

COMMITTEE ON RADIO FREQUENCIES (CORF)



*The National
Academies of*

SCIENCES
ENGINEERING
MEDICINE



Radio frequencies are important to observe

Light is emitted by a range of objects and phenomena at radio frequencies with specific values set by the laws of nature. These signals provide information on the temperature, composition, and motion of oceans, clouds, soil, forests, and celestial objects. Many scientific observations using the radio spectrum involve “passive use”– requiring no active transmissions, just the collection of data.

Passive radio observations provide critical benefits, such as:

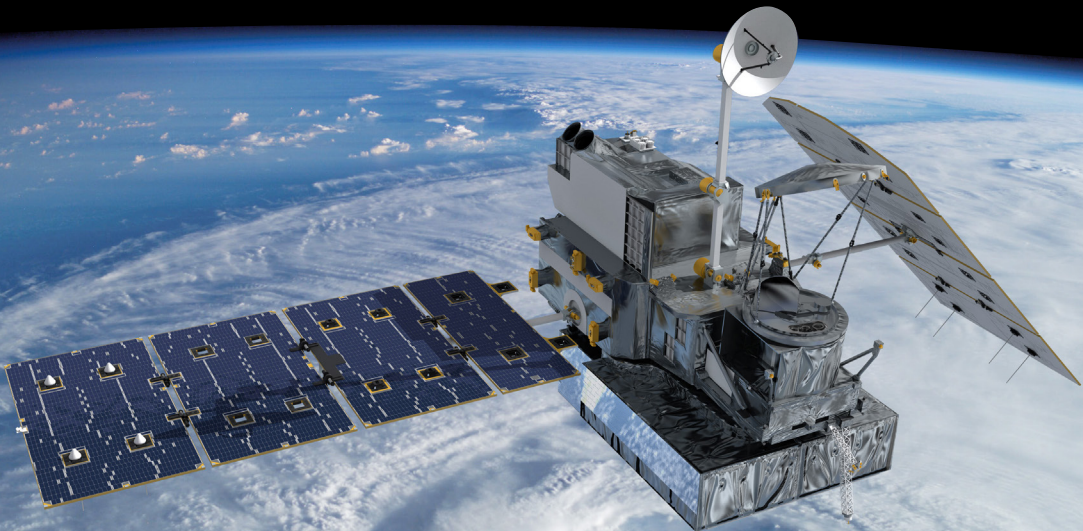
- Continued and improved weather prediction and disaster monitoring
- Increased understanding of humanity’s place in the universe
- Advances in technological development in receiver design and signal processing

Radio Astronomy: Looking outward

- The Radio Astronomy Service (RAS) frequency allocations are used to investigate the Universe, to examine the possibility of life in other solar systems, and to explore matter in extreme environments.
- Radio astronomy observations revealed the first image of a black hole, discovered the first planets outside our solar system, and provided images of the imprint of structure in the early universe.
- Ground-based radio telescopes around the world represent billions of dollars of government and private investment.

Earth Measurements: Looking inward

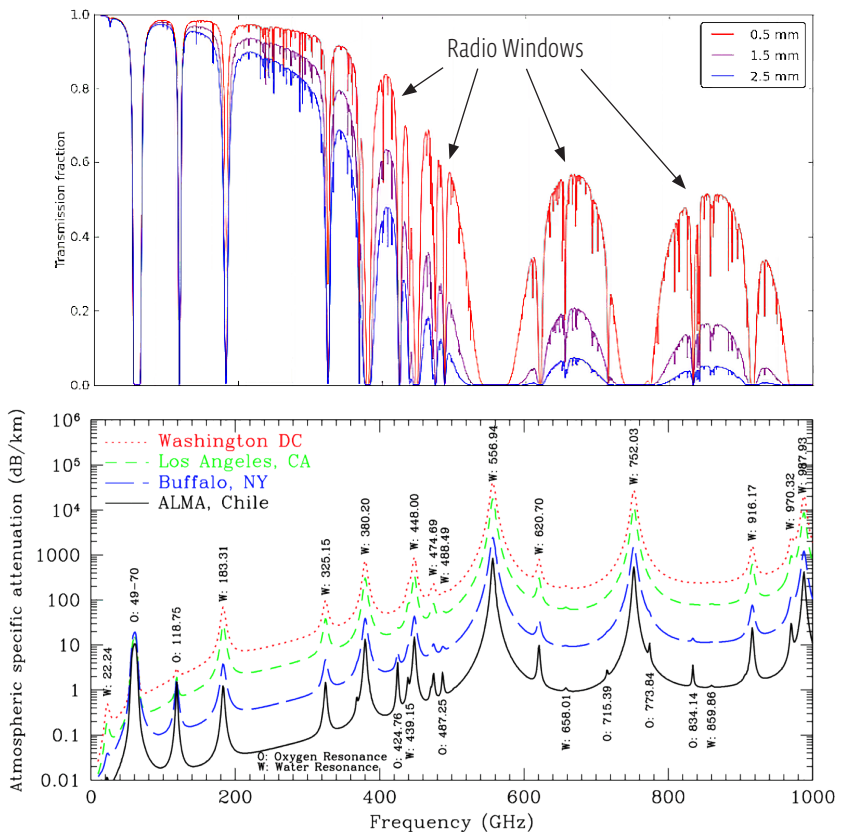
- The Earth Exploration-Satellite Service (EESS) uses radio observations from hundreds of instruments and satellites in orbit to monitor Earth's climate, weather, soil moisture, and ocean temperature.
- Measurements help forecast weather, monitor forest fires, estimate crop production, track dangerous storms, and assess climate change.
- The EESS provides data for NOAA, NASA, DOD, FEMA, USGS, USDA, and USFS on issues impacting hundreds of billions of dollars of the U.S. economy, including food, transportation, energy, and national security.





