601 Pennsylvania Ave., NW
Suite 800
Washington, DC 20004
202-654-5900

March 27, 2018

***EX PARTE* VIA ECFS**

Ms. Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, D.C. 20554

Re: GN Docket No. 14-177; IB Docket Nos. 15-256, 97-95; WT Docket No. 10-112

Dear Ms. Dortch,

T-Mobile USA, Inc. ("T-Mobile")[1] appreciates the Commission's efforts to move quickly to make millimeter wave spectrum available for 5G use, particularly the Chairman's stated intention to auction the 28 GHz band starting November 14, 2018.[2] But the spectrum auction planned for November should include additional millimeter-wave bands that the Commission has already allocated for mobile broadband.[3] Auctioning as much millimeter-wave spectrum as possible will promote the deployment of 5G technologies, increase competition and help ensure U.S. economic growth in an increasingly competitive global economy. In addition to auctioning bands already allocated for mobile broadband use, the Commission must also continue to adopt rules for the licensing and operations of additional millimeter wave spectrum bands under consideration in this proceeding. To that end, T-Mobile writes to update and reaffirm its analysis demonstrating how coordination between the radio astronomy community and 5G operators can readily allow for coexistence between the two services in the 32 GHz band. T-Mobile's analysis is consistent with analysis provided by space science organizations in concluding that the relatively small number of radio astronomy sites that use spectrum adjacent to the 32 GHz band can be fully protected without significantly impairing use of this spectrum for mobile broadband. Quickly adopting rules for the licensing and operation of the 32 GHz band — as well as for other millimeter-wave frequencies currently under consideration for 5G deployment — will help

[1] T-Mobile USA, Inc. is a wholly owned subsidiary of T-Mobile US, Inc., a publicly traded company.
[2] Ajit Pai, FCC, *No Spring Break for the FCC* (March 26, 2018), https://www.fcc.gov/news-events/blog/2018/03/26/no-spring-break-fcc.
[3] The millimeter wave bands include the 24 GHz, 28 GHz, 37 GHz, 39 GHz and 47 GHz bands. *See, e.g.*, Letter from Steve B. Sharkey, Vice President, Government Affairs, Technology, and Engineering, T-Mobile, to Marlene H. Dortch, Secretary, FCC, WT Docket No. 10-4, PS Docket No. 18-64, WP Docket No. 07-100, GN Docket No. 17-258, GN Docket No. 14-177, 3 (filed March 15, 2018).

ensure the U.S. wireless industry remains a guiding force of economic progress for years to come.

I. Summary

The National Radio Astronomy Observatory, the Green Bank Observatory and the Long Baseline Observatory (collectively, NRAO) recently encouraged the FCC to adopt mobile broadband exclusion zones around authorized radio astronomy sites that use the 31.3-31.8 GHz band to protect these sites against harmful interference.[4] While the final results of the NRAO study differ somewhat from T-Mobile's earlier analysis due to different assumptions about 5G operations, NRAO reaches the same conclusion as T-Mobile: 5G deployments and radio astronomy can coexist in the 32 GHz band by adopting exclusion zones around radio astronomy sites. Given the small number and remote location of radio astronomy sites, these exclusion zones will not have a significant negative effect on mobile broadband operations.

The NRAO identifies an emissions mask that might apply to 5G operations and asks the FCC to derive consistently sized exclusion zones on 5G operations around the nation's radio astronomy observatories.[5] NRAO does not specify the size of these exclusion zones, but proposes using a base station emissions mask of −13 dBm as the basis for developing the 5G exclusion zones.[6] The −13 dBm limit, of course, is a regulatory construct, not a performance level: real-world base stations simply will not emit power at −13 dBm across all frequencies. But even applying NRAO's worst-case assumptions would result in exclusion zones that are only slightly larger than the worst-case models T-Mobile's original coexistence study identified. In other words, even if one were to derive exclusion zones based on the FCC emissions mask of −13 dBm and to take the dimmest view of all material mitigating circumstances associated with 5G operations at these frequencies, the resulting exclusion zones would be just 85.5 kilometers in diameter and would affect only three percent of the United States population.

