

RECOMMENDATION 794*

TECHNIQUES FOR MINIMIZING THE IMPACT ON THE OVERALL BSS SYSTEM
PERFORMANCE DUE TO RAIN ALONG THE FEEDER-LINK PATH**

(Questions 86/11 and 98/11)

(1992)

The CCIR,

considering

- a) that any degradation on the feeder links will impact on the broadcasting-satellite service (BSS) performance over the whole service area;
- b) that the BSS satellite transponder should be maintained at nominal output level to minimize the impact of feeder-link fading on reducing the down-link e.i.r.p.;
- c) that while excessive use of on-board automatic gain control (AGC) can result in increasing the inter- and intra-system interference it can maintain the transponder operation at or near nominal output level noting however that the feeder link carrier-to-noise will not be improved;
- d) that while feeder link power control can potentially increase inter-system interference its application can maintain transponder operation at or near nominal output level without degrading the feeder link C/N ;
- e) that while use of site diversity can lead to complex operational considerations, it is an effective technique for reducing feeder link fading, particularly in high rain rate areas,

recommends

that the following techniques be used to the extent practicable for alleviating BSS system degradation due to rain fading on the feeder link:

- on-board satellite AGC (see Annex 1);
- up-link power control (see Annex 2);
- site diversity (see Annex 3).

ANNEX 1

On-board automatic gain control (AGC)

AGC on board spacecraft minimizes the effect of rain fades at the feeder-link station on the down-link C/N ratio by keeping the TWTA at saturation. The AGC operates on individual channels and increases the transponder gain of the wanted signal and of any portion of an interfering signal which falls within the filter bandwidth of the wanted channel. Therefore, during rain at the feeder-link station(s) the use of AGC permits the operation of the transponder close to saturation but the ratio of the wanted carrier to the portion of the interfering adjacent cross-polarized carrier which falls into the filter bandwidth of the wanted channel remains constant. Therefore, the use of AGC has no effect on the cross-polar C/I_u of the two feeder links under consideration.

* This Recommendation should be brought to the attention of Study Group 4.

** Note from the Director, CCIR – Report 952-2 (§ 5.4.1, 5.4.2 and 7) was used in preparing this Recommendation.

However, the satellite using AGC radiates on the down link a constant level of the wanted signal which is attenuated on the feeder link, but re-radiates on the down link a higher level of the interfering cross-polar signal on the adjacent channel, which is not attenuated when there is no rain on the interfering feeder link. This situation may cause an increase in down-link interference to other systems receiving this re-radiation as co-channel interference. This problem could be significant only for co-located satellites serving common or adjacent service areas.

A limit on the range of AGC, in co-located satellites with cross-polarized channels, to less than 10 to 15 dB may be needed to guard against this problem of re-radiation on the down link. This problem can be reduced if satellites with cross-polarized channels serving the same service area or adjacent service areas are separated by at least 0.3° on the geostationary orbit. Non-co-located satellites with cross-polarized channels need not be subject to this limit of AGC range. A 10 dB limit on AGC range could be insufficient to maintain a constant TWTA output in some rain climates for certain elevation angles. The use of some other mechanism (power control, site diversity) might be required in these circumstances to maintain a constant signal level on the down link.

The Region 2 feeder-link Plan is based on a limit of 15 dB on the dynamic range of AGC on board some cross-polarized spacecraft to guard against this problem of re-radiation on the down link.

ANNEX 2

Feeder link power control

Power control of feeder links is the rapid, automatic adjustment of earth-station transmitter power to compensate for rain-induced attenuation in the path of the desired signal to a satellite.

1. Application of power control

In the presence of feeder-link power control (PC), the input level of the signal at the satellite transponder is maintained approximately constant and rain attenuation along the feeder-link path is effectively compensated.

As a consequence, during rain at the feeder-link station only, the use of feeder-link power control maintains a constant value of C/N_T as illustrated in Fig. 1.

