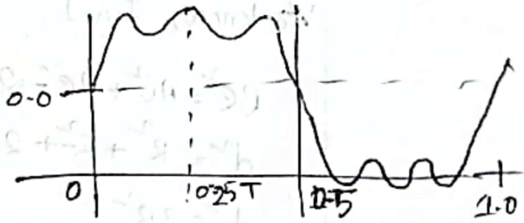
Spring-2023 (Decipher)

2

a) Here, positive pulse : 0
negative pulse : 1

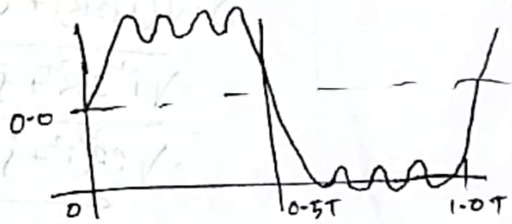
Data rate = 2f bps
Duration of each pulse = $1/2f$

Case-1:



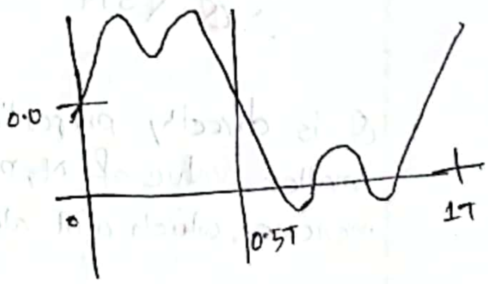
Let, $f = 10^6$ cycle/sec = 1 MHz
frequency components = 1f, 3f, 5f
Bandwidth = 5f − f = 4f = 4×1 MHz = 4 MHz
Time period, $T = \frac{1}{10^6} = 10^{-6} = 1\ \mu s$
Duration of each pulse = $\frac{1}{2\times10^6}$ [2 because 1 bit occurs at every $0.5\ \mu s$]
Data Rate = 2×1 = 2 mbps

Case-2: (Frequency increased)



Let, $f = 2\times10^6$ cycle/sec = 2 MHz
frequency component = 1f, 3f, 5f
Bandwidth = 5f − f = 4f = 4×2 = 8 MHz
Time period, $T = \frac{1}{2\times10^6} = 0.5\ \mu$
Duration of each pulse = $\frac{1}{2\times2\times10^6}$ [4 because 1 bit occurs at every $0.25\ \mu s$]
Data Rate = 2f = 2×2 = 4 mbps

Case-3: (Frequency component decreased)



Let, $f = 2\times10^6$ cycle/sec = 2 MHz
frequency component = 1f, 3f
Bandwidth = 3f − f = 2f = 2×2 = 4 MHz
Time period, $T = \frac{1}{f} = \frac{1}{2\times10^6} = 0.5\ \mu s$
Duration of each pulse = $\frac{1}{2\times2\times10^6}$
Data Rate = 2f = $2\times2\times10^6$ = 4 mbps

From Case 1 and 2:
- Bandwidth increases
  data rate increases
  same signal quality

From 1 and 3:
- Same bandwidth
  data rate decreases
  signal quality increases

From 2 and 3:
- Same data rate
  Bandwidth increase
  higher signal quality.

b)

For same size of cells and same power transmitted from Base station

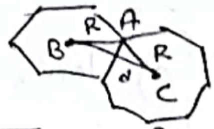


fig: I

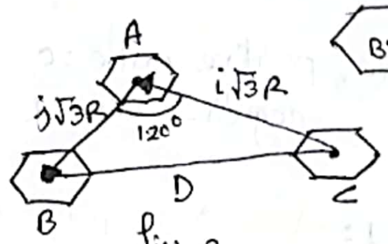


fig:-2

We know, fig-1

$$BC^2 = AB^2 + AC^2 - 2.AB.AC.\cos(120^0)$$

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

$$d^2 = 3R^2$$

$$d = \sqrt{3}R$$

Now, fig-2

$$D = \sqrt{(i\sqrt{3}R)^2 + (j\sqrt{3}R)^2 - 2.(i\sqrt{3}R).(j\sqrt{3}R).\cos(120^0)}$$

$$= \sqrt{i^2 3R^2 + j^2 3R^2 - 2.i\sqrt{3}R.j\sqrt{3}R.\left(-\frac{1}{2}\right)}$$

$$= \sqrt{3R^2(i^2 + j^2 + ij)}$$

$$= R\sqrt{3N}$$

$$\therefore D = R\sqrt{3N}$$

D = minimum distance between the centre of co-channel cells.