Another leading radio astronomy observatory organization, the Committee on Radio Astronomy Frequencies (CRAF), prepared an analysis of separation distances in a submission to the International Telecommunication Union (ITU) in connection with Agenda Item 1.13 of the World Radiocommunication Conference of 2019 (WRC-19).[7] Using the methodologies and

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[4] Letter from Harvey S. Liszt, Astronomer and Spectrum Manager, NRAO, et al. to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, IB Docket Nos. 15-256, 97-95, and WT Docket No. 10-112 (filed Feb. 7, 2018) ("NRAO Proposal").

[5] NRAO Proposal at 1-2. T-Mobile's earlier coexistence study did not propose a new emissions mask for 5G operations in the 32 GHz band, but rather sought to demonstrate how real-world operating parameters provide ample latitude for coexistence between 5G and radio astronomy services. *See* T-Mobile, Coexistence of Mobile Broadband Operations With the Earth Exploration Satellite Service and Radio Astronomy Service (2017) ("Coexistence Study"), attached to Letter from Steve B. Sharkey, Vice President, Government Affairs, Technology, and Engineering, T-Mobile, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 14-177, IB Docket Nos. 15-256, 97-95, and WT Docket No. 10-112 (filed Oct. 2, 2017).

[6] *See id*.

[7] WRC Agenda Item 1.13 will "consider identification of frequency bands for the future development of International Mobile Telecommunications (IMT), including possible additional allocations to the mobile service on a primary basis, in accordance with Resolution 238 (WRC-15)." International Telecommunications Union, *ITU-R*

assumptions of ITU Working Party 5D in its analysis, CRAF proposed using the –13 dBm emissions mask as the basis for exclusion zones but otherwise incorporated less conservative assumptions for modeling 5G operations at 32 GHz than the T-Mobile coexistence study. Consistent with ITU procedures and modeling methods, CRAF derived exclusion zones that are 53 kilometers in diameter, which is a constraint that would affect little more than one percent of the United States' population. CRAF also proposed using a more traditional, "stair-stepped" emissions mask that recognizes the reality of roll-off from the center frequency. Adopting CRAF's alternative, stair-stepped emissions mask would allow for exclusion zones of just 35 kilometers[8] in diameter for channels 400 MHz from the edge of the 31.3-31.8 GHz passive band.

NRAO's insight of using enforceable emissions masks to extrapolate wireless broadband exclusion zones in the 32 GHz band is sound. The Commission can use a well-defined emission mask developed consistent with ITU practices to extrapolate narrowly tailored exclusion zones for the benefit of radio astronomy. Adopting exclusion zones to ensure radio astronomy receives protection against harmful interference will help the Commission to license the 32 GHz band for wireless broadband use without delay.

II. NRAO Proposes to Use Exclusion Zones Based on Wireless Broadband Emissions Masks.

In comments filed February 7, 2018, the NRAO and other radio observatory organizations acknowledged the operating parameters T-Mobile placed in the record in its coexistence study, characterized them as "plausible" and asked the FCC to ensure that the exclusion zones around observatories that use the 31.3-31.8 GHz band are large enough to prevent mobile broadband operations from creating harmful interference into radio observatory sites.[9] Adopting exclusion zones in the 31.3-31.8 GHz band around authorized radio astronomy sites can ensure radio astronomy operates without suffering harmful interference while constraining mobile broadband coverage to less than two percent of the United States' population in a worst-case scenario.

III. Emissions Masks Are Maximalist Limits that Provide a Conservative Approach Relative to Actual Wireless Broadband Performance.

The NRAO proposes to use emissions masks to define the size of exclusion zones around radio astronomy observatory sites.[10] Emissions masks are regulatory constructs that define the outer

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Preparatory Studies for WRC-19, https://www.itu.int/en/ITU-R/study-groups/rcpm/Pages/wrc-19-studies.aspx (last visited March 27, 2018).

