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

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| Amendment of Footnote US246 of | ) | RM-11847 |
| Section 2.106 of the Commission's | ) | |
| Rules to Enable More Efficient | ) | |
| Interference-Free Sharing of Spectrum | ) | |
| Above 95 GHz | ) | |
| | ) | |
| Spectrum Horizons | ) | ET Dkt. 18-21 |

# OPPOSITION TO PETITION FOR RULEMAKING

The National Academy of Sciences, through its Committee on Radio Frequencies (hereinafter, "CORF"[1]), hereby opposes the Petition for Rulemaking (the "Petition") filed by the mmWave Coalition ("mmWC") in the above-captioned proceeding.[2] The proposal to modify Footnote US246[3] to allow emissions into the exclusive passive bands listed therein should be rejected because it is inconsistent with and cannot be executed under the rules and procedures of the International Telecommunications Union ("ITU"). Furthermore, interference-free access to the US246 bands is uniquely

---

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

[2] CORF hereby seeks leave to file these Comments after deadline set forth in Section 1.405 of the Commission's rules. This was necessitated by the press of business on CORF, along with time associated with CORF's mandatory peer review process. The public interest would be served by accepting these comments, since mmWC's proposal would directly impact radio astronomy and Earth remote sensing facilities, and no other parties representing these passive users of the spectrum have filed in this proceeding. Thus, these comments will provide information important for the Commission's consideration in this proceeding. Acceptance of this Opposition should not harm the mmWC, as CORF anticipates that the mmWC will file an *ex parte* response to this pleading, and CORF fully supports mmWC's doing so.

[3] 47 C.F.R. § 2.106, Footnote US246 ("US246").

important for scientific use of the spectrum. While CORF appreciates mmWC's recognition of this and its proposal to protect passive use, CORF believes that the mmWC Petition would cause harmful interference to current scientific observations in the US246 bands. Furthermore, even if, *arguendo*, such protection could be accomplished in the present, its Petition cannot protect innovative, new *future* scientific uses of these bands. Just like the commercial innovation that mmWC seeks to promote, scientific innovation will undoubtedly continue to occur, with increasingly sensitive instruments and new discoveries in the US246 bands. This scientific innovation will be unnecessarily and prematurely limited if the spectral "windows" where leading-edge science occurs are closed by active use. Such a loss would be a significant economic, scientific, and cultural loss for all humankind.

## I. The Unique Value of Passive-Use-Only US246 Bands.

CORF has a substantial interest in this proceeding, as it represents the interests of the scientific users of the radio spectrum, including users of the Radio Astronomy Service ("RAS") and Earth Exploration-Satellite Service ("EESS") bands. The Commission has long recognized that Earth remote sensing and radio astronomy are vitally important tools used by scientists to study our rapidly changing Earth, and the universe. The Petition also recognizes the importance of this science and the vulnerability of passive scientific observation to human-made interference, so CORF will not discuss those topics generally in this Opposition.[4] Rather, CORF will briefly

---

[4] *See* Comments of CORF filed March 30, 2018, in ET Docket 18-21 ("Spectrum Horizons") at pages 1-5, incorporated herein by reference.

illustrate the unique value of passive scientific observations in the US246 bands, and of reserving those bands for passive use only.

### A. Satellite Remote Sensing – EESS

The ability to make repeated remote sensing measurements that cover the entirety of Earth from spaceborne observatories has revolutionized our understanding of Earth as a system, and it has enabled dramatic improvements in the accuracy of forecasts of its evolution over timescales from hourly to decadal and longer. Passive observations at frequencies of 95 GHz and higher represent a significant component of this capability, providing unique information on key processes related to weather, climate, and atmospheric chemistry, as well as information on the couplings between these disciplines and their links with other aspects of Earth science. In many cases, no other spaceborne systems are able to observe the relevant atmospheric and terrestrial parameters.

Satellite remote sensing data are a key resource for accurate weather prediction. The National Oceanic and Atmospheric Administration ("NOAA") and its National Weather Service are major users of these data. NOAA has estimated that about one-third of the U.S. economy – trillions of dollars annually – is sensitive to weather and climate.[5] A recent NOAA report[6] estimated that weather forecasts generate $35 billion in annual economic benefits to U.S. households alone. NOAA has also stated that "NOAA weather forecasts and warnings are critical to people living in areas subject to

---

[5] *See* NOAA, "Weather," https://www.noaa.gov/weather, accessed October 22, 2019.

