Pre-Lab Reading: Geostationary Satellites

Introduction to Geostationary Satellites

Geostationary satellites are essential for global communications, weather monitoring, and military applications. Unlike satellites in low Earth orbit (LEO), which move across the sky, geostationary satellites remain fixed over a specific location on Earth by orbiting at the same angular velocity as the planet's rotation. This is possible only at a specific altitude where the satellite's orbital period matches Earth's sidereal day. To be truly geostationary, a satellite must orbit along Earth's equatorial plane (0° inclination). If the orbit were inclined, the satellite would appear to move in a figure-eight pattern in the sky. In this module, you will explore the physics behind this type of orbit and its role in modern communication systems.

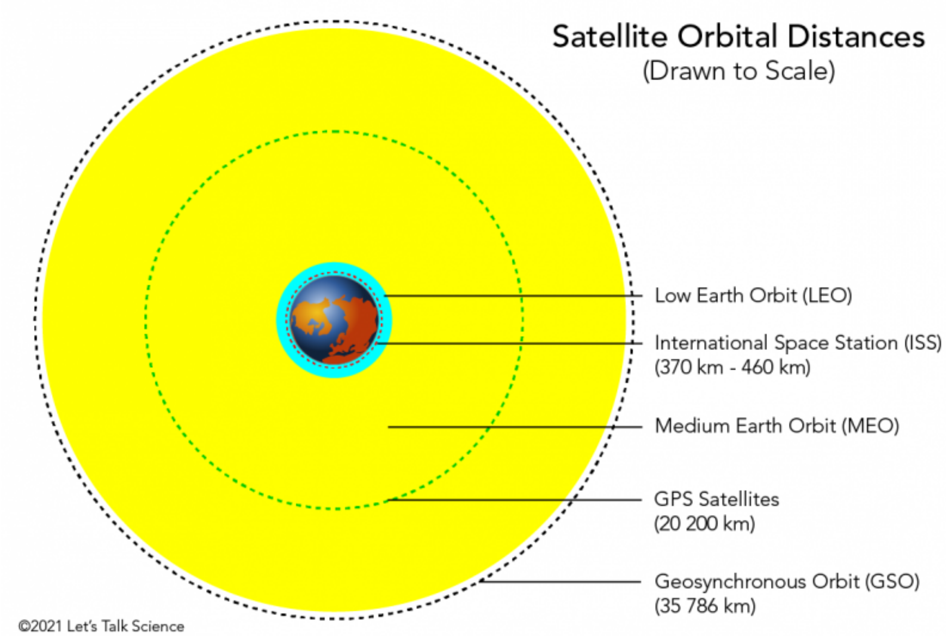

Figure 1: Diagram of different satellite orbits, including geostationary orbit.

How Geostationary Satellites Enable Global Communication

Geostationary satellites play an important role in global communications by acting as fixed relay points in space. Because they remain stationary relative to the Earth's surface, they can provide continuous coverage to specific regions. Signals sent from a ground station travel up to the satellite, which then retransmits the signal back down to another ground station or to another satellite. This enables long-distance communication, overcoming the curvature of the Earth that limits direct line-of-sight transmissions.

The satellite can beam signals down in a wide cone, allowing one transmission to cover an entire region. This is used for TV broadcasting, internet services, and weather data distribution. Some satellites communicate with other satellites in orbit using radio links. This allows data to be relayed from one satellite to another before reaching the final destination, extending coverage beyond a single satellite's range. A network of geostationary satellites can ensure continuous worldwide coverage, enabling international telephone calls, secure military communication, and real-time data transfer for remote regions.

