RECOMMENDATION ITU-R SF.674-2

Determination of the impact on the fixed service operating in the 11.7-12.2 GHz band when geostationary fixed-satellite service networks in Region 2 exceed power flux-density thresholds in Resolution 77 (WRC-2000)

(1990-1997-2002)

The ITU Radiocommunication Assembly,

considering

a) that the band 11.7-12.2 GHz is allocated to the fixed service (FS) on a worldwide basis and the fixed-satellite service (FSS) in Region 2;

b) that the use of this band for the FSS is subject to prior agreement with administrations with services that comply with the Table of Frequency Allocations of the Radio Regulations (RR), according to No. 5.488 of the RR as revised by the Word Radiocommunication Conference (Istanbul, 2000) (WRC-2000);

c) that the identification of affected administrations using the FS will be facilitated by the use of appropriate power flux-density (pfd) values;

d) that the pfd is one of the technical parameters used for the determination of criteria which facilitate sharing between the FSS and terrestrial services;

e) that Resolution 77 (WRC-2000) specifies that an administration that plans to operate a geostationary (GSO) FSS system in Region 2 in the 11.7-12.2 GHz band shall seek the agreement of any administration in Regions 1, 2 and 3 that has a primary allocation to terrestrial services in the same frequency band if the pfd produced on its territory exceeds the specified thresholds;

f) that FS networks may be either analogue or digital,

noting

a) that in the frequency band 11.7-12.2 GHz shared between systems in the FSS in Region 2 and systems in the FS, Resolution 77 (WRC-2000) establishes the following pfd thresholds:

-124	$\text{dB(W/(m}^2 \cdot \text{MHz))}$	for $0° \le \theta \le 5°$
$-124 + 0.5\,(\theta - 5)$	$\text{dB(W/(m}^2 \cdot \text{MHz))}$	for $5° \le \theta \le 25°$
-114	$\text{dB(W/(m}^2 \cdot \text{MHz))}$	for $\theta > 25°$

where θ is the angle of arrival (degrees) on the surface of the Earth of the radio-frequency wave;

b) that the above values relate to the pfd and angles of arrival which would be obtained under free-space propagation conditions,

recommends

1 that the methodology presented in Annex 1 may be used as a means for determining the interference levels caused to FS systems by the FSS when the threshold pfd levels contained in Resolution 77 (WRC-2000) are exceeded.

ANNEX 1

Determining interference into FS systems

Introduction

This Annex expands upon the methodology that is used in Recommendation ITU-R F.1107 for analogue FS systems and Recommendations ITU-R F.1107 and ITU-R F.1108 for digital FS systems. Recommendation ITU-R SF.358 provides guidance as to how satellite network pfd levels that protect the FS should be determined. Appendix 1 to Annex 2 of that Recommendation indicates that the absolute values of pfd should be selected in such a way that the maximum permissible interference power of Recommendation ITU-R SF.357 (1 000 pW) would be exceeded in a small fraction of the FS systems sharing that band for analogue FS stations. Recommendation ITU-R F.1108 uses the concept of fractional degradation of performance (FDP) for digital FS stations. The FDP is the fractional increase in the percentage of time that the controlling performance criterion will not be met because of the presence of interference. Recommendation ITU-R F.1108 suggests a value of 10% for FDP as appropriate for sharing studies. Accordingly, the methodologies described here will determine the fraction of FS receivers for which the FDP will exceed 10%. The FDP should exceed 10% for no more than an agreed small percentage of the terrestrial stations. Appendix 1 discusses the methodology used to analyse interference into analogue fixed systems and Appendix 2 discusses the methodology used to analyse interference into digital systems. It should be noted that neither of the methodologies presented here makes use of any orbital avoidance.

