Before the
National Telecommunications and Information Administration
U.S. Department of Commerce

Comments of the mmWave Coalition

Docket No. 181130999-8999-01

Developing a Sustainable Spectrum Strategy for America's Future

SUMMARY

The mmWave Coalition submits these comments to urge NTIA to facilitate greater access to spectrum above 95 GHz for non-Federal use. At present, with minor exceptions, no licensed or unlicensed use of this spectrum is allowed under FCC rules. Since virtually all of this spectrum has Government/Non-Government ("G/NG") shared allocations, NTIA policies are key for access to these bands. Such access is essential for both the international competitiveness of the United States.

The spectrum above 95 GHz is very different than the lower spectrum where many basic concepts of spectrum policy were developed. These technical differences include propagation issues which become much more dependent on directional antennas and adaptive beamforming, and a much higher impact of passive allocations on bands above 95 GHz than in lower bands. In contrast to US NG entities, which are being held back by such policies, many of our foreign economic competitors are actively pursuing use of this spectrum with coordinated government supported R&D and supportive national spectrum policies.

Allowing increased shared use of bands above 95 GHz is consistent with the National Spectrum Strategy, which calls for actions to "(i)ncrease spectrum access for all users, including on a shared basis." Unfortunately, to date, NTIA has not applied this strategy to passive services above 95 GHz, but rather has applied what is essentially a blanket prohibition of commercial sharing in these bands. We urge NTIA to review whether present passive spectrum policy above 95 GHz is compliant with the goals of the Communications Act, the National Spectrum Strategy, and the Department of Commerce that are cited below.

More specifically we request:

- A review of the present total prohibition of all transmitters in the bands above 95 GHz that are enumerated in US Allocation Table footnote US246 and the possible replacement of this prohibition with a performance-based standard derived from ITU-R recommendations to protect critical passive scientific uses of these bands.

• Coordination with the FCC to permit the creation of at least one band above 95 GHz with contiguous bandwidth of 20 GHz or greater for point-to-point communications in situations where fiber optics technology is not practical.

• Specific suggestions for federally funding R&D to explore the feasibility of spectrum sharing with passive services above 95 GHz using technologies that would not be feasible at lower bands and thus were not considered when present policies were adopted.

• A transparent national policy to allow terahertz spectroscopy use for both G and NG users with explicit technical criteria for indoor use and some provision for outdoor use.

• Change NTIA procedures for coordination of FCC experimental licenses to assure that any restrictions on NG experiments to protect EESS allocations be based on the minimum conditions necessary to prevent interference to federal systems at the location and time of the experiment.

• Upgrade NTIA/ITS and NIST analysis, simulation and antenna test facilities to allow sophisticated studies of co-channel and adjacent channel interference for the potential of sharing between terrestrial communications and sensing systems that use very directional adaptive antennas, and space-based systems, as well as measurement sidelobe patterns above 95 GHz to allow confirmation of whether evolving commercial technologies achieve adequate suppression to permit sharing with satellite-based sensors in these bands.

The next two proposals are more long term in nature, but we believe attention to them will yield substantial economic benefits for the international competitiveness of the US and will aid in ensuring the US spectrum policy keeps pace with other global leaders who are aggressively developing systems and rulemakings above 95 GHz.

• A review of EESS allocations above 95 GHz focusing on whether monitoring each allocated band is adding information about the environment or is merely redundant with information derived from other bands or sources. Thus, the basis for continuing allocations in the long term should be their actual marginal contribution to environment monitoring, not just the theoretical contribution the original allocations were based on.

• A change to the OMB Circular No. A-10 Spectrum Certification Process to require, in the case of non-classified passive EESS satellites with sensors above 95 GHz, a dialogue between satellite planners and potential terrestrial users of the same spectrum to see if the designs of new satellites and the designs of terrestrial systems can be adjusted to maximize sharing potential while also enabling the desired EESS functionality.

Introduction

The mmWave Coalition ("mmWC" or the "Coalition") is pleased to respond to this Request for Comments from NTIA on this key issue. The mmWC is a group of innovative companies and universities united in the objective of removing regulatory barriers to technologies using frequencies ranging from 95 GHz to 275 GHz. The Coalition does not limit itself to supporting any particular use or technology but rather it is working to create a regulatory structure in the United States for these frequencies that would encompass all technologies and all possible uses, limited only by the constraints of physics, innovation, and the imagination. A list of Members and principals of the Coalition are listed in an Attachment to these Comments. For more information, please visit http://mmwavecoalition.org/.

The spectrum in the 95-275 GHz region is very promising for both communications and noncommunications uses due to the wide bandwidths that are available and the opportunities for very intensive spectrum reuse because of the unusual nature of radio propagation here and the new antenna techniques enabled by the very small wavelengths involved.

mmWC has been an active participant in the FCC's "Spectrum Horizons" proceeding (Docket 18-21), which addresses possible new service rules and allocations above 95 GHz.[1] Our main goals include seeking commercial access to contiguous blocks of spectrum greater than the maximum 5 GHz block sizes which are at 71-76 and 81-86 GHz, first made available by FCC in 2003.[2] We have requested blocks greater than 20 GHz wide and comparable to the 116-134 GHz block made available in Japan by its national spectrum regulator in 2014.[3] The mmWave Coalition has also sought a transparent policy for obtaining the use of terahertz spectroscopy technology.

The U.S. Approach to Bands above 95 GHz Should be Reconsidered to Enhance US Competitiveness

While the 95 GHz to 275 GHz spectrum region has allocations that were made decades ago, only in the past decade has technology become available that makes this region viable for commercial applications. These applications include both communications uses and non-communications short range uses such as terahertz spectroscopy. At present, all FCC service rules for non-Federal Government ("NG") licensed or unlicensed use end at 95 GHz, a limit reached in 2003. Agenda Item 1.15 of WRC-19 will also consider the use of 275-450 GHz although specific allocations for this region are not expected at this time.

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[1] C*omments* of the mmWC, FCC Docket 18-21, May 2, 2018 (https://ecfsapi.fcc.gov/file/105022677816290/MMWC%20Comments%20in%20Docket%2018-21%205-2-18.pdf)
Reply Comments of the mmWC, FCC Docket 18-21, May 17, 2018 (https://ecfsapi.fcc.gov/file/10517084821360/MMWC%20Reply%20Comments%20in%20Docket%2018-21%20F.pdf)
Ex Parte Supplement of mmWave Coalition, FCC Docket 18-21, November 30, 2018 (https://ecfsapi.fcc.gov/file/113010791160/Ex%20Parte%20Supplement%20of%20mmWave%20Coalition%20FINAL.pdf)

[2] 47 C.F.R. §101.1501,1525

[3] FCC, *NPRM* in Docket 18-21 ("*NPRM")* at para. 12, February 22, 2018 (https://docs.fcc.gov/public/attachments/FCC-18-17A1_Rcd.pdf)

This spectrum is being explicitly targeted by the national economic competitors of the US who are supporting their industries in this area with both R&D funding and coordinated spectrum policies to ensure rapid transition of new technology into actual products.[4]

Present policies for this upper spectrum fail to strike the appropriate balance mandated by the statutory goals of spectrum regulation stated in Sections 1, 7(a) and 901[5] of the Communications Act of 1934, as amended ("the Act"). Attachment 1 lists the statutory provisions we are concerned about here.

The Request For Comments (RFC) states that the National Spectrum Strategy includes

> "improv(ing) the global competitiveness of United States terrestrial and space-related industries and augment the mission capabilities of Federal entities through spectrum policies, domestic regulations, and leadership in international forums."

US competitiveness may be falling behind other countries in the area of spectrum technology above 95 GHz. Today's vitally important transition to 5G is based, in part, on pioneering US spectrum policy innovation from NTIA and FCC starting in 1995 to open up spectrum above 60 GHz. American competitiveness in future generations of technology at high bands is being challenged by a coordinated effort in many countries and is adversely impacted by the lack of a clear and effective national policy above 95 GHz supporting the general goals of the National Spectrum Strategy

Existing Policies Governing Lower Bands Should not be Applied to Bands above 95 GHz Because of Fundamental Technical Differences

Spectrum above 95 GHz differ in several key ways from lower bands where present basic spectrum policies were established decades ago. So, while such policies may well be appropriate for lower spectrum where they were originally implemented, extending them into the highest available spectrum without revalidation has proved to be unduly restrictive.

Virtually all spectrum[6] between 48.2 GHz and the present US and ITU upper allocation limit at 275 GHz is G/NG shared and thus subject to parallel deliberations by FCC and NTIA[7]

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[4] THE European Telecommunications Standards Institute (ETSI), AND EU-supported standards and planning group haspublished it goals in this spectrum region: ETSI, millimetre Wave Transmission (mWT);Applications and use cases of millimetre wave transmission, ETSI GS mWT 002 V1.1.1 (2015-08) (https://www.etsi.org/deliver/etsi_gs/mWT/001_099/002/01.01.01_60/gs_mWT002v010101p.pdf)
FCC has observed that its European counterparts in CEPT are " developing a recommendation containing guidelines for deployment of fixed services operating in bands from 92 GHz to 174 GHz", *NPRM* at para. 15
CEPT and Japanese regulators have been pressing for WRC-19 action on 275-450 GHz - 2nd ITU INTER-REGIONAL WORKSHOP ON WRC-19 PREPARATION (Geneva, 20-22 November 2018)
Land mobile and fixed services WRC-19 agenda items1.11,1.12,1.14,1.15 at Slides 10-16 (https://www.itu.int/dms_pub/itu-r/md/15/2ndwrc19prepwork/c/R15-2NDWRC19PREPWORK-C-0002!!PDF-E.pdf)

[5] 47 USC §§ 151, 157(a), 901

[6] The only exceptions are the ISM bands at 122.50 GHz and 245.00 GHz and the primary Amateur Radio Service allocations at 134-136 GHz and 248-250 GHz where Radio Astronomy is secondary.

[7] 47 USC §§ 301,301

Spectrum above 30 GHz is often called "millimeter wave spectrum" because the wavelength corresponding to such frequencies is in the millimeter range. The region of 30-300 GHz is often called Extremely High Frequency or EHF. The ability of antennas to focus radio power is basically a function of the ratio of the antenna size to the wavelength of the frequency it is operating at. In the early days of spectrum regulation, wavelengths were hundreds of meters and antenna directionality options were very limited due to the large size needed for multiwavelength antennas at such frequencies. At EHF, antenna sizes of tens or hundreds of wavelengths are very practical due to their modest size and the focusing ability of antennas becomes a key part of system design unlike at lower frequencies.[8]

EHF frequencies also differ from lower bands by the presence of many molecular resonances and the impact they have on radio propagation, particularly due to aerosols in the lower atmosphere. This just like a cup of water in a consumer microwave oven absorbs 2.4 GHz energy and heats up from that absorption, EHF radio waves interact with aerosol molecules such as oxygen and water vapor and, depending on frequency and altitude, can experience additional absorptive path losses far greater than the free space loss that dominates in lower microwave. Indeed, the exponential form of mathematical formula for this path loss is very different than the formulas for losses at lower frequencies and in many cases the absorptive loss is so high that other losses are insignificant. A 1997 FCC report discusses these losses and their impact on spectrum management issues.[9]

EHF spectrum differs from lower bands in the absence of "anomalous propagation" modes that result in intermittent significantly reduced propagation loss and therefore more greater range of radio propagation depending on terrestrial or upper atmospheric conditions, such as ducting or sporadic E propagation.[10] Thus in these lower bands it is impossible to predict an absolute upper range limit for signals from an authorized transmitter since they can occasionally propagate much larger distances than normal. Therefore, the only way to prevent all harmful interference to scientific measurements is to prevent all co-frequency transmitters in these lower bands. This approach has little impact in these lower bands where protected passive allocations are minimal.

These strict prohibitions do not make sense in EHF bands. The very same molecular resonances that impact propagation, also make EHF of great interest to both radio astronomy ("RAS") and satellite-based remote sensing of the Earth called in spectrum policy jargon the Earth Exploration Satellite Service ("EESS"). These resonances are much more common in EHF than they are in lower spectrum due to physical laws and this has resulted in regulatory action taken decades ago at both the international and US national levels to protect passive scientific uses of these bands. mmWC recognizes the vital contributions of both RAS and EESS and fully supports the long-term protection of both radio service.

FCC and NTIA Memorandum of Understanding on Spectrum Coordination, January 31, 2003 (https://www.ntia.doc.gov/other-publication/2003/fcc-and-ntia-memorandum-understanding-spectrum-coordination)

[8] Even though antennas at EHF can focus energy very well and achieve high antenna gain, suppression of undesired radiation at angles away from the main beam is controlled mainly by the antenna design and not the ratio of its size of the wavelength.

[9] FCC, Millimeter Wave Propagation: Spectrum Management Implications, OET Bulletin No. 70, July 1997 (https://www.fcc.gov/bureaus/oet/info/documents/bulletins/oet70/oet70a.pdf)

[10] https://en.wikipedia.org/wiki/Tropospheric_propagation; https://en.wikipedia.org/wiki/Sporadic_E_propagation

However, when the present protection framework and its detail formulation were created, the currently contemplated use-cases for EHF were not well understood. The Department of Commerce website declares

> "Regulations that are unnecessary and burdensome are harmful to the economy. They increase the time and cost of doing business, and therefore increase prices and kill jobs."[11]

The Department's Strategic Plan similarly states

> "Economists agree that innovation drives economic growth, creates jobs, raises wages, and helps Americans lead better lives. The United States has long led the world in innovation and technological advancement. To ensure that our country remains the global leader, we must innovate more and faster than the rest of the world."[12]

mmWave Coalition respectfully suggests that the current environment is overly prohibitive and fails to strike the balance that could facilitate robust commercial uses above 95 GHz while protecting U.S. government passive uses. In light of this, mmWave Coalition asks NTIA to consider whether there are alternative ways, given today's technology, to protect RAS and EESS effectively and that also to encourage investment in advanced radio technology to maintain US technological leadership.

EESS and RAS Protection Issues

EESS and RAS spectrum are primarily protected[13] presently in the US by the provisions of US Allocation Table footnote US246 given in Attachment II.

The specific terms of US246 are not required by any present law – that is, the FCC and NTIA have discretion in how they implement its terms. International Allocation Table footnote 5.340, has similar, but not identical provisions and is a treaty obligation of the US.[14] While this is a treaty obligation, Radio Regulation 4.4 ("RR 4.4") applies to national compliance with it and has

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[11] https://www.commerce.gov/issues/regulatory-reform

[12] U/S/Department of Commerce Strategic Plan 2018-2022, Strategic Objective 1.2 (https://www.commerce.gov/sites/default/files/us_department_of_commerce_2018-2022_strategic_plan.pdf)

[13] There are other RAS and EESS bands above 95 GHz which have primary RAS and/or EESS allocation but are not listed in US246, *e.g.* 116-122.25 GHz. It is unclear what NTIA's present position is on sharing such bands with other spectrum users.

[14] The present terms of 5.340 are:

> "All emissions are prohibited in the following bands: 1400-1427 MHz, 2690-2700 MHz, except those provided for by No. 5.422, 10.68-10.7 GHz, except those provided for by No. 5.483, 15.35-15.4 GHz, except those provided for by No. 5.511, 23.6-24 GHz, 31.3-31.5 GHz, 31.5-31.8 GHz, in Region 2, 48.94-49.04 GHz, from airborne stations 50.2-50.4 GHz*, 52.6-54.25 GHz, 86-92 GHz, 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz, 250-252 GHz
>
> > * The allocation to the Earth exploration-satellite service (passive) and the space research service (passive) in the band 50.2-50.4 GHz should not impose undue constraints on the use of the adjacent bands by the primary allocated services in those bands.

been used by the US in the past.[15] Under the terms of RR 4.4, FCC and NTIA may legally elect to authorize transmitters on the frequencies enumerated in 5.340 as long as such transmitters, individually and collectively, do "not cause harmful interference to" the passive RAS and EESS systems that have primary allocations in such bands.

While US246 applies to both RAS and EESS use of the enumerated bands, RAS issues have not had a major impact on NG spectrum use and the major impact in practice only involves EESS use. RAS observations at these frequencies, unlike lower frequencies, benefit greatly from both high altitude and low humidity. Most of the RAS facilities in this spectrum are in rural areas and most are west of the Mississippi River. There is a long history of successful frequency coordination between Fixed Service stations and RAS facilities under the terms of §2.107 of the FCC Rules[16] with FS stations being designed and operated under mutually agreed terms that have been acceptable to the RAS community. Also, put simply, since RAS antennas are pointed up, their sidelobes are somewhat vulnerable to cochannel signals from other services, but their main lobes are not.

The capabilities of present US RAS facilities in this part of the spectrum was given by the National Academy of Science's Committee on Radio Frequencies in an FCC filing[17] and are shown in Table 1.

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[15] The present terms of Radio Regulation 4.4 are:

> "Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations."

[16] 47 C.F.R. §2.107

[17] Comments of National Academy of Science's Committee on Radio Frequencies, FCC Docket 18-21, March 30, 2018 (https://ecfsapi.fcc.gov/file/103301405612430/CORF_Above%2095%20GHz_FINAL.pdf)

Name of RAS Facility	Frequencies Covered above 95 GHz
Smithsonian Astrophysical Observatory Submillimeter Array(SMA)/Hawaii	180-418 GHz
James Clerk Maxwell Telescope (JCMT)/Hawaii	211.5-276.5 GHz, 330-335 GHz, 340-375 GHz, and 620-710 GHz
Owens Valley Radio Observatory (OVRO)/California	85-115 GHz and 215-265 GHz
Arizona Radio Observatory(ARO)/Arizona	75-250 GHz
Submillimeter Telescope/Arizona	205-720 GHz
Haystack Radio Telescope/Massachusetts	85-115 GHz
Green Bank Telescope (GBT)/West Virginia	75-105 GHz and 80-115.3 GHz
Next Generation Very Large Array (ngVLA)/ New Mexico & Texas	"up to 116 GHz"

Table 1. US RAS Facility Capability

In contrast to RAS, for EESS, the antennas, out of necessity, are sometimes pointed downward towards the Earth. The angle of pointing between the satellite path and the Earth's surface depends on the phenomenon being observed.[18] Thus, mutual coupling between the EESS and FS antennas is much more of a concern than in the RAS case. Also, EESS systems need to cover all or most of the Earth and are vulnerable emissions anywhere in this coverage area.

US246 has not historically been a static list of strict prohibitions. It contains two footnotes of its own that resulted from NTIA and FCC collaborations in the past two decades that determined that in each of two bands the original total prohibitions of all authorized transmitters could be replaced with carefully tailored provisions that allowed limited transmitter uses that were capable of sharing with the primary RAS and EESS allocations. These were past examples of NTIA agreeing to modify "(r)egulations that are unnecessary and burdensome are harmful to the economy". It is our understanding that these previous changes remain uncontroversial today and that this sharing experience under the technical terms agreed to by FCC and NTIA has satisfied all parties.

The impact on US spectrum use of the present US246 provisions are shown in Figures 3 and 4 below which show data about US246 restrict bands at different spectrum regions from VHF to EHF. It should be noted that, while US246 protects most present US allocations for EESS and RAS, there are other allocations, discussed more below, that also have coprimary allocations with these services but do not have US246 protection. It is unclear what NTIA's protection goals are for these non-US246 bands and this ambiguity is also a barrier to capital formation by US firms for R&D.

[18] Some EESS systems antennas point directly down from the satellite, some point straight ahead in the satellite path, and some have conical motion at angles in between these limits.

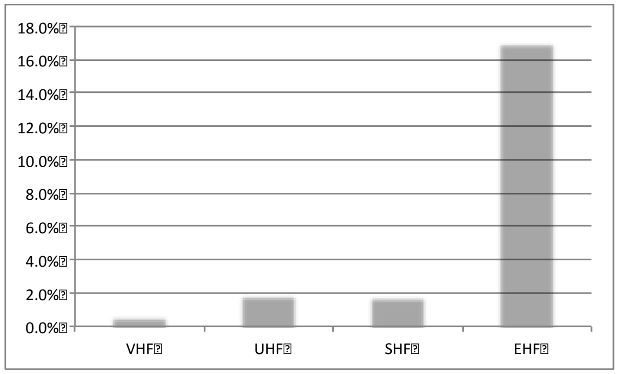

Figure 3: Fraction of band covered by US246 prohibitions

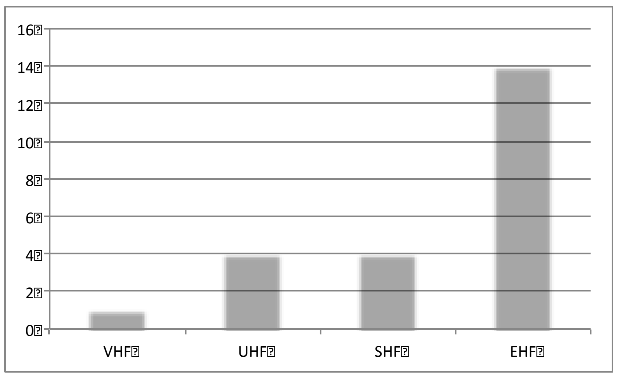

Figure 4: Number of spectrum blocks covered by US246 prohibitions

Figures 3 shows the fraction of each spectrum range in which transmitters are banned by US246. The 17% banned in EHF dwarfs the fractions in the lower three ranges. But this is exacerbated by the number of forbidden blocks shown in Figure 4. The 14 forbidden blocks in EHF balkanize the spectrum and limit the potential access to large contiguous blocks which is the key attractiveness of EHF.

In VHF, UHF, and SHF passive allocations are a minor use of spectrum and have little impact on other spectrum uses. For example, in the original 83 channel mostly contiguous VHF and UHF television allocations, only 1 channel (TV Channel 37/608-614 MHz) was affected by passive allocations. But the high density of molecular resonance frequencies above 30 GHz results in many more passive bands in EHF and coupled with the present absolute prohibition terms of US246 has a major impact on other spectrum uses.

mmWC Proposals to Further the Goals of the National Spectrum Strategy above 95 GHz

1. Review Alternative Formulations of US246 to Balance Better Protection of EESS and Terrestrial Use Issues

In the mmWC November 30, 2018 *Ex Parte* Supplement filing at FCC,[19] we proposed an update to US246 provisions above 95 GHz. This would modify the method of protecting the enumerated passive bands above 95 GHz, while leaving the lower bands unchanged. The proposed alternatives would take better account of the difference of EHF spectrum that were discussed above.

Specifically, we proposed eliminating the absolute prohibition of transmitters in these bands with a requirement that that any transmitters authorized on the enumerated US246 frequencies above 95 GHz must individually and collectively not produce enough power at EESS and RAS receiver locations to exceed the existing ITU-R protection criteria for these receivers. It further provides for tighter protection levels as long as a US proposal is pending at ITU-R proposing such a level.

This would allow rapid updating of a protection criteria on at least a temporary basis when new issues appear. We believe that this alternative better furthers the sharing goals of the National Spectrum Strategy than the present US246 provisions while protecting vital EESS and RAS assets

2. NTIA and FCC Cooperation to Open an EHF Band with at Least 20 GHz Contiguous Bandwidth

In our November 30, 2018 *Ex Parte* Supplement filing at FCC we also asked for large spectrum blocks with more than 20 GHz bandwidth for Fixed Service Use.[20] Pending proposals in the *NPRM* have a maximum bandwidth of 7.5 GHz, not significantly greater than the 5 GHz permitted since 2003. It appears that NTIA's concerns were a major factor in limiting this maximum bandwidth. By contrast, FCC *NPRM* states that its Japanese counterpart has permitted an 18 GHz wide band at 116-134 GHz since 2014.[21]

It appears that such bandwidths are being blocked by NTIA objections based on both US246 issues as well as issues related to the 116-122.25 GHz band which has a coprimary EESS allocation although it also has a designated ISM band with unlimited emission limits at 122.50 GHz ±500.0 MHz.[22]

We ask that FCC and NTIA cooperate with industry in a transparent way to address this issue. While many federal spectrum matters cannot be fully discussed publicly due to valid national security issues, we believe that this need not apply to this case since the passive spectrum uses here are not classified.

[19] mmWC Ex Parte Supplement, *op. cit* at Attachment A
[20] *IBID.* at p. 2-6
[21] *NPRM* at para. 12
[22] 47 C.F.R. §18.301

3. Increased Federal R&D and Analysis Needed on EESS/FS Sharing Feasibility

One of the stated goals of the National Spectrum Strategy is to

> "Use ongoing research, development, testing, and evaluation [RDT&E] to develop advanced technologies, innovative spectrum- utilization methods, and spectrum-sharing tools and techniques that increase spectrum access, efficiency, and effectiveness;"

The RFC also asks "How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?" We see several opportunities here for federally funded RDT&E to improve access to EHF for NG users while protecting passive systems.

1) The National Science Foundation Millimeter-Wave Research Coordination Network (RCN) spans the important and timely area of millimeter-wave (mmW) wireless networks that is the focus of intense current research in academia and industry for achieving multi-Gigabit data rates and low latency as part of the emerging vision for 5G wireless networks. It is driven by innovations in communication and signal processing techniques, mmW hardware, circuits, and antennas, and digital hardware, wireless networking protocols.[23] NSF also funds much research in millimeter wave technology. However, we are not aware of any funding to date into technology to facilitate sharing between terrestrial millimeter wave use and EESS use. We suggest that NTIA explore with NSF including such research as an integral part of its RDT&E program since access to large contiguous blocks of spectrum will continue to be severely limited if the absolute prohibitions of US246 remain in place indefinitely.

2) NTIA's Institute for Telecommunications Sciences (ITS) is the research and engineering arm of NTIA and provides core telecommunications research and engineering services to promote more efficient use of the radio frequency spectrum. ITS and its DOC National Institute of Standards and Technology (NIST) colleagues in Boulder have various antenna test ranges to make precise measurements of antennas to support spectrum policy development. Sharing of spectrum above 100 GHz with EESS will require new types of antenna systems with unusually low sidelobe levels - something that would not be practical with conventional dish and horn antennas in lower bands. At present there is no test facility in the US that can measure very low sidelobe levels in these bands. However, this may well be practical with quasioptical antennas that are practical at such frequencies as well as MIMO-like adaptive antennas that can both maximize the signal-to-noise ratio as the desired receiver as well as minimize the effectivities isotropic radiated in the direction of the known orbit of EESS satellites that pass overhead. Such measurements require measurement sensitivities in excess of present or planned capabilities. We urge NTIA to consult with ITS and NIST on the feasibility of improving the sensitivity of antenna sidelobe measurement facilities at ITS/NIST and make such measurements part of the goals for future updates to such systems.

3) The National Academy of Sciences Committee on Radio Frequencies (CORF) represents the interests of U.S. scientists who use radio frequencies for research—for example, radio astronomers and remote sensing researchers and is supported by both NASA and NSF funding. The committee deals with radio-frequency requirements and interference protection primarily

[23] https://mmwrcn.ece.wisc.edu/

through filing comments under the aegis of the National Academy of Sciences in public proceedings of the Federal Communications Commission.[24] CORF has published two reports which are key resource to describe passive uses of spectrum for both EESS and RAS.[25] However, neither of these reports delve at all into the feasibility of sharing passive spectrum with any terrestrial users nor do the CORF comments to FCC discuss such issues. We urge NTIA to discuss with CORF's financial sponsors, NASA and NSF, broadening the charge of CORF analyses and making the feasibility of increased responsible sharing in line with the goals of the National Spectrum Strategy.

4. An Effective Terahertz Spectroscopy Policy for the US is Urgently needed

Terahertz spectroscopy[26] is a recent noncommunications short range technology for characterizing objects and their structure. While the US spectrum policy with respect to this technology is ambiguous, it appears that both G and NG use is growing. However, the current regulatory ambiguity imposes unreasonable regulatory risk on both developer and users.
The FCC NPRM in Docket 18-21 states

> "(w)e are aware of interest in using the spectrum above 95 GHz for devices that use terahertz spectroscopy to analyze material properties and for imaging applications, which could possibly be considered ISM applications."[27]

However, the situation is advanced beyond just "interest." There are products being marketed in the U.S. and worldwide for terahertz spectroscopy. Some of these products are from U.S. manufacturers while others are from foreign companies. A milestone in the commercialization of terahertz spectroscopy was R&D investment by NASA to use such technology to address critical Space Shuttle Program safety issues in both fuel tank insultation[28] and adhesion of heat resistant tiles to the Space Shuttle that were critical for safe reentry[29].

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[24] http://sites.nationalacademies.org/bpa/bpa_048819
[25] *Handbook of Frequency Allocations and Spectrum Protection for Scientific* Uses (2015) (https://www.nap.edu/catalog/21774/handbook-of-frequency-allocations-and-spectrum-protection-for-scientific-uses); *Spectrum Management for Science in the 21st Century (*2010) (https://www.nap.edu/catalog/12800/spectrum-management-for-science-in-the-21st-century)
[26] M. Naftali, Ed., *Terahertz Metrology,* Artech House, 2015
https://en.wikipedia.org/wiki/Terahertz_spectroscopy_and_technology
[27] *See* ¶ 61
[28] D. Zimdars, J. S. White, G. Stuk, A. Chernovsky, G. Fichter, and S. Williamson, “Large area terahertz imaging and non-destructive evaluation applications,” Insight, vol. 48, no. 9, pp. 537–537, 2006
D. Zimdars, "Technology and Applications of Terahertz Imaging Non-Destructive Examination: Inspection of Space Shuttle Sprayed On Foam Insulation".2005 (https://www.researchgate.net/publication/253386662_Technology_and_Applications_of_Terahertz_Imaging_Non-destructive_Examination_Inspection_of_Space_Shuttle_Sprayed_On_Foam_Insulation)
[29] NASA Orbiter Project Office, Terahertz NDE Application for Corrosion Detection and Evaluation under Shuttle Tiles (https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20070016023.pdf)

The record of the FCC *NPRM* is clear that since 2012 at least one US manufacturer has been marketing terahertz spectroscopy equipment that is used by industry, academia, the U.S. DoD and NASA."[30] These uses have included

> "imag(ing) the Space Shuttle external tank, the Space Shuttle thermal protection system, (NASA) Orion spacecraft thermal protection system, military aircraft coatings, military ship coatings, radomes, food, pharmaceuticals, and other products".[31]

Thus, this technology is already being used in NTIA's jurisdiction although there is no public record of what NTIA's policy has been for its spectrum authorization.

Terahertz spectroscopy equipment is now not only designed and manufactured in the US, but it is also used to improve the productivity of U.S. manufacturers in both high tech applications and bulk products, *e.g.* wall board and plywood, where the U.S. manufacturing has faced competitiveness challenges in recent years. Thus a comprehensive US policy for the authorization of terahertz spectroscopy technology under parameters that protect passive allocations is a competitiveness issue in terms of NTIA's statutory § 901(b)(3) goal with respect to **both** the US manufacturers of terahertz spectroscopy equipment **and also** the US manufacturers of non-spectrum products who could use this technology in their factories to improve their own productivity and competitiveness in world markets and thus increasing manufacturing employment - a key goal of both the Administration and DOC.

Creating a clear policy for use of terahertz spectroscopy technology in the U.S. and removing barriers to its use in both high tech and commodity manufacturing facilities will improve US competitiveness both in this technology and in bulk manufacturing facilities where it is used for real time quality control.

The *NPRM* offer no specific proposal for terahertz spectroscopy, only indicating that it would continue to be considered "on a case-by-case basis". We suspect that this vagueness is due to NTIA concerns and request that NTIA and FCC collaborate on a more transparent policy that will encourage R&D and use of this technology while also protecting key EESS and RAS systems.

Developers and manufacturers cannot be expected to spend large amount of resources on innovative technologies with no regulatory guidance at all on what criteria are used to approve the technology for market access. The Coalition urges that NTIA consider this technology in the shared spectrum above 47 GHz and develop with FCC reasonable conditions to allow this. Since most use of this technology is indoors in industrial facilities we suggest that rules for such use be a top priority. For the interim, outdoor use might be treated by experimental licenses as is done in the case of GPS re-radiators under the provisions of Redbook Sections 8.3.28 to 8.3.30.

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[30] Comments of TeraMetrix, Docket 18-21,May 15, 2018 at p. (https://ecfsapi.fcc.gov/file/1051556006218/TeraMetrix%20NPRM%20the Commission%2018-21%20comments%20R1.pdf)

[31] *IBID.*

5. Experimental Licenses Issues

FCC experimental licenses are a key part of R&D programs for advanced radio technology. Since nearly all spectrum above 47 GHz is G/NG shared, there is FCC/NTIA coordination on virtually all experimental application for spectrum mmWC advocates for 95 GHz. In cases where proposed experiments impinge on EESS allocations, either those protected by US246 or not so protected, there have been recurring problems that appear to have resulted by NTIA input to FCC during interagency coordination process. These problems have either delayed experiments, significantly increased their cost, or made them impractical.

FCC Rules explicitly provide for the possibility of experimental licenses in bands with passive allocations although they point out that long term use of such spectrum may not be possible. [32] There are two reasons why experiments in passive bands may be needed:

> 1. In the present commercial market, transmitters above 95 GHz in serial production are not available at all frequencies. The models and frequencies available are often byproducts of previous federally funded R&D programs. The cost of using such current production models for an early stage experiment on new technology to determine its feasibility is significantly less than a custom-made transmitter. Once feasibility is established, it is easier to justify the higher cost of equipment for subsequent experiments at frequencies with long term feasibility.
>
> 2. For radio propagation experiments wide bandwidth channel sounders are very helpful for characterizing and understanding the nature of propagation. Due to the balkanization of EHF spectrum by passive bands, use of wideband channel sounders might impinge on passive bands during the proposed experiment's duration.

It might appear that FCC's recently added category of "Program Experimental Radio Licenses"[33] might avoid problems with US246 protected spectrum, the explicit provisions of §5.303(a) indicate that it does not.[34]

mmWC urges NTIA to amend the Redbook provisions to coordination on experimental license to provide that conditions on licenses greater than 95 GHz recommended by NTIA to FCC must be the minimum conditions needed to protect G systems during the duration of the license and at the location of the license and that consideration of possibly creating precedents are inappropriate in the experimental license coordination process.

Experimental licenses are often part of early R&D in radio technology. Since the government funding of such R&D is less significant in the US than in some of our national competitors, US entities usually need private capital formation for support such R&D. Even in large US private

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[32] 47 U.S.C. § 5.85(a)(2)
[33] 47 C.F.R. §5.301,313
[34] 47 C.F.R. §5.303(a) provides for program licenses the following "Licensees may operate in any frequency band, including those above 38.6 GHz, **except for frequency bands exclusively allocated to the passive services** (including the radio astronomy service). In addition, licensees may not use any frequency or frequency band below 38.6 GHz that is listed in §15.205(a) of this chapter. (Emphasis added)

entities where outside funding is not needed, regulatory uncertainty could discourage allotment of internal funds to projects vis-a-vis other projects in other technologies that do not face this special risk factor in additional to other risks such as future market demand and likelihood of technical success within the budgeted time frame.

6. A Fresh look and Upgrades Needed to Support EHF Spectrum Sharing

The historic evolution of mobile communications up through this decade has focused primarily on the use of omnidirectional antennas, and it has only been in the past few years, through the evolution of 5G and millimeter wave communications, that the global wireless industry now realizes that highly directional antennas will be a fundamental part of future of mobile communications and sensing above 6 GHz.[35] This fact requires a new and fair look at spectrum policy above 95 GHz, where directional antennas in terrestrial systems will be exploited to make up for the increased close-in free space loss, as well as weather-related channel loss. This move to highly directional antennas is a sea change in mobile communications and must be considered when making spectrum policy above 95 GHz. The use of directional antennas in terrestrial networks may now be relied upon to substantially reduce interference to satellites, thereby requiring consideration of sharing or adjacent frequency allocations above 95 GHz when it has been previously forbidden.[36] Such a foundational change in future mobile communications promises that terrestrial use of spectrum above 95 GHz would not interfere with space-based systems, and should be considered in opening up spectrum.[37]

NTIA's Institute for Telecommunications Sciences (ITS) is the research and engineering arm of NTIA and provides core telecommunications research and engineering services to promote more efficient use of the radio frequency spectrum. ITS and its DOC National Institute of Standards and Technology (NIST) colleagues in Boulder have various antenna test ranges to make precise measurements of antennas to support spectrum policy development. Sharing of spectrum above 100 GHz with EESS will require understanding of array patterns and may require new types of antenna systems with unusually low sidelobe levels - something that would not be practical with conventional dish and horn antennas. However, even conventional antennas are likely to be found to provide sufficient sidelobe rejection to incumbent space-based EHF users when commercially realizable directional antennas are employed in terrestrial communication networks or used in low power applications for communications, sensing, and imaging.

