3.1 Satellite Uplink and Downlink Analysis and Design

Introduction

The link-power budget calculations basically relate two quantities, the transmit power and the receive power, and show in detail how the difference between these two powers is accounted for. Link-budget calculations are usually made using decibel or decilog quantities. Where no ambiguity arises regarding the units, the abbreviation dB is used. For example, Boltzmann's constant is given as 228.6 dB, although, strictly speaking, this should be given as 228.6 deci logs relative to 1 J/K.

Equivalent Isotropic Radiated Power

A key parameter in link-budget calculations is the *equivalent isotropic radiated power*, conventionally denoted EIRP. The maximum power flux density at some distance '*r*' for transmitting antenna of gain '*G*i'

$$Pr= \frac{GP}{4\pi^2}$$

An isotropic radiator with an input power equal to GP*S* would produce the same flux density. Hence, this product is referred to as the EIRP, or EIRP is often expressed in decibels relative to 1 W, or dBW. Let *PS* be in watts; then [EIRP] = [*PS*] x [*G*] dB , where [*PS*] is also in dBW and [*G*] is in dB.

Transmission Losses

The [EIRP] may be thought of as the power input to one end of the transmission link, and the problem is to find the power received at the other end. Losses will occur along the way, some of which are constant. Other losses can only be estimated from statistical data, and some of these are dependent on weather conditions, especially on rainfall.

The first step in the calculations is to determine the losses for *clear-weather* or *clear-sky conditions*. These calculations take into account the losses, including those calculated on a statistical basis which does not vary with time. Losses which are weather-related, and other losses which fluctuate with time, are then allowed for by introducing appropriate *fade margins* into the transmission equation.

Free-space transmission:

As a first step in the loss calculations, the power loss resulting from the spreading of the signal in space must be determined.

Feeder losses:

Losses will occur in the connection between the receive antenna and the receiver proper. Such losses will occur in the connecting waveguides, filters, and couplers. These will be denoted by RFL, or [RFL] dB, for *receiver feeder losses*.

Antenna misalignment losses:

When a satellite link is established, the ideal situation is to have the earth station and satellite antennas aligned for maximum gain, as shown in Figure 2.14. There are two possible sources of off-axis loss, one at the satellite and one at the earth station. The off-axis loss at the satellite is taken into account by designing the link for operation on the actual satellite antenna contour; this is described in more detail in later sections. The off-axis loss at the earth station is referred to as the *antenna pointing loss*. Antenna pointing losses are usually only a few tenths of a decibel. In addition to pointing losses, losses may result at the antenna from misalignment of the polarization direction. The polarization misalignment losses are usually small, and it will be assumed that the antenna misalignment losses, denoted by [AML], include both pointing and polarization losses resulting from antenna misalignment.

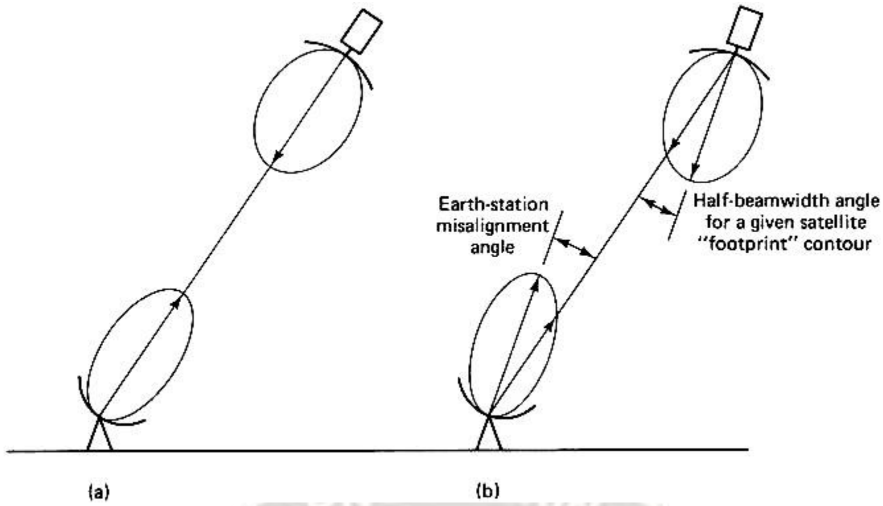

Fig 2.14 (*a*) Satellite and earth-station antennas aligned for maximum gain; (*b*) earth station situated on a given satellite "footprint," and earth-station antenna misaligned.

The Link-Power Budget Equation

The losses for the link have been identified, the power at the receiver, which is the power output of the link, may be calculated simply as [EIRP] [LOSSES] [G_R], where the last quantity is the receiver antenna gain. The major source of loss in any ground-satellite link is the free-space spreading loss [FSL], the basic link-power budget equation taking into account this loss only. However, the other losses also must be taken into account, and these are simply added to [FSL].

The losses for clear-sky conditions are

[LOSSES] = [FSL] +[RFL] +[AML]+[AA] -[PL] equation for the

received power is then [P_R] = [EIRP] X [G_R] -[LOSSES]

Where

[PR] - the received power, dBW

[EIRP] - equivalent isotropic radiated power, dBW [FSL] free-space

spreading loss, dB [RFL] - receiver feeder loss, dB

[AML] -antenna misalignment loss, Db [AA] - atmospheric absorption loss, dB [PL] polarization mismatchloss, dB