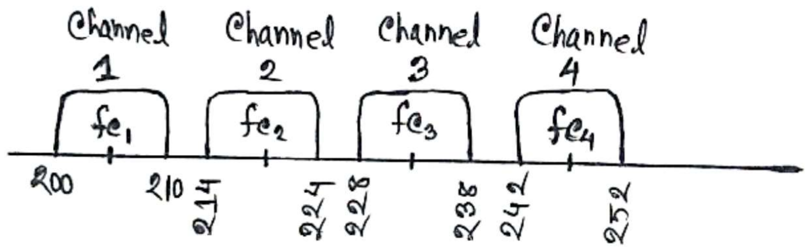
Answer to the question no. 1

(i) Given, Baseband signals bandwidth, $B_m = 5\,kHz$

$$B_{AM} = 2 \times B_m$$
$$= 10\,kHz$$

Guard band $= 4\,kHz$

Each channels spacing $= (10 + 4)\,kHz$
$= 14\,kHz$



Carrier frequency for channel 1, $f_{c_1} = \frac{200+210}{2} = 205\,kHz$

" " " channel 2, $f_{c_2} = \frac{214+224}{2} = 219\,kHz$

" " " channel 3, $f_{c_3} = \frac{228+238}{2} = 233\,kHz$

" " " channel 4, $f_{c_4} = \frac{242+252}{2} = 247\,kHz$

Ans:

(ii) Time domain equations:

Let the 4 baseband signals be $m_1(t)$, $m_2(t)$, $m_3(t)$, $m_4(t)$.

AM modulated signal for channel 1,

$$S_1(t) = [A_{c_1} + m_1(t)] \cos(2\pi \times 205 \times 10^3 \times t)$$

AM modulated signal for channel 2,

$$S_2(t) = [A_{c_2} + m_2(t)] \cos(2\pi \times 219 \times 10^3 \times t)$$

AM modulated signal for channel 3,

$$S_3(t) = [A_{c_3} + m_3(t)] \cos(2\pi \times 233 \times 10^3 \times t)$$

AM modulated signal for channel 4,

$$S_4(t) = [A_{c_4} + m_4(t)] \cos(2\pi \times 247 \times 10^3 \times t)$$

FDM multiplexed signal,

$$s(t) = S_1(t) + S_2(t) + S_3(t) + S_4(t)$$

Frequency domain description:

- Each AM signal occupies 10 kHz.
- Adjacent channel separated by 4 kHz guard band.
- Overall spectrum spans 200 - 252 kHz.

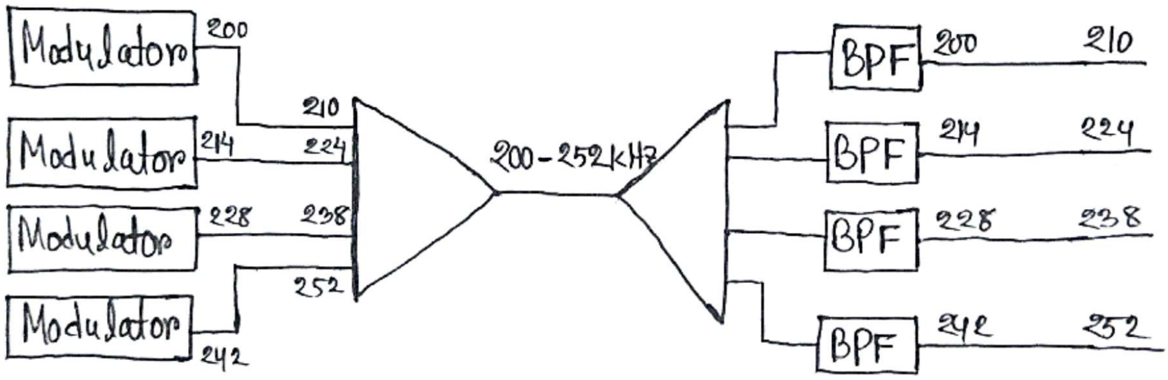
Channel - 1 $\longrightarrow$ f_{c_1} = 200 - 210 kHz

Channel - 2 $\longrightarrow$ f_{c_2} = 214 - 224 kHz

Channel - 3 $\longrightarrow$ f_{c_3} = 228 - 238 kHz

Channel - 4 $\longrightarrow$ f_{c_4} = 242 - 252 kHz

Representation:



FDM demultiplexer with AM:

For each channel,

(i) Bandpass filter (BPF) to separate the channel:

$$x_i(t) = BPF\{s_i(t)\} \approx s_i(t)$$

where $1 \leq i \leq 4$

(ii) Full AM demodulation:

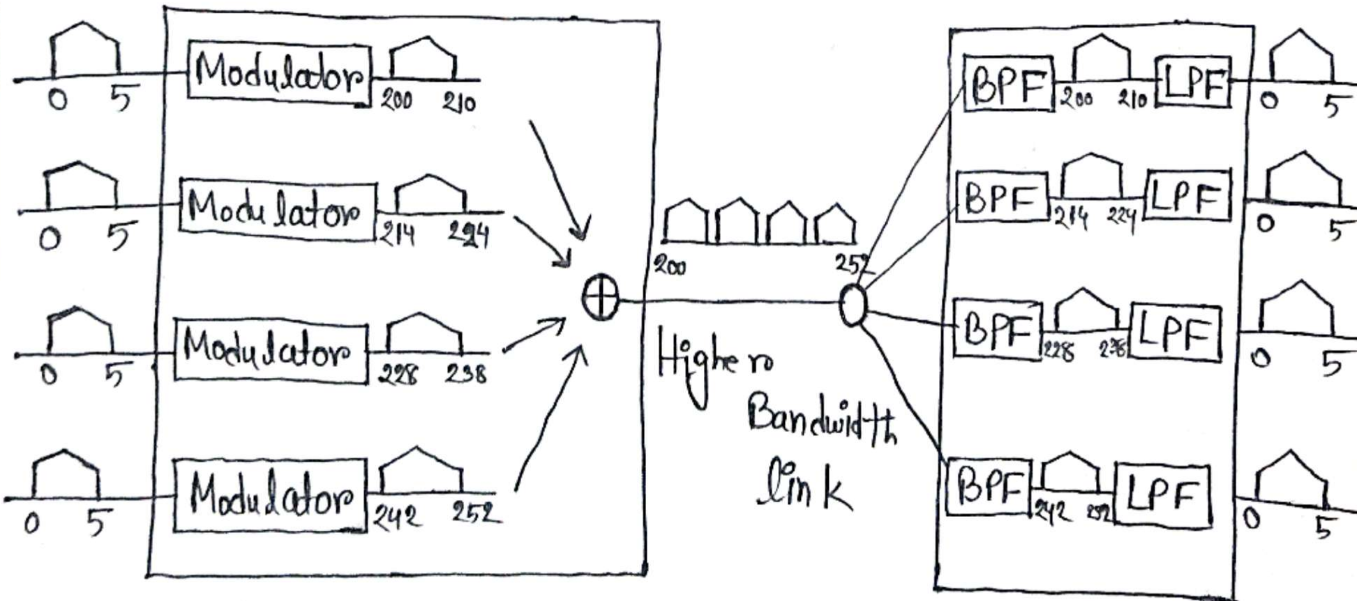
$$y_i(t) = x_i(t) \cdot 2\cos(2\pi f_{c_i} t)$$

where $1 \leq i \leq 4$

(iii) Low Pass filter (LPF) to recover the baseband:

$$m_i(t) = LPF\{y_i(t)\}$$

Illustrating,



Answer to the question no. 2

(i) Given, Uplink band = 14.25 to 14.50 GHz

Total Bandwidth = 14.50 − 14.25

= 0.25 GHz

= 250 MHz

Ground stations = 5

Guard band = 5000 kHz

= 5 MHz

Total guard band = (4×5) MHz

= 20 MHz

Usable bandwidth = (250 − 20) MHz

= 230 MHz

Bandwidth per station = $\frac{230}{5}$ MHz

= 46 MHz

(ii) We know,

Bit rate, $R_b = 2 B_w \log_2(L)$

Nyquist bit rate for BPSK $= 2 \times 46 \times \log_2(2)$

$= 92$ Mbps

" " " " QPSK $= 2 \times 46 \times \log_2(4)$

$= 184$ Mbps

" " " " 16-QAM $= 2 \times 46 \times \log_2(16)$

$= 368$ Mbps

" " " " 64-QAM $= 2 \times 46 \times \log_2(64)$

$= 552$ Mbps

(iii) We know,

$$\frac{E_b}{N_0} = 10^{\frac{dB}{10}}$$

Converting dB to linear,

$$2dB = 10^{\frac{2}{10}}$$
$$= 1.58$$

$$4dB = 10^{\frac{4}{10}}$$
$$= 2.5$$

$$6dB = 10^{\frac{6}{10}}$$
$$= 3.98$$

For BPSK:

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

$$2dB = Q\left(\sqrt{2 \times 1.58}\right)$$
$$= Q(1.77)$$
$$= 3.83 \times 10^{-2}$$

$4dB = Q\left(\sqrt{2\times 2.5}\right)$
$= Q(2.24)$
$= 1.3\times 10^{-2}$

$6dB = Q\left(\sqrt{2\times 3.98}\right)$
$= Q(2.82)$
$= 2.4\times 10^{-3}$

For QPSK:

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

$2dB = Q\left(\sqrt{2\times 1.58}\right)$
$= 3.83\times 10^{-2}$

$4dB = Q\left(\sqrt{2\times 2.5}\right)$
$= 1.3\times 10^{-2}$

$6dB = Q\left(\sqrt{2\times 3.98}\right)$
$= 2.4\times 10^{-3}$

For M-QAM:

$$P_b = \frac{4}{\log_2 M}\left(1-\frac{1}{\sqrt{M}}\right)Q\left(\sqrt{\frac{3\log_2 M}{M-1}\frac{E_b}{N_0}}\right)$$

16-QAM: $M = 16$

$$2dB = \frac{4}{\log_2(16)}\left(1-\frac{1}{\sqrt{16}}\right)Q\left(\sqrt{\frac{3\log_2(16)}{16-1}\times 1.58}\right)$$

$$= \frac{3}{4}\times Q(1.12)$$

$$= 0.09825$$

$$\cancel{4dB = \frac{4}{\log_2(16)}}$$

$$4dB = \frac{3}{4} Q\left(\sqrt{\frac{4}{5} \times 2.5}\right)$$

$$= \frac{3}{4} \times Q(1.41)$$

$$= 7.92 \times 10^{-2} \times \frac{3}{4} = 0.0594$$

$$6dB = \frac{3}{4} Q\left(\sqrt{\frac{4}{5} \times 3.98}\right)$$

$$= \frac{3}{4} \times Q(1.78)$$

$$= 0.028$$

b) <u>For 64-QAM:</u> $M = 64$

$$2dB = \frac{4}{\log_2(64)} \left(1 - \frac{1}{\sqrt{64}}\right) Q\left(\sqrt{\frac{3\log_2(64)}{64-1} \times \frac{E_b}{N_0}}\right)$$

$$= \frac{7}{12} \times Q\left(\sqrt{\frac{2}{7} \times 1.58}\right)$$

$$= \frac{7}{12} \times Q(0.67)$$

$$= 0.146$$

$$4dB = \frac{7}{12} \times Q\left(\sqrt{\frac{2}{7} \times 2.5}\right)$$

$$= \frac{7}{12} \times Q(0.85)$$

$$= 0.115$$

$$6dB = \frac{7}{12} \times Q\left(\sqrt{\frac{2}{7} \times 3.98}\right)$$

$$= \frac{7}{12} \times Q(1.06)$$

$$= 0.084$$

(iv) BPSK and QPSK both same because they use the same minimum Euclidean distance between constellation points and identical decision boundaries when expressed in terms of $\frac{E_b}{N_0}$. QPSK is essentially two orthogonal BPSK systems.

Answer to the question no. 3

(i)

For the first two channels,

Bit rate $= 50 \times 8$

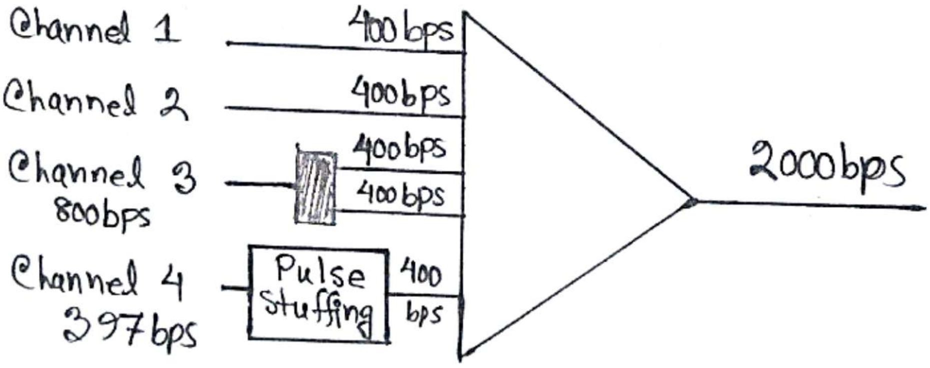
$= 400$ bps

Third channels bit rate $= 100 \times 8$

$= 800$ bps

Fourth channels bit rate $= 397$ bps

The data rate mismatch problems solution:



(ii) ~~Frame rate~~ $\cancel{= \frac{\text{frame size}}{\text{Frame}}}$

$\cancel{= \frac{5 \times 8}{8}}$

(ii) Channel 1 sends 50 bytes/sec and gets 1 byte per frame.

$\therefore$ Frame rate $= \dfrac{50 \times 8}{8}$

$= 50$ frames/sec

(iii) Frame duration, $T_f = \dfrac{1}{\text{Frame rate}}$

$= \dfrac{1}{50}$

$= 0.02$ sec

(iv) Output link bit rate $= 5 \times 8 \times$ Frame rate

$= 5 \times 8 \times 50$

$= 2000$ bps

(v) Output bit duration, $T_b = \dfrac{1}{2000}$

$= 0.5$ ms

Ans: