

Defining Spectrum Rights

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- The opinions expressed in this talk are those of the authors and do not necessarily represent the views of the FCC or any other members of its staff



Dimensions of spectrum

- Frequency
- Space
- Time



Interference

- Interference occurs when more than one user operate in the same frequency and area at the same time
- To avoid interference most spectrum licenses separate users in frequency or geography and permit 24/7 usage in time



Defining Flexible Exclusive Licenses

- The exclusive right to operate a transmitter within a given frequency range in a given geographic area is only part of the definition of a flexible spectrum license
- To limit interference additional obligations on the licensee must be specified
 - ◆ Out-of-band emissions limits - How much power is the licensee permitted to emit out of its frequency band?
 - ◆ Out-of-area emissions limits – How much power is the licensee permitted to emit within its permitted frequency range but out of its permitted geographic area?
 - ◆ In-band power limits – How much power is the licensee permitted to emit within its band and geographic area?

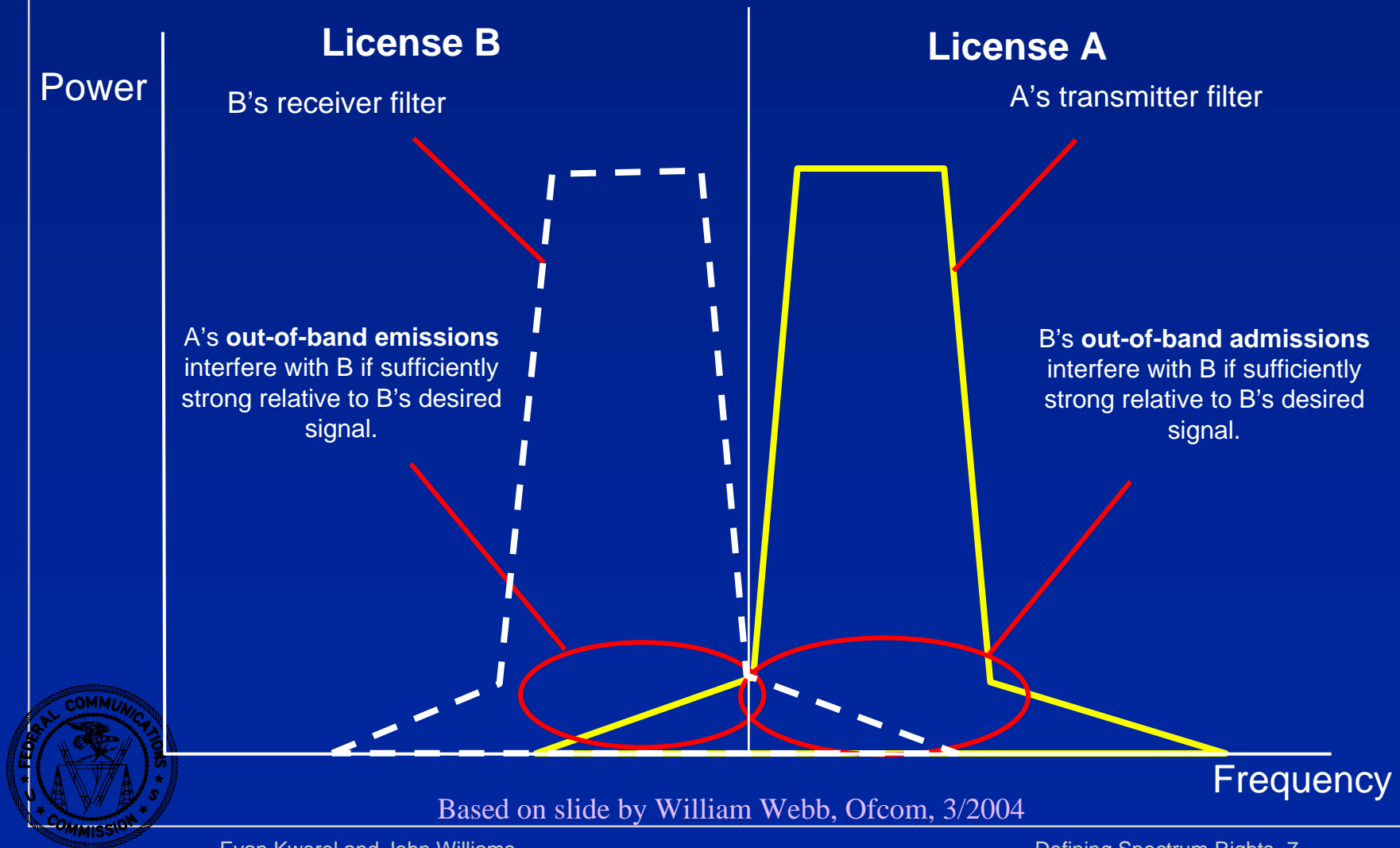


Analogy with Land

- Geographic boundary is primary dimension of a land property right
- Defining geographic boundaries is not sufficient to prevent externalities among land owners
- Like spectrum, most land titles have additional restrictions to manage externalities
 - ◆ Limits on noise (like out-of-area emissions limits)
 - ◆ Limitations on building heights (like in-band power limits)
 - ◆ Setback requirements for structures (like guard bands)
- Unlike spectrum, land users cannot be separated by frequency



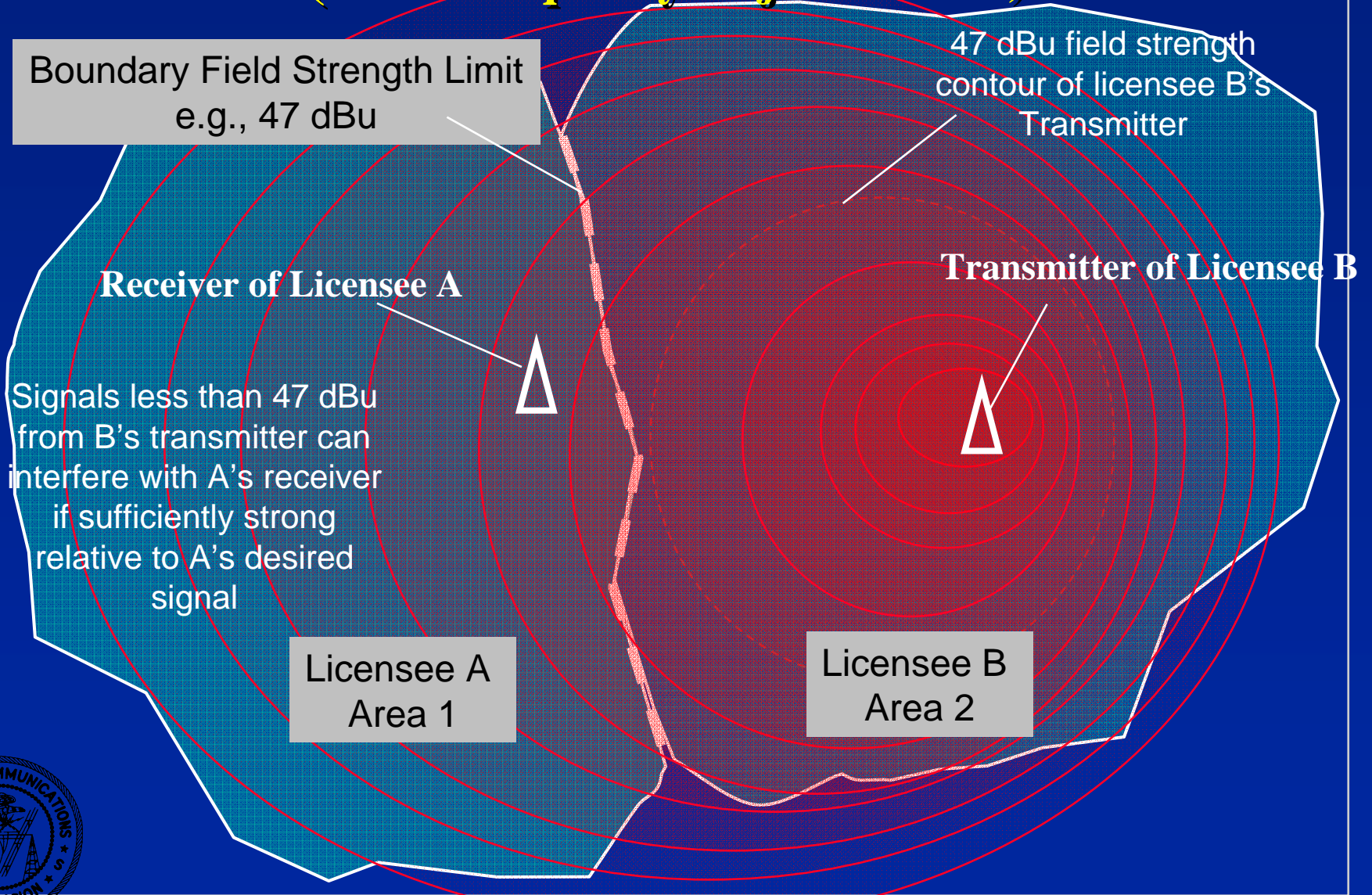
Frequency Boundary Interference (Same Area - Adjacent Frequency)



