Identifying Likely Locations for TV Station RFI in the GBO CHIME Outrigger

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Abstract

The Green Bank Observatory's Canadian Hydrogen Intensity Mapping Experiment (CHIME) Outrigger is located within both the National Radio Quiet Zone (NRQZ) and the West Virginia Radio Astronomy Zone, but raw data suggests strong radio frequnecy interference (RFI) likely emanating from television stations (according to FCC allocations and the characteristics seen in the data). We seek to identify the locations of likely main contributors. Using the rounded obstacle modification of the Longley-Rice propagation model in the Terrain Analysis Package 7.7, we are able to determine that, in general, the likely strongest sources of TV station RFI are located close to the border of the NRQZ. Some locations, with sites as distant as Ohio and Pennsylvania, are also potential candidates for strong RFI in the CHIME Outrigger data.

Contents

Changelog

165.0 Dunnagan et al. (2025-09-04) — Initial published version.

1 Introduction

The Canadian Hydrogen Intensity Mapping Experiment (CHIME) telescope was initially built in British Columbia, Canada, finishing construction in 2017 and commencing science activities in 2018. Initially built to study dark energy in the Universe, its science goals are wide-ranging, from furthering our understanding of Galactic magnetic fields to pulsar timing experiments (such as gravitational wave detection) and radio transient events (such as fast radio bursts) (CHIME Collaboration, 2025).

In pursuit of triangulating radio transient events in the sky, CHIME has since constructed three Outriggers: one outside of Princeton, British Columbia, Canada; one at the Hat Creek Observatory in Hat Creek, California; and one at the Green Bank Observatory (GBO), in Green Bank, West Virginia. The Outrigger at the GBO operates at the same frequencies as the other antennas in the array, from 400 to 800 MHz. While this Outrigger is located within the National Radio Quiet Zone (NRQZ), there are strong sources of RFI visible in the data.

Starting at 470 MHz we see strong emission likely produced by television station broadcasting as defined by federal rules and regulations. This broadcasting is allocated by the Federal Communications Commission (FCC) in 6 MHz blocks. At 608 MHz, the FCC begins allocating to cellular bands in blocks of 5 and 6 MHz (FCC, 2017).

While we acknowledge the presence of other allocated radio emission within the CHIME observed band, this memo serves as an initial analysis on likely locations of the broadcasting television stations, both inside and outside of the NRQZ. We will also discuss whether or not these stations have previously coordinated with the NRQZ Office at the NRAO and future steps this study could take.

2 Methodology

TV station radio frequency interference (RFI) has a generally characteristic signature - it appears as distinctive "bars" in time-averaged data at varying intensities dependent on the strength of the signal. When these "bars" are adjacent, there is an apparent dip between each allocated block stemming from a bandwidth usage of approximately 5.38 MHz (out of an allocated 6 MHz). Figure 1 shows an example of 24 hours' worth of data from the GBO CHIME Outrigger, where the RFI is apparent both in the waterfall plot portion of the figure and the time averaged plot above.

From this information, we utilized the FCC's Licensing and Management System (Federal Communications Commission, 2022) to systematically identify TV stations within a certain radius (approximately 450 miles, at the longest - including stations from as distant as Chattanooga, TN). Many of the individual stations identified provide sufficient detailed technical data to run through a propagation model. Due to publicly available technical information and time constraints, several assumptions were made for all digital TV stations reviewed in this memo. We assume an omnidirectional antenna for all TV station analyses, where the max effective radiated power (ERP) is the transmitter power output (TPO) with a max gain of 2.15 dBi (or 0 dBd) to account for missing antenna radiation pattern information. In addition, no system losses were considered, and a receiver gain of 0 dBi was utilized. We note that these assumptions follow the current standard for a worst-case analysis by NRAO regarding GBO coordination in the NRQZ.

For all cases we used the Rounded Obstacle propagation model (P. L. Rice, A. G. Longley, K. A. Norton, and A. P. Barsis, 1967), which is a modification of the more widely known Longley-Rice propagation model. This is the same model used in the NRAO coordination for GBO within the NRQZ. The software used to evaluate the propagation characteristics of the Rounded Obstacle model is the most recent version of the SoftWright Terrain Analysis Package (TAP), in this case version 7.7 (Softwright LLC, 2025). The following model inputs were used, all of which are standard practice for the NRAO coordination for GBO within the NRQZ:

1. 10 meter USGS topography data
2. No surface features/clutter
3. 10 meter step; FCC 4-point interpolation

4. 5 foot obstacle resolution
5. Minimum loss model

A point-to-point study from the TV station to GBO was performed. Also to keep consistency with the NRAO coordination of the GBO in the NRQZ, the reference point for the receiver used was the Green Bank Telescope's prime focus at 139.6 meters above ground level. After running propagation studies with the TV station locations, we compared the ERP of the transmitter from the publicly available data on the FCC Licensing and Management System to the allowed ERP (AERP) as defined by the NRAO limits within the NRQZ coordination process. The AERP formula can be seen by:

$$\text{AERP}_\text{d}(\text{W}) = \frac{4358.2 \times (\text{BW}(\text{MHz}) \times 50) \times \text{PFD}_\text{lim}\left(\frac{\text{W}}{\text{m}^2}\right) \times 10^{\left(\frac{\text{TPA}_\text{dB}}{10}\right)}}{f^2(\text{MHz})}$$

where BW is the carrier bandwidth, PFD is the public NRAO power-flux density limit, TPA is the total path attenuation, and f is frequency. The constants are a result of the effective antenna aperture term simplification, and the public NRAO PFD limit being in respect to a 20 kHz bandwidth. To more directly compare the TV stations max ERP to the AERP, both results were converted from Watts to dBm. The maximum signal strength comparison in dB was then calculated by subtracting the AERP from the ERP, seen by:

$$\text{Maximum Signal Strength (dB)} = 10 \times \log(1000 \times \text{Max ERP (W)}) - 10 \times \log(1000 \times \text{AERP (W)})$$

This allowed us to determine likely (and unlikely) TV station candidates for RFI production. Any station with a negative value met the theoretical NRAO AERP limit, and stations with positive values exceeded the theoretical limit.

3 Results

TV stations just outside of the NRQZ are the largest contributing sources, generally speaking, to RFI in the GBO CHIME Outrigger data (as seen in Table 1).

However, there are two sites that are within the NRQZ and are above the NRAO theoretical AERP limits, under worst case scenario analysis. The contributing factor to the inclusion of these sites as brightest sources within their channel is assuming omnidirectional antennas. However, sites within the NRQZ, through coordination with NRAO, often deploy proprietary antenna beams and mitigation techniques in order to limit the ERP toward GBO. Therefore, it is likely that these sites are indeed under the ERP limits that NRAO established and distant, stronger channels are to be considered. Included in Table 1 for channels 15 and 20 are the second brightest likely sources of RFI. Though our analysis did not account for the directionality of CHIME (where it is angled to point at the same patch of sky as the main array in British Columbia), we speculate that this directionality could contribute to more distant sources, such as stations in Ohio and Pennsylvania, being amplified.

Channel Number	Frequency (MHz)	In The NRQZ?	Max dB "Over Limit"	Location of Source
Channel 14	470 - 476	No	24.215107	Grundy, VA
Channel 15	476 - 482	Yes*	35.121428*	Staunton, VA*
		No	21.858464	Portsmouth, OH
Channel 16	482 - 488	No	23.418050	Pittsburgh, PA
Channel 17	488 - 494	No	54.398000	Bluefield, WV
Channel 18	494 - 500	No	14.179469	Charleston, WV
Channel 20	506 - 512	Yes*	21.302921*	Harrisonburg, VA*
		No	21.265802	Pittsburgh, PA
Channel 21	512 - 518	No	32.897772	Lynchburg, VA
Channel 23	524 - 530	No	29.398145	Richmond, VA
Channel 24	530 - 536	No	33.300614	Clarksburg, WV
Channel 25	536 - 542	No	36.475368	Bluefield, WV
Channel 27	548 - 554	No	48.315131	Roanoke, VA
Channel 28	554 - 560	No	32.675533	Petersburg,VA
Channel 30	566 - 572	No	50.938768	Roanoke, VA
Channel 31	572 - 578	No	25.217778	Oak Hill, WV
Channel 33	584 - 590	No	48.732809	Weston, WV
Channel 34	590 - 596	No	51.865090	Roanoke, VA
Channel 35	596 - 602	No	24.709015	Johnstown. PA
Channel 36	602 - 608	No	50.374361	Roanoke, VA

Table 1: The "brightest" radio stations surveyed in this study. Channels 15 and 20 also include an additional site each that we believe is more likely to contribute to CHIME RFI based on the assumptions used for this study.

