Satellite Communications

Part IV-Lecture 4-Satellite Link Design

Lecturer Madeeha Owais

Learning Objectives

- Solving calculations of Link Budget for various satellite systems
- We have learnt the calculation of C/N ratio for a single link (uplink or downlink)
- We shall now learn the calculation of C/N ratio for a complete satellite communication link

Calculating C/N ratio for a Complete Satellite Communication Link

Combining C/N and C/I values in Satellite Links

- To measure BER or S/N ratio in the baseband channel of an E/S receiver we find C/N in the IF amplifier at the input of the demodulator
- The noise present in the IF amplifier comes from many sources
- Till now in our analysis of uplinks and downlinks, we have considered only the receiver thermal noise and noise radiated by atmospheric gases and rain
- When a complete satellite link is engineered, the noise in the earth station IF amplifier will have contributions from:
    - Receiver itself
    - Receiving Antenna
    - Sky noise
    - Satellite Transponder from which it receives the signal
    - Adjacent satellite and terrestrial transmitters which share the same frequency band

Combining C/N and C/I values in Satellite Links

- When more than one C/N ratio is present in the link, we add the individual C/N ratios reciprocally to obtain an *overall C/N ratio* ,denoted by $(C/N)_o$
- The overall $(C/N)_o$ ratio would be measured in the earth station at output of IF amplifier
- $(C/N)_o = 1/[1/(C/N)_1 + 1/(C/N)_2 + 1/(C/N)_3 + \ldots..]$
- This is referred to as the *reciprocal C/N formula*
- The C/N values must be linear ratios, NOT decibel values
- To calculate the performance of a satellite link we must determine the uplink $(C/N)_{up}$ ratio in the transponder and the downlink $(C/N)_{dn}$ in the receiver earth station
- Also if there is any interference present ,either in satellite receiver or the earth station receiver, a C/I value is included in the calculation of $(C/N)_o$

Combining C/N and C/I values in Satellite Links- Numerical Example

- Thermal noise in an earth station receiver results in a $(C/N)_{dn}$ ratio of 20.0dB.A signal is received from a bent pipe transponder with a carrier to noise ratio $(C/N)_{up}$=20.0dB.What is the value of over all $(C/N)_o$ at the earth station? If the transponder introduces inter-modulation products with C/I ratio=24 dB,what is the $(C/N)_o$ at the receiving earth station

- $$(C/N)_o = \frac{1}{1/(C/N)_{up} + 1/(C/N)_{dn}}$$

- $(C/N)_o$ = [1/(0.01+0.01)]=50 or 17.0 dB

- With a (C/I) value of 24 dB, which corresponds to ratio of 0.004,the $(C/N)_o$ is
- $(C/N)_o$ = [1/(0.01+0.01+0.004)]

  = 41.7 or 16.2 dB

Overall $(C/N)_o$ with Uplink and Downlink Attenuation

- The effect of a change in the uplink C/N ratio has an impact on overall $(C/N)_o$ ratio depending on the operating mode and gain of the transponder
- Three different transponder operating modes are:
  - Linear Transponder: $P_{out}=P_{in} + G_{xp}$ dBW
  - Non-linear Transponder: $P_{out}=P_{in} + G_{xp} - \Delta G$ dBW
  - Regenerative Transponder: $P_{out}=\text{constant}$ dBW
- where P_{in} is the power delivered by satellite's receiving antenna to the input of the transponder, P_{out} is the power delivered by the transponder HPA to the input of satellite's transmitting antenna, G_{xp} is transponder gain
- ΔG is dependent on P_{in} and accounts for the loss of gain caused by nonlinear saturation characteristics of transponder
- Our discussion shall pertain to only Linear Transponders for this course !!

Overall $(C/N)_o$ with Uplink and Downlink Attenuation

- **Uplink and Downlink Attenuation in Rain**
  - Rain affects uplink and downlink differently
  - Usually it is assumed that rain either occurs on uplink or downlink for geographically separated E/S's
  - Heavy rains occur with random geographic distribution, so probability of significant attenuation on both uplink and downlink simultaneously is small
  - In our analysis of uplink and downlink attenuation effects, it will be assumed that one link is attenuated and the other is operating in clear air

Overall $(C/N)_o$ with Uplink and Downlink Attenuation

- **Uplink Rain Attenuation and $(C/N)_{up}$**
  - No increase in uplink noise power because satellite antenna beam sees the top of cumulonimbus clouds above the rain, which are always colder than 270 K
  - Rain attenuation on uplink path carrier power at satellite receiver input
  - Reduction in $(C/N)_{up}$ is in direct proportion to the attenuation
  - With transponder is linear mode:
    - Output power will be reduced equal to attenuation ,A_{up} dB
    - This will cause $\mathbf{(C/N)}_{dn}$ to fall by A_{up} dB
    - Thus, $\mathbf{(C/N)}_{o}$ will also be reduced by A_{up} dB

