Chettinad
College of Engineering & Technology
Approved by AICTE-New Delhi and Affiliated to Anna University-Chennai

Department of Electronics and Communication Engineering

TOPIC: SATELLITE LINK DESIGN

Prepared by,
Mrs.A.Karthikeyani
Assistant Professr/ECE

INTERFERENCE ANALYSIS

Key terms:

- Earth station → Associated with satellite circuits
- Terrestrial station → Associated with ground based microwave LoS circuits

Possible modes of Interference

- A1: Terrestrial station txion (I→ES)
- A2:ES txion(I→TS)
- B1: Space station txion of 1 space system→(I→Rx by ES of another space system)
- B2: ES txion of 1 space system→(I→ Rx by space station(SS) of another space system)

- C1: SS txion(I→ RX by a terrestrial station)
- C2: TS txion(I→ Rx by a SS)
- E: SS txion of 1 space system(I→ Rx SS by an another space system)

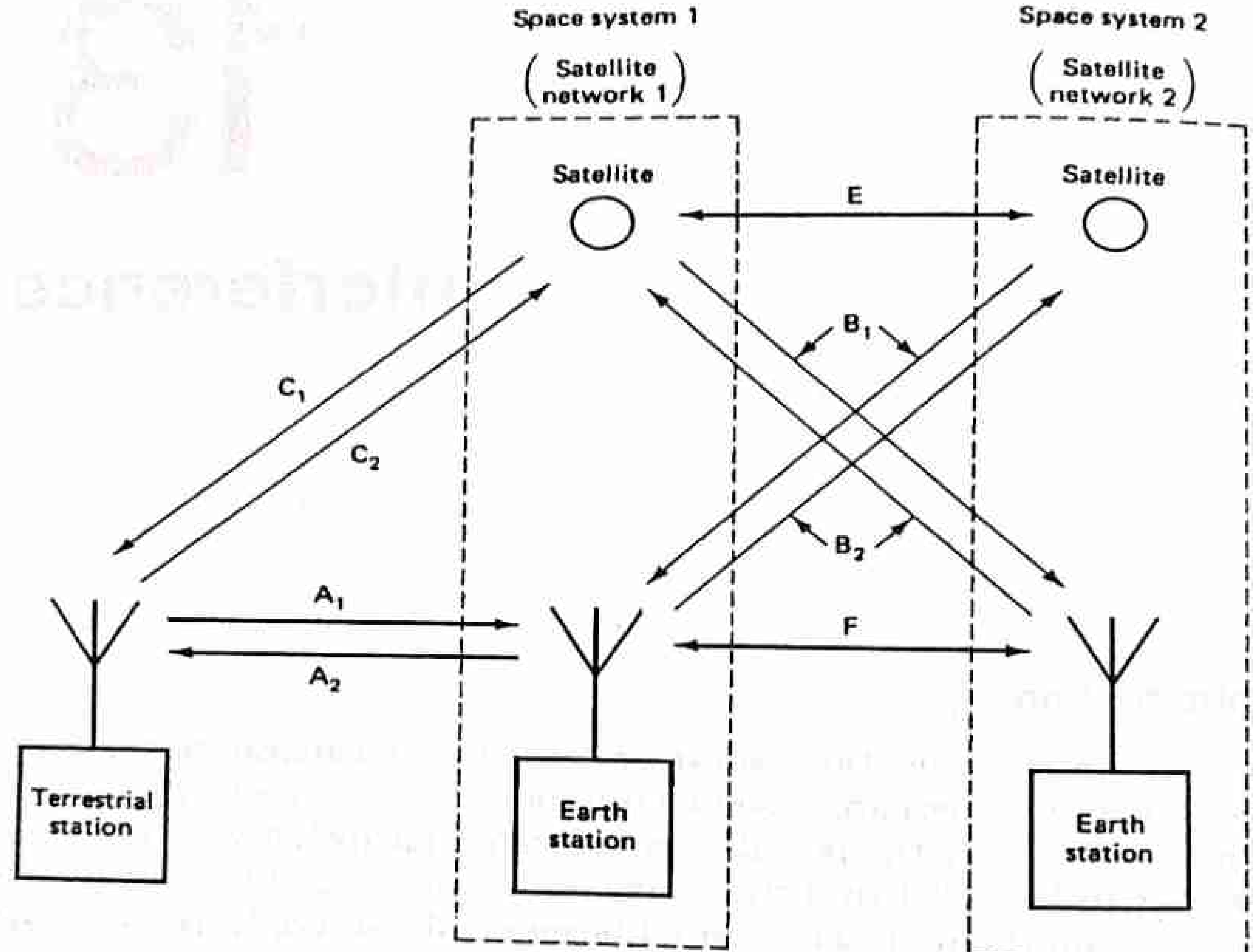


Figure 13.1 Possible interference modes between satellite circuits and a terrestrial station. (*Courtesy of CCIR Radio Regulations.*)

