Nutan Maharashtra Vidya Prasarak Mandal's

NUTAN MAHARASHTRA INSTITUTE OF ENGINEERING AND TECHNOLOGY

Department of
Electronics & Telecommunication Engineering

LABORATORY MANUAL

SUBJECT: Digital Communication Laboratory

[SUBJECT CODE: 304186]

CLASS: T.E. E&TC

YEAR: 2025-26

PREPARED BY:
Dr. Neeta P.Karhadkar

APPROVED BY:

H.O.D. [E&TC]

Vision and Mission of the Institute

1. **Vision of the Institute-**To be a notable institution for providing quality technical education, ensuring ethical, moral, and holistic development of students.
2. **Mission of the Institute**- To nurture engineering graduates with highest technical competence, professionalism and problem solving skills to serve the needs of industry and society.

Vision and Mission of the Department

Department Vision:

To be a renowned department of Electronics and Telecommunication engineering for providing quality technical education through holistic development of the students.

Department Mission:

3. To impart quality technical education for students with continuous upgraded teaching learning process.
4. To enhance employability and entrepreneurship through Industry Institute association.
5. To enhance the research competency in students by adapting state of art technology in Electronics and Communication Engineering.
6. To inculcate the needs of profession for the society.

Program Educational Objectives (PEOs):

1. To provide graduates with a professional career in Electronics, Communication, and allied disciplines.
2. To develop managerial and entrepreneurial skills among the students to solve societal problems.
3. To impart analytical skills in order to develop a multidisciplinary approach to relate engineering issues and innovations.
4. To inculcate effective communication skills, teamwork spirit and professional ethics in students to meet employer needs at large and prepare them for higher studies.

Program Outcomes

1. **Engineering knowledge**:

Graduates can apply the knowledge of mathematics, science, engineering fundamentals and an engineering specialization to Civil Engineering related problems.

2. **Problem analysis**:

An ability to identify, formulate, review research literature, and analyse Civil engineering problems reaching substantiated conclusions using principles of mathematics and engineering sciences.

3. **Design/development of solutions**:

An ability to plan, analyse, design, and implement engineering problems and design system components or processes to meet the specified needs.

4. **Conduct investigations of complex problems**:

An ability to use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage**:

An ability to apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

6. **The engineer and society**:

An ability to apply contextual knowledge to assess societal, legal issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability**:

An ability to understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics**:

An ability to apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and teamwork**:

An ability to function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings to accomplish a common goal.

10. **Communication**:

An ability to communicate effectively on engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation and make effective presentations.

11. **Project management and finance**:

Ability to demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning**:

An ability to engage in independent and life-long learning in the broadest context of technological change.

Program Educational Objectives (PEOs)

1. To provide graduates with a professional career in Electronics, Communication and allied disciplines.
2. To develop managerial and entrepreneurial skills among the students to solve societal problems.
3. To impart analytical skills in order to develop a multidisciplinary approach to relate engineering issues and innovations.
4. To inculcate effective communication skills, teamwork spirit and professional ethics in students to meet employer needs at large and prepare them for higher studies

Program Specific Outcomes (PSOs)

PSO1: An ability to apply design and development of complex system in the areas of signal processing, Semiconductor Technologies, Communication, Embedded and Power System.

PSO2: Demonstrate proficiency in the use of Software and Hardware for the need of Industry and society.

Course Outcomes (CO)

CO1	Implementation of BFSK and BPSK, QPSK transmitter & receiver using hardware setup
CO2	Implementation of DSSS transmitter and receiver and Analyze Baseband receiver performance in presence of Noise using suitable hardware setup.
CO3	Simulation of Performance of BPSK, M-ary PSK
CO4	Simulation of random processes and Analyze statistical parameters of the random process
CO5	Simulation of Source Coding technique and Entropy Techniques.
CO6	Simulation of different types of coding techniques.

List of Experiments with Mapping

Sr. No.	Name of the Experiment	CO mapping	Level of CO mapping
1.	Study of BFSK transmitter & receiver using suitable hardware setup/kit		
2.	Study of BPSK/QPSK transmitter & receiver using suitable hardware setup/kit.		
3.	Study of DSSS transmitter and receiver using suitable hardware setup/kit.		
4.	Study of FHSS transmitter and receiver using suitable hardware setup/kit.		
5.	Simulation study of random processes. Find various statistical parameters of the random process		
6.	Simulation Study of performance of BPSK receiver in presence of noise.		
7.	Simulation study of Performance of M-ary PSK .		
8.	Simulation study of Source Coding technique.		
9	Simulation Study of cyclic codes.		
10	Simulation Study of Convolutional codes/LBC		

Rubrics for Evaluation

Sr. No	Evaluation Criteria	Marks for each Criteria	Rubrics
1	Timely submission	5 or 10	Punctuality reflects the work ethics. Students should reflect that work ethics by completing the lab assignments and reports in a timely manner .
2	Journal Presentation	5 or 10	Students are expected to prepare the journal. The journal presentation of the course should be complete, clear, and understandable.
3	Performance	5 or 10	After performance, the students should have good knowledge of the experiment.
4	Understanding	5 or 10	The student should be able to explain methodology used for designing and developing the program/solution. Student should clearly understand the purpose of the assignment and its outcome.
5	Oral	5 or 10	The student should be able to answer the questions related to the lab assignments.

EXPERIMENT NO. 1

AIM: To Study Generation & Detection of BFSK.

OBJECTIVE: Study of working of generation of Binary Frequency Shift Keying (BFSK) with waveforms and demodulation at Receiver.

APPARATUS : FSK Modulator and Demodulator Kit, CRO, DSO.

Range of DSO=

Range of CRO=

THEORY:-

In binary frequency shift keying (BFSK), the frequency of a sinusoidal carrier is shifted between two discrete values. One of these frequencies(fH)represents a binary "1"and other value represents(fL) a binary "0". There is no change in amplitude and phase of the carrier. The BFSK generator consists of two oscillators which produce carriers at frequencies corresponding to binary "1" and binary "0". The oscillator outputs are applied to the inputs of the multipliers (balance modulators). The other input to the multipliers is given by the digital data generator. The multiplier outputs are then added together to get the BFSK signal. In the de modulators the data is regenerated to get the raw data. This signal is then applied to the decision device which compares it with the threshold level to zero volts. Then the receiver decides that a "1" was transmitted or a zero.

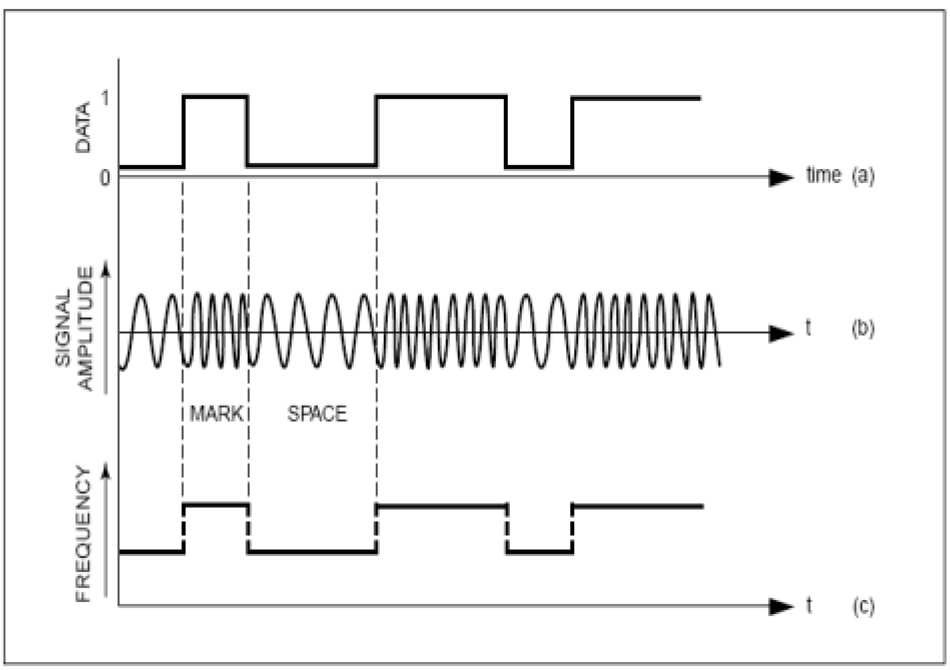
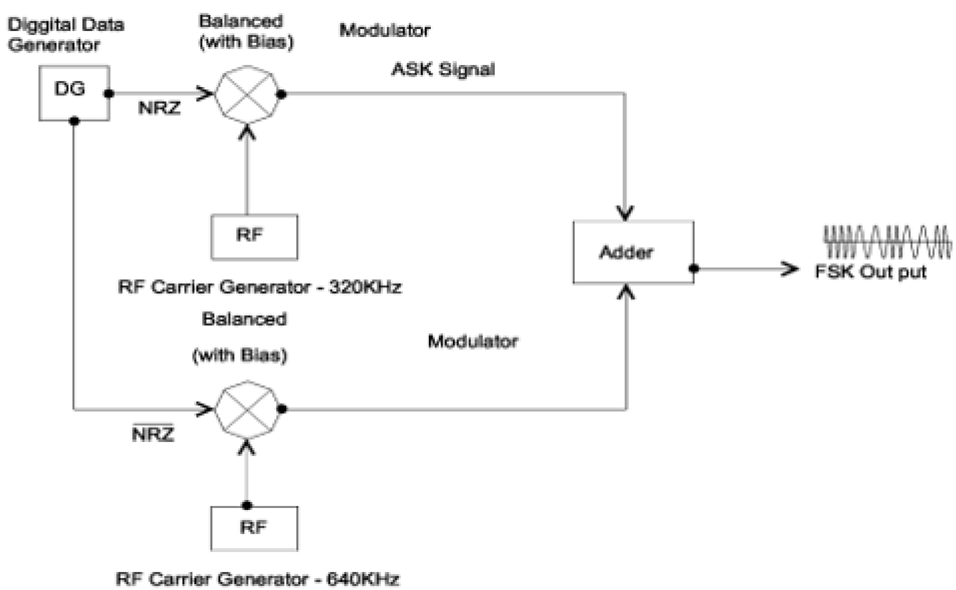


Figure 1. FSK modulation. Binary data (a) frequency modulates the carrier to produce the FSK signal (b) which has the frequency characteristic (c).

