Informing Spectrum Policy through Focused Research

Commerce Spectrum Management Advisory Committee (CSMAC)

Boulder, CO

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Institute for Telecommunication Sciences (ITS)

National Telecommunications and Information Administration (NTIA)

Outline

- **Introduction to ITS**
- Project Summaries
- Questions

ITS History: 100 Years of Research

1916
NBS Radio Section funded

1940
Interservice Radio Propagation Laboratory formed

1946
IRPL → CRPL (Central Radio Propagation Laboratory)

1954
CRPL moves to Radio Building in Boulder

1964
CRPL → ITSA Institute for Telecommunication Sciences & Aeronomy in ESSA

1967
ITSA splits 4 ways, one is Institute for Telecommunication Sciences (ITS)

1970
ITS joins Office of Telecommunications (OT)

1978
ITS becomes part of the National Telecommunications and Information Administration

2014
ITS & NIST form Center for Advanced Communications (CAC)

1916

2016

Radio Section → IRPL → CRPL → ITSA → ITS

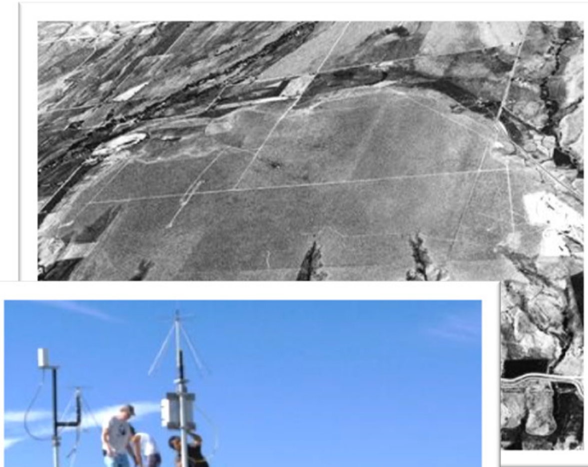
Institute for Telecommunication Sciences (ITS)

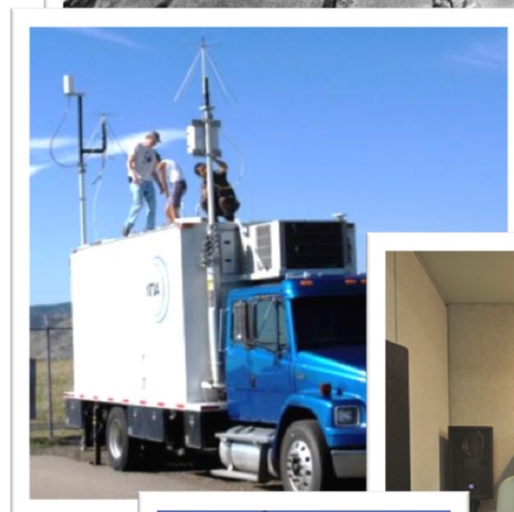
- The Institute for Telecommunication Sciences (ITS) is the U.S. government’s premier telecommunications laboratory
- ITS mission:
  - Perform the research and engineering required to inform policy
  - Solve the telecommunications concerns of other Federal agencies
    - ITS receives over 50% of funding from other government agencies
- ITS strategic thrusts:
  - Electromagnetic compatibility (EMC) and systems analysis
  - Propagation measurement and modeling
  - Spectrum monitoring/analysis/enforcement
  - User experience evaluation
  - Mission-critical communications

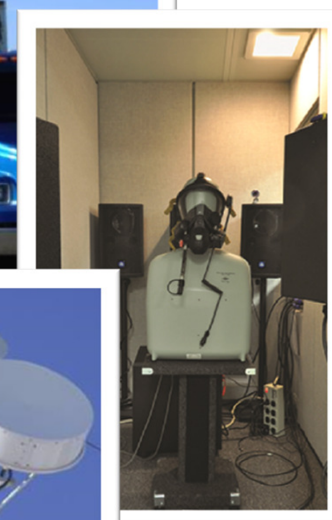
ITS At-A-Glance

- **Radio propagation theory** (Mike Cotton)
  - Maintain and enhance standard RF propagation models:
  - Aggregate models
  - EMC analysis
- **RF measurement** (Eric Nelson)
  - High-density RF measurements
  - Interference detection and mitigation
- **Software Engineering** (Julie Kub)
  - Tool & web-site development
  - CMMI certification
- **System Engineering and Evaluation** (Andy Thiessen)
  - Audio and visual user experience evaluation
  - International standards development

