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

In the Matter of	)	
	)	
Battelle Memorial Institute, Inc.	)	RM-11713
	)	
Petition for Rulemaking to Adopt Service Rules for the 102-109.5 GHz Band	)	

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

The National Academy of Sciences, through the National Research Council's Committee on Radio Frequencies (hereinafter, CORF), hereby submits its comments in response to the Commission's February 24, 2014, *Public Notice* regarding the above-captioned Petition for Rulemaking.[1] In these Comments, CORF discusses the potential impact on radio astronomy from the proposals in the Petition for Rulemaking (*Petition*) filed by Battelle Memorial Institute, Inc. (Battelle) that led to the initiation of this proceeding, as well as the ways to minimize that impact. CORF does not oppose fixed commercial use of the sort proposed in the *Petition*, as long as the Commission's rules provide for appropriate frequency coordination sufficient to protect Radio Astronomy Service (RAS) observations.[2]

[1] CORF hereby moves for leave to file these comments after the filing deadline. The public interest would be served by accepting the comments, since Battelle's proposal would directly impact radio astronomy observatories, and no other parties in this proceeding have filed any information regarding that impact or the proposals to limit that impact. Thus, these comments will provide information important for the Commission's consideration in this proceeding. Further, no parties will be harmed by the acceptance of these comments, as further rounds of comments are anticipated if the Commission grants the Battelle Petition and initiates a rulemaking proceeding.

[2] The interference from out-of-band emissions is also a concern for spaceborne instruments operating under the Earth Exploration-Satellite Service.

I. Introduction: The Role of Radio Astronomy 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 RAS bands. RAS observers 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 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 only experimental evidence so far 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. 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 has led to the recognition that galaxies, including our own Milky Way, may 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 have discovered the cosmic microwave background (CMB), the radiation left over from the original Big Bang, which has now cooled to only 2.7 K above absolute zero. Later observations discovered 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. Within our own solar system, radio astronomy observations of the Sun have been used for more than half a century to aid in the prediction of terrestrial high-frequency radio propagation.

Since 1974, eight scientists, six of whom are American, have received the Nobel Prize in physics for their work in radio astronomy.

However, the 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 weak, distant in-band man-made emissions can preclude RAS use.

In sum, the important science performed by radio astronomers 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 from the information learned and the technologies developed.

II. Observations at 102-109.5 GHz Are Important and Are Regularly Performed at U.S. Observatories.

Of particular concern to CORF in this proceeding is protection of RAS observations at 102-109.5 GHz (100 GHz Band). The RAS has a co-primary allocation in the 100 GHz Band, as well as protection mandated by Footnote US342.[3] Observations in the 100 GHz Band are critical for scientific research and are, have been, and will continue to be regularly performed at U.S. observatories.

Observations in the 100 GHz Band are essential to astronomical research. Because there is only modest absorption from atmospheric oxygen and water in this Band, it is one of the best high-frequency resources for both continuum and line observations of celestial objects.[4] In particular, because this Band is so close to the fundamental or lowest-energy transition of the carbon monoxide (CO) molecule, it is especially useful for observations of redshifted emissions of CO and isotopes of CO. Because the CO molecule is ubiquitous, its emission is the principal tool used by astronomers today in the study of star-forming gas in the Milky Way galaxy and other galaxies. CO studies provide critical information about disks around newly forming stars and insights into bursts of star-formation activity. Such bursts have recently been related to collisions between galaxies and possibly to the formation of massive black

[3] US342 provides that "all practicable steps shall be taken to protect the radio astronomy service from harmful interference" in this Band.

[4] Frequencies such as 102.5 GHz and 107.014 GHz are among the frequency lines of greatest importance to the RAS. *See*, ITU Handbook On Radio Astronomy, (ITU Radiocommunications Bureau, 2013) at Table 3.2. In addition, Table 3.1 of the ITU Handbook lists 76-116 GHz as one of the frequency bands preferred for continuum observations.

holes and quasars.[5] Observations in the 100 GHz Band also give insight into theories of nucleosynthesis in stars and are of fundamental importance to the investigation of galactic chemical evolution.

