Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and	)	ET Docket No. 14-165
	)	
Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap	)	
	)	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	)	GN Docket No. 12-268

COMMENTS OF THE
NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

The National Academy of Sciences, through the National Research Council's Committee on Radio Frequencies (hereinafter, CORF[1]), hereby submits its Comments in response to the Commission's September 30, 2014 Notice of Proposed Rulemaking (NPRM) in the above-captioned docket. In these Comments, CORF discusses the nature of observations by the Radio Astronomy Service (RAS) in the 608-614 MHz band (i.e., Channel 37), which is allocated on a primary basis to the RAS and the Wireless Medical Telemetry Service (WMTS).

CORF generally supports the sharing of frequency allocations, where practical. In light of the difficulty for sensitive RAS facilities to track and limit interference from unlicensed devices such as TV white space devices (TVWSDs), successful and

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

practical sharing could be enabled by the following actions:

(1) Prohibiting TVWSD transmissions on Channel 37 in rural areas, since numerous other unused TV channels would be available for TVWSDs;

(2) Prohibiting TVWSD transmissions on Channel 37 in the National Radio Quiet Zone (NRQZ) and the Puerto Rico Coordination Zone (PRCZ), as proposed in the NPRM; and

(3) Limiting any TVWSD transmissions on Channel 37 to certain distance separations from Very Long Baseline Array (VLBA) RAS facilities, if such transmissions are not covered by (1) above.[2]

Similarly, any TVWSD operations on guard bands around Channel 37 should be subject to certain minimum separation distances, to prevent against harmful out-of-band (OOB) interference. CORF also supports the Commission's proposal to maintain the current prohibition on TVWSD operation on any channel within 2.4 kilometers of any protected RAS observatory. None of these proposals should significantly limit the provision of TVWSD service to consumers. Lastly, CORF also supports the Commission's proposal to prohibit the operation of unlicensed wireless microphones on Channel 37, as well as additional protections for operation of such microphones in any guard bands surrounding Channel 37.

I. Introduction: The Role of Radio Astronomy, the Special Vulnerability of Passive Services to Interference, and the Importance of Observations on TV Channel 37.

CORF has a substantial interest in this proceeding because it represents the

[2] CORF proposals herein address only protection of RAS facilities, and do not address proposals necessary to protect operations in the WMTS.

interests of the passive scientific users of the radio spectrum, including users of the RAS bands. RAS observers perform extremely important yet vulnerable research.

As the Commission has also long recognized, radio astronomy is a vitally important tool used by scientists to study our universe. It was through the use of radio astronomy that scientists discovered the first planets outside the solar system, circling a distant pulsar. The discovery of pulsars by radio astronomers has led to the recognition of a widespread galactic population of rapidly spinning neutron stars with gravitational fields at their surface up to 100 billion times stronger than at the Earth's surface. Subsequent radio observations of pulsars have revolutionized our understanding of the physics of neutron stars and have resulted in the only experimental evidence so far for gravitational radiation. Radio astronomy has also enabled the discovery of organic matter and prebiotic molecules outside our solar system, leading to new insights into the potential existence of life elsewhere in our galaxy. Radio spectroscopy and broadband continuum observations have identified and characterized the birth sites of stars in the galaxy, the processes by which stars slowly die, and the complex distribution and evolution of galaxies in the universe. Observation of the enormous energies contained in the enigmatic quasars and radio galaxies discovered by radio astronomers has led to the recognition that galaxies, including our own Milky Way, probably contain supermassive black holes at their centers, a phenomenon that appears to be crucial to the creation and evolution of galaxies. Synchronized observations using widely spaced radio telescopes around the world give extraordinary angular resolution, far superior to that which can be obtained using the largest optical telescopes, on the ground or in space.

Radio astronomy measurements led to the discovery of the cosmic microwave

background (CMB), the radiation left over from the original Big Bang that has now cooled to only 2.7 K above absolute zero. Later observations revealed the weak temperature fluctuations in the CMB of only one-thousandth of a percent—signatures of tiny density fluctuations in the early universe that were the seeds of the stars and galaxies we know today. The CMB is a unique probe for the ongoing search for gravity waves in the inflationary period of growth after the Big Bang, a particularly active topic in modern astrophysics. Within our own solar system, radio astronomy observations of the Sun have been used for more than half a century to aid in the prediction of terrestrial high-frequency (HF) radio propagation.