A_1: terrestrial station transmissions, possibly causing interference to reception by an earth station

A_2: earth station transmissions, possibly causing interference to reception by a terrestrial station

B_1: space station transmission of one space system, possibly causing interference to reception by an earth station of another space system

B_2: earth station transmissions of one space system, possibly causing interference to reception by a space station of another space system

C_1: space station transmission, possibly causing interference to reception by a terrestrial station

C_2: terrestrial station transmission, possibly causing interference to reception by a space station

E: space station transmission of one space system, possibly causing interference to reception by a space station of another space system

F: earth station transmission of one space system, possibly causing interference to reception by an earth station of another space system

- A1,A2,C1 and C2→ Possible modes of interference between space and terrestrial services
- B1 and B2→ Possible modes of interference between diff. Space system station
- E and F→ extensions to B1 and B2

Interference between Satellite Circuits (B1 and B2 Modes)

- No. of Neighboring satellite circuits→ aggregate interference
- 'I' considered as a form of noise→ s/m performance is estimated by Interfering powers C/I ratio
- Imp. Parameter for controlling 'I'→RP of ES antenna

C/I must be related with ant. RP

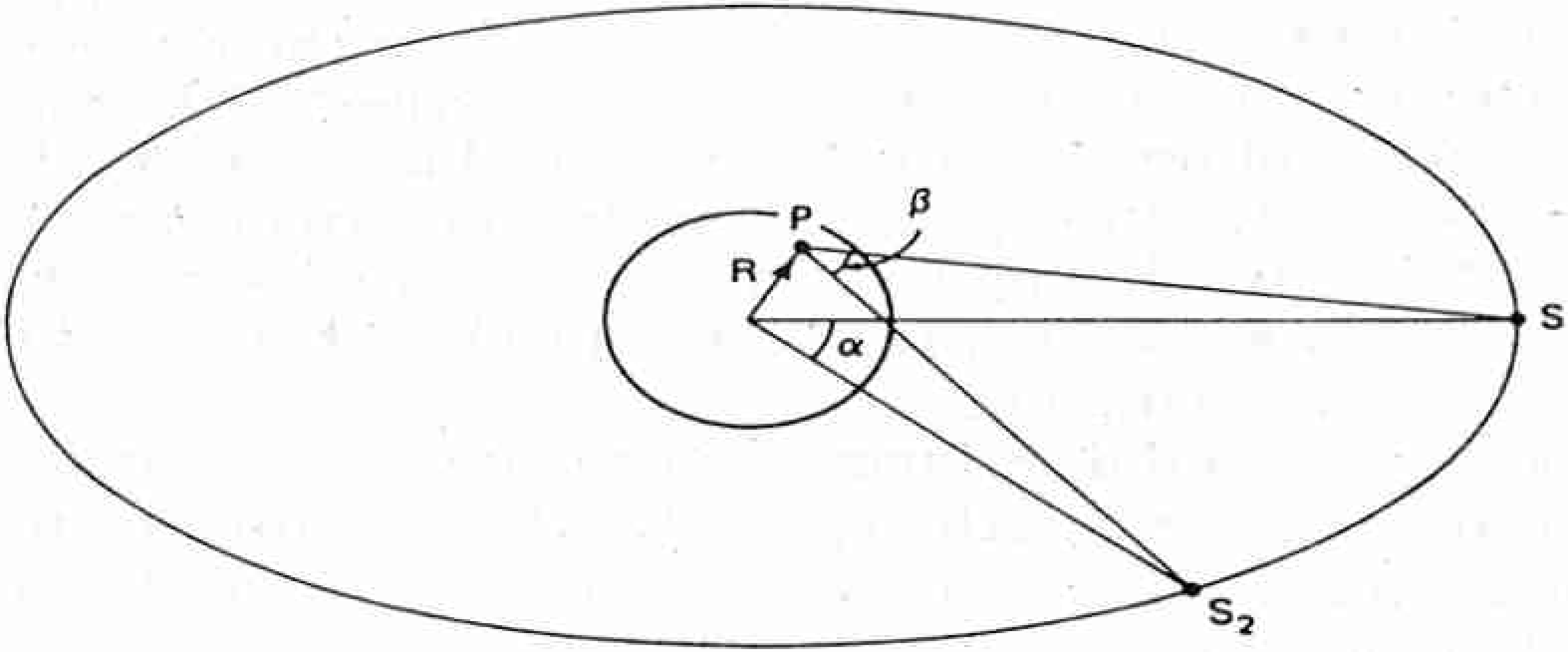


Figure 13.2 Geocentric angle α and the topocentric angle β.

