The Case for 4 GHz:

A More Practical Near-Term Path for Wide-Area 5G/6G Capacity Than 7 GHz

July 30, 2026

Rysavy Research

https://www.rysavy.com

Table of Contents

NOTICE 2
SUMMARY 3
BANDS IN QUESTION 3
HISTORY OF HARNESSING HIGHER FREQUENCY BANDS 6
MASSIVE MIMO EVOLUTION 7
INDOOR PENETRATION AND LINE OF SIGHT CONSIDERATIONS 11
OPERATORS ALREADY USING 4 GHZ 11
4 GHZ INCUMBENTS 12
INTERFERENCE TO RADIO ALTIMETERS 12
CONCLUSION 13
ABOUT RYSAVY RESEARCH 13

Notice

Summary

The United States has committed to finding 800 MHz of new spectrum for cellular networks, ideally making 600 MHz available by 2030. The bands currently under study to meet this goal include 2.69–2.9 GHz, 4.4–4.94 GHz, and 7.125–7.4 GHz. Today, mid-band spectrum between 2.5 and 4 GHz already serves as an optimal frequency range for 5G, providing excellent coverage and performance. The key technology enabling 5G mid-band operation today is multiple-input multiple-output (MIMO), typically deployed in a 64T64R configuration. To further exploit these frequencies, the FCC has adopted auction rules for the release of 160 MHz of spectrum in the upper C-Band (3.98–4.2 GHz), applying consistent rules across both upper and lower C-Band.

The primary spectrum options to increase future capacity for 5G and 6G are the 4.4 GHz and 7 GHz bands. Of the two, the 4.4 GHz band will be considerably easier and faster to deploy in the near term. Operators can deploy the 4.4 GHz band using either 64T64R or already available 128T128R massive MIMO, whereas the 7 GHz band would optimally use 256T256R, but commercial products are not yet available. Such products could arrive by 2030, but will have to overcome challenges related to complexity, power consumption, and cost.

Although 7 GHz has the potential of greater spectrum availability in other countries, in the United States it is limited to a maximum of 275 MHz, far less than the maximum of 540 MHz at 4.4 GHz.

4.4 GHz also holds a meaningful propagation advantage over 7 GHz. 4 GHz signals offer significantly better indoor penetration than 7 GHz signals and are less susceptible to blockage. 4-watt user-equipment operation, newly permitted for upper and lower C-Band, will further enhance the near-term utility of this band.

Incumbents already operating in the 4.4 GHz band will require coexistence measures or relocation, a process that will dictate how the band can actually be used and how much spectrum can be operationalized. As explained in this paper, the 4.4 GHz band under study by NTIA will be most effective if allocated at the upper end of the band.

While 4.4 GHz is the stronger near-term choice for quickly expanding 5G capacity, 7 GHz is important longer term for reaching the full 800 MHz that Congress has mandated NTIA identify for commercial use.

This report discusses the bands under study, the history of selected bands, the role and evolution of massive MIMO technology, the relative merits of the 4.4 GHz and 7 GHz bands, 4.4 GHz incumbents, and radio altimeter interference. Parts of this report are tutorial in nature.

Bands in Question

The One Big Beautiful Bill Act (OBBBA), officially Public Law 119-21, was signed into law on July 4, 2025. The bill mandated 800 MHz of new spectrum be made available for cellular operation. A subsequent

Presidential Memorandum released December 19, 2025, titled *Winning the 6G Race*,[1] provided additional guidance, including studies of the 2.69–2.9 GHz, 4.4–4.94 GHz, and 7.125–7.4 GHz bands.

In response to OBBBA, the FCC issued a Notice of Proposed Rulemaking (NPRM)[2] to make upper C-Band spectrum available for terrestrial wireless flexible use and has since adopted auction rules for the release of 160 MHz of spectrum in the upper C-Band.

