KLS Vishwanathrao Deshpande Institute of Technology

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

University / Model Question Paper Scheme & Solution

Faculty Name	:	Nikhil A. Kulkarni
Course Name	:	Digital Communication
Course Code	:	21EC51
Year of Question Paper	:	Dec 2023 / Jan 2024
Date of Submission	:	06/09/2024

Faculty Member

HoD

Head of the Department
Dept. of Electronic & Communication Engg.

Dean (Acad.)

Dean Academics
KLS VDIT, HALIYAL

Modified

CBCS SCHEME

USN

21EC51

Fifth Semester B.E. Degree Examination, Dec.2023/Jan.2024
Digital Communication

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Derive the expression for error probability of binary phase shift keying using coherent detection. **(08 Marks)**

b. An FSK system transmits binary data at the rate of 2×10^6 bit per sec. During the source of transmission, AWGN of zero mean and two sided power spectral density 10^{-20} W/Hz is added to the signal. The amplitude of received wave for digit 1 or 0 is 1 microvolt. Determine the average probability of symbol error assuming non-coherent detection. **(06 Marks)**

c. Explain the concept of M-ary PSK. **(06 Marks)**

OR

2 a. With a neat block diagram, explain non-coherent detection of binary FSK technique. **(08 Marks)**

b. Binary data is transmitted over AWGN channel using BPSK at a rate of 1Mbps. It is desired to have average probability of error $p_e \leq 10^{-4}$. Noise PSD = 10^{-12} W/Hz. Determine the average carrier power required at receiver input if the detector is of coherent type. [Assume erfc (3.5) = 0.00025]. **(06 Marks)**

c. Explain the generation and detection of DPSK with neat block diagram. **(06 Marks)**

Module-2

3 a. Explain the geometric representation of set of in energy signals as combination of N orthonormal basis function. Illustrate the case of N = 2 and M = 3 with necessary diagrams and expressions. **(08 Marks)**

b. Explain the correlation receiver using coherent detection. **(06 Marks)**

c. Explain the design of band limited signals with controller ISI-partial response signal. **(06 Marks)**

OR

4 a. Using Gram-Schmidt orthogonalization procedure find the set of orthonormal basis function to represent the signals $s_1(t)$, $s_2(t)$ and $s_3(t)$ as shown in Fig.Q.4(a). Also express each of these signals interms of set of basis function.

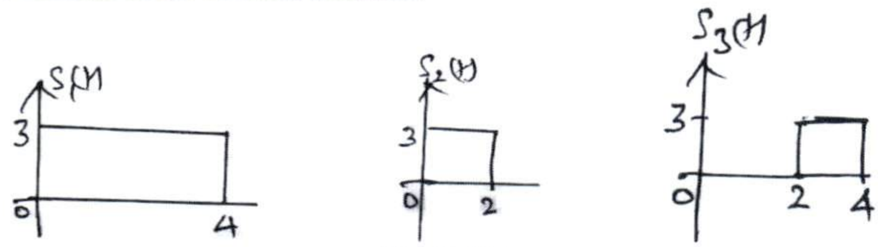


Fig.Q.4(a)

(10 Marks)

b. State and prove Nyquist condition for zero ISI. **(10 Marks)**

Module-3

5 a. Explain the model of spread spectrum digital communication system. **(10 Marks)**
b. With a neat block diagram, explain the CDMA system band on IS-95. **(10 Marks)**

OR

6 a. Explain the frequency hopped spread spectrum technique with neat transmitter and receiver block diagram. **(08 Marks)**
b. The SNR required at the detector to achieve reliable communication in a DSSS communication system is 13dB. If the interference to signal power at the receiver is 20dB. Determine the processing gain required. **(04 Marks)**
c. Write a note on application of DS spread spectrum systems. **(08 Marks)**

Module-4

7 a. Define the following with respect to information theory :
i) Self information
ii) Entropy
iii) Source efficiency
iv) Rate of information. **(08 Marks)**
b. Construct binary code for the following source using Shannon's binary encoding procedure. $s = \{s_1, s_2, s_3, s_4, s_5\}$ $p = \{0.4, 0.25, 0.15, 0.12, 0.08\}$. **(08 Marks)**
c. Explain the types of methods of controlling error. **(04 Marks)**

OR

8 a. Six messages symbols with probability of 0.4, 0.2, 0.2, 0.1, 0.07, 0.03, construct a binary code by using Shannon's Fano encoding procedure. Also determine code efficiency and redundancy. **(10 Marks)**
b. A source produces 5 symbols with probabilities of 0.1, 0.3, 0.4, 0.12 and 0.08.
i) Construct a binary Huffman code
ii) Determine efficiency and redundancy of the code
iii) Draw code-tree. **(10 Marks)**

Module-5

9 a. A (7, 4) linear block code having partly matrix $P = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$
i) Find all possible code vector
ii) Draw the encoding circuit
iii) Draw the syndrome circuit. **(10 Marks)**
b. A (3, 1, 2) convolutional code with $g^{(1)} = (110)$, $g^{(2)} = (101)$ and $g^{(3)} = (111)$.
i) Draw the encoder block diagram.
ii) Find the generator matrix.
iii) Find the code word for information sequence (11101) using transform domain approach. **(10 Marks)**

OR

10 a. For a (2, 1, 4) convolutional encoder as shown in Fig.Q.10(a). **(10 Marks)**

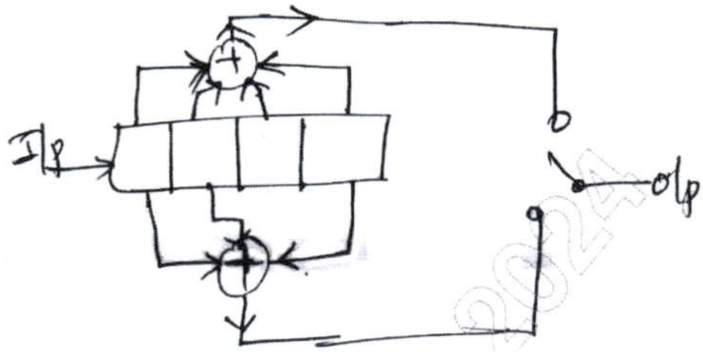


Fig.Q.10(a)

Find the codeward corresponding to the information source (10111). Using time domain and transform domain approach. **(10 Marks)**

b. A, (2, 1, 2) binary convolutional encoder as shown in Fig.Q.10(b). Draw the state table, state transition table, state diagram and corresponding code tree, for the message 10111. Find the encoded sequence.

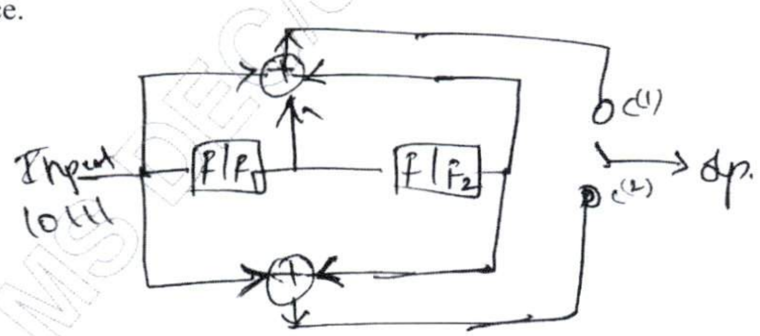


Fig.Q.10(b)

* * * * *

Q.No Module - 1

1a) Derivation of the expression for error probability of BPSK. — 8M

Soln: Let $s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t$

$s_2(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi)$

$= -\sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t$ 4M

Let $\phi(t) = \sqrt{\frac{2}{T_b}} \cos 2\pi f_c t$

$s_1(t) = \sqrt{E_b}\, \phi_1(t), \quad s_2(t) = -\sqrt{E_b}\, \phi_1(t)$

$(0 < t < T_b)$.

$s_{11} = \sqrt{E_b} \quad s_{21} = \sqrt{E_b}$

$f_{x_1}(x_1/0) = \frac{1}{\sqrt{\pi N_0}} \exp\left[-\frac{1}{N_0}(x_1 - s_{21})^2\right]$

$= \frac{1}{\sqrt{\pi N_0}} \exp\left[-\frac{1}{N_0}(x_1 + \sqrt{E_b})^2\right]$ 4M

$P_{e0} = \int_0^\infty f_{x_1}(x_1/0)\, dx_1 = \frac{1}{\sqrt{\pi N_0}} \int_0^\infty \exp\left[-\frac{1}{N_0}(x_1 + \sqrt{E_b})^2\right] dx_1$

$P_{e0} = \frac{1}{\sqrt{\pi}} \int_{\sqrt{E_b/N_0}}^{\infty} \exp(-x^2)\, dx$

$$\boxed{P_{e0} = \frac{1}{2}\, \mathrm{erfc}\sqrt{E_b/N_0}}$$

1b) Non-coherent detection of FSK — 6M

$P_e = \frac{1}{2} e^{-[E_b/2N_0]}$

$P_e = \frac{1}{2} e^{-\left[\frac{5\times10^{-13} \times \frac{1}{2\times10^6}}{2\times2\times10^{-20}}\right]}$ 2M

Given $\frac{N_0}{2} = 10^{-20} \frac{W}{Hz}$; $T_b = \frac{1}{2\times10^6}$ sec; $E_b = P \cdot T_b$ 2M

$P = \frac{A^2}{2} = \frac{(1\times10^{-6})^2}{2} = 5\times10^{-13} = 0.001$ 2M

1c) Concept of M-ary PSK – 6M

In M-ary PSK, the phase of the carrier takes on one of M-possible values

$\phi_i = 2(i-1)\frac{\pi}{M}$, where $(i = 1, 2 \dots M)$.

$\phi_1(t) = \sqrt{\frac{2}{T}} \cos 2\pi f_c t \quad (0 < t < T)$.

$S_i(t) = \sqrt{2E/T} \cos\left[2\pi f_c t + \frac{2\pi}{M}(i-1)\right]$,

$i = 1, 2 \dots M$.

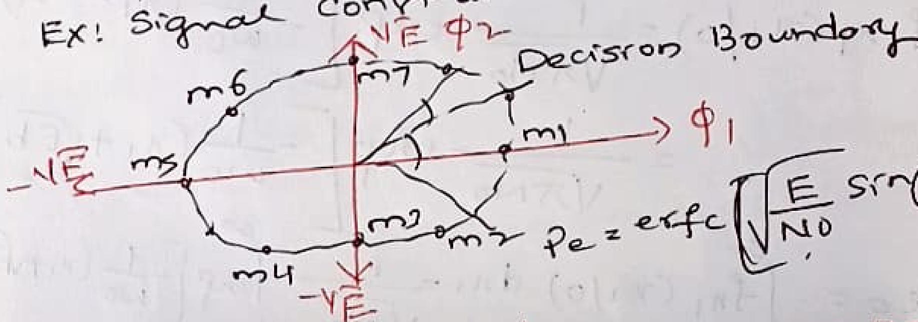
$\phi_2(t) = \sqrt{\frac{2}{T}} \sin(2\pi f_c t) \quad (0 < t < T)$

E – Energy signal, f_c = Carrier freq.

Each $S_i(t)$ is expanded by two basic function $\phi_1(t)$ & $\phi_2(t)$

function constellation diagram.

