Application of AsiaSat-3S satellite in CAPS system

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Abstract. CAPS is an integrated system of navigation and communication. The orbit position of AsiaSat-3S satellite has been pushed from 105.5E to 147.5E. It has become a SIGSO satellite, which plays a certain role in improving the constellation DOP of CAPS navigation system. According to the characteristic parameters of AsiaSat-3S satellite (mainly including orbit parameters, polarization parameters, frequency offset parameters, etc.), this paper expounds the changes of azimuth, elevation angle and polarization angle of 16-meter paraboloid antenna in Tianjin pointing and tracking AsiaSat-3S satellite in CAPS ground system, and analyzes the dynamic changes of frequency offset of AsiaSat-3S satellite transponder through the spontaneous receiving of navigation signals. The parameter model prediction of CAPS repeater navigation system has a good reference value.

1. Introduction
The signal of CAPS navigation system is sent from the ground station [1]. The pointing accuracy of the ground station antenna to the satellite (including three main parameters of azimuth, elevation and polarization) has a great influence on the pseudo-range measurement of the satellite navigation link. In this paper, the 16-meter paraboloid antenna in Tianjin of CAPS navigation system is used to track the direction of AsiaSat-3S satellite, and the uplink navigation signal link of CAPS is constructed [2]. The frequency offset of transponder is analyzed in the form of spontaneous receiving of navigation signal, so as to obtain the basic characteristic parameters of AsiaSat-3S SIGSO satellite comprehensively, which provides a good foundation for the construction of CAPS navigation system.

2. 16-meter Satellite Communication Antenna of CAPS Ground Station
The 16-meter antenna of CAPS satellite navigation communication has the communication characteristics of C + Ku compatibility, which can well meet the needs of a large number of C and Ku transponders used in navigation communication through AsiaSat-3S satellites, so as to build an anti-jamming repeater navigation system of multi-frequency navigation.

At present, the North-South drift of AsiaSat-3S satellite is about ±5° every day, and the drift speed is relatively fast every day. In order to obtain a stable navigation signal uplink, the 16-meter antenna of CAPS navigation system must have a stable and reliable satellite tracking foundation. Therefore, the 16-meter antenna servo system of CAPS has developed a mono-pulse tracking mode to direct to AsiaSat-3S accurately in real time [3].

Mono-pulse is in each beam, only need to be compared the same beam, you can get all the position information of the target, “mono-pulse” is the term evolved from this. The mono-pulse tracking
receiving system has the advantages of wide tracking frequency band, high accuracy and fast tracking. Figure 1 is the mono-pulse tracking pattern based on the sum and difference signal.

![Figure 1. The mono-pulse tracking pattern based on the sum and difference signal.](image)

3. Calculation of Main Parameters of Ground Station Antenna Directing to Satellite

Geosynchronous orbit communication satellites are all located above the Earth’s equator [4]. Only the longitude is different, the latitude is same. Taking the equator as the dividing line, the satellite antenna in the northern hemisphere faces south, on the contrary, the satellite antenna in the southern hemisphere faces north. In the northern hemisphere, the satellite antenna increases clockwise with zero degree in the north and 180 degree in the south. The azimuth angle is determined by the location of the ground station, and the calculation of the azimuth angle can be solved by the receiver. In the case of similar latitude, the smaller the difference between the local longitude and the satellite longitude in orbit, the larger the antenna elevation.

SIGSO satellite is no longer controlled in the north-south direction, which drifts at a certain angle in the north-south direction. At present, the North-South drift of AsiaSat-3S satellite is about ± 5.5 degrees, so the 16-meter antenna of the ground station needs to start the tracking mode to aim at the satellite in real time. According to the longitude and latitude of the ground station antenna and the longitude of the satellite, the azimuth (AZ), elevation (EL) and polarization angle (A_{pol}) of the antenna aiming at the satellite can be calculated, and the AZ and EL are used to adjust the antenna to aim at the corresponding satellite. For the linear polarization ground station, the polarization angle of the ground station antenna needs to be adjusted to match the polarization of the stationary satellite. For the polarization angle of SIGSO satellite, the satellite drifts in the north-south direction, and the polarization angle of ground station to SIGSO satellite is not a fixed value, which needs to be adjusted dynamically in real time.

