



# NATIONAL RADIO ASTRONOMY OBSERVATORY

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

In the Matter of	)	
	)	
Expanding the Economic and Innovation	)	Docket No. 12-268
Opportunities of Spectrum Through Incentive	)	
Auctions	)	

### 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 Rule Making (“the NPRM”) regarding repacking and rebanding of the UHF spectrum, including the spectrum band at 608 – 614 MHz in TV broadcast channel 37.
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 United States telescopes currently using the 608 – 614 MHz band (*aka* “channel 37”).

#### Allocation of the 608 – 614 MHz band and use by existing radio astronomy facilities

3. In the US, channel 37 is allocated on a primary basis to the radio astronomy service (RAS) and to the land mobile service which operates medical telemetry and medical telecommand as the wireless medical telemetry service (WMTS). The band is subject to US246 prohibiting all emissions except those of WMTS, whose use is coordinated under Section 95.1119 of the FCC rules to preclude interference to RAS.
4. In response to the request for information at 204 of the NPRM, NRAO notes that in the US, channel 37 is currently used by RAS at NRAO’s 10 VLBA stations (whose locations are given in US355) and at the 100m Robert C. Byrd Green Bank Telescope (GBT) in Green Bank, W. VA within the National Radio Quiet Zone. As noted in the NPRM at 201 and footnote 301, the VLBA and GBT may observe simultaneously in the band on a temporary basis to form the High Sensitivity Array.

5. Each of the VLBA antennas is equipped with a bandpass filter operating over 5.6 MHz within the 6 MHz-wide channel 37 band, to prevent reception of out of band TV emissions inside the RAS band edges, and to prevent inadvertent reception of broadcast signals on adjacent channels, which could result in receiver overload. Operation of the VLBA depends on simultaneous coordinated observing in the same frequency band at all of its stations, hence all of the VLBA antennas must have identical receiving facilities and all must have access to the same spectrum at the same time.
6. At 206 of the NPRM, the Commission asks whether the VLBA requires a single interference-protected band throughout the entire United States and whether a single, contiguous band is needed or RAS requirements can be satisfied through the use of multiple small, noncontiguous bands. As noted at 5 here, the VLBA telescopes must all observe identically at the same time, so using different bands at different locations cannot be considered. If the available bandwidth is fixed, a single contiguous band is greatly preferable when hardware filtering of the receivers is required because losses at passband edges would be incurred multiply with multiple passbands and to a larger fractional extent with narrower bands. Moreover the VLBA operates by recording the electromagnetic field strength for future reference (whereas foreign implementations typically take advantage of local infrastructure, lacking in the US, which enables simultaneous correlation) and it is of the utmost importance to minimize the amount of spectrum that must be recorded to achieve a given usable bandwidth.
7. Several other sites have observed at 608 – 614 MHz in the past (eg Arecibo) and/or could straightforwardly do so in the future. For instance the Pisgah Astronomical Research Center (PARI) currently operates at 327 and 1400 MHz and has facilities that are generally suitable for observing at 608 – 614 MHz. NRAO's Very Large Array (VLA) cannot easily observe at 500 – 1000 MHz owing to the configuration of its optics. Contrary to information available on the internet, the Allen Telescope Array cannot operate below 900 MHz, according to information provided by staff at the SETI Institute.
8. As noted in the NPRM at 204 and footnote 307, a comparable sharing of the band between RAS and WMTS exists in Canada, where WMTS observes an 80 km exclusion zone about the Dominion Radio Astronomy Observatory (DRAO) in Penticton, BC, about 60 km north of the US border. Although no present DRAO instrument uses channel 37, DRAO has informed NRAO that they very strongly wish to reserve future use of the band for a planned project called CHIME.
9. Although the band is not regionally allocated to RAS on a primary basis except in ITU-R Region 2 (the Americas), it is subject to various footnotes in the international frequency allocation table, specifically 5.149 urging administrations to take all practicable steps to protect RAS from harmful interference and 5.304 – 5.307 allocating the band to RAS on a primary basis in Africa, India and China, with a more general secondary allocation in Regions 1 and 3.

