Çankaya University – ECE Department – ECE 376

Student Name :
Student Number :

Duration : 2 hours
Open book exam

Questions

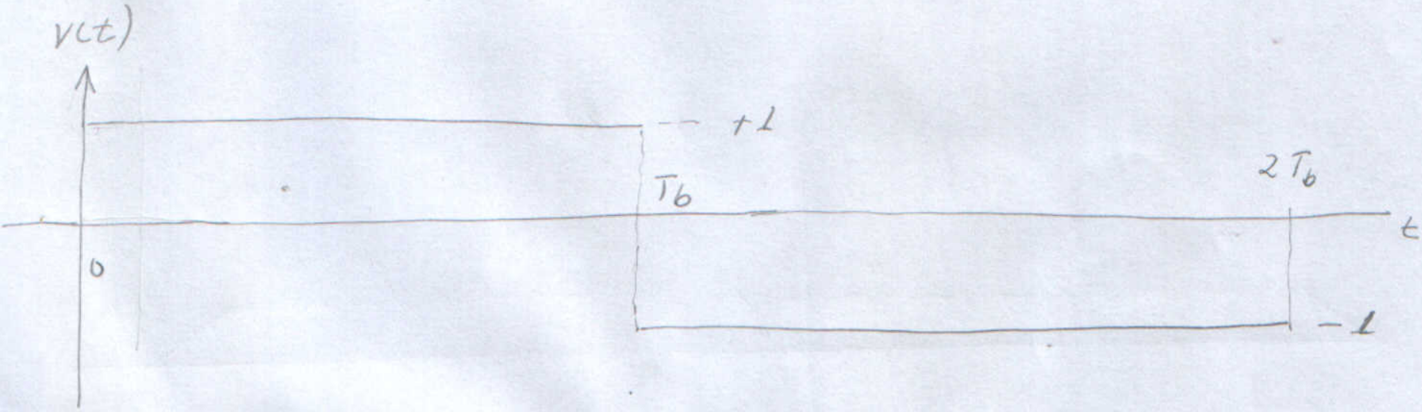
1. (35 Points) A) A message signal of $v(t) = a_0 g_T(t) + a_1 g_T(t - T_b)$, where $a_0,\ a_1 = \mp 1$, $T_b = 0.5$ msec. and $g_T(t) = \begin{cases} 1 & \text{for } 0 \le t \le T_b \\ 0 & \text{otherwise} \end{cases}$, gets multiplied by a PN sequence of $c(t) = \sum_{n=0}^{N} c_n p(t - nT_c)$, where $c_n = \mp 1$, $T_c = 0.5$ µsec. and $p(t) = \begin{cases} 1 & \text{for } 0 \le t \le T_c \\ 0 & \text{otherwise} \end{cases}$

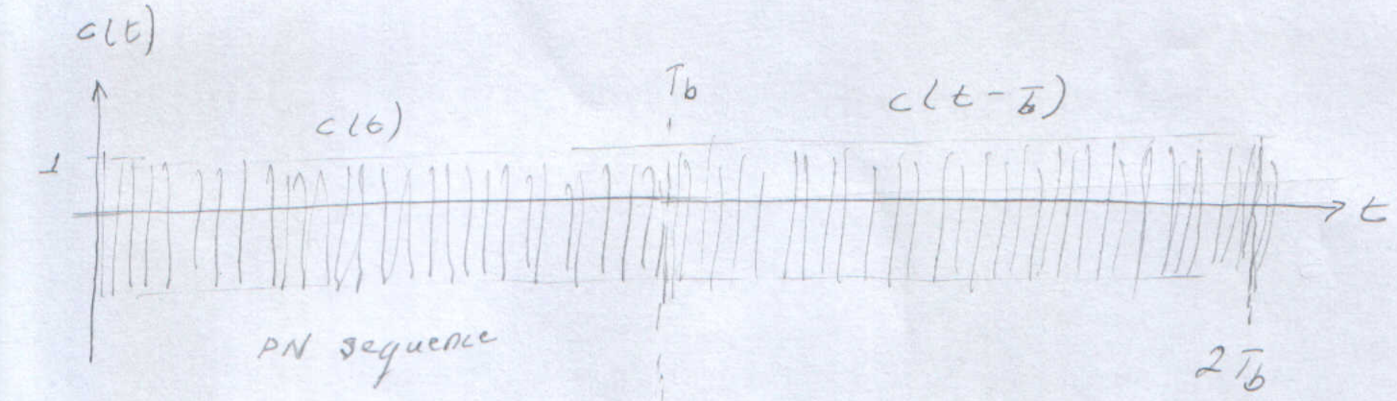
Considering one T_b duration covers the entire time duration of $c(t)$, what should be N?. For the given case, plot time waveforms and frequency spectrums, appropriately marking the numeric values on the time and propagation axes.