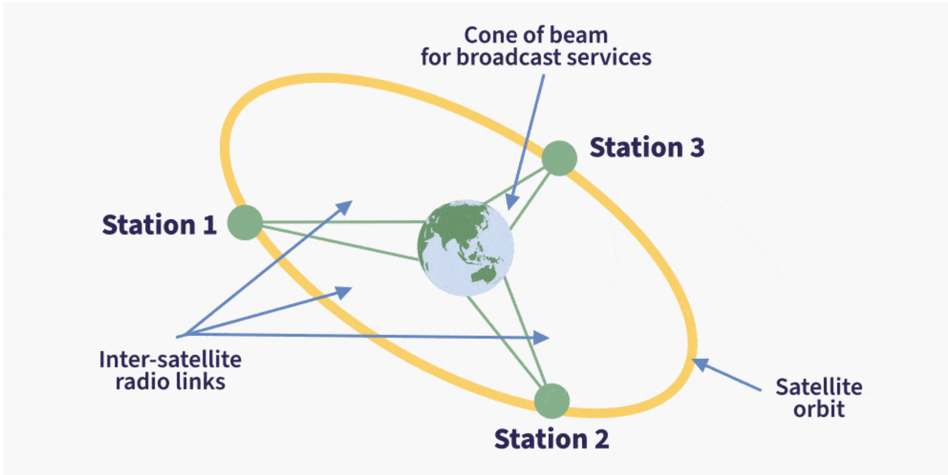

Figure 2: A geostationary satellite relay system extending global communications.

Understanding the Signal from GOES-17

In this lab, you will analyze a recorded transmission from GOES-17 (Geostationary Operational Environmental Satellite), a weather satellite operated by NOAA. The data was captured using the Allen Telescope Array, centered at 1.693 GHz. This signal consists of modulated radio waves carrying digital weather data used for forecasting and environmental monitoring.

A satellite transmission typically consists of:

- A carrier wave at a fixed frequency, which serves as the baseline signal.
- Modulated sidebands containing data, spread around the carrier frequency.
- A specific bandwidth, depending on the type of modulation and data rate.

By examining the structure of the received signal, you will infer properties such as its bandwidth and modulation type, which provide insight into how digital data is transmitted via geostationary satellites.

Digital Modulation and Data Transmission

To efficiently send digital information, satellites use modulation techniques that encode bits into radio signals. The modulation scheme determines how many bits can be transmitted per symbol and affects the bandwidth requirements. Common modulation types in satellite communications are shown in Figure 1:

The modulation scheme used in GOES-17's transmission allows for reliable data transfer while maintaining efficient bandwidth usage. By analyzing the signal, you will determine which type of modulation is used and how it impacts the transmission rate.

Digital communication systems use modulation to encode information into a radio signal. Modulation is the process of varying a property of a carrier wave—such as amplitude, frequency, or phase—to represent digital data. Each distinct state of the modulated signal is called a symbol, and each symbol carries one or more bits of information.

Modulation	Bits per Symbol	Bandwidth Efficiency
BPSK	1	Low
QPSK	2	Medium
8-PSK	3	High
16-QAM	4	Very High
64-QAM	6	Very High

Table 1: Common modulation types and their data efficiency.

The symbol rate (R_s) is the number of symbols transmitted per second, measured in baud. The bit rate (R_b) is the actual data transmission rate, measured in bits per second (bps). The relationship between symbol rate and bit rate is:

$$R_b = R_s \times k$$

where:

- R_b is the bit rate (bps).
- R_s is the symbol rate (baud).
- k is the bits per symbol.

Higher-order modulation schemes, like 16-QAM or 64-QAM, allow more bits per symbol, increasing data efficiency while keeping the symbol rate lower. However, they require higher signal-to-noise ratio (SNR) to be accurately decoded.

Preparing for the Lab

Before beginning the lab, ensure you have:

- Installed GNU Radio on your computer (see: `https://wiki.gnuradio.org/index.php/InstallingGR`).
- Downloaded the `GOES-17DATA` recorded data file.
- Reviewed the modulation types discussed in this pre-lab reading.
- Read through the lab manual to understand the steps you will perform.

By the end of the lab, you will have measured key properties of the GOES-17 signal and explored how real-world geostationary satellite transmissions function. These concepts are fundamental to satellite communications, weather data systems, and remote sensing.