NATIONAL RADIO ASTRONOMY OBSERVATORY

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Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
Use of Spectrum Bands Above 24 GHz For Mobile Radio Services	)	GN Docket No. 14-177
Establishing a More Flexible Framework to Facilitate Satellite Operations in the 27.5-28.35 GHz and 37.5-40 GHz Bands	)	IB Docket No. 15-256
Petition for Rulemaking of the Fixed Wireless Communications Coalition to Create Service Rules for the 42-43.5 GHz Band	)	RM-11664
Amendment of Parts 1, 22, 24, 27, 74, 80, 90, 95, and 101 To Establish Uniform License Renewal, Discontinuance of Operation, and Geographic Partitioning and Spectrum Disaggregation Rules and Policies for Certain Wireless Radio Services	)	WT Docket No. 10-112
Allocation and Designation of Spectrum for Fixed-Satellite Services in the 37.5-38.5 GHz, 40.5-41.5 GHz and 48.2-50.2 GHz Frequency Bands; Allocation of Spectrum to Upgrade Fixed and Mobile Allocations in the 40.5-42.5 GHz Frequency Band; Allocation of Spectrum in the 46.9-47.0 GHz Frequency Band for Wireless Services; and Allocation of Spectrum in the 37.0-38.0 GHz and 40.0-40.5 GHz for Government Operations	)	IB Docket No. 97-95

Comments of the National Radio Astronomy Observatory

Introduction

1. Here, the National Radio Astronomy Observatory ("NRAO" or "the Observatory") provides its comments responding to the Commission's Notice of Proposed Rulemaking ("the NPRM") regarding the effort to promote a flexible regulatory environment for the next generation of wireless services above 24 GHz.

2. NRAO (http://www.nrao.edu), operated by Associated Universities, Inc. (AUI), (http://www.aui.edu) under a cooperative agreement with the National Science Foundation, is the largest observatory dedicated to radio astronomy and one of the largest astronomical observatories in the world. NRAO operates the Jansky Very Large Array (JVLA) in New Mexico, the 100m Robert C. Byrd Green Bank Telescope (GBT) in West Virginia and the 10-element Very Long Baseline Array (VLBA) that is distributed from St. Croix to Hawaii). All of these stand to be affected by various aspects of the proposed rules. The Kitt Peak 12m telescope in Arizona, at a site originally created by NRAO and currently operated by the University of Arizona Radio Observatory (http://aro.as.arizona.edu/) also stands to be affected.

Spectrum use by the radio astronomy service

3. Figure 1 shows the system noise temperatures for receivers currently available on NRAO's 100m Robert C. Byrd Green Bank Telescope, taken from the online guide to proposal preparation at https://science.nrao.edu/facilities/gbt/. Other GBT receivers working at 90 - 110 GHz are being commissioned. There will be complete coverage of the spectrum at 68-110 GHz and, with one gap at 2.6 – 3.9 GHz, from 0.3 to 50 GHz.

4. The system temperatures cited in ITU-R Recommendation RA. 769 below 50 GHz are shown for comparison in Figure 1, and it is seen that the GBT receivers generally beat RA. 769 by 1-2 dB over most of the spectrum below 50 GHz: At 89 GHz the RA. 769 value is 70 K, 3 dB better than Green Bank but comparable to the value obtained at the international ALMA mm/sub-mm array at 5000m elevation in Northern Chile. NRAO is the North American partner for ALMA, see https://almascience.nrao.edu/.

