To avoid EM interference → shields

S-parameters :

Describes power reflect back.

↳ Relation / flow of EM signal b/w

I/p & O/p.

S parameters works for linear system.

X-parameters → Accounts non linearity too

Z, Y, ABCD, h → Good at low frequency

At high freq difficult to measure V & I which keeps on varying, here we go with power.

In Transmission lines / high frequency - no possibility of short circuit and open circuit but possible for low frequency parameters

Eg: $Z_{11} = \frac{V_1}{I_1}\Big|_{I_2=0}$.

For 2×2 port

$$\underbrace{\begin{bmatrix} a_1 \\ a_2 \end{bmatrix}}_{\text{i/p power}} \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} = \underbrace{\begin{bmatrix} b_1 \\ b_2 \end{bmatrix}}_{\text{o/p power}}$$

S_{11} → I/p reflection coefficient

↓

return loss (should be not negative)

S_{nm} → i/p port

↓

o/p port

If return loss = 3]
ref. coeff = -3] dBm

↳ millimeter Watt level

$10 \log(P[W]) = dB$

$10 \log P[mW] = dBm$.

S_{12} → o/p reflection coefficient

S_{21} → Transmission coefficient / Gain interms of x^{r}

Insertion loss interms of passive devices

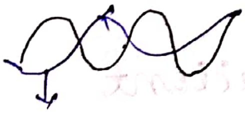
since age loss from i/p port to o/p port in directional coupler, Attenuator.

S_{12} → Isolation loss / Attenuation loss in passive devices

All S parameters are dependable on Impedance factors.

Return loss = 0 [majority of incident power to port 2]

standing wave won't generate when Terminators are present such that i/p & o/p port are matched perfectly.



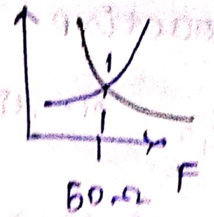
↓
standing wave (reflect)

$$\boxed{|\Gamma| = \frac{Z_L - Z_0}{Z_L + Z_0}}$$

Z_L & Z_0 should match almost to 50Ω then $\Gamma = 0$ (Ref. coef = 0)

$Z_0 = 50\,\Omega$

As Freq ↑ the power ↑.



Tx lines are purely dependable on freq.

when width is similar no change in Impedance value.

17.07.25

UNIT - V

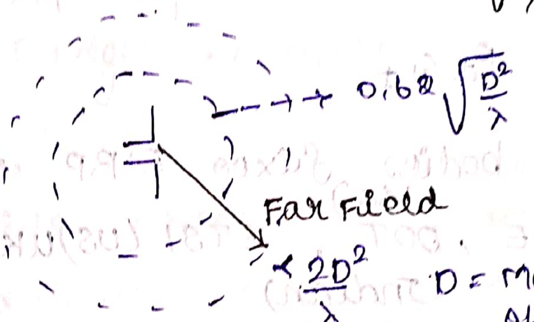
Fields and power radiated by Antenna

→ Near Field — Reactive Near field (closest to Antenna)
— Radiative Near field

$0.62\sqrt{\frac{D^2}{\lambda}} < d < \frac{2D^2}{\lambda}$

→ Far Field

$d > \frac{2D^2}{\lambda}$



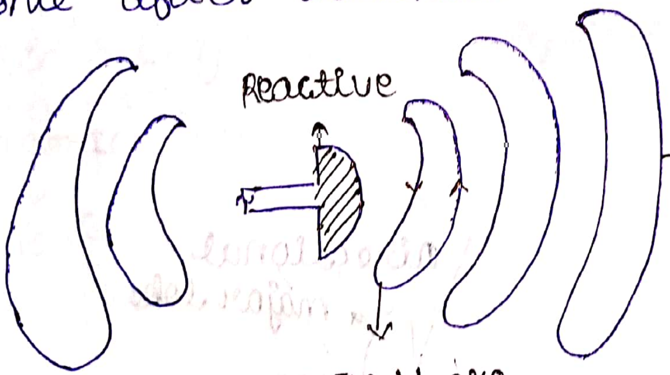
D = max Dimension of Antenna

λ = Wavelength

(no movement of field)

Reactive nature → no Radiation (EM wave)

once after detached radiation occurs.



