Radio Frequency Spectrum, Interference and Satellites Fact Sheet

Updated June 25, 2013

Main Author: Brian Weeden, bweeden@swfound.org

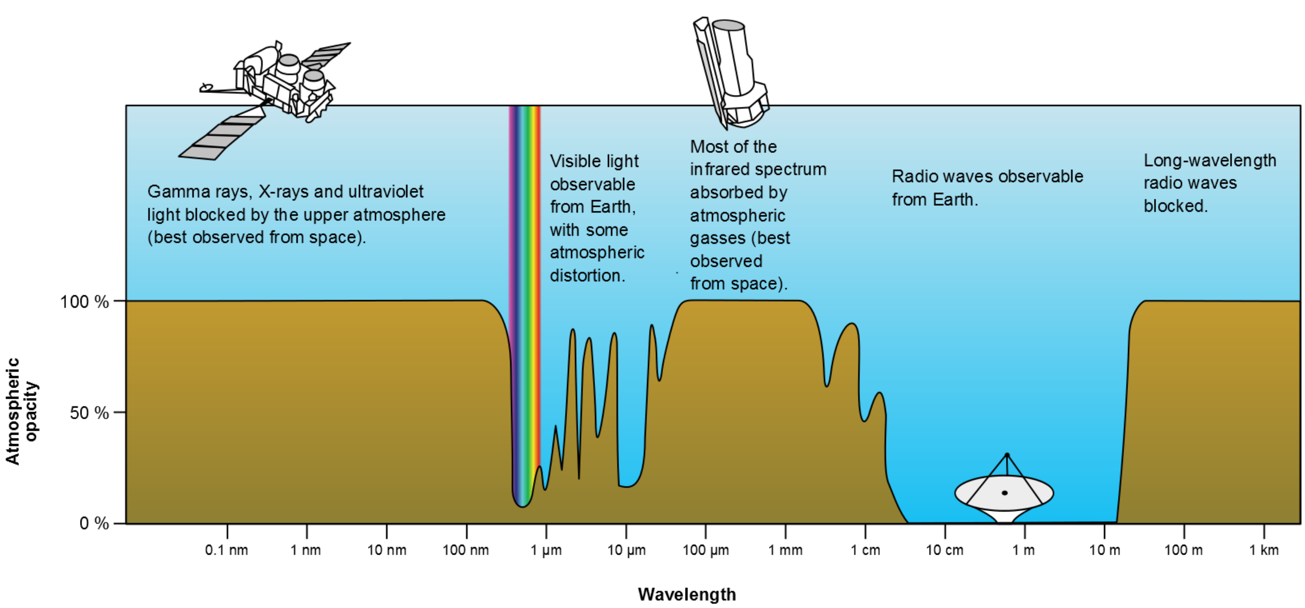
www.swfound.org

Summary

The radio frequency (RF) spectrum is a critical component of space activities. Nearly every satellite uses some portion of the RF spectrum to communicate with the ground or other satellites. As the RF spectrum is a limited natural resource, the increase in the number of terrestrial and space users leads to RF congestion that could result in unintentional radio frequency interference (RFI). Natural events such as space weather can also create RFI, as can intentional activities such as jamming. Management of the RF spectrum is a complicated policy issue, with various entities at the national and international level providing oversight and coordination. With a growing number of space actors and reliance on space, RFI is a significant challenge for ensuring space sustainability and security.

The Electromagnetic Spectrum

Radio frequencies are part of the electromagnetic (EM) spectrum, the range of all possible frequencies of electromagnetic radiation. The EM spectrum ranges from very high frequency, short wavelength radiation such as x-rays through very low frequency, long wavelength radiation such as radio waves. A significant portion of the EM spectrum is absorbed by Earth's atmosphere, greatly diminishing or even blocking these frequencies. Visible light, the only portion of the EM spectrum detectable by humans, and shorter radio waves are parts of the EM spectrum not absorbed by the Earth's atmosphere, making them ideal for space to ground transmissions.



Plot of Earth's atmospheric transmittance (or opacity) to various wavelengths of EM radiation.[1]

Basic RF Concepts and Terminology

RF energy, like other parts of the EM spectrum, is identified by either its ***frequency (Hertz or Hz)*** or ***wavelength (meters)***. The two concepts are inverses: as frequency goes up wavelength goes down (and vice versa). The ***power*** or strength of an RF signal is often measured in ***Watts***.

