SATELLITE COMMUNICATIONS AND GPS

MODULE 3

Module 3

Module 3:

Satellite Link Design: The space link: EIRP, Transmission losses, Link power budget equations, System noise, Carrier to Noise ratio, Uplink C/N_o, Downlink C/N_o, Combined uplink and downlink C/N_o ratio.
Interference: Interference between satellite circuits, Combined C/I due to interference. (Text Book 1)

Deals with link power budget calculations, relating to two quantities, transmit power and receive power. Difference between the two are accounted for.

Link budget calculations expressed in decibel or decilogs.

Equivalent Isotropic Radiated Power (EIRP):

Main parameter in calculations. Maximum power flux density at a distance r from Tx with antenna gain G is

$\psi_M = GPs/4\pi r^2$

Means an isotropic radiator with input power of GPs produces the same flux density.

EIRP= GPs expressed in dB relative to 1W or dBW. If Ps is in Watts, [EIRP]= [Ps] + [G] dBW [Ps] is also in dBW and [G] is in dB

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Ex: Satellite downlink at 12GHz, has transmit power of 6W. Antenna gain is 48.2dB. Find EIRP in dBW.

[EIRP]= 10 log (6W/1W0 + 48.2= 56dBW

Convenient to operate with frequency (known) than wavelength. For a paraboloidal antenna

G= η (10.472fD)^2

Carrier frequency is f , reflector diameter D in m, aperture efficiency η (usually in the range 0.55 to 0.73).

If D is in feet, G= η(3.192fD)^2

Ex: 3m paraboloidal antenna at 12GHz has η of 0.55 and if η=0.73 find gain in dB.

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For $\eta = 0.55$

$G = 0.55 \times (10.472 \times 12 \times 3)^\wedge = 78168$

$[G] = 10 \log 78168 = 48.9\text{dB}$

For $\eta = 0.73$, $G = 103750$

$[G] = 10 \log 103750 = 50.159 \text{ dB}$

Transmission Losses: EIRP assumed as power input to one end of transmission link. Required to find the power at the receiver. Some of the losses occurring along link are constants, others are estimated by statistical data , some are weather dependent (rainfall).

Losses for clear sky condition or clear weather are found first, taking into account the losses, include from statistical data which do not vary with time. Losses that are due to weather condition and fluctuating losses are accounted for by introducing fade margins in Tx equation.

Free Space Transmission:

Spreading of signal in space which causes power loss is found. Calculation is same as for uplink and down link of circuit.

Power Flux density at receiving antenna ψ_M =EIRP/ 4лr^2

Received power at the matched receiver= P_R= ψ_M Aeff

=(EIRP/ 4лr^2) (λ^2 G_R/4л) = (EIRP) (G_R)(λ/4лr)^2   r- distance or range between Tx and Rx antenna. G_R isotropic power gain of receive antenna. In decibels $[P_R]= [EIRP] + [G_R] – 10 \log (4\pi r/\lambda)^2$

Received power in dBW is sum of transmitted EIRP in dBW, plus receiver antenna gain in dB, minus the third term (losses) in dB.

Free space loss in dB is $[FSL] = 10 \log (4\pi r/\lambda)^2$

Taking $\lambda= c/f$ as f is known, c being velocity of light, frequency in MHz, distance in km,

$[FSL] = 32.4 + 20 \log r +20 \log f$

$[P_R] = [EIRP] + [G_R] –[FSL]$

Received power $[P_R]$ will be in dBW

EX: Ground station to satellite range is 42000km. Find free space loss loss at 6GHz.

$[FSL]= 32.4 + 20 \log 42000 + 20 \log 6000= 200.4$dB, very big loss.

If [EIRP] is 56dBW, for a radiated power of 6W and receive antenna height is 50dB. Received power= 56+ 50 -200.4=- 94.4dBW, or 355pW, or -64.4dBm, ie., 64.4dB below 1mW level.

Antenna gain proportional to $(1/\lambda)^2$. If frequency is increased, it appears that antenna gain and receive power are increased. As free space losses increase as $(1/\lambda)^2$, effects cancel. Hence for a constant EIRP received power is independent of frequency.

If transmit power is specified constant and not EIRP, received power increases as frequency increases for given antenna dish sizes at TX and Rx.

Feeder Loss: Receiver and receiver antenna are connected. Losses will occur in connections, connecting waveguides, filters and couplers.

RFL or [RFL] dB for receiver feeder losses, these are added to [FSL]. Losses similar to this occur in filters, couplers and waveguides connecting Tx antenna to high power amplifier (HPA) output.

EIRP if specified these need not be used. These are taken into account when, EIRP to HPA output to be related.

Antenna Misalignment Losses: Ideally when earth station antenna and satellite antenna are aligned for maximum gain.

Fig. 12.1 shows how misalignment can happen. One loss at satellite and the other at earth station.

