GRAPHS:

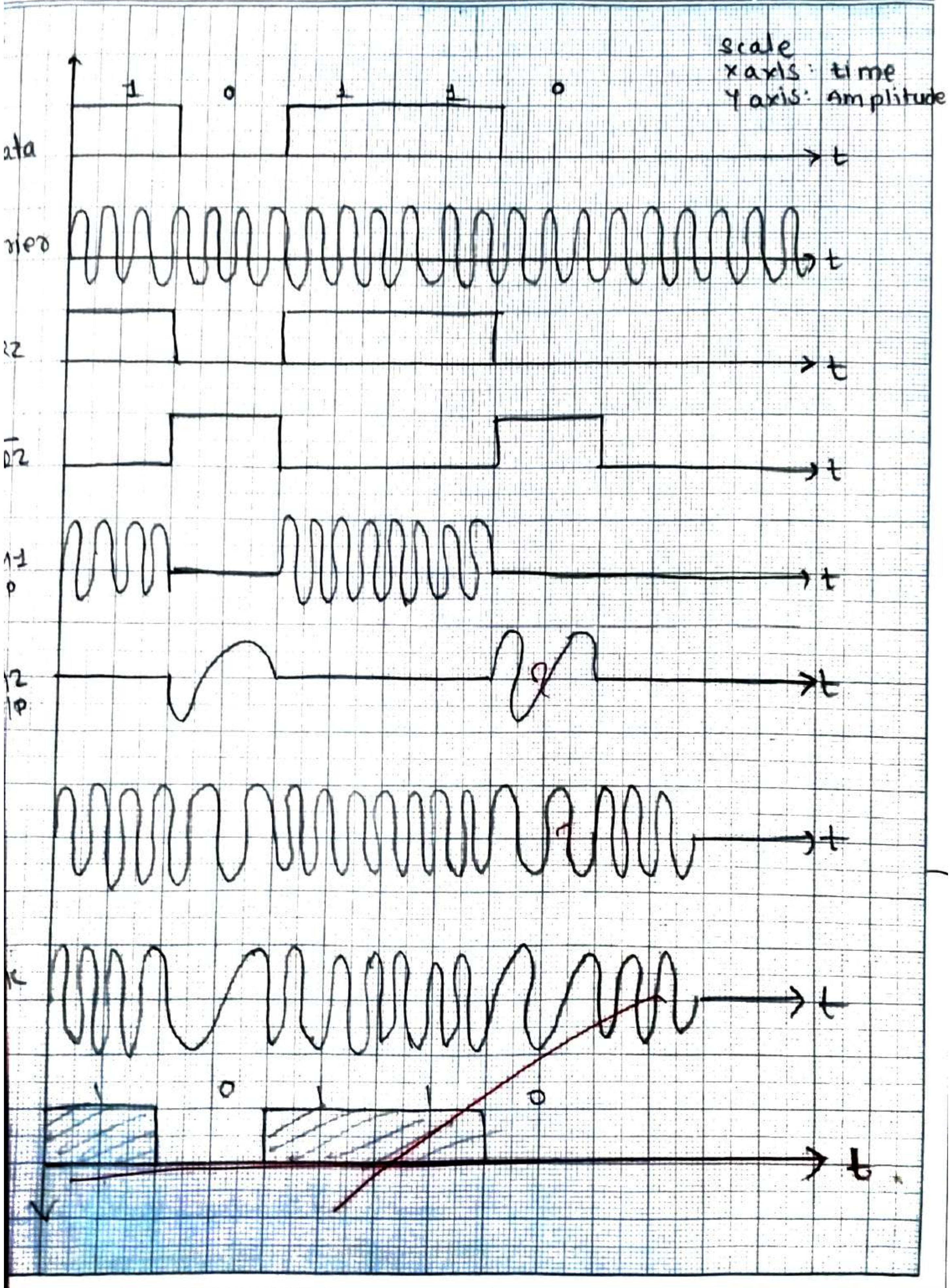
Plot the Graph of each test points on graph paper.

OBSERVATION TABLE:

Test points/Signals	Frequency(Hz)	Voltage(V)
Data sequence	18.52 KHz	5 V
NRZ Data sequence NRZ	18.52 KHz	5 V
RF Carrier 1	500 KHz	5 V
RF Carrier2	296.3 KHz	1 V
Output of BM-1	615.4 KHz	20 V
Output of BM-2	79.37 KHz	20 V
Output Of Adder	588.2 KHz	20 V
Output of Demodulator	181.8 KHz	50 V

Oral Questions:

1. Define BFSK? Give comparison between ASK,PSK,FSK.
2. For the given 8 bit data 10111010 draw the FSK output waveform.
3. Draw the constellation diagram of FSK.
4. What will happen if the same frequency is used for both the carriers.
5. List some applications of FSK,PSK,ASK?
6. Why NRZ Data sequence signal changes to NRZ.
7. Why are used two balanced Modulators.
8. Draw experimental block diagram of BFSK.
9. Define digital modulation schemes.
10. Identify the differences between Pass band and Base band Communication.


scale
x axis: time
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1 0 1 1 0
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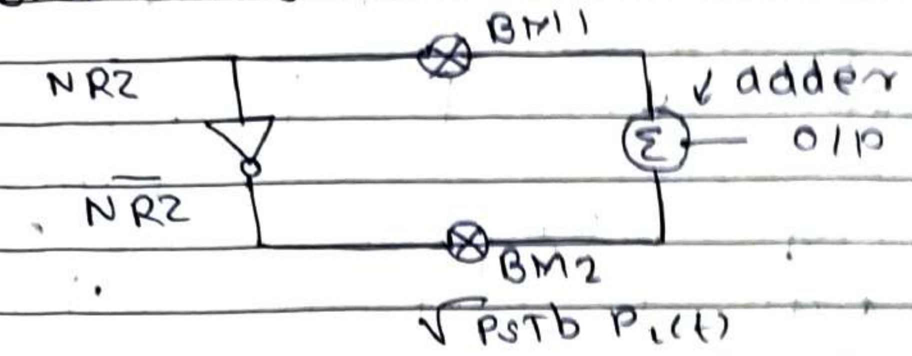
1) BFSK Transmitter

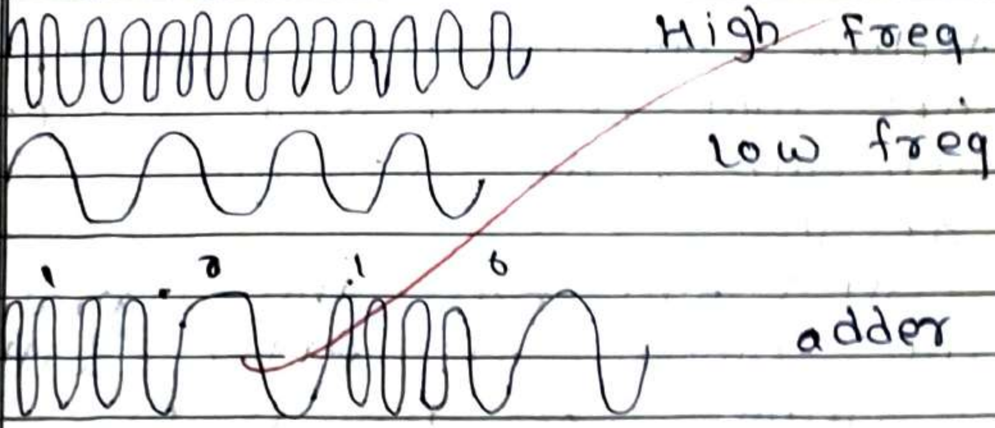


the BFSK consists of two signals NRZ & $\overline{NRZ}$ produces carrier for high and low freq.

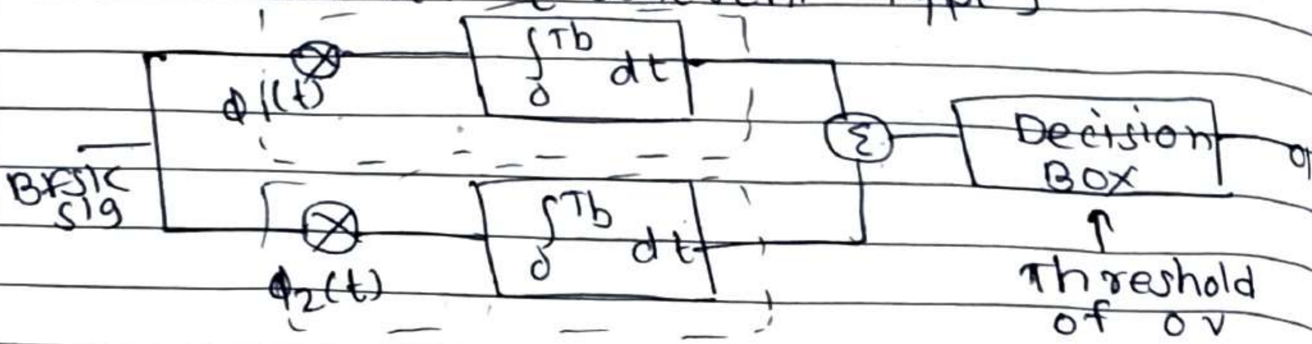
- These NRZ signals are added to two balanced modulator i.e BM1 & BM2
- For BM1 high freq. is applied with mathematical expression $\sqrt{2/Tb}\ \cos \omega_H t$
- for BM2 low freq. is applied with mathematical expression $\sqrt{2/Tb}\ \cos \omega_L t$

Data bit	value of d(t)	$P_H(t)$	$P_L(t)$
0	-1	0	1
1	+1	1	0

waveform (1010)

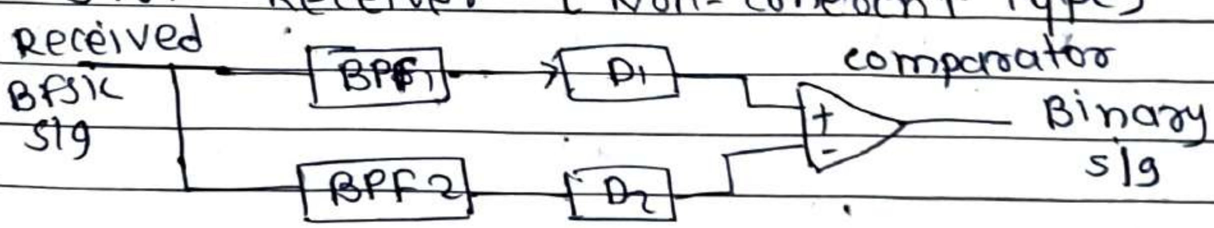


- BFSK Receiver [coherent type]



- It is supposed to generate original digital data signal from both input signal.
- The received BFSK signal is denoted by $x(t)$ and applied to two correlator
- This correlator are supplied with locally generated coherent reference signal ϕ_1, ϕ_2.

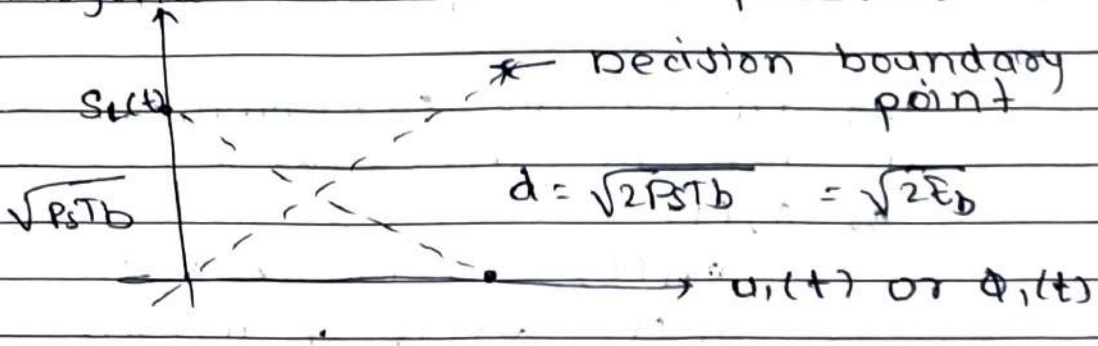
- BFSK Receiver [Non-coherent type]



- The envelope detector are simple diode detectors that rectify and filter I/P, to generate a dc voltage proportional to ac i/p.
- Thus BPF 1 will pass this signal to D_1 the output of BPF 2 will be 0 hence output of D_2 is 0.
- Therefore comparator output will be positive respresenting logic 1.

2) Geometric Representation of orthogonal & non-orthogonal BFSK.

1) orthogonal Geometric Representation



- In order to make $u_1(t)$ and $u_2(t)$ orthogonal, the freq. f_H and f_L should be integer multiple of freq. f_0 (where $f_0 = 1/T_b$)

That means, $f_H = mf_b$
and $f_L = nf_b$

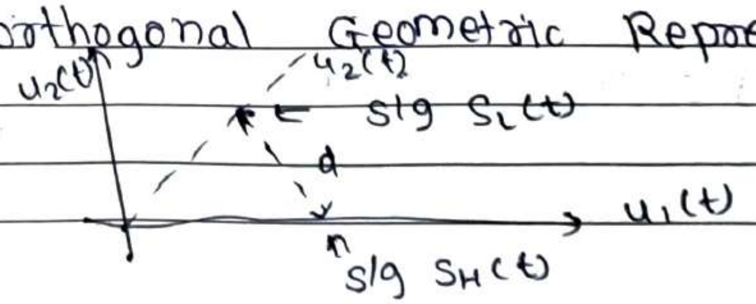
- Therefore the two carrier $u_1(t)$ & $u_2(t)$ are given by

$$u_1(t) = \sqrt{2/T_b}\cos 2\pi m f_b t \quad — (1)$$
$$u_2(t) = \sqrt{2/T_b}\sin 2\pi n f_b t \quad — (2)$$

using eq^n (3) and (4) we have plotted signal space representation of orthogonal BFSK as shown above.

- The Euclidean distance for orthogonal BFSK is $d = \sqrt{2E_b}$

2) Non-orthogonal Geometric Representation.