ITS Assets







- **Table Mountain**
  - 1800 acre mesa in Boulder County
    - Radio quiet zone
    - One of 2 in the United States
  - Facilities include laboratory buildings, turntable, antennas
- **RSMS Vehicles and portable systems**
  - Mobile RF shielded laboratories
  - Precision measurement equipment
- **Laboratories**
  - Faraday cages, waveform generators
  - Controlled test, sound isolation chambers
- **Public Safety (PSCR) Over-the-Air LTE Network**

Spectrum Demand

- Demand for radio frequency spectrum is exploding
  - Proliferation of wireless devices
  - Increasing demand for bandwidth hungry data such as video
- But, spectrum is a finite resource
  - Exclusive rights to spectrum is not sustainable
  - Spectrum sharing is the new reality
- *Unleashing the Wireless Broadband Revolution* – Presidential Memorandum 2010
  - Make available 500 megahertz of Federal/non-federal spectrum by 2020
  - Ensure no loss of critical existing and planned government capabilities
- Sharing is a *strategic imperative*
  - Exclusive use of spectrum will be the exception in the future

Enablers of Spectrum Sharing

- Spectrum Monitoring
  - Determine the occupancy characteristics of selected spectral bands
  - Inform the process of identifying and prioritizing bands for potential sharing
- Propagation Measurement and Modeling
  - Measure RF propagation characteristics in various bands and environments
  - Upgrade RF propagation models with additional measurements
  - Apply measurements and modeling to inform sharing parameters
- Electromagnetic Compatibility Analysis
  - Determine potential interference from equipment operating in a common environment
  - Develop interference protection criteria
  - Develop approaches to interference mitigation

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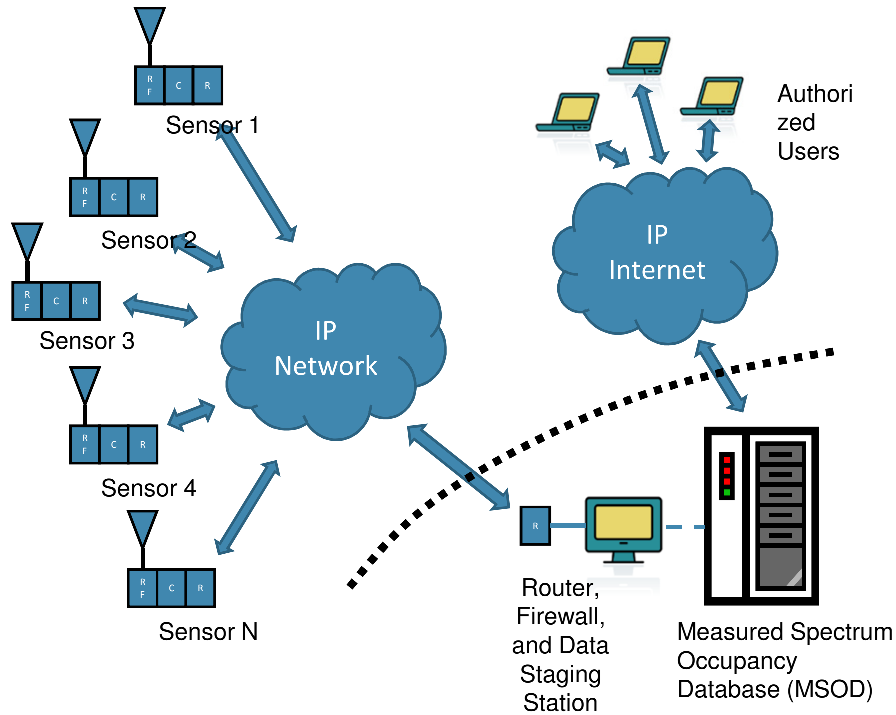
Spectrum Monitoring

- Joint effort of
  - NTIA/ITS
  - NIST/CTL
- 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

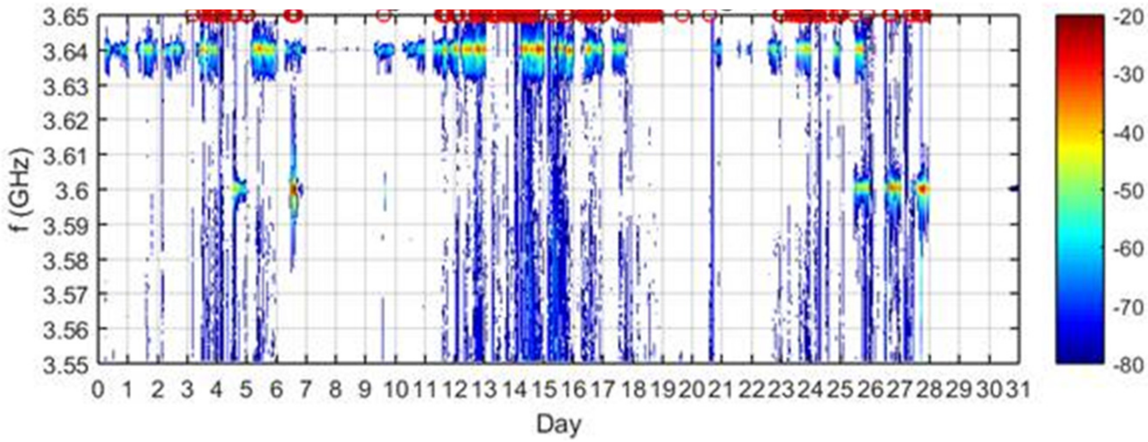
Measured spectrum occupancy data is required for evaluation of spectrum sharing opportunities and enforcement of license agreements.



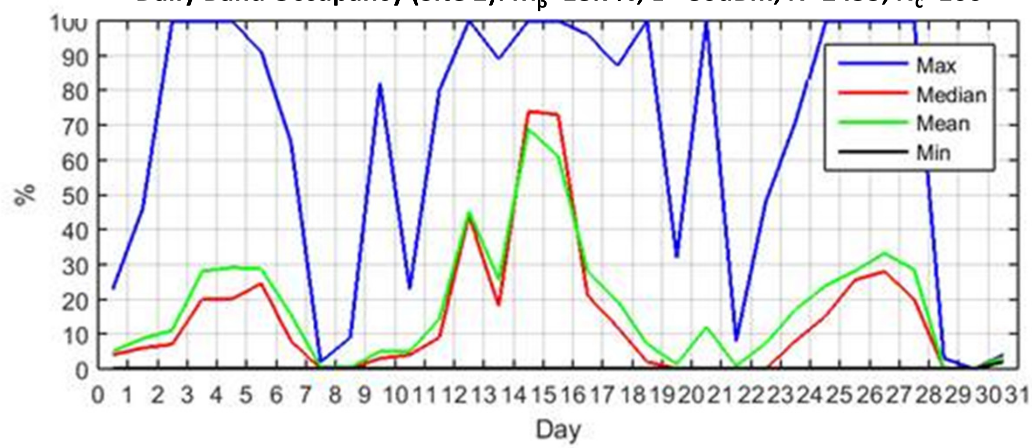
Challenge: Develop spectrum monitoring technology that is interoperable, low-cost, high-resolution, and privacy-preserving.

Example
Monthly Band Occupancy (3.55 – 3.65 GHz)

Measured Signal Power (dBm): Site 2, Year 1



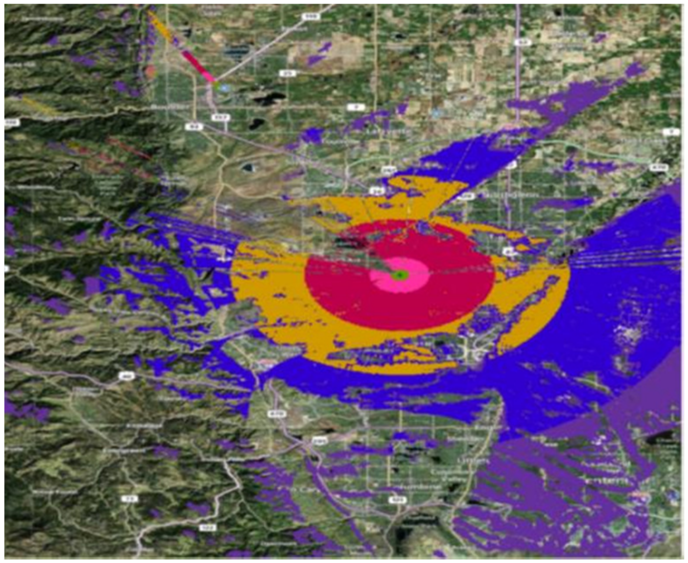
Daily Band Occupancy (Site 2): M_{β}=18.7%, L=-80dBm, N=2453, N_c=100



RF Propagation Measurement and Modeling

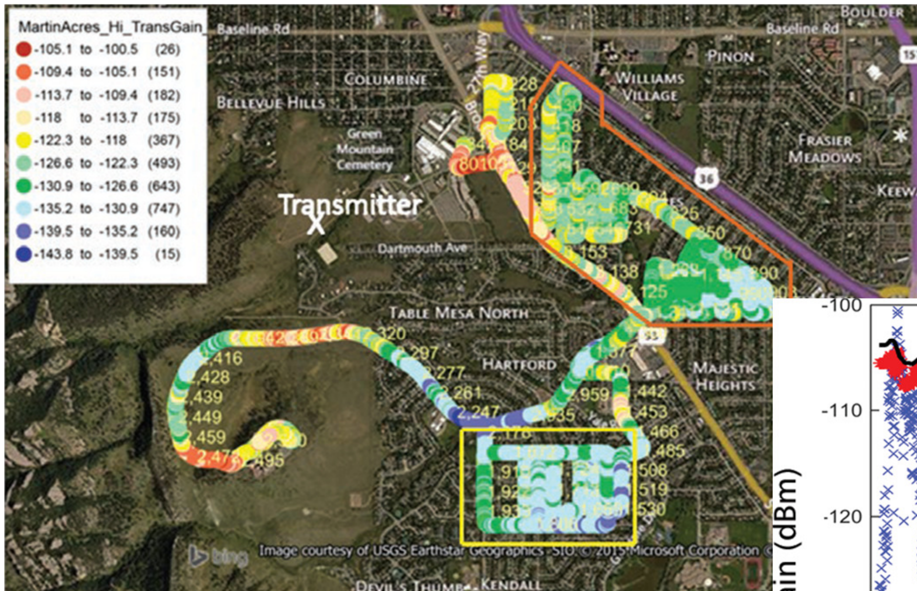
- Understand and quantify real-world propagation effects
  - *e.g.*, measure transmission loss due to clutter: terrain, structures, foliage, …
- Robust measurements inform enhanced propagation models
  - *e.g.*, clutter distributions enable more accurate predictions of path loss
- Propagation models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