  - For linear transponder: $\mathbf{(C/N)}_{o\ uplink\ rain} = \mathbf{(C/N)}_{o\ clear\ air} - A_{up}$ dB

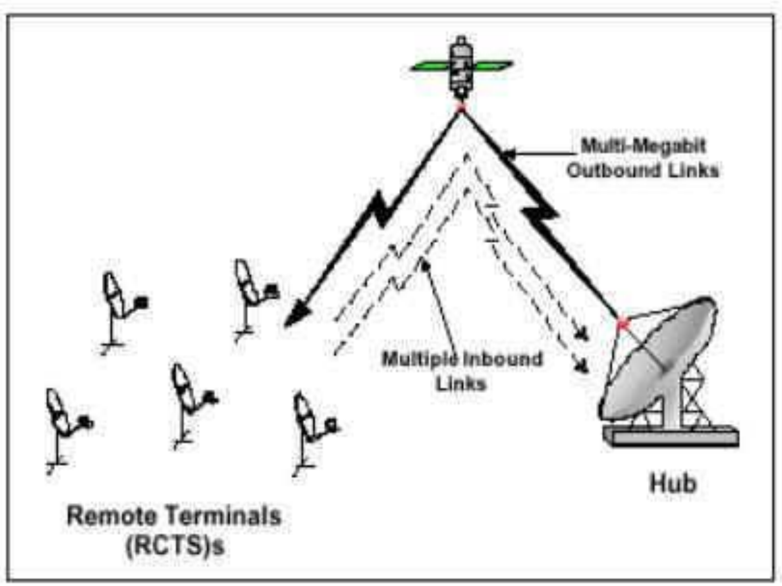
Overall $(C/N)_o$ with Uplink and Downlink Attenuation

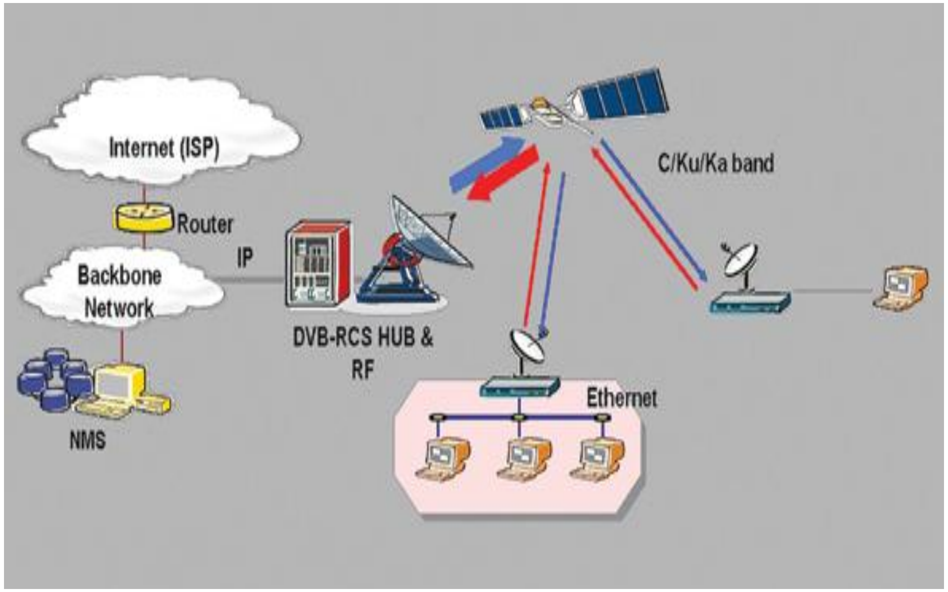
- **Downlink Rain Attenuation and $(C/N)_{dn}$**
  - E/S receiver noise temperature changes significantly with rain in downlink
  - Sky noise temp can increase to close to physical temp of individual rain drops
  - The received power level,C, is reduced
  - The noise power, N,in the receiver increases
  - For linear transponder: $(C/N)_{dn\ rain} = (C/N)_{dn\ clear\ air} - A_{up} - \Delta N_{rain}$ dB
  - The overall C/N is given by

