

RECOMMENDATION ITU-R S.1525-1

Impact of interference from the Sun into a geostationary-satellite orbit fixed-satellite service link

(Question ITU-R 236/4)

(2001-2002)

The ITU Radiocommunication Assembly,

considering

- a) that Sun transits are a natural phenomena in geostationary-satellite orbit fixed-satellite service (GSO FSS) networks, which occur over a period of 3-9 days twice a year, depending on the antenna diameter;
- b) that GSO FSS earth station operators and customers plan for the Sun transits and implement appropriate means to minimize their impact;
- c) that GSO FSS earth station operators should have a methodology available to analyse the magnitude of the interference from the Sun and the timing of the interference events,

recommends

- 1 that, in designing GSO FSS links, the methodology given in Annex 1 may be used to assess the level of carrier-to-noise ratio (C/N) degradation of a GSO link resulting from Sun transit;
- 2 that GSO FSS earth station operators may use the method in Annex 2 to predict the date and time of a Sun transit at an earth station.

ANNEX 1

Calculation of the level of interference from the Sun into a GSO FSS link

Sun transits occur twice a year near the spring and autumn equinoxes when the Sun passes close to the main beam of the receiving GSO earth station. During these Sun transits, the microwave radiation from the Sun acts as a source of interference, increasing the effective noise temperature of

the satellite link and therefore degrading the link performance. If the amount of degradation exceeds the clear-sky margin of the link, then the link will suffer an outage – usually termed a Sun-outage.

For frequencies below about 30 GHz, emission from the Sun can be considered as having three components: the thermal emission from the “quiet” Sun, a slowly-varying component related to the number and size of sunspots, and occasional intense bursts of emission due to Sun flares. All three components are time-varying, and so it is extremely difficult to use the Sun as a reference source for accurate evaluation of the performance of earth station antennas.

In the satellite communication bands, the thermal emission from the quiet Sun decreases with increasing frequency. The emission is generally unpolarized.

Sunspots are magnetic regions on the Sun, appearing as dark spots on its surface. They typically last for several days, although very large ones may last for several weeks. Although the number of sunspots varies greatly from day to day, there is an underlying pattern with a period of approximately 11 years. Every 11 years, the Sun undergoes a period of activity called the “Sun maximum”, followed by a period of quiet called the “Sun minimum”. During the Sun maximum there are many sunspots, Sun flares, and coronal mass ejections, all of which can affect communications and the weather on Earth. There is a rough correlation between the total solar flux and the number of sunspots. As this increased flux is associated with several small areas of the Sun’s surface, it is unsafe to assume a uniform brightness distribution across the face of the Sun. In fact, if the GSO earth station has an antenna beamwidth smaller than the apparent diameter of the Sun, then it could experience varying levels of interference during a single Sun transit event. Emission due to sunspots is somewhat circularly polarized, although this effect is diluted by the random polarization of the thermal emissions from the quiet Sun.

Sun flares or bursts may double or triple the Sun flux, occasionally reaching factors of 100 times the usual level. In the satellite communication bands, most events are fairly short – 5 min to about an hour. Occurrence is unpredictable, but as already noted the events are more frequent around the Sun maximum. Typically there could be a couple of events per day.

The apparent diameter of the Sun at microwave frequencies is slightly larger than the optical diameter. Also, the Earth-Sun distance varies slightly during the year, resulting in a variation in the apparent diameter of the Sun and thus in apparent brightness temperature. However these effects are small compared with other uncertainties (such as the sunspot number), and may thus be neglected. A reasonable estimate of the apparent diameter of the Sun at the equinox is 0.53° .

Although the foregoing material indicates that significant and unpredictable variations exist in the effective level of the Sun flux in the satellite communication bands, a number of simple models have been proposed for the average level. These models are adequate for assessment of the typical levels of interference which can be expected during Sun transits. One expression for the brightness temperature of the quiet Sun at microwave frequencies is:

$$T_{Sun} = 120\,000 \times \gamma \times f^{-0.75}$$

where:

T_{Sun} : equivalent brightness temperature (K)

f : frequency (GHz)

γ : factor to account for the polarization of the emissions from the Sun, which could be taken to be 0.5 for the reasons given above.

