January 23, 2020

Report to the Astronomy and Astrophysics Advisory Committee (AAAC)
The 2020s: A decade with new opportunities

Credit: LSST

Credit: almaobservatory.org
The 2020s: A decade with new opportunities and new challenges
...the original protected frequency regions have been eroded both from external challenges, as well as significant out-of-band emission from competing sources and harmonics overlapping with key astronomical lines.

The original protected frequencies do not include emission lines that have become increasingly important as astrophysical diagnostics since the 1970’s, nor do the protected frequencies encompass known lines that are redshifted out of the protected bands.
Demand for spectrum is unrelenting
Finding (12): Competing interests continue to provide a severe and unrelenting threat to astronomers’ ability to detect electromagnetic signals from space. Without clean access to these wavelengths, the ability of astronomers to obtain fundamental knowledge about the universe is profoundly impaired. This is particularly important as time-variable astronomy gains visibility (for example in detecting gravitational wave counterparts or other multi-messenger astronomy activities). Mobile and transient noise sources form a large and growing threat.

Finding (13): The resources currently available to the NSF and NASA are not sufficient to protect essential astronomical wavelengths in an arena of competing commercial interests with deep financial support and professional lobbyists.
Epoch of Reionization

HI: 21 cm -> 1.5 m
Freq ~ 1420 MHz -> 200 MHz

\[ 1 + z = \frac{f_{\text{emit}}}{f_{\text{obsy}}} \]

Image Credit: w.astro.berkeley.edu

Image Credit: Djorgovski et al. (Caltech); www.haystack.mit.edu
To achieve 2 uJy RMS requires integration time on source of:

**2 GHz bandwidth:**
5.5 hours

**1.4 GHz bandwidth:**
6 hours

**50 MHz bandwidth:**
185 hours (more than one week)

NSF-funded Astronomy research relies on access to electromagnetic spectrum

ESM resides in MPS/AST because historically spectrum usage has been focused primarily around the needs of a few large facilities and the National Radio Quiet Zone.

Arecibo Observatory, Puerto Rico

Very Large Array, NM

Very Long Baseline Array

Green Bank Observatory
National Radio Quiet Zone
• The United States has significant scientific assets / large facilities outside of its national borders.

• Observatories tend to be in geographically remote sites, but radio emission from moving emitters: car radars, satellites and high altitude delivery systems will be an increasing challenge.
NRQZ (established 1958) needs updated protections from airborne transmitters; other radio telescopes need also need newly established coordination zones.

We need new quiet/coordination zones for coordinating access to wider bandwidths for the VLA, Arecibo, VLBA, ALMA and other facilities.

Description
The National Radio Quiet Zone (NRQZ) was established by the Federal Communications Commission (FCC) in Docket No. 11745 (November 19, 1958) and by the Interdepartment Radio Advisory Committee (IRAC) in Document 3867/2 (March 26, 1958) to minimize possible harmful interference to the National Radio Astronomy Observatory (NRAO) in Green Bank, WV and the radio receiving facilities for the United States Navy in Sugar Grove, WV. The NRQZ is bounded by NAD-83 meridians of longitude at 78d 29m 59.0s W and 80d 29m 59.2s W and latitudes of 37d 30m 0.4s N and 39d 15m 0.4s N, and encloses a land area of approximately 13,000 square miles near the state border between Virginia and West Virginia.
Recommendation (14): Given their common interests in access to the spectrum, NASA and NSF should enhance their collaboration with each other and with other groups, including international agencies and commercial interests, to protect the accessibility of essential astronomical wavelengths to researchers.

Recommendation (15): Efforts, ideally coordinated with all three agencies, should be made to increase awareness of spectrum management issues among astronomers, the general public, and government agencies. Possible agents for meeting this recommendation might include the NSF-funded national facilities for operations at radio and optical wavelengths. Efforts to engage and coordinate with other international agencies should continue.
I. **Outreach - Presented at the AAS 235th meeting**

II. **Ongoing regular meetings with NASA and NOAA**

III. Represented U.S. scientific interests at the World Radio Conference 2019, beginning WRC-23 prep cycle

IV. Stepping into a role to consider the optical impacts from satellites as well as the radio impacts

V. **NSF-wide Coordination Group**
Treaty conference convened every four years
Just completed; held in Egypt, Oct-Nov, 2019
Astronomy outcomes at WRC-19:
- 275 – 450 GHz protections for RAS from FSS/LMR
- Protection of 1610-1613 MHz
- Language for development of a recommendation for protection of RAS sites from 5G (especially at 24 and 42 GHz)
- RAS protections from HAPS (coordination distances required)
- Still ambiguous how RAS limits are treated from out-of-band emissions from nearby services
World Radiocommunication Conference
Key WRC-2019 Outcomes

- IMT (Mobile Broadband)
  - Identification in 24.25-27.25 GHz, 37-43.5 GHz
    - In-band and adjacent to radio astronomy frequencies
    - Further ITU documentation for protection to be developed
  - Modifications to numerous country footnotes adding IMT identification

- High-altitude platforms
  - Significant protections for radio astronomy (more strict than Recommendation ITU-R RA.739-2)

