Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Spectrum Horizons	)	ET Docket No. 18-21
	)	
James Edwin Whedbee Petition for Rulemaking to Allow Unlicensed Operation in the 95-1,000 GHz Band	)))	RM-11795 (Proceeding terminated)

FIRST REPORT AND ORDER

Adopted: March 15, 2019 **Released: March 21, 2019**

By the Commission: Chairman Pai and Commissioners O'Rielly, Carr, Rosenworcel and Starks issuing separate statements.

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I. INTRODUCTION

1. Innovators continue to push technological boundaries in wireless communications. Frequency bands once thought of as unusable are now well within the range of modern communications systems. With this First Report and Order, we take steps to provide new opportunities for innovators and experimenters to push those boundaries even further, and to develop new equipment and applications for spectrum between 95 GHz and 3 THz. These frequencies — long considered to lie at the outermost horizons of usable radio spectrum —are becoming increasingly well-suited for the development and deployment of new active communications services and applications. The rules we adopt in this First Report and Order will permit enhanced experimental licensing and unlicensed applications within this

spectrum band as well as advance our overall commitment to identify and make available unused and underused spectrum regardless of the frequency range.

2. We save for future consideration the proposals in the Spectrum Horizons Notice of Proposed Rulemaking (*Notice*)[1] associated with licensed use of the band.[2] Although these proposals were designed to ensure that we would not constrain the ways in which the bands above 95 GHz can develop or foreclose innovation through too-rigid service rules,[3] several commenters raised concerns about the risks of adopting service rules for these frequencies at this time.[4] We similarly conclude that added time and experience under the new unlicensed and experimental rules we are adopting will provide us with valuable perspective. While we defer action on licensed service rules for now, we continue to believe that the frequencies above 95 GHz are potentially suitable for licensed use.

II. BACKGROUND

3. Both industry and academia have expressed interest in the bands above 95 GHz, as evidenced by the wide range of ongoing research and experimentation. Institutions such as Brown University and the New York University Tandon School are conducting propagation measurements at frequencies as high as 400 GHz. Companies such as Boeing and Raytheon have undertaken testing of antennas and radar receivers at frequencies near 100 GHz.[5] Frequencies above 95 GHz have also been identified as optimal for instantaneous temporary data links that can enable the transmission of large bandwidth uncompressed high-definition (HD) video signals and other high-speed data for other types of applications. For example, in 2008, Japan's NTT used wireless links in the 120 GHz band to provide live TV coverage of the 2008 Beijing Olympics.[6] Further, the shorter wavelengths associated with frequencies above 95 GHz may be particularly well-suited for non-communication sensing applications such as spectroscopy and imaging, including detection of drugs and explosives, detection of cancerous tissue, as well as materials analysis and quality control.[7]

4. The Commission has recognized the budding interest in developing new technologies and services that could operate in the frequency bands between 95 GHz and 3 THz, while at the same time acknowledging the need for continued use of passive services in these frequency bands for scientific research, including the radio astronomy service (RAS), the Earth exploration-satellite service (EESS), and the space research service (SRS).[8] Passive sensing is based on detection of electromagnetic energy

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[1] *Spectrum Horizons*, Notice of Proposed Rulemaking and Order, 33 FCC Rcd 2438 (2018) (*Notice*).

[2] In the *Notice*, the Commission sought comment on whether to adopt rules for fixed point-to-point operations in ten band segments based on the rules currently in place for the 70/80/90 GHz band and asked whether mobile operations would be appropriate in any of the above-95 GHz bands. *See Notice*, 33 FCC Rcd at 2452, para. 28.

[3] *See Notice*, 33 FCC Rcd at 2451-2, para. 27.

[4] *See, e.g.*, Google Comments at 7-8 (The Commission should wait to adopt service rules for bands above 95 GHz until it has access to sufficient technical and market data to avoid miscalculations that limit developing of other systems and services that better meet consumer and business needs.) Apple Comments at 7-8 (questioning the balance of licensed and unlicensed rules and stating that even high-level allocation decisions can undermine the Commission's goal.).

[5] *See Notice*, 33 FCC Rcd at 2446, para. 11.

[6] *See Notice*, 33 FCC Rcd at 2446, para. 12. In 2014, Japan allocated the 116 -134 GHz band to accommodate such service.

[7] *See Notice*, 33 FCC Rcd at 2447, para. 14.

[8] The passive spectrum services (i.e. SRS (passive), EEES (passive), and RAS) use sensors (i.e. receivers) to access spectrum and do not transmit radio signals. Thus, these stations are not protected by traditional licensing, but are instead generally protected by limiting transmitter energy (e.g., low power levels and/or low out-of-band emissions from adjacent bands) into those frequency bands. Protection requirements are provided in footnotes in the Table of

generated by natural sources, such as the surface of the Earth and its atmosphere.[9] The EESS includes passive radio sensing operations that have many applications in agriculture, weather forecasting, and the study of global changes of the Earth and its environment. Similarly, the RAS is a passive service in which U.S.-based astronomers operate several large single dish telescopes and interferometers, either by themselves or as part of an array, to receive radio waves of cosmic origin in order to try to gain a better understanding of the universe. Frequencies above 95 GHz are particularly well-suited for studies of star formation, the properties of the interstellar medium, the chemical evolution of the universe, detection of extra-solar planets and many other phenomena. In addition to the passive services, there are allocations between 95 GHz and 275 GHz for the fixed satellite, mobile satellite, fixed, mobile, radiolocation, radionavigation, radionavigation-satellite, and inter-satellite services.[10]

5. In the Commission's Table of Frequency Allocations (Allocation Table),[11] the frequency range 95-275 GHz (comprising 180 gigahertz) is divided into 40 frequency bands that are allocated for federal/non-federal shared use.[12] FCC-authorized use of these frequencies is currently extremely limited, consisting of industrial, scientific, and medical (ISM) devices,[13] amateur radio operations[14] in certain small segments of the band, and traditional radio experiments under Part 5 experimental licensing rules. Unlicensed operations of intentional radiators under Part 15 rules are explicitly prohibited in these bands.[15]

6. Many factors informed the *Notice*, including present band uses, the existing record of high-band spectrum proposals and research, recent technical and international developments, and consideration of the engineering issues and propagation characteristics associated with the use of the spectrum. At the same time, the *Notice* acknowledged that we cannot predict what technologies may ultimately develop for operations in these frequency bands. The result was a suite of proposals to: (1)

Frequency Allocations (Allocation Table) (*see, e.g.*, 47 CFR § 2.106 footnote US342) and provisions in our service rules (*see, e.g.*, 47 CFR § 97.303(f)).

[9] Passive sensors detect naturally reflected or radiated energy from the Earth's surface at some altitude above the ground and use the amount of energy emitted, transmitted, or reflected to observe and measure objects from a distance in order to determine certain physical properties of the object. For example, parameters such as temperature and water vapor profiles, and the concentration of ozone and other trace gases that are radiantly and chemically active can be measured regionally and globally only by passive sensors aboard satellites.

[10] The Air Force Research Laboratory operates an active denial system which provides a non-lethal repelling radio frequency effect for the purpose of area denial or perimeter control. The Air Force also operates experimental systems to test millimeter wave radars. These experimental systems provide all-weather video images, similar to electro-optical/infrared (EO/IR) images.

[11] The Table of Frequency Allocations can be found in Section 2.106 of the Commission's rules. 47 CFR § 2.106.

[12] Most of this spectrum between 95 GHz and 275 GHz is allocated on a primary basis to both active (transmitting and receiving) and passive (receive-only) services (106.9 gigahertz); the remainder of this spectrum is allocated on a primary basis either to active services only (39.75 gigahertz) or exclusively to passive services (33.35 gigahertz). Frequencies above 275 GHz are currently unallocated.

[13] ISM equipment is designed for the local generation and use of radio frequency energy for industrial, scientific, medical, domestic or similar purposes, excluding applications in the field of telecommunications. Typical ISM applications are the production of physical, biological, or chemical effects such as heating, ionization of gases, mechanical vibrations, hair removal and acceleration of charged particles. 47 CFR § 18.107(c). ISM operations are permitted in the 122-123 GHz and 244-246 GHz bands (47 CFR § 18.305(a)), subject to the provisions of footnote 5.138, 47 CFR § 2.106, note 5.138.

[14] Amateur radio use is permitted in the 122.25-123 GHz, 134-141 GHz, and 241-250 GHz bands as well as use of frequency bands above 275 GHz. 47 CFR § 97.301(a). *See also* 47 CFR §97.303(c), (e), (f) and (t).

[15] 47 CFR § 15.205 identifies restricted frequency bands where unlicensed devices generally may not operate except as specifically provided elsewhere in the rules. All spectrum above 38.6 GHz is identified as a restricted frequency band.

make 15.2 gigahertz of spectrum available for unlicensed use; (2) create a new category of experimental licenses to increase opportunities for entities to develop new services and technologies from 95 GHz to 3 THz with no limits on technology; and (3) introduce limited licensing for fixed point-to-point operations. These flexible options were driven by a singular objective—to provide incentives and opportunities for investment to spur development of innovative new technologies and services while accounting for and protecting the already extensive and planned passive uses of these bands. While we withhold action on our proposal for licensed fixed point-to-point operations, we find that it is appropriate to move forward with our unlicensed and experimental proposals at this time.

III. DISCUSSION

7. The record developed in this docket is marked by an enthusiasm for the possibilities that the spectrum above 95 GHz holds for short-range applications,[16] but also includes expressions of caution to ensure that we do not diminish the important scientific research that takes place in these frequencies.[17] Taking this record into account, this First Report and Order focuses exclusively on uses that, by their nature, are only permitted to operate on a non-interference basis within the band: experimental operations and unlicensed use. We address each in greater detail, below. By providing new experimental licensing opportunities and making spectrum available for unlicensed use, we are taking the appropriate first steps towards developing the bands above 95 GHz. We expect to gain knowledge from real-world operation that will inform the Commission's future consideration of more expansive use, including non-experimental licensed uses, in these spectrum bands.

A. Spectrum Horizons Experimental Radio Licenses

8. To accelerate the development of new technologies in the spectrum range between 95 GHz and 3 THz, we adopt a new subpart to the existing Part 5 Experimental Radio Service (ERS) rules for a new and unique license type—the Spectrum Horizons Experimental Radio license (or "Spectrum Horizons License"). With their low barriers to entry and minimal costs to obtain, experimental licenses provide an engine for innovation and offer extraordinary flexibility in system design and technical specifications (such as frequency range, power, and emissions) while ensuring that no harmful interference is caused to existing authorized users. The experimental licensing program, which has played a key role throughout the years in the creation of many of the products and services that are now integral parts of the modern communications environment, is a core component of our plan to promote the responsible commercial development of this frequency range.

9. We expect the new Spectrum Horizons Licenses to make experimentation in these bands more attractive, resulting in a greater number of thoughtful and innovative experiments. Such experiments are vital for the development of new applications and services suited for the unique properties of the bands above 95 GHz. These applications and services, in turn, will generate additional interest in these bands and can ultimately provide a basis for the further expansion of permissible uses throughout the frequency range. The Spectrum Horizons License rules will incorporate the proposals that the Commission made in the *Notice.* Specifically, the Spectrum Horizons License will be available for experiments and demonstrations of equipment designed to operate exclusively on any frequency above 95

[16] Potential applications include high-throughput millimeter wave systems as well as devices that can analyze material properties or provide imaging capabilities.

[17] For example, two committees of the Institute of Electrical and Electronics Engineers (IEEE) filed sharply different comments. The IEEE 802 LAN/MAN Standards Committee expresses support for extending the FCC's unlicensed rules and updating the experimental licensing program. IEEE 802 LAN/MAN Standards Committee Comments at 3 (IEEE 802). By contrast, the IEEE Geoscience and Remote Sensing Society, Technical Committee of Frequency Allocations in Remote Sensing raises concerns that the proposed rules could create an environment that could potentially disrupt Earth-exploration satellite service operations. IEEE Geoscience and Remote Sensing Society, Technical Committee of Frequency Allocations in Remote Sensing Comments at 2-3 (IEEE (GRSS)).

GHz.[18] Broad license eligibility rules, along with an extended ten-year license term (the longest of any experimental license), should encourage innovation from the widest variety of stakeholders and produce solid data to support future Commission decisions concerning these bands. Additionally, licensees will be able to request the area(s) of operation for their experiment and will be able to market experimental equipment more widely than currently permitted under the Commission's experimental market trial rules.[19] Collectively, these Spectrum Horizons License features should promote a more rapid development of new products and services that will reach a larger number and wider variety of users than would be possible under the existing experimental licensing rules.[20]

10. While there is enormous potential for new commercial use of frequencies above 95 GHz, we remain cognizant of the important ongoing and planned scientific work in these bands. The nascent state of technology above 95 GHz for commercial applications and the benefits of further long-term studies and research in these bands makes the use of an experimental licensing model especially appropriate here. As with all experimental licenses, the exchange for the flexibility we give researchers to design and conduct experiments and tests is that experimental operations will not be protected from harmful interference from allocated services and they must not cause harmful interference to stations of authorized services, including secondary services.[21]

11. *Available Frequencies*. Applicants for Spectrum Horizons Licenses may request authorization on any frequency within the 95 GHz to 3 THz frequency range. We will not, by rule, preclude the use of any specific frequencies. By adopting this expansive approach to experimental licensing for these bands, we seek to foster an environment where innovators can develop new products and applications absent unnecessary limitations. Given the unique characteristics of these bands, we are hesitant to take any action that may stifle innovation or limit an applicant from developing new and novel methods for coexisting with existing services. We appreciate the important research that is conducted by passive operations in these bands but, as discussed below, find no reason to explicitly prohibit use of these frequencies as long as existing and future operations operating in accordance with the Table of Frequency Allocations are adequately protected.[22]

12. The majority of commenters support the Commission's proposal not to limit experimental applicants' flexibility to request use of any frequency in the bands above 95 GHz.[23] However, the National Academy of Sciences' Committee on Radio Frequencies (CORF) and the National Radio Astronomy Observatory (NRAO) request that we exclude certain bands from consideration or codify additional procedures to protect incumbent licensees in the bands above 95 GHz where passive

[18] Experimental equipment used in conjunction with a Spectrum Horizons License may incorporate transmitters previously authorized by the Commission (e.g., equipment certified for the 5 GHz U-NII bands) but may not include experimental equipment designed to work in bands below 95 GHz.

[19] 47 CFR § 5.602.

[20] Because Spectrum Horizon Licenses have a distinct set of features and are limited to a specific frequency range, they are best characterized as a new type of experimental radio license. Thus, we are not pursuing Boeing's recommendation to "reduce [the] eligibility restrictions for Program experimental licenses" in lieu of creating a new license type. Boeing Comments at 14.

[21] *See* 47 C.F.R. § 5.85. *See also* 47 C.F.R. § 2.102(b)(2) and (3).

[22] Current and planned radio astronomy facilities include: the Smithsonian Astrophysical Observatory Submillimeter Array, James Clerk Maxwell Telescope, Owens Valley Radio Observatory, Arizona Radio Observatory, Haystack Radio Telescope, the Next Generation Very Large Array, and the Stratospheric Observatory for Infrared Astronomy.