Appendices 1 and 2 contain the details of the methodologies used and some results. The analyses presented in Appendices 1 and 2 show that the increased performance degradation in both analogue and digital FS systems, due to FSS systems that exceed that pfd thresholds of Resolution 77 (WRC-2000) is dependant on the chosen parameters. The results are based on a noise temperature of 1 500 K for analogue FS stations and 1 100 K for digital FS stations. These values are taken from Table 7b of Annex 7 of Appendix 7 of the RR.

The methodologies also take into account the effects of attenuation by atmospheric gases, using the methodology of Recommendation ITU-R SF.1395.

The methodologies applied in this Annex do not take account of the loss due to the spreading of the satellite antenna beam on the Earth-space path. According to Fig. 1 of Recommendation ITU-R P.834, the average long-term beam spreading loss could be 2.5 dB at a 0.1° elevation angle, 0.85 dB at a 1° elevation angle and 0.45 dB at a 2° elevation angle.

One interference mitigation technique that may be applicable to existing FS receiving antennas is to implement a slight antenna reorientation to reduce the main-beam coupling to the satellite emissions. Theoretical analyses suggest that the improvements are generally modest, that they depend on the initial off-main-beam angle to the satellite and that they increase with increasing interference-to-noise ratio (I/N). For I/N of +10 dB, improvements up to several dB may be possible when the satellite is initially outside of the three-dB beamwidth of the FS antenna. The practical considerations of implementing this mitigation technique have not been considered, and its effectiveness has not been confirmed in field trials.

APPENDIX 1

TO ANNEX 1

Determining interference into analogue FS systems

1 Methodology

The analysis methodology of Recommendation ITU-R F.1107 is summarized as follows. FSS networks are placed in order at equally spaced intervals: e.g. 2º. They are assumed to radiate pfd levels onto the surface of the Earth as follows:

$$pfd_{low} \qquad \text{for } 0° \leq \theta \leq 5°$$

$$pfd_{low} + 0.05\,(pfd_{high} - pfd_{low})\,(\theta - 5) \qquad \text{for } 5° \leq \theta < 25°$$

$$pfd_{high} \qquad \text{for } 25° \leq \theta \leq 90°$$

where the values for pfd_{low} and pfd_{high} are taken from Resolution 77 (WRC-2000), e.g. $pfd_{low} = -124$ dB(W/(m^2 · MHz)) and $pfd_{high} = -114$ dB(W/(m^2 · MHz)).

For this analysis it is assumed that the analogue FS network consists of 51 radio-relay stations, spaced 50 km apart, for a total length of 2 500 km per route. This is consistent with the analysis described in Recommendation ITU-R F.1107. However, other Recommendations, such as Recommendation ITU-R M.1143, assume fewer numbers of hops, i.e. 13 stations, also spaced 50 km apart for special situations. A smaller number of stations would result in a smaller amount of cumulative interference. However, the amount of interference per station would stay about the same. Since the total permissible interference, 1 000 pW0p, is based on a hypothetical reference circuit of about 2 500 km, a route of 51 stations is used in the analysis presented here. It is assumed that each link has two antennas: one pointed directly at the link directly in front of it and one pointed directly at the link directly behind it. The centre of the route has a given latitude and a random longitude. The azimuth angle of the route trend-line (i.e. its direction) is simulated as a uniformly distributed random value between 0º and 360º. Another random factor is the exact placement of each relay along the linear route. In the analysis presented here, each relay may be located up to 10 km from the trend line of the route. The total interference seen by each route is calculated through a double summation: first, the interference contributions from each FSS satellite is summed over each link on the route, and second the interference to each link is summed to obtain the total interference for the route.

