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

In the Matter of	)	
	)	
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 September 27, 2018 *Further Notice of Proposed Rulemaking* (FNPRM) in the above-captioned dockets. In these comments, CORF addresses concerns regarding potential interference to protected passive scientific observations from downlinks to Earth Stations in Motion ("ESIMs") at 10.6-11.7 and 18.6-18.8 GHz. CORF recommends ways to protect these important observations.

I. The Role of Radio Astronomy and Earth Remote Sensing, Scientific Observation at 10 and 18 GHz, and the Unique Vulnerability of Scientific Services to Interference.

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

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

A. Radio Astronomy

As the Commission has also long recognized, radio astronomy is a vitally important tool used by scientists to study the 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.

In its Comments filed on October 2, 2017, in Docket No. 17-183, CORF extensively discussed the nature and importance of radio astronomy observations of specific *frequency lines* and of a *continuum* of frequencies at 5-24 GHz. Those Comments are included herein by reference. In particular, the 10.6-11.7 GHz frequency band provides some of the best angular resolutions using Very Long Baseline Interferometry to study quasars. These objects produce surprisingly large amounts of energy for their size and have been found to vary in intensity with periods of weeks and months. Indeed, monitoring the intensity and spatial distribution of the flux emitted from these enigmatic objects are critical to understanding the structures of quasars and the fundamental physics that can produce such events. Similarly, monitoring the radio continuum emission of the Sun provides insight into the nature and evolution of coronal magnetic fields. Such monitoring observations are time sensitive and cannot be repeated at a later time if observations are corrupted by interference, since the emitting source will have evolved. Observations in this band are also used for a wide variety of studies of star formation (both within the Milky Way and in other galaxies) and active galactic nuclei (AGN), to name just a few.

The critical scientific research 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 human-made emissions are weak and distant.

B. Earth Remote Sensing - EESS

The Commission has also long recognized that satellite-based Earth remote sensing, including sensing by users of EESS bands, is a critical and uniquely valuable resource for monitoring the Earth and the 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 attenuated by 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 endeavors, and government operations in areas such as defense, security, meteorology, atmospheric chemistry, climatology, cryospheric science, and oceanography. Examples are measurement of parameters—such as ocean surface temperature, wind velocity, salinity, sea-surface elevation, significant wave height, snowfall, sea ice extent/concentration and precipitation rate over the ocean—needed to understand ocean circulation and the associated global redistribution of heat. They also include monitoring soil moisture, a parameter needed for agriculture, flood, and drought assessment; weather prediction (heat exchange with the atmosphere); and for defense (planning military deployment, assessing trafficability, surveillance, among many other applications). 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 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.

Among the primary concerns for remote sensing in this proceeding are protection of EESS observations at 10.6-10.7 GHz and 18.6-18.8 GHz. These bands are used for a number of EESS applications, including observations of sea-surface temperature and surface winds, sea ice, snow, atmospheric water vapor, clouds and precipitation. Measurement of these geophysical parameters is critically important for weather prediction, climate monitoring, and understanding changes in the global water cycle. Observation of the hydrologic cycle at these frequencies is critical to the dynamical and thermo-dynamical functioning of the global climate system and to its impacts on human society. The distributions of water vapor, cloud liquid water, and cloud ice in the

atmosphere and the evolution of these distributions with time determine, to a great extents the radiation characteristics of clouds, with consequent large impacts on the radiation balance of the atmosphere. These observations are key in improving the forecasting of extreme weather and precipitation events that lead to natural hazards and disasters (such as storms and hurricanes); they allow access to accurate and timely global information on precipitation, on which the world's population depends on a daily basis. Examples of instruments making observations at 10.6-10.7 GHz and 18.6-18.8 GHz are the Global Precipitation Measurement Mission's Microwave Imager (GMI), WindSat, and the Advanced Microwave Scanning Radiometer 2 (ASMR-2). These measurements are of major use for meteorological research and forecasting and military applications.

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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, extreme event prediction and disaster assessment, and climate monitoring. CORF generally supports the sharing and flexible use of frequency allocations where practical, but protection of passive scientific observations, as discussed herein, must be addressed.

II. Specific Protection of Passive Observations.

A. <u>Radio Astronomy at 10.6-11.7 GHz</u>

The NPRM at paragraph 91 seeks comments on allowing ESIM downlinks at 10.7-10.95 GHz, and particularly on the "possible effects expanding the frequencies available to ESIMs … may have on existing or future services in these bands or adjacent frequency bands …." As noted above, radio astronomers make important observations at 10.6-11.7 GHz. There is a significant risk of interference to radio astronomy observations from such downlinks: as the Commission well knows, and as stated in footnote US342, "[e]missions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service…."

However, RAS observations in the 10.6-11.7 GHz band are subject to significant protection:[2]

- In the 10.68 GHz – 10.70 GHz portion of the band, RAS has a primary allocation and is protected domestically by footnote US246, and by RR No. 5.340 worldwide. Pursuant to US246, "[n]o station shall be authorized to transmit" at 10.68-10.7 GHz, and pursuant to RR 5.340, "[a]ll emissions are prohibited" at 10.68-10.7 GHz.[3]

- Similarly, in footnote US211, applicants for airborne or space station assignments at, among other bands, 10.7-11.7 GHz, are urged to take all practicable steps to protect radio astronomy observations *in the adjacent bands* from harmful interference; however, US74 applies.