Independent to source (Far Field)

E & H ⊥ dirⁿ of propagation

E & H are not ⊥ar to each other, unpredictive Radiation, dependable on source

In Reactive power decays at rate of $\frac{1}{r^3}$ r = distance (power drops)

In Radiative Near field $1/r^2$ (power drops)

For Far Field $1/r$ (power drops over the distance)

Link Budget Analysis

Tx power at one end (knowing it) → Distribute it

power at receiver (may differ sensitivity may be low)

EIRP → Effective Isotropic Radiative power

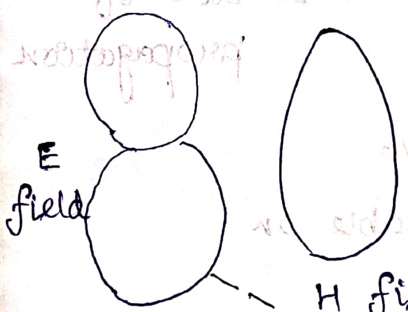
EIRP → $P_t G_t$

Governing bodies (GG) fixes EIRP includes FCC, (US) ITC, IEEE, DOT, ETSI (US)UK) (US) (Indian)

Based on the power level (differ) in EIRP in a system if the frequency band of applications are same.

P = ∫ in terms of E & H
↳ Radiation Intensity
↓ in terms of
D, G, P

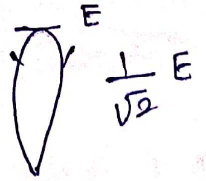
omnidirectional



Radiation distributed more

directional

minor lobe = Back lobe + Side lobe



$$P = \frac{P_{rad}}{4\pi r^2} \qquad D = \frac{4\pi U(\theta,\phi)}{P_{rad}}$$

$$P = \int |E \times H| \qquad U = r^2 S(\theta,\phi) \qquad S = |E \times H|$$

$$U_0 = \frac{P_{rad}}{4\pi}$$

$$G = \frac{4\pi U(\theta,\phi)}{P_{in}}$$

21.07.25 Link Budget Analysis → Reliable comm^n possible/ remedial action performed before sending to the receiver.

Link margin:

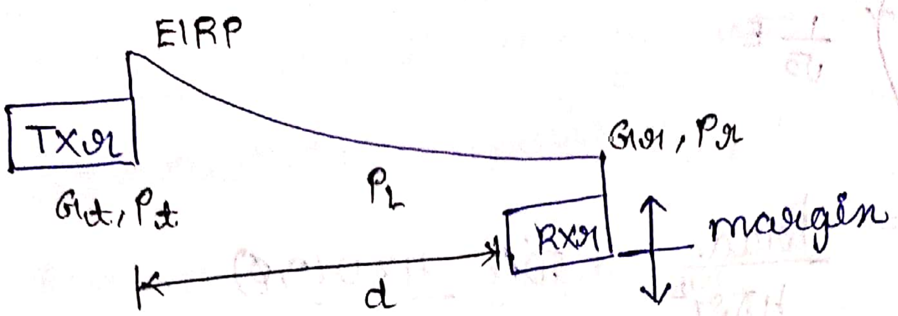
* Marginal value, Excess power to address some Emergency cond^n.
* Difference between actual power received and the maximum required power (sensitivity) of the system for reliable communication.

$$M = \underset{\substack{\downarrow \\ Rx\ power}}{P_R} - S \rightarrow \text{Sensitivity}$$

$$P_R = EIRP + G_R - \underbrace{L_p - L_o}$$ Losses depends on applications

$$EIRP = P_t G_t$$

$$= P_t + G_t - L_o$$ (Loss at the Txr)



Margin condn

+ve → Reliable commn / Robust link

-ve → Non-Reliable commn

0 → marginal commn.

1. A Geostationary Satellite link operates at 12GHz over a distance of 36000 Km. The Tx power is 10W with Txr Antenna Gain of 50 dBi and cable loss of 2dB. The Rxr Antenna has an antenna gain of 40dBi and require minimum received power of -100dBm for having reliable communication. Assume free space path loss with additional loss of 5dB due to the Rain fade and atmospheric effect. calcula[te] link margin. State to have a reliable commn how much pr can be?