The 6G vision, as articulated in IMT-2030, calls for peak data rates as high as 200 Gbps.[3] Meeting 6G requirements could require radio channels as wide as 400 MHz.[4]

Given the need for such wide radio channels, the key candidate bands in the United States are the upper 4 GHz and lower 7 GHz bands. In other parts of the world, the upper half of the 6 GHz band and the 7.125–8.4 GHz band are being considered for 6G, potentially providing regulators with far more spectrum to license for 6G than is possible in the United States. In the United States, the entire 6 GHz band (5.925–7.125 GHz) has been assigned for unlicensed operation. In addition, the OBBBA specifically excluded 7.4–8.4 GHz for national security reasons.

The ITU World Radiocommunication Conference 2027 to be held in Shanghai, China, from October 18 to November 12, 2027, will, as part of Agenda Item 1.7,[5] finalize recommendations for 6G bands, with global harmonization a primary goal. The bands that WRC-27 will address are 4.4–4.8 GHz,[6] 7.125–8.4 GHz, and 14.8–15.35 GHz. These bands partially overlap with those being studied in the United States, as summarized in Table 1.

---

[1] The White House, "Winning the 6G Race," Dec. 19, 2025. https://www.whitehouse.gov/presidential-actions/2025/12/national-security-presidential-memorandum-nspm-8-0bda/.

[2] FCC, "FCC Proposes Upper C-Band Rules for 2027 Auction," Nov. 21, 2025. https://www.fcc.gov/document/fcc-proposes-upper-c-band-rules-2027-auction-0.

[3] International Telecommunication Union (ITU), *M.2160: Framework and overall objectives of the future development of IMT for 2030 and beyond,* Nov. 2023. https://www.itu.int/rec/R-REC-M.2160-0-202311-I/en. See also 5G Americas, *ITS'U IMT-2030 Vision: Navigating Towards 6G in the Americas*, Sep. 2024. https://www.5gamericas.org/wp-content/uploads/2024/08/ITUs-IMT-2030-Vision_Id.pdf.

[4] Qualcomm presentation, "From Spectrum to Edge Intelligence: Engineering 6G for Efficiency, Sensing, and AI," Apr. 2026. https://lr-resources.lightreading.com/free/w_advr59/?p=w_advr59.

[5] Transfinite Systems, "WRC 2027 Agenda Items for WP 3M." https://www.transfinite.com/content/wrc2027wp7.

[6] The 4.8–4.99 GHz band was studied at WRC 23.

Table 1: Summary of United States Band Studies Versus ITU WRC Studies

Band	United States	ITU WRC
2.69–2.9 GHz	2.69–2.9 GHz study	Not part of WRC
3.98–4.2 GHz	Current NPRM with 160 MHz to be licensed in 2027.	Not part of WRC
4.4–4.94 GHz	4.4–4.94 GHz study	WRC 27 studying 4.4–4.8 GHz 4.8–4.99 GHz studied at WRC 23
6.425–7.025 GHz	Unlicensed operation	WRC 23 identified this band for 5G
7.125-8.4 GHz	7.125–7.4 GHz study with 7.4–8.4 GHz excluded for security reasons	WRC 27 studying 7.125–8.4 GHz
14.8–15.35 GHz	Not being studied	WRC 27 studying 14.8–15.35 GHz

The 4.4 GHz band has one huge advantage: it is much closer in frequency to the current U.S. C-Band allocation of 3.7–3.98 GHz. Moreover, with the FCC NPRM targeting 3.98–4.2 GHz, the proposed 4.4–4.94 GHz band is even closer in frequency. Taking advantage of this spectrum requires a much smaller technological leap than operating at 7 GHz, as discussed in detail below.

Another advantage is that much more spectrum is potentially available at 4.4 GHz in the United States. 7 GHz has the potential of greater spectrum availability in other countries, but in the United States it is limited to a maximum of 275 MHz, far less than the maximum of 540 MHz at 4.4 GHz.

Beyond technical feasibility, other entities are currently using all the discussed bands. Therefore, coexisting with or relocating incumbent users will also be major considerations in determining both how these bands are used and what portions of them can be licensed.

