Locating and Mitigating 800 MHz Interference

Prepared by

Pericle Communications Company
1910 Vindicator Drive, Suite 100
Colorado Springs, CO 80919

For

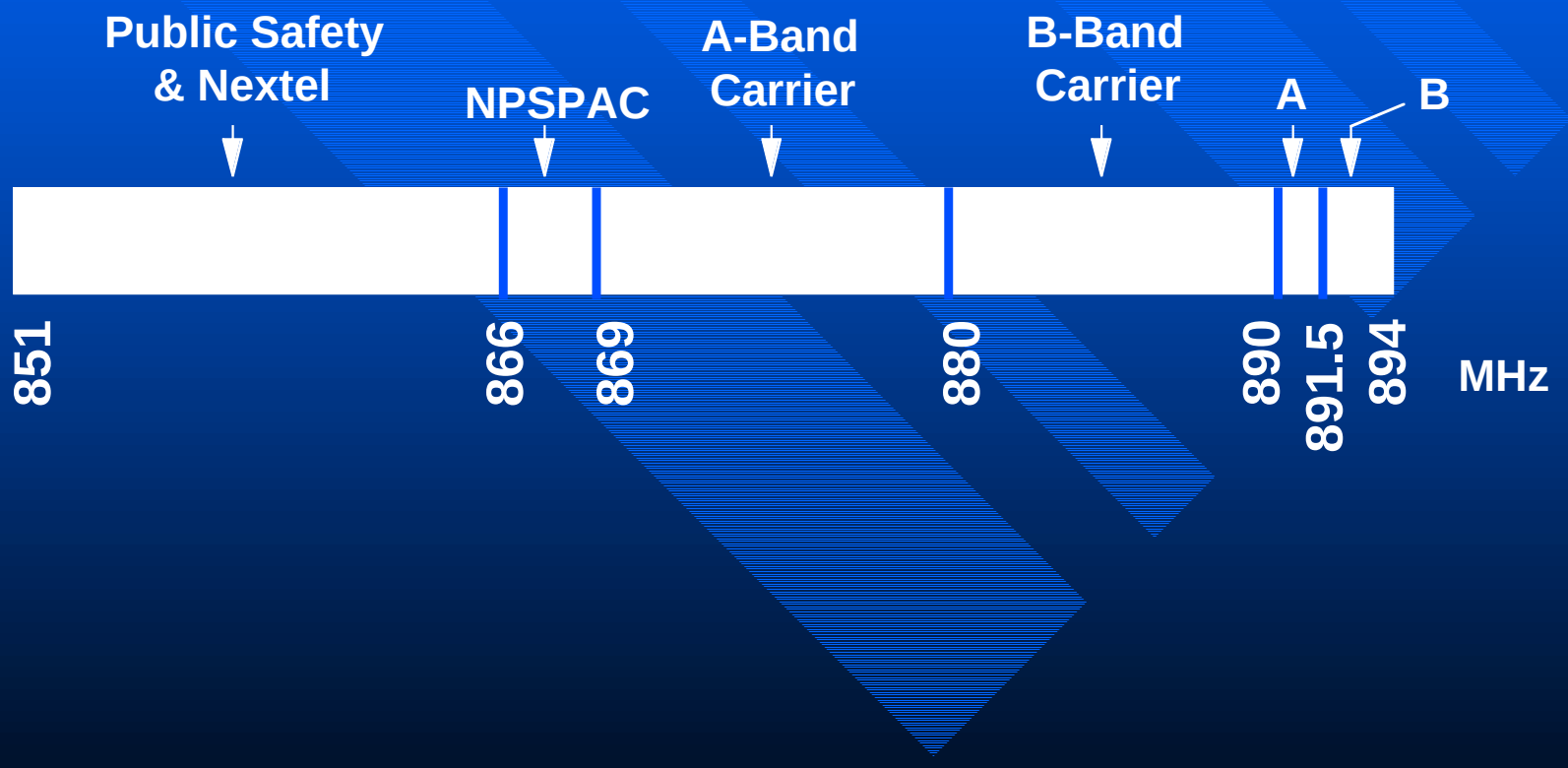
IWCE 800 MHz Road Show

Outline

- 800 MHz Interference
  - Sources of Interference
  - Types of interference
- Protection Criteria & Measurements
- Mitigation Techniques
  - What's been tried
  - What doesn't work
  - What works
- Case Study - Denver, CO
- How Does Re-Banding Solve The Problem?

800 MHz Interference

800 MHz Band Today



The Near-Far Problem

- 800 MHz interference is an example of the Near-Far Problem
- Weak signal from distant tower site cannot overcome strong signals from nearby cell site
- Notwithstanding the cell site fully complies with FCC emission rules

Interference Types

- **Out-of-Band Emissions**
  - Generated at Nextel or A-Band carrier cell site
  - Falls in the RF and IF passband of receiver
- **Receiver Intermodulation**
  - Non-linear mixing of external carriers in receiver front end
  - Interference is created inside the receiver
  - Can be Nextel-only mixes or Nextel/A/B cross products
- **Other Types Have Lesser Effect**
  - Receiver “overload”
  - Transmitter intermodulation

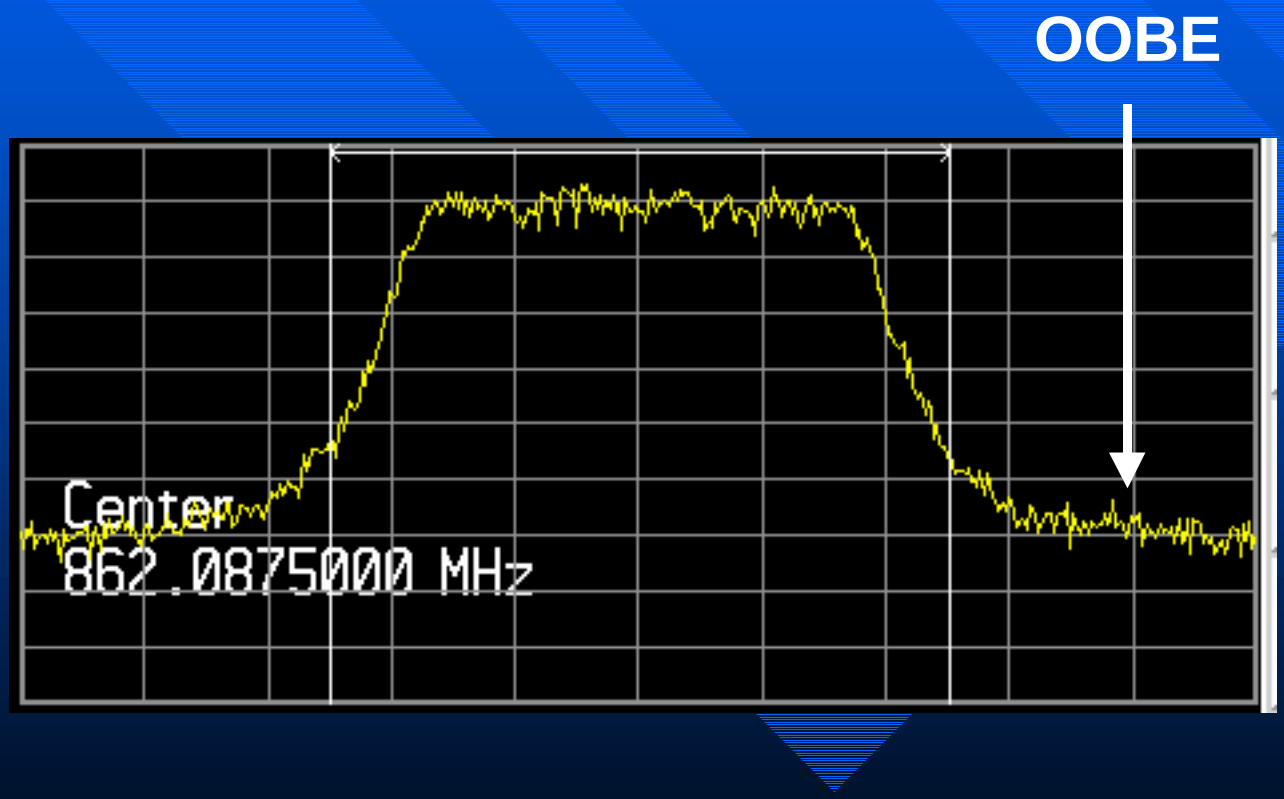
Out-of-Band Emissions

- Out-of-Band Emissions (OOBE) comprise radio frequency energy that falls outside the assigned channel for the transmitter

- OOBE Include
  - Radio carrier harmonics
  - Broadband transmitter “noise” typical of digital radio transmitters

Nextel iDEN Signal

- OOBE Typically 63 dB Below Carrier



Receiver Intermodulation

- Receiver intermodulation (IM) is a non-linear combining of two or more interfering signals inside the receiver front-end (low-noise amplifier and/or mixer)

- Products:

  3rd Order

  IM Frequency = A + B - C, 2A-B

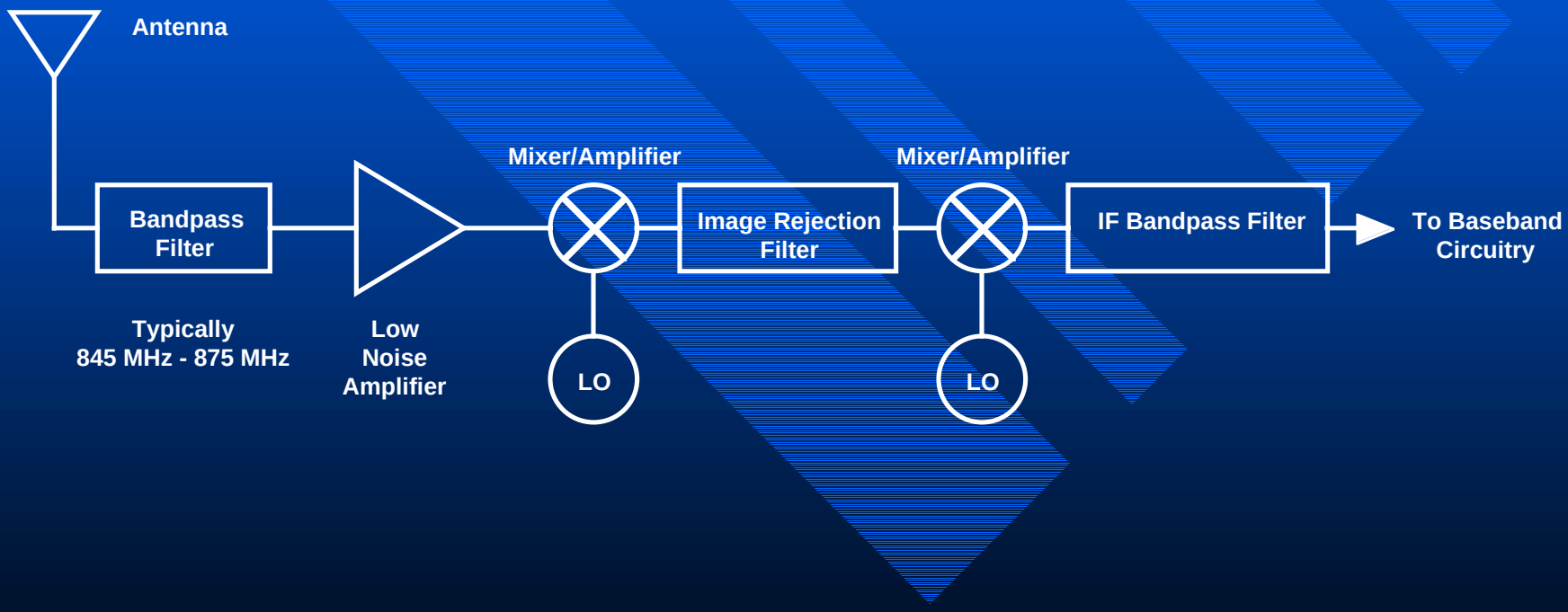
  5th Order

  IM Frequency = A + B + C - D - E, 3A - 2B, etc.

- 3rd Order Products Cause the Most Trouble

Public Safety Receiver

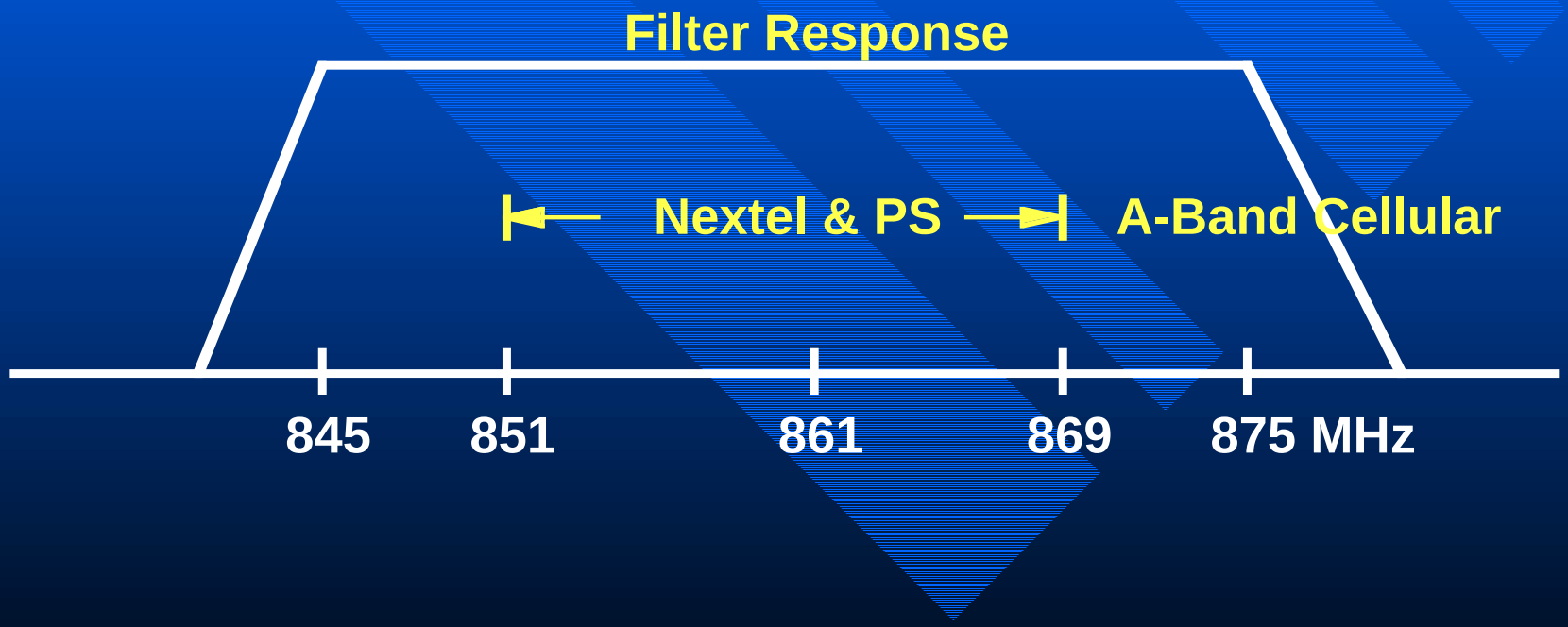
- Weakness Is Bandpass Filter
- Today It Passes All of SMR, Much of A-Band Cellular



Typical Bandpass Filter

(Public Safety Receiver)

- No Protection From Nextel or A-Band Carrier

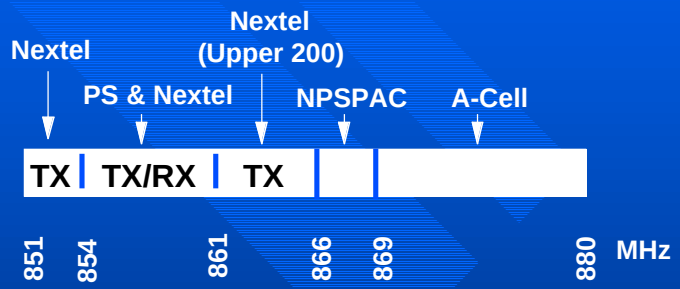


Intermodulation Products

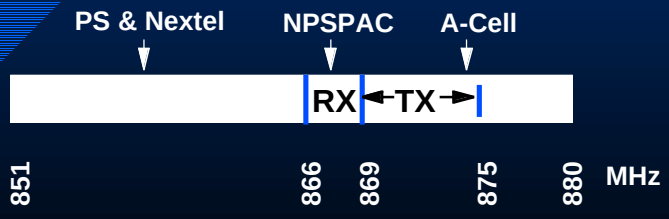
- Consider a Cell Site with N Channels
  - There are N(N-1) products of the type 2A-B
  - There are N(N-1)(N-2)/2 products of type A+B-C
  - E.g., a 15-channel site has 1,575 3rd order products
- But What If You Must Create IM-Free Sets?
  - Only known approach is trial-and-error

IM Products (cont'd)

- **Example 1 (All Products On-Channel):**
  - Nextel GC, interleaved and upper 200 (366 total)
  - Public safety channels 854-861 (70 total)
  - 7,097 products of type 2A-B
  - 1,935,439 products of type A+B-C



- **Example 2 (Products Within +/- 12 kHz):**
  - A-Band carrier below 875 MHz, 30 kHz channels (199 total)
  - NPSPAC channels 866-869 MHz (230 total)
  - 12,775 products of type 2A-B
  - 978,427 products of type A+B-C



Importance of Guard Bands

- **Property of 3rd Order IM Products**
  - Limit cell carriers to the range [fmin, fmax]
  - The lowest IM frequency = 2 fmin - fmax
  - The highest IM frequency = 2 fmax - fmin
- **So, The Lower Guard Band = [2 fmin - fmax, fmin]**
  - Width of guard band always equals Δ = |fmax - fmin|