Soln

$d = 36000$ Km $\qquad L_o = 5$ dB.

$P_T = 10W$

$G_T = 50$ dBi

$L_{cab} = 2$dB

$G_R = 40$dBi

$S = -100$dBm

$P_L =$ Free space path loss

By Friss Eq^n

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi r)^2} \rightarrow \left(\frac{c}{4\pi f r}\right)^2$$

$$P_{FSPL} = 20 \log d + 20 \log f + 20 \log \left(\frac{4\pi}{c}\right)$$

$d \rightarrow m \quad f \rightarrow Hz$

$$L_p = 20 \log (86\times10^6) + 20 \log (12\times10^9) + 20 \log \left(\frac{4\pi}{3\times10^8}\right)$$

$$L_p = 151.126 + 201.583 - 147.558$$

$$L_p = 205.151$$

$$L_p = 205.151 \, dB$$

$10W \rightarrow 10000 mW$

$P_T = 10W$

$P_R = 10W \Rightarrow P_r(dBm) = 10 \log (10000)$ — $P_T(dBm)$

$= 40 \, dBm$

Always $P_T = P_T + 30$, $P_R = P_R + 30 = P_R(dBm)$

$$EIRP = P_T + G_T - L_{cab} = 40 + 50 - 2$$

$$= 88 \, dBm$$

$$P_R = EIRP + G_r - L_p - L_o$$

$$= 88 + 40 - 205.15 - 5$$

$$= -82.15 dBm.$$

$$M = P_R - S = -82.15 + 100$$

$$M = 17.85 \, dBm$$

Reliable communication

Q. A WI-FI network operates at 2.4 GHz over 50 m. The Access point has the Tx power of 20 dBm and Antenna gain of 2 dBi with cable loss of 1 dB. The client device has a Rx antenna gain $G_R = 0$ dBi and sensitivity of -85 dBm. Assume the path loss model of L_p as $L_p = 40 + 35 \log(d)$ where d is m and additional loss of 10 dB due to the presence of walls and furniture calculate link margin and suggest a soln for reliable commn.

<u>soln</u>

$f = 2.4$ GHz

$d = 50$ m

$P_T = 20$ dBm

$G_T = 2$ dBi

$L_{cab} = 1$ dB

$G_R = 0$ dBi

$S = -85$ dBm

$L_O = 10$ dB.

$$L_p = 20 \log(d) + 20 \log(f) + 20 \log\left(\frac{4\pi}{c}\right)$$

$$= 33.979 + 187.6042 - 147.558$$

$$= 74.0252 \text{ dB}.$$

Scanned with CamScanner

Given $L_p = 40 + 35 \log d$

$L_p = 99.463$ dB.

128.1

$EIRP = P_T + G_T - L_{cab}$

$= 20 + 2 - 1$

$= 21$ dBm 42

$P_R = EIRP + G_R - L_p - L_o$

$= 21 + 0 - 99.463 - 10$

$= -88.463$ dBm -154.1

$M = P_R - S = -88.463 + 85$

-90 $M = -3.463$

It is a Non-Reliable commn.

-74.1

Ways

→ Increase the G_T in EIRP, power level

→ Increase G_R in Rx system, loss minimum

22.07.25

Microwave LOS | Establishment of Radio link path profile

* Graphical representation
* path profile Analysis between Tx and Rx by accounting obstacles in between atmospheric attenuation if any → accounting Earth curvature effect. (flat surface)

Accounts parameters

- Azimutal
- distance between TX & RX
- Location (latitude / longitude)
- Height of obstacle
- Direction of propagation
- Terrain profile
- Effective Earth radius

Data collection for proper link created between TX & RX.