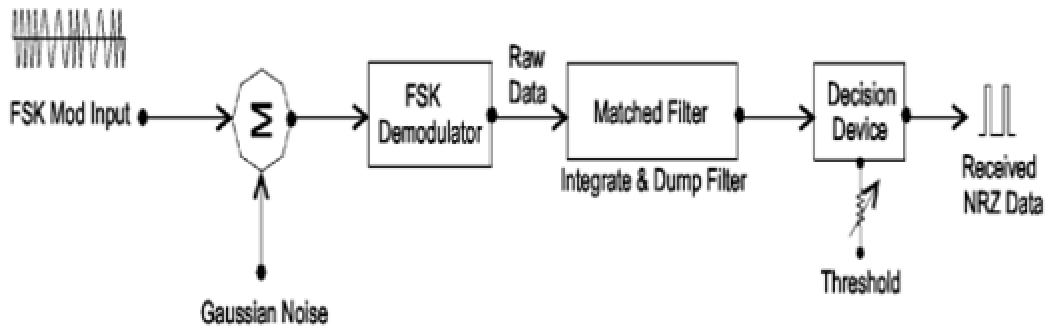
In Frequency shift keying, the carrier frequency is shifted (i.e. from one frequency to another) corresponding to the digital modulating signal. If the higher frequency is used to represent a data '1' & lower frequency a data '0', the resulting FSK waveform appears. Thus Data =1 High Frequency Data =0 Low Frequency It is also represented as a sum of two ASK signals. The two carriers have different frequencies & the digital data is inverted. The demodulation of FSK can be carried out by a PLL. As known, the PLL tries to 'lock' the input frequency. It achieves this by generating corresponding O/P voltage to be fed to the VCO, if any frequency deviation at its I/P is encountered. Thus the PLL detector follows the frequency changes and generates proportional O/P voltage. The O/P voltage from PLL contains the carrier components. Therefore to remove this, the signal is passed through Low Pass Filter. The resulting wave is too rounded to be used for digital data processing. Also, the amplitude level may be very low due to channel attenuation.

A.FSK MODULATION:



Frequency-shift keying modulation is a form of frequency modulation (FM) where the modulating waveform is a digital waveform. In this system the amplitude of the carrier is constant while its frequency is switched directly from one frequency to another by the modulating signal. Although there could be more than two frequencies involved in an FSK signal, in this experiment the message will be a binary bit stream, and so only two frequencies will be involved.

(B) FSK DEMODULATOR (PLL DETECTOR)



Theory of spectrum & Bandwidth Calculation:

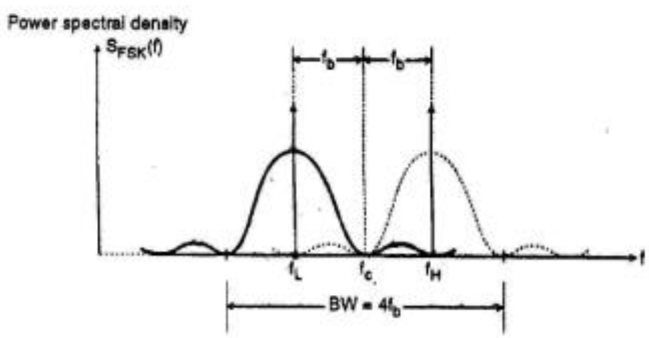


Fig.3 : Spectrum of BFSK

PROCEDURE:-

1.Connect CRO Channel-1 at Carrier Clock (Ck) socket and observe it.

2.Connect CRO Channel-1 at Bit Clock (Bk) socket and observe it.

3.Connect CRO Channel-1 at NRZ DATA socket and observe it.

4.Connect CRO Channel-1 at NRZ DATA socket and observe it.

5.Connect CRO Channel at RF Carrier socket (in carrier generator section) for frequency 320kHz

6.Connect CRO Channel-1 at NRZ DATA (NRZ) socket.

7.Connect CRO Channel 2 at the output of balance modulator-1. Observe ASK output.

8. Similarly connect CRO Channel 2 at the output of balance modulator-2. Observe ASK output.

9. Connect CRO channel-2 at output of adder. Observe FSK output With respect to NRZ..

10. Observe recovered raw data signal at output of FSK demodulator.

11. Observe received pure NRZ data at the output data square.

GRAPHS:

Plot the Graph of each test points on graph paper.

OBSERVATION TABLE:

Test points/Signals	Frequency(Hz)	Voltage(V)
Data sequence		
NRZ Data sequence NRZ		
RF Carrier 1		
RF Carrier2		
Output of BM-1		
Output of BM-2		
Output Of Adder		
Output of Demodulator		

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.

Conclusion: -

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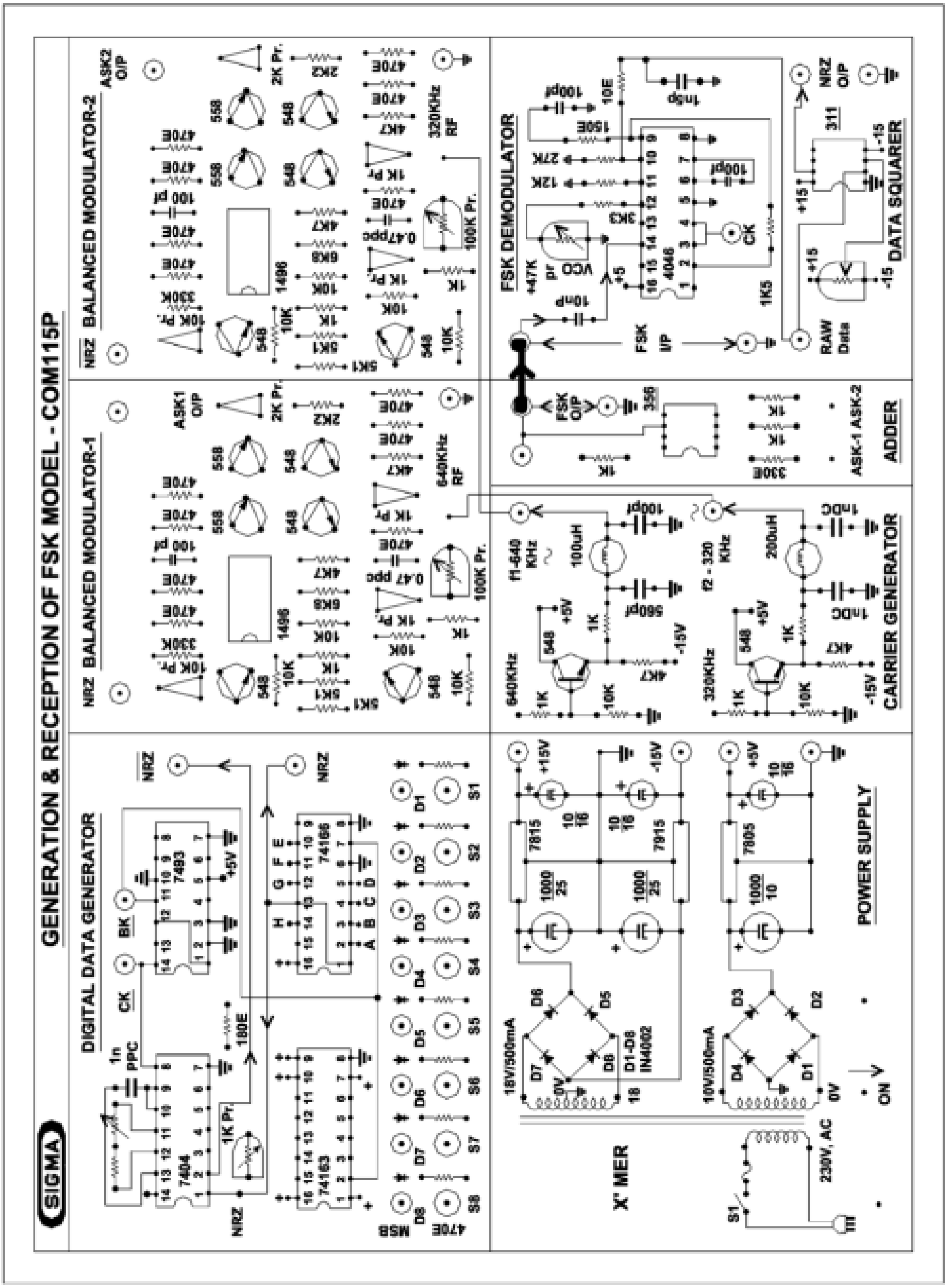
Questions:

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:					


SIGMA
GENERATION & RECEPTION OF FSK MODEL - COM115P
DIGITAL DATA GENERATOR
NRZ BALANCED MODULATOR-1
NRZ BALANCED MODULATOR-2
FSK DEMODULATOR
CARRIER GENERATOR
ADDER
DATA SQUARER
POWER SUPPLY
X' MER

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 '$\Phi$' 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.

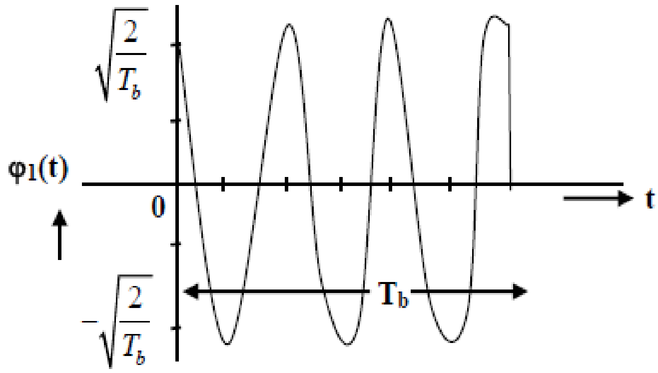


Fig. 5.24.1: (a) *Sketch of the basis function $\varphi_1(t)$ for BPSK modulation*

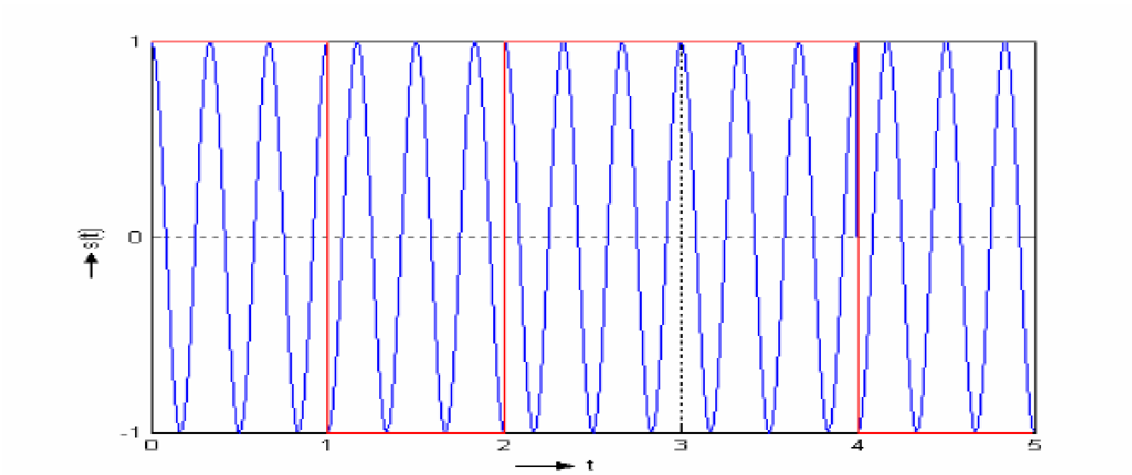


Fig. 5.24.1: (b) *BPSK modulated waveform for the binary sequence 10110. Note that the amplitude has been normalized to ± 1, as is a common practice.*

Fig. 5.24.1: (c) shows the signal constellation for binary PSK modulation. The two pints are equidistant from the origin, signifying that the two signals carry same energy.