Based on slide by William Webb, Ofcom, 3/2004

Geographic Boundary Interference

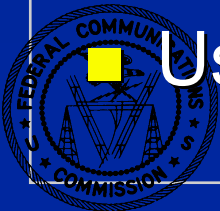
(Same Frequency Adjacent Area)



Frequency Boundary Interference: Avoidance by Receiver Owner

(Same Area - Adjacent Frequency)

- Costs and benefits all internalized
- Reduce undesired signal
 - ◆ Move away from frequency boundary (internal guard band)
 - ◆ Improve receiver filtering to admit less out-of-band energy
 - ◆ Move away in geography from interfering transmitter
 - ◆ Point antenna away from interfering transmitter
- Increase desired signal
 - ◆ Move closer to desired transmitter
 - ◆ Increase power of desired transmitter
- Use technology more tolerant of interference



Frequency Boundary Interference: Abatement by Transmitter Owner

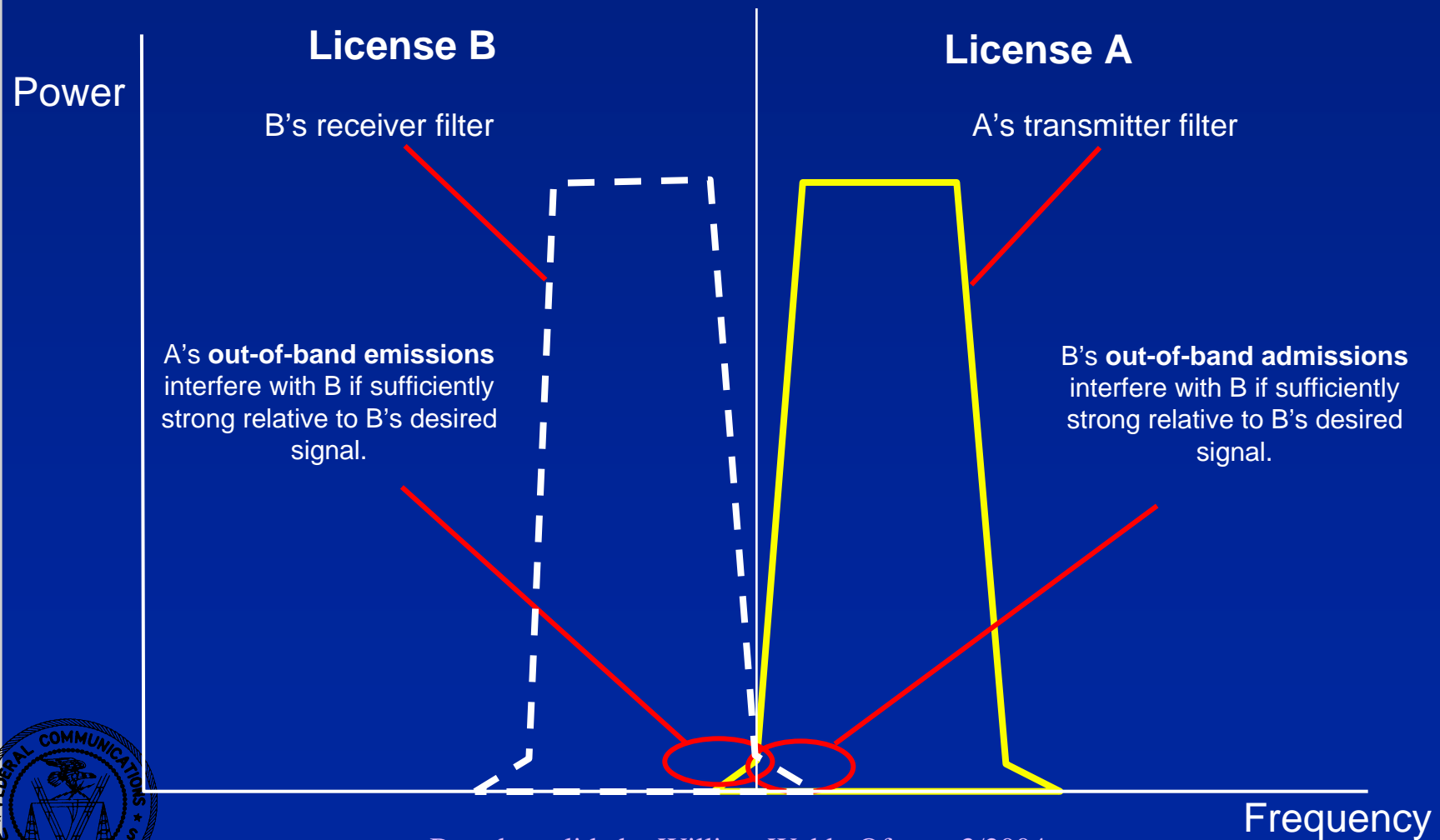
(Same Area - Adjacent Frequency)

