## **Pre-Conference Primer: Spectrum Sharing and Interference Resolution**

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**2022 Spectrum Policy Initiative Conference October 6. 2022** 

## **Today's Selected Topics**

- Growth in spectrum usage and scarcity (why spectrum management is important!)
- Basic 4-step Spectrum Management Framework
- Spectrum Sharing in frequency, time and space
- Receiver performance and harmful interference
- National Spectrum Strategy

# What is Spectrum?

### Conceptual tool used to organize and map a set of physical phenomena

- Electric and magnetic fields produce (electromagnetic) waves that move through space at different frequencies
- Set of all possible frequencies called the "electromagnetic spectrum"
- Infinitely renewable resource
- Availability subject to interference







U.S. DEPARTMENT OF COMMERCE Vational Telecommunications a Office of Spectrum Management



THE PADIOSPECTRUM MAGNIFIEDABOVE

## **Mobile Economy** Indicators

Large Growth in Spectrum **Usage Driven by Increasing Demand for Mobile Services** or Wireless Devices

Source: GSIA, The Mobile Economy 2022



## **Mobile Economy** Indicators (cont'd) As Mobile Economy Grows, **Increasing Scarcity of Spectrum Resource**

Source: <u>GSIA</u>, The Mobile Economy 2022



## 4-Step Spectrum Management Framework All activities regulating the use of the radio spectrum

- Fundamental steps:
  - Allocation
  - Service Rules
  - Assignment
  - Enforcement

### UNITED STATES FREQUENCY **ALLOCATIONS**

### THE RADIO SPECTRUM





### Source of Slides: CYBR 5420 Spectrum Management Course (co-taught with Dale Hatfield)

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## Allocation **Process of dividing usable spectrum into bands of** frequencies for specific services

- Service allocations determine type of use allowed over the frequencies
  - Example service classifications: broadcast, fixed, mobile, and radio navigation (e.g., radar systems)
- How do policy makers decide spectrum allocation questions?
  - Public need, benefits, opportunity costs
  - Technical considerations (propagation, service requirements)
  - Device limitations (antennas, receivers, etc.)



## Spectrum Allocation (cont'd)

- Federal Communications Commission (FCC) only allocates for private, state, and local government uses
  - Also decides amount of spectrum (bandwidth) in license
- National Telecommunications and Information Administration (NTIA) allocates for federal government and military
  - State Department coordinates with International **Telecommunications Union (ITU)**
  - Issues assignments (not licenses) that are mainly site-based



## **Service Rules** Regulatory capabilities and limitations placed on service allocation

- Service rules can do the following:
  - Set technical standards of transmission
  - Determine goals for license eligibility
  - Establish geographic service areas
  - Establish other requirements for use of an allocation
  - Set rules for auction of a particular band
- How do policy makers decide service rules?
  - Public interest considerations in managing band
  - Some overlap between allocations and service rules



# Service Assignment **Process of granting authority (a license) for entity to operate radio systems on individual channels at specific locations**

- In accordance with service rules governing allocation
- Recent trend to expand licenses to include multiple channels covering large geographic areas employing multiple transmitter sites
- If, because of interference considerations, specific assignment is restricted to one party, assignment is mutually exclusive
- Competing applications for mutually exclusive licenses can be awarded via different mechanisms
  - first-come, first-served basis
  - through comparative hearings (up to 1980s)
  - by lottery (late 1980s)
  - through auctions (early 1990s to present)





## Enforcement Conformance to the applicable rules and regulations of the spectrum license

- Undertaken to ensure compliance with rules and regulations designed to protect:
  - Integrity of spectrum management process
  - Prevent harmful interference between and among users
  - Protect radio environment from unintended or incidental radiation (aka interference)



## Spectrum Management **Roles of FCC** and NTIA





### National Spectrum Management

Picture Source: NTIA.gov

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# Spectrum Management Models

Command and Control Exclusive Use Commons

# **Key Elements of Spectrum Policy**

- Maximizing <u>flexibility</u> to find highest valued use, subject to interference limitations
  - Choice of use, technology, and right to transfer, lease, or subdivide spectrum rights

- Clear and exhaustive definition of spectrum rights and responsibilities Designated frequency range and bandwidth
  - Geographic scope of right to operate
  - Maximum power output, both in-band and out-of-band
  - Interference protection (max interference allowed from other sources)
    - Note uncertainty defining "harmful interference"



## **Traditional "Command and Control" Regulation**

- After the Communications Act of 1934, FCC decided who and what was worthy of using spectrum
- Granted renewable licenses for specific government-defined uses
- Service rules define eligibility and service restrictions, power limits, and build-out requirements
- Users had no ownership right in spectrum
- Rules designed to prevent "harmful interference"



## **Exclusive Use of Licensed Spectrum Regulation**

- Licensee has exclusive and transferable rights to use of specified spectrum in defined geographic area
- Flexible use rights with technical rules to protect other users against interference
  - Exclusive rights resemble property rights
- Weight of the owners, acting as "band managers," can sell or lease spectrum
- Ø 5G) spectrum

 Coase's Theorem: with well-defined property rights, free market will allocate resources to their most efficient use

Steps to date: auctions, license flexibility for mobile (4G and



# **Commons (aka Unlicensed) Model**

- Allows unlimited numbers of unlicensed users to share frequencies
- Usage rights governed by technical standards that set power limits
- No right to protection from interference • Popular examples: amateur radio, CB radio, Bluetooth,
- Wi\_Fi

## Exploiting "White Space" to Share Spectrum White spaces are unused portions of spectrum in terms of frequency, time, and space

- Underlay technologies
  - Ultrawideband)
- Overlay technologies
  - Detects and utilize unused spectrum
  - GPS for location, beacons, and "listen-before-talk" protocols

### - Transmit at power levels below the electromagnetic noise floor (e.g.,

Dynamic Frequency Selection capability based on technologies such as

## **Exploiting "White Space"**

### Channel Occupancy



### "White Space" (Guard Bands & Unused Channel)





## **Spectrum Sharing and Interference**

- - Frequency
  - Space
  - Time
- unavoidable in a practical sense
- Managing interference is a key element of spectrum management!

## Just reviewed how spectrum can be shared in 3 dimensions:

# Some interference ("spillover") in each spectrum dimension is

## The Radio Spectrum Resource Things to remember

- Wireless systems are inherently open
- Interference occurs in receivers
- In addition to the desired wireless signal, radio noise and interference are always present in a radio receiver



## **Radio Interference** Natural and Manmade Interference



### Note:

- 1. Somewhat typically, for successful reception, the structure sum of the natural and manmade noise
- 2. Receivers that pick-up noise and interference far ou Proceeding on Promoting Receiver Performance

1. Somewhat typically, for successful reception, the strength of the desired signal must be 10 times (10db) stronger than the

Receivers that pick-up noise and interference far outside the channel they are assigned exacerbate interference. See FCC



## **Radio Interference**

- Interference Defined As:
  - - unwanted energy

## • Harmful Interference Defined As:

applicable radio regulations

 Effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system

 Manifested by any performance degradation, misinterpretation, or loss of information which could otherwise be extracted in the absence of such

 Interference which endangers the functioning of a radionavigation service or other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with

## **Radio Interference** Important note

- would have little or no value
- Hence, total avoidance of interference is impractical and counter-productive

## Unless the possibility of some interference is accepted, no wireless communications would occur and the spectrum

## **Interference Resolution and Enforcement Problem setting**

- Increased use of innovative wireless systems can rapidly change the interference environment
  - Places increased pressure on traditional interference resolution and enforcement methods
- Dynamic frequency selection and increased mobility of wireless devices creates interference that is more transient in nature and more difficult to identify and locate
- Increased spectrum sharing between government and commercial systems also creates problems detecting, identifying, locating, reporting, and mitigating unintentional interference and malicious interference or jamming





# **National Spectrum Strategy**

## Began with NTIA Request for Comments in 2019 for Developing a **Sustainable Spectrum Strategy for America's Future**

- Create models for spectrum management including flexible-use
- to develop advanced spectrum-sharing tools and techniques
- Build secure, automated capability to facilitate assessments of spectrum use and expedite coordination of shared access
- industries and mission capabilities of Federal entities

 Increase shared spectrum access for all users through improved cooperation between Federal and non-Federal spectrum stakeholders

spectrum licenses while accounting for safety and security concerns

• Use ongoing research, development, testing, and evaluation [RDT&E]

Improve global competitiveness of U.S. terrestrial and space-related



## **FCC/NTIA Focus on National Spectrum Strategy**

 Renew efforts to develop a National Spectrum Strategy FCC and NTIA will collaborate to develop national spectrum strategy, increase transparency around spectrum use and needs, and establish long-term spectrum planning and coordination

- Cooperatively develop spectrum engineering compatibility analysis including interference protection criteria and propagation models
- Proactive technical engagement with industry and other federal agencies
  - FCC observe the Commerce Spectrum Management Advisory Committee, and NTIA will observe FCC's Technological Advisory Council and the Communications Security, Reliability, and Interoperability Council

Update from 02/2022: FCC Chairwoman and NTIA Assistant Secretary **Advance U.S. Spectrum Policymaking through Closer Coordination** 





# What is a National Spectrum Strategy?

Example provided by Aspen Institute's Toward a National Spectrum Strategy Report (September 2022)

### Strategic

National Plan Spectrum Ab

Balanced Na Spectrum Po

<b>Principle</b>	Recommendation
n for bundance	As part of its National Spectrum Strategy, U.S. should issue a 10 plan with clear national goals to release more spectrum into the commercial marketplace
ational ortfolio	In making new spectrum available commercial use, Congress, FCC and Administration should ensu- balance of licensed, unlicensed shared authorization models as appropriate for the bands under consideration



# What is a National Spectrum Strategy? (cont'd)

## **Example provided** by Aspen Institute's **Toward a National Spectrum Strategy Report** (September 2022)

### Strategic

More Produc Flexible, and Use of Spec

**Digital Equity** Inclusion

<b>Principle</b>	Recommendation
ctive, d Innovative trum	FCC and NTIA should enhance expand policies that enable man and technology-driven determin and evolution of spectrum uses
y and	National Spectrum Strategy sho provide assurance that all Amer have access to all generally-use wireless services, regardless of geography, income level, race, sexual orientation, or education







# What is a National Spectrum Strategy? (cont'd)

Example provided by Aspen Institute's Toward a National Spectrum Strategy Report (September 2022)

### Strategic

Global Tech Leadership

Spectrum G

Competitive Marketplace

Policymaking

<b>Principle</b>	Recommendation
nology	Promote U.S. leadership in strat spectrum platform technologies
overnance	Modernize spectrum governance ensure U.S. lead in spectrum po
Wireless e	FCC and DoJ/FTC, should revie wireless competition policy.
g Toolkit	Implement reforms to build capa for ongoing improved spectrum



## **Silicon Flatiron's Spectrum Initiative 2022** Conference

# the Radio Spectrum

- Conference promises to explore:
  - Policy, technical, economic, and social conflicts that arise when multiple interests collide over access to spectrum
  - Methodologies for dealing with allegations of "harmful interference" between competing new and incumbent uses
  - Concerns raised by potentially ineffective domestic and international institutional and governance regimes for making sound spectrum policy decisions

**Resolving Interference Conflicts among "Highest and Best" Uses of** 

## **Questions or Comments?**

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