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

In the Matter of Use of Spectrum Bands Above 24 GHz For Mobile Radio Services Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services	)))))))))))))	GN Docket No. 14-177 WT Docket No. 10-112

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 June 7, 2018, *Third Further Notice of Proposed Rulemaking* ("FNPRM") in the above-captioned dockets. In the FNPRM, the Commission proposes to protect important passive scientific observation of the spectrum. Such protections serve the public interest, and CORF appreciates the Commission's recognition of the importance of such observations. In these comments, CORF discusses the details of such protections.

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

CORF has a substantial interest in this proceeding, as it represents the interests

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

of the scientific users of the radio spectrum, including users of the Radio Astronomy Service ("RAS") and Earth Exploration-Satellite Service ("EESS") bands. These users perform extremely important, yet vulnerable, research that has direct societal benefits.

As the Commission has also 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. The Nobel Prize winning discovery of pulsars by radio astronomers has led to the recognition of a widespread population 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 understanding of the physics of neutron stars and have resulted in the first experimental evidence for gravitational radiation, which was recognized with the awarding of another Nobel Prize. 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.

Radio astronomy measurements led to the Nobel Prize winning discovery of the cosmic microwave background (CMB), the radiation left over from the original Big Bang that has now cooled to only 2.7 K above absolute zero. Later observations revealed the weak temperature fluctuations in the CMB of only one-thousandth of a percent – signatures of tiny density fluctuations in the early universe that were the seeds of the stars and galaxies we know today. The CMB is a unique probe for the ongoing search for gravity waves in the inflationary period of growth after the Big Bang, a particularly active topic in modern astrophysics.

CORF notes that these observations of cosmic radio emissions cannot be obtained in any other portion of the electromagnetic spectrum. In addition, because some astronomical radio emissions are associated with short duration events, such as supernova explosions, or transient objects, such as near-earth asteroids and comets, some RAS observations are time sensitive and cannot be re-observed at a later time if observations are corrupted by interference. Indeed, this critical science undertaken by RAS observers 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 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, 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.

The Commission has also long recognized that satellite-based Earth remote sensing, including sensing by users of the EESS bands, is a critical and uniquely valuable resource for monitoring the Earth and our environment. Satellite-based microwave remote sensing presents a global perspective and, in many cases, is the only practical method of obtaining atmospheric and surface data for the entire planet, particularly when optical and infrared remote sensing is blocked by clouds and water vapor. Instruments operating in the EESS bands provide data that are important to human welfare and security, and includes support for scientific research, commercial endeavor, and government operations in areas such as meteorology, atmospheric chemistry, climatology, and oceanography. Examples are measurement of parameters—such as ocean surface temperature, wind velocity, salinity, sea surface elevation, significant wave height, and precipitation rate over the ocean —needed to understand ocean circulation and the associated global re-distribution of heat. They also include monitoring soil moisture, a parameter needed for agriculture and drought assessment, and for weather prediction (heat exchange with the atmosphere) and even for defense (planning military deployments). Passive sensors provide temperature and humidity profiles of the atmosphere, information to monitor changes in polar ice cover in the persistently cloudy polar regions, and direct measurements useful in assessing hazards such as hurricanes, wildfires, and drought. Users of these data include the National Oceanic and Atmospheric Administration, the National Science Foundation, the National Aeronautics and Space Administration, the Department of Defense, the Department of Agriculture, the U.S. Geological Survey, the Agency for International Development, the Federal Emergency Management Agency, and the U.S. Forest

Service. Most of these data sets are also available free to anyone anywhere in the world.

Passive instruments in space are particularly vulnerable to human-made emissions because they rely on very faint signals emitted naturally from the Earth's surface and atmosphere. This is especially a concern for EESS because sensors in space monitor globally and view large swaths of the surface at one time. In this sense, the issue for EESS differs from that of RAS, which generally involves receivers at fixed locations that often can be protected with regionally specific restrictions.

In sum, the important science performed by radio astronomers and Earth remote sensing scientists cannot be performed without access to interference-free bands. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, as well as a loss of the practical applications enabled by this access, which can include both financial loss and potential loss of human life arising from impaired weather forecasting and climate monitoring. CORF generally supports the sharing of frequency allocations where practical, but protection of passive scientific observations, as discussed herein, must be addressed.

II. Protection of Passive Scientific Use of Specific Frequency Bands.

The FNPRM's inquiries regarding certain specific bands are discussed below.[2]

[2] As stated in footnote 269 of the FNPRM, on May 31, 2018, the Elefante Group filed a petition for rulemaking to establish a Stratospheric-Based Communications Services (SBCS). Petition of Elefante Group for Rulemaking to Modify Parts 2 and 101 of the Commission's Rules to Enable Timely Deployment of Fixed Stratospheric-Based Communications Services in the 21.5-23.6, 25.25-27.5, 71-76, and 81-86 GHz Bands, RM No. 11809 ("Petition"). While this Petition is pending, and the Commission has not initiated the requested rulemaking proceeding at this time, the FNPRM seeks comments on compatibility between Elefante's proposal and other services at 26 GHz. CORF has no comment at this time regarding 26 GHz, but takes this opportunity to express serious concern regarding use of the 23.6-24.0 GHz band. Elfante's Petition seeks rules for SBCS service at 21.5-23.6 GHz, but in slide 7 of a presentation from an April 26, 2018 *ex parte* meeting with FCC staff (filed April 30, 2018 in this

A. RAS in the 43 GHz Band

In the FNPRM, the Commission provided extensive and detailed information regarding the importance of radio astronomy observations in the 42.5-43.5 GHz band, the sites where such observations occur, the vulnerability of such observations not only to in-band interference, but also to spurious out-of-band and harmonic emissions, and to the protection due to such emissions under Footnotes US211 and US342. *See* FNPRM at paras. 47 and 55. CORF concurs with those statements, and it is grateful for the Commission's recognition, in the FNPRM and in prior Orders and NPRMs in this proceeding, of the need to protect RAS in this band.[3] In that context, the FNPRM seeks comments on how to protect RAS at 42.5-43.5 GHz band from interference from fixed and mobile service operations at 42.0-42.5 GHz.

As stated in ITU-R RA.769, the detrimental levels of interference for continuum and spectral line radio astronomy observations for single dishes at 43 GHz are -227 dBW/m^2/Hz and -210 dBW/m^2/Hz, respectively, for the average across the full 1 GHz band and the peak level in any single 500 kHz channel. For observations using Very Long Baseline Interferometry (VLBI), the corresponding limit is -175 dBW/m^2/Hz.

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proceeding), reference is made to user "[down]links at 21.5-24 GHz." Further, footnote 64 in the Petition states that "Elefante Group and Lockheed Martin continue to study the potential for use of 23.6-24.0 GHz for STRAPS-UT links as ancillary to operations in the 21.5-23.6 GHz band." CORF notes that the 23.6-24.0 GHz band is allocated solely to the EESS(passive), RAS and SRS(passive) services, and is subject to ITU RR 5.340 as well as Footnote US246, which states that "No station shall be authorized to transmit in the following bands: … 23.6-24.0 GHz…." Elefante has provided no justification for proposing to violate the prohibition in US246. CORF does not believe a reasonable justification could be provided, particularly for space or airborne use. CORF urges the Commission to reject any such proposal.

[3] The FNPRM also properly noted that radio astronomers often attempt to make important observations in bands not allocated to the RAS, due to the Doppler Effect. *See* FNPRM at note 172. CORF appreciates the Commission's acknowledgement of this important scientific practice, and for the Commission's attempts in certain proceedings to provide protection to such observations.

The FNPRM asks at para. 56 whether rules for protection of RAS should be based on ITU-R RA.769, or on other criteria. Recommendation ITU-R RA.769 is the most basic of the ITU-R RA recommendation series, setting out the criteria for the protection of radio astronomy observations. These criteria were adopted in the early days of radio astronomy, in the 1960s, and the principles have been maintained ever since. The detrimental thresholds criteria in Tables 1-3 of the Recommendation can be defined as the level at which the root mean square (rms) error of the measurement is increased by 10%, increasing the required observing time if accuracy of the measurement is to be maintained. Given that most modern radio telescopes are enormously oversubscribed, and that observing time at any one of them is very costly, such a loss is already considerable.

