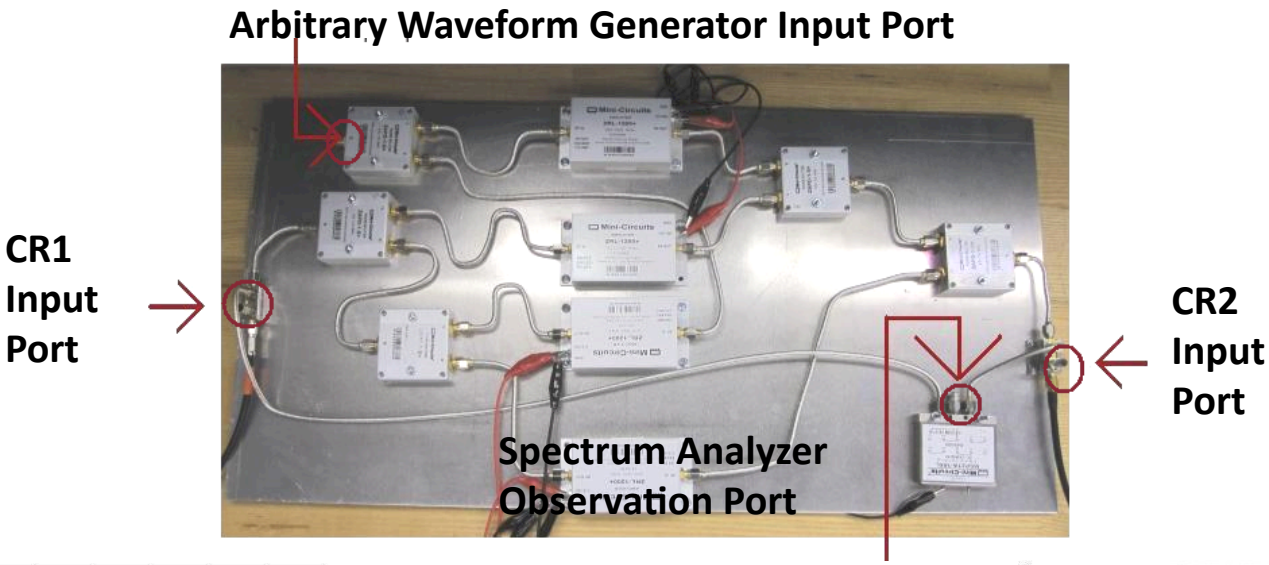
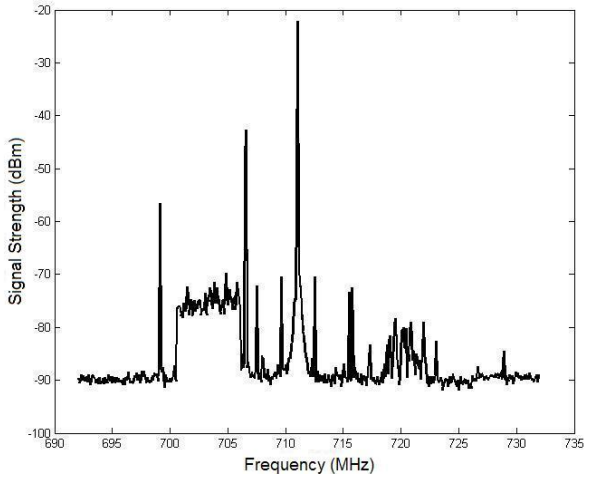


