

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Advancing Understanding of Non-Federal	)	WT Docket No. 23-232
Spectrum Usage	)	
	)	

**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 these comments in response to the Commission's August 4, 2023, Notice of Inquiry (NOI) in the above-captioned docket. In these Comments, CORF notes that in defining and understanding “spectrum usage,” it is important to remember that passive use (i.e., receive-only, with no transmission) of the spectrum for scientific research, involving the detection and measurement of naturally occurring radio signals with highly sensitive radiometrically calibrated receivers, constitutes “usage” of the spectrum.

I. Background—Passive Scientific Use of the Spectrum.

Scientific research through passive observation at specific frequencies is primarily associated with Earth remote sensing, including observations of bands allocated to the Earth Exploration Satellite Service (EESS) and radio astronomy, including observations in bands allocated to the Radio Astronomy Service (RAS). In

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

addition, both services make critical observations in bands outside of those allocated to their respective services.²

A. Earth Remote Sensing—The Earth Exploration Satellite Service

The Commission has long recognized that satellite-based Earth remote sensing is a critical and uniquely valuable resource for monitoring the state of the global atmosphere, oceans, land, and cryosphere. For certain applications, satellite-based passive microwave remote sensing [“EESS (passive)”] represents the only practical method of obtaining atmospheric and surface data for the entire planet. EESS (passive) data have made critical contributions to the study of meteorology, atmospheric chemistry, climatology, and oceanography. Currently, instruments operating in the EESS (passive) bands provide regular and reliable quantitative atmospheric, oceanic, land, and cryospheric measurements to support a variety of scientific, commercial, and government (civil and military) data users. EESS (passive) satellites represent billions of dollars in investment and provide data for major governmental users, including the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), the Department of Defense (especially the U.S. Navy), 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. These agencies use

² CORF recognizes that the NOI seeks comments on “non-Federal” spectrum usage. Passive scientific observation of the spectrum is performed by both federal and non-federal entities. While much Earth remote sensing is performed by federal agencies such as NOAA and NASA, an increasing amount of such sensing is performed by private, non-governmental entities. The latter case would certainly constitute “non-federal” usage. While a few U.S. radio astronomy facilities are operated by government agencies, the operations of most U.S. radio astronomy facilities typically are not directly controlled by any federal agency, although most receive some funding from federal agencies such as NSF and NASA.

EESS data in their work on issues impacting hundreds of billions of dollars in the U.S. economy, as well as safety of life, national security, and scientific investigation, particularly regarding climate change. Other countries, notably those within the European Union, have made comparable investments, and international agreements are in place to ensure continual sharing of EESS (passive) observations to inform operational numerical weather prediction and Earth system research. Additional international collaboration, mediated by the World Meteorological Organization, includes efforts to ensure coordination among agencies developing next-generation spaceborne sensor assets, including optimizing their orbital parameters to maximize temporal and spatial coverage.

Satellite remote sensing data are an essential resource for accurate measurement and prediction of weather and climate. Whether collected by non-government or government organizations, NOAA and its National Weather Service are major users of these data. NOAA has estimated that about one-third of the U.S. economy—hundreds of billions of dollars annually—is sensitive to weather and climate. NOAA estimated that weather forecasts alone generated \$35 billion in annual economic benefits to U.S. households in 2016.³ NOAA has also stated that “NOAA weather forecasts and warnings are critical to people living in areas subject to severe weather, and to all Americans who depend on the economic vitality that these regions contribute. Accurate predictions of extreme weather location and severity are essential. Having

³ J.K. Lazo, R.E. Morss, and J.L. Demuth, 2009, “300 Billion Served: Sources, Perceptions, Uses, and Values of Weather Forecasts,” *Bulletin of the American Meteorological Society* 90(6):785-798.

time to prepare for extreme events limit their impact.”⁴ Furthermore, in rural areas where farming is the dominant source of income, accurate weather forecasting and climate prediction have been shown to have direct impact on investments and profits from agricultural products.

B. The Radio Astronomy Service

As the Commission has 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 surface gravitational fields up to 100 billion times stronger than that on Earth. 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

⁴ NOAA, 2018, *NOAA's Contribution to the Economy; Powering America's Economy and Protecting Americans*, <https://www.noaa.gov/sites/default/files/legacy/document/2019/Nov/NOAA-Contribution-to-the-Economy-Final.pdf>, p. 8.

galaxies discovered by radio astronomers have led to the recognition that most galaxies, including the Milky Way, contain supermassive black holes at their centers, a phenomenon that appears to be crucial to the creation and evolution of galaxies. Indeed, the first image of a super massive black hole, in the M87 galaxy⁵—followed, most recently, by observations of the black hole at the center of the Milky Way⁶—was obtained by an array of radio telescopes. 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.

II. Passive Scientific Observation Constitutes “Usage” of the Spectrum.

Paragraphs 16-21 of the NOI seek comments on defining “usage” of the spectrum. No reference is made therein to passive scientific observation. Nevertheless, passive scientific observation clearly constitutes “usage” of the spectrum.

It is essential for the Commission to recognize that passive scientific observation of the spectrum constitutes “usage” of the spectrum. Such usage has wide regulatory recognition throughout the world. The numerous allocations to RAS and EESS in the

⁵ See, The Event Horizon Collaboration, 2019, “First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole,” *The Astrophysical Journal Letters*, 875:L1. See also H. Greene, 2019, “The Black Hole Photo Was No Big Surprise to Scientists. Here’s Why It’s Still a Big Deal,” Opinion, *Washington Post*, April 12, <https://www.washingtonpost.com/opinions/2019/04/12/black-hole-photo-was-no-big-surprise-scientists-heres-why-its-still-big-deal/>; S. Kaplan and J. Achenbach, 2019, “See a Black Hole for the First Time in a Historic Image from the Event Horizon Telescope,” *Washington Post*, April 10, <https://www.washingtonpost.com/science/2019/04/10/see-black-hole-first-time-images-event-horizon-telescope/>; and D. Overbye, 2019, “Darkness Visible, Finally: Astronomers Capture First Ever Image of a Black Hole,” *New York Times*, April 10, <https://www.nytimes.com/2019/04/10/science/black-hole-picture.html>.

⁶ See, The Event Horizon Collaboration, 2022, “First Sagittarius A* Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole in the Center of the Milky Way,” *The Astrophysical Journal Letters*, 930:L2; D. Overbye, 2022, “The Milky Way’s Black Hole Comes to Light,” *New York Times*, May 12, <https://www.nytimes.com/2022/05/12/science/black-hole-photo.html>.

domestic and international tables of allocations demonstrate that the Federal Communications Commission (FCC) and the International Telecommunication Union (ITU) both recognize that RAS and EESS constitute use of the spectrum equal to that of active services. Indeed, many of the allocations to RAS and EESS are the primary and sole service in that particular band. See, for example, the Table of Allocations in Section 2.106 of the Commission's rules for 73-74.6 MHz, 1400-1427 MHz, 1660.5-1668.4 MHz, 2690-2700 MHz, and 4990-5000 MHz.

In addition to frequency allocations, the FCC has recognized the importance of passive use of the spectrum in other regulations. Examples of geographic protection include Section 1.924(a) of the Commission's rules, which creates a National Radio Quiet Zone designed to protect the National Radio Astronomy Observatory in Green Bank, West Virginia, from interference. Section 1.924(d) of the Commission's rules similarly establishes notification requirements for a "Puerto Rico Coordination Zone" designed to protect radio astronomy at the Arecibo Observatory.⁷ Non-geographic-based protection for passive services is established in numerous other Commission rules. For example, Section 15.205 of the rules prohibits intentional emission of radiation from unlicensed devices in a number of bands allocated to passive services, including 13.36-13.41 MHz, 25.55-25.67 MHz, 38.0-38.25 MHz, 73-74.6 MHz, 401-403 MHz, 608-614 MHz, 1400-1427 MHz, 1660.5-1668.4 MHz, 2690-2700 MHz, 4.5-5.15 GHz, and 5.35-5.46 GHz.⁸

⁷ See also, *Amendment of the Commission's Rules to Establish a Radio Astronomy Coordination Zone in Puerto Rico*, Report and Order, 12 FCC Rcd 16522 (1997).

⁸ In addition, ITU RR 5.340 and Footnote US246 state that in specific listed bands, including bands allocated to passive scientific services, "all emissions are prohibited".

In sum, numerous U.S. and international regulations protect passive scientific observation of the spectrum. This clearly demonstrates that such observations are “usage” of the spectrum.

Attempts to define spectrum “usage” based on metrics for “band occupancy” or “spectrum occupancy,” as discussed in para. 17 of the NOI, may have limited usefulness when applied to passive scientific observations. For example, the “band occupancy” metric refers to the presence of “a detected signal level that exceeds a default or user-defined threshold.”⁹ In the context of radio astronomy or Earth remote sensing, natural radio emissions occur at all frequencies and arrive from all directions, carrying data about Earth’s environment and the cosmos. Certain bands, often associated with the natural frequencies of specific atomic and molecular emission lines, are particularly critical for Earth remote sensing and astronomy and hence are protected by frequency allocations. Yet while U.S. and international rules define thresholds for protection of these frequencies, the data are present at these frequencies even at levels lower than those thresholds.