R = Radius of the cell

d = distance between centers of adjacent cells.

N = number of cells, where $N = i^2 + ij + j^2$

$Q = \frac{D}{R}$; co-channel reuse ratio

We know,

$$Q = \frac{D}{R} = \frac{R\sqrt{3N}}{R}$$

$$\therefore Q = \sqrt{3N}.$$

Q is directly proportional to $\sqrt{N}$. A smaller value of Q means a smaller value of N, means reuse will be more and the capacity will increase, which will also generate higher co-channel interference.

$Q\downarrow$ $N\downarrow$ capacity$\uparrow$ CCI$\uparrow$

c) Without Sectoring

Here, $N = 7$
$n = 4$
$i_0 = 6$ (hexa)

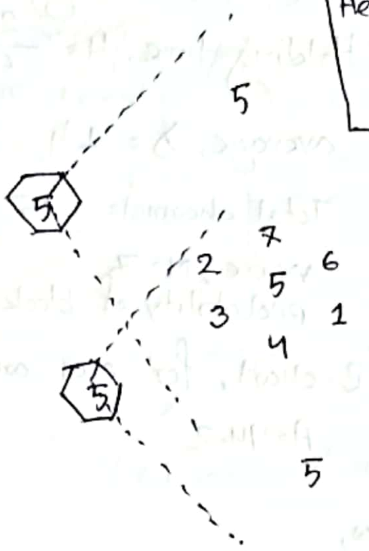
We know,

$$SIR = \frac{(\sqrt{3N})^n}{i_0} = \frac{(\sqrt{3 \times 7})^4}{6}$$

$$= 73.5$$

$$= 10 \log(73.5)$$

$$= 18.66 \text{ dB}$$



With sectoring

$$SIR = \frac{(\sqrt{3N})^n}{i_0} = \frac{(\sqrt{3 \times 7})^4}{2}$$

$$= 220.5$$

$$= 10 \log(220.5)$$

$$= 23.45 \text{ dB}$$

For 120°;
- 3 sectors.
- number of affected clusters $= 2 = i_0$

∴ SIR increases with sectoring.
For 120° sectoring 3 antennas are used, as SIR is increased, other co-channel cannot affect their signal.
∴ CCI is low.

Our accepted SIR value is 18.66 dB, so, with sectoring we need to decrease the N to acheive the SIR value.

For $N = 4$ $(i = 2, j = 0)$

$$SIR = \frac{(\sqrt{3 \times} \;)^4}{2} = 72 = 18.57 \text{ dB}$$

So, N ↓
∴ capacity increases.
∴ Q or reuse ratio decreases

Assume, (without sectoring)

Holding time, $H = \frac{2\,min}{60} = \frac{1}{30}$ hour

average, $\lambda = 1$ h

Total channel: 395

reuse, $N = 7$

probability of blocking = 0.01

$\therefore$ channel per cell: $\frac{395}{7} \approx 57$

From B-chart, for 0.01 and 57;

$A = 44.2$

We know,

$A = U A_u$

$U = \frac{A}{A_u} = \frac{44.2}{0.03333}$

$= 1326$

Here, $A_u = \lambda H$

$= 1 \times \frac{1}{30}$

$= 0.03333$

A_u = Traffic intensity per user
U = Total no. of user supported per cell
A = Traffic intensity per cell

With sectoring

For 120° sector;

3 sectors.

$\therefore$ number of channel per sector $= \frac{57}{3} = 19$

For B-chart for 0.01 and 19;

$A = 11.2$

$\therefore U = \frac{11.2}{0.03333}$

$= 336$

$\therefore$ for 3 sectors = $(336 \times 3) = 1008$

Efficiency = $\left(\frac{1326 - 1008}{1326}\right) \times 100 = 24\%$

$\therefore$ sectoring decreases trunking efficiency.

d)

GSM Frame structure for transmission

3	57	1	26	57	1	3	8.25
trail bits	Encrypted bits	Stealing bits	training bits	Encrypted bits	Stealing bits	trail bits	Guard bits

Here 1 Slot
8 fields

The system sends = 216.66 frame/sec

Frame duration: $\frac{1}{216.66} = 4.61 ms$

Each slot duration: $\frac{4.61}{8} = 0.57625 ms$

Each slot contain 8 fields

Total traffic bits: 57+57 = 114 bits (65 digitized voice)
49 bits for error detection

Total control bits: 3+1+26+1+3+8.25 = 42.25 bits
Slot width = 114+42.25 = 156.25 bits
Frame width = 156.25 × 8 = 1250 bits/frame

Total transmission rate = 1250 bits/frame × 216.66 frame/sec = 270825 bps
= 270.825 kbps

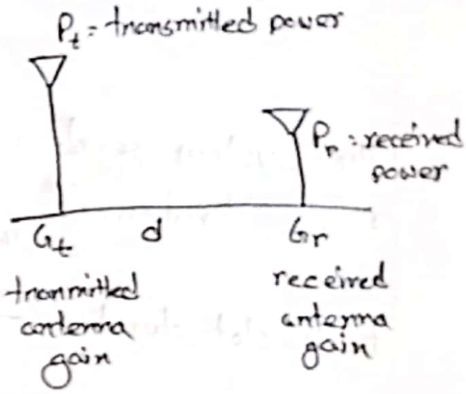
(Ans)

GSM transmission: each voice channel is digitized and compressed to 13 kbps each slot carries 156.25 bits. Each slots here share a frame (TDMA). Each 270.8 kbps digital channel modulates a carrier using GMSK and results 200 kHz analog signal. Finally 124 analog channel of 200 kHz are combined using FDMA and results in 25 MHz band.

d)

e) Free Space loss: refers to naturally weakening of a signal as it travels through free space, without any obstacles, interfence affecting it. This happens because the signal energy spreads out over a larger area as it moves further from the source.

According to Friis Free Space Equation;



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

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2 G_t G_r} \quad \text{---} (\mathrm{i})$$

According Antenna Gain formula:

$$G = \frac{4\pi A_e}{\lambda^2} \quad \text{---} (\mathrm{ii})$$

Putting (ii) in (i);

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

$$\frac{P_t}{P_r} = \frac{\lambda^2 d^2}{A_t A_r}$$

Free space loss: $L_{DB} = 10 \log \left(\frac{P_t}{P_r}\right)$

$$\therefore L_{DB} = 10 \log \left(\frac{\lambda^2 d^2}{A_t A_r}\right)$$

$$= 10 \log (\lambda^2 d^2) - 10 \log (A_t A_r)$$

$$= 10 \log (\lambda^2) + 10 \log (d)^2 - 10 \log (A_t) - 10 \log (A_r)$$

$$= 10 \log \left(\frac{c^2}{f^2}\right) + 10 \log (d)^2 - 10 \log (A_t) - 10 \log (A_r)$$

$$= 10 \log ((3\times10^8)^2) - 10 \log (f)^2 + 10 \log (d)^2 - 10 \log (A_t) - 10 \log (A_r)$$

$$= 169.54\,dB - 20 \log (f) + 20 \log (d) - 10 \log (A_t A_r)$$ (Ans)

Lecture-11

Prove:

f) ① Compute E_{TOT}:

For Geometric calculation, we take Electric field (E-field)

Let, E_0 = Free space E-field (V/m) at a distance d_0, propagating Free space E-field at distance $d > d_0$ is given by;

$$E(d,t) = \frac{E_0 d_0}{d} \cos\left(\omega \left(t - \frac{d}{c}\right)\right) \text{ --- ①}$$

