Kolodzy Consulting, LLC

Spectrum Management with Technical Flexibility

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Spectrum Management 2008
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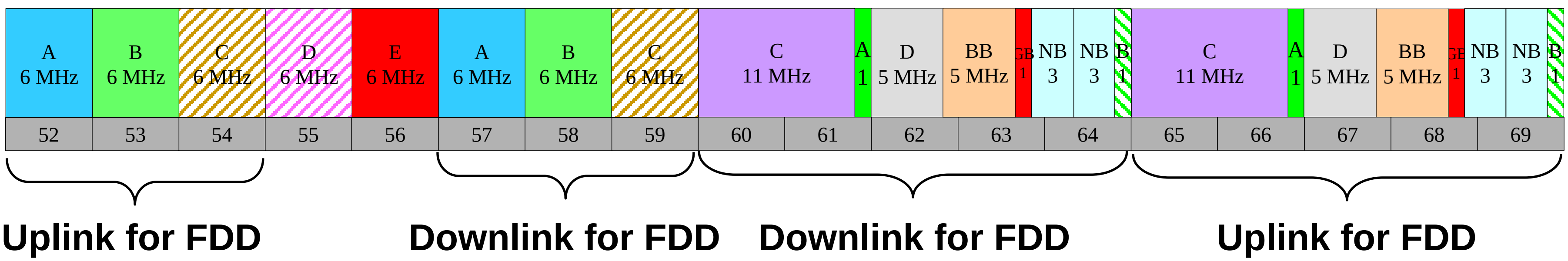
Impact of Technical Flexibility

- **Started with PCS → Premise: Technical flexibility provides additional competition and enables greater innovation**

- **More recently, two divergent allocations:**
  - **AWS-1**
    - Duplexing Scheme specified (FDD)
    - Transmission Power Limits based on Power Flux Density
  - **700 MHz & BRS/EBS**
    - No Duplexing Scheme specified (TDD, FDD, HFDD)
    - Transmission Power Limits based on Power Flux Density
    - Mixture of High Power and Low Power Operations

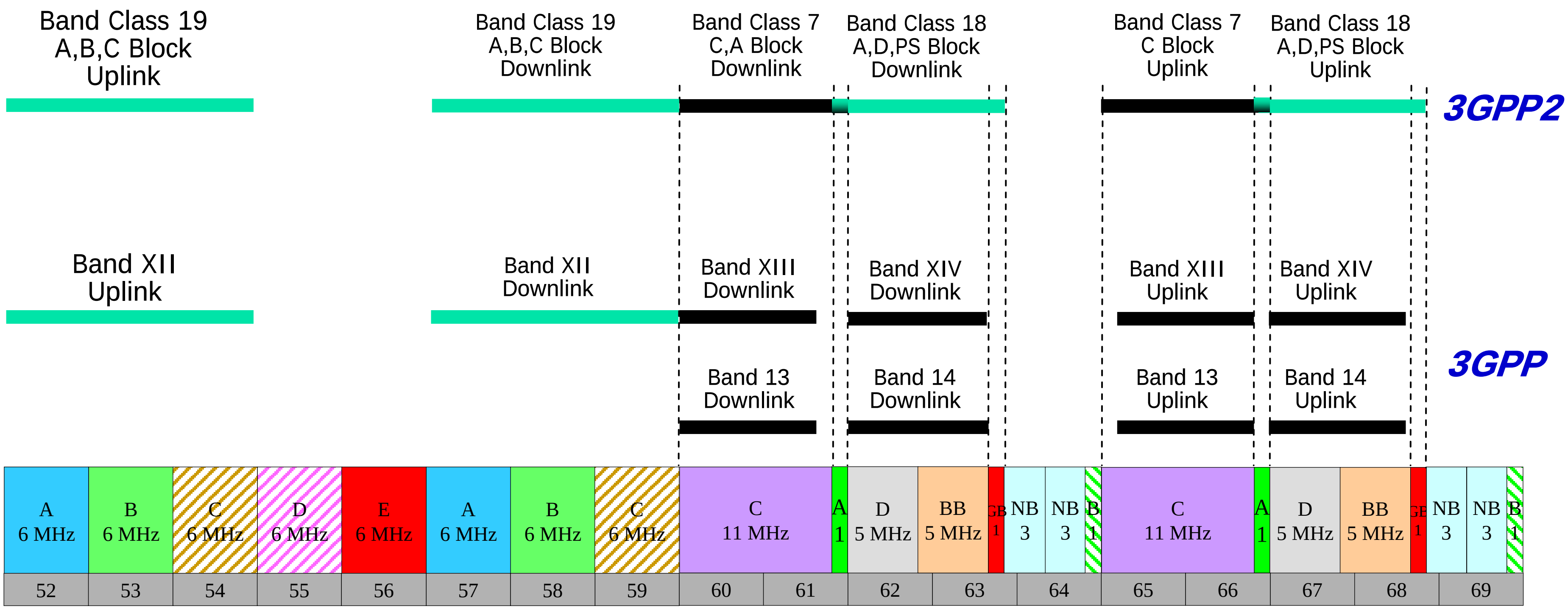
700 MHz Allocation



- **Lower 700 D-Block and E-Block are single, unpaired blocks**
- **All other blocks are paired but can be used as unpaired blocks**