Experiments using the BSE of Japan have shown that power control is effective in maintaining a nearly constant level of desired carrier during periods of rain. In this experiment, at 14 GHz a variation of power received at the satellite of 6 dB (peak-to-peak) and 1.5 dB r.m.s. without power control, was reduced through the use of power control to 1.5 dB (peak-to-peak) and 0.5 dB r.m.s., respectively.

2. Conditions for use of power control without increased interference

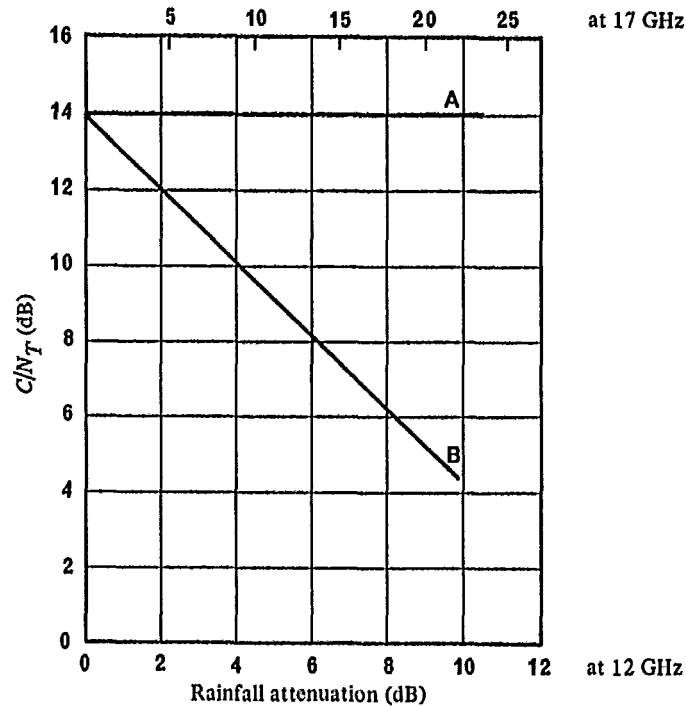
Use of power control to increase the availability of feeder links beyond the values used for planning is analysed in this section.

In studying feeder-link interference problems, the geographical locations of interfering earth stations and wanted feeder-link beam areas are important factors affecting the feeder-link carrier-to-interference ratio. These factors affect the cross-polarization discrimination (XPI_{sat}) of the wanted-satellite antenna because XPI_{sat} is a function of the ratio of the off-axis angle ϕ to the half-power beamwidth ϕ_0 .

For the satellite-receiving antenna reference pattern in Fig. 10 of Recommendation 652, the XPI_{sat} can be graphically expressed as in Fig. 2.

FIGURE 1

The effect of rainfall attenuation on C/N_T in the presence of feeder-link power control (PC)



Clear-sky $C/N_u = 24$ dB

Clear-sky $C/N_d = 14.5$ dB

Curves A: rain at feeder-link station only

B: correlated rain at feeder-link station and down-link station

In order to analyse the effect of the XPI_{sat} on C/I_u , the equation of C/I_u which includes the parameter XPI_{sat} explicitly, is given in equation (1).

$$\frac{C}{I_u} = \frac{P_w}{P_i} \cdot \frac{L_i}{L_w} \cdot \frac{R_i}{R_w} \cdot \frac{G_{rcww}}{G_{rcwi}} \cdot \frac{1}{A + \frac{1}{XPI_{sat}} + \frac{1}{XPI_{es}}} \quad (1)$$

where:

P_w : transmitter power at the wanted earth station

P_i : transmitter power at the interfering earth station

L_w : spreading ("free space") loss on the wanted path

L_i : spreading ("free space") loss on the interfering path

R_w : rain attenuation on the wanted path

R_i : rain attenuation on the interfering path

G_{rcww} : co-polar gain of the wanted-satellite receiving antenna in the direction of the wanted earth station

G_{rcwi} : co-polar gain of the wanted-satellite receiving antenna in the direction of the interfering earth station

A : coefficient of depolarization due to rain as expressed in the following equation:

$$A = 10^{-(XPD/10)}$$

where:

XPD : rain polarization given by:

$$XPD = 30 \log f - 40 \log (\cos \theta) - V \log A_p \quad \text{dB} \quad \text{for } 5^\circ \leq \theta \leq 60^\circ$$

where:

V = 20 for below 15 GHz

V = 23 for above 15 GHz

A_p : co-polar rain attenuation exceeded for 1% of the worst month

f : frequency (GHz)

θ : elevation angle (degrees).