Access to the right frequencies is needed for successful radio observations

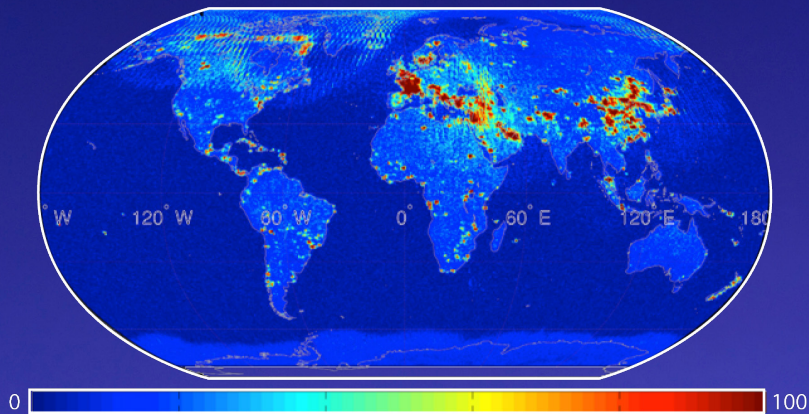
- Only certain ranges of frequencies can travel through Earth's atmosphere without being absorbed, and ground-based radio telescopes can only use those windows to study the universe.
- Radio frequencies observed range from 3 kHz to ~ 1 THz. Currently, only 1.4% of spectrum below 5 GHz – the frequency range where there has been the most commercial development – is allocated on a primary basis for passive measurements.
- Earth-observing satellites can use only specific frequencies to study water vapor, oxygen, and other components that are critical for making measurements of Earth's surface and atmosphere.



Atmospheric transparency (top) and absorption (bottom) enable study of cosmic sources and properties of the Earth's surface and atmosphere. The top panel illustrates which frequencies are able to make it through the atmosphere to be studied (the "radio windows"), while the bottom panel shows the counterpart: the frequencies most absorbed by the atmosphere due to oxygen and water vapor. Atmospheric conditions are highly variable and depend on the combination of temperature, humidity, and elevation. Shown in the bottom panel are conditions for a humid summer day (red), a "standard" atmosphere (green), a cold winter day (blue), and a high elevation site (black).

Crucial radio astronomy and Earth measurements need protection from radio frequency interference (RFI)

- Passive radio observations involve collecting extremely weak signals from naturally occurring phenomena. These signals are many orders of magnitude weaker than those generated by humans, which means they can be easily drowned out by active transmissions at nearby frequencies.
- Transmissions from human-made sources can overlap with the frequency bands being monitored by passive sensing and cause interference that can result in permanent loss of information, limit the utility of observations, generate erroneous scientific results, and damage instruments.
- The increasing demand for commercial use of the spectrum and the potential development of commercial applications at higher (millimeter wave) frequencies mean that vigilance is needed to protect passive EESS and RAS. When assessing spectrum demand, it is important to note that passive use is still use.



RFI experienced by the L-Band (1.4 GHz) Aquarius satellite sensor for estimating Earth's sea surface salinity and soil moisture. Red (100%) indicates total loss of data caused by surface transmissions.

Aside from prohibiting transmission on certain frequencies, RFI can be mitigated through:

- **Coordination of shared spectrum:** Most frequency allocations for passive scientific use are shared with active services, and coordination is needed for effective sharing. All passive users can share easily with other passive users of the spectrum.
- **Band separation:** Allocating a small bandwidth buffer adjacent to passive service frequency bands will reduce the effects of spurious emissions.
- **Geographic separation:** The combination of physical distance and natural geographic barriers between active transmitters and passive receivers will lessen their impact on scientific observations.
- **Technology solutions:** Modifying or adapting hardware and software for signal transmission or data collection can reduce the amount or effects of RFI.

The Committee on Radio Frequencies (CORF) of the National Academies of Sciences, Engineering, and Medicine represents the interests of U.S. scientists who use radio frequencies for research in the international and national regulatory process. CORF deals with radio-frequency requirements and protection primarily through filing comments in public proceedings of the Federal Communications Commission. The committee also acts as a channel for representing the interests of U.S. scientists in working groups of the Radio-communication Sector of the International Telecommunication Union (ITU-R). CORF is funded by NSF and NASA.

Learn more about CORF's work by visiting our website at nas.edu/corf and by downloading our reports:

Handbook of Frequency Allocations and Spectrum Protection for Scientific Uses: Second Edition - nap.edu/21774

Spectrum Management for Science in the 21st Century – nap.edu/12800

The National Academies of
SCIENCES • ENGINEERING • MEDICINE

The nation turns to the National Academies of Sciences, Engineering, and Medicine for independent, objective advice on issues that affect people's lives worldwide.

www.national-academies.org