Similarly, para. 17 of the NOI refers to an ITU definition of “spectrum occupancy” that includes use of a frequency band for “transmission of information.”¹⁰ It is certainly the case that there is an immense amount of data in the natural emissions that are observed by Earth scientists and astronomers, and accordingly, the presence of that data could be argued to constitute the “transmission of information.” That said, CORF

⁹ NOI at para. 17, citing to M. Cotton et al., 2020, *3.45–3.65 GHz Spectrum Occupancy from Long-Term Measurements in 2018 and 2019 at Four Coastal Sites*, National Telecommunications and Information Administration Report 20-548, April, <https://perma.cc/X9R5-SJEV>.

¹⁰ Citing, ITU, 2016, *Spectrum Occupancy Measurements and Evaluation*, Report ITU-R SM.2256-1 at 37, June, <https://perma.cc/Q7ND-L6S3>.

takes no position at this time on the definition of that term; rather, it focuses on the point that passive usage of the spectrum cannot be quantified through any purely measurement-based approach.

In sum, it appears that attempts to use the above-cited National Telecommunications and Information Administration (NTIA) and ITU definitions are likely not useful in addressing passive scientific usage of the spectrum. Rather, as suggested in para. 17 of the NOI, they “obscure or limit greater comprehension” of passive scientific usage. In any case, it is clear that passive scientific observation constitutes “usage” of the spectrum observed.

III. Band-Specific Observations.

In paragraphs 22-24 of the NOI, comments are sought on whether band-specific considerations are relevant in understanding spectrum usage. Para. 22 of the NOI notes that “several bands may exhibit infrequent usage that are nonetheless mission critical for their intended uses.” For the purposes of this discussion, CORF considers “exhibit” in the quoted sentence to be synonymous with actual passive usage, given that, as discussed previously, passive usage does not manifest in any directly-measurable signature in the radio spectrum. Earth remote sensing satellites typically are observing continuously though not (as yet) covering all regions of the Earth at any given time; RAS observatories include facilities making diverse, targeted observations (that may constitute “infrequent usage”) as well as survey instruments that operate on a continuous basis.

The natural sources of radiation measured by passive EESS applications are often broadband and extremely low power relative to the signals generated and received by active services. As a result, observation over the entire allocated bandwidth is often required for accurate measurements. Observed phenomena tend to be globally distributed as well, and observations are required on short timescales; given the number of EESS assets currently in use, each point on Earth is observed in a passive allocation multiple times each day, 7 days per week.

The critical research performed by Earth remote sensing scientists cannot be performed without access to interference-free bands. A report recently released by the NTIA stated that “due to the extreme sensitivity required to sense physical phenomena such as water vapor—in different heights of the atmosphere—and ocean surface salinity, passive sensing bands are extremely vulnerable to interference coming from transmitters operating in adjacent bands with unwanted emissions extending into the passive band.”¹¹

The natural sources of radiation measured by passive RAS applications may be either broadband or narrowband. They are extremely low power relative to the signals generated and received by active services. The entire allocated bandwidth is usually needed for sufficiently sensitive observations of the broadband sources. The narrowband sources (e.g., the 1420 MHz emission line of neutral hydrogen) have varying apparent frequency depending on the relative motion or cosmological redshift of the emitting astronomical source. Observations of narrowband sources often use the

¹¹ NTIA, 2021, *The Spectrum Needs of U.S. Space-Based Operations: An Inventory of Current and Projected Uses*, Office of Spectrum Management, p. 15, <https://www.ntia.doc.gov/report/2021/spectrum-needs-us-space-based-operations-inventory-current-and-projected-uses> .

entire allocated bandwidth to measure the change in the observed frequency of the emission line over the field of interest (e.g., a rotating galaxy), which carries velocity information.

The critical scientific research 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 (OOBE) 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.

It also should be noted that scientific observation in the passive bands constitutes efficient use in the sense that no observer prevents any other party from observing on the same frequency. Indeed, there is essentially no limit to the number of parties that can observe on the same frequency, or to the number of independent detectors or receivers employed by a given passive instrument or facility.

IV. Conclusion.

It is essential for the Commission to recognize that passive scientific observation of the spectrum constitutes “usage” of the spectrum. Such usage has wide regulatory recognition. The numerous allocations to RAS and EESS in the domestic and international tables of allocations, and related FCC rules, demonstrate that the FCC and

the ITU both recognize that passive scientific observation (RAS and EESS) constitutes “usage” of the spectrum on par with that of active services.

Respectfully submitted,
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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Appendix

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