[8] Smaller, 35-kilometer exclusion zones would apply below 29.4 GHz and above 32.2 GHz, which is 400 MHz outside of the radio astronomy band at 31.3-31.8 GHz. A 53-kilometer exclusion zone would apply to channels transmitting in the band from 29.4 to 31.3 GHz and from 31.8 to 32.2 GHz.

[9] NRAO Proposal at 1-2.

[10] While the NRAO asserts that T-Mobile's Coexistence Study proposed a new emissions mask for 5G operations in the 32 GHz band, the purpose of the Coexistence Study was not to propose an emissions mask, but rather to use realistic yet conservative assumptions about key parameters of terrestrial mobile broadband operations to demonstrate how broadband exclusion zones around radio astronomy sites could protect observatories from experiencing harmful interference. *See* Coexistence Study at 1. The Coexistence Study demonstrated that generous exclusion zones for radio astronomy based on real-world deployment scenarios would not pose a meaningful burden

limits of permissible radiofrequency emissions in any given block of spectrum. They identify simple, easily reproduced limits at values higher than equipment in the band will produce to avoid undue constraints on the variety of waveforms that manufacturers' products might need to introduce into the band.

Just as regulators use emissions masks to prevent harmful interference among licensees, standards bodies use emissions masks to provide a consistent level of guidance to designers and manufacturers throughout the global supply chain for telecommunications equipment. Standards bodies must adopt design criteria that are at least as stringent as regulatory limits. To provide vendors maximum flexibility when designing equipment, the standards bodies' emissions masks are permissive and typically envision emissions higher than would ever occur under real-world conditions. As the National Institute for Standards and Technology (NIST) said in October 2016, the assumption that transmitters operate at emissions masks required by standards bodies is "nearly always false."[11] NIST explained that "transmitter out-of-band . . . and spurious emissions are usually substantially lower than emission mask limits, often by tens of decibels."[12] Emissions masks, in short, are designed to be conservative representations of real-world radiofrequency waveforms.

IV. Using Emissions Masks as Surrogates for Actual Broadband Performance Results in Conservatively Large Exclusion Zones from Wireless Broadband Deployment.

Any assumption that equipment produces emissions at the limits defined by an emissions mask will overestimate transmitter power levels. Exclusion zones based on unrealistically high wireless transmitter power levels result in unnecessarily large exclusion zones that impose constraints on wireless broadband operations without any corresponding benefit to radio astronomy observatories. However, exclusion zones that neatly track the actual emissions characteristics of any one transmitter, but are not enforced by a mask that matches those transmissions, then the resulting exclusion zones could allow another transmitter that operates with different peaks to cause harmful interference. In this case, even excessively large exclusion zones based on a conservative emission mask around radio astronomy observatories would have

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on wireless broadband deployments in the 32 GHz band. *See id*. at 23-29. If the Coexistence Study had proposed an emissions mask, the NRAO is correct that the profile used in the Coexistence Study would have been inconsistent with note US74 in the Table of Allocations which relies on the FCC emission mask to set the level of interference that radio astronomy must accept. 47 C.F.R. § 2.106. The U.S., however, does not necessarily agree with the mask prescribed for the ITU studies and, in fact, has proposed an alternative approach in which studies are instead structured to determine the mask required to protect passive services, rather than specifying a mask and then determining whether the passive service will be protected. *See* U.S., Sharing and compatibility of the RAS in the 31.3-31.8 GHz frequency range and IMT operating in the 31.8-33.4 GHz frequency range, Document 5-1/XX-E, Contribution 64, at 10 (Sept. 7, 2017). The ITU continues to explore the compatibility of radio astronomy operations in the 31.3-31.8 GHz band and wireless broadband operations in the 31.8-33.4 GHz band. The ITU study effort should not, however, delay action in the US given the ability of mobile services to protect the adjacent operations. *See, e.g.*, ITU Radiocommunication Study Groups, Attachment 4 to Annex 5 to Task Group 5/1 Chairman's Report, Document 5-1/TEMP/70 (Feb. 9, 2018).