Since 1974, eight scientists, six of whom are American, have received the Nobel Prize in Physics for their work in radio astronomy.

However, the critical science undertaken by RAS observers cannot be performed without access to interference-free spectrum. Notably, the emissions that radio astronomers receive are extremely weak—a radio telescope receives less than 1 percent of one-billionth of one-billionth of a watt (10^{-20} W) from a typical cosmic object. Because radio astronomy receivers are designed to pick up such remarkably weak signals, radio observatories are particularly vulnerable to interference from in-band emissions, spurious and out-of-band emissions from licensed and unlicensed users of neighboring bands, and emissions that produce harmonic signals in the RAS bands, even if those man-made emissions are weak and distant.

In sum, the important science performed by radio astronomers cannot be performed without access to interference-free spectrum. Loss of such access constitutes a loss for the scientific and cultural heritage of all people, as well as a loss of the practical applications from the information learned and the technologies

developed.

Of particular concern in this proceeding is protection of RAS observations in the TV Band, including at 608-614 MHz (TV Channel 37). This band was originally allocated to RAS to provide appropriate spectral sampling of the spectral energy distribution of astronomical sources. For example, continuum (broadband) observations in the TV Band are used to study the interstellar medium, pulsars, and the Sun. In addition, observations in this band are a critical resource for two important areas of astrophysics: (1) observations of neutral hydrogen (with a rest frequency of 1420 MHz) shifted in frequency by the Doppler effect (red shift) into this band are a critical probe of state of the universe at a time 2.8 billion years after the Big Bang, when the Universe was only 20 percent of its current age; and (2) pulsar timing measurements can be made with extraordinary precision in this band and are expected to yield detections of black hole mergers, which cause ripples in the space-time fabric of space. Such observations are used to investigate interstellar matter and the evolution of galaxies. In regard to the interstellar medium, the TV Band is used to investigate the thermal and non-thermal diffuse radiation in our own Milky Way. Such observations give information on the high energy cosmic-ray particles in our galaxy and their distribution, and also on the hot ionized plasma in the disk of our galaxy.

Important observations in the TV Band are also made of radio-frequency outbursts from our Sun that precede bursts of high-energy particles that interact with Earth's atmosphere. These bursts can cause severe interruptions in radio communications and power systems and have dangerous effects on aircraft flying at altitudes above 15,000 meters. Study of these solar bursts can enable prediction of failures in radio communications. In addition, knowledge regarding high-energy solar

bursts is essential for safe and successful space exploration, both manned and unmanned.

II. Protection of the RAS against Interference from Unlicensed Devices.

CORF appreciates that one of the Commission's stated goals in this proceeding is to protect RAS observations on Channel 37.[3] CORF recognizes the importance of maximizing spectrum efficiency through thoughtful sharing of spectrum bands, where practical. RAS observations on Channel 37 should remain protected, now and in the future,[4] as described below.

A. Rural Areas.

In Section III.A.1.b.iii of the NPRM, the Commission seeks comments on the operation of TVWSDs in rural areas, which are defined as "those where at least half of the TV channels are unused for broadcast services and available for white space use" (NPRM at para. 45). The radio astronomy community is well aware that there is typically much less use of the spectrum (by TV and other services) in rural areas, and it is for that very reason that most RAS observatories are located in rural areas. In light of that fact, in response to NPRM proposals that TVWSDs operate with greater power and increased antenna height in rural areas, CORF suggests an additional proposal: that TVWSDs not transmit on Channel 37 in rural areas or in areas where more than 10% of the TV channels are unused for broadcast services and available for TVWSD use. Use of Channel 37 in such areas would be unnecessary, since many of the TV channels are unused for broadcast services and available for white space use.

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[3] *E.g.*, NPRM at para. 100.

[4] The amount of RAS observation at any particular frequency is driven by the then-current state of the science. Thus, observation at a particular frequency may increase and decrease over time, but bands allocated to RAS must still be protected, as a new scientific discovery can occur at any time, driving increased need to observe at that frequency.

Furthermore, when combined with another proposal in the NPRM to prohibit TVWSD transmission on Channel 37 in the NRQZ and the PRCZ, the net result may well be to eliminate all or the vast majority of potential direct interference between TVWSDs and RAS facilities on Channel 37. This would be a good result for all affected parties—TVWSD operators, consumers, and the RAS community—and thus would serve the public interest.