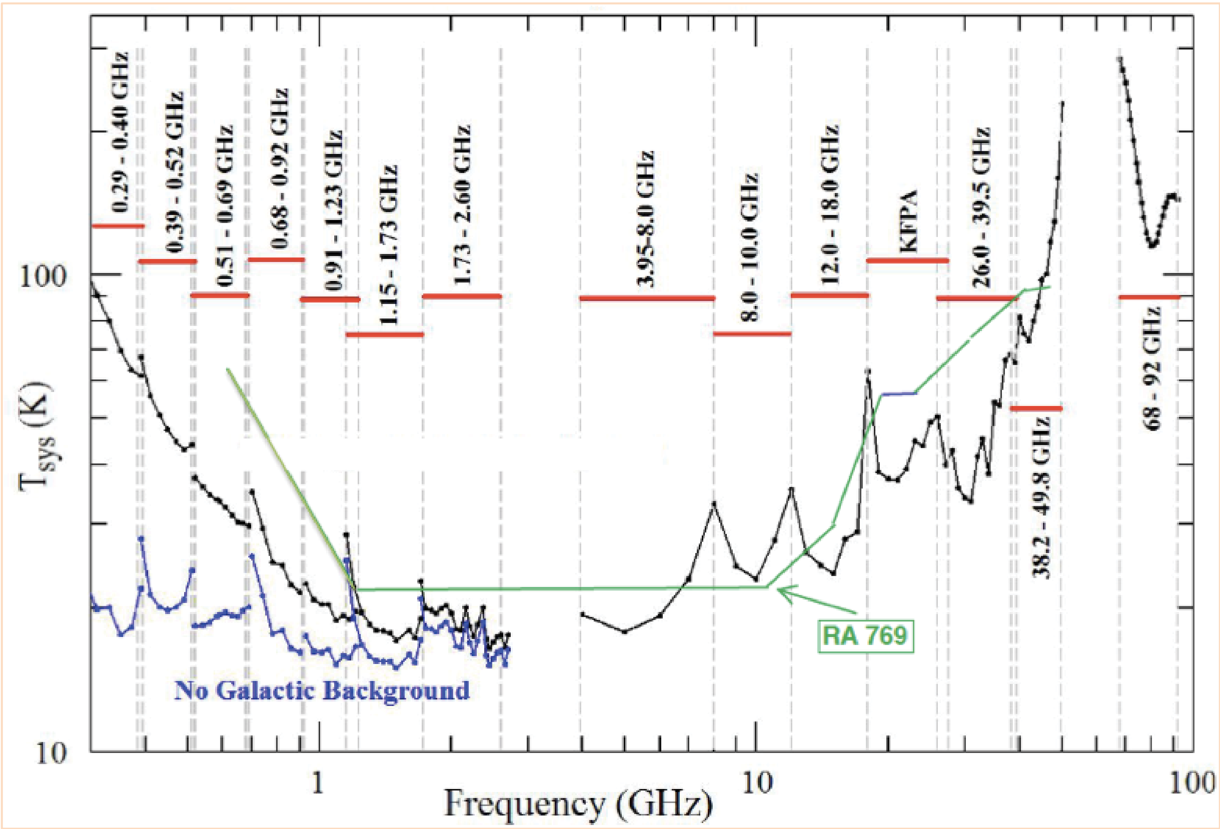
5. Figure 1 illustrates that radio astronomy observations are not conducted from the ground from approximately 52 – 68 GHz owing to the high telluric opacity of molecular oxygen and resultant high system temperatures. Transmissions wholly contained within this band are generally not of concern to radio astronomy. However, as noted at ¶305 of the NPRM, harmonics of frequencies in this band fall in passive service bands protected by RR 5.340 and US246 and require consideration when rules are set for operation at the fundamental frequencies.

6. NRAO's Jansky VLA with HQ in Socorro, New Mexico has complete frequency coverage from 1 – 50 GHz and coverage in several bands in the spectrum from 60 – 500 MHz. It does not observe at 0.5 – 1.0 GHz owing to the design of the optical path on its (27) antennas.

7. The VLBA observes in spectrum bands at 21.7 – 24.1, 41 – 45 and 80 – 90 GHz at its 10 stations.

8. The Kitt Peak 12m telescope currently operates in the band 84 – 116 GHz and plans to introduce new receivers operating down to approximately 68 GHz.

Figure 1: System noise temperatures for the Green Bank Telescope



Compatibility and sharing for radio astronomy and mobile service operations

9. The power levels used for existing mobile service transmissions are generally incompatible with operation within line of sight of radio astronomy stations, whether in-band or in adjacent or harmonic bands, except with very large (sometimes described as being "astronomically" large) physical separation or when the telluric opacity is very high. Studies were recently conducted at frequencies 1 – 5 GHz in the context of Agenda Item 1.1 for WRC-12 and the results are published in ITU-R Report RA.2322. Separation distances were several hundreds of km for in-band sharing and several tens of km for adjacent band scenarios with spurious emission limits of -30 dBm/MHz, below the usual 43 + 10 log (P) dB attenuation of the primary emission.

10. To quantify the discussion at higher frequencies we calculate the line of sight separation distance R at which a signal received in the 0 dBi sidelobe of a radio astronomy antenna has strength equal to the inherent system noise power in the radio astronomy receiver at system temperatures illustrated in Figure 1. By using a 0 dBi

sidelobe the calculation is intended to be independent of the direction in which the radio astronomy antenna is pointed, requiring only that the interfering signal impinge on the physical structure of the antenna: Moreover, the calculation applies equally to all radio astronomy antennas and types of telescopes. In the best case, interference at this level, doubling the system temperature, increases by a factor four the amount of observation time required to reach a given rms noise. At yet much higher levels the radio astronomy receiver will begin to saturate and, eventually, overload.

