Radar / 4G Compatibility Challenges

The Impetus for a New Spectrum Use Standard?

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Mr. Bruce Naley is a native of Edison, New Jersey. He graduated from the United States Naval Academy in 1992 with a B.S. in Systems Engineering. After a nine-month assignment as a Military Research Assistant at Los Alamos National Laboratory, he reported in February 1994 to Pensacola, FL to begin the U.S. Navy's flight school program. His active duty service includes tours as a Naval Flight Officer at Fleet Air Reconnaissance Squadron Three (VQ-3) and as an instructor at the Navy Reserve Officer Training Command (ROTC) unit Purdue University. On each active duty tour, he earned an advanced degree on his off duty time – completing an M.B.A. from Oklahoma City University in May 1998 and a Masters degree in Electrical Engineering from Purdue University in May 2001.

Mr. Naley left active duty in September 2001 and began his new career as a practicing engineer at the Naval Surface Warfare Center, Dahlgren Division. After three years in Chemical and Biological Weapons Defense, he transferred to Dahlgren's Spectrum Management group, where he has been ever since. As a spectrum engineer Bruce has done Research and Development (R&D) and Test and Evaluation (T&E) to resolve spectrum issues with the prototype SPY-3 radar, CREW systems, and the SM2 missile. Additionally, he provides technical support to the NAVCENT frequency manager and the U.S. delegations attending bi-annual RF interference resolution meetings with the Gulf Cooperation Council (GCC) member Arab nations.

Still an officer in the Navy Reserves, Mr. Naley has served in several Science & Technology units that support the Naval Research Laboratory. Additionally, he was mobilized to Active duty August 2007 to be the Officer in Charge (OIC) of a Scan Eagle Unmanned Aerial Vehicle (UAV) unit deployed to Iraq.

Back from Iraq and again in a civilian capacity, Mr. Naley is now leading three programs at Dahlgren: Installation of a spectrum monitoring system for the Dahlgren Naval Base, a joint RF propagation study with the National Radio Astronomy Observatory (NRAO) and Virginia Tech University, and the T-REX spectrum monitor installation for the Pacific Missile Range Facility (PMRF).

The Situation

- Globally, nations have authorized mobile broadband wireless access (BWA) services in the 3.3-3.7 GHz bands.
- Frequently, incumbent radar users exist in the same or adjacent frequency bands.
- Based on ongoing analysis and testing, there is a potential for electromagnetic interference (EMI) among 4G and radar systems.

The Challenge

- Radars typically have very low duty cycles but have very high peak power.
- Out-of-band (OOB) noise, although very low relative to the fundamental, can be high compared to base station received power levels.
- High-power radar emissions may result in degradation of 4G link performance.
  - increased packet error rates
  - Increased frame error rates
  - Packet delays
  - Overload of receiver front-ends

Adjacent Band Sharing Problem Recent Example

- Legal OOB radar emissions caused degradation to 4G system.
  - Effect to 4G system can be severe when there is strong atmospheric ducting.
  - Enough power to saturate 4G front end during worst atmospheric ducting conditions.

Radar OOB Power on 4G Frequencies

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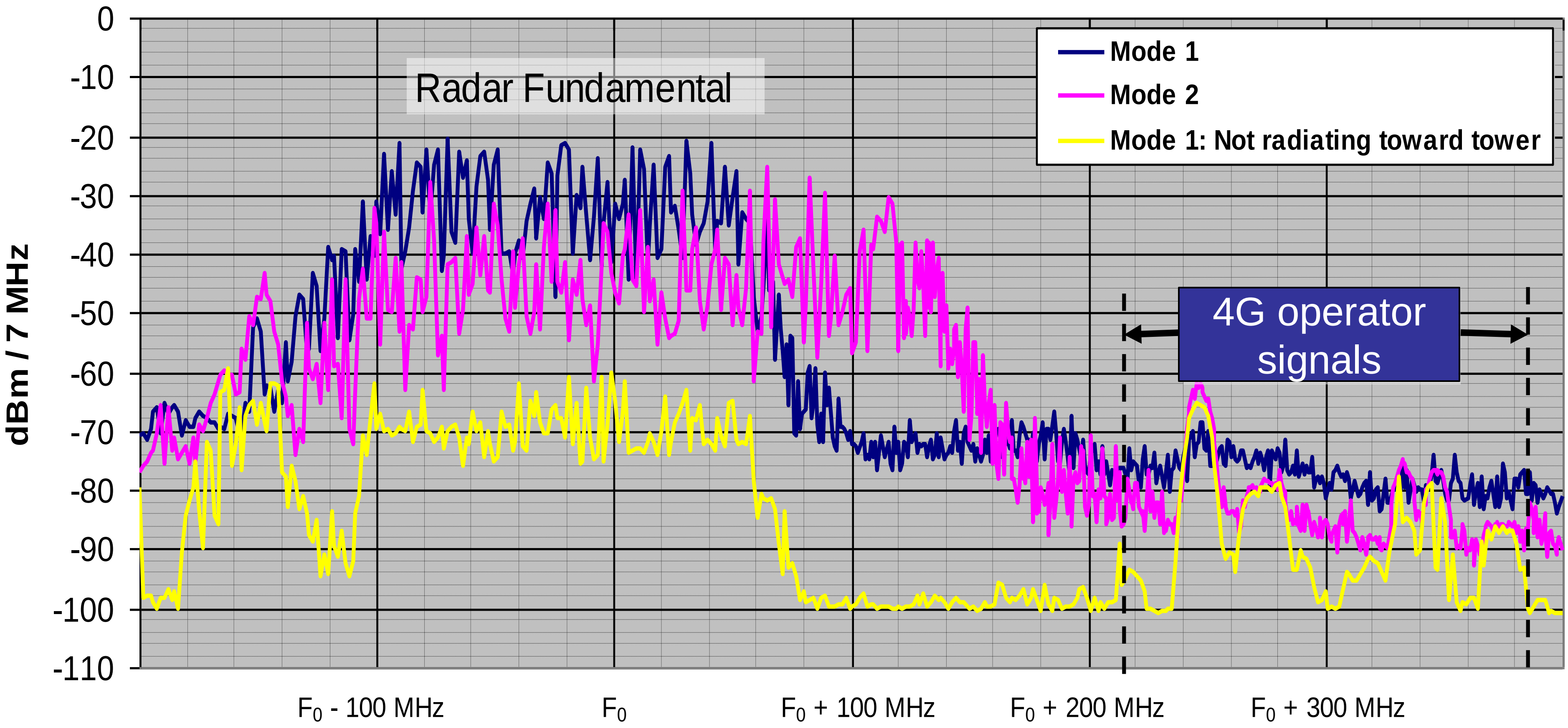
Measured Power at 4G Base Station Tower



