

RECOMMENDATION ITU-R BO.1506

A methodology to evaluate the impact of solar interference on geostationary (GSO) broadcasting-satellite service (BSS) link performance

(Question ITU-R 220/11)

(2000)

The ITU Radiocommunication Assembly,

considering

- a) that the GSO link can be optimized for arid regions, with very small link margin thus it is sensitive to interference;
- b) that such interference-sensitive GSO links will have performance levels driven by other sources of fading and degradation than rain;
- c) that one of these degradations is caused by solar transits in the main beam of the receiving antennas and that these degradations could be severe for links with small margins or large antenna diameters;
- d) that the performances of GSO links are used in some methodologies to determine acceptable interference levels between systems,

recommends

1 that, in designing GSO BSS links, the methodology attached in Annex 1 of this Recommendation may be used to assess the level of performance degradation on GSO BSS links resulting from solar transit.

NOTE 1 – It should be noted that some GSO systems can implement operational measures (such as site or satellite diversity) in order to diminish the impact of the solar transit on the system performances.

ANNEX 1

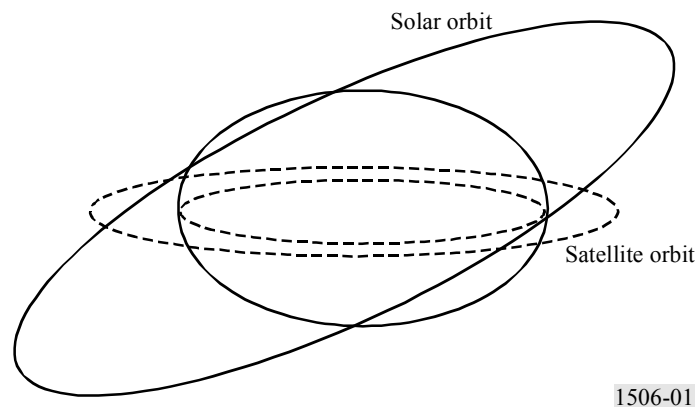
A methodology to evaluate the impact of solar interference on GSO BSS link performance**1 General approach**

The solar transit in the GSO receiver is a phenomenon that can be easily assessed as the geometry is well known. The following method is proposed to fully describe the solar transit effect on GSO link budgets thus allowing for proper assessment of the performances of some links that do not need margins to compensate for rain fades. The impact of solar transit is not a fade but an increase of the system noise temperature that can be significant for some low margin, low noise GSO links.

The proposed method is based on the well-defined geometry of Sun position relative to a specified location on the Earth: the Sun is approximately a 0.53° diameter disk as seen from an Earth point. The solar transit effect is significant when the disk intersects the main beam of the BSS receiving antenna. The impact may be determined by using either a detailed approach or a simplified approach. The detailed approach varies the antenna gain over the optical disc of the Sun in accordance to the assumed antenna gain pattern. The simplified approach assumes a constant antenna gain over the optical disc of the Sun corresponding to the gain towards the centre of the Sun's disk.

The geometry is described in Fig. 1. The Sun can be considered as a noise source moving in a well-defined trajectory across the sky. During the period of the spring and autumn equinoxes, the Sun is located at or near the intersection of the equatorial and ecliptic planes. During this time, the Sun is in line with the receiving BSS antenna and the GSO BSS satellite. This leads to an increase of the antenna noise temperature that affects the BSS receiver figure-of-merit (G/T) of the link and thereby degrading the carrier-to-noise ratio (C/N). Depending on the link clear-sky margin this degradation can result in link outage for a short period of time.

FIGURE 1



2 Methodology

The methodology is based on the calculation of the relative position of the Sun to the boresight of the receiving antenna, and thus on the estimation of the antenna noise temperature increase due to solar interference.

Step 1: Select the duration over which the calculations are performed on the basis of the beginning and end dates. Select the time step as a function of the antenna size for which the calculations are done.

Step 2: For each time step considered, determine the orbital parameters of the Sun:

$$w = 282.9404$$

$$e = 0.016709$$

$$M = 356.0470 + 0.98560 T$$

where:

w : argument of perihelion (degrees)

e : eccentricity

M : mean anomaly (degrees)

T : time (days).

Step 3: Convert these orbital elements into the equatorial, rectangular, geocentric coordinates (X_{Sun} , Y_{Sun} , Z_{Sun}). The eccentric anomaly E is defined by:

$$E = M + e \sin(M) (1.0 + e \cos(M))$$

then:

$$X1 = D_{Sun} (\cos(E) - e)$$

$$Y1 = D_{Sun} \left(\sqrt{1 - e^2} \right) \sin(E)$$

and:

$$V = A \tan 2 (Y1, X1)$$

$$R = \sqrt{X1^2 + Y1^2}$$

with:

D_{Sun} : distance between the Earth and Sun centres

$A \tan 2()$: function that an x, y coordinate pair to the correct angle.

The longitude of the Sun, lonSun , is then determined by:

$$\text{lonSun} = V + w$$

and finally:

$$X_{Sun} = R \cos(\text{lonSun})$$

$$Y_{Sun} = R \sin(\text{lonSun}) \cos(\text{ecl})$$

$$Z_{Sun} = R \sin(\text{lonSun}) \sin(\text{ecl})$$

where ecl is the obliquity of the ecliptic that can be estimated with: $\text{ecl} = 23.4393^\circ$.

Step 4: Determine the equatorial, rectangular, geocentric coordinates (X_{ES} , Y_{ES} , Z_{ES}) for the earth station (ES) and the GSO satellite (SAT):

$$X_{ES} = R_{Earth} \cos(\text{lat}_{ES}) \cos(\text{lon}_{ES} + (\omega_{Earth} T))$$

$$Y_{ES} = R_{Earth} \cos(\text{lat}_{ES}) \sin(\text{lon}_{ES} + (\omega_{Earth} T))$$

$$Z_{ES} = R_{Earth} \sin(\text{lat}_{ES})$$

where:

R_{Earth} : Earth radius (6 378 km)

lat_{ES} , lon_{ES} : latitude and longitude of the earth station

ω_{Earth} : angular speed of the Earth, (rad/days) ($2\pi = 6.2831$)

T : time step considered (days).

and for the GSO satellite:

$$X_{SAT} = (R_{Earth} + H) \cos(lat_{SAT}) \cos(lon_{SAT} + (\omega_{Earth} T)) = (R_{Earth} + H) \cos(lon_{SAT} + (\omega_{Earth} T))$$

$$Y_{SAT} = (R_{Earth} + H) \cos(lat_{SAT}) \sin(lon_{SAT} + (\omega_{Earth} T)) = (R_{Earth} + H) \sin(lon_{SAT} + (\omega_{Earth} T))$$

$$Z_{SAT} = (R_{Earth} + H) \sin(lat_{SAT}) = 0$$

with:

$$lat_{SAT} = 0$$

H : altitude of the GSO satellite (35 786 km).

Step 5: The angle α between the Sun, S , the earth station, E , and the GSO satellite, G , can be obtained by:

$$\vec{ES} \cdot \vec{EG} = |\vec{ES}| |\vec{EG}| \cos(\alpha)$$

so:

$$\alpha = \arccos \left\{ \frac{(X_{Sun} - X_{ES})(X_{SAT} - X_{ES}) + (Y_{Sun} - Y_{ES})(Y_{SAT} - Y_{ES}) + (Z_{Sun} - Z_{ES})(Z_{SAT} - Z_{ES})}{\sqrt{[(X_{Sun} - X_{ES})^2 + (Y_{Sun} - Y_{ES})^2 + (Z_{Sun} - Z_{ES})^2] [(X_{SAT} - X_{ES})^2 + (Y_{SAT} - Y_{ES})^2 + (Z_{SAT} - Z_{ES})^2]}} \right\}$$

This angle is the off-axis angle of the Sun viewed from the antenna.

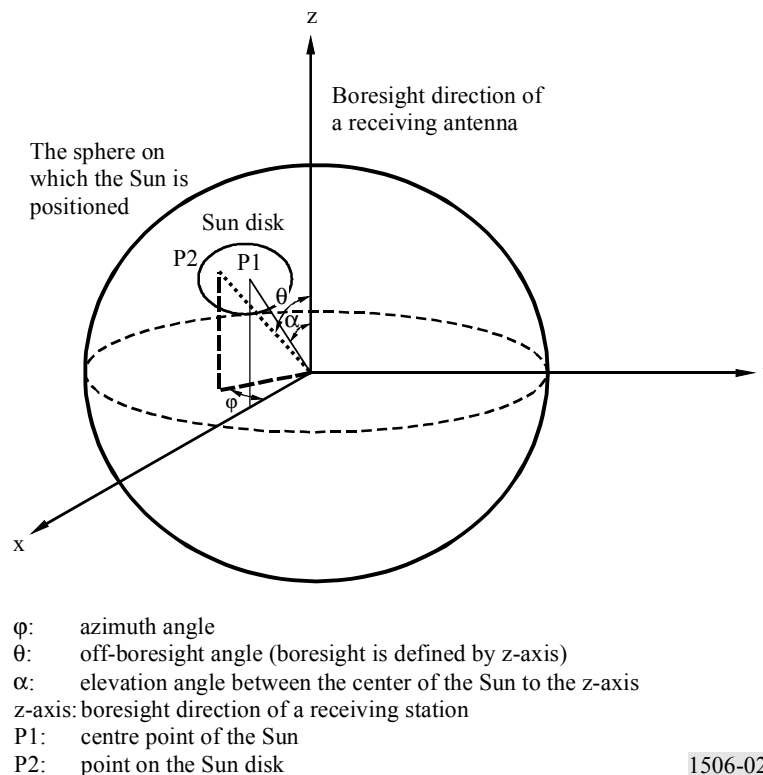
Step 6: Determine the value of the antenna gain over the Sun's disk: $\iint_{Sun} G(\theta, \varphi) d\Omega$

where θ is the off-axis angle and φ is the azimuth angle.

a) Detailed approach

The Sun is modelled by a disk positioned on a sphere centred on the receive earth station. The sphere represents the space seen by the antenna using the spherical angles θ and ϕ .

FIGURE 2



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The z-axis is in the direction of the pointing direction of the receive antenna.

The computation can use the axis symmetry of the geometry: the points with the same gain form arcs. These result from the intersection of a plan perpendicular to the axis antenna z with the portion of sphere containing the Sun.

The value of the integral is so determined by the addition of the different lengths of the iso-gain arcs, multiplied by the value of the gain for the arc.