Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of Part 90 of the Commission's Rules	)	WP Docket No. 07-100
	)	
	)	

**COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES**

The National Academy of Sciences, through its Committee on Radio Frequencies (hereinafter, CORF),[1] hereby submits its Comments in response to the Commission's Eighth Further Notice of Proposed Rulemaking (FCC 20-137) in the above-captioned docket ("*8th FNPRM*"). In these Comments, CORF discusses proposed terrestrial and aeronautical mobile use of spectrum at 4940-4990 MHz and the Commission's inquiry regarding unlicensed use of this band. CORF has long supported the thoughtful sharing of spectrum among services, when such sharing is practical. However, an aeronautical service transmitting down to Earth is the worst-case scenario in regard to potential interference problems for Radio Astronomy Service ("RAS") observatories, as recognized in a number of footnotes to the U.S. Table of Frequency Allocations. CORF recommends against revision of the Commission's rules to authorize aeronautical use of the 4.9 GHz band. The Commission has long recognized the risks of interference to RAS from aeronautical use of the 4.9 GHz band. If, however, the Commission

[1] See Appendix 2 for the membership of the Committee on Radio Frequencies.

nevertheless chooses to allow such use in its rules, then protections for the RAS that were proposed in the *Sixth Further Notice of Proposed Rulemaking* in this proceeding,[2] along with other protections, must be adopted to minimize harmful interference to radio astronomy observatories. Similar protections should be adopted for terrestrial users.

I. Introduction: The Role of Radio Astronomy, and the Unique Vulnerability of Passive Services to Interference.

CORF has a substantial interest in this proceeding because it represents the interests of the passive scientific users of the radio spectrum, including users of the RAS bands. RAS observers perform extremely important yet vulnerable research.

As the Commission has long recognized, radio astronomy is a vitally important tool used by scientists to study our universe. It was through the use of radio astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. Ongoing radio observations of nearby extrasolar planets aim to detect the presence of a magnetic field that could be a prerequisite for life, since current theory suggests that the lack of a Martian magnetic field to protect it against solar storms and cosmic rays might explain why it is relatively barren compared to Earth, which has a strong magnetic field. The Nobel Prize–winning discovery of pulsars by radio astronomers has led to the recognition of a widespread population in the Milky Way Galaxy of rapidly spinning neutron stars with gravitational fields at their surface up to 100 billion times stronger than on Earth's surface. Subsequent radio observations of pulsars have revolutionized the understanding of the physics of neutron stars and

[2] *Amendment of Part 90 of the Commission's Rules*, WP Docket No. 07-100, Further Notice of Proposed Rulemaking, 33 FCC Rcd 3261, 3262, para. 2 (2018) (*Sixth Further Notice*).

resulted in the first experimental evidence for gravitational radiation, which was recognized with the awarding of another Nobel Prize.[3] Within our own solar system, radio astronomy observations of the Sun have been used for more than half a century to aid in the prediction of terrestrial high-frequency radio propagation. Radio astronomy has also enabled the discovery of organic matter and prebiotic molecules outside our solar system, leading to new insights into the potential existence of life elsewhere in the Milky Way Galaxy. Radio spectroscopy and broadband continuum observations have identified and characterized the birth sites of stars in the Milky Way, the processes by which stars slowly die, and the complex distribution and evolution of galaxies in the universe. The enormous energies contained in the enigmatic quasars and radio galaxies discovered by radio astronomers have led to the recognition that most galaxies, including our own Milky Way, contain supermassive black holes at their centers, a phenomenon that appears to be crucial to the creation and evolution of galaxies. Synchronized observations using widely spaced radio telescopes around the world give extraordinarily high angular resolution, far superior to that which can be obtained using the largest optical telescopes on the ground or in space. Beyond astrophysics, a critical practical application of regular observations of a grid of quasars associated with supermassive black holes is space geodesy, which provides measurements of the mass distribution of Earth as well as determination of Earth orientation parameters. These are important ingredients in precise position determination, navigation, and timing, and in studying geophysical phenomena such as sea-level rise and earthquake effects that have substantial public impact.

[3] Radio astronomy measurements led to yet another Nobel Prize–winning discovery of the cosmic microwave background (CMB), the radiation left over from the original Big Bang.

This critical science undertaken by RAS observers, however, cannot be performed without access to interference-free bands. Notably, the emissions that radio astronomers receive are extremely weak—a radio telescope receives less than one percent of one-billionth of one-billionth of a Watt (10^{-20} W) from a typical cosmic object. Because radio astronomy receivers are designed to pick up such remarkably weak signals, radio observatories are particularly vulnerable to interference from in-band emissions, spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and emissions that produce harmonic signals in the RAS bands, even if those human-made emissions are weak and distant.

Of particular concern in this proceeding is protection of RAS observations in the 4.9 GHz band.[4] As stated in footnote 57 of the *Sixth Further Notice*, radio astronomy observations in the 4.9 GHz band are extremely useful in studying the brightness distributions of objects such as ionized hydrogen clouds surrounding young stars, remnants of supernovae that mark the cataclysmic end of stars, and ejecta traveling at nearly the speed of light from black holes in the nuclei of galaxies. Such observations allow scientists to construct detailed maps of such phenomena, to understand their structures and dynamics, and to derive physical parameters from the sources, such as their total masses. Observations of radio emissions from neutron stars and black holes are particularly sensitive to interference due to their natural variability, and one cannot just re-observe such phenomena at a later time. The current benefits of this scientific research, obtained through years of work and substantial federal investment, as well as

[4] International footnote 5.339 states that the 4950-4990 MHz band is also allocated to the space research and Earth exploration satellite services on a secondary basis. However, CORF is unaware of any current usage of these bands for Earth and space sciences beyond their application to VGOS (VLBI Geodetic Observing System), as described later in these Comments.

future benefits, must be protected.

In recognition of the importance of the radio astronomy research done in the 4.9 GHz band, Footnote US385 states that "[i]n the bands . . . 4950-4990 MHz, every practicable effort will be made to avoid the assignment of frequencies to stations in the fixed and mobile services that could interfere with radio astronomy observations" at certain RAS observatories listed therein and further states that "every practicable effort will be made to avoid assignment of frequencies in these bands to stations in the aeronautical mobile service that operate outside of those geographic areas, but which may cause harmful interference to the listed observatories." Similarly, Footnote US342 states that "all practicable steps shall be taken to protect the radio astronomy service" at 4950-4990 MHz and also states that "[e]missions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service" Footnote US342 does not limit that protection to only the RAS observatories listed in Footnote US385.

II. CORF Opposes Authorizing Aeronautical Use at 4940-4990 MHz.

In paragraph 60 of the *8th FNPRM*, the Commission seeks comments on a number of technical options for use of 4940-4990 MHz ("4.9 GHz band"), including allowing "manned aeronautical mobile, not including unmanned aeronautical systems (UAS)." While CORF supports thoughtful use of spectrum sharing, an aeronautical service transmitting down to Earth is the worst-case scenario in regard to potential interference problems for radio astronomy observatories, as recognized in Footnotes US342 and US385. Accordingly, CORF opposes revising Section 90.1205(c) of the

Commission's rules to remove the prohibition on aeronautical use of the 4.9 GHz band. In reviewing filings in this comment cycle, the Commission should be mindful that brief statements of support for such a rule revision are easy to make, but by themselves provide no basis for projecting wide-spread aeronautical use or for revising this long-standing rule. Yet the costs of revising the rule, particularly without substantial protections for RAS, could include the loss of use of this critical band for scientific research.

III. If the Commission Chooses to Authorize Aeronautical Use of the 4.9 GHz Band, It Should Also Enact Protections for RAS.

As noted above, CORF opposes revising the Commission's rules to authorize aeronautical use of the 4.9 GHz band. However, if the Commission chooses to so revise its rules, then any revision should include provisions to protect RAS observations at 4950-4990 MHz from interference. Such protections were proposed by the Commission in the *Sixth Further Notice*. Additional protections should be considered if the Commission also authorizes the leasing of this band.

The *Sixth Further Notice* recognized the significant risks of interference to RAS facilities from aeronautical transmissions at 4.9 GHz and proposed specific means of protecting RAS. While terrestrial services are quite capable of causing interference to sensitive RAS facilities, aeronautical uses are even more capable of such effects, due to the breadth of the geography "seen" by an airborne transmitter and the ease with which such transmissions can be made directly into the RAS receiver due to lack of intervening obstructions.[5] Thus, preventing line-of-sight transmission is critical to any

[5] See Footnote US342.

practical sharing of the 4.9 GHz band between RAS and aeronautical mobile uses.