[6] *See* NOAA, "NOAA *by the* Numbers," June 2018, p. 8, https://www.performance.noaa.gov/economics/.

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 time to prepare for extreme events limit their impact."[7] Furthermore, in rural areas, where farming is usually the dominant source of income, accurate weather forecasting and climate prediction has been shown to have direct impact on investments and profits from agricultural products.[8] The accuracy of these protective weather predictions is *largely a function of accurate data* assimilated into the numerical models.

Furthermore, understanding the *space* weather environment is a national priority[9] and is essential to the design and operation of human systems in near-Earth space, with an aggregate value in the trillions of dollars. The best attempts to characterize space weather drivers in the upper reaches of the atmosphere now require accurate knowledge of lower-atmosphere dynamics produced by, for example, satellite remote sensing data. In fact, a 2019 review article in the journal *Space Weather* states: "with respect to predicting the Earth's upper atmosphere, there has been a recent paradigm shift; it is now clear that any self-respecting model of this region needs to include some representation of impacts from below (the lower atmosphere) as well as from above

---

[7] *See*, NOAA, "NOAA's Contribution to the Economy; Powering America's Economy and Protecting Americans,"2018, p. 8, https://www.performance.noaa.gov/economics/.

[8] *See*, National Bureau of Economic Research, "Forecasting Profitability," August 2013, https://www.nber.org/papers/w19334.

[9] *See*, Executive Office of the President, "National Space Weather Strategy and Action Plan," March 2019, https://www.whitehouse.gov/wp-content/uploads/2019/03/National-Space-Weather-Strategy-and-Action-Plan-2019.pdf.

(solar variability and the effects of solar wind fluctuations)."[10] In other words, protection of U.S. space-borne assets, including the Global Positioning System (GPS), the International Space Station, and commercial satellites, among others, requires a whole-atmosphere approach to developing accurate space weather models.

The main application of Earth remote sensing satellite observations at frequencies of 95 GHz and above is atmospheric research, including weather forecasting. The unique utility of the millimeter spectral range primarily derives from two factors. First, many atmospheric constituents have clear emission/absorption features in this region, enabling measurements of not only atmospheric composition, but also temperature and pressure. Second, signals at these wavelengths are not affected significantly by scattering from atmospheric aerosols (including dust, pollution particulates such as black carbon, and volcanic plumes) and many classes of cloud particles. This crucially enables temperature, humidity, and composition measurements to be made in regions of the atmosphere inaccessible to sounding at shorter wavelengths (ultraviolet, visible, and infrared) due to pollution or cloud cover. Such capability is a particularly important advantage for studies of extreme weather. Conversely, signals toward the higher frequencies of this range (e.g., 200-800 GHz) are affected by scattering from cloud ice particles, and observations in this spectral region are increasingly being used to characterize this hitherto poorly observed and incompletely understood class of particles and its role in weather and climate.

---

[10] See, D.R. Jackson, T.J. Fuller-Rowell, D.J. Griffin, M.J. Griffith, C.W. Kelly, D.R. Marsh, and M.-T. Walach, "Future Directions for Whole Atmosphere Modeling: Developments in the Context of Space Weather,:1342–1350, 2019, https://doi.org/10.1029/2019SW002267.

The widest use of this spectral region for passive Earth observation is for remote sounding of atmospheric temperature and humidity from the surface through the mesosphere (~100 km). For temperature sounding, an increasing number of instruments are targeting the oxygen signature at 118 GHz, because oxygen is generally chosen for temperature measurements as its atmospheric abundance is well known and stable, and therefore such observed signals are indicative of temperature and pressure.[11] The use of this higher frequency brings advantages, including the ability to employ smaller optics while achieving the same spatial resolution, enabling more compact and lower-cost instruments.

For humidity sounding, the 183 GHz water vapor line is central and is observed by essentially every microwave sounder employed to measure atmospheric humidity profiles.[12] In contrast with the lower-frequency observations at 18, 24, and 37 GHz, which are predominantly sensitive to near-surface humidity, the 183 GHz spectral region provides unique information on water vapor at higher altitudes (and is the only part of the spectrum below 320 GHz that provides this information).