K factor : 4/3

K<1 (chill Environment)

[deviations not much, more density]

K>4/3 (Hot environment)

Distance between TX & RX

Havarsine formula

$$D = 2 R_{arc} \sin \sqrt{\sin^2 \frac{\Delta \phi}{2} + \cos \phi_1 \cos \phi_2 + \sin^2 \left(\frac{\Delta \lambda}{2}\right)}$$

ϕ_1 & ϕ_2 → Latitude of TX & RX

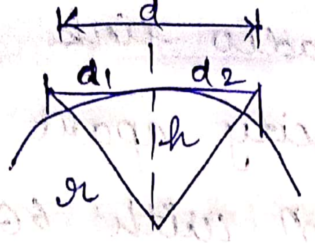
$\Delta \phi$ → Diff between latitudes

$\Delta \lambda$ → Diff between longitudes

R → Radius of the Earth

Earth bulge (curvature)

R = 6371 Km



$$h = \frac{d_1 d_2}{2R}$$

Accounting K - factor

$$h = \frac{d_1 d_2}{2RK}$$

$d_1 = d_2 = 25$ Km $d = 50$ Km

$r = 6371$ Km

$K = 4/3$

Without K

$$h = \frac{d_1 d_2}{2R} = 49m$$

With K

$$h = \frac{d_1 d_2}{2RK} = 36.75 m.$$

Fresnel zone
Region where Antenna goes for multipath reflections

$$F = 17.3 \sqrt{\frac{d_1 d_2}{fD}}$$

Design of LOS link :
0. Data collection
1. Antenna parameter
2. path profile (link budget Analysis)
3. Establishment
4. Validation

3. create a LOS Radio link considering 2 towers in a city apart from 30km each other and commⁿ with 6 GHZ freq Assuming low attenuation and K takes standard value $\left(\frac{4}{3}\right)$ and establish a high speed data rate of 100 Mbs.

1. Data collection

EIRP = 10 dB

sensitivity of system = -170 dBm

Data rate = 100 Mbps.

2. Azimuthal distance = 30 km = d

$d_1 = d_2 = 15$ km

with (K) factor

$$h = \frac{d_1 d_2}{2RK} = \frac{(15 \times 15)\text{ km}}{2 \times 6371 \times \text{km} \times (4/3)}$$

$$= \frac{225}{2 \times 6371 \times 4/3}$$

$$= 0.01324 \text{ m}$$

$$= 13.243 \times 10^{-3} \text{ m}$$

$$F = 17.3 \sqrt{\frac{d_1 d_2}{fD}}$$

let Terrain T = 50m

Total Antenna height = $h+F+T$

$G_A = 0\,dB$ [Based on EIRP take the value]

NF

SNF

3. Link Budget Analysis

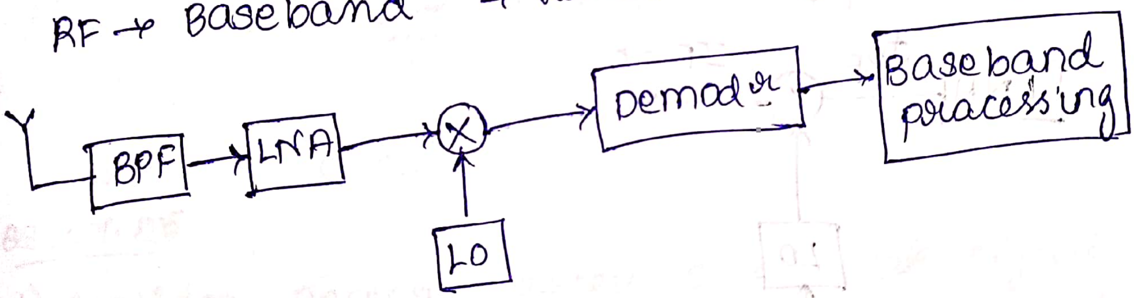
check for whether $M = +ve$
$-ve \rightarrow$ Adjust

4. choice of modulation
↳ data rate

5. Establish and Validate.

24.07.25 RF Receiver:

RF → Baseband ⇒ Direct conversion Rxr



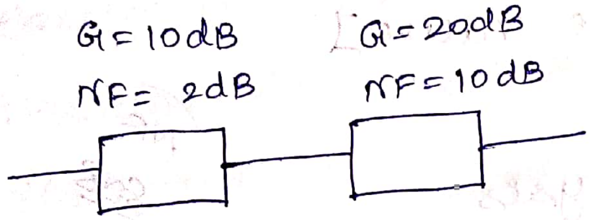
Direct conversion Rxr

channel Filter → Accuracy Better selectivity not achieved channel is filtered.