$$(C/N)_o = 1/[1/(C/N)_{dn\ rain} + 1/(C/N)_{up}]$$

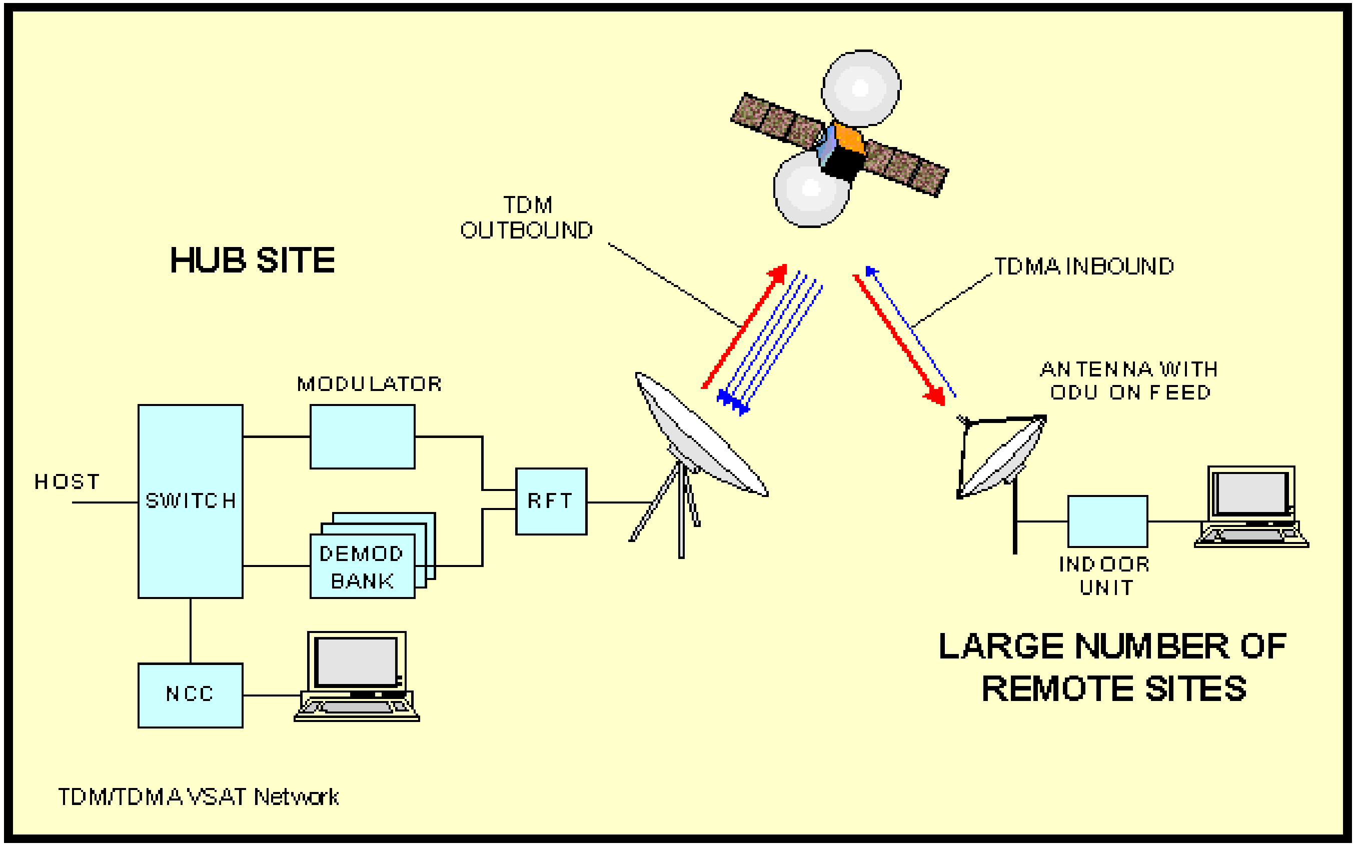
Two way Satellite Communication Link Diagram

- **Four Paths**
  - An outbound uplink from one terminal to the satellite and an outbound downlink to the second terminal
  - An inbound uplink from the second terminal to the satellite and an inbound downlink





Two way Satellite Communication Link Diagram



Satellite Communication Link Design Procedure

- **The design for a one way communication link can be summarized by following 10 steps. The return link design follows same procedure.**
  1. Determine the frequency band in which the system must operate. Comparative designs may be required to help make the selection
  2. Determine the communications parameters of the satellite. Estimate any values that are not known
  3. Determine the parameters of the transmitting and receiving earth stations
  4. Start at the transmitting earth station. Establish an uplink budget and a transponder noise power budget to find $\mathbf{(C/N)}_{up}$ in the transponder
  5. Find the output power of the transponder based on transponder gain of output backoff
  6. Establish a downlink power and noise budget for the receiving earth station. Calculate $\mathbf{(C/N)}_{dn}$ and $\mathbf{(C/N)}_{o}$ for a station at edge of coverage zone(worst case)
  7. Find link margins. Calculate S/N or BER

Satellite Communication Link Design Procedure

8. Evaluate the result and compare with specification requirements. Change parameters of the system as required to obtain acceptable $\mathbf{(C/N)}_o$ values. This may require several trial designs
9. Determine the propagation conditions under which the link must operate. Calculate outage time for both uplinks and downlinks
10. Redesign system by changing some parameters if link margins are inadequate. Check all parameters are reasonable and that the design can be implemented within the expected budget.

System Design Example

Do system design example 4.8.2 (till page 146)
Personal Communication System Using Low Earth Orbits

Assignment Number 3

- Exercise Questions Chapter 4
  - Question Number 12 (all parts 12.1 to 12.6)
  - Question Number 14 (14.1,14.2,14.3)
- Due date: 30 January,2009
- Time:3:10 pm (CR to deliver assignments to office after collection)