Broadening of spectral lines by molecular collisions crucially enables all of these observations to be vertically resolved. Linewidths typically broaden at a rate of ~3 MHz

---

[11] *See, e.g.,* NASA, "TROPICS: Mission Overview," https://tropics.ll.mit.edu/CMS/tropics/Mission-Overview, accessed October 22, 2019.

[12] *See, e.g.,* NASA, "TROPICS: Mission Overview," *id. See also,* NOAA's Advanced Technology Microwave Sounder, which observes at 183 GHz, as well as at 165.5 GHz, at NOAA, "STAR JPSS: Advanced Technology Microwave Sounder (ATMS)," https://www.star.nesdis.noaa.gov/jpss/ATMS.php, accessed October 22, 2019; NOAA's Advanced Microwave Sounding Unit-B, which observes at 183 GHz, as well as at 150, 157, and 190 GHz, at R.R. Ferraro, H. Meng, and NOAA CDR Program, 2016, NOAA Climate Data Record of Advanced Microwave Sounding Unit (AMSU)-B, Version 1.0, NOAA National Climatic Data Center, doi:10.7289/V500004W, https://www.ncdc.noaa.gov/cdr/fundamental/amsu-bmhs-brightness-temperature accessed October 22, 2019; and NASA's Global Precipitation Measurement Microwave Imager (GMI), at NASA, "GMI," https://pmm.nasa.gov/gpm/flight-project/gmi, accessed October 22, 2019.

per millibar of atmospheric pressure (surface pressure is 1000 mb), so that observations at a range of frequencies away from line centers provide critical information about different layers in the atmosphere (see, e.g., Figure 1). Accordingly, continued, simultaneous, interference-free access to multiple wide spectral regions that, taken together, provide information on different key atmospheric parameters at different altitudes underpins the accuracy of weather forecasts.

The submillimeter spectrum also provides unique information on atmospheric composition. In contrast with oxygen and water vapor discussed above, signals for more tenuous gases are too weak to provide useful information in nadir-viewing geometry. However, a wealth of information on such trace species is provided by observing the atmospheric limb (i.e., looking at the atmosphere “edge on”). Vertically scanning an instrument’s field of view across the limb provides excellent vertical resolution, and the long atmospheric path lengths significantly increase the number of molecules observed, and thus the signal strength.

The record of such spaceborne observations extends back to the 1991 launch of NASA’s Upper Atmosphere Research Satellite. The latest generation Microwave Limb Sounder (“MLS”) on NASA’s Aura mission (launched in 2004 and still operating at the time of writing) provides what is generally acknowledged to be the “platinum standard” for global atmospheric ozone measurements, based on spectral limb radiances measured over a large fraction of the 230-250 GHz region. MLS also observes in several other bands, measuring many other species affecting stratospheric ozone and its recovery in response to international agreements to curtail emissions of chlorofluorocarbons.[13]

It is critically important to note that the needs of EESS(passive) are far from geographically limited. Polar-orbiting satellites make measurements in these spectral regions at essentially all locations on Earth multiple times per day. The broad fields of view of EESS(passive) instruments make them specifically susceptible to aggregate interference, including potentially from scattering of nominally "line-of-sight" ground-to-ground transmissions by topography, buildings, and – most critically for weather forecasts – cloud particles and precipitation hydrometeors (hail, snow, rain, etc.).

Furthermore, rather than thinking of each remote sensing instrument as a separate entity, with corresponding concerns about radio frequency interference just at that specific frequency, it is critical to recognize that observation of multiple bands operates as a unified system, since the measurements made at multiple frequency bands are necessary to interpret the data from any single observation due to the many different sources of natural emission within the footprint of each instrument. In particular, weather forecasting relies on the simultaneous combination of measurements at several different radio frequencies in order to deduce temperature and humidity profiles. Only with information from multiple bands, in well-chosen spectral locations, can the different fingerprints that water vapor and temperature have at each level of the atmosphere be disentangled from the measurements in the individual bands, and the state of the atmosphere deduced. See Figure 1, below. It is the combination of data across the radio spectrum that enables the accurate weather forecasts that we have

---

[13] *See,* NASA Jet Propulsion Laboratory, "Microwave Limb Sounder: The EOS MLS Instrument," https://mls.jpl.nasa.gov/eos/instrument.php, accessed October 22, 2019.

come to expect. In other words, radio frequency interference in any of the EESS(passive) bands, including the US246 bands, can have a negative effect not only on those measurements, but on the interpretation and analysis of all measurements made by Earth remote sensing satellites.