A specific portion of RF spectrum is known as a ***band***, and often will have a certain letter or name designated to it. Common examples are the AM and FM band used in terrestrial radio broadcasts. Within a band, a slice of spectrum is referred to as ***bandwidth***. For example, if a signal is transmitted between 300 Hz to 325 Hz of spectrum it is said to have a total of 25 Hertz of bandwidth. Bandwidth can also be used to describe how much information a signal can carry within a certain timeframe, which is a function of the frequency being used, the power of the signal, and the amount of noise in the band.

RF transmission and reception requires an ***antenna,*** a passive device that converts electrical energy in a circuit to radio energy that is broadcast or vice versa. The ***gain*** of an antenna is a measure of how well it can amplify the signal either received or transmitted in a certain direction. Gain is usually measured in ***decibels (dB)***, a way of measuring quantities that can vary by large amounts. An antenna with a gain of 3dB is capable of doubling the power of a signal.

A ***parabolic dish*** is one type of antenna commonly used for receiving satellite signals because of its high gain. A parabolic dish reflects RF energy hitting its curved surface and concentrates it at a single point, resulting in a much stronger signal. Broadcast communications satellites frequently use ***transponders***, which are circuits that receive signals over one or more uplink frequencies and rebroadcast them over one or more downlink frequencies.

Common Radio Frequency Band and Applications

There are certain RF bands that are commonly used for specific applications. This is due to RF bands having unique properties that result in advantages and disadvantages for particular uses.

Band Name			Frequency (ITU)	Common Uses	
ITU	NATO	IEEE		Space	Ground
Very High Frequency (VHF)	A Band (0-250 MHz)	VHF	30MHz to 300MHz	satellite uplinks	analog TV
Ultra High Frequency (UHF)	B Band (250-500 MHz) C Band (500-1000 MHz)	UHF (300-1000 MHz) L Band (1-2 GHz) S Band (2-3 GHz)	300MHz to 3000MHz	Mobile Satellite Services satellite navigation signals	analog TV, 2-way radios, cordless phones, WiFi, Bluetooth, mobile phones
Super High Frequency (SHF)	F Band (3-4 GHz) G Band (4-6 GHz) H Band (6-8 GHz) I (8-10 GHz) J (10-20 GHz) K Band (20-30 GHz)	S Band (3-4 GHz) C Band (4-8 GHz) X Band (8-12 GHz) Ku Band (12-18 GHz) K Band (18-27 GHz) Ka Band (26.5-40GHz) V Band (40-75 GHz) W Band (75-110 GHz)	3GHz to 30GHz	Fixed Satellite Services Broadcast Satellite Services satellite uplinks and downlinks	weather radar amateur radio imaging radar air traffic control
Extremely High Frequency (EHF)	K Band (30-40 GHz) L Band (40-60 GHz) M Band (60-100 GHz)		30GHz to 300GHz	inter-satellite links military survivable satcom	microwave data links active denial system

Regulation of RF Spectrum Used by Satellites

A complex regulatory framework has been created to manage the RF spectrum because it needs to be shared by many different applications and users. At the international level, the International Telecommunication Union (ITU) is the competent body for the management of the RF spectrum, including for space applications. The ITU Convention recognizes the RF spectrum and specific orbital regions as limited resources and provides for their efficient and economic use, and equitable access.

Allocation of a frequency band designates its use for specific space or terrestrial applications. The ITU allocates frequencies either globally or in one of the three ITU regions.[2] An allocated band can be further divided into ***allotments*** or channels that designate its use in one or more geographic areas. Nations that have acceded to the ITU treaty are required to designate an entity (public or private) as an ***administration*** to provide further oversight of the use of RF spectrum at the national level. Through ***assignment***, administrations authorize or license a specific terrestrial or space operator to use specific frequencies or channels for a specific use. Administrations This happens after a process of advanced publication, coordination, notification and recording procedures applying the so-called “first come, first served” principle. In the United States, the Federal Communications Commission (FCC) has broad authority to regulate RF spectrum and issue licenses for non-governmental users and the National Telecommunications and Information Administration (NTIA) does so for governmental users.