[11] *See* National Advanced Spectrum and Communications Test Network (NASCTN), *Draft AWS-3 Out of Band Emissions Measurements, Test and Methodology Phase II Test Plan*, at 12 (Oct. 11, 2016), https://www.nist.gov/sites/default/files/documents/2017/01/11/nasctn_aws3_testplan.pdf.

[12] *Id.*

a relatively small effect on the ability to provide 5G wireless broadband services in the 32 GHz band because of the small number of radio astronomy observatories that depend on the 31.3-31.8 GHz spectrum. Furthermore, radio astronomy observatories are typically situated in remote locations that, with only a few exceptions, are far removed from the nation's population centers. Realizing the optimum public interest benefit for the country, however, requires the Commission to identify exclusion zones large enough to ensure radio astronomy observatories can continue to operate without experiencing harmful interference while minimizing the constraints on wireless operators' ability to deploy next-generation broadband technologies.

a. Coexistence between 5G Operations and Radio Astronomy Remains Readily Feasible Even With Large Exclusion Zones Based on Highly Conservative Parameters.

NRAO asks the FCC to base the size of radio astronomy protection zones on regulatory emissions masks because only regulatory emission masks offer predictable, enforceable bases for calculating all the possible permutations of waveforms that radio astronomy might encounter.[13] While such an approach overprotects radio astronomy facilities, T-Mobile agrees that, in this case, adopting exclusion zones represents a reasonable approach to addressing any concerns about the potential for harmful interference. The radio astronomy facilities that use the 31.3-31.8 GHz band are few in number and typically remote in location. Under these circumstances, adopting exclusion zones will protect radio astronomy observatories that depend on the 31.3-31.8 GHz band against any meaningful risk of harmful interference without unduly delaying investment and innovation in the deployment of mobile broadband services. Where multiple emissions masks exist, however, regulators should recognize that actual emissions operate well below the level of the mask and make allowances for actual operating conditions to avoid imposing excessive and unnecessary burdens on wireless broadband deployment while still fully protecting incumbent operators against harmful interference. The question, therefore, is not whether to define an exclusion zone based on an emissions mask, but rather the proper size of the exclusion zones for the 31.3-31.8 GHz band based on the operational characteristics of 5G systems likely to be deployed in the band.

[13] *See* NRAO Proposal at 2.