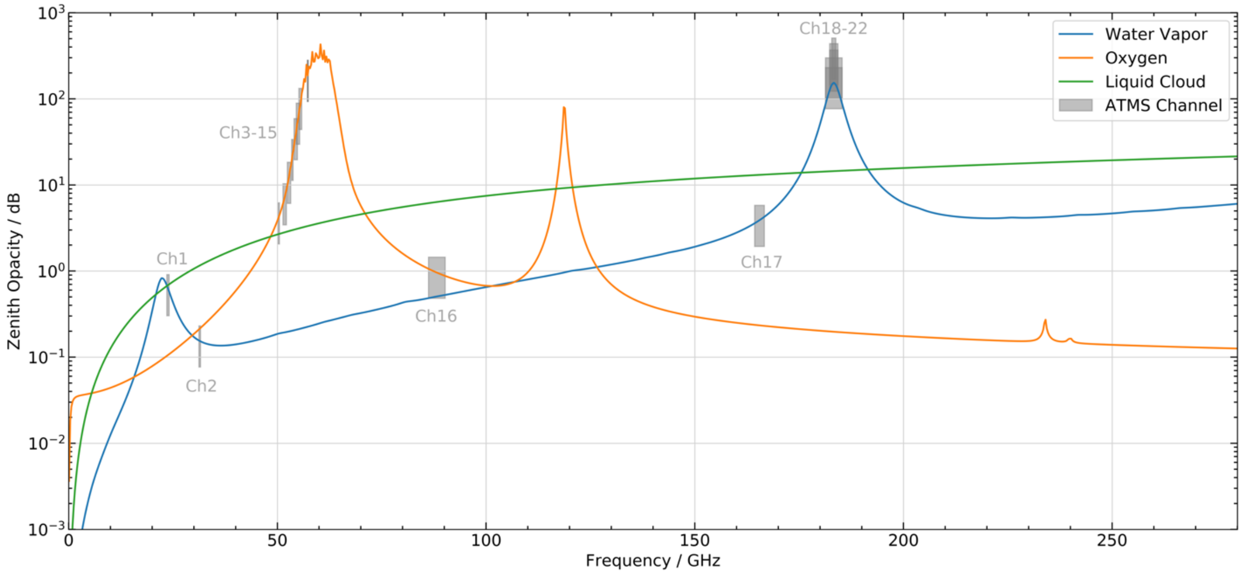

Figure 1: The EESS (passive) bands operate as a system, where measurements are made across the radio spectrum. Illustrated above are the emission/absorption signatures of oxygen (used to measure atmospheric temperature) and water vapor in Earth's atmosphere.  Grey boxes show the spectral regions ("channels") observed by the spaceborne Advanced Technology Microwave Sounder (ATMS) instruments that are used extensively in weather prediction (the same channels are also observed by both older and planned future instruments). The use of a combination of measurements at multiple frequencies is essential, as the different channels provide information about temperature and water vapor at different heights in the atmosphere and under different conditions (e.g., moist/dry). Radio frequency interference in any of these channels adversely impacts not just the single measurement, but the interpretation of all measurements and thus the validity of the atmospheric temperature and humidity profiles inferred. See also S.J. English, C. Guillou, C. Prigent, and D.C. Jones, 1994, *Q. J. R. Meteorol. Soc.* 120:603-625, for a similar illustration of the AMSU instruments.

## B. Radio Astronomy

Observations of the faint natural radio emission from astronomical objects fall into two broad categories: continuum and spectral line. Continuum observations are designed to measure the spectral energy distribution of cosmic sources and benefit from broad bandwidth detectors, as the signal-to-noise ratio can be increased by integrating over the entire band. At high frequencies, modern single-dish telescopes, such as the Green Bank Telescope, and interferometric arrays, such as the Submillimeter Array (SMA),[14] are equipped with flexible receivers having multi-GHz bandwidths that can cover one or more of the US246 bands in their entirety in a single observation.[15]

Continuum measurements at a range of frequencies are often required to deduce the origin of the radio frequency continuum emission. For example, the spectral energy distribution for synchrotron emission is distinctly different than that from a thermal source. At millimeter wavelengths, continuum observations of the cosmic microwave background provide insight into the structure in the early universe. Closer to home, continuum observations of the Milky Way and other galaxies detect free-free emission from the ionized gas in star-forming regions; thermal continuum emission from cold, dusty, regions; and continuum emission from non-thermal synchrotron radiation

---

[14] A list of U.S.-based radio astronomy facilities that currently observe, or are projected to observe, in these frequency bands is provided in Comments of CORF filed March 30, 2018, in ET Docket 18-21 (“Spectrum Horizons”) at pages 13-15, incorporated herein by reference.