Footnote 5 of the *Petition* raises questions regarding the degree to which radio astronomers actually observe in this Band. In response, CORF notes the following regarding its understanding of observations in the 100 GHz Band in the United States. First, observations in the 100 GHz Band regularly occur at the Combined Array for Research in Millimeter-wave Astronomy (CARMA) observatory in California.[6] Indeed, since 2013, approximately 33% of the observations at CARMA are in the 100 GHz Band.[7] Second, the 12-meter telescope at Kitt Peak, Arizona,[8] has observed in the 100 GHz Band for many years. While the original 12-meter telescope was decommissioned, a new 12-meter telescope was installed in December 2013, and it is expected that the 100 GHz Band will be the principal band used for observations once the new telescope is fully brought online. In addition, CORF brings to the Commission's attention the Haystack Observatory in Massachusetts and the Green Bank Telescope (GBT) in West Virginia. CORF understands that the GBT plans to begin observations in the 100 GHz Band in late 2014, while Haystack may commence observations in this Band in the foreseeable future. Further, while CORF believes that the observatories at Mauna Kea, Hawaii, and at Mt. Graham (part of the Arizona Radio Observatory) do not currently

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[5] *See, e.g.,* Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses (National Academies Press, 2007) at page 72.

[6] CARMA is an interferometer encompassing 23 antennas used in combination to image the universe at millimeter wavelengths. It is located on a high-altitude site in the Inyo Mountains of California. CARMA is operated as a partnership among Caltech and other universities, with significant funding from the National Science Foundation.

[7] Source: CARMA Observatory.

operate at the 100 GHz frequency range, they do have millimeter-wave telescopes that could observe at that range with the proper receivers.

While the above statements reflect CORF's understanding of the current RAS use of the Band in the United States, changes will certainly occur over time. Any rules for proposed fixed use of the Band should provide for changes in those RAS sites entitled to protection.

III. Frequency Coordination.

Battelle states that it "is committed to working with the Commission, NTIA [National Telecommunications and Information Administration] and the affected stakeholders to assure that co-primary users are appropriately protected as fixed services are deployed in the 102-109.5 GHz band" (*Petition* at page 9). Such commitment is appropriate, since the RAS is a co-primary service in that Band, and RAS observations in the 100 GHz Band will need to be protected. Where RAS observations in the Band occur, the observations can occur for a large fraction of the observing time (in the range of one-third at CARMA). Many different spectral lines of interest to the RAS fall in the Band, and commercial transmissions received by RAS observatories are likely to severely compromise the observations or even damage the RAS receivers.

Nevertheless, CORF does not oppose fixed terrestrial use of the 100 GHz Band, and frequency coordination, if properly designed and executed, should provide the

[8] The Arizona Radio Observatory at Kitt Peak is operated by the University of Arizona, with funding in part from the National Science Foundation.

protection required for RAS observatories.[9] CORF notes that the *Petition* seeks a rulemaking for fixed terrestrial use of the 100 GHz Band. The 100 GHz Band is not allocated for mobile and aeronautical uses, and any such uses would raise significant additional interference issues for the RAS.

There is a limited number of RAS facilities that observe in the Band, and those facilities can be identified with relative ease. While CORF does not have direct experience with the existing coordination system for the 70/80/90 GHz bands, it is logical that a similar system of geographic coordination through the NTIA can be applied to the 100 GHz Band. It is CORF's understanding that the criteria used by NTIA for coordination of the 70/80/90 GHz bands' links with RAS facilities are taken from ITU-R Recommendation RA.769-2. That is appropriate, and criteria for coordination in the 100 GHz Band should do so as well.

At a minimum, coordination of 100 GHz Band links should occur where the transmitters are in radio line-of-sight to RAS facilities that observe in the 100 GHz Band, or where the transmitter's directional beam passes over the observatory. Procedures should be adopted for notification to NTIA when additional RAS facilities commence observing in the 100 GHz Band.

IV. Conclusion.

Observations at 102-109.5 GHz are critical for astronomical research and are, have been, and will continue to be regularly performed at U.S. observatories.

[9] CORF also notes that unlicensed use of this Band is currently prohibited, and any such use could cause harmful interference to scientific use of the Band. CORF recommends either that unlicensed operations in the Band not be authorized, or that such operations be authorized only in areas with a geographic separation from RAS facilities observing in the Band which is sufficient to protect those facilities from interference.

Nevertheless, CORF does not oppose fixed commercial use of the sort proposed in the *Petition*, as long as the Commission's rules provide for appropriate frequency coordination sufficient to protect RAS observations.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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