- α → Geocentric angle (subtended at the centre of the earth)
- β → Topocentric angle (from P→ the satellite woud appear to subtend)
- Practically, $\alpha = \beta$
- S1→ wanted sat
- S2→ interfering sat

Orbital spacing angle

2^0 to 4^0 in 0.5^0 intervals in C band

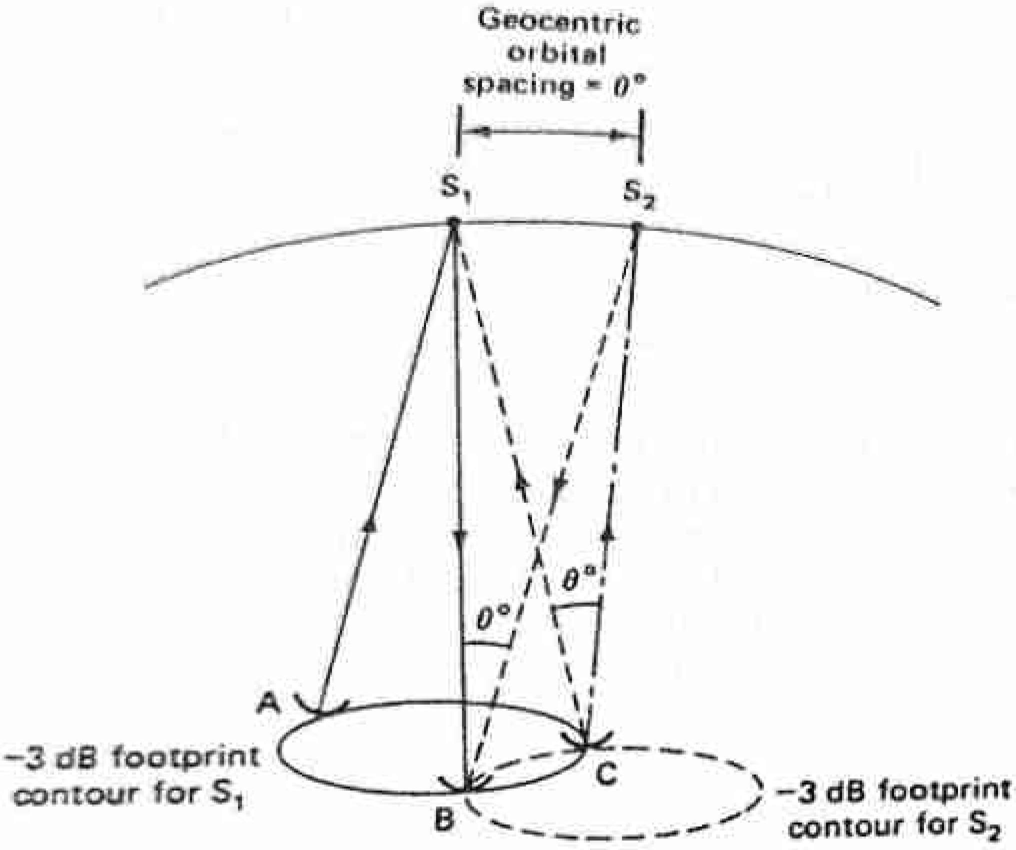


Figure 13.3 Orbital spacing angle.

Interference b/w sat. ckts:

=> Neighbour sat. ckts.

=> Aggregate interference

=> C/I ratio.

=> Important factor for controlling interf.: => "R.P" of ES ant/:

=> Large dim. - Reflector has narrow BW

=> Eg: 10 m ant/: at 14 GHz has a -3 dB BW not 0.15°.

=> 'α' => subtended at sat.

⇓

orbital separation.

(Geocentric)

D/L:

$$[C] = [EIRP]_1 - 3 + [G_R] - [FSL]$$

$$[I] = [EIRP]_2 - 3 + [G_R(\theta)] - [FSL] - [Y]_D$$

↓ polar. discrimination

$$[C] - [I] = [EIRP]_1 - [EIRP]_2 + [G_R] - [G_R(\theta)] + [Y]_D$$

$$\left[\frac{C}{I}\right]_D = \Delta[E] + [G_R] - [G_R(\theta)] + [Y]_D$$

U/L:

$$\left[\frac{C}{I}\right] = \Delta[P] + [G_R] - [G_c(\theta)] + [Y]_U$$

$[G_R]$ → Bore sight

$[G_c(\theta)]$ → off-axis (Focused ... & collimated beam)

$\Delta[P]$ → wanted & interfering powers.