While the protection criteria of the Recommendation may appear to be difficult to achieve for some of the active services, they are in fact only modest goals from a radio astronomy point of view. Indeed, the levels are based on receiver temperatures generally higher than what is achieved easily today. Further, the levels are calculated on an assumed integration time of 2000 seconds. Much longer observations are currently used to detect faint radio sources. Properly taken into account, both of these improvements would drive the required protection levels to be more restrictive. Nevertheless, in an effort to compromise with the requirements of the active services, and because the current protection levels have worked well so far, radio astronomers have been reluctant to update ITU-R Recommendation RA.769 to reflect these improvements. CORF wishes to emphasize, therefore, that the Recommendation and the detrimental threshold values therein remain the cornerstone of protection for the radio astronomy service.

The FNPRM also seeks comments, at para. 56, on the use of coordination zones, and coordination distance appropriate for protection of RAS. With proper coordination, fixed service operations at 42.0-42.5 GHz could probably protect RAS adequately. The minimum distance between prospective fixed stations and RAS sites will need to be calculated for each individual case, based on factors such as altitude and surrounding terrain. Note that for high-altitude RAS sites, the required distance might result in the Earth's curvature providing the main screening. For the Kitt Peak, Arizona station of the Very Long Baseline Array (VLBA), for example, using D(km) = 4.12*sqrt(H)(m), the result is a horizon distance, and thus the minimum distance for a fixed station itself at ground level would be about 160 kilometers.

Establishing parameters for use of coordination zones for licensed and unlicensed mobile devices is another matter, however. The Commission should require out-of-band emission limits for such devices that meet the requirements of ITU-R RA.769. In order to achieve this, the coordination distance should be based on the power of the mobile devices, and the number of such devices in a particular area, neither of which is certain at this moment. More broadly, CORF is concerned that coordination of mobile devices, particularly unlicensed ones, may by itself be impractical to protect radio astronomy stations, unless extremely large coordination distances are adopted. For instance, if the Commission adopted an approach to the 42 – 42.5 GHz band similar to what it took in establishing the rules for the 38.6-40.0 GHz band (e.g., a similar OOBE mask),[4] then a guard band of 200 MHz within the radio horizon around radio astronomy sites meets the ITU-R RA.769 protection criteria. Radio astronomy sites observing in the 42.5-43.5 GHz band in the United States include the Very Large Array (VLA), the Green Bank Telescope (GBT), and Haystack Observatory. Under similar assumptions, an exclusion zone of 3 km around the 10 stations of the Very Long Baseline Array (VLBA) is required to achieve the ITU-R RA.769 limits for VLBI observations in the 42.5 – 43.5 GHz band. Thus, a 200 MHz guard band, combined with an exclusion zone for licensed and unlicensed mobile devices, is required to meet the ITU-R RA.769 limits for the adjacent 42.5 – 43.5 GHz RAS band.

B. EESS at 50 GHz

At para. 94, the FNPRM proposes to adopt rules permitting licensing of individual FSS earth stations in the 50.4-51.4 GHz band. There is a primary allocation for EESS at 50.2-50.4 GHz, with additional protection (transmissions prohibited) for that allocation from Footnote US246.

A prior Further Notice in this proceeding recognized the need to protect vital EESS observations at 50.2-50.4 GHz, noting that “at WRC-12, the WRC recognized that long-term protection of the EESS in the [, *inter alia*, 50.2-50.4 GHz band] is vital to

