Response of the mmWave Coalition

To

National Science Foundation's
Request for Information on the National Spectrum Research and Development Plan
(89 FR 12871)

The mmWave Coalition, "mmWC" is pleased to present to NSF these suggestions for future funding areas to support the development of new communications technology above 100 GHz and to support US leadership in this technology. mmWC is a group of innovative companies and universities[1] united in the objective of removing unnecessary regulatory barriers to technologies and using frequencies ranging from 95 GHz to 450 GHz. The Coalition does not limit itself to supporting any particular use or technology but rather it is working to create a regulatory structure for these frequencies that would encompass all technologies and all possible uses, limited only by the constraints of physics, innovation, and the imagination.

The term "subTerahertz" or sub-THz is often used now to describe frequencies between 100 and 300 GHz, an area where there is little present active spectrum use, where

[1] Members of the mmWC are : 2π-LABS GmbH, American Certification Body, Inc., Azbil North America Research and Development, Inc., Brown University, Keysight Technologies, Nokia Corporation, Northeastern University, Nuvotronics, Inc., NXP Semiconductors, NYU WIRELESS, Oklahoma State University, Qualcomm, RaySecur, TCB Council, The University of Arizona, VEGA Americas, Virginia Diodes, Inc., and VUBIQ Networks

the FCC has authorized experimental use since 2019 resulting in products being spawned in such frequencies[2], and where national and international spectrum policies complicate such use due to a high density of passive frequency allocations. ITU Radio Regulation 5.340, which protects many of these bands, begins with a phrase first used for lower frequency allocations in passive bands; "All emissions are prohibited in the following bands:". There are additional passive allocations that are protected by regulatory terms that are somewhat more flexible. National and international spectrum regulations, together, prevent the use of transmitters with bandwidth greater than about 30 GHz, essentially negating the main benefit of operating in such high bands.

Most of the allocations above 100 GHz were made at the ITU's 2000 World Radio Conference, "WRC-2000", as a result of parallel proposals from both the US and European countries represented by CEPT. Both the US and CEPT proposals for multiple passive bands above 100 GHz expressed doubt as to whether the classic, "all emissions are prohibited" terms of 5.340 were necessary at these higher bands, due to the different physics at these high bands with respect to both radio propagation and short wavelengths that enable antenna design options that are impractical at lower bands. WRC-2000 adopted both the new allocations along with Resolution 731, "Res. 731", requesting ITU-R study of the feasibility of sharing passive bands in 71-275 GHz with communications

[2] T. S. Rappaport et al., Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond, IEEE Access, pp 78729 - 78757, May 2019. DOI: 10.1109/ACCESS.2019.2921522 (.https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8732419)

subject to specific quantitative limits of the resulting interference to passive users.[3] This adopted resolution also specifically stated,

> "that, to the extent practicable, the burden of sharing among active and passive services should be equitably distributed among the services to which allocations are made".

Res. 731 has been revised at both WRC-19[4] and WRC-23[5], but the basic provisions considering sharing at 71-275 GHz and for "burden sharing" have never been changed.