With the help of ①;

$$E_{LOS}(d', t) = \frac{E_0 d_0}{d'} \cos\left(\omega \left(t - \frac{d'}{c}\right)\right) \text{ - ⑪}$$

$$E_g(d'', t) = \frac{E_0 d_0}{d''} \cos\left(\omega \left(t - \frac{d''}{c}\right)\right) \text{ --- ⑪⑪}$$

Here,

E_{TOT} = Total Received E-field

E_{LOS} = Direct LOS component

E_g = Ground reflected component

h_t = Height of the Transmitter (T_x)

h_r = " " " Receiver (R_x)

d = distance between T_x and R_x

d' = distance of LOS

d'' = " " reflected wave

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

(-1) = Reflection coef co-efficient

Now,

We know,

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

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

Assume, for $t = \frac{d''}{c}$

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

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

If d becomes very large, $d'' = d' = d$

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

Using phasor diagram;

$$E_{TOT}(d) = \sqrt{\left(\frac{E_o d_o}{d}\right)^2 (\cos\theta_\Delta - 1)^2 + \left(\frac{E_o d_o}{d}\right)^2 \sin^2\theta_\Delta}$$

$$= \frac{E_o d_o}{d}\sqrt{2 - 2\cos\theta_\Delta}$$

$$= 2 \cdot \frac{E_o d_o}{d} \sin\left(\frac{\theta_\Delta}{2}\right)$$

$$= 2\,\frac{E_o d_o}{d}\left(\frac{\theta_\Delta}{2}\right) \quad \text{--- (IV)}$$

(2) Compute Path difference, Phase difference and Time delay

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

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

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

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

Path $= \dfrac{2h_t h_r}{d}$

Phase, $\theta_\Delta = \omega \tau_d = 2\pi f \dfrac{\Delta}{c} = 2\pi f \dfrac{\Delta}{\lambda f} = \dfrac{2\pi\Delta}{\lambda}$

Time delay, $\tau_d = \dfrac{\Delta}{c} = \dfrac{\theta_\Delta \lambda}{2\pi \cdot f\lambda} = \dfrac{\theta_\Delta}{2\pi f}$

③ Compute received Power

From (iv)

$$E_{TOT}(d) = 2\frac{E_0 d_0}{d}\left(\frac{\theta_\Delta}{2}\right) = \frac{2E_0 d_0}{d} \times \frac{2\pi\, 2h_t h_r}{2\pi d}$$

$$= \frac{4\pi E_0 d_0 h_t h_r}{\lambda d^2}$$

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

$$P_r(d) = \frac{(4\pi)^2 E_0^2 d_0^2 h_t^2 h_r^2}{\lambda^2 d^4} = \frac{(4\pi)^2 P_0 d_0^2 h_t^2 h_r^2}{\lambda^2 d^4} \quad [P_0 \propto E_0^2]$$

--- (v)

Free Space Loss for LOS;

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

$$P_0 = P_r;\quad P_0 = P_t G_t G_r \frac{\lambda^2}{(4\pi d_0)^2}$$

From (v),

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

$$= P_t G_t G_r \frac{h_t^2 h_r^2}{d^4}$$

$$P_r \propto \frac{1}{d^4}$$

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

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

3) a)

i) Area $= \frac{\sqrt{3} \cdot 3}{2} \times R^2 \times N$

$= \frac{3\sqrt{3}}{2} \times (1.6)^2 \times 32$

$= 212.83 \text{ km}^2$

ii) Total bandwidth = 33 MHz

Channel bandwidth $= 25 \times 2$ KHz

$= 50$ KHz

Total available channel $= \frac{33000}{50} = 660$ channel

$\therefore S = 660$

$S = KN$; $N = 12$

$K = \frac{S}{N} = \frac{660}{12} = 55$

iii) $S = KN$

$= 55 \times 32$

$= 1760$ channels

iv) 1 MHz for control channel.