[23] *See* Apple Comments at 7, Ericsson Comments at 20, Facebook Comments at 5, Google Comments at 4, Starry Comments at 8.

services have primary status.[24] NRAO opposes experimental use of bands protected by US246 and RR No 5.340,[25] and opposes operation under a too-strict "cloak of secrecy." More specifically, NRAO requests that proposed experimental use would be subject to a compatibility study and a coordination process at the NTIA, that specific technical parameters, including the number of devices, be disclosed and that license terms be limited.[26]

13. We find that a blanket prohibition is not necessary here. All bands between 95 GHz and 275 GHz are allocated on a shared basis for federal and non-federal use. Above 275 GHz, there are no allocations, but a number of bands are identified for use by passive services in footnote US 565.[27] Spectrum Horizons Licenses in this range will only be granted on a non-interfering basis, only following coordination with federal users (including bands identified/allocated for passive services) through the NTIA and the IRAC process,[28] and unless a sufficient methodology for preventing harmful interference is detailed, such operations will not be permitted.[29] While we will not require any specific compatibility analysis, we will require, as proposed, any application for a Spectrum Horizons License to include, as a prerequisite to grant, a narrative statement that sufficiently explains the proposed new technology/potential new service and an interference analysis.[30] Contrary to NRAO's assertion that our proposal provides applicants a "cloak of secrecy," we note that certain parameters of experimental license applications are required to be disclosed publicly, including frequency(s), types of emissions, power, and location. We are not making any exception here.[31] Thus, interested Federal parties will have full information available to evaluate whether proposed experimental licenses are compatible with existing federal operations.

14. Moreover, Spectrum Horizons License applicants that propose to use spectrum exclusively allocated for passive use(s), must provide an explanation why nearby bands with non-passive allocations are not appropriate or adequate for the experiment and also acknowledge that they intend to

[24] CORF Comments at 29-30; NRAO Comments at 3 (further noting that absent changes to US246, devices developed in the listed bands could never be routinely authorized, and such devices would not meet international standards).

[25] US246 and RR 5.340 prohibit the use of certain passive service bands, including several above 95 GHz. The bands identified above 95 GHz in US246 and RR 5.340 are identical. *See* 47 CFR §2.106, US246 and 5.340.

[26] NRAO Comments at 3-4. *See also* CORF comments at 29-30 (seeking exclusion of certain bands from consideration for experimental licenses).

[27] Passive uses in the 275-1000 GHz range do not preclude use of these frequencies by active services. However, ITU studies have identified certain segments as usable by fixed and mobile services under certain conditions with minimal risk of causing harmful interference to passive services.

[28] *Notice,* 33 FCC Rcd at 2470, para. 77; These requirements are the same as those applicable to current experimental licensees. *See* 47 CFR § 5.85(a). The basic functions of the IRAC are to assist the Assistant Secretary in assigning frequencies to U.S. Government radio stations and, with respect to such stations, in developing and executing policies, programs, procedures, and technical criteria pertaining to the allocation, management, and use of the electromagnetic spectrum. *See* https://www.ntia.doc.gov/page/interdepartment-radio-advisory-committee-irac.

[29] The mmW Coalition is concerned that the current IRAC coordination process "effectively gives a government agency the ability to veto an experimental application regardless of whether there is any potential for real-world interference to government spectrum users." mmWave Comments at 9-10. The mmW Coalition urges NTIA to require IRAC participants to show, within a reasonable timeframe, that the proposed experimental license will have an adverse impact on the operations of federal systems. *Id.* We note that the FCC/NTIA coordination as agreed to in the Memorandum of Understanding between the two agencies is conducted via the IRAC process and any consideration of changes to the established process is beyond the scope of this proceeding. With respect to showing a sufficient methodology for preventing harmful interference, we note that parties are always free to seek guidance

transition any potential long-term use to a band with appropriate allocations.[32] We are adopting this approach rather than prohibiting use of the passive bands because we do not want to unnecessarily hobble valuable research in situations that pose no significant risk to incumbent operations. The coordination of experimental use of the passive frequencies through the IRAC process will provide an opportunity for dialogue between affected parties and applicants which in many cases will provide a path for coexistence with the passive services.

15. ARRL opposes the issuance of Spectrum Horizons Licenses in two bands with primary amateur radio allocations — 134-136 GHz and 248-250 GHz bands, claiming it would be difficult for an applicant to demonstrate non-interference with amateur radio and radio astronomy operations, both of which rely on an RF environment with low noise levels.[33] Alternatively, absent an outright prohibition, ARRL suggests that such applications be coordinated with it in a manner similar to NTIA's IRAC coordination process.[34] Further, ARRL suggests that Spectrum Horizons License applicants notify it of the intent to commence operations in three bands with secondary amateur allocations — the 122.5-123 GHz, 136-141 GHz and the 241-248 GHz bands — because of potential increase in the noise floor that would make it difficult to locate the source of interfering signals or to differentiate such signals from ISM devices.[35]

16. As with the passive bands, we will not adopt a rule precluding use of the bands allocated for amateur use or impose blanket special coordination procedures in such bands. Given that both the amateur radio service and the experimental licensing program are designed to contribute to the

from the FCC and/or discuss their specific proposals with incumbent operators prior to filing an application. *See* Letter from Prof. Josep M. Jornet to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-21 (filed March 4, 2019).

[30] *See* Appx. A, § 5.702. The analysis will be coordinated with the federal agencies through the IRAC process, where the affected agencies will have an opportunity to review and comment on as necessary to ensure federal spectrum use is not subject to harmful interference.

[31] We note that, similar to all other ERS licensees, holders of Spectrum Horizons Licenses will be allowed to request that portions of their filings (applications, request for modification and interim reports) be considered confidential. See 47 CFR § 5.63(b) (citing procedures for requesting confidentiality under 47 CFR § 0.459.). We would not generally consider basic technical data (e.g., frequency bands, maximum power, emission designators, areas of operation including latitude and longitude, etc.) to be "proprietary information" nor would we expect that it would be routinely withheld.

[32] 47 CFR § 5.85(a)(2). NRAO asserts that the prohibition of US 246 would make it difficult to obtain a permanent authorization on such frequencies and suggests that applicants should be required to address their plans for the device after the conclusion of the experiment. NRAO Comments at 3.In contrast, the mmWave Coalition urges the Commission to "begin discussions with NTIA to examine [less restrictive] alternative formulations of US 246." Letter from Prakash Moorut, Chair of Steering Group, mmWave Coalition, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-21 (filed March 5, 2019) (mmWave Coalition March 5 Ex Parte). We believe that NRAO's concerns are sufficiently accounted for by the aforementioned rule section and that any additional requirements for

advancement of radio knowledge,[36] we see value in continuing to allow licensed operations under both Parts 5 and 97 of our rules because doing so supports the objectives that are common to both rule parts. We reject ARRL's proposals as both overly restrictive and counterproductive to this objective and we will instead require all Spectrum Horizons License applicants to submit an interference analysis that would address the potential effects of the experimental operation on existing services. These interference analyses are intended to provide adequate information to allow the Commission to make an informed decision on the propriety of granting a Spectrum Horizons License and whether any conditions, such as coordination requirements, should be imposed in the circumstances of a particular case. Furthermore, these analyses will contain as much or more information than ARRL would have received under its notification proposal, and they will allow the Commission to evaluate experimental license applications while considering the potential for interference to authorized services. As a practical matter, we expect parties to seek experimental use of these bands only if the frequencies hold unique characteristics of value to their research and experiments, given that other frequencies will likely be available for use with significantly lower risk that the Commission will impose special conditions on the authorization grant. Accordingly, we decline to adopt any unique requirements for use of the bands allocated for primary or secondary amateur use.

17. Finally, the rules provide that the Commission may, at any time without notice or hearing, modify or cancel a Spectrum Horizons License, if, in its discretion the need for such action arises.[37] Some commenters express concern that parties could abuse the complaint process and discourage experimentation for non-technical reasons.[38] We note that cancelling a license is an action of "last resort"[39] and the Commission routinely works with parties to resolve potential or actual issues prior to issuing an experimental license or in rare instances of actual interference, by authorizing modifications that allow for interference-free operations.

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the frequencies specified in US246 are unwarranted. As for the mmWave Coalition's suggestion that we take steps to modify US 246, such an initiative is beyond the scope of this proceeding.

[33] ARRL Comments at 5.

[34] *Id.* (suggesting that Spectrum Horizons License applicants for these bands be required to demonstrate convincingly that there are no other allocations that would be suitable for the specific experiment, and coordinate with ARRL at the time of filing the application, to ensure that there is no conflict with ongoing or planned amateur radio or amateur-satellite operations). *See also* Robert Bosch Comments at 10-11 (suggesting both public announcements, either by the Commission or by the holder of the Spectrum Horizons License, and coordination with local incumbents prior to commencement of the experimental operations).

[35] ARRL Comments at 8-9 (alternatively suggests that the Commission maintain a public database of outstanding Spectrum Horizons experimental authorizations, the frequency ranges, operating locations and file numbers, so that interference sources can be located).

[36] 47 CFR §§ 5.3(a)-(e), (j) and 97.1(b). *See also* ARRL Comments at 4 (stating its interest in "preserv[ing] the ability of radio Amateurs to continue experimentation … in these allocations").

[37] 47 CFR § 5.83(b).

[38] mmWave Coalition Comments at 10-11 (requesting that this provision apply to Spectrum Horizons licenses only in cases of actual interference and permit appeal of interference determinations; failing to provided such a procedural safeguard to protect experimental licensees who invest significant sums of money in developing technologies would undo the benefits of the greater certainty provided under the proposed rules); *see also* Google Comments at 5-6 (Spectrum Horizons licensees "should only be obligated to remedy actual cases of harmful interference, and incumbents and other experimental licensees should not be allowed to use worst-case predictions of potential interference to block a Spectrum Horizons license; nor should a Spectrum Horizons license be

18. *Eligibility*. We will make Spectrum Horizons Licenses broadly available to persons qualified to conduct the types of operations described in existing experimental radio service rules.[40] Our rules in this regard have enabled a wide variety of businesses and individuals with spectrum experience and knowledge to develop new products and services. We believe these same eligibility requirements will similarly encourage widespread experimentation in the bands above 95 GHz while providing adequate safeguards that such experimenters have the knowledge necessary to ensure incumbent services are protected from harmful interference.[41]

19. We will evaluate applicants' qualifications as part of the general application process and seek any additional necessary information on an application-by-application basis. TIA suggests that Spectrum Horizons License applicants be required to establish their eligibility for these licenses by including a description of their technical qualifications and prior experience in RF issues with their application unless they already meet the specific eligibility categories associated with an Experimental Program License.[42] We reject this proposal because incorporating specific eligibility exhibit requirements into the Spectrum Horizons License rules would be overly prescriptive for a band whose users and use models are still evolving and the general application process gives us ample flexibility to consider each applicant's qualifications on a case-by-case basis.

20. *License Term and Interim Reporting Requirements*. We adopt the Commission's proposal to authorize Spectrum Horizons Licenses for the longest license term—ten years—of any experimental license to encourage entrepreneurs to invest in this largely untested spectrum, and yield more useful long-term information and data in support of subsequent rulemaking activity or waiver requests for operations in these bands.[43] While some commenters are concerned that longer license terms could affect the licensees' ability to maintain control of their experiments,[44] we believe that a single ten-year grant issued under the conditions outlined above, as opposed to a five-year grant with an expectation of renewal, is less burdensome and more efficient for both the licensees and the Commission. We will not provide for the renewal of a Spectrum Horizons License, as ten years is sufficient time to determine whether the experimental operations provide adequate support for licensees to determine the feasibility of authorizing their experimental devices for more permanent use through a petition for rulemaking or waiver request..[45] However, we note that there are no assurances that experimentation will lead to the

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retroactively limited or terminated based on allegations of interference, without clear technical showings of harm as well as causation").

[39] The cancellation of an ERS license is subject to a petition for reconsideration or an application for review. *See* 47 CFR §5.83(b).

[40] 47 CFR §§ 5.3, 5.51. *See Notice*, 33 FCC Rcd at 2470, para. 76.

[41] *See* Boeing Comments at 14-15 (stating there is not a risk that unqualified parties would secure experimental authorizations because "[t]he Commission's application review process for experiential licenses … effectively ensures that only qualified parties (*i.e.*, those who are sufficiently competent to prepare a credible technical showing) are granted experimental licenses").

[42] TIA Comments at 2-3. The following entities are eligible for program licenses: a college or university with a graduate research program in engineering that is accredited by the Accreditation Board for Engineering and Technology (ABET); a research laboratory; a hospital or health care institution; a manufacturer of radio frequency equipment; or a manufacturer that integrates radio frequency equipment into its end product. *See* 47 CFR § 5.302.

[43] *Notice*, 33 FCC Rcd at 2471, para. 79.

[44] *See* Boeing Comments at 16-17; Boeing Reply at 7-8 (suggesting that license terms should not be extended beyond 7 or 8 years as ten years would be a long time to go without interaction between the licensee and the Commission; but noting that an interim reporting requirement would mitigate some of these concerns).

[45] The Commission did not propose, and we are not adopting a requirement for licensees to submit a final report. If the experiment leads to a petition for new service rules or a waiver request, we expect that such data would be provided to the Commission at that time to support such requests. *See* Google Comments at 6-7.

establishment of an authorized service.

21. We adopt the Commission's proposal to require licensees to submit an interim report on the progress of the experiment no later than five years from the date of grant.[46] Given the expected wide variety of innovative experiments in the bands above 95 GHz, these interim reports will enable the Commission to be more aware of ongoing technological developments as it contemplates rulemaking proposals, and will allow the public to better assess innovative uses of the bands and encourage further experimentation.

22. *Geographic Area*. A Spectrum Horizons License may be authorized over any geographic area. Consistent with current practice for experimental licensing, applicants will be able to request operations over any area they deem appropriate for their experiment, and the Commission may impose limitations on the geographic extent of a license based on circumstances including recommendations based on consultation with NTIA. The City of New York expressed concerns that nationwide licenses could be difficult to monitor and control.[47] TIA comments that because the bands above 95 GHz are most likely unsuitable for very-long-distance (inter-city) communications, it would not object to wider-area experimental applications being granted after a sufficient showing and/or through a waiver process.[48] We find that such concerns are best addressed on a case-by-case basis and do not warrant the adoption of a blanket rule imposing geographic area restrictions for Spectrum Horizons Licenses.[49] Applicants have the burden of justifying their intended experimental operations, including the geographic area over which they intend to operate and any methods for avoiding causing harmful interference to other spectrum users. Thus, we will consider and authorize, as appropriate to each license, any geographic area applied for and sufficiently justified, and impose any limits as needed.

23. *Marketing*. Lastly, we adopt our proposal to give Spectrum Horizons licensees greater flexibility to market devices than what is currently permitted under the existing experimental licensing rules. Under the rules we adopt, we will permit licensees to market experimental devices designed to operate in the bands above 95 GHz via direct sale. These rules diverge from the existing market trial rules which only permit devices to be sold to other holders of experimental licenses or to lease devices to trial participants, by allowing direct sales to members of the general public.[50] In the *Notice*, the Commission observed that devices in this frequency range are likely to be more expensive to produce and it is unlikely that they could easily be derived from existing lower-band equipment.[51] Thus, we are encouraging experimenters to overcome these challenges by permitting device sales, which can allow early adopters and other eager trial participants to help offset the costs of developing systems and equipment for use above 95 GHz. Additionally, we will not limit the number of devices a licensee can

[46] *Notice,* 33 FCC Rcd at 2471, para. 79. *See* Appx. A, § 5.705. We note that this section was inconsistently referred to as "Supplemental report" in the proposed Part 5, subpart I table of contents entry included in the *Notice.* This section will be properly referred to as "Interim report" in the adopted table of contents. *See* Qualcomm Comments at 11; Google Comments at 6-7; mmWave Coalition Comments at 10-11 (supporting our overall Spectrum Horizons experimental license proposal).