[15] These wide bandwidths also enable observations of RAS allocations that are shared with active services, including those identified in US342. The passive-only (US246) bands are vital to enable operation in a shared environment, since the passive-only bands provide calibration and instrument characterization, without which it would be impossible to identify and excise instances of radio frequency interference in the shared bands.

produced by high-energy electrons spiraling around magnetic-field lines. Continuum observations separated by about an octave in frequency are needed to determine the broad spectral character (spectral index) of astronomical sources that identify the emission processes at work. Continuum observations must be conducted in parts of the radio spectrum that have low atmospheric opacity and are free of radio frequency interference.[16] Thus, the frequency bands listed in US246 provide an important and unique resource for studies of faint cosmic sources where it is important to be confident that the signal received by the telescope is not contaminated by human-made emissions.[17]

In contrast to continuum observations, spectral line observations must be obtained at frequencies dictated by the laws of quantum mechanics and the physics of an expanding universe. Each atomic and molecular species has its own unique set of spectral lines. In addition to providing information about physical conditions and local kinematics, observations of spectral lines allow astronomers to measure the Doppler

---

[16] For example, the well-publicized first image of a black hole was obtained with observations within the US246 band at 226-231.5 GHz due to its wide bandwidth, low atmospheric opacity, and low noise (interference-free) characteristics *See*, The Event Horizon Telescope Collaboration, K. Akiyama, A. Alberdi, W. Alef, K. Asada, R. Azulay, A.-K. Baczko, et al., "First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole," *Astrophysical Journal Letters* 875:L1, 2019, https://doi.org/10.3847/2041-8213/ab0ec7. See also J. Greene, "The Black Hole Photo Was No Big Surprise to Scientists. Here's Why It's Still a Big Deal," *Washington, Post*, April 12, 2019, 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, "See a Black Hole for the First Time in a Historic Image from the Event Horizon Telescope," *Washington Post,* April 10, 2019, https://www.washingtonpost.com/science/2019/04/10/see-black-hole-first-time-images-event-horizon-telescope/; and D. Overbye, "Darkness Visible, Finally: Astronomers Capture First Ever Image of a Black Hole," *New York Times*, April 10, 2019, https://www.nytimes.com/2019/04/10/science/black-hole-picture.html.

[17] *See,* Table 3 of ITU-R RA.314-10 for a list of the frequency bands below 275 GHz that are preferred for continuum observations. Although US246 bands 182-185 and 190-191.8 GHz are not listed in that Table, due to the severe attenuation from atmospheric water vapor, these frequency bands are used for critical calibration of RAS science observations, since atmospheric water vapor column density is a critical component for correcting measured fluxes for atmospheric attenuation.

shift arising from the relative motion of the source and the observer. The observed frequency of the spectral line, often reported as a redshift, is a combination of the systemic motion of the celestial object and local kinematic motions of the emitting or absorbing medium. Study of the source location, kinematics, and angular sizes of the regions provide important information about the physical conditions in and near the source and about motions within the source.

All of the US246 bands are used for observations of molecular transitions, many of which are identified by the ITU-R to be the ones most important to radio astronomy. For example, 100-102 GHz, 109.5-111.8 GHz, and 114-116 GHz enable observations of CO (J=1-0) and its isotopologues ($^{13}$CO, C$^{18}$O) in the Milky Way and more distant galaxies. CO observations provide fundamental information on the molecular gas content and distribution, in part because CO is a stable molecule and is very abundant. Other molecular species with rest-frequency transitions in these bands include methyl acetylene and the cyano radical. The 226-231.5 GHz frequency band includes the CO (J=2-1) transition as well as spectral lines from the cyano radical. In addition, the 182-185 GHz frequency band is critically important, both as a band to detect $H_2O$ in astronomical sources and as a measurement of atmospheric water vapor that is needed to calibrate submillimeter observations. The other US246 bands also include molecular transitions that illuminate the physical properties of celestial objects: the rest frequency of spectral transitions of nitric oxide lie within both the 148.5-151.5 GHz frequency band and the 250-252 GHz frequency band; $CH_3CN$ has transitions within the 164-167 GHz, 182-185 GHz, and 200-209 GHz bands; $CH_3OH$ has transitions within the 164-167 GHz and 190-191.8 GHz bands; many other complex molecules have been detected from cosmic sources within the US246 bands.[18]

