RECOMMENDATION ITU-R BO.793*,**

Partitioning of noise between feeder links for the broadcasting-satellite service (BSS) and BSS downlinks***

(Questions ITU-R 86/11)

(1992)

The ITU Radiocommunication Assembly,

considering

a) that the broadcasting-satellite service (BSS) is normally expected to provide service to a relatively large geographical area encompassing a large population of receivers;

b) that in minimizing the effects of feeder-link noise on the overall link noise budget the cost and complexity of the BSS receiver will be minimized;

c) that the satellite output e.i.r.p. is maintained at the nominal output level during feeder-link fades by employing techniques such as automatic gain control (AGC);

d) that higher uplink power requirements would affect only a few feeder-link stations;

e) that in terms of availability, rain fades on the down link would only have a local affect on the performance whereas rain fade on the feeder link would affect performance over the whole service area;

f) that a further degradation of the overall link due to thermal noise occurs due to the non-linearity of the satellite high power amplifier coupled with AM/PM conversion (see Annex 1),

recommends

that as a guide to system design, for a given service availability objective for analogue-modulated emissions in the BSS, the apportionment of the downlink noise contribution to the feeder-link noise contribution should be of the order of 10:1 (see Annex 1).

---

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

** Radiocommunication Study Group 6 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44.

****Note* – Report ITU-R BO.952-2 (§ 3.2 and 3.3) was used in preparing Annex 1.

ANNEX 1

Partitioning of noise between feeder links and downlinks

For the purposes of planning, the WARC-BS-77 adopted a maximum reduction of 0.5 dB of the overall carrier-to-noise (*C*/*N*) ratio, to represent the contribution of the feeder link to the *C*/*N* ratio for 99% of the worst month. This corresponds to a difference of about 10 dB between the carrier-to-noise ratios of the downlinks and feeder links.

According to an EBU study, the contribution of the noise resulting from the feeder link may be rendered negligible by adopting a relatively small margin in the carrier-to-noise ratio of the down-link. This study considered the case of automatic gain control (AGC) in the satellite and was based on a statistical analysis of the attenuations on the feeder link and downlink.

Numerical applications have been made assuming that the attenuations (in dB) follow a log-normal relationship for which the parameters fit measurements made in Europe. It is seen, first, that the results obtained assuming either total correlation or total independence between feeder-link and downlink fadings, are more or less identical. The influence of a margin of 0.5 dB on the downlink, however, is crucial. The improvement due to this margin is better than that obtained by dimensioning the *C*/*N* ratio of the feeder link for 99.9% of the worst month instead of for 99%. Hence, if a downlink *C*/*N* ratio of 14 dB for 99% of the worst month is assumed, the noise contribution from the feeder link to the overall circuit causes the overall link *C*/*N* to drop below 14 dB, 50% to 10% more often (depending on whether the feeder link is dimensioned to give a *C*/*N* ratio of 24 dB for 99% or 99.9% of the worst month). If account is taken of the 0.5 dB margin on the downlink, the percentage of the time during which the overall *C*/*N* drops below 14 dB, including the noise contribution of the feeder link is still smaller than the specified 1% of the worst month in both cases.

