Strategic Planning for Wireless Innovation

Radio Frequency Spectrum Management Workshop

Mayaguez, Puerto Rico

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&

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Office of Spectrum Management (OSM)

Outline

- Introduction (NTIA and ITS)
- Strategic Planning - Spectrum Sharing
- Policy Enablers for Spectrum Sharing
- State-of-the-Art – Examples
- Summary
- Questions

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National Telecommunications and Information Administration (NTIA)

- The National Telecommunications and Information Administration (NTIA) is principally responsible for advising the President on telecommunications and information policy issues.
- NTIA is a branch of the Department of Commerce (DOC)
- NTIA offices include:
  - Office of Spectrum Management (OSM)
  - Institute for Telecommunication Sciences (ITS)
- NTIA is responsible for:
  - Managing Federal use of spectrum (OSM)
  - Identifying additional spectrum for commercial use (OSM)
  - Performing cutting-edge telecommunications research and engineering (ITS)

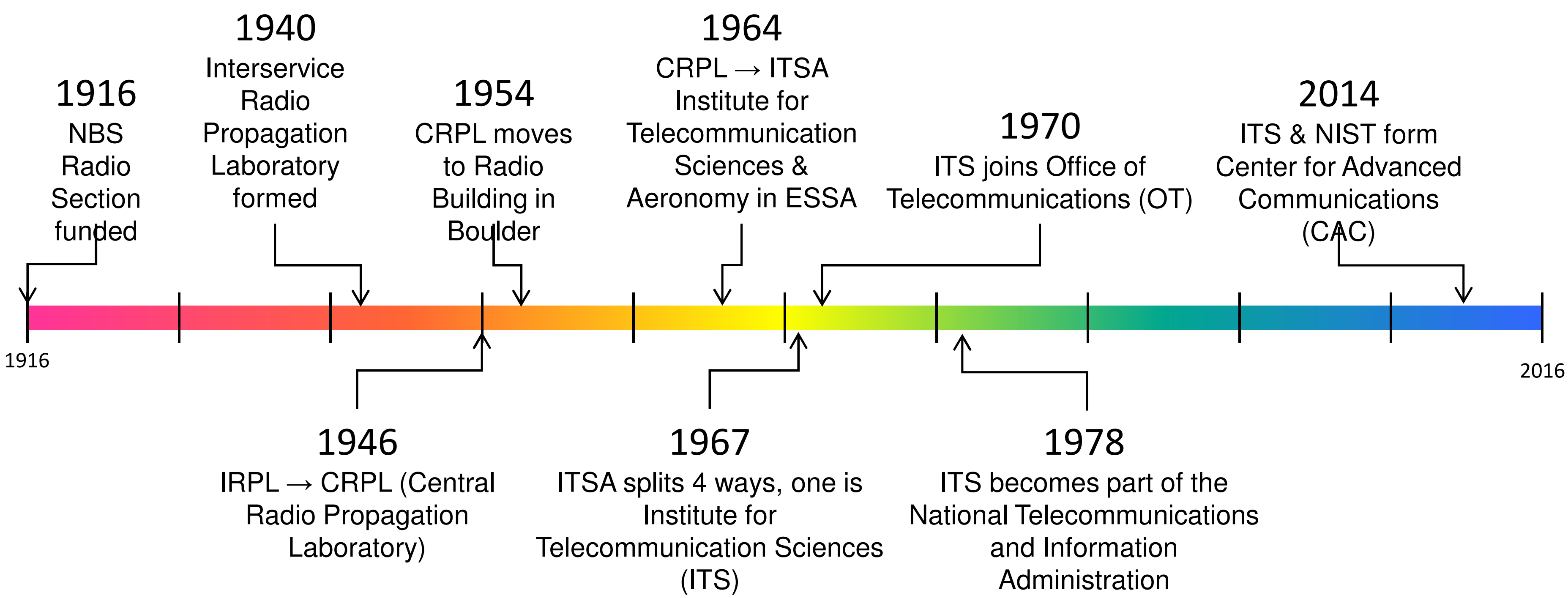
Office of Spectrum Management (OSM)

- Manages the Federal government's use of the radio frequency spectrum
  - Establishing and issuing policy regarding allocations and regulations governing the Federal spectrum use
  - Developing plans for the peacetime and wartime use of the spectrum;
  - Assigning frequencies
  - Maintaining spectrum use databases
  - Reviewing Federal agencies' new telecommunications systems and certifying that spectrum will be available
  - Providing the technical engineering expertise needed to perform specific spectrum resources assessments and automated computer capabilities needed to carry out these investigations
- Paige Atkins - OSM Associate Administrator

Institute for Telecommunication Sciences (ITS)

- The Institute for Telecommunication Sciences (ITS) is the U.S. government's premier telecommunications laboratory
  - Located in Boulder, Colorado
  - 100-year history of telecommunications research
- ITS mission:
  - Perform the research and engineering that enables the U.S. Government, national and international standards organizations, and many aspects of private industry to manage the radio spectrum
  - Ensure that innovative, new technologies are recognized and effective
  - Serve as a principal Federal resource for solving the telecommunications concerns of other Federal agencies, state and local governments, private corporations and associations, and international organizations
- Dr. Keith Gremban – ITS Director

ITS History: 100 Years of Research



Radio Section → IRPL → CRPL → ITSA → ITS

Boulder, CO

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- **Strategic Planning - Spectrum Sharing**
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Spectrum Demand

- Demand for radio frequency spectrum is exploding
  - Proliferation of wireless devices
    - In 2014, Americans used 4.1 terabytes of data over 355.4 million cellular devices[1]
    - 69% of adults access the Internet on a smartphone[2]
    - Nearly half of U.S. homes have only cellular phones[3]
    - By 2019, 11.5 billion "smart" devices will connect to mobile networks [4]
  - Increasing demand for bandwidth hungry data such as video
    - Standard definition -> high definition -> 4K
- But, spectrum is a physically limited asset
  - Exclusive rights to spectrum is not sustainable
  - Spectrum sharing is the new reality

[1]http://www.ctia.org/ your-wireless-life/how-wireless-works/annual-wireless-industry-survey
[2]http://www.leichtmanresearch.com/press/120315release.html
[3]http://www.cdc.gov/nchs/data/nhis/earlyrelease/wireless201512.pdf
[4]http://www.cisco. com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white_paper_c11-520862.html

U.S. Objectives for Spectrum

- *Unleashing the Wireless Broadband Revolution* – Presidential Memorandum 2010
  - Make available 500MHz of Federal and non-federal spectrum by 2020
  - Ensure no loss of critical existing and planned government capabilities
    - E.g., national security, emergency communications, aviation, maritime, weather, …
- Sharing is required to meet the objectives
  - Between Federal and non-federal systems
  - Across combinations of space/time
  - Dynamically
- Sharing is a *strategic imperative*
  - Exclusive use of spectrum will be the exception in the future

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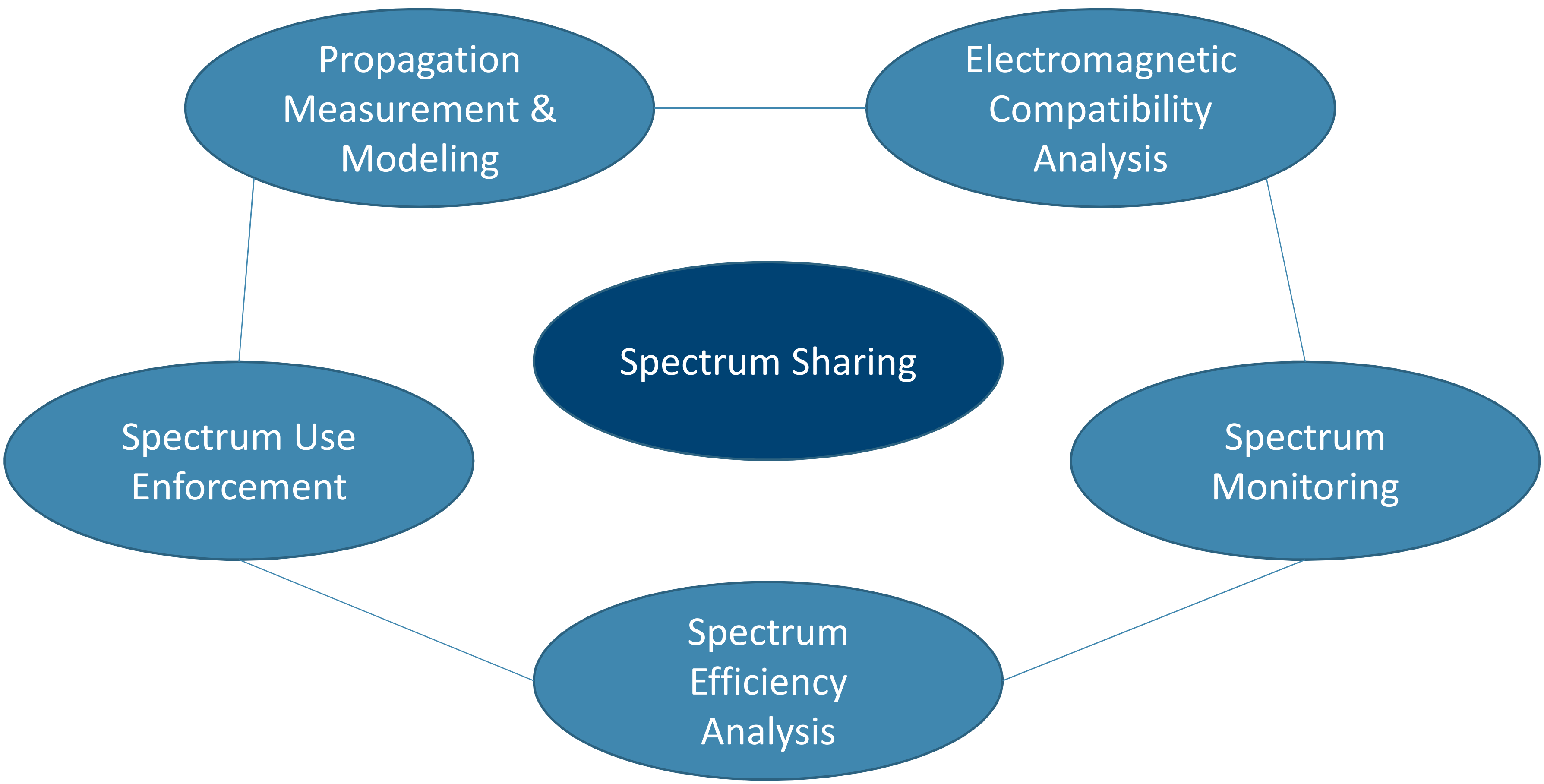
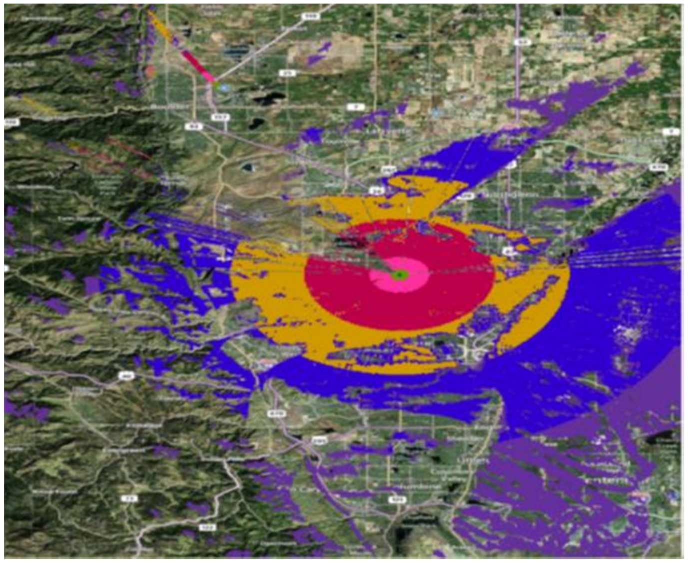
Strategic Technology for Spectrum Sharing



RF Propagation Measurement and Modeling

- Understand and quantify real-world propagation effects
  - E.g., measure transmission loss due to clutter: terrain, structures, foliage, …
- Robust measurements inform enhanced propagation models
  - E.g., clutter distributions enable more accurate predictions of path loss
- Propagation models predict
  - Regions of acceptable reception
  - Areas of potential interference

Propagation models provide insight into operations and effects prior to deployment.

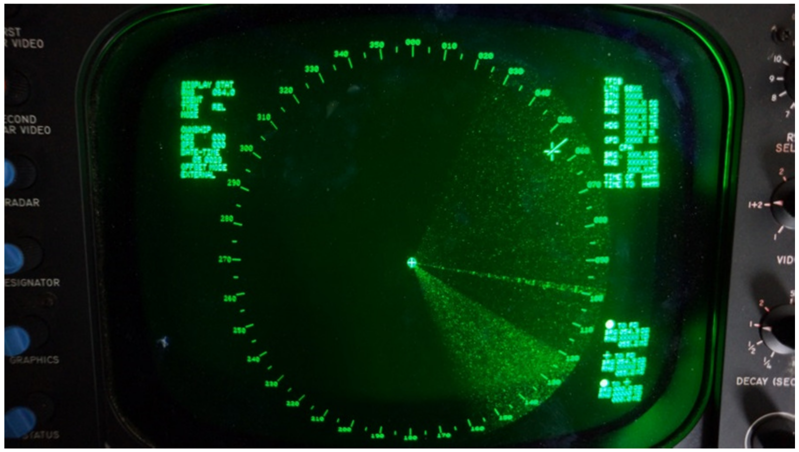


Challenge: Develop propagation models to accurately account for clutter and other effects (foliage, weather, …) using high-resolution terrain/feature data.