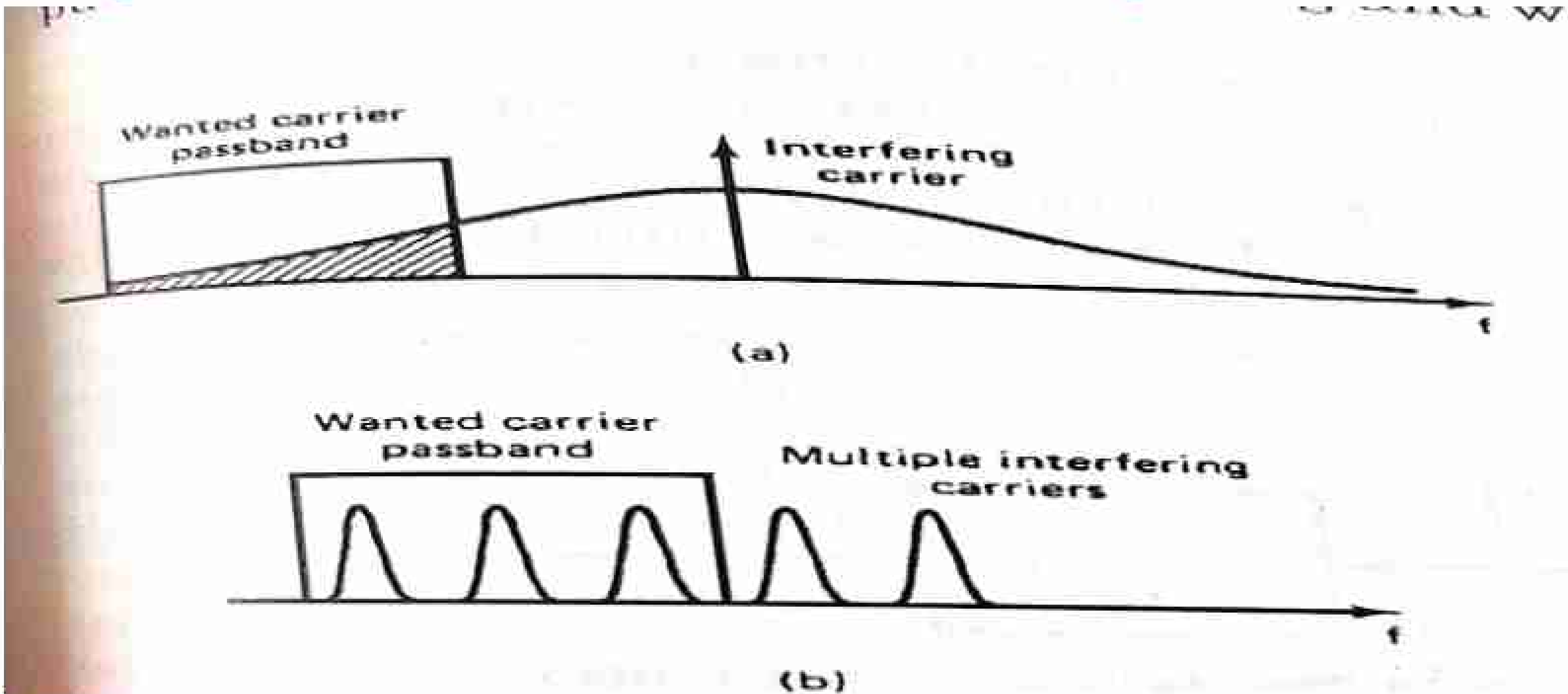
ANTENNA GAIN FUNCTION

- R.P→ ÷ed into 3 regions
- 1. Mainlobe region
- 2. Sidelobe region
- 3. Transition region
- AGF defined the interference levels
- Off-axis angle = θ

$$[G(\theta)] = \begin{cases} 29 - 25\log\theta & 1 \le \theta \le 7 \\ +8 & 7 < \theta \le 9.2 \\ 32 - 25\log\theta & 9.2 < \theta \le 48 \\ -10 & 48 < \theta \le 180 \end{cases}$$