10. NRAO has been informed that the 608 – 614 MHz band is especially important for use at the Giant Metre-Wave Telescope (GMRT) in India and that the band is heavily used at the 100m Effelsberg Telescope in Germany, with national coordination of wireless microphones and low-power TV repeaters. The band is subject to national radio quiet zone restrictions in parts of South Africa and Australia. World RAS stations and local radio quiet zones are shown on a map at <http://tinyurl.com/yrvszk>, with links to the websites of the various telescope operators.
11. Thus the channel 37 band is in relatively common use world-wide. Nevertheless, it has not been the subject of simultaneous global observations employing internationally-linked telescopes.
12. A particular cautionary tale may be told whereby in the UK the RAS allocation in the channel 37 band was auctioned even while being used on a daily basis for pulsar monitoring at Jodrell Bank Observatory. Owing to restrictions on transmit power to avoid interference to nearby nations still observing the RAS allocation, the band was subsequently allocated to wireless microphones without bringing in revenue sufficient to cover promised compensatory costs to UK RAS. And, although RAS and wireless microphones might perhaps have coexisted in the band with coordination, the main TV transmitter in the British midlands (Sutton Coldfield next to Birmingham) was moved to an adjacent band, producing RFI 20 dB above the detrimental interference value defined in Recommendation ITU-R RA.769, well within the channel 37 band at Jodrell, as the result of out-of-band emissions.

### **Whither the RAS allocation at 608 – 614 MHz?**

13. The FCC asks whether and where the RAS band should be relocated, including (footnote 311) down to very distant VHF frequencies such as those in channels 2-6. NRAO notes that its VLA already observes in the band 58 – 84 MHz on a mostly unprotected basis (ie except in a narrow spectrum slice at 73 - 74.6 MHz) and that a number of existing full-power TV broadcast stations would need to be relocated to provide a protected RAS band. Moreover, interference to RAS operations at VHF frequencies arises from TV broadcasts in Mexico and from power lines.
14. As far as the science is concerned, the channel 37 band is fungible within certain limits. Moving the frequency +/-20% would preserve the science and could be accommodated, at some expense and with some loss of efficiency (and a loss of angular resolution at lower frequency), by the current VLBA optics. Receivers on the GBT are continuously tunable over much wider ranges so there would be essentially no effect, absent other changes in the electromagnetic environment.
15. Moving the RAS band upward by anything near a factor of two in frequency would place it so close to the existing allocation at 1400 – 1427 MHz as to be pointless. Moving it down by a factor of two would very detrimentally cause a loss of a factor two in resolution for the VLBA while still nominally doing somewhat the same kind of science. This is a poor outcome for RAS, even if such low frequencies can be

accommodated on the VLBA antennas which currently do not observed below 608 MHz.

16. Moreover, RAS already has a co-primary allocation at 322 – 328.6 MHz that is used at the VLA and GBT. We conclude that, for the particular science that is currently done at 608 – 614 MHz, and operationally for the VLBA, any new RAS allocation between 300 and 1400 MHz will have to be relatively close to the existing channel 37 band to be worthwhile.
17. Some alternative relocation schemes, for instance that shown above in Figure 14 of the NPRM, are similar to the baseline re-banding plan in their disposition of active services with respect to RAS and would have similar effect on RAS operations if implemented nationally (because the VLBA requires the same frequency band at all locations).
18. Other schemes, for instance Figure 14 at bottom, are not. The example shown below in Figure 14 is advantageous to RAS in having a guardband between RAS and downlinks, but the effect of uplinks directly above RAS would require compatibility studies based on detailed local deployment scenarios as noted below here at 22.
19. Each of the alternatives in Figure 14 employs guard bands interspersed between the uplink-downlink-TV boundaries that are absent in the baseline plan or in the status quo. NRAO finds it somewhat perverse that guard bands are used to prevent interference between active services but not between active services and RAS which employs the most sensitive receivers.
20. With respect to guard bands, these might be used with local coordination in Green Bank, or at the VLA below 500 MHz, but would have to be allocated nationally to be useful to the VLBA.