The importance of having passive-only (US246) bands cannot be overstated in this context. The passive-only bands are designated so that observations of natural phenomena can be undertaken without concern of corruption by human-made transmissions. Passive radio receivers (whether on Earth or in space) are spectacularly sensitive to interference from active transmissions. Accordingly, scientific measurements of faint naturally occurring radio emissions are especially vulnerable to human-made transmissions. Instances of weak radio frequency interference are particularly pernicious since they corrupt the data, but at a level wherein the measurements may still be included in the analysis as they are still within the expected range of physical phenomena. The inclusion of contaminated measurements results in incorrect scientific analysis.

## II. The Need to Maintain Clean Spectral "Windows" For Innovative Future Scientific Exploration.

Satellite remote sensing and radio astronomy both have a long history of innovation and remarkable discoveries, using observations of Earth and the universe through certain spectral "windows." Just like the commercial innovation that mmWC seeks to promote,[19] scientific innovation relying on passive observation will undoubtedly

---

[18] *See also*, Table 1 of ITU-R RA.314-10 for a list of radio frequency lines of the greatest importance to radio astronomy at frequencies below 275 GHz. That Table includes nine rest frequencies and eleven suggested minimum bands within the US246 bands above 95 GHz.

[19] In attempting to support the claim that grant of the Petition would enhance U.S. innovation, the Petition asserts, at page 7, that "[i]t is expected that the increase in transparency for access to this spectrum would in turn increase private capital formation in US industry for R&D in this spectrum which is already targeted by other countries which are economic competitors of the US with government

continue to occur.[20] Yet, with increasingly sensitive instruments, such innovation will require spectral windows that have not been "fogged" by human-made interference.

CORF appreciates mmWC's recognition of the importance of passive scientific observation. However even if, *arguendo*, the proposed protection could be accomplished in the present (and it is not clear that it could as a practical or as a regulatory matter), mmWC's Petition cannot protect innovative, new *future* scientific uses of these bands.

We do not know what new scientific discoveries will take place in the coming decades, and therefore we cannot predict fully which frequency bands will be in the highest demand for passive observations. We can, however, predict that there will be continuing need for regions of the electromagnetic spectrum that are uncontaminated by human-made emissions. These emission-free spectral windows provide the critical role of calibration and low-noise environments that cannot be replicated. Once these windows are contaminated by human-made transmissions, it will likely be impossible to

---

supported R&D funding." There is no evidence offered to support this assertion, other than perhaps Figure 3 therein, showing examples of millimeter-wave research in certain other countries. Yet, no evidence is provided that the existence of millimeter-wave research in those countries is the direct result of spectrum allocation or regulatory policy in those countries, as opposed to alleged "government supported R&D funding." Furthermore, in regards specifically to the frequency bands listed in US246 above 95 GHz, the regulatory policies for all countries, including the United States, must be made with the recognition that the relevant international radio regulation is RR 5.340: "All emissions are prohibited in the following bands..." Accordingly, Figure 3 does not support the argument that "lack of transparency" or "regulatory uncertainty" is a primary cause for the alleged lack of funding for, or development of, millimeter-wave research in the United States, and to attribute it to the U.S. spectrum policies protecting the passive services is invalid.

[20] Radio astronomy has a long history of creating innovative technologies that are spun off into extremely valuable commercial uses. *See, e.g.,* National Research Council, *Astronomy and Astrophysics in the New Millennium,* The National Academies Press, Washington, DC, 2001, pp. 146-153, https://www.nap.edu/catalog/9839. *See also,* International Astronomical Union, "From Medicine to Wi-Fi, Technical Applications of Astronomy to Society," 2019, https://iau.org/static/archives/announcements/pdf/ann19022a.pdf.

return them to their pristine state, and the potential for scientific discovery in these bands will be lost permanently.