1 MHz = 1000 KHz

$\therefore$ Available Control channel $= \frac{1000}{50}$

$= 20$

$\therefore$ Available traffic channel $= 660 - 20 = 640$

So, Control channel per cell $= \frac{20}{12} \approx 2$

Traffic channel per cell $= \frac{640}{12} \approx 54$

b) System-A

Probability of blocking $= 2\% = 0.02$

Holding time $= \frac{3}{60} = \frac{1}{20}$ hr

Average, $\lambda = 2$

channel per cell $= 19$

Total cell $= 394$

From Graph,

$A = 12.5$

We know,

$$A_u = \lambda H = 2 \times \frac{1}{20} = \frac{1}{10} = 0.1 \text{ Erlangs}$$

$$U = \frac{A}{A_u} = \frac{12.5}{0.1} = 125 \text{ user per cell}$$

$\therefore$ total user supported by System A $= (125 \times 394)$
$= 49250$

System-B

channel per cell $=$ ~~98~~ 57

total cell $= 98$

From Graph, $A = 47$

$$U = \frac{47}{0.1} = 470 \text{ user per cell}$$

$\therefore$ total user supported by System B $= (470 \times 98)$
$= 46060$

System-C

channel per cell $= 100$

total cell $= 49$

From Graph, $A = 88$

$$U = \frac{88}{0.1} = 880$$

$\therefore$ total user by system C $= (880 \times 49)$
$= 43120$

total user supported by 3 systems.

$= (49250 + 46060 + 43120) = 138430$

Market penetration for system A;

$$\frac{49250}{2000000} = 0.024 = 2.46\%$$

System B;

$$\frac{46060}{2000000} = 2.303\%$$

System C;

$$\frac{43120}{2000000} = 2.156\%$$

Combined 3 system;

$$\frac{138430}{2000000} = 6.92\%$$

(Ans.)

3(c) use the process of 2(c)

e) (i) Gain for parabolic antenna, $G = \frac{7A}{\lambda^2}$

$$= \frac{7Af^2}{c^2}$$

$$= \frac{7 \times \pi \times (0.6)^2 \times (2\times10^9)^2}{(3\times10^8)^2}$$

$$= 351.85$$

$$Gain_{dB} = 25.46 \text{ dB}$$

(ii) Effective area $= 0.56A$

$$= 0.56\,(\pi \times (0.6)^2)$$

$$= 0.633 \text{ m}.$$

(iii) $\frac{P_t}{P_r} = \frac{(4\pi)^2 (d)^2}{G_r G_t \lambda^2}$; $d = 24 \text{ km} = 24\times10^3 \text{ m}$

$$= 20 \log \log(4\pi) + 20 \log(d) + 20\log(f) - 20\log(c) - 10\log(G_r) - 10\log(G_t)$$

$$= 21.48 + 87.60 + 186.02 - 169.54 - 25.46 - 25.46$$

$$= 75.14 \text{ dB}$$

The transmitted power $= 10 \log(0.1) = -10$

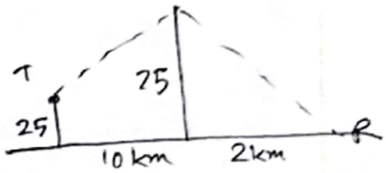
The available received signal power $= 75.14 - 10$

$$= 65.14.$$

f) a)

$f = 900$ MHz

$\therefore \lambda = \dfrac{c}{f} = \dfrac{3\times10^8}{900\times10^6} = \dfrac{1}{3}$ m



$\beta = \tan^{-1}\left(\dfrac{75\text{ m}-25}{10000}\right) = 0.2864^\circ$

$\gamma = \tan^{-1}\left(\dfrac{75}{2000}\right) = 2.1475^\circ$

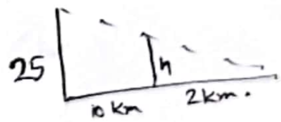
$\alpha = \beta+\gamma = 2.43^\circ = 0.0424$ rad

$v = h\sqrt{\dfrac{2\times(10000\times2000)}{1/3\times(10000+2000)}} = 4.24$

diffraction loss $= 20\log\left(\dfrac{0.225}{4.24}\right) = -25.50$ dB

b) For 6 dB ; $v = 0$

$\dfrac{h}{2000} = \dfrac{25}{10000}$



$h = 4.16$ m.