[4] The out-of-band emission limit in Section 30.203 of the FCC’s rules includes the requirement that “The conductive power or the total radiated power of any emission outside a licensee’s frequency block shall be -13 dBm/MHz or lower. However, in the bands immediately outside and adjacent to the licensee’s frequency block, having a bandwidth equal to 10 percent of the channel bandwidth, the conductive power or the total radiated power of any emission shall be -5 dBm/MHz or lower.“ Section 30.404 includes the requirement that “The mean power of emissions must be attenuated below the mean output power of the transmitter in accordance with the following schedule: … (b) On any frequency removed from the assigned frequency by more than 100 percent up to and including 250 percent of the authorized bandwidth: At least 35 decibels.” Assuming a typical bandwidth of 100 MHz (para 57) and a similar OOBE mask, a guard band of at least 200 MHz (i.e., 42.3 – 42.5 GHz) is necessary to protect radio astronomy sites.

weather prediction and disaster management."[5] Given the critical importance of this band, the Commission should take seriously the US246 prohibition on any transmission of out-of-band emissions ("OOBE") into the 50.2-50.4 GHz band. This frequency is important for atmospheric profiling when then drives numerical forecast models. Alternatively, the standard in Footnote US157 could be used to establish that OOBE into the adjacent 50.2-50.4 band shall not exceed -33 dBW/100 MHz, measured at the input of the transmit antenna.

C. EESS at 37 GHz

In the FNPRM, the Commission seeks comment on coordination mechanisms between federal and non-federal stakeholders in the Lower 37 GHz band. CORF notes that the passive scientific users of this band and the neighboring 36-37 GHz band are in fact federal stakeholders. NASA, DoD, and NOAA have extensive investments in satellite instruments that include observations from 36-38 GHz. These include the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager (SSM/I) and SSM/I/Sounder (SSM/IS) instruments operating on four separate satellites (both with a center frequency of 37 GHz and a 1 GHz and 1.5 GHz bandwidth, respectively); DoD's WindSat mission (with a center frequency of 37 GHz and a 2 GHz bandwidth); NASA's Global Precipitation Measurement Mission (GPM) Microwave Imager (GMI) (with a center frequency of 36.5 GHz and a 1 GHz bandwidth) and the Advanced Microwave Scan Radiometer 2 (AMSR2) (with a center frequency of 36.5

[5] *In the Matter of Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, Report and Order and Further Notice of Proposed Rulemaking, 31 F.C.C. Rcd. 8014 (2016) at para. 416, *citing* 47 CFR § 2.106 n.5.338 and WRC-12 Resolution 750.

GHz and a 1 GHz bandwidth). The 37 GHz channel of SSM/I and SSM/IS is critical to the operational mapping of sea ice extent and concentration, as well as measuring parameters such as ocean surface wind speed and direction and measuring cloud liquid water and surface rain rate. The 36.5/37 GHz channels are also used indirectly for measuring columnar water vapor. These missions represent a significant federal investment, with EESS data critical to activities impacting hundreds of billions of dollars in the U.S. economy, as well as national security.

Most coordination mechanisms are primarily geographic in nature. However, if the Commission includes a temporal component to this coordination, all concerns related to emissions into EESS bands and other remote sensing observations might be alleviated. For example, to minimize out-of-band emission into the EESS bands, the Commission could implement a database system for the lowest 100 MHz band of the Lower 37 GHz band in which the database includes the ephemerides of the federal EESS satellite assets. All of the microwave instruments are flown on polar orbiting satellites, so it is in principle possible to predict the satellites overpass. Transmissions can be ceased for the roughly two minutes per pass that the asset is overhead. This provides both the spectral access desired by the non-federal users as well as the protection needed by the federal incumbents. If, as the R&O contends, there is sufficient protection provided by existing OOB limits, then this constraint can be removed at a later date with a simple database modification. A similar database system could also be used to enable sharing between DoD remote sensing assets (such as WindSat and future DoD microwave weather missions planned with similar wide bandwidths and frequencies) and other federal and non-federal users of the entire Lower 37 GHz band.

III. Conclusion.

In this proceeding, the Commission has taken a number of steps to protect important passive scientific observation of the spectrum. Such protections serve the public interest, and CORF appreciates the Commission's recognition of the importance of such observations in the FNPRM. CORF generally supports the sharing of frequency allocations, where practical, but protection of passive scientific observations, as discussed herein, must be addressed.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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