### **Future protection of RAS operations from out of band emissions**

21. In the FCC's baseline plan, and in other scenarios, the downlink band immediately below the RAS allocation will be occupied wherever the auction succeeds to any degree, hence ubiquitously. For those RAS stations that will inevitably find themselves in direct line of sight to downlink base stations, for instance the VLBA station on Kitt Peak AZ that is within direct line of sight to metro Phoenix and smaller cities to the west such as Sells, operations in the band will only be possible with very heavy filtering. Even so, aggregation of downlink out of band (OOB) signals could overwhelm the practicable limits of filtering, absent geographic coordination based on detailed local deployment scenarios.
22. In this context NRAO does not understand the remarks at 135 of the NPRM to the effect that "In addition, we do not anticipate needing a guard band between the downlink band and existing channel 37 operations (radio astronomy and wireless medical telemetry), because they currently operate adjacent to broadcast television

bands without interference.” Current VLBA operations sacrifice some 200 kHz of the band at either end (about 7% in total) owing to the use of filters. Whether heavier filtering is required, possibly sacrificing more of the band, or whether the band is rendered useless by aggregated OOB emissions, depends on deployment scenarios and separation distances, not on the mere fact that a downlink base station emits less powerfully than a TV station. Comparable remarks occur at 155 and 191 of the NPRM.

23. Even in cases where RAS stations are not in immediate line of sight to heavy population centers, some geographic separation will still likely be required to prevent RFI into the RAS band, even with filtering. Again, this will require deployment scenarios that will only be available after the auction or when the final band plan is understood.
24. Moreover, although base stations emit more strongly than handset uplinks, the numbers of uplinking devices will be far higher and their potential for RFI consequently increased. Control of uplink OOB emissions into an RAS band could be achieved partly by coordination of base stations (ie uplinks would not occur at frequencies that are not serviced locally) but uplinking devices might also need to be locally instructed by base stations to remain mute at frequencies adjacent to the RAS band, in physical proximity to an RAS station.
25. Finally, repacking of the UHF band TV transmissions could also lead to an increase in the number of TV channels broadcasting on channels adjacent to an RAS band. The repacking should be structured such that relocation of broadcasts into channels adjacent to the RAS band should be disfavored in proximity to RAS sites, lest a situation like that described above here at 12 be re-created.

### **Protection of RAS operations from in-band emission**

26. RAS and WMTS share the 608 – 614 MHz band because WMTS has alternatives that permit it to forgo operation in the band in those very few cases where WMTS and RAS stations are even approximately co-located. The sensitivity of RAS observations is such that in-band emissions cannot be tolerated within direct line of sight whether from wireless broadband, up or downlinks, TV stations, TV Whitespace devices, and so on.
27. For example, consider an isotropic 1Watt transmission in the channel 37 band. At a distance of 100 km in free space the power flux is  $-111 \text{ dB (W/m}^2\text{)}$ . By comparison, the threshold for detrimental interference to singledish continuum operations at 611 MHz in Table 1 of ITU-R Recommendation RA. 769 (relevant to operation in Green Bank) is  $-185 \text{ dB (W/m}^2\text{)}$ . So sharing is only possible in this single-entry case if 74 dB of additional attenuation (beyond normal free-space losses) of even 1W of in-band emission is assured. For VLBA in Table 3 of the Recommendation, the required additional attenuation of 1 W at 100 km is (only) 33 dB. This may be possible for some VLBA stations far from major population centers but it is manifestly impractical for the VLBA antenna on Kitt Peak that is within line sight to metropolitan Phoenix.

### Summary and conclusions

28. The allocation at 608-614 MHz is a valuable asset that permits astronomers to use very powerful US instruments in a protected band which is widely available internationally. It is the hope of NRAO that this allocation, or one relatively close in frequency, will be available in the future.
29. Even if protected RAS use of the channel 37 band is preserved, conditions will change drastically after the UHF rebanding plan is implemented, as adjacent spectrum is re-purposed and/or re-packed. Even continued use of the same channel 37 allocation may not be a zero-cost option for astronomy.
30. The worst possible outcome for all concerned would be to create or preserve an allocation to RAS that is rendered unusable by RAS because it is not adequately supported. This will require strong coordination of a variety of emissions that may occur in adjacent spectrum, and a comprehensive, if not absolute, prohibition on emissions in-band.

Respectfully submitted,  
National Radio Astronomy Observatory



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