[47] City of New York Reply at 2 (objecting to any loosening of restrictions on licenses and "at a minimum" wants the Commission to adopt geographic limits and other appropriate provisions to protect users in densely populated areas, to ensure that experimental licenses are carefully monitored, and their license terms are strictly enforced).

[48] TIA Comments at 3-4 (though seeking a geographic area limitation for wideband experimental licenses so that other applicants may experiment in different cities, it is not objecting to wider-area experimental applications being granted after a sufficient showing and/or through a waiver process).

[49] *See Notice,* 33 FCC Rcd at 2470-71, para. 78.

[50] *See* 47 CFR § 5.601.

[51] *Notice*, 33 FCC Rcd at 2469-70, paras. 72-75.

market as part of the experiment.[52] We offer this added marketing flexibility because the characteristics of signals in the bands above 95 GHz effectively limit the range of each device to such an extent that a larger number of devices can operate without increasing the potential of harmful interference to authorized services.

24. We proposed and are adopting measures to ensure that licensees are able to exhibit control over their equipment. We will require licensees to ensure that trial devices are either rendered inoperable or retrieved at the conclusion of the trial.[53] Additionally, each device sold under this program must be labeled as "Authorized Under An Experimental License and May be Subject to Further Conditions Including Termination of Operation" and carry with it a licensee-assigned equipment ID number.[54] While the rules do not include a specific format for the identifying data,[55] licensees who take advantage of these marketing provisions should uniquely identify each device (e.g., through a serial number) in a manner that would enable them to easily track each one. Moreover, at the time of sale, the licensee will be required to provide trial participants with a written disclosure that clearly states that the equipment being purchased is part of an experiment that may be terminated at any time by the licensee or the Commission, and the device will be surrendered or rendered inoperable at the conclusion of the experiment.

25. These actions are supported by many parties.[56] Nevertheless, Boeing expressed concern that the flexible marketing rules will result in licensees losing control of the experiment or market trial, particularly if the number of devices marketed is not limited, resulting in interference that may be difficult to eliminate.[57] We disagree. The requirements we are adopting provide multiple layers of tracking and control that extend beyond what it is traditionally required of experimental licensees and are sufficiently robust to encourage more widespread experimentation while minimizing the potential for harmful interference from untracked devices. NRAO stresses that the "existence and expected number of each type of experimental device should be made known."[58] We are not persuaded that NRAO's approach would serve the public interest. The maximum number of devices a licensee may deploy for an experiment does not necessarily reflect the actual number of devices deployed; nor does it represent the density of devices in any particular geographic area. Thus, such information provides no benefit in preventing potential harmful interference, while at the same time increases the burden on experimental operations. As noted above, the purpose of the flexible Spectrum Horizons Licenses is to incentivize the development of novel technologies for use above 95 GHz while preventing instances of harmful interference to other spectrum users, thus providing the Spectrum Horizons Licensees with the opportunity to explore the real market opportunities before they approach the Commission with petitions

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[52] Existing experimental market trial rules require licensees to limit the number of devices in a market trial to the minimum quantity necessary. *See* 47 CFR § 5.602(d)(3).

[53] *Notice,* 33 FCC Rcd at 2469-70, paras. 74-75.

[54] As with other devices operated under an ERS license, devices operated in accordance with a Spectrum Horizons license will be covered by the exception to our Part 2 equipment authorization rules that allows use and marketing of such devices without an equipment authorization. *See* Appx. A (§ 2.803((c)(1)). Absent an equipment certification requirement, these devices will not be required to be associated with a Commission-generated FCC identifier. *See* 47 CFR § 2.926. *See also* Appx. A, § 5.704.

[55] *See* Appx. A, § 5.704(b).

[56] *See* Apple Comments at 4 (adopting the Commission's flexible proposals will help spur innovation in the band), Facebook Comments at 5 (supporting the Commission's proposals), Starry Comments at 8 (establishing a new type of license for bands above 95 GHz can enhance the technological development of these bands), Qualcomm Comments at 11 (noting that the proposed modifications to the licensing rules will spur innovative wireless services), Google Comments at 4 (the proposed licensing rules are an appropriate mechanism to achieve greater opportunity for bands above 95 GHz); mmWC Comments at 8-9.

[57] Boeing Comments at 16-19.

[58] NRAO Comments at 4.

for rulemaking to establish service rules.

26. As with other experimental license applications, applicants for a Spectrum Horizons License will be required to show how the experimental operations (and any related devices) will be controlled so that they do not cause harmful interference to other services. Further, as with all experimental licenses, Spectrum Horizons License operations will not be entitled to exclusive use; will not be protected from harmful interference from allocated services; and will be prohibited from causing harmful interference to stations of allocated services.[59] In addition, the Commission has broad authority to place specific conditions on experimental licenses to minimize the risk of causing harmful interference to incumbent spectrum users. Similarly, NTIA's Interdepartment Radio Advisory Committee (IRAC) may recommend license conditions to the extent the frequencies in question are shared as part of a co-primary allocation for federal and non-federal use.[60] For example, operations can be limited to specific geographic areas, frequencies and power levels. Additional limitations can include indoor-only operation or notification or coordination requirements. We will not impose specific requirements by rule on Spectrum Horizons licensees regarding how to control their experiment, but we do point out that the licensee remains responsible to ensure compliance with our rules. The application review process as well as any additional conditions placed on these licenses will ensure the integrity of experimental operations above 95 GHz and address Boeing's and NRAO's concerns.

B. Unlicensed Operations

27. Following our evaluation of the record, we free up 21.2 gigahertz of the Spectrum Horizons bands for unlicensed use: the 116-123 GHz band, the 174.8-182 GHz band, the 185-190 GHz band, and the 244-246 GHz band.[61] In the *Notice*, the Commission sought comment on whether it should allow unlicensed operations in these bands under technical parameters similar to those for unlicensed operation in the 57-71 GHz band.[62] A number of commenters support unlicensed operation in these bands at the power levels we proposed in the *Notice*.[63] Several parties express concern about the potential for unlicensed operation to cause interference, but as explained below, unlicensed devices can operate in these frequency bands at the power levels we proposed in the *Notice* without causing harmful interference to services in these or adjacent bands.[64] For example, spectrum users, including passive services, must

[59] 47 CFR § 5.84.

[60] *See* paras 12-14, *supra.*

[61] We are modifying Section 15.205, which generally prohibits unlicensed operation above 38.6 GHz, to reflect the availability of these bands for unlicensed devices.

[62] *Notice*, 33 FCC Rcd at 2461-62, paras. 52-54. The Commission sought comment on whether it should allow unlicensed operation in the 122-123 GHz, 174.8-182 GHz, 185-190 GHz and 244-246 GHz bands. The Commission also sought comment on whether it should permit unlicensed devices to operate in the 116-122 GHz band due to its adjacency to the 122-123 GHz ISM band. *Notice*, 33 FCC Rcd at 2463, para. 57.

[63] Telecommunications Industry Association Reply Comments at 8 (TIA Reply)(expressing general agreement with the Commission's proposal); Consumer Technology Association Comments at 7-8 (CTA) (the proposed bands are well suited for unlicensed operation because two of them are ISM bands, and the other two are in a frequency range with high atmospheric attenuation); Qualcomm, Inc. Comments at 10 (Qualcomm) (supports operation in the four proposed bands subject to technical requirements similar to those for the 57-71 GHz band); IEEE 802 Comments at 2 (supports operation in the four proposed bands subject to technical requirements similar to those for the 57-71 GHz band, although the Commission should consider even higher power, and supports operation in the 116-122 GHz band); Robert Bosch LLC Comments at 5, 9 (Bosch) (the Commission should permit Part 15 operation in the 122-123 GHz and 244-246 GHz bands for radiodetermination applications and should permit operation in the 116-122 GHz band); CTIA Comments at 12-13; Charter Communications, Inc. Reply Comments at 8 (Charter); and Starry, Inc. Comments at 7 (Starry). The Boeing Company offered qualified support for unlicensed operation in the 116-122 GHz band, provided "passive services in these frequencies can be adequately protected." The Boeing Company Comments at 11-12 (Boeing).

[64] CORF Comments at 20; NRAO Comments at 6; IEEE GRSS Comments at 2-3.

already accept interference from high power industrial, scientific, and medical (ISM) equipment designated for operations in the 122-123 GHz and 244-246 GHz bands.[65]

28. The bands made available for unlicensed devices are summarized in the table below. These devices would operate on a non-interference basis while protecting both passive and active services. Most notably, several bands contain or are adjacent to passive Earth exploration-satellite service and radio astronomy service allocations. We recognize that these services require stringent protection levels and are the primary focus of the discussion below. The space research service is also passive, but as explained more fully below, because stations in this service are space-based and looking away from Earth, there is no risk of harmful interference from unlicensed devices. There are also a number of active service allocations in the bands we are identifying for unlicensed use. Some, such as the fixed service, the mobile service and the radiolocation and radionavigation services cannot be deployed because there are no service rules in place. Thus, protection criteria need not be adopted at this time.[66] The inter-satellite service also does not have service rules in place but has been permitted to operate on a case-by-case basis.[67] Like the space research service, the inter-satellite service operates solely between satellites in space and therefore there is no significant risk of harmful interference from relatively low power unlicensed devices operating on the Earth, even if terrestrial operations were to occur in high volumes. In addition, the amateur radio service is permitted to operate in the 122.5-123 GHz band, and as discussed below is unlikely to receive interference from unlicensed operations in that band.[68] Finally, the 122-123 GHz and 244-246 GHz bands are also allocated for ISM equipment. As such, all authorized services (regardless of whether they are active or passive) operating inside those bands cannot claim protection from ISM emissions. Further, the rules do not limit the emissions levels from ISM equipment in these bands.[69] Therefore, radio astronomy and other passive services cannot reasonably expect a lack of emissions in these bands. Thus, for the 122-123 GHz and 244-246 GHz bands, lower power unlicensed devices should have no significant impact on these passive operations as long as their emissions are confined within those bands.

Table 1: Frequency Bands Designated for Unlicensed Use and Adjacent Bands(1)

Band (GHz)	Included in New Part 15.258	Current Allocation
114.25-116		EARTH EXPLORATION-SATELLITE (passive) RADIO ASTRONOMY SPACE RESEARCH (passive)
116-122.25	Yes	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive) Industrial Scientific and Medical (122-123)(2)
122.25-123	Yes	FIXED/MOBILE/INTER-SATELLITE Amateur Industrial Scientific and Medical (122-123)(2)

[65] 47 CFR § 18.111(c) and (d).

[66] The Commission will consider whether and what protection criteria are necessary to protect these primary services in connection with consideration of the need for service rules for these services.

[67] 47 CFR § 25.202(b).

[68] 47 CFR §§ 97.303 (sharing requirements), 97.305 (emission types), 97.307 (emission standards) and 97.313 (power standards).

[69] 47 CFR § 2.106, footnote 5.138 and 47 CFR § 18.301. The Commission's rules permit unlimited radiated energy in designated ISM bands. 47 CFR § 18.305(a).

123-130		FIXED-SATELLITE ↓ MOBILE-SATELLITE↓ RADIONAVIGATION RADIONAVIGATION-SATELLITE Radio astronomy
. . .		
174.5-174.8		FIXED/MOBILE/INTER-SATELLITE
174.8-182	Yes	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive)
182-185		EARTH EXPLORATION-SATELLITE (passive) RADIO ASTROMONY SPACE RESEARCH (passive)
185-190	Yes	EARTH EXPLORATION-SATELLITE (passive) INTER-SATELLITE SPACE RESEARCH (passive)
190-191.8		EARTH EXPLORATION-SATELLITE (passive) SPACE RESEARCH (passive)
. . .		
241-248	Yes (244-246)	RADIO ASTRONOMY RADIOLOCATION Amateur/Amateur-satellite Industrial Scientific and Medical (244-246)(2)
248-250		AMATEUR/AMATEUR-SATELLITE Radio astronomy

[1]Primary allocations are shown in all caps; secondary allocations are shown in lower case.
[2]The 122-123 GHz (center frequency 122.5 GHz) and 244-246 GHz (center frequency 245 GHz) bands are designated for ISM equipment. ISM equipment is not subject to any limits on radiated energy within these bands.

29. We will not, at this time, provide additional frequency bands for unlicensed device operation above 95 GHz beyond the 21.2 gigahertz designated above.[70] Our efforts in this First Report and Order provide a considerable amount of spectrum for unlicensed use in multiple bands that is sufficient to enable development of new unlicensed devices and applications. Moreover, the Commission may reassess the spectrum allocations based on how uses of this spectrum develop and revisit this issue at a later date.

30. In the discussion below, we address the concerns raised in the record regarding interference protections for incumbent radio services. Our discussion is informed by the characteristics of the frequencies above 95 GHz — in particular, the generally high propagation losses in these bands, the high losses due to atmospheric effects at specific frequencies, as well as the tendency of objects in the transmission path to block signals at these frequencies and prevent them from reaching and thus causing

[70] Bosch, the only commenter suggesting a specific band not addressed in the *Notice,* did not provide sufficient detail for the proper consideration of its proposal. *See* Bosch Comments at 9-10 (suggesting ultrawideband radiodetermination use in the 123-140 GHz band to facilitate international harmonization of product development).

harmful interference to authorized service receivers.[71] First, we address interference protections for passive observations made in the radio astronomy and Earth exploration-satellite services in these bands. Then, we address interference protections for other allocations and services, including the space research service and the amateur radio service. Finally, we adopt technical rules for unlicensed devices to minimize the risk of causing harmful interference to the various radio services.

1. Protection of Radio Astronomy

31. We find that unlicensed devices can co-exist with radio astronomy in the same and adjacent spectrum bands above 95 GHz because of factors such as the high atmospheric losses associated with these frequency bands and the use of highly directional antennas. As shown in Table 1, the only frequency band in which unlicensed devices will be permitted to operate co-channel with radio astronomy is 244-246 GHz. The other bands being made available for unlicensed devices are adjacent to radio astronomy allocations. As noted above, the 244-246 GHz band is also designated for use by ISM devices which are not subject to field strength limits within the band – unlicensed devices would operate at significantly lower power levels than ISM devices.[72]

32. CORF asserts that the Commission should take several measures to protect radio astronomy observations. It argues for indoor use of unlicensed devices operating in the 244-246 GHz band to minimize the risk of potential interference.[73] It also argues that out-of-band emissions must not exceed the levels specified in ITU Recommendation RA.769 to protect adjacent band radio astronomy observations.[74]

33. CORF, using the protection values and analysis procedures of ITU Recommendation RA 769 claims that the separation distances for two radio astronomy sites – Kitt Peak, Arizona and Manua Kea, Hawaii – operating co-channel with unlicensed devices could be as large as 61 and 121 kilometers respectively.[75] However, CORF's analysis assumes 12 dB more power for unlicensed operations than

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[71] Frequencies in this range are best suited to short range applications as they experience large propagation losses as well as losses from water vapor absorption as well as blocking and scattering from foliage, rain, buildings and other objects. *See, e.g.,* Rappaport, Theodore S., *et. al., Wideband Millimeter-Wave Propagation Measurements and Channel Models for Future Wireless Communication System Design*, IEEE Transactions on Communications, Vol. 63, No. 9, September 2015, pg. 3029 ("Only at certain frequency bands, such as 60, 180, or 380 GHz, do molecular resonances create high atmospheric attenuation causing signals to attenuate much more rapidly with distance than today's UHF/microwave bands. These specific high attenuation mmWave bands will be better suited for local or personal area communications, or 'whisper radios' with coverage distances of a few meters (m)") and Pi, Zhouyue, *et. al*., *An introduction to millimeter-wave mobile broadband systems*. IEEE Communications Magazine, Vol. 49, Iss. 6, pgs 101-107 ("The absorption rate by water vapor (H_2O) depends on the amount of water vapor and can be up to tens of dBs in the range of 164–200 GHz [4]. … the transmission range in these bands will be limited." "While signals at lower frequencies can penetrate more easily through buildings, millimeter wave signals do not penetrate most solid materials very well." "Foliage losses for millimeter waves are significant and can be a limiting impairment for propagation in some cases." "Millimeter-wave transmissions can experience significant attenuations in the presence of heavy rain.").

