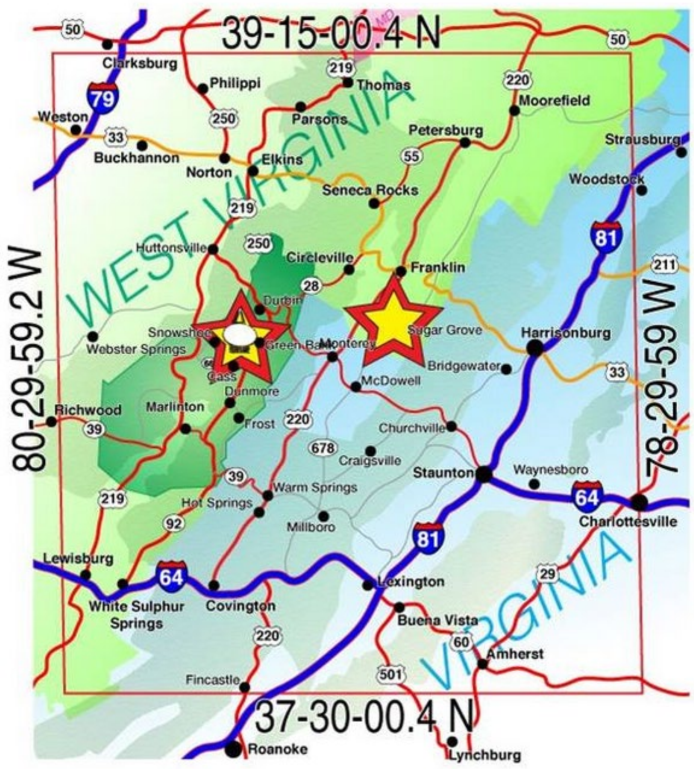
Protecting the National Radio Quiet Zone

Sheldon Wasik, Zone Regulatory Services Coordinator – National Radio Astronomy Observatory

Background

- National Radio Quiet Zone (NRQZ) was established in 1958 by the Federal Communications Commission (FCC) and the Interdepartment Radio Advisory Committee (IRAC)
- Encloses approximately 13,000 square miles
- Fixed transmitters in the NRQZ require coordination to minimize interference.
  - NRAO issues concurrence letters for completed coordination – not licenses!



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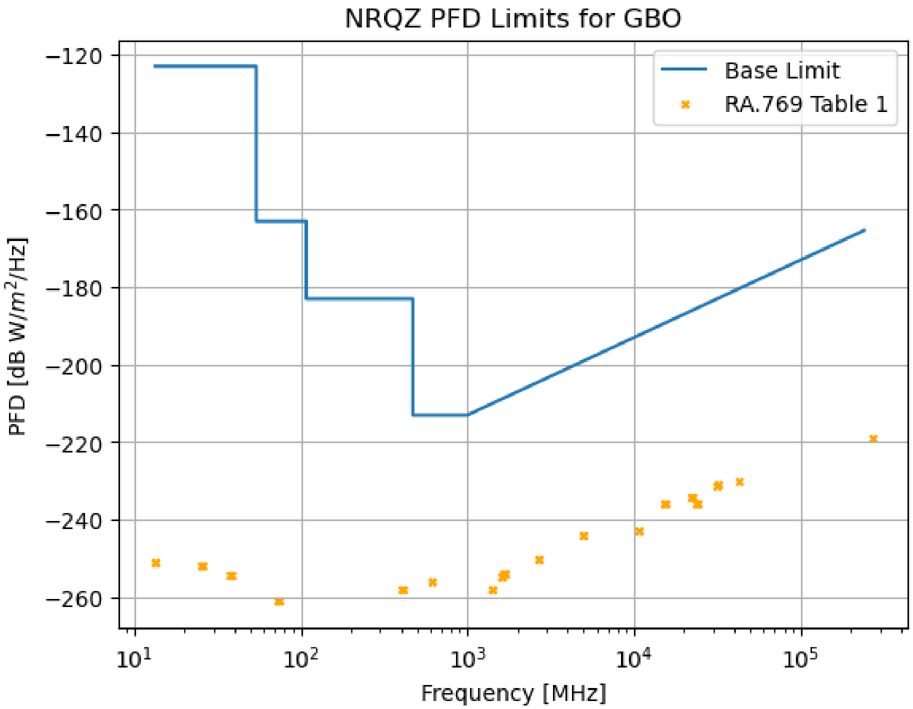
Green Bank Observatory Protection Criteria