One example of scientific discovery that was not originally anticipated with the frequency allocations in US246 has been the detection of highly redshifted sources in these spectral windows.[21] High-order spectral-line transitions are redshifted to these lower frequencies due to the expansion of the universe. In addition, due to the finite travel time of light, observations of distant (high-redshift) sources enable measurements of physical properties of objects as they were billions of years ago. In essence, radio frequency observations of astronomical sources at a range of redshifts are snap-shots of the universe from its infancy (as imprinted on the cosmic microwave background) to the present. Use of the US246 bands for these observations of spectral transitions from a variety of complex molecules are likely to expand as the sensitivity of radio telescopes improve due to the development of low-noise receivers and new facilities, leading to an enhanced understanding of the origins and evolution of the universe.

Society continues to demand greater accuracy from the Earth-system models used to derive forecasts on timescales ranging from hours-to-days (for weather), through seasonal (e.g., for agricultural forecasting), to decadal (for longer term climate variability and changes). These models require high-quality observational data for initialization, assimilation, and validation. With demands on model fidelity continuing to increase, we can fully expect to see ever more exacting measurement requirements

---

[21] For example, the rest-frequency $^{12}$CO (5-4) transition at 576.3 GHz was detected at 101.2 GHz toward the radio-blazar BR1202-0725 ($z = 4.69$), placing it in the middle of the 100-102 GHz band protected by US246. [K. Ohta, T. Yamada, K. Nakanishi, K. Kohno, M. Akyama, and R. Kawabe, “Detection of Molecular Gas in the Quasar BR1202-0725 at Redshift z=4.69,” *Nature* 382:426-428, 1996.

being levied. In the case of weather forecasting, contaminated measurements may result in incorrect weather forecasts and the subsequent incorrect allocation of resources to cope with natural disasters, such as hurricanes and tornados. Significant financial and human loss may occur when people are not able to prepare in advance due to an incorrect weather forecast. Loss of access to interference-free regions of the radio spectrum protected by US246 seriously jeopardizes the success of current and future forecasting capabilities that are increasingly being demanded of the Earth science community.

As stated earlier, the needs of an increasingly spacefaring society also demand better understanding of space weather and its impacts on humans and systems beyond the planet. For improved operational space weather forecasts, the latest science points to a whole-atmosphere approach for accurate modeling of drivers that not only involves *in situ* space observations, but also relies heavily on millimeter-wave radiometer data on lower-atmosphere dynamics that are precisely the subject of US246 protection. A primary example is provided by the fact that sudden stratospheric warming effects, occurring within the domain of lower-atmosphere weather, are now known to dramatically affect the whole atmosphere into near-Earth space.[22]

Further, we should not rule out the capability of the Earth system to offer "surprises" that defy the expectations of the scientific community. The 1986 discovery of the Antarctic "ozone hole" is the foremost example of such events,[23] to which one can

---

[22] *See, e.g.,* N.M. Pedatella, J.L. Chau, H. Schmidt, L.P. Goncharenko, C. Stolle, K. Hocke, V.L. Harvey, B. Funke, and T.A. Siddiqui, "How Sudden Stratospheric Warming Affects the Whole Atmosphere," *EOS*, March 20, 2018, https://eos.org/features/how-sudden-stratospheric-warming-affects-the-whole-atmosphere.

[23] *See, e.g.,* NASA, "NASA Ozone Watch: History of the Ozone Hole," https://ozonewatch.gsfc.nasa.gov/facts/history_SH.html, updated October 18, 2018. The latest-

add recent dramatic declines in summertime Arctic sea ice cover and recent evidence for significant ice sheet loss in Greenland. Now is clearly not the time to take our eyes off the Earth system, nor to allow the required spectral windows to become fogged over.

## III. mmWC's Petition Is Inconsistent With and Could Not Be Implemented Under Standard ITU Regulations and Procedures.

If the Commission were to implement the mmWC Petition, it would make frequency assignments that are inconsistent with the International Table of Frequency Allocations provided in ITU RR 5.340 (which includes all of the frequency bands under consideration here). While ITU Article 4.4 generally allows administrations to make assignments at variance with the International Table of Frequency Allocations, that Article provides that such assignments "shall not cause harmful interference to … a station operating in accordance with the provisions of the Constitution, the Convention, and these Regulations." Thus, as an initial matter, any assignment under the mmWC Petition would have to protect stations in neighboring countries from interference. Moreover, as noted in comments recently submitted in ET Docket 18-21,[24] operations under Article 4.4 are provided for in the ITU Rules of Procedure ("RoP").[25] Under RoP's 1.5 and 1.6, the notifying administration must establish that the non-conforming assignment will not cause harmful interference to other administrations, demonstrate a plan for shutting down devices if they do so interfere, and afford other administrations the ability to make their own determination of the potential for interference.

