RECOMMENDATION ITU-R S.1758

Characterization of HEO-type systems in the fixed-satellite service

(2006)

Scope

This Recommendation characterizes high Earth orbit (HEO)-type fixed-satellite service (FSS) systems for the purpose of sharing studies. It intends to provide administrations with information on HEO-type FSS systems for use in sharing studies with other types of non-GSO FSS systems, with GSO FSS networks, and with systems and networks in other services allocated on a co-primary basis with the FSS. The information includes items such as orbit characteristics, active arc, repeating grounds tracks, antennas of associated earth stations, elevation angles, handovers and angular discrimination from the GSO arc.

The ITU Radiocommunication Assembly,

considering

a) that fixed-satellite service (FSS) frequency bands may be used by both geostationary-satellite orbit (GSO) satellite networks and non-GSO satellite systems in accordance with the Radio Regulations (RR);

b) that most of these FSS bands are also shared with terrestrial services;

c) that high Earth orbit (HEO) type satellite systems characterized in this Recommendation are non-GSO systems;

d) that the characteristics of the interference caused to GSO networks by most HEO-type FSS systems are due to the fact that their service links operate only in active arcs which maintain a large separation angle with respect to GSO links;

e) that HEO-type FSS systems can provide services to high-latitude regions with higher elevation angles than GSO FSS networks;

f) that HEO-type FSS systems have a potential to increase the utilization of FSS bands without adding to the congestion of the GSO;

g) that it would be helpful for administrations to have a source of information on HEO-type FSS systems for use in sharing studies with other types of non-GSO FSS systems, with GSO FSS networks, and with systems and networks in other services allocated on a co-primary basis with the FSS,

recognizing

a) that several HEO-type satellite systems have successfully been operating in the FSS for many years;

b) that recently additional HEO-type FSS systems have been communicated to the ITU BR;

c) that the ITU-R has been and is continuing study of the interference effects of HEO-type FSS satellites on FS receivers taking into account the characteristics of HEO-type FSS satellites;

d) that ITU-R Recommendations regarding HEO-type FSS systems have been established and are being developed, but common characterizations and references for HEO-type FSS systems do not yet exist;

e) that there may be differences between the characterization of HEO-type FSS systems and HEO-type systems in some other radiocommunication services,

recommends

1 that the term "HEO" should be used to refer to the types of non-GSO FSS systems that are generally characterized in § 1 of Annex 1 to this Recommendation;

2 that the material in Annex 1 to this Recommendation should be used in sharing studies involving HEO-type FSS systems.

Annex 1

Characteristics of HEO-type FSS satellite systems

1 General characteristics of HEO FSS satellites and HEO FSS satellite systems

An HEO-type FSS satellite system is a non-GSO system that includes a satellite or satellites using an elliptical orbit with all the following orbital and operational characteristics:

- A geosynchronous period (23 h 56 min) multiplied by m/n, where m and n are integers, resulting in n apogees every m days. The ratio m/n may be less than, equal to, or greater than 1 (thereby having a fixed ground track that repeats every m days) resulting in the following three kinds of orbits:
  - *Geosynchronous HEO:* an HEO with an orbital period of 23 h and 56 min (m/n = 1).
  - *Sub-geosynchronous HEO:* an HEO with a geosynchronous period multiplied by m/n less than one (e.g. 11 h and 58 min, 5 h and 59 min, etc.).
  - *Super-geosynchronous HEO:* an HEO with a geosynchronous period multiplied by m/n larger than one (e.g. 47 h and 52 min, etc.).
- An inclination between 35 and 145°.
- An apogee altitude that is at least 18 000 km.
- Service carrier transmissions other than telemetry and command carrier transmissions are confined to one or more active arc or arcs within an orbit as described fully in § 1.1.

The term "HEO" is used to identify this type of orbit.

Many variations in an HEO system design and operation are possible. These variations arise because HEO systems have different missions or a different optimization criteria. Examples of characteristics that differ from system to system are frequencies; the size of the service area; minimum elevation angles; use of full-motion, limited-tracking, or fixed earth terminal antennas; the size of the active arcs; the number of satellites that operate simultaneously; and the number of active arcs within which a satellite operates.

Constellations of HEO satellites with adjustable spot beams are likely to have service areas within the coverage zone that correspond to high elevation angles to the active satellite, except in such cases as HEO systems designed to provide wide east-west service at northern latitudes.

Typical HEO FSS satellite systems share some or all of the following specific operational features:

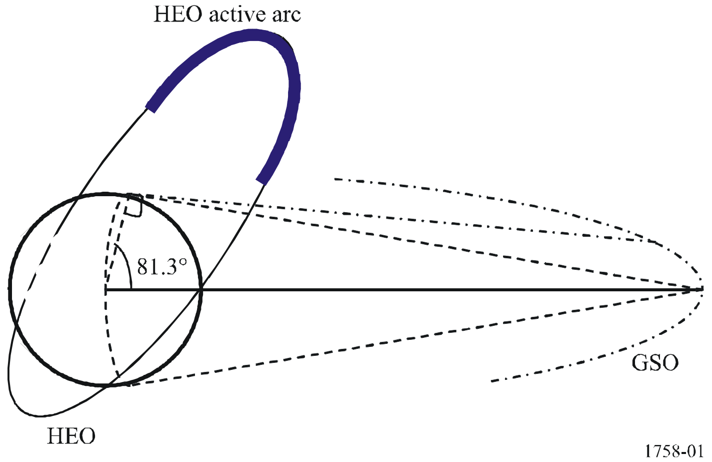
1.1 Active arc

Except for space operations functions, each satellite in an HEO FSS satellite system operates only during a specific portion of its orbit known as the active arc. All service carrier transmissions in the FSS to and from a particular HEO satellite for the FSS are ceased whenever that satellite is outside of its active arc. Depending on the orbit period, the active arc portion of the orbit will recur over one or more locations on the Earth. In the case of nearly circular orbits, note that there could be two active arcs within an orbit, one each over the southern and northern hemispheres.

The size of the active arc(s) for a particular system is a function of the particular system design. An active arc is generally designed to encompass the apogee point or the highest latitude of the orbit. This is done to minimize the variation in azimuth and elevation of the satellite from the perspective of the earth stations that are operating with it. Furthermore, in order to avoid excessive interference to and from co-frequency GSO/FSS networks, the length of an active arc is generally established so that it does not intersect any line between the GSO and the Earth's surface (see Fig. 1). In order to provide continuous service, at least one satellite from a given HEO FSS satellite system will be in each active arc at all times.

FIGURE 1

Illustration of an HEO active arc that is limited so that it does not intersect any line between the GSO and the Earth's surface



1.2 Repeating ground tracks

HEO satellites have repeating ground tracks (i.e. a line which is the set of sub-satellite points as the satellite moves around the Earth) designed to ensure that their active arcs occur in optimum positions for the required coverage areas. To achieve a repeating ground track, the period of the orbits is a multiple or sub-multiple of that of the Earth spinning on its axis. Depending on the size of the active arc and the number of satellites within the HEO FSS satellite system, repeating ground tracks may help increase frequency reuse between separate HEO FSS systems using these types of orbits. The characteristics of the active arc may also result in near-constant look angles from the earth stations. An HEO FSS system can be comprised of multiple HEO satellites following a single repeating ground track, or of multiple HEO satellites using different repeating ground tracks.

1.3 Antennas of associated earth stations

Depending on the size of the active arc and orbit details of a given HEO FSS system, one of the following four types of antennas are generally used with associated earth stations (Note that there may be more than one type of earth station associated with a particular HEO system):

– twin tracking antennas;
– antennas having interrupted tracking capability to switch to the satellite entering the active arc from the one leaving it;
– a single tracking antenna in the special case where the two satellites involved in a handover are very closely spaced at the moment of hand-off;
– a single non-tracking antenna whose beam is wide enough to cover the entire active arc.

1.4 High elevation angles from HEO FSS satellite system earth stations in medium to high latitude service areas

This allows locations that have low-elevation angles to the GSO to obtain the benefits of high-elevation angles.

1.5 Continuous service with handovers

HEO FSS satellite systems using a sufficient number of satellites are able to ensure that there is at least one satellite within each active arc at all times therefore providing continuous coverage. Handovers between satellites may be infrequent, with continuous service from a single HEO satellite lasting many hours, depending on the orbit chosen and system design objectives.

1.6 Angular discrimination from the geostationary-satellite orbit

An HEO FSS satellite system can be operated such that at all points within the HEO service area there is a large angular discrimination between its satellites anywhere within their active arc(s) and all points in the geostationary-satellite orbit (see Recommendation ITU-R S.1713). For FSS applications, in which directional antennas are used, this enhances sharing between an HEO FSS satellite system and satellite networks in the geostationary-satellite orbit without significantly restricting the usable coverage of the HEO system.