- Radio sources are allowed in the NRQZ!
- Protection criteria is a frequency dependent power-flux density (PFD) limit
  - ITU defined "1% of the system temperature at 0 dBi gain"
  - a 1% increase in system temperature requires a 2% increase in observing time to compensate the increased noise (2% is the usual level of acceptable data loss)

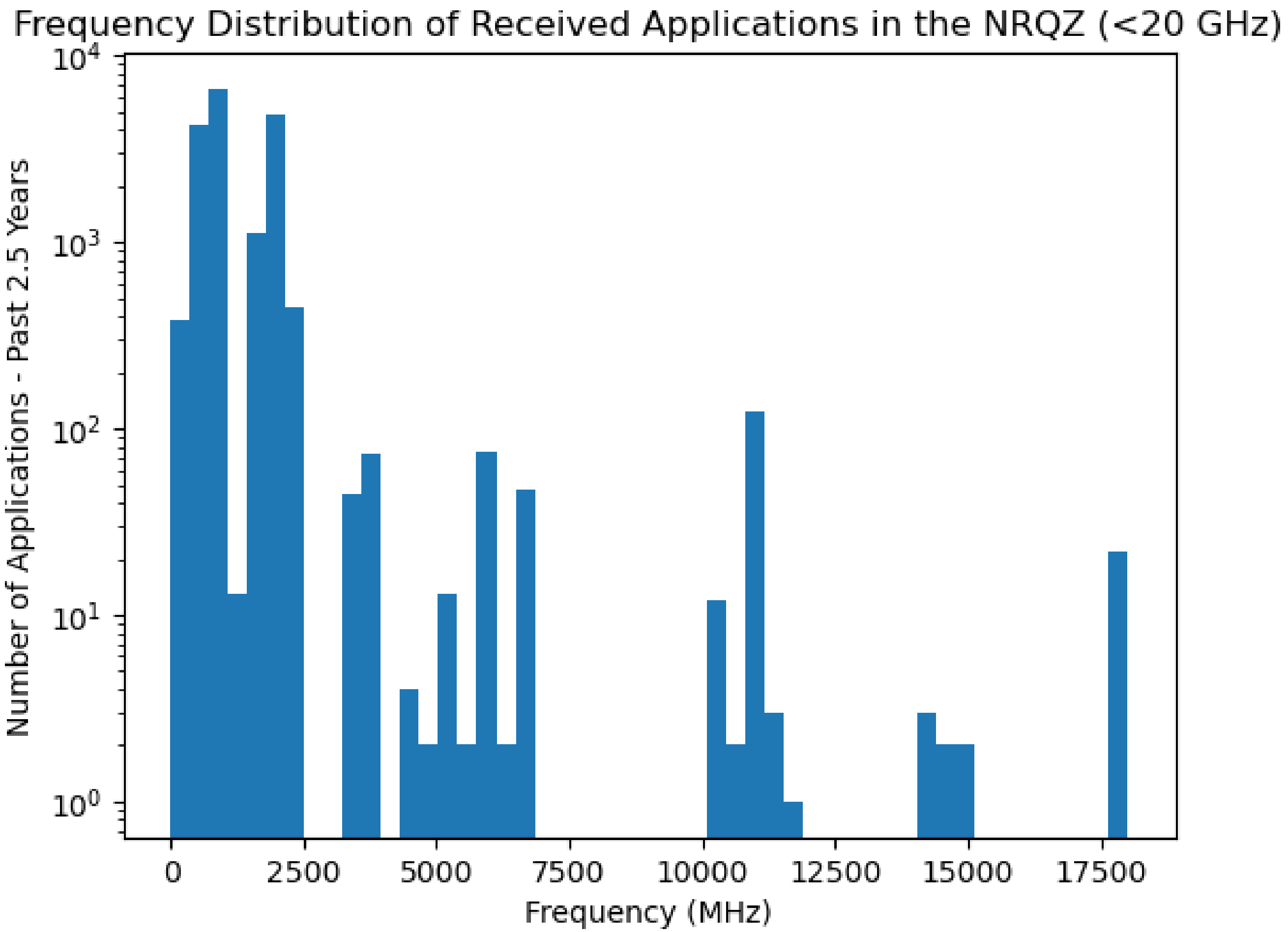
- Much more restrictive limits for Radio Astronomy protected bands (RA.769 Table 1)
- (Not pictured) West Virginia Radio Astronomy Zoning act restricts operation of electrical equipment within a 10 mile radius
  - More restrictive the closer to GBO
  - Often more restrictive