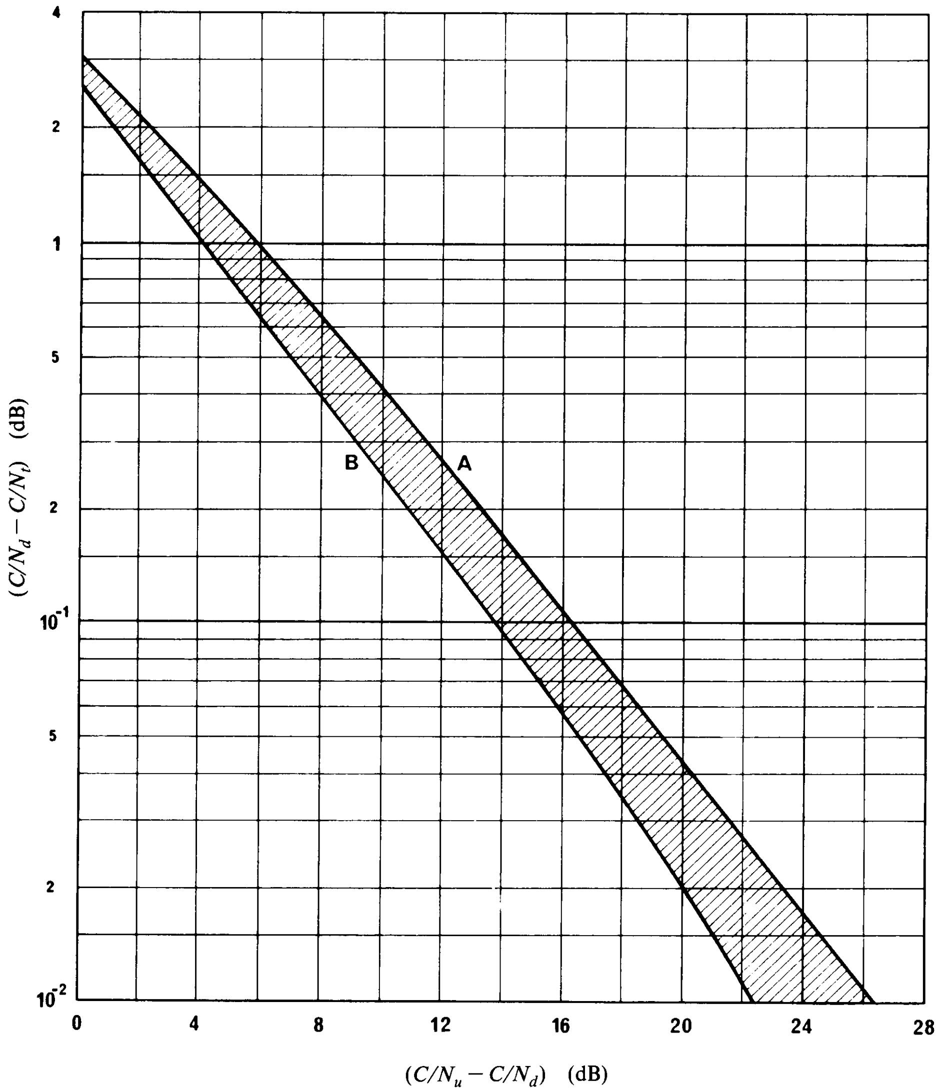
This result confirms the suitability of the choice, made by the WARC-BS-77, to take account of the feeder link by means of such a margin, even at frequencies of the order of 18 GHz.

Similar studies were conducted in Canada on the effects of rain attenuation and satellite transponder characteristics as related to the partitioning of the noise contributions on the feeder links and down-links in a broadcasting-satellite service.

Some of the results can be found in Fig. 1, where the same assumptions as in the above-mentioned study were made. The curves in this figure represent the degradation of the downlink *C*/*N* due to the noise contribution from the feeder link, ($C/N_d - C/N_t$) as a function of the difference between the *C*/*N* of the feeder link and the *C*/*N* of the downlink ($C/N_u - C/N_d$). Full correlation and independence of the fadings on both links are illustrated. All *C*/*N* values are specified for 99% of the worst month.

FIGURE 1

Noise contribution of the feeder link



A: correlated
B: uncorrelated

D01-sc

Partitioning of noise need not be specified as a planning element for Region 2 because the overall carrier-to-noise ratio is the applicable criterion when planning feeder links and downlinks at the same time. However, some assumption of noise partitioning is required in order to determine feeder-link characteristics, such as e.i.r.p. needed to satisfy broadcasting-satellite service requirements.

As a guidance to the development of all the Plans, the noise contribution of the feeder link to the overall link was assumed not to exceed 0.5 dB for 99% of the worst month.