Thus, the first step in fulfilling the footnote US246 and RR 5.340 requirements to

[2] More broadly, footnote US131 states that "[i]n the band 10.7-11.7 GHz non-geostationary satellite orbit licensees in the fixed-satellite service(space-to-Earth), prior to commencing operations, shall coordinate with the following radio astronomy observatories to achieve a mutually acceptable agreement regarding the protection of the radio telescope facilities operating in the band 10.6-10.7 GHz" and lists the Arecibo Observatory, the Green Bank Telescope, the Very Large Array, and the Very Long Baseline Array (VLBA) Stations. In addition to the observatories listed in US131, Owens Valley Solar Array, the Allen Telescope Array (ATA), and Kokee Park Geophysical Observatory also have receivers that operate at this frequency range.

[3] Exceptions are made in RR 5.340 for wireless medical telemetry devices and white space devices, but those devices are not at issue here.

protect RAS is for the Commission to ensure that there are no emissions from ESIM downlinks into the 10.68-10.70 GHz portion of the band. Indeed, pursuant to Footnote US211, the Commission should ensure that the out-of-band emission standard for ESIM downlinks is sufficient to protect RAS observations at 10.68-10.70 GHz from harmful interference.[4] CORF recognizes that US211 is modified by Footnote US74, which provides that "the radio astronomy service shall be protected from unwanted emissions only to the extent that such radiation exceeds the level which would be present if the offending station were operating in compliance with the technical standards or criteria applicable to the service in which it operates." But this does not mean that the Commission cannot modify those technical standards in a way sufficient to protect RAS observations in adjacent bands through a combination of coordination agreements, guard bands, and stringent out-of-band emission masks.[5]

B. <u>Remote Sensing-EESS at 10.6-10.7 GHz and 18.6-18.8 GHz</u>

As noted above, remote sensing at 10.6-10.7 GHz and 18.6-18.8 GHz provides data critical to a wide variety of applications required for weather forecasting and climate study. EESS has primary allocations at 10.6-10.7 GHz, shared primarily with

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[4] RAS observations should be protected from interference at least at the levels provided in ITU-R RA.769, with a threshold interference level of -240 dB(W/m^2/Hz) at 10.6-10.7 GHz for continuum observations at single dish telescopes (Table 1) and a threshold level of -193 dB(W/m^2/Hz) for Very Long Baseline Interferometry observations (Table 3).

[5] The Commission has sought comments on possible revisions to satellite out-of-band-emission standards in IB Docket No. 18-314. CORF will address the issue primarily in comments filed in that docket. However, CORF notes that stringent OOBE filters have been able to protect RAS allocations in the past (Green Bank Interference Office Memo #2, 1993, on Observations of the Geostationary Belt at 10.68-10.7 GHz) and it is appropriate to require similar OOBE filters to protect the passive bands from transmission in adjacent or neighboring bands for current and future FSS (s-E).

other passive services. Pursuant to US246, "[n]o station shall be authorized to transmit" at 10.68-10.7 GHz, and pursuant to RR 5.340, "[a]ll emissions are prohibited" at 10.68-10.7 GHz. The FNPRM seeks comments on a proposal to authorize use of 10.7-10.95 GHz for ESIM downlinks.

As was the case with radio astronomy, fulfilling the footnote US246 and RR 5.340 requirements to protect EESS should require the Commission to ensure that there are no emissions from ESIM downlinks into the 10.68-10.70 GHz portion of the band. This could be accomplished through use of a guard band of 25 MHz, so that the lowest frequency of this ESIM downlink band would be 10.725 GHz.[6] Alternatively, the Commission should ensure that the out-of-band emission standard for ESIM downlinks is sufficient to protect EESS observations at 10.68-10.70 GHz from harmful interference.[7]

In the Ka-band,[8] EESS(passive) has a co-primary allocation at 18.6-18.8 GHz which, as noted in CORF's previous filing in this proceeding, is already subject to increasing instances of radio frequency interference (RFI).[9,10] CORF has significant concerns that the use of Ka-band for ESIMs may further contaminate EESS

6 Since, by their nature, passive observations cannot interfere with other services, the width of the guard band should be based on the width of the active service transmission. Adopting at least a 10% guard band width, similar to those of OFDM communication applications, corresponds to a guard band of at least 0.025 GHz (25 MHz) for the full width of the 10.7-10.95 GHz adjacent band.

7 EESS observations should be protected from interference at least at the levels provided in Table 2 of ITU-R RS.2017, with a maximum interference level of -166 dBW over 100 MHz at 10.6-10.7 GHz and -163 dBW over 200 MHz at 18.6-18.8 GHz.