B. Separation Distances for VLBA RAS Sites.

In paragraph 116 of the NPRM, the Commission proposes different separation distances for protection of the 10 VLBA sites versus single dish RAS operations at Green Bank, West Virginia and Arecibo, Puerto Rico. CORF generally supports this concept, but recommends specific figures to replace the generalized separation distances proposed in paragraph 118, as follows:

RA.769-2 Limit, dBm					
			Separation Distance		
Station	VLBI or Single Dish	In Isotropic Antenna	km (4 W)	km (0.1 W)	km (0.04 W)
Brewster, WA	VLBI	-131	49	34	29
Fort Davis, TX	VLBI	-131	76	24	18
Hancock, NH	VLBI	-131	174	72	63
Kitt Peak, AZ	VLBI	-131	341	304	289
Los Alamos, NM	VLBI	-131	235	142	142
Mauna Kea, HI[5]	VLBI	-131	278	278	278
North Liberty, IA	VLBI	-131	180	99	99
Owens Valley, CA	VLBI	-131	138	92	92
Pie Town, NM	VLBI	-131	148	103	103
St Croix, VI	VLBI	-131	173	158	155

[5] For Mauna Kea, the calculated distance is much greater, but is mostly over the ocean. In that case, the range has been taken as the limit of U.S. territory.

The results in the above table are based on the following detailed calculations: from RA-769-2 Table 1, the threshold for interference for single dish observations at 611 MHz is a spectral pfd of -253 dB(W/(m^2-Hz)). From RA-769-2 Table 3, the threshold is -212 dB(W/(m^2-Hz)) for Very Long Baseline Interferometry (VLBI) observations. Translating this into dBm at the receiver, assuming an isotropic receiving antenna, the threshold becomes -172 dBm/6 MHz for single dish astronomy, and -131 dBm/6 MHz for VLBI observations. Using Longley-Rice Irregular Terrain Model (ITM) point-to-point path loss over the actual terrain surrounding the radio astronomy observatories, these limits translate into a necessary separation distance between a transmitter and the radio astronomy antenna, shown in the table above.

The necessary separation distances are calculated for effective isotropic radiated power (EIRP) of 4 W, 0.1 W and 0.04 W.[6]

C. Prohibition on TVWSD Transmission on Ch. 37 in the NRQZ and PRCZ.

In order to protect the Green Bank Telescope and the Arecibo Observatory single dish facilities, the NPRM proposes (at para. 123) to prohibit TVWSD operations in the NRQZ and the PRCZ. CORF supports this proposal as an efficient and effective method for protecting RAS observations on Channel 37 at those two single-dish RAS sites.[7] As the NPRM noted, there are likely to be numerous other TV channels

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[6] The in-band and out-of-band interference thresholds and minimum required separation distances have been calculated assuming a single interfering device, but where several devices are in use in nearby locations, the aggregate interference level will be correspondingly higher, requiring the permitted power levels for all of the transmitting devices to be reduced or the minimum separation distances increased. The likely future density of emitting devices is difficult to estimate, but the Commission could address the issue of aggregate interference levels through remedial software in devices connected to a database. Alternatively, the general requirements for single device power levels could be reduced or minimum separation distances increased, to account for the possibility of aggregate interference.

[7] CORF also notes that some facilities that currently operate as part of the VLBA could, in the future, operate on a stand-alone, single dish basis. The Commission's rules should account for the possibility of such changes, as well as the addition of other new or existing major radio astronomy facilities commencing observations in the 608-614 MHz band. For example, the NTIA could alert the Commission

available for TVWSD operation in those locations.

In paragraph 124 of the NPRM, the Commission seeks comments as to whether minimum separation distances smaller than the NRQZ and the PRCZ could be properly established. In response, CORF notes that using the methodology described above for calculating minimum separation distances for VLBA sites, the minimum separation distance for the Green Bank single-dish site should be 195, 250, and 331 km for 40 mW, 100 mW, and 4 W devices, respectively. Yet, the NRQZ protects less than that area, because it is circumscribed by a circle with a radius of only 131 km. Similarly, the calculated separation distance for the Arecibo Observatory is 272 kilometers, an area larger than the size of the PRCZ.

D. TVWSD Operations in Guard Bands.

In paragraph 90 of the NPRM, the Commission proposes to allow TVWSDs to operate in any guard bands surrounding Channel 37. Assuming operation at 40 mW, as proposed in paragraph 81, the protection of RAS observations in Channel 37 would require distance separation. The necessary separation distances are shown in the table below, assuming that the OOB emissions into Channel 37 are -55 dB/6 MHz with respect to the main transmission. For the VLBI stations, where the distance is only a few kilometers, the distance is calculated assuming free space propagation with no terrain blocking. For single dish (SD) stations, the distances are calculated using the Longley-Rice point-to-point propagation model over the actual terrain around the radio astronomy station.

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to such new operations, and the Commission could then issue a Public Notice, requiring revisions to the database of protected sites.

RA.769-2 limit, dBm					
			Separation Distance		
Station	VLBI or Single Dish	In Isotropic Antenna	km (4 W)	km (0.1 W)	km (0.04 W)
Arecibo, PR	SD	-172	157	145	106
Brewster, WA	VLBI	-131	16	3	2
Fort Davis, TX	VLBI	-131	16	3	2
Green Bank, WV	SD	-172	63	27	21
Hancock, NH	VLBI	-131	16	3	2
Kitt Peak, AZ	VLBI	-131	16	3	2
Los Alamos, NM	VLBI	-131	16	3	2
Mauna Kea, HI	VLBI	-131	16	3	2
North Liberty, IA	VLBI	-131	16	3	2
Owens Valley, CA SD	VLBI	-131	16	3	2
Pie Town, NM	VLBI	-131	16	3	2
St Croix, VI	VLBI	-131	16	3	2

E. Unlicensed Wireless Microphones.

Wireless microphones are just as capable of causing interference to RAS facilities as TVWSDs. CORF thus supports the proposal at paragraph 149 to prohibit unlicensed wireless microphone operation on Channel 37.

The NPRM proposes, however, to allow operation of unlicensed wireless microphones on guard bands surrounding Channel 37. While the Commission

proposes to reduce the permissible power levels in the guard bands to 20 mW, even at this reduced power, interference to RAS observations is a real possibility. Thus, CORF supports the proposal in paragraph 163 of the NPRM that such wireless microphone operations be limited to those connected to a database. CORF assumes that the relative OOB emission from 20 mW wireless microphones will be similar to that from TVWSDs operating adjacent to Channel 37, and that up to 5 wireless microphones could be operated simultaneously in adjacent channels. That implies that the limitation for wireless microphone operation should be similar to that proposed above for 100 mW TVWSDs in the adjacent channels—namely, a minimum separation distance of 3 km from VLBA stations, 145 km from the Arecibo Observatory, and 27 km from the Green Bank Telescope.

F. Other Distance Separations.

In addition to exclusion zones around certain RAS observatories for operation of TVWSDs on Channel 37 and in the guard bands around Channel 37, it will also be necessary to maintain the Section 15.712(h)(1) prohibition of operation of such devices on any channel within 2.4 km of certain radio astronomy observatories. Unlicensed wireless microphones should be subject to a similar prohibition.

III. Conclusion.

CORF appreciates the Commission's attempts to protect RAS observations in Channel 37. While CORF generally supports the sharing of frequency allocations where practical, in light of the difficulty for sensitive RAS facilities to track and limit interference from unlicensed devices such as TVWSDs, successful and practical sharing could be maximized by first prohibiting TVWSD transmission on Channel 37 in rural areas, since numerous other unused TV channels would be available for

TVWSDs. This prohibition should eliminate the issue of direct interference in the large majority of situations. For situations not covered by this rural prohibition, the Commission should prohibit TVWSD transmission on Channel 37 in the NRQZ and PRCZ, as proposed in the NPRM, and limit any TVWSD transmissions on Channel 37 to certain distance separations from VLBA facilities. Similarly, any TVWSD operations on guard bands around Channel 37 should be subject to certain minimum separation distances, to prevent against harmful OOB interference. CORF also supports the Commission's proposal to maintain the current prohibition on TVWSD operation on any channel within 2.4 km of any protected RAS observatory. None of these proposals should significantly limit the provision of TVWSD service to consumers. Lastly, CORF also supports the Commission's proposal to prohibit the operation of unlicensed wireless microphones on Channel 37, as well as additional protections suggested above for operation of such microphones in any guard bands surrounding Channel 37.

Respectfully submitted,

NATIONAL ACADEMY OF SCIENCES'
COMMITTEE ON RADIO FREQUENCIES

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Appendix

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