The line-of-sight issue is triggered when aircraft fly above the horizon of an RAS observatory. This is a function of flight altitude, but also of local geography and the presence or absence of terrain-shielding mountains. The *Sixth Further Notice* proposed (at para. 20) a maximum operational altitude of 1,500 feet above ground level. CORF supports that proposal as a simple method for minimizing line-of-sight transmissions into RAS facilities provided that operation is prohibited within 100 kilometers[6] of an observatory listed in footnotes US385 or US161,[7] as also proposed in para. 22 of the *Sixth Further Notice*.[8] A clear and unambiguous limit eliminates the proliferation of confusing, site-specific altitudes close to RAS facilities that may be easily violated, even unintentionally. It also limits the risk associated with disagreements over the

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[6] The size of the exclusion zone is based on the line-of-sight, which is a function of operational altitude. If the maximum operational altitude is revised, the exclusion zone radius would also need to be revised to protect radio astronomy observatories. CORF acknowledges that in previous comments in this proceeding, it has agreed to proposals for an aeronautical exclusion zone of 80.5 kilometers at 1,500 feet above ground level. However, upon re-review and analysis of such proposals, CORF has concluded that the correct radius is 100 kilometers. *See* Appendix 1 attached hereto for the calculations. Notably, while Footnote US385 establishes geographic protection areas for certain observatories, including 80-kilometer radii around the individual sites of the Very Long Baseline Array (VLBA) and the site in Goldstone, California, that was for *terrestrial* users, since section (a) of US385 goes on to recommend *additional* protections for "aeronautical mobile service which operate outside of those geographic areas, but which may cause harmful interference to the listed observatories." In any case, Footnote US342 requires that "all practicable steps shall be taken to protect the radio astronomy service from harmful interference" at 4950-4990 MHz, and does contain any specific geographic limitations.

[7] Procedures should also be defined for notification when and if additional RAS observatories commence observing at this frequency band.

[8] Section 90.1219(f) as proposed in the *Sixth Further Notice* referred to the Allen Telescope Array ("ATA"). If the Commission adopts such a rule section in this proceeding, it should revise the coordinates for the ATA to use 40° 49' 03" North latitude, 121° 28' 24" West longitude. That proposed rule section also provided for waivers of the geographical restriction, but required any such waiver to be served on the affected observatory. For sake of ease, CORF recommends that such service be sent to the National Science Foundation Spectrum Management Unit, esm@nsf.gov. RAS representatives must have at least 30 days to respond to such waiver requests.

effectiveness of terrain-blocking features in a particular scenario.

The other core method for protecting RAS observations is sufficient frequency separation from the active transmissions. Accordingly, CORF supports the proposal in para. 15 of the Commission's *Sixth Further Notice* to limit aeronautical use of this band to Channels 1-5, i.e., 4940-4945 MHz, thus creating a "guard band" of separation from the RAS allocation at 4950-4990 MHz.[9] The Commission should also be mindful of the issue of out-of-band emissions, by requiring the specific emission mask in the rule Section 90.1219(b) proposed in the *Sixth Further Notice*.

CORF also supports the requirement in proposed Section 90.1219(d) in the *Sixth Further Notice* that applicants provide a description of their operations to demonstrate that such operations will protect radio astronomy (and other terrestrial uses) from interference. This requirement would help focus applicants on the requirements of Section 90.1219, and provide some basis for evaluating their compliance.[10]

Finally, CORF also supports other protections for RAS proposed in the *Sixth*

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[9] The *8th FNPRM* also seeks comments on use of this band by robotic devices. Limiting robotic use to the lower five megahertz of the 4.9 GHz band, as proposed in para. 60 of the *8th FNPRM*, would be a good solution for protecting RAS observatories. CORF recommends that any robotic use of this band be limited to public safety agencies: due to the limited number of exigent circumstances in which such robots are anticipated to be used for public safety purposes, as well as the remote location of radio astronomy observatories, CORF does not anticipate a significant number of cases of interference to RAS observations from public safety use of robots. However, this may not be the case with private or commercial use of such robots. If robotic use of the 4.9 GHz band is authorized but not limited to the lower five megahertz, then such use should be subject to any general coordination requirements, except in obviously exigent circumstances. In such exigent circumstances, a public safety agency that would otherwise be subject to coordination requirements should notify the impacted observatory as soon as possible.