This model gives a value of around 21 000 K for the quiet Sun at a frequency of 4 GHz. By comparison, a typical value at sunspot maximum would be 90 000 K.

1 General approach

The Sun transit of a GSO receiver is a phenomenon that can be easily assessed as the geometry is well known. The method described in detail in Recommendation ITU-R BO.1506 which evaluates the impact of solar interference into broadcasting-satellite service (BSS) links may be used also in the case of FSS links. That Recommendation fully describes the Sun transit effect on GSO FSS link budgets. The impact of Sun 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.

2 Application of the methodology to different antenna sizes

The detailed approach described in Recommendation ITU-R BO.1506 has been applied to different antenna sizes.

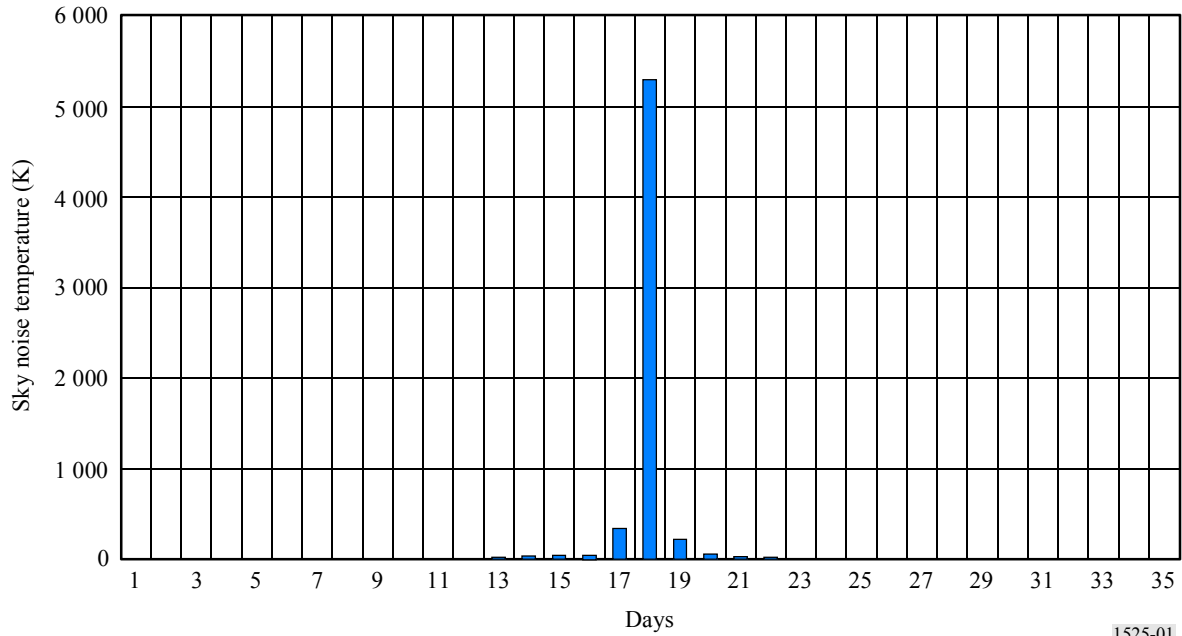
Two possible approaches could be used to generate the solar noise temperatures for the off-axis angle θ and the azimuth angle ϕ as seen at the focal point of an FSS earth station antenna:

- Full simulation of the motion of the Sun, using for example the algorithm developed in Annex 2.
- A simplified approach based on the fact that the declination angle of the Sun changes at approximately 0.4° per day at the equinoxes and its hour angle changes at approximately 0.25° per min.

The results in Figs. 1 to 6 are typical of those produced using these methods. In all the cases the initial noise temperature used is 150 K and the antenna patterns used are according to Recommendation ITU-R S.465 at 11 GHz.