[72] 47 CFR § 18.305(a).

[73] The National Academy of Sciences' Committee on Radio Frequencies Academy of Sciences' Committee on Radio Frequencies Comments at 20 (CORF) (pointing to section 15.257 of the Commission's rules for 92-95 GHz devices). CORF states that the band 244-246 GHz is used for observations of rotational transitions of carbon monosulfide. It suggests that unlicensed operations in the band be restricted to indoor locations in a manner similar to the requirements for unlicensed devices in the 92-95 GHz band in Section 15.257(a). CORF Comments at 19-20.

[74] *See* CORF Comments at 17-19. CORF states that ITU Recommendation RA.769 specified protection levels ranging from -208 dBW/m^2/Hz to -199 dBW/m^2/Hz. *See also Protection criteria used for radio astronomical measurements*, Recommendation ITU-R RA.769-2 (05/2003).

what the rules we are adopting would allow.[76] If the analysis is adjusted to reflect the appropriate power level for unlicensed devices the separation distances would be reduced by a factor of four. Furthermore, we anticipate that unlicensed devices operating at frequencies above 95 GHz will employ highly directional antennas, similar to operations in the 70/80/90 GHz bands, to compensate for the extreme path losses at these frequencies. Moreover, such operations can be expected to be line-of-sight because intervening objects and terrain would effectively block the transmissions. In addition, radio astronomy observation sites for these frequencies utilize very large antennas that are generally located in remote areas far away from any other potential sources of radio noise[77] which also tend to be far away from locations where unlicensed devices usually operate.[78] Further, because we are only allowing terrestrial unlicensed use in these bands,[79] terrain and clutter will also attenuate signals to such an extent that they would not reach radio astronomy sites. Under the normal operating configuration where radio telescope antennas making astronomical observations look skyward, the antenna discrimination inherently provides significant interference protection from unlicensed device operations located near or on the horizon.[80] However, in instances where radio astronomy receivers do operate from horizon to horizon as described in ITU-R S.1586-1,[81] the high atmospheric losses[82] in conjunction with the factors discussed above will significantly reduce the potential of harmful interference to co- and adjacent channel radio astronomy operations in the 244-246 GHz band without limiting such operations to indoor usage.[83] We recognize that the bands above 95 GHz are largely uncharted territory and we will require unlicensed users to protect primary radio astronomy use against harmful interference, address promptly any complaints of harmful interference, and revisit the rules, if warranted, in the future as technology and applications develop in this region of the spectrum.

34. With respect to bands where unlicensed devices would transmit adjacent to radio astronomy operations, NRAO asserts that unlicensed operations should be coordinated with radio observatories. NRAO calculates separation distances as large as 17 kilometers within which it states coordination would be necessary.[84] We disagree that the large separation distances and corresponding coordination requirements suggested by NRAO are needed, not only for the reasons discussed above, but

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[75] Separation distance is the required distance between a potential source of interference and a receiver such that the source does not cause interference to the receiver, as defined by the receiver's interference threshold.

[76] CORF assumes a power 25 dBW/MHz for unlicensed devices. *See* CORF Comments at 17. Our rules will only permit a maximum peak power of 43 dBm for unlicensed devices. *See* Appx. A, § 15.258(a)(1). We are only considering the power levels for non-point-to-point systems as CORF acknowledges the low probability of main beam to main beam coupling between point-to point-systems and radio astronomy receivers. *See* CORF Comments at 17-18.

[77] The Green Bank Telescope (Green Bank, West Virginia) is located in the National Radio Quiet Zone (an area of approximately 34,000 km^2), in which radio transmission are restricted so as to minimize possible impact to the radio astronomy service. *See* 47 CFR § 1.924.

[78] CORF cites the following eight observatories that currently observe or have plans to observe signals in these bands: The Smithsonian Astrophysical Observatory Submillimeter Array and the James Clerk Maxwell Telescope, both located atop Mauna Kea in Hawaii; the Owens Valley Radio Observatory located near Bishop, California; Arizona Radio Observatory located at Kitt Peak and Mt. Graham in Arizona; the Haystack Radio Telescope located near Westford, Massachusetts; the Green Bank Telescope located in Green Bank, West Virginia, the Next Generation Very Large Array located at sites across New Mexico, Texas, and Mexico; and the Stratospheric Observatory for Infrared Astronomy designed to operate high in the atmosphere. CORF Comments at 14-15.

[79] *See* Appx. A., § 15.258(a).

[80] For example, an antenna operating at 116-122 GHz that has a gain of 60 dB looking skyward will have a gain of approximately -27 dB towards the horizon. Following the methodology of NRAO, but using our assumption of antenna horizon gain, the resulting separation distance from a radio astronomy receive antenna ranges from 0.35 km to 0.98 km, a distance that is within the property lines and the control of radio astronomy observatories.

[81] Recommendation ITU-R S.1586-1 *Calculation of Unwanted Emission Levels Produced by a Non-Geostationary Fixed-Satellite Service System at Radio Astronomy Sites* (2002-2007) at 4.

also because we are adopting stringent out-of-band emission limits.[85] Further, a radio observatory site can determine if unlicensed devices operating on its property would cause harmful interference and take measures, such as posting signs, to control such usage within their property.

35. The ability for unlicensed devices to share spectrum with radio astronomy operations in these bands comes into clearer focus when considering the significant propagation losses in these bands. For example, free space path loss over 30 meters at 122 GHz and 244 GHz is 104 dB and 110 dB, respectively.[86] The high propagation and atmospheric absorption losses at 122 GHz and 244 GHz when combined with other factors will significantly reduce the likelihood of harmful interference to the radio astronomy service.[87] For all the reasons specified, we believe unlicensed device operations can co-exist with radio astronomy operations in the specified bands.

2. Protection of Earth Exploration-Satellite Service

36. CORF and IEEE Geoscience and Remote Sensing Society, Technical Committee of Frequency Allocations in Remote Sensing (IEEE GRSS) object to introducing unlicensed devices in the bands above 95 GHz, or seek restrictions on such operations, on the grounds that they may cause interference to Earth exploration-satellite operations.[88] CORF's objections are centered on the potential for unacceptable levels of interference into these or adjacent bands, if unlicensed devices are numerous or airborne.[89] CORF argues that if unlicensed devices are permitted in these bands, the power level must be limited such that aggregate emissions fall below the levels recommended in ITU-R RS.2017.[90]

37. As an initial matter, we are prohibiting unlicensed devices above 95 GHz from operating on aircraft, thus addressing CORF's first objection regarding airborne use. CORF's aggregate interference argument is based on calculations that assume conditions at high latitude and winter temperatures, referred to as the "best (most transparent) atmospheric conditions."[91] We disagree with CORF's analysis as it does not properly reflect spectrum conditions in the United States.[92] First, CORF's assumptions relate to locations of interest at latitudes above the continental U.S. (i.e., CORF assumes

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[82] We note that for the frequencies under consideration in this proceeding, atmospheric losses are significant thus any deviation from the minimum atmospheric path (zenith) may further exacerbate the already challenging task of making astronomical observations.

[83] We also note that under similar circumstances, the Commission, in 2012 and again in 2017, found that vehicular radars could coexist on an uncoordinated basis with radio astronomy sites (many of which are the same sites that observe in the bands above 95 GHz) in the 76-81 GHz band. *See Amendment of Sections 15.35 and 15.253 of the Commission's Rules Regarding Operation of Radar Systems in the 76-77 GHz Band/Amendment of Section 15.253 of the Commission's Rules to Permit Fixed Use of Radar in the 76-77 GHZ Band*, ET Docket No. 11-90, Report and Order, 27 FCC Rcd 7880 (2012) at 7885, paras. 14-15. *See Amendment of Parts 1, 2, 15, 90 and 95 of the Commission's Rules to Permit Radar Services in the 76-81 GHz Band*, ET Docket No. 15-26, Report and Order, 32 FCC Rcd 8822 (2017). It is noteworthy that vehicular radars can operate everywhere and at a much higher power levels than what we are adopting in this order. Moreover, the atmospheric attenuation of radio frequency signals is greater at the higher frequencies under consideration in this proceeding. Vehicular radars are currently operating in the 76-81 GHz band with no reported incidents of harmful interference to RAS operations.

[84] NRAO Comments at 6-7. NRAO also indicates that the radio astronomy service finds observations of a spectral line of carbon monoxide at 115.271 GHz, a widely-used surrogate for the detection of molecular hydrogen, to be particularly useful and, unwanted emissions from unlicensed devices operating in the 116–122 GHz band should not be allowed to interfere with radio astronomy operations in the US246 band at 114.25–116 GHz.

[85] *See* Appx. A, §15.258(c)(3).

[86] Free space path loss (FSPL) is determined using the following equation: $FSPL = 32.44 + 20\log_{10}(d_{km}) + 20\log_{10}(f_{MHz})$, where d_{km} is the distance in kilometers and f_{MHz} is the frequency in MHz.

[87] Thirty meters is used as an illustrative example as it is well within the areas over which radio astronomy facilities can control the transmitters permitted near their sites and free space path loss will increase at greater distances.

latitudes greater than 60°, but the continental U.S. is located below 49° latitude).[93] Second, because Earth exploration-satellite scans are performed over the entire United States (including Alaska and Hawaii) with various atmospheric conditions,[94] we find CORF's assumptions of ideal conditions for propagation are overly restrictive. Instead, we believe that the U.S. Standard Atmosphere model, which is an internationally recognized model for sharing between passive and active services (ITU-R RA.2189) and also acknowledged by CORF,[95] is the appropriate analytical model.[96]

38. To assess whether unlicensed devices can co-exist with the Earth exploration-satellite service, we determine how many unlicensed devices would produce aggregate emissions that would exceed the harmful interference protection threshold, as set forth in ITU-R RS.2017. Using the U.S. Standard Atmosphere model and assuming all point-to-point systems are operating at maximum power,[97] we determine that the potential for harmful interference into Earth exploration-satellite services in the 174.8-182 GHz and 185-190 GHz bands is insignificant. Our analysis shows that up to 42,704 outdoor unlicensed devices can operate simultaneously at maximum power per square kilometer[98] and still meet the protection levels for the vertical satellite scan of an Earth exploration satellite[99] (also referred to as nadir scan or sounding).[100] For an Earth exploration satellite angle scan (also referred to as limb sounder sensing)[101] our analysis shows that up to 96.5 million unlicensed devices can operate simultaneously at maximum power per square kilometer without causing harmful interference.[102] Based on these large device densities, we conclude that the potential for harmful interference to Earth exploration satellite operations is negligible. The same analysis is also applicable to the 116-122 GHz band but would result in an even lower likelihood of harmful interference because that band is subject to 20 dB higher atmospheric attenuation than the 174.8-182 GHz and 185-190 GHz bands. IEEE GRSS notes that Earth

[88] CORF Comments at 27-28. IEEE GRSS does not support unlicensed use of this band, and states that should such operation be permitted, the Commission should limit unlicensed device power levels, aggregate interference and only permit low density deployments. IEEE GRSS Comments at 2.

[89] CORF Comments at 28.

[90] *Id. Performance and interference criteria for satellite passive remote sensing*, Recommendation ITU-R RS.2017-0 (08/2012).

[91] CORF Comments at 11. Attenuation of millimeter and sub-millimeter wave frequencies varies with, among other factors, the temperature and latitude of the location of interest. CORF's comments include a chart (Figure 3) showing the sensitivity of millimeter and sub-millimeter wave frequencies to atmospheric temperature and water vapor for different seasons and latitudes. Model C is based on winter and high latitude locations. See also CORF Comments at 28 and Klein et al., *Nadir sensitivity of passive millimeter and submillimeter wave channels to clear air temperature and water vapor variations*, Vol. 105, JOURNAL OF GEOPHYSICAL RESEARCH, 17481, 17485, July 16, 2000.

[92] CORF Comments at 12, 28.

[93] Even though the State of Alaska is located above 49° latitude, it is sparsely populated, and any unlicensed spectrum deployments will effectively be low-density and very small in number. Therefore, we do not anticipate any potential harmful interference into the Earth exploration satellites.

[94] It should also be noted that the aggregate emission level is associated with a certain measurement area (2,000,000 km^2) of which 0.01% can exceed the aggregate emission level. *See* ITU-R RS.2017-0 at 6.

exploration satellite sensors in these bands are not only space-based, but also located on the ground.[103] Such ground-based systems are pointed skyward, making them less susceptible to interference from energy received from ground-based unlicensed devices. Also, because EESS operations require a relatively quiet spectrum environment, we believe the majority, if not all, ground-based EESS sensors are located in rural, isolated areas. These same factors should similarly deter widespread installation of unlicensed devices in this band in these areas as there are much more cost-effective ways to cover large rural areas at lower frequency bands which have less propagation loss. Further, due to the aforementioned characteristics of this band, we expect deployed unlicensed systems to use highly directional antennas and/or be used for short distance localized operations. Together, all these factors will limit single entry and aggregate interference, not only to space-based stations, but also to ground-based receivers.

39. CORF expresses concern about the out-of-band emissions from unlicensed operations in the 174.8-182 GHz and 185-190 GHz bands because it has Earth exploration-satellite operations in the adjacent 182-185 GHz band.[104] We do not share CORF's concerns as emissions in those bands experience significant atmospheric attenuation. To assess unlicensed device compatibility in bands adjacent to Earth exploration-satellite bands, we make certain assumptions about the out-of-band emissions of each device toward the EESS sensor. Although we believe NRAO overstates the impact of unlicensed devices by using an OOBE level of -40 dBm/MHz[105] (because it assumes that the OOBE is directed toward a potential EESS satellite victim receiver in the case of a nadir scan), we use this value to determine an upper bound on the potential impact. Using the U.S. Standard Atmosphere Model, our analysis shows that the nadir scan sensor can coexist with up to 3.38 billion simultaneously operating unlicensed devices per square kilometer in each of these bands without causing harmful interference to EESS operations in 182-185 GHz band.[106] Similarly, for limb sounder sensing, our analysis shows that up to 2.42×10^{16} unlicensed devices can simultaneously operate per square kilometer without causing harmful interference to EESS operations in 182-185 GHz band.[107] We do not expect unlicensed devices in these

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[95] CORF Comments at 7-8. *See, also, Sharing between the radio astronomy service and active services in the frequency range 275-3 000 GHz*, Report ITU-R RA.2189 (10/2010).

[96] The U.S. Standard Atmosphere is a model of how the pressure, temperature, density and viscosity of the Earth's atmosphere changes over a range of altitudes and elevations.

[97] The likelihood of all point-to-point systems operating at maximum power is very low. Nevertheless, we use such an assumption to determine the lower bound of the number of systems that could operate in the band. The actual number of such systems that could co-exist with EESS operations would be higher. Our analysis considers the higher power outdoor point-to-point systems rather than access systems, because we believe that highly directional point-to-point systems present a higher potential for interference to Earth exploration satellite service. The maximum power we are adopting for point-to-point systems is 85 dBm/100 MHz. *See* Appx. A §15.258(b)(2).

[98] At nadir, the most sensitive EESS sensor (denoted as Q7 in ITU-R RS.1861) has a scan area of 16 square kilometers. See ITU-R RS.1861, "Typical technical and operational characteristics of Earth exploration-satellite service (passive) systems using allocations between 1.4 and 275 GHz."

[99] We made the following assumptions: an average of approximately 45 dB of standard atmospheric loss in the 174.8-182 GHz and 185-190 GHz bands and an activity factor of 20 percent. Using the typical technical and operational characteristics of EESS systems and based on free space path loss (assuming the EESS station is 708 km above earth - 194 dB of path loss) and additional atmospheric loss, a link budget calculation determines the maximum number of point-to-point transmitters that can exist without causing harmful interference to the most sensitive EESS sensor (denoted as Q7 in ITU-R RS.1861). Due to the limited power generation capacity at these frequencies, we conservatively assume peak output power to be 24 dBm/100 MHz. To reach maximum EIRP, the antenna on each transmitter is assumed to have a boresight gain of 61 dB and a 90°off boresight gain of -27 dB. Based on the transmitter antenna gain and power, the peak power toward the satellite sensor is -3 dBm/100 MHz (i.e., 61 dB peak antenna gain minus -27 dBm off boresight gain yields 88 dB of total antenna gain reduction. Reducing the peak EIRP of 85 dBm/100 MHz by this antenna gain reduction yields -3 dBm/100 MHz). Then assuming the worst case of the 174.8-182 GHz band being fully occupied, the resulting peak power in the band is 23 dBm/MHz. We believe this analysis to be conservative because it neglects a number of factors including rain, clouds, scintillation, and clutter. This analysis only assumes sidelobe antenna coupling with the fixed point-to-point

bands to ever approach such densities. Thus, we are confident that unlicensed operations at the power levels adopted herein[108] can successfully coexist with the passive services. However, we recognize that the bands above 95 GHz are largely uncharted territory and, as such, any conclusions regarding compatibility with the passive services may require revision as use of this spectrum evolves. We will require unlicensed users to protect primary use against harmful interference, address promptly any complaints of harmful interference, and revisit the rules, if warranted, in the future as technology and applications develop in this region of the spectrum.

3. Other Allocations

40. Space Research Service. The space research service (SRS) is defined as a "radiocommunication service in which spacecraft or other objects in space are used for scientific or technological research purposes."[109] This service has no receivers on Earth and those in space are aimed away from Earth into deep space. Hence, there are no interference concerns for this service in these bands. Further, there are no current or anticipated space research operations in the 174.8-182 GHz, and 185-190 GHz bands, so potential harmful interference from unlicensed operations in those bands is essentially irrelevant to SRS, despite the nominal SRS allocation there.[110]

41. Inter-Satellite Service. This service relates to communications between two or more satellites on the same or different orbit/layer. It is used primarily for "networking" of a constellation of satellites. At this time there are no inter-satellite links in the bands discussed in this order. However, intersatellite links can be authorized under an existing allocation, even if there are no specific service rules.[111] Intersatellite links are, by definition, between satellites whereby satellite transmitters and receivers are located in space and aimed at each other. Thus, there are no interference concerns from unlicensed terrestrial operations to intersatellite links.[112]

42. Amateur Radio. Amateur services have a secondary allocation in bands designated for ISM equipment. ARRL states in its comments that radio amateurs already must plan for ISM emissions and those emissions generally have not caused harmful interference to amateur operations.[113] We believe

devices. We recognize that mainbeam antenna coupling could occur, but such a scenario is highly unlikely. At the high frequencies that are under consideration in this proceeding, high gain antennas have nearly optical behavior, and because they are characterized by high propagation and atmospheric losses, any communication between a transmitter and a receiver would require beam-to-beam alignment between the respective antennas. Accordingly, it is highly unlikely for a transmitter, when communicating with a terrestrial receiver, to have an elevation look angle of 90° (the elevation look angle required for mainbeam coupling to a satellite making a nadir scan).

[100] Nadir sounding (also known as vertical sounding) is used to retrieve vertical profiles of temperature trace gases, such as water vapor, by making observations at wavelengths that have significant attenuation. The principle behind nadir sounding is that by making observations at numerous wavelengths near a broad absorption line, different altitudes in the atmosphere can be investigated. *See 76-81 GHz* Order, 19 FCC Rcd at 3215, n.18.

[101] A Microwave Limb Sounder ("MLS") measures naturally-occurring microwave thermal emissions from the Earth's atmosphere to remotely sense vertical profiles of selected atmospheric gases, temperature and pressure. For example, a limb-sounding millimeter-wave radiometer (183 GHz, 184 GHz, and 204 GHz) can be used to map global distributions of water vapor, ozone, and chlorine monoxide. *See 76-81 GHz* Order, 19 FCC Rcd at 3215, n.18.

[102] We used similar methodology as the calculations for the nadir scan and the following assumptions: an average of approximately 100 dB of standard atmosphere loss in the 174.8-182 GHz and 185-190 GHz bands, a distance of 3000 km and an elevation angle of 26 degree. We based the limb sounder analysis on the limb sounder characteristics of ITU-R RS.1861 (denoted sensor Q3). *See* also Jorgensen et al., *A 5-Frequency Millimeter Wave Antenna for a Spaceborne Limb Sounding Instrument*, Vol 49, No. 5, IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, 703,704, May 2001. The activity factor is assumed to be 20 percent.

[103] IEEE GRSS Comments at 2.

[104] *See generally* CORF Comments at 28. As noted above, there are no current or projected EESS operations in these two bands.

the addition of unlicensed devices would be unlikely to have a marked impact on the noise environment as compared to high-power ISM devices and decline to adopt any specific rules for unlicensed devices in the amateur radio allocations.

4. Technical Requirements

43. We adopt, with certain modifications, technical rules for unlicensed operations in the bands 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz, that are consistent with the rules proposed in the *Notice*.[114] Several commenters express general support for this approach.[115] As proposed, new section 15.258 provides that devices may operate in all of these bands with a maximum EIRP of 40 dBm (average) and 43 dBm (peak), measured with a detection bandwidth that encompasses the band of operation.[116] It also permits outdoor fixed point-to-point devices to operate with a higher maximum EIRP of 82 dBm (average) and 85 dBm (peak), also measured with a detection bandwidth that encompasses the band of operation. Use of the higher power limits also requires that devices use antennas with a minimum gain of 51 dBi, with a 2 dB reduction in the maximum permissible EIRP for each dB the antenna gain falls below 51 dBi. These highly directional antennas with very narrow beamwidths will ensure that the likelihood of harmful interference is minimized. We will not at this time permit even higher power levels as suggested by IEEE 802.[117] We find that the power levels we are adopting will allow us to make additional spectrum available for new and innovative unlicensed devices while protecting other uses of the bands.

44. We specify power limits for devices operating in these bands in terms of EIRP, and do not specify a maximum conducted power limit as we proposed.[118] While we modeled the proposed technical rules after those for operation in the 57-71 GHz band, i.e., specifying conducted power and antenna gain limits, we are persuaded by Bosch that devices operating in frequency bands above 95 GHz will likely not have a detachable antenna or port that could be used for measuring conducted power,

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[105] NRAO Comment at 7.

[106] We make the following assumptions: an average of approximately 80 dB of standard atmosphere loss in the 182-185 GHz band and an activity factor of 20 percent.

[107] We make the following assumptions: an average of approximately 170 dB of standard atmosphere loss in the 182-185 GHz band, a distance of 3000 km, and an elevation angle of 26 degrees. The activity factor is assumed to be 20 percent.

[108] *See* Appx. A, §§15.258(b)&(c).

[109] *See* 47 CFR § 2.1(c).

[110] *See Notice*, 33 FCC Rcd at 2499, Appx. B, Passive Satellite Operations Above 95 GHz.

[111] *See* 47 CFR § 5.202(b).

[112] Boeing states that sharing between FS and ISS in these high frequency bands should not be a problem. *See* Boeing Comments at 5.

[113] ARRL Comments at 5.

[114] *See Notice*, 33 FCC Rcd at 2462-63, para. 56-57. The proposed rules were based on the rules for unlicensed devices operating in the 57-71 GHz band. We are not adopting rules on RF exposure requirements at this time. *See* mmWave Coalition March 5 *Ex Parte*. All RF exposure requirements will be addressed in the ongoing proceeding in ET Docket No. 13-84. *Reassessment of Federal Communications Commission Radiofrequency Exposure Limits and Policies; Proposed Changes in the Commission's Rules Regarding Human Exposure to Radiofrequency Electromagnetic Fields*, ET Dkt. No. 13-84, First Report and Order and Further Notice of Proposed Rule Making and Notice of Inquiry, 28 FCC Rcd 3498 (2013). We are also not addressing measurement procedures for emissions

making such measurements difficult.[119] In addition, because the interference potential of a device is a function of its EIRP, rather than the transmitter conducted power, it is necessary to only specify EIRP limits. Further, because devices are unlikely to have interchangeable antennas, a conducted output power limit is not necessary to reduce the likelihood that a user could install a higher-gain antenna and substantially raise the EIRP, and interference potential, of a device. We will also require devices that operate with an emission bandwidth of less than 100 megahertz to reduce their maximum power to achieve a power spectral density no greater than that of a device operating with a bandwidth of 100 megahertz.[120] This will ensure low spectral power densities within these frequency bands. Together, these measures ensure that the potential of causing harmful interference to authorized services remains low, even if significant numbers of unlicensed devices are operating.

45. As proposed, we are adopting an out-of-band emission limit of 90 picowatts per square centimeter at a distance of three meters applicable at frequencies above 40 GHz.[121] This emission limit will protect radio astronomy and other services operating in adjacent bands.[122] While we initially proposed specifying 200 GHz as the upper limit for measuring compliance with the out-of-band emission requirements, we recognize the concerns of parties that note such a limit would be below the highest frequency band (244-246 GHz) in which we proposed to allow unlicensed operation.[123] We agree with Underwriters Laboratory that out-of-band emissions measurements of unlicensed devices operating above 95 GHz should be required up to the third harmonic of the fundamental frequency to ensure that at least one even order and one odd order harmonic are measured.[124] We also agree with Underwriters Laboratory that we should specify an upper frequency limit for making measurements that corresponds to the upper frequency limit, e.g., 750 GHz, of standard waveguides used in making compliance measurements.[125] Accordingly, we will require unlicensed devices operating under new Section 15.258 to comply with an out-of-band emission limit of 90 picowatts per square centimeter at a distance of three meters. We are also amending Section 15.33 to require measurements of out-of-band emissions from

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above 95 GHz. OET will continue to publish Knowledge Database (KDB) measurement guidance and will incorporate appropriate procedures from relevant industry standards organizations.

[115] TIA Reply at 8; Qualcomm Comments at 10-11; and CTIA Comments at 14-15.

[116] Appx. A, § 15.258(b)(3). We decline to adopt rules to specifically classify devices that operate above 95 GHz as either Part 15 or Part 18 and will instead determine the appropriate classification of new types of devices on a case-by-case basis. This way, we will allow innovators to take advantage of rules in either rule part, as appropriate, so that new and developing technologies can flourish. Parties that need guidance on the applicability of the rules to a device or a design may submit details to OET via the KDB inquiry system.

[117] IEEE 802 urges the Commission to consider increased power levels "reflecting the increased path loss at higher frequencies to maintain the same coverage as the 57-71 GHz band." IEEE 802 Comments at 2. However, we note that IEEE GRSS does not support higher power levels. IEEE GRSS Comments at 2.

[118] *See Notice*, 33 FCC Rcd at 2462-63, para. 56.

[119] Bosch Comments at 7. Bosch states that the 122-122.25 GHz, 122.25-123 GHz and 244-246 GHz bands are available for use in Europe. Bosch argues that it is very difficult to measure conducted power from devices in these bands because most do not have connectors, few have external antennas, and devices are typically highly integrated on a chip. It states that for these reasons, there are no conducted emission limits applicable to these bands in Europe.

[120] In the *Notice*, the Commission proposed to limit the conducted power of devices with a bandwidth of less than 100 megahertz to limit the power spectral density. Because we are adopting power limits based on EIRP, rather than conducted power, the final rules limit the EIRP of devices with a bandwidth of less than 100 megahertz in the same manner as proposed in the *Notice*. *Notice,* 33 FCC Rcd at 2487, Appx. A, § 15.258(d)(1).

[121] Appx. A, § 15.258(c)(3).

[122] See *supra* paras. 31-42.

[123] Underwriters Laboratory Comments at 1, 13; CORF Comments at 29; NRAO Comments at 6.

[124] Underwriters Laboratory Comments at 13.

devices operating above 95 GHz at frequencies up to the third harmonic of the highest fundamental frequency or 750 GHz, whichever is lower. Consistent with the requirements for most other Part 15 intentional radiators, we will require devices to limit out-of-band radiated emissions at frequencies below 40 GHz to the limits specified in Section 15.209(a).[126] No party disagreed with Underwriters Laboratory's recommended frequency range for measuring out-of-band emissions or argued that different out-of-band emission limits are necessary for below 40 GHz emissions.

46. We are also adopting operational restrictions for devices in the 116-123 GHz, 174.8-182 GHz, 185-190 GHz, and 244-246 GHz bands that are similar to those for unlicensed devices in the 57-71 GHz band. Specifically, we will not permit equipment to operate on satellites or onboard aircraft. This requirement, consistent with the requests of IEEE and CORF, will limit the potential for unlicensed devices to cause interference to radio astronomy and other passive services. The 182-185 GHz band is a critical band for passive sensing and transmissions in the band are prohibited under footnote US 246. Therefore, in addition to emission limits from adjacent bands into this band, equipment operating in the 174.8-182 GHz and 185-190 GHz bands should not be designed to operate in the 182-185 GHz band. Additionally, because devices operating above 95 GHz are a new technology, we are taking a conservative approach in protecting radio services from harmful interference by not adopting the proposed exemptions that would have allowed operation onboard aircraft under certain conditions.[127] No party indicates that such exemptions are necessary.

5. Related Matters

47. *James Edwin Whedbee Petition for Rulemaking.* In the *Notice,* the Commission granted a petition for rulemaking filed by James Edwin Whedbee ("Whedbee") — which proposed that the Commission initiate a proceeding to allow unlicensed operations throughout the 95-1000 GHz range with a bandwidth limited to 500 megahertz — but only to the extent the rulemaking proceeding initiated by the Commission's *Notice* covered Whedbee's proposal.[128] The Commission also kept the door open on whether to broaden this proceeding to include consideration of the remaining aspect of Whedbee's proposal by seeking comment on any costs or benefits that would be associated with the proposal to the extent it went beyond what the *Notice* otherwise sought comment on.[129] With the exception of the petitioner himself, no other parties address this proposal.[130] Given the apparent lack of interest, and our decision to make 21.2 gigahertz of spectrum available for unlicensed use, we are not persuaded that Whedbee's petition, to the extent it remains pending, warrants further consideration, and we are denying it.