700 MHz Band Plans *(as of March 2008)*

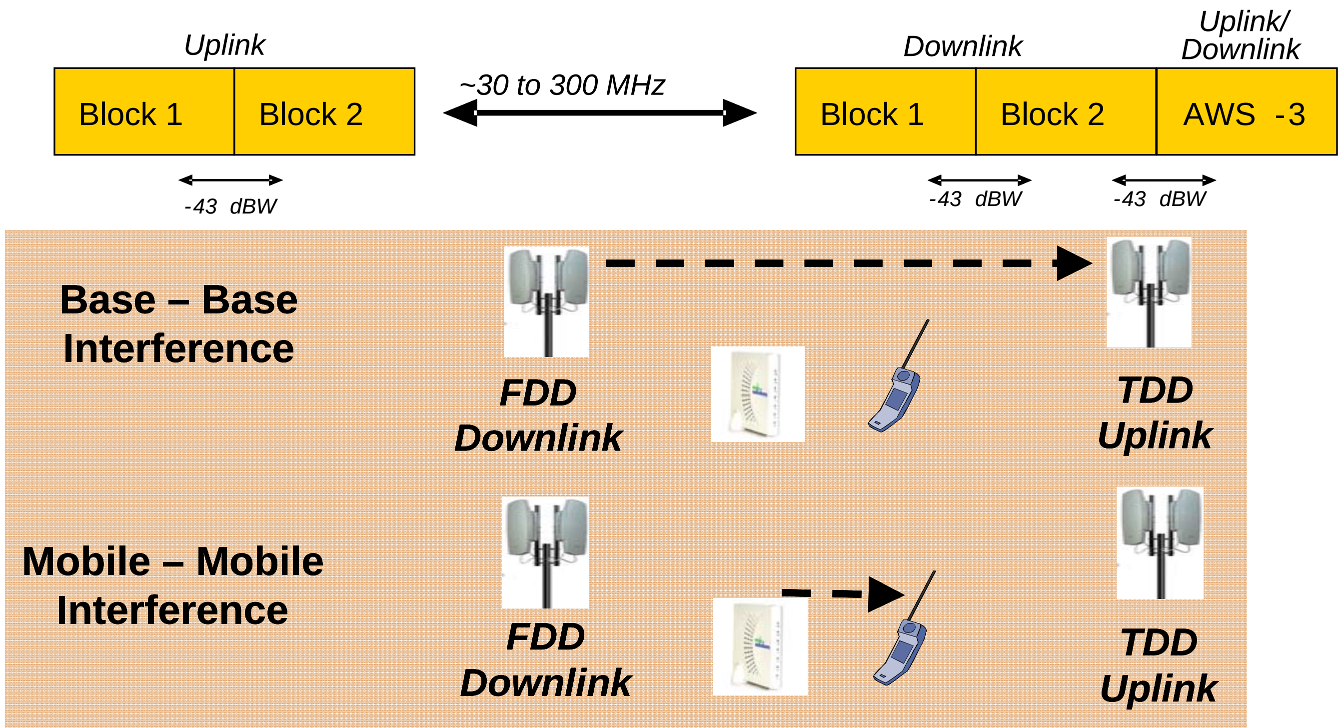
3GPP2 and 3GPP



BB – Public Safety Broadband, NB – Public Safety NarrowBand,
GB – Guard Band

The New Challenge

FDD (Commercial) – TDD (DoD)

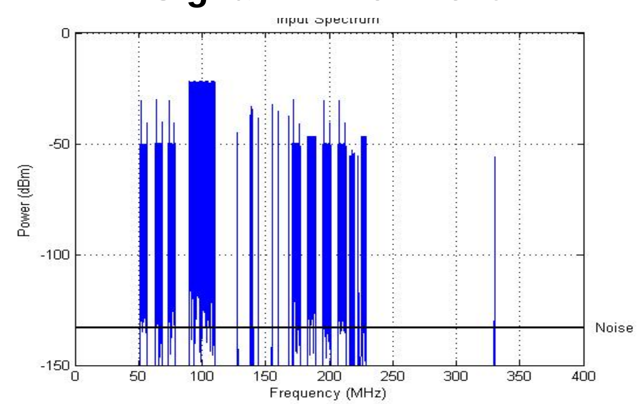


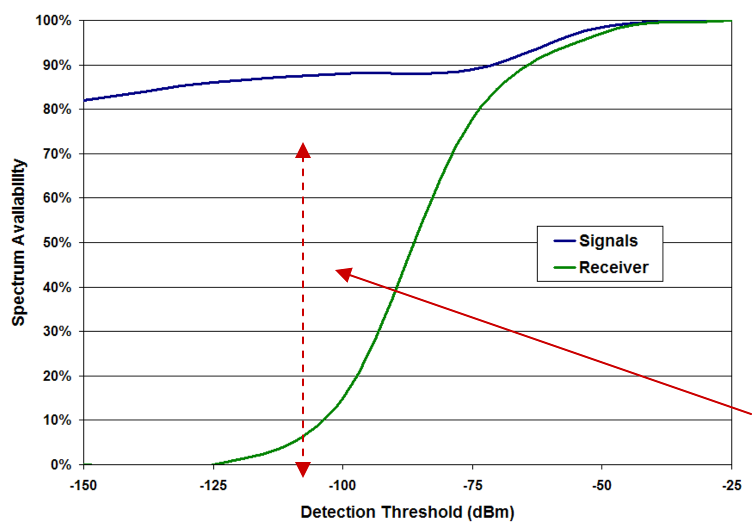
FDD and TDD in adjacent bands will become a reality, what technologies will enable such operation?

