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# Before the

**FEDERAL COMMUNICATIONS COMMISSION**

**WASHINGTON, D.C. 20554**

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| In the Matter of  Spectrum Horizons | **)**  **)**  **)**  **)** | ET Docket No. 18-21 |

**Comments of the National Radio Astronomy Observatory**

14 March 2018

The National Radio Astronomy Observatory (NRAO), on behalf of itself and its sister AUI-operated Green Bank Observatory (<https://greenbankobservatory.org/>), is taking this opportunity to remark on the FCC’s First Report and Order as contained in FCC-CIRC1903-1 (“the R&O”) on operations above 95 GHz in this Docket. The Commission’s earlier Notice of Proposed Rule Making FCC 18-17 is henceforth referred to as “the NPRM” and the comment filing from the NAS Committee on Radio Frequencies (CORF) is “the CORF filing” or similar.

NRAO’s interest in this proceeding as the operator of US radio telescopes observing in the mm-wave domain was established in its earlier comment in this proceeding that is mentioned in several places in the R&O. NRAO pioneered the development of mm-wave astronomy at the NRAO Kitt Peak (AZ) 36’ (later 12m) telescope where Bob Wilson, Arno Penzias and Keith Jefferts of Bell Telephone Laboratories first observed carbon monoxide (CO) in the interstellar medium of the Milky Way in 1970 through observations of its J=1-0 spectral line at 115.3 GHz.

1. **Contentious compatibility calculations**

At ¶30 of the NPRM, the Commission sought comment on proposed rules for licensed fixed point-to-point operations in 36 gigahertz of spectrum in the 95-100 GHz, 102-109.5 GHz, 111.8-114.25 GHz, 122.25-123 GHz, 130-134 GHz, 141-148.5 GHz, 151.5-158.5 GHz, 174.5-174.8 GHz, 231.5-232 GHz, and 240-241 GHz bands based on the 70/80/90 GHz rules. At ¶33 the NPRM stated “Under our proposal, licensees will be limited to a maximum EIRP of 25 dBW/MHz …”

CORF commented on this proposal for licensed, fixed, point-point use by calculating separation distances for radio telescopes on Kitt Peak (Arizona) and Mauna Kea (Hawaii) in Table 1 of its filing, using 0 dBi radio astronomy antenna gain and threshold pfd values for interference as per ITU-R Rec. RA.769, atmospheric attenuation per km relevant to the sites in question as given in their table, and 25 dBW/MHz eirp density as proposed. The separation distances so calculated are large, ranging from 41 – 130 km and 79 - 270 km for the two sites, where the larger value in each case is the effective distance to the horizon from these elevated sites.

CORF’s calculation was discussed by the Commission at ¶33 of the R&O in an example that elucidates the vast gulf in understanding and approach between the Commission and radio astronomy service operators.

At ¶33 the R&O states that

“CORF, using the protection values and analysis procedures of ITU Recommendation RA 769 claims that the separation distances for two radio astronomy sites – Kitt Peak, Arizona and Manua Kea, Hawaii – operating co-channel with unlicensed devices could be as large as 61 and 121 kilometers respectively. However, CORF’s analysis assumes 12 dB more power for unlicensed operations than what the rules we are adopting would allow.” [underlining by NRAO]

Although the Commission attributes to CORF a calculation for unlicensed devices that it did not actually perform, this is somewhat explained in the Commission’s footnote 76:

“76CORF assumes a power 25 dBW/MHz for unlicensed devices. *See* CORF Comments at 17. Our rules will only permit a maximum peak power of 43 dBm for unlicensed devices. *See* Appx. A, § 15.258(a)(1). We are only considering the power levels for non-point-to-point systems as CORF acknowledges the low probability of main beam to main beam coupling between point-to point-systems and radio astronomy receivers. *See* CORF Comments at 17-18.”

Thus, the Commission interprets CORF’s use of 0 dBi RAS antenna gain, CORF’s explanation of why 0 dBi gain is standardly applied in such circumstances and CORF’s calculated separation distances, to imply that no interference could be received, absent main-beam coupling. Moreover, the discussion implies that unlicensed devices should be considered, because of the possibility of main-beam coupling.

The R&O then discusses the use of 12 dB (= 16 times) lower power and states

“If the analysis is adjusted to reflect the appropriate power level for unlicensed devices the separation distances would be reduced by a factor of four.”

This is incorrect. Such scaling is appropriate when atmospheric attenuation is negligible, but it inappropriate for mm-wavelengths where a substantial portion of the attenuation in propagation calculations arises from the atmospheric absorption. Moreover, it is incorrect in those cases where CORF’s calculated separation distances are limited by the horizon. In Table 1 here, NRAO re-calculated the separation distances in CORF’s filing for 12 dB lower eirp, with new values highlighted in red. When there are differences they are at most about 20%, not a factor 4, manifesting a seemingly paradoxical aspect of relying on atmospheric attenuation to achieve compatibility.

If the power level for unlicensed operations is really 25 – 12 = 13 dBW/MHz, the entries in Table 1 make clear that such unlicensed devices cannot operate compatibly within very large distances about radio telescopes. That said, the Commission may, in citing a 12 dB lower power for unlicensed devices, have conflated the 25 dBW/MHz eirp density of the proposed fixed point-point transmitters in the NPRM with the peak total eirp of 43 dBm = 13 dBW for unlicensed devices in the R&O. This could in some cases imply somewhat smaller separation distances for unlicensed devices having bandwidths well in excess of 1 MHz.