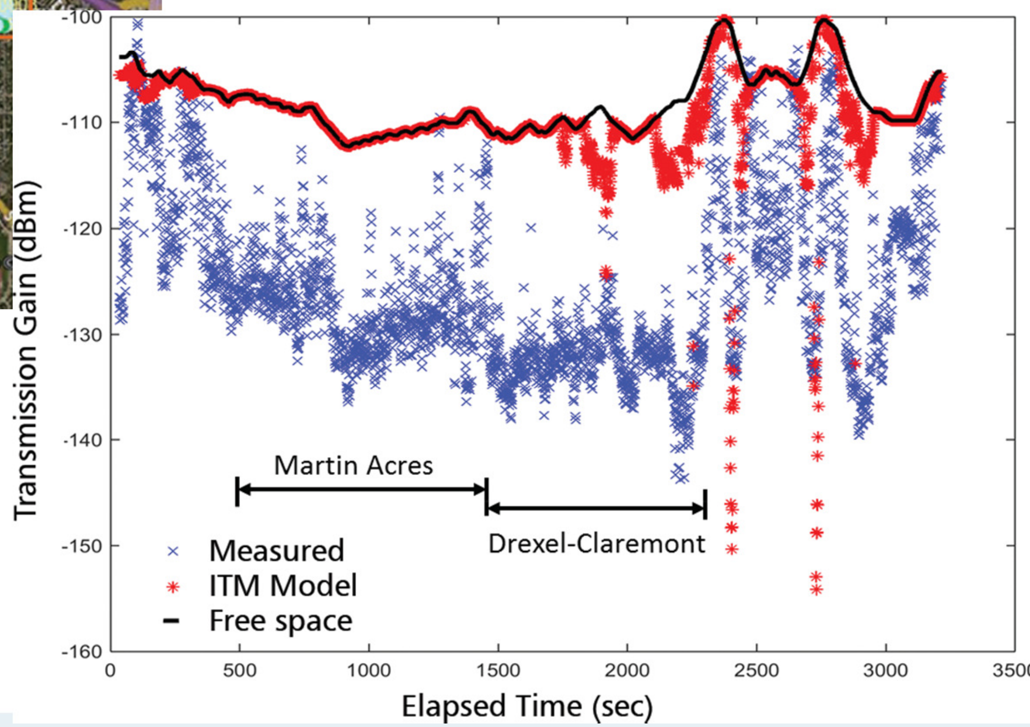
Propagation models provide insight into operations and effects prior to deployment.



Challenge: Develop propagation models to accurately account for clutter and other effects using high-resolution terrain/feature data.

