

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Unlicensed Use of the 6 GHz Band	)	ET Docket No. 18-295
	)	
Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz	)	GN Docket No. 17-183
	)	

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

The National Academy of Sciences, through its Committee on Radio Frequencies (hereinafter, CORF¹), hereby submits its comments in response to the Commission's *Second Further Notice of Proposed Rulemaking* ("*Second FNPRM*"), released November 1, 2023, in the above-captioned dockets. CORF acknowledges that the Commission has previously in this proceeding recognized the public interest need to protect important radio astronomy and remote sensing observations at 6 GHz. As discussed below, CORF urges the Commission to again be mindful of that public interest need and not to undercut the protections already enacted in this proceeding.

I. Introduction

CORF has a substantial interest in this proceeding, as it represents the interests of scientific passive users of the radio spectrum, including users of the Radio Astronomy Service ("RAS") and the Earth Exploration Satellite Service ("EESS").

Radio astronomers perform important research that is extremely vulnerable to

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

interference. The emissions that radio astronomers observe are extremely weak—a radio telescope receives less than 1 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, from spurious and out-of-band emissions associated with licensed and unlicensed use of neighboring bands, and from 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 mobile 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 interference from such devices, to identify the operator of such devices, and to remedy the interference.

The RAS is an important and protected incumbent in the U-NII-7 sub-band. The 6650-6675.2 MHz band (the “6.7 GHz RAS band”) is important to the RAS for observations of methanol that play a critical role in research into star formation, astrochemistry, and precision astrometry. Accordingly, this band is protected by footnote US342, which states that “all practicable steps shall be taken to protect the radio astronomy service from harmful interference” in this band. In particular, the spectral line at 6668.518 MHz, associated with the $5_1 \rightarrow 6_0$ A⁺ transition of the methanol molecule, is among those of greatest observational importance to RAS. (See, Recommendation ITU-R RA.314-10 at Table 1.²) This transition is widely observed in

² See also ITU Radiocommunications Bureau, 2013, *ITU Handbook on Radio Astronomy*, Table 3.2.

bright, non-thermal maser³ emission in high mass star-forming regions. Such astrophysical masers, in which collisional or radiative pumping of interstellar gas creates a medium that amplifies natural radio emissions at particular molecular line frequencies, are observed in only a handful of interstellar molecules that have the density, quantum structure, and environmental interaction necessary to produce a state-inverted population supporting maser amplification. These masers serve as probes of the physical conditions and processes in their local environments, providing vital insight into star formation and other processes. Additionally, by virtue of their intensity, compactness, and narrowband emission, masers serve as beacons for precision mapping of the structure and kinematics of our galaxy. Among all observed maser transitions, the 6.7 GHz methanol line stands out for its ubiquity and intensity. This unique role amply justifies its explicit protection in footnote US342 and international footnote 5.149.

CORF is also concerned about the continued ability to make Earth remote sensing observations in bands overlapping the bands under consideration in this proceeding. International footnote 5.458 notes that frequencies between 6425 and 7250 MHz are used for passive microwave measurements (with the lower fraction, 6425-7075 MHz, used for ocean remote sensing) and states that administrations should bear in mind the needs of these services in their planning. Observations at these frequencies are an essential component for both weather prediction and observing climate change. EESS (passive) sensors are uniquely able to measure sea surface temperature, ocean

³ The term maser comes from an acronym for Microwave Amplification by Stimulated Emission of Radiation and is the same term used to describe technological masers used as precision atomic clocks and low-noise microwave amplifiers.

surface wind speed, and sea ice temperature, and cover/concentration and type, all of which are classified as essential climate variables.⁴ Further, in contrast with observations in the infrared and visible regions of the spectrum, EESS (passive) sensors can make such measurements regardless of cloud cover. As with EESS (passive) observations generally, these ocean observations must be made in multiple bands, because no single band provides unambiguous information on any one of these variables. Rather, the ocean/atmosphere state must be deduced from consideration of simultaneous observations in multiple bands. The frequencies between 6425 and 7250 MHz are particularly valuable in this observing system, because sea surface temperature measurements in this frequency range are least affected by clouds in the atmosphere, including by absorption and scattering from rain drops and snow.⁵ Observational approaches employing this band provide the most precise measurements. The 6.9 GHz region also provides important information on ocean surface wind speeds, including in rainfall conditions. This latter capability makes this band crucial for observations of tropical cyclones—measurements that are directly fed into hurricane forecast systems and thus of great societal importance. Additionally, observations in this band made over land regions convey information on soil moisture.

CORF acknowledges that the Commission has previously in this proceeding recognized the public interest need to protect RAS and EESS observations. In its April

⁴ See, for example, Global Climate Observing System, “Essential Climate Variables,” <https://gcos.wmo.int/en/essential-climate-variables/>, accessed 12/17/2023.

⁵ See L. Kilic, C. Prigent, F. Aires, J. Boutin, G. Heygster, R.T. Tonboe, et al., 2018, “Expected Performances of the Copernicus Imaging Microwave Radiometer (CIMR) for an All-Weather and High Spatial Resolution Estimation of Ocean and Sea Ice Parameters,” *Journal of Geophysical Research: Oceans*, 123:7564–7580, <https://doi.org/10.1029/2018JC014408>, specifically, page 7566. See also, E. Lancheros, A. Camps, H. Park, P. Rodriguez, S. Tonetti, J. Cote, and S. Pierotti, 2019, “Selection of the Key Earth Observation Sensors and Platforms Focusing on Applications for Polar Regions in the Scope of Copernicus System 2020–2030.” *Remote Sens.* 11:175. <https://doi.org/10.3390/rs11020175>.

24, 2020, Report and Order (“*First R&O*”),⁶ the Commission also recognized the public interest in protecting RAS observations in this band and implemented protection of RAS observations from interference from standard power operations by using the Automatic Frequency Coordination (AFC) system to determine exclusion zones within the radio line-of-sight distance between the radio astronomy antenna and the unlicensed access point. To protect EESS, the Commission prohibited standard-power and low-power indoor access points aboard ships and on oil platforms. CORF greatly appreciates the Commission’s actions in this regard. Furthermore, the Commission also prohibited unlicensed devices in the 6 GHz band—whether standard-power or low-power devices—from operating on unmanned aircraft systems, and limited use aboard large aircraft to altitudes above 10,000 feet. This is helpful for protecting both RAS and EESS observations. CORF urges the Commission to again be mindful of the public interest in protecting important but extremely vulnerable RAS and EESS observations, and not to undercut the protections already enacted in this proceeding.

II. Protecting RAS Observations

CORF first addresses concerns related to the new rules for very-low-power (VLP) 6 GHz devices enacted in the Commission’s October 19, 2023, Second Report and Order in this proceeding. CORF then turns to the proposed rules for a new class of geofenced higher-power VLP devices in the accompanying *Second Further NPRM*, for which its considerations are similar.

⁶ Federal Communications Commission, 2020, *Unlicensed Use of the 6 GHz Band; Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz*, Report and Order and Further Notice of Proposed Rulemaking, 35 FCC Rcd 3852, 3855.

In comments filed in response to the Commission's April 2020 Further Notice of Proposed Rulemaking leading to the present R&O, CORF noted⁷ that for a *single* VLP device radiating in the 6.7 GHz RAS band with a spectral effective isotropic radiated power (EIRP) of -8 dBm/MHz, the free-space separation needed to protect a victim RAS observatory from harmful interference at the thresholds defined in ITU-R RA.769 is some 900 km. Since this is larger than the radio horizon distance of any ground-based observatory, the practical implication is that any such VLP device lying within the observatory's radio horizon and not shielded by structures or terrain is a potential source of harmful interference. Because of this, CORF recommended that where geofencing is not practicable, such devices should avoid radiating at frequencies within the 6.7 GHz RAS band.

In its response at para. 84 of the *Second R&O*, the Commission took note of these earlier CORF comments but chose not to implement CORF's recommendations. Instead, the Commission argued that experience with 6 GHz low-power indoor (LPI) devices in this band can be extrapolated to infer that VLP devices will not create harmful interference to RAS observatories. Apart from the implicit assumption that the limited experience to date with LPI devices is sufficient to make this inference, CORF sees several additional problems with this reasoning. First, within its radio horizon, a remotely located observatory in an undeveloped area is much more likely to be exposed to the emissions from a portable outdoor device than from an indoor device located within a

⁷ National Academy of Sciences' Committee on Radio Frequencies Comments at 4 (filed May 28, 2020). In para. 83, the Commission uses the word "claim" to describe the evidently surprising result of this easily verified calculation. It is helpful to note that the Radio Astronomy Service makes calibrated measurements of natural radio noise with integration times that can exceed 10^3 seconds, in stark contrast with telecommunication systems operating at symbol rates of order 10^7 Hz. This 10^{10} ratio in signal averaging time corresponds to 50 dB difference in sensitivity.

structure. Second, the difference between the maximum permitted spectral density of equivalent isotropic radiated power (spectral EIRP) for LPI devices (5 dBm/MHz maximum) and that for the proposed VLP devices (assuming -8 dBm/MHz typical spectral EIRP under transmit power control for devices permitted to operate up to a maximum spectral EIRP of -5 dBm/MHz) is 13 dB. This is at the low end of the building entry loss estimates near 6 GHz in ITU Recommendation ITU-R P.2109, corresponding to structures built with “traditional” as opposed to “thermally efficient” materials, for which the estimated building entry loss exceeds 30 dB. This further calls into question the validity of extrapolating the likelihood of interference from LPI device experience to VLP devices. Finally, the Commission stated that “observatories can restrict such [VLP] devices from being used at their facilities.” Since the required separation distance extends to the radio horizon as noted above, this would not come close to achieving protection.

Responding to CORF’s suggestions that VLP devices therefore avoid the 6.7 GHz RAS band, the Commission stated that “we cannot justify requiring VLP devices to notch out this band as requested as this would increase device complexity and result in less efficient spectrum use.” This would be a tenable concern if indeed additional filtering or other hardware were required. However, the devices in question are generally channelized, and it is not difficult to block out an appropriate set of channels in device firmware. Taking the WiFi 6E channel plan (Figure 1) as an example, a guard band of 10 MHz or greater would be realized by avoiding 2 out of the 59 available 20 MHz channels, 2 out of the 29 40 MHz channels, 2 out of the 14 available 80 MHz channels, and 1 of the 7 160 MHz channels. The corresponding loss of

observatory could manually enable these channels through a user configuration interface as simple as a check box.

Also shown in Figure 1 are the 320 MHz channels associated with the emerging WiFi 7 standard. It should be noted that WiFi 7 will require support of static band puncturing within wide channels, in 20 MHz increments, to enable efficient protection of incumbent services. CORF encourages the Commission to look toward these future technical developments to support protection of critical passive bands, including those with “all practicable steps” footnote protection, adopting rules that take these device capabilities into account. For current and legacy standards without such capabilities, protection can be provided with only modest loss of spectral efficiency as discussed above.

Turning now to the proposed new rules for geofenced VLP devices, the Commission states (at para. 123): “We further propose that geofenced VLP devices protect certain radio astronomy sites and FSS [Fixed Satellite Services] receive sites as provided in the Commission’s rules.” CORF appreciates this recognition of the importance of protecting radio astronomy. As discussed above, CORF proposes that the protection afforded to the observatories and protection zones defined in the proposed rules (Appendix B) at 47 CFR §15.407(q) be that the device avoid transmitting in any channel less than 10 MHz away from the 6.7 GHz RAS band defined in footnote US342.

Strictly interpreted, the Commission’s proposed §15.407(o) implies that if a geofenced VLP device cannot determine its location or access a geofencing system to obtain exclusion zone data, the device should not transmit at all. Possibly, the intent is

that the device may fall back to operation under the rules for non-geofenced VLP devices. Here, CORF requests that the Commission consider the discussion above regarding avoiding channels that overlap the 6.7 GHz RAS band.

Finally, as recognized by the Commission in response to CORF's prior comments in this and other proceedings, radio astronomy facilities are particularly vulnerable to interference from airborne transmissions. While CORF continues to oppose airborne use of frequencies in or adjacent to protected RAS bands, if the Commission is to authorize further airborne use of VLP devices, such use must be limited to inside of full fuselage aircraft and then only when those aircraft are operating at altitudes above 10,000 feet. In addition, any VLP transmissions should be limited to frequencies within the U-NII-5 band only, which will provide essential protection to the 6.7 GHz RAS band. Lastly, given the limited attenuation from unmanned aircraft systems (UAS) fuselages, the limits on UAS altitudes, and the relatively uncontrolled and undocumented nature of UAS operations, the Commission must continue to prohibit VLP transmissions in all UAS operations. All of these limitations on airborne use of VLP devices will serve the public interest in protecting important scientific research.

III. Protecting Remote Sensing/EESS

As the Commission knows, remote sensing using EESS (passive) bands is critical to both weather prediction and the study of climate change and of the Earth system in general.⁹ The prospect of sea level rise in a changing climate greatly

⁹ *ITU News Magazine*, 2023, Volume 5 (https://www.itu.int/en/itu/news/Documents/2023/2023-05/2023_ITUNews05-en.pdf, accessed 12/18/2023) includes significant discussion on the value of EESS (passive) observations.

accentuates the need for uninterrupted (in both space and time) observations of the complete ocean state, including surface temperature and winds, for which the 6.9 GHz band is key. Such measurements are needed both for trend monitoring and, critically, for studies of key oceanic processes. The coastal zones are of particular importance in this regard, with an estimated 146 million people (2 percent of the world population) living in areas 1 m or less above mean high tide, and over 40 percent of the population living within 100 km of the coast. Increases in sea level, as well as stronger storm systems and increased encroachment of sea water into coastal zone water tables, are under intense study given their profound impacts on ecosystem, societal, and economic well-being. The need for such research is driving requirements for coastal zone observations to ever finer spatial resolution. For example, the planned European Copernicus Imaging Microwave Radiometer (CIMR) includes a 7-m diameter antenna, resulting in ~15 km spatial resolution at 6.9 GHz (with finer resolutions at higher frequencies), more than threefold finer resolution than that of predecessor instruments. This improvement enables observations to be made closer to coastlines than previously possible as pixels need to be land-free in order for oceanographic observations to be made.

The starting point for any consideration of interference into these observations is recommendation ITU-R RS.2017, which states an interference threshold of -166 dBW in a 200 MHz reference bandwidth. A single VLP (14 dBm max EIRP) device lying with the beam and passband of the planned CIMR instrument described above would result in a -134 dBW signal, with the current-generation Advanced Microwave Scanning

Radiometer (AMSR) series of instruments¹⁰ receiving –145 dBW.¹¹ Such interference levels are 33 dBW and 22 dBW in excess of the RS.2017 threshold, respectively. These exceedances are substantial, even before one factors in aggregate emissions when multiple such devices are active within a locale—which is, after all, the intended implementation. This degree of interferences is highly unlikely to be reduced to acceptable levels by expected building entry losses documented in ITU-R P.2109-2, nor would the –6 dB power control mechanisms noticeably reduce the degree of interference. Furthermore, it is unlikely that these exceedances would be markedly reduced by any beam directionality (which would be expected to be minimal in many cases, particularly for any hand-held devices). However, given that EESS (passive) observations are made in the region covered by the U-NII-6, 7, and 8, bands, in CORF’s view, transmissions from VLP and higher-power-level devices in U-NII-5 would have negligible ill effects on remote sensing. Geofencing seems the logical route to accomplishing the needed protection, with devices programmed to avoid the U-NII-6, 7, and 8 bands in oceanic zones, including in coastal waters, and non-geofenced usage being restricted to the U-NII-5 band only. Impacts on active users could be further

¹⁰ AMSR-E flew on NASA’s Aqua mission, and operated from 2002–2011. AMSR-2 flies on the Japan Aerospace Exploration Agency’s (JAXA’s) Global Change Observation Mission for Water (GCOM-W) mission launched in 2012. AMSR-3 is expected to launch on Global Observation Satellite for Greenhouse Gases and Water Cycle (GOSAT-GW), again operated by JAXA, in 2024.

