

Public Safety in the Spectrum Squeeze

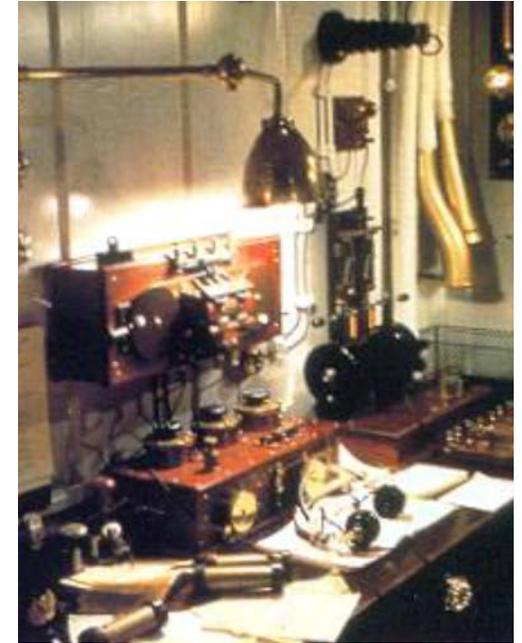
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Introduction

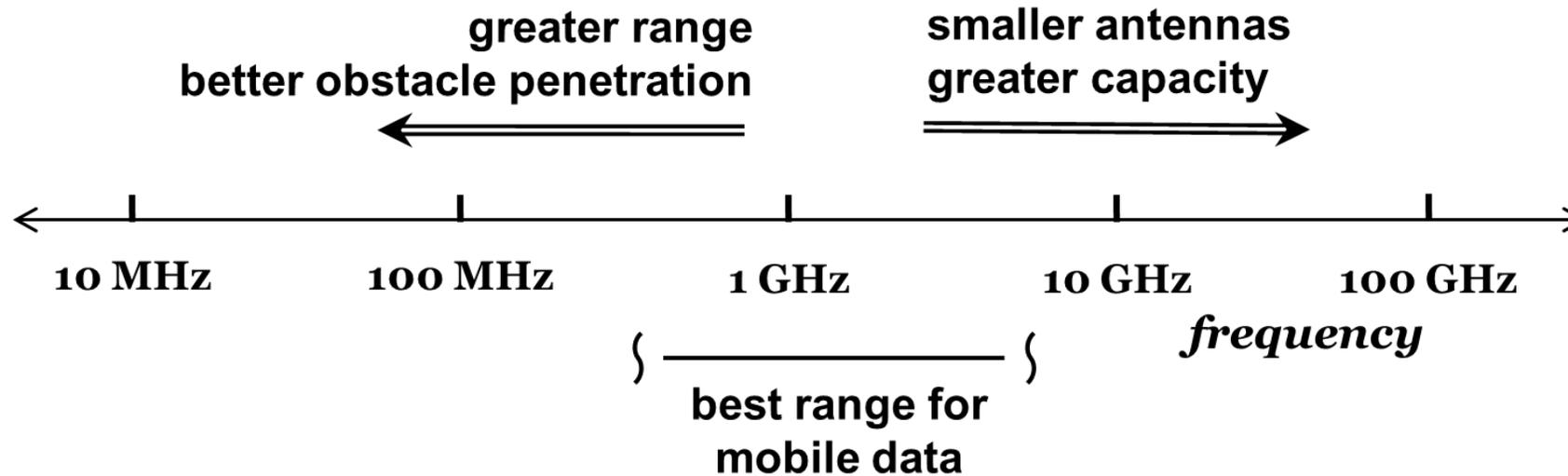
- ✦ Radio has served public safety needs from the beginning
 - first application: to and from ships at sea
 - SOS from *Titanic* saved 700+ lives
- ✦ FCC has traditionally given safety communications very strong interference protection
- ✦ But as needed spectrum becomes scarce, safety becomes one consideration among many.



**Radio Room on
the *Titanic***

Managing the Spectrum Squeeze

Spectrum Squeeze for Mobile Data



- ✦ Sweet spot for mobile data: a few hundred MHz to a few GHz
- ✦ Limited range subject to large, fast-growing demand
 - needed for phones, tablets, laptops, smart speakers, Internet-of-things, smart appliances, commercial / industrial gear, much more
 - needed for both licensed (4G, 5G) and unlicensed (Wi-Fi, etc.)

Best Mobile Spectrum is Fully Occupied

- ✦ ... and has been fully occupied for decades
 - used by dozens of services
 - many allocations long precede uses for mobile data
- ✦ Ongoing task for the FCC is repurposing this spectrum.

Adding New Users to Occupied Spectrum

1. Adding a licensed service (4G, 5G):
 - a) FCC clears incumbent users from range of frequencies
 - repacks incumbents into other frequencies
 - b) FCC auctions off freed-up spectrum to providers of new service
 - protects nearby bands against interference from new service
2. Adding an unlicensed service (Wi-Fi, etc.):
 - FCC overlays newcomers onto same frequencies as incumbents
 - usually at lower power
 - protects incumbents against interference from new service.

Spoiler Alert

- ✦ Two case studies – both raise safety issues:
 1. Wi-Fi added to 5.92–7.125 GHz
 - threatens interference to fixed microwave, carries safety-critical services
 2. 5G added to 3.7–3.98 GHz
 - threatens interference to radar altimeters at 4.2–4.4 GHz, essential to aviation safety.

In Typical Spectrum Proceedings ...

- ✦ Newcomer and incumbent both claim high public interest
- ✦ Both sides present detailed technical studies:
 - newcomer shows it will not cause interference to the incumbent
 - incumbent shows newcomer will cause devastating interference.

Why Different Interference Predictions?

- ✦ Both sides use similar analyses
 - often use similar interference criteria
- ✦ But disagree on assumptions about:
 - newcomer's transmitter characteristics
 - incumbents' receiver characteristics
 - geometries, distances, propagation between the two
- ✦ Different assumptions can produce very different predictions.

Hardware Tests

- ✦ Sometimes a party, the FCC, NTIA, etc. conducts lab tests and/or field studies to assess interference
 - these rarely settle anything
- ✦ Parties typically disagree on:
 - whether test set-up is realistic
 - whether measurements are taken correctly
 - whether data are analyzed correctly
 - what results imply for real-world operations
- ✦ Record may contain multiple tests, some showing interference and some not.

Note on Receivers

- ✦ For transmitters: FCC rules set limits on out-of-band emissions
- ✦ For receivers: no limits on out-of-band reception (w/ a few exceptions)
 - wide passbands make receivers more susceptible to interference
 - better selectivity adds cost, can impair performance
 - manufacturers design receivers for their expected environments
 - may be vulnerable to later-arriving new service in nearby band
- ✦ Newcomers often blame interference on incumbents' receivers
 - but must avoid interference into existing receivers as they are
- ✦ FCC recently issued a Notice of Inquiry on receiver standards¹
 - similar NOI in 2003;² no action resulted.

1. FCC 22-29, 87 FR 29248
2. 18 FCC Rcd 6039

Case Studies

Wi-Fi in 6 GHz Fixed Service Band

- ✦ Frequencies: 5.925–7.125 GHz
- ✦ Incumbent: microwave fixed service (FS)
- ✦ Carries safety-critical information:
 - coordinates railroad trains, controls oil and gas pipelines, balances electric grid, manages water utilities, backhauls 911 calls.

Disclosure: The speaker represented the fixed microwave industry in this proceeding.



photo: George Kizer

Wi-Fi in 6 GHz FS Band – 2

- ✦ **Newcomer: unlicensed, uncontrolled, indoor-only Wi-Fi at 30 dBm EIRP**
 - **will not consider here:**
 - indoor/outdoor at 5.150–5.250, 5.725–5.850 GHz, 36 dBm EIRP with automatic frequency control (coming soon)
 - uncontrolled outdoor at 14 dBm EIRP (pending at the FCC).



6 GHz Wi-Fi router

Wi-Fi in 6 GHz FS Band – 3

- ✦ Most indoor Wi-Fi devices will not cause interference to FS
 - will be outside FS main beams, on unused frequencies, shielded by building walls, terrain, ground clutter, etc.
- ✦ Concern is for small fraction of devices on frequency in use, in main beam, with line-of-sight to microwave receive antenna
 - Wi-Fi interests project 958,062,017 Wi-Fi devices
 - among ~100,000 6 GHz FS receivers
 - small fraction of devices: large numbers of interference cases
- ✦ Conflicting studies:
 - Wi-Fi interests predict insignificant chance of interference
 - FS interests predict statistically certain interference.

Wi-Fi in 6 GHz FS Band – 4

✦ Why analyses gave different results:

	FS Interests (worst case)	Wi-Fi Interests (average case)
Wi-Fi Power (EIRP)	30 dBm	6 dBm (multiply by 0.4% duty cycle)
Building Attenuation	zero (device near plain glass window)	weighted average of common building materials
Path Loss	free space	WINNER II (buildings, ground clutter, etc.)
FS Fade Margin	(protected)	(available to absorb interference)
[several others]		

Wi-Fi in 6 GHz FS Band – 5

- ✦ Record before Commissioners predicted:
 - Wi-Fi interests showed average devices would not cause interference
 - FS interests showed worst-case devices would cause interference
- ✦ Both are likely true
- ✦ Record is confusing because differing assumptions not always clearly stated
 - *e.g.*, Wi-Fi interests argued worst cases would be rare without using all worst-case assumptions.

5G in Lower C-Band

- ✦ Incumbent: radar altimeters at 4.2–4.4 GHz
 - sends radar beam toward ground, measures time for return:

$$\text{altitude (feet)} \cong \frac{\text{return time (nsec)}}{2}$$

- ✦ Newcomer: 5G at 3.70–3.98 GHz
 - auctioned for \$81 billion
 - plus \$13 billion (estimated) to relocate satellite downlinks
- ✦ No frequency overlap: separated by 220 MHz.



5G in Lower C-Band – 2

✦ Interference threat due to overlap between:

- 5G out-of-band emissions
- altimeter out-of-band reception

✦ Disagreement on interference:

- aviation interests claim possibility of “[c]atastrophic impact with the ground, leading to multiple fatalities”¹
- 5G interests claim “[no] credible evidence that 5G deployments in the C-band will adversely affect radio altimeters ...”²

1. RTCA, Inc. in Docket No. 18-122, Annex B at 5 (Oct. 20, 2020)

2. Verizon in Docket No. 18-122 at 2 (Nov. 24, 2021)

5G in Lower C-Band – 3

✦ Why analyses gave different results:

	Aviation Interests (worst case)	5G Interests (average case)
5G out-of-band emissions	high	low
Altimeter off-channel reception	high	typical
Aircraft attitude	pitch and roll	level
Reflectivity of the ground	low (foliage)	high (runway)
	[others]	

✦ Again, highly contradictory predictions in the record.

Nature of Interference Predictions

- ✦ Studies and tests do not predict interference as binary yes / no
- ✦ Instead, show differing probabilities for various degrees of interference
- ✦ Parties often disagree on:
 - whether a given level of interference will happen often enough to matter
 - whether a given level of interference will impair victim receiver
 - whether effect on victim receiver will produce bad outcomes
- ✦ Complex, multi-dimensional maze of conflicting uncertainties
- ✦ Stakes are highest when incumbents predict newcomers' interference will threaten safety.

FCC Decision-Making

FCC Decision-Makers

- ✦ Final decisions on spectrum allocations are made by the five FCC Commissioners
- ✦ Political appointees, nominated by President, confirmed by Senate
 - sensitive to political concerns
- ✦ Four now in office are all lawyers – no technical backgrounds
 - pending nominee is also a lawyer.



Rosenworcel



Carr



Starks



Simington

Considerations in Decision-Making

- ✦ No case of an FCC Commissioner knowingly putting public safety at risk
- ✦ Commissioners can legally reach any result having at least some support in the record
 - ... even if the record more strongly supports an opposite result
- ✦ Commissioners are not well equipped to evaluate complex engineering arguments
 - must rely on FCC engineering staff to resolve competing claims.

FCC Did Not Claim Zero Interference Risk

✦ Approved 6 GHz Wi-Fi:

- “fixed microwave links will have an insignificant chance of experiencing harmful interference from indoor low-power unlicensed operations.”¹
 - FCC need only “reduce[] the possibility of harmful interference to the minimum that the public interest requires”²

✦ Approved 5G at 3.7–3.98 GHz:

- “harmful interference [not] likely [to] result under ... reasonably foreseeable scenarios.”³

1. 35 FCC Rcd 3852 at ¶ 141
2. *Id.* at ¶ 146
3. 35 FCC Rcd 2343 at ¶ 395

Decision Based on Record

- ✦ Record in both the 6 GHz and 5G proceedings showed strong disagreement on how much safety protection is needed
 - record could support wide range of decisions
- ✦ But record showed uncontradicted public interest in expanded Wi-Fi and 5G
 - fully protecting against worst-case interference would severely limit new Wi-Fi and 5G services
- ✦ FCC accepted non-zero safety risks to gain benefits of expanded Wi-Fi and 5G
 - when risk assessments are contradictory, public safety becomes one factor among many.

Conclusion

- ✦ Congress requires the FCC to regulate “in the public interest”
 - the FCC decides how much safety protection the public interest requires
- ✦ Regulation, like engineering, is a sequence of trade-offs
 - FCC balances public safety against other public-interest considerations
 - more likely to tip against safety when engineering studies disagree
- ✦ As demand for spectrum continues to grow, likely to see increasing threats of interference to other safety-critical services.

Thank you!



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Watch for the July 2022 issue of *IEEE Spectrum*:
“How the FCC Settles Radio-Spectrum Turf Wars”