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Tracking Subsystem in Satellite

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Abstract

The central nervous system and operating system of all satellite and spacecraft missions is called Satellite Telemetry, Tracking and Control (STT&C). Ground controllers can keep an eye on and manage the spacecraft's position, velocity, and location thanks to the tracking subsystem of the satellite. A key component of satellite TV for PC operations is tracking, which makes sure that satellites maintain their precise orbits and the right attitude to complete their tasks. To monitor and adjust satellite orbits and orientations as necessary, this requires a combination of ground-based tracking stations, telemetry data, and certain control systems. Additionally, data from sensors and satellite payloads are gathered using it. Various tracking methods might be employed based on the requirements of the task. It is first important to investigate ways to increase the GPS's navigation solution accuracy to augment the IRNSS with GPS. Satellite-receiver geometry, which describes the geometrical placements of the Navigation satellites observed by the GNSS receiver, affects the accuracy of the GPS navigation solution even while the delay problems caused by air layers and multipath are reduced. Doppler tracking, angle tracking, and distance tracking are a few popular tracking methods. This study evaluates the advancements achieved and the elements required for the design and execution of the tracking subsystem, encompassing significant satellite components.

Keywords: Tracking, attitude, subsystem, angle tracking, doppler tracking, and range tracking

INTRODUCTION

A key component of satellite TV for PC operations is tracking, which makes sure that satellites maintain their precise orbits and the right attitude to complete their tasks. To monitor and adjust satellite orbits and orientations as necessary, this requires a combination of ground-based tracking stations, telemetry data, and certain control systems. Satellites need to be precisely monitored for their position, orientation, and movement within an area to be utilized to the most extent possible. The Indian Regional Navigation Satellite System, which serves as the subcontinent's regional navigation system, is poised to revolutionize the Indian civil aviation industry. Any satellite-based navigation system's navigation accuracy is impacted by several issues, including clock drift errors, multipath errors, delay caused by refraction in atmospheric layers, and satellite-receiver geometry. Any regional navigation system can have its navigation solution accuracy increased by adding a global satellite-based navigation system, like the widely used and fully functional Global Positioning System or the Global Navigation Satellite System [1-3]. It is first important to investigate ways to increase the GPS's navigation solution accuracy to augment the IRNSS with GPS. Satellite-receiver geometry, which describes the geometrical placements of the Navigation satellites observed by the GNSS receiver, affects the accuracy of the GPS navigation solution even while the delay problems caused by air layers and multipath are reduced. Surveillance in satellite TV for PC technology is the ongoing tracking and management of a satellite's orbit and attitude to make sure it stays

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in the preferred function and has the potential to achieve project goals. This is a summary of tracking in operations right now:

Orbit Determination

A satellite's intended mission determines which orbit it should be in. Geostationary, low Earth orbit (LEO), medium Earth orbit (MEO), and various configurations are possible for these orbits. A satellite's orbit needs to be established and projected to be tracked. Onboard sensors, satellite GPS receivers, and ground tracking stations are used to do this. Ground control will calculate orbital parameters by continuously tracking the satellite's position, acceleration, and speed. The topic of discussion is GPS-Aided Geo Augmented Navigation (GAGAN) in India of the article presented by Ranjit Singh et al. [4].

Ground Tracking Stations

To guarantee constant satellite coverage, ground tracking stations are positioned strategically all over the world. To interact with the satellites and obtain telemetry data—which includes details about the satellite's performance, position, and health—these stations employ specialised antennas. Satellite operators can identify and track a satellite's position by combining signals from several ground stations. Geometric Dilution of Precision (GDOP) is a measure of the satellite-receiver geometry, and its monitoring is required to ascertain the accuracy of the navigation solution. The IGS Station, NGRI, Hyderabad (Lat./Long: 17.407430/78.526620) dual frequency GPS receiver data is gathered using SOPAC in the work of Raja Sekhar et al. [2] to conduct the necessary examination of the navigation solution accuracy using DOP, by choosing four optimal satellites. By considering both GPS and IRNSS satellite locations, this work can be expanded.

Attitude Control

In addition to tracking the position of a satellite in orbit, tracking also includes tracking its position or orientation. Satellites have sensors and thrusters on board that control their orientation and keep them in the right direction. Position tracking ensures that antennas, cameras, and other payload instruments are properly oriented to perform their functions. A Visibility Gap Analysis and a Phased Array Antenna layout with 13 panels have been considered to receive signals from GPS satellites as discussed in the study of Raghu et al [1]. The eight panels on the base of the PAA make an octagonal shape, while the remaining five panels on top form a pentagonal shape with the least amount of space above Bangalore. The PAA's geometry is hemispherical. Additionally, analysis has shown that for two days, a minimum of five and a maximum of eleven GPS satellites can be seen at a time after travelling over the hemispherical geometry of the PAA. Additionally, analysis has shown that for two days, a minimum of five and a maximum of eleven GPS satellites can be seen at a time after travelling over the hemispherical geometry of the PAA. With an azimuth of 45 degrees separated for the base panels and 60 degrees for the top, the Satellite Tool Kit has been employed for the analysis in which sensor objects have been taken into consideration in place of panels, covering the full 360 degrees. The software in the satellite tool set is used to visualise the satellite orbits around the Earth and to ascertain the satellite coverage patterns.

Telemetry and Telecommand

Tracking also includes communication with the satellite to receive telemetry data and send telecommands. Telemetry data includes information about satellite health, power status, temperature, and other parameters. Telecommands are instructions sent from the ground to a satellite to perform specific tasks, such as adjusting its orbit, changing its orientation, or reconfiguring its payload. Anyaegbunam [5] went on the fundamentals required for the planning and execution of TT&C, a crucial part of the suggested satellite subsystem. The functions and connections between different subsystems are highlighted, and the fundamental parts, design overview, and programming process of the TT&C subsystems are described.

Tracking Accuracy: Accurate tracking is essential to the success of satellite missions. Even small tracking errors can result in deviations from the planned orbit, which can affect communication, navigation and Earth observation capabilities. Satellite operators therefore use sophisticated tracking systems and algorithms to minimize tracking errors and ensure that the satellite remains in its designated orbital "box".

Orbit Maintenance

Spacecraft may gradually stray from their planned orbits because of atmospheric drag, gravitational pull, and other causes. For orbit maintenance, tracking and monitoring must be done continuously. Satellite operators can modify the orbit and move the satellite back to the intended location if necessary using the on-board propulsion systems. A new satellite-based navigation system called the Indian Regional Navigation Satellite System (IRNSS) provides independent location and timing services over India and its surrounding areas. Precise orbits for the first two inclined geosynchronous satellites (IRNSS-1A/B) have been established based on satellite laser ranging data gathered by a few International Laser Ranging Service (ILRS) stations. The IRNSS navigation messages are evaluated based on these orbits. The accuracy evaluation provided in the message itself is consistent with the confirmed Signalling-Space Range Error (SISRE) at the five-metre level. Although standalone navigation is not yet supported by the current three-satellite constellation, the results provide an initial indication of the navigation quality that customers can anticipate in the future [4]. Elements of Tracking Subsystem are shown in Figure 1.

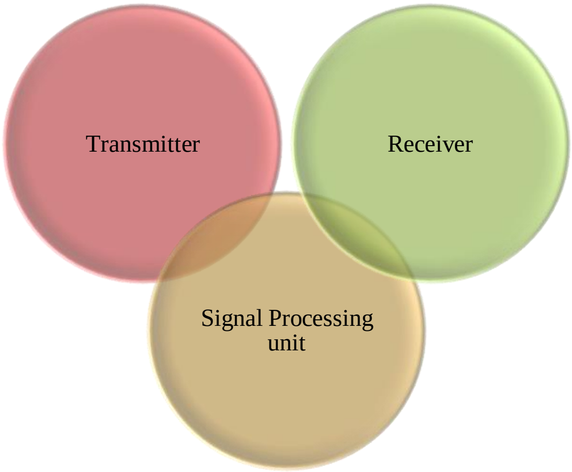

Figure 1. Elements of tracking subsystem.

TRACKING TECHNIQUES USED IN SATELLITE OPERATIONS

Angle Tracking

Angle tracking, sometimes referred to as angle-of-arrival tracking, is determining the angle at which satellite signals arrive at the antenna of a ground station. Specialised antennas, like parabolic dishes, that can be electrically guided to point at the satellite are used by ground-based tracking stations. It is possible to calculate the angle at which the satellite is seen by accurately determining the orientation of the antenna. Geometry used in determining the look angles for Geostationary Satellites is shown in Figure 2 and it’s related geometry in spherical form is shown in Figure 3. Angle tracking is crucial for satellite communication and is frequently used to track geostationary spacecraft. It makes it possible for ground stations to keep a straight line of sight with the satellite, guaranteeing steady and uninterrupted communication. The Phased Array Antenna [PAA] geometry presented in the study of Raghu et al [1] used the Satellite Tool Kit [STK] to analyse the Visibility Gap between the satellites and individual panels as well as the panels' constellation. Instead of using panels, this proposed design considered sensor items. The base panels' azimuth and elevation angles are 45° and 34°, respectively, covering the full 360°, 90° of elevation angle, and 0° of azimuth angle for the top panel. It does not cover anything below 10°. The satellite tool kit programme is used to visualise the satellite orbits around the Earth and to ascertain the coverage patterns of the satellites and sensors [7].

Look Angle Determination

The azimuth and elevation angles are the look angles for the ground station antenna. For the antenna to aim straight towards the satellite, they are necessary. When calculating look angles, the elliptical orbit is considered. The purpose of these angles is to track the satellite. These angle values are constant for geostationary orbit since the satellites remain stationary about the earth. Large earth stations are thus employed in business communications. Since the beamwidth of house antennas is rather wide, tracking is not necessary. This results in these antennas being anchored in place.

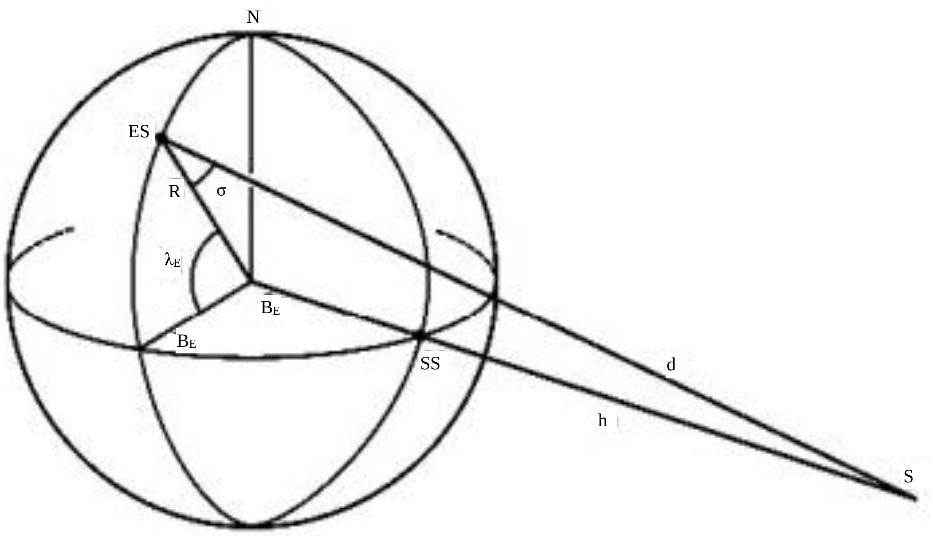

Figure 2. Geometry used in determining the look angles for geostationary satellites.

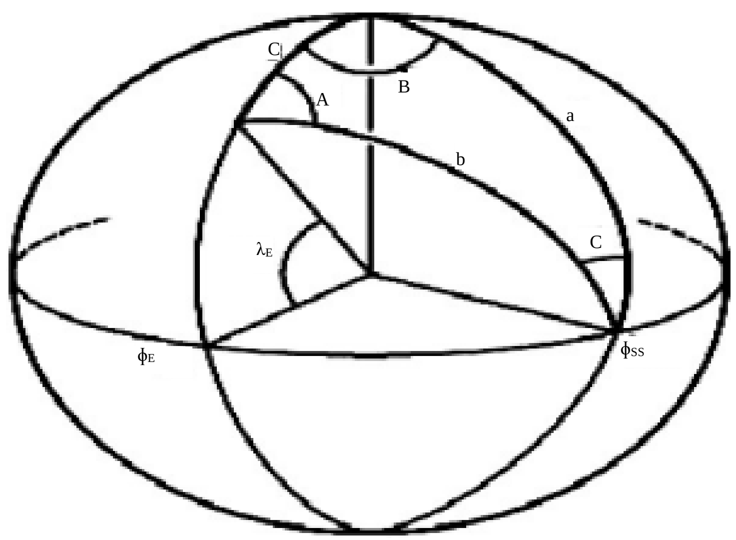

Figure 3. Spherical geometry related to Figure 2.

DOPPLER TRACKING

Doppler tracking is a technique used to determine the velocity and relative position of satellites. It involves measuring the Doppler shift in the frequency of signals received from the satellite. As the satellite moves along its orbit, the frequency of the signals it transmits changes due to the relative motion between the satellite and the receiving station. Ground stations use this frequency shift to calculate the satellite's velocity and relative position. Doppler tracking is widely used in satellite navigation systems like GPS. It helps determine a receiver's position on Earth based on signals from multiple satellites. It is also used for tracking spacecraft in deep space missions. Some satellites' transmission frequencies can be controlled from the ground. The method used involves the satellite locking onto a transmitter on the ground and then transmitting at a frequency that is a fixed ratio of the frequency that it receives. For satellites using the USAF SGLS (Satellite-Ground Link System), the ratio is 256/205. For example, SGLS Channel 9 has an uplink at a very precise and tightly controlled 1795.752 MHz, and the downlink is 2242.500 MHz. When tracking a satellite that is transmitting in this mode, the frequency often appears to change at a different rate than expected if the satellite was simply generating its own signal. This is because the signal reaching the ground from the satellite carries the combined Doppler effects of the relative movement between the ground station and the satellite, and between the satellite and the tracking station. Calculating the time of closest approach is more complicated when tracking a satellite in this mode. The location of the ground station needs to be known to subtract its Doppler effect from the received signal, so that a usable Doppler curve remains. The satellite transmits at a frequency that is a set ratio of the frequency it receives after locking onto a ground-based transmitter using the procedure. The ratio is 256/205 for satellites that use the USAF SGLS (Satellite-Ground Link System). For instance, SGLS Channel 9 has a downlink of 2242.500 MHz and an uplink of 1795.752 MHz, both of which are extremely controlled and exact. Tracking a satellite in this mode frequently results in frequency changes that appear to occur more quickly than they would if the spacecraft were just producing its own signal. This is since the signal that the satellite sends to Earth has the combined Doppler effects of the relative movements of the tracking station and the satellite as well as the ground station. Tracking a satellite in this mode involves more work in determining the time of closest approach. To leave a usable Doppler curve as shown in Figure 4 after deducting the ground station's Doppler effect from the received signal, one must know the ground station's location [8-10].

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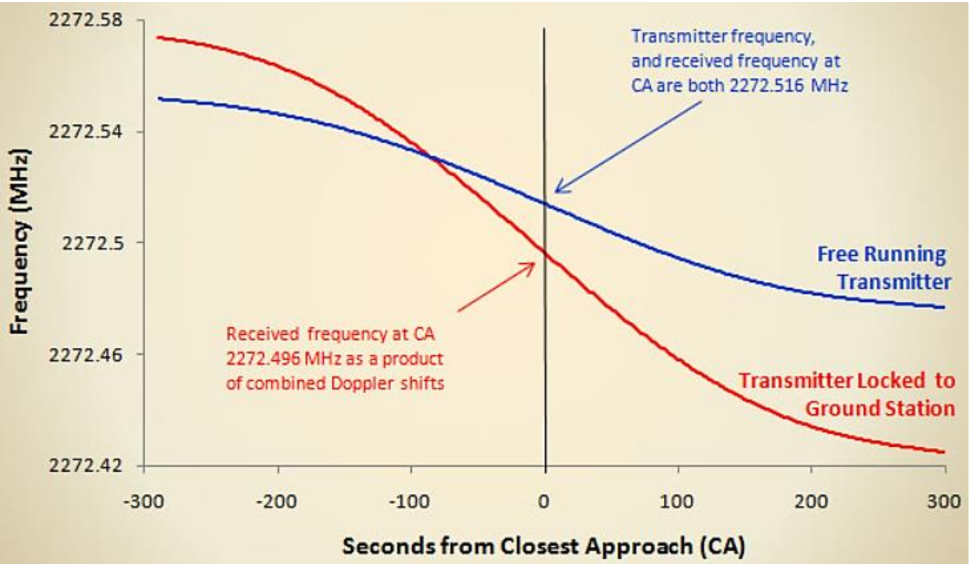

Figure 4. Doppler Curves- Free Running V Locked.

Range Tracking (Figure 5)

Regularly measuring the distance between a satellite and the Earth's surface is called ranging. The Satellite Control Center (SCC) generates a signal that is transmitted to the satellite. The satellite receives, repeats, and amplifies the signal before sending it back to the SCC. By knowing the delay time of the uplink, downlink, and satellite turnaround time, we can calculate the signal's speed in space. Using this information, we can determine the satellite's distance from Earth. The telemetry signals are modulated using FSK or PSK, and the Doppler Effect is used to measure the frequency and phase shift of the signal. This process is called "Satellite Ranging" and requires specialized equipment. Range tracking is shown in Fig.5. To ensure accuracy, time measurement is done using clocks with atomic precision. By using multiple ground earth stations (ES) to measure the distance of a satellite from ES, we can pinpoint the satellite's location in three-dimensional space, like how the Global Positioning System (GPS) works. SCC periodically performs Satellite Ranging to track satellites, which is called "Satellite Tracking."

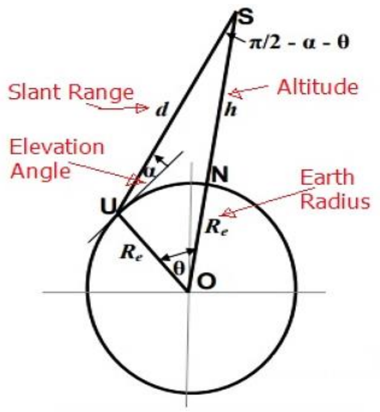

Figure 5. Range tracking.

DISCUSSION

The satellite communication compound has a source antenna that may be used for the business of navy ship satellite correspondence, duty, data, fixed position, and search for current information, among other things. It is difficult to fully aim at and follow the satellite when carrying out the actual navy ship body trip, which causes the signal to wander and prevent contact. Gang Yao provided a solution to the accuracy challenge by using engineering inference and real data collection to compute a method using Carl Man's mathematics to carry out the longitude exaltation. Quickly solve the follow longitude problem using the satellite solid; the realisation correspondence system converses with the function realisation.

CONCLUSION

Satellite tracking systems are essential components that enable satellites to function effectively and achieve their mission objectives. They play a crucial role in ensuring accurate positioning, optimizing data transmission and reception, maintaining safety, and extending a satellite's operational life. Advances in tracking technology have significantly enhanced the capabilities and reliability of satellites in various applications, such as communication, Earth observation, navigation, and scientific research.

Satellite tracking systems have been installed at SHAR, which are the first of their kind in India. These systems have provided tracking data that helped generate satellite ephemeris for Aryabhata. It's important to note that to achieve improved accuracy in tracking by electronic systems, the frequency of operation should be above 1 GHz. Additionally, a good calibration system for interferometry is essential.

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