(1)

Tuesday
09 July 24

Here,

E_{Los} = Direct LOS component.

E_g = Ground Reflected component.

E_{TOT} = Total received feild.

h_t = Height of the Tx

h_r = " " " Rx

Propagation delay = $\frac{\text{distance}(d)}{\text{speed}(c)}$

d = Distance betn Tx and Rx

Let, E_0 = Free space E-field (V/m) at distance d_0

$$E(d,t) = \frac{E_0 d_0}{d} \cos\left(\omega\left(t - d/c\right)\right)$$ [d/c = propagation delay (t)

E-field for LOS

$$E_{Los}(d',t) = \frac{E_0 d_0}{d'} \cos\left(\omega\left(t - \frac{d'}{c}\right)\right)$$ [d' = distance of LOS wave]

E-field for reflected wave,

$$E_g(d'',t) = \frac{E_0 d_0}{d''} \cos\left(\omega\left(t - \frac{d''}{c}\right)\right)$$ [d'' = distance of reflected wave]

$$E_{TOT} = E_{Los} + E_g$$

$$\Rightarrow E_{TOT}(d,t) = \frac{E_0 d_0}{d'} \cos\left(\omega\left(t - \frac{d'}{c}\right)\right) + (-1)\frac{E_0 d_0}{d''} \cos\left(\omega\left(t - \frac{d''}{c}\right)\right)$$

[(-1) = Reflection co-efficient]

Evaluate E-field when reflected path arrives at receiver $\rightarrow$

$$E_{TOT}\left(d, t=\frac{d''}{c}\right)=\frac{E_0 d_0}{d'}\cos\left(\omega\left(\frac{d''-d'}{c}\right)\right)-\frac{E_0 d_0}{d''}\cos 0^\circ$$

$$=\frac{E_0 d_0}{d'}\cos\theta_\Delta-\frac{E_0 d_0}{d''}$$

If d becomes large then $d''=d'=d$

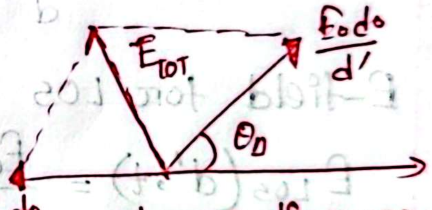
$$E_{TOT}(d)=\frac{E_0 d_0}{d}\cos\theta_\Delta-\frac{E_0 d_0}{d}=\frac{E_0 d_0}{d}(\cos\theta_\Delta-1) \longrightarrow (I)$$

$\rightarrow$ Electric Feild

Here $E =$ Power

$$E_{TOT}(d)=\sqrt{\left(\frac{E_0 d_0}{d}\right)^2(\cos\theta_\Delta-1)^2+\left(\frac{E_0 d_0}{d}\right)^2\sin^2\theta_\Delta}$$ [Pythagorus]

$$=\frac{E_0 d_0}{d}\sqrt{2-2\cos\theta_\Delta}$$



phasor diagram

$$=2\frac{E_0 d_0}{d}\sin\left(\frac{\theta_\Delta}{2}\right)$$

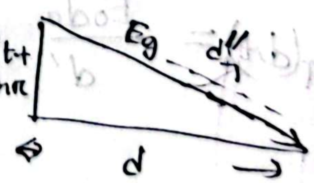
$$=2\frac{E_0 d_0}{d}\left(\theta_\Delta/2\right)$$ [Since $\sin\left(\frac{\theta_\Delta}{2}\right)=\frac{\theta_\Delta}{2}$] $\longrightarrow$ (II)

② Path difference,

Now, Path diff $\Delta = d''-d'$

$$=\sqrt{(h_t+h_r)^2+d^2}-\sqrt{(h_t-h_r)^2+d^2}$$

[Slide 8 diagram Xm-এ এটাকে proof করতে হবে]



$d'' =$ 

$$\Delta = d\sqrt{1+\left(\frac{h_t+h_r}{d}\right)^2} - d\sqrt{1+\left(\frac{h_t-h_r}{d}\right)^2}$$

$$= d\left(1+\frac{1}{2}\left(\frac{h_t+h_r}{d}\right)^2\right) - d\left(1+\frac{1}{2}\left(\frac{h_t-h_r}{d}\right)^2\right)$$

[$\sqrt{1-x} = 1+\frac{x}{2}$, Tylor series.]

$$= \frac{1}{2d}\left((h_t+h_r)^2 - (h_t-h_r)^2\right) \qquad \left[(a+b)^2-(a-b)^2 = 4ab\right]$$

$$\boxed{\Delta = \cancel{2h_t h_r}\ \frac{2h_t h_r}{d}} \leftarrow \text{Path difference.}$$

distance

Phase diff^n, $\theta_\Delta = \omega \tau_d = 2\pi f \frac{\Delta}{c} = 2\pi f \frac{\Delta}{\lambda f} = \frac{2\pi\Delta}{\lambda}$

Time delay. $\tau_d = \frac{\Delta}{c} = \frac{\theta_\Delta \lambda}{2\pi f \cancel{\lambda}} = \frac{\theta_\Delta}{2\pi f}$

From Equation (4)

$$E_{TOT}(d) = 2\frac{E_0 d_0}{d}\left(\theta_\Delta/2\right)$$

$$= 2\frac{E_0 d_0}{d}\left(\frac{2\pi\Delta}{2\lambda}\right)$$

$$= 2\frac{E_0 d_0}{d}\ \frac{2\pi\ 2h_t h_r}{2\lambda d}$$

$$\boxed{E_{TOT}(d) = \frac{4\pi E_0 d_0 h_t h_r}{\lambda d^2}}$$

$$|E_{TOT}(d)|^2 = \left| \frac{4\pi E_0 d_0 \, h_t h_r}{\lambda d^2} \right|^2 \quad [P \propto E^2]$$

$$\cancel{d(d} \; P_r(d) = \frac{(4\pi)^2 E_0^2 d_0^2 h_t^2 h_r^2}{\lambda^2 d^4}$$

$$= \frac{(4\pi)^2 P_0 d_0^2 h_t^2 h_r^2}{\lambda^2 d^4} \quad \text{—— (iii)}$$

Free space loss for LOS;

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_t G_r \lambda^2} \Rightarrow P_r = P_t G_t G_r \frac{\lambda^2}{(4\pi d)^2}$$

Here, $P_0 = P_r$, $P_0 = P_t G_t G_r \dfrac{\lambda^2}{(4\pi d)^2}$

From (iii),

$$P_r(d) = P_t G_t G_r \frac{\cancel{\lambda^2}}{(4\pi d_0)^2} \times \frac{(4\pi d_0)^2 h_t^2 d_r^2}{\cancel{\lambda^2} d^4}$$

$$\boxed{P_r(d) = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4}}$$

[Proved]

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Free Space Loss for 2-ray model,

$$\frac{P_t}{P_r} = \frac{d^4}{G_t G_r h_t^2 h_r^2} \quad \text{(Proved)} \; \text{---} (2)$$

