Communication Subsystems on Spacecrafts

by

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Prior to launching a spacecraft into space, mission planners must determine which subsystems will be required to ensure a successful mission. Their list of optional subsystems to consider are lengthy and may include: structural, attitude control and sensing, propulsion, communications, command and data handling, power supply and distribution, thermal control, pyrotechnic, and landing. Scientific instruments can be considered its own spacecraft subsystem, too. Arguably, communication is the key to any successful space mission, therefore mission planners must rely on a robust communication subsystem.

When any space mission is in the works, there is an abundance of planning and designing. This is especially true when it comes to communications subsystems. There are numerous details that need to be considered. Braeunig (1999) explained the situation very well when he said, “Telecommunication components for a particular spacecraft are chosen in response to the requirements of the mission it will perform. Anticipated distances, planned frequency bands, data rates and available on-board transmitter power are all taken into account.” When discussing communication subsystems, a few aspects may require some explanation: high-gain antenna, low-gain antenna, medium-gain antenna, transmitter, receivers, and radio frequencies. Antenna gain refers to two things – directivity (which is the antenna parameter) and electrical efficiency. The gain just refers to how efficiently the antenna converts power into radio waves in a specific direction (Bevelacqua, n.d.). It’s common to have multiple antenna gains (high, medium, and low) on any spacecraft because they all function slightly differently and, let's face it, it’s always good to have a backup on board. High-gain antennas are strictly directional and usually are required to be pointed within a fraction of a degree of Earth. Low-gain antenna are omnidirectional but have lower data rates within several astronomical units. Medium-gain antennas are the real in-between of the three. It provides a better data rate than low-grain antenna and about 20 to 30 degrees wider angles of directional coverage when compared to high-gain antenna. A transmitter generates and amplifies the desired radio frequency from an antenna (commonly referenced as the downlink) where it is then sent to the receiver. The receiver then processes those radio frequencies (at this point in the exchange the frequencies are called the uplink) and converts them into something that we can understand. Often, the transmitter and receiver are combined into one device (Braeunig, 1999). On the electromagnetic spectrum, radio frequencies are at the lowest end with a range from 1 Hz to 3 THz. Regarding space communications specifically, the radio frequency range we use is about 30 MHz to 30 GHz and even then, there can be interruptions due to absorption. Within that range, it can be further broken down into bands: VHF (about 136 – 270 MHz), UHF (about 399.9 – 470 MHz), L (about 1.2 – 1.71 GHz), S (2.025 – 2.67 GHz), C (about 3.4 – 6.4 GHz), X (about 8 – 9 GHz), Ku (about 10.7 – 18.1 GHz), Ka (about 23 – 27 GHz). In order to minimize interference and overusage of any given frequency, designated frequency ranges are utilized for space communication. For example: the Russian ISS module uses 628 – 632 MHz while China uses 180 MHz for their weather satellite downlinks. Typically, amateur satellites use either 144 – 146 or 435 – 438 MHz. NASAs Deep Space Network (DSN) started on S band, moved to X band, and has since been using a combination of X and Ka band (Australian Space Academy, n.d.).

Looking at how far our communication technology has come is mind-blowing. Sputnik 1 (launched in 1957 by Russia) used two frequencies: 20.005 and 40.002 MHz - both of which transmitted pulses that were received on Earth in order to collect data on electron density in the ionosphere. The Signal Communications by Orbiting Relay Equipment satellite (known as Project SCORE) was launched by the US in 1958 and the first purpose-built communications satellite in orbit. It "consisted of a receiver, a transmitter, and a continuous-loop tape recorder capable of recording a message or playing one back for four minutes in total" (Wilcox & APPEL News Staff, 2015). There were four ground stations that were in communications with this satellite which gave each location the ability to issue commands to the spacecraft as well as relay a prerecorded or live message. While it only lasted three weeks in orbit, it was the first human voice broadcasted in space (Wilcox & APPEL News Staff, 2015). In 1960, the US launched Echo 1A (now known as Echo I). This was a vital step towards putting the US in the running for the space race. Echo 1A was just a giant metal balloon shaped spacecraft that was used to bounce signals off to receive somewhere else in the world. This successful project resulted in the first coast-to-coast telephone call using a satellite as well as advancing our understanding in atmospheric density, solar pressure, transmitting videos via satellite, and several other communication needs before reentering the atmosphere in 1968 (*50 Years of Communications in Space*, 2010). Fast forward to 1977 when NASA launched Voyager 1. Voyager 1 is equipped with a high-gain antenna that uses S band for uplink and X band for downlink. See the figure below that shows the high-gain and low-gain antennas patterns – specifically the gain and beamwidth values. Voyager 1 is said to probably run out of power by 2025 (*Voyager - The Spacecraft*, n.d.). Even more recently, the 2020 Mars Perseverance Rover is equipped with three different communication antennas: an ultra-high frequency (UHF) antenna, X band high-gain antenna, and a x band low-gain antenna. The UHF antenna allows data to be transmitted from Mars to Earth via orbiters. The high-gain antenna allows for direct communication between the two planets. And the low-gain antenna is used for receiving data since it is omnidirectional and does not require to be aimed (*Communications*, n.d.).