Reasoning

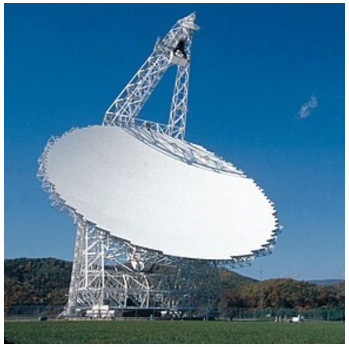
- Green Bank Telescope
  - 290 MHz to 115.3 GHz; 100 meter diameter single dish
  - Fully steerable antenna (5-90 deg elevation, 360 deg azimuth)
  - GBT Science: Pulsars, Star Formation, SETI, Solar System Astronomy, H1, Cosmology
  - Pointing accuracy of the GBT is 2 arc seconds
    - able to resolve a quarter at 3 miles
  - ~600 users a year;~6,500 hrs a year
  - Quickly adaptable to new science (!!)
- In the NRQZ over the last 2 years
  - 2022: 666 applications; 3,910 facility/technology/frequency
  - 2023: 637 applications; ~5,000 facility/technology/frequency
  - Additional "smart meter" projects with 10,000s of locations
  - 60% of applications are fine, the other 40% often need additional engineering to meet the NRQZ/NRAO limit
    - Some technology/bands are more prone to objections (propagation/limit dependent)

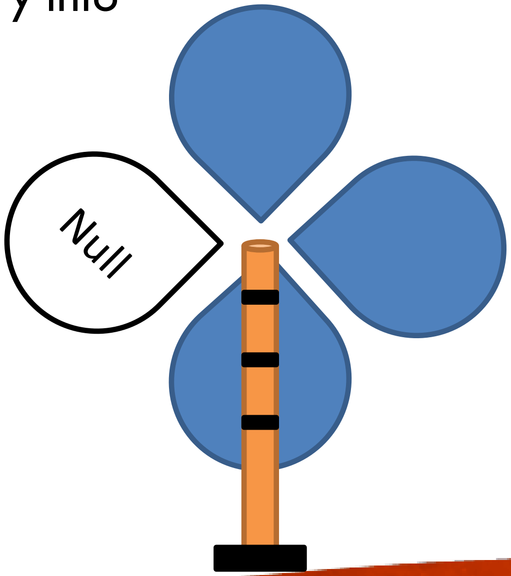
Application Distribution



Analysis

- Use the GBT as a reference point
  - 458 ft (139.6 m) receiver height
- All assumptions are done on a worst case scenario (more on this later)
  - Just like TXs "over-estimate" path loss to ensure XX% coverage is met, we "under-estimate" to ensure protection criteria is met at all time metrics
- Full "specs" of the applicants transmitter is required
  - Frequency, power, bandwidth, antenna azimuth, antenna pattern, etc.
  - We acknowledge/respect proprietary info