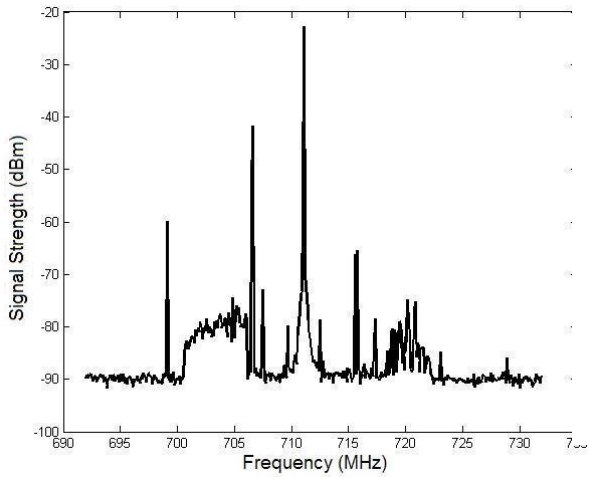


Spectrum playback using the USNA Cognitive Radio Hardware Testbed

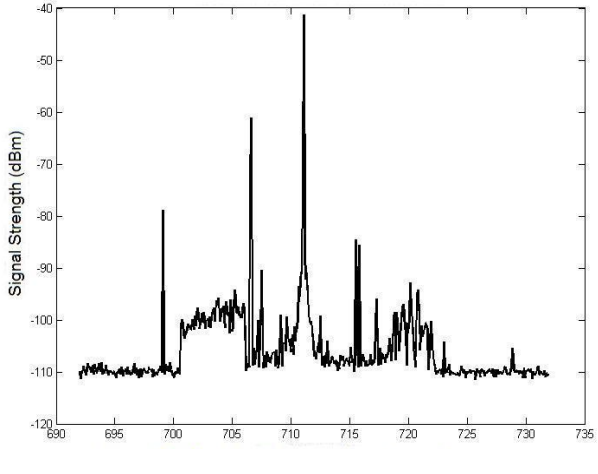




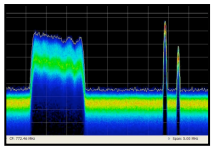
Modeled Spectrum from Signal Generator as Detected at CR1



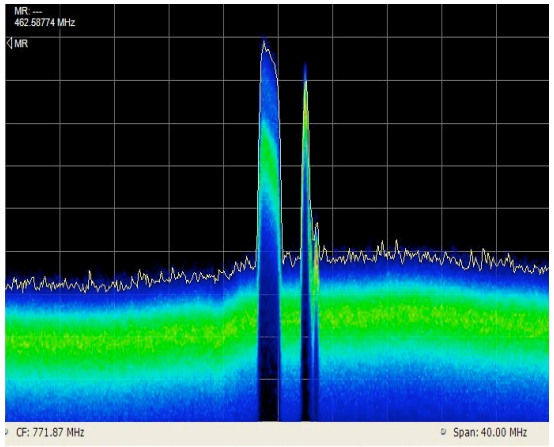
Modeled Spectrum from Signal Generator as Detected at CR2



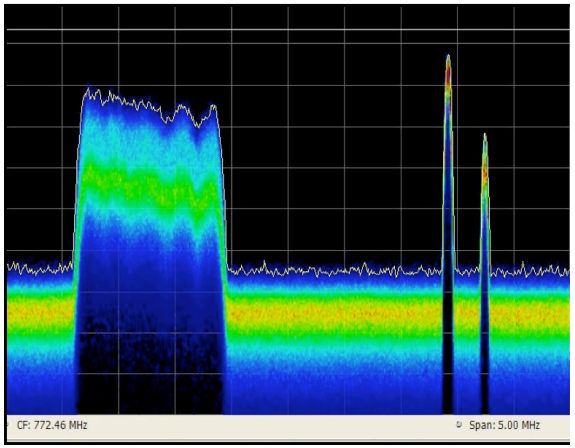
Modeled Spectrum from Signal Generator as Detected at RF Switch