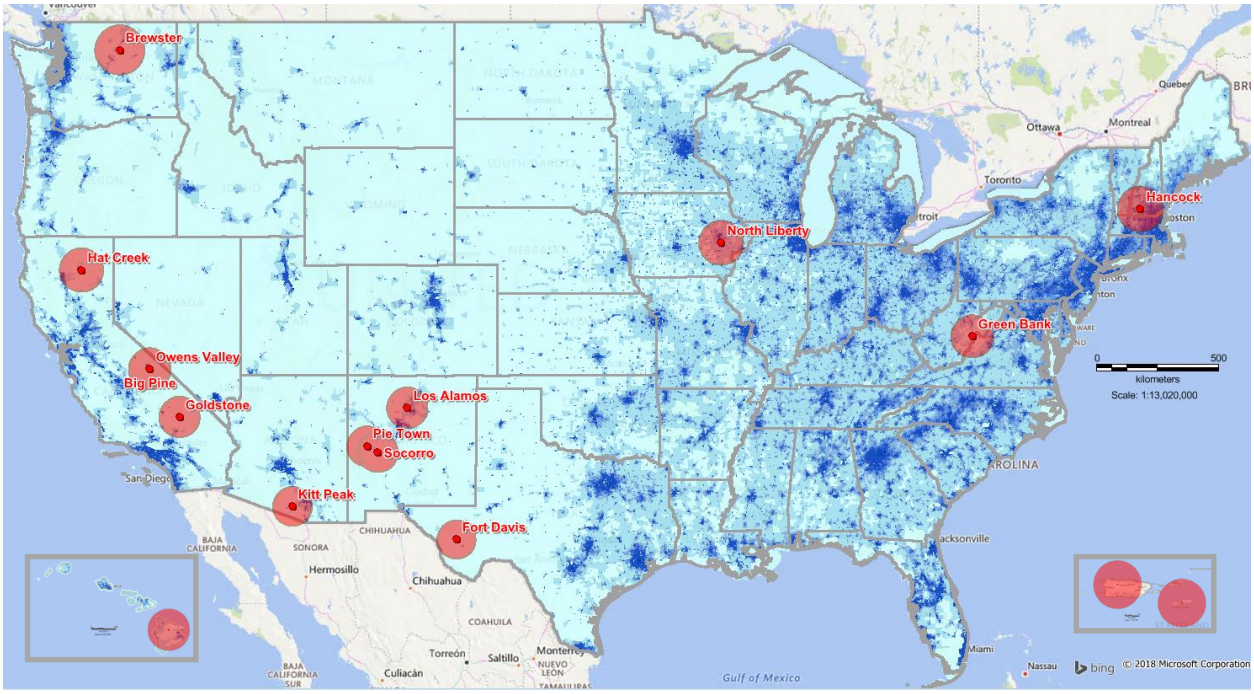

Figure 1: 85-kilometer Radio Astronomy Exclusion Zones

As described earlier, a single, flat-line emissions mask of −13 dBm/MHz is at odds with reality. Nevertheless, we calculated the separation distances around radio astronomy observatories based on intensive broadband operations at this unrealistic emissions mask. Our separation distance calculations used the same very conservative assumptions and methodology used in the T-Mobile coexistence study, such as free space path loss, no polarization loss, and an activity factor of 100%.[14] We assumed that every radio astronomy location listed in footnote US385 to the Table of Allocations must receive protection even though only a handful of these sites appear to actually use the 31.3-31.8 GHz band.[15] Our deterministic analysis assumed these worst of the worst case scenarios to assess whether the outer limits of radio astronomy exclusion zones would make broadband deployment in the 32 GHz band impractical. Far from imposing constraints on the service that would seriously impede provision of broadband service, the worst-case assumptions imposed only modest constraints on broadband operations. Figure 1 shows the 85.5 kilometer exclusion zones necessary to protect radio astronomy from intensive broadband operations occurring at the full extent of the FCC regulatory emissions mask of -13 dBm/MHz. Based on 2010 population figures, the population living inside 85.5 kilometer circles around

[14] In other words, the *only* difference between the conclusions shown in the T-Mobile coexistence study and the 85.5 kilometer zones shown here is the assumed value for out-of-band emissions and for spurious emissions.

[15] Hat Creek and Arecibo appears to use frequencies only up to 11.2 and 10 GHz, respectively. *See* SRI International, *Hat Creek Radio Observatory Allen Telescope Array (ATA) Specifications*, https://www.sri.com/research-development/specialized-facilities/hat-creek-radio-observatory/ata-specifications (last visited March 27, 2018); Arecibo Observatory, *Arecibo Technical Information Relevant to Proposal Preparation*, http://outreach.naic.edu/ao/scientist-user-portal/proposals/tech-information (last visited March 27, 2018). Similarly, Owens Valley and Mauna Kea use frequencies much higher than 31 GHz. If these or other sites do not use the 31.3-31.8 GHz band, no exclusion zones are required in those areas and the effect on mobile deployments in the 32 GHz band will become even less consequential for the deployment of service in the band.

each of the fifteen radio astronomy locations listed in footnote US385 to the Table of Allocation is approximately 9.5 million, or 3.1% of the total U.S. population.[16]

b. Coexistence Between 5G and Radio Astronomy Is Even Less Impactful Using the Somewhat More Realistic Exclusion Zones Proposed by the Committee on Radio Astronomy Frequencies.