Frequency Filter → complexity is less (widefilter)

Band Filter → Between 2 bands takes all frequencies

LNA : To amplify weak signal because antenna provides weak signal

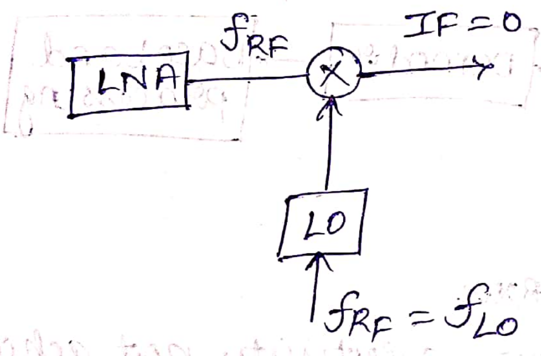


cummulative Gain = 30dB
cummulative NF = 3 dB ? How

→ cummulative noise won't get added by using LNA

→ Mixer is of Non Linear device

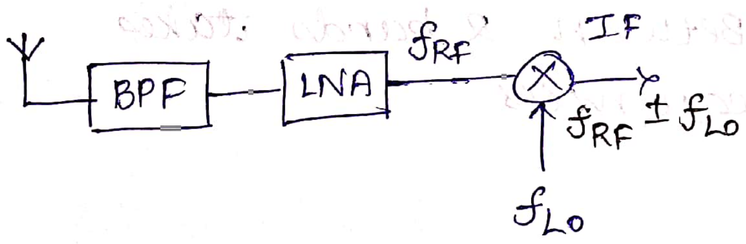
→ LO frequency will be tuned to the same RF frequency f_{RF}



Super Heterodyne Rxr

In superheterodyne Rx

RF ⇒ IF ⇒ Baseband.



Real time Rxr takes only difference in frequencies

Employing with IF somehow effects to Imaging effect (cloning)

same IF will be produced for different RF frequencies which leads to severe problems.

$$Im = RF - 2LO$$

To prevent Imaging some prefiltering methods are done so put LNA and then BPF to prevent Imaging

$$F_1 = f_1 + \frac{(f_2 - 1)}{G_1} + \frac{(f_3 - 1)}{G_1 G_2}$$

$$= 1.584 + \frac{9}{90} = 1.584 \; 2.484$$

$$F_2 = 10 + \underline{0.584}$$

08.07.25

1) consider Antenna receives a weak signal of -100dB that's been passed to RF receiver ckt where the first stage LNA has a gain of 20 dB and noise figure of LNA is of 2dB and been passed through mixer with gain of -5dB with noise figure of 8dB and connected by IF amplifier whose Gain is 30dB and Noise figure of 6dB.

LNA $\Rightarrow G_1 = 20dB$; $NF = 2dB$

Mixer $\Rightarrow G_2 = -5dB$ (loss) ; $NF = 8dB$

IF $A^r \Rightarrow G_3 = 30dB$; $NF = 6dB$.

case 1: presence of LNA

Friss Eq^n

$-KT$ $f = 1MHz$.

$P_n = -173 dB + 10\log(f)$

$P_n = -174 dB + 10\log(10^6)$

$\boxed{P_n = -114 dB.}$

$$NF_{TOT} = NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1 G_2} + \ldots$$

$NF_1 = 10^{2/10} = 1.58$ $G_1 = 10^{20/10} = 100$

$NF_2 = 10^{8/10} = 6.31$ $G_2 = 10^{-5/10} = 0.32$

$NF_3 = 10^{6/10} = 3.98$ $G_3 = 10^{30/10} = 1000.$

$$NF_{TOT} = 1.58 + \frac{5.31}{100} + \frac{2.98}{32}$$

$= 1.58 + 0.0531 + 0.093125,$

$= 1.726$

$(NF)_{dB} = 2.37dB$

$(SNR)_{i/p} = P_{in} - P_{NP}$

$= -100dB + 114dB$

$= 14 dB.$

case 2: Absence of LNA.

