A STUDY ON QUASI-GEOSTATIONARY SATELLITE ORBIT (QGSO) SYSTEM

Rumiko YONEZAWA, and Isamu CHIBA
Mitsubishi Electric Corporation
5-1-1 Ofuna, Kamakura-city, Kanagawa 247-8501, Japan
E-mail : rumiko@isl.melco.co.jp

1. Introduction

Quasi-geostationary satellite orbit (QGSO) is commonly recognized as an orbit with a certain inclination generally more than 10 degrees. When the orbit is elliptical, the apogee point becomes very high and is sometimes referred to as HEO (High Earth Orbit). When the period of the satellite in this orbit coincides with that of the earth (approximately 24 hours), the ground trace of the satellite becomes as the shape of the figure 8, thus the orbit sometimes is called a “figure 8 orbit”. The satellites on this orbit travel from north to south according to its inclination, and from higher latitude regions, they could be observed easily than the ones in GSO. There are QGSOs with shorter period such as 16-hour and 12-hour period. When studying several types of QGSO system, one needs to be aware of the relation of the satellite period and the number of apogee points that appear on the surface of the earth. In this paper, we have studied the relationship between the satellite period, number of apogee points on appearing on earth surface and the necessary number of satellites when servicing 24 hours a day. Also, frequency sharing problem with the GSO is discussed in this paper from the viewpoint of separation angle.

2. Satellite Period and Number of Apogee Points

In a QGSO system, the velocity of the satellites appears to become slow near the apogee point, thus it is expected to be utilized based on the system of GSO. Therefore, when studying the system configuration of this orbit, one needs to determine the number of the apogee points at which the satellites would be operating. Here, when the number of the apogee points is Na, the following formula could be formed.

$$Te \times Nc \div Na = Ts \qquad (1)$$

Te is the period of the earth (app. 24 hours), Nc is the number of days necessary for the satellite to synchronize with the earth and Ts is the period of the satellite. Here, Nc and Na are integers that cannot be divided by a same integer other than 1. In other words, when Na=12, Nc is an integer other than 2 or 3. For example, when the following equation

$$Nc = Ncx \times a, \quad Na = Nax \times a \qquad (2)$$

is true, equation (1) could be expressed as follows.

$$Te \times Nc \div Na = Te \times (Ncx \times a) \div (Nax \times a)$$

$$= Te \times Ncx \div Nax \qquad (3)$$

and from this, the number of apogee points would become Nax which is different from the initially determined number Na. Also, for the satellite to synthesize with the earth, the number Ts must not be an infinite decimal.

To give 24 hours a day service towards a certain earth station, the necessary number of the satellites would be given from the equation below.

$$Te \times Nc \div To = Ns \qquad (4)$$

Here, To is the time of operation per satellite to give service to a certain area.

The above equations (1) and (4) are derived empirically.

3. Calculation Example

Here, we consider arranging the satellites in the longitude direction every 30 degrees, in which case the number of apogee points would be 12. As can be determined from the above equations, when Nc is set to 5, Ts would be 10 hours and the orbit altitude would be too high, so we will set Nc to 7. This means that a satellite in this orbit would be synthesizing with the earth every 7 days (1 week) and its period Ts would be 14 hours.

Figure 1 shows the ground trace of this satellite. The operation time of the satellite is set to 8 hours, and the area drawn in dark line is the period of time when the satellite is in operation. The parameters of this orbit are as follows,

Perigee height : 9000km, Apogee height : app. 37000km, eccentricity : 0.48

From fig.1, one can see that the operating satellite is distributed in the range of 30 degrees to 45 degrees north latitude. From equation (4), the necessary number of satellites in this case is calculated to be 21. That is, in a ratio of less than 2 satellites per apogee point are necessary, and from the viewpoint of the number of satellites per service area, it can be said that this system has an efficient property.

4. Frequency Sharing with GSO

In this section, the frequency sharing problem with the GSO system is studied. The interference of the Non-GSO (NGSO) towards the GSO earth station becomes worst when the NGSO satellite is on the line that connects the GSO satellite and the GSO earth station. This is because the interference source would be in the direction that the GSO earth station is oriented and this interference is called “in-line interference”. Normally, to avoid this in-line interference, the NGSO would be controlled to stop its transmission towards the GSO earth station when the NGSO satellite comes within 10 degrees from the orientation sight (separation angle) of the GSO earth station. This control is called GSO Arc Avoidance (GSO-AA) and the general view of the separation angle is shown in fig.2. In the present definition of the QGSO being a NGSO, the satellites in this orbit must have this control. We will examine the impact of this control against the look-angle property of this system. The terms of this examination are as follows,

(1) The satellite is observed from Tokyo.
(2) The longitude of the GSO satellite and the GSO earth station is the same with

that of the QGSO satellite.

