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

In the Matter of	)	
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Amendment of Parts 2 and 25 of the Commission's Rules to Facilitate the Use of Earth Stations in Motion Communicating with Geostationary Orbit Space Stations in Frequency Bands Allocated to the Fixed Satellite Service	))))))	IB Docket No. 17-95

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 May 19, 2017, *Notice of Proposed Rulemaking* (FNPRM) in the above-captioned dockets. In these comments, CORF responds to questions regarding important protections for passive scientific use of the spectrum.

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 of the passive 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.

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

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

astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. The discovery of pulsars by radio astronomers has led to the recognition of a widespread galactic 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. 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 our galaxy, the Milky Way. Radio spectroscopy and broadband continuum observations have identified and characterized the birth sites of stars in the galaxy, 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.

The 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 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 man-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. Instruments operating in the EESS bands provide data that is 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, and precipitation rate over the ocean—needed to understand ocean circulation and the associated global distribution of heat. They 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 deployment). Passive sensors provide temperature and humidity profiles of the atmosphere, information to monitor changes in the polar ice cover and information needed in assessing hazards such as hurricanes, wildfires, and drought. Users of this data include the National Oceanic and Atmospheric Administration, the National Science Foundation (NSF), 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. Much of this data is also available free to anyone anywhere in the world.

Passive instruments in space are particularly vulnerable to manmade emissions because they rely on very small signals emitted naturally from 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 financial loss 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 NPRM's inquiries regarding certain specific bands are discussed below.

A. 14.47-14.50 GHz – Radio Astronomy

In paragraph 47 of the NPRM, the Commission proposes unifying language for the requirements for all Earth stations in motion (ESIMs) to be included in Section 25.228(j), including the requirement to coordinate transmissions at 14.47-14.50 GHz with radio astronomy observatories. Such coordination is in the public interest.

The 14.47-14.50 GHz band is used for important scientific observation by radio astronomers, particularly for observation of formaldehyde. Observation of formaldehyde is valuable in the study of interstellar clouds. Formaldehyde maser emission and absorption are found in a growing number of galaxies, including our own, and observation of the distribution of formaldehyde clouds helps scientists understand the structure of galaxies. Indeed, the formaldehyde spectral line in this band is among the lines of greatest importance to radio astronomy. *See*, *Handbook on Radio Astronomy*, (ITU Radiocommunications Bureau, 2013) at Table 3.2.

As properly proposed in the NPRM, operations of ESIMs in the 14.47-14.5 GHz (Earth-to-space) frequency band in the vicinity (for ESVs [Earth stations on vessel] and VMESs [vehicle-mounted Earth stations]) or within radio line of sight (for ESAAs [Earth stations aboard aircraft]) of RAS observatories observing in the 14.47-14.5 GHz band is to be subject to coordination with NSF.[2] CORF notes that RAS is particularly vulnerable to airborne or high-altitude emissions because radio telescopes point toward the sky. CORF concurs that unifying the coordination requirements among different ESIMs serves the public interest, and the proposed coordination distances are appropriate. CORF also agrees that requiring ESIMs to use GPS to ensure their compliance with the coordination requirement serves the public interest.

The Commission should clarify, however, the proper meaning of the term "radio line of sight." It is particularly important to note that in general, the radio and geometric horizons are different because of atmospheric refraction. Thus, for an atmosphere

[2] Footnote US133(b) also requires such coordination.

having a standard refractivity gradient, the effective radius of Earth is about four-thirds that of the actual radius, which corresponds to approximately 8,500 km.[3] This increases the radio horizon by about 15 percent compared to the geometric horizon. In addition, it should be noted that the 50 km coordination distances given in Appendix A, Table 1, are inadequate for many of the antennae in the table. For example, the Very Long Baseline Array (VLBA) antenna at Mauna Kea has an altitude of 3,763 m, giving a radio horizon from the curvature of the earth of ~250 km. Similarly, the altitude of the Kitt Peak VLBA antenna is 1,902 m, giving a radio horizon taking into account the curvature of Earth and the height of local terrain of ~130 km. CORF agrees that the appropriate contact to initiate coordination is the electromagnetic spectrum manager of NSF, via e-mail at esm@nsf.gov.[4] CORF also agrees that the public interest would best be served by licensees notifying the International Bureau once they have completed coordination.

B. 18.6-18.8 GHz – EESS

In paragraph 53 of the NPRM, the Commission proposes to amend an existing footnote to the Table of Allocations to facilitate the operation of ESIMs as an application

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3 *See* Recommendation ITU-R P.310-9 at definition C15 (“Effective radius of the Earth”): “Radius of a hypothetical spherical Earth, without atmosphere, for which propagation paths are along straight lines, the heights and ground distances being the same as for the actual Earth in an atmosphere with a constant vertical gradient of refractivity. Note 1 – The concept of effective radius of the Earth implies that the angles with the horizontal planes made at all points by the transmission paths are not too large. Note 2 – For an atmosphere having a standard refractivity gradient, the effective radius of the Earth is about 4/3 that of the actual radius, which corresponds to approximately 8 500 km.”

4 In the NPRM, proposed rule Section 25.228(j)(3) provides a physical address for sending coordination notices to the Electromagnetic Spectrum Manager of the National Science Foundation. As a general matter, that is acceptable, but CORF understands that the physical address of NSF is expected to change by September 1, 2017 from the one stated in the NPRM to 2415 Eisenhower Avenue, Alexandria, VA 22314. However, the specific room number for the ESM has not yet been established. Accordingly, the Commission should consider updating that address once finalized by the NSF.

of the Fixed-Satellite Service (FSS) with primary status in the conventional Ka-band.[5] Comment is sought on the Commission's "belief that ESIMs operating in the conventional Ka-band in accordance with our proposed rules would not pose more of a risk of interference to, nor require more protection from interference from other radiocommunication systems than other Earth stations operating in the frequency band on a primary basis today."

CORF notes that the EESS has a co-primary allocation at 18.6-18.8 GHz. Frequency bands in the 18.6-18.8 GHz range are used extensively in many current operational environments for EESS (see Table 1 below) to provide critical measurements for weather forecasting and studies of climate and environmental impacts. These measurements enable studies of clouds, precipitation, freeze-thaw transition, sea-surface winds, snow, and ice. In addition, these measurements enable water-vapor profiling and include measurements of sea-surface temperatures, winds, and topography. CORF has significant concerns that the use of this band for ESIM may further contaminate EESS observations, which are already affected by space-Earth transmissions reflected from Earth's surface.

Despite existing protections in the radio regulations, WindSat, AMSR2, and the Global Precipitation Measurement (GPM) microwave imager have repeatedly reported radio frequency interference (RFI) over the continental United States at 18.7 GHz.[6] RFI from satellite signals reflected from the surface impedes measurements of precipitation,

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[5] We follow the FCC NPRM usage here. However, it should be noted that according to the IEEE, definition of K-band is 18-27 GHz and Ka band is 26.5-40 GHz. The band under consideration would be K-band.

[6] S. Curry et al., "K-Band Radio Frequency Interference Survey of Southeastern Michigan," Proceedings of the 2010 International Geoscience and Remote Sensing Symposium, Honolulu, Hawaii, pp. 2486-2489, July 25, 2010.

wind, sea-surface temperatures that are necessary for hurricane prediction and tracking, and many other parameters. Several studies indicate an increasing RFI trend in this band. An example documenting this is the report by McKague et al.[7] where the data indicate an increase in RFI from 2005 to 2010 and a seasonal dependence. The data also indicate that signals from satellite downlinks, reflected from Earth's surface, are a source of the RFI detected in the EESS passive sensors observing important variables necessary for accurate weather forecasts and other studies.[8] CORF is concerned that new applications by the proposed ESIM in this important portion of the spectrum will lead to increased satellite services, further increasing RFI.