8 FCC FNPRM usage is followed 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.

9 D. McKague, J. Puckeet, 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. 2492-2484, July 25, 2010.

10 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, NM, October 2016, doi:10.1109/RFINT.2016.7833526.

observations, as RFI from moving targets is even more difficult to flag and remove than RFI from fixed stations. In addition, ESIMs on ships at sea will increase the potential for RFI from sea surface reflections as the ocean is far more reflective than is the land (Figure 1). A flat sea surface represents a strong specular reflection that will most likely overwhelm the weak signals emitted from the sea surface. A turbulent sea surface will decrease this reflection slightly, but the reflections will still be much greater than over the land. It should be noted that most of the passive microwave sensors are designed to measure over the ocean (sea-surface temperature, wind velocity, atmospheric water vapor, precipitation rate, and sea ice conditions). As noted by the Commission in paragraph 63 of the Report and Order, any new use by ESIMs in these frequency bands should be mindful of the need to preserve the extensive existing scientific use of the 18.6-18.8 GHz band. Current instruments include AMSR-2 (18.7 GHz), WindSat (18.7 GHz), GMI on the Global Precipitation Measurement Mission (18.7 GHz), the Special Sensor Microwave/Imager (SSM/I) (19.35 GHz), and the Special Sensor Microwave/Imager Sounder (SSMIS) (19.35 GHz),[11] as well as instruments on many international satellites. The Ka-band frequencies proposed for ESIMs downlinks (17.8 – 18.3 GHz on a secondary basis; 19.3-19.4 and 19.6-19.7 GHz on a primary basis; and 18.8-19.3 GHz (s-E) on an unprotected basis with respect to NGSO FSS satellite systems) are adjacent or overlapping these frequency bands. In previous Comments in this proceeding, CORF recommended using the adjacent bands, instead of 18.6-18.8

[11] CORF understands that the Department of Defense, through the Air Force, has contracted for the construction of a new remote sensing instrument, the Weather System Follow On – Microwave (“WSF-M”), which when launched will observe at 18.6-19.3 GHz, among others. The WSF-M will be instrumental in measurement of ocean surface vector winds and tropical cyclone intensity, key factors in weather prediction.

GHz, to reduce the potential for RFI in this critical band. Nonetheless, CORF notes that increased usage of the adjacent bands may also further degrade this critical band if out-of-band emission is not severely curtailed. As noted in Table 2 of ITU Recommendation RS.2017, the threshold level for interference at 18.6-18.8 GHz is -163 dBW and less than 0.1% of the time/area.

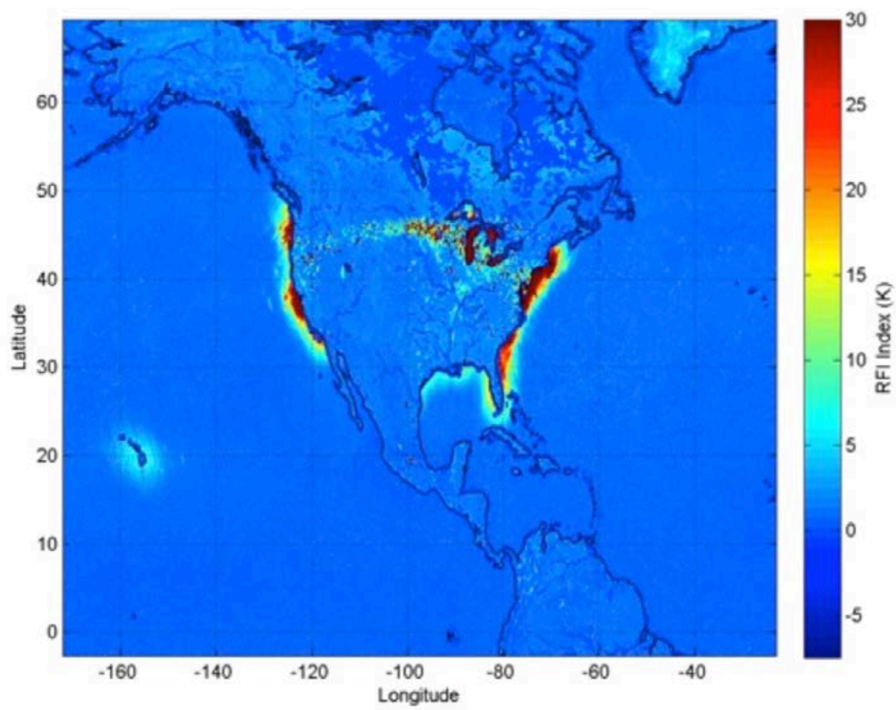

Figure 1: Maximum daily average radio frequency interference (RFI) index from March through September 2014, as detected by GPM's GMI at 18.7 GHz. Note the strong RFI over water, which extends spatially to the full footprint of the satellite system inferred to be the source of the interference. Source: Draper, 2015, "Report on GMI Special Study #15: Radio Frequency Interference", https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160003316.pdf.

III. Conclusion.

CORF generally supports the sharing and flexible use of frequency allocations where practical, but protection of scientific observations, as discussed herein, must be addressed.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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