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- If two carrier, $u_1(t)$ and $u_2(t)$ expressed by $u_1(t) = \sqrt{2/T_b} \cos 2\pi m f_b t$ — (1)

$u_2(t) = \sqrt{2/T_b} \sin 2\pi n f_b t$ — (2)

By eq^n (1) and (2) can be represented in form of $u_1(t)$ or $\phi_1(t)$ and $u_2(t)$ or $\phi_2(t)$.

$S_H(t) = \sqrt{P_S T_b} \times u_1(t)$ — (3)

$S_L(t) = \sqrt{P_S T_b} \times u_2(t)$ — (4)

$$d^2 \approx 2 E_b \left[1 - \frac{\sin(\omega_H - \omega_L) T_b}{(\omega_H - \omega_L) T_b} \right] \quad — (3)$$

3) Compare Binary ASK, Binary FSK, PSK

Parameter	BPSK	BFSK	BASK
1) modulation	phase	Freq.	Amplitude
2) Noise immunity	High	moderate	low
3) BW	low	High	Low
4) complexity	moderate	moderate	simple
5) sig states	0 to 180°	Two diff. freq.	Amplitude modulation

4) compare orthogonal and non-orthogonal BFSK

Parameter	Orthogonal BFSK	Non-Orthogonal
1) Freq. Gap	Larger	smaller
2) S/g overlap	No overlap	some overlap
3) Error chance	Low error rate	High error rate
4) B/W use	more	less
5) Efficiency	less	more

Conclusion: -

The experiment successfully demonstrated the generation and detection of BFSK generation signal, where binary data was transmitted using two distinct carrier frequencies.

Questions:

1. Explain BFSK Transmitter & Receiver Coherent & non coherent with diagram?
2. State geometric representation of orthogonal and non-orthogonal BFSK?
3. Compare Binary ASK, Binary FSK, Binary PSK?
4. Compare Orthogonal and non-orthogonal BFSK?

Timely submission (10)	Journal Presentation(10)	Performance(10)	Understanding(10)	Oral(10)	Total (50)
Sub Teacher Sign:		15/7/25			

EXPERIMENT NO. 2

AIM: To Study of BPSK transmitter & receiver using suitable hardware setup/kit.

OBJECTIVE: Generation & reception of BPSK & its spectral analysis (DSO).

APPARATUS: BPSK kit, DSO, CRO, Connecting Wires.

THEORY:

Binary Phase Shift Keying (BPSK)

BPSK is a simple but significant carrier modulation scheme. The two time-limited energy signals $s_1(t)$ and $s_2(t)$ are defined based on a single basis function $\varphi_1(t)$ as:

$$s_1(t)=\sqrt{\frac{2E_b}{T_b}}.\cos 2\pi f_c t \quad \text{and} \quad s_2(t)=\sqrt{\frac{2E_b}{T_b}}.\cos\left[2\pi f_c t+\pi\right] = -\sqrt{\frac{2E_b}{T_b}}.\cos 2\pi f_c t \qquad 5.24.1$$

The basis function, evidently, is, $\varphi_1(t)=\sqrt{\frac{2}{T_b}}.\cos 2\pi f_c t$; $0 \le t < T_b$. So, BPSK may be described as a one-dimensional digital carrier modulation scheme. Note that the general form of the basis function is, $\varphi_1(t)=\sqrt{\frac{2}{T_b}}.\cos(2\pi f_c t+\phi)$, where 'Φ' indicates an arbitrary but fixed initial phase offset. For convenience, let us set $\Phi = 0$.

As we know, for narrowband transmission, $f_c >> \frac{1}{T_b}$. That is, there will be multiple cycles of the carrier sinusoid within one bit duration (T_b). For convenience in description, let us set, $f_c = n\times\frac{1}{T_b}$ (though this is not a condition to be satisfied theoretically).

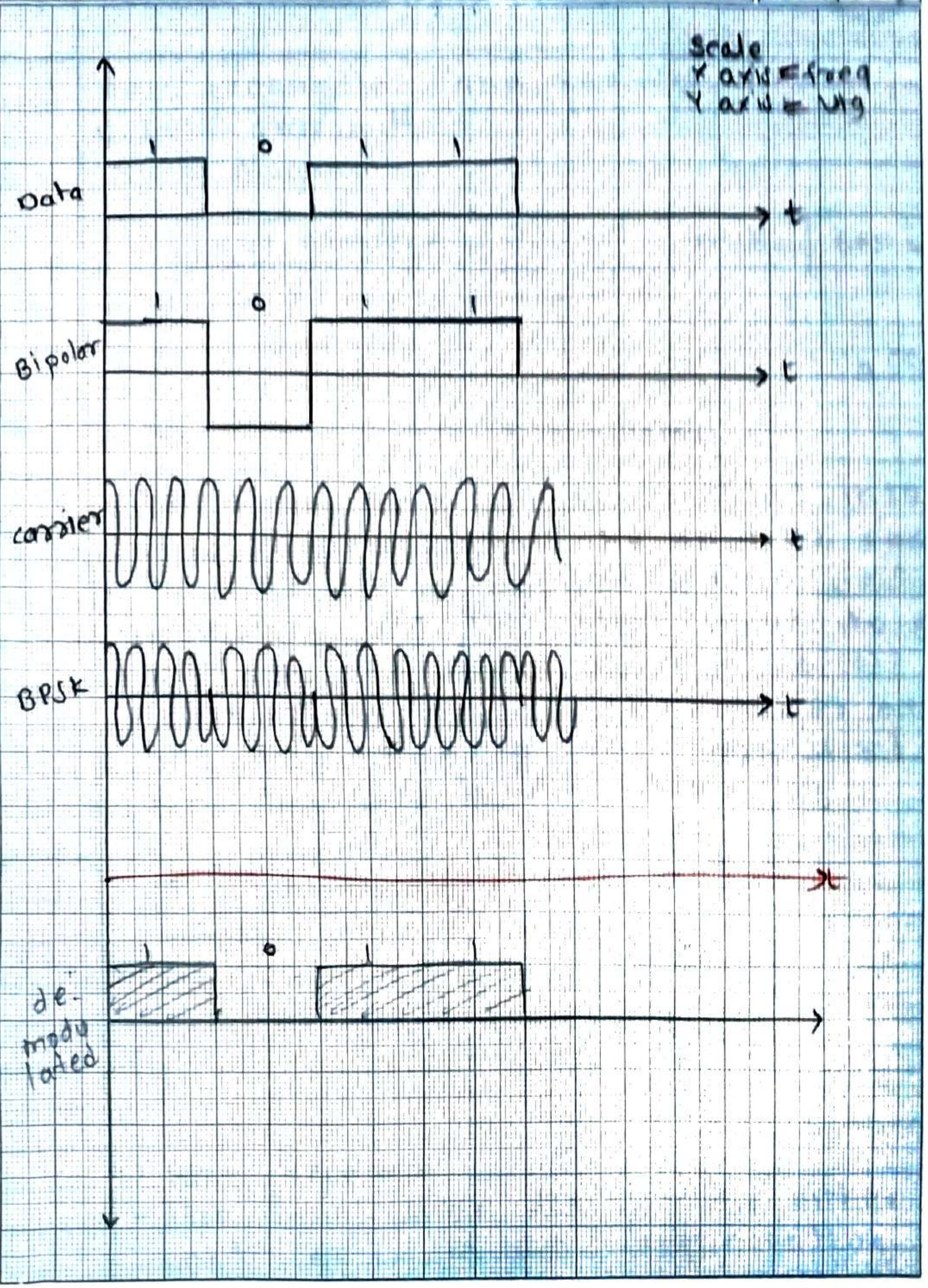
Now, we see,

$$s_1(t)=\sqrt{E_b}.\varphi_1(t) \quad \text{and} \quad s_2(t)=-\sqrt{E_b}.\varphi_1(t), \qquad 5.24.2$$

The two associated scalars are:

$$s_{11}(t)=\int_0^{T_b} s_1(t).\varphi_1(t)dt=+\sqrt{E_b} \quad \text{and} \quad s_{21}=\int_0^{T_b} s_2(t).\varphi_2(t)dt=-\sqrt{E_b} \qquad 5.24.3$$

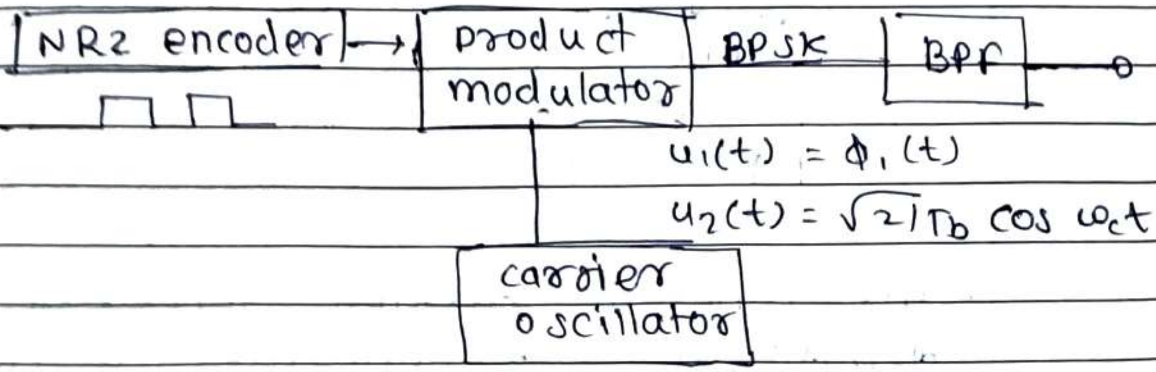
Fig. 5.24.1 (a) presents a sketch of the basis function $\varphi_1(t)$ and **Fig. 5.24.1 (b)** shows the BPSK modulated waveform for a binary sequence. Note the abrupt phase transitions in the modulated waveform when there is change in the modulating sequence. On every occasion the phase has changed by 180^0. Also note that, in the diagram, we have chosen to set $\sqrt{\frac{2E_b}{T_b}} = 1$, i.e. $\frac{E_b}{T_b} = \frac{1}{2} = 0.5$, which is the power associated with an unmodulated carrier sinusoid of unit peak amplitude.


Scale
X axis = freq
Y axis = Vtg
Data
1 0 1 1
t
Bipolar
1 0 1 1
t
carrier
t
BPSK
t
de-modulated
1 0 1 1

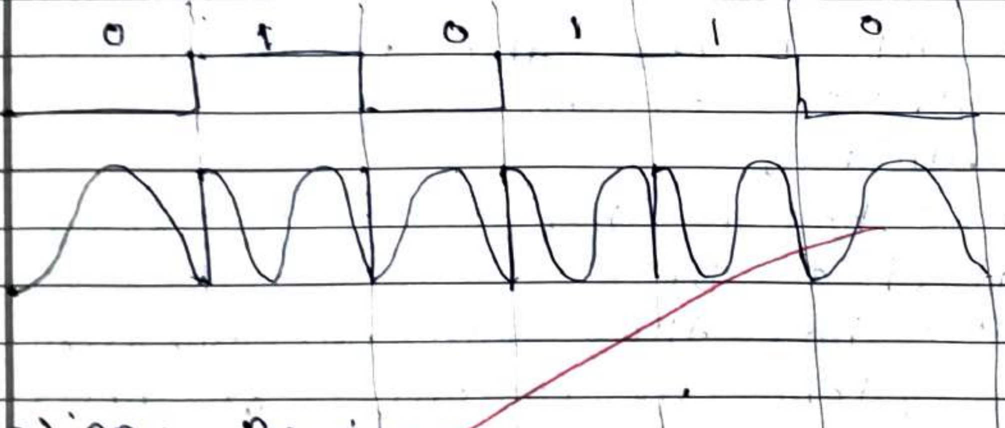
1) BPSK transmitter and receiver

1) BPSK transmitter

Block diagram

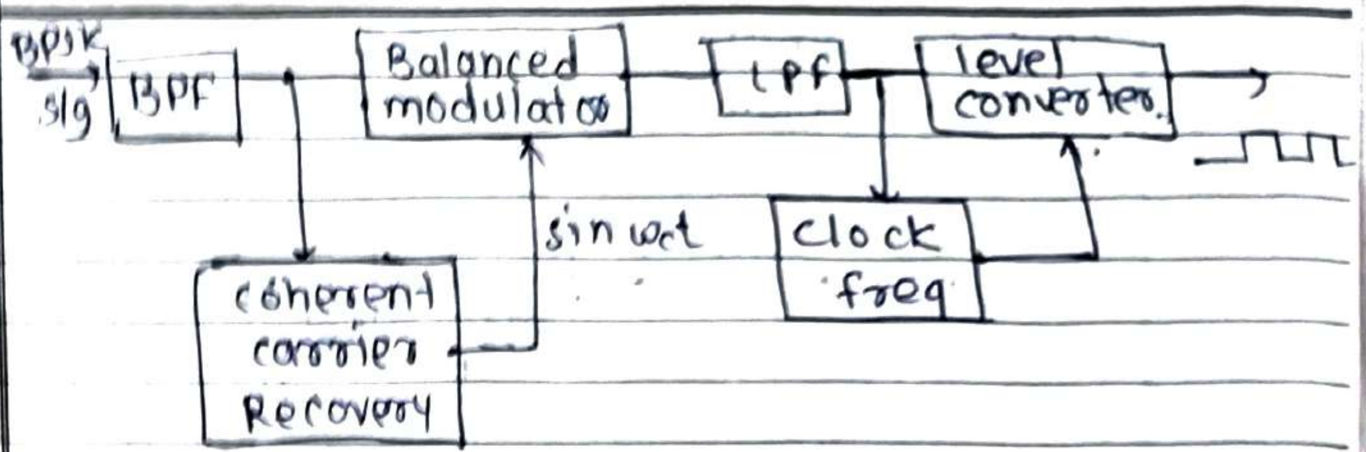


- The binary data sig is converted into a NRZ bipolar signal by an NRZ encoder.
- The NRZ sig is applied to an product modulator and the other input to product multiplier is basic function $\phi_1(t) = \sqrt{2/T_b}\cos\omega_c t$ produced by carrier osc
- the data bits 0s & 1s are first converted into bipolar NRZ sig



2) BPSK Receiver

- The input BPSK sig can be either $+\sin\omega_c t$ or $-\sin\omega_c t$ representing either logic 1 or 0 respectively.