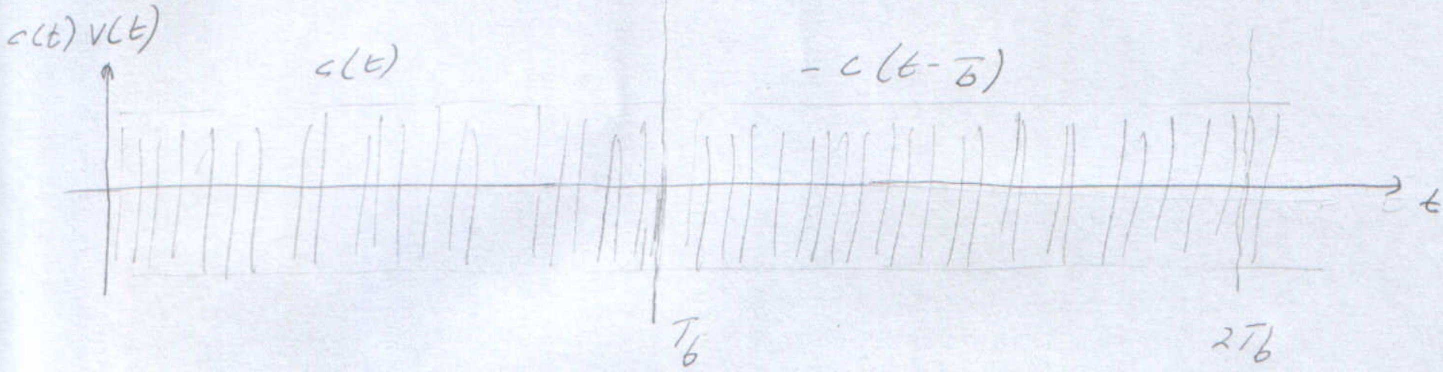
B) For a DS spread spectrum system employing five users (i.e., five different message signals), draw the transmitter and receiver block diagrams explaining the function of each block.

Solution: A) Since one T_b duration should cover one $c(t)$ then $N = \frac{T_b}{T_c} = L_c = 1000$

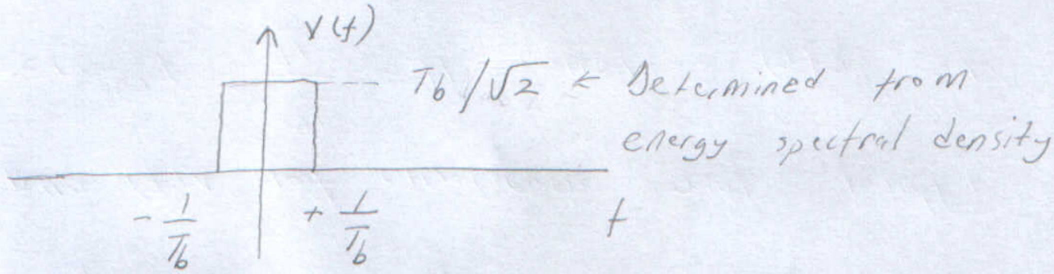
Typical time waveforms for $v(t)$ and $v(t)c(t)$ are shown below. It is assumed that $c(t)$ repeats itself within every T_b duration (set; $a_0 = +1$, $a_1 = -1$)

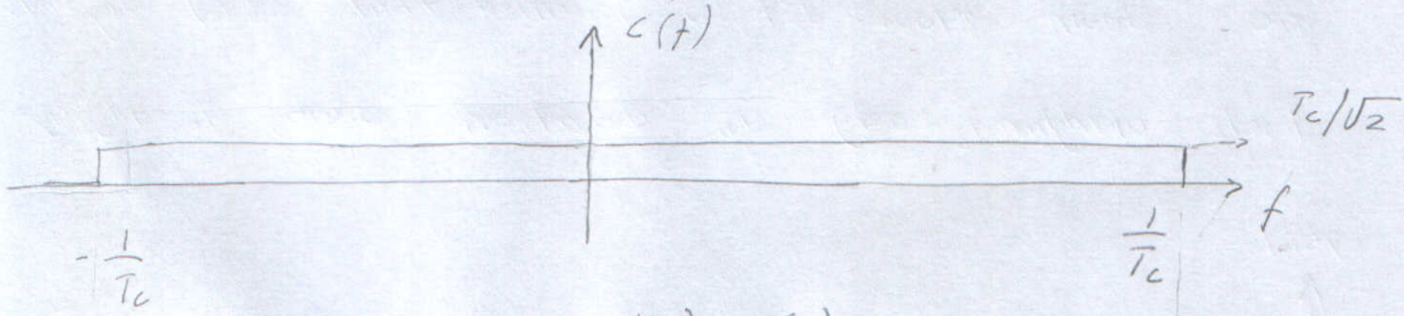


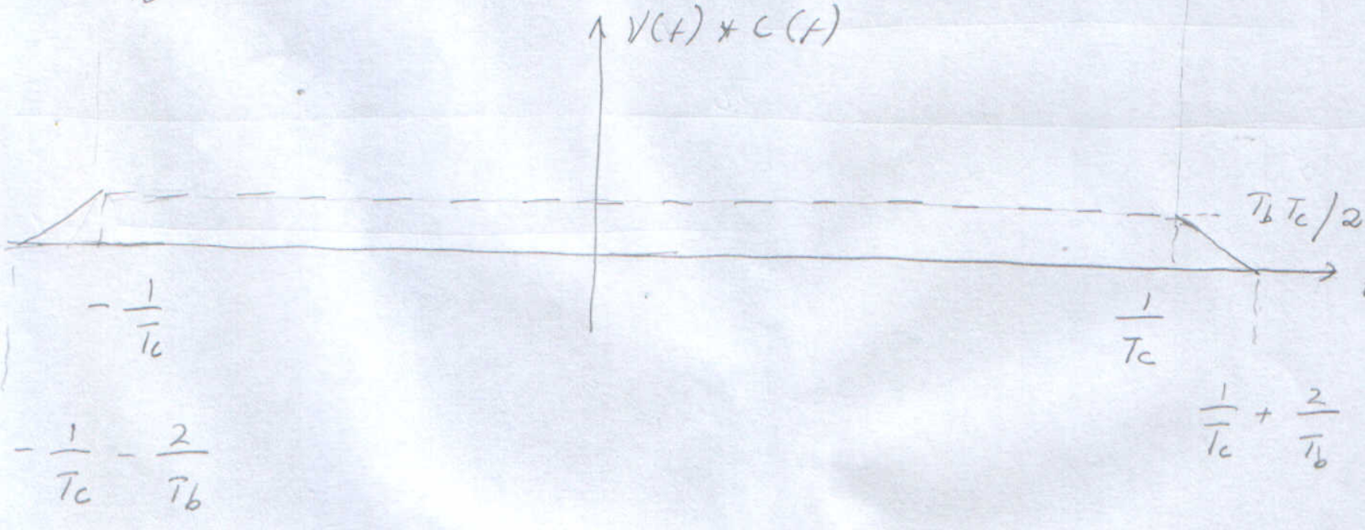




Approximate spectrums (rounded to window functions)







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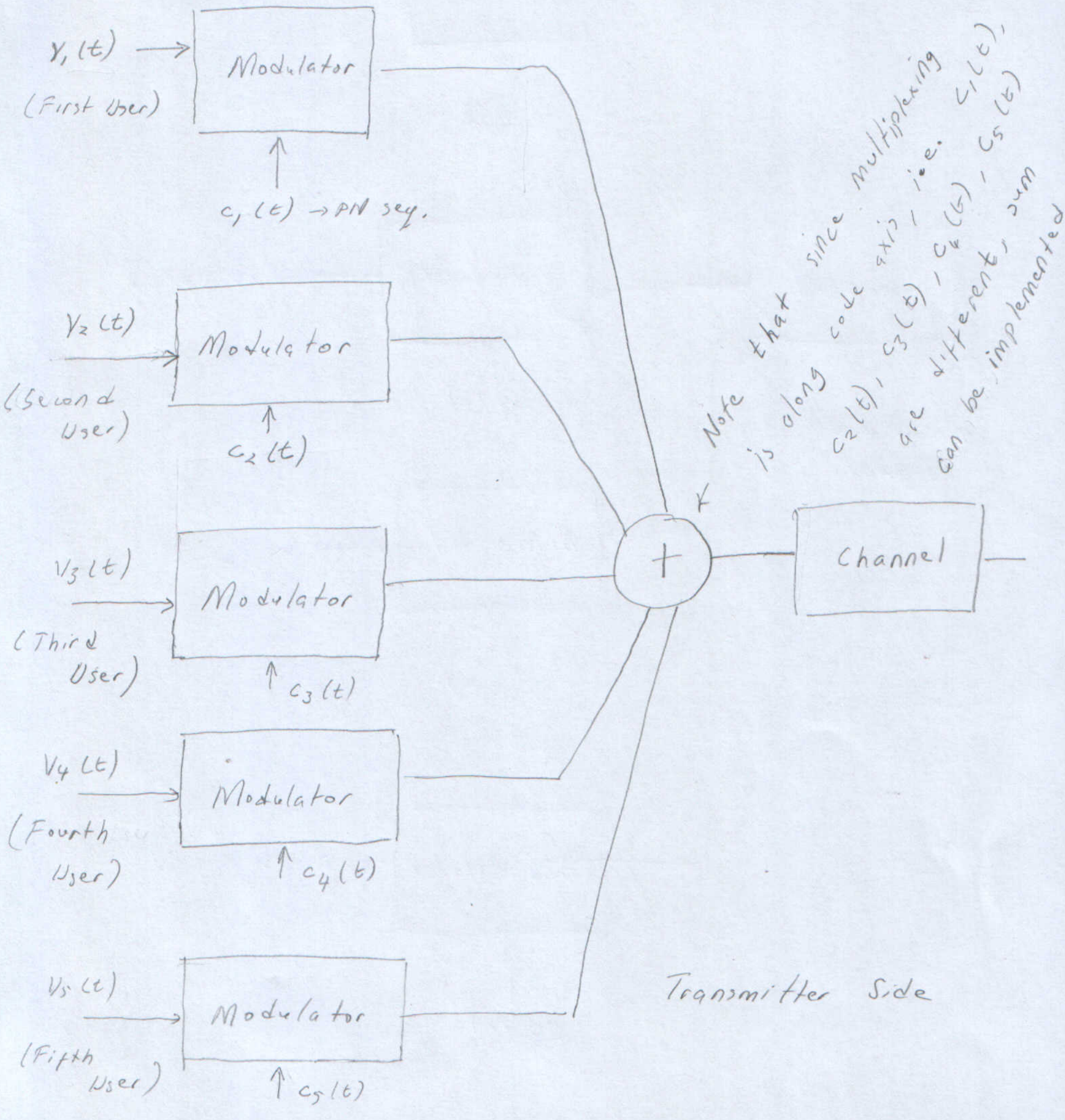
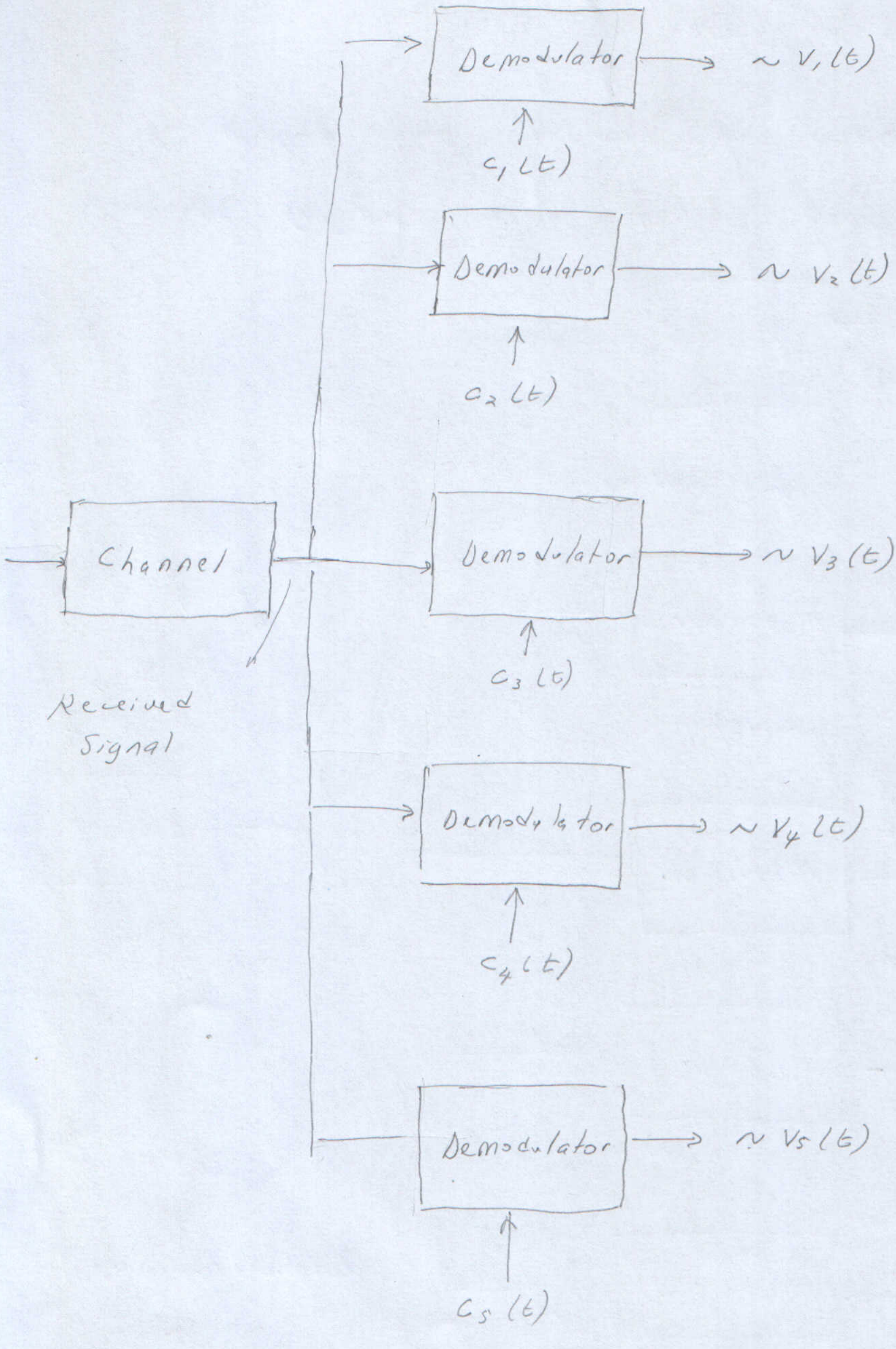
B) Below we show the block diagram of DS spread spectrum system employing five users



Receiver Side



2. (35 Points) An OFDM system with four sub-carriers is to be designed for a 4 QAM signal with a rate of 1 k symbols / sec. By choosing the appropriate sub-carries and the frequency spacing between them, show that each symbol of 4 QAM, when placed on a sub-carrier, is orthogonal to all other three symbols, if integrated over a symbol period, even if the symbols have different phase shifts. Draw and explain the functioning of block diagram of transmitter and receiver for this OFDM system.

Solution : Since symbol rate is 1 k symbols/sec

$T_s = 10^{-3}$ sec $= 1$ m sec and a symbol is placed

on the same carrier every $4T_s$, then $T = 4T_s = 4$ m sec.

So (excluding a shift of f_c), if $f_1 = 1$ kHz → 1st sub carrier

$f_k - f_1 = \frac{n}{T_s}$ where $k = 2, 3, 4$, $n = 1, 2, 3$
sub carriers

Then we find $f_2 = 2$ kHz, $f_3 = 3$ kHz, $f_4 = 4$ kHz

Note that the spacing between subcarrier can also be adjusted with T, in this case by keeping $f_1 = 1$ kHz

$f_2 = 1250$ Hz, $f_3 = 1500$ Hz, $f_4 = 1750$ Hz

Now perform the integration below

$$\int_0^{T_s} \cos(2\pi f_k t + \phi_k) \cos(2\pi f_j t + \phi_j)\, dt$$

$$= \frac{1}{4\pi(f_k - f_j)} \sin\left[2\pi(f_k - f_j)t + \phi_k - \phi_j\right]\Big|_0^{T_s} +$$

$$\frac{1}{4\pi(f_k+f_j)} \sin\left[2\pi(f_k+f_j)t + \phi_k + \phi_j\right]\Big|_0^{T_s}$$