An example of how this system works can be seen in geostationary Earth orbit (GEO), where many communications satellites reside. Satellites in GEO are all orbiting in close proximity to each other and many use the same or similar frequencies. To help reduce unintentional interference, the ITU has allocated specific frequency bands for specific services. For example, the ITU has designated 14.0 to 14.5 Ghz for uplink to satellites providing fixed-satellite services (FSS) and 10.7 to 12.7 Ghz for FSS downlinks.[3]

Unintentional and Natural RFI

There are many ways in which other RF sources or natural events can interfere with or disrupt RF communications. Generating a RF signal is never a perfect process, and a signal always includes some power in frequencies other than the main one. A more powerful signal can drown out a weaker one, or two signals on the same frequency being broadcast near each other can make it difficult for a receiver to pick out the correct one. This can occur in the active GEO region if a transmitting satellite drifts past another transmitting satellite or a satellite has its transponders misconfigured. Unintentional RFI can also occur if a uplink antenna on the ground is pointed at the wrong satellite in orbit.

Another source of unintentional RFI can be the result of overlap or interference between signals used to communicate with satellites and those used for terrestrial networks such as mobile phone systems. As the demand for high-speed wireless networks grows, a growing number of countries are looking to repurpose or share spectrum originally allocated to satellite communications with terrestrial applications. This is extremely challenging to do, as even terrestrial signals next to a satellite RF band can create problems by raising the signal-to-noise ratio or spilling over into the satellite band, either of which makes it harder to receive the satellite signal. Nature can also interfere with satellite communications. Transmissions in certain frequencies such as Ku and Ka bands can experience interference from heavy rain or snow. Energetic particles and radiation from the Sun, especially during solar storms, can create periodic outages or even permanently damage satellites.

Intentional RFI and Jamming

The growing importance of satellites for many applications, including national security, and the relative fragility of RF communications also leads to intentional RFI. Many countries have developed devices and techniques for jamming or interfering with specific types of satellite communication. A number of militaries are adopting these techniques as a way of denying or degrading an adversary's ability to use space capabilities. As part of so-called temporary and reversible means, intentional RFI is seen by some to have advantages over alternatives such as physical destruction of satellites or ground stations for counter-space applications. Global Navigation Satellite Services (GNSS) such as the U.S. military's Global Positioning System (GPS) are especially vulnerable to jamming due to their relatively low power signal. GPS jammers can be easily found on the Internet, are beginning to spread to non-military users and are starting to impact commercial and civil users of GPS.

Example of a commercially available GPS jammer[4]

Some countries consider satellite broadcasts into their territory a violation of their sovereign rights, especially if those broadcasts carry political or cultural messages with which they do not agree. As a result, some attempt to selectively jam certain transmissions to prevent those broadcasts. While jamming is technically a violation of the ITU Convention, the ITU lacks enforcement mechanisms to prevent or penalize it. Thus far the international community has been unable to create sufficient political will to create or implement such enforcement mechanisms, though it is increasingly a topic of discussion in international fora.

Endnotes

1. Wikipedia. Electromagnetic spectrum. Retrieved from: http://en.wikipedia.org/wiki/File:Atmospheric_electromagnetic_opacity.svg
2. Frequency Allocation Table. (2010, October). SMS4DC Training Seminar. Retrieved from: http://www.itu.int/ITU-D/asp/CMS/Events/2010/SMS4DC/SMS4DC2_AllocationsV2.pdf
3. ITU Radio Regulations, 2012 Edition. Retrieved from: http://www.itu.int/pub/R-REG-RR/en
4. Brandon, J. (2010, March 17). GPS jammers illegal, and very easy to buy. *Fox News*. Retrieved from: http://www.foxnews.com/tech/2010/03/17/gps-jammers-easily-accessible-potentially-dangerous-risk/

Additional Resources

Stine, J.A. & Portigal, D.L. (2004, March) Spectrum 101: An introduction to spectrum management. MITRE Corporation. Retrieved from: http://www.mitre.org/work/tech_papers/tech_papers_04/04_0423/04_0423.pdf