---

generation remote sensing ozone-profiling instrument, the Microwave Limb Sounder (MLS), is flying onboard NASA's Aura satellite, and observes using the US246 bands at 114-116 GHz, 182-185 GHz, 200-209 GHz, and 226-231 GHz. *Id.*

[24] *See,* Comments of the National Radio Astronomy Observatory, submitted August 27, 2019.

[25] *See* International Telecommunications Union, "Rules of Procedure," 2017, https://www.itu.int/pub/R-REG-ROP-2017.

In addition to those obligations, however, the grant of such U.S. assignments would trigger notification requirements under ITU Article 4.4, but the relevant ITU procedures essentially prohibit such notifications for frequencies listed in ITU RR 5.340. Section 2 of the RoP for Article 4.4 addresses assignments in frequency bands where the assigned use is specifically forbidden. Section 2.1 prohibits assignments in frequency bands protected by RR 5.340 where "all emissions are prohibited." Section 2.2 of the RoP goes on to state: "The Board considers that, in view of this prohibition, a notification concerning any other use than those authorized in the band or on the frequencies concerned cannot be accepted even with a reference to No. 4.4; furthermore the administration submitting such a notice is urged to abstain from such usage" (emphasis added). That is, Article 4.4 requires an administration to submit a notification regarding a non-conforming use, but such notifications will not be accepted regarding assignments contrary to RR 5.340. The only way out of this regulatory dilemma is addressed in a footnote to RoP 1.5: Notifications "could be achieved through bilateral/multilateral arrangements or mechanisms." Thus, the Commission, along with the State Department, would have to negotiate and sign bilateral agreements in order to implement the mmWC Petition.

In sum, the mmWC Petition is so inconsistent with ITU rules and procedures that significant work outside of the proposed rulemaking would be required to implement the Petition. There is no guarantee that such outside efforts would succeed. This is to be expected, given the great importance of ITU RR 5.340's protection of passive-only bands.

## IV. Conclusion

Interference-free access to the US246 bands is uniquely important for innovative scientific use of the spectrum. While CORF appreciates mmWC's recognition of this and its Petition to protect passive use, CORF believes that the mmWC Petition would cause harmful interference to current scientific observations in the US246 bands. Furthermore, even if, *arguendo*, such protection could be accomplished in the present, its Petition cannot protect innovative, new *future* scientific uses of these bands. Just like the commercial innovation that mmWC seeks to promote, scientific innovation will undoubtedly continue to occur, with increasingly sensitive instruments and new discoveries in the US246 bands. This scientific innovation will be unnecessarily and prematurely limited if the spectral "windows" where leading-edge science occurs are closed by active use that could not predict, but nevertheless limits, such scientific innovation. That would be a significant economic, scientific, and cultural loss for all humankind. Furthermore, mmWC's Petition to modify Footnote US246 to allow emissions into the exclusive passive bands listed therein should be rejected because it is inconsistent with and cannot be executed under the standard rules and procedures of the ITU. For all of these reasons, the Commission should dismiss or deny the mmWC Petition and retain the current protections for passive-only uses under US246.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

By: Marcia McNutt
Marcia McNutt
President, National Academy of Sciences

Direct correspondence to:

CORF
Keck Center of the National Academies
of Sciences, Engineering, and Medicine
500 Fifth Street, NW, Keck 954
Washington, D.C. 20001
(202) 334-3520

November 20, 2019

# Appendix A

## Committee on Radio Frequencies

### Members

Liese van Zee, Indiana University, *Chair*
Nathaniel Livesey, Jet Propulsion Laboratory, California Institute of Technology, *Vice Chair*
William Emery, University of Colorado
Dara Entekhabi, Massachusetts Institute of Technology
Philip Erickson, Haystack Observatory, Massachusetts Institute of Technology
Kelsey Johnson, University of Virginia
Mahta Moghaddam, University of Southern California
Scott Paine, Center for Astrophysics | Harvard & Smithsonian
Frank Schinzel, National Radio Astronomy Observatory
Gail Skofronick-Jackson, NASA Headquarters

### Consultants

Darrel Emerson, retired
Tomas E. Gergely, retired