(a) $\frac{1+\beta}{2T} = 1\text{ MHz} \Rightarrow \boxed{T = 0.75\,\mu\text{sec}}$

symbol duration

with 1.2 msec ~~frame~~ slot $\Rightarrow$ 1600 symbols/slot

& 5 slots/frame $\Rightarrow$ 8000 symbols/frame

(b) $\text{worst case Guard Time} = \frac{RTT}{T}$ Round Trip Time

for 9 km radius, $RTT = (9\times2)\times\frac{10}{3}\,\mu\text{sec} = 60\,\mu\text{sec}$;

$\therefore$ worst case Guard Time $= 60/0.75 = \boxed{80 \text{ symbols}}$;

(c) 10% overhead and 80 Guard-slot symbols and 8-PSK,

the bit rate per slot (i.e., per user)

$= (1600 - 80 - \underbrace{160}_{10\%})$ every 1.2 msec

$\Rightarrow \frac{1360 \times \overbrace{3}^{8PSK}}{1.2\times10^{-3}} = \boxed{3.4\text{ Mbps}}$;

(d) If RF-BW increases $2\text{ MHz} \xrightarrow{\text{to}} 20\text{ MHz}$, $T' = \frac{T}{10} = 0.075\,\mu\text{sec}$

~~$\therefore$~~ $\text{worst case Guard Time} = \frac{RTT}{0.075} = 800$ symbols

and, finally with 8-PSK, the bit rate

$= \boxed{16\text{ Mbps}}$;

note: In 1st system with $W = 2\text{MHz}$ | In 2nd system with $W = 20\text{MHz}$

per-user Bit Rate $= \frac{3.4}{5} = \boxed{0.68\text{ Mbps}}$ per user | per user bit rate $= \frac{16}{50} = \boxed{0.32\text{ Mbps}}$ per user

# of users (slots)

which is lower!!

B

(e1) $MDS = -174 + 60 + 3 + 6 + 8 = \underline{\underline{-97}}$

(for $W = 2MHz$)

$P_T = 1$ watt

MDS

$$-97 = 30 - 47 - 10\log_{10}(d^2)$$

$$\Rightarrow 80 = 20\log_{10} d \Rightarrow d = 10^4 = \boxed{10{,}000\text{ m}; (10\text{ km})}$$

(e2) for $W = 20MHz$

$$MDS = -174 + 70 + 3 + 6 + 8 = \underline{\underline{-87}}$$

$$\Rightarrow 70 = 20\log_{10} d \Rightarrow d = 10^{3.5} = \boxed{3162.28\text{ m}; (3.16\text{ km})}$$

(e3) Clearly, 9km users cannot be served in the 20MHz system with $P_T = 1W$; to serve them, we require

$$-87 = P_T - 47 - 10\log_{10}(9000^2)$$

$$\Rightarrow P_T = -40 + 20\log_{10}(9000) = 39\text{ dBm}$$

$P_T = 1$ watts $\Rightarrow$ 30 dBm

39 dBm

$\boxed{P_T = 8\text{ watts}} \Leftarrow$

39.08 dBm

$\boxed{P_T = 8\text{ watts}}$

Needs 8 times more power to use $W = 20MHz$ (than $W = 2MHz$)

(a) 2 user case: $s_1(t)$ and $s_2(t)$ can be easily seperated for $\hat{j} = 0, 1, 2 \& 3$ for τ_2

(b) 3 user case: $s_1(t)$, $s_2(t)$, and $s_3(t)$ can be seperated for $\hat{j} = 0, 1, 2, 3$ for τ_2 & $\hat{j} = 0, 1, 2, 3$ for τ_3

Note: In both of the above situations, no other value of $\hat{j}$ will work for all bit modulations on the individual streams.

(c) 4 user case: $s_1(t)$, $s_2(t)$, $s_3(t)$ & $s_4(t)$ can be seperated only for $\hat{j} = 0$ for τ_1, τ_2 and τ_3. No other choice of $\hat{j}$ will work.

#3.

(a) $E[\varepsilon_{i,j}^2]$

for $i = j$: $= E[N^2] = \boxed{N^2;}$

for $i \neq j$: $= E\left[\left(c_i^{T} c_j\right)^2\right]$

$= E\left[\left(\sum_{l=1}^{N} c_l\right)^2\right]$ uncorrelated Bernoulli r.v.s. $c_l \rightarrow$ with equal priors

Since all cross-terms go to zero with uncorrelatedness

$= \sum_{l=1}^{N} E[c_l^2]$

$= \boxed{N;}$

(b) 1st user $SINR_1 = \dfrac{|\alpha_1|^2 \sigma_1^2 N^2}{\sigma_n^2}$

(c) After 2nd user is added, $SINR_1 = \dfrac{|\alpha_1|^2 \sigma_1^2 N^2}{|\alpha_2|^2 \sigma_2^2 N + \sigma_n^2}$

(d) For $\sigma_1^2 = \sigma_2^2 = 1$ and $\sigma_n^2 << 1$ and with $N = 32$ and $\alpha_1 = 10\,\alpha_2$

$\longrightarrow$

(d) contd :

$$SINR_{\#1} = \frac{|\alpha_1|^2 \cdot 1 \cdot N^2}{|\alpha_2|^2 \cdot 1 \cdot N} = 3200 \,;$$

$$SINR_{\#2} = \frac{|\alpha_2|^2 \cdot 1 \cdot N^2}{|\alpha_1|^2 \cdot 1 \cdot N} = 0.32 \,;$$

note huge difference ; (Near-far problem in DS-CDMA)

(e) For $N = 256$,

$SINR_{\#1} = 25600 \,;$ $SINR_{\#2} = 2.56 \,;$

(f) When 3rd user with $\alpha_3 = 4\alpha_2$ is added to system with $\alpha_1 = 10\alpha_2$

$SINR_{\#1} = 1505.88$

$SINR_{\#2} = 2.207$ ⟵ poor !!