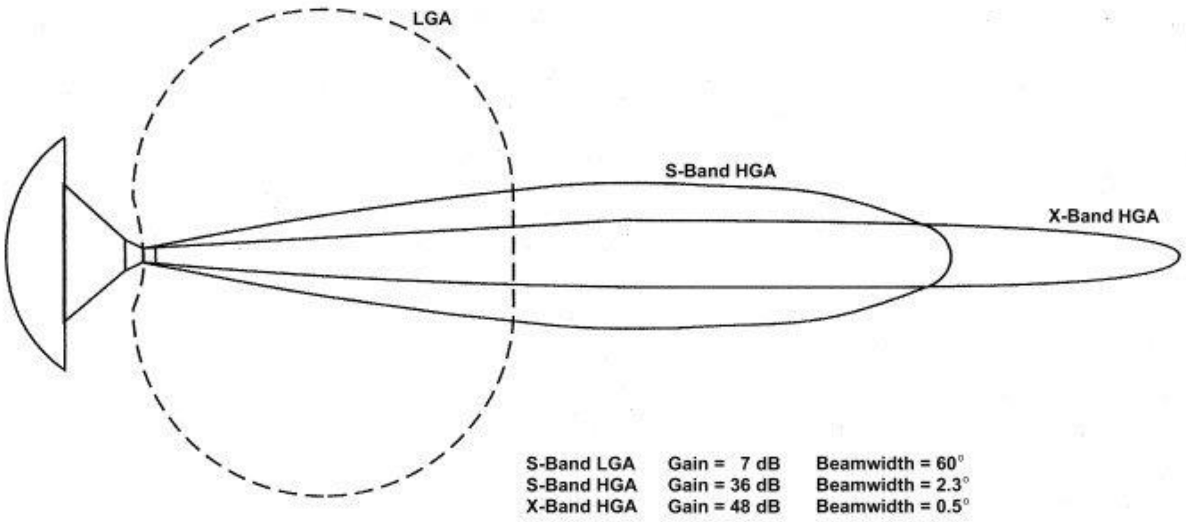

Image of Voyager beam patterns from DESCANSO—Spacecraft Telecom System Design (PDF)

While communication subsystems have come a long way since the beginning of the space age began, we still have ways to go. Our current advancement seems to be in the direction of lasers and SpaceFibre. Lasers (or optic communications) will allow us to pack in more data being sent at one time when compared to our current methods. According to O'Neill (2021), using lasers to transmit data would be 10 to 100 times faster. For example, with our current technology, it would take about nine weeks to send a full map of Mars to Earth but if we used lasers (with their boost of how much data can be transmitted), it would only take about nine days instead. SpaceFibre (the successor to SpaceWire) is an onboard network technology that is currently made in Europe. It runs via electric or fiber optic cables and is advertised as having a data rate improved by more than “10 times, reducing the cable mass by a factor of two and providing quality of service (QoS) and fault detection, isolation and recovery (FDIR) capabilities. Multi-laning improves the data-rate further to well over 40 Gbits/s” (*What Is SpaceFibre?*, 2021).

The communication subsystems on spacecrafts are critical and need to constantly be researched. This subsystem is a way of relaying data and information from virtually anywhere – even from outside of our solar system. Current technologies are phenomenal and awe-inspiring but imagine how much better we could make it if we continued putting in research efforts to this topic! Consider what we could do if we combined the data rates of SpaceFibre and the amount of data transmitted by lasers if we combined these two technologies. Our advances could be almost limitless.

Resources

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