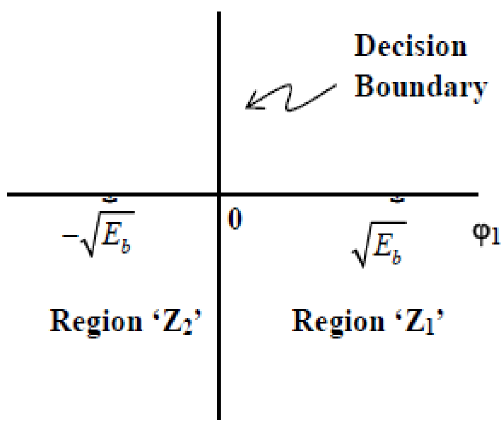


Fig. 5.24.1: (c) *Signal constellation for binary PSK modulation. The diagram also shows the optimum decision boundary followed by a correlation receiver*

Fig. 5.24.2 shows a simple scheme for generating BPSK modulated signal without pulse shaping. A commonly available balanced modulator (such as IC 1496) may be used as the product modulator to actually generate the modulated signal. The basis function $\varphi_1(t)$, shown as the second input to the product modulator, can be generated by an oscillator. Note that the oscillator may work independent of the data clock in general.

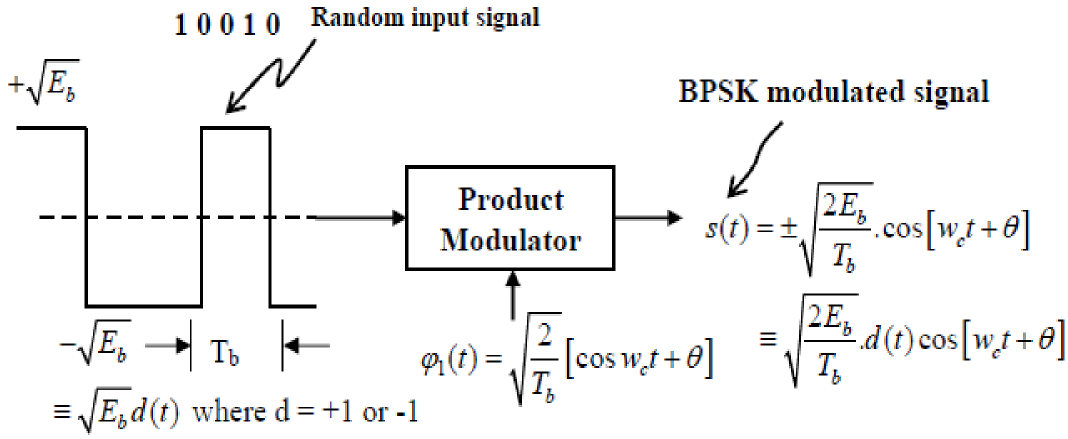


Fig. 5.24.2 *A simple scheme for generating BPSK modulated signal. No pulse-shaping filter has been used.*

Fig. 5.24.3 presents a scheme for coherent demodulation of BPSK modulated signal following the concept of optimum correlation receiver. The input signal r(t) to the demodulator is assumed to be centered at an intermediate frequency (IF). This real narrowband signal consists of the desired modulated signal s(t) and narrowband Gaussian noise w(t). As is obvious, the correlation detector consists of the product modulator, shown as an encircled multiplier, and the integrator. The vector receiver is a simple binary decision device, such as a comparator. For simplicity, we assumed that the basis function phase reference is perfectly known at the demodulator and hence the $\varphi_1(t)$, shown as an input to the product demodulator, is phase-synchronized to that of the modulator. Now it is straightforward to note that the signal at (A) in **Fig. 5.24.3** is:

$$r_A(t) = \left[s(t) + w(t)\right].\sqrt{\frac{2}{T_b}}.\cos\left(w_c t + \theta\right) \qquad 5.24.4$$

The signal at (B) is:

$$r_1 = \sqrt{\frac{2}{T_b}}\int_0^{T_b}\left[d(t).\sqrt{\frac{2E_b}{T_b}}.\cos(w_c t + \theta) + w(t)\right]\cos(w_c t + \theta)dt$$
$$= \sqrt{E_b}.d(t) + \sqrt{\frac{2}{T_b}}\int_0^{T_b} w(t).\cos(w_c t + \theta)dt \qquad 5.24.5$$

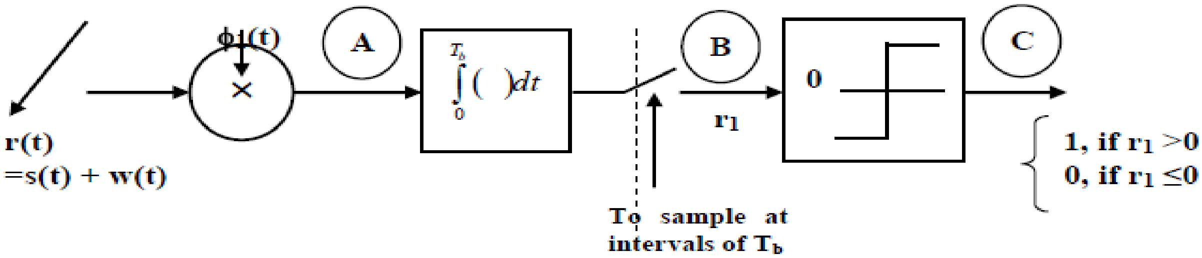


Fig. 5.24.3 *A scheme for coherent demodulation of BPSK modulated signal following the concept of optimum correlation receiver*

Note that the first term in the above expression is the desired term while the second term represents the effect of additive noise. We have discussed about similar noise component earlier in Module #4 and we know that this term is a Gaussian distributed random variable with zero mean. Its variance is proportional to the noise power spectral density. It should be easy to follow that, if d(t) = +1 and the second term in **Eq. 5.24.5** (i.e. the noise sample voltage) is not less than -1.0, the threshold detector will properly decide the received signal as a logic '1'. Similarly, if d(t) = -1 and the noise sample voltage is not greater than +1.0, the comparator will properly decide the received signal as a logic '0'. These observations are based on 'positive binary logic'.

Power Spectrum for BPSK Modulated Signal

Continuing with our simplifying assumption of zero initial phase of the carrier and with no pulse shaping filtering, we can express a BPSK modulated signal as:

$$s(t) = \sqrt{\frac{E_b.2}{T_b}}.d(t)\cos w_c t \text{, where } \quad d(t) = \pm 1 \qquad 5.24.6$$

The baseband equivalent of s(t) is,

$$\tilde{u}(t) = u_I(t) = \sqrt{\frac{2E_b}{T_b}}.d(t) = \pm g(t), \qquad 5.24.7$$

where $g(t) = \sqrt{\frac{2E_b}{T_b}}$ and $u_Q(t) = 0$.

Now, $u_I(t)$ is a random sequence of $+\sqrt{\frac{2E_b}{T_b}}$ and $-\sqrt{\frac{2E_b}{T_b}}$ which are equi-probable. So, the power spectrum of the base band signal is:

$$\rightarrow U_B(f) = \frac{2E_b.\sin^2(\pi T_b f)}{(\pi T_b f)^2} = 2.E_b.\sin c^2(T_b f) \qquad 5.24.8$$

Now, the power spectrum S(f) of the modulated signal can be expressed in terms of $U_B(f)$ as:

$$S(f) = \frac{1}{4}\left[U_B(f - f_c) + U_B(f + f_c)\right] \quad 5.24.9$$

'Fig.5.24.4 shows the normalized base band power spectrum of BPSK modulated signal. The spectrum remains the same for arbitrary non-zero initial phase of carrier oscillator.'

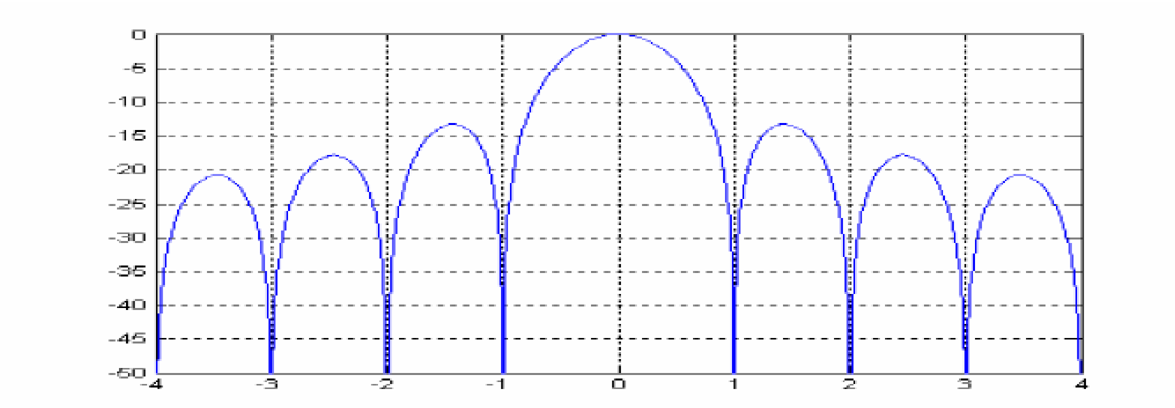


Fig.5.24.4: Normalized base band power spectrum of BPSK modulated signal

9.3.4 Properties of BPSK Signals

The power spectral density of a BPSK signal using rectangular data pulses is given by

$$P_{\mathrm{BPSK}} = \frac{E_b}{2}\left[\left(\frac{\sin\left[\pi\left(f - f_c\right)T_b\right]}{\pi\left(f - f_c\right)T_b}\right)^2 + \left(\frac{\sin\left[\pi\left(f + f_c\right)T_b\right]}{\pi\left(f + f_c\right)T_b}\right)^2\right] \quad (9.3.3a)$$

$$= \frac{E_b}{2}\left[\mathrm{sinc}^2\left(\left(f - f_c\right)T_b\right) + \mathrm{sinc}^2\left(\left(f + f_c\right)T_b\right)\right] \quad (9.3.3b)$$

$$= \frac{E_b}{2}\left[\mathrm{sinc}^2\left(\frac{f - f_c}{R_b}\right) + \mathrm{sinc}^2\left(\frac{f + f_c}{R_b}\right)\right] \quad (9.3.3c)$$

9.3.5 Error Performance

It can be shown (see [25]) that the probability of bit error for BPSK is obtained as

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right) \quad (9.3.4)$$

Observation Table:

Sr.No	Testpoints	Frequency(Hz)	Voltage(V)
1	NRZ data generator O/p		
2	Unipolar to Bipolar Convertor o/p		
3	Carrier Generator o/p		
4	Balanced Modulator o/p		
5	BPSK demodulator o/p		

Conclusion:

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

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

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.