Free Space loss for 2-ray model in dB

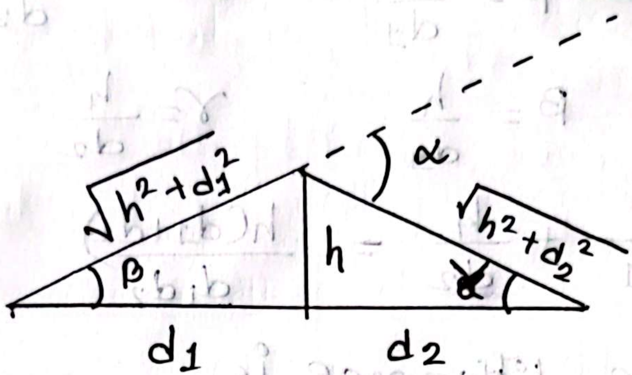
$$L_{dB} = 40 \log(d) - 10 \log(G_t G_r) - 20 \log(h_t h_r)$$

(Proved) - (3)

(*) এই Formula use করে Rappaport বইয়ে math আছে করতে হবে।

(11) lecture

Knife-edge Diffraction model:



The electrical field due to the differacted path is,

$$E_d = E_0 \exp(-j\phi) \quad \text{---(1)}$$

The difference between the direct path and the diffracted path called the excess path length (Δ) can be obtained

$$\Delta = \sqrt{h^2+d_1^2} + \sqrt{h^2+d_2^2} - (d_1+d_2)$$

$$= d_1\sqrt{1+\frac{h^2}{d_1^2}} + d_2\sqrt{1+\frac{h^2}{d_2^2}} - d_1 - d_2$$

$$= d_1\left(1+\frac{h^2}{2d_1^2}\right) + d_2\left(1+\frac{h^2}{2d_2^2}\right) - d_1 - d_2 \quad \left[\begin{array}{l}\sqrt{1+x} = 1+\frac{x}{2} \\ x \ll 1\end{array}\right]$$

$$= d_1 + \frac{d_1h^2}{2d_1^2} + d_2 + \frac{d_2h^2}{2d_2^2} - d_1 - d_2$$

$$= \frac{h^2}{2}\left(\frac{1}{d_1} + \frac{1}{d_2}\right)$$

$$= \frac{h^2(d_1+d_2)}{2d_1d_2}$$

The angle $\alpha = \beta + \gamma$ since $d_1, d_2 >> h$

$$\tan\beta = \frac{h}{d_1} \qquad \tan\gamma = \frac{h}{d_2}$$

$$\beta = \frac{h}{d_1} \qquad \gamma = \frac{h}{d_2} \qquad [\tan x \simeq x]$$

$$\alpha = \frac{h}{d_1} + \frac{h}{d_2} = \frac{h(d_1+d_2)}{d_1 d_2}$$

The phase difference is,

$$\phi = \omega T_d$$

$$= 2\pi f \frac{\Delta}{c}$$

$$= 2\pi f \frac{\Delta}{f\lambda}$$

$$= \frac{2\pi\Delta}{\lambda}$$

$$= \frac{\cancel{2}\pi}{\lambda} \frac{h^2(d_1+d_2)}{\cancel{2}d_1 d_2}$$

$$= \frac{\pi h^2 (d_1+d_2)}{\lambda d_1 d_2}$$ if keep 2

$$\phi = \frac{\pi}{2} \frac{h^2\, 2(d_1+d_2)}{\lambda d_1 d_2} \quad \text{——} \quad (4)$$

The phase difference is usually normalized using Fresnel kirchhoff parameter v given by.

$$v = h\sqrt{\frac{2}{\lambda}\left(\frac{d_1+d_2}{d_1 d_2}\right)} = \alpha\sqrt{\frac{2}{\lambda}\left(\frac{d_1 d_2}{d_1+d_2}\right)}$$

$$v^2 = h^2 \frac{2(d_1+d_2)}{\lambda\, d_1 d_2}$$

From equa (11) →

$$\phi = \frac{\pi}{2} v^2$$

From equ^n (1) →

$$E_d = E_0 \exp\left(-j \frac{\pi}{2} v^2\right)$$

Now we include all other rays produced by the Hygen's sources. These are produced for all the Hygen's sources above the screen and hence we sum or integrate from v to ∞

$$E_{TOT} = E_0 \frac{1+j}{2} \int_v^{\infty} \exp\left(-j \frac{\pi}{2} t^2\right) dt.$$

$$\Rightarrow \frac{E_{TOT}}{E_0} = \frac{1+j}{2} \int_v^{\infty} \exp\left(-j \pi/2\, t^2\right) dt$$

$$\Rightarrow \frac{E_{TOT}}{E_0} = F(v) \rightarrow \text{Complex Fresnal Integral.}$$

$$\Rightarrow \left|\frac{E_{TOT}}{E_0}\right|^2 = |F(v)|^2$$

$$\Rightarrow G_d\,(dB) = 20 \log |F(v)|$$

$G_d\,(dB)$ = Diffraction gain for positive value.

for negative value → Diffraction loss

Example 3.6 A mobile is located 5km away from a base station and uses a verticle $\lambda/4$ monopole antenna with gain of 2.55 dB to receive cellular radio signals. The E-field at 1km from the transmitter is measured to be 10^{-3} V/m. The carrier frequency used for this system is 900 MHz.

(a) Find the ~~Gain~~ length and the gain of receiving antenna.

Ans: Given,

T-R seperation distance, d = 5km = 5000m.

E-field at a distance of 1km = 10^{-3} V/m.

$d_0 = 1km = 1000$

Frequency $f = 900 MHz$

$$\lambda = \frac{3\times10^8}{900\times10^6} = \frac{1}{3}$$

$$\text{Length of antenna, } L = \frac{\lambda}{4} = \frac{1/3}{4} = 0.0833 m$$

$$= 8.33 cm.$$

$$\text{Gain} = \frac{4\pi A_e}{\lambda^2}$$ যেহেতু Ae value নাই,

$$\text{Gain} = 10^{2.55/10} = 1.8.$$

(b) Find the received power at the mobile using the 2-ray ground reflection model assuming the height of the transmitting antenna is 50 m and receiver antenna 1.5m above ground.

Ans: Since $d \gg \sqrt{h_t + h_r}$, the electric field,

$$E_R(d) = \frac{2E_0 d_0}{d} \frac{2\pi h_t h_r}{\lambda d}$$

$$= \frac{2\times10^{-3} \times 1000 \times 2\times3.1416\times50\times1.5}{5000 \times 0.333\times 5000}$$

$$= 113.1\times10^{-6}\, V/m.$$

The received power at a distance d can be obtained

$$P_r(d) = \frac{(113.1\times10^{-6})^2}{377}\left[\frac{1.8(0.33)^2}{4\pi}\right]$$

$P_r(d) = P_d A_e$

$= \frac{|E(d)|^2}{120\pi} A_e$

$A_e = \frac{G\lambda^2}{4\pi}$

$120\times3.1416 = 376.99$

$\simeq 377$

$$\Rightarrow P_r(5km) = \cancel{5.3}\ 5.4\times10^{-13}\, W$$

$$= 10 \log 5.4\times10^{-13}$$

$$= -122.68\ dBW$$

$$= 10\log_{10}\left(\frac{5.4\times10^{-13}}{10^{-3}}\right) dBm.$$

$$= -92.68\ dBm.$$

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Example 3.7 Compute the diffraction loss for 3 cases assume $\lambda = \frac{1}{3}m$, $d_1 = 1km$, $d_2 = 1km$ and (a) $h = 25m$, (b) $h = 0$ (c) $h = -25m$. For each of these cases, identify the Fresnel zone within which the tip of the obstruction lies.