$SINR_{\#3} = 40.554$

(a) $\dfrac{20.48\ MHz}{N = 1024} \Rightarrow 20\,KHz = \Delta f_{sub}$

(b) $T_{\cancel{useful}} = \dfrac{1}{\Delta f_{sub}} = 50\ \mu sec$;

$N_{cp} = \dfrac{N}{4} \Rightarrow T_{cp} = \dfrac{T_{useful}}{4} = 12.5\ \mu sec$

$\therefore T_{OFDM} = 50 + 12.5 = 62.5\ \mu sec$;

(c) # of useful subs $= 471 + 471$

$= 942$

$\Rightarrow 942 \times 2 \overset{QPSK}{=} 1884$ bits in $62.5\ \mu sec$

~~(1/2)//2017~~

$\therefore$ Bit Rate $= \dfrac{1884 \times 10^6}{62.5}$;

spectral efficiency $= \dfrac{\text{Bit Rate}}{20.48\ MHz}$

$= \dfrac{1884}{62.5 \times 20.48} = \boxed{1.4718\ \text{bit/s/Hz}}$

(d) $10 \overset{5+5}{}$ ppm $\Rightarrow \dfrac{10}{10^6} \times 20.48 \times 10^6$

$= 204.8$ sample slips / sec

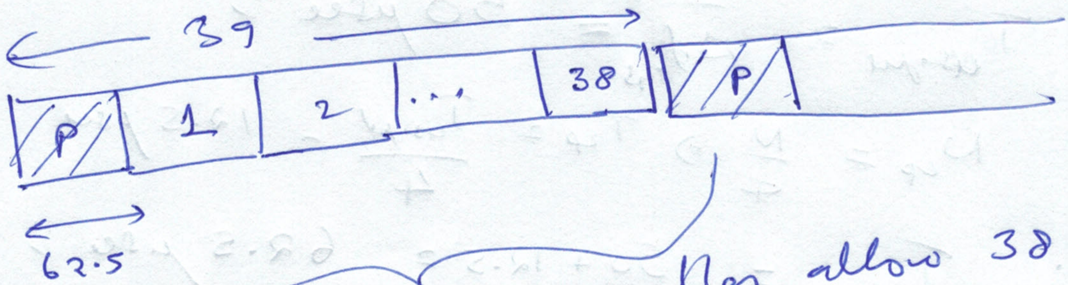
$\Rightarrow 204.8 \longleftarrow 1$ sec

$0.5 \qquad ? \Rightarrow \dfrac{0.5}{204.8}$

1/2 sample slip every $\Rightarrow$ 2.441 msec

62.5

⇒ every 39 symbols 1/2 sample shift



Between preambles, allow 38 symbols

⇒ one preamble every (frame) → 2437.5 μsec

→ 2.4375 msec

∴ frame rate = $\frac{16000}{39}$ frames/sec

(e) ——→ = $\boxed{410.256 \text{ frames/sec}}$

(f) Nett spectral efficiency.

every 9th sub pilot ⇒ $942 \times \frac{8}{9}$ ← useful subs (data)

$$\therefore \text{Nett spectral eff.} = \frac{942 \times (8/9) \times \left(\frac{38}{39}\right) \times 2}{62.5 \times 20.48}$$

preamble, QPSK

$= 1.27478$

Actual S.E → ≈ $\boxed{1.2748 \text{ bits/s/Hz}}$

$N = 1024$ $\quad \Big\| \Rightarrow \quad \Delta f_{sub} = 20\,\text{kHz}$

$\Rightarrow T_{useful} = \dfrac{1}{\Delta f_{sub}} = 50\,\mu\text{sec};$

$T_{cp} = \dfrac{T_{useful}}{8} = 6.25\,\mu\text{sec};$

(a) Rx sensitivity (minimum detectable signal strength or MDS)

for $N = 1024$ (i.e., $W = 20.48$ MHz)

$$MDS = -174 + \underbrace{73.11}_{20.48\,\text{MHz}} + \underbrace{6}_{NF} + \underbrace{8}_{\text{SNR required}}$$

$$= -86.89 \approx \boxed{-87\,\text{dBm}}$$

$$-87\,\text{dBm} = \underbrace{36}_{P_T} - 10\log_{10} d^3\Big|_{\alpha=3} - \underbrace{33}_{L_{im}}$$

$$\Rightarrow -90 = -10\log_{10} d^3 \Rightarrow \boxed{d = 1000\,\text{m}}$$

(b) with $T_{cp} = 6.25\,\mu\text{sec}$, maximum relative time-of-flight difference allowed between 2 (unranged) users can be $\dfrac{6.25}{2} = 3.125\,\mu\text{s}$

$\therefore$ Max link distance possible $= \dfrac{3.125}{3.3\,\mu\text{s}} = \boxed{947\,\text{m};}$

$947\,\text{m} < 1000\,\text{m} \Rightarrow$ No problem to support 20.48 MHz

(c) for $BW = 100$ kHz

$$MDS' = -174 + \underbrace{50}_{\text{for } 50\,\text{kHz}} + 6 + 8 = -110\,\text{dBm};$$

$\Rightarrow$ Max link distance possible $= \boxed{3687\,\text{m}}$, which is $> 947\,\text{m}$

Hence, those users above 947 m cannot be supported even if they see signal stronger than MDS'.