- Cost are internal but benefits are external
 - ◆ Too little abatement w/o regulation or bargaining
- Reduce undesired signal
 - ◆ Reduce out-of-band emissions
 - ☞ Improve filtering
 - ☞ Create internal guard band
 - ☞ Move transmitters away in geography from other licensee's receivers
 - ◆ Reduce in-band emissions
 - ☞ Reduce transmitter in-band power
 - ☞ Move transmitters away in geography from other licensee's receivers



Good Filters Make Good Neighbors

Tomorrow's Filters – Less Interference Across Frequency Boundary



Based on slide by William Webb, Ofcom, 3/2004

Geographic Boundary Interference: Avoidance by Receiver Owner

(Same Frequency - Adjacent Area)

- Costs and benefits all internalized
- Reduce undesired signal
 - ◆ Move away from geographic boundary (internal guard area)
 - ◆ Point antenna away from geographic boundary (directional antenna)
- Increase desired signal
 - ◆ Move desired transmitter closer to own receiver
 - ◆ Increase power of desired transmitter
 - ◆ Increase power of desired transmitter
 - ☞ Higher output power
 - ☞ Higher gain antenna
- Use technology more tolerant of interference



Geographic Boundary Interference: Abatement by Transmitter Owner

(Same Frequency - Adjacent Area)

- Costs are internal but benefits are external
 - ◆ Too little abatement w/o regulation or bargaining
- Reduce undesired signal
 - ☞ Move away from geographic boundary (internal guard area)
 - ☞ Use directional transmitter antenna and point away from boundary
 - ☞ Reduce transmitter power



Optimal Level of Interference

- Optimal interference minimizes the total cost of interference, which is the sum of the cost of
 - ◆ Damage from interference (to receivers)
 - ◆ Interference avoidance (by receivers)
 - ◆ Interference abatement (by transmitters)
 - ◆ Regulatory and bargaining cost
- With uncertainty and change need to minimize expected value of total cost or some function that also accounts for cost of uncertainty
- Optimal level difficult to determine in practice
- Interference levels are regulated indirectly by defining licenses



Suggested Approach

- Define licenses in terms of transmitter outputs, not limits on actual interference (except to certain incumbents)
- Limit extremes of parameters having greatest effect on interference, e.g., very high in-band powers and out-of-band emissions, and leave the rest to licensees
- Provides licensees significant flexibility in choice of services and technologies without need to negotiate with neighbors



Thank You

For further information

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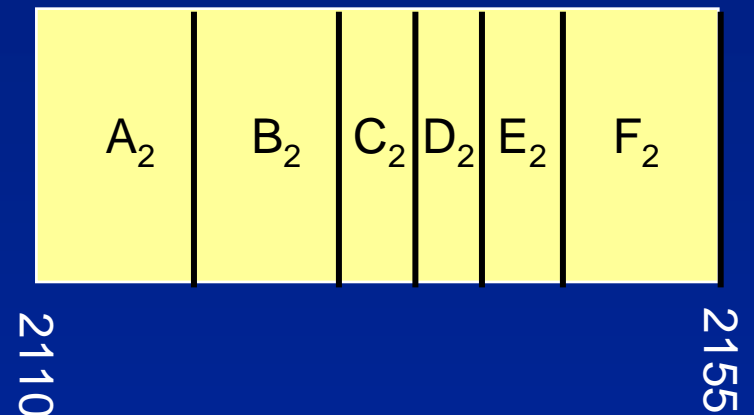
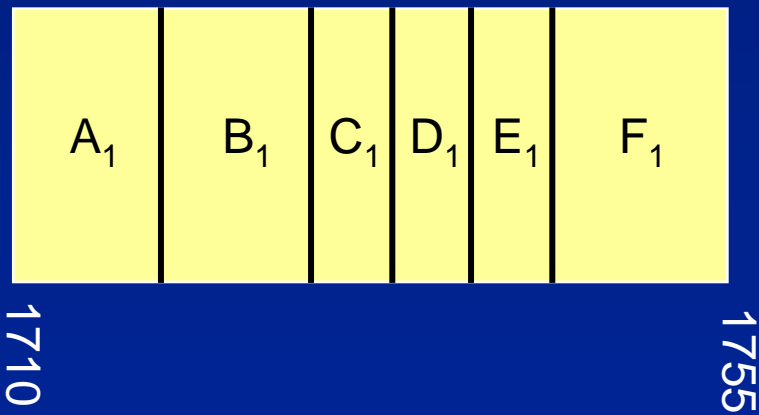


Supplemental Slides

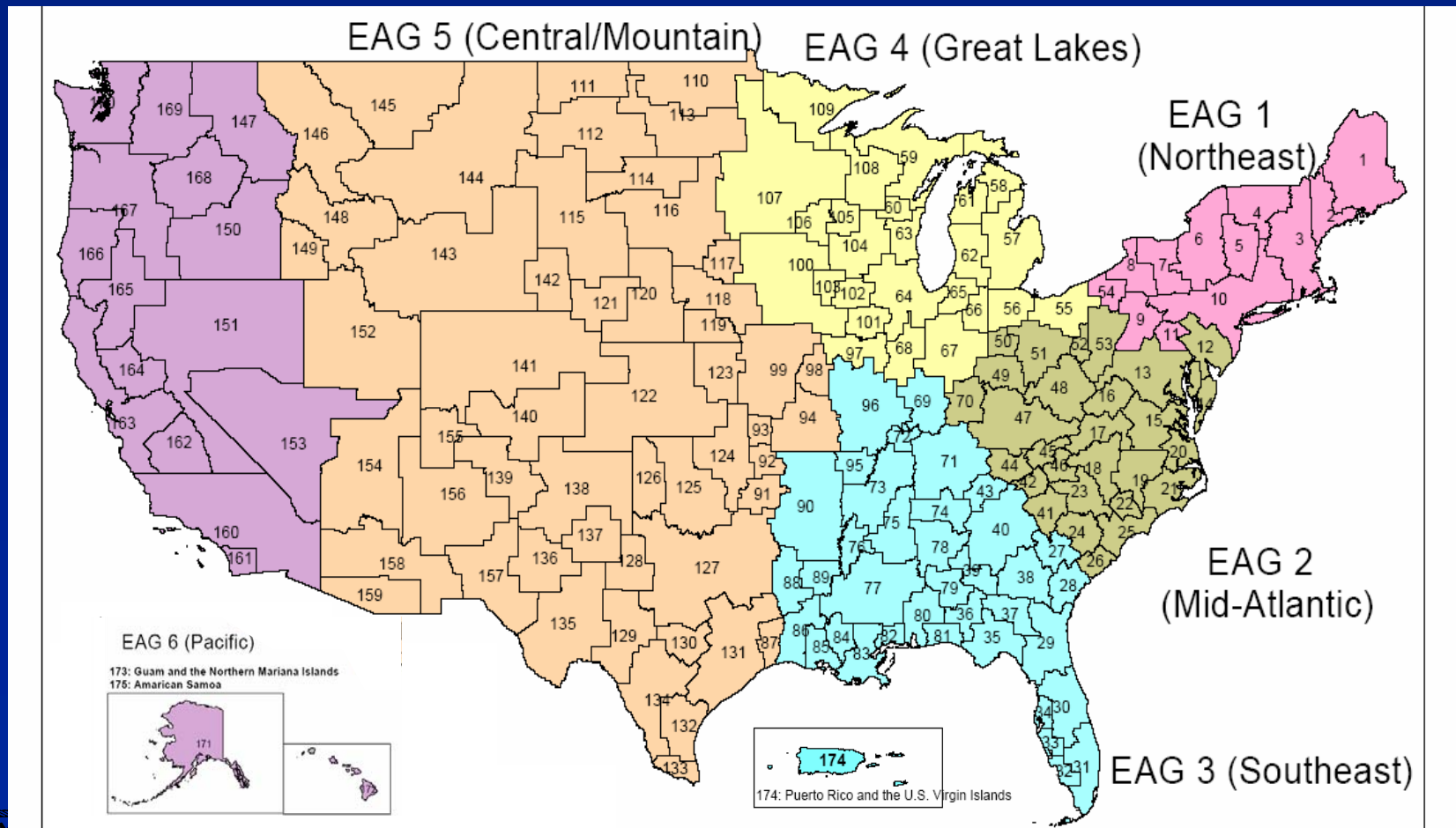


Licenses Separated in Frequency

Advanced Wireless Services



Licenses Separated in Area



Transition to Flexible Rights

- Option 1: License White Space and Establish Level of Protection for Incumbents
- Option 2: Vest incumbents with flexible rights and rely on bargaining (U.K. initial model)
- Option 3: “Big Bang” auction: Sell encumbered and unencumbered spectrum in a band in a single auction



Transition Options (1)

- Option 1: License White Space and Establish Level of Protection for Incumbents
 - ◆ Define explicit protection rights for incumbents
 - ◆ Policies may differ for adjacent band and in-band incumbents, e.g.,
 - ☞ In-band incumbents must move if compensated
 - ☞ Adjacent band incumbents allowed to remain but protection may be reduced over time
 - ◆ Issues
 - ☞ How much interference is “unacceptable”?
 - ☞ How long are incumbents protected?
 - ☞ Are incumbents required to clear if compensated?
 - ☞ Hold-outs and free riders



Transition Options (2)

- Option 2: Vest incumbents with flexible rights and rely on bargaining (U.K. initial model)
 - ◆ Incumbent may change use (and expand into the white space) if no interference to others
 - ◆ Issues
 - ☞ Protection rights of incumbents
 - ☞ Dispute resolution (regulator, courts, arbitration)
 - ☞ Resolving mutually exclusive proposed changes (first-in-time, beauty contest, lottery, auction)
 - ☞ Bargaining problems
 - many incumbents potentially affected
 - free riders
 - hold-outs



Transition Options (3)

- Option 3: “Big Bang” auction: Sell encumbered and unencumbered spectrum in a band in a single auction
 - ◆ FCC sells white space overlays in a band – exhaustively licenses frequency and geographic area dimensions
 - ◆ Incumbents sell existing licenses (or given vouchers based on auction values)
 - ◆ Issues
 - ☞ Voluntary or mandatory participation by incumbents
 - ☞ Dividing revenue between Treasury and incumbents
 - ☞ Potentially large number of properties being sold (package bidding complexities)
 - ☞ Legal authority