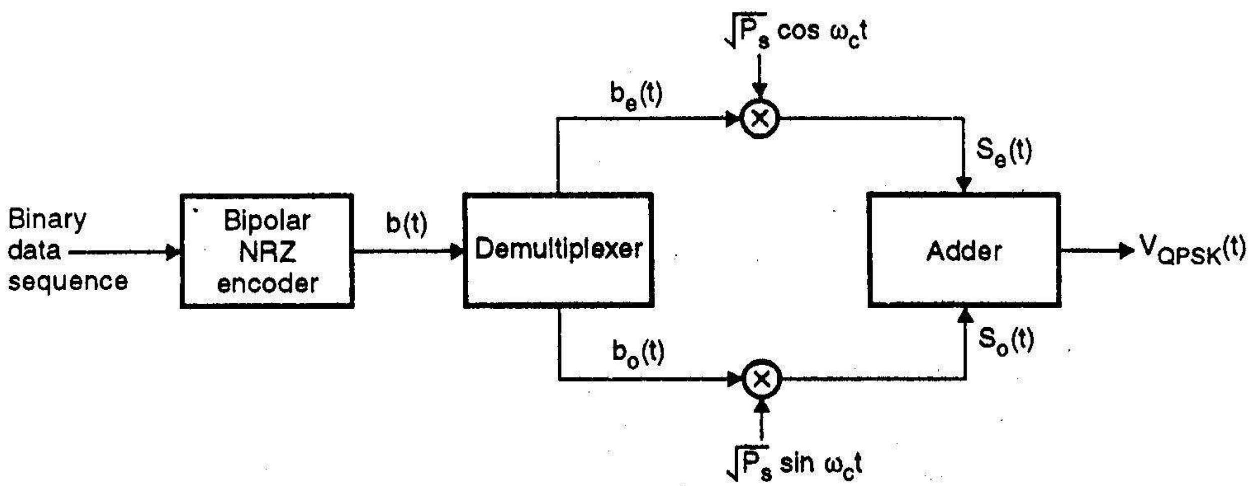
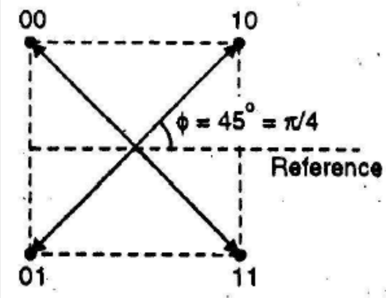


Fig.1 : An offset QPSK transmitter

The symbols and corresponding phase shifts are shown in the following table:

Sr. No	Symbol	Input successive bits		Phase shift in carrier
1	S_1	1	0	$\frac{\pi}{4}$
2	S_2	0	0	$\frac{3\pi}{4}$
3	S_3	0	1	$\frac{5\pi}{4}$
4	S_4	1	1	$\frac{7\pi}{4}$



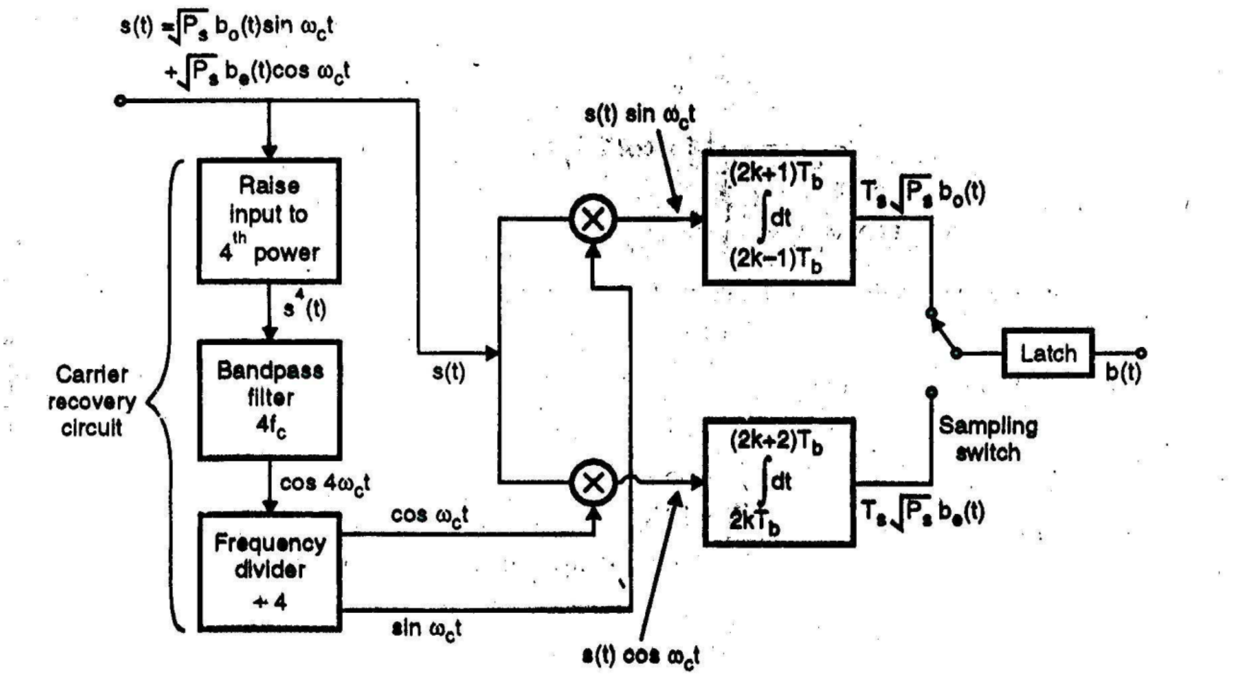


Fig. 3 : A QPSK receiver.

QPSK’ technique comes under ‘carrier modulation’ type. Here I/P to the transmitter is digital data, in between processing is in analog form & finally O/P of receiver is again digital data same as fed to transmitter.

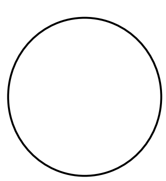
‘Q’ in ‘QPSK’ means quadrature i. e. 4, four phases of carrier are transmitted depending upon bit pattern. e.g. we know that incoming bit pattern is divided into ‘odd’ & ‘even’ bit patterns. Odd pattern is multiplied by sine wave, & even pattern is multiplied by cos wave. Sine & cos waves are 90 degree phase shifted. Now resulting two PSK’s are added & we get vector addition O/P i. e. if both odd & even pattern bits are ‘1’ we get 45 degree phase shifted carrier. If odd bit is 1 & even bit is 0 we get 135 degree phase carrier. If odd bit is 0 & even also 0 we get 225 degree. If odd bit is 0 & even bit is 1 we get 315 degree.

In QPSK , two consecutive bits are stored & for resulting four combinations (4) different phases of carrier are transmitted. By using 'D' flip-flop type arrangement incoming bit pattern is divided into two bit patterns Viz.odd pattern & even pattern, for obtaining this, basic clock whose frequency is 'fb' is divided by two, resulting odd & even clock frequencies are 'fb/2 '& they are complementary. Each bit is stored for 2Tb**.** time period.Odd pattern will have bit no. 1,3,5,7, etc. each stored for '2Tb' & even bit pattern will have bit no.2,4,6, etc. stored for '2 Tb'. Here active edges of, odd & even clocks are seperated by time 'Tb'. So out of two bits only one bit is changing (either odd or even) after each 'Tb' period but every bit is there for 2 Tb time ; so in this offset QPSK system every time phase changes by 90 degree only.

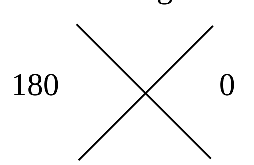
At receiver carrier is recovered from QPSK Signal itself. This is Synchronous reception. To recover carrier QPSK signal is raised to power Four by using analog multiplier. Then resulting signal is passed through Bandpass filter whose center frequency is adjusted to 4 times carrier Frequency. Then O/p of bandpass filter is divided by 4 to get carrier Frequency. In this kit IC 1496 is used as analog multiplier.

Then QPSK signal is multiplied by 'SINE & COS' carrier waves. As a result we get odd & even patterns after filtering & integrating multiplier Outputs. Now by combining these two patterns we can get original bit Patterns. This is done by using switch (analog switch).

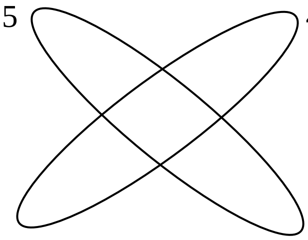
To observe QPSK, we have given two bit patterns (i. e. repeated after 5 bits.) so that on analog CRO we can observe the wave forms. Here carrier phase changes every after time 'tb' (bit period) depending upon odd & even bit combination. It is difficult to observe this on analog CRO. Details of these phase changes are shown in diagram attached. To observe QPSK we can use lissageous patterns. i. e. If we connect 'SINE' wave to one channel & 'COS' wave to the other channel & press 'XY' button of CRO we get circle on screen. (this is lissageous pattern for 90 degree phase shifted waves)



Now if we connect 'SINE' & its associated PSK signal to two channels & press 'XY' mode button we get two crossed lines.(One of 0 degree & the other for 180 degree phase)



If 'SINE' & 'QPSK' signals are connected to two channels, on 'XY' mode we get two crossed ellipses. This is because for 45 ,135 ,225 & 315 degree we get ellipse as lissageous fig.



Also at transmitter observe that 'SINE', 'COS' wave amplitudes are lesser than resulting 'QPSK' wave because of vector addition.

We are doing this complex processing to save on bandwidth requirement of the system. This can be observed on CRO also. Observe bit pattern on CRO along with odd or even bit pattern, you will come to know that odd or even bit pattern frequency is lesser than original bit pattern frequency.

Comments on carrier recovery section: -

Here we extract original carrier from transmitted QPSK signal itself. To raise QPSK signal to power 4 first we use squaring cct. & then again one more squaring cct. to raise QPSK to power 4, if we observe O/P of 1^{st} SQ. cct. its frequency is double that of original 'SINE' wave at transmitter (observe these two signals simultaneously on dual trace CRO) also O/P's of both SQ. ccts. are not exact SINE wave shape, since it contains other harmonics also. O/P of 2^{nd} SQ. cct. is having 4 times freq. that of 'SINE' to suppress other harmonics we use band pass filter whose center freq. is 4 times original 'SINE' wave freq. Then we divide this freq. by four. Since 4 possible phases are transmitted, finally we get exact 'SINE' wave but it will have 4 diff. Possible phase shifts. So we cannot use same carrier directly at receiver. This recovered carrier has to be passed through all pass N/W to match phase shift. This is not included in this kit to avoid complexity.

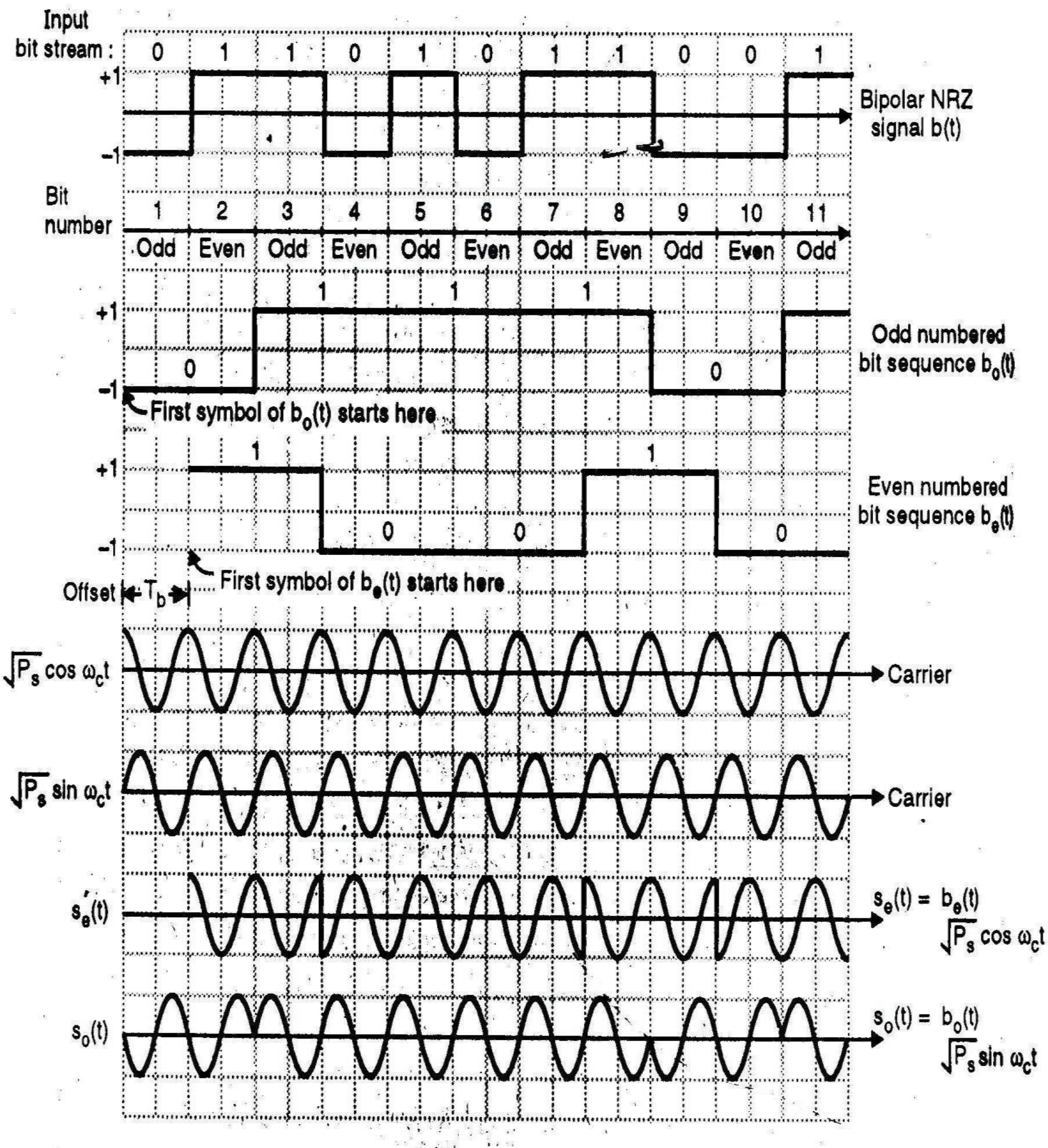


Fig. 2 : Waveforms for OQPSK transmitter

<u>Procedure: -</u>

1] Observe ‘CLK’O/p, measure its frequency. This is nothing but ‘Fb’

2] Connect ‘CLK’O/p to I/p of ‘Odd & Even CLK Gen’ observe ‘O’CLK (i. e. odd CLK) & ‘E CLK’ Frequency is ‘fb/2’.

3] Observe two patterns of pattern gen. & connect first pattern to I/p of O & E Data generator.

4] Observe ‘O Data’ (i. e. Odd Data) & ‘E’ Data along with I/p pattern on dual trace CRO.

5] Connect ‘O’ Data to ‘O’ Data pt. Pf 1496 Mul’. [I.e. 1496 Multiplier].

6] Connect ‘E. Data’ to ‘E data’ pt. of 1496 ‘Mul’.

7] observe ‘SINE & COS waves & measure their frequencies. & also observe on ‘XY’ mode of CRO.

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?

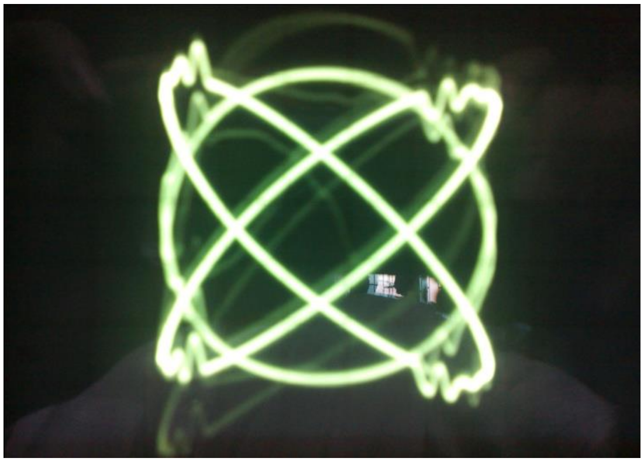
20] Observe pt. ‘C’ & ‘D’. These are odd & even bit patterns received at receiver.

Observation Table:

Sr. No	Test points	Frequency (Hz)	Voltage (V)
1	Clock signal		
2	Bit Pattern P1		
3	Bit Pattern P2		
4	Even data signal		
5	Odd data signal		
6	Cosine carrier		
7	Sine carrier		
8	O/p of QPSK modulator		
9	O/p of QPSK Demodulator		
10	Received NRZ data at Receiver.		
11			

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: -

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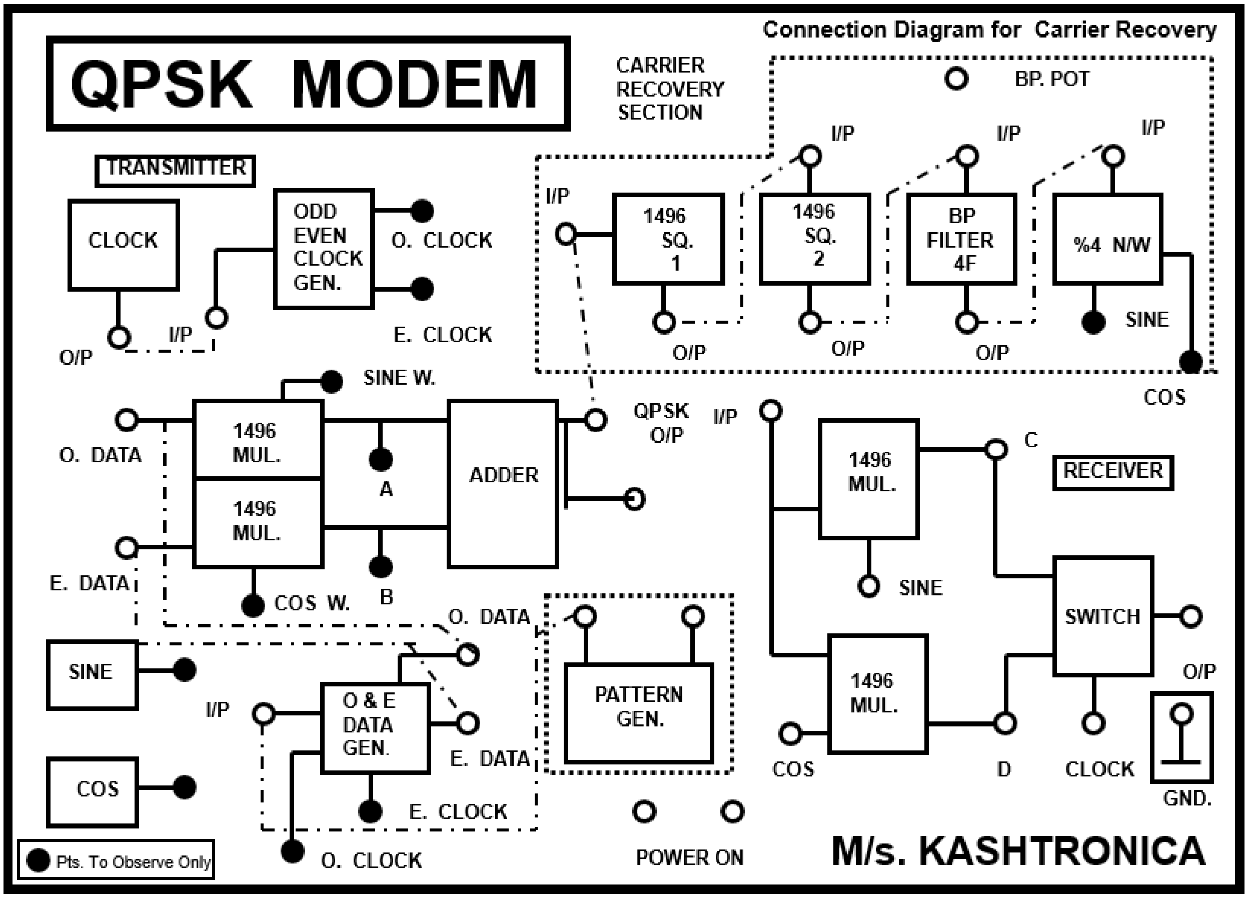
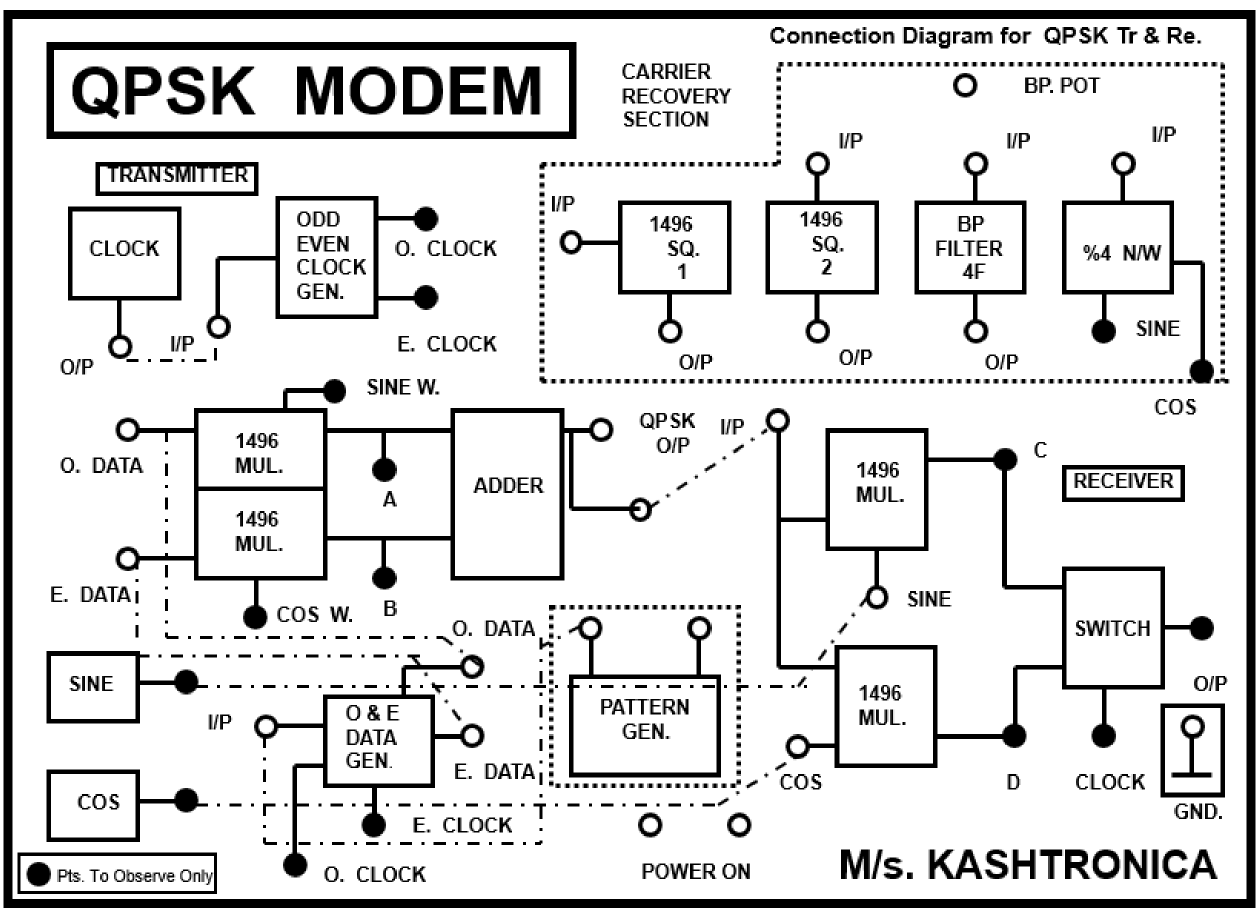
Questions:

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:					


Connection Diagram for Carrier Recovery
QPSK MODEM
CARRIER RECOVERY SECTION
BP. POT
TRANSMITTER
CLOCK
ODD EVEN CLOCK GEN.
O. CLOCK
E. CLOCK
O/P
I/P
1496 SQ. 1
1496 SQ. 2
BP FILTER 4F
%4 N/W
SINE
COS
SINE W.
O. DATA
E. DATA
1496 MUL.
ADDER
QPSK O/P
A
B
COS W.
RECEIVER
SWITCH
C
D
CLOCK
GND.
PATTERN GEN.
O & E DATA GEN.
POWER ON
Pts. To Observe Only
M/s. KASHTRONICA


Connection Diagram for QPSK Tr & Re.
QPSK MODEM
CARRIER RECOVERY SECTION
BP. POT
TRANSMITTER
CLOCK
ODD EVEN CLOCK GEN.
O. CLOCK
E. CLOCK
O/P
I/P
1496 SQ. 1
1496 SQ. 2
BP FILTER 4F
%4 N/W
SINE
COS
SINE W.
O. DATA
E. DATA
1496 MUL.
ADDER
QPSK O/P
A
B
COS W.
RECEIVER
SWITCH
C
D
CLOCK
GND.
PATTERN GEN.
O & E DATA GEN.
POWER ON
Pts. To Observe Only
M/s. KASHTRONICA

EXPERIMENT NO. 3

AIM: Study of DS-SS transmitter and receiver using suitable hardware setup/kit.

OBJECTIVE: Experimental Study of Generation &detection of DS-SS coherent BPSK & its spectrum

APPARATUS: DS-SS kit, DSO, CRO, Connecting wires.

THEORY: -

Spread Spectrum techniques were and are still used in military applications, because of their high security, and their less susceptibility to interference from other parties. In this technique, multiple users share the same bandwidth, without significantly interfering with each other. The spreading waveform is controlled by a Pseudo-Noise (PN) sequence, which is a binary random sequence. This PN is then multiplied with the original baseband signal, which has a lower frequency, which yields a spread waveform that has a noise like properties. In the receiver, the opposite happens, when the pass band signal is first demodulated, and then dispreads using the same PN waveform. An important factor here is the synchronization between the two generated sequences. In this report, I will try to illustrate the design process of such a system, and then come up with a full circuit design.

Pseudo Noise (PN): As we mentioned earlier, PN is the key factor in DS-SS systems. A Pseudo Noise or Pseudorandom sequence is a binary sequence with an autocorrelation that resembles, over a period, the autocorrelation of a random binary sequence [Rap96]. It is generated using a Shift Register, and a Combinational Logic circuit as its feedback. The Logic Circuit determines the PN words. In this design i used the so-called Maximum–Length PN sequence. It is a sequence of period 2m. 1 generated by a linear feedback shift register, which has feedback logic of only modulo–2 adders (XOR Gates). Some properties of the Maximum–Length sequences are:

In each period of a maximum–length sequence, the number of 1s is always one more than the number of 0s. This is called the Balance property.

Among the runs of 1s and 0s in each period of such sequence, one–half the runs of each kind are of length one, one–fourth are of length two, one–eighth are of length three, and so on. This is called the Run property.

The Autocorrelation function of such sequence is periodic and binary valued. This is called the Correlation property1. A block diagram of a Maximum–Length PN generator is shown in fig.1.1 with a 4–bit register and one modulo–2 adder. This has a period of 24 .1 = 15, and it was the configuration used in this design as we will show later.

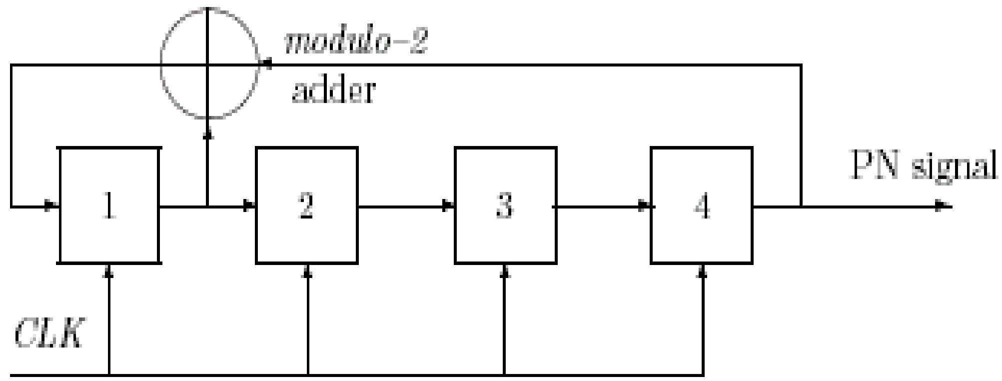


Figure 1.1: PN Generator Block Diagram

Direct Sequence - Spread Spectrum: In Direct Sequence-Spread Spectrum the baseband waveform is multiplied by the PN sequence. The PN is produced using a PN generator. Frequency of the PN is higher than the Data signal. This generator consists of a shift register, and a logic circuit that determines the PN signal. After spreading, the signal is modulated and transmitted. The most widely modulation scheme is BPSK (Binary Phase Shift Keying). The equation that represents this DS-SS signal is shown in eq. (1.1), and the block diagram is shown in fig. (1.2).

$$S_{ss} = \sqrt{\frac{2E_s}{T_s}} m(t)p(t)\cos(2\pi f_c t + \theta) \quad (1.1)$$

Where m (t) is the data sequence, p (t) is the PN spreading sequence, fc is the carrier frequency, and. is the carrier phase angle at t=0. Each symbol in m (t) represents a data symbol and has duration of Ts. Each pulse in p (t) represents a chip, and has duration of Tc. The transitions of the data symbols and chips coincide such that the ratio Ts to Tc is an integer [Rap96]. The waveforms m (t) and p (t) are shown in fig. (1.3). Here we notice the higher frequency of the spreading signal p (t). The resulting spread signal is then modulated using the BPSK scheme.

The carrier frequency fc should have a frequency at least 5 times the chip frequency p (t).

In the demodulator section, we simply reverse the process. We Demodulate the BPSK signal first, Low Pass Filter the signal, and then Dispread the filtered signal, to obtain the original message. The process is described by the following equations:

$$\hat{m}(t) = S_{ss}(t) \times \cos(2\pi f_c t + \theta)$$

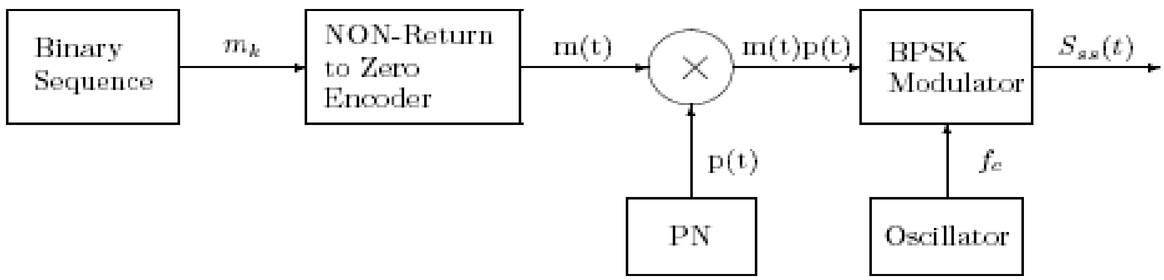


Figure 1.2: *DS-SS* Transmitter Block Diagram

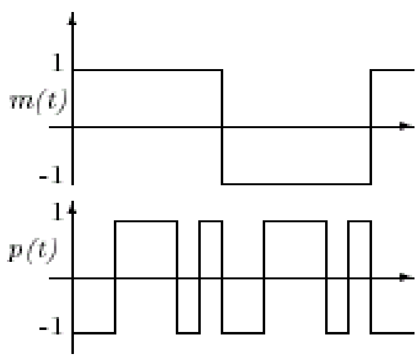


Figure 1.3: m(t) and p(t) for a *Maximum Length* PN generator, with m=3.

and we know that ,

$$\cos\alpha \times \cos\alpha = \frac{1}{2}[1 + \cos(2\alpha)]$$

this yields,

$$\hat{m}(t) = \sqrt{\frac{2E_s}{T_s}} m(t)p(t)\frac{1}{2}[1 + \cos(4\pi f_c t + \theta)] \qquad (1.3)$$

As shown in eq. (1.2) and eq. (1.3) when we multiply two cosine signals together, we will obtain two expressions, one of which has twice the frequency of the original message. And this part can be removed by a LPF. The output is mss (t) as shown in fig. (1.4). my design is based on Coherent Detection BPSK, so we don’t have to worry about carrier synchronization issues.

As for the PN sequence in the receiver, i mentioned earlier that it should be an exact replica of the one used in the transmitter, with no delays, cause this might cause severe errors in the incoming message. Again, my design is based on the idea that PN sequences are matched, and actually i am going to use the same generator for both to ease the design. There are various techniques that deals with PN delay problems and mismatches, but i am not going to encounter any in this design.

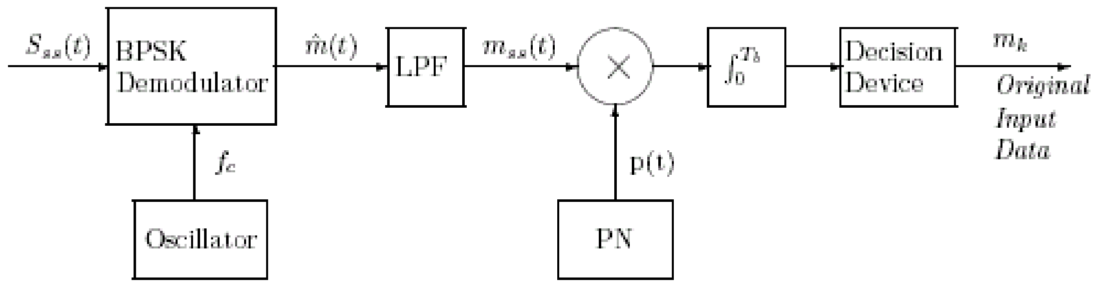


Figure 1.4: *DS-SS* receiver.

After the signal gets multiplied with the PN sequence, the signal dispreads, and we obtain the original bit signal m (t) that was transmitted. The block diagram of the receiver is shown in fig. (1.4).

This simple straightforward description of DS-SS systems, will allow us to design the Modulator / Demodulator circuits with some ease. We are going to take advantage of the block diagrams for each one of them.

Procedure: -

1] Switch on the Power supply.

2] Observe O/p of PN sequence Generator, P1, P2, on C. R. O i. e. P1 = 10000 , P2 = 10100

3] Connect O/p of PN sequence generator to PN sequence I/p of transmitter multiplier Block.

4] Connect either P1 or P2 to pattern I/p of Tran.multiplier Block.

5] Observe O/p of transmitter multiplier Block which looks like a random signal.

6] Connect O/p transmitter multiplier Block to I/p of PSK transmitter.

7] Observe O/p of PSK tran. together with carrier of PSK transmitter on XY mode of CRO. You can observe two cross lines corresponding to 0 & 180 phases, i.e. BPSK signal.

8] Connect PSK transmitter O/p to I/p of 1496 squaring circuit & **I/p2** of PSK receiver.

9] Observe O/p of 1496 squaring circuit & O/p of Bandpass filter. Adjust it properly using pot provided near B. P. Filter section.

10] Connect O/p of frequency divider to **I/p 1** of PSK receiver.

11] Observe O/p of PSK receiver & O/p of filter & comparator.

12] Connect O/p of filer & comparator to receiver multiplier Block & also connect PN Sequence to receiver multiplier Block.

13] Observe O/p of receiver miltiplier Block which is our transmitted pattern.

Observation Table:

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

Spectrum Setup

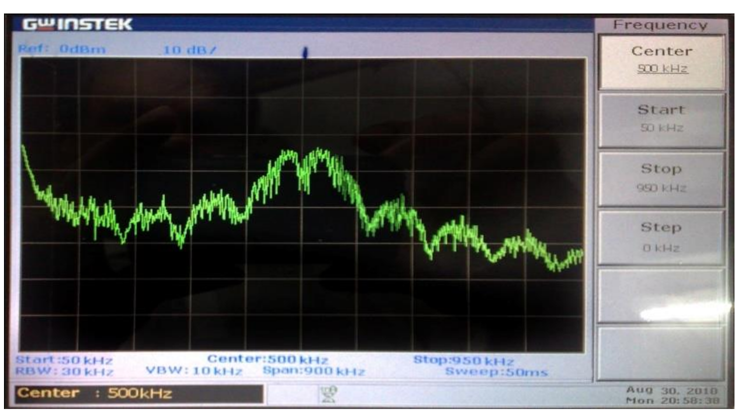
1. Center Frequency : 500 KHz
2. Span : 1000 KHz

   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



Conclusion:

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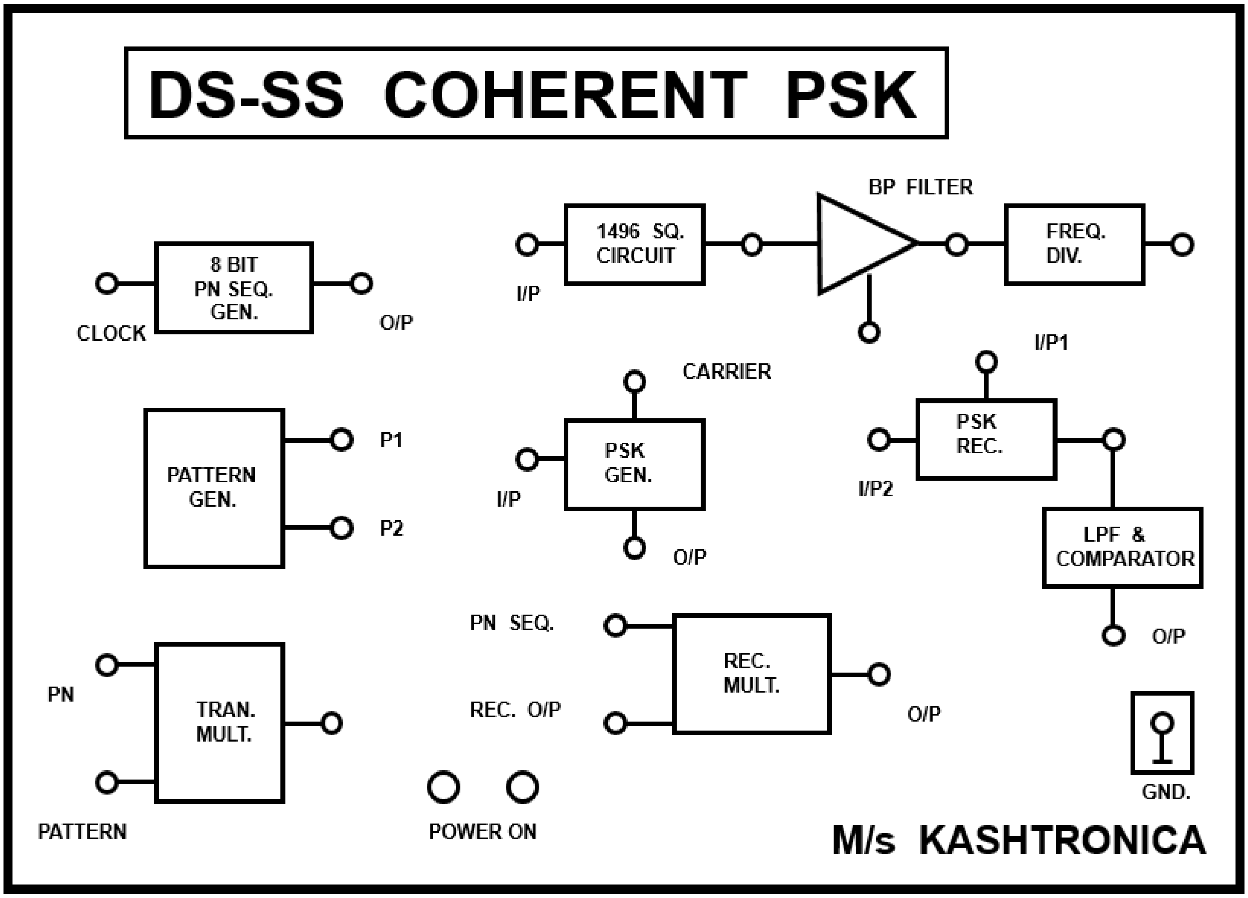
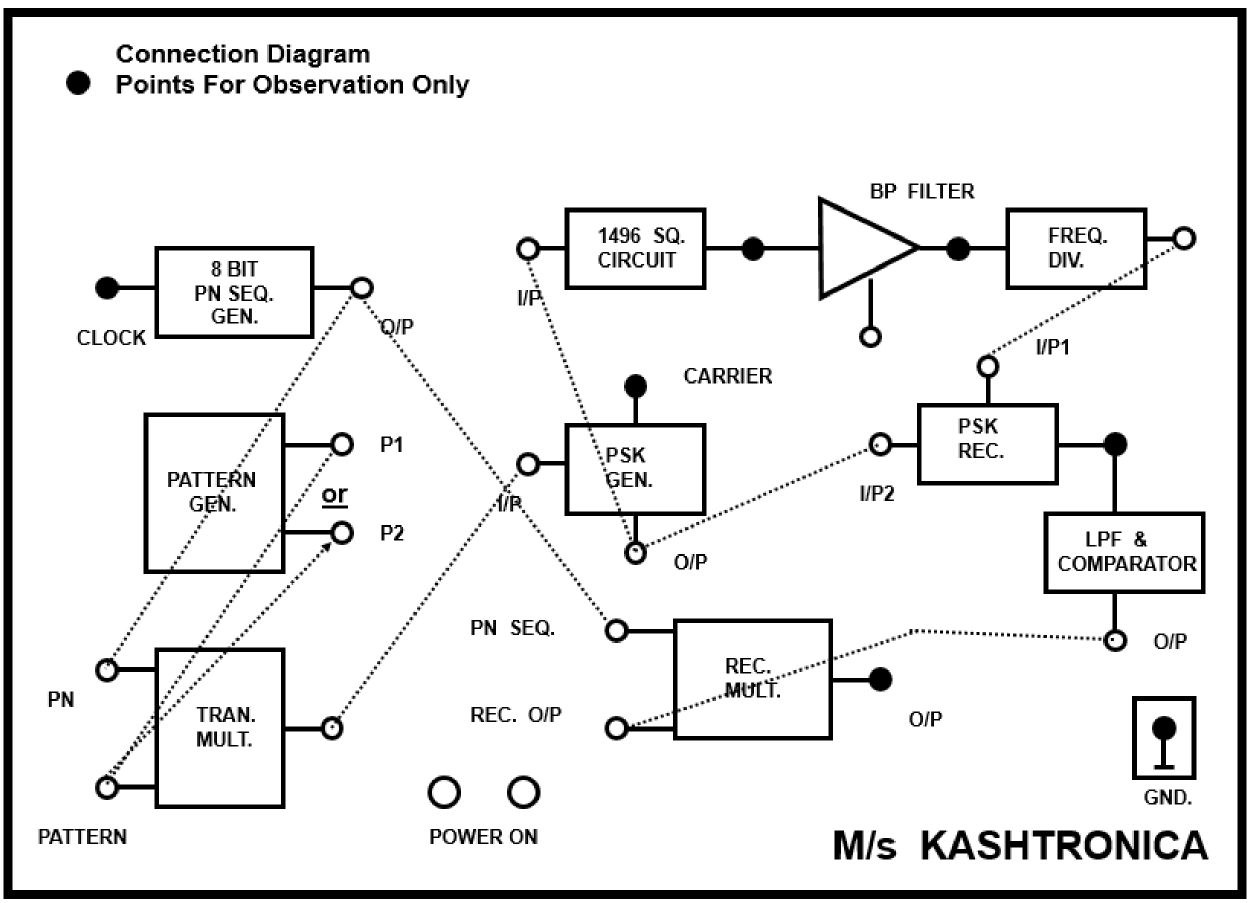
Questions:

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:					


DS-SS COHERENT PSK
8 BIT
PN SEQ.
GEN.
CLOCK
O/P
1496 SQ.
CIRCUIT
I/P
BP FILTER
FREQ.
DIV.
PATTERN
GEN.
P1
P2
CARRIER
PSK
GEN.
I/P
O/P
I/P1
PSK
REC.
I/P2
LPF &
COMPARATOR
O/P
PN
TRAN.
MULT.
PATTERN
PN SEQ.
REC. O/P
REC.
MULT.
O/P
POWER ON
GND.
M/s KASHTRONICA


Connection Diagram
Points For Observation Only
8 BIT
PN SEQ.
GEN.
CLOCK
O/P
1496 SQ.
CIRCUIT
I/P
BP FILTER
FREQ.
DIV.
PATTERN
GEN.
P1
or
P2
CARRIER
PSK
GEN.
I/P
O/P
I/P1
PSK
REC.
I/P2
LPF &
COMPARATOR
O/P
PN
TRAN.
MULT.
PATTERN
PN SEQ.
REC. O/P
REC.
MULT.
O/P
POWER ON
GND.
M/s KASHTRONICA

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 _______.

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.

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:

:

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

(2)

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

for m=1,2,…,M+1

where M is the number of lags.

Some of its properties are listed in table 1.1.

The *cross correlation* function however measures the dependence of the values of one signal on another signal. For two WSS (Wide Sense Stationary) processes x(t) and y(t) it is described by:

$$R_{xy}(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_{-T}^{T} x(t)y(t+\tau)dt \quad (3)$$

or

$$R_{yx}(\tau) = \lim_{T \to \infty} \frac{1}{T} \int_{-T}^{T} y(t)x(t+\tau)dt \quad (4)$$

where T is the observation time.

For sampled signals, it is defined as:

$$R_{yx}(m) = \frac{1}{N} \sum_{n=1}^{N-m+1} y(n)x(n+m-1) \quad (5)$$

m=1,2,3,..,N+1

Where N is the record length (i.e. number of samples).

The properties of cross correlation function are listed in table 1.2.

Autocorrelation Properties
[1] Maximum Value: *The magnitude of the autocorrelation function of a wide sense stationary random process at lag m is upper bounded by its value at lag m=0:* $$R_{xx}(0) \geq \lvert R_{xx}(k) \rvert \text{ for } k \neq 0$$
[2] Periodicity: *If the autocorrelation function of a WSS random process is such that:* $R_{xx}(m_0) = R_{xx}(0)$ *for some* m_0, *then* $R_{xx}(m)$ *is periodic with period* m_0. *Furthermore* $E[\lvert x(n) - x(n-m_0) \rvert^2] = 0$ *and x(n) is said to be mean-square periodic.*
[3] The autocorrelation function of a periodic signal is also periodic: *Example: if* $x(n) = A\sin(\omega_0 n + \varphi)$, *then,* $R_{xx}(m) = \frac{A^2}{2}\cos(\omega_0 m)$ *Therefore if* $\omega_0 = \frac{2\pi}{N}$, *then* $R_{xx}(m)$ *is periodic with periodic N and x(n) is mean-square periodic.*
[4] Symmetry: *The autocorrelation function of WSS process is a conjugate symmetric function of m:* $$R_{xx}(m) = R_{xx}^{*}(-m)$$ *For a real process, the autocorrelation sunction is symmetric:* $R_{xx}(m) = R_{xx}(-m)$
[5] Mean Square Value: *The autocorrelation function of a WSS process at lag, m=0, is equal to the mean-square value of the process:*

$$R_{xx}(0) = E\left\{|x(n)|^2\right\} \geq 0$$

[6] If two random processes x(n) and y(n) are uncorrelated, then the autocorrelation of the sum x(n)=s(n)+w(n) is equal to the sum of the autocorrelations of s(n) and w(n):

$$R_{xx}(m) = R_{ss}(m) + R_{ww}(m)$$

[7] The mean value:

The mean or average value (or d.c.) value of a WSS process is given by:

$$mean, \bar{x} = \sqrt{R_{xx}(\infty)}$$

Properties of cross correlation function
[1] $R_{xy}(m)$ *is always a real valued function which may be positive or negative.*
[2] $R_{xy}(m)$ *may not necessarily have a maximum at m=0 nor* $R_{xy}(m)$ *an even function.*
[3] $R_{xy}(-m) = R_{yx}(m)$
[4] $\left|R_{xy}(m)\right|^2 \leq R_{xx}(0)R_{yy}(0)$
[5] $\left|R_{xy}(m)\right| \leq \frac{1}{2}\left[R_{xx}(0) + R_{yy}(0)\right]$
[6] When $R_{xy}(m) = 0$*, x(n) and y(n) are Sid to be 'uncorrelated' or they are said to be statistically independent (assuming they have zeros mean.)*

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:

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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:					

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 _______.

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

$$I(t) = R(t)\cos\theta$$
$$Q(t) = R(t)\sin\theta$$

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.

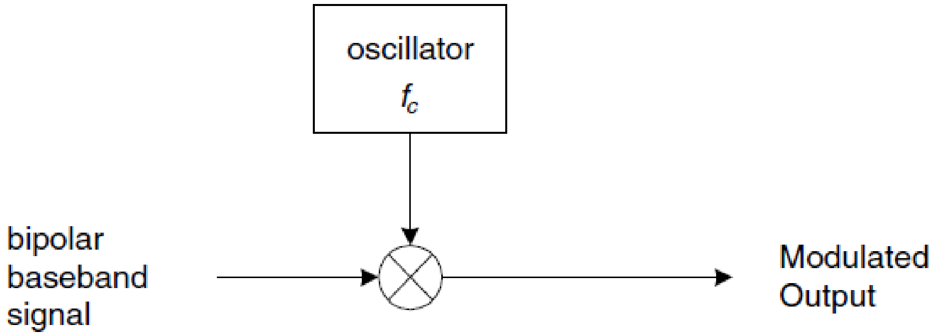


Figure 9.18 BPSK modulator.

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.

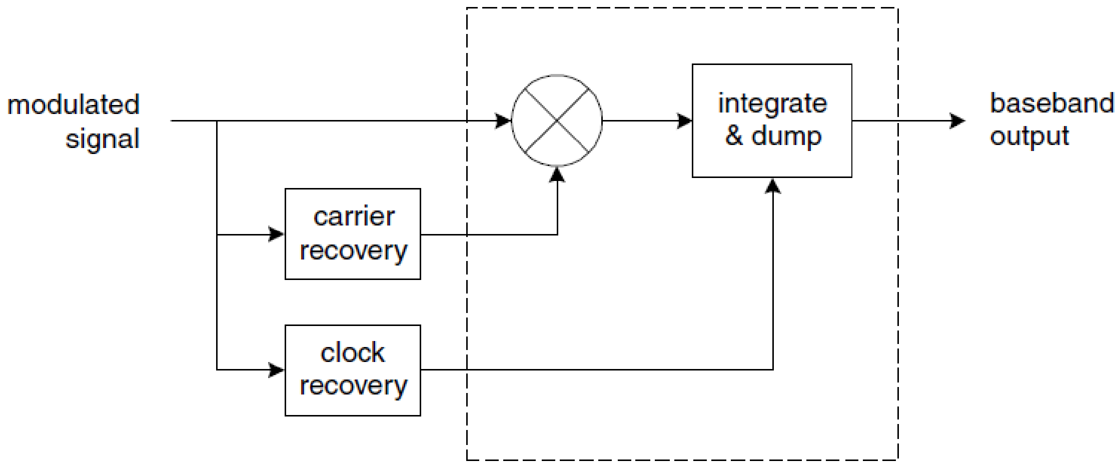
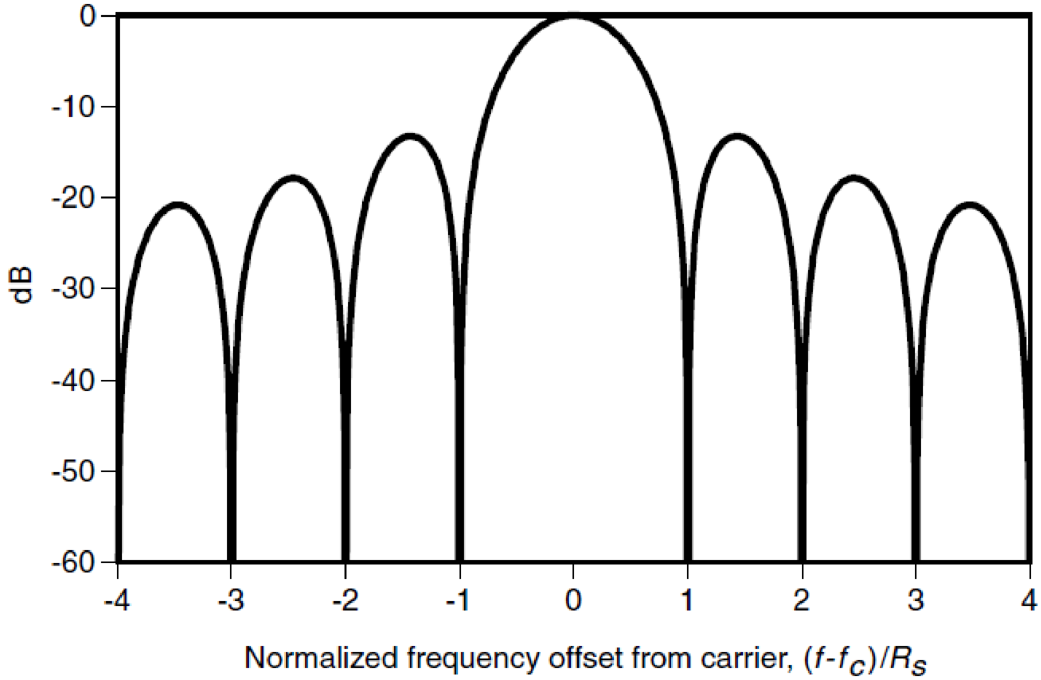


Figure 9.19 Correlation receiver for BPSK.

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:



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:

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Questions:

Write mathematical expression of BPSK?

Draw a signal space diagram of BPSK?

Draw spectrum of BPSