Comparing Spectrum Valuations Across Multiple Potential Users

Transportation Applications of the Radio Frequency Spectrum
Economics of Transportation and Infrastructure in the 21st Century
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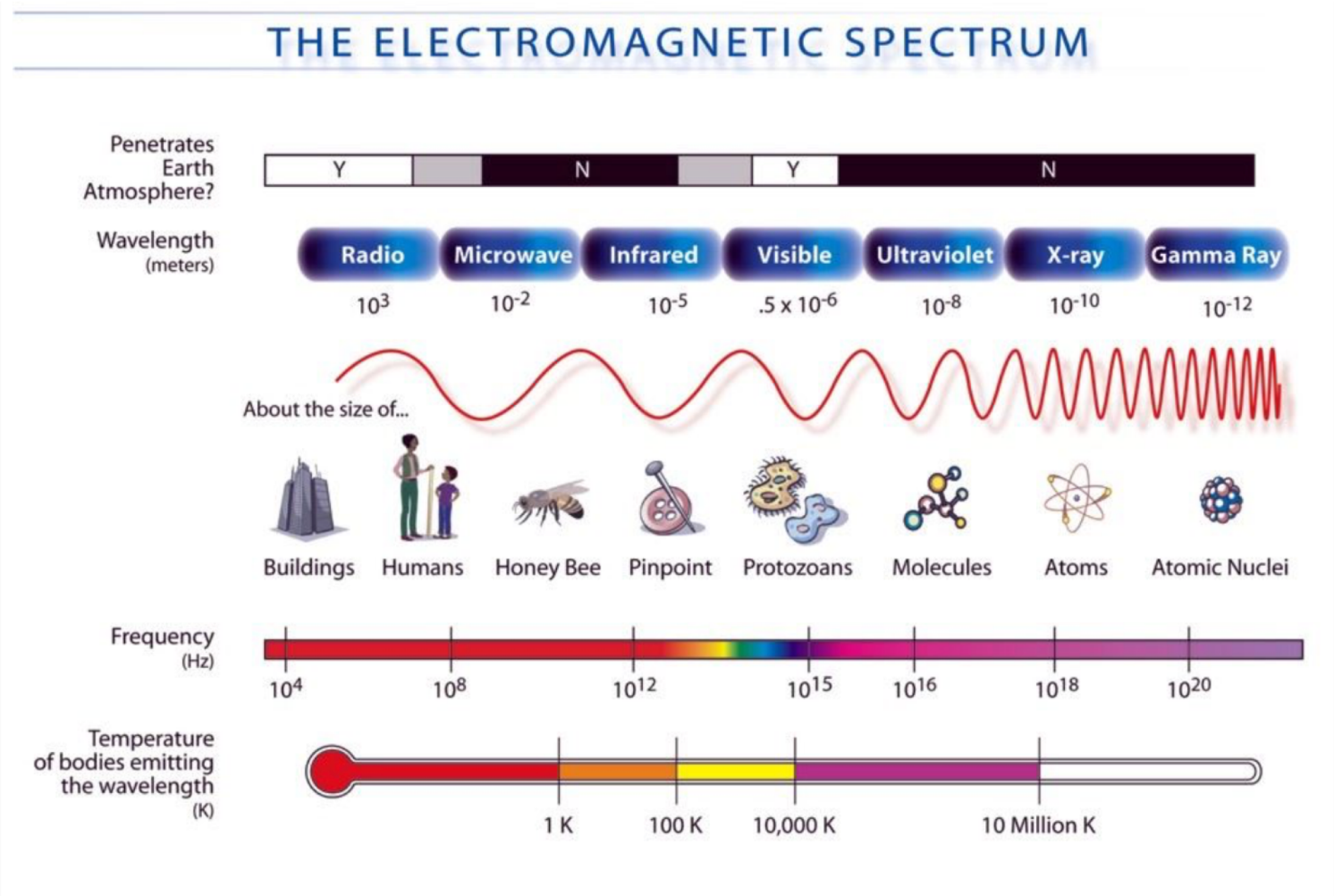
Primer on Spectrum

Electromagnetic Spectrum

range of frequencies of electromagnetic radiation and their respective wavelengths (Hz per one second cycle) and photon energies

- frequency = speed of light/wavelength
  - long wavelengths ⇔ low frequencies
  - short wavelengths ⇔ high frequencies
- Energy increases proportionately with frequency
- Different propagation based on frequency and signal power
  - Higher Frequencies: ↑ data rate but ↓ distance covered



Source: https://byjus.com/physics/electromagnetic-spectrum-microwave/

Primer on Radio Spectrum:
3 Hz to 3000 GHz

NTIA

Federal Government's use

≈ 43% of "high value" frequencies (225 to 3700 MHz)

FCC

Non-Federal use

Majority Licensed to single entities (Cellular holds most)

Traditionally

Use: broadcasting, cellular communication, mobile broadband (BB), fixed wireless BB, satellite...

Exponential growth of demand

Allocation:

primarily single license by freq. & geo.

can lease or resell licenses

fairly static

Highest Valuations: < 2 GHz

Current Evolution

Use: Continued growth of data traffic

- because of mobile BB: esp. video
- ↑ variety of uses of spectrum for new activities (using 5G & other):

  real-time control/automation, AI, IoT, smart cities, smart supply chains, autonomous cars, telehealth, etc.

Allocation:

- ↑ Ability to use higher frequency spectrum
- ↑ Ability to share spectrum (hoping to develop extremely dynamic spectrum sharing)

Spectrum is an increasingly valuable input for transportation and infrastructure.

Increased Ability to Use Higher Frequency Spectrum

Now consider 3 Key Frequency Ranges

Low: < 1 GHz	good coverage, works in urban, suburban, and rural
Mid: 1 – 6 GHz	good mix of coverage and capacity/speed (upcoming CBRS and C-Band auctions)
High: > 6 GHz	millimeter wave, ultra-high capacity/speed, lower coverage

Ex: Spectrum Frontiers Auctions (101, 102, 103) of Upper Microwave Flexible Use Service Licenses

- 28 GHz (Jan 2019)
  - Gross Bids ≈ $702 million
  - Two 425 MHz blocks, county-based, 2965 licenses sold
  - Top 3 winners by expense: Verizon (72%), US Cellular, T-Mobile
- 24 GHz (May 2019)
  - Gross Bids ≈ $2 billion
  - Seven 100 MHz blocks, PEA, 2904 licenses sold,
  - Top 3 winners: AT&T (49%), T-Mobile (40%), US Cellular (6.3%)
- Upper 37 GHz, 39 GHz and 47 GHz (March 2020)
  - Gross Bids ≈ $7.6 billion, Note: Incentive Payments ≈ $3.1 billion

Increased Ability to Share Spectrum

Importance

- Spectrum is finite
- Few "Green Fields" of unused/unencumbered usable frequencies
- Reallocation slowed by current use and license holders

Technological progress improving ability to share spectrum

- where (geographic sharing)
- when (time)
- how (process) prioritized or not, static or dynamic (day, hour, minute, second, or millisecond)

CBRS Auction 3.5 GHz Band (July 2020)

move from federal use to 3 tiered managed access using Spectrum Access System (SAS)

reallocates resources on daily basis

Priority - Incumbents (mainly Fed)

Secondary - Priority Access Licenses (PALs) will be auctioned (70 MHz, using 100 of total 150MHz)

Tertiary - Generalized Authorized Access (GAA) – licensed but not protected

Difficulty of Predicting the Future

Current valuations (both by frequency and use) don't tell us what future relative valuations will be.

- Most valuation estimates from auctioned or resold licenses
- Quickly evolving technology
  - increases range of frequencies that are economically viable for commercial use
  - changes the relative value of different frequency ranges
  - changes the ability for multiple use and users of same frequency bands through spectrum sharing

Valuation Estimates from Auctioned Licenses

Ideally, a well-designed auction

- identifies the entity able to make the best economic use of a given license and
- reveals a lower bound to the winner's true valuation of the license

  (Incentive Auction theoretically revealed true valuations)

But, the revealed lower bound valuation of the spectrum is heavily influenced *by the rules of the auction itself*.

Beyond intrinsic value considerations (frequency and location-urban/rural, topography, mkt demand), auction rules impact

- the types of entities potentially interested in the license
- as well as their relative valuations of the spectrum being licensed

Key auction rules:

bandwidth, size of geographical area, license duration and renewal expectations, power and interference rules, single or shared use, secondary market rules

Moreover, preferential treatments impact

- winning bids => shading of true valuation of spectrum due to decreased auction competition
- and likely the allocation of license to entity with highest true valuation
- Cellular Licenses from 1997 – 2015:

  47% won by designated entities (42% bid credits, 5% set-asides, 10% both) = 27% of real dollar value (Connolly et al., 2018)

Moving Forward without a Crystal Ball

FCC must consider

- Relative use of licensed vs. unlicensed vs. hybrid
- Advances in dynamic spectrum access
- Building in future ability to repurpose spectrum
  - use or lose
  - spectrum fees (in cases of unauctioned licenses)
  - reverse auctions (esp. in cases of unauctioned licenses)
    TV Broadcast- 600 MHz, C-Band (Satellite- 3.7-4 GHz)
  - introduce sharing with prioritization or interference protection,
  - anticipated reauctioning rather than presumed renewal (Milgrom)

NTIA/Gov't

- Spectrum usage fees for Federal Government (suggested by GAO)
- Increased Sharing with Prioritization