History of Harnessing Higher Frequency Bands

Not long ago, people called sub-1 GHz "beachfront spectrum."[7] Since then, advanced radio technology has made higher frequencies much more desirable. With 5G, 2.5–4 GHz has emerged as the sweet spot for enabling both wide-area coverage and practical deployment.

But making this frequency range practical took a long time. Sprint had licenses for large amounts of 2.5 GHz spectrum dating back to 2005 but could never fully take advantage of it. It was only after T-Mobile's acquisition of Sprint in 2020 and the roll-out of 5G that 2.5 GHz spectrum finally was put into widespread use—fifteen years later.[8]

The technological innovation that finally made 2.5 GHz and C-Band spectrum practical was massive MIMO. With massive MIMO, antenna panels with multiple antenna elements can focus radio beams to overcome the inherent reduction in coverage that occurs at higher frequencies. Massive MIMO not only improves coverage but also increases spectral efficiency by using multiple simultaneous beams.

Massive MIMO enabled operators to deploy higher frequencies in much of their coverage area using their existing cellular base station footprint. Lower frequencies, such as 600 MHz and 700 MHz, continued to provide the coverage layer, particularly in less-dense areas with larger cells.

Beginning in 2019, the United States licensed multiple gigahertz of spectrum in mmWave bands, including 24 GHz, 28 GHz, 37 GHz, 39 GHz, and 47 GHz. The higher frequencies have poorer propagation than mid-band frequencies and almost no indoor penetration. As such, although these mmWave bands constitute far more spectrum than in mid-band frequencies, they are not widely used. Over time, technology will likely evolve to enable far greater use of mmWave bands, but in the meantime, regulators and industry stakeholders remain focused on lower frequencies.

Table 2 summarizes when different bands became available in the United States and when they were or will be fully exploited.

---

[7] Peter Rysavy/GigaOM, "Learn how technology will turn less desirable airwaves into 'beachfront' spectrum," Jun. 28, 2013. https://rysavy.com/wp-content/uploads/2026/06/2013-gigaom-beachfront-spectrum.pdf.

[8] Clearwire, beginning in 2008, used this spectrum for its WiMAX network beginning in 2008, but only for a limited time and with limited coverage.

Table 2: Bands and When Fully Exploited

Band	Available for Use	Fully Exploited
2.5 GHz	2005	2020
mmWave	2019	Not yet
3.7–3.98 GHz (C-Band)	2021	Almost immediately
3.98–4.14 GHz (Upper C-Band)	2027	No delay expected
4.4 GHz	TBD	No delay expected
7 and 15 GHz	TBD	Technology not yet available for widespread commercial deployment but possibly available for 7 GHz by 2030

Massive MIMO Evolution

With massive MIMO, the greater the number of antenna elements and radio transmitters and receivers, the higher the system performance, including channel diversity and spectral efficiency. Higher-order MIMO also enables narrower radio beams that can mitigate path loss at higher frequencies. However, more radios and more antenna elements translate into higher power consumption, higher complexity, and higher cost.

Today, the most common base station antenna configuration is 64T64R, meaning 64 transmit radios and 64 receive radios, for a total of 64 transceivers. These radios typically connect to 192 physical antenna elements arranged in a grid of 12 rows and 8 columns of “X” patches, each containing a cross-polarized pair of elements oriented at +45 degrees and −45 degrees. Polarization addresses the situation that a user device might be oriented at any angle, allowing one polarization or the other to provide a stronger connection.

32 transceivers drive the +45-degree subarrays, each consisting of three antenna elements, and 32 transceivers drive the −45-degree antenna subarrays. Although one transceiver drives three antenna elements, the system applies different transmission delays to each antenna element in a process called phase shifting, which steers the transmitted beam in a technique known as beamforming. Figure 1 shows a 64T64R antenna array with 192 antenna elements.

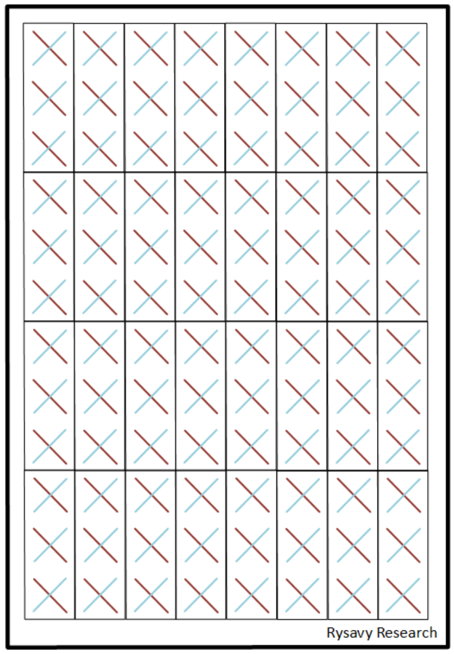

Figure 1: 64T64R Antenna Array with 192 Antenna Elements

The purpose of this explanation is to illustrate how sophisticated antenna technology has become and how it will need to evolve support operation at higher frequencies. Depending on the deployment situation, such as site density and urban versus rural, operators also use 32T32R and 16T16R massive MIMO configurations, but these operate at lower capacity and deliver lower throughputs to users.

A beneficial property of massive MIMO antenna systems is that higher frequencies demand more focused beams to overcome propagation losses. These narrower beams require more antenna elements. However, because higher frequencies correspond to shorter wavelengths and antenna element spacing is proportional to wavelength, higher-order MIMO antennas operating at higher frequencies need not be any larger than those operating at lower frequencies, as illustrated in Figure 2. A 256T256R antenna panel with 1,024 elements at 7 GHz can be the same size as a 64T64R panel with 192 elements at 3 GHz.

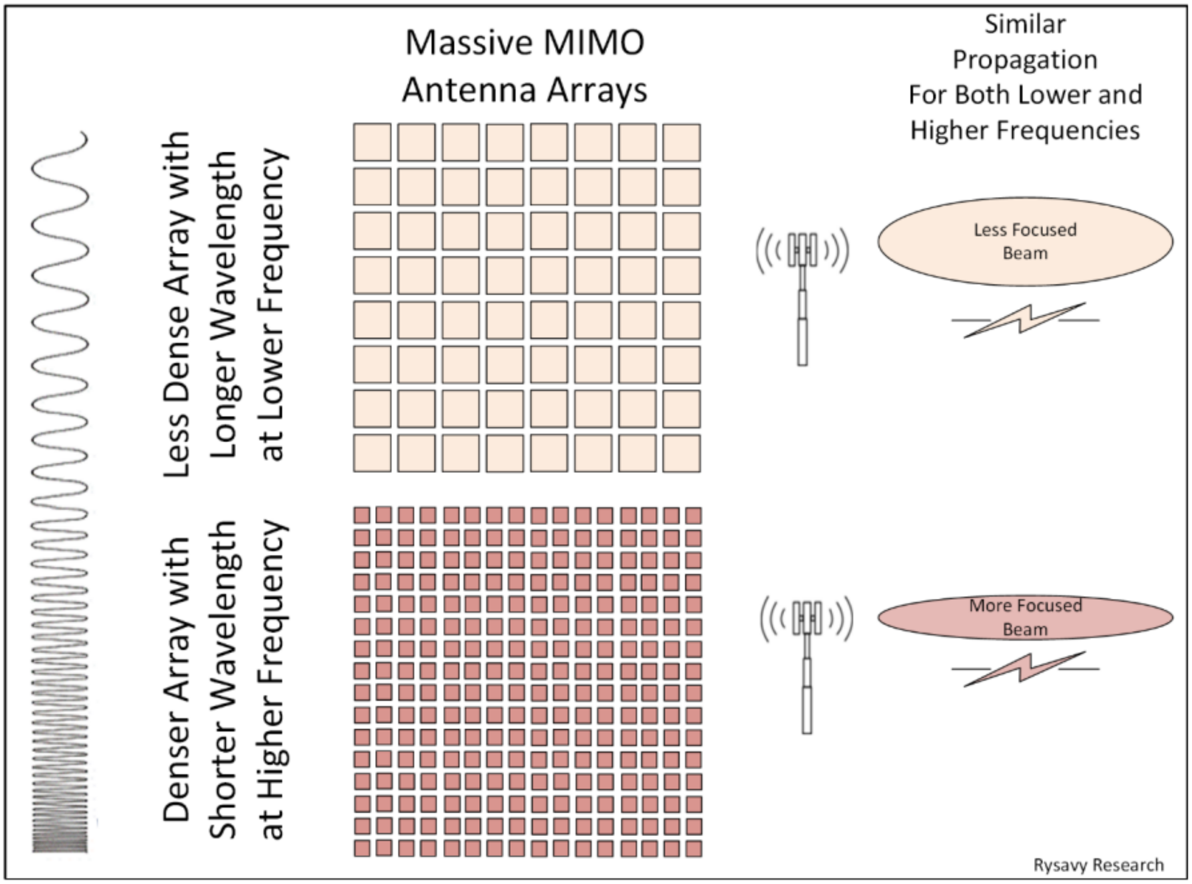

Figure 2: Higher-Order MIMO Compensation for Poorer Propagation

64T64R is the workhorse of today's 5G systems operating in the 2.5 GHz band and C-Band. It will also support operation in the forthcoming upper C-Band allocation of 3.98–4.14 GHz.

As for the 4.4–4.94 GHz band, radio-access network (RAN) vendors indicated the need to use either 64T64R or 128T128R. Vendors already have 128T128R products, which makes this band highly attractive from a technological perspective. One RAN vendor indicated that its next-generation C-Band product will employ a 128T128R configuration, increasing capacity relative to 64T64R systems.

7 GHz, however, is a different story. RAN vendors privately indicated the need to use up to 256T256R antenna arrays, with some citing 1,024 antenna elements. For 6G, the 3rd Generation Partnership Project (3GPP) is evaluating antenna configurations ranging from 768 to 2048 antenna elements. Public information corroborates the need for this higher level of MIMO, which some refer to as giga MIMO and

others as extreme MIMO.[9] In some scenarios, 128T128R could be sufficient for 7 GHz. A 128T128R system with either 384 or 768 antenna elements would operate at lower spectral efficiency than a 256T256R system with 1,024 antennas, as would a 64T64R system, although such lower-order MIMO configurations could be used in some deployment scenarios. To overcome inherent path loss of 7 GHz compared to C-Band, operators will need to use up to 256T256R if deploying over a C-Band 64T64R cellular footprint. Failing to do so could result in incomplete coverage and would not deliver the throughput performance and capacity intended for 6G.

Based on both theory and field trials, these higher levels of MIMO could enable the deployment of 7 GHz systems on a 3 GHz footprint, without the need to densify networks.

In contrast to 64T64R and 128T128R, 256T256R products are still in field trials. Given that these trials are occurring now, practical commercial products could be available by the time 6G is ready for deployment around 2030, assuming 7 GHz spectrum is available. However, it is not certain. Vendors will have to address serious challenges of computational complexity, power consumption, and cost. A cautionary example is the limited use of mmWave networks.

One vendor stated that its mmWave base station systems already use 1,024 antenna elements to support advanced beamforming, showing how the industry is progressing toward more advanced antenna systems.

256T256R networks could increase spectral efficiency by a factor of two or more compared to 64T64R systems.[10] Spectral efficiency at higher frequencies can also be increased by using more antennas in the user device. The typical maximum number of receive antennas in the user device could increase from four

[9] See Samsung Research, "Upper Mid-Band Spectrum for 6G: Opportunities and Key Enablers," Aug. 2024. https://research.samsung.com/blog/Upper-Mid-Band-Spectrum-for-6G-Opportunities-and-Key-Enablers. See also, Seunghyun Lee, Jungmin Yoon, Sangwon Jung, Younghan Nam, Gary Xu, Chan-Byoung Chae, Juho Lee, Jianzhong Zhang, "Extreme-MIMO Field Trials in 7 GHz Band: Unlocking the Potential of New Spectrum for 6G," Mar. 2026. https://www.microsoft.com/en-us/research/publication/extreme-mimo-field-trials-in-7-ghz-band-unlocking-the-potential-of-new-spectrum-for-6g/. See also Qualcomm presentation, "From Spectrum to Edge Intelligence: Engineering 6G for Efficiency, Sensing, and AI," Apr. 2026. https://lr-resources.lightreading.com/free/w_advr59/?p=w_advr59.

[10] Samsung Research, "Upper Mid-Band Spectrum for 6G: Opportunities and Key Enablers," Aug. 2024. https://research.samsung.com/blog/Upper-Mid-Band-Spectrum-for-6G-Opportunities-and-Key-Enablers. Also stated by a vendor in private communications.

at C-Band frequencies to eight at 7 GHz.[11] Coupled with wide radio channels, these networks could offer high capacity and performance depending on the amount of available spectrum.

But as explained above, the United States has only a limited amount of spectrum available at 7 GHz. Moreover, the assumption that finer beamforming resolution with larger MIMO yields better performance is contingent on high channel estimation precision, as well as the channel propagation characteristics being favorable for spatial multiplexing. Further verification is needed on whether these conditions are met in practice with 7 GHz spectrum. Additionally, signal blockage at the user equipment, such as hand grip, may be more severe at 7 GHz compared to 4 GHz.

Indoor Penetration and Line of Sight Considerations

4 GHz signals will have significantly better indoor penetration than 7 GHz signals, and 7 GHz signals will be more susceptible to blockage. In urban environments, 4 GHz signals can reach users without a direct line of sight through diffracted propagation paths, such as around buildings. In contrast, 7 GHz signals will not diffract as effectively; they will need to reach non-line-of-sight users through reflected propagation paths, if available, requiring more complex management of the radio environment.

Lower and upper C-Band technical rules allow higher user equipment transmit power of up to 4 watts, compared to typical 1-watt levels of lower frequency bands.[12] This higher permitted power can offset the additional propagation loss at the higher 4.4 GHz frequencies and further supports the feasibility of mobile operation in the band.

Operators Already Using 4 GHz

A proof of concept for operation in the 4 GHz band is that NTT DoCoMo in Japan operates its 5G network in the 4.5–4.6 GHz band. According to one source, the network uses 64T64R massive MIMO.[13] KDDI in

[11] Seunghyun Lee, Jungmin Yoon, Sangwon Jung, Younghan Nam, Gary Xu, Chan-Byoung Chae, Juho Lee, Jianzhong Zhang, “Extreme-MIMO Field Trials in 7 GHz Band: Unlocking the Potential of New Spectrum for 6G,” Mar. 2026. https://www.microsoft.com/en-us/research/publication/extreme-mimo-field-trials-in-7-ghz-band-unlocking-the-potential-of-new-spectrum-for-6g/.

[12] FCC. *Upper C-band (3.98–4.2 GHz); Expanding Flexible Use of the 3.7 to 4.2 GHz Band,* Jul. 2026. https://docs.fcc.gov/public/attachments/DOC-422738A1.pdf. See paragraph 72.

[13] CafeTel, “5G NR PHY for NTT DoCoMo Engineers — n78, n79, mmWave (n257),” https://www.cafetele.com/5g-nr-for-ntt-docomo-engineers/.

Japan operates its 5G network in the 4.0–4.1 GHz band.[14] Commercial operation by these operators at 4 GHz suggests that operation in the 4.4–4.94 GHz band will not be problematic.

4 GHz Incumbents

Assessing the difficulty of coexistence with, or reassignment of, federal incumbents in the 4.4 GHz band is beyond the scope of this report. However, this issue could be a major factor in determining how much of the 4.4–4.94 GHz band can be made available for cellular use and under what conditions. But of all the bands under study, this band offers the potential for the largest block sizes. The amount made available will significantly determine the utility of the band.

The band is allocated mainly for federal use, including by the Department of Defense. Uses of the band include tactical military communications, point-to-point microwave links, telemetry, and other government operations.[15]

Non-federal uses include radio astronomy, which can be affected by interference.[16]

To maximize the utility of the band for commercial mobile broadband, the maximum possible amount of the band should be made available. Additionally, any repacking or relocation of 4 GHz incumbents should be concentrated at the lower end of the 4.4–4.94 GHz band.

Interference to Radio Altimeters

Radio altimeters operate in the 4.2–4.4 GHz band, immediately adjacent to the 4.4–4.94 GHz band under study. Fortunately, the altimeter retrofits being planned as part of the FAA/FCC effort addressing upper C-Band (3.98–4.2 GHz) operations will protect altimeters from interference caused by cellular operations above 4.4 GHz. Such operations, however, will require a guard band between 4.2 GHz and the frequencies licensed for cellular operation.

---

[14] Qualcomm, "Global 5G spectrum update," Jun. 2020. https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/20200625_mipi_-_5g_spectrum_-_dean_brenner_4.pdf.

[15] Hogan Lovells, "America's New Commercial Spectrum Pipeline (Part 1)," Oct. 2025. https://www.hoganlovells.com/en/publications/americas-new-commercial-spectrum-pipeline-part-1. See also Amir Hossein Fahim Raouf, İsmail Güvenç, "Multi-Year Spectral Structure of 6G Candidate Bands at 2.7 GHz and 4.4 GHz," Mar. 2026. https://arxiv.org/html/2603.15837v1. See also NTIA, "Spectrum.gov." https://www.spectrum.gov/.

[16] National Library of Medicine, "Measurement Campaign of Radio Frequency Interference in a Portion of the C-Band (4–5.8 GHz) for the Sardinia Radio Telescope," Oct. 2024. https://pmc.ncbi.nlm.nih.gov/articles/PMC11479349/.

Conclusion

4.4 GHz is a natural extension of the existing C-Band ecosystem and can leverage the momentum of existing U.S. C-Band developments. It does not require a technology leap and is able to leverage existing network planning assumptions, antenna designs, site grids, and device evolution paths. Overall, 4.4 GHz provides a better balance of capacity and coverage: it can support wide channels needed for 5G-Advanced and 6G capacity while preserving materially better propagation, indoor penetration, diffraction, and mobility performance compared to 7 GHz.

4.4 GHz is deployable on existing macro networks with less densification pressure, whereas 7 GHz will require more aggressive beamforming, tighter link budgets, and potentially greater reliance on reflected paths in non-line-of-sight conditions.

Although the 7 GHz band will become important in the longer term, the 4 GHz band is the practical, lower-risk, nearer-term band for wide-area licensed mobile broadband capacity.

About Rysavy Research

Rysavy Research LLC is a consulting firm specializing in computer networking, wireless technology, and mobile computing since its founding in 1993. Projects include spectrum and capacity analysis, reports on the evolution of wireless technology, network security assessments, strategic consultations, system design, articles and reports, courses and webcasts, network performance measurements, and serving as an expert witness in patent litigation. Peter Rysavy has written more than 200 articles and reports. Clients include more than 100 organizations.

From 2000 to 2016, Peter Rysavy was the executive director of the Wireless Technology Association, an industry organization that evaluated wireless technologies, investigated mobile communications architectures, and promoted wireless data interoperability.

Peter Rysavy graduated with BSEE and MSEE degrees from Stanford University in 1979. More information is available at https://www.rysavy.com.