Satellite Communication

Lecture # 9

Link Budget

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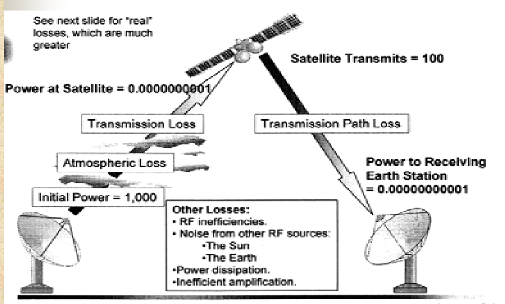


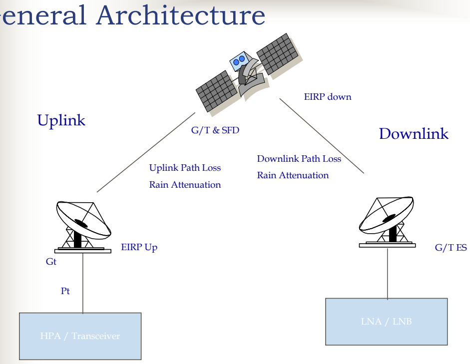
Introduction

Overall design of a complete satellite communications system involves many complex trade-offs to obtain a cost-effective solutions

Factors which dominate are

- Downlink EIRP, G/T and SFD of Satellite
- Earth Station Antenna
- Frequency
- Interference

General Architecture



Transmit Earth Station

- Antenna Gain
- Power of Amplifier

Uplink

- Path Loss
- Rain Attenuation

Satellite

- **G/T**
- **EIRP** (Equivalent Isotropic Radiated Power)
- **SFD** (Saturated Flux Density)
- **Amplifier Characteristic**

Downlink

- **Path Loss**
- **Rain Attenuation**

Receiving Earth Station

- **Antenna Gain**
- **LNA /LNB Noise Temperature**
- **Other Equipment**

Signal Power Calculation

Antenna Gain

$G = \eta (\Pi * d / \lambda)^2$ [dBi]

Where,

$\lambda = C / f$,

C = Speed of light

f = frequency of interest

η = efficiency of antenna (%),

d = diameter of antenna (m)

Signal Power Calculation

Antenna Beam width

$\theta_{3dB} = 70 * C / df$ [degrees]

Where,

$C = 3x10^8$ m/s (Velocity of Light)

EIRP

Is the effective radiated power from the transmitting side and is the product of the antenna gain and the transmitting power, expressed as

$EIRP = G_t + P_t - L_f$ [dB]

Where,

L_f is the Feed Losses

Signal Power (Pr)

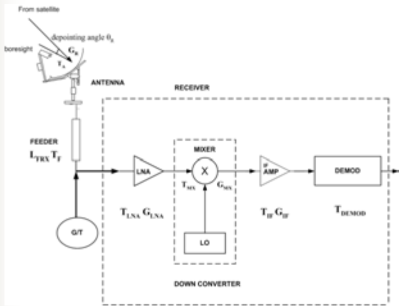
$P_r = EIRP - Path\ Loss + Gr_{(sat)}$ [dB]

Where,

Path Loss = $(4\Pi D / \lambda)^2$

D is the Slant Range (m)

Noise Calculation



Thermal Noise

Is the noise of a system generated by the random movement of electronics, expressed as

Noise Power = KTB

Where,

- **K= (-228.6 dBJ/K)**
- **T= Equivalent Noise Temperature (K)**
- **B= Noise Bandwidth of a receiver**

Effective Temperature

$$Te = T1 + (T2/G1)$$

Where,

- **T1= Temperature of LNA**
- **T2= Temperature of D/C**
- **G1= Gain of LNA**

Noise Temperature

$$T_s = T_{ant} / L_f + (1 - 1/L_f) T_f$$

Where,

- **Tant = Temperature of antenna**
- **Lf = Feed Losses**
- **Tf = Feed Temperature**

Effective Temperature

$$T_{sys} = T_s + T_e$$

- Being a first stage in the receiving chain, LNA is the major factor for the System Temperature Calculation
- Lower the noise figure of LNA lower the system temperature
- Antenna temperature depends on the elevation angle from the earth station to satellite

G/T (Gain to System Noise Temperature)

- This is the Figure of merit of any receiving system
- It is the ratio of gain of the system and system noise temperature

$$G/T = G - 10\log(T_{sys}) \quad [dB/K]$$

Link Analysis

C/N Uplink

$(C/N)_u = (EIRP)_e - (\text{Path Loss})_u + (G/T)_{sat} - K - \text{Noise BW}$ [dB]

C/N Downlink

$(C/N)_d = (EIRP)_{sat} - (\text{Path Loss})_d + (G/T)_e - K - \text{Noise BW}$ [dB]

C/N Total

$(C/N)_T^{-1} = (C/N)_u^{-1} + (C/N)_d^{-1} + [C/I]_{IM}^{-1} + [C/I]_{adj}^{-1} + [C/I]_{xp}^{-1}$ [dB]

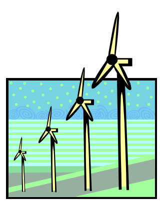
Eb/No (Energy per bit per Noise Power Density)

- Is the performance criterion for any desire BER
- It is the measure at the input to the receiver
- Is used as the basic measure of how strong the signal is
- Directly related to the amount of power transmitted from the uplink station

$E_b/N_o = (C/N)_T$ + Noise BW – Information Rate

Carrier Parameters

- Solution - Carrier Performance:
  - Eb/No Threshold
  - Bit Error Rate (BER)
  - Rain Attenuation



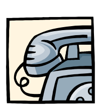
Bit Error Rate (BER)

- Why is it used? - To represent the amount of errors occurring in a transmission
  - To express the link quality
- What is it? - BER is an equipment characteristic
  - BER is directly related to Eb/No
  - BER improves as the Eb/No gets larger

$P = 1/2\ e^{-Eb/No}$ (with P = Probability of error)

Carrier Parameters

- Performance:
  - Application specific
    - Digital voice links:
      - BER threshold 10^{-3}
  - Data links:
    - BER threshold: 10^{-4}



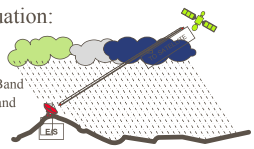
Carrier Parameters

- Performance:
  - Typical Eb/No values for different FEC

Eb/No for FEC 1/2 (dB)	Eb/No for FEC 3/4 (dB)	Eb/No for FEC 7/8 (dB)	BER
6.5	8.0	9.1	10^{-6}
7.1	8.7	9.7	10^{-7}
7.6	9.2	10.4	10^{-8}
9.9	11.0	12.1	10^{-10}

Rain Attenuation

- Performance - Rain Attenuation:
  - Availability
    - Rain Margins
      - Typically 99.60 % for Ku-Band
      - Typically 99.96 % for C-Band



- Performance - Additional Margins:
  - Adjacent Satellite Interference (ASI)
  - Interference Margins

Questions?