- The coherent carrier recovery circuit detects and regenerates a carrier signal sin wct.
- This regenerated carrier signal sin wct
- This has the same freq and phase synchronized with the transmitter.
- The filtered BPSK sig along with the regenerated carrier is applied to balanced modulator.

2) State Advantages and Disadvantages of BPSK system

•) Advantages

1) BPSK has a BW which is lower than that of a BFSK sig.
2) BPSK has the best performance of all systems in presence of noise. It gives the minimum possibility of error.
3) BPSK has a very good noise immunity.

• Disadvantages

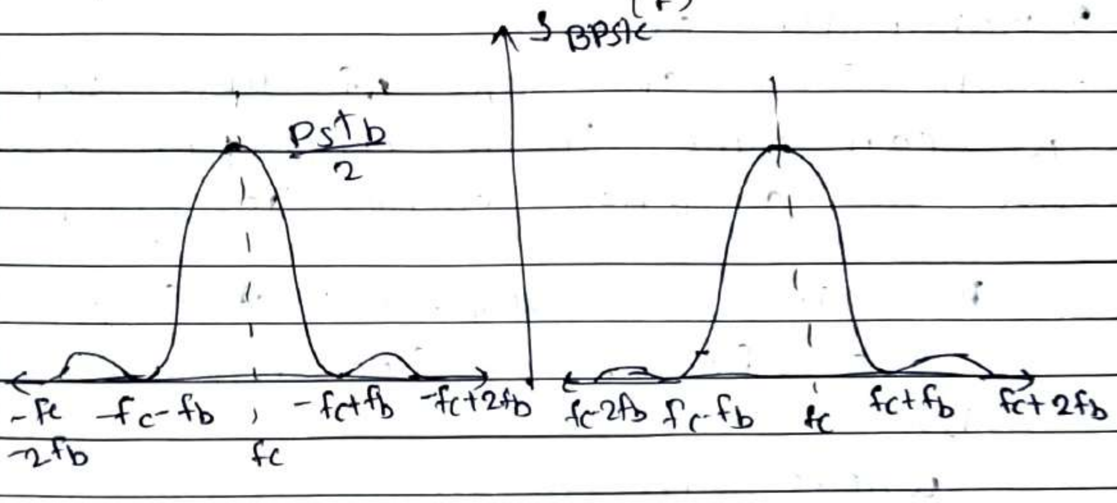
1) The only disadvantage of BPSK is that generation & detection of BPSK is not easy. It is quite complicated

2) Since BPSK uses only two phases (0° and 180°)

3) Not suitable for very high data rates, as it transmits 1 bit / symbol.

3) Draw and derive expression of spectrum and calculate BW of BPSK

→ spectrum of BPSK



• Expression

1) signal model (polar NRZ BPSK)

• BPSK passband signal

$$s(t) = \sqrt{\frac{2E_b}{T_b}}\, m(t) \cos(2\pi f_c t + \theta)$$

2) spectrum derivation

shift to passband for BPSK

Let $x(t) = \sqrt{\frac{E_b}{T_b}}\, m(t)$. Then $s(t) = \sqrt{2}\, x(t) \cos(2\pi f_c t)$

· By modulation property of PSD

$$S_g(f) = \frac{1}{2}\left[S_x(f-f_2) + S_x(f+f_2)\right],$$

$$S_x(f) = \frac{E_b}{T_b}\, S_m(f)$$

substitute $S_m(f)$

$$S_s(f) = \frac{E_b}{2}\left[\operatorname{sinc}^2((f-f_c)T_b) + \sin^2((f+f_c)T_b)\right]$$

$$\boxed{\therefore\ S_s(f) = \frac{E_b}{2}\left[\operatorname{sinc}^2((f_c-f_1) + \sin^2((f+f_c)T_b)\right]}$$

3) Bandwidth of BPSK

- From freq spectrum of BPSK signal, we can come to a conclusion that the BW of a BPSK signal is given by,

$$BW = \text{Highest freq} - \text{Lowest freq}$$
$$= (f_c + f_b) - (f_c - f_b)$$
$$BW = 2f_b$$
where $f_b = \frac{1}{T_b}$

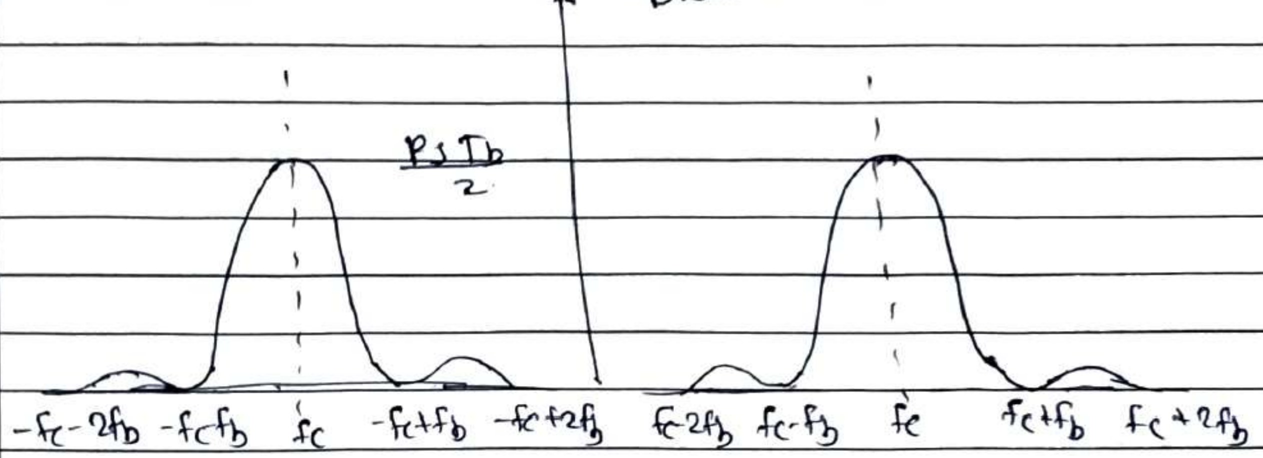
4) Calculate BW of BPSK? Draw a spectrum of BPSK?

→ Calculate Bandwidth of BPSK

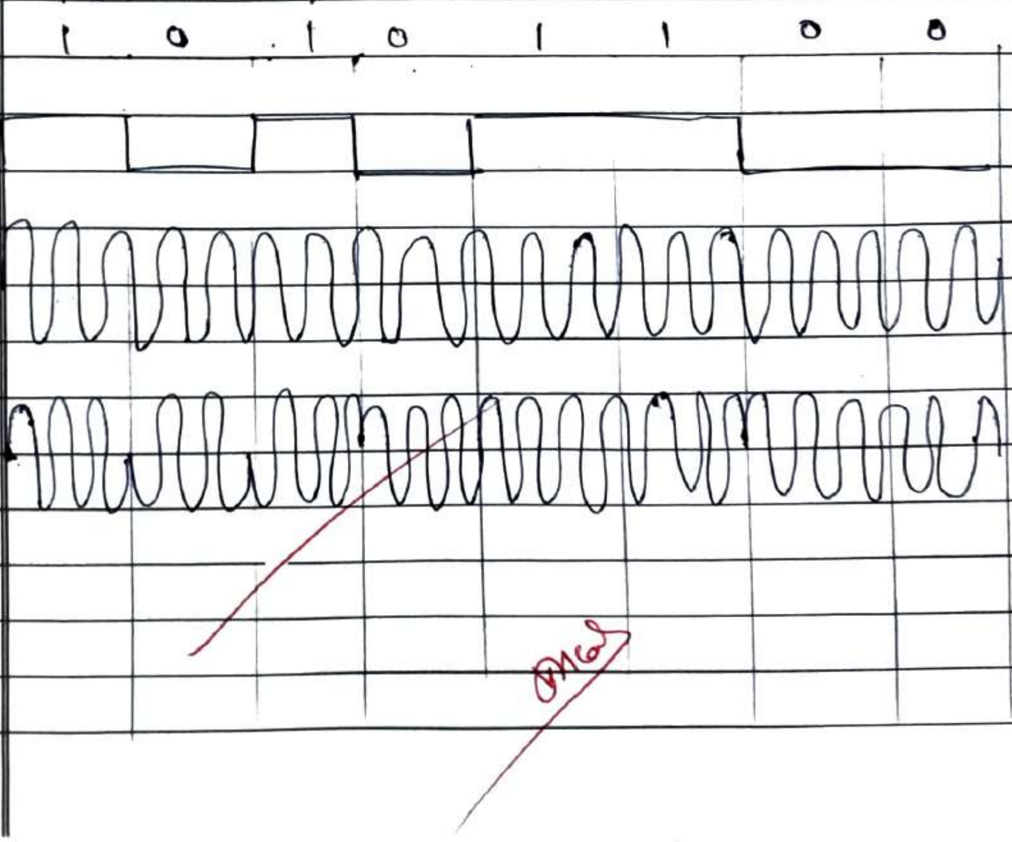
$$BW = \text{Highest freq} - \text{Lowest freq}$$
$$= (f_c + f_b) - (f_c - f_b)$$
$$= 2f_b$$

Thus the minimum BW of BPSK sig is equal to twice the highest freq. contained in baseband signal.

• Spectrum of BPSK



5) Draw BPSK wave from for i/p bit seq. 10101100.



Observation Table:

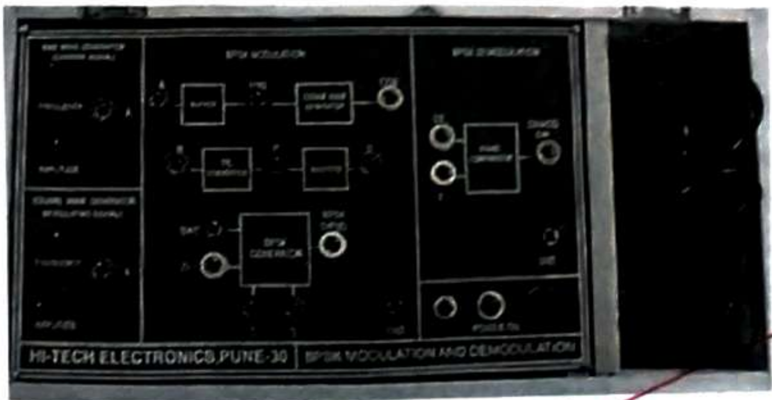
Sr.No	Testpoints	Frequency(Hz)	Voltage(V)
1	NRZ data generator O/p	2.41 KHz	898.4 V
2	Unipolar to Bipolar Convertor o/p	9.24 KHz	1.84 V
3	Carrier Generator o/p	9.25 KHz	1.48 kV
4	Balanced Modulator o/p	9.901 KHz	222.7 V
5	BPSK demodulator o/p		

Conclusion:

The experiment demonstrated the working of a BPSK transmitter and receiver using the hardware kit, showing how binary data is transmitted by phase shifting the carrier.

Questions:

1. Explain BPSK transmitter and Receiver?
2. State advantage and dis advantage of BPSK system?
3. Draw and derive the expression of spectrum and calculate the BW of BPSK?
4. Calculate Bandwidth of BPSK? Draw a spectrum of BPSK?
5. Draw the BPSK waveforms for input bit sequence 10101100.



BPSK Trainer Kit

EXPERIMENT NO. 2

AIM: To Study of QPSK transmitter & receiver using suitable hardware setup/kit.

OBJECTIVE: Generation & reception of BPSK & its spectral analysis (DSO).

APPARATUS: QPSK kit, DSO, CRO, Connecting Wires.

THEORY:

To transmit digital data on analog lines (viz. telephone) or into space, modulation of analog signal is required. Simplest way is BPSK where one phase of carrier is transmitted for '1' and inverted carrier is transmitted for digital '0'. Here if bit rate is t_b then the bandwidth required is $2f_b$. To reduce this bandwidth requirement QPSK can be used. In QPSK bandwidth requirement is half of that of BPSK.

In QPSK two consecutive bits are stored and for resulting 4 combinations, 4 different phases of carrier are transmitted. Incoming bit pattern is divided into two bit patterns viz. odd pattern and even pattern. For obtaining this, 2 resulting into odd divide basic clock and even clock and they are complementary to each other. Say, clock frequency is f_b, and then odd and even clock frequency is $f_b/2$. Each bit is stored for $2t_b$.

Odd bit pattern is modulated into PSK using sine as carrier, while even bit pattern is modulated into PSK using cosine as carrier. Then two PSK signals are added to give QPSK signal. Here active edges of odd and even clocks are separated by time t_b . So ou of two bits one bit is changing (either odd or even) after each t_b period but every bit is there for $2t_b$ time, so this is offset QPSK system. In this system every time phase changes by 90^0 only.