LNA is not there

$(SNR)_{o/p} = -114 + 2 + 20$

$\Rightarrow P_{in} - 92$

$= 45$

$$NF_{TOT} = 6.31 + \frac{2.98}{0.32}$$

$= 15.62$

$(NF)_{dB} = 11.93dB.$

$(SNR)_{o/p} = (P_{in} + G_1) - (P_n + G_1 + NF)$

$= -80 - (-114 + 2 + 20)$

$= -80 - (-92)$

case 3 : LNA is post IF x^{r} $\bar{\upsilon}$

Mixer → IF → LNA

$$NF_{TOT} = 6.31 + \frac{2.98}{0.32} + \frac{0.58}{320}.$$

$$= 6.31 + 9.3125 + 1.8125 \times 10^{-3}$$

$$= 15.6$$

$$(NF)_{dB} = 11.93 \text{ dB}.$$

case 2 :

$(SNR)_{i/p} \Rightarrow 14 \text{dB}$

$$(SNR)_{o/p} = (P_{in} + G_1) - (P_n + G_1 + NF).$$

$$= (-100-5) - (-114 + (-5) + 8)$$

$$= -105 + 111$$

$$= 6 \text{ dB}.$$

performance deg from 14 dB → 6 dB.

case 3 :

$(SNR)_{i/p} = 14 \text{dB}.$

ii) Now consider

LNA : $G_1 = 20$ dB NF = 2 dB

Mxr : $G_2 = -5$ dB NF = 8 dB.

IF x^{r} : $G_3 = 50$ dB . NF = 6 dB.

$$G_3 = 10^{50/10} = 100 \times 10^3$$

$$NF_{TOT} = NF_1 + \frac{NF_2 - 1}{G_1} + \frac{NF_3 - 1}{G_1 G_2}$$

$$= 1.58 + \frac{5.31}{100} + \frac{2.98}{32}$$

$$= 1.72$$

iii) Now take

$G_1 = 30dB \quad NF = 2dB$

$G_2 = -5dB \quad NF = 8dB$

$G_3 = 30dB \quad NF = 6dB.$

$G_1 = 30dB = 1000.$

$$NF_{TOT} = 1.58 + \frac{5.31}{1000} + \frac{2.98}{32000}$$

$$= 1.58 + \frac{5.31}{1000} + 9.3125 \times 10^{-5}$$

$$= 1.585$$

$(NF)_{dB} = 2dB.$

$(SNR)_{i/p} = P_{in} - P_n = 14dB.$

$(SNR)_{o/p} = (P_{in} + G_1) - (P_n + G_1 + NF)$

$= -70 - (-82)$

$= 12dB.$

Scanned with CamScanner

iv) $G = 10\,dB \quad NF = 2\,dB$

$G = -5\,dB \quad NF = 8\,dB$

$G = 30\,dB \quad NF = 6\,dB.$

$G_1 = 10\,dB = 10$

$$NF_{TOT} = 1.58 + \frac{5.31}{10} + \frac{2.98}{3.2}$$

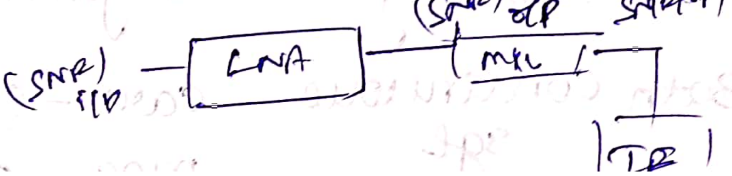
$$= 1.58 + \frac{5.31}{10} + 0.93125$$

$$= 3.04225$$

$$= 4.8319\,dB.$$

$$(SNR)_{o/p} = (-90) - (-102)$$

$$= 12\,dB.$$



29.07.25

modulation purpose ? use?

* Handling noise in a better way.

Analog	Digital	pulse
Both continuous sgl	carr - cont	msg - cont
	msg - digitized	carr - digitized

Analog
- AM
- FM
- PM

Digital
- ASK
- FSK
- PSK (BPSK)

CIA-I portion

unit - 5

unit - 1 till wavelength measurements

BPSK, QPSK

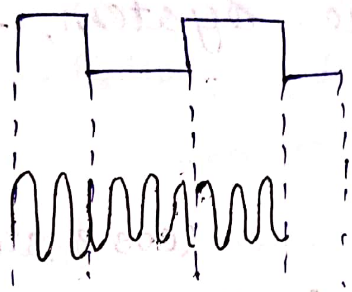
30.07.25

Digital Mod^n

ASK, FSK, PSK (BPSK), QPSK, QAM, OFDM.