Ex: Signal constellation

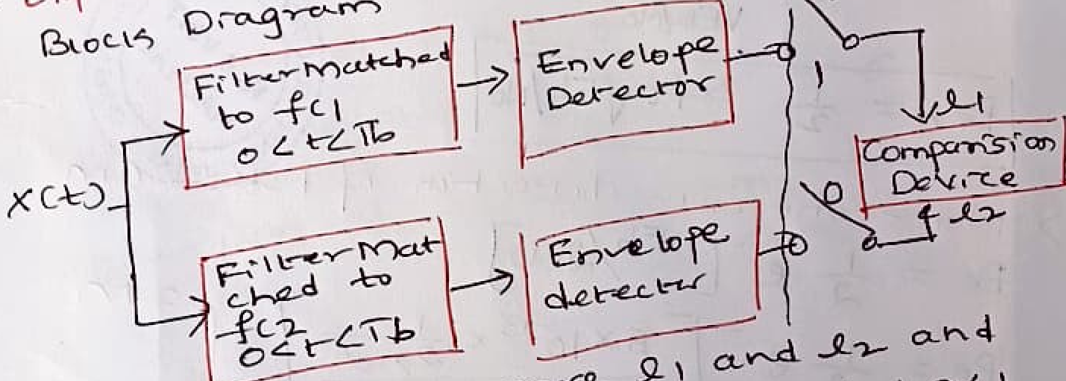


$P_e = \text{erfc}\left[\sqrt{\frac{E}{N_0}} \sin\left(\frac{\pi}{M}\right)\right]$

Module – 1

2a) Explain non-coherent detection of BFSK

Block Diagram



It is used to compare l_1 and l_2 and then it choses symbol as 1 if $l_1 > l_2$ it choses symbol as 0 else if $l_1 < l_2$

where

$$S_i(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_{c1} t), & 0 < t < T_b \rightarrow 1 \\ \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_{c2} t) & < T_b \rightarrow 0 \end{cases}$$

$P_e = \frac{1}{2} \exp\left(\frac{-E_b}{2N_0}\right)$

Q.NO Module - 1

2b $P_e = \frac{1}{2} \operatorname{erfc} \sqrt{\frac{E_b}{N_0}}$, where $E_b = P \cdot T_b$.

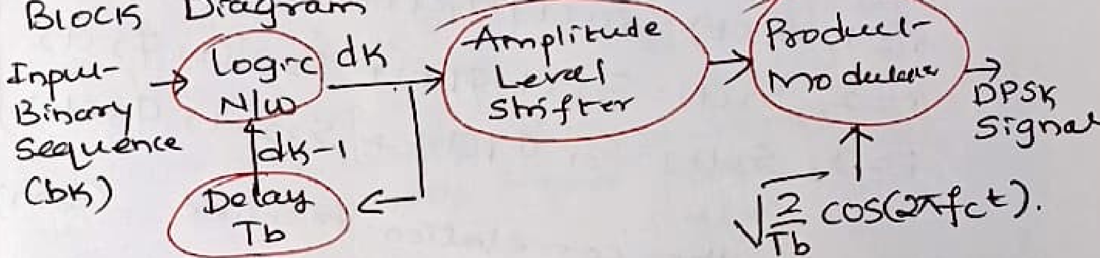
$10^{-4} = \frac{1}{2} \operatorname{erfc} \sqrt{\frac{P}{1\times10^{6} \times 2\times10^{-12}}}$

$2\times10^{-4} = \operatorname{erfc} \sqrt{\frac{P}{2\times10^{-6}}}$

$\operatorname{erfc}(\,) = \operatorname{erfc} \sqrt{\frac{P}{2\times10^{-6}}} = 2.45\times10^{-5}\,W.$

2c Generation and Detection of DPSK

Block Diagram



It takes binary i/p sequence as, let -

→ bK = 1 0 0 1 0 0 1 1 (d8 … d1)

and delay applied which gives

→ dK-1 = is the XOR value

dK-1 = 1 1 0 1 1 0 1 1

→ Differential -1 1 0 1 1 0 1 1 1

Transmitted phase 0° 0° π 0° 0° π° 0° 0° 0°

Explanation of working - 2M

Module-2

3a) Let $S_i(t) = \{S_1(t), S_2(t) \ldots S_m(t)\}$ 8M

$i = 1, 2, 3 \ldots M$ energy signal

$\phi_j(t) = \{S_1(t), S_2(t) \ldots \phi_N(t)\}$, 3M

$j = 1, 2 \ldots N$, orthobasis function.

Relation b/w energy signal and basic function

$$S_i(t) = \sum_{j=1}^{N} S_{ij}\,\phi_j(t), \text{ where } S_{ij} = \int_0^T S_i(t)\,\phi_j(t)\,dt$$ 2M

For $i = j$; $M = 3$ and $N = 2$, we get

$i = 1$, $S_1(t) = S_{11}(t)\,\phi_1(t) + S_{12}(t)\,\phi_2(t)$.

$i = 2$, $S_2(t) = S_{21}(t)\,\phi_1(t) + S_{22}(t)\,\phi_2(t)$. 3M

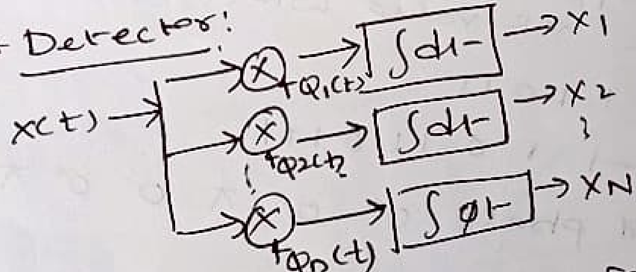
$i = 3$, $S_3(t) = S_{31}\,\phi_1(t) + S_{32}(t)\,\phi_3(t)$

3b) Explain the corelation receiver (6M)

* Corelation receiver has two subsystem

→ Detector → ML Decoder.

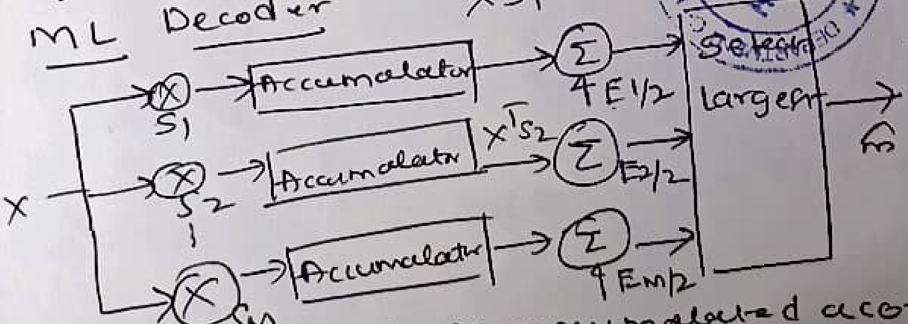
* Detector:



2M

The job of the detector is to seperate the signals based on their phase as shown above (1M)

ML Decoder



2M

The detector o/p is accumalated according to the phase and frequency of the signals then depending on the Ex/y rate is diverted to the largest selector. 1M

Module - 2

Q3c Design of Band limited Signals with ISI - partial signal — 6M

#1 $x(nT) = \begin{cases} 1, & n=0 \\ 0, & \text{otherwise} \end{cases}$ — ①

#2 $z_n = \begin{cases} T, & n = 0, -1 \\ 0, & \text{else} \end{cases}$ — ②

#3 $z(t) = \sum_{n=-\infty}^{\infty} z_n e^{j2\pi nfT}$ — ③

3M

Put ② in ① $z(t) = T + Te^{-j2\pi fT}$, where $T = 1/2W$

$\therefore X(f) = \begin{cases} 1/2W[1+e^{-j\pi f/W}] & |f|<W \\ 0 & \text{else} \end{cases}$

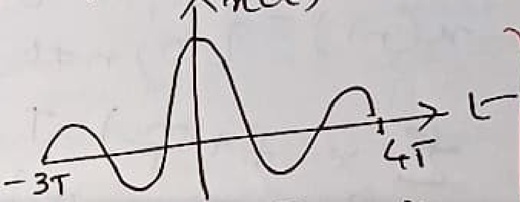
$X(f) = \begin{cases} \frac{1}{W} e^{-j\pi f/2W} \cdot \cos\left(\frac{\pi f}{2W}\right), & |f|<W \\ 0, & \text{else} \end{cases}$

$\therefore x(n) = \text{Sinc}(2Wt) + \text{sinc}(2Wt-1)$.

It is a Duobinary signal pulse

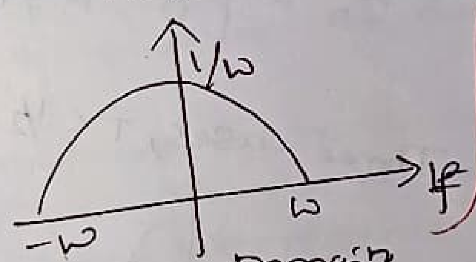
2M

Time domain →



Time Domain

Freq Domain →



Freq Domain

1M

Q4a) - 10M

$\phi_1(t) = s_1(t)/\sqrt{E_1}$ $E_1 = \int_0^4 3^2\,dt = 36$

$\phi_1(t) = \begin{cases} 1/2, & 0<t<4 \\ 0, & \text{else} \end{cases}$

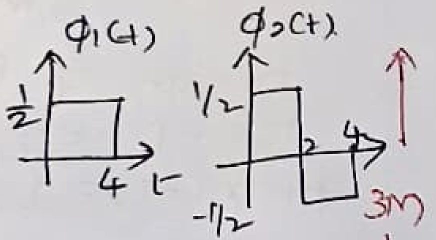
$\phi_2(t) = \frac{S_2(t)}{\sqrt{E_{S_2}}}$, $S_{21}(t) = \int_0^T S_2(t)\phi_1(t)\,dt = 3$

$g_2(t) = S_2(t) - S_{21}(t)\phi_1(t)$

$S_2(t) = \begin{cases} 3/2, & 0<t<2 \\ -3/2, & 2<t<4 \end{cases}$

7M

$$\phi_2(t) = \begin{cases} 1/2, & 0<t<2 \\ -1/2, & 2<t<4 \end{cases}$$



3M

$S_1(t) = 6\,S_1(t)$, $S_2(t) = 3\,S_1(t) + 3\,S_2(t)$

$S_3(t) = 3\phi_1(t) - 3\phi_2(t)$

4b) Let $X(f) = G_T(f) \cdot C(f) \cdot G_R(f)$

$= G_T(f) \cdot G_R(f)$

$$\phi(mT) = X(0)\,a_m + \sum_{n\neq m} a_n\, x(mT-nT) + w(mT)$$

Desired symbol, ISI, additive noise

To remove ISI, $x(mT-nT)=0$, for $n \neq m$

$$x(nT) = \begin{cases} 1, & n=0 \\ 0, & n\neq 0 \end{cases}$$ Nyquist condition for zero ISI

7M

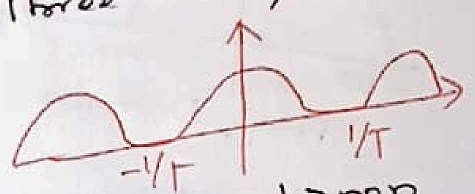
$$\sum_{m=-\infty}^{\infty} X\left(f+\frac{m}{T}\right) = T$$