Channel 17 shows a significant output above our limits; however, in the CHIME data presented in Figure 1, it is not an exceptionally bright source (in comparison to other bright stations). Our analysis assumes that each station is transmitting the maximum ERP in an omnidirectional pattern that the FCC allows in its license, which may not be reality. Additionally, atmospheric conditions play a significant role in radio wave propagation. While the theoretical maximum ERP in the direction of GBO is quite high, due to these factors (and potentially other contributors), we do not observe this level of interference in the data we used for this project.

Although the primary focus of this analysis was RFI emanating from TV stations, we acknowledge that there is modest RFI in bands allocated to cellular transmissions, as well as others. After research into the $617-622$ MHz allocation ("600B Lower", in Figure 1), the NRQZ Office is exploring the reasoning behind the observed signals and the best next steps in any appropriate mitigation techniques. More analysis is necessary to draw any further conclusions about this band and other detected bands in the CHIME Outrigger data.

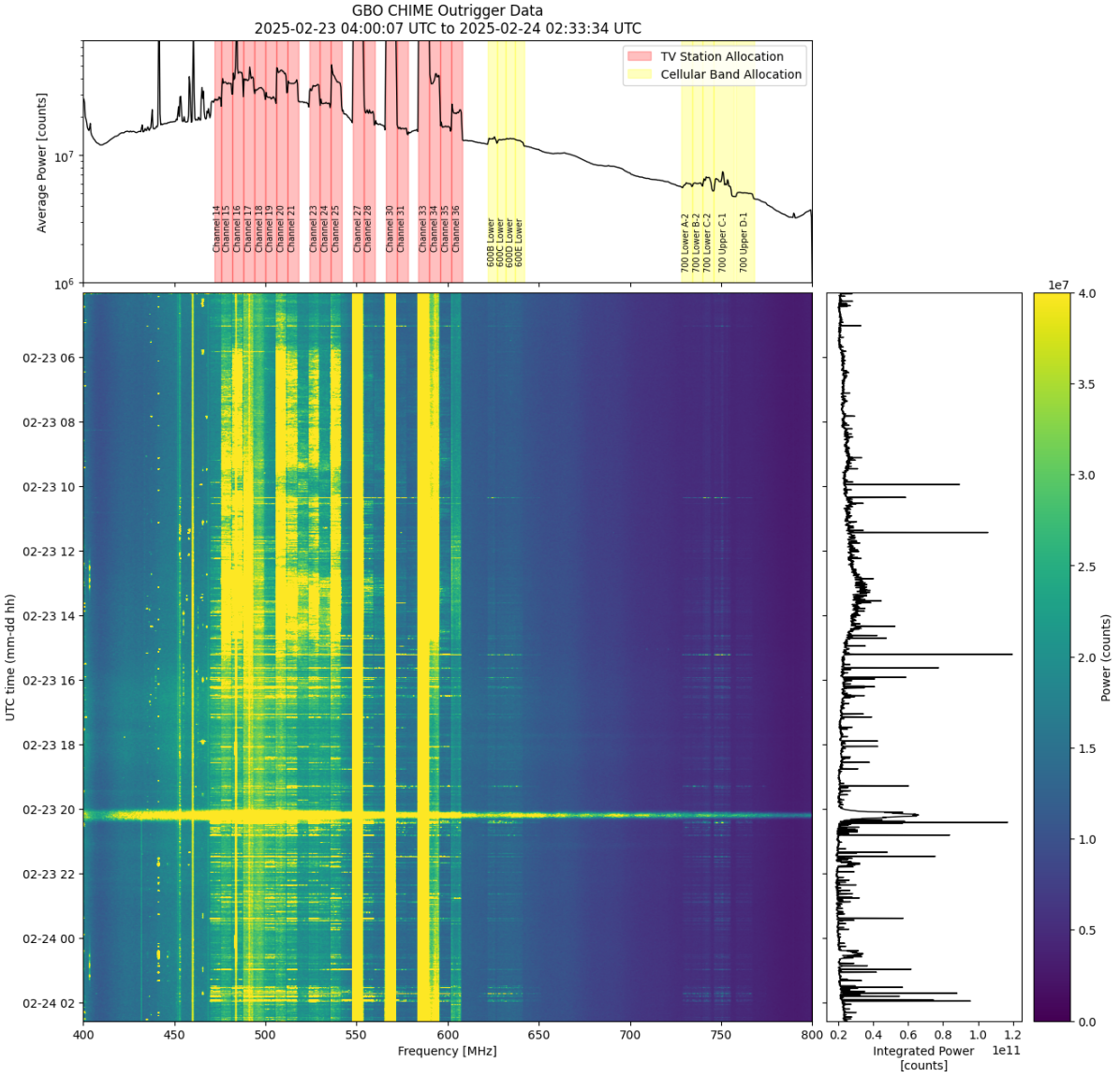

Figure 1: An example of 24 hours' worth of GBO CHIME Outrigger data. Highlighted in red vertical bars and labeled are each of the TV station allocation bands detectable in the data. Starting at 617 MHz, the naming convention changes to account for a switch to cellular band transmissions. While the FCC allocates 6 MHz to each channel, TV stations often broadcast at a bandwidth of 5.38 MHz. The bright emission across the band shortly after 02/23 20:00 hours UTC is the Sun passing through the CHIME Outrigger beam.

4 Limitations and Future Work

The scope of this overview is limited to observed RFI in an approximately 24 hour period of CHIME data. Certain conditions, such as terrestrial and solar weather, affect the propagation of radio waves over the terrain between stations and the GBO site. We acknowledge that a larger sample of datasets would increase the fidelity of this data. However, by keeping the scope of the project to TV station transmitters nearest to GBO, we are intrinsically limiting potential sources to only those that are the most likely recurring contributors to the RFI environment in CHIME. Depending on weather conditions, there could potentially be stations that are spreading across the

continent, but we do not believe that this regularly occurs. It is also possible that the amplitude of the signals observed is a combination of multiple stations. We have not included this in our analysis to continue to resemble standard NRQZ coordination processes and have noted aggregate interference potential in the NRAO Spectrum Management risk register. We also acknowledge the possibility of installing a television along the signal path to the Outrigger to scan channels for broadcasts. However, this requires significant resources and coordination, which led to our decision to rely on propagation studies for this memo.