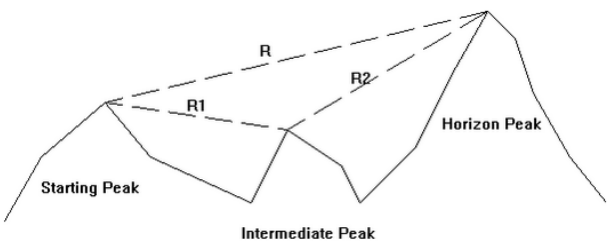


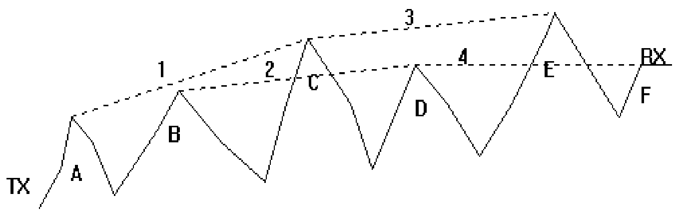
Analysis - Calculations

- In principle:
  - Received Field = Tx Power + Tx Gain – Path Loss – System Losses.
  - Compare received field to Power Density Limit
- In practice:
  - Allow for re-engineering
    - Directional antenna pointing, downtilts, power reductions, etc
  - Licensing agencies (FCC and NTIA) work with Effective Radiated Power (ERP)
  - "Reverse" the calculation, comparing applicants ERP vs max ERP that would be allowed in the direction of GBO
    - AERP [Watts] = $(4358.2 * PFD_{[W/m^2/20kHz]} * 10^{(TPA\,[dB]\,/\,10)} * (50*BW\,[MHz]))\ / f\,[MHz]^2$
- Propagation models are used for path loss/total path attenuation

Analysis – Propagation Model

- Path Loss/Total Path Attenuation
  - Reduction in power density of an electromagnetic wave as it propagates through space
  - Utilize SoftWright Terrain Analysis Package
    - Rounded Obstacle propagation model
      - Based on Section 7 ("Diffraction Over a Single Isolated Obstacle") of Tech Note 101 (*Transmission Loss Predictions for Tropospheric Communication Circuits*, 1967, NTIS)
      - Described as "Rounded out Longley-Rice" – Appalachia is round!





If the indirect path length exceeds the direct path length by .088 wavelength or more, the intermediate point is considered to not affect the study and is discarded.

Analysis – Propagation Model (cont.)

- Use 10 meter topography data
  - Acknowledge higher resolution data is available. Changes in our models provide larger discussions to regular applicants
- Minimum loss (freespace + diffraction/troposcatter)
- Point-to-Point
- No additional losses (worst case)
  - No tree cover/clutter
  - No building cover/clutter
  - Conservative weather parameters
- Why no losses?
  - Can't get something back that was given up
  - Assists in protections from model error
  - Environment is changing (deforestation, forest fires, etc.)

Analysis – Bringing it Together

- If the applicant's proposal won't be above the limit, a concurrence letter is issued
  - Not a license!
  - FCC and NTIA will require the applicant attach this letter to their license proposal
- If the GBT will pick up harmful interference:
  - Applicant must re-engineer the system (tilt antenna, reduce power, etc)
  - Site inspection must be performed once constructed

Other Studies

- We are always trying to better understand the RF environment, where certain designs could go, etc.
  - Leads to a variety of analysis (coverage studies, comparing "industry standard models," economical reasonings, potential RFI sources)

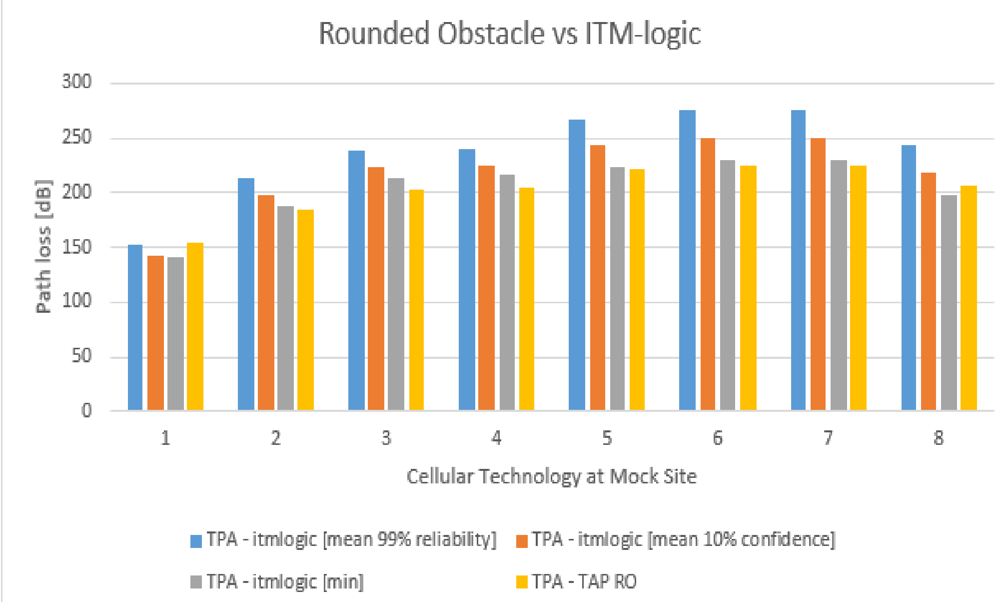


Fig 1: Rounded obstacle model vs itmlogic's open sourced Longley-Rice model, with focus on reliability and confidence variations.

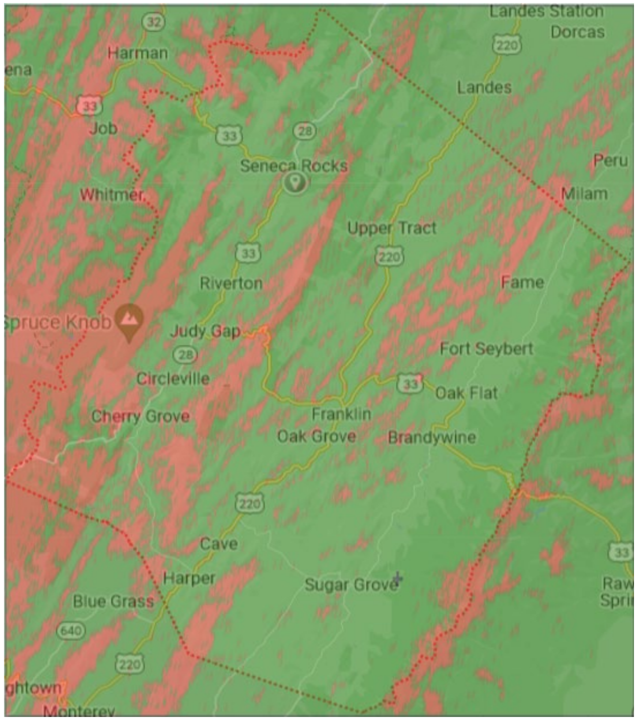


Fig 2: Coverage plot of nearby County where a WV site wide emergency 100 W system could be placed, based on NRQZ limits.

Challenges and Concerns

- We want a good relationship with the community
  - Public safety, WiFi, understanding
- Aggregate impact
  - If hundreds of coordinated sites are right at the limit, what are the consequences?
- Propagation model variations.
  - Reasoning for comparing "industry standards" vs our models
- Once you lose a frequency, it is very hard to get it back
- Sources often not required to coordinate (satellites, airborne, etc)
  - Non-terrestrial transmissions always pose a telescope main beam threat – much greater RFI, potential receiver damage
  - Unknown in our database
- Limits for GBO were developed before cooled receivers – sensitivity!

Conclusions

- The NRQZ coordination process:
  - Compare the received power of a transmitter with limits set by the ITU
    - Involves propagation software for known path losses (Rounded Obstacle model)
    - All calculations assume a worst case scenario for GBO
  - Applicant may re-engineer their system to meet the limits
  - Historical models are often kept, as a slight change in limits is a big deal
  - Letter of concurrence issued (not a license)
- Constantly utilizing models to understand RF environment for protection purposes, and general spectrum management
- We want a good relationship with the community, while protecting the science we are able to do

Thank You!

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