(a)

Given, $\lambda = \frac{1}{3}m$

$d_2 = d_1 = 1km = 1000m$.

$h = 25$.

We know, $v = h\sqrt{\frac{2(d_1+d_2)}{\lambda d_1 d_2}} = 25\sqrt{\frac{2(1000+1000)}{\frac{1}{3}\times 1000\times 1000}}$

$= 2.74$

if $v = 2.74$ is greater than 2.4 than Gain,

$G_d(dB) = 20\log\frac{0.225}{v} = 20\log\frac{0.225}{2.74}$

$= -21.71$ dB. (negative)

So the Diffraction loss is 21.71 dB.

Now To find the Fresnel zone in which the tip of the obstruction lies we need to compute n which satisfies the relation $\Delta = \frac{n\lambda}{2}$

$\lambda = \frac{1}{3}$

$\Delta = \frac{h^2(d_1+d_2)}{2d_1d_2} = \frac{25^2(1000+1000)}{2\times 1000\times 1000} = 0.625m$

$n = \frac{2\Delta}{\lambda} = \frac{2\times 0.625}{1/3} = 3.75$

Therefore, the tip of the obstruction completely blocks the first three ~~Freset~~ Fresnel zones.

(b) $h = 0$

$\nu = 0$ ν = Fresnel Diffraction Parameter.

$G_{dB} = 20 \log 0.5 - 0.62\nu = 20 \log 0.5 = -6 \text{ dB}.$

Diffraction loss = 6dB.

Now $h = 0$ $\Delta = 0$ & the tip of the obstruction lies in the middle of the First Fresnel zone.

(c) $h = -25$

$$\nu = -25 \sqrt{\frac{2(1000+1000)}{1/3 \times 1000 \times 1000}} = -2.74$$

if $\nu \leq -1$

$G_d dB = 0$.

Since the absulate value of h ~~and~~ is same as part (a) n & Δ will be same. It should be noted that although the tip of the obstruction completely blockes the first 3 Fresnel zones, the diffraction losses are negligibles Since the obstruction is below the line of sight (h is negative)

(10)

Reactive Near Field: $R < 0.62\sqrt{\frac{D^3}{\lambda}}$ R = region.

- Power calculate করি না
- Store energy

Radiative Near-Field: (Fresnel) Region.

- Starting point to power generate. energy gather করে just
- Power calculation করি না।
- $0.62\sqrt{\frac{D^3}{\lambda}} < R < \frac{2D^2}{\lambda}$

Far-Field (Fraunhofer) Region:

- The radiation pattern doesnot change shape with distance
- $R > \frac{2D^2}{\lambda}$ $R >> D$ $R >> \lambda$

  D = size of antena.
- Power calculation হবে।
- $R = \frac{2D^2}{\lambda}$

Ex1 The audio power of the human voice is concentrated at about 300 Hz.

(a) What is the length of an antena one-half wavelength long for sending radio at 300Hz?

Ans: wave length $\lambda = \frac{c}{f} = \frac{3\times10^8}{300Hz} = 1000km$.

Length of antenna $L = \frac{\lambda}{2} = 500km$.

(b) Antennas of the appropriate size for this frequency are impracticably large so need higher frequency modulation.

(b) suppose we would like a half-wave antenna to have a length of 1m. What carrier frequency would we use?

$L = \frac{\lambda}{2} = 1$; $\lambda = 2$

$f = \frac{3\times10^8}{2} = 1.5\times10^8 = 150MHz$.

Antenna Gain

$$G = \frac{\text{Power radiated by an antenna} \rightarrow \text{(directed antenna)}}{\text{Power radiated by reference antenna} \rightarrow \text{(omnidirectional)}}$$

$10\log 2 = 3\,dB \rightarrow$ direction 2 times more power generate হয়

$10\log 1 = 0$

$10\log 4 = 6\,dB \rightarrow$ " 4 times more power generate হয়

Effective Area of antenna

is a measure of how well an antenna can receive power from a radio wave. It describes antenna's ability to capture energy from an incomming electromegnatic wave and is related to the antenna's gain.

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$ relation with Gain

$$\lambda = \frac{c}{f}$$

isotropic $\rightarrow \lambda^2/4\pi \rightarrow 1$

dipole $\rightarrow 1.5\lambda^2/4\pi \rightarrow 1.5$

Halfwave $\rightarrow 1.64\lambda^2/4\pi \rightarrow 1.64$

Parabolic face area A $\rightarrow 0.56A \rightarrow 7A/\lambda^2$

Ex-2 For a parabolic reflective antenna with a diameter of 2m, operating at 12 GHz, what is the effective area and gain?

Ans: $A_e = 0.56A = 0.56\pi$ $\quad [A = \pi r^2 = \pi 1^2 = \pi$. $\quad [d = 2, r = 1]$

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{12\times10^9} = 0.025$$

$10^9 H = 1 GHz$.

$$\cancel{G = \frac{4\pi \times 0.56\pi}{1/40}}$$

$$G = \frac{4\pi\, 0.56A}{\lambda^2} = \frac{7A}{\lambda^2}$$

$$G = \frac{7A}{\lambda^2} = \frac{7\times\pi}{(0.025)^2} = 35185.92$$

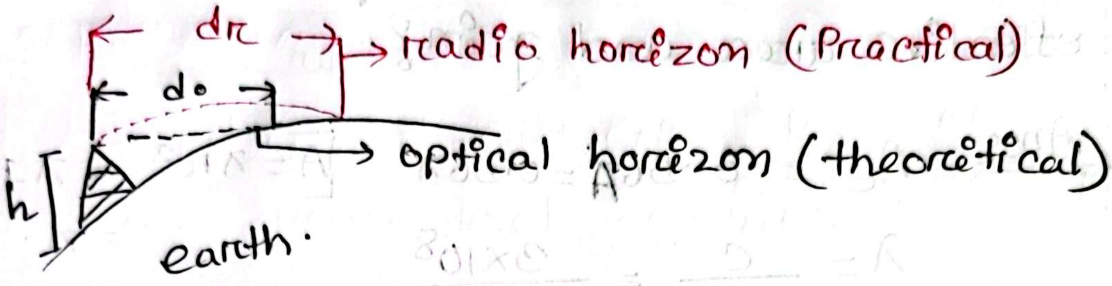
$$G_{dB} = 10 \log_{10}(35185.92) = 45.56$$

Propagation mode

1. Ground $< 3MHz$
2. Sky $\quad 3MHz$ to $30MHz$
3. Effective Line of Sight [LOS] $> 30MHz$.

(30MHz — 900THz)

LOS calculation:



What is the relationship between h and d?