Off axis loss at satellite is accounted by designing the link for operation on the actual satellite antenna contour. Off axis loss at earth station – referred to as antenna pointing loss, only few tenths

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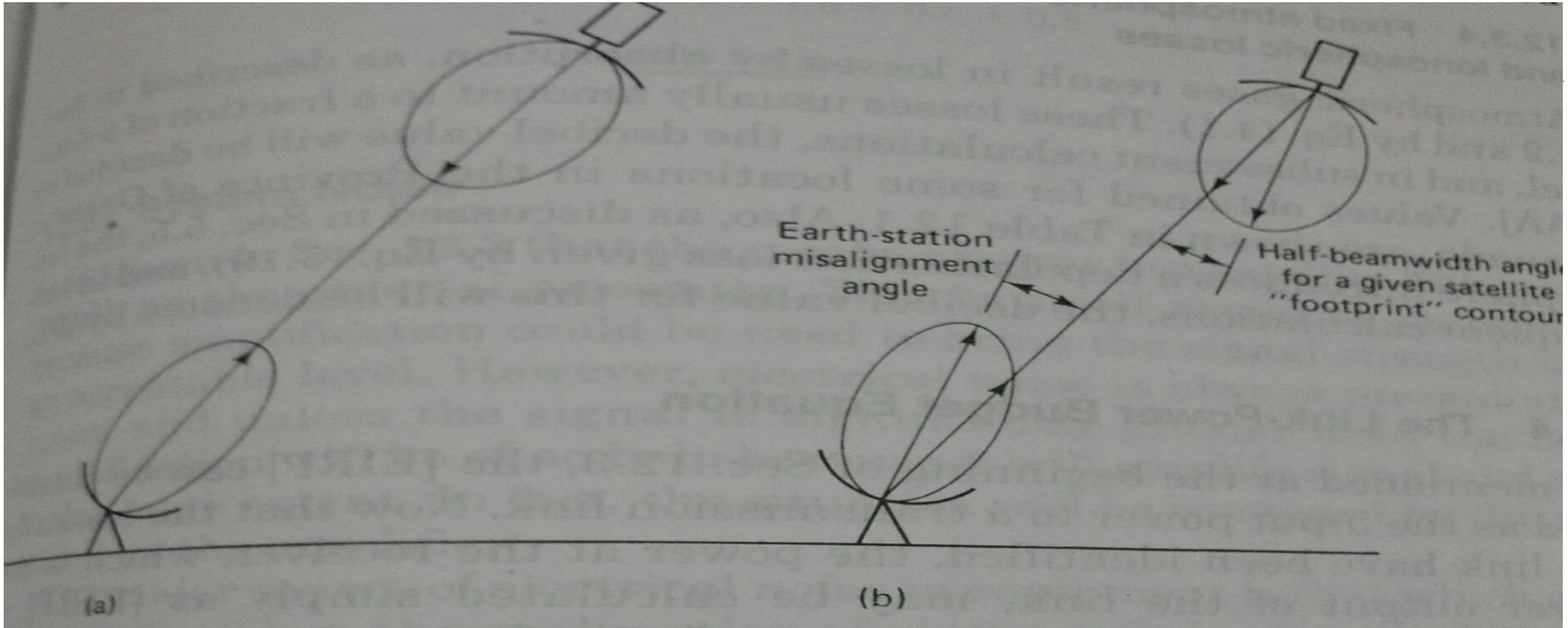

gure 12.1 (*a*) Satellite and earth-station antennas aligned for maximum gain; (*b*) ea
ation situated on a given satellite "footprint," and earth-station antenna misaligr

of decibel. Values are as in table 12.1.

Other losses at antenna due to misalignment of polarization direction (polarization misalignment losses) are small and antenna misalignment losses [AML] include both pointing and polarization losses due to antenna misalignment. AML are estimated from statistical data based on observation of actual errors from a large no. of earth stations.

Separate antenna misalignment losses for uplink and must be accounted .

Fixed Atmospheric and Ionospheric Losses : Losses by absorption due to gases. Usually a fraction of dB. This is denoted by [AA].

of decibel. Values are as in table 12.1.

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For some locations in Province of Ontario, Canada are in Table 12.1.

Ionosphere introduces a depolarization loss, this value is denoted by [PL].

Link Power Budget Equation: [EIRP] is input power to a transmission link. Power at receiver= power output of link= [EIRP]-[Losses]+ [G_R]. Last one is receiver antenna gain. Decibel addition must be used.

[LOSSES]= [FSL] + [RFL] + [AML] +[AA] +[PL]

Received power in dB = [P_R] =[EIRP] + [G_R] –[LOSSES]

[P_R]= received power in dBW [EIRP] in dBW, [FSL] in dB, Receiver feeder loss [RFL] in dB, [AML] in dB, Atmospheric absorption loss

[AA] in dB , [PL] = polarization mismatch loss in dB.

Ex: Satellite link at 14GHz has receiver feeder loss of 1.5dB, free space loss 207dB, atmospheric absorption loss 0.5dB, antenna pointing loss o.5dB. Depolarization losses can be neglected. Find total link loss for clear sky condition.

Total link loss= [LOSSES]= [FSL] + [RFL] + [AA] +[AML]

= 207 + 1.5 + 0.5 + 0.5 = 209.5dB

System Noise: Receiver power in a link is very small of the order of picowatts. But amplification can increase the signal strength, if no electrical noise is present. Receiver signal strength must be >> noise level, as amplification amplifies both signal and noise alike. If noise is added by amplifier, the situation is worse.