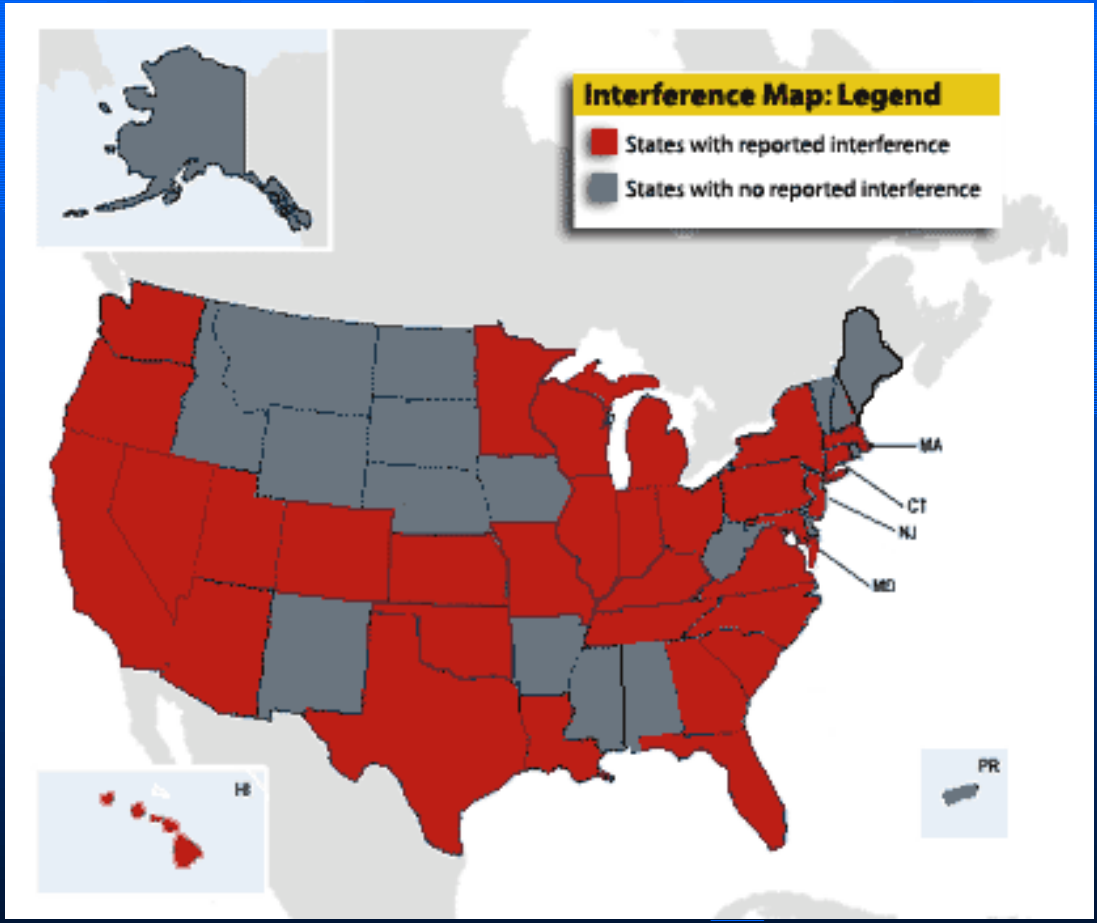
GSM & CDMA Issues

- **Today, Nextel Operates iDEN on 25 kHz Channels**
  - **Future might be GSM, cdma2000, or W-CDMA?**
- **A-Band Carrier Will Be GSM, CDMA or W-CDMA**
  - **GSM = 200 kHz wide, GMSK modulation, frequency hop**
  - **CDMA = 1.25 MHz wide, OQPSK w/raised cosine**
  - **W-CDMA = 5 MHz (3.84 Mcps)**
  - **cdma2000 = 1.25, 5, 10 MHz**

GSM & CDMA Issues

- Pros
  - Fewer channels = fewer IM products
  - More efficient airlink standard = lower power
  - Downlink power control limits interferer power
  - Lower power density means less power in 25 kHz
- Cons
  - Wider bandwidth creates wider IM product
  - GSM frequency hopping creates more potential products
  - Third generation data services have higher duty cycle, power

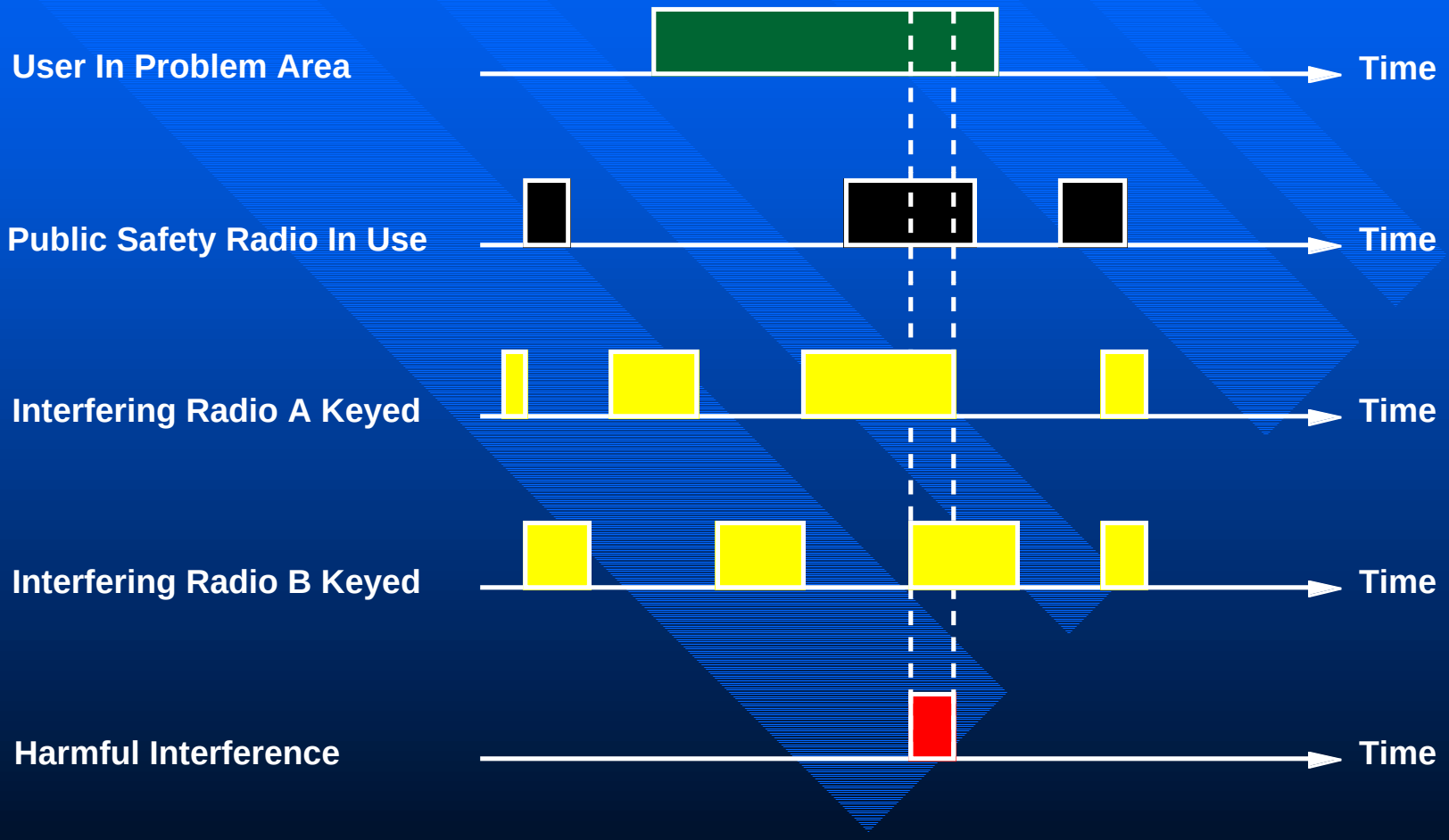
Reported Interference



Protection Criteria & Measurements

Interference is Intermittent

(Intersection of Events, 2A-B IM)



Courtesy of Glen Nash, APCO

Protection Criteria
(FCC 04-168)

- Victim System Entitled to Protection Based On
  - Achieved performance
  - Measured median signal strength
- Portable radios protected down to -101 dBm
- Mobile radios protected down to -104 dBm
- Protection Level Afforded is 20 dB C/(I+N)
- Interference Definition:

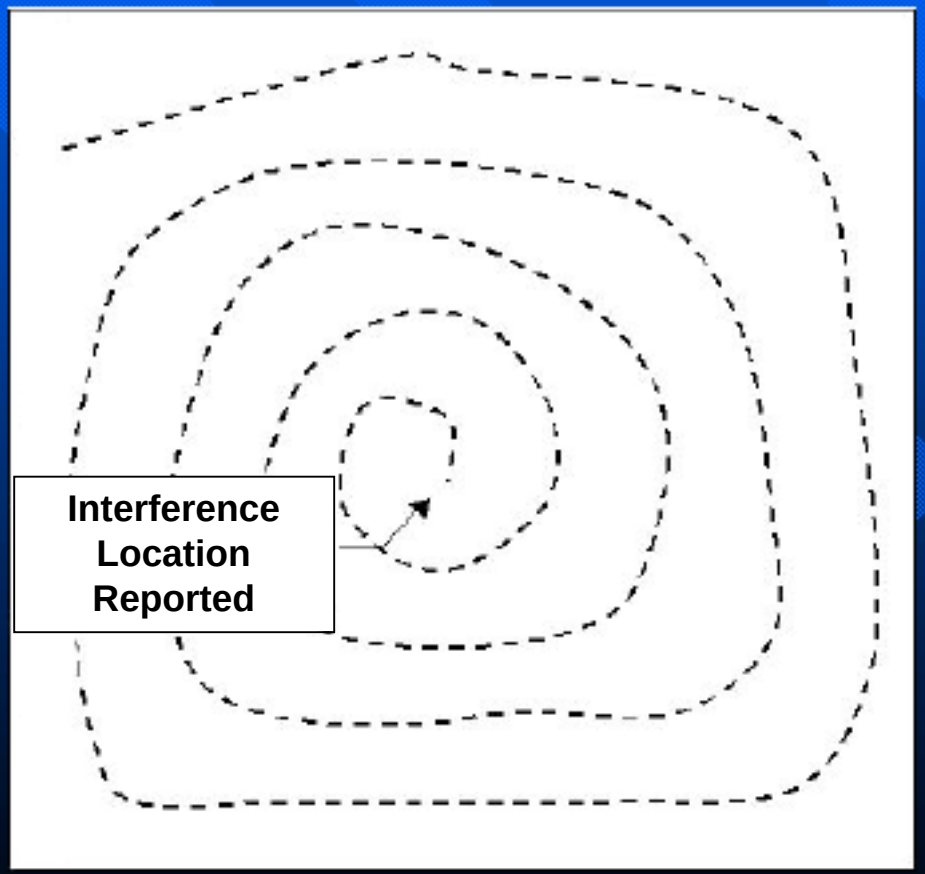
  >> Any Degradation to 20 dB C/(I+N)

Proving Entitlement
(FCC 04-168)

- Measurement Area To Be
  - No less than 300’ x 300’
  - Large enough to encompass affected area
- Uniformly Distributed Measurements
- Multiple Samples Per Wavelength
- Filters/Frequency Selectivity to Prevent Test Receiver-Generated IM

Proving Entitlement
(FCC 04-168)

- **Measurement Route to Determine Qualification for Protection:**



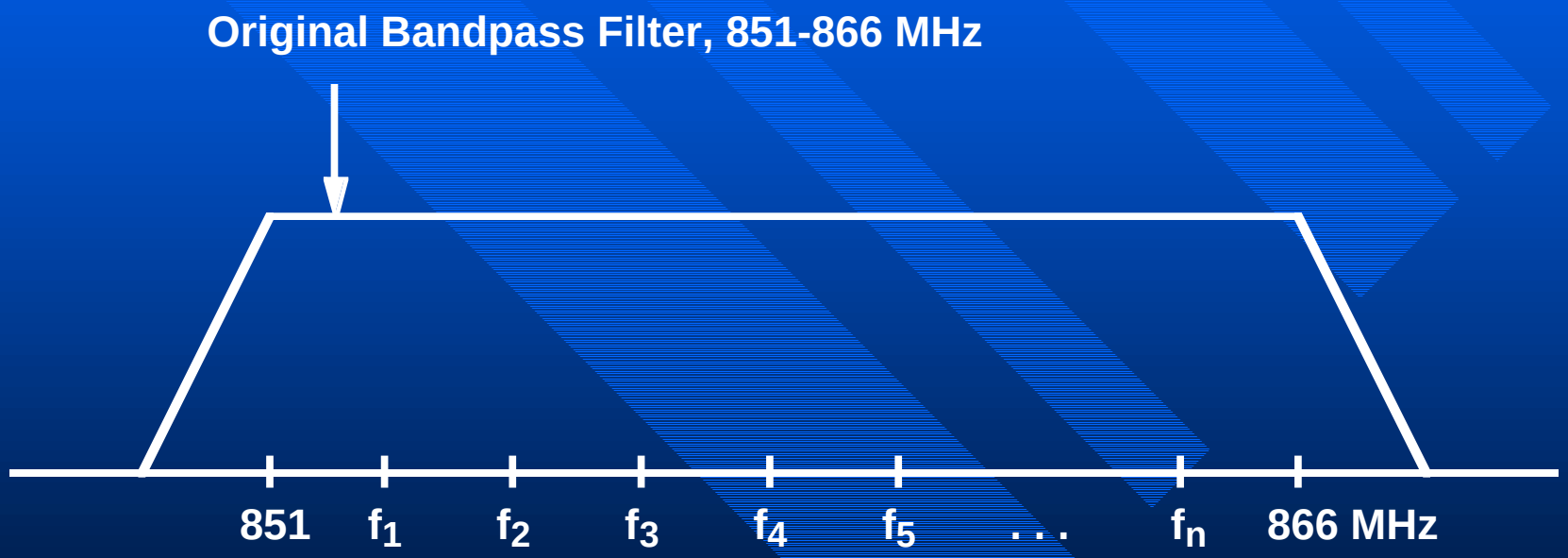
Mitigation Techniques

Problem Mitigation
Transmitter Out-of-Band Emissions (OOBE)

- **Actions**
  - Auto-tune cavity combiners
  - Greater filter selectivity reduces out-of-band emissions
- **Results**
  - Only effective when channel separation is wide enough
- **Limitations**
  - Not effective for closely spaced frequencies (< 150 kHz)
  - E.g., 81 Interleaved Nextel < 150 kHz from a Denver channel

Filter Comparison

(Nextel Transmitter Combiner)



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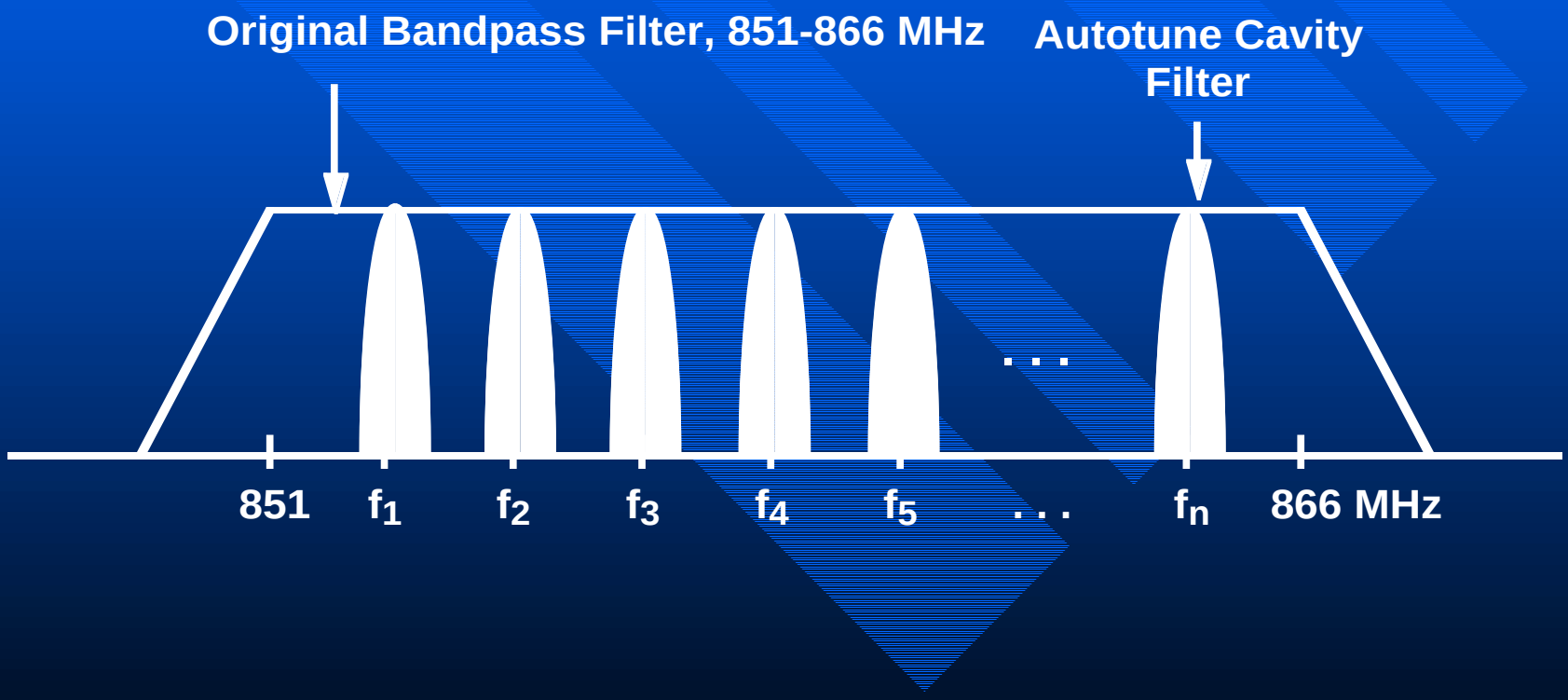

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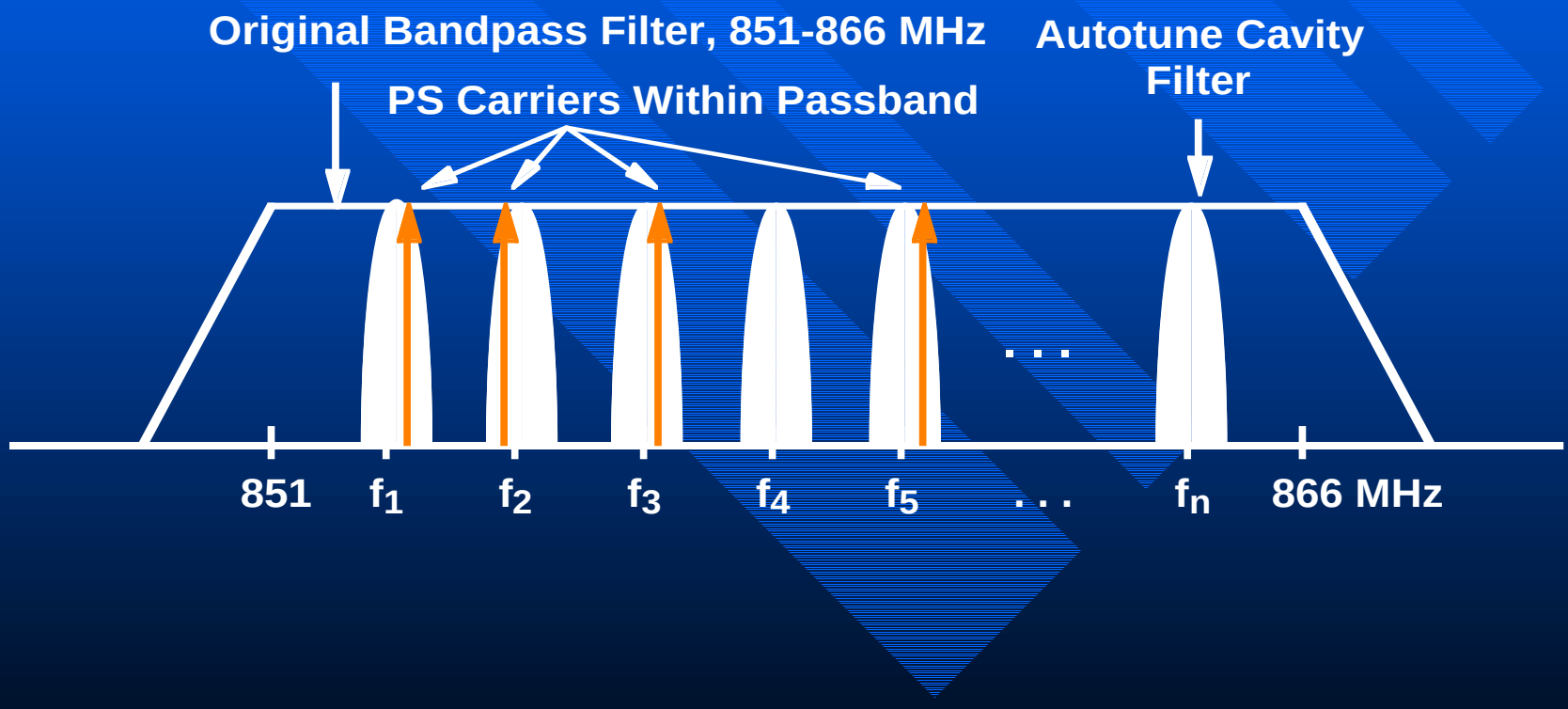


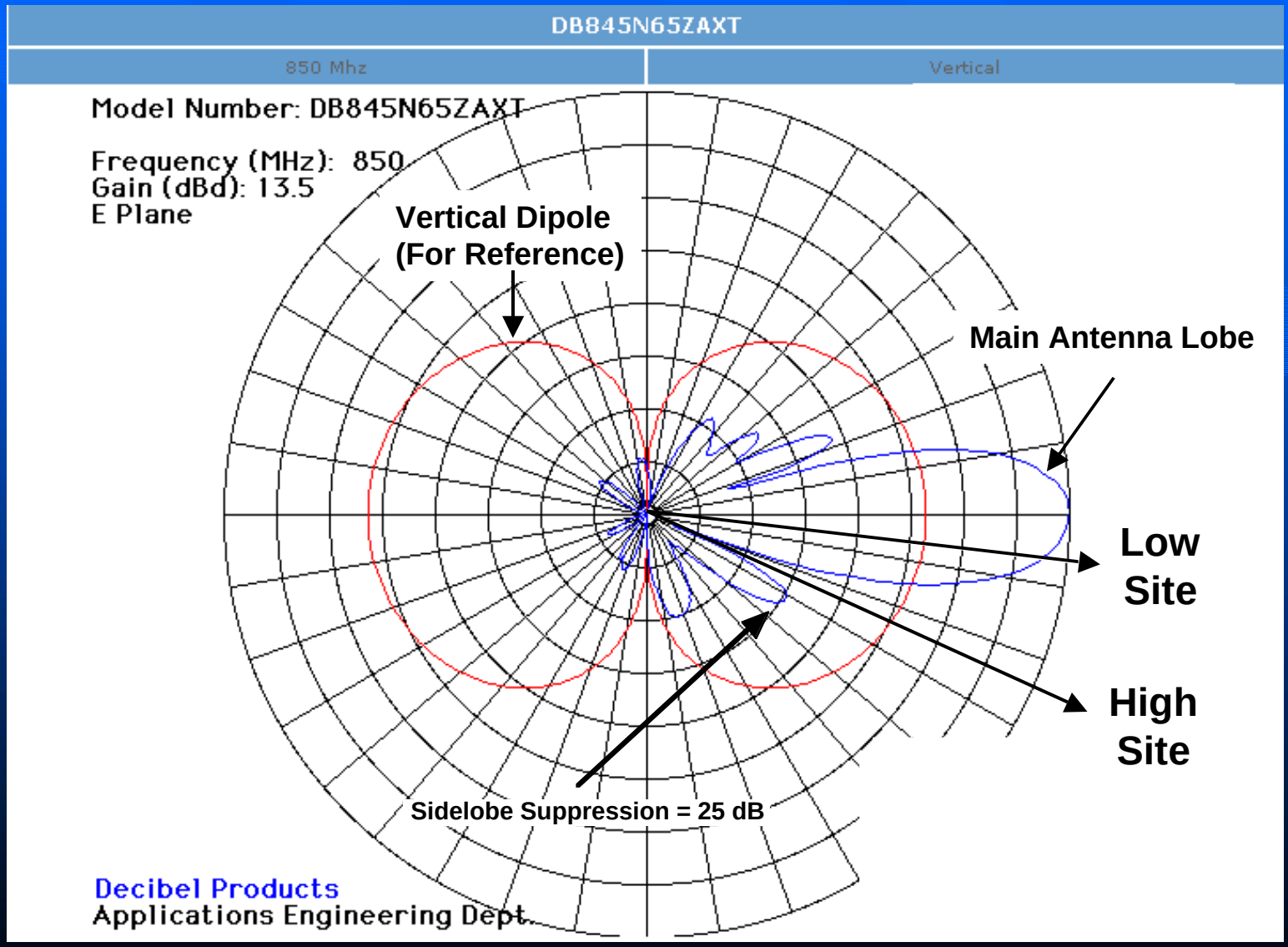
Problem Mitigation
Intermodulation (IM) Protection

- **Actions**
  - "Tune" Nextel site to preclude harmful IM products
  - Practically, can only protect control channels
- **Results**
  - In Denver, effective at roughly 18 of 24 problem sites
- **Limitations**
  - Only control channels are protected
  - Voice channels still experience interference
  - System often assigns user to a bad voice channel (one with IM)
  - Nextel limited in use of their spectrum

Problem Mitigation
Antenna Sidelobe Suppression

- **Actions**
  - Install antennas with reduced downward radiation
- **Results**
  - Reduces Nextel signal level on the street
  - IM products reduced by roughly 3 to 1 ratio in dB
- **Limitations**
  - Not effective for low sites
  - Can be close-in and still in main antenna lobe

Vertical Antenna Pattern



Antenna Issues

- In Denver, Tried Sidelobe Suppression at Two Sites:
  - City Bank, 8-10 stories high, good results
  - 14th & Market, ~ 3 stories high, not effective
- Only works on relatively high sites (look down angle issue)

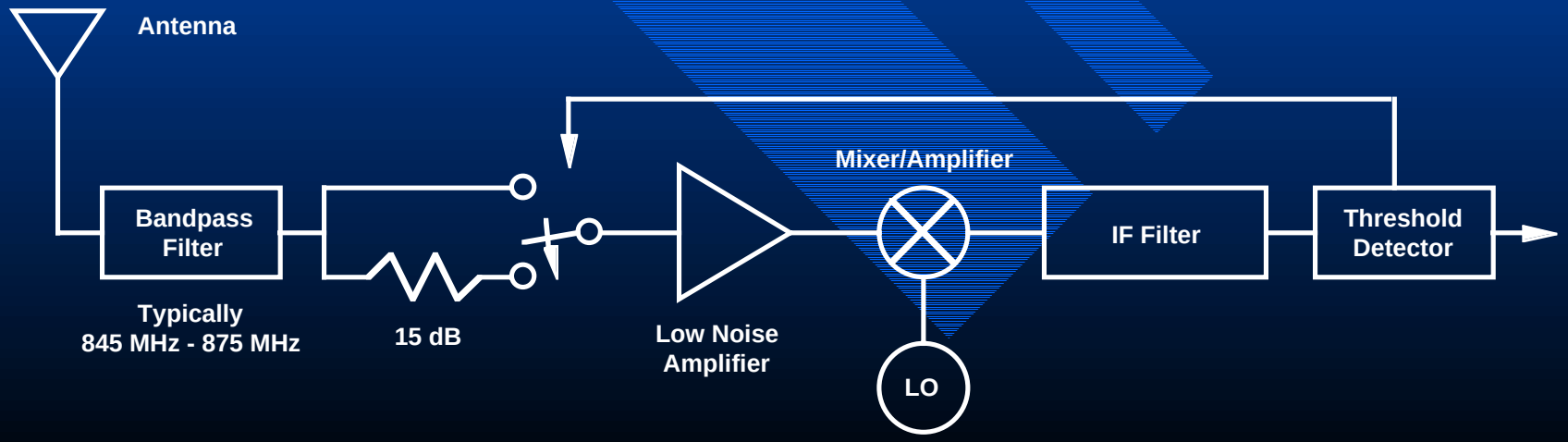
But It's Usually the Low Site

(Alameda & Federal)

Another Low Site
(48th & Elm)

Problem Mitigation
Switchable Attenuator

- Motorola Innovation
- Automatically switch in attenuator when desired signal is strong
  - 3:1 dB reduction in interference
  - 1:1 dB degradation in sensitivity
- Switch Out Attenuator When Signal is Weak
  - Avoids sensitivity degradation when we cannot afford it



What Doesn’t Work?

Tried With Limited Success

- IM Tuning
  - Limits Nextel & A-Band carrier frequency choices too much
  - Only practical to protect a handful of frequencies (control ch's)
  - Still strong IM on voice channels
  - Nextel alone can't control the Nextel/A-Band mixes
- Auto-Tune Cavity Combiners
  - Cavities have finite isolation
  - Not good for close-in channels (< 150 kHz)
  - Further limits Nextel's frequency choices
- Antenna Patterns
  - Won't work at low sites where problem typically occurs

Other Techniques

- Varactor-Tuned Bandpass Filters
  - Motorola suggestion, detune to create attenuator
  - Good idea, same effect as attenuator (below)
- Switchable Attenuator
  - Works well when desired signal is strong
  - But the problem occurs when signals are weak
  - Introduces complex signal estimation problems

What Works?

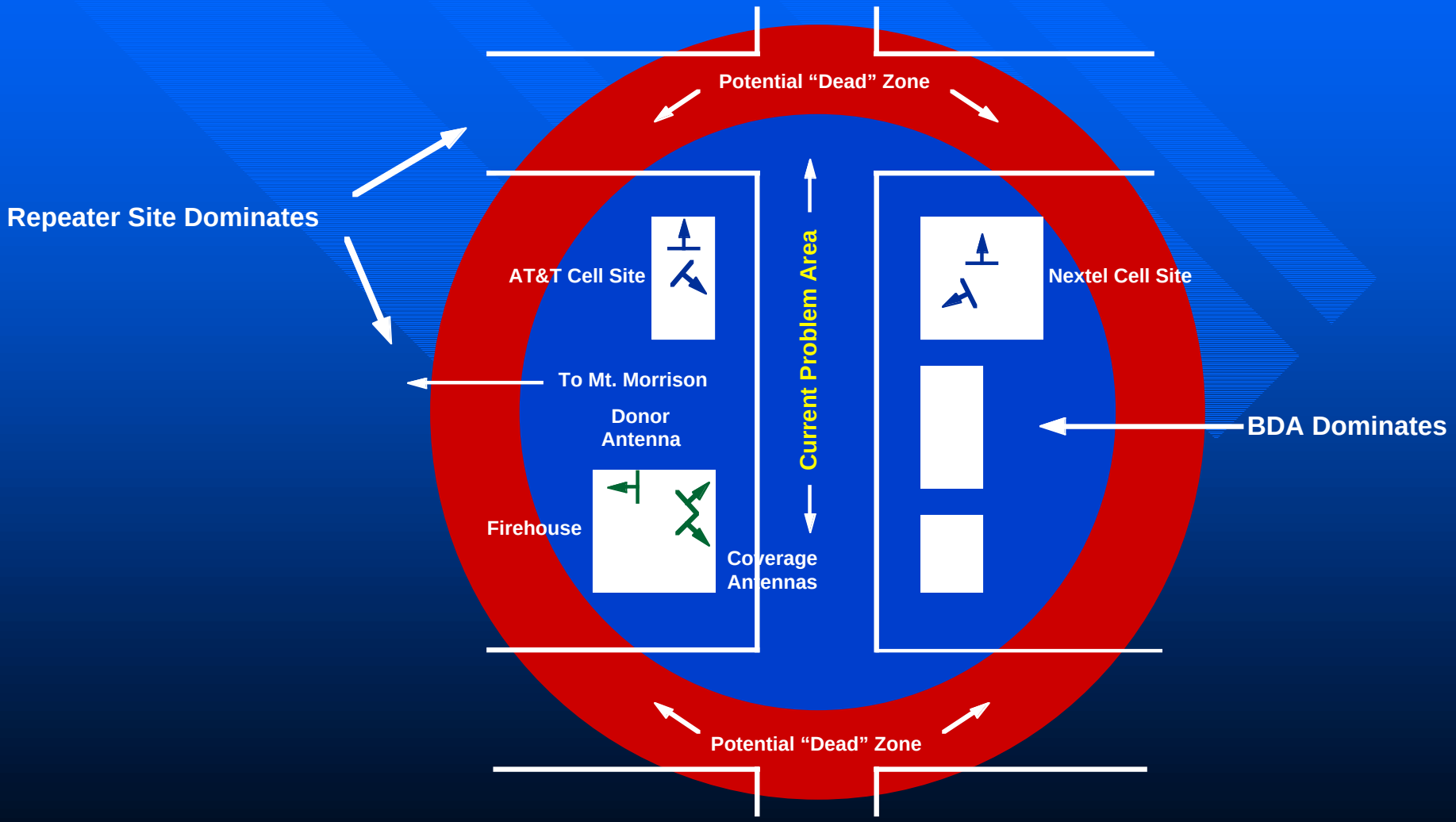
Effective Techniques

- **Band Separation**
  - Create guard band, so IM products fall in guard band
  - Guard band also isolates OOBE
  - Not practical today due to interleaved channels
- **Boost Public Safety Signal**
  - More repeater sites
  - Simulcast sites
  - Booster amplifiers

Booster Amplifier Issues

- Two Types: Broadband & Narrowband (Channelized)
- Broadband Pros & Cons
  - Pro: Inexpensive
  - Pro: Minimal group delay
  - Con: Prohibited by FCC for outdoor use
- Narrowband Pros & Cons
  - Pro: Can be used outdoors
  - Con: High group delay may cause problems in overlap areas
  - Con: Expensive
  - Con: More components subject to failure

The Doughnut Problem



The Need for Re-Banding

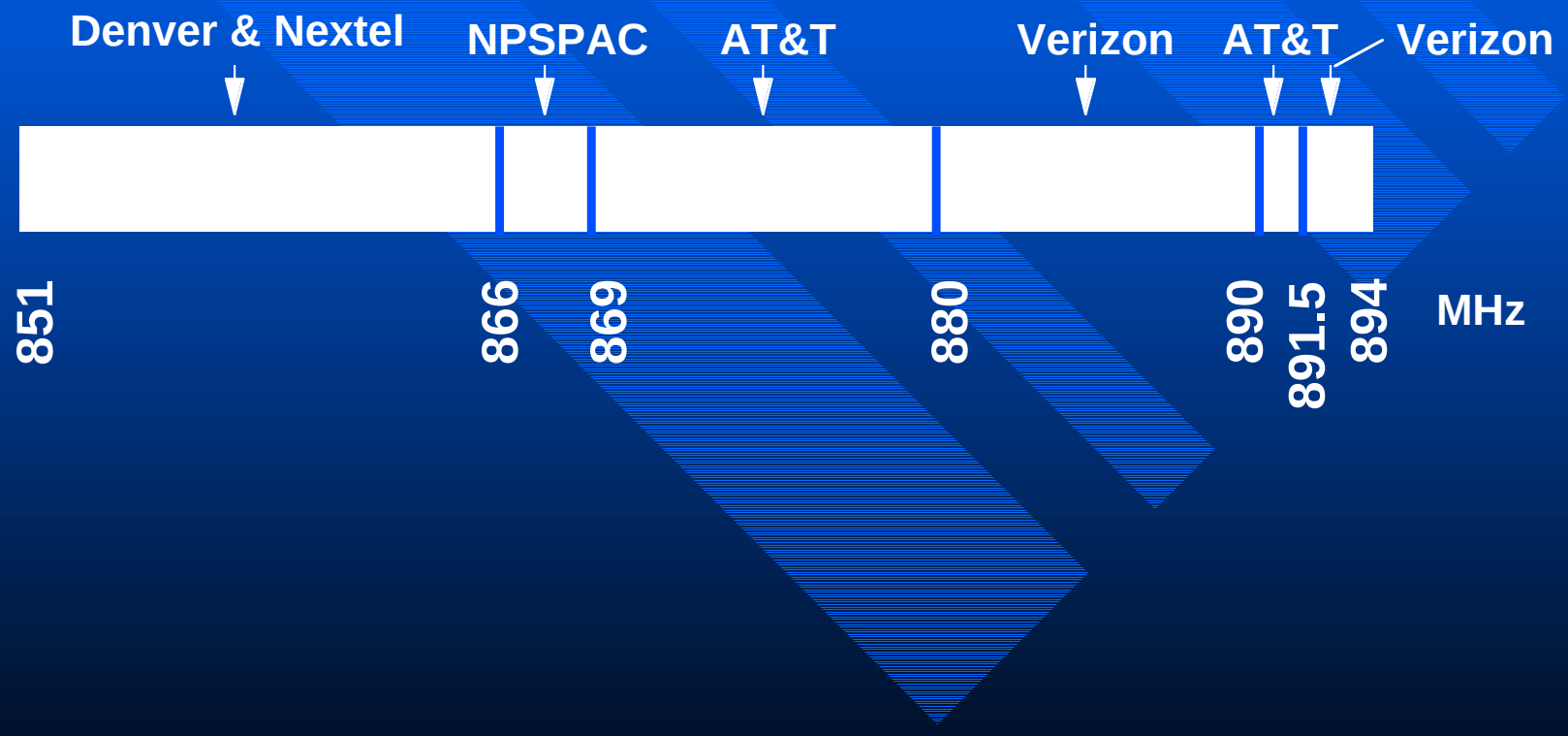
- Denver & Others Tried the “Technical Toolbox” for 3.5 Years
  - Only partial improvements
  - These are stop-gap measures
- Filtering at Receivers & Transmitters Only Effective w/Re-Banding
- Receiver Technology Will Not Save Us
  - Amplifier & mixer technology is mature
  - No significant advances on the horizon
- The Problem Will Only Get Worse
  - Nextel & A-Cell will continue to build sites with low antenna heights
  - Indoor wireless systems will increase

