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

In the Matter of	)	
	)	
Spectrum Horizons	)	**ET Docket No. 18-21**
	)	
and	)	
	)	
Petition for Partial Reconsideration by Robert Bosch LLC	)	

Comments of the Arizona Radio Observatories, University of Arizona, Tucson AZ

These comments are in response to the Petition for Partial Reconsideration, submitted by Robert Bosch LLC and dated 1 July 2019 (hereafter "the Bosch petition"), in the matter of unlicensed transmissions at frequencies above 95 GHz. As the Commission has long recognized, the Radio Astronomy Service (RAS) is acutely susceptible to harmful interference because of the exceptionally low power levels of the cosmic emissions which we study.

The Arizona Radio Observatories (ARO) are a division of the Steward Observatory, a research unit of the University of Arizona in Tucson. We operate two high precision paraboloidal antennas capable of receiving cosmic radio emissions at millimeter and submillimeter wavelengths. The antennas include the 12-m diameter radio telescope at Kitt Peak, Arizona (elevation 1900 m) and the 10-m diameter Submillimeter Telescope ("SMT") on Mt. Graham, Arizona (elevation 3200 m). The frequency band of concern to the Bosch petition covers 123 to 140 GHz, which is part of the spectrum observed by these telescopes. In these Comments, we wish to point out several important errors of fact in the Bosch petition, from which wholly unsupportable conclusions are drawn specifically with respect to observatories at high, dry mountain sites and operating in this frequency range. The undersigned authors of this Comment are faculty members of the University of Arizona and users of the ARO telescopes. As radio astronomers, we therefore have a direct interest in this matter.

The Bosch petition, in essence, requests that the FCC allow unlicensed use of the 123 – 140 GHz band, in the interests of "internationally harmonized" standards. Footnote 14 of the Bosch petition would therefore imply that the maximum radiated power of such emissions could be +43 dBm (20 Watts) for each operating device. In footnote 2, the petition argues that the FCC's previous R&O included compatibility calculations which find that exceedingly large numbers of transmitters could operate in the 116 – 123 GHz band and also in the 174.8 – 182 GHz and 185 – 190 GHz bands without causing harmful interference to passive users of spectrum, specifically the Earth Exploration Satellite Service (EESS). Footnote 2 then concludes by stating that the same conclusion "would inevitably be applicable to the band 123 – 140 GHz." This statement is completely unfounded, however, and betrays a serious lack of understanding of basic atmospheric physics.

This erroneous assertion ignores two crucial facts about atmospheric attenuation at millimeter wavelengths. First, the absorption of mm-waves by air is highly dependent on frequency. The frequency bands referenced in footnote 2 of the Bosch petition are specifically centered on the strong resonance absorption lines of molecular oxygen and of water vapor at 118 GHz and 183 GHz respectively. Radio astronomers have long understood that there is a broad frequency band between these absorption resonances, extending approximately from 125 GHz to 170 GHz, where the absorption is substantially lower than at the frequencies referenced in the Bosch petition. This frequency range is referred to as the "2 mm atmospheric window". The second crucial fact is that, at high elevations on the Earth, atmospheric attenuation is dramatically lower than at sea level (or typical continental elevations), by an order of magnitude or more. For this reason, radio observatories for mm-wavelengths are always located at high mountain sites and at locations where the water vapor content is low. The ARO facilities at Kitt Peak and Mt. Graham are exactly such locations. The atmospheric attenuation in the "2 mm window" at both sites is so low that high quality observations can be conducted for a large fraction of the year.

These facts are illustrated in Figure 1, which shows the attenuation (along a horizontal path) vs. frequency for 3 terrestrial locations. The red dashed curve is for the ITU standard atmosphere which is essentially at sea level for temperate conditions (based on ITU-R P.676-11: *Attenuation by atmospheric gases*). The blue dot-dash curve is for the Kitt Peak ARO telescope (1900 m. elevation) and the solid black curve is for the Mt. Graham ARO site (3200 m. elevation). The 2 strong absorption features due to O_2 and H_2O are labelled. The "2 mm window" is indicated, as is the frequency band specifically requested in the Bosch petition (123 – 140 GHz) which overlaps substantially the lower part of the 2 mm window. Also shown are the frequency ranges referenced in footnote 2 of the Bosch petition, from 116 – 123 GHz (labeled "Bosch 1") and from 174.8 – 182 GHz and 185 – 190 GHz (labeled "Bosch 2"). As is clear in the Figure, these frequency bands exactly straddle the oxygen and water vapor absorption features, so the attenuation in these bands is very high compared to the intermediate "2 mm window". It is also evident that at the high mountain sites, the attenuation in the 2 mm window is dramatically lower than for the ITU standard, upon which the claims in footnote 2 of the Bosch petition are based.

We point out that the RAS is a co-primary user at 130-134 GHz and 136-141 GHz, and also has a secondary allocation at 134-136 in the US. The Commission's rules, specifically US342 and RR 5.149, require that "all practicable steps" must be taken to avoid harmful interference to primary or secondary users, including 130-134 GHz and 136-148.5 GHz as well as small windows at 128.33-128.59 and 129.23-129.49 GHz. We argue therefore that both the co-primary allocation and US342 give RAS standing in these frequency bands.