1.7 HEO constellations supporting small antenna, non-tracking earth stations

In some systems identical, equally time-phased HEO satellites forming a constellation with a single repeating ground track, operating only in active arcs having a very small angular range around apogee, describe a system with satellite visibility characteristics similar to those in a GSO network. Even though their orbits are clearly non-GSOs, the operating satellites in such an HEO constellation remain approximately fixed relative to points on the Earth’s surface.

2 Examples of HEOs

Four examples of HEOs are shown in Figs. 2 to 5.

Figure 2 shows the ground track of an HEO with an orbit that has a period of 7 h 59 min, eccentricity of 0.64 and an inclination of 63.4°. The highlighted portion of the orbit denotes an active arc of greater than 45° north latitude.

Figure 3 shows the ground track of an HEO using an orbit that has a period of 11 h 58 min, eccentricity of 0.72 and inclination of 63.4°. The highlighted portion of the orbit denotes an active arc of greater than 25° north latitude.

Figure 4 shows the ground track of an HEO using an orbit that has a period of 23 h 56 min, eccentricity of 0.1 and inclination of 45°; the highlighted portion of the orbit denotes an active arc of greater than 30° north latitude.

Figure 5 shows the ground track of a super-geosynchronous HEO using an orbit that has a period of 47 h 52 min, an inclination of 63.4° and an eccentricity near 0; the highlighted portion of the orbit denotes two active arcs of greater than 25° south and north latitude.

FIGURE 2

Ground track of a sub-geosynchronous HEO using 8-hour orbits

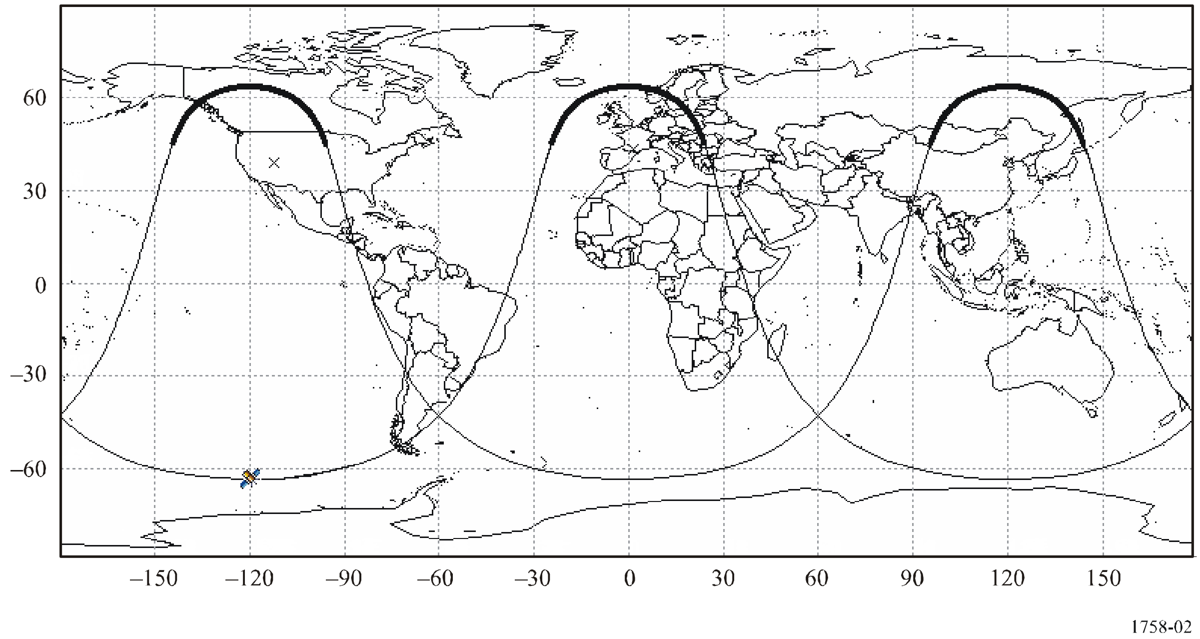


FIGURE 3

Ground track of a sub-geosynchronous HEO using 12-hour orbits

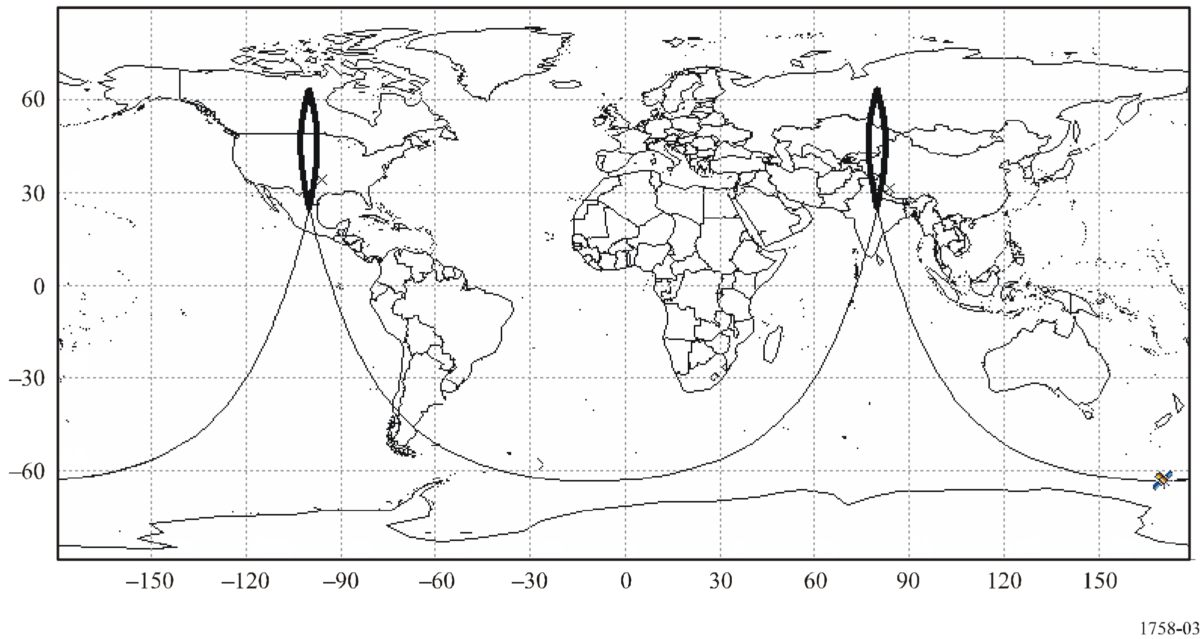


FIGURE 4

Ground track of a geosynchronous HEO system using 24-hour orbits

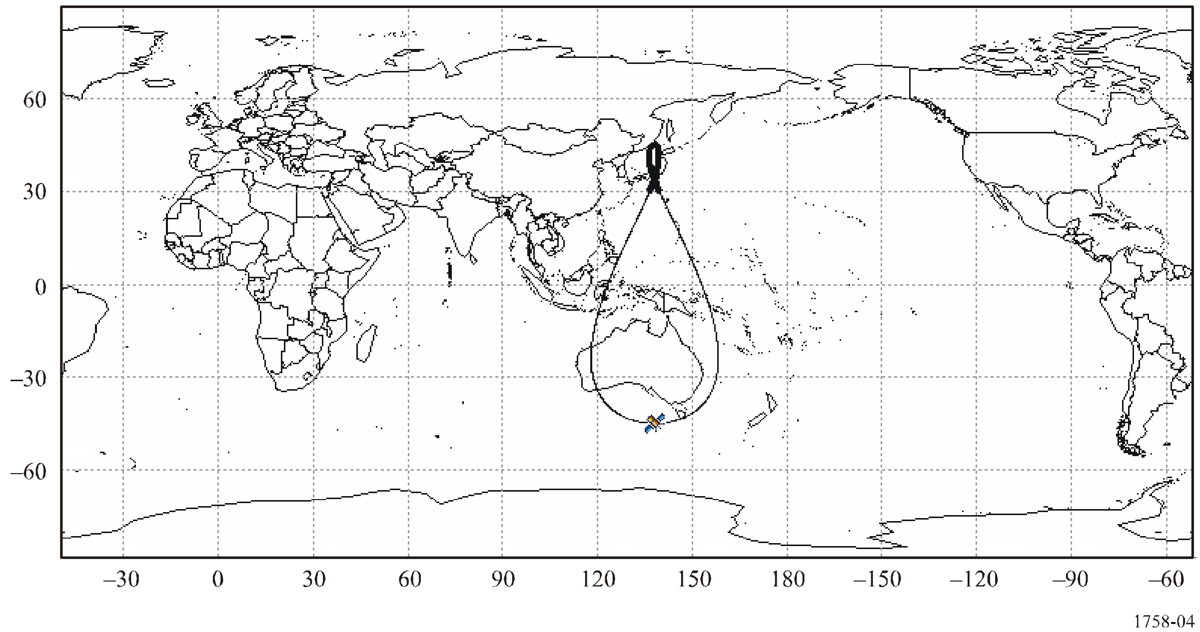


FIGURE 5

Ground track of a super-geosynchronous HEO using 48-hour orbits