Level Of 4G Degradation vs. Radar OOB Power Levels Measures

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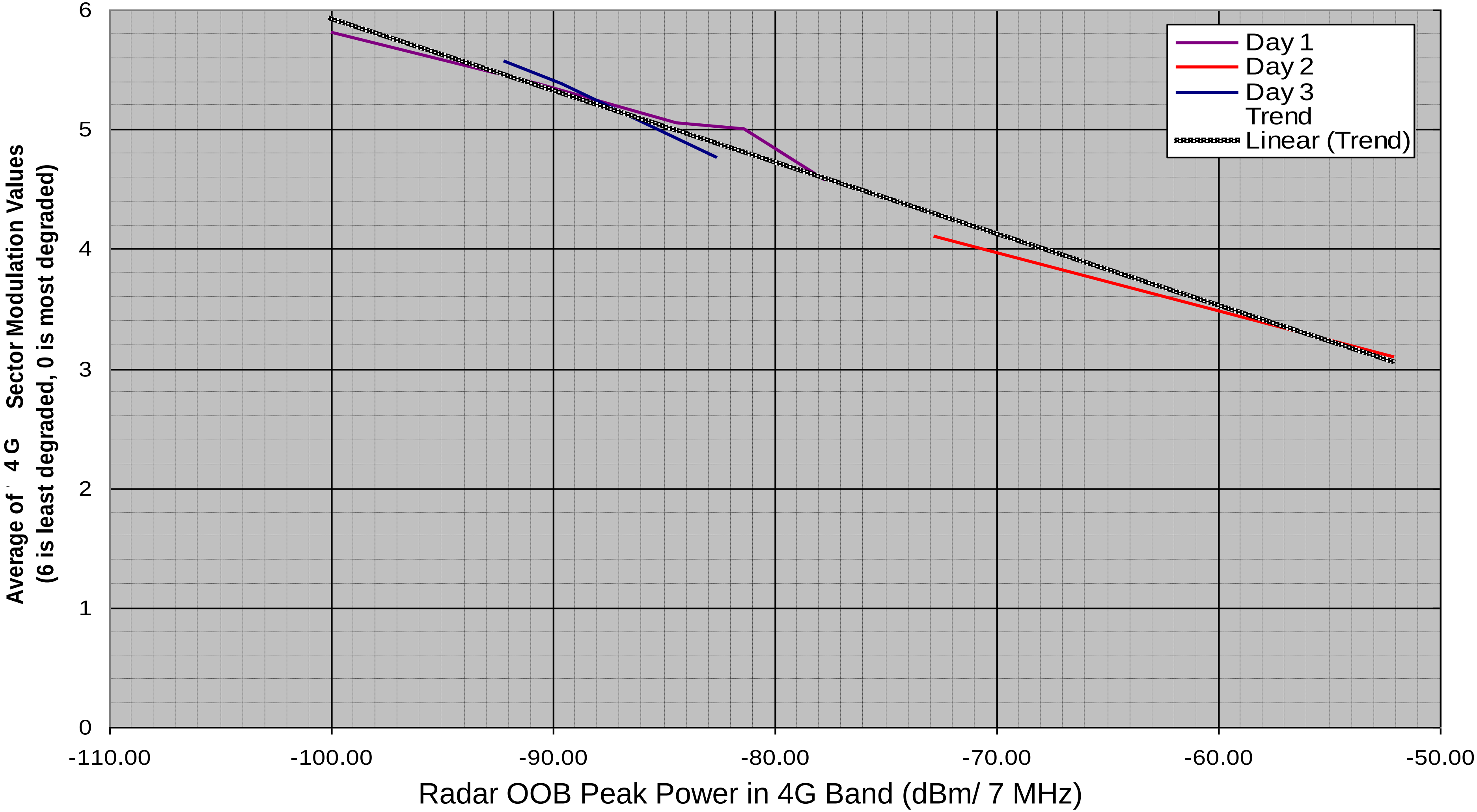


The Goal

- Identify methods to effectively reduce EMI between radars and communications systems.
- Push for acceptance of these methods in the form of national / international standards.
  - For Radar/Comms shared or Adjacent Bands.

Interference Mitigation Techniques – 4G systems

- Spectrally
  - Receiver bandpass filters
  - Dynamic Spectrum Allocation
- Spatially
  - Reducing potential antenna coupling
    - Separation distance
    - Antenna null on horizon
    - Beam forming
- Other
  - MIMO implementation in 4G
  - Forward error correction tailored to pulsed interference.
  - Site Shielding

Spectrally

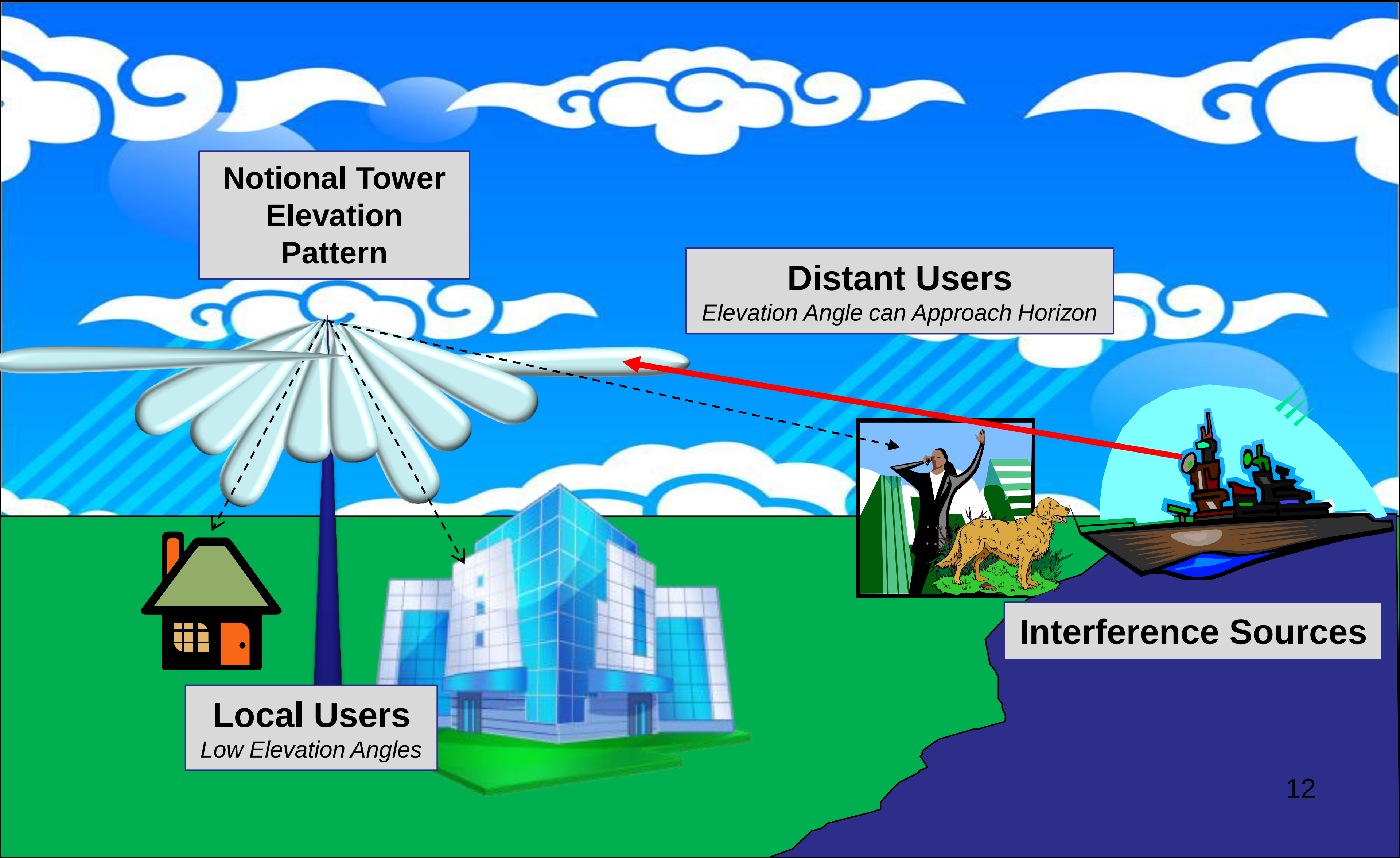
- **Receiver bandpass filters**
  – Protect against out-of-band radar interference.
- **Dynamic Spectrum Allocation**
  – Avoiding, or vacating, a channel that is identified as being occupied by a radar based on cognitive detection, or by database methods.
    - In areas where not all the frequency resources are fully utilized
  – Network frequency plan would need to be self configuring.
  – Most effective if operators purchased non-contiguous spectrum.

Spatially

- Potentially interfering radar emissions at horizon or above.
  - Ship and ground-based radars search near and above the horizon.
  - Airborne radars look down toward the ground.
- **Reduce antenna coupling**
  - **Separation distance**
  - **Antenna null** on horizon / sharp max elevation cut-off
    - Increase Antenna Beam Down-Tilt
  - **Beam-Forming**
    - Steer maxima towards the desired signal
    - Steer nulls towards interfering signals
      - Effective for small numbers of strong interferers
    - Downlink sub-sectorization as an alternate method.

Spatial "Sideview"