The Bosch petition suggests that a very large number of unlicensed emitters could operate in the 123-140 GHz band without causing harmful interference to RAS users. Footnote 16 of the Petition states that "… unlicensed devices can co-exist with radio astronomy in the same and adjacent spectrum bands above 95 GHz because of factors such as the high atmospheric losses associated with these frequency bands and the use of highly directional antennas." In fact, neither of these factors allow for co-existence. As shown in Figure 1, the atmospheric losses are not great at the high, dry sites always chosen for millimeter-wave radio astronomy observatories. Atmospheric models that typically assume sea-level pressure and humidity may lead to such a conclusion, but these models are not

appropriate for the locations chosen for observatories – see Figure 1.

The criteria developed internationally for an acceptable threshold of interference (e.g. ITU-R RA.769) assume that interference is received in the far out sidelobes of the radio telescope, never in the main beam. The fact that the main beam of an RAS antenna is highly directional plays no part in mitigating interference. For example, from column 8 of Table 2 of ITU-R RA.769, the threshold interference level in pfd at a radio observatory varies from -148 dBW/m^2 to -144 dBW/m^2 at 89 and 150 GHz. Assuming that an interfering signal in this frequency range is produced, by manufacturing or other applications (page 2 of the Bosch petition), it is likely to be radiated nearly isotropically. Taking +43 dBm as the allowed radiated power, and taking 0.2 dB/km (see Figure 1) as a probable atmospheric attenuation in this frequency range at a site such as Kitt Peak, then a separation distance of 200 km is required for the interference from a single source to be reduced to -144 dBW/m^2. This distance assumes the interference is received in the far-out sidelobes of the radio telescope, which are typically at a level of 80 dB or more below the sensitivity of the main antenna beam.[1]

Coexistence between unlicensed emitters and the RAS users would therefore require a **coordination zone** around the telescope. A single device operating in the open with a peak radiated power of +43 dBm, as suggested in the Bosch petition for "internationally harmonized" regulations, would cause harmful interference in the above-noted protected RAS bands, for transmitters at 200 km, which lies beyond the radio horizon of the Kitt Peak telescope. Smaller coordination zones would be required for devices that are limited to indoor use only or are housed in contained vessels, due to the additional attenuation expected from internal structures. Implementing such a coordination zone would clearly be problematic in practice.

These concerns about harmful interference at frequencies above 95 GHz should not be confined to the RAS users. A significant part of the western United States lies at elevations comparable to or even higher than Kitt Peak, and has typically very dry weather conditions. The attenuation in the 123 – 140 GHz band at such locations (e.g., Flagstaff, Arizona, or Laramie, Wyoming) would be comparable to that shown in Figure 1. If commercial applications for unlicensed devices are to be permitted by the Commission, as requested in the Bosch petition, careful attention should be paid to the distance at which harmful interference would occur between a transmitter and other unrelated receivers. The assumption in the Bosch petition that strong atmospheric attenuation would isolate such devices to very short distances is clearly flawed. A proliferation of devices for example in automotive object detection systems, could lead to interfering signals resulting in spurious detections or possibly in confusion-caused failures to detect real objects, with potentially tragic results.

Out of Band Emissions (OOBE): An additional concern relating to the Bosch petition is the potential for harmful out of band emissions. If the devices to be developed include ultra-wide-bandwidth transmitters, it seems plausible that the emissions will contain significant

1 We point out that in the R&O, the Commission used the free space path loss (FSPL) equation that includes a frequency dependence due to diffraction beam size of the radio telescope, which is not the correct way to calculate compatibility between other services and RAS. This point was discussed in detail by the Comments dated 14 March 2018 submitted by the National Radio Astronomy Observatory.

harmonic or intermodulation products. A large fraction of mm-wavelength observations by RAS users are made at frequencies above 210 GHz. An example of such observations is the Event Horizon Telescope (EHT), a world-wide array of radio telescopes including the ARO, which operate as an interferometer. This array recently succeeded in making an image of the “shadow” of a supermassive black hole in the center of a galaxy at a distance of about 100 million light-years. The observations were at a frequency of about 225 GHz, marked in Figure 1. To succeed, this achievement required extremely sensitive measurements and points the way to future work by the EHT which will include both of the ARO telescopes as part of the array.

As shown in Figure 1, the atmospheric attenuation at 225 GHz is comparable to that in the 2 mm window, so if devices designed for 123 – 140 GHz produce significant OOBE, there is a strong potential for harmful interference to RAS users, including bands for which RAS has primary protection. If substantial OOBE from transmitters above 95 GHz becomes the norm, such sensitive observations as needed for the EHT and a host of other RAS users may become impossible. We therefore urge the Commission to place stringent limits on OOBE from transmitters operating above 95 GHz.