The methodology used here differs from that of Recommendation ITU-R F.1107 in one important aspect. In order to measure the effect of an FSS satellite exceeding the pfd thresholds, the analysis allows the specification of additional satellites (at any orbital locations) to exceed the pfd thresholds by β dB. The pfd's produced by these satellites are all assumed to have the following form:

$$pfd_{low} + \beta \qquad \text{for} \quad 0° \le \theta \le 5°$$

$$pfd_{low} + 0.05\ (pfd_{high} - pfd_{low})\ (\theta - 5) + \beta \qquad \text{for} \quad 5° \le \theta < 25°$$

$$pfd_{high} + \beta \qquad \text{for} \quad 25° \le \theta \le 90°$$

2 Results

Figures 1, 2 and 3 present results of an interference analysis of a network of digital FSS GSO satellites spaced 2° apart causing interference into an analogue FS network. The FSS system baseline run is performed with $pfd_{low} = -124$ and $pfd_{high} = -114$ dB(W/(m^2 · MHz)) transmitting at a frequency of 11.95 GHz. The FS system is centred at a latitude of 40°. In this example each FS site antenna is assumed to have a maximum gain of 44 dB with all receivers having a noise temperature of 1 500 K. A feeder loss of 3 dB is used and the antenna radiation pattern follows Recommendation ITU-R F.1245. In the key, "Nsats" refers to the number of satellites that exceed the pfd baseline by $\beta = 10$ dB: i.e. these satellites have $pfd_{low} + \beta = -114$ and $pfd_{high} + \beta = -104$ dB(W/(m^2 · MHz)). In Fig. 1, the satellites that exceed the pfd threshold were the Nsat satellites closest to the horizon of the FS network, as seen from the centre of route (lowest elevation angles). In Fig. 2, the satellites that exceed the pfd threshold were the Nsat satellites closest to the centre of the FS network (highest elevation angles). In Fig. 3, various alternative scenarios are presented. The baseline graph here is for Nsats = 30 and with these satellites closest to the horizon of the FS network.

FIGURE 1

Digital FSS into analogue FS, Nsats satellites closest to the horizon

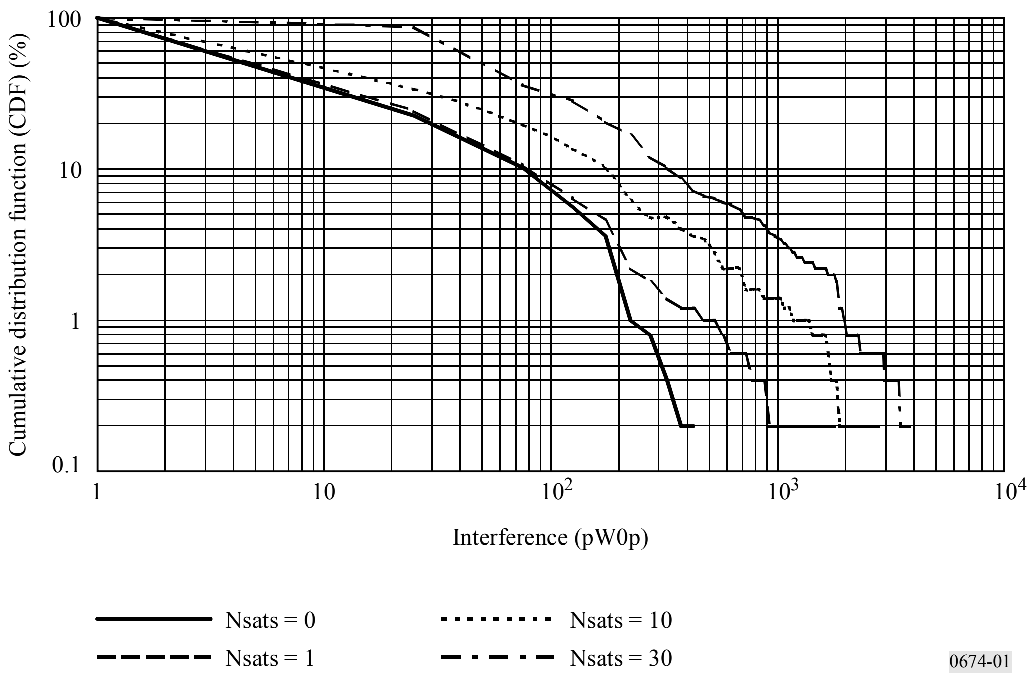


FIGURE 2

Digital FSS into analogue FS, Nsats satellites closest to FS network centre

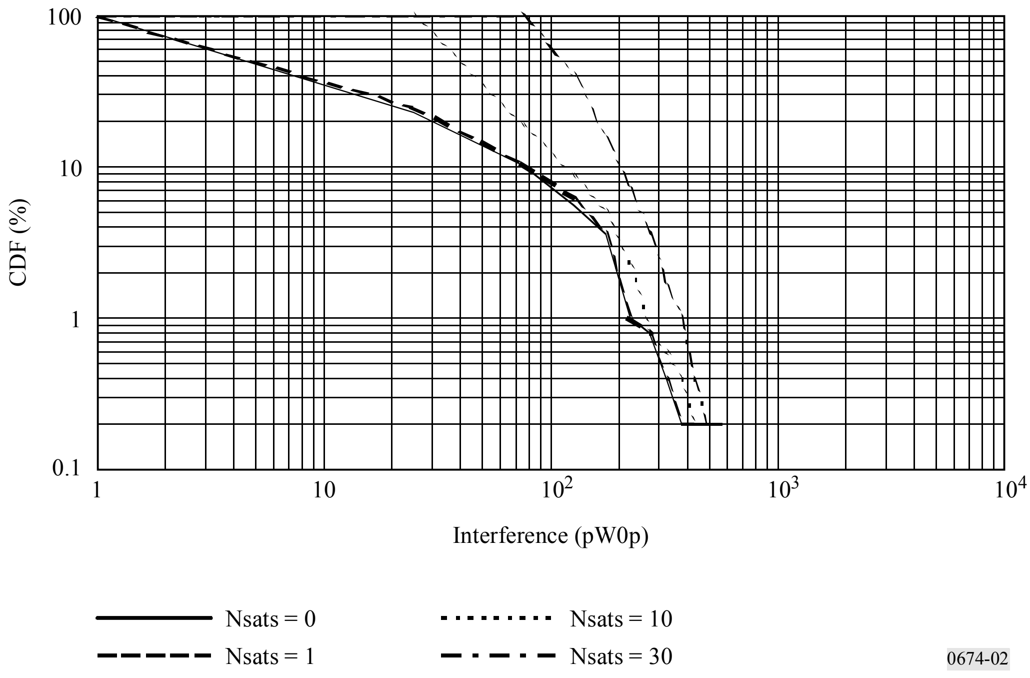
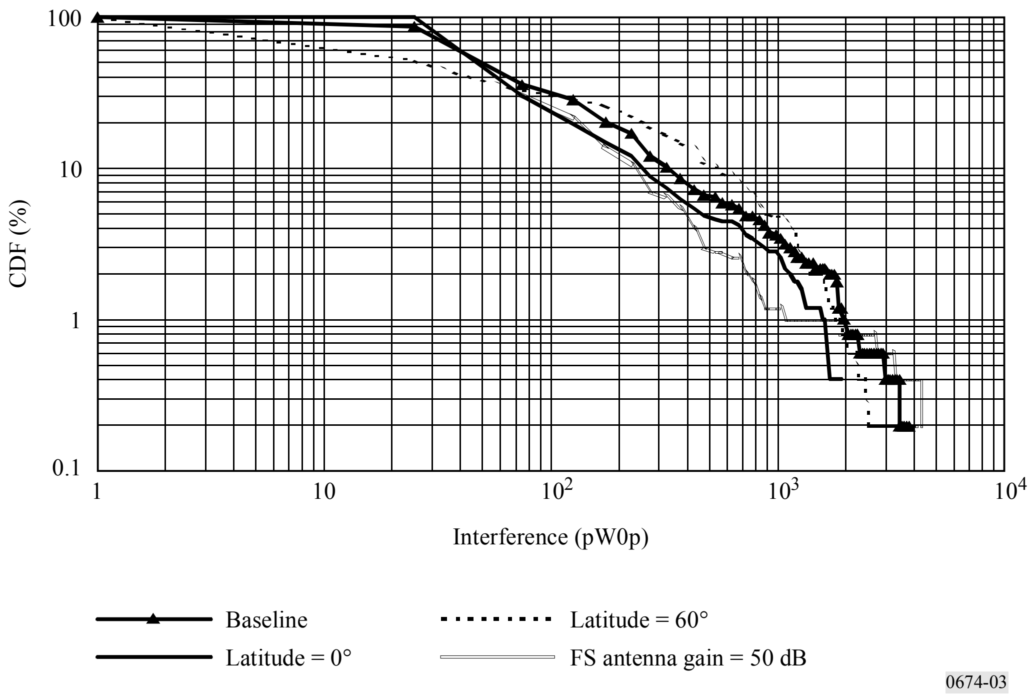


FIGURE 3

Digital FSS into analogue FS, alternative scenarios



The results of Figs. 2 and 3 show that in both cases, less than 10% of the FS networks would experience an interference level exceeding 1 000 pW0p, even when 30 satellites at the assumed positions each exceeds the pfd threshold by $\beta = 10$ dB. There is, however, a significant difference between the two cases. For the low angle case, it is possible to have significantly higher interference levels when Nsats gets large in comparison to the Nsats = 0 case, although with a low probability. This graph shows that when the FS system latitude is changed to 60º or to 0º, then the interference changes only slightly. When the FS maximum antenna gain is increased to 50 dB the interference decreases, except in low probability, high interference areas, where it increases.

APPENDIX 2

TO ANNEX 1

Determining interference into digital FS systems

1 Methodology

The analysis methodology used here is similar to that used for analogue FS systems, but with some important differences. Each digital station is analysed independently of all others. For the purposes of interference analysis, an ensemble of receivers is modelled so that each station has the same latitude, but a longitude whose value is picked randomly over a 60° range (this latter part is similar to the methodology used in Recommendation ITU-R F.1107). Each FS antenna has a 0° elevation angle and a randomly chosen azimuth angle uniformly distributed between 0° and 360°. The interference is converted into an FDP value for each, as in Recommendation ITU-R F.1108. A cumulative distribution is then calculated for the FDP.

2 Results

Figures 4, 5 and 6 present results of an interference analysis of a network of digital FSS GSO satellites spaced 2º apart causing interference into a digital FS network. The FSS system baseline run is performed with $pfd_{low} = -124$ and $pfd_{high} = -114$ dB(W/(m^2 · MHz)). It transmits with a frequency of 11.95 GHz. The FS system latitude is 40º. In this example each FS site antenna is assumed to have a maximum gain of 44 dB with all receivers having a noise temperature of 1 100 K. A feeder loss of 3 dB is used and the antenna radiation pattern follows Recommendation ITU-R F.1245. In the key, "Nsats" refers to the number of satellites that exceed the pfd baseline by $\beta = 10$ dB: i.e. these satellites have $pfd_{low} + \beta = -114$ and $pfd_{high} + \beta = -104$ dB(W/(m^2 · MHz)). In Fig. 4, the satellites that exceed the pfd threshold were the Nsats satellites closest to the horizon of the FS network (lowest elevation angles). In Fig. 5, the satellites that exceed the pfd threshold were the Nsats satellites closest to the centre of the FS network (highest elevation angles). In Fig. 6, various alternative scenarios are presented. The baseline graph here is for Nsats = 30 and with these satellites closest to the horizon of the FS network.

FIGURE 4

Digital FSS into digital FS, Nsats satellites closest to the horizon

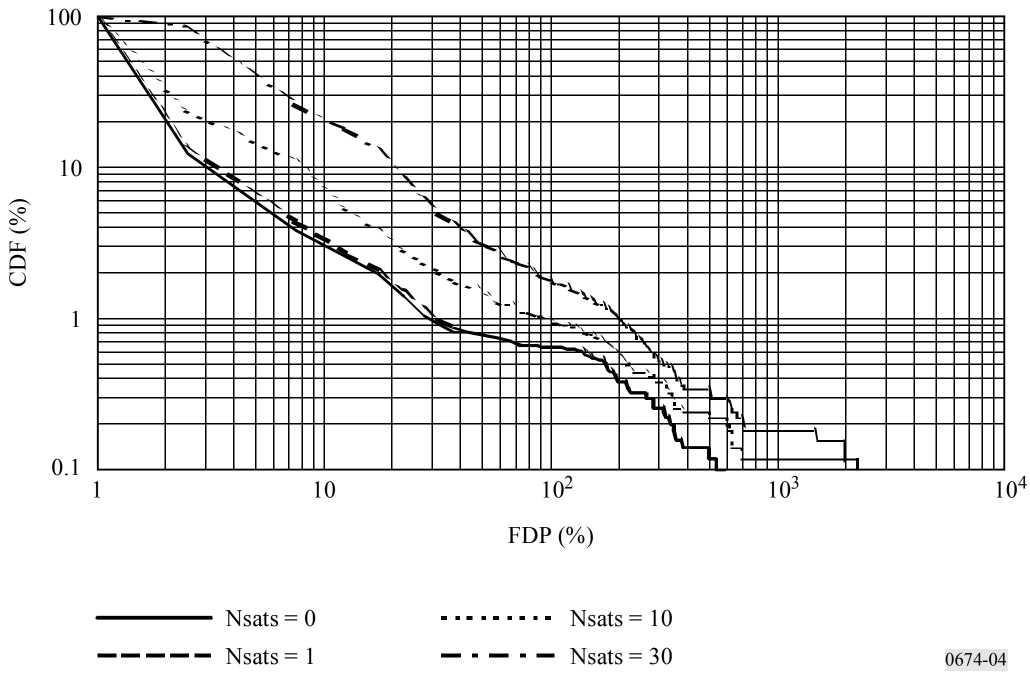


FIGURE 5

Digital FSS into digital FS, Nsats satellites closest to FS network centre

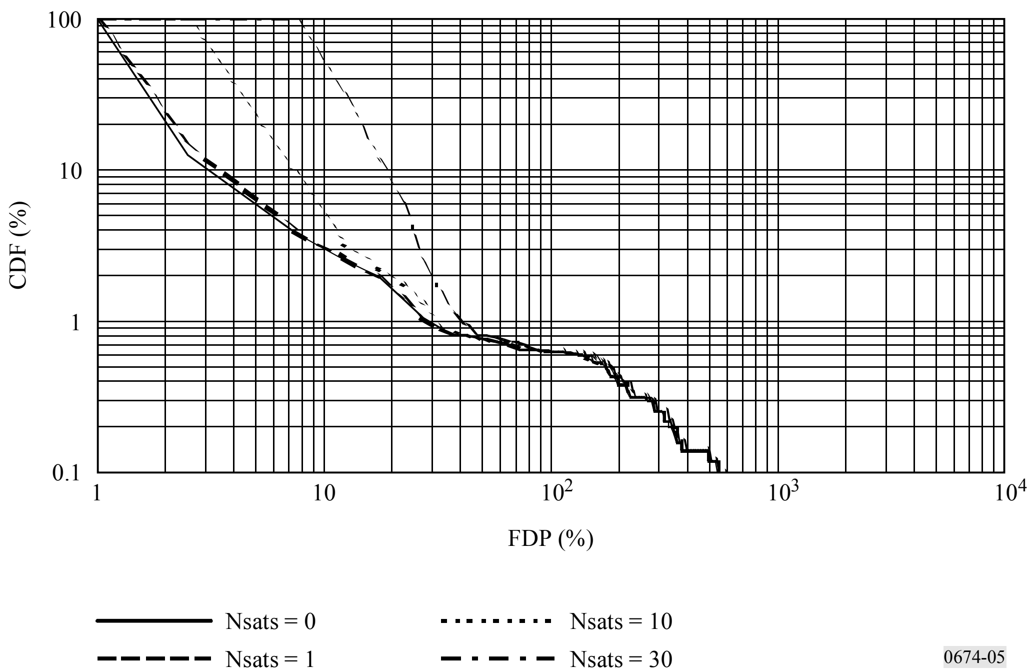
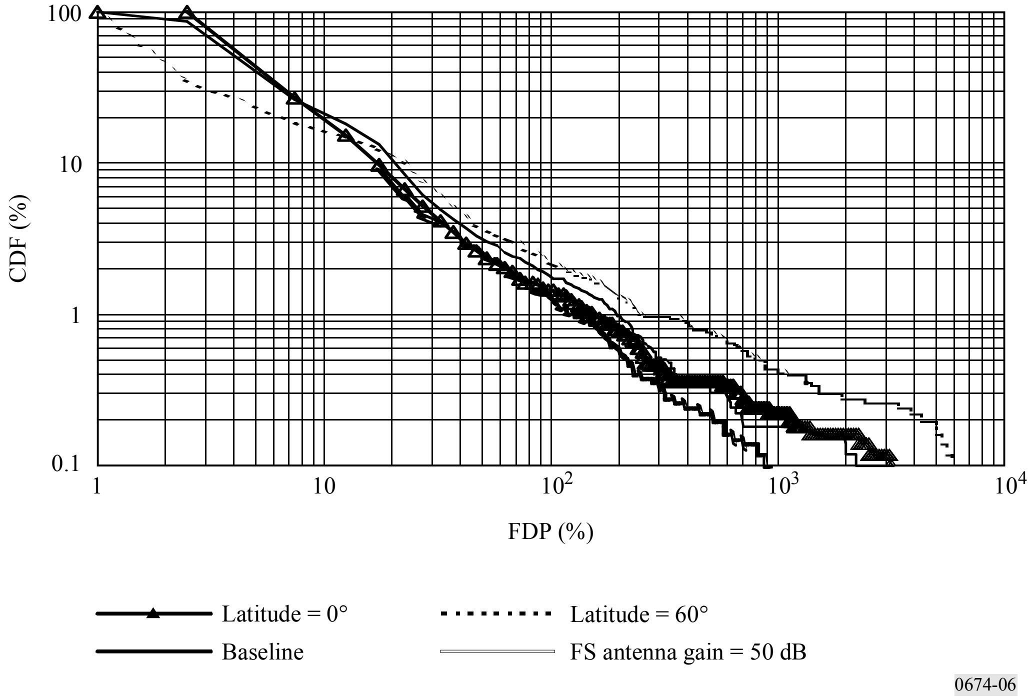


FIGURE 6

Digital FSS into digital FS, alternative scenarios



The results of Figs. 4 and 5 demonstrate that in both cases there would be a negligible increase in interference when a single satellite exceeds the pfd baseline by $\beta = 10$ dB, that somewhat less than 10% of the FS stations would experience an FDP exceeding 10% when 10 satellites exceed this baseline, and that all FS stations would experience an FDP exceeding 10% when 30 satellites exceed this baseline. There is, however, a significant difference between the two cases. For the low angle case, it is possible to have significantly higher interference levels when Nsats gets large in comparison to the Nsats = 0 case, although with a low probability. This graph shows that when the FS system latitude is changed to 60º or to 0º, then the interference changes only slightly, except for the 60º case, in which interference increases for low probability values. When the FS maximum antenna gain is increased to 50 dB the interference decreases.