Bit error rate.

BPSK → 2 phases 0°, 180°



(Avoids phase noise)

QPSK → 0°, 90°, 270°, 180° → depends on 2 bit positions

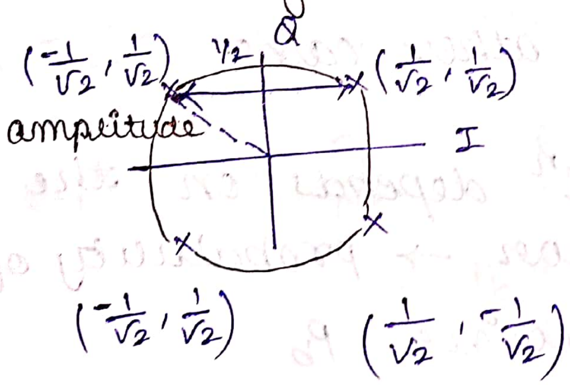
(split sge ito 2 halt)

Even → I phase (cos)
odd → Q phase (sine)
} orthogonal (90°)

Gray code → differentiate bit rep

00
01
11
10

constellation diagram: I & Q bit representation.



BER → lesser → QPSK → wider band can't cover

QAM

Amp phase

modulated at a time

16 - QAM (4 bit representation)

2^M bit

$M=4$ $2^4 = 16$ - QAM

Increasing bit → Increases Bandwidth

→ creates Naise on the system, leads complexity

OFDM :

Divide carrier → subcarrier (I & Q) sgl (cos & sin mix)

multiplied with $w_1, w_2, w_3 \ldots$ diff phases

Each freq exhibit diff phase - orthogonal to each other

OFDM → Multiple frequencies with diff phase & Amp hence no interference can engange more Bandwidth with a single spectrum. Bit Error rate is much lower than the other cases.

Quality of mod^n depends on the measure of Error → probability of Error at the receiver. P_b

P_b depends on ratio of $\frac{E_b}{n_0}$

E_b = Energy per bit

n_0 = power spectral density of a noise channel

$P_b = \frac{E_b}{n_o}$ (Bit Error rate)

E_b = signal strength / data rate

$E_b = \frac{S}{R_b} = S T_S$ $\qquad n_o = \frac{N}{B}$

$P_b = \frac{S}{R_b n_o} = \frac{S T_S}{n_o}$ $\qquad$ N = Noise, B = Bandwidth

$$\frac{E_b}{n_o} = \frac{S}{R_b}$$

$$\boxed{\frac{E_b}{n_o} = \frac{S}{\frac{N}{B} \cdot R_b} = \frac{S}{N} \cdot \frac{B}{R_b}}$$

Defining BER can be related to (S/N) ratio

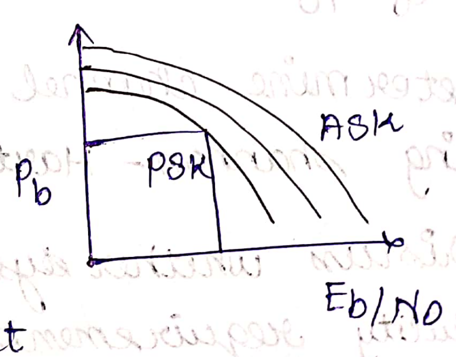
$\frac{E_b}{n_o} \downarrow\downarrow R_b \uparrow\uparrow$

$B >>> R_b \Leftrightarrow$ Better $\frac{S}{N}$ maintained

Normally $\frac{S}{N}$ should be higher.

$P_b = \frac{E_b}{N_o}$ (Not mathematically)

P_b depends on $\frac{E_b}{N_o}$



BER → NF → Link Budget

04.08.25

2. A satellite commⁿ system is designed to TX data from a ground station to a satellite in geostationary orbit at a distance of 36000 km. The system operates at a frequency of 12 GHz in Ku band using QPSK modⁿ. The Ground station has a TX power of 20W and antenna gains for ground station and satellite are 50dBi and 40 dBi. The receiver noise Temperature is 300K and system BW is 10 MHz. The atmospheric loss is 2dB and other losses (pointing loss, polarisation mismatch) totals 3dB. The required BER for reliable commⁿ is 10^{-6}

i) perform link budget analysis to determine received (S/N) ratio at satellite

ii) calculate the bit error rate (BER) for QPSK modⁿ and verify if it meets required BER of 10^{-6}

iii) Determine channel capacity of system using Shannon-Hartley theorem

iv) Discuss whether system meets the reliability requirements and suggest the improvements if necessary.

Soln : $x \propto \frac{1}{Q}$

signal power → Free space analysis

Given:

$P_t = 20W$

$f = 12GHZ$ $K = 1.38 \times 10^{-23}$

$d = 36000 Km$ $T = 300K$

$G_t = 50 dBi$

$G_r = 40 dBi$

$La = 2dB$; $Lm = 3dB$

$B = 10MHZ$

$$dBW = 10 \log \left(\frac{P(W)}{1W} \right)$$

$$dBm = 10 \log \left(\frac{P(W)}{1(mW)} \right) = 10 \log \left(\frac{P(W)}{1 \times 10^{-3}} \right)$$

i) Link Budget Analysis

$$S/N = (S/N)_{dB} = S_{dB} - N_{dB}$$

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi r)^2} \quad \text{Now}: \left(\frac{c}{4\pi f r} \right)^2$$

$$P_{FSPL} = 20 \log d + 20 \log f + 20 \log \left(\frac{4\pi}{c} \right)$$

$$= 20 \log (36 \times 10^6) + 20 \log (12 \times 10^9) + 20 \log \left(\frac{4\pi}{3 \times 10^8} \right)$$

$$= 151.126 + 201.583 - 147.558$$

$$= 205.151 \text{ dB}$$

Scanned with CamScanner

$P_t = 20W \quad = 10 \log(20) = 13.01 \text{ dBW}$

$P_r(dBW) = P_t(dBW) + G_t(dB) + G_r(dB) - \underbrace{P_{Lf} - L_a - L_m}_{(dB)}$

$\left.\begin{matrix} G_t \\ G_r \end{matrix}\right\}$ dBi = dB (Taken)

$= 13.01 + 50 + 40 - 205.151 - 2 - 3$

$\boxed{P_r(dBW) = -107.141 \text{ dBW.}}$

$N = KTB$

$N = 4.14 \times 10^{-14}$

$N(dB) = 10 \log(4.14 \times 10^{-14})$

$\boxed{N_{dB} = -133.829 \text{ dB}}$

$S/N = S_{dB} - N_{dB}$

$= -107.141 + 133.829$

$\boxed{S/N = 26.688 \text{ dB}}$

ii) BER

$\frac{E_b}{N} = \frac{C}{N} - 10 \log(R_b) \qquad \frac{C}{N} = \frac{S}{N}$

$R_b = 2 \times B \quad = 2 \times 10 \times 10^6 = 2 \times 10^7$

$\frac{E_b}{N} = 26.688 - 10 \log(2 \times 10^7)$

$= 26.688 - 73.010$

$= -46.332 \text{ dB.}$

$$BER = Q\sqrt{2\left(\frac{Eb}{N}\right)} \rightarrow \text{linear}$$

$$\left(\frac{Eb}{N}\right) \Rightarrow 10 \log x = -46.332$$

$$\log x = -4.6332$$

$$\frac{Eb}{N} = 2.327 \times 10^{-5} = 0.2344 \times 10^{-6}.$$

Goes lesser not matches 1×10^{-6}

iii) channel capacity

$$c = B \log_2 (1 + (S/N))$$

$$(S/N) \text{ Linear} = 10 \log x = 26.688$$

$$\log x = 2.6688$$

$$x = 466.444.$$

$$C = 10^7 \times \log(1 + 466.444) \times 3.322$$

$$\boxed{C = 88 \text{ Mbps}}$$

→ Increase Transmitt power

→ Better Antenna Gain

→ change modulation scheme.