→ For optical LOS : $d_o = 3.57\sqrt{h}$

→ For effective/radio LOS: $d_r = 3.57\sqrt{kh}$

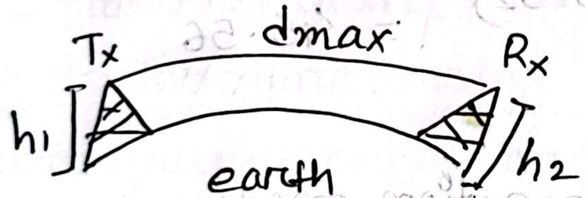
k use করে দুটোকে same আনা হয়েছে।

h = Antenna height

d = distance

k = adjustment factor for refraction, $k = \frac{4}{3}$

⊛



উপরের math এ $h_2 = 0$ = ground level

$$d_{max} = 3.57\left(\sqrt{kh_1} + \sqrt{kh_2}\right)$$

o

$$= 3.57\left(\sqrt{k \times 100} + 0\right)$$

$$= 3.57\sqrt{\frac{4 \times 100}{3}}$$

$$= 41 \text{ km}.$$

Now if we add h_2 = receiver ~~to~~ antenna's height = 10m

find $h_1 = ?$

$d_{max} = 41$ km.

$$41 = 3.57\left(\sqrt{\frac{4h_1}{3}} + \sqrt{\frac{4\times10}{3}}\right)$$

$h_1 = 46.2$m

previously it was 100m now 46.2m

so if we add receiver antenna height transmitter antenne will reduce it's height.

P-1 Find the optimum distance from the ground level for half-wave diopde antenna of frequency 15 MHz.

$\Rightarrow$ Transmitter Antenna height, $H_1 = \frac{\lambda}{2} = \frac{\frac{c}{f}}{2} = \frac{\frac{3\times10^8}{15\times10^6}}{2}$

$= \frac{20}{2}$

$= 10$m

$H_2 = 0$ = ground level.

$$d_{max} = 3.57\left(\sqrt{kH_1} + \underbrace{\sqrt{kH_2}}_{\to 0}\right)$$

$$= 3.57 \times \sqrt{\frac{4\times10}{3}}$$

$$= 13.036.$$

An

2. Determine the height of an antenna for a TV station that must be able to reach customer up to 80km away.

→ যেহেতু কোনো height ই দেয়া নেই তাই receiver customer-কে ground level ধরে নিবো as TV তে যাবে।

$d = 3.57\sqrt{kh}$

80

1km — 1000m.

$\Rightarrow 80 = 3.57\sqrt{kh}$

$\Rightarrow 80^2 = (3.57)^2 kh$

$\Rightarrow h = \dfrac{80^2}{(3.57)^2 \frac{4}{3}}$

$= 376.6$

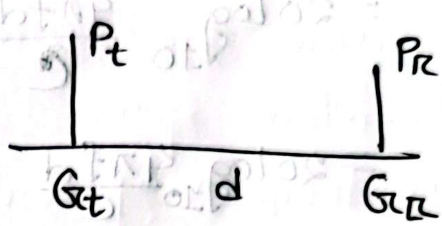
$\simeq 376.7$ km.

Friis Free space Equation

দূরত্ব বাড়ার সাথে সাথে signal ছড়িয়ে যায়। অনেকগুলো signal·

The ~~equation~~ relation between the transmit and receiver power is given by Friis Free space equation.

$$P_r = P_t G_t G_r \frac{\lambda^2}{(4\pi d)^2}$$



Free space loss:

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2} \quad \boxed{\lambda = \frac{c}{f}}$$

isotropic antenna gain = 1

$$\downarrow$$

$G_t = G_r = 1$

d & λ are in same unit (m)

$$L_{dB} = 10 \log_{10} \frac{P_t}{P_r}$$

$$= 10 \log_{10} \left(\frac{4\pi d}{\lambda}\right)^2$$

$$= 2 \times 10 \log_{10} \frac{4\pi d}{\lambda}$$

$$= 20 \log_{10} 4\pi d - 20 \log_{10} \lambda$$

$$= 20 \log_{10} (4\pi) + 20 \log_{10} (d) - 20 \log_{10} (\lambda)$$

$$= 21.98\,dB + 20 \log_{10} (d) - 20 \log_{10} (\lambda)$$

(Ans:)

Again,

$$L_{dB} = 10 \log_{10} \frac{P_t}{P_r}$$

$$= 10 \log_{10} \left(\frac{4\pi f d}{c}\right)^2$$

$$= 20 \log_{10} \frac{4\pi f d}{c}$$

$$= 20 \log_{10} \frac{4\pi f d}{c}$$

$$= 20 \log_{10} \frac{4\pi}{c} + 20 \log_{10} (f) + 20 \log_{10} (d)$$

$$= 20 \log_{10} \frac{4 \times 3.1416}{3 \times 10^8} + 20 \log_{10} (f) + 20 \log_{10} (d)$$

$$= -147.56 dB + 20 \log_{10} (f) + 20 \log_{10} (d).$$

(Ans:)

এইগুলো prove করার আগে Pic দিয়ে $\frac{P_t}{P_r}$ figure explain করে then prove.

→ Free space loss accounting for Gain of other antenna

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_t G_r \lambda^2} \qquad G_t = \frac{4\pi A_t}{\lambda^2} \qquad G_r = \frac{4\pi A_r}{\lambda^2}$$

$$= \frac{(4\pi)^2 d^2}{\lambda^2} \times \frac{\lambda^2 \times \lambda^2}{4\pi A_t \times A_r 4\pi}$$

$$= \frac{(4\pi)^2 d^2}{\cancel{\lambda^2}} \times \frac{\lambda^4}{A_t A_r (4\pi)^2}$$

$$= \frac{\lambda^2 d^2}{A_t A_r} = \frac{(\lambda d)^2}{A_t A_r} = \frac{(cd)^2}{A_t A_r f^2} \qquad \boxed{\lambda = \frac{c}{f}}$$

$$L_{dB} = 10 \log_{10} \frac{P_t}{P_r} = 10 \log_{10} \frac{(\lambda d)^2}{A_t A_r}$$

$$= 10 \log_{10} (\lambda d)^2 - 10 \log_{10} (A_t A_r)$$

$$= 20 \log_{10} \lambda d - 10 \log_{10} (A_t A_r)$$

$$= 20 \log_{10} \lambda + 20 \log_{10} d - 10 \log_{10} (A_t A_r)$$

$$L_{dB} = 10 \log_{10} \frac{(cd)^2}{A_t A_r f^2}$$

$$= 10 \log_{10} \left(\frac{cd}{f}\right)^2 - 10 \log_{10} A_t A_r$$

$$= 20 \log_{10} cd - 20 \log_{10} f - 10 \log_{10} (A_t A_r)$$

$$= 20 \log_{10} c + 20 \log_{10} d - 20 \log_{10} f - 10 \log_{10} A_t A_r$$

Example: Assume that two antennas are half-wave dipoles and each has a directive gain of 3dB. If the transmitted power is 1W and the two antennas are seperated by a distance of 10 km What is the received Power? Assume that antennas are aligned so that the directive gain numbers are correct and that the frequency used is 100MHz.

Ans:

Given,

$d = 10km = 10\times10^3 m$

$G_t = 10\log_{10}(2) = 3dB$ so $G_t = 2$

$G_r = 10\log_{10}(2) = 3dB$ $G_r = 2$

$P_t = 1W$. $P_r = ?$ $f = 100MHz = 100\times10^6 Hz$.

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{100\times10^6} = 3m$$

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_t G_r \lambda^2}$$

$$\Rightarrow P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2}$$

$$\Rightarrow P_r = \frac{1\times2\times2\times3^2}{(4\times3.1416\times10\times10^3)^2}$$

$$= 2.28\times10^{-9} \text{ Watt.}$$

$$L_{dBm} = 10\log_{10}\frac{P_t}{1mW}$$

$$= 10\log_{10}\frac{P_t}{10^{-3}W}$$

$$L_{dB} = -86.42 dB$$

② If a transmitter produces 50 Watt of power, express the ~~p~~ transmitt power in units of (a) dBm (b) dBW. If 50 Watt is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna, what is P (1 0 km)?

Assume unity gain for the receiver antenna.

Ans: (a) Given $P_t = 50W$ dBm → mili watt

~~1 Watt = 1000~~

$$P_t (dBm) = 10 \log_{10} \frac{P_t}{10^{-3} W}$$

1 Watt = 1000 mili Watt

$1mW = 10^{-3} W$

$$= 10 \log_{10} P_t \times 10^{3}$$

$$= 10 \log_{10} 50 \times 10^{3} = 47.0 dBm.$$

$$P_t (dBW) = 10 \log_{10} P_t / 1W$$

$$= 10 \log_{10} 50 = 17.0 dBW.$$

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2}$$

$$\lambda = \frac{3\times10^8}{900\times10^6} = \frac{1}{3}$$

$$= \frac{50\times1\times1\times(\frac{1}{3})^2}{(4\times3.1416\times100)^2}$$

Unity Gain means $G_r = 1$.

$= 3.51\times10^{-6}$ W.

$= 3.51\times10^{-3}$ mW.

$$P_r(\text{dBm}) = 10\log_{10}(3.51\times10^{-3})$$

$= -24.5$ dBm.

Again received power at 10km

$$P_r(10\text{km}) = P_r(100) + 20\log\left[\frac{100}{10{,}000}\right]$$

$= -24.5$ dBm $- 40$ dBm

$= -64.5$ dBm

$$\left[10\log P_r\left(\frac{d}{d_\cdot}\right)^2\right]$$

(3) Determine the isotropic free space loss at 4 GHz for the shortest path to a synchronous satellite from earth (35,863 km). What is the power received at the satellite antenna?

(Assume antenna gain of both the satellite and ground based antennas are 44dB and 48dB respectively, a transmit power of 250W at the earth station)

$$\Rightarrow \lambda = \frac{3\times10^8}{4\times10^9} = \frac{3}{40} = 0.075$$

$$L_{dB} = 21.98\,dB + 20\log_{10}(d) - 20\log_{10}(\lambda)$$

$$= 21.98\,dB + 20\log_{1}(35863\times10^3) - 20\log_{10}(0.075)$$

$$= 195.6\,dB.$$

Now here is given two gain,

$$\frac{P_t}{P_R} = \frac{(4\pi d)^2}{G_t G_R \lambda^2}$$

$$L_{dB} = 10\log_{10}\frac{(4\pi d)^2}{\lambda^2 G_t G_R} = 10\log\left(\frac{4\pi d}{\lambda}\right)^2 - 10\log G_t G_t$$

$$= \underbrace{20\log(4\pi) + 20\log(d) - 20\log(\lambda)}_{195.6} - 10\log G_t G_r$$

$$= 195.6 - 10\log_{10} G_t - 10\log_{10} G_R$$

$$= 195.6 - 44 - 48$$

$$= 103.6\,dB.$$

Now, $P_t = 250W$.

$$P_t(dB) = 10\log_{10} 250 \approx 24\,dBW.$$

Receiver power, $P_r = 24 - 103.6$

$$= -79.6\,dBW.$$

Wednesday
23 Oct 2024

Telecommunication
Lecture-9
GSM Network Architecture

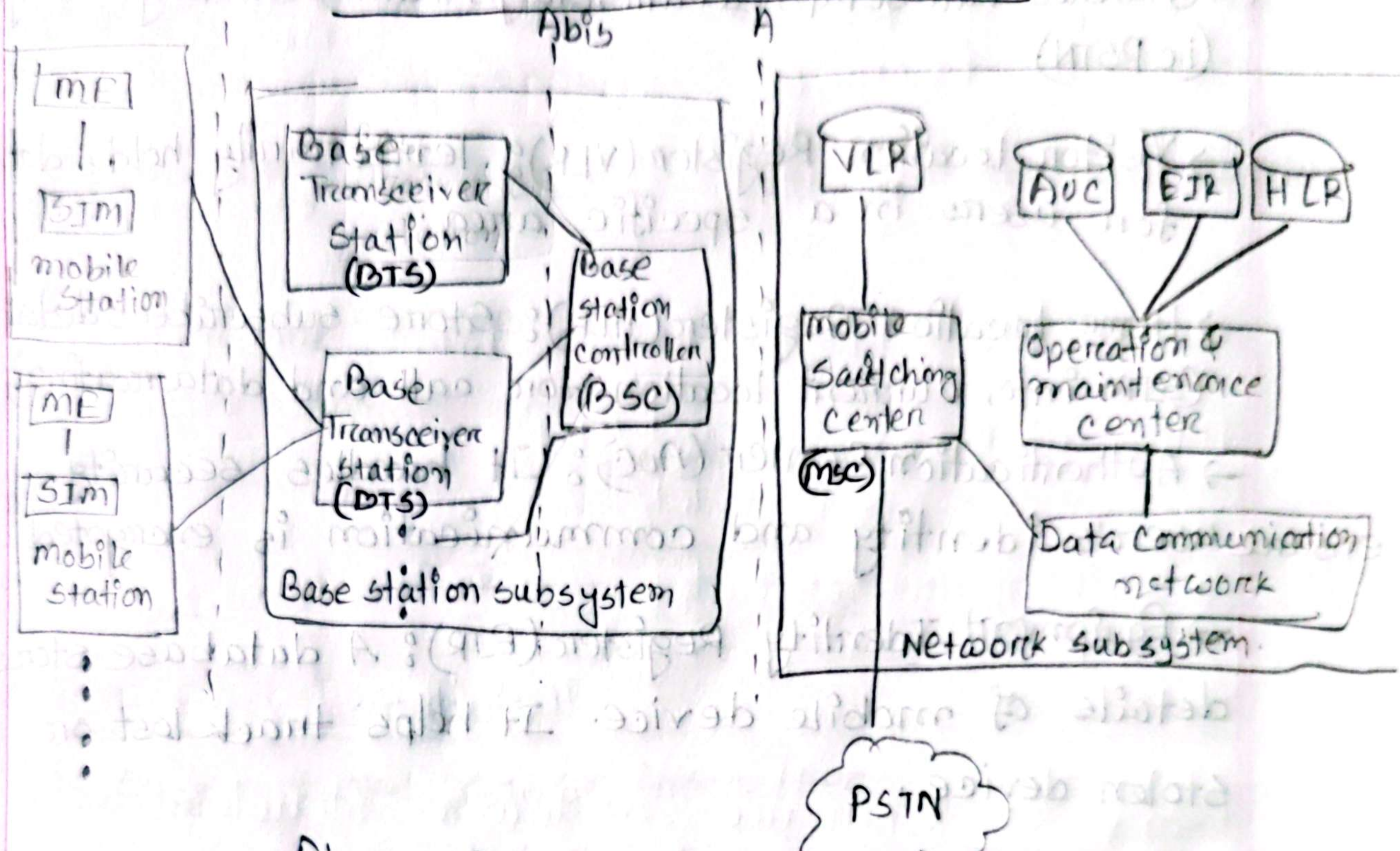


Figure: Overall GSM Architecture.

① **Mobile station (MS):** ~~The~~

→ ME (mobile equipment): physical mobile or device

→ SIM (Subscriber Identity Module): Stores subscriber identity authentication & encryption details.

② **Base Station subsystem:**

→ BTS: Handles radio communication with mobiles. receiving & Transferring signals.

→ BSC: Manage multiple BTS units and control connections. (allocate radio channel, ensure seemless handover between calls)

③ Network subsystem:

→ MSC: The core switch for call routing and management (handles call setup, location registration, mobility management) (i.e PSTN)

→ Visitor Location Register (VLR): Temporarily holds data for users in a specific area.

→ Home Location Register (HLR): Store subscribers details (SIM info, current location for call and data routing)

→ Authentication Center (AuC): It handles security. ensure user's identity and communication is encrypted

→ Equipment Identity Register (EIR): A database stores details of mobile device. It helps track lost or stolen device.

④ Operations and maintenance Center (OMC): This part manages the overall network, ensuring smooth operations and monitoring of network performance.

Interfaces:

Um : Inteface between MS and BTS

Abis : BTS & BSC

A : BSC & MSC

External Networks: (PSTN) → Public Switched Telephone Network: The traditional phone network that the GSM system can connect to for voice service.

GSM-900 bands:

Reverse link (m to B) (uplink): 890 - 914 MHz = 25 MHz.

Forward link (B to M) (Downlink): 935 - 960 MHz = 25 MHz.

Channel Band width = 200 kHz.

FL: $\frac{25\,MHz}{200\,kHz} = 125\,ch = 124\,ch + 1$ guard band (200 kHz)

RL: $\frac{25\,MHz}{200\,kHz} = 125\,ch$ = "

Full duplex channel = FL + RL.

GSM Transmission

TDMA + FDMA.

GSM Frame structure:

The system sends 216.66 frame/sec.

Frame duration = $\frac{1}{216.66} = 4.615\,ms$.

Each slot duration = $\frac{4.615\,ms}{8} = 576.94\,\mu s$

Each slot contains = 8 field.

Total traffic bits = 57 + 57 = 114 bits

[65 bits → digitized voice + 49 bits → redundant bits for error correction]

Total TDMA control bits = (2×3) + (2×1) + 26 + 8.25

= 42.25 bit

3	57 encrypted bit		26 training seq	57 encrypted bit		3	8.25

trail bit

Stealing bit (traffic or controlling) identify

Stealing bit

trail

guard bit.

Slot width: 144 bits + 42.25 bits = 156.25 bits.

Frame width = $\frac{(156.25 \text{ bits/slot})}{\times (8 \text{ slot/frame})}$ = 1250 bits/Frame.

Total Transmission rate: 216.66 frame/sec × 1250 bits/fram

= 270.8 kbps.

Example-1 GSM uses a frame structure where each frame consists of 8 time slots, each time slot contains 156.25 bits and data is transmitted over a channel at 270.833 kbps.

(1) Time duration?

Given channel data rate = 270.833 kbps

Time duration of a bit, $T_b = \frac{1}{\text{data rate}}$

$= \frac{1}{270.833}$

$= 3.692 \mu s$

1 mili (s) = 1000 microsecond.

(ii) Time duration for a time slot?

Given,

\# of bits in a time slot = 156.25 bits.

Time duration of a time slot, $T_{slot} = \cancel{156.25}\ 156.25 \times T_b$

$= 156.25 \times 3.69 \mu s$

$= 577 \mu s$.

$= 0.577 ms$.

(iii) Time duration of a TDMA frame,

\# of time slot in per TDMA frame = 8

Time duration of a fram, T_f = # of time slot $\times T_{slot}$

$= 8 \times 577 \mu s$.

$= 4616 \mu s$

$= 4.616 ms$.

(iv) How long must a user wait when occupying a single time slot between two successive transmissio

→ has to wait for a time duration of a frame

Hence a user has to wait for 4.616 ms between two successive transmissions.

CamScanner

→ Each multiframe → 51 or 26 frame
→ " superframe → 51 or 26 multiframe.
→ Each hyperframe → 2048 superframe.

⊛ If GSM uses Traffic channel then the frame heirarchy will be:

Multiframe = 26

Superframe = 51

Hyperframe = 2048.

There will be total (26 × 51 × 2048) = 2715648 frame for sending traffic information into traffic channel.

⊛ If GSM uses Control channel then the ~~form~~ frame heirarchy will be:

Multiframe = 51.

Superframe = 26.

Hyperframe = 2048

Total = (51 × 26 × 2048) = 2715648 frames for sending control information into control channel.

For traffic:

* 1 Frame duration = 4.615 ms.

1 multiframe duration = 26 × 4.615 ms = 120 ms.

1 superframe duration = 51 × 120 ms = 6.12 s.