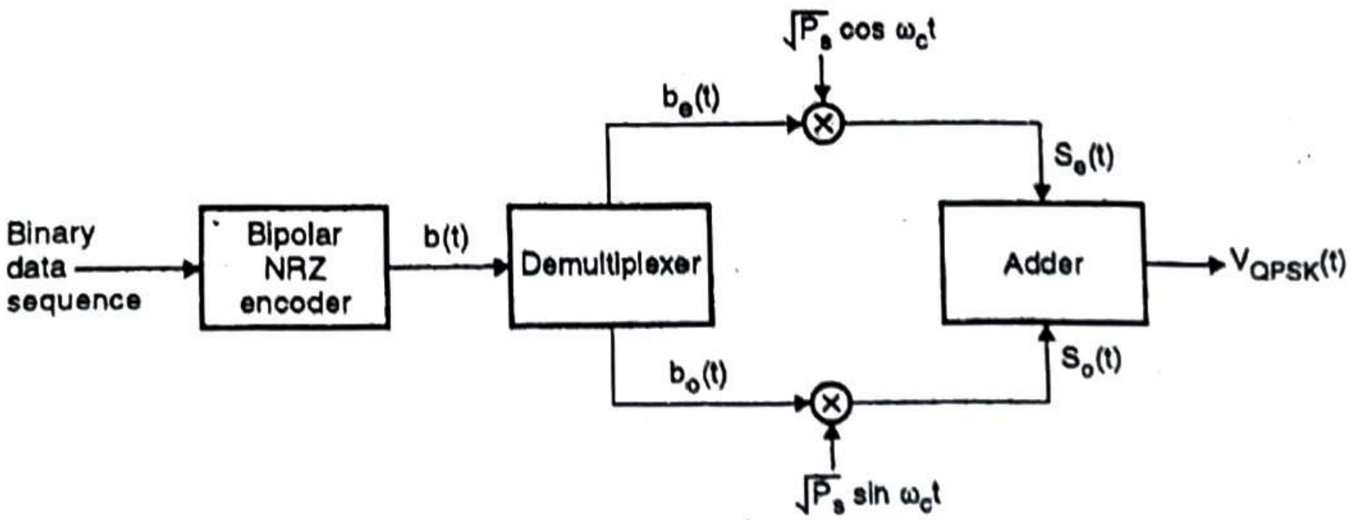


Fig.1 : An offset QPSK transmitter

8] Observe pt. A with 'O. Data' on dual trace CRO. This is PSK signal of 'O' Data.

9] Observe pt. A with sinewave on CRO. ('XY' mode)

10] Observe pt. 'B' with 'E' Data', this is PSK signal of 'E. Data'.

11] Observe pt. B with coswave on CRO. ('XY' mode)

12] Observe QPSK O/p with bit pattern. & then with Sine wave. Press 'XY' mode & observe two ellipses.

13] Connect QPSK O/p to I/p of '1496 Sq. 1' block, observe its O/p, this is squared O/p. (frequency doubled).

14] Connect O/p. of above to I/p of '1496 sq. 2' block & observe its O/p, it is powered 4 O/p (its frequency is 4 times carrier Frequency).

15] Connect O/p of 1496 Sq. 2' to I/p of 'BP Filter 4F' adjust pot given above this block to get carrier properly at the O/p of BP Filter.

16] Connect O/p of 'BP Filter' to I/p of -: - 4 N/W' observe SINE & COS O/ps.

17] Connect QPSK O/p to common I/p pt. of 2, 1496 Mul blocks.

18] Connect SINE wave from transmitter section to SINE of 1496 MUL block.

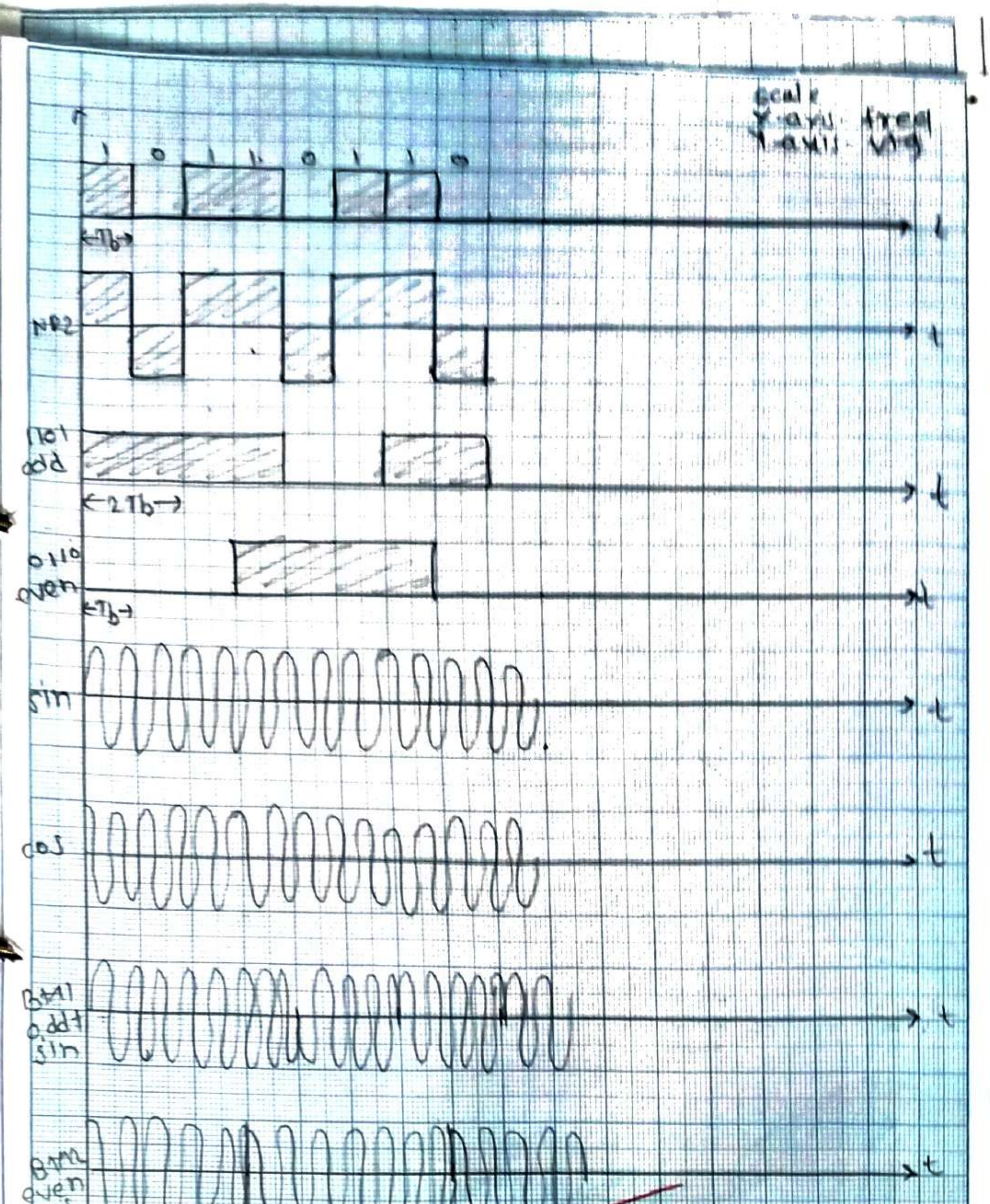
19] Connect COS wave from transmitter section to COS of 1496 MUL Block.

19] Observe final O/p with the original I/p bit pattern. There is delay between i/p & o/p. Why?

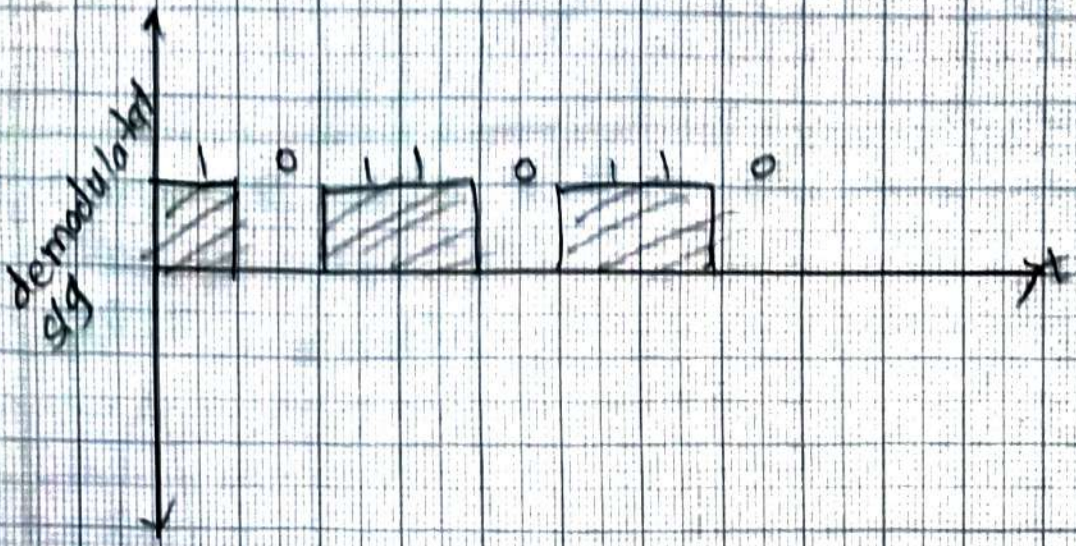
20] Observe pt. 'C' & 'D'. These are odd & even bit patterns received at receiver.

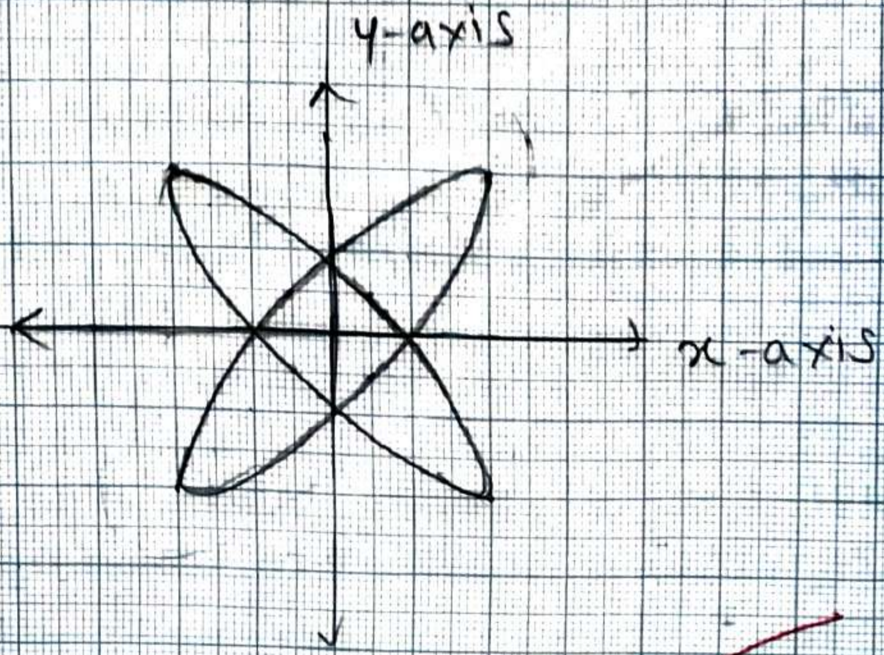
Observation Table:

Sr. No	Test points	Frequency (Hz)	Voltage (V)
1	Clock signal	3.9 KHz	5 V
2	Bit Pattern P1	1.3	5
3	Bit Pattern P2	1.95	5
4	Even data signal	390 Hz	5
5	Odd data signal	390	5
6	Cosine carrier	15.63 KHz	500 mV
7	Sine carrier	15.63	500 mV
8	O/p of QPSK modulator	15.63	500 mV
9	O/p of QPSK Demodulator	1.95	20 V
10	Received NRZ data at Receiver. odd	390.6	20
11	Received NRZ data at Receiver (even)	390.6	20



- main lobe wid...





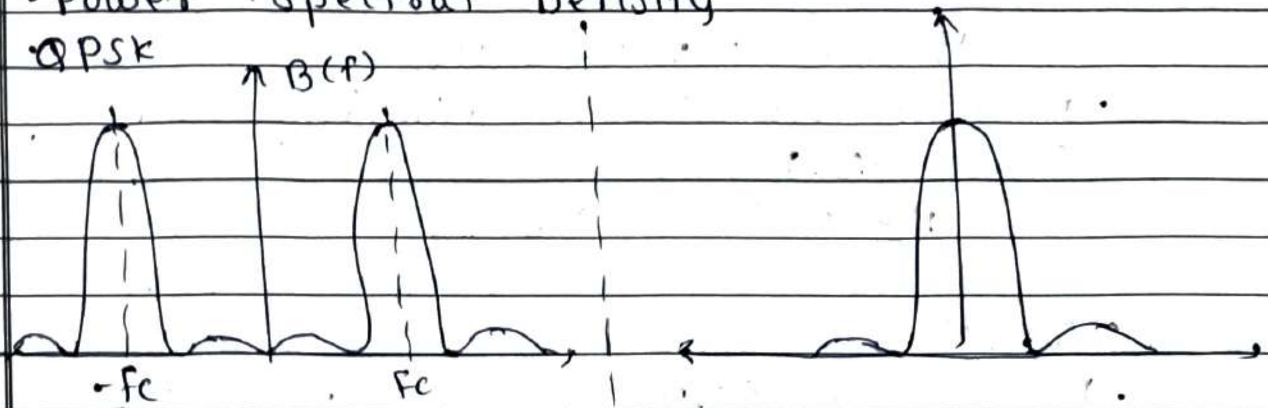
X-Y trigger Mode

rate is halted.
- main lobe width = Rb.

1) Compare PSD & B.W of QPSK and BPSK

→ • Power spectral Density

QPSK



1) Power spectral density

• BPSK

- PSD is similar to that of baseband rectangular NRZ sig, shifted to that of baseband rectangular NRZ sig, shifted to carrier freq.
- the spectrum has $sinc^2$ shape centered at carrier
- since only two phases (0° and 180°) are used symbols are transmitted at same bit rate
- main lobe width $= 2 \times R_b$

• QPSK

- uses four phases [0°, 90°, 180°, 270°]
- Each symbol carries 2 bits, so symbol rate $= \frac{R_b}{2}$
- PSD is similar in shape ($sinc^2$), but narrower in freq. because symbol rate is halfed.
- main lobe width $= R_b$

2) Bandwidth

- BPSK
- Bandwidth $= 2 \times R_b$ Hz
- with raised cosine filtering (roll-off factor α:)

$$B_{PSK} = (1+\alpha) R_b$$

- QPSK
- Bandwidth (null-to-null) $\approx R_b$ Hz.
- with raised cosine filtering (roll-off factor α)

$$B_{QPSK} = (1+\alpha) R_b/2$$

2) Explain mathematical expression, spectral diagram, signal space representation of QPSK

→ 1). Mathematical Representation of QPSK ?

- $v_{QPSK}(t) = \sqrt{2P_s} \cos\left[\omega_c t + (2m+1)\frac{\pi}{4}\right]$ $m = 0, 1 \ldots$

- By substituting value of m from 0 to 3 we get four messages.

i.e $v_{QPSK} = s_1 = \sqrt{2P_s} \cos\left[\omega_c t + \pi/4\right]$ for $m=0$

$v_{QPSK} = s_2 = \sqrt{2P_s} \cos\left[\omega_c t + 3\pi/4\right]$ for $m=1$

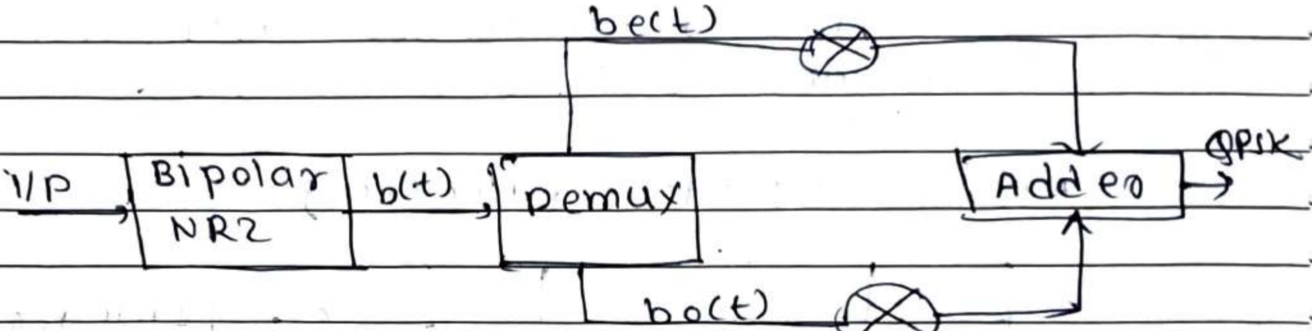
- similarly we can obtain QPSK output for $m=2$ and $m=3$.
- As explained earlier, we can substitute P_s in terms of symbol energy and

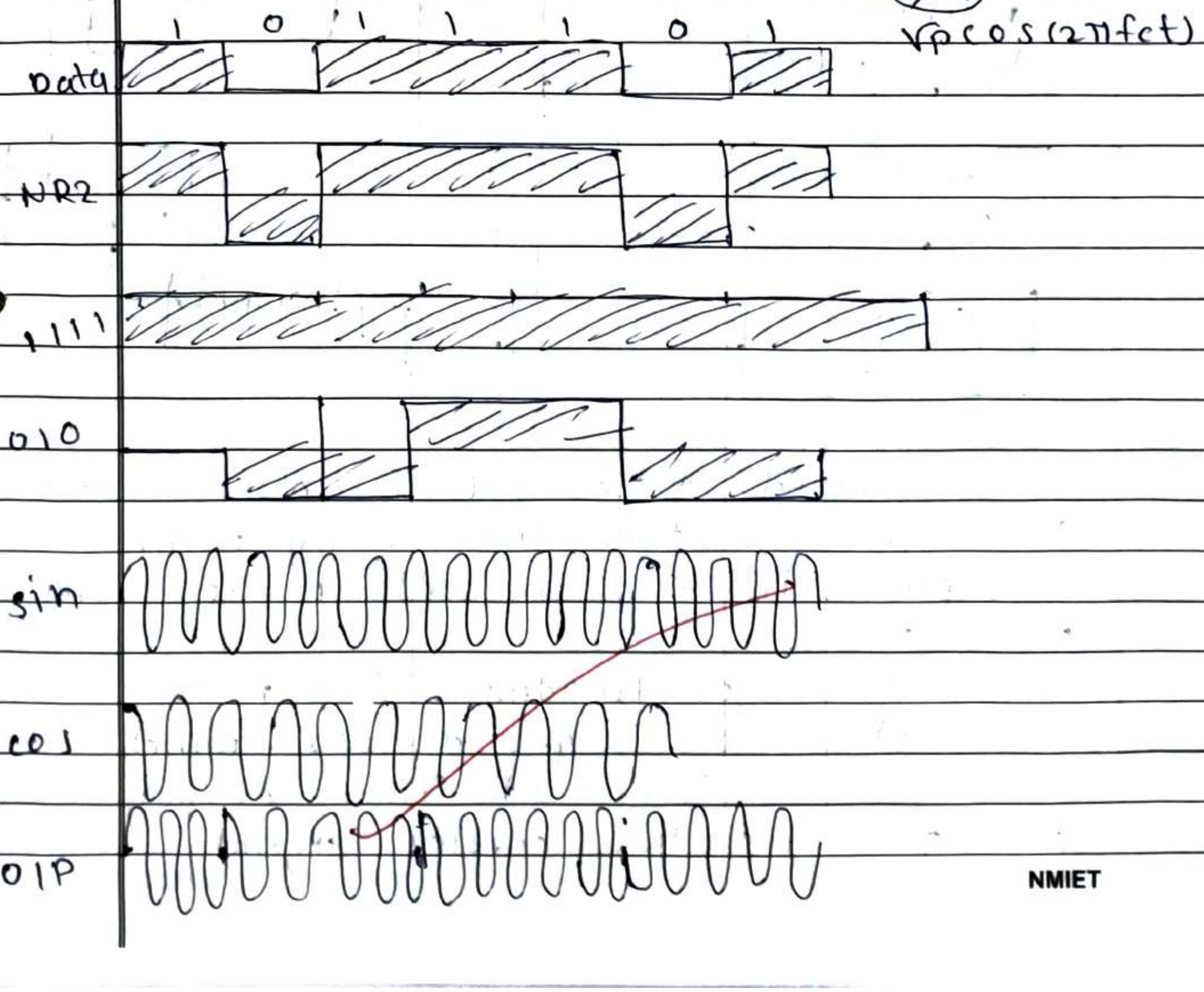
symbol duration a $P_S = E/T$

- the QPSK system of modulation is caused as four state PSK (or 4 PSK)

3) With the waveform explain generation and detection of QPSK?

→ 1) Generation of QPSK [transmitter]





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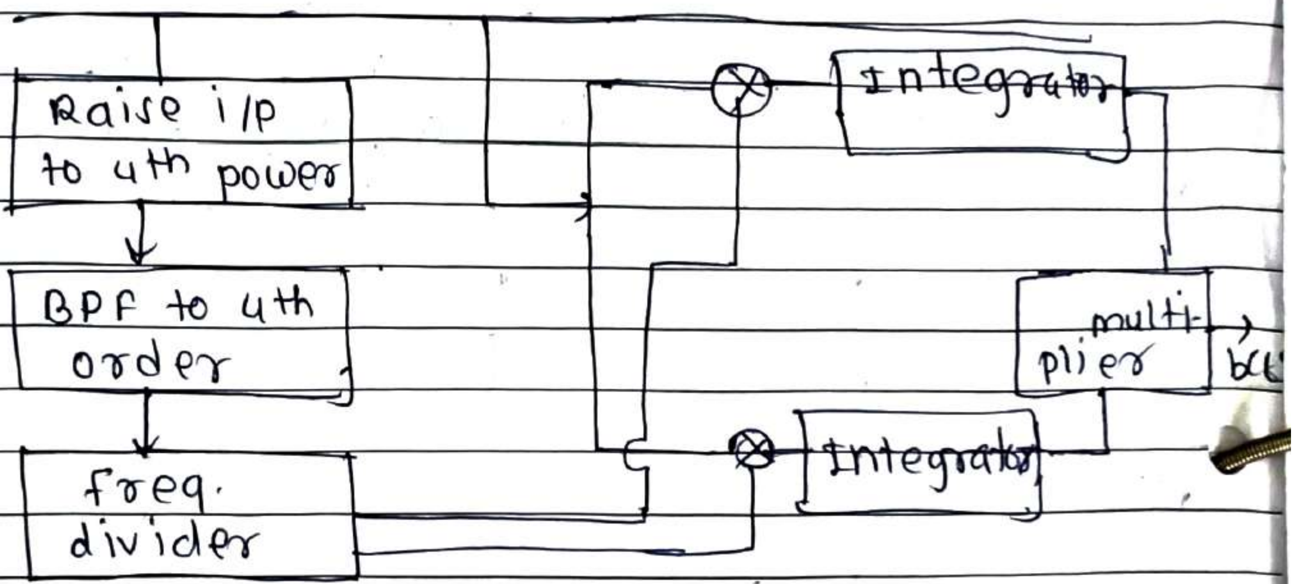
Explanation

- The i/p binary data is first converted into a bipolar NRZ, b(t)
- The value of b(t) = +1V for logic high and b(t) = -1V for logic low.
- The demux devides into two separate bit streams $b_e(t)$ and $b_o(t)$
- Each bit is hold for $2T_b$ period of even and odd

• QPSK detection [Receiver]



- The received QPSK s(t) is raised to 4th the signal is then filtered by using bandpass filter with with centre freq. of $4\omega_c t$.
- The output of Bandpass filter is $\cos 4\omega_c t$, the freq. divider which divides the freq. at filter output and generates two carrier signal.

- The integrator will integrate it's i/p s/g over a symbol period of $T_s = 2T_b$.

4) State Difference between QPSK & non-QPSK

Parameters	Non-offset QPSK	offset QPSK
1) Phase change	0° to 180°.	max upto 90°
2) Amplitude variation	Abrupt change → Higher	smoother → less.
3) Spectral Efficiency	1 bits per symbol	2 bits per symbol.
4) Hardware Requirement	Simple	Needs Q-channel delay ckt
5) I/Q bit charge	can change simultaneously	only one bit changes at a time
6) Application	wireless LAN	mobile comm^n.

5) Advantages and disadvantages of QPSK

• Advantages

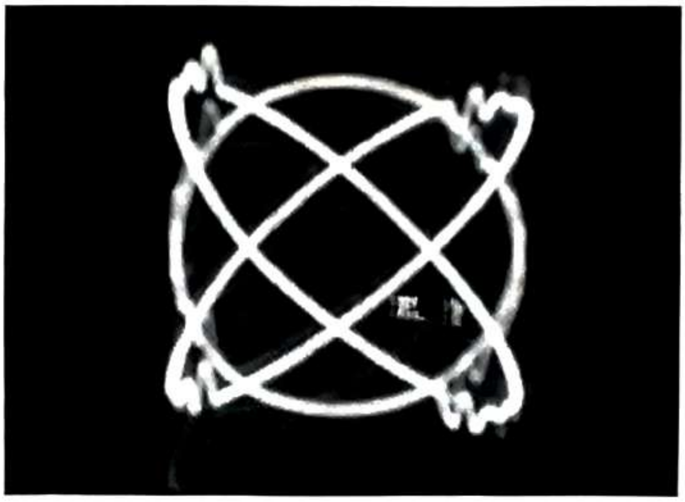
1) Very good noise immunity
2) Baud rate is half the bit rate therefore more effective utilization of available bandwidth of the transmission channel.
3) Low error probability
4) Better Bandwidth efficiency than Binary systems.

• Disadvantages

1) The generation and detection of QPSK is complex.
2) Higher signal distortion.
3) More sensitive to phase noise in practical systems.
4) Requires coherent detection for optimal performance

TO OBSERVE CONCILIATION DIAGRAM OF QPSK

1. **Apply NRZ data "00001111"**
2. Keep Channel-1 amplitude at 0.5V
   Connect CRO Channel-1 (X) at RF Carrier socket (in Carrier generator section).
3. Keep Channel-2 amplitude at 50mv.
   Connect CRO Channel-2 (Y) at QPSK output.
4. Keep CRO on X-Y Trigger Mode and observe conciliation diagram as under.



Conclusion: -

The practical successfully illustrated the generation and reception of QPSK sig using the hardware kit.

Questions:

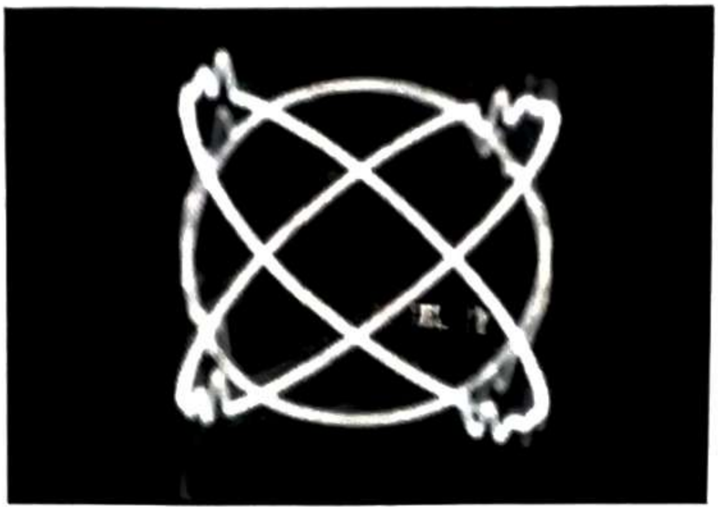
1. Compare PSD and BW of QPSK and BPSK?
2. Explain mathematical expression, spectral diagram signal space representation of QPSK?
3. With the waveforms explain generation and detection of QPSK?
4. State the difference between OQPSK and non-QPSK?
5. Advantages and disadvantages of QPSK?

Timely submission (10)	Journal Presentation(10)	Performance(10)	Understanding(10)	Oral(10)	Total (50)
Sub Teacher Sign:					

29/7/25

TO OBSERVE CONCILIATION DIAGRAM OF QPSK

1. **Apply NRZ data "00001111"**
2. Keep Channel-1 amplitude at 0.5V
   Connect CRO Channel-1 (X) at RF Carrier socket (in Carrier generator section).
3. Keep Channel-2 amplitude at 50mv.
   Connect CRO Channel-2 (Y) at QPSK output.
4. Keep CRO on X-Y Trigger Mode and observe conciliation diagram as under.



Conclusion: -

The practical successfully illustrated the generation and reception of QPSK sig using the hardware kit.