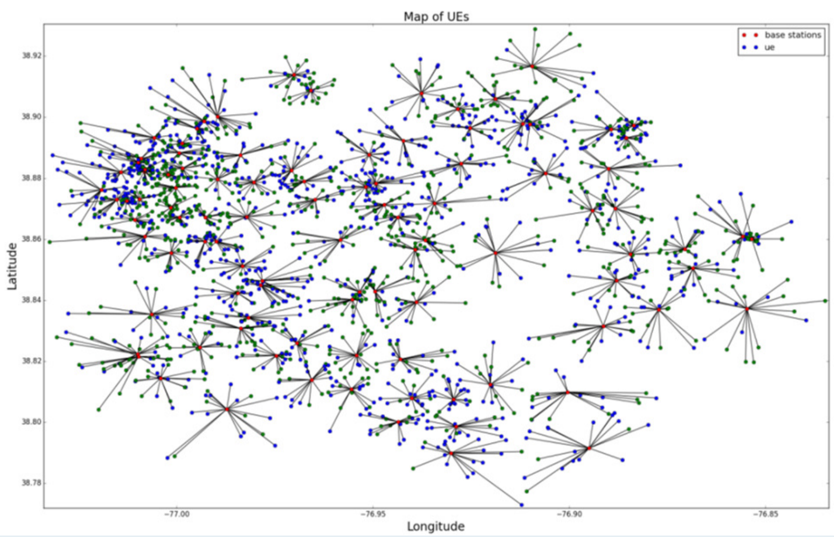
Case Study – Clutter Loss





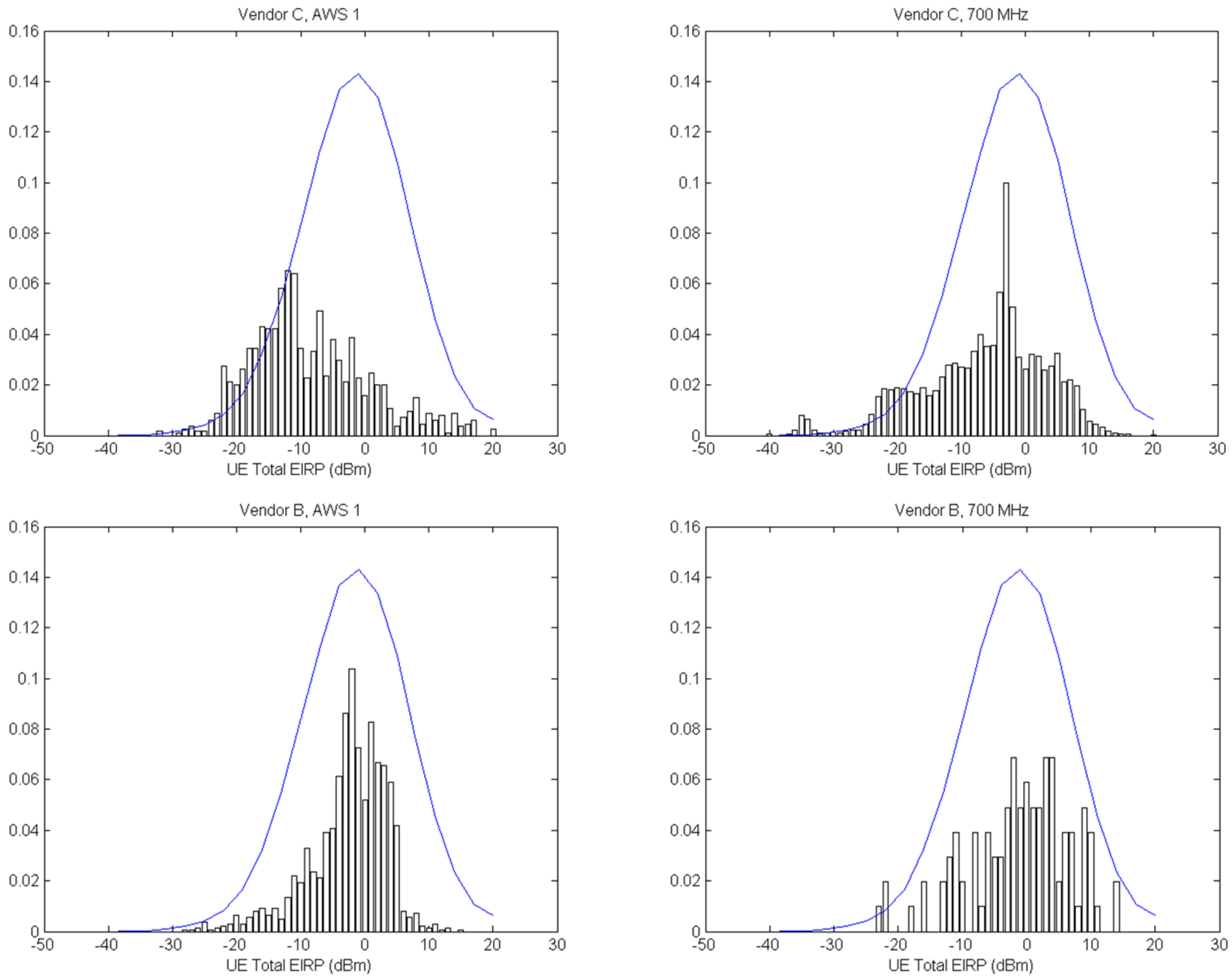
Aggregate Modeling

- 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