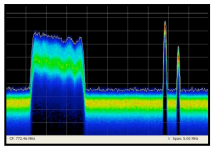
Spectrum playback with real-time system



Playback screenshot, CF = 772 MHz, BW = 40 MHz

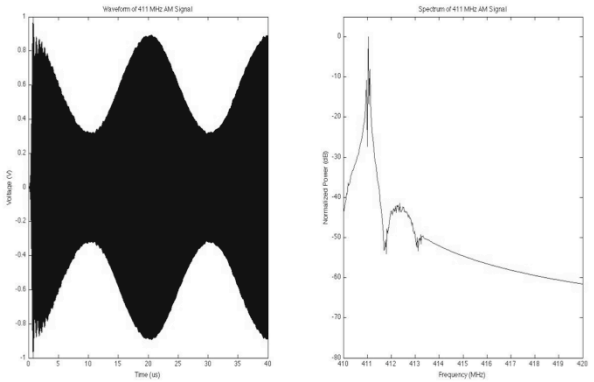


Playback screenshot, CF = 772 MHz, BW = 5 MHz

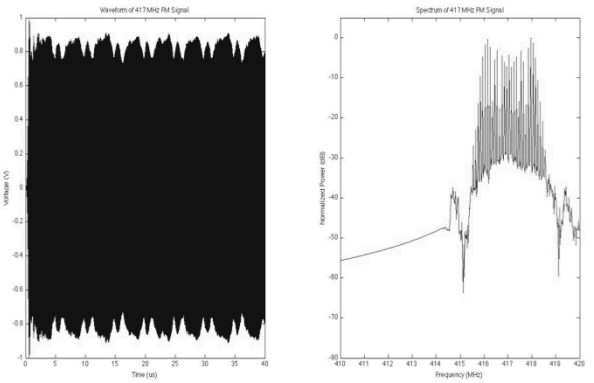


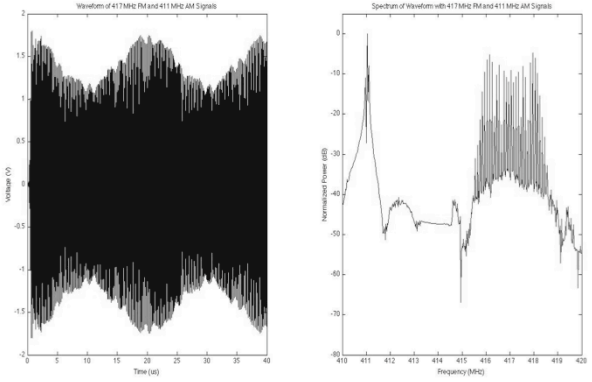
Data Manipulation

(a) AM

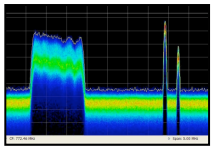


(b) FM

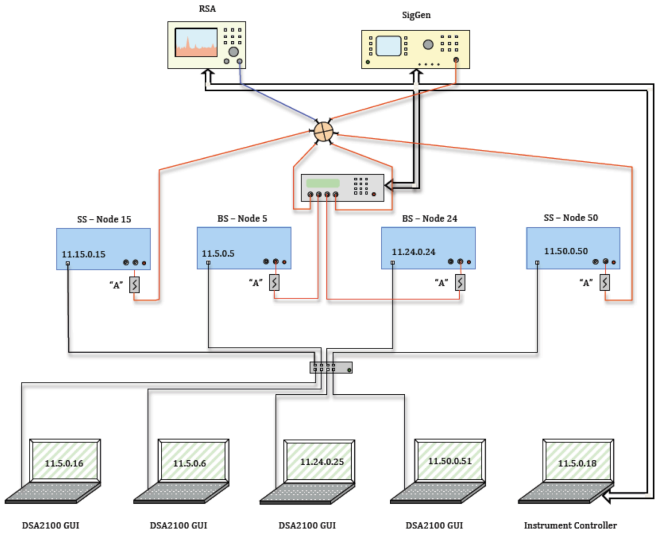




(c) AM/FM



A CR/DSA Radio Testbed at NRL



Conclusions

- Presented two methods to recreate realistic electromagnetic testbed environments to support CR/DSA R&D.
- Swept Spectrum method is less accurate at modeling a dynamic environment, but provides flexibility in Matlab modeling.
- Real-Time method has less flexibility, but accurately records I&Q components in highly dynamic environments.
- Future works
  - Refine data modeling and manipulation
  - Adding a library of waveforms that can be inserted into waveform playback to emulate a variety of real-world scenarios.

Questions?