At present there are few test facilities in the US that can measure how commercially viable antennas or new antennas with very low sidelobe levels would impact the sharing in these bands.

However, in the event conventional antennas are found to not offer the desired low sidelobe levels, quasi-optical antennas, that are practical at such frequencies, as well as MIMO-like adaptive antennas, can both maximize the signal-to-noise ratio as the desired receiver as well as

[35] A. Ghosh, et. al, " Millimeter-Wave Enhanced Local Area Systems: A High-Data-Rate Approach for Future Wireless Networks," IEEE JSAC, Vol. 32, No. 6, pp. 1132-1144 (https://ieeexplore.ieee.org/abstract/document/6824746)

[36] Rappaport, et. al, : Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!, IEEE ACCESS, Vol. 1, May 2013, pp. 335 – 349 ; https://ieeexplore.ieee.org/document/6515173].

[37] T. Rappaport, "Future Wireless Technologies: mmWave, THz, & Beyond – presentation to the mmWave Coalition," Sept. 27, 2018. (https://youtu.be/RAv8eYYbaw4)

minimize the effectivities isotropic radiated in the direction of the known orbit of EESS satellites that pass overhead. Such measurements require measurement sensitivities in excess of present or planned capabilities at NTIA. We urge NTIA to consult with ITS and NIST on the feasibility of analyzing co-channel interference for realistic commercial antenna designs above 95 GHz and improving the sensitivity of antenna sidelobe measurement facilities at ITS/NIST and make such measurements and co-channel spectrum analysis above 95 GHz a part of the budget goals for future updates to such systems.

8. Long Term Need Review for Review of EHF EESS Allocations Based on Operational Experience

When the present allocations were made for EESS at EHF the spectrum needs were based on molecular resonances and analysis that indicated which bands could provide important environmental sensing information. Opportunity costs for other possible spectrum uses were not included in policy deliberations because such uses were not under consideration because of technology limitations.

But at the present time there are more than two decades of experience with operational data from such sensors. This data could be reviewed to see which sensors produce measurement data which is redundant with measurement other measurements from EESS sensor or even other sources. This review could then either verify that all the presently allocated or protected bands are needed in the long term or else identify some bands that produce interesting information which is redundant with other sources. Given the present-day opportunity cost with respect to terrestrial use of these bands, we do not believe their long-term protection should be based solely on determination decades ago that they might be of interest.[38]

9. Planning of Future Passive Satellite Systems with Explicit Consideration of Possible Sharing with Terrestrial Fixed Service Systems

Increased sharing of federal spectrum is a key goal of the National Spectrum Strategy. Just as NTIA has observed in the challenge of sharing G radar spectrum with NG communications users when the radar technology was designed decades ago with no consideration of spectrum sharing, sharing potential of G EESS spectrum is complicated by the design of the EESS systems - which is this case are in orbit and actually impossible to modify once placed in service.

NTIA has been a leader in adopting spectrum sharing alternatives, for example for the NG/G frequencies of 3.55 – 3.7 GHz, in the Citizens Broadband Radio Service (CBRS) set for commercial launch in 2019. Even with such broad coverage and properties of building penetration, NTIA has agreed to provide access to these frequencies through interference mitigation strategies, rather than taking an "all or none" position that prevents usage of a valuable spectrum allocation that otherwise is vastly underutilized within the continental USA. NTIA should also consider the successful utilization of relaxed interference regulations regarding adjacent channel interference, which have led to substantial build out of mobile

[38] Such a review might be analogous to ongoing reviews of federal land use restrictions under E.O. 13792 of Apr 26, 2017, 82 FR 20429

communication systems, where protections were unreasonably harsh for adjacent channel satellite systems. Consider, for example, the successful reallocation of 30 MHz of underutilized Wireless Communications Service (WCS) spectrum for cellular/mobile services at frequencies closely adjacent to the SiriusXM satellite radio systems at 2.3 GHz.[39] . It is important to note that when the FCC relaxed the interference protections on satellites, 30 MHz of prime mobile spectrum was made available, while still ensuring sufficient protection to the satellite system through tractable analysis and simulation.[40] Another example is the 28GHz band for which FCC determined in 2016 that limitations on 5G are not required to manage co-channel aggregate interference from 5G networks into satellite receivers based on simulations provided by Nokia, working with AT&T, T-Mobile, Verizon and Samsung that consider sophisticated beamforming and other features of 5G systems.[41] [42] This important FCC decision of not imposing any unnecessary burden on 5G systems was motivated by engineering decisions and effectively opened 850MHz of spectrum at 27.35-28.5GHz that is being used for 5G deployment to be supplemented by more 28GHz spectrum being auctioned currently by FCC.[43]

OMB Circular No. A-11 specifies in Section 33.4:

> "You must obtain a certification by the National Telecommunications and Information Administration, Department of Commerce that the radio frequency required can be made available before you submit estimates for the development or procurement of major radio spectrum-dependent communications-electronics systems (including all systems employing space satellite techniques)".[44]

mmWC urges that NTIA modify Redbook Chapter 10 for the case of passive satellites above 95 GHz to require a review of whether details of satellite design can be traded off with details of potential cochannel terrestrial Fixed Service systems in a cost-effective way. NTIA should require a constructive and transparent dialogue between the designers of such EESS systems and potential terrestrial users of cochannel spectrum to explore mutual design options to minimize coupling of transmissions between such users and the EESS satellite and facilitate possible spectrum sharing. Thus, parameters such as bandwidth, antenna pattern, antenna pointing with respect to the spacecraft, and signal processing might be modified to facilitate sharing, particularly if policies are developed that allow the potential terrestrial users to support par to the costs incurred to facilitate spectrum sharing. Costs incurred by the terrestrial users to permit sharing, such as large antenna sidelobe reductions, would remain the responsibility of those wishing to share the EESS spectrum.