[10] This requirement would also provide a basis for the Commission to impose special conditions or restrictions on individual licensees, where necessary to reduce the risk of interference to RAS operations, as set forth in the Section 90.1219(g) proposal in the *Sixth Further Notice*. The Commission should clarify that it may impose special conditions not just at the time of issuing an authorization, but subsequently as well, if interference to RAS results from the authorized aeronautical operations.

Further Notice, such as the proposal in para.19 therein (and in para. 60 of the *8th FNPRM*) to prohibit the use of the band by unmanned aerial systems. Such vehicles are likely to be used by non-professionals and thus more likely to inadvertently or purposely violate other limitations such as distance and frequency separations, leading to interference.

IV. Terrestrial Licensed Operations Should Protect RAS Observations.

While aeronautical use of the 4.9 GHz band poses risks to RAS observations due to enhanced line of sight and the ease with which such transmissions can be made directly into the RAS receiver due to lack of intervening obstructions, terrestrial operations can pose a threat as well. Footnote US342 requires that “all practicable steps shall be taken to protect the radio astronomy service from harmful interference” at 4950-4990 MHz, and in this case, the practicable steps could include exclusion or coordination zones.

Footnote US385 provides, at section (a), that “In the bands 1350-1400 MHz and 4950-4990 MHz, every practicable effort will be made to avoid the assignment of frequencies to stations in the fixed and mobile services that could interfere with radio astronomy observations within the geographic areas” set forth in the beginning of the footnote. Accordingly, CORF recommends that the Commission establish exclusion zones identical to those in US385, in which transmission would be prohibited.[11]

Alternatively, consistent with the coordination proposal in para. 47 of the *8th FNPRM*, the Commission should include a requirement to coordinate with RAS when

[11] An exception could be made for public safety operations made in immediate response to emergency/safety-of-life situations, for the duration of the emergency status.

the proposed 4.9 GHz band facilities would operate within the geographic areas set forth in US385.[12] Such coordination should be through the National Science Foundation's Spectrum Management Unit, esm@nsf.gov.

V. Unlicensed Operations Should Protect RAS Observations.

In para. 86 of the *8th FNPRM*, the Commission seeks comments on unlicensed use of the 4.9 GHz band. Unlicensed use of the spectrum, even at low power, can cause particularly troublesome interference for passive users. Because radio astronomy receivers are designed to pick up remarkably weak cosmic signals, radio observatories are particularly vulnerable to interference from in-band emissions, spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and emissions that produce harmonic signals in the RAS bands, even if those human-made emissions are weak and distant. Even when, as in the present case, a band already has incumbent fixed operations, transmissions by unlicensed devices into protected RAS bands can be particularly harmful because, due to their mobility and lack of licensing records, it is very difficult to identify the operator of such devices and to remedy the interference.

In addition, low levels of interference can be particularly harmful to passive scientific observational data. Signals that cause a high level of interference to passive observations can be reliably identified and the affected data excised from the record. This reduces efficiency, and the associated irrevocable loss of information from the affected measurements can lead to reductions in accuracy and utility of the observation if

[12] Of course, there may be emergency situations where such coordination is not possible. Radio astronomers are good citizens and would be unlikely to object to interference resulting from legitimate public safety aeronautical use during and immediately following a natural disaster or other critical emergency.

the degree of loss becomes large. However, an arguably greater threat comes from unwanted signals captured by passive receivers that are at a lower level and not easily recognizable, and thus can masquerade as valid scientific data. This interference creates an “insidious” corruption of data that can significantly skew the validity of the conclusions based on that data.