Table 1: CORF’s Table 1 with red highlighted values re-calculated for 12 dB lower power

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Frequency (GHz) | RA.769  threshold for spectral line observations (dB(W/(m2 Hz))) | Atmospheric Attenuation Kitt Peak, Arizona  (dB/km) | Avoidance Distance Kitt Peak, Arizona  (km) | Atmospheric Attenuation Mauna Kea, Hawaii  (dB/km) | Avoidance Distance Mauna Kea,  Hawaii  (km) |
| 98 | -208 | 0.16 | 130 130 | 0.07 | 270 270 |
| 105 | -208 | 0.18 | 130 130 | 0.08 | 270 270 |
| 113 | -208 | 0.28 | 130 130 | 0.13 | 270 270 |
| 123 | -208 | 0.38 | 130 126 | 0.17 | 267 248 |
| 132 | -204 | 0.28 | 130 126 | 0.12 | 270 270 |
| 145 | -204 | 0.33 | 130 130 | 0.15 | 270 253 |
| 155 | -201 | 0.42 | 123 102 | 0.19 | 237 196 |
| 174.7 | -202 | 1.54 | 41 35 | 0.71 | 79 67 |
| 217 | -199 | 0.81 | 69 57 | 0.36 | 137 111 |
| 231.8 | -199 | 0.87 | 65 53 | 0.39 | 128 104 |
| 240.5 | -198 | 0.92 | 61 50 | 0.41 | 121 98 |

Further into ¶33 the R&O again asserts that radio telescopes will not receive RFI unless pointed at interfering terrestrial sources on the horizon, taking issue with a calculation that was made using 0 dBi radio astronomy gain by NRAO. The R&O states:

“Under the normal operating configuration where radio telescope antennas making astronomical observations look skyward, the antenna discrimination inherently provides significant interference protection from unlicensed device operations located near or on the horizon.”

The Commission then cites ITU-R Rec. S.1586 that is used in so-called epfd simulations of radio astronomy observations in the presence of a fixed-satellite service constellation, whose use is not appropriate here. The Commission employs this citation in footnote 80:

“80For example, an antenna operating at 116-122 GHz that has a gain of 60 dB [sic] looking skyward will have a gain of approximately -27 dB [sic] towards the horizon. Following the methodology of NRAO, but using our assumption of antenna horizon gain, the resulting separation distance from a radio astronomy receive antenna ranges from 5 km to 0.98 km, a distance that is within the property lines and the control of radio astronomy observatories.”

However, an antenna with a gain of 60 dBi at 120 GHz has a diameter of approximately 0.8m and does not correspond to a radio astronomy antenna which the Commission at various points in the R&O characterizes (in ¶33) as needing to be “large”. As for the gain toward the horizon, none is specified in S.1586 while ITU-R Rec. RA.1631 that is suggested in S.1586 has an off-axis gain in the range -7 to -12 dBi for off-axis beam angles above 34o. No model antenna beam pattern that is familiar to the NRAO has an off-axis gain as small as -27 dBi.

However, this begs the question of why the Commission did not accept CORF’s and NRAO’s explanations of their use of 0 dBi gain, and why the Commission consistently advocates that radio telescopes do not receive interference when pointing away from the interferer.

1. **Directivity, interference and gain**

The high directivity of large antennas is necessary for the discrimination (detection) of weak sources of cosmic radio radiation, but this does not protect against the presence of extraneous interfering signals in antenna sidelobes. Radio waves impinging on the antenna structure from anywhere may eventually enter the signal chain and be detected in sidelobes that are an unavoidable consequence of all antenna design.

The response of any antenna integrated over its beam pattern is 0 dBi, and the interference thresholds that form the basis for protecting the radio astronomy service are calculated in ITU-R Rec. RA.769 for 0 dBi gain in the general case and for +15 dBi gain in the particular case of data loss from sky blockage by the GSO satellite belt. The use of 0 dBi gain is tantamount to acknowledging that interference may arise from all directions, including those away from the boresight. Procedures for dynamic numerical simulation of radio astronomy observation in the presence of non-GSO satellites (as in ITU-R Rec. S.1586) utilize knowledge of an antenna pattern over the entire sky so that interfering signals in the main beam may be averaged with those arising in all other directions. Experience has shown that such simulations lead to somewhat higher calculated levels of interference than when 0 dBi is assumed: High directivity generally has a slightly damaging effect.

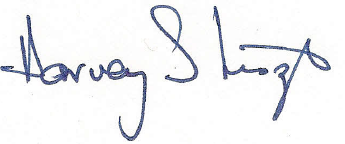
NRAO and CORF did not invent the use of 0 dBi gain in their compatibility studies for terrestrial transmitters, they adopted the best practice. Compatibility studies of just the sort that are relevant here with 0 dBi radio astronomy gain are on-going in many venues, for instance studies with the land mobile and fixed services for AI 1.15 of WRC-19. ITU-R studies for AI 1.14 use 0 dBi RAS gain for HAPS uplinks and +30 dBi for HAPS downlinks. Other Agenda Items for which studies have been performed using 0 dBi RAS gain include AI 1.9.1 and 9.1.9.

1. **Some minor matters arising**

The list of mm-wave telescopes in CORF’s filing includes two telescopes belonging to the Arizona Radio Observatory that do not appear in footnote 78 of the R&O where CORF’s list is quoted.

ITU-R Rep. RA.2189 that is mentioned in the R&O in footnote 95 has been updated to 2189-1 (09/2019), and has somewhat different conclusions regarding compatibility of passive and active service operations in the frequency range 275 – 450 GHz.

Respectfully submitted,



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