11. System temperatures T_{sys} are shown in Figure 1. Equating the noise power spectral density in a radio astronomy receiver $k_B T_{sys}$ to that received in an isotropic sidelobe (whose effective area is $\lambda^2/4\pi$) from a transmitter with power spectral density P/MHz at frequency ν_{GHz} in GHz, attenuated by a factor $10^{-aR/10}$ with R in km and a measured in dB/km, results in Equation 1:

$$R(km) = 6.43x10^3 \, (10^{-aR/10} \, P/T_{sys})^{1/2}/\nu_{GHz} \qquad (1)$$

Table 1: Separation distances (km) from Equation 1 for three values of P (dBm/MHz)

ν_{GHz}	T_{sys} (K)	a (dB/km)	30 (dBm/MHz)	0 (dBm/MHz)	-13 (dBm/MHz)
20	30	0.031	1066	418	202
30	30	0.050	699	264	131
40	70	0.099	351	133	65
50	100	0.560	79	37	31
70	300	0.560	71	28	15
76	150	0.210	157	56	26
86	140	0.091	293	81	32

Notes to Table 1 and derivation of Equation 1:
$k_B T_{sys}=(\lambda^2/4\pi)(P*10^{-6}*10^{-aR/10}/4\pi R^2)$; $R=(\lambda/4\pi)*(P*10^{-6}*10^{-aR/10}/k_B T_{sys})^{1/2}$; $k_B = 1.38x10^{-23}$ W/K; $\lambda(m)=0.3/\nu_{GHz}$; a ≡ attenuation in dB/km. With a ≠ 0 the solution for R is done numerically. Values of a are taken from an atmospheric model for the ALMA site and scaled relative to the value a = 0.15 dB/km in dry air at 79 GHz, see ITU-R Recommendation M.2322.

12. Introducing the atmospheric attenuation drastically changes the nature of such a calculation, shortening the distances and softening the dependence on P, even at frequencies where the atmosphere is relatively transparent.

13. The values in Table 1 are not so much separation distances to prevent interference, which following ITU-R Recommendation RA. 769 would be larger, but separation distances needed to prevent overload of the radio astronomy receiver beyond an I/N ratio of unity. Already at these distances it takes four times as long for the radio astronomy receiver to reach a given noise level in the best of cases.

14. Large distances are required even at levels corresponding to adjacent band compatibility requirements, -13 dBm/MHz. Except perhaps within the band 52 – 68

GHz, transmissions should not be directed at a radio astronomy station within direct line of sight of it. However, the freer propagation of higher harmonics of 60 GHz band radiation that fall in radio astronomy protected bands at 115 and 230 GHz must also be considered, as noted at ¶305 of the NPRM. So transmissions must also not be directed at a radio astronomy station within line of sight over some portion of the 60 GHz band as well.

Comments on the 64 - 71 GHz band

15. Portions of this band differ very importantly from the adjacent spectrum at 57 – 64 GHz with which the Commission proposes to conjoin it in the rules: Above 67 – 68 GHz the atmosphere becomes sufficiently transparent that anthropogenic signals travel longer distances and cosmic radio waves penetrate the entire depth of the atmosphere to be observed at the surface. Applications using the upper portion of the 64 – 71 GHz band will be able to use significantly lower signal levels to achieve the same range and/or throughput, but may interfere over much longer distances.

16. As noted above, radio astronomy does not observe from the ground in the spectrum band 52 – 68 GHz, where the upper end is somewhat approximate. Radio astronomy's concerns, if such exist, are more likely with the harmonics above the fundamental that propagate more freely.

17. Boeing has broached the subject of possible aeronautical use of the 60 GHz band (see ¶306 of the NPRM) in recent discussions with NSF, NRAO and JPL representatives from the passive services radio astronomy and remote sensing. These discussions have suffered from a lack of clarity about the implementation of on-board 60 GHz WiGig and such basic quantities as the power levels and distribution of signals inside the plane and the expected leakage from the fuselage and windows. During these discussions it became apparent that the concerns of remote sensing for the protection of its satellite weather monitoring operations outweigh the concerns of radio astronomy for interference from the harmonic spurious emissions, although these still need to be considered. NRAO notes in the strongest possible terms that there has been no basis in these discussions for lifting the prohibition against aeronautical use of the 60 GHz band, indeed, just the opposite.

Fixed service

18. In the NPRM the FCC discusses conditions in a long list of bands for which it is not proposing rules. With regard to fixed service applications in these bands, NRAO notes that existing coordination procedures appear to have worked well, including up to 81 – 86 GHz. If fixed service parameters continue to resemble those currently in place (which may not be the case if low-cost phased arrays replace large fixed dishes), co-existence between fixed service applications and radio astronomy operations should be readily achievable using current practices at even higher frequencies.

Summary: Sharing and compatibility with mobile service operations

19. In matters of sharing and compatibility, mobile service applications should not transmit in the direction of radio astronomy stations while within direct line of sight of them. Strong terrain-shielding of mobile service base stations, such that emissions from both the base stations and the handsets with which they are in touch do not reach the radio astronomy stations, seems the simplest solution to sharing and compatibility concerns.

Respectfully submitted,
National Radio Astronomy Observatory

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