(3) The latitude of the GSO earth station is from 20 to 80 degree north latitude (5 degrees step).

The ground trace of QGSO with 16-hour period is shown in fig.3. In this case, the satellite travels 48 hours to trace the ground on earth and during that period, three apogee points appear with 120 degrees spacing in longitude. When one of the apogee points is put above Japan, the other two appear above central North America and the midst of the Mediterranean. The time variation of the look-angle of the satellite seen from Tokyo is shown in fig.4. Here, 6 satellites are used with 8-hour operation time per satellite per apogee point. A sufficiently high look-angle can be realized in this case.

In the case when the interference towards the GSO system is considered, the time variation of GSO-AA separation angle is shown in fig.5 when the GSO earth station is within 20 and 80 degrees north latitude. From this figure, one can see that when the separation angle from the GSO satellite direction is small, it does not depend on the latitude of the GSO earth station. During the operation time-period (colored in gray in the figure), sufficient separation angle of more than 30 or 26 degrees could be achieved even when the earth station is in 80 degrees latitude north. Therefore, as long as 6 satellites are used in a 16-hour period QGSO system, there would be no problem in the in-line interference with the GSO system.

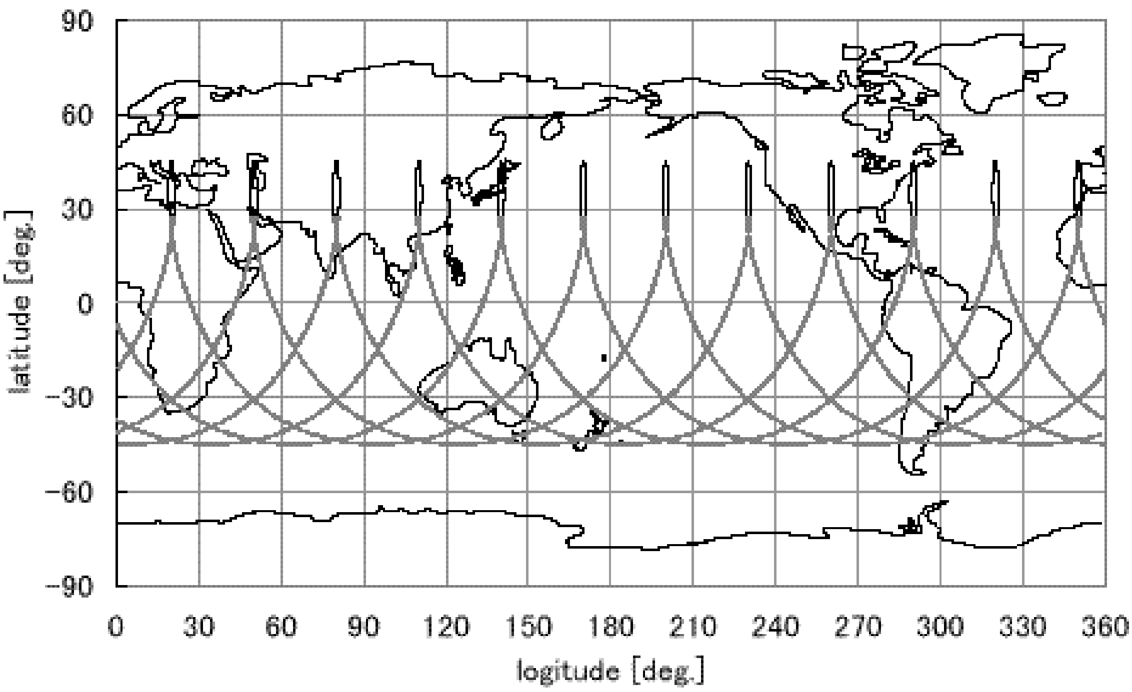

Fig.1 : Ground trace of a QGSO satellite with 14-hour period.

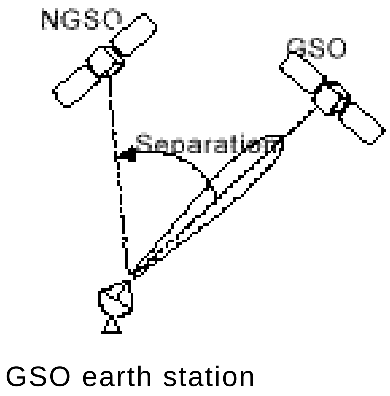

Fig.2 : Definition of the separation angle

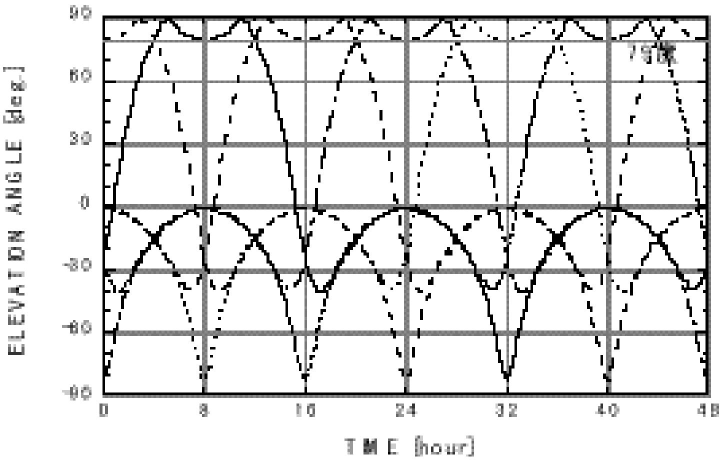

Fig.4 : Look-angle of the satellite observed from Tokyo.

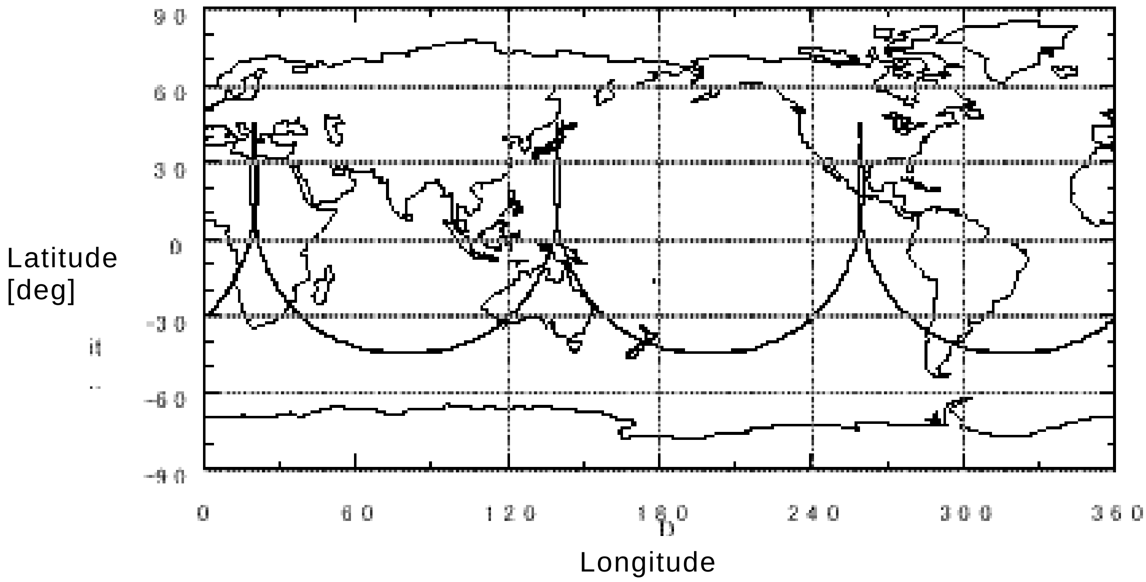

Fig.3 : Ground trace of the satellite in 16-hour period QGSO orbit.

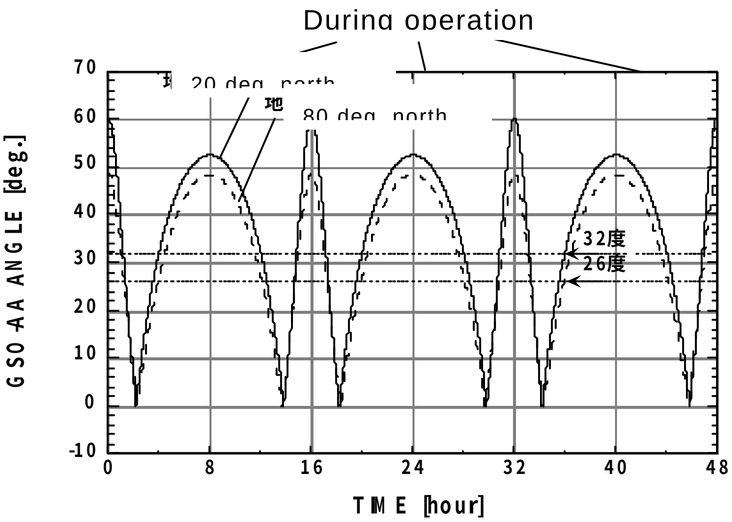

Fig.5 : GSO-AA separation angle.