Questions:

1. Compare PSD and BW of QPSK and BPSK?
2. Explain mathematical expression, spectral diagram signal space representation of QPSK?
3. With the waveforms explain generation and detection of QPSK?
4. State the difference between OQPSK and non-QPSK?
5. Advantages and disadvantages of QPSK?

Timely submission (10)	Journal Presentation(10)	Performance(10)	Understanding(10)	Oral(10)	Total (50)
Sub Teacher Sign:					

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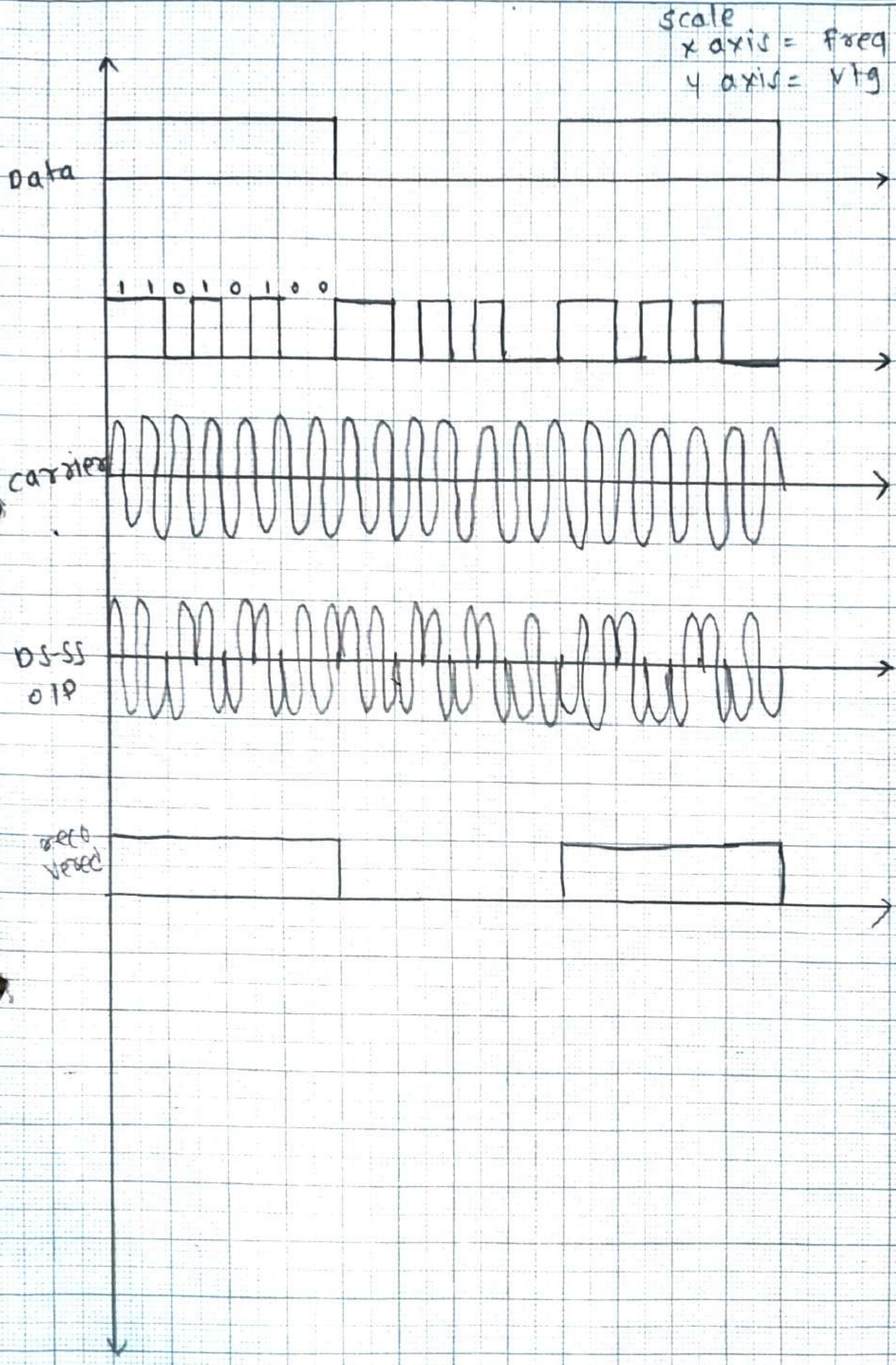
Observation Table:

Sr.No	Testpoints	Frequency(Hz)	Volatge(V)
1	Clock Signal	500	5
2	Pattern P1	57.14	5
3	Pattern P2	95.24	5
4	PN Sequence signal	500 Hz	5
5	Output of spreading code Mixer	1 kHz	5
6	Carrier output	19.99	2
7	Output of DS-SS modulator	21.1 kHz	2
8	Output of Coherent DS-SS detector	19.99	2
9	Output of LPF	666.7 Hz	550 mV
10	Output of Code dispreading section	95.24 Hz	1.62 V

Spectrum Setup

1.	Center Frequency	:	500 KHz
2.	Span	:	1000 KHz
	Hence Start of Span	:	0 KHz
	End of Span	:	1000 KHz
3.	Step	:	10KHz
4.	Resolution Bandwidth	:	3 KHz
	Markers	:	OFF
6.	Amplitude Unit	:	dbmv
7.	System Save Setup	:	Position 8


scale
x axis = freq
y axis = vtg
Data
1 1 0 1 0 1 0 0
carrier
DS-SS
O/P
reco
vered

Q. 1)

Features	DSSS	FHSS
1) Expansion	Direct seq^n spread spectrum	Freq^n hopping spread spectrum
2) Spreading method	PN code spread s/g continuously	carrier freq^n hops among many channels.
3) BW	wideband continuous	Narrowband each hop, but hops over wide-band.
4) Interface	Resistant to narrowband	very resistant to jamming & I/F.
5) Data rate	Higher	lower.

Q. 2 properties of PN seq^n

1) Randomness property
- Even though it is generated by a mathematical algorithm, it looks like random noise.
- Distribution of 1s and 0s is nearly equal.

2) Balance Property
- In one full period of a PN seq^n, the no. of 1s & 0s are nearly equal
- This ensures no DC bias.

3) Run property
- A 'run' = consecutive identical bits.
- In a good PN seq^n:

- Half of the runs are of length
- 1/4 of the runs are of length 2
- 1/8 of the runs are of length 3
- This makes it appear random.

4) Autocorrelation property
- Autocorrelation property of seq with a shifted version of itself
For PN seq.
- At zero shift → autocorelation is more
- At non-zero shifts → autocorrelation is very low
- This helps in synchronization & sig detection in DSSS / CDMA

5) Cross-correlation property
- cross-correlation := similarity betn 2 different PN seq.
- Ideally very low ; so different users codes do not interface much.

Feature	slow freq^n Hopping	fast freq^n hopping
1) Hot rate	$\leq$ symbol rate	$\geq$ symbol rate
2) Symbols/hop	many	less than one
3) I/F resistance	Lower	Higher
4) B.W use	less	More
5) complexity	Low	High
7) Reliability	moderate	very high
8) Appl^n	military comm^m	satellite

Conclusion:

The experiment demonstrated the working of a DS-SS transmitter and receiver using the hardware kit, where the data signal was spread over a wider bandwidth using a pseudo-noise code.

Questions:

1. Comparison between DS-SS and FH-SS?
2. Draw and explain PN Sequence Generation?
3. Explain properties of PN Sequence?
4. Compare Slow Freq hoping and fast freq hoping?
5. Generate a PN Sequence using 5 shift registers to generate a sequence with intial value of shift register are 10000.

Timely submission (10)	Journal Presentation(10)	Performance(10)	Understanding(10)	Oral(10)	Total (50)
Sub Teacher Sign:		23/7/25			

EXPERIMENT NO. 5

AIM: Simulation study of random processes. Find various statistical parameters of the random process.

OBJECTIVE: Write a program to study two random Processes:

- Auto correlation
- Cross correlation on MATLAB.

APPARATUS /SW: MATLAB Version 9.

THEORY:

Autocorrelation and cross-correlation are statistical measures used to analyze random processes. Autocorrelation quantifies the similarity between a random process and a time-shifted version of itself, while cross-correlation measures the similarity between two different random processes at different time points.

Autocorrelation:

- Definition:

Autocorrelation measures how well a random process correlates with itself at different time lags. It essentially checks how predictable a process is based on its past values.

Cross-correlation:

- Definition:

Cross-correlation measures the similarity between two different random processes at different time lags.

Mathematical Representation:

Autocorrelation:

For a random process $X(t)$, the autocorrelation function $R_{XX}(\tau)$ is defined as $R_{XX}(\tau) = E[X(t)X(t+\tau)]$, where E is the expected value and τ is the time lag.

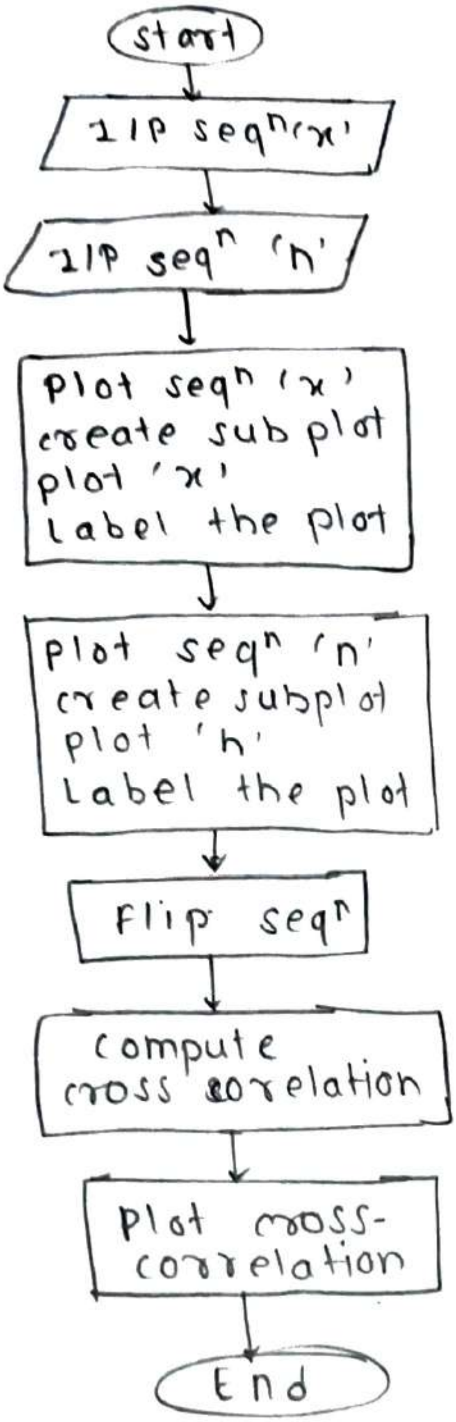
Cross-correlation:

For two random processes $X(t)$ and $Y(t)$, the cross-correlation function $R_{XY}(\tau)$ is defined as $R_{XY}(\tau) = E[X(t)Y(t+\tau)]$, where E is the expected value and τ is the time lag.

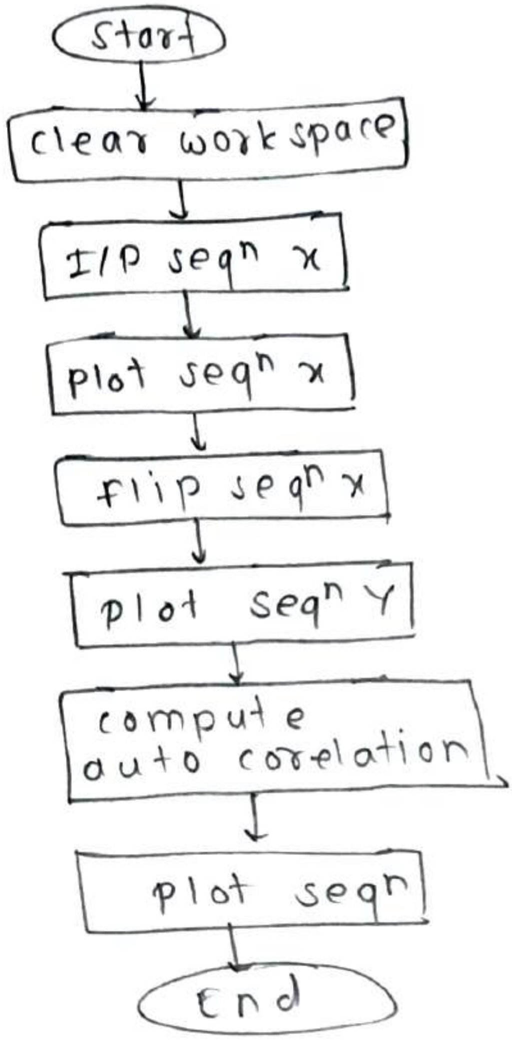
Applications:

- Signal Processing: Analyzing audio signals, image processing, communication systems.
- Finance: Modeling stock prices, predicting market behavior, portfolio optimization.
- Economics: Understanding relationships between economic indicators.
- Engineering: Analyzing system behavior, detecting anomalies, control systems.

cross correlation



Auto correlation



The autocorrelation function of a random signal describes the general dependence of the values of the samples at one time on the values of the samples at another time. Consider a random process x(t) (i.e. continuous-time), its autocorrelation function is written as:

$$R_{xx}(\tau) = \lim_{T\to\infty} \frac{1}{2T} \int_{-T}^{T} x(t)x(t+\tau)dt \qquad (1)$$

Where T is the period of observation.

$R_{xx}(\tau)$ is always real-valued and an even function with a maximum value at $\tau = 0$.

For sampled signal (i.e. sampled signal), the autocorrelation is defined as either biased or unbiased defined as follows:

:

$$R_{xx}(m) = \frac{1}{N-|m|} \sum_{n=1}^{N-m+1} x(n)x(n+m-1) \qquad [Biased\ Autocorrelation]$$

(2)

$$R_{xx}(m) = \frac{1}{N} \sum_{n=1}^{N-m+1} x(n)x(n+m-1) \qquad [Uniased\ Autocorrelation]$$

for m=1,2,…,M+1

1) → In MATLAB, the subplot is used to divide a single fig window into multiple sections (subplots)
so that you can display multiple plots in the same fig. for comparison.

syntax
subplot(m, n, p)
m = no. of row
n = no. of columns
p = position index

2) → 1) grid -
The grid command controls whether grid lines are displayed on a plot
syntax
i) grid on % Turns grid lines ON
ii) grid off % turns grid lines off
iii) grid minor % Shows minor grid lines in addition to major ones.

2) stem
The stem f^n is used to plot discreate data (like impulses or sampled sig)
It draws vertical lines (stems) from a baseline to data points, with a marker at the tip.
syntax
i) stem(y) % stem plot of vector y

ii) stem (x, y) % stem plot of y v.s x

iii) stem (x, y, filled) % fills the marker

3) | Feature | Auto-correlation | cross-correlation |
|---|---|---|
| 1) Def^n | correlation of sig with itself | correlation bet^n 2 diff. sig. |
| 2) formula | $R_{xx}(T)$ | $R_{xX}(T)$ |
| 3) Purpose | Find periodicity, self-similarity | measure similarity bet^n 2 sig |
| 4) Max value | At zero delay $(T=0)$ | Depends on alegnment of sig. |
| 5) Appl.^n | Detect periods sig | sig detection |

4) Solve the Autocorrelation for [4 5 6 7] & crosscorelation for [2 1 4 6] manually

→

Autocorrelation

$x = [4 \quad 5 \quad 6 \quad 7]$

$$R_{xx}[K] = \sum_{n} x[n] \cdot x[n+K]$$

Lag 0 [K = 0]:

$R[0] = 4\cdot4 + 5\cdot5 + 6\cdot6 + 7\cdot7 = 126$

Lag +1 (k=1):-

$R[1] = 4\cdot5 + 5\cdot6 + 6\cdot7 = 92$

Lag +2 (k=2):

$R[2] = 4\cdot6 + 5\cdot7 = 59$

Lag +3 (k=3):

$R[3] = 4\cdot7 = 28$

Since autocorelation is symmetric

$R = [28, 59, 92, 126, 92, 59, 28]$

- cross correlation for [2 1 4 6]

For two same eq^n

$R_{xx}[k] = \sum_n x[n]\, y[n+k]$

Lag 0 (k=0):

$R(0) = 2\cdot2 + 1\cdot1 + 4\cdot4 + 6\cdot6 = 57$

Lag +1 (k=1)

$R(1) = 2\cdot1 + 1\cdot4 + 4\cdot6 = 30$

Lag +2 (k=2)

$R(2) = 2\cdot4 + 1\cdot6 = 14$

Lag +3 (k=3)

$R(3) = 2\cdot6 = 12$

$R(-k) = R(k)$

$R = [12, 14, 30, 57, 30, 14, 12]$

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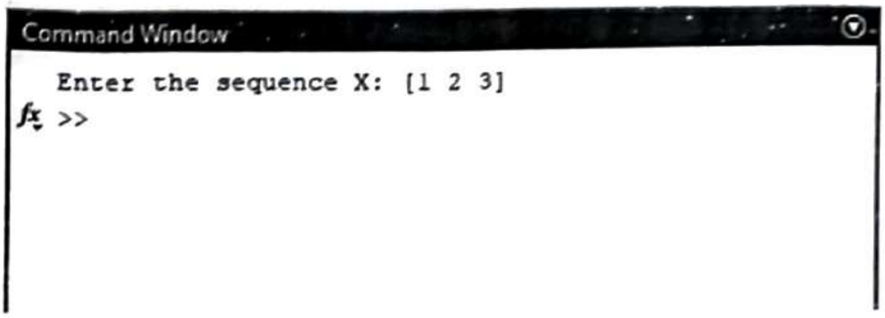
Autocorrelation

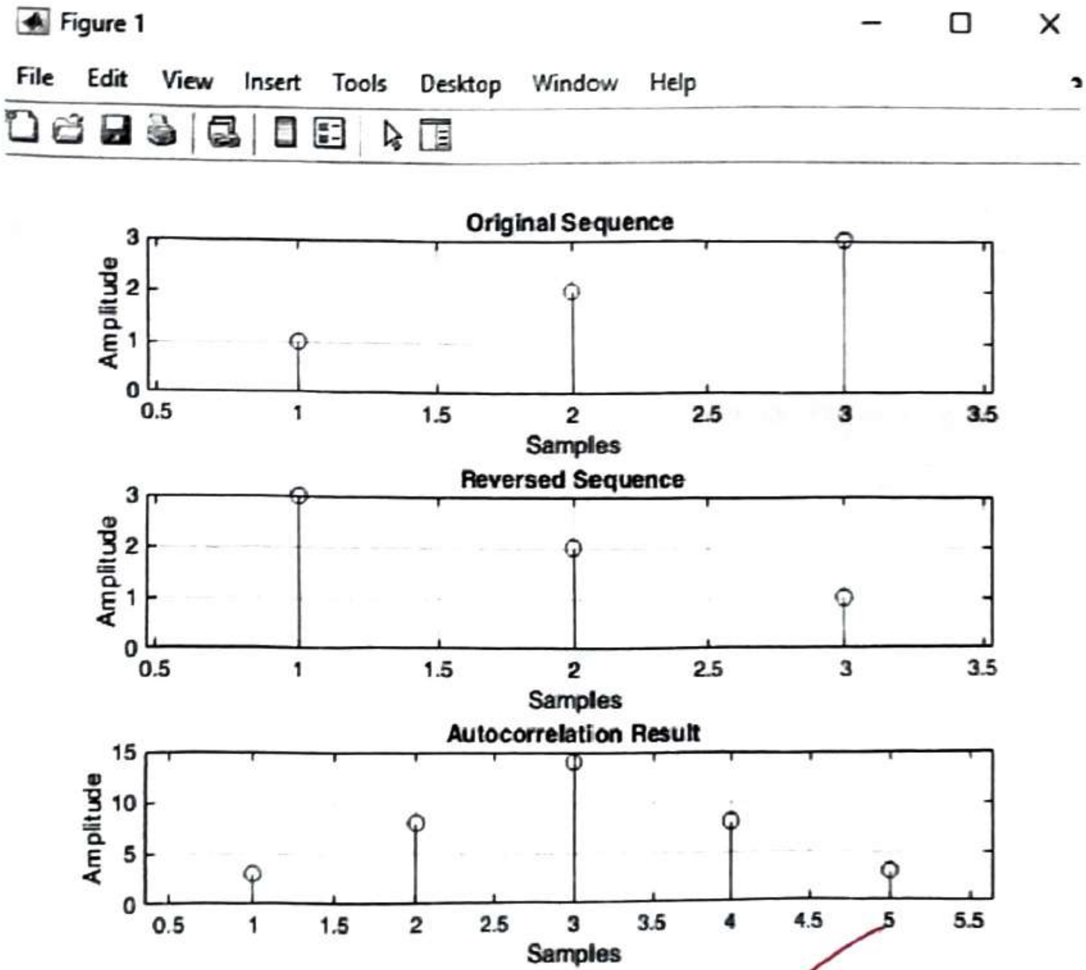
```
clc;
clearall;
closeall;
%input sequence
X=input("EnterthesequenceX:");
%Plottheinputsequence
subplot(3,1,1);
stem(X);
title('OriginalSequence');
xlabel('Samples');
ylabel('Amplitude');
grid on;
%Reversethesequence Y
= fliplr(X); subplot(3,1,2);
stem(Y);
title('Reversed Sequence');
xlabel ('Samples');
ylabel('Amplitude');
grid on;
%Computetheautocorrelationusingconvolution C
= conv(X, Y);
subplot(3,1,3);
stem (C);
title('Autocorrelation Result');
xlabel('Samples');
```

```
ylabel('Amplitude');

grid on;
```



OUTPUT:



Crosscorrelation

```
clc;
clearall;
closeall;
%Input sequences
X=input('EnterthesequenceX:');
h=input('Enterthesequenceh:');
%PlottheinputsequenceX
subplot(3,1,1);
stem(X);
title('Sequence X');
xlabel('Samples');
ylabel('Amplitude');
grid on;
%Plottheinputsequenceh
subplot(3,1,2);
stem(h);
title('Sequence h');
xlabel('Samples');
ylabel('Amplitude');
grid on;
%Reversethesequenceh Y
= fliplr(h);
%Computethecross-correlationusingconvolution C
= conv(X, Y);
%Plotthecross-correlationresult
subplot(3,1,3);
stem(C);
title("Cross-Correlation Result");
xlabel('Samples');
```

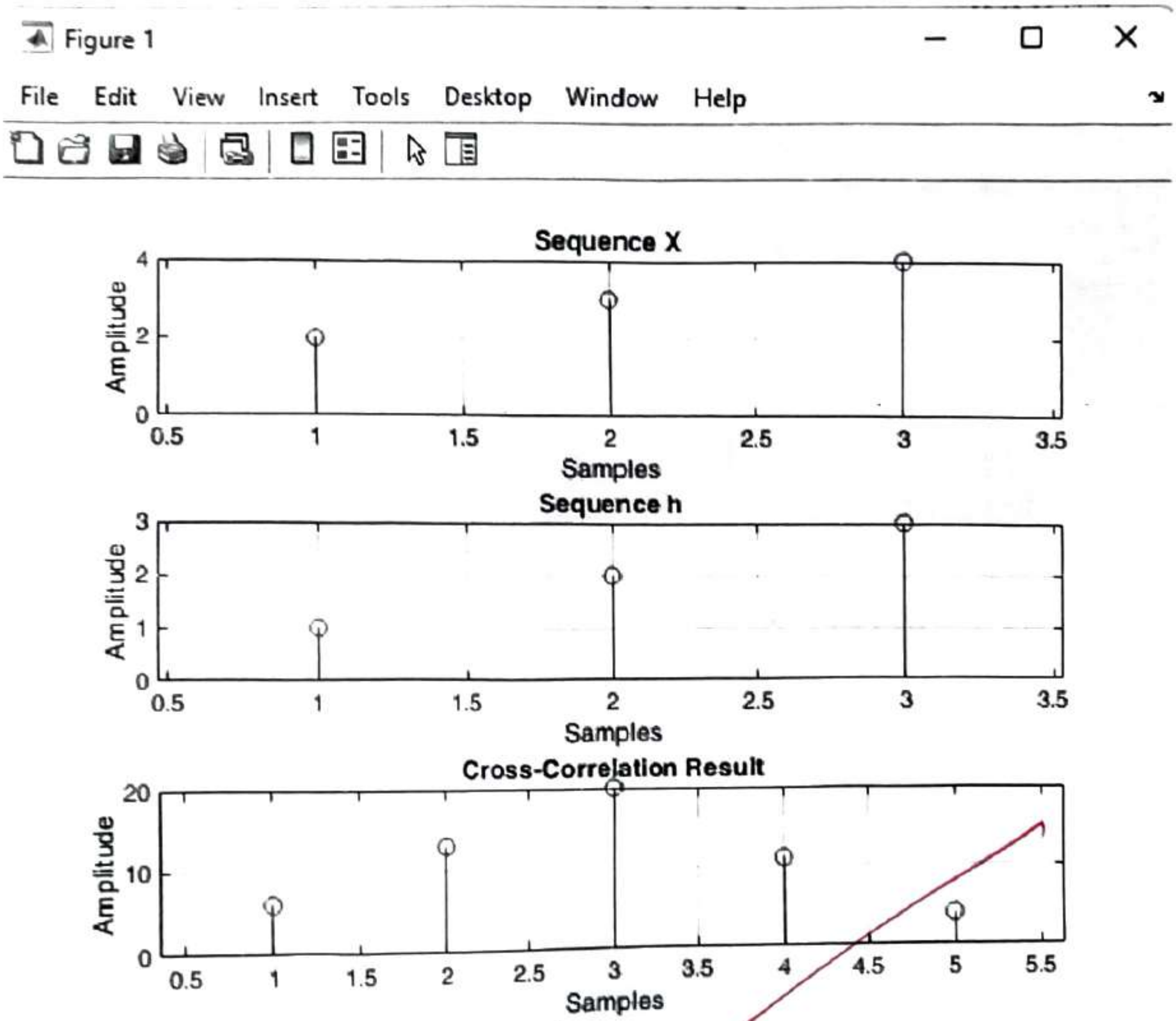
```
ylabel('Amplitude');

grid on;
```

Command Window

```
Enter the sequence X: [2 3 4]
Enter the sequence h: [1 2 3]
fx >>
```

OUTPUT:



Conclusion:

The simulation of autocorrelation confirmed the relationship between radom process's present and past values, showing that the correlation decreases as the time lag increases.

Questions:

1. **Explain the subplot in MatLab?**
2. **Explain Grid and stem?**
3. **Explain difference between auto correlation and cross correlation?**
4. **Solve the Autocorrelation for [4 5 6 7] samples and crosscorelation for [2 1 4 6] manually.**

Timely submission (10)	Journal Presentation(10)	Performance(10)	Understanding(10)	Oral(10)	Total (50)
Sub Teacher Sign:					

9/9/25

EXPERIMENT NO. 6

AIM: Simulation program to implement Binary Phase Shift Keying (BPSK) with noise.

OBJECTIVE: Write a program to study BPSK on MATLAB.

APPARATUS /SW: MATLAB Version 9.