Assuming that the latitude is \( \phi \) (north latitude is positive, south latitude is negative), longitude \( \lambda_c \) (east longitude is positive, west longitude is negative), satellite longitude \( \lambda_s \) (east longitude is positive, west longitude is negative), azimuth to north is zero, clockwise is positive, using the geometric relationship between the stationary satellite and the ground station, the azimuth (AZ) of the ground station antenna aiming at the satellite can be deduced from geometry and spherical trigonometry, The
calculation formulas of elevation angle \((EL)\) and polarization angle \((A_{pol})\) are given. When the ground station antenna is located in the northern hemisphere, the calculation equation is as follows:

\[
AZ = 180^\circ - \arctan \frac{\tan(\lambda_s - \lambda_g) \tan(\phi_s - \phi_g)}{1 + \tan(\lambda_s - \lambda_g) \tan(\phi_s - \phi_g)} \tag{1}
\]

\[
EL = \arctan \left( \frac{\cos(\lambda_s - \lambda_g) \cos(\phi_s - \phi_g) - \frac{R_e}{R_e - H}}{\sqrt{1 - \cos^2(\lambda_s - \lambda_g) \cos^2(\phi_s - \phi_g)}} \right) \tag{2}
\]

\[
A_{pol} = \arctan \left( \frac{\sin(\lambda_s - \lambda_g) / \sin(\phi_s - \phi_g)}{\cos(\lambda_s - \lambda_g) \cos(\phi_s - \phi_g)} \right) \tag{3}
\]

Where \(R_e\) -- the radius of the Earth (6378km); \(H\) -- the height of the synchronous satellite from the Earth surface (35786km).

4. Actual Measurement of Ground Station Antenna Aiming at Satellite

After the AsiaSat-3S satellite was transformed into a small inclination satellite, its motion characteristics changed greatly. Although it has a high accuracy in the east-west direction, it has a large range in the north-south direction. Since the space trajectory of SIGSO satellite is in the shape of "8" at the position of its sub satellite point, the azimuth, elevation and polarization angles of the ground station antenna aiming at the satellite will change with the change of satellite position.

CAPS satellite navigation system obtains the pseudo-range measurement datum for satellite orbit determination [1, 5]. The orbit determination data is obtained by fitting, so that accurate orbit information can be obtained at any time. According to the orbit information, it can be directly converted into the longitude and latitude of the satellite in equation (1)-(3). When the longitude and latitude of the ground station are known, the direction and polarization angle of the ground station can be calculated, and the real-time motion can be realized state adjustment.

![Figure 2. Azimuth\,Elevation\,Polarization value with time at CAPS ground station in Tianjin when accurately pointing to AsiaSat-3S satellite in 24 hours.](image-url)
As shown in Figure 2, the AsiaSat-3S satellite reached the southernmost position at 11:59 and the northernmost position at 23:44 on February 5, 2021, with a north-south drift angle of 9.56 degrees. The maximum polarization angle is 37.45 Deg at 0:56 AM and the minimum is 25.77 Deg at 16:15pm.

AGC level value directly reflects the accuracy of antenna aiming at satellite. In CAPS antenna servo tracking system, AGC level value of 0.2V corresponds to the received signal strength of about 1dBm. Figure 3 shows the variation of AGC value with time when accurately pointing to AsiaSat-3S satellite in one day.

![2021-02-05 AGC in 24 hours a day](image)

**Figure 3.** AGC value with time when accurately pointing to AsiaSat-3S satellite in 24 hours.

As shown in Figure 3, the AGC value ranges from 4.357 to 4.557 in the whole day, and the variation amplitude is 0.2V. The signal variation amplitude of CAPS ground station antenna pointing to AsiaSat-3S satellite in 24 hours a day is 1dB, which can well meet the stability requirements of navigation signal.

5. Frequency Offset of the Transponder in AsiaSat-3S Satellite

The conversion frequency of C-band on AsiaSat-3S satellite is 2225MHz, however there will be a certain deviation in local oscillator frequency. In order to better reflect the influence of AsiaSat-3S on uplink signal forwarding and improve the acquisition speed of the receiver for the transmitted signal, this paper calculates the vibration range of the conversion frequency of AsiaSat-3S satellite’s transponder. Figure 4 shows the frequency offset map of AsiaSat-3S C3H transponder in 24 hours one day.

As shown in Figure 4, there is a frequency deviation of 4.04KHz for 2225MHz local oscillator of AsiaSat-3S satellite transponder, which is centered at 4.04MHz at ± 561Hz frequency drift.
6. Conclusion
This paper introduces the pointing and tracking of the 16-meter Earth station satellite antenna of CAPS in Tianjin, and the frequency offset of the C3H transponder of AsiaSat-3S satellite. The North-South drift of the AsiaSat-3S of the SIGSO satellite increases day by day, and the amplitude has reached 10 degrees. The local oscillator frequency offset of the satellite transponder is about 4.04KHz ± 561Hz. The measured parameters are stable for the CAPS satellite navigation signal uplink broadcast initiated to good composition.

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