The Radio Engineering View of Interference

- **Cumulative Energy in Receiver Filter Increases Noise Floor, Reducing Detection Distance**
  - **Combination of multi-band operation and high spectrum use can create significant challenges**
  - **High dynamic range vs. low-power consumption**
  - **Current technology is challenged to allow sensitive reception in the presence of strong signals and densely occupied spectrum**

Signal Environment

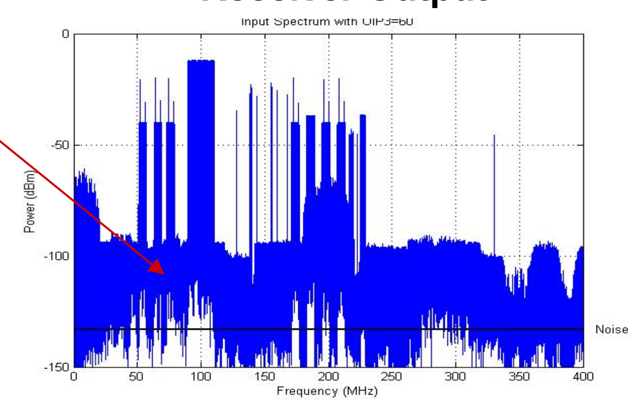




~20 dBm Increase in Noise Floor

~88% Reduction in Spectrum Availability

Receiver Output

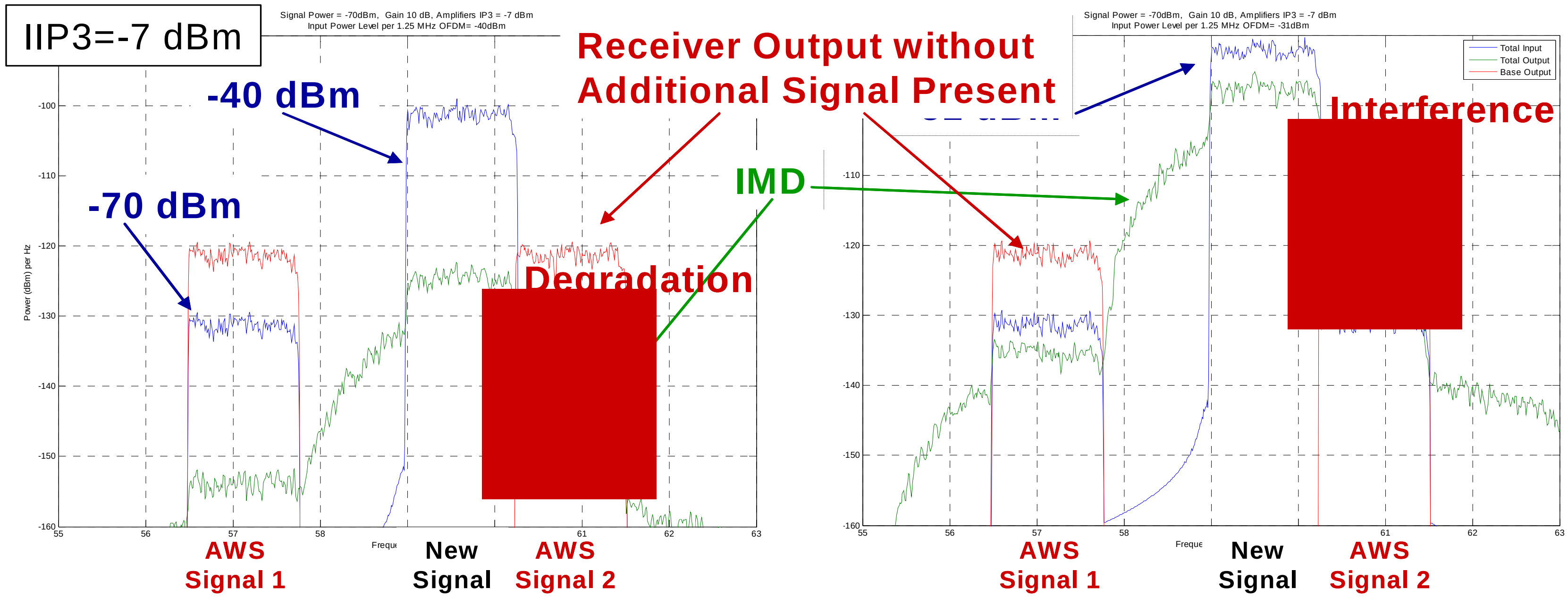


DARPA Tuner Utilization Study, PR #8587, Shared Spectrum Company

Results Shown for Ultra High Quality LNA 10dB Gain, IIP3 = 50dBm, 10W consumption

"Open Spectrum / Channel" Use

Intermodulation Distortion (IMD)