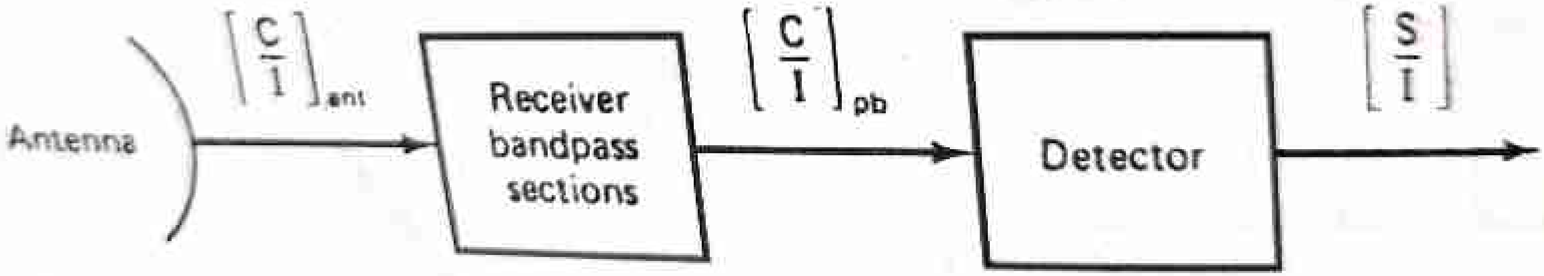
PASSBAND INTERFERENCE

"The amount of interference reaching the detector will depend on the amount of frequency overlap between the interfering spectrum and the wanted channel passband"



RECEIVER TRANSFER CHARACTERISTICS

- Baseband Interference
- [S/I]=[C/I]+[RTC]
- RTC→ analogous



SPECIFIED INTERFERENCE OBJECTIVES

- For TV, viewing tests are conducted
- By gradually increasing the interference level, quality impairment factor can be established (1 to 5)

- **Protection Ratio** → "Minimum [C/I]
- **Energy dispersal** → Effective in reducing all modes of interference but particularly that occurring between ES and TS and also effective in reducing intermodulation noise
- **Interference levels**

$$[I_1]=[U_S]+[G'_S]+[G_E]-[L_D]$$

Rain induced attenuation and interference

- Rain attenuation is **a major challenge to microwave satellite communication especially at frequencies above 10 GHz, causing unavailability of signals most of the time**.

- Rain attenuation predictions have become one of the vital considerations while setting. up a satellite communication link.

Rain induced attenuation and interference

"The attenuation of a signal due to rain is the extent to which the strength of a signal is reduced when passing through rain from a transmitter to a receiver, Also called rain fade."

EFFECTS OF RAIN

- Rainfall causes attenuation of radio waves by scattering and by absorption of energy from the wave.
- Signal fading which affects the signal strength is caused mainly by rainfall

EFFECTS OF RAIN

Rain Attenuation:

- Rain attenuation increases with increasing frequency.
- It is worse in the Ku band than C band.
- Also, rain attenuation is accompanied by noise generation and both the attenuation and the noise affect the satellite circuit performance badly.

Rain Depolarization:

- When raindrops fall through the atmosphere, they get flattened in shape and become elliptical.

- If the wave has some arbitrary polarization, it becomes elliptically polarized due to depolarization.

- Depolarizing devices can be installed to compensate for rain depolarization in places where frequency reuse is achieved

Effects on Radome

- Some earth station antennas are operated under cover of a radome.
- Rain falling on a hemispherical radome forms a water layer of constant thickness.
- This layer introduces losses by absorption and reflection.
- Results show that a 1-mm thick layer introduces an attenuation of 14 dB.
- Therefore, earth station antennas should be operated without radomes wherever possible.

Signal fading caused by rainfall places two limits which are:

- Uplink rain fade margin
- Downlink rain fade margin

UPLINK RAIN-FADE MARGIN

- Rainfall attenuates the signal and increases the noise temperature.
- This degrades the carrier to noise density ratio [C/N0] at the satellite in two ways:
- 1. By increasing the noise
- 2. By affecting power output

DOWNLINK RAIN FADE MARGIN

The Rainfall introduces attenuation by absorption and scattering of signal energy.