TABLE 1 Passive EESS Sensors in the Bands Under Consideration

Sensor	Satellite	Center Frequency (GHz)	Bandwidth (MHz)
Advanced Microwave Scanning Radiometer (AMSR2)	GCOM-W1	18.7	200
GPM Microwave Imager (GMI)	GPM	18.7	200
Polarimetric Microwave Radiometer (PMR)	WindSat	18.7	750
Advanced Microwave Radiometer (AMR)	Jason-2 & 3	18.7	200
MWI	MetOp-SGI	18.7	200
Multi-frequency Microwave Scanning Radiometer (MADRAS)	Megha-Tropiques	18.7	200
MTVZA-GY	METEOR-M	18.7	200

7 D. McKague, J. Puckett, and C. Ruf, "Characterization of K-band Radio Frequency Interference from AMSR-E, WindSat and SSM/I," Proceedings of the International Geoscience Remote Sensing Symposium, Honolulu, Hawaii, pp. 2492-2494, July 25, 2010.

8 D. Draper, "Terrestrial and space-based RFI observed by the GPM microwave imager (GMI) within NTIA semi-protected passive earth exploration bands at 10.65 and 18.7 GHz," IEEE Radio Frequency Interference Conference, Socorro, N.M., October 2016, doi:10.1109/RFINT.2016.7833526.

Microwave Radiation Imager (MWRI)	FY-3	18.7	200
Microwave Radiometer Imager (MWRI)	HY-2A	18.7	250

Given that RFI from FSS signals reflected from Earth's surface are already harming weather data from passive sensors in the protected band, having additional transmitters on airborne platforms is expected to have a similar but amplified detrimental effect. This is particularly of concern considering that the distance from airplanes to Earth's surface is much smaller than that to satellites, and therefore, their signals will have less attenuation due to a shorter atmospheric path.

In addition, the number of airborne (ESIM) transmitters would further exacerbate the aggregate RFI effects on EESS sensors data. The potential impact of aggregate interference that these airborne ESIM transmitters can have on the measurements of passive 18.7 GHz sensors could render a large percentage of their vital weather data unusable.

In addition, it should be noted that if the ESIM communicate directly with satellites, there is a potential for increased RFI and contamination of data from the sensitive EESS passive instruments. The existing RFI appears to be generated by signals from distant satellite transmission reflected from the surface (i.e., weakened by propagation and then again by reflection). ESIMs transmitting directly from an airborne platform to space may cause direct interference, sending strong signals into the sensitive down-looking receivers of EESS instruments.

Another concern is the collective contribution of out-of-band emissions from many ESIM. Satellite sensors which integrate signals over a large field-of-view (tens of kilometers) can be susceptible to the collective effect of many small, albeit weak transmissions. This has been observed in Japan in EESS sensors operating in the protected band at 1.413 GHz.[9] In this case, the collective leakage into the protected band from a large number of individual satellite broadcast receivers (primarily located in homes) has rendered it impossible to obtain soil moisture measurements in the region.

Any new ESIM uses should strictly preserve the extensive existing scientific use of the 18.6-18.8 GHz band. An inventory of recent changes in number and location of fixed Earth stations and ESIMs would help assess the potential impact. Until further information is available on the technical parameters of the proposed ESIM, and studies are performed demonstrating no further harmful RFI effects on passive services sharing this band, CORF recommends restricting ESIM use of frequencies adjacent to the 18.6-18.8 GHz EESS allocation.

III. Conclusion.

In the NPRM in this proceeding, 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 the NPRM. CORF generally supports the sharing of frequency allocations, where practical, but protection of passive scientific observations, as discussed herein, must be addressed.

[9] P. Mohammed, M. Aksoy, J. Piepmeier, J. Johnson, and A. Bringer, SMAP L-Band microwave radiometer: RFI mitigation prelaunch analysis and first year on-orbit observations, IEEE Transactions on Geoscience and Remote Sensing 54(10):6035-6047, 2016.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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Appendix

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