- 275-450 GHz terrestrial operation
  - 275-296 GHz, 306-313 GHz, 318-333 GHz and 356-450 GHz identified for land-mobile and fixed service applications
  - Means to protect radio astronomy assets indicated as necessary
World Radiocommunication Conference

Key WRC-2019 Outcomes

- GMDSS identification for Iridium system (1616-1626 MHz)
  - Out of band interference from Iridium system into OH maser band (1610-1613 MHz) noted for more than two decades
  - Significant discussion at WRC-19 revolved around resolving ongoing interference situation

- End result:
  - GMDSS operation allowed in frequency band 1621.35-1626 GHz
  - Restrictions on out-of-band emissions greatly strengthened
  - Radio astronomy limits incorporated into the radio regulations for emissions into the OH maser band
  - Several loopholes in compliance were fixed
The most challenging issues from a radio astronomy perspective were redirected to the WRC-27 agenda.

Issues of interest on WRC-23 agenda:

- IMT (Mobile Broadband) in 3300-3400 MHz, 3600-3800 MHz, 6425-7 025 MHz, 7025-7125 MHz and 10.0-10.5 GHz
- Use of high-altitude platforms for provision of IMT services in 694-960 MHz, 1710-1885 MHz, 2500-2690 MHz
- Sub-orbital vehicles (frequencies to be determined; of interest to NASA)
- More GMDSS
- Upgrade of SRS allocation in 14.8-15.35 GHz
- Review of frequency allocations for EESS (passive) in the frequency range 231.5-252 GHz
- Space weather sensors
World Radiocommunication Conference
WRC-27 Agenda

• Approaching cautiously; these issues may never be studied
• Items of concern:
  • New allocations and identifications to the radiolocation service in 275-700 GHz
  • ESIMs in 37.5-39.5 GHz (space-to-Earth), 40.5-42.5 GHz (space-to-Earth), 47.2-50.2
    GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space)
  • Fixed satellite service allocations in 43.5-45.5 GHz, 71-76 GHz, 81-86 GHz
  • Space-to-space inter-satellite links in 1525-1544 MHz, 1545-1559 MHz, 1610-1645.5,
    1646.5-1660.5 MHz, and 2483.5-2500 MHz
  • IMT studies in 1300-1350 MHz
Scientists use the entire spectrum but only 8.3 kHz to 275 GHz is regulated:

- **Radio Frequency Spectrum**: frequency region of the EM Spectrum that is managed via international and national laws and regulations

- Limited regulations in the near-infrared and optical region (e.g., laser coordination & safety standards)
What is coming?

• Constellations of thousands of NGSO satellites (10-50+ GHz transmitters) such that from any location you would always “see” at least one and up to 3 or 4 satellites or more!
• Mobile telecommunications (5G, IMT)
• High altitude platform systems
Optical image of NGC 5353/4 galaxy group (25 May 2019)

Image Credit: Victoria Girgis / Lowell Observatory

https://www.iau.org/public/images/detail/ann19035a/
Summary

- Keep protected *allocations* as RFI-free as possible
  - *Emissions may be prohibited at certain frequencies, out-of-band emissions can still be problematic*
    - New challenges above the regulated regime (above 275 GHz, into optical)

- Utilize technology developments and advancements to **increase** spectrum availability, esp. in strategic geographic locations
  - *Research in RFI excision techniques and receiver technology*
  - *Astronomy needs enhanced ESM geographical protections*
    – a new coordinated quiet zone for the upcoming decade (VLA has no quiet zone, NRQZ in WV does not protect from airborne emitters)

- **Coordination** – internal at NSF and external stakeholders
  - *Spectrum sharing*
  - *Costs must be considered; resources required for dynamic sharing*

- Educational opportunity - Increased awareness of the spectrum as a finite resource
Questions?

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Thank you
NSF Coordination Group on Electromagnetic Spectrum Management

Jim Ulvestad
Chief Officer for Research Facilities, Office of the Director

Jonathan Williams
Coordination Group Chairman

NSF Coordination Group includes representation from

- Mathematical and Physical Sciences
- Geosciences
- Computer and Information Science and Engineering
- Engineering
- Biological Sciences
- Social and Behavioral Sciences
- Education and Human Resources
- Office of the General Counsel
- Office of International Science and Engineering
Allocations and Coordination

- Radio Regulations:
  - (1) International (ITU-R Radio Regulations; [www.itu.int](http://www.itu.int))
  - (2) Regional (bilateral agreements)
NSF ESM Unit Activities

- Represent NSF as a Federal Agency to the National Telecommunications and Information Administration
  - 10 subcommittees including
    - IRAC
    - FAS (NRQZ coordination)

- Representation on official U.S. Delegations to the Inter-American Telecommunications Commission (CITEL) of the Organization of American States (OAS)

- Representation on official U.S. Delegations to the International Telecommunication Union’s World Radiocommunication Conference (WRC 2019), including leading 7D – Radio Astronomy
NSF ESM Unit Activities

- At NSF – Coordination with other Directorates and Divisions with spectrum needs, and manage spectrum related grants portfolio, including the National Academies of Sciences Committee on Radio Frequencies (CORF)

- Coordinate with other US Agencies, especially science agencies

- Interface with commercial interests to advocate for their taking “practicable” steps to not cause interference to passive services
JWST plans to use the Ka-band downlink...

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