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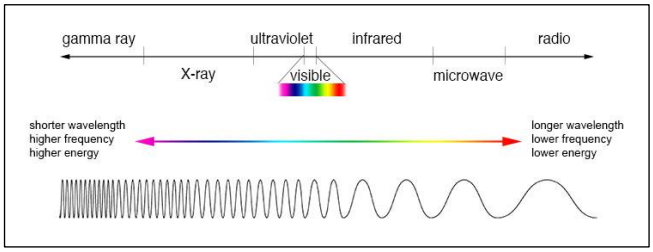
Defense Primer: Military Use of the Electromagnetic Spectrum

Since the introduction of the two-way radio in the early 1900s, militaries have been interested in the electromagnetic spectrum ("the spectrum"). The proliferation of spectrum-dependent systems in all military domains—air, land, sea, space, and cyberspace—along with Department of Defense (DOD) concepts, such as net-centric warfare and multidomain battle, increases the military's dependence on the spectrum.

What Is the Spectrum?

The electromagnetic spectrum is a series of frequencies ranging from radio waves to microwaves, visible light, X-rays, and gamma rays. As the wavelength of the electromagnetic radiation shortens, the waves have a higher frequency—how quickly electromagnetic waves follow each other—and therefore more energy.

Figure 1. The Electromagnetic Spectrum



Source: https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html.

Different parts of the spectrum serve different military purposes. Radio transmissions have relatively low data rates—particularly in the very low frequency range. However, they are able to travel long distances and pass through solid objects like buildings and trees, and are often used for communications equipment. Microwaves have higher throughput—data upload and download rates—than radio waves and therefore are able to transmit more data, but are more limited in range and can be disrupted by solid objects. Hence, microwaves are often used for radars and satellite communications. Infrared waves, which emit energy, can be used for intelligence and targeting data because they are closely associated with heat sources. X-rays are routinely used for aircraft maintenance to identify cracks in airframes. Finally, gamma rays are high-energy radiation and help identify potential nuclear events. The following discussion focuses on the DOD's use of the radio wave, microwave, and infrared aspects of the spectrum.

Applications of the Spectrum

The military uses the entire spectrum to support intelligence and military operations. These applications range from using very low frequency radio waves to communicate with submarines underwater, to microwaves as a continuous datalink between aircraft, and to lasers in the infrared and ultraviolet ends of the spectrum to dazzle satellite sensors and destroy drones. The majority of military communications capabilities use radio waves, microwaves, and infrared frequencies. Nearly every modern weapons system—airplanes, satellites, tanks, ships, and radios—depends on the spectrum to function. These applications can be combined to provide an overall military capability, such as command and control or electronic warfare. The following discussion provides a few examples of spectrum applications.

Communications

Military commanders have become accustomed to communicating with their forces near-instantaneously. Communication includes a range of options from low bandwidth options, such as transferring small strings of text, to high data-intensive applications, such as full motion video and video teleconferencing. Radio frequencies are the primary mechanism to transmit this data. These systems can be located terrestrially (either with ground forces or on ships), in the air, or in space (i.e., on satellites). In general, communications systems use radio and microwave frequencies; however, emerging communications technologies use lasers—transmitting light, instead of radio waves, between antennas. Radios use different frequencies depending on the range and amount of data they are required to transmit. Ground-based radios are typically used at short ranges, limited by the line of sight. These short ranges span no more than 50 miles. In general, militaries use satellites to communicate over longer distances.

Situational Awareness

Another application of the spectrum is using radio or microwave frequencies to develop a picture of the battle space by providing the location of friendly and enemy forces. The most common application is radar, however recently light detection and ranging (LIDAR) systems are also used. Both technologies send out a signal that is then reflected back to sensors to determine the distance, speed, and potentially altitude of an object. Radars operate on different radio and microwave frequencies, depending on their purpose. Lower-band frequencies provide a larger picture of the battle space, although, due to the amount of clutter or radar return (how much radio signal is returned to the radar), these systems are not able to provide target-quality pictures. Higher-band frequencies provide target-quality pictures, yet lack the same effective range. Radar and LIDAR systems are commonly associated with air defense, military aviation, artillery, and space systems.

Signals intelligence (SIGINT) systems primarily collect spectrum emissions. These passive systems—systems that do not emit their own signal—can listen to radio and radar

frequencies or observe heat signatures of personnel, missiles, aircraft, artillery, and vehicles.