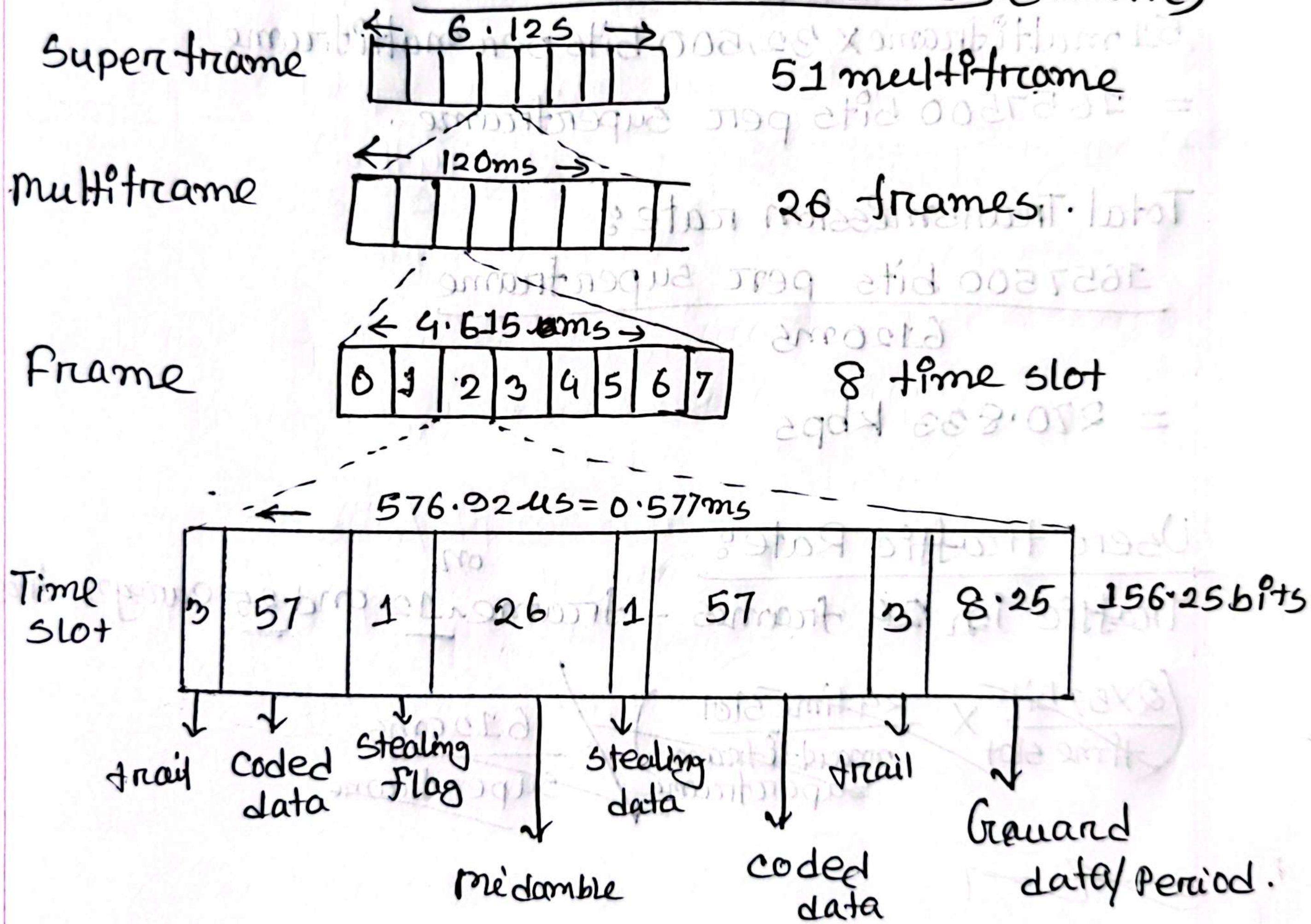
For control channel

* 1 Frame duration = 4.615 ms.

1 multiframe " = 51 × 4.615 ms = 235 ms.

1 superframe " = 26 × 235 ms = 6.12 s.

GSM Frame Structure (Traffic)



GSM Data Rate for traffic channel:

Time slot width: 114 traffic bits + 42.25 control bits
= 156.25 bits.

Frame width: 8 time slot per frame x 156.25 bit per slot
= 1250 bits per frame.

Multiframe width:

26 frames x 1250 bits per frame = 32,500 bits per multiframe

Superframe width:

51 multiframe x 32,500 bits per multiframe
= 1657500 bits per superframe.

Total Transmission rate:

$$\frac{1657500 \text{ bits per superframe}}{6120\text{ms}}$$

= 270.833 kbps

User traffic Rate:

Traffic in 24 frames — frame 12 and 25 carry no traffic on

$$\left(\frac{2\times 57 \text{ bit}}{\text{time slot}} \times \frac{24 \text{ time slot}}{\cancel{\text{multiframe}}\ \text{superframe}}\right) \Big/ \frac{6120\text{ms}}{\text{superframe}}$$

= ~~[illegible]~~

$t = (2 \times 57$ bits per time slot $\times$ 24 time slots per multiframe $\times$ 51 multiframe per superframe) / 6.120 s

$$= \frac{2 \times 57 \times 24 \times 51}{6.120 s} = 22800 \text{ bps} = 22.8 \text{ kbps}.$$

If we use just multiframe then,

$$\text{user } t = \frac{2 \times 57 \times 24}{120 ms} = 22.8 \text{ kbps}.$$

Control $\rightarrow$ $\left.\begin{array}{l} 51 \times \text{ multiframe} \\ 26 \times \text{ superframe} \end{array}\right\}$ হবে just বাকি সব calculation same.

~~Speep~~ Speech Coding

1. A/D conversion → Analog to digital
2. Compressed digital voice.

<u>A/D conversion</u>: using PCM technique,

We know, voice range – (3–4) kHz.

Here we take 4KHz = 4000 Hz.

now double this value to generate sample per second = 2×4000 = 8000 sample/second.

In A/D conversion we have to ~~split~~ calculate the sample ~~so that~~ during 20ms → (algorithm)

$1s = 1000ms \longrightarrow 8000$ sample.

$\therefore \quad 1\,ms \longrightarrow \frac{8000}{1000}$ "

for $20ms \longrightarrow \frac{8\cancel{000} \times 20ms}{1\cancel{000}}$ "

$= 160$ sample/20ms.

অর্থাৎ প্রতি 20ms-এ 160 sample করে পাঠাবো।

Here 160 sample contains 2080 bits $= \frac{2080}{160}$

$= 13$ bit/sample

→ A/D conversion rate = (8000 sample/sec) × (13 bit/sample)

= 104 kbps.

অর্থাৎ প্রতিটা sample-এ 13টা bit আছে।

8000টা sample তো 160 sample/20ms → পাঠাতে

104 Kbps conversion rate লাগবে।

<u>So in short:</u> 13bit linear predictive codding (LPC)

(1) GSM full Rate speech is sampled = 8 kHz
= 8000 sample/s

(2) <u>Frame duration:</u>

→ GSM speech range 20ms of voice data.

→ In 20ms the no of sample is = ~~[illegible]~~ $(8000 \times 0.02) = 160$ sample.

So 160 sample per 20ms.

(3) <u>Bit per sample:</u> Each sample in GSM Full Rate is encoded using 13 bits (it is the precision of LPC encoder).

Total bits per frame = 160 sample × 13 bits/sample
= 2080 bits.

(4) A/D conversion rate = 8000 × 13 = 104kbps.

Analog voice (from microphone of telephone) → $\boxed{\text{RPE-LPC Encoder}}$ → 20ms blocks of 260bit at a bit rate 13kHz.

(used vocal characteristic and previous samples to encode the waveform)

160 sample/20ms from A/D (2080 bits) → RPE-LTP Speech encoder → 36 LPC bits/20ms, 9 LTP bits/5ms, 47 RPE bits/5ms } 260 bits/20ms to channel encoder

LPC → Linear prediction coding filter.

LTP → long term prediction - pitch + input

RPE → Residual Prediction Error.

① 36 bits/20ms,

② 9 bits/5ms so, $\frac{9 \times 20ms}{5ms} = 36$ bit/20ms.

③ 47 bits/5ms so, $\frac{47 \times 20ms}{5ms} = 188$ bits/20ms.

Total = (36 + 36 + 188) bits/20ms.

= 260 bits/20ms.

$= \frac{260}{20}$

= 13kbps.

Uncompressed data rate = 104 kbps., bit = 2080

Compressed data rate = 13kbps. bit = 260

Channel Coding.

Error reduce করার জন্য কিছু extra-bit use করা হয়
Suppose some redundant bit for error detection.
So এই extra-redundant bit add করতে channel coding use হয় কারণ ও কিছু process follow করে → Like ↓

→ 260 bit কে 3 ভাগে ভাগ করে।

→ Class Ia : 50 bit → most sensitive to bit errors
error হওয়া chance বেশি।

→ Class Ib : 132 bit → moderately.

→ Class II : 78 bit → least sensitive

The different classes codded differently.

→ 50 bits protected by → 3 bit Cycle Redundant check (CRC) error detection code.

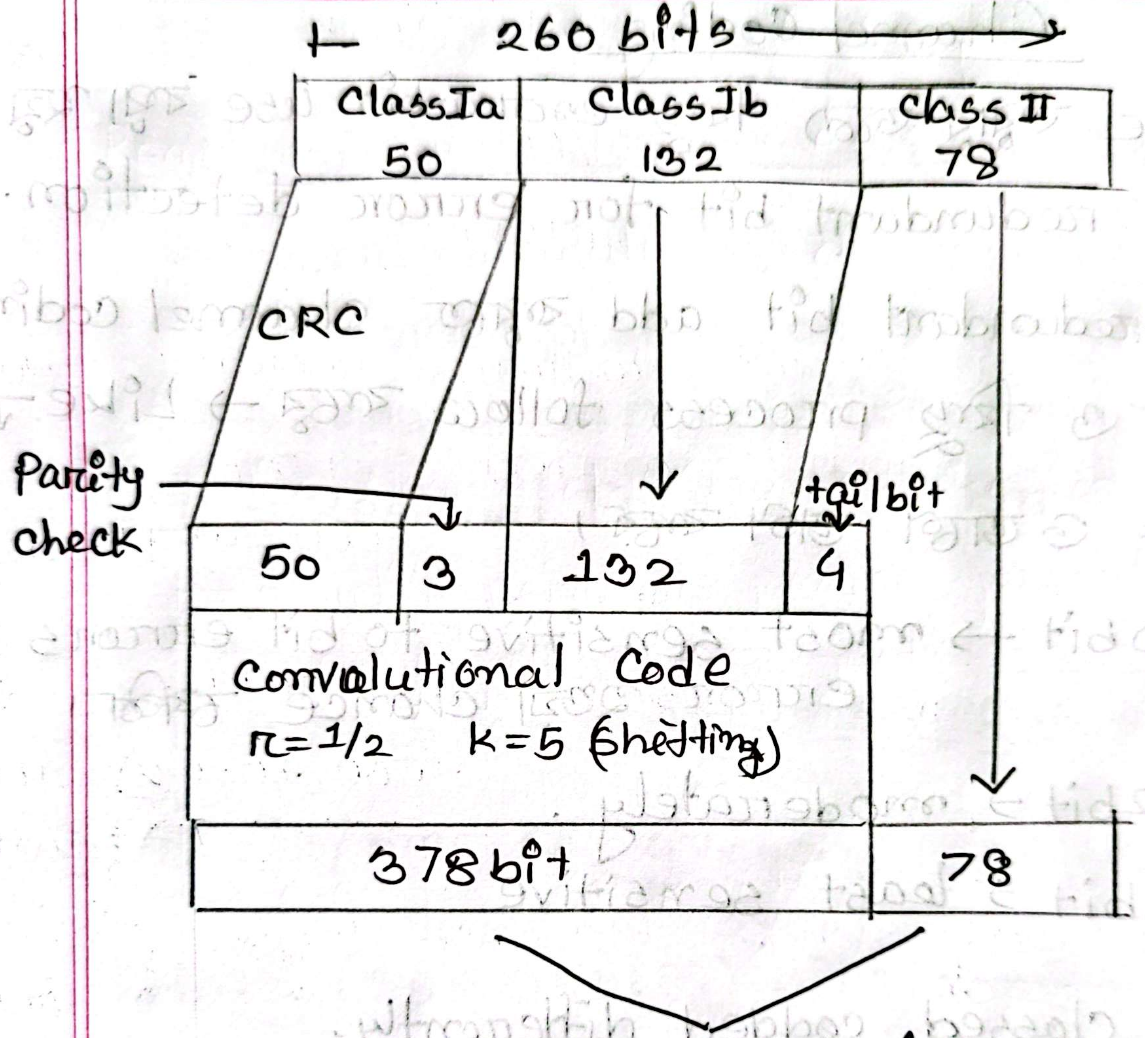
$(50+3)=53$

→ $53 + 132 +$ 4-bit tail sequence $= 189$ protected by convolutional (2, 1, 5) error Correcting code

output ↓ 2, input ↑ 1, → shift (right or left) 5

$(189 \times 2) = 378$ bits.

→ 78 bit → unprotected



456 bit in 20ms

= 22.8 kbps.

Interleaving

57+57 = 114bit গুলোর position ~~process~~ কিভাবে select করে further protectionর জন্য সেটা explain করে।

From slide.

GPRS (General Packet Radio Service)

$3\times4 = 12$

USF → uplink Status Flag (3bit) $2^3 = 8$ combination

8 user-কে allocate করা যায়।

CS1 → USF 3bit → Block code + tail bit → Convolutional 1/2 → interleaving → modulation.

CS2 CS3 → USF 3bit → USF 3bit → Blockcode + tailbit → convolutional 1/2 → Puncturing → interleave → m

CS4 → USF 3bit → USF pre-coding → blockcode → interleaving → Mode..

GPRS codding scheme

	Duration of radio block	Net number of bits	Precoded USF	BCS	Tail bit	Number of coded bits	Puncturing	Net data rate
CS1	20ms	181	3	40	4	456	0	$\frac{181}{20ms}$ 9.05 kbps
CS2	20ms	268	6	16	4	588	132	$\frac{268}{20ms}$ = 13.4 kbps
CS3	20ms	312	6	16	4	676	220	15.6 kbps
CS4	20ms	428	12	16	0	456	0	21.4 kbps