CRAF has analyzed the proper emissions mask level and, by extension, the proper size for a radio astronomy exclusion zones in the 31.3-31.8 GHz band in analysis filed with the ITU Working Party 5D. CRAF is comprised of 75 member organizations from 30 countries across Europe and defines its mission as keeping "the frequency bands used by radio astronomy and space sciences free from interference."[17] In its ITU study, CRAF developed two different emission mask scenarios for the 32 GHz band.[18] CRAF first considered the ITU Working Party 5D recommendation of a single, flat-line emissions mask of −13 dBm/MHz in both the out-of-band and spurious emissions domains.[19] This flat-line emissions mask standard led CRAF to their most conservative conclusion that separation distances between radio astronomy and wireless broadband operations should be up to 53 kilometers.[20] According to CRAF, terrestrial mobile base stations should maintain separation distances of "49 [kilometers] for a single interferer and 51 [kilometers] for the aggregate scenario, assuming a constant density of [base stations] and [user equipment]."[21] A table in CRAF's study then shows a "clustered" aggregate scenario that identifies the separation distance between aggregated mobile broadband deployments and radio astronomy as 53 kilometers.[22] The separation zones CRAF derived in its analysis are not based on actual operating conditions, but rather are calculated consistent with ITU methodologies to identify the worst-case separation distances between mobile broadband operations and radio astronomy as 53 kilometers.[23] Figure 2 above shows 53-kilometer exclusion zones based on CRAF's analysis. Even assuming that all fifteen radio astronomy observatories in the United States use the 31.3-31.8 GHz band in their observations, the population affected by the 53-kilometer operating constraint that CRAF's study identifies is only a little more than one percent of all Americans.[24]

[16] If only the 50 states were included in the calculation, the total population affected would be approximately 6.2 million, or roughly two percent of the total U.S. population.
[17] CRAF, *About CRAF*, https://www.craf.eu/about-craf/ (last visited March 27, 2018).
[18] CRAF, Sharing and compatibility of the RAS in the 31.3-31.8 GHz frequency range and IMT operating in the 31.8-33.4 GHz frequency range, Document ITU-R TG5.1.AR, Contribution 175 (Jan. 10, 2018) ("CRAF Study").
[19] *Id.* § 1.3.6.
[20] *Id.* Tbl. A-2.
[21] CRAF Study § 1.3.6.
[22] *Id.* Tbl. A-2.
[23] *Id.*
[24] The total population affected is 3.4 million, 1.63 million of which are located in Puerto Rico and the U.S. Virgin Islands.