Feeder-link carrier-to-noise ratio

Assuming that there is no transponder output back-off, a 0.5 dB noise contribution of the feeder link to the overall link requires that:

$$(C/N)_u = (C/N)_d + 10 \qquad \text{dB} \tag{1}$$

is exceeded for 99% of the worst month. Under clear-sky conditions, the $(C/N)_u$ is then:

$$(C/N)_u = (C/N)_d + 10 + L_{Att} \qquad \text{dB} \tag{2}$$

where:

$(C/N)_u$: feeder-link carrier-to-noise ratio

$(C/N)_d$: downlink carrier-to-noise ratio

L_{Att}: feeder-link rain attenuation exceeded for 1% of the worst month.

A margin of 1 dB is also needed for planning purposes for possible mispointing of the earth-station transmitting antenna.

Furthermore, the high-power, non-linear amplifier of the repeater introduces, on account of its AM/PM conversion factor, a degradation by the thermal noise in the demodulated signal. The impairment caused to the frequency demodulated signal by the AM/PM phenomenon is given by:

$$D = \frac{\alpha + I}{1 + I} \tag{3}$$

where:

D: decrease in post detection signal-to-noise ratio (S/N) (see Fig. 2) due to increase in post-detection noise in the presence of AM/PM conversion

$I = (C/N)_u / (C/N)_d$

$\alpha = 1 + \left(\frac{K}{6,6} \right)^2$ (for frequency modulation)

K: AM/PM conversion factor.

K is of the order of 5 to 6 degrees/dB with present-day amplifier technology. This gives a value for α in the region of 2.0 to 2.6 dB, which has been demonstrated theoretically and experimentally.

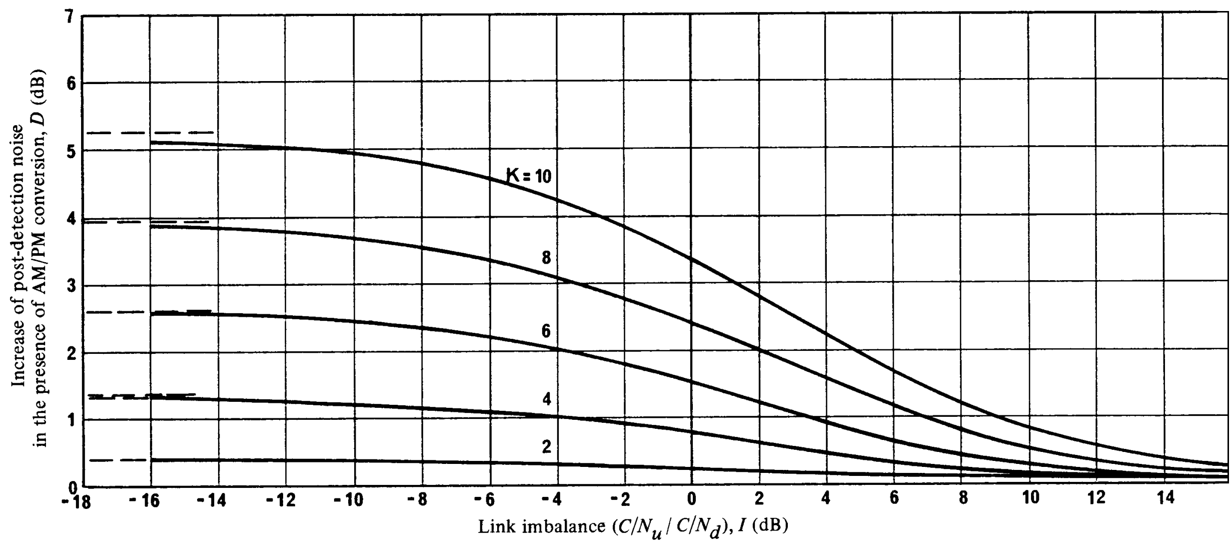
The degradation caused by AM/PM conversion cannot be observed by means of direct radio-frequency carrier-to-noise (C/N) measurements. However, this degradation can be measured by other means. It must be taken into account when calculating feeder-link budgets and can be compensated for by an increase in C/N_u of 10 log α dB. AM/PM conversion was not taken into account in the development of the Region 2 Plan.

In a plan based on homogeneous characteristics of feeder-link stations which in turn leads to homogeneous nominal (clear sky) power flux-densities at the satellites, the C/N_u varies with satellite receive antenna gain. In Region 2, the range of interest of the satellite receive antenna gain at the –3 dB edge of coverage area varies from about 28 dB for a large country-wide feeder-link beam of 3° × 8° to 46 dB for a small spot beam of 0.6°. With a system noise temperature at the satellite of 1 500 K, which is readily achievable for satellite receivers at 18 GHz, the range of interest of G/T varies from –4 dB(K^{-1}) to 14 dB(K^{-1}) at the edge of coverage area. The choice of feeder-link power into the transmitting antenna may be in the range of 500 to 1 000 W. The Region 2 feeder-link Plan is based on a maximum radio-frequency power of 1 000 W delivered at the input of the feeder-link antenna. Table 1 gives a range of C/N_u at 17.5 GHz assuming an antenna efficiency of 65%, a filter bandwidth of 24 MHz and 1 dB gain loss due to mispointing of the earth-station antenna for 500 and 1 000 W transmitted power. In Region 2, the Plan is based on a 5 m antenna diameter but larger and/or smaller antennas can be used.

For example, in the case of 14.5 dB C/N_d on the downlink and a possible 1 dB mispointing of the earth-station transmitter antenna, a very small number of cases in Table 1 would give a noise contribution of the feeder link greater than 0.5 dB to the overall noise of the communication channels. These few cases are italicized in the table. In Regions 1 and 3, the Plan is based on 5 and 6 m antenna diameters for the frequency bands 17 and 14 GHz, respectively, and 500 W transmitter power. These values correspond to an e.i.r.p. of 84 and 82 dBW, respectively, and aim to achieve a carrier-to-noise ratio (C/N) of 24 dB exceeded for 99% of the worst month.

FIGURE 2

Effect of AM/PM conversion on the post-detection noise power



K: AM/PM conversion factor (degrees/dB)

— — —: I → -∞ dB

D02-sc

TABLE 1

Range of carrier-to-noise ratio calculated for earth-station antenna mispointed by 1 dB and transmitting 500 or 1 000 W of power (Region 2)*

Earth-station antenna diameter (m)	**Minimum *G*/*T* of satellite receive antenna (edge of coverage area) (dB(K^{-1}))**	**Carrier-to-noise ratio C/N_u (dB)**					
		Clear sky		**With 5 dB rainfall attenuation**		**With 10 dB rainfall attenuation**	
		Transmitted power (W)					
		500	**1 000**	**500**	**1 000**	**500**	**1 000**
2.5	– 4	*19.2*	*22.2*	*14.2*	*17.2*	*9.2*	*12.2*
	+ 2	25.2	28.2	*20.2*	*23.2*	*15.2*	*18.2*
	+ 8	31.2	34.2	26.2	29.2	*21.2*	*24.2*
	+ 14	37.2	40.2	32.2	35.2	27.2	30.2
5	– 4	25.2	28.2	*20.2*	*23.2*	*15.2*	*18.2*
	+ 2	31.2	34.2	26.2	29.2	*21.2*	*24.2*
	+ 8	37.2	40.2	32.2	35.2	27.2	30.2
	+ 14	43.2	46.2	38.2	41.2	33.2	36.2
8	– 4	29.3	32.3	24.3	27.3	*19.3*	*22.3*
	+ 2	35.3	38.3	30.3	33.3	25.3	28.3
	+ 8	41.3	44.3	36.3	39.3	31.3	34.3
	+ 14	47.3	50.3	42.3	45.3	37.3	40.3
11	– 4	32.1	35.1	27.1	30.1	*22.1*	25.1
	+ 2	38.1	41.1	33.1	36.1	28.1	31.1
	+ 8	44.1	47.1	39.1	42.1	34.1	37.1
	+ 14	50.1	53.1	45.1	48.1	40.1	43.1

* In the case of the feeder link Plan for Regions 1 and 3, the figures in this Table should be reduced by 0.5 dB, with a reference bandwidth of 27 MHz.