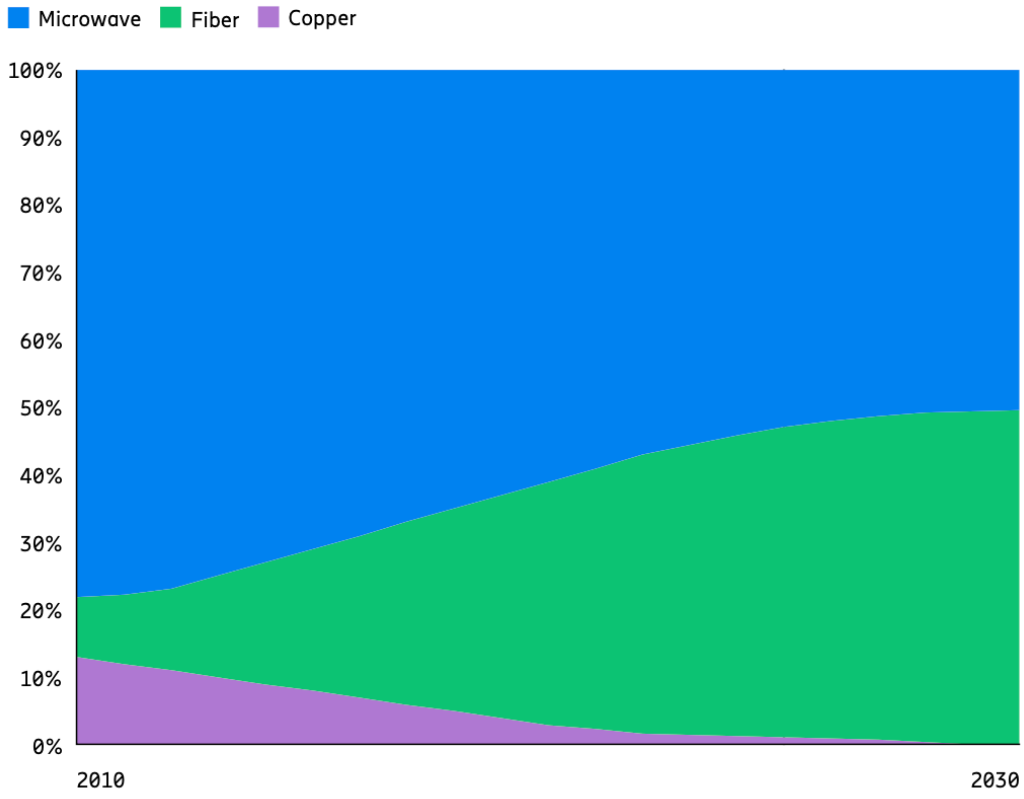
Most of the 5G and 6G spectrum policy discussions to date have focused on lower frequencies. A key reason for this is that it is hard to justify a business case for sub-THZ mobile spectrum use at present as there are now basic technical questions, technological hurdles, and cost issues, yet these are fertile and active areas of research which may eventually lead to compelling opportunities for mobile use in this spectrum. [6] However, 5G and 6G in US policy deliberations addresses **both** fixed and mobile users, and the 5G and 6G mobile uses are dependent on fronthaul and backhaul which are essentially fixed services. While these fixed links are often implemented in non-spectrum fiber optic links, there is a vast, growing need for wireless backhaul, especially in rural, underserved areas often where fixed wireless access is vital for rural households, and often backhaul requirements cannot always be implemented in fiber technology, due to installation

[3] https://www.itu.int/net/ITU-R/conferences/docs/ties/res-731-en.pdf
[4] https://www.itu.int/dms_pub/itu-r/oth/0C/0A/R0C0A00000F00149PDFE.pdf
[5] Res. 731 (Rev. WRC-23) WRC-23 Prov.Fin.Acts p. 412 (https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.15-2023-PDF-E.pdf)
[6] T. Rappaport *et al.*, Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond, *IEEE Access*, June 2019 (https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8732419)

urgency requirements, local terrain features that delay or block installation, cost, or short term requirements that make fiber optic installation uneconomical.

A recent publication[7] by a major equipment manufacturer predicts that backhaul will continue to be implemented in a mix of both spectrum and non-spectrum technology as shown below:

Figure 1: Predicted global backhaul media distribution up until 2030



The growing interest in Fixed Wireless Access[8] as well as growing reliance upon 5G millimeter wave spectrum to support massive data rates in stadiums, concert venues, and

[7] Ericsson Microwave Outlook, 10th Edition, October 2023 (https://www.ericsson.com/en/reports-and-papers/microwave-outlook)

[8] https://newsroom.uscellular.com/uscellular-qualcomm-inseego-launches-5g-mmwave-high-speed-internet-service-in-10-cities/

urban cores by two of the three major US cellular carriers[9] will also increase demand for future mobile users as well as increase the demand for even greater high speed fixed wireless links that cannot be implemented in present allocations below 100 GHz. It is important to note that "killer applications" for 5G have not yet been realized but are being developed and created, and will come to consumers just as has always happened in past generations of cellular technology and expansion of the Internet. Thus, the Fixed Service and Mobile Service needs for wide bandwidths in sub-THz can justify considering mobile and fixed terrestrial technology that will allow sharing with space-based passive satellites under the conditions specified in Res. 731 based solely on the present fixed communication requirements, without waiting for resolution on whether mobile links would be needed. Research and development of technology for terrestrial based mobile and fixed links and devices must be fostered, in light of the viability for sharing with passive bands that meet the limits of Res. 731. All the Fixed and Mobile Service allocations above 100 GHz are now actually coprimary Fixed and Mobile allocations, so both services are entitled to access to the spectrum. NSF should help foster fundamental and eventual commercialization of mobile and fixed terrestrial communications, sensing, antenna technologies, and innovative spectrum management in light of Res. 731.

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https://newsroom.uscellular.com/uscellular-qualcomm-inseego-launches-5g-mmwave-high-speed-internet-service-in-10-cities/

[9] https://www.sdxcentral.com/articles/analysis/verizon-taylor-swifts-swifties-are-the-ultimate-mmwave-use-case/2023/12/
https://www.fiercewireless.com/tech/5g-drives-network-capacity-super-bowl-srg

While sharing passive bands below 71 GHz is very challenging and may be nearly impossible due to many reasons, not limited to congestion of the spectrum, difficulty in controlling mobile and fixed device radiation patterns from existing antenna technology, Res. 731 recognizes there is uncertainty whether such limitations on practical sharing between space-based passive receivers and terrestrial transceivers that is also applicable to 71-275 GHz, where atmospheric absorption has a large impact on radio propagation[10] and where the small wavelengths enable alternative antenna designs that are more focused/directional and are not practical in lower bands. Several possible sharing approaches for this band have been described in the literature[11] and it is likely that further research will contribute fundamental knowledge useful for achieving tremendous capacity and capability advances in terrestrial based networks used by humans and machines on Earth.

Research on sharing the sub-Terahertz spectrum is not only very technically challenging but it also has a high burden of "regulatory risk" for corporations contemplating investment, because such technology cannot be implemented without both national and international regulatory changes that could require 5 to 10 plus years to be approved. As a result, private sector funding in this area has been complicated and substantially limited,

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[10] M. Marcus, X. C. Roman and J. Jornet, "Millimeter-Wave Propagation: Spectrum Management Implications-An Update for >100 GHz [Speaker's Corner]," in *IEEE Microwave Magazine,* vol. *24,* no. 1, pp. 91-94, Jan. 2023, doi: 10.1109/MMM.2022.3211599.
Y. Xing, et. al., Terahertz Wireless Communications: Co-Sharing for Terrestrial and Satellite Systems Above 100 GHz*, IEEE Wireless Communications Letters*, Vol. *25*, No. 10, pp. 3156-3160, Oct. 2021, doi: 10.1109/LCOMM.2021.3088270.

[11] M. Polese *et al*., "Coexistence and Spectrum Sharing Above 100 GHz," in *Proceedings of the IEEE*, vol. *111*, no. 8, pp. 928-954, Aug. 2023, doi: 10.1109/JPROC.2023.3286172

requiring NSF and other government agencies to realize the importance of funding in this area for the long term national competitiveness of the US wireless and integrated circuit industries, as well as the potential benefit of massively broadband wireless networks for US consumers. mmWC urges NSF to make funds available for new initiatives for communications systems that are designed to occupy large contiguous blocks of spectrum in 71-275 GHz while also protecting the allocated passive users in those bands to the levels of interference permitted by Res. 731.

mmWC also suggests that NSF fund collaborations between the communications technology community and the passive scientific communities involved in 71-275 GHz usage in the Radio Astronomy Service and the Earth Exploration-Satellite (passive) Service to explore possible approaches to "burden sharing" involving design tradeoffs in the active and passive systems using overlapping spectrum. For example, one possible sharing approach could be using multiple element antennas for terrestrial communication transmitters that used antenna nulling technology to minimize the effective radiated power towards any passive satellite that is in line of sight as it passes within the radio horizon of the transmitted signals of terrestrial devices.[12] This type of protection would only work if the number of satellites in a specific frequency band visible above the horizon at the transmitter as well as the number of terrestrial transmitters with a given sidelobe attenuation level, are subject to known maximums. Thus, the active and passive technology participants in the study of these options should consider the impact of

[12] Y. Xing*, et. al.,op. cit.*
M. Polese *et al.*, *op. cit.*

requiring operators of passive satellites to coordinate their orbit parameters in ways that have never been done before.

Another important topic for NSF to consider relates to its long-term funding of NASEM's Committee on Radio Frequencies "CORF".[13] The role of CORF is to

> "consider the needs for radio frequency requirements and interference protection for scientific and engineering research, coordinates the views of the U.S. scientists, and acts as a channel for representing the interests of U.S. scientists in the work of the inter-union commission on frequency allocations for radio astronomy and space science (IUCAF) of the International Council of Scientific Unions."

CORF in its analyses, publication, and advocacy before FCC historically has opposed *any* spectrum policy change that might result in *any* increases of interference to passive systems. Thus NSF-funded CORF has never been willing to review spectrum sharing options involving passive spectrum because of its interpretation of the funding it receives from NSF and NASA. While CORF's Statement of Work from the agencies that fund it, including NSF, are not readily available, NASEM representatives have stated that CORF is not funded to consider many spectrum sharing issues and focuses solely on protecting passive users. However, in the case of spectrum in 71-275 GHz this refusal to consider appears inconsistent with the Res. 731 framework that the US originally proposed at WRC-2000 and which has remained intact, despite explicit review and updating of the resolution at two different WRCs.

[13] https://www.nationalacademies.org/our-work/committee-on-radio-frequencies#sectionProjectScope

mmWC urges NSF to include in CORF's future Statement of Work *some* level of consideration of how the sharing goals in Res. 731 can be implemented, subject to the explicit protection levels in that long standing document, as the benefit to US competitiveness, and potential gains by US industry and consumers are at stake.

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