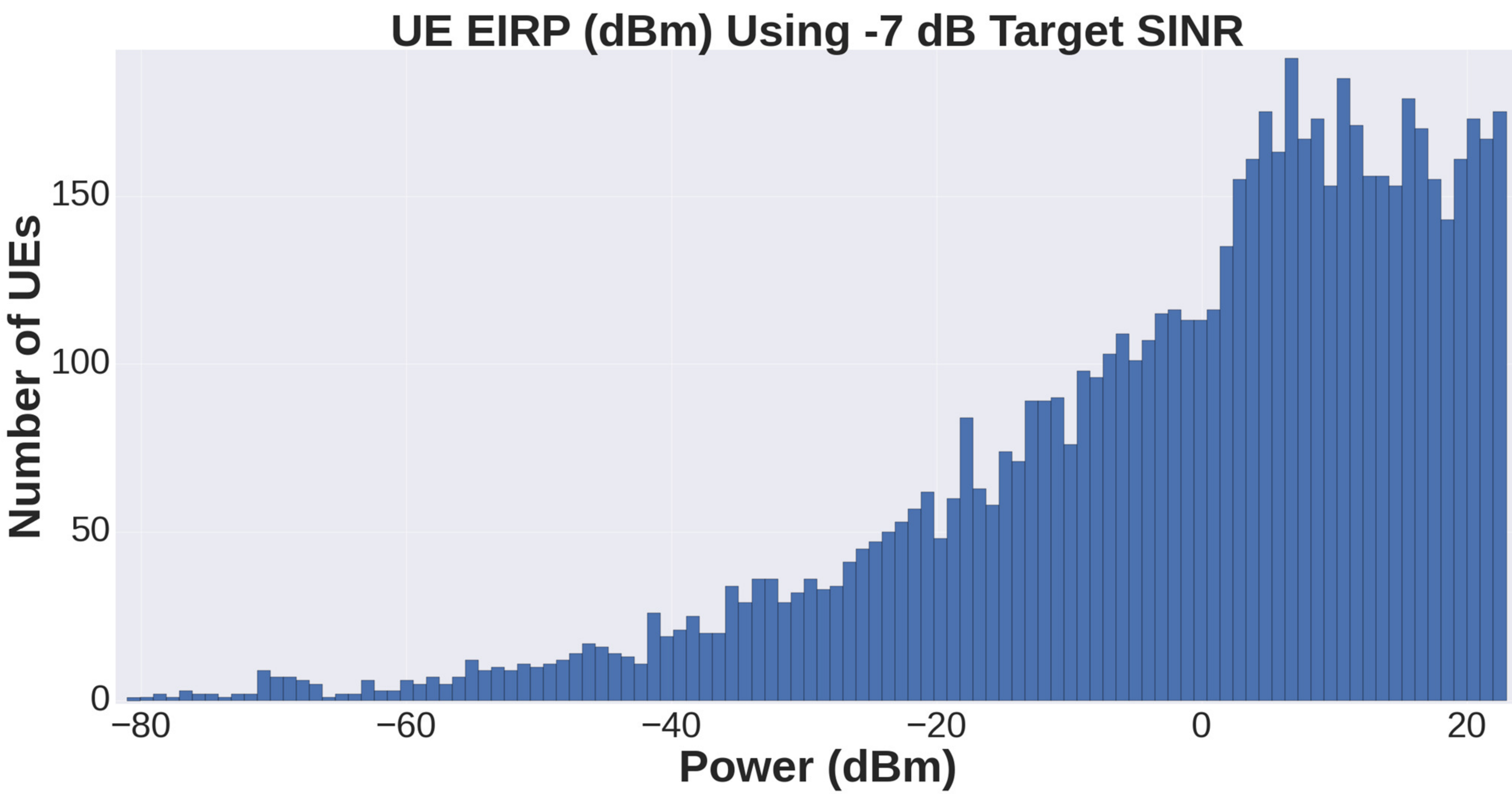


Challenge: Understand and quantify the effects that result from collections of transmitters all operating within range of target systems.

Aggregate Modeling: What Do We Expect?



