RECOMMENDATION ITU-R S.484-3*

Station-keeping in longitude of geostationary satellites in the fixed-satellite service

(1974-1978-1982-1992)

The ITU Radiocommunication Assembly,

considering

a)   that the geostationary-satellite orbit (GSO) is of unique usefulness to telecommunication services;

b)   that the interference imposes a limit on the number of satellites which may operate in the same frequency band in the same part of the orbit but the number will tend to increase as the degree of accuracy of station-keeping is improved;

c)   that the number of satellites using this orbit for operational purposes is likely to grow significantly in the next few years;

d)   that it is technically feasible to maintain satellite position to within $\pm 0.1°$; although this standard may not be achieved by some satellites designed before 1982;

e)   that the capacity of the GSO is only slightly impaired by moderate orbital inclinations but is greatly reduced when longitudinal positional drifts approach values comparable with the minimum permissible satellite spacing,

recommends

that space stations on geostationary satellites using frequency bands allocated to the fixed-satellite service:

1   should maintain their positions within $\pm 0.1°$ of longitude of their nominal positions irrespective of the cause of variation; but

2   need not comply with § 1 as long as the satellite network to which the space station belongs does not produce an unacceptable level of interference into any other satellite network whose space station complies with the limits of § 1;

3   that the position in § 1 should be the longitude at which the satellite crosses the equatorial plane for the case of slightly inclined geostationary orbit;

4   that the following Notes will be considered part of this Recommendation:

NOTE 1 – For experimental stations on board geostationary satellites, the limits specified in § 1 may be replaced by $\pm 0.5°$.

NOTE 2 – Annex 1 describes the factors which affect longitudinal station-keeping.

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*   Radiocommunication Study Group 4 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44 (RA-2000).

ANNEX 1

Factors affecting longitudinal station-keeping

1 Perturbations in orbital elements

A satellite is ideally geostationary if its orbital elements satisfy the following conditions:

– semi-major axis a = synchronous radius = 42 165 km

– eccentricity $e = 0$

– inclination $i = 0$.

The orbit gradually departs from the geostationary state, however, due to the perturbation forces acting on the satellite.

The distortion of the Earth's gravitational field due to the non-sphericity of the Earth causes either a steady increase or decrease in the semi-major axis, according to the stationary longitude of the satellite. No change however occurs at four special longitudes called the equilibrium points. When the semi-major axis deviates from the synchronous radius by Δa (km) the satellite longitude drifts at the rate of $-0.013\,\Delta a$ degrees per day. The solar radiation pressure, acting in proportion to the ratio of satellite cross section to mass, changes the eccentricity with time. There is also a minor effect due to the Moon's gravity. A non-zero eccentricity e yields a diurnal libration motion in the satellite longitude of as much as $\pm 2e \times 180/\pi$ degrees. The gravity of the Moon and the Sun acting as a tidal force on the satellite changes the inclination at a rate that varies from year to year between 0.75° and 0.95° per year. A non-zero inclination i (degrees) yields a half-diurnal longitudinal libration motion of as much as $\pm (i^2/4)\,(\pi/180)$ degrees. This becomes significant for longitudinal station-keeping when the inclination is greater than a few degrees.

2 Errors in longitudinal station-keeping

2.1 Orbit determination error

The accuracy of the station-keeping depends to some extent on the accuracy of orbit determination. The orbit determination of geostationary communications satellites is generally based on ranging at two distantly located stations or on ranging and azimuth/elevation angle measurements at a single station; orbit determination based on ranging at only a single station is not feasible.

Appropriate calibration of the ranging and, in particular, of the angle measurement yields an accuracy of satellite longitude determination within a few thousandths of a degree.

2.2 Orbit correction error

Longitudinal station-keeping is carried out with East-West orbital corrections that adjust the semi-major axis and the eccentricity to their target values. In practice, the adjusted orbital elements after a correction have errors due to the efficiency of satellite thruster performance. The North-South orbital correction, which is to keep the inclination within a given limit, is kept from disturbing

longitudinal motion by selecting the ideal North-South thrust direction. In practice, however, the thrust has a non-North-South component due to attitude-control errors. An unexpected change in the longitudinal motion is therefore possible. The thrust for attitude control may also have a minor effect on the longitudinal motion.

These factors together comprise the longitudinal station-keeping error, but the most significant is usually the coupling between the North-South orbital correction and longitudinal motion.

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