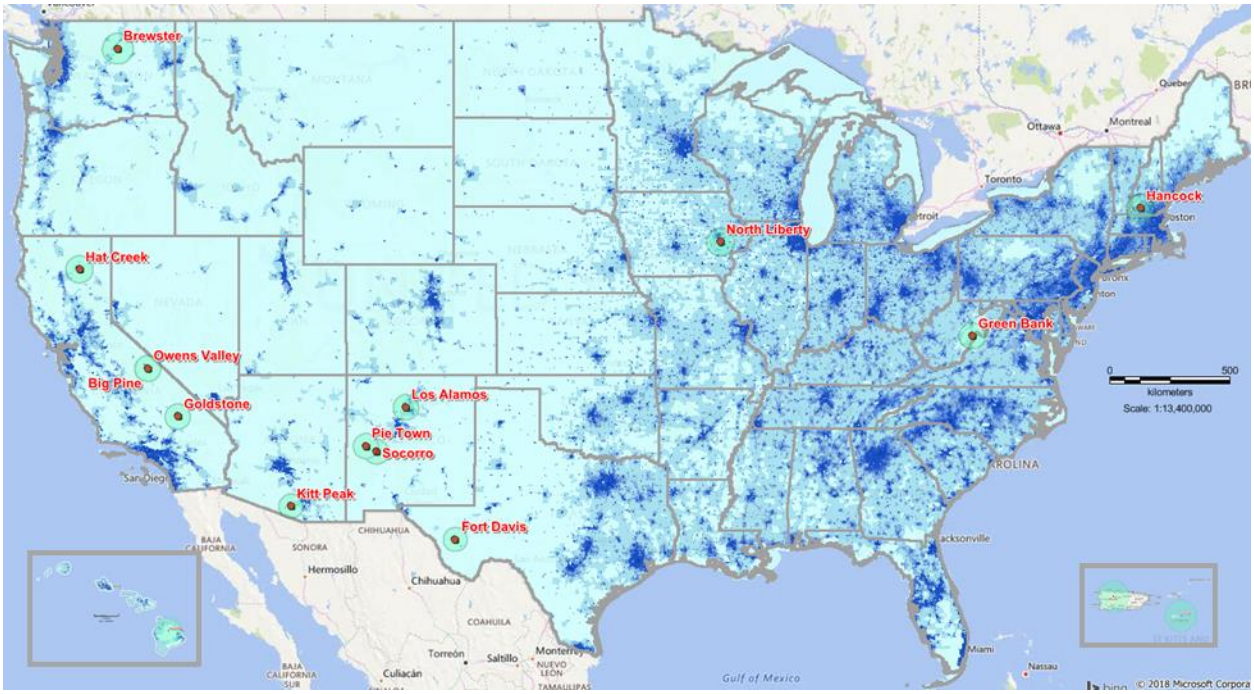

Figure 2: 53-Kilometer Radio Astronomy Exclusion Zones

CRAF subsequently considered an alternative to the ITU Working Party 5D recommendation that employed a stair-stepped emissions mask in which the limit in the spurious emissions domain will be 17 dB more stringent at −30 dBm/MHz.[25] This stair-stepped emissions mask, which still exceeds any waveform a transmitter would actually produce but more closely approximates real-world conditions, would result in separation distances between radio astronomy and wireless broadband operations of up to 35 kilometers for channels 400 MHz from the edge of the 31.3-31.8 GHz passive band.[26]

The stair-stepped emission mask under CRAF's second scenario offers a more reasonable and realistic assumption than the flat-line emissions mask of CRAF's first scenario, which was based on the current ITU Working Party 5D requirement. In real world implementation, emissions decrease as frequency separation increases.[27] As a result, a geographic separation requirement that applies to all channels equally will be overly prescriptive for most channels in the 32 GHz band.

[25] *Id.* § 1.3.6. CRAF provided an alternative emissions mask to -13 dBm/MHz for comparison purpose because -30 dBm/MHz is a more stringent level of spurious domain emissions defined in ITU-R SM.329 and "has been routinely used for other IMT compatibility studies." *Id.* § 1.3.4.1

[26] *Id.* Tbl. A-2

[27] Harmonics can occur far from the fundamental channel, but these can be predicted and addressed through means other than applying exclusion zones to all channels in the band.

V. Conclusion

The NRAO offers a constructive contribution that further supports the feasibility of interference-free coexistence between terrestrial mobile broadband operations and radio astronomy in the 31.3-31.8 GHz band. While it misconstrues the real-world parameters found in the Coexistence Study as an emissions mask, protecting the ability of radio astronomy observatories to continue to use the 31.3-31.8 GHz band is manageable even when multiple worst-case assumptions are incorporated into the same analysis. Detailed analysis and mutual cooperation between the radio astronomy and 5G operators can readily allow for coexistence between the two services. The Commission should take into account the NRAO's recommendation for narrowly tailored wireless broadband exclusion zones in the 31.3-31.8 GHz spectrum and expeditiously license the 32 GHz band for wireless broadband use.

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Next-generation wireless deployments offer the potential for transformative technological change. But the United States cannot capture broadband investment and innovation on the basis of a single spectrum auction. Auctioning the 24 GHz, 28 GHz, 37 GHz, 39 GHz, and 47 GHz bands this year and moving quickly to adopt rules for other bands under consideration in the proceeding, including the 32 GHz band, as quickly as possible offers the best hope of preserving U.S. technical and economic leadership for the future.

Under section 1.1206(b)(2) of the Commission's rules, we have filed an electronic copy of this letter with the Commission. Please direct any questions regarding this filing to me.

Respectfully submitted,

/s/ Steve B. Sharkey

Steve B. Sharkey
Vice President, Government Affairs
Technology and Engineering Policy
T-Mobile USA, Inc.
(202) 654-5900