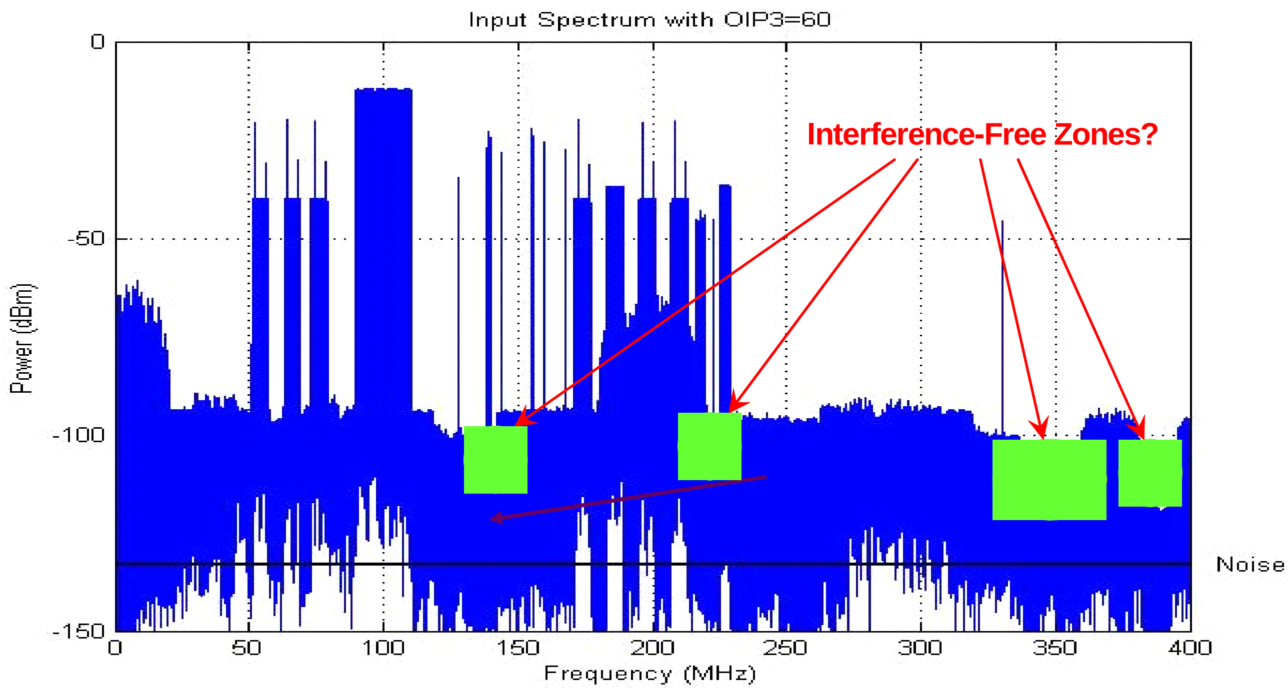


- **Insertion of Signal May Create Out of Band Interference**
  - **Appears proper when viewed as "white space"**
  - **Actual result is a reduction in SNR, resulting in potentially harmful interference**

This is why Carrier Colocate Transmitters!

DSA for Interference Avoidance?!

Radio that Can Estimate the Interference Environment, Can "Search" for Spectral Regions that Do Not Create Interference for the Radio



Dynamic Interference Avoidance Radio Systems combine the understanding of both the RF environment and the Radio RF characteristics

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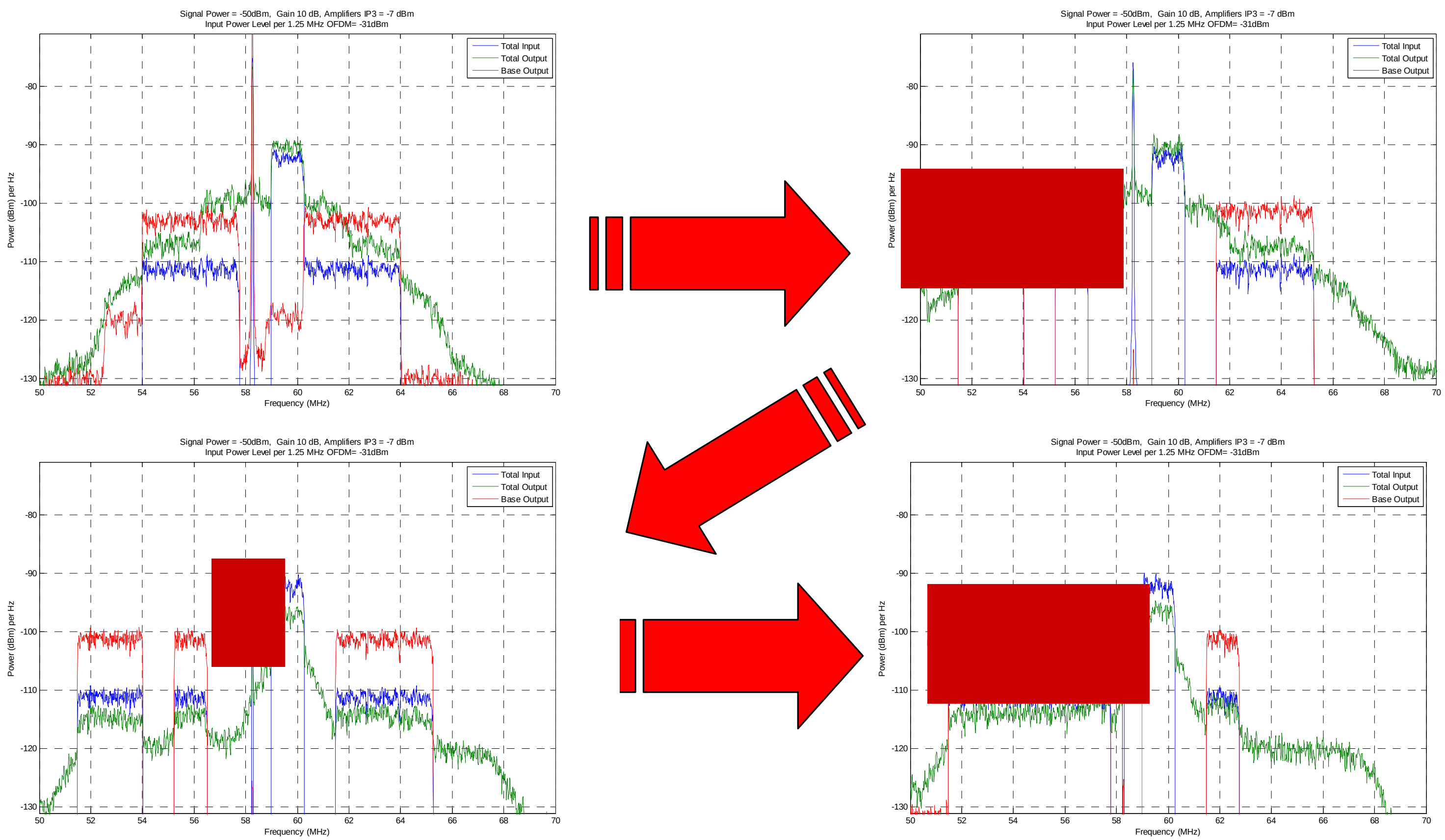
Dynamic Interference Avoidance