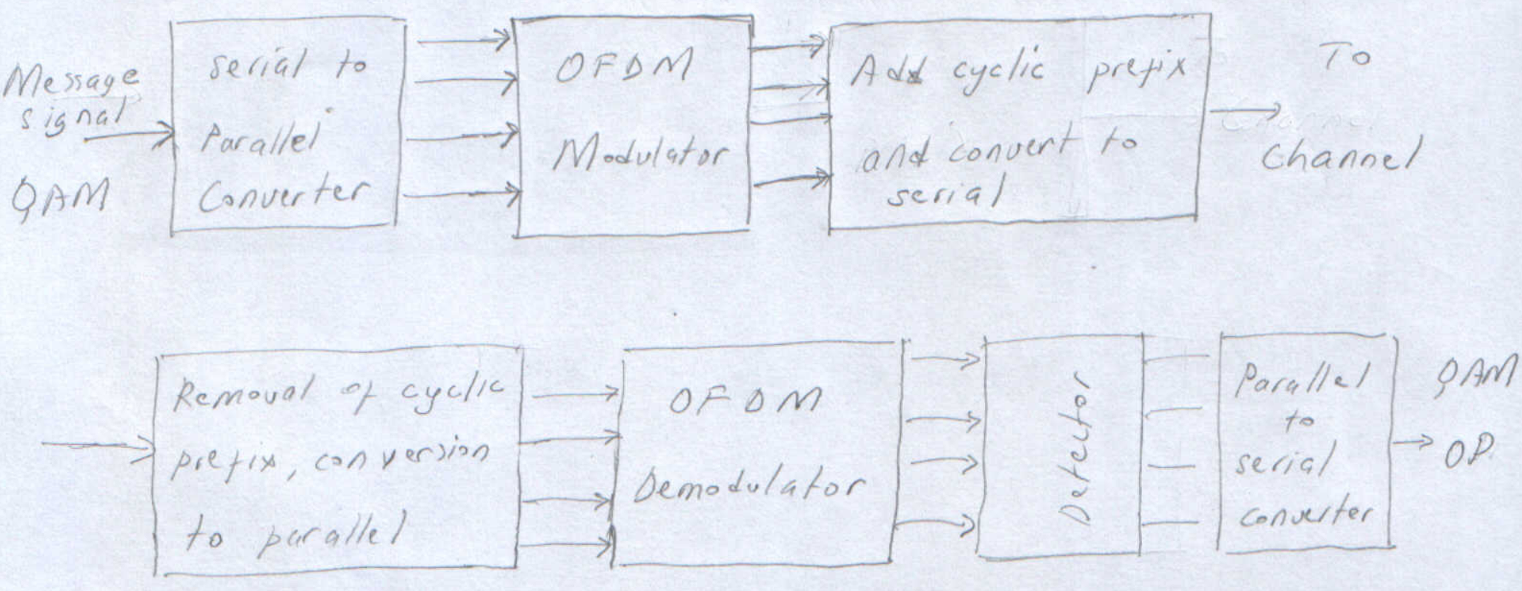
$$= \frac{1}{4\pi(f_k-f_j)} \left\{ \sin\left[2\pi(f_k-f_j)T_s + \phi_k - \phi_j\right] \right.$$

$$\left. - \sin(\phi_k - \phi_j) \right\} + \frac{1}{4\pi(f_k+f_j)} \left\{ \sin\left[2\pi(f_k+f_j)T_s + \phi_k + \phi_j\right] \right.$$

$$\left. - \sin(\phi_k + \phi_j) \right\}$$

where the first difference of sines reduces to zero since $f_k - f_j = \frac{n}{T_s}$, but for second group of sines to evaluate to zero it must be that $f_j = \frac{n}{T_s}$ or the starting $f_l = \frac{n}{T_s}$.

Block diagram of OFDM system is shown below



3. (30 Points) Answer the following questions as **True** or **False**. For the **False** ones give the correct answer or the reason. For the **True** ones, justify your answer.

a) Prob. of error in 4 QAM is higher than prob. of error in 8 PSK : If compared on equal power (or equal energy) basis, this cannot be true, since the constellation of 8 PSK is more crowded than 4 QAM.

b) In MF detection, distance metrics, $D(\mathbf{r}, \mathbf{s_m})$ calculation gives the correlation of received signal vector **r** with the axis of basis functions : False, since $D(r, s_m)$ gives the distance between the signal vector r and all signal vectors of the constellation

c) The number of dimensions in a set of signals can be determined by eye inspection :

Partiall true, but if this is not possible, then Gram-Schmidt orthogonalization procedure must formally be applied

d) FSK is a combination of QAM and PSK : False, QAM can be considered to be a combination of ASK and PSK.

e) For detection, receiver attempts to determine the constellation diagram sent by transmitter : False, the receiver already knows the constellation diagram, the receiver attemps to determine which of the signals in this constellation diagram was transmitted

f) After successful MF detection, we can say that we have completely eliminated noise from the received signal : True, if the detection is successful, then MF detector outputs a clean copy (without noise) of transmitted signal.