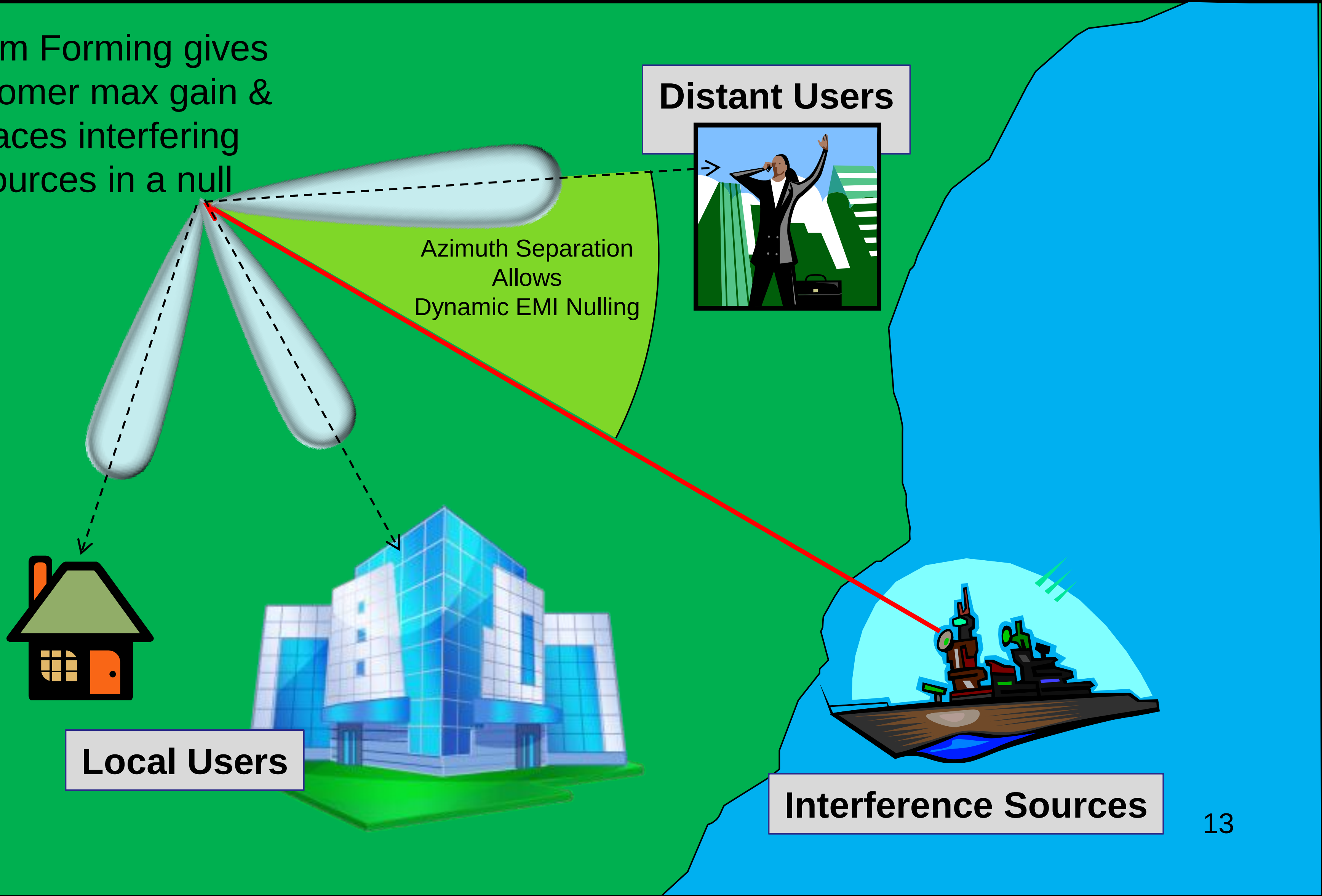
Horizon Null



Spatial "Overhead View"

Beam Forming

Beam Forming gives customer max gain & places interfering sources in a null



Other

- **Multiple Input Multiple Output (MIMO) / Space Time Block Code (STBC) implementation**
  - Redundant data transmission on multiple frequencies/time slots/polarizations/etc.
- **Forward error correction tailored to pulsed interference.**
- **Site Shielding**
  - Using physical or natural shielding at the 4G station.