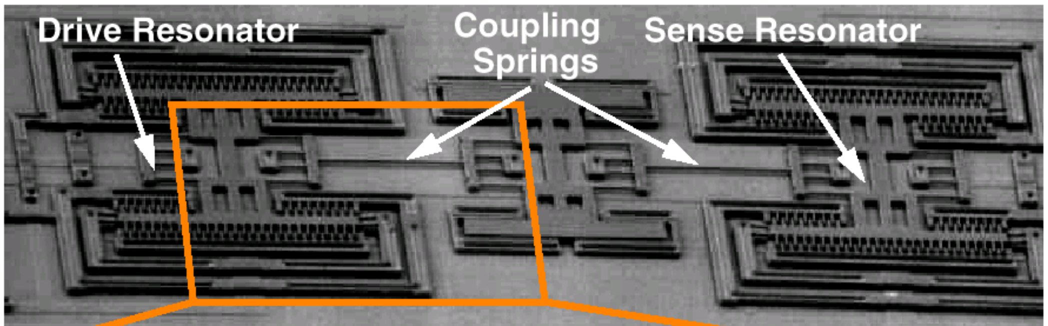


NG Radios that are Aware of Interference Effects Can Adapt to Mitigate Effects

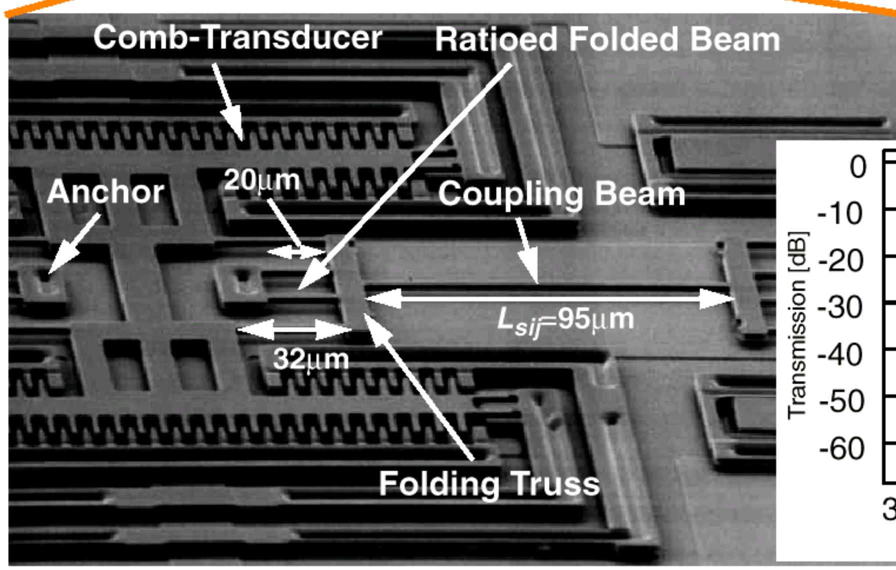
New Directions / New Tools

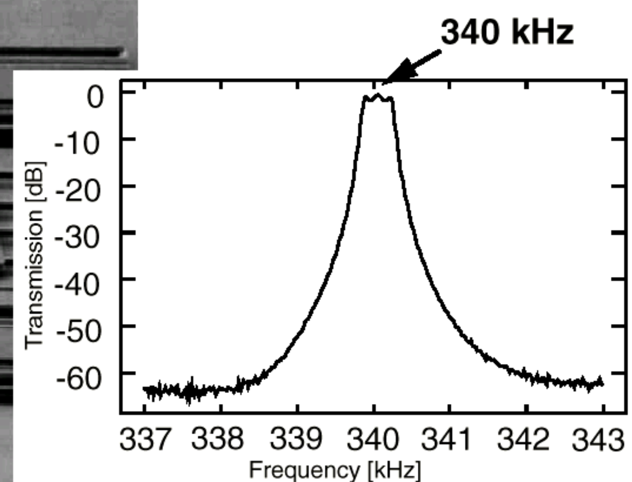
- Static, Worst-case Analysis vs Statistical Analysis
  - Monte-Carlo Techniques
  - Propagation Models, Component Models
- Spectral and Spatial Filtering Improvement
  - Antenna Pattern Shaping for Gain and Interference Avoidance
  - Advanced Filters and Adaptive Modulation
- Dynamics Become Increasing Important
  - Spectral Sharing for Capacity
  - Spectral Sharing for Interference Avoidance
  - Network Optimization via Radio Operations

High-Order Filter

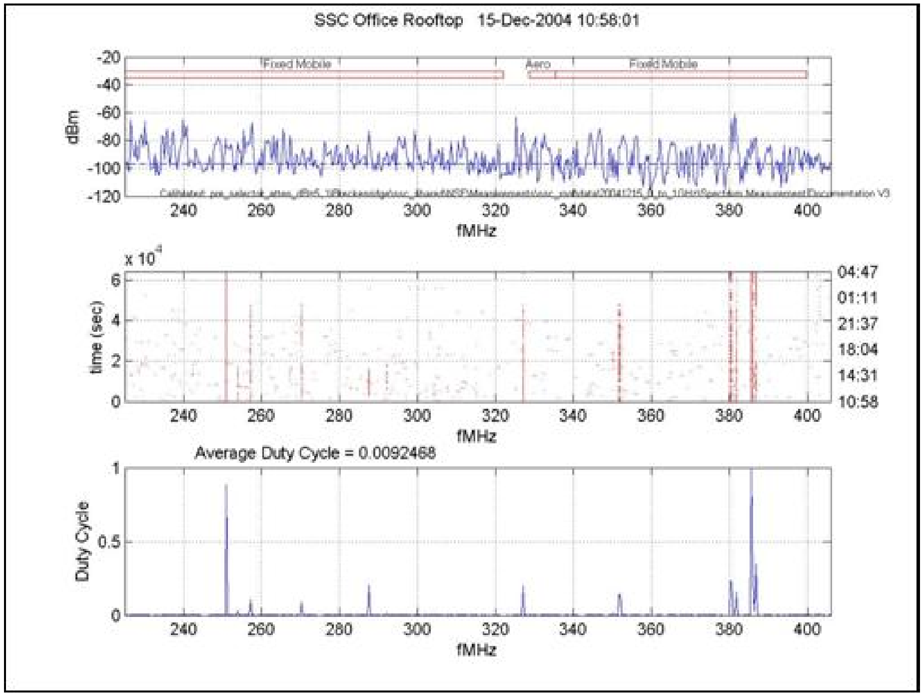


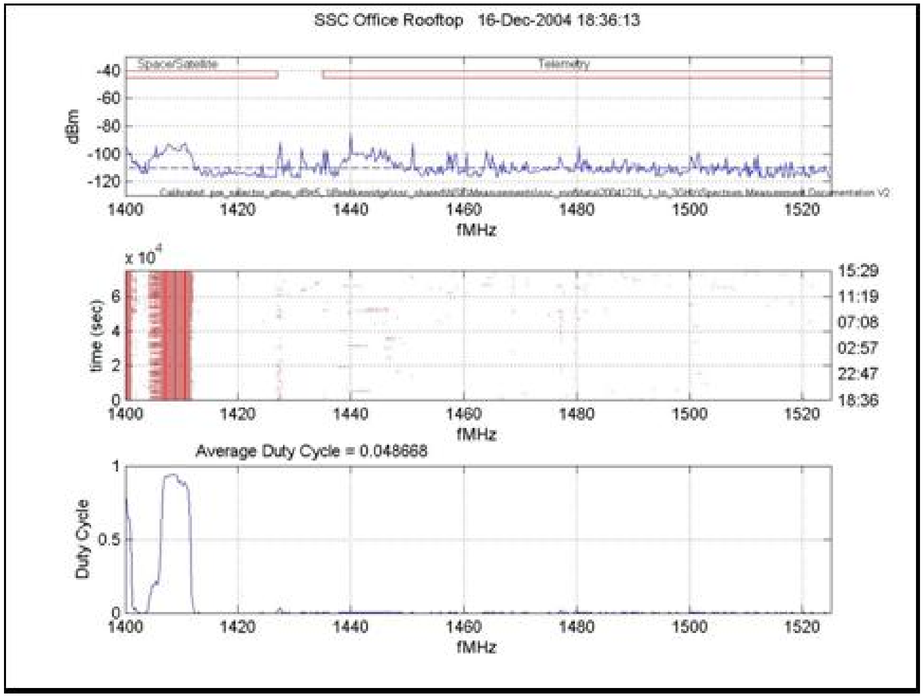
3-Resonator MF
(6th Order, 1/5-Velocity Coupled)
***f_o*=340kHz**
***BW*=403Hz**
***%BW*=0.09%**
***Stop.R.*=64 dB**
***I.L.*<0.6 dB**
[Wang, Nguyen 1997]





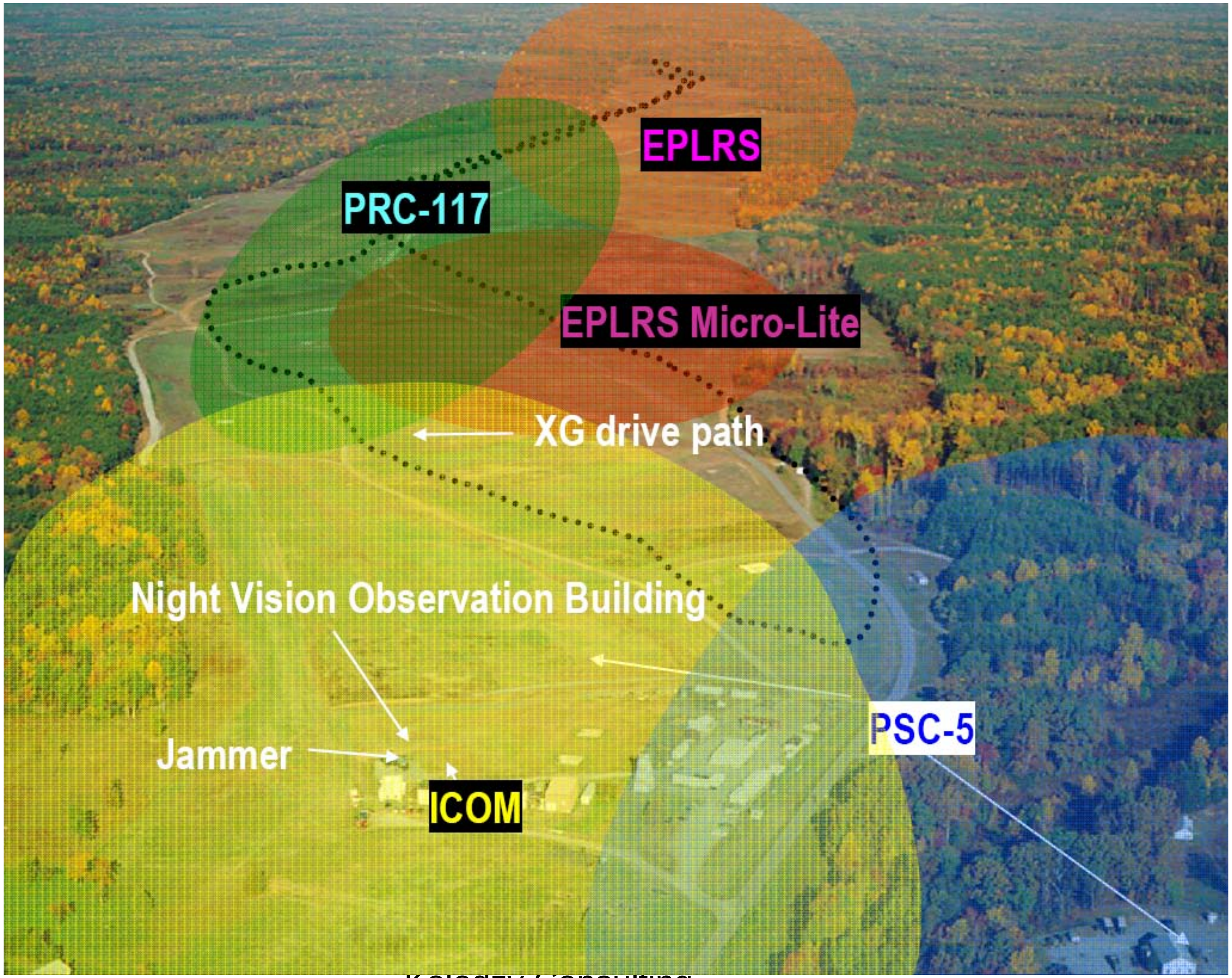
Spectral Utilization





High Peak-to-Average Ratio utilization in some bands provide impetus for new thinking in RF Spectrum sharing … Technology to provide insight into utilization is prevalent

Dynamic Spectrum Status



Quick List of Technologies

Interference

- Smart Antennas
- Dynamic Spectrum Access
- Interference Cancellation
- Statistical Analysis

Base Stations

- High Level of Integration
- Higher Power (EIRP)
- Waveform Complexity
- In-building Wireless/femtocells

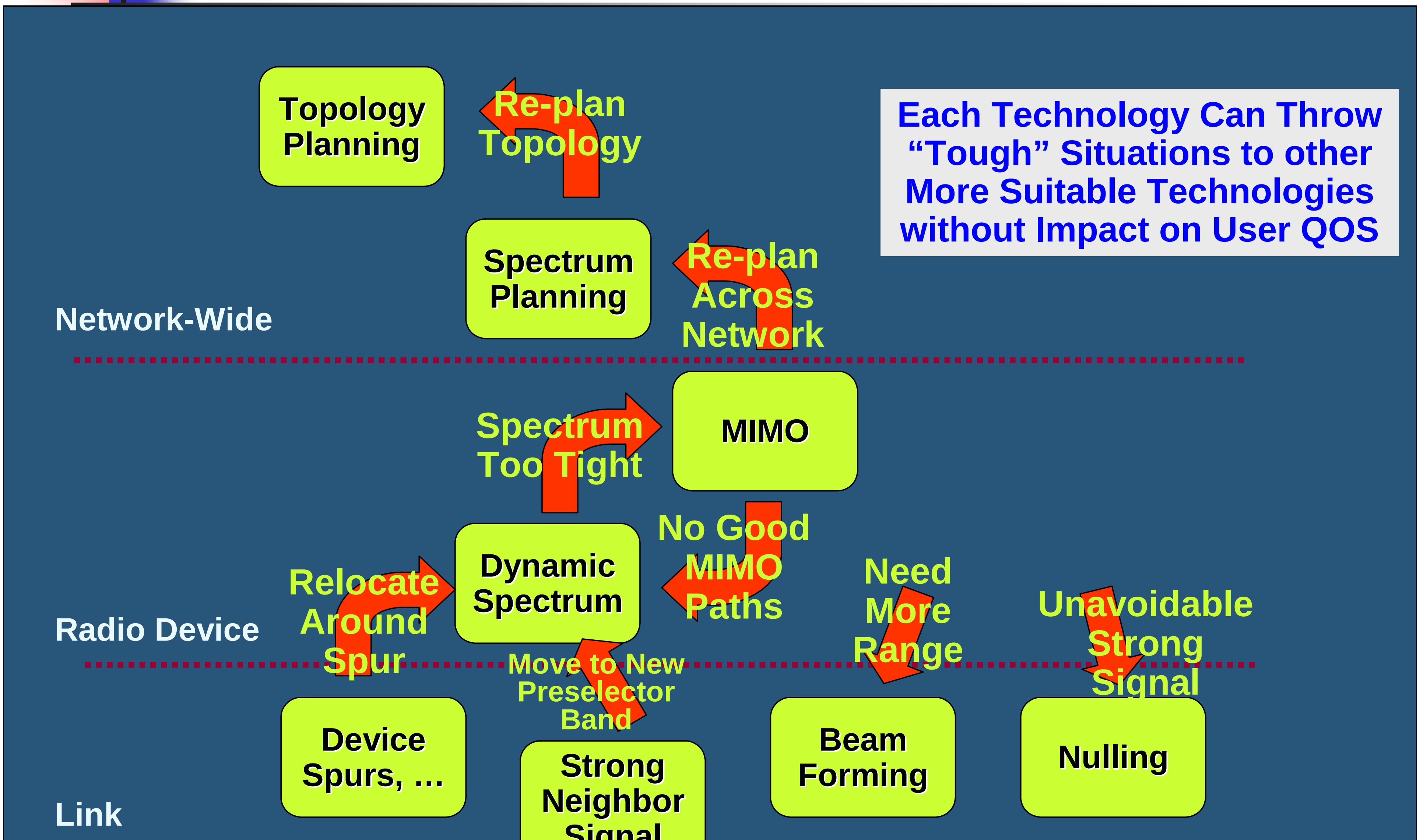
FDD/TDD

- Technology and Device Solutions
- Spectral Flexibility

Rights and Responsibilities

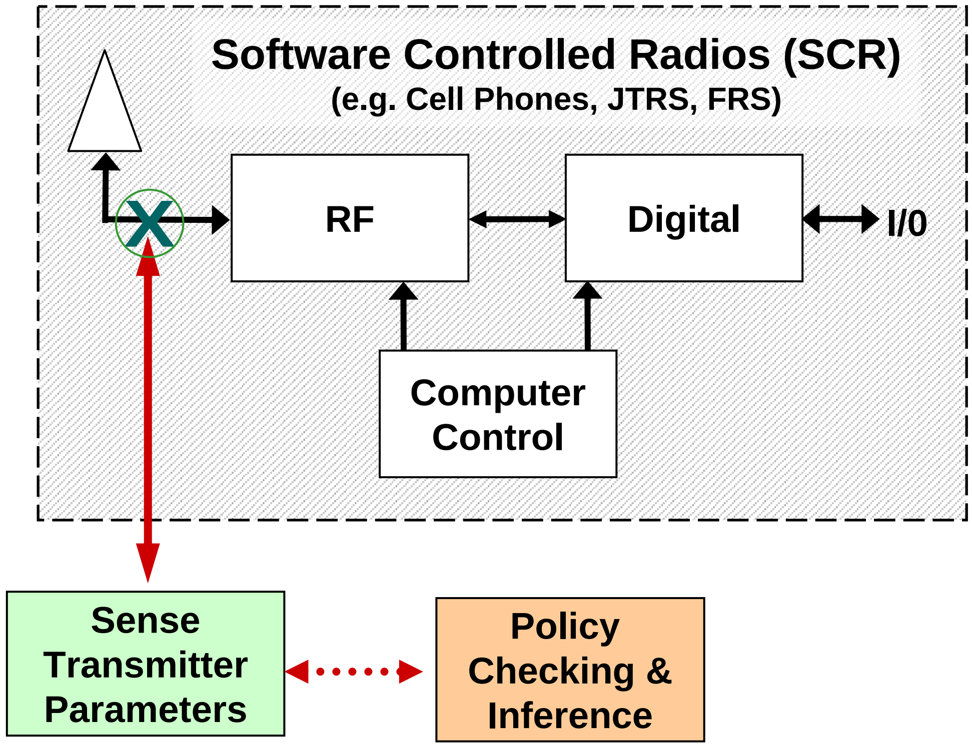
- Accordion Spectrum … and variations
- Macro Dynamic Spectrum Access
- Peer-to-Peer Networking
- Policy Engines

Adaptive Radio Avoids Solving All Problems Itself



Approved for Public Release (DARPA Case #5702)

Policy Embedded in the Radio



Multi-Disciplinary

Not just in Words

"highest and best use"

"transaction costs"

"auctions"

"OOBE"

"Structure Programming"

"LNA"

"child processes"

"dB"

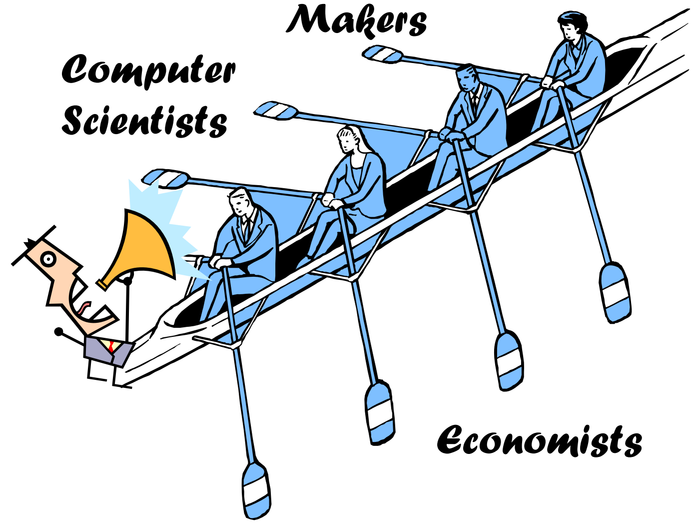
"Intermods"

"Ontologies"

"dynamic range"

"Provability"

Electrical Engineers, Computer Scientists, Communications Engineers, Lawyers, Policy Makers, Economists, Physicists, Material Scientists, Pontificators



IEEE SYMPOSIA ON NEW FRONTIERS IN DYNAMIC SPECTRUM ACCESS NETWORKS

IEEE DySPAN 2008

Dynamic Spectrum Access Networks

Chicago, Illinois • 14-17 October 2008

www.ieee-dyspan.org/2008

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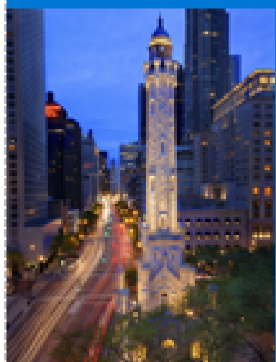


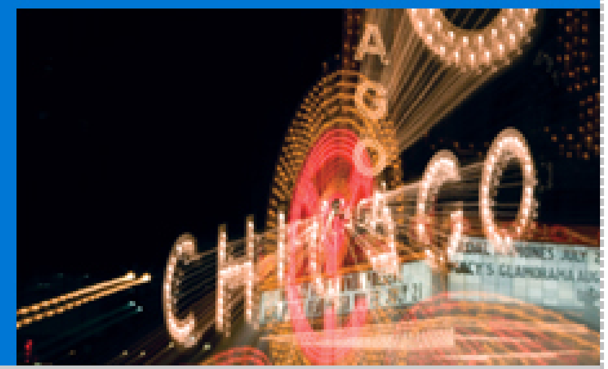

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After the success of DySPAN 2005 in Baltimore and DySPAN 2007 in Dublin, the IEEE DySPAN Conference has firmly established itself as the premier forum for discussion of all aspects of devices and networks that utilize spectrum on a dynamic basis. DySPAN 2008 aims to further build on this success and bring to fore new cutting-edge research in the technology, policy, economic and legal dimensions of dynamic, decentralized access to the radio spectrum both on a consensual and non-consensual basis. In the near future two complementary trends are emerging. First, the networks and devices will operate in wider bands, process large amounts of information to make intelligent decisions, and become reconfigurable via software defined capabilities. Second, the regulators around the world can exploit these technology advances to foster increased and more effective spectrum utilization. These trends are making dynamic spectrum access critically important to the future for wireless communications and networks.