For values of θ greater than 60° , use $\theta = 60^\circ$ in the above equation.

XPI_{sat} : ratio of co-polar gain (G_{rcwi}) to cross-polar gain (G_{rxwi}) of the wanted-satellite receiving antenna in the direction of the interfering earth station as expressed in the following equation:

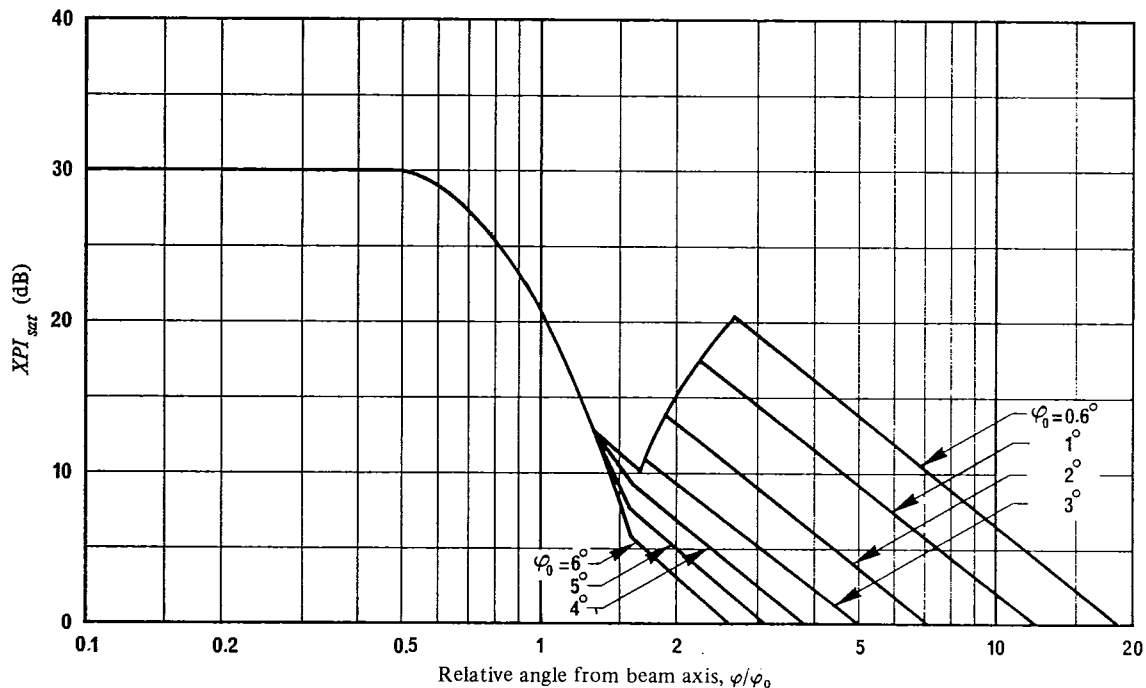
$$XPI_{sat} = G_{rcwi}/G_{rxwi}$$

XPI_{es} : ratio of co-polar (G_{tci}) to cross-polar (G_{txi}) of the interfering earth-station transmitting antenna in the direction of the wanted-satellite as expressed in the following equation:

$$XPI_{es} = G_{tci}/G_{txi}$$

FIGURE 2

Cross-polarization discrimination (XPI_{sat}) of satellite-receiving antenna
(reference patterns are assumed as shown in Fig. 10 of Recommendation 652)



(ϕ_0 : half-power beamwidth)

$$XPI_{sat} \text{ (dB)} = G_{rcwi} \text{ (dB)} - G_{rxwi} \text{ (dB)}$$