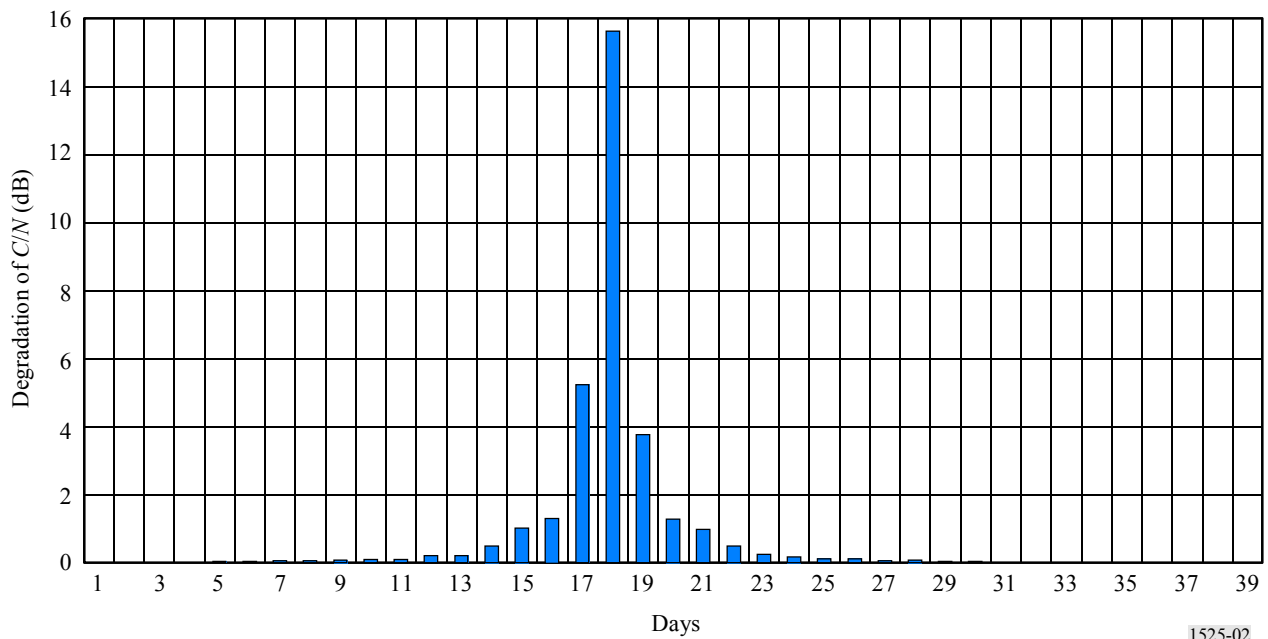
FIGURE 1

Daily maximum sky noise temperature increase for a 10 m antenna



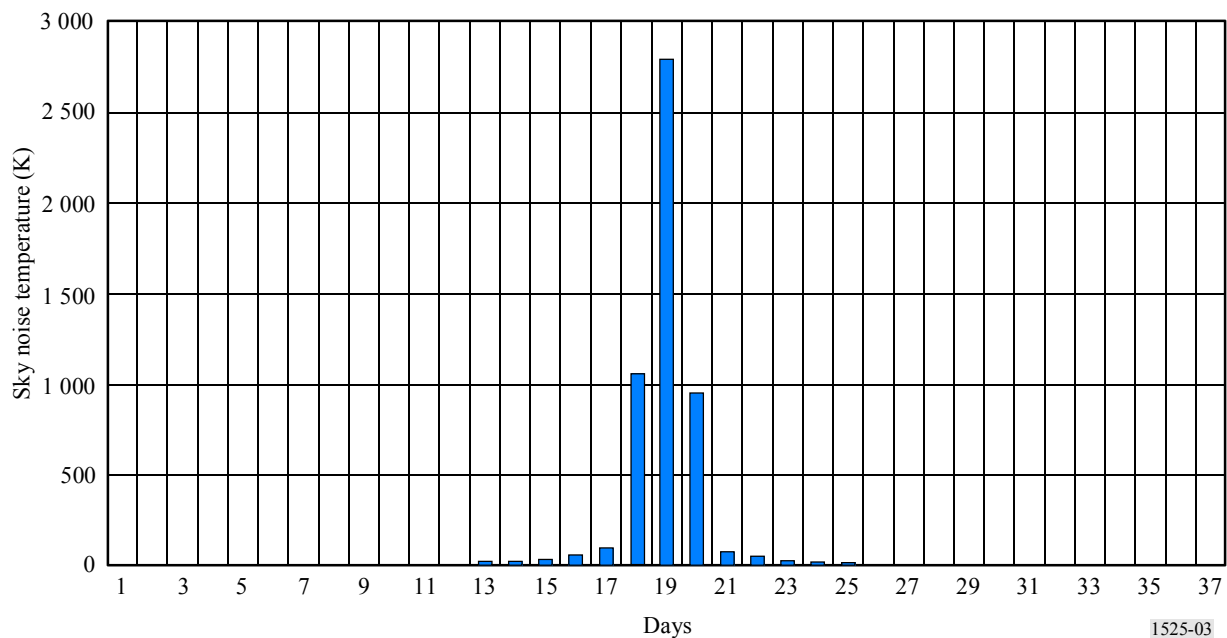
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FIGURE 2

Daily maximum degradation of the received C/N of a 10 m antenna

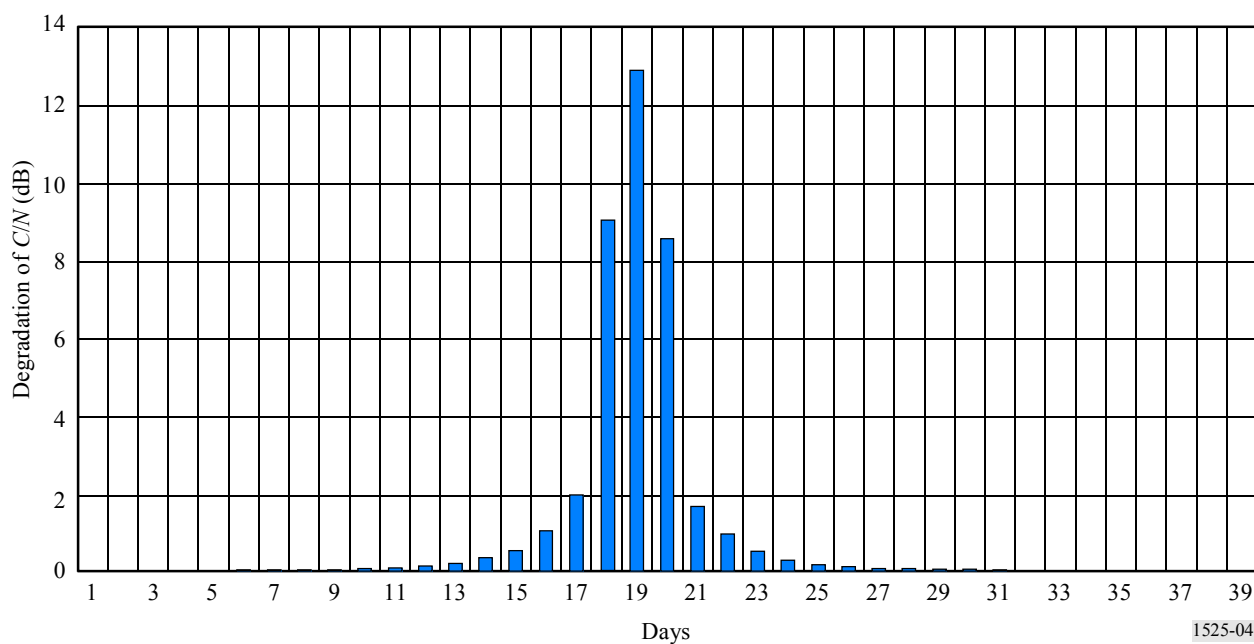
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FIGURE 3

Daily maximum sky noise temperature increase for a 3 m antenna

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FIGURE 4

Daily maximum degradation of the received C/N of a 3 m antenna

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