Satellite Communications

Communication satellite link budget

Chapter two

Lecture 10

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Carrier-to-Noise Ratio

To measure the performance of a satellite link use the ratio of carrier power to noise power at the receiver input and the link-budget calculations are often concerned with determining this ratio. In terms of decibels:

$$\frac{C}{N} = \frac{P_r}{P_N}$$

where $C = P_r$ *= carrier receiving power*

$P_r = P_t\ G_t\ G_r / LF$

$EIRP = P_t\ G_t$

$P_N = K\ Ts\ B$

Carrier-to-Noise Ratio (cont.)

Then

$$C/N = \frac{Pt\ Gt}{LF} \cdot \frac{Gr}{Ts} \cdot \frac{1}{K\ B}$$

In dB

$$\left[\frac{C}{N}\right] = [\text{EIRP}] + [G_R] - [\text{LOSSES}] - [k] - [T_S] - [B_N]$$

Note that the losses is the same of the LF or FSL

Noise Density

It is a power presented at 1 KHz bandwidth

$$N_o = \frac{P_N}{B_N} \quad (W/Hz)$$

$$= KT_N$$

The ratio of carrier power to noise power density may be the quantity actually required then

$$\left[\frac{C}{N}\right] = \left[\frac{C}{N_o B_N}\right]$$

$$= \left[\frac{C}{N_0}\right] - [B_N]$$

Noise Density (cont.)

[C/N] is a true power ratio in units of decibels
[B_N] is in decibels relative to one hertz, or dB Hz.

Thus the units for [C/N_o] are dB Hz.

$$\left[\frac{C}{N_o}\right] = [EIRP] + \left[\frac{G}{T}\right] - [LOSSES] - [k]$$

Figure of merit (G / T Ratio for Earth Station)

This ratio is widely used to specify the quality of an earth station & sat. it is defined as the ratio of receiver antenna gain $Gr = G$ to the receiver system noise temperature Ts.

$$\left[\frac{G}{T}\right] = [G] - [T_s] \quad dBk^{-1}$$

So the C/N equation [link equation] will be

$$\left[\frac{C}{N}\right] = [EIRP] + [G] - [LOSSES] - [k] - [T_s] - [B_N]$$

Therefore the link equation becomes

$$\left[\frac{C}{N}\right] = [EIRP] + \left[\frac{G}{T}\right] - [LOSSES] - [k] - [B_N]$$

The Uplink

The uplink of a satellite circuit is when the earth station is transmitting the signal and the satellite is receiving it. The subscript *U* will be used to denote specifically for uplink.

$$\left[\frac{C}{N_o}\right]_U = [EIRP]_U + \left[\frac{G}{T}\right]_U - [LOSSES]_U - [k]$$

The values to be used are the earth station EIRP, the satellite receiver feeder losses, and satellite receiver *G/T.* The free space loss and other losses which are frequency-dependent are calculated for the uplink frequency.

The carrier-to-noise density ratio can write it in dB as:

$$\left[\frac{C}{N_o}\right]_U = 10\ Log\ P_T G_T - 20\ Log\ \left(\frac{4\pi D}{\lambda}\right) + 10\ Log\ \left(\frac{G}{T}\right) - 10\ Log\ k$$

The Downlink

The downlink of a satellite circuit is when the satellite is transmitting the signal and the earth station is receiving it. The subscript D will be used to denote specifically for downlink.

$$\left[\frac{C}{N_o}\right]_D = [EIRP]_U + \left[\frac{G}{T}\right]_D - [LOSSES]_D - [k]$$

The values to be used are the earth station EIRP, the satellite receiver feeder losses, and satellite receiver G/T. The free space loss and other losses which are frequency-dependent are calculated for the downlink frequency.

The carrier- to-noise density ratio can write it in dB as:

$$\left[\frac{C}{N_o}\right]_D = 10\ Log P_T G_T - 20 Log\left(\frac{4\pi D}{\lambda}\right) + 10 Log\left(\frac{G}{T}\right) - 10 Log\ k$$

Antenna Gain

1. Consider first (ideal) antenna with a physical aperture area of $A\ (m^2)$.

So the gain of the ideal antenna with a physical aperture area A is defined as

$$G_{ideal} = \frac{4\pi A}{\lambda^2}$$

Antenna Gain (cont.)

Physical antennas are not ideal to account for this, an effective aperture, Ae, is defined in terms of an aperture efficiency, η_A, and physical aperture area A such that:

$$A_e = \eta_A A$$

Then, defining the physical antenna gain as G,

$$G = \frac{4\pi A_e}{\lambda^2} \quad \text{or} \quad G = \eta_A \frac{4\pi A}{\lambda^2}$$

$$G = 10 \log[\eta_A \frac{4\pi A}{\lambda^2}], \quad dBi$$