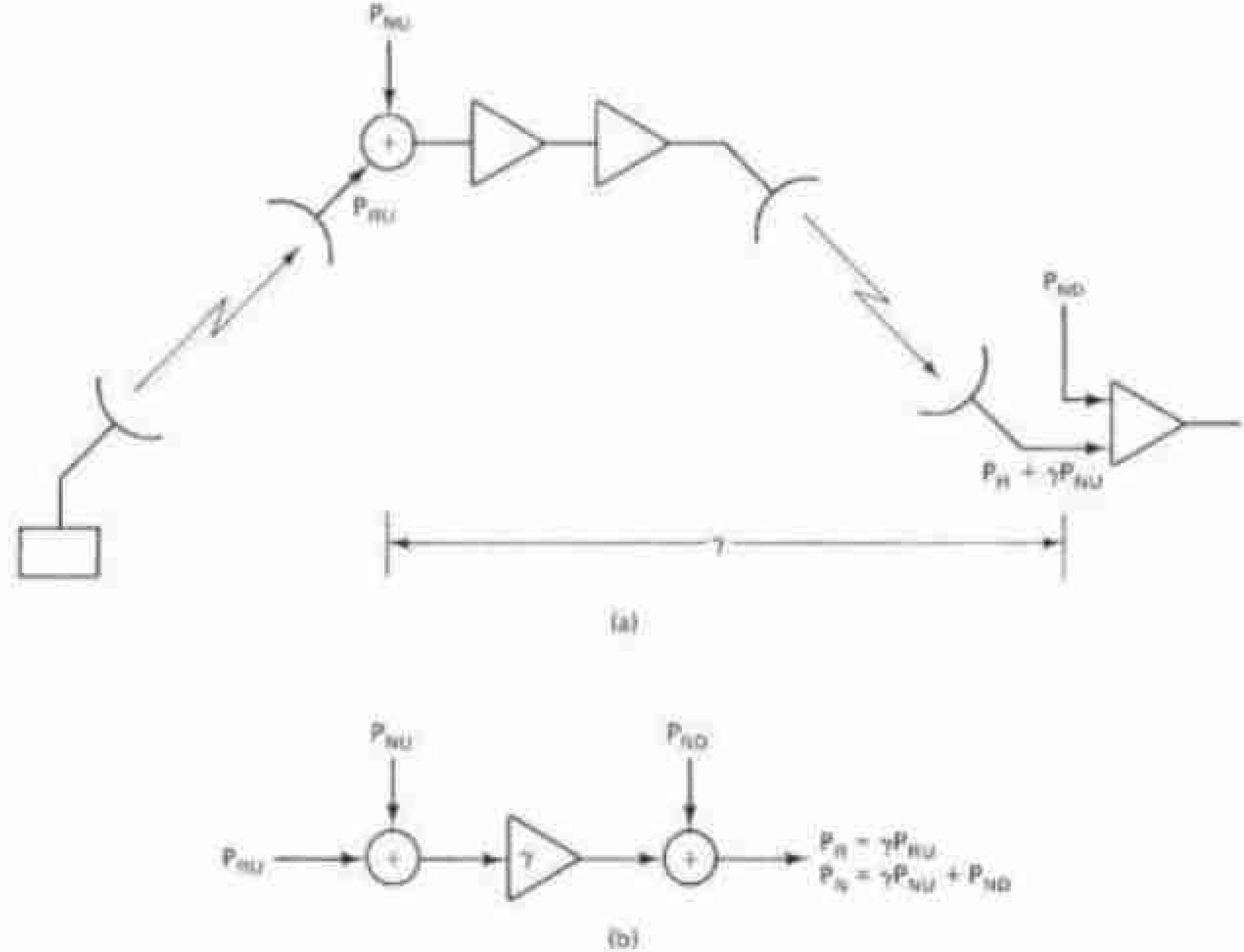
Therefore, the received carrier – to – noise density ratio [C/N0] is degraded by the rainfall in 2 ways.

1. By attenuating the carrier wave
2. By increasing the sky noise temperature

COMBINED UPLINK AND DOWNLINK C/N RATIO

- Uplink rain-fade margin→ Uplink power control for compensating rain fades

- Downlink rain fade margin→ The C/N_0 ratio for the downlink alone, not counting the P_{NU} contribution, is P_R/P_{ND}, and the combined C/N_0 ratio at the ground receiver is