Denver

Denver Public Safety Radio

- **Frequencies**
  - Public Safety: 33 channels, 854-861, 866-869 MHz
  - Utilities: 15 channels (25 kHz), 854-861 MHz
- **Equipment**
  - MA/COM EDACS Trunked Radio System
  - Analog FM
  - Activated 1989
- **Site**
  - Main transmitter site on Mt. Morrison (7,750’ AMSL)

800 MHz Band in Denver



Background

- Problem Discovered in Feb 2000 Following Officer Complaints
- Eventually 24 Sites Identified
  - Not static, still finding more
- Two Main Problems:
  - Transmitter out-of-band emissions from Nextel transmitter
  - Receiver Intermodulation in public safety receiver
- Actions Taken & Proposed
  - Near-term: mitigation
  - Long-term: a phased channel swap and re-banding

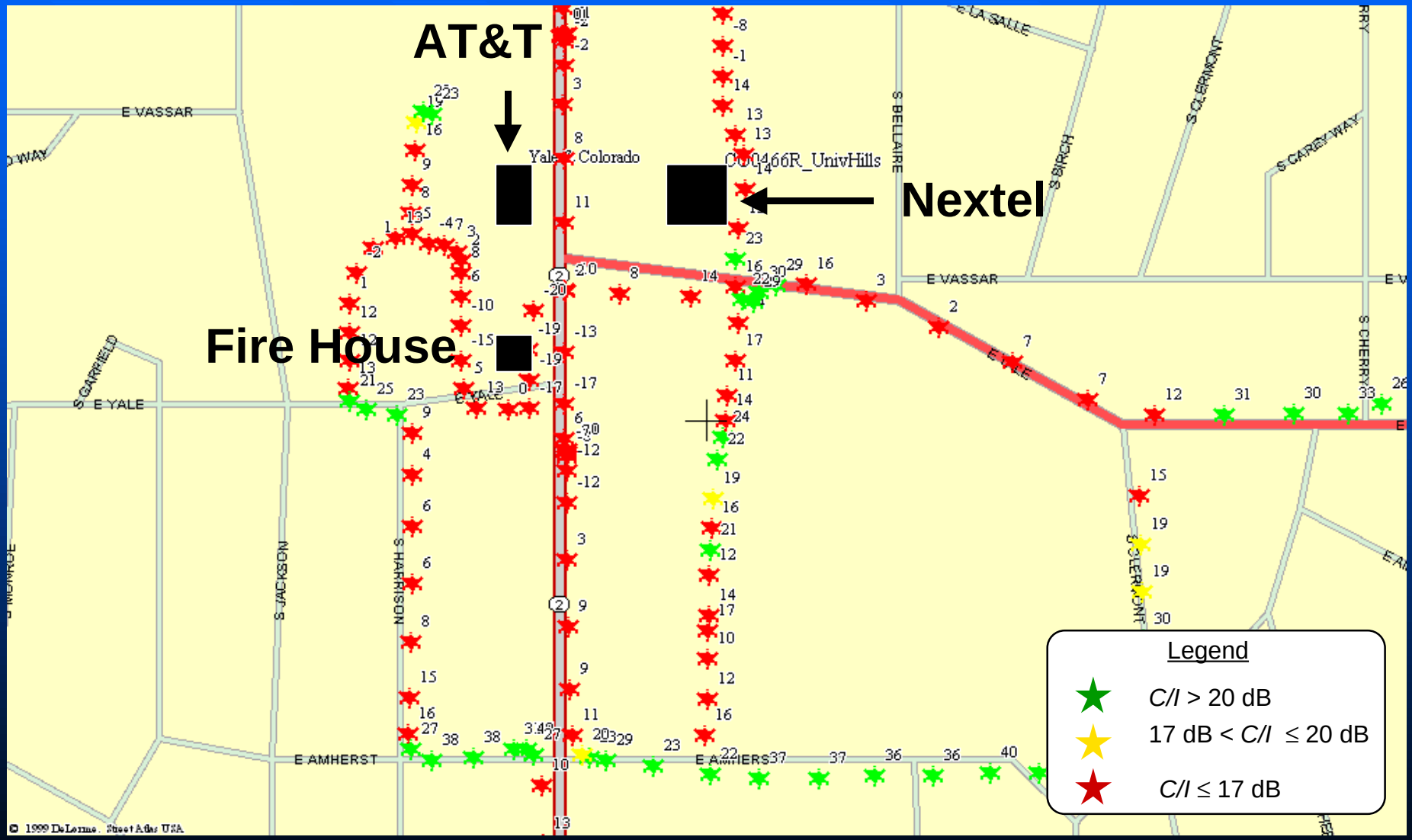
Example: Yale & Colorado

Nextel Site
(East Side)

AT&T Site
(West Side, north
of Fire House)

Denver Fire House
(West Side)

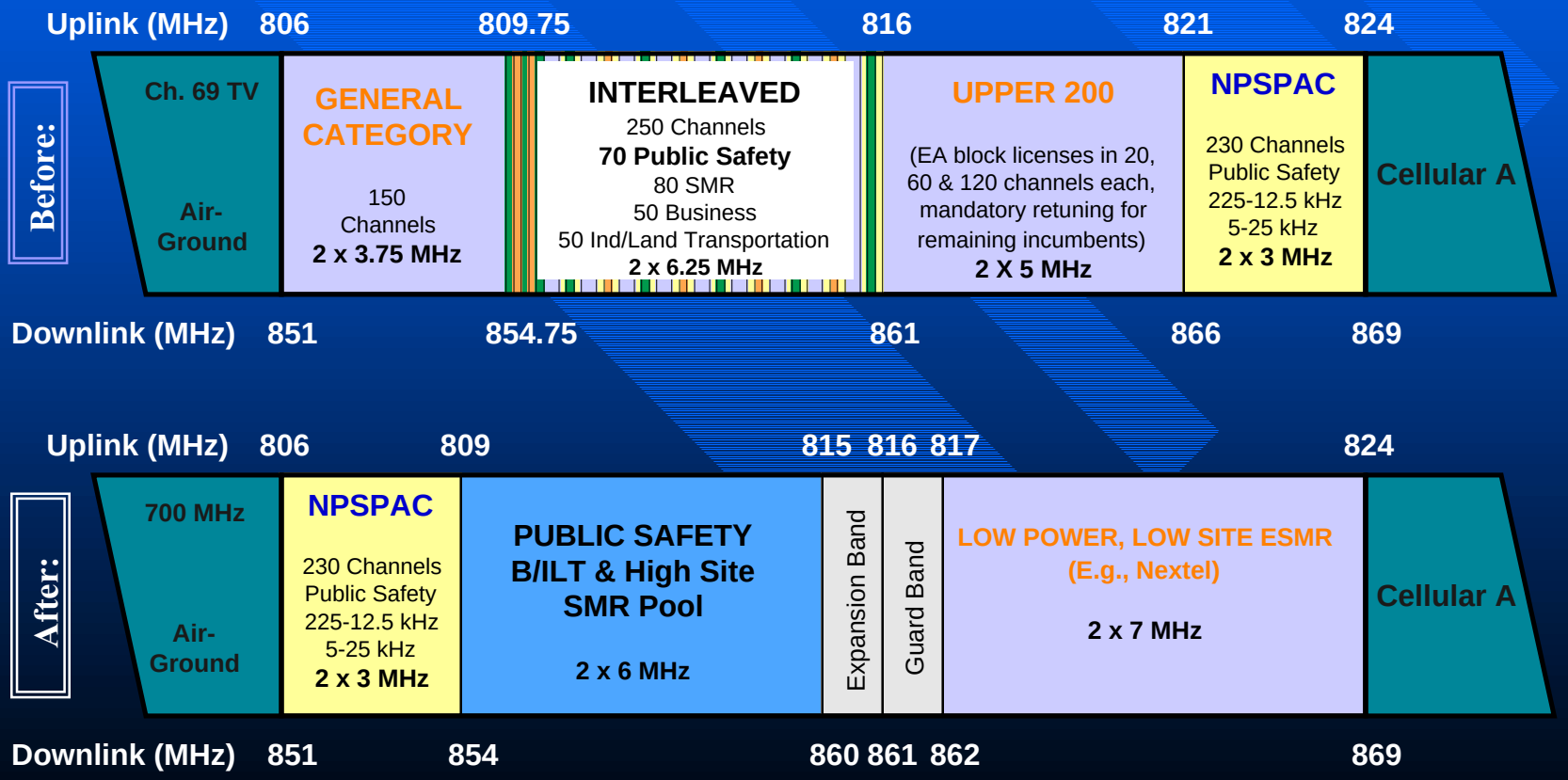
Yale & Colorado



How Does Re-Banding Eliminate Interference?

Re-Banding (Per FCC R&O)

- **Before: Interleaved Channels Plus 4 PS/Cellular Band Edges**
- **After: No Interleaving And One Band Edge**



What Does Re-Banding Do?

- **OOBE - Filtering is Now Feasible & Straightforward**
- **Receiver Intermodulation**
  - **Does It Eliminate Receiver IM Alone? NO**
  - **Does It Enable Creation of IM-Free Channel Sets? YES**
  - **FCC R&O (formerly Appx. F) is the enforcement tool**
- **But Co-Located Sites Remain a Problem**
  - **These are Nextel/A-Band cellular co-location sites**
  - **Small fraction of total problem sites**
  - **Regardless, it still has a solution post-rebanding**

The IM-Free Channel Set Rule

- Public Safety is Below 860 MHz After Re-Banding
- Nextel and A-Cell Rule:
  - In each sector, confine channels to the range $[f_{min}, f_{max}]$ such that

$$2f_{min} - f_{max} > 860 \text{ MHz}$$

- It's That Simple!
- Examples: [861, 862] [862, 864] [863, 866]

IM-Free Frequency Sets

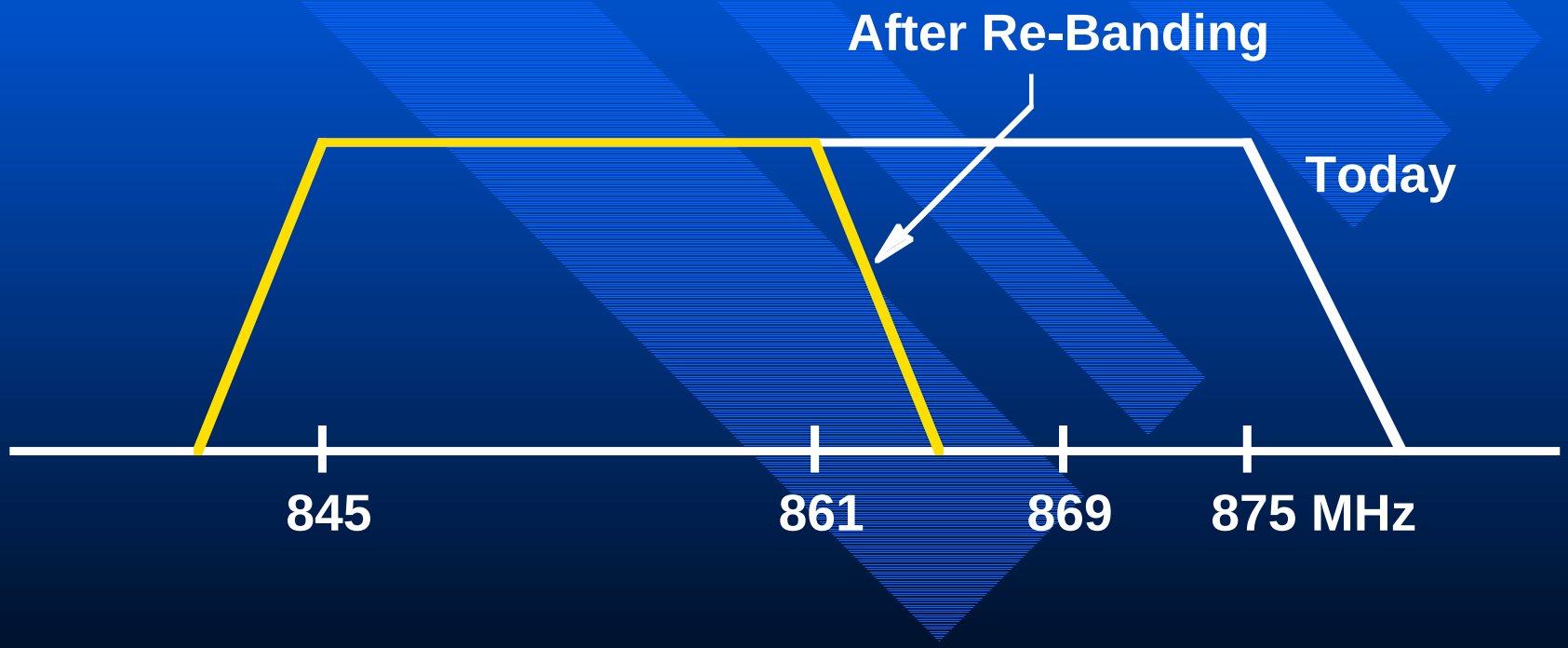
(One of Many Possibilities)

Table 2 - Potential Frequency Sets (Compatible with N=3 Reuse) (A,B,C = cell, 1,2,3 = sector)						
Set	**Span**	**Channels**	**fmin (MHz)**	**fmax (MHz)**	**Lowest IM Sector (MHz)**	**Lowest IM Cell (MHz)**
A1	675 kHz	27	862.0125	862.6625	861.3625	860.0125
A2	675 kHz	27	862.6875	863.3375	862.0375	
A3	675 kHz	27	863.3625	864.0125	862.7125	
B1	825 kHz	33	864.0375	864.8375	863.2375	861.5875
B2	825 kHz	33	864.8625	865.6625	864.0625	
B3	825 kHz	33	865.6875	866.4875	864.8875	
C1	825 kHz	33	866.5125	867.3125	865.7125	864.0375
C2	825 kHz	33	867.3375	868.1375	866.5375	
C3	850 kHz	34	868.1625	868.9875	867.3375	

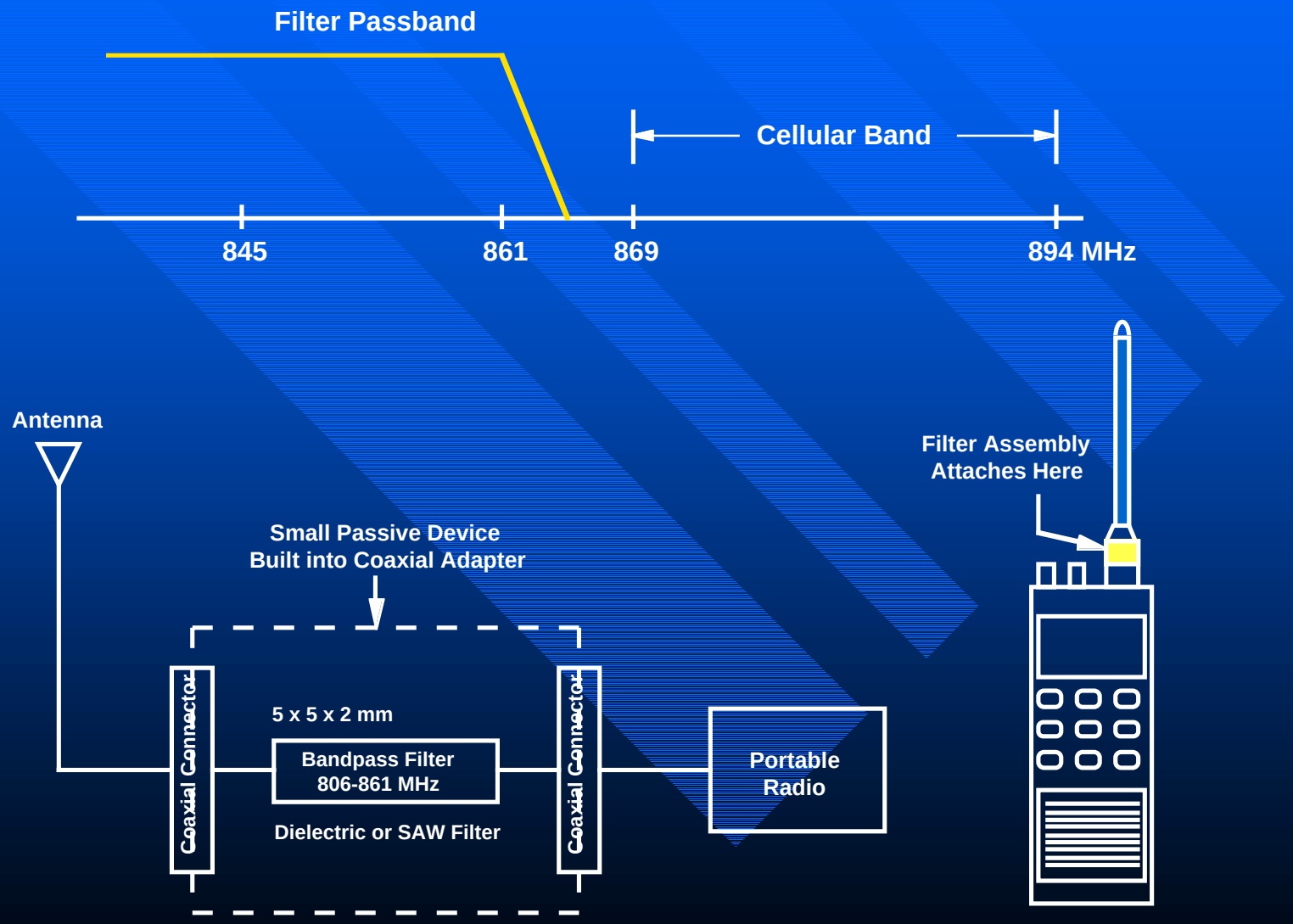
Filter Comparison

(Public Safety Receiver)

- Post Re-Banding Allows Effective Filtering at Receiver
- Eliminates IM From A-Band Carrier & Nextel/A-Band IM



A Solution for Co-Location



Bottom Line

- **Re-Banding creates band separation and contiguous spectrum that together make it possible to eliminate harmful out-of-band emissions and receiver intermodulation.**
- **Without Re-Banding, Public Safety Was Faced with Unsolvable Problem**

Points of Contact

Jay M. Jacobsmeyer, P.E.
Pericle Communications Company
1910 Vindicator Drive, Suite 100
Colorado Springs, CO 80919
(719) 548-1040
Fax: (719) 548-1211
jacobsmeyer@pericle.com

M. Daniel Mieszala
Pericle Communications Company
1910 Vindicator Drive, Suite 100
Colorado Springs, CO 80919
(720) 344-9556
Fax: (303) 346-8794
mieszala@pericle.com

David L. McGinley
Pericle Communications Company
1910 Vindicator Drive, Suite 100
Colorado Springs, CO 80919
(719) 548-5014
Fax: (719) 548-1211
mcginley@pericle.com