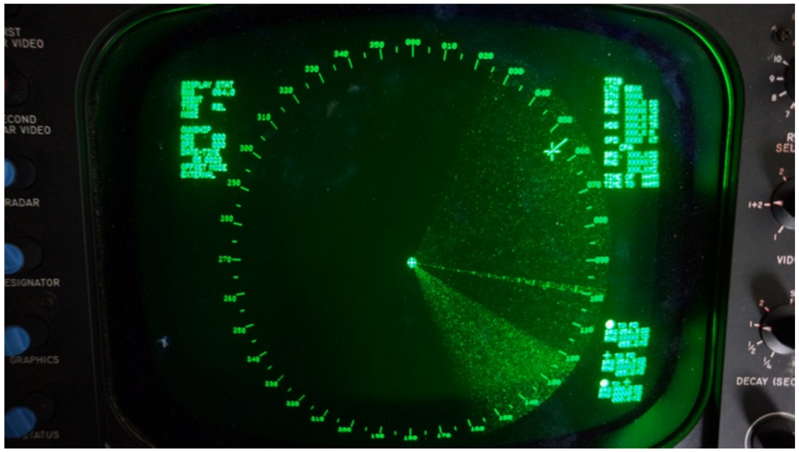
Aggregate Modeling: What Do We Get?



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.

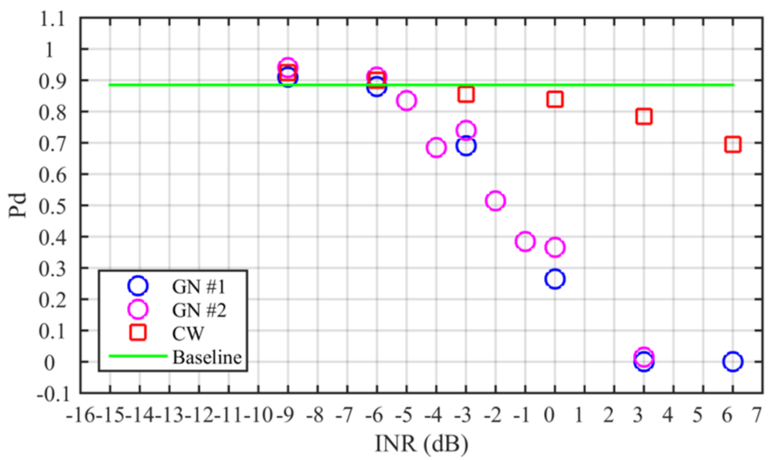


Strobe created by -6 dB INR LTE interference

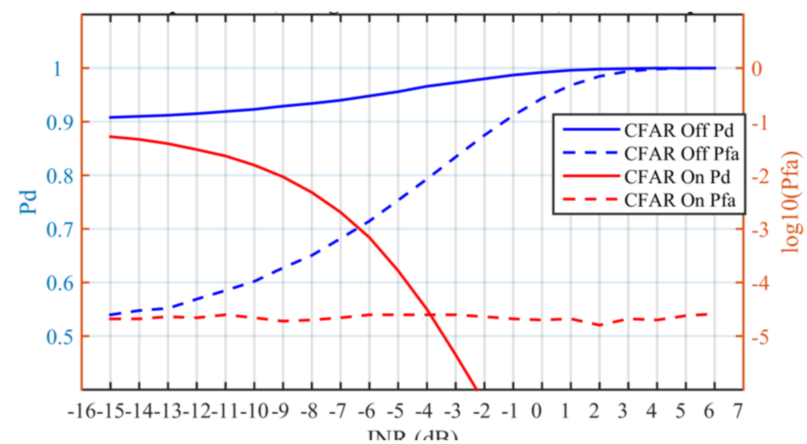
Challenge: Develop tools to rapidly determine electromagnetic compatibility between legacy systems and new/evolving systems.

Receiver IPC Simulation

Measurement
Pd vs. INR, CFAR off



Simulation
Pd/Pfa vs. INR, CFAR on/off



Advantages of simulation

- Less uncertainty
- Can quantify false alarms
- Able to do 'what if' tests such as turning CFAR on and off

Summary

- ITS is organized around core technical capabilities
  - RF Theory
  - RF Measurement
  - Systems Engineering and Evaluation
  - Software Engineering
- ITS research portfolio
  - Reviewed and updated annually
  - Targets challenges 1-5+ years out
  - Focuses on foundational research and tool development
    - *e.g.*, science and tools required to support spectrum sharing decisions

ITS is advancing the science and engineering to inform policy decisions and support deployment of new telecommunications technologies.

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