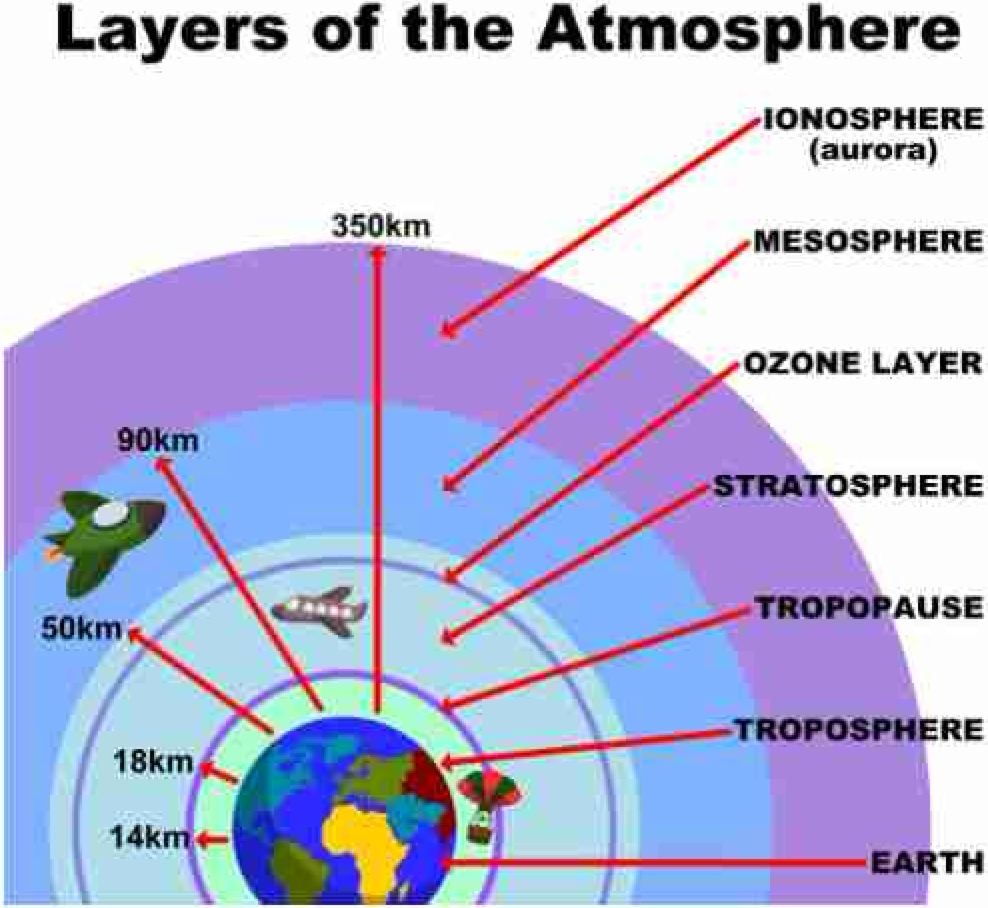


(a) Combined uplink and downlink; (b) power flow diagram

$$
\begin{aligned}
\frac{N_0}{C} &= \frac{P_N}{P_R} \\
&= \frac{\gamma P_{\mathrm{NU}} + P_{\mathrm{ND}}}{P_R} \\
&= \frac{\gamma P_{\mathrm{NU}}}{P_R} + \frac{P_{\mathrm{ND}}}{P_R} \\
&= \frac{\gamma P_{\mathrm{NU}}}{\gamma P_{\mathrm{RU}}} + \frac{P_{\mathrm{NU}}}{P_R} \\
&= \left(\frac{N_0}{C}\right)_U + \left(\frac{N_0}{C}\right)_D
\end{aligned}
$$

- https://www.youtube.com/watch?v=TmKnR8F2V2k
- https://www.youtube.com/watch?v=rcOY13FCoqY

IONOSPHERIC CHARACTERISTICS



"The ionosphere is **where Earth's atmosphere meets space**"

- **Upper region** of Earth's atmosphere which has been ionized mainly by solar radiation
- This area of the atmosphere consists of several **conductive layers that reflect** radio waves
- Radio wave travelling between satellites and ES must pass through the ionosphere

- The free e^- in Ionosphere are **not uniformly distributed** but form in layers.

- Clouds of e^- may travel thru' it → give rise to fluctuations in s/l → only be determined on statistical basis

The **effects** include,

1. **Scintillation**
2. **Absorption**
3. **Variation in the direction of arrival**
4. **Propagation Delay**
5. **Dispersion**
6. **Frequency change**
7. **Polarization rotation**

Scintillation:

- Variations in amplitude, phase, polarization or angle of arrival of radio waves
- Caused by irregularities in ionosphere → change with time
- Main effect→ Fading of signal→ severe→ necessary to include a fade margin in link power budget calculations

Absorption:

- EM waves are absorbed in atm. According to W/L
- 2 Compounds are responsible for the majority of signal adsorption → O_2(63GHz) and Water(22GHz)

Propagation Delay

- "Time required for a signal to travel from S to D"

Dispersion:

- Signals are distributed over a wide area

Polarization rotation:

- Phenomenon in which waves of light or other radiation are restricted in direction of vibration.