THEORY:

Binary Phase Shift Keying

In BPSK, individual data bits are used to control the phase of the carrier. During each bit interval, the modulator shifts the carrier to one of two possible phases, which are 180 degrees or π radians apart. This can be accomplished very simply by using a bipolar baseband signal to modulate the carrier 's amplitude, as shown in Figure . The output of such a modulator can be represented mathematically as

$$x(t) = R(t)\cos(\omega_c t + \theta)$$

where $R(t)$ is the bipolar baseband signal, ω_c is the carrier frequency, and θ is the phase of the unmodulated carrier. If the output of the modulator is to be represented in complex-envelope form referenced to the carrier frequency, the modulated signal is given as

$$\tilde{x}(t) = I(t) + jQ(t)$$

where

$$\begin{aligned} I(t) &= R(t)\cos\theta \\ Q(t) &= R(t)\sin\theta \end{aligned}$$

In the special case of $\theta = 0$, Eq. (9.3.2) reduces to

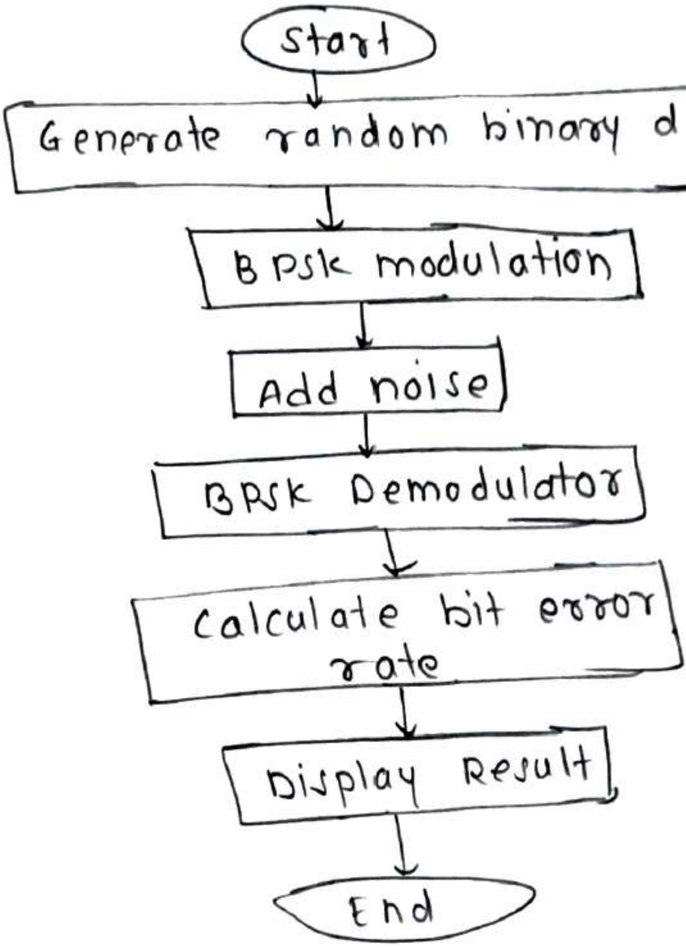
$$\tilde{x}(t) = R(t)$$

and the real-valued baseband signal can be used directly as the complex-envelope representation of the modulator output. However, to allow for subsequent phase shifting, the signal's complex-envelope representation should always be implemented as a complex-valued signal. For the special case of $\theta = 0$, the imaginary part of the complex signal is simply set to zero.

BPSK Modulator:

For all but the highest data rates, it is usually sufficient to model the multiplier in Figure 9.18 as ideal, with all of the modulator's nonideal behavior being attributed to degradations of the baseband data waveform. Two different BPSK models are provided on the Web site. The model `BpskBandpassModulator`, summarized in Table 9.8, implements Eq. (9.3.1) to produce a real-valued bandpass output signal. The file `bpsk_mod.cpp` contains the model `BpskModulator`, summarized in Table 9.9, which produces a complex-valued lowpass output signal.

Flowchar



Start
Generate random binary data
BPSK modulation
Add noise
BPSK Demodulator
Calculate bit error rate
Display Result
End

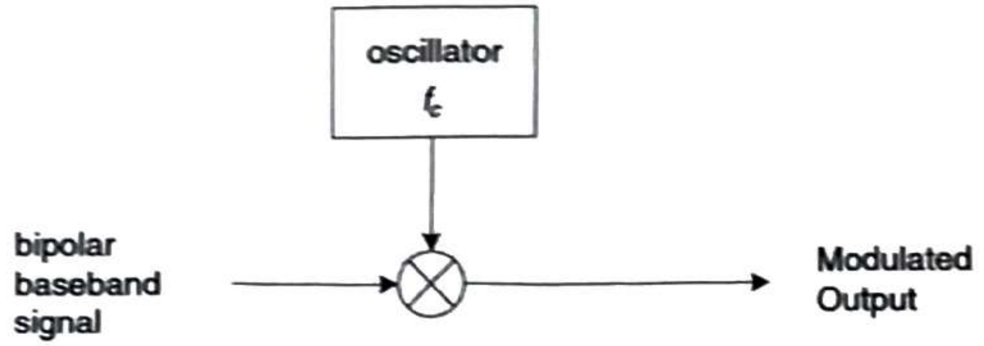


Figure 9.18 BPSK modulator.

BPSK Demodulation:

A correlation receiver for BPSK is shown in Figure 9.19. The modulated signal is multiplied by the recovered carrier, and this product is integrated over a bit interval. If the integration result is positive, the received bit is deemed to be 1; if the integration result is negative, the received bit is deemed to be 0. The BPSK demodulator models provided on theWeb site include only those functions shown inside the dotted box of the figure. Carrier recovery and clock recovery are provided by separate model, summarizes the model `BpskBandpassDemod`, which accepts as input a real-valued bandpass input signal. The recovered carrier input to the model is in the form of a real-valued sinusoid, and the recovered clock input to the model is in the form of an integer-valued sequence that has zero values everywhere except at the sampling instants corresponding to the end of each bit interval.

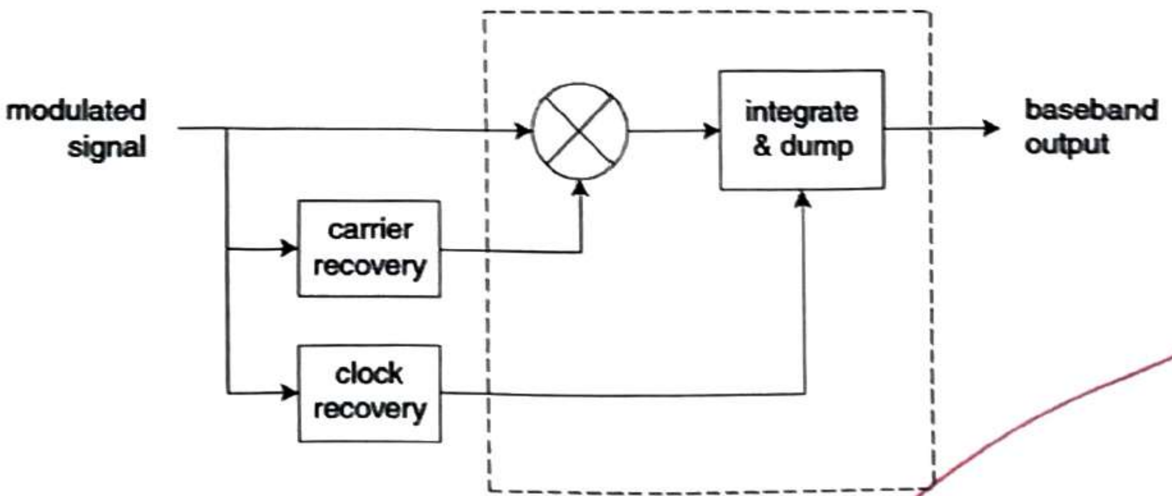


Figure 9.19 Correlation receiver for BPSK.

input a complex envelope representation of the modulated signal. The recovered carrier input to the model is in the form of a real-valued signal that represents the instantaneous phase of the recovered carrier. As it is for the bandpass model, the recovered clock input is in the form of an integer-valued sequence that has zero values everywhere except at the sampling instants corresponding to the end of each bit interval.

Spectrum of BPSK:

Algorithm

1) start

2) set parameters: Define the no of bits & the sig to noise ratio in dB

3) Generate random binary Data

4) BPSK modulation

5) Add Guassian Noise

6) BPSK Demodulation

7) Calculate bit error Rate

8) Display results

9) END

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BPSK

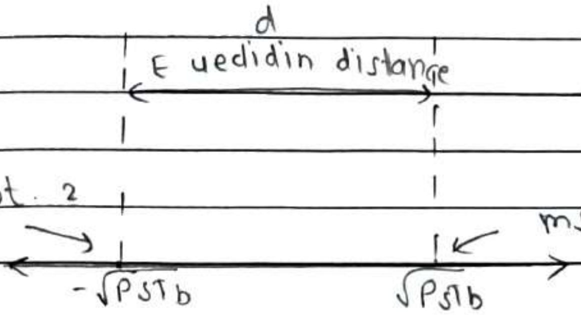
```
clc;
clearall;
closeall;
%Timevector t
= 0:0.001:1;
%Input parameters
fc=input('Enterfrequencyofcarriersinewave:'); fm
= input('Enter message frequency: ');
amp=input('Enterthecarrierandmessagesignalamplitude:');
%Messagesignal(squarewave) m
= square(2*pi*fm*t);
subplot(3,1,1);
plot(t,m,'LineWidth', 1.5);
xlabel('Time (s)');
ylabel('Amplitude');
title('MessageSignal(SquareWave)'); grid
on;
%Carriersignal(sinewave) C=
amp*sin(2*pi*fc*t); subplot
(3,1,2);
plot(t,C,'LineWidth',1.5);
xlabel ('Time (s)');
ylabel('Amplitude');
title('CarrierSignal(SineWave)'); grid
on;
%BPSKmodulatedsignal x=C.*
m;
```

1) * Mathematical expression of BPSK

$$s(t) = \sqrt{\frac{2E_b}{T_b}} \cos\left(2\pi f_c t + \pi(1-b_k)\right], \quad 0 \le t < T_b$$

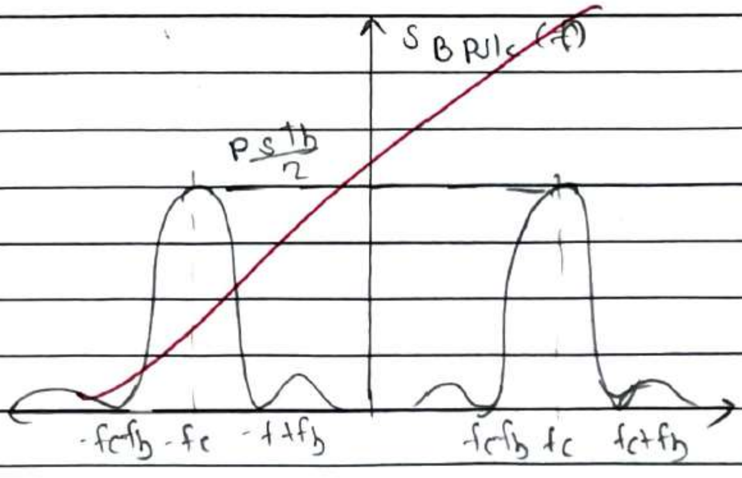
where, E_b = energy per bit
T_b = bit duration
f_c = carrier freq^n
$b_k \in 0, 1$ is the binary bit.

2) Draw signal space diagram for BPSK

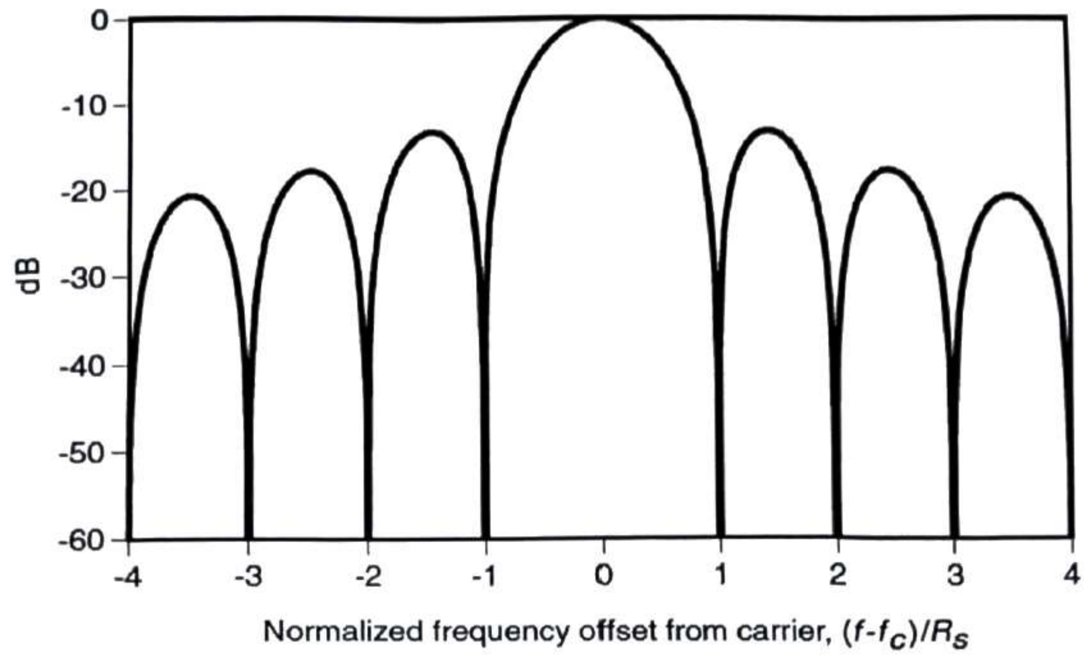


$$V_{BPSK}(t) = +\sqrt{P_s T_b}\, u_1(t) \text{ or } -\sqrt{P_s T_b}\, u_1(t)$$

3) Spectrum of BPSK



$BW = f_b$



Flowchart: Draw on blank page

Algorithm: Draw on blank page

Program: Attach the Printout of Program

Input, Output, Result: Attach the printout of Input Output and Result.

Conclusion:

The simulation successfully implemented BPSK modulation and demodulation in the presence of noise. Results showed reliable data recovery, demonstrating BPSK's robustness and error performance under noisy channel conditions.

Questions:

Write mathematical expression of BPSK?

Draw a signal space diagram of BPSK?

Draw spectrum of BPSK?