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[125] *Id.* Underwriters Laboratory states that 750 GHz is the upper frequency limit of a standard waveguide band.

[126] 47 CFR §§ 15.209(a). The Commission proposed to require unlicensed devices to comply with the Section 15.209(a) limits at frequencies below 40 GHz. *Notice*, 33 FCC Rcd at 2487, proposed Section 15.258(c)(2).

[127] *Notice*, 33 FCC Rcd at 2463 para. 56. Specifically, the *Notice* proposed to allow operation onboard aircraft when the aircraft is on the ground, and while airborne in closed exclusive on-board communication networks within the aircraft.

[128] *Notice,* 33 FCC Rcd at 2464, para. 59.

[129] *Id.*

[130] Whedbee again requests expanding unlicensed use across large bands of spectrum above 95 GHz and requests that the Commission initiate a further notice of proposed rulemaking in this regard. James Edwin Whedbee Reply at 2.

IV. PROCEDURAL MATTERS

48. *Final Regulatory Flexibility Analysis*. — As required by the Regulatory Flexibility Act of 1980 (RFA),[131] as amended, the Commission has prepared a Final Regulatory Flexibility Analysis (FRFA) regarding the possible significant economic impact on small entities of the policies and rules adopted in this First Report and Order, which is found in Appendix B. The Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, will send a copy of the First Report and Order, including the FRFA, to the Chief Counsel for Advocacy of the Small Business Administration.[132]

49. *Paperwork Reduction Act Analysis*. — This document contains new or modified information collection requirements. The Commission, as part of its continuing effort to reduce paperwork burdens, invites the general public and the Office of Management and Budget (OMB) to comment on the information collection requirements contained in this document, as required by the Paperwork Reduction Act of 1995, Public Law 104-13. In addition, pursuant to the Small Business Paperwork Relief Act of 2002, Public Law 107-198, *see* 44 U.S.C. 3506(c)(4), we previously sought, but did not receive specific comment on how we might further reduce the information collection burden for small business concerns with fewer than 25 employees.

50. *Congressional Review Act*. — The Commission will send a copy of this First Report and Order to Congress and the Government Accountability Office pursuant to the Congressional Review Act, s*ee* 5 U.S.C. § 801(a)(1)(A).

51. *Further Information*. — For further information, contact Brian Butler of the Office of Engineering and Technology, Policy and Rules Division, at 202-418-2702 or Brian.Butler@fcc.gov.

V. ORDERING CLAUSES

52. IT IS ORDERED that pursuant to Sections 4(i), 7(a), 301, 302, 303, 307, and 310 of the Communications Act of 1934, as amended, 47 U.S.C. §§ 154(i), 157(a), 301, 302a, 303, 307, 310, this Report and Order IS ADOPTED.

53. IT IS FURTHER ORDERED that the rules and requirements adopted herein WILL BECOME EFFECTIVE 30 days from the date of publication in the Federal Register with the exception of the modifications of Sections 5.59, 5.77, 5.121, 5.702, 5.703, 5.704, 5.705 and 15.258 of the rules which contain new or modified information collection requirements that require review by the OMB under the PRA, which WILL BECOME EFFECTIVE after OMB review and approval, on the effective date specified in a notice that the Commission will publish in the Federal Register announcing such approval and effective date.

54. IT IS FURTHER ORDERED, pursuant to Section 4(i) of the Communications Act of 1934, 47 U.S.C. § 154(i), and Section 1.407 of the Commission's Rules, that the Petition for Rulemaking of James Edwin Whedbee filed on November 5, 2013 is DENIED as described herein and Docket RM-11795 IS TERMINATED.

55. IT IS FURTHER ORDERED that the Commission's Consumer and Governmental Affairs Bureau, Reference Information Center, SHALL SEND a copy of this First Report and Order, including the Final Regulatory Flexibility Analysis, to the Chief Counsel for Advocacy of the Small Business Administration and to Congress and the Government Accountability Office pursuant to the Congressional Review Act, *see* 5 USC § 801(a)(1)(A).

FEDERAL COMMUNICATIONS COMMISSION

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[131] *See* 5 U.S.C. § 603.

[132] *See* 5 U.S.C. § 603(a). In addition, the *Notice* and RFA (or summaries thereof) will be published in the Federal Register.

Marlene H. Dortch
Secretary

APPENDIX A

Final Rules

The Federal Communications Commission amends title 47 of the Code of Federal Regulations, parts 2, 5, and 15, as follows:

PART 2 – FREQUENCY ALLOCATIONS AND RADIO TREATY MATTERS; GENERAL RULES AND REGULATIONS

1. The authority citation for part 2 continues to read as follows:

Authority: [INSERT CURRENT AUTHORITY CITATION]

2. Section 2.803 is amended by revising paragraph (c)(1) to read as follows:

§ 2.803 Marketing of radio frequency devices prior to equipment authorization.

* * * * *

(c) * * *

(1) Activities conducted under market trials pursuant to subpart H of part 5 or in accordance with a Spectrum Horizons experimental radio license issued pursuant to subpart I of part 5.

3. Section 2.1091 is amended by revising paragraph (c)(2) to read as follows:

§ 2.1091 Radiofrequency radiation exposure evaluation: mobile devices.

* * * * *

(c) * * *

(2) Unlicensed personal communications service devices, unlicensed millimeter-wave devices, and unlicensed NII devices authorized under §§15.255(g), 15.257(g), 15.258, 15.319(i), and 15.407(f) of this chapter are also subject to routine environmental evaluation for RF exposure prior to equipment authorization or use if their ERP is 3 watts or more or if they meet the definition of a portable device as specified in §2.1093(b) requiring evaluation under the provisions of that section.

* * * * *

4. Section 2.1093 is amended by revising paragraph (c)(1) to read as follows

§ 2.1093 Radiofrequency radiation exposure evaluation: portable devices.

* * * * *

(c) * * *

(1) Portable devices that operate in the Cellular Radiotelephone Service pursuant to part 22 of this chapter; the Personal Communications Service (PCS) pursuant to part 24 of this chapter; the Satellite Communications Services pursuant to part 25 of this chapter; the Miscellaneous Wireless Communications Services pursuant to part 27 of this chapter; the Upper Microwave Flexible Use Service pursuant to part 30 of this chapter; the Maritime Services (ship earth station devices only) pursuant to part 80 of this chapter; the Specialized Mobile Radio Service, the 4.9 GHz Band Service, and the 3650 MHz Wireless Broadband Service pursuant to part 90 of this chapter; the Wireless Medical Telemetry Service (WMTS), the Medical Device Radiocommunication Service (MedRadio), and the 76-81 GHz Band Radar

Service pursuant to subparts H, I, and M of part 95 of this chapter, respectively; unlicensed personal communication service, unlicensed NII devices and millimeter-wave devices authorized under §§15.255(g), 15.257(g), 15.258, 15.319(i), and 15.407(f) of this chapter; and the Citizens Broadband Radio Service pursuant to part 96 of this chapter; are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use.

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PART 5 – EXPERIMENTAL RADIO SERVICE

5. The authority citation for Part 5 continues to read as follows:

Authority: [INSERT CURRENT AUTHORITY CITATION]

6. The Table of Contents of Section 5 is amended by adding Subpart I to the end as follows:

Subpart I—Spectrum Horizons Experimental Radio Licenses

§5.701 Applicable rules.

§5.702 Licensing requirement - necessary showing

§5.703 Responsible party

§5.704 Marketing of devices under Spectrum Horizons experimental radio licenses.

§5.705 Interim report

7. Section 5.3 is amended by revising paragraph (l) and adding paragraph (m) to read as follows:

§ 5.3 Scope of service.

* * * * *

(l) Marketing of equipment designed to operate only on frequencies above 95 GHz.

(m) Types of experiments that are not specifically covered under paragraphs (a) through (l) of this section will be considered upon demonstration of need for such additional types of experiments.

8. Section 5.54 is amended by renaming paragraph (f) as paragraph (g) and adding a new paragraph (f) to read as follows:

§ 5.54 Types of authorizations available.

* * * * *

(f) *Spectrum Horizons experimental radio license.* This type of license is issued for the purpose of testing and marketing devices on frequencies above 95 GHz, where there are no existing service rules.

* * * * *

9. Section 5.55 is amended by revising paragraphs (c) and (d) to read as follows:

§ 5.55 Filing of applications.

* * * * *

(c) Each application for station authorization shall be specific and complete with regard to the information required by the application form and this part.

(1) Conventional and Spectrum Horizons license and STA applications shall be specific as to station location, proposed equipment, power, antenna height, and operating frequencies.

(2) Broadcast license applicants shall comply with the requirements in subpart D of this part; Program license applicants shall comply with the requirements in subpart E of this part; Medical Testing license applicants shall comply with the requirements in subpart F of this part; Compliance Testing license applicants shall comply with the requirements in subpart G of this part; and Spectrum Horizons license applicants shall comply with the requirements in subpart I of this part

(d) Filing conventional, program, medical, compliance testing, and Spectrum Horizons experimental radio license applications:

(1) Applications for radio station authorization shall be submitted electronically through the Office of Engineering and Technology Web site *http://www.fcc.gov/els.*

(2) Applications for special temporary authorization shall be filed in accordance with the procedures of §5.61.

(3) Any correspondence relating thereto that cannot be submitted electronically shall instead be submitted to the Commission's Office of Engineering and Technology, Washington, DC 20554.

* * * * *

10. Section 5.59 is amended by revising paragraph (a) to read as follows:

§ 5.59 Forms to be used.

(a) *Application for conventional, program, medical, compliance testing, and Spectrum Horizons experimental radio licenses.* (1) *Application for new authorization or modification of existing authorization.* Entities must submit FCC Form 442.

* * * * *

11. Section 5.71 is amended by adding paragraph (d) to read as follows:

§ 5.71 License period.

* * * * *

(d) *Spectrum Horizons experimental radio license*. Licenses are issued for a term of 10 years and may not be renewed.

12. Section 5.77 is amended by revising the introductory text of paragraph (a) and paragraph (b) to read as follows

§ 5.77 Change in equipment and emission characteristics.

(a) The licensee of a conventional, broadcast, or Spectrum Horizons experimental radio station may make any changes in equipment that are deemed desirable or necessary provided:

* * *

(b) For conventional or Spectrum Horizons experimental radio stations, the changes permitted in paragraph (a) of this section may be made without prior authorization from the Commission provided that the licensee supplements its application file with a description of such change. If the licensee wants these emission changes to become a permanent part of the license, an application for modification must be filed.

* * * * *

13. Section 5.79 is amended by revising the section title and paragraph (a) to read as follows:

§ 5.79 Transfer and assignment of station authorization for conventional, program, medical testing, Spectrum Horizons, and compliance testing experimental radio licenses.

(a) A station authorization for a conventional experimental radio license or Spectrum Horizons experimental radio license, the frequencies authorized to be used by the grantee of such authorization, and the rights therein granted by such authorization shall not be transferred, assigned, or in any manner either voluntarily or involuntarily disposed of, unless the Commission decides that such a transfer is in the public interest and gives its consent in writing.

* * * * *

14. Section 5.107 is amended by adding paragraph (f) to read as follows:

§ 5.107 Transmitter control requirements.

* * * * *

(f) *Spectrum Horizons experimental radio licenses*. The licensee shall ensure that transmissions are in conformance with the requirements in subpart I of this part and that the station is operated only by persons duly authorized by the licensee

15. Section 5.121 is amended by revising paragraph (a) to read as follows:

§ 5.121 Station record requirements.

(a)(1) For conventional, program, medical testing, compliance testing experimental radio stations, the current original authorization or a clearly legible photocopy for each station shall be retained as a permanent part of the station records but need not be posted. Station records are required to be kept for a period of at least one year after license expiration.

(a)(2) For Spectrum Horizons experimental radio stations, the licensee is solely responsible for retaining the current authorization as a permanent part of the station records but need not be posted. Station records are required to be kept for a period of at least one year after license expiration.

* * * * *

16. A new Subpart I is added to Part 5 to read as follows:

Subpart I—Spectrum Horizons Experimental Radio Licenses

§ 5.701 Applicable rules.

In addition to the rules in this subpart, Spectrum Horizons experimental radio station applicants and licensees shall follow the rules in subparts B and C of this part. In case of any conflict between the rules set forth in this subpart and the rules set forth in subparts B and C of this part, the rules in this subpart shall govern.

§ 5.702 Licensing requirement – necessary showing.

Each application must include a narrative statement describing in detail how its experiment could lead to the development of innovative devices and/or services on frequencies above 95 GHz and describe, as applicable, its plans for marketing such devices. This statement must sufficiently explain the proposed new technology/potential new service and incorporate an interference analysis that explains how the proposed experiment would not cause harmful interference to other services. The statement should include technical details, including the requested frequency band(s), maximum power, emission designators, area(s) of operation, and type(s) of device(s) to be used.

§ 5.703 Responsible party.

(a) Each Spectrum Horizons experimental radio applicant must identify a single point of contact responsible for all experiments conducted under the license and ensuring compliance with all applicable FCC rules.

(b) The responsible individual will serve as the initial point of contact for all matters involving interference resolution and must have the authority to discontinue any and all experiments being conducted under the license, if necessary.

(c) The license application must include the name of the responsible individual and contact information at which the person can be reached at any time of the day; this information will be listed on the license. Licensees are required to keep this information current.

§ 5.704 Marketing of devices under Spectrum Horizons experimental radio licenses.

Unless otherwise stated in the instrument of authorization, devices operating in accordance with a Spectrum Horizons experimental radio license may be marketed subject to the following conditions:

(a) Marketing of devices (as defined in §2.803 of this chapter) and provision of services for hire is permitted before the radio frequency device has been authorized by the Commission.

(b) Licensees are required to ensure that experimental devices are either rendered inoperable or retrieved by them from trial participants at the conclusion of the trial. Licensees are required to notify experiment participants in advance of the trial that operation of the experimental device is subject to this condition. Each device sold under this program must be labeled as "Authorized Under An Experimental License and May be Subject to Further Conditions Including Termination of Operation" and carry a licensee assigned equipment ID number.

(c) The size and scope of operations under a Spectrum Horizons experimental license are subject to limitations as the Commission shall establish on a case-by-case basis.

§ 5.705 Interim report.

Licensee must submit to the Commission an interim progress report 5 years after grant of its license. If a licensee requests non-disclosure of proprietary information, requests shall follow the procedures for submission set forth in §0.459 of this chapter.

PART 15 – RADIO FREQUENCY DEVICES

17. The authority citation for Part 15 continues to read as follows:

Authority: . [INSERT CURRENT AUTHORITY CITATION]

18. Section 15.33 is amended by revising paragraphs (a)(4) and adding a new paragraph (a)(5) to read as follows:

§15.33 Frequency range of radiated measurements.

* * * * *

(a) * * *

(4) If the intentional radiator operates at or above 95 GHz: to the third harmonic of the highest fundamental frequency or to 750 GHz, whichever is lower, unless specified otherwise elsewhere in the rules.

(5) If the intentional radiator contains a digital device, regardless of whether this digital device controls the functions of the intentional radiator or the digital device is used for additional control or function purposes other than to enable the operation of the intentional radiator, the frequency range shall be investigated up to the range specified in paragraphs (a)(1) through (a)(4) of this section or the range applicable to the digital device, as shown in paragraph (b)(1) of this section, whichever is the higher frequency range of investigation.

* * * * *

19. Section 15.205 is amended by revising paragraph (d)(4) to read as follows:

§ 15.205 Restricted bands of operation.