¹¹ Both CIMR and AMSR have a local incidence angle of 55°, and orbit at 820 and 705 km altitudes, respectively, giving path distances of 1,293 km for CIMR and 1,124 km for AMSR-E, and thus 6.9 GHz path losses of 171 and 180 dB, respectively. Antenna gains are 53.7 dBi for CIMR, 41 dBi for AMSR (assuming a conservative 93% efficiency, per M. Brogioni et al., 2022, "Preliminary Studies on CIMR Antenna Pattern Brightness Temperature Compensation," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 15:173-183, doi: 10.1109/JSTARS.2021.3124829). Sensor parameters obtained from World Meteorological Organization, "Observing Systems Capability Analysis and Review Tool (OSCAR) website at <https://space.oscar.wmo.int>, accessed 12/17/2023.

reduced if the geofencing system was capable of acting upon (externally provided and updatable) information on overpass times for EESS (passive) satellites.

In paragraph 170, the Commission asks whether the emission levels for VLP devices are low enough to warrant lifting of the restriction of their use on oil platforms. Again, given the calculations detailed above, CORF urges the Commission to continue to prohibit use of such devices operating in the U-NII-6, 7, and 8 bands on oil platforms and boats, including ocean-going vessels. Similarly, given the growing scientific research related to impact of climate change on coastal regions discussed above, CORF urges continued prohibition of transmissions from boats in coastal waters in the U-NII-6, 7, and 8 bands.

CORF also notes a trend within the EESS community toward extending historically ocean-focused observations into some inland waterbodies such as wide rivers and large lakes. For example, such observations are a specific focus of NASA's recently launched Surface Water and Ocean Topography (SWOT) mission. While SWOT does not observe in the frequencies of concern in this proceeding, CORF anticipates a desire to continue this scientific trend, with the potential for the CIMR sensor to provide useful measurements over the Great Lakes. Accordingly, CORF urges the Commission not to allow VLP devices on boats in large inland water bodies, and to sustain existing restrictions on the use of higher-power devices in such vessels. Again, such restrictions could be enacted through suitable geofencing, with non-geofenced operations restricted to the U-NII-5 band.

CORF thanks the Commission for its recognition in paragraph 97 of the importance of protecting EESS (passive) allocations (and RAS observatories) by

restricting airborne use of VLP and higher-power devices to commercial aircraft above 10,000 ft., and furthermore restricting such operations to the U-NII-5 band that does not overlap EESS (passive) or RAS measurements. In paragraph 168, the Commission asks for comment on relaxing these restrictions. CORF urges the Commission to continue to prohibit use of the U-NII 6, 7, and 8 bands for airborne emissions over oceans, and it asks the Commission to consider enacting similar restrictions for airborne use over large inland water bodies. Again, a combination of geofencing and restriction of non-geofenced operations to the U-NII-5 band would accomplish the needed protections.

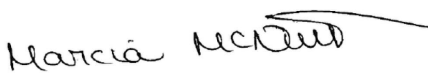
IV. Conclusion.

The Commission has recognized the public interest in protecting RAS and EESS observations in the 6 GHz band, and in the First R&O, it implemented a number of rules designed to protect RAS and EESS observations from interference. CORF greatly appreciates the Commission's actions in this regard. Presently, CORF urges the Commission to

- Protect RAS observations by enacting the geofencing proposal in Section 15.407(q) with any such device avoiding transmission in any channel less than 10 MHz away from the 6.7 GHz RAS band defined in footnote US342;
- Limit any further authorization of airborne use of VLP devices to operation at altitudes above 10,000 ft. and transmitting within the U-NII-5 band only, with a continued prohibition on use on or communicating with UAS vehicles; and
- Protect EESS observations by limiting VLP transmissions on oil platforms and boats to the U-NII-5 band in oceans and large inland bodies of water, and retain existing restrictions on the use of higher-power devices in such platforms and vessels.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
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