Summary: We show that the Request for Partial Reconsideration filed by Robert Bosch LLC contains seriously flawed assumptions regarding atmospheric absorption in the 123 -140 GHz. As a result their arguments are unfounded, that unlicensed (and unlimited) use of transmitters in this band will not cause harmful interference to RAS users. We show that in fact such unlicensed use of spectrum is very likely to produce harmful interference at the radio observatories which are operated by ARO. We therefore urge the Commission to carefully evaluate any reconsideration of the original R&O, based on a ***correct*** analysis of the relevant atmospheric physics. We also urge that in any case, the Commission place strong restrictions on out of band emissions at frequencies above 95 GHz.

Respectfully submitted,

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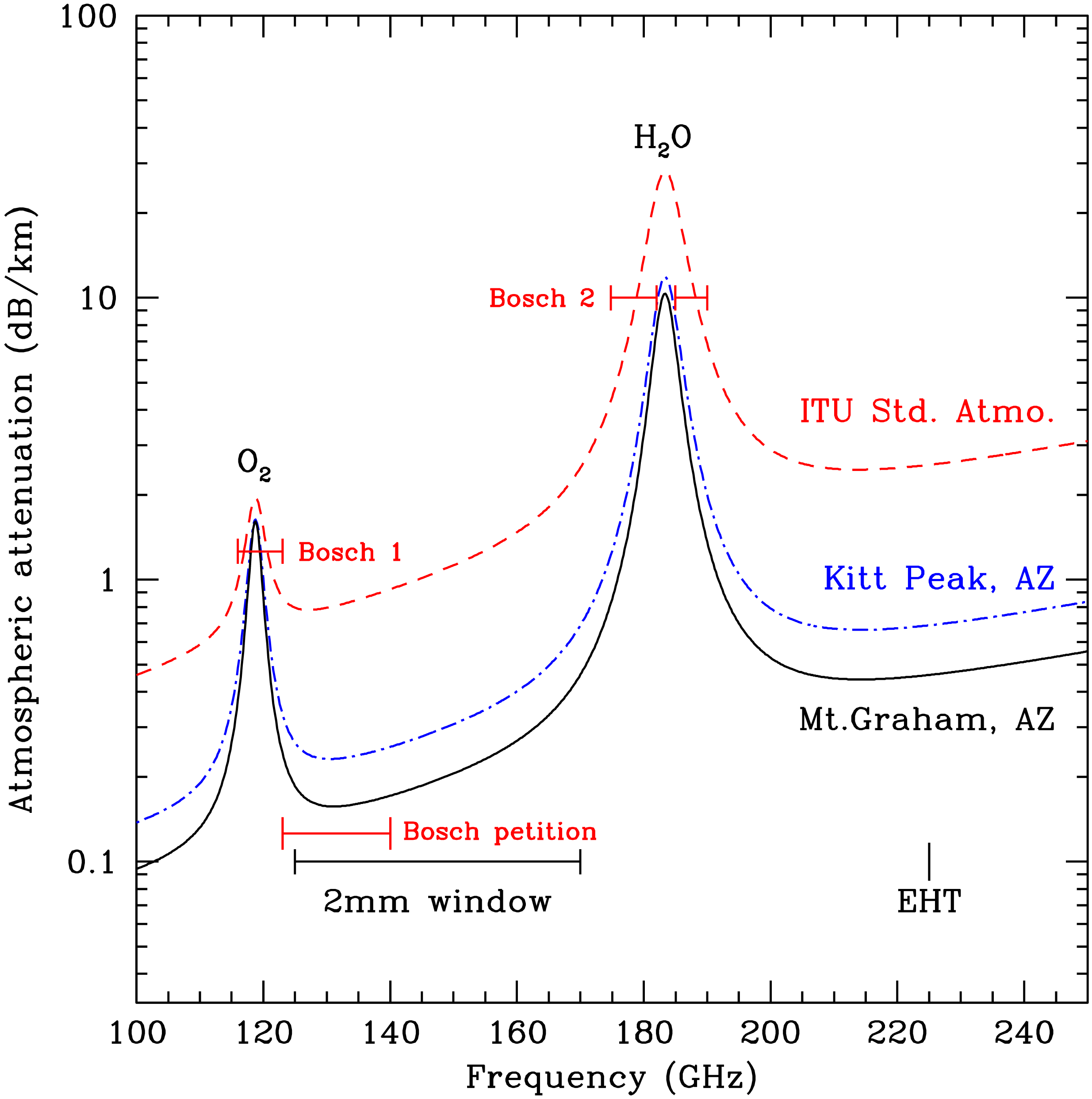

Figure 1 - Atmospheric attenuation as a function of frequency, for three locations based on ITU-R-P.676-11. Under typical conditions, the high, dry sites chosen for millimeter and submillimeter telescopes have significantly lower atmospheric attenuation than the standard atmosphere model. Furthermore, the frequency range at issue in the Bosch petition for reconsideration (123 - 140 GHz) lies within the 2mm atmospheric window, where the overall atmospheric attenuation is relatively low. RAS has co-primary allocations at 130-134 GHz and 136-141 GHz precisely because it is possible to detect faint cosmic sources due to the excellent atmospheric transparency at these frequencies.