$$z_n = \begin{cases} T, & n=0 \\ 0, & n\neq 0 \end{cases}$$

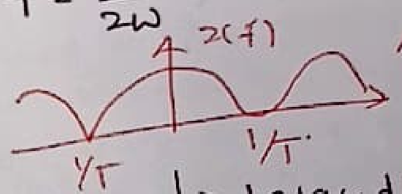
$Z(f) = T$

$$\sum X\left(f+\frac{m}{T}\right) = T$$

Three cases, $T < 1/2W$, $T = \frac{1}{2W}$



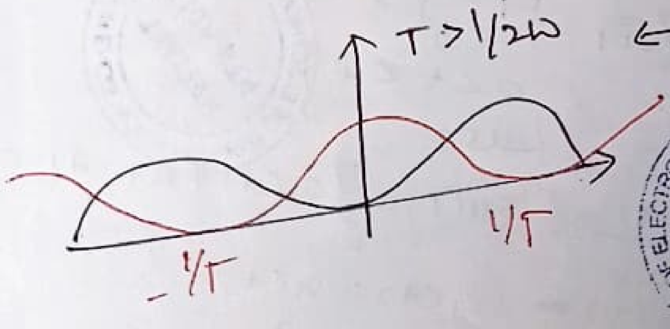
↳ non overlap



↳ overlapped

3M

$T > 1/2W$ ← overlapped



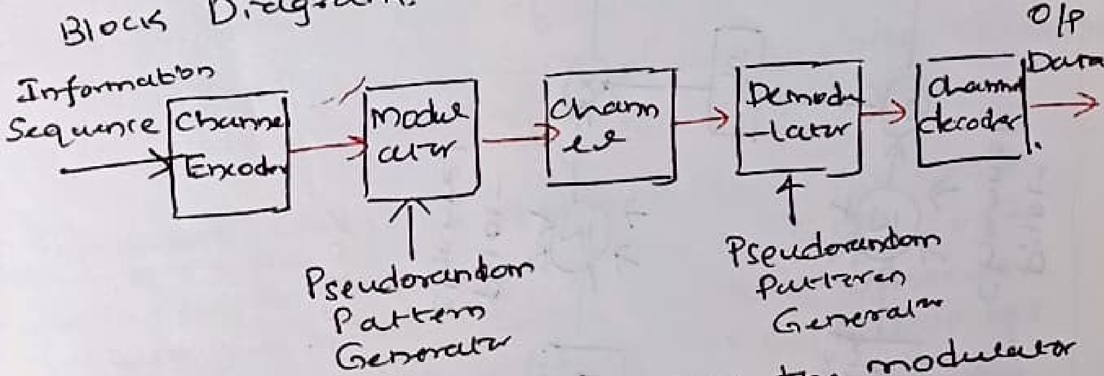
Module-3

Q.No

5a) Block Diagram : model of SSDCS -10M

Block Diagram -6M Explanation-4M

Block Diagram.

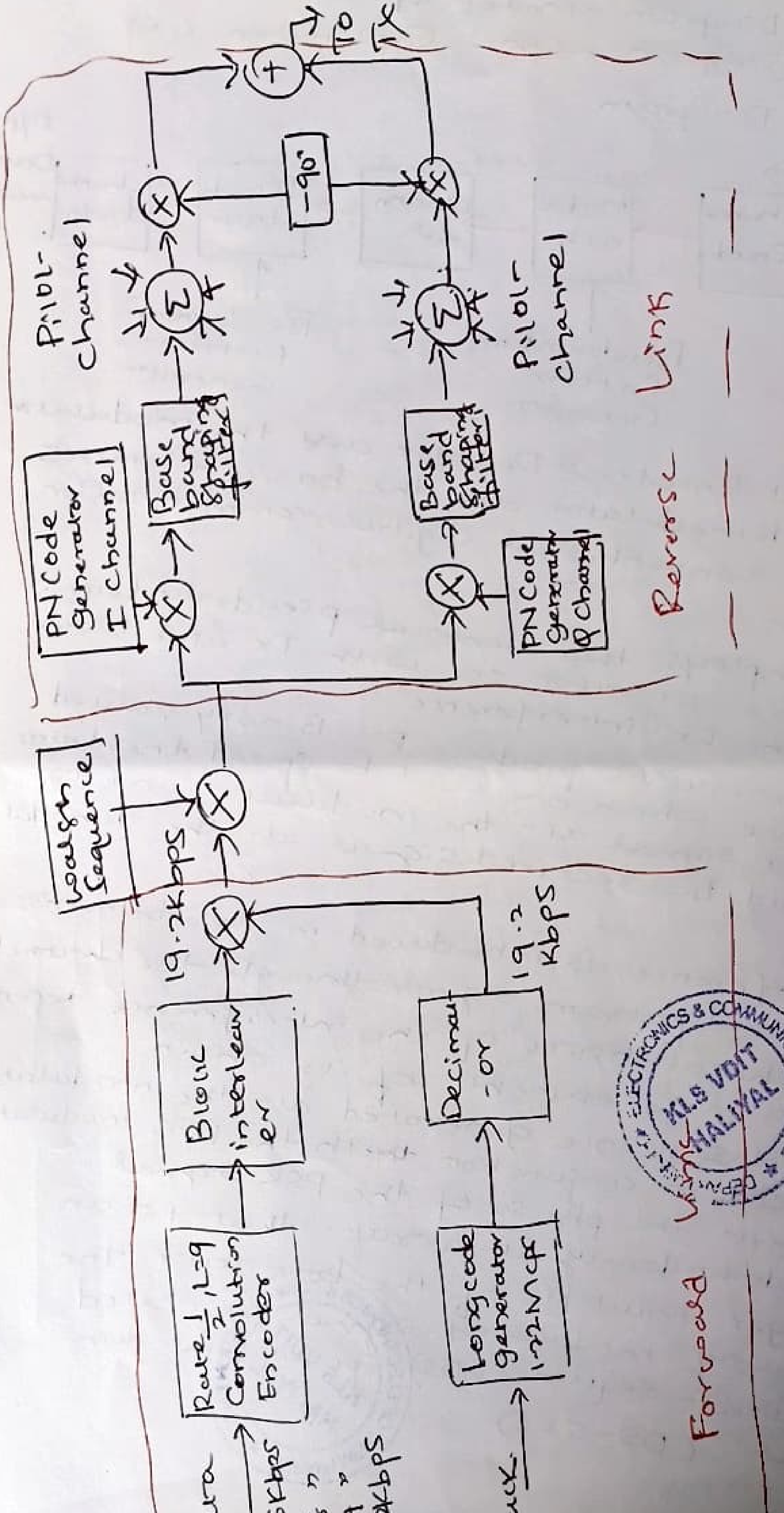


* Channel Encoder & Decoder and the modulator and demodulator are the basic elements of a conventional digital communication system.
* SS employs two identical pseudorandom sequence generator one with Tx and other with the Rx interference
* The generators produce PN Binary valued sequence which are used to spread the transmitted signal at the modulator and to despread the received signal at the demodulator
* Interference is introduced in the transmission of spread spectrum signal through the channel. The characteristics of the interference depends on a large extent of its origin
* The PN sequence generated at the modulator is used in conjunction with the PSK modulation to shift the phase of the PSK signal pseudorandomly at a rate that is an integer multiple of the bit rate. The resulting modulated signal called a direct-sequence (DS) spread spectrum signal (DS-SSS)

Q.No Module - 3

5b) CDMA system Band on IS-95.

Block Diagram - 7M



5b) (Continued)

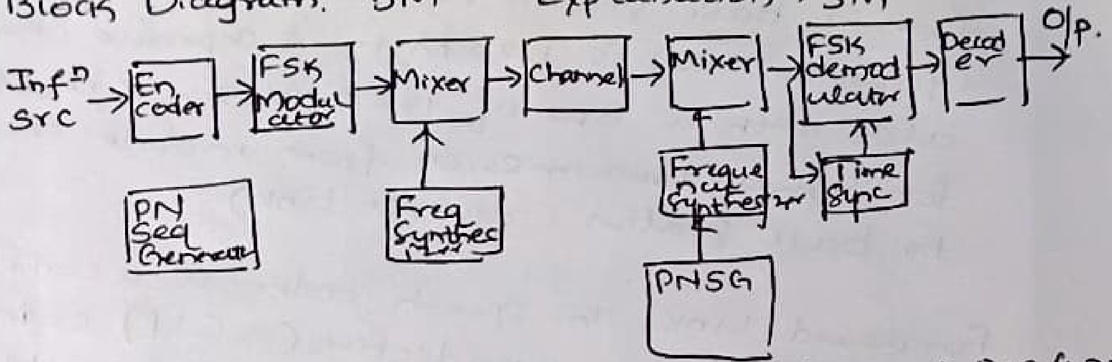
The nominal b/w used for transmission from a base station to the mobile receiver (forward Link) is 1.25 MHz. A seperate channel also with a BW of 1.25 MHz, is used for signal transmission from mobile receivers to base station (reverse link)

Forward Link) The speech coder is a code-excited linear predictive (CELP) coder that generates data at the variable rates of 9600, 4800, 2400 and 1200 bps. where data rate is the function of the users speech activity in frame interval of 20 msec, rate of 1/2, constraint length of L=9 codes. Depending on the data rate (low speech) are repeated 2 times, 4 times or 8 times. The interleaver is used to overcome the effects of burst errors. that may occur during TX. Each channel user is assigned with a walsh code with sequence of 64; means 64 channels are available. Each user using walsh code sequence multiplies the data sequence by the assigned walsh sequence. If $N = 2^{15}$, this creates inphase (I) and quadrature (Q) signal. hence binary data is converted to a four phase signals of both I & Q.

Reverse Link: To compensate major limitations, a rate 1/3, K=9 convolution code is used in reverse link. These code have an AWGN channel rate 1/2 code used in forward link. To reduce interference to other user the time position of the transmitted code symbol repetition is randomized. (Block Diagram of reverse Link).

Q.6a) Frequency hopped Spread Spectrum technique with Tx & Rx

Block Diagram: 5M   Explanation: 3M



→ In this method the available channel BW (W) is divided in to a large number of non-overlapping freq slots.

→ According PN Sequence, the selection of the frequency slot (s) in each signal is made available

→ The prefered modulation is either FHSSS: M-ary FSK or binary

→ For binary FSK is employed to select two frequencies f_0 or f_1

→ These frequencies further mixed with the o/p of the FSK modulator and resultant signal is transmitted over the channel.

→ For m bits we get 2^m.

→ At Receiver, there is a PN seq. Generator, which is used to control the o/p of the freq synthesizer.

→ hence at demodulator PN freq of Tx is removed, the resultant signal is then demodulated via an FSK demodulator.

→ The frequency-hopping rate, denoted as Rh, may be either equal to the symbol rate, lower than the symbol rate. If Rh higher than the symbol rate. If Rh = or less than symbol rate, it's called slow hopping else fast-hopping.

Module-3

Q.no 6b) Given (SNR). = 13 dB ≃ 20

$\left(\frac{PI}{Po}\right)_{dB} = 20\,dB \simeq 100$ — 2M

$(SNR)_D = \frac{2 P_o}{PI/L_c} \Rightarrow L_c = \frac{1}{2}(SNR)_D \frac{PJ}{P_o}$

$= \frac{1}{2} \times 20 \times 100 = 1000$ — 2M

Q.no 6c) Applications of DS-Spread Spectrum Systems:

i) Low detectability of signal Tx
ii) code division Multiple Access
iii) communication over channel with multipath
iv) Wireless LAN's

Module-4

Q.no 7a)

① Self Information: It is the measure of the info content of a random variable expressed as unit of info $I_K = \log \frac{1}{P_K}$

② Entropy: It is the randomness of a source of Information. $H(S) = \sum_{i=1}^{q} P_i \log \frac{1}{P_i}$

③ Rate of Information: Given by $R = r_s H(S)$ where $r = 2B$ mps, product of entropy and info rate

④ ~~Rate of Information~~ Source efficiency: It is the ratio of Entropy to the maximum % of entropy

$H(S) = \frac{H(S)}{H(S)_{max}} \times 100\%$

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Module-4

7b> S_1 S_2 S_3 S_4 S_5 8M

0.4 0.25 0.15 0.12 0.08

$\alpha_1 = 0$ $\alpha_2 = 0.4, \alpha_3 = 0.65, \alpha_4 = 0.8, \alpha_5 = 0.92$ – 1M

$\alpha_6 = 1$

$2^{l_i} > 1/p_i$, $l_1 = 2, l_2 = 2, l_3 = 3, l_4 = 4, l_5 = 4$ – 2M

$\alpha_1 = 0, \alpha_2 = (0.11)_2, \alpha_3 (0.101)_2, \alpha_4 = (0.1100)_2$ – 2M

$\alpha_5 = (0.1110)_2$

P_i	code	l_i	S_i
0.4	00	2	S_1
0.25	01	2	S_2
0.15	101	3	S_3
0.12	1100	4	S_4
0.08	1110	4	S_5

3M

7c> Types of Error: 4M

Their are two types of error Random error and Burst-error

* Random error is a chance difference b/w the observed and true values of some previous values
* If there are errors in ~~one or~~ two or more bits in the data unit then it is called as burst-error

2M

* Any two controlling methods 2M

8a> S_1 0.4 1 | 0.4 | 1

S_2 0.2 1 | 0.2 | 0

S_3 0.2 0 | 0.2 | 1

S_4 0.1 0 | 0.1 | 0 | 0.1 | 1

S_5 0.07 0 | 0.07 | 0 | 0.07 | 0 | 0.07 | 1

S_6 0.03 0 | 0.3 | 0 | 0.03 | 0 | 0.03 | 0

Code	l_i
11	2
10	2
01	2
001	3
0001	4
0000	4

1M

8a) Continued--

$L = 2.3$ bpms

$H(S) = \sum_{i=1}^{0} P_i \log \frac{1}{P_i} = 2.208$ bpms

$\eta_s = \frac{H(S)}{L} = 96.04\%$ $R_\eta = 3.96\%$ (3M)

8b)

0.4	1	0.4	1	0.4	1	0.0	0
0.3	00	0.3	00	0.3	00	0.4	1
0.12	011	0.18	010	0.3	01		
0.10	0100	0.12	011				
0.08	0100						

(3M)

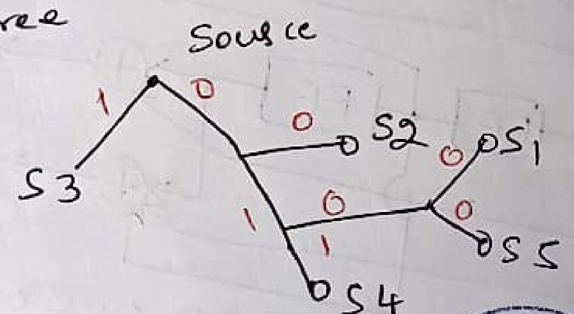
Avg Length $L = \sum_{i=1}^{5} P_i l_i = 2.08$ bpms

Entropy $H(S) = \sum_{i=1}^{5} P_i \log \frac{1}{P_i} = 2.04$ bpms

efficiency $\eta_c = \frac{H(S)}{L} = \frac{2.04}{2.08} \times 100 = 98.11\%$

Redudancy $R_{\eta c} = 1.89\%$ (5M)

code tree



(2M)

Module 5

9a) $G = \left[\begin{array}{cccc|ccc} 1 & 0 & 0 & 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 & 1 & 1 \end{array}\right]$ 10M

code vector $[C] = [D][G] = [1101][G]$ 6M

$\therefore [C] = [0111][G] = 0111000$

$[C] = [d_1, d_2, d_3, d_4, (d_1+d_2+d_3)(d_1+d_2+d_4)(d_1+d_3+d_4)]$

Q.no 9a> continued

Encoder ckt

$S = R H^T \quad H = [P^T \mid I_{n-k}]$

$$H = \left[\begin{array}{cccc|ccc} 1&1&1&0&1&0&0 \\ 1&1&0&1&0&1&0 \\ 1&0&1&1&0&0&1 \end{array}\right]$$

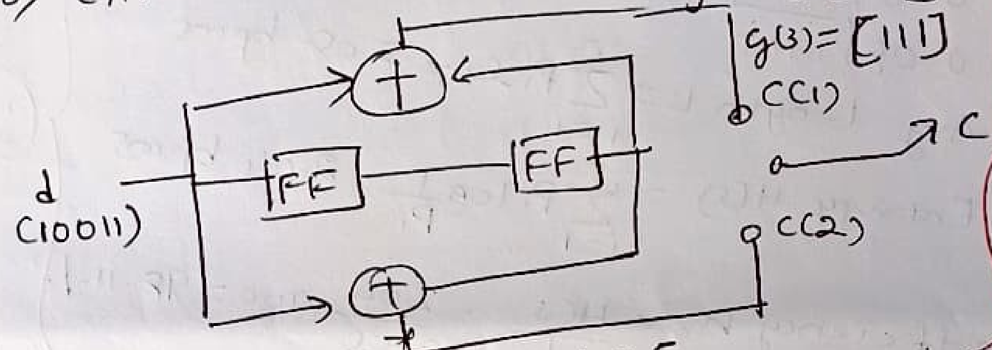
$S = [S_1 \, S_2 \, S_3]$

$= (r_1 + r_2 + r_3 + r_5)(r_1 + r_2 + r_4 + r_6)$

$(r_1 + r_3 + r_4 + r_7)$.