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[39] https://www.fcc.gov/wireless/bureau-divisions/mobility-division/wireless-communications-service-wcs

[40] T. S. Rappaport, S. DiPierro, R. Akturan, "Analysis and Simulation of Interference to Vehicle-Equipped Digital Receivers From Cellular Mobile Terminals Operating in Adjacent Frequencies," IEEE Trans. Veh. Tech., Volume: 60 , Issue: 4 , May 2011, pp. 1664-1676, https://ieeexplore.ieee.org/document/5723770

[41] FCC Report & Order and Further Notice of Proposed Rulemaking, Use of Spectrum Bands Above 24 GHz For Mobile Radio Services, released July 14, 2016

[42] *See* AT&T, Nokia, Samsung, T-Mobile, Verizon May 6, *Ex Parte* Letters filed on May 6, May 12 and June 1, 2016, https://ecfsapi.fcc.gov/file/60001840902.pdf, https://ecfsapi.fcc.gov/file/60001841699.pdf , https://ecfsapi.fcc.gov/file/60002090275.pdf , https://ecfsapi.fcc.gov/file/60002090276.pdf

[43] https://www.fcc.gov/auction/101

[44] Redbook, Section 10.1.2

Adding this interaction between satellite designers and terrestrial use parties before NTIA certification of a new satellite would give more options for consideration of the spectrum sharing endorsed by the National Spectrum Strategy

Respectfully submitted,
mmWAVE COALITION

/s/Prakash Moorut

By: Prakash Moorut
Chair of Steering Group
mmWave Coalition

January 22, 2019

Attachment I: Statutory Provisions from the Communications Act of 1934, as Amended Relating to Spectrum, Innovation, and Competitiveness

§1

For the purpose of regulating interstate and foreign commerce in communication by wire and radio so as to make available, so far as possible, to all the people of the United States, ... a rapid, efficient, Nation-wide, and world-wide wire and radio communication service with adequate facilities at reasonable charges, for the purpose of the national defense ...there is created a commission to be known as the "Federal Communications Commission...

§7(a)

It shall be the policy of the United States to encourage the provision of new technologies and services to the public. Any person or party (other than the Commission) who opposes a new technology or service proposed to be permitted under this chapter shall have the burden to demonstrate that such proposal is inconsistent with the public interest.

§ 901(b)

(2) Rapid technological advances being made in the telecommunications and information fields make it imperative that the United States maintain effective national and international policies and programs capable of taking advantage of continued advancements.

(3) **Telecommunications and information policies and recommendations advancing the strategic interests and the international competitiveness of the United States are essential aspects of the Nation's involvement in international commerce.**

§ 901(c)

The NTIA shall seek to advance the following policies:

(1) **Promoting the benefits of technological development in the United States for *all* users of telecommunications and information facilities.**

(2) Fostering national safety and security, economic prosperity, and the delivery of critical social services through telecommunications.

(3) Facilitating and contributing to the full development of competition, efficiency, and the free flow of commerce in domestic and international telecommunications markets.

(4) **Fostering full and efficient use of telecommunications resources, including effective use of the radio spectrum by the Federal Government, in a manner which encourages the most beneficial uses thereof in the public interest.**

(5) Furthering scientific knowledge about telecommunications and information. (emphasis added)

Attachment 2: Present Provisions of US246 and Proposed Changes

Present Text:

US246 No station shall be authorized to transmit in the following bands: 73-74.6 MHz, 608-614 MHz, except for medical telemetry equipment[1] and white space devices,[2] 1400-1427 MHz, 1660.5-1668.4 MHz, 2690-2700 MHz, 4990-5000 MHz, 10.68-10.7 GHz, 15.35-15.4 GHz, 23.6-24 GHz, 31.3-31.8 GHz, 50.2-50.4 GHz, 52.6-54.25 GHz, 86-92 GHz, 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz, 250-252 GHz.

[1] Medical telemetry equipment shall not cause harmful interference to radio astronomy operations in the band 608-614 MHz and shall be coordinated under the requirements found in 47 CFR 95.1119.

[2] White space devices shall not cause harmful interference to radio astronomy operations in the band 608-614 MHz and shall not operate within the areas described in 47 CFR 15.712(h).

(Legally, these provisions are regulations that have been adopted by FCC under the terms of the Administrative Procedures Act and which have in parallel been incorporated by NTIA into the *Manual of Regulations and Procedures for Federal Radio Frequency Management* (Redbook))

mmWC Proposal for Change of Provisions Above 95 GHz:

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US246 No station shall be authorized to transmit in the following bands: 73-74.6 MHz, 608-614 MHz, except for medical telemetry equipment[1] and white space devices[2], 1400-1427 MHz, 1660.5-1668.4 MHz, 2690-2700 MHz, 4990-5000 MHz, 10.68-10.7 GHz, 15.35-15.4 GHz, 23.6-24 GHz, 31.3-31.8 GHz, 50.2-50.4 GHz, 52.6-54.25 GHz, 86-92 GHz,

In the following bands all unlicensed devices and all mobile stations are forbidden and FCC and NTIA will only issue licenses or assignments under mutually agreed procedures that assure that authorized Radio Astronomy Service facilities and Earth Exploration Satellite Service stations are protected from both the individual and aggregate emissions to the criteria given in ITU-R RS.2017, ITU-R RS.1858, ITU-R RA.517, ITU-R RA.517, ITU-R RA.611, ITU-R RA.769-2 and ITU-R RA.1031.: 100-102 GHz, 109.5-111.8 GHz, 114.25-116 GHz, 148.5-151.5 GHz, 164-167 GHz, 182-185 GHz, 190-191.8 GHz, 200-209 GHz, 226-231.5 GHz, 250-252 GHz.

In cases where there is a formal coordinated FCC/NTIA/DOS US proposal to ITU-R to adopt a stricter standard protection limit, that draft position will apply as long as the draft is pending in ITU-R.

[1] Medical telemetry equipment shall not cause harmful interference to radio astronomy operations in the band 608-614 MHz and shall be coordinated under the requirements found in 47 CFR 95.1119.

[2] White space devices shall not cause harmful interference to radio astronomy operations in the band 608-614 MHz and shall not operate within the areas described in 47 CFR 15.712(h).

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