Other Applications

Militaries use the spectrum to target and potentially attack adversaries. Missiles in general, and anti-air munitions in particular, use either infrared or radar for terminal guidance (i.e., guiding a missile once it has been launched) to targets. Electronic jammers are used to deny an adversary access to the spectrum. These jammers are primarily used in the radio and microwave frequencies (and sometimes paired together), preventing communications (both terrestrially and space-based) as well as radar coverage. Militaries have also begun using lasers to disable intelligence collection sensors, destroy small unmanned aerial systems (aka "drones"), and communicate with satellites.

Types of Spectrum Operations

Numerous military operations use the spectrum. One type is command and control. Command and control (C2) uses all of these applications to develop a common operating picture and communicate the commander's orders. C2 is resourced according to a unit's size and mission focus, from a few radios and computers for platoon- and company-level operations to specialized satellites and aircraft for joint operations such as nuclear C2. Aircraft like the E-8C Joint STARS, use communications systems and radars to develop a picture of the battlespace to direct forces to their most effective positions for countering enemy forces.

Electronic warfare uses the spectrum to gain and maintain military access to the spectrum. SIGINT capabilities allow military forces to understand where adversary forces are located as well as what frequencies they use for communications and radars. This intelligence, called electronic support by the military, is then used to develop an operational plan to jam (i.e., attack an adversary's use of the spectrum) radio frequencies. Militaries can develop techniques to protect themselves from attacks using SIGINT capabilities on their own forces.

Low-observable weapons systems manipulate the spectrum to reduce their electromagnetic signature—such as radar return, radio emission, and even heat. This can be achieved by reducing radar signature, creating narrow radio beams to reduce the probability of detection, or reducing spectrum emissions entirely. A few examples of these design approaches include the Zumwalt-class destroyer, the B-2 Spirit and the F-35 Lightning II, and the AN/APG-81 active electronically scanned array radar.

Congressional Interest in the Spectrum

Congress has actively supported the deployment of fifth generation (5G) technologies, identifying spectrum used for 5G, and amending federal rules and regulations to facilitate deployment of infrastructure. The Federal Communications Commission is auctioning spectrum for 5G, which DOD currently uses for satellite communications and weather radars; these auctions would potentially eliminate DOD's ability to use these systems. DOD could use funds from these auctions, through the Spectrum Relocation Fund, to develop new technologies and relocate displaced technologies to new frequencies. DOD is investigating spectrum sharing applications, to allow commercial uses on traditional military frequencies.

Congress continually passes legislation through the annual National Defense Authorization Act (NDAA) affecting the military's use of the spectrum, particularly regarding governance, spectrum allocation, and electronic warfare. Recent NDAA actions include the following:

- **FY2019 NDAA.** Section 255 required DOD to perform an independent assessment of current electronic warfare plans and programs. Section 1053 directed the Secretary of Defense to establish process and procedures to "develop, integrate and enhance electronic warfare mission area and the conduct of joint electromagnetic spectrum operations in all domains across the Department of Defense and ensure that such processes and procedures provide for integrated defense-wide strategy, planning, and budgeting with respect to the conduct of such operations."
- **FY2020 NDAA.** Section 254 required DOD to develop a strategy and implementation plan for 5G systems. Section 265 required DOD to perform an independent assessment of current electronic warfare plans and programs, similar to the FY2019 section.
- **FY2021 NDAA.** Section 152 transferred the responsibilities of electromagnetic spectrum operations (EMSO) from Commander, United States Strategic Command to a responsible entity. Sections 1661-1664 prevent funding and direct an independent assessment of 5G use in the 1550 MHz band, potentially affecting the Global Positioning System.
- **FY2022 NDAA.** Section 378 directs the Secretary of Defense to review "current electromagnetic spectrum emissions control tactics, techniques, and procedures across the joint force." Section 907 directs the Secretary of Defense to designate a senior official to implement the Electromagnetic Spectrum Strategy. Section 1627 requires the Defense Intelligence Agency to provide a briefing on adversary electronic warfare capabilities.

CRS Products

CRS Report R46564, *Overview of Department of Defense Use of the Electromagnetic Spectrum*, by John R. Hoehn, Jill C. Gallagher, and Kelley M. Sayler

CRS In Focus IF11118, *Defense Primer: Electronic Warfare*, by John R. Hoehn

Other Resources

DOD. Electromagnetic Spectrum Superiority Strategy

DOD Directive 3610.01. *Electromagnetic Spectrum Enterprise Policy*

Joint Pub. 3-85 *Joint Electromagnetic Spectrum Management Operations*

GAO-21-64, *DOD Needs to Address Governance and Oversight Issues to Help Ensure Superiority*

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