* * * * *

(d) * * *

(4) Any equipment operated under the provisions of §§ 15.255 and 15.256 in the frequency band 75-85 GHz, § 15.257 in the 92-95 GHz band or § 15.258 of this part.

* * * * *

20. A new section 15.258 is added as follows:

§ 15.258 Operation in the bands 116-123 GHz, 174.8-182 GHz, 185-190 GHz and 244-246 GHz.

(a) Operation on board an aircraft or a satellite is prohibited.

(b) Emission levels within the 116-123 GHz, 174.8-182 GHz, 185-190 GHz and 244-246 GHz bands shall not exceed the following equivalent isotropically radiated power (EIRP) limits as measured during the transmit interval:

(1) The average power of any emission shall not exceed 40 dBm and the peak power of any emission shall not exceed 43 dBm; or

(2) For fixed point-to-point transmitters located outdoors, the average power of any emission shall not exceed 82 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi. The peak power of any emission shall not exceed 85 dBm and shall be reduced by 2 dB for every dB that the antenna gain is less than 51 dBi. The provisions in this paragraph for reducing transmit power based on antenna gain shall not require that the power levels be reduced below the limits specified in paragraph (b)(1) of this section.

(3) The peak power shall be measured with a detection bandwidth that encompasses the entire occupied bandwidth within the intended band of operation, e.g., 116-123 GHz, 174.8-182 GHz, 185-190 GHz or 244-246 GHz. The average emission levels shall be measured over the actual time period during which transmission occurs.

(4) Transmitters with an emission bandwidth of less than 100 MHz must limit their peak radiated power to the product of the maximum permissible radiated power (in milliwatts) times their emission bandwidth divided by 100 MHz. For the purposes of this paragraph, emission bandwidth is defined as the instantaneous frequency range occupied by a steady state radiated signal with modulation, outside which the radiated power spectral density never exceeds 6 dB below the maximum radiated power spectral density in the band, as measured with a 100 kHz resolution bandwidth spectrum analyzer. The center frequency must be stationary during the measurement interval, even if not stationary during normal operation (e.g., for frequency hopping devices).

(c) Limits on spurious emissions:

(1) The power density of any emissions outside the band of operation, e.g., 116-123 GHz, 174.8-182 GHz, 185-190 GHz or 244-246 GHz, shall consist solely of spurious emissions.

(2) Radiated emissions below 40 GHz shall not exceed the general limits in §15.209.

(3) Between 40 GHz and the highest frequency specified in § 15.33, the level of these emissions shall not exceed 90 pW/cm^2 at a distance of 3 meters.

(4) The levels of the spurious emissions shall not exceed the level of the fundamental emission.

(d) *Frequency stability.* Fundamental emissions must be contained within the frequency bands specified in this section during all conditions of operation. Equipment is presumed to operate over the temperature range −20 to + 50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage, unless justification is presented to demonstrate otherwise.

(e) Regardless of the power density levels permitted under this section, devices operating under the provisions of this section are subject to the radiofrequency radiation exposure requirements specified in §§1.1307(b), 2.1091 and 2.1093 of this chapter, as appropriate. Applications for equipment authorization of devices operating under this section must contain a statement confirming compliance with these requirements for both fundamental emissions and unwanted emissions. Technical information showing the basis for this statement must be submitted to the Commission upon request.

(f) Any transmitter that has received the necessary FCC equipment authorization under the rules of this chapter may be mounted in a group installation for simultaneous operation with one or more other transmitter(s) that have received the necessary FCC equipment authorization, without any additional equipment authorization. However, no transmitter operating under the provisions of this section may be equipped with external phase-locking inputs that permit beam-forming arrays to be realized.

(g) Measurement procedures that have been found to be acceptable to the Commission in accordance with §2.947 of this chapter may be used to demonstrate compliance.

APPENDIX B

Final Regulatory Flexibility Analysis

21. As required by the Regulatory Flexibility Act of 1980, as amended (RFA),[133] an Initial Regulatory Flexibility Analysis (IRFA) was incorporated in the *Notice of Proposed Rule Making* (NPRM) ET Docket 18-21.[134] The Commission sought written public comment on the proposals in the *NPRM*, including comment on the IRFA. This present Final Regulatory Flexibility Analysis (FRFA) conforms to the RFA.[135]

A. Need for, and Objectives of, the First Report and Order

22. The purpose of this First Report and Order is to implement the rules that will make the spectrum above 95 GHz more readily accessible for new innovative services and technologies. The frequencies above 95 GHz have long been considered to represent the outer edge of the usable radio spectrum for FCC-authorized communications purposes, but advances in research and technology development have stirred interest in commercial use of these bands. Adopting rules in Part 15 to provide for unlicensed operations in several bands and expanding our Part 5 experimental licensing program will increase the opportunities for entities to develop new services and technologies in the bands above 95 GHz.

23. This First Report and Order addresses unlicensed spectrum use in the 95 GHz to 275 GHz range, with additional provisions for experimental licensing up to 3000 GHz. The frequencies in the 95 GHz to 275 GHz range are, with minor exceptions, allocated on a co-primary basis for federal government and non-federal government use, while the frequencies above 275 GHz are not allocated. Because we presently have no rules in these bands to permit licensed or unlicensed telecommunications use other than for experimental and amateur radio operations, there is limited Commission-authorized use above 95 GHz. Our adopted rules serve the public interest by providing incentives and opportunities for investment in the development of innovative new FCC-authorized technologies and services.

B. Summary of Significant Issues Raised by Public Comments in Response to the IRFA

24. There were no comments filed that specifically addressed the rules and polices proposed in the IRFA.

C. Response to comments by the Chief Counsel for Advocacy of the Small Business Administration

25. Pursuant to the Small Business Jobs Act of 2010, which amended the RFA, the Commission is required to respond to any comments filed by the Chief Counsel for Advocacy of the Small Business Administration (SBA), and to provide a detailed statement of any change made to the proposed rules as a result of those comments.[136] The Chief Counsel did not file any comments in response to the proposed rules in this proceeding.

D. Description and Estimate of the Number of Small Entities to Which the Rules Will Apply

26. The RFA directs agencies to provide a description of, and where feasible, an estimate of

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[133] *See* 5 U.S.C. § 603. The RFA, *see* 5 U.S.C. § 601 – 612, has been amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA), Pub. L. No. 104-121, Title II, 110 Stat. 857 (1996).

[134] *See Spectrum Horizons, ET* Docket No. 18-21, RM-11795, Notice of Proposed Rulemaking, 83 FR 9315 (2018).

[135] *See* 5 U.S.C. § 604.

[136] 5 U.S.C. sec 604 (a)(3).

the number of small entities that may be affected by the proposed rules, if adopted.[137] The RFA generally defines the term "small entity" as having the same meaning as the terms "small business," "small organization," and "small governmental jurisdiction."[138] In addition, the term "small business" has the same meaning as the term "small business concern" under the Small Business Act.[139] A "small business concern" is one which: (1) is independently owned and operated; (2) is not dominant in its field of operation; and (3) satisfies any additional criteria established by the Small Business Administration (SBA).[140]

27. The Commission has not developed a definition of small entities applicable to Radio Frequency Equipment Manufacturers (RF Manufacturers). The most analogous definition of small entity is that which is contained in the rules applicable to manufacturers of "Fixed Microwave Services, Other Communications Equipment Manufacturing, Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing." This notice also addresses the repair of devices that are subject to the Commission's equipment authorization rules. For this reason, we also include small entities associated with an additional category, "Communication Equipment Repair and Maintenance," in our analysis.

28. *Other Communications Equipment Manufacturing***.** This industry comprises establishments primarily engaged in manufacturing communications equipment (except telephone apparatus, and radio and television broadcast, and wireless communications equipment).[141] Examples of such manufacturing include fire detection and alarm systems manufacturing, Intercom systems and equipment manufacturing, and signals (e.g., highway, pedestrian, railway, traffic) manufacturing.[142] The SBA has established a size standard for this industry as all such firms having 750 or fewer employees.[143] U.S. Census Bureau data for 2012 shows that 383 establishments operated in that year.[144] Of that number, 379 operated with fewer than 500 employees and 4 had 500 to 999 employees.[145] Based on this data, we conclude that the majority of Other Communications Equipment Manufacturers are small.

29. *Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing*. This industry comprises establishments primarily engaged in manufacturing radio and television broadcast and wireless communications equipment.[146] Examples of products made by these

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[137] *See* 5 U.S.C. § 603(b)(3).

[138] 5 U.S.C. § 601(6).

[139] 5 U.S.C. § 601(3) (incorporating by reference the definition of "small-business concern" in the Small Business Act, 15 U.S.C. § 632). Pursuant to 5 U.S.C. § 601(3), the statutory definition of a small business applies "unless an agency, after consultation with the Office of Advocacy of the Small Business Administration and after opportunity for public comment, establishes one or more definitions of such term which are appropriate to the activities of the agency and publishes such definition(s) in the Federal Register."

[140] 15 U.S.C. § 632.

[141] *See* U.S. Census Bureau, 2017 NAICS Definitions, NAICS Code "334290 Other Communications Equipment Manufacturing", https://www.census.gov/cgi-bin/sssd/naics/naicsrch?input=334290&search=2017+NAICS+Search&search=2017.

[142] *Id.*

[143] See 13 CFR 121.201, NAICS Code 334290.

[144] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1231SG2, Manufacturing: Summary Series: General Summary: Industry Statistics for Subsectors and Industries by Employment Size: 2012, NAICS Code 334290, https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/31SG2//naics~334290.

[145] *Id.*

[146] The NAICS Code for this service is 334220. 13 CFR § 121.201. *See also* U.S. Census Bureau, 2012 NAICS Definitions, "334220 Radio and Television Broadcasting and Wireless Communications Equipment Manufacturing"

establishments are: transmitting and receiving antennas, cable television equipment, GPS equipment, pagers, cellular phones, mobile communications equipment, and radio and television studio and broadcasting equipment.[147] The SBA has established a small business size standard for this industry of 1,250 employees or less.[148] U.S. Census Bureau data for 2012 show that 841 establishments operated in this industry in that year.[149] Of that number, 828 establishments operated with fewer than 1,000 employees, 7 establishments operated with between 1,000 and 2,499 employees and 6 establishments operated with 2,500 or more employees.[150] Based on this data, we conclude that a majority of manufacturers in this industry are small.

30. *Communication Equipment Repair and Maintenance***.** This U.S. industry comprises establishments primarily *engaged* in repairing and maintaining communications equipment without retailing new communication equipment, such as telephones, fax machines, communications transmission equipment, and two-way radios.[151] The SBA has developed a size standard for this industry which is that any firm whose annual receipts are $11 million or less is defined as a small business.[152] Census Bureau data for 2012 indicate that in this industry, 1,185 firms operated for the entire year. Of these firms, 1,148 operated with annual receipts of less than $10 million dollars. Based on this data, the Commission concludes that the majority of firms operating in this industry are small.[153]

E. Description of Projected Reporting, Recordkeeping, and Other Compliance Requirements for Small Entities

31. The First Report & Order adopts a number of, rule changes that would affect reporting, recordkeeping and other compliance requirements in spectrum above 95 GHz. The Report & Order will make 21.2 gigahertz of spectrum above 95 GHz available for unlicensed use in four frequency bands (116-123 GHz, 244-246 GHz, 174.8-182 GHz, and 185-190 GHz). Equipment designed for unlicensed use would be subject to the existing requirements of Subpart J of Part 2 of the Commission's rules, which governs equipment authorization procedures.[154]

32. The First Report & Order also creates a new subpart of the Commission's Part 5 Experimental Radio Service rules to better encourage experiments in the spectrum range between 95 and 3000 GHz. These rules, which would permit new experimental licensees substantial flexibility to conduct long-term experiments over a wide geographic area and frequency range, would set forth an application requirement that includes an analysis explaining why the experiment would not result in harmful interference to other spectrum users. Licensees would also have to maintain station records and file an interim report halfway through their license term. Under our marketing rules, licensees would have to disclose information to users of equipment operated under the experimental license authority.

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https://factfinder.census.gov/faces/affhelp/jsf/pages/metadata.xhtml?lang=en&type=ib&id=ib.en./ECN.NAICS2012.334220#.

[147] *Id*.

[148] 13 CFR § 121.201, NAICS Code 334220.

[149] U.S. Census Bureau, *2012 Economic Census of the United States*, Table EC1231SG2, Manufacturing: Summary Series: General Summary: Industry Statistics for Subsectors and Industries by Employment Size: 2012, NAICS Code 334220, https://factfinder.census.gov/bkmk/table/1.0/en/ECN/2012_US/31SG2//naics~334220.

[150] *Id*.

[151] https://www.census.gov/cgi-bin/sssd/naics/naicsrch?input=811213&search=2012+NAICS+Search&search=2012.

[152] 13 CFR § 121.201, NAICS Code 811213

[153] https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ECN_2012_US_81SSSZ4&prodType=table.

[154] 47 CFR § 1.913(a)(1).

F. Steps Taken to Minimize the Significant Economic Impact on Small Entities, and Significant Alternatives Considered

33. The RFA requires an agency to describe any significant alternatives that it has considered in reaching its proposed approach, which may include the following four alternatives (among others): (1) the establishment of differing compliance or reporting requirements or timetables that take into account the resources available to small entities; (2) the clarification, consolidation, or simplification of compliance or reporting requirements under the rule for small entities; (3) the use of performance, rather than design, standards; and (4) an exemption from coverage of the rule, or any part thereof, for small entities.[155]

34. The rules adopted in the First Report & Order provide potential users of the spectrum above 95 GHz easier access to that spectrum to provide innovative new services and technologies. We believe that we have streamlined these rules appropriately to afford small entities new opportunities to access that spectrum in a cost-effective manner. We believe that by creating a new experimental radio service license for use above 95 GHz, we will minimize the reporting, recordkeeping and other compliance requirements to require only those that are narrowly tailored to meet our responsibilities to effectively manage the different shared Federal and non-Federal uses of the band. For example, the license term for our new experimental radio service license is longer than that which is currently available under our conventional experimental license. This longer-term license will reduce the burdens associated with license renewals and subsequent applications. Nevertheless, conventional experimental radio service licenses will still be available for that spectrum to the extent that a potential experimental user of the spectrum above 95 GHz finds that such a license is more appropriate for its needs. Furthermore, because users of devices operating under our Part 15 rules do not need to obtain a Commission license, we expect that small entities will find the rules we have adopted to permit unlicensed use of several bands above 95 GHz convenient and economical.

35. The regulatory burdens, such as filing applications on appropriate forms, are necessary in order to ensure that the public receives the benefits of innovative services and technologies in a prompt and efficient manner and apply equally to large and small entities, thus without differential impact. We will continue to examine alternatives in the future with the objective of eliminating unnecessary regulations and minimizing any significant impact on small entities.

Report to Congress: The Commission will send a copy of the First Report & Order, including this FRFA, in a report to be sent to Congress pursuant to the Congressional Review Act.[156] In addition, the Commission will send a copy of the First Report & Order, including this FRFA, to the Chief Counsel for Advocacy of the SBA. A copy of the First Report & Order, including this FRFA (or summaries thereof), will.

[155] 5 U.S.C. § 603(c)(1)-(c)(4).

[156] *See* 5 U.S.C. § 801(a)(1)(A).

APPENDIX C

List of Commenters

NPRM Comments:

Apple Inc.
ARRL, the National Association for Amateur Radio
Consumer Technology Association
CTIA
Ericsson
Facebook, Inc.
Google LLC
IEEE 802 LAN/MAN Standards Committee
IEEE Geoscience and Remote Sensing Society (IEEE GRSS)
mmWave Coalition
NAS Committee on Radio Frequencies
National Radio Astronomy Observatory (NRAO)
Professor Daniel Mittleman
Qualcomm Inc.
Robert Bosch LLC
Satellite Industry Association
Sierra Nevada Corporation
Starry, Inc.
Telecommunications Industry Association
TeraMetrix, a Division of Luna Innovations, Inc.
The Boeing Company
Thomas Kürner
T-Mobile USA, Inc.
Underwriters Laboratories
Wi-Fi Alliance

NPRM Reply Comments:

Charter Communications, Inc.
City of New York
Competitive Carriers Association
CTIA
EchoStar Satellite, Hughes Network Systems, LLC
Inmarsat, Inc
Keysight Technologies, Inc.
mmWave Coalition
Nokia
SES,O3b Limited
Telecommunications Industry Association
The Boeing Company

STATEMENT OF CHAIRMAN AJIT PAI

Re: *Spectrum Horizons*, ET Docket No. 18-21; *James Edwin Whedbee Petition for Rulemaking to Allow Unlicensed Operation in the 95-1,000 GHz Band,* RM-11795 (proceeding terminated).

The horizon for air travel was once thought to be the speed of sound—Mach 1. But on October 14, 1947, test pilot and World War II Air Force Captain Chuck Yeager stepped into his Bell X-1 airplane, the "Glamorous Glennis." Despite having two broken ribs, which prevented him from being able to shut his cockpit door by himself, he made the first airplane flight to break the sound barrier.[157] And he didn't stop there. By 1953, Yeager, who celebrated his 96th birthday last month, had once again extended the horizon for flight, setting a new air speed record of 1650 mph—nearly 1000 mph faster than the flight that broke the sound barrier.[158]

Today, we too extend the horizon—this time with respect to spectrum. Just like Mach 1 speeds, the airwaves above 95 GHz—extremely high-frequency, short-wavelength bands of spectrum—were previously thought to be unapproachable (in our case, for wireless applications). However, recent evolutions in technology have led us to look to these "spectrum horizons" for new services and applications, such as personal health monitoring systems, see-in-the dark imaging, and centimeter-level position, as mentioned in Professor Rappaport's presentation.

Today, we take big steps towards making productive use of this spectrum. We allocate a massive 21 gigahertz for unlicensed use and we create a new category of experimental licenses. This will give innovators strong incentives to develop new technologies using these airwaves while also protecting existing uses.

These steps are groundbreaking, but I'm confident that there will be more ground to break. We will continue to watch the development of spectrum horizons, including for potential non-experimental, licensed uses of spectrum above 95 GHz in the future. And we will continue to act boldly so that the United States continues to lead the world in wireless innovation.

Today's item would not be possible without the work of our forward-thinking staff, in particular Bahman Badipour, Brian Butler, Rashmi Doshi, Michael Ha, William Hurst, Steven Jones, Ira Keltz, Julie Knapp, Nicholas Oros, Aspasia Paroutsas, Siobahn Philemon, Jamison Prime, and Hugh Van Tuyl from the Office of Engineering and Technology; Stephen Buenzow from the Wireless Telecommunications Bureau; Nicole Ongele from the Office of Managing Director; Maura McGowan from the Office of Communications Business Opportunities; and Andrea Kearney and Deborah Broderson from the Office of General Counsel.

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[157] Jason Paur, *October 14, 1947: Yeager Machs the Sound Barrier*, WIRED, (Oct. 14, 2009), https://www.wired.com/2009/10/1014yeager-breaks-mach-1/.

[158] *Pioneer Profile: Chuck Yeager (1923-Present)*, AAIA, https://www.aiaa.org/SecondaryTwoColumn.aspx?id=15204.

STATEMENT OF
COMMISSIONER MICHAEL O'RIELLY

Re: *Spectrum Horizons,* ET Docket No. 18-21*; James Edwin Whedbee Petition for Rulemaking to Allow Unlicensed Operation in the 95-1,000 GHz Band,* RM-11795 (proceeding terminated).

Count me all in for efforts to provide spectrum to the wireless community to create the new, innovative technologies and applications of the future – even if they may be a few years away. I look forward to watching what America's entrepreneurs, innovators, and scientists can do with frequencies above 95 GHz. These bands have their propagation challenges and, right now, we do not know what services they will support; but not too long ago people scoffed at the idea of commercial use in the millimeter waves. Therefore, I support allocating these frequencies for experimental and unlicensed use.

While I strenuously advocate for both licensed and unlicensed spectrum opportunities, I understand that it may be a bit premature to establish exclusive-use licenses above 95 GHz when there is great uncertainty about what technologies will be introduced, what spectrum would be ideal, or what size channel blocks are needed. Therefore, I can support waiting to see what develops. Better that than being forced to undo a mess later. Further, I have been assured that the bands being allocated for unlicensed use in this item are not ideal for licensed services; therefore, today's allocation should not interfere with future licensing activities.

Finally, today's action in no way reduces the need for unlicensed allocations elsewhere, especially in the mid bands. While we are providing opportunities for the technologies of the future, there is still great need for spectrum to expand the unlicensed technologies of today. Two items that the Commission can and should move quickly on are: (1) revisiting the sordid history of the 5.9 GHz band and (2) taking the necessary steps to open the 6 GHz band for unlicensed use.

STATEMENT OF
COMMISSIONER BRENDAN CARR

Re: *Spectrum Horizons*, ET Docket No. 18-21; *James Edwin Whedbee Petition for Rulemaking to Allow Unlicensed Operation in the 95-1,000 GHz Band,* RM-11795 (proceeding terminated).

One reason the U.S. leads the world in wireless is that we've moved quickly to open up new spectrum bands for innovative uses. We don't wait around for technologies to develop fully before unlocking spectrum so that entrepreneurs have the incentives to invest and experiment. You can see it with our steps in the 1980s to identify unlicensed spectrum, which years later allowed Wi-Fi to flourish. You can see it in the early 2000s when we freed up spectrum above 40 GHz, which is commonly used today for vehicle radar and other technologies. And you can see it when we opened up millimeter wave spectrum back when many still doubted that it could support 5G.

We continue this trend today by giving entrepreneurs greater access to spectrum above 95 GHz, which is already home to a number of pioneering technologies. This will help ensure that innovators in the U.S. have the incentives to invest and develop new technologies for the benefit of all Americans.

It took a lot of hard work from the FCC teams in the Office of Engineering and Technology, the Wireless Telecommunications Bureau, and the International Bureau to get this order across the finish line. So I want to thank you for developing today's Order. It has my support.

STATEMENT OF COMMISSIONER JESSICA ROSENWORCEL

Re: *Spectrum Horizons*, ET Docket No. 18-21; *James Edwin Whedbee Petition for Rulemaking to Allow Unlicensed Operation in the 95-1,000 GHz Band,* RM-11795 (proceeding terminated).

Welcome to the far frontier of spectrum policy—the airwaves above 95 GHz. Today we put these stratospheric frequencies to use by adopting a new set of experimental rules for their operation. Access will be granted on a non-interfering basis, following federal coordination. In addition, we authorize unlicensed activity in a set of four bands and specify the power limits and out-of-band emission limits for their operation.

This is good for starters. However, going forward we need to remember that the policies that led to spectrum success in lower frequencies won't necessarily be the policies that serve us in these way-up-there airwaves. After all, our century-old approach to spectrum policy, with its rigid, exclusively licensed bands allocated over large geographic regions is not especially well-suited to the airwaves we open today. That is because the propagation challenges with spectrum above 95 GHz are real. At the upper bounds, signals over these airwaves may not travel much further than from one end of this dais to the other before losing their strength. Moreover, there are no existing systems to protect in much of this spectrum. Plus, these high frequencies permit the use of newer antenna designs, like quasi-optical antennas, which allow transmitters to better control the direction of their signals. Add all this up, and the likelihood of interference is too low to justify a traditional approach with high administrative costs.

To this end, I do not believe that this order gets it quite right when it suggests that the frequencies above 95 GHz are suitable for licensed use. I am pleased that we do not take up such an approach in today's decision. I believe that with these way-up-there frequencies, where the potential for interference is so low, we should flip the script. The burden should be on those seeking exclusive licenses to demonstrate the interference case and justify why we should carve up an otherwise open space for innovation and experimentation. So I hope we can continue with a modern approach to spectrum allocation that is better suited to these far flung frequencies.

Finally, it is worth noting that the spectrum we work with here is different from our lower frequency bands in another important way—much of it is subject to the authority of both this agency and the National Telecommunications and Information Administration. As recent experience demonstrates, we need more meaningful and transparent coordination with our federal partners so that we can realize the full opportunities in these stratospheric airwaves. Otherwise, I fear that opportunities for new experimental operations could be blocked and important scientific research could be diminished.

STATEMENT OF
COMMISSIONER GEOFFREY STARKS

Re: *Spectrum Horizons*, ET Docket No. 18-21; *James Edwin Whedbee Petition for Rulemaking to Allow Unlicensed Operation in the 95-1,000 GHz Band,* RM-11795 (proceeding terminated).

One of the defining features of our human experience is our curiosity: the drive to understand why the apple falls from the tree or to see what's on the other side of the mountain. It is fitting then that this proceeding is entitled "Spectrum Horizons," as we prepare to explore uncharted territory in our spectrum. The spectrum we open today was once thought to be too high frequency for any mainstream use. But we now see that it has the potential to change lives for the better. Terahertz spectrum imaging could change the way doctors and researchers understand biological processes on the cellular, and smaller, level.[159] Doctors may be able to use this technology to conduct non-invasive cancer screening tests, meaning earlier detection and more lives saved.[160] In security settings, terahertz spectroscopy can be used to identify dangerous materials and weapons, meaning threats to safety can be identified without body scans.[161]

Opening previously unused bands of spectrum can spur unexpected innovation. In the most authentic sense, we step into the unknown today. While today's action is bold, we also must act smartly. As we modernize our approach to these bands, we should also modernize our approach to a problem that will demand our attention: harmful interference. It's happened before. As we have authorized new technologies or the use of new bands of spectrum, we have encountered unexpected interference, whether it is interference to wireless calls from consumer signal boosters[162] or LED lights,[163] unauthorized operations in the recently-authorized Citizens Band Radio Service (CBRS) band[164] or interference to weather radar operations from unlicensed wireless broadband transmission systems.[165] In each instance, unexpected interference issues required the Commission to investigate the situation and respond, whether with enforcement actions, policy changes, or both.

Thus, as we look to the future today, we should consider how we will address the interference issues that will inevitably arise. This comports well with a core mission of the Commission and one of my overall goals: to support rules that are clear and well-defined so that if any infractions occur, we can address it and hold any violators accountable. To that end, I would like to highlight two important points: the Commission's interference resolution capabilities and its spectrum management policies.

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[159] Trends in Biotechnology, *Biomedical Applications of Terahertz Spectroscopy and Imaging*, https://www.cell.com/trends/biotechnology/fulltext/S0167-7799(16)30027-0?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0167779916300270%3Fshowall%3Dtrue (last visited Mar. 13, 2019).

[160] The Optical Society, *New Terahertz Imaging Approach Could Speed Up Skin Cancer Detection*, https://www.osa.org/en-us/about_osa/newsroom/news_releases/2017/new_terahertz_imaging_approach_could_speed_up_skin/ (last visited Mar. 13, 2019).

[161] Engineering and Physic Sciences Research Council, *Winner of the 2003/04 Research Councils' Business Plan Competition – 24 February 2004*, https://web.archive.org/web/20140315232115/http://www.epsrc.ac.uk/newsevents/news/2004/Pages/rcukbusinessplan.aspx (last visited Mar. 13, 2019).

[162] *Use and Design of Signal Boosters*, Report and Order, 28 FCC Rcd 1663, 1667, para. 3 (2013).

[163] *LED Sign Marketers Must Comply With FCC Rules*, Public Notice, DA 19-90 (2019).

[164] See *EB Proposes Fine for Unauthorized Operation in the 3650-3700 MHz band*, Notice of Apparent Liability, DA 19-64 (2019).

[165] *Enforcement Bureau Takes Action to Prevent Interference to FAA-Operated Terminal Doppler Weather Radars Critical to Flight Safety*, Public Notice, Advisory, DA 12-459, 27 FCC Rcd 10800, 10800-801 (2012).

First, the FCC has a critical role in detecting and resolving interference issues. Once the Commission authorizes service in a band, parties can and do reasonably expect that their operations in that band will be free from harmful interference in violation of our rules. Our talented staff in the Office of Engineering and Technology (OET) work hard to set technical standards to ensure just that. And, where needed, the Enforcement Bureau's hard-working agents and attorneys investigate and take appropriate action.

But the Commission's staff cannot investigate without the necessary tools and training. Today we open up bands above 95 GHz, including terahertz bands ranging up to 3 THz. The plain fact of the matter, though, is that I have serious questions about the Enforcement Bureau's tools to detect interference in these and other high-frequency bands. In fact, we are not currently capable of policing a significant amount of millimeter wave spectrum – the very high-frequency bands critical for 5G. I am concerned that without dedicated and sufficient resources to developing 21st Century enforcement tools against interference, our efforts to promote 5G will be undermined.

This is not to say that the Commission has erred in making these bands available. To the contrary, the Commission has a statutory responsibility to identify new spectrum bands and apply innovative policy ideas to maximize spectrum efficiency. But the bands we discuss today could be critical to both private health and public safety. More broadly, we owe it to the American people and our employees to ensure that we can be an effective "cop on the beat" in every spectrum neighborhood. That means devoting the funds necessary for the equipment and training that will allow our staff to identify and fully resolve interference issues in all the bands subject to our jurisdiction.

Second, we must continue to evaluate whether we should reconsider our approach to spectrum management, for both new and existing bands. Spectrum is the foundation for innovation, and as we make more spectrum available, we must ensure that our rules maximize the use of all our bands. How do we get the most out of our new and existing spectrum? OET has already asked that question. In February 2017, in response to a recommendation from the agency's Technological Advisory Council (TAC), OET sought comment on whether the agency should adopt a policy statement setting forth spectrum management guidance and principles.[166] Through its recommendation, the TAC made clear that, if we are to use our spectrum in the most efficient manner, we must address some hard questions, including:

- Is our current definition of harmful interference appropriate?
- Should we reconsider what constitutes an acceptable level of interference?
- How should the Commission assess the risk of harmful interference?
- When the Commission assesses interference disputes, have we unreasonably favored the operations of incumbents over those of new entrants?
- Should the Commission provide researchers with access to interference case data to identify interference trends and other issues?

The comment period in this proceeding closed more than a year ago. I welcome the opportunity to tackle these questions head on, as we must modernize our spectrum policy to serve our current and future spectrum needs.

Opening spectrum once thought commercially unusable is good policy. It will encourage

[166] *Comment Sought on Tech. Advisory Council's Spectrum Recommendations*, Public Notice, 32 FCC Rcd 10160, 10160 (2018).

innovation and the deployment of new technologies that will change lives for the better. Before we cross over that spectrum horizon, we must make sure we are equipped and prepared for the journey. The Enforcement Bureau needs the resources and training to investigate fully and resolve interference in all bands subject to FCC jurisdiction. And I look forward to hearing from experts inside and outside the agency about how to make the most of our spectrum resources.

Finally, my thanks to the staff of OET for their hard work in identifying and setting standards for new bands of spectrum, and for their work on this item.