In addition, we have listed only the brightest sources in Table 1. This is not an exhaustive list; there are usually multiple bright stations after studying typical propagation. We did not account for any ground clutter in our analysis due to the time-variant nature of clutter and its effects on the overall result. This study was designed as a ”worst case” scenario for each of the stations pulled.

We also acknowledge that there is cellular band RFI in the CHIME band, which has been escalated in the NRQZ Office. Due to the technical differences between a typical Digital TV station and a permanent fixed cellular tower deployment it is unlikely, though not impractical, the cellular band RFI is being received from transmission sites outside of the NRQZ. As noted previously in this memo, the NRQZ Office is exploring the reasoning behind the observed signals and the best next steps in any appropriate mitigation techniques.

Other future work for a more complete analysis includes considerations of CHIME Outrigger's beam pattern and directionality, as alluded to in Section 3. We expect that stations to the northwest of CHIME Outrigger would be amplified due to antenna's pointing, though this has not been empirically tested. Similarly, obtaining more technical details, such as antenna beam patterns and system losses, of the TV station transmissions from public resources can be explored in future work. This information would provide a more complete analysis, and were excluded from this analysis due to time constraints and simplicity. The result of this initial analysis provides a comprehensive “short list” of television stations to explore in greater detail in future work if additional technical information becomes available. Our analysis also used the location of the Green Bank Telescope (GBT), located within a mile of the CHIME Outrigger, as the target for our propagation studies–in a more rigorous analysis, this would change to center on CHIME Outrigger. For the purpose of this initial analysis, though, previous NRAO studies of distant transmissions indicate the results from a GBT observation point-of-view are sufficient in a worst-case scenario.

Because of the limitations imposed by targeting a single 24 hour period, further detailed analysis would measure the average power over longer periods. This would give us a more consistent view of the average powerful contributors to RFI in the CHIME Outrigger.

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