MIMO
Radar Mitigating Effects

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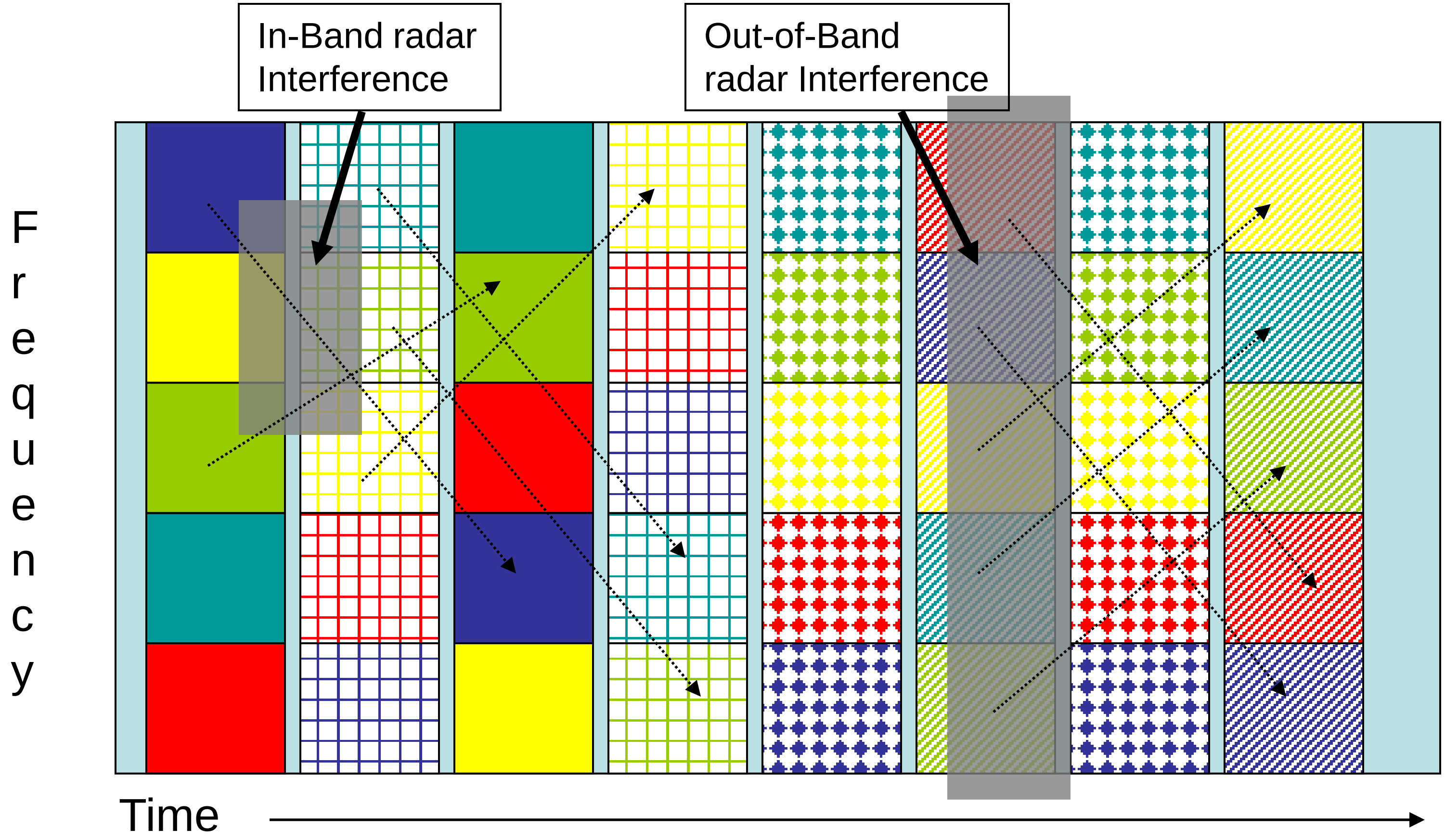
Each color represents a particular subscriber – Each pattern a different data packet.

Every data packet is sent twice, on a different frequency and/or time slot.



At least one copy of each data packet is not interfered with

Interference Mitigation Techniques – Radars

- Spectrally
  - Reduced OOB emissions
    - Filtering
    - Pre-distortion
    - Phase canceling
    - Cleaner amplification stages
  - Frequency agility
- Spatially
  - Steerable Nulls
  - Lower sidelobes
    - Taper on transmit
  - Sectoring
    - Power sectoring (multiple power levels)
- Other
  - Variable chirps / pulse widths / PRFs
  - Low Duty Factor
  - Orthogonal waveforms

Summary

- The spectrum is becoming more and more crowded.
- Adjacent Band and In-Band operation between radars and communications systems will be more common.
- Effort now to create the proper standards will improve the future compatibility of radar and 4G services.

Way Ahead

- Work Together to Draft "Best Practices" EMC Guidance in Shared or Adjacent Bands.
- Research Existing EMC, Communications, and Radar Standards for Appropriate Committee/Focus Area(s) to Insert This New IEEE Standard.
  - Update an Existing Standard?
- Spread the Word! ☺