Electromagnetic Compatibility (EMC) Analysis

- Sharing between Federal and non-federal systems must preserve mission-critical functions
  - Need quantitative determination of interference protection criteria (IPC)
  - Receiver IPC are needed to determine minimum separation distances between systems

Coupled with measurement and modeling, EMC analysis is required to protect systems from harmful effects.

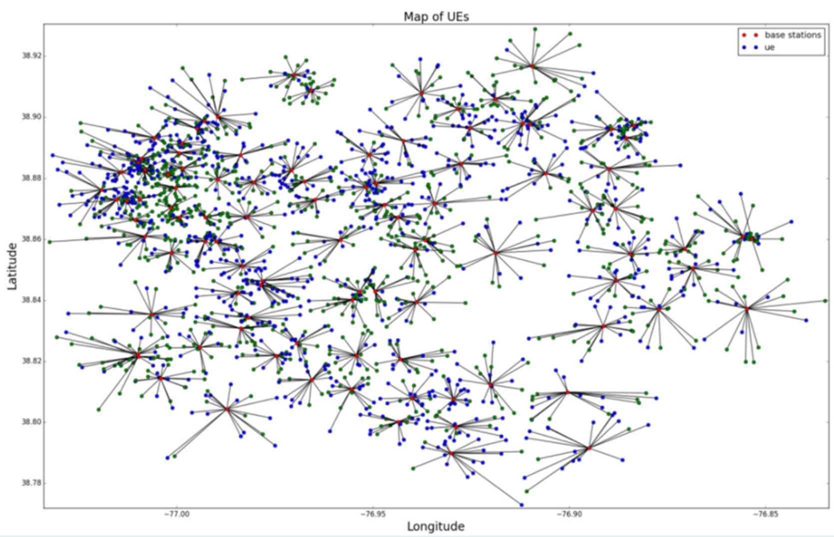


Strobe created by -6 dB INR LTE interference

Challenge: Develop tools to rapidly determine electromagnetic compatibility between legacy systems and new/evolving systems.

Aggregate Modeling

- Determine accurate predictions of probable aggregate interference from a collection of transmitters
  - e.g., overall effects of large numbers of cellphones in operation
- Critical tool for spectrum sharing
  - Risk assessment for geographic proximity of systems
  - Evaluation of proposed exclusion zones

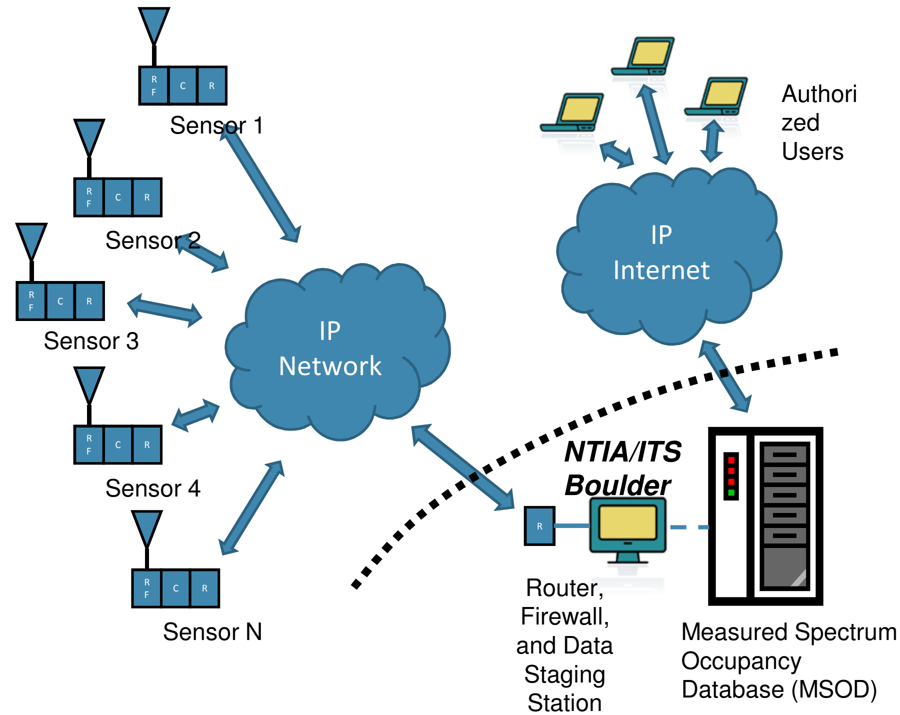


Challenge: Understand and quantify the effects that result from collections of transmitters all operating within range of target systems.