(4M)

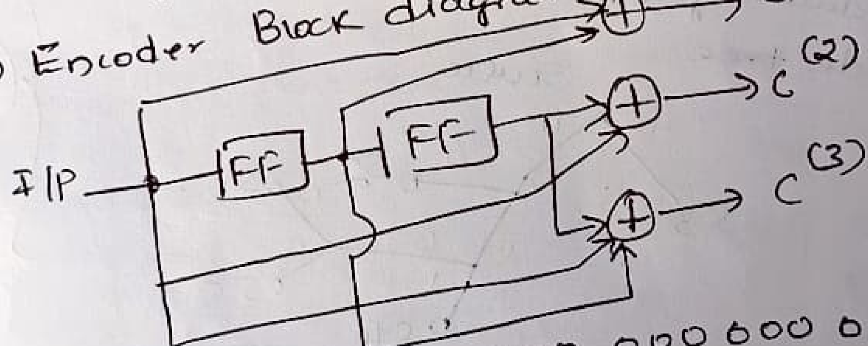
Q9b> Given $n=3, k=1, m=2$ $\quad g^{(1)} = [110]$, $g^{(2)} = [101]$, $g^{(3)} = [111]$



(3M)

$n=3, k=1, m=2$ $\quad L=5$

(i) Encoder Block diagram



(3M)

$$G = \begin{bmatrix} 111 & 101 & 011 & 000 & 000 & 000 & 000 \\ 000 & 111 & 101 & 011 & 000 & 000 & 000 \\ 000 & 000 & 111 & 101 & 011 & 000 & 000 \\ 000 & 000 & 000 & 111 & 101 & 011 & 000 \\ 000 & 000 & 000 & 000 & 111 & 101 & 011 \end{bmatrix}$$

Q 9b) continued

Transform domain approach — 4M

$d = [10011]$, $d(x) = 1 + x^3 + x^4$

$s^1(x) = 1 + x + x^2$, $s^2(x) = 1 + x^2$

$c^1(x) = d(x)\, s^1(x) = (1 + x^3 + x^4)(1 + x + x^2)$

$= 1 + x + x^2 + x^3 + x^6$

$c^2(x) = d(x)\, s^2(x) = (1 + x^3 + x^4)(1 + x^2)$

$= 1 + x^2 + x^3 + x^5 + x^6$

4M

$c(x) = c^1(x^2) + x\, c^2(x)\, (x^2)$.

$= 1 + x + x^2 + x^4 + x^5 + x^6 + x^7 + x^9 + x^{11} + x^{12} + x^{13}$

$d_P = [11, 10, 11, 11, 01, 01, 11]$

$g(1) = [01111]$, $g(2) = [01101]$.

Module 5

10a) $g^{(1)} = [01111]$, $g^{(2)} = [01101]$

$d = [10111]$ given

$L = 5$, $n = 2$, $K = 1$, $m = 4$

$G = n(L + m) = 2(5 + 4) = 18$

$$[G] = \begin{bmatrix} 00 & 11 & 11 & 10 & 11 & 00 & 00 & 00 & 00 \\ 00 & 00 & 11 & 11 & 10 & 11 & 00 & 00 & 00 \\ 00 & 00 & 00 & 11 & 11 & 10 & 11 & 00 & 00 \\ 00 & 00 & 00 & 00 & 11 & 11 & 10 & 11 & 00 \\ 00 & 00 & 00 & 00 & 00 & 11 & 11 & 10 & 11 \end{bmatrix}$$

5M

$[C] = [D][G]$

$[D] = [10111]$

$[C] = [00, 11, 11, 01, 11, 10, 10, 01, 11]$

Time domain result

ii) $Q(x) = 1 + x^2 + x^3 + x^4$

$S^1(x) = x + x^2 + x^3 + x^4, \quad S^2(x) = x + x^2 + x^4$

$c^1(x) = d(x)\, S^1(x) = x + x^2 + x^4 + x^5 + x^6 + x^8$

$c^2(x) = d(x)\, S^2(x) = x + x^2 + x^3 + x^4 + x^7 + x^8$

O/P encoder $c(x) = c^1(x^2) + x \cdot c^2(x^2)$

$= x^2 + x^3 + x^4 + x^5 + x^7 + x^8 + x^9 + x^{10} + x^{12} + x^{15} + x^{16} + x^{17}$ 5M

$[C] = [00, 11, 11, 01, 11, 10, 10, 01, 11]$

State table

State	S0	S1	S2	S3
Binary	00	10	01	11

10(b) State Transition Table

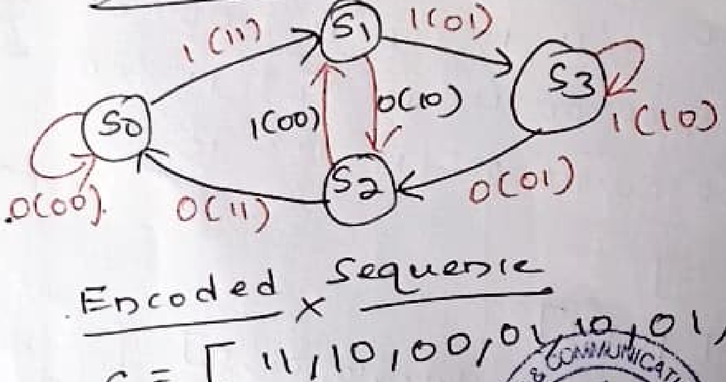
$c^{(1)} = d_l + d_{l-1} + d_{l-2}$

$c^{(2)} = d_l + d_{l-2}$

State		I/P			d_0	d_{l-1}	d_{l-2}	O/P
S0	00	0	S0	00	0	0	0	00
		1	S1	10	1	0	0	11
S1	10	0	S2	01	0	1	0	10
		1	S3	11	1	1	0	01
S2	01	0	S0	00	0	0	1	11
		1	S1	10	1	0	1	00
S3	11	0	S2	01	0	1	1	01
		1	S3	11	1	1	1	10

3M

State Diagram:



3M

2M

Encoded sequence

$c = [11, 10, 00, 01, 10, 01, 11]$ – 2M