CORF recognizes that advocates of unlicensed use of this band will assert that such use will be at very low power. It should be noted that consideration of what constitutes “very low power” is in part relative to the sensitivity of the service for which protection is sought. As noted above, the receivers used in radio astronomy observatories are the most sensitive ones in existence. The level of protection for RAS is set by ITU-R RA.769. For spectral line observations at 4995 MHz, a spectral power flux density of -230 dB(W/(m^2 Hz)) is considered harmful, whereas the power level that is harmful to continuum observations at this frequency is even lower, at -241 dB(W/(m^2 Hz)), based on Tables 2 and 1 of ITU-R RA.769, respectively. For facilities strictly dedicated to Very Long Baseline Interferometry (VLBI) observations, such as the stations of the Very Long Baseline Array (VLBA) and the VLBI Geodetic Observing System (VGOS), interference is incoherent between stations, and so the harmful interference threshold is higher, although nevertheless quite stringent at -200 dB(W/(m^2Hz)) (RA.769 Table 3). Given that there is very little atmospheric attenuation at this frequency band, this confirms that aggregate power levels for outdoor devices located near a radio astronomy facility would have to be extremely low to avoid harmful interference. In other words, protection of RAS requires significant geographic separation or frequency separation for unlicensed devices.

Accordingly, pursuant to the requirements of Footnote US342 that “all practicable steps shall be taken to protect the radio astronomy service from harmful interference” at 4950-4990 MHz, if a proposed device is able to sense its geographic location, then geographic exclusion zones similar to those listed in Footnote US385 should be implemented. These exclusion zones should include geographic regions around protected RAS sites in the United States explicitly tabulated in US385 that operate in the 4.9 GHz band, including the Arecibo Observatory,[13] the Green Bank Observatory, the Very Large Array and its follow-on development the ng-VLA, the 10 stations of the VLBA, and the Allen Telescope Array, as well as other sensitive sites considered under US342, including the existing and future VGOS sites and the Owens Valley Deep Synoptic Array-110 (DSA-110) and proposed follow-on DSA-2000, located near the VLBA station tabulated in US385. Alternatively, if a device is not able to sense and respond to its geographic location, a reasonable accommodation on any device with a user interface is to provide a feature to turn off the device, analogous to the “airplane mode” that is common and often desired by users of such devices, and to restrict operation of simpler devices lacking a user interface to the lowest five channels. In any case, for the reasons set forth in Section II above, the Commission should not authorize airborne uses of unlicensed 4.9 GHz band devices, or it should limit such devices to operating use on Channels 1-5, i.e., 4940-4945 MHz, thus creating a “guard band” of separation from the RAS allocation at 4950-4990 MHz.

VI. Conclusion.

[13] Although the main Arecibo Telescope has been decommissioned, a VLBI station continues to operate at the site, and proposals to replace the main telescope are in development.

The Commission has long recognized the risks of interference to RAS from aeronautical use of the 4.9 GHz band. For the same reasons, CORF generally opposes aeronautical use of the 4.9 GHz band. However, if the Commission chooses to revise its rules to remove the current prohibition on such use, it must enact the protections discussed above, in order to provide an adequate level of protection to RAS. Similarly, any unlicensed operations in the 4.9 GHz band should include protections for RAS as described above.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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November __, 2021

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Appendix 1

Calculation of Aeronautical Exclusion Zone Radius

Section 15.407(m) of the Commission's rules implements the proper formula for calculating the radio line-of-sight to create an exclusion zone to protect radio astronomy observatories. The formula in this rule was suggested by CORF and implemented in the Commission's Report and Order, *In the Matter of Unlicensed Use of the 6 GHz Band*, 35 FCC Rcd. 3852 (2020) at para. 88 and footnote 222. Specifically, for radio line-of-site **D**:

$$\mathbf{D = 4.12 \times [sqrt(H_{tx}) + sqrt(H_{rx})]},$$

where **D** is in kilometers, and the heights above terrain $\mathbf{H_{tx}}$ and $\mathbf{H_{rx}}$ of the transmit and receive antennas are in meters. Along with the curvature of Earth, this takes into account the typical vertical gradient in the radio refractive index of the atmosphere.

Using $\mathbf{H_{tx}}$, the height of the aircraft as 1,500 feet (457 meters), and 10 meters as a representative height $\mathbf{H_{rx}}$ of the radio astronomy antenna, we arrive at a radio line of sight of **D = 103 kilometers**. Rounding this to 100 kilometers, we suggest that this is the appropriate minimum avoidance radius for an aircraft or drone flying up to 1,500 feet.

Appendix 2

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