Spectrum Monitoring

- Spectrum monitoring can provide real-time and historical data to:
  - Validate occupancy/usage models
  - Field test coordination technology
  - Facilitate spectrum sharing
  - Inform planners and policy makers

Measured spectrum occupancy data is required for evaluation of spectrum sharing opportunities and enforcement of license agreements.

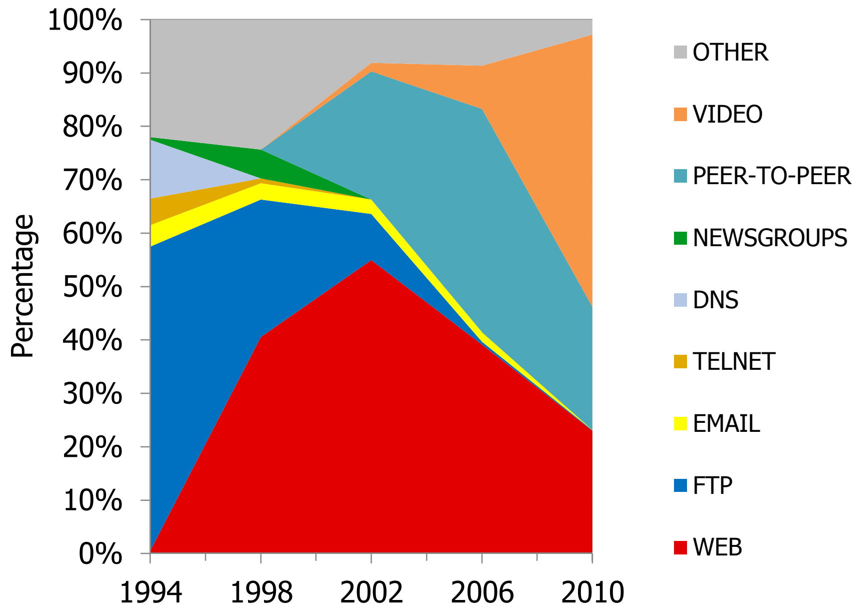


Challenge: Develop spectrum monitoring technology that is interoperable, low-cost, high-resolution, and privacy-preserving.

Spectrum Efficiency

- Exploit options to make efficient use of spectrum
- Video is dominating communications
  - Bandwidth intensive
  - Demand for increased resolution
    - SD -> HD -> 4K -> ....
- Compression for efficiency
  - MPEG-2 (1996) OTA broadcast
  - AVC/H.264 (2003) blu-ray, satellite
  - HEVC/H.265 (2013) in progress

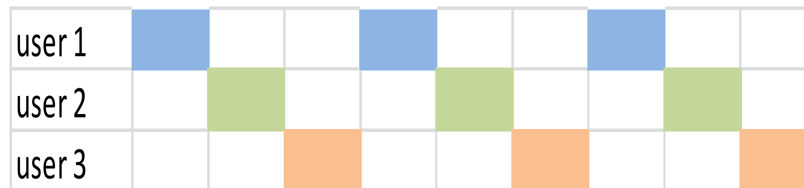
End-user experience is the bottom line for evaluation of video quality.



Challenge: Develop automated tools that accurately reflect subjective evaluations of video (and audio) quality.

Sharing Efficiency

- Not as simple as maximizing occupancy or throughput
- Need to measuring the amount of sharing and info transfer (overhead) required for sharing
- Traffic type dictates the granularity of sharing possible
- Need to consider
  - Time occupied
  - Spatial extent
  - Transmitter power



Challenge: Automatically compute real-world measurands that reflect sharing efficiency while preserving privacy.

Sharing Enforcement

- Enable detection, location, classification, and identification of:
  - Inadvertent interference/occupancy
  - Algorithm/technology failures
  - Bad actors
- Translate sharing agreements/licenses into measureable parameters
  - (easy) Enforcement of exclusion zones with RF perimeter monitors
  - (harder) Dynamic sharing using SAS and ESC monitoring systems – geographic + temporal restrictions
  - (hardest) Dynamic sharing in same time/space – e.g., unlicensed spectrum

Challenge: Translate sharing agreements into measurable parameters, and develop software to monitor compliance and detect violations while preserving privacy.

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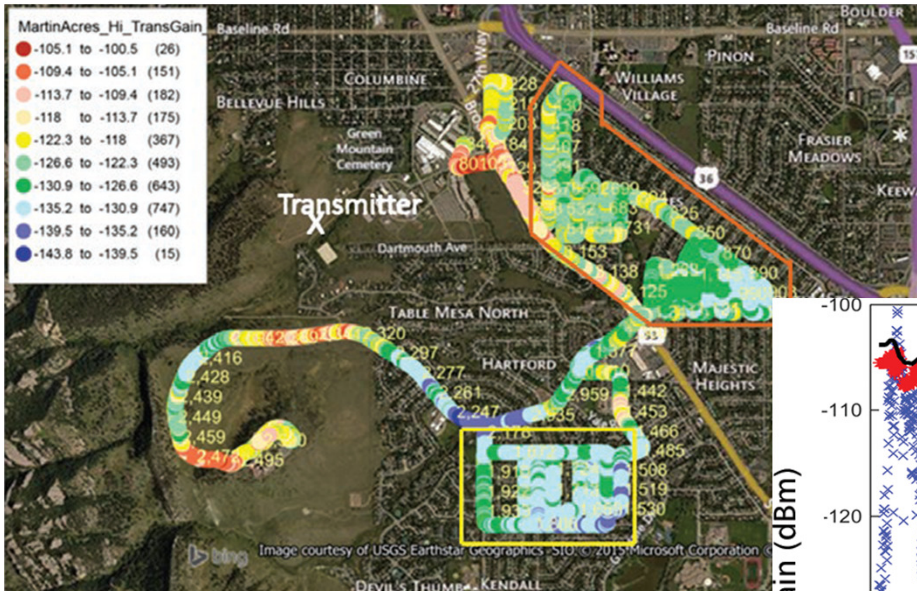
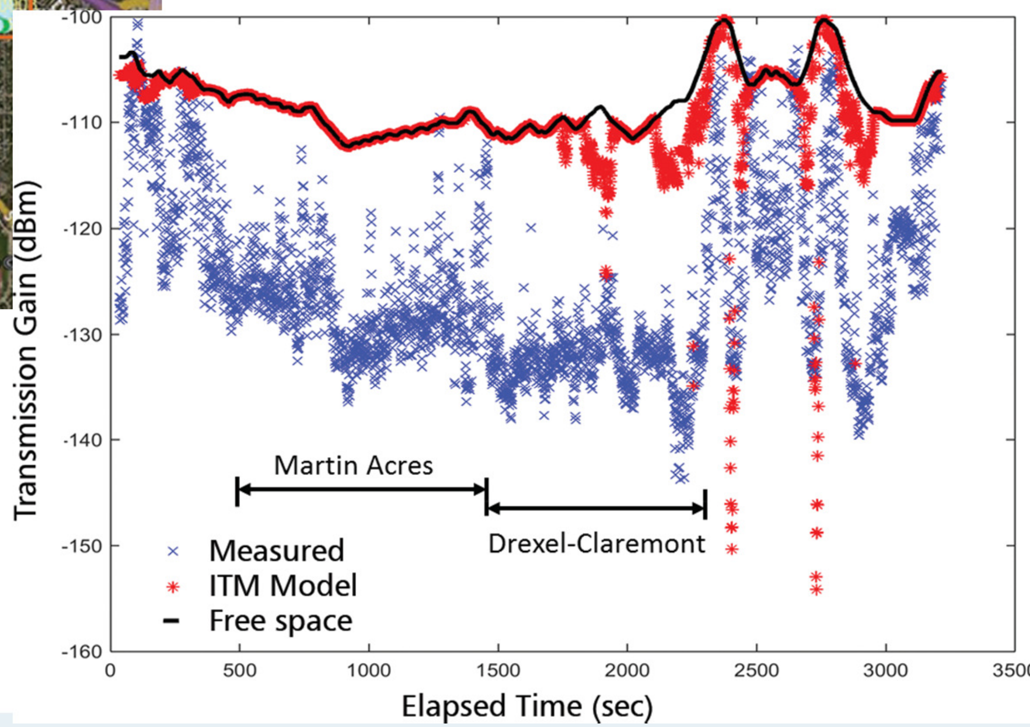
Case Study – Clutter Loss





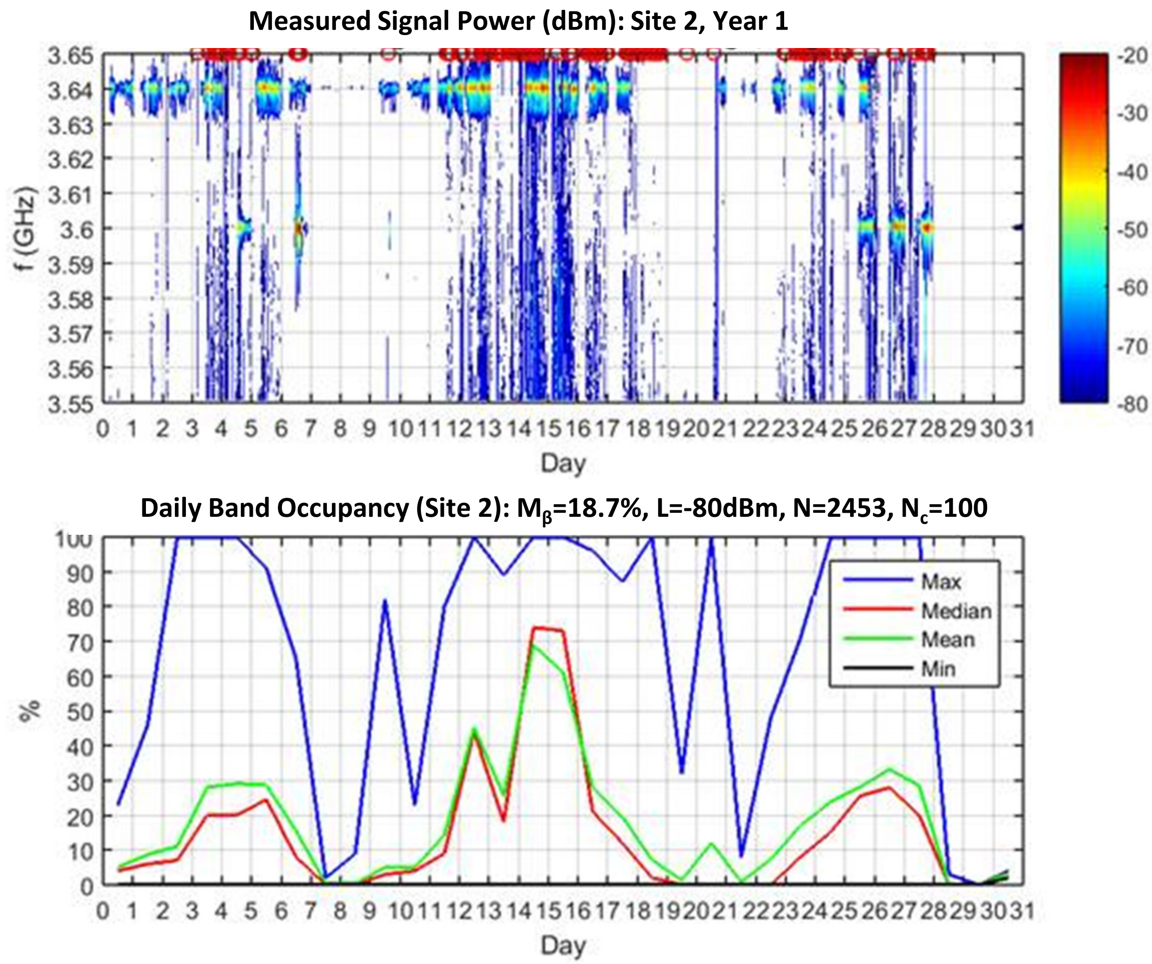
Case Study
3.5 GHz Exclusion Zone Analysis

- Exclusion zone defines the geographic separation between macro-cell networks and radars
- 2010 Fast Track Report recommended exclusion zones of 40-60 km
  - Simplified propagation model
- Revised 2014 NTIA analysis reduced exclusion zones by >77%
  - Enhanced propagation model
  - Enhanced clutter model

Fast Track exclusion zone

NTIA revised exclusion zone

Case Study
Monthly Band Occupancy (3.55 – 3.65 GHz)



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Summary

- Spectrum access is a requirement for 21st century life
  - Key enabler for world-leading consumer technologies
  - Key infrastructure for Federal and non-federal sectors
- Spectrum sharing is the future – a *strategic imperative*
- Spectrum sharing can work
  - 1755-1780 MHz band affected 15 Federal agencies
    - Geographic sharing over 10-year transition period
  - 3.5 GHz made available for shared small cell use
    - Spectrum Access System (SAS) and Environmental Sensing Capability (ESC) provide technology for dynamic sharing and interference mitigation

Innovative technologies, policies, and processes will enable effective and efficient spectrum sharing.

SPECTRUM FORENSICS

… spectrum measurements that support interference monitoring, investigation, and enforcement.

… the gathering of information by a trusted agent, using rigorous repeatable scientific engineering methods, to inform an enforcement action …

… the use of spectrum measurement systems to identify the cause and source of interference …

… spectrum monitoring, signal identification, interference detection, transmitter location …

As more and more spectrum users are pressed to operate in shared bands, effective spectrum sharing will require an entirely new legal and regulatory environment, as well as sophisticated technologies that can reliably thread the three parameters of time, frequency, and location to deliver acceptable service in shared bands without interfering with other users of the same or adjacent bands. Spectrum forensics will help build and maintain good fences to make good neighbors.

ISART
INTERNATIONAL SYMPOSIUM ON ADVANCED RADIO TECHNOLOGIES
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ISART 2016: SPECTRUM FORENSICS

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SPECTRUM FORENSICS

August 1–3, 2016
Boulder, Colorado

www.its.bldrdoc.gov/ISART

DRAFT AGENDA

Monday, August 1, 2016

Morning:

Tours of ITS Labs:
- *Indoor Propagation Measurements*
- *Aggregate Signal Analysis*
- *3.5 GHz Measurements*

Tours of CTL Labs
- *Antenna Metrology, CROMMA*
- *Shared Spectrum Metrology, NBIT*
- *Wireless Systems Metrology, 5G Channel Sounder*

WSRD Meeting

Afternoon:

Tutorial: Spectrum Forensics Case Studies

The tutorial provides essential background for ISART participants who are not familiar with the FCC Enforcement Bureau's criteria and process for both civil and criminal spectrum interference investigations and enforcement actions.

CSMAC Meeting

Tuesday, August 2, 2016

- **8:00 Registration**
- **8:00-5:00 Vendor Demos and Posters**
- **9:00 Opening Address and Keynote**
- **10:00-12:00 Panel: Regulatory Considerations**
  This panel will focus on regulatory considerations in applying spectrum forensics to the classification, identification, location, reporting, and enforcement of spectrum regulations. This panel will explore the existing FCC enforcement framework and draw from other enforcement regimes to determine what new approaches, processes, and technical disciplines will be required to expand capabilities within the radiofrequency spectrum forensics community. Currently, spectrum forensics has applications in a regulatory and enforcement framework ranging from measurement of system occupancy for proposed rulemakings to identification and mitigation of harmful interference through both legal and technical channels. To mitigate interference, spectrum engineers will need to discriminate among malfunctioning transmitters, poorly designed transmitters, and intentional misuse of spectrum enabled by the democratization of software defined radios. This will present even greater demands on regulators.
- **1:30-2:30 Presentations**
- **3:00-5:00 Panel: Spectrum Monitoring – Purposeful Data Collection**
  Economic and technical constraints limit the scope of data available for spectrum forensics. Good architectural design can maximize limited resources and provide novel processes for data acquisition, integration, management, and use. Spectrum data architects and users on this panel will discuss, evaluate, and weigh ideas for a national infrastructure that (1) supports data aggregation from diverse sources and (2) establishes a logical separation between infrastructure and information, to promote specialization and economies of scale in areas such as sensor design, data visualization, and information extraction. The panel will start with a strawman spectrum monitoring architecture with well-defined constraints (e.g., budget, privacy, storage, throughput). It will evaluate ideas, options, and recommendations for design requirements, business models, and next steps.

Wednesday, August 3, 2016

- **8:00-5:00 Vendor Demos and Posters**
- **8:00-9:45 Presentations**
- **10:00-11:30 Panel: Enabling Technologies and Standards**
  The technical enablers of spectrum forensics span monitoring instrumentation, computational resources, and standards for recording spectrum measurements. Monitoring instrumentation includes not only the downconverters, digitizers, and signal analyzers capable of analyzing the wide bandwidths of current and future wireless broadband systems, but also antenna arrays and related technologies for direction finding and localization of emitters. Storage architectures will also be needed to record vast amounts of data and make them readily available for subsequent analysis. Computational resources will be needed to detect anomalous spectrum behavior in real time as well as to analyze captured data off-line. Finally, standard formats for signal waveforms and associated metadata would bring the benefits of open architectures to future spectrum forensics solutions. This panel will report on the state-of-the-art in the technologies and standards that make spectrum forensics possible and identify gaps where future development and standardization are needed.
- **1:30-2:30 Presentations**
- **3:00-5:00 Panel: Data Analytics**
  This panel will focus on the mathematical techniques for analyzing captured signal data, with an emphasis on machine learning, data mining and artificial intelligence techniques. Classical pattern recognition and other statistically-based methods may also be included. The limitations and potential pitfalls of each technique will be considered along with the advantages and capabilities. Related to this topic is the question of what type and quantity of data need to be captured and retained in order to use each technique. Time and frequency resolution and appropriate quantization are examples of this. The panel will not only discuss current research results but will help identify specific topics and techniques where future research is still needed.

Wednesday, Thursday, and Friday, August 3–5, 2016

- **WInnForum:** *Wireless Innovation Forum: Spectrum Sharing Committee Meeting*

ISART 2016 Contacts

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Questions?