Carrier to Noise Ratio: $\left[\frac{C}{N}\right]$ (or) CNR

"A measure of the performance of a satellite link"

⇒ Denoted by C/N

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

$$\left[\frac{C}{N}\right] = [P_R] - [P_N]$$

W.K.T,

$$[P_R] = [EIRP] + [G_R] - [Losses]$$

$$P_N = K T_S B_N$$

$$[P_N] = [K] + [T_S] + [B_N]$$

$$\therefore \left[\frac{C}{N}\right] = [EIRP] + [G_R] - [Losses] - [K] - [T_S] - [B_N]$$

⇒ $\frac{G}{T}$ ratio is a key parameter in specifying the receiving s/m performance.

i.e., $[G/T] = [G_R] - [T_S]$ dBK^{-1}

$$\therefore \left[\frac{C}{N}\right] = [EIRP] + \left[\frac{G}{T}\right] - [Losses] - [K] - [B_N]$$

⇒ $P_R = C$, $P_N = N$

$$\therefore P_N = K T_N B_N = N_0 B_N$$

(NPSD)

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

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

$$\therefore \left[C/N_0\right] = \left[\frac{C}{N}\right] + [B_N]$$

$$\left[\frac{C}{N_0}\right] = [EIRP] + \left[\frac{G}{T}\right] - [\text{Losses}] - [K]$$

In terms of decilogs :

1. FSL → − 206
2. AAL → − 2
3. APL → − 1
4. FL → − 1
5. Pol. Mismatch L → 0
6. Rx G/T → 19.5
7. EIRP → 48
8. − [K] → 228.6
9. [C/No] → 86.1 ⇒ dBHz ;

The Uplink : ('U' ⇒ used as subscript).

$$\left[\frac{C}{N_0}\right]_U = [EIRP]_U + \left[\frac{G}{T}\right]_U - [\text{Losses}]_U - [K]$$

⇒ Values to be used are the ES − EIRP, Feeder Losses, Rter G/T.

⇒ **Saturation flux Density :**

" A measure of how much power a signal must have to saturate a detector."

⇒ "The flux density required at the receiving antenna to produce saturation of TWTA"

$$\Psi_M = \frac{EIRP}{4\pi r^2}$$

In dB,

$$[\Psi_M] = [EIRP] + 10\log\frac{1}{4\pi r^2} \longrightarrow (1)$$

W.K.T. :

$-[FSL] = 10\log\frac{\lambda^2}{4\pi} + 10\log\frac{1}{4\pi r^2}$

$\Rightarrow [\psi_M] = [EIRP] - [FSL] - 10\log\left(\frac{\lambda^2}{4\pi}\right) \longrightarrow (2)$

$\frac{\lambda^2}{4\pi} \Rightarrow$ Effective Area of an isotropic antenna.

$[A_0] = 10\log\left[\frac{\lambda^2}{4\pi}\right]$

$= 10\log\left(\frac{(3\times10^8)^2}{4\pi\times(10^9)^2}\cdot\frac{1}{f^2}\right)$ ψ_M pass

$= 10\log\left(\frac{9\times10^{16}}{4\pi\times10^{18}}\right) - 20\log f$

f in GHz

$= 10\log\left(\frac{9}{4\pi}\times10^{-2}\right) - 20\log f$

$= -21.45 - 20\log f$

$= -(21.45 + 20\log f)$.

$\therefore$ Eqn (2) $\Rightarrow [EIRP] = [\psi_M] + [FSL] + [A_0]$

other losses.

$= [\psi_M] + [A_0] + [FSL] + [AA] + [PL] + [AmL]$

$[EIRP] = [\psi_M] + [A_0] + [\text{Losses}] - [RFL]$

$[EIRP_s]_U = [\psi_s] + [A_0] + [\text{Losses}]_U - [RFL]$.

Input Backoff :

If a no. of carriers present simultaneously in a TWTA, the operating point must be backed off to a linear portion of the transfer characteristics to reduce the effects of intermodulation distortion.

$\Rightarrow$ occurs with FDMA

$\Rightarrow$ Backoff must be considered.

$$[EIRP]_U = [EIRP_S]_U - [BO]_i$$

∴ W.K.T,

$$[EIRP_S]_U = [\Psi_S] + [A_0] + [LOSSES]_U - [RFL]$$

$$\therefore \left[\frac{C}{N_0}\right]_U = [\Psi_S] + [A_0] - [BO]_i + \left[\frac{G}{T}\right]_U - [K] - [RFL]$$

Downlink:

⇒ Sat. is transmitting the signal & the earth station is receiving it.

$$\therefore \left[\frac{C}{N_0}\right]_D = [EIRP]_D + \left[\frac{G}{T}\right]_D - [LOSSES]_D - [K]$$

W.K.T

$$P_N = kT_N B_N$$

$$kT_N = N_0$$

$$\therefore \left[\frac{C}{N}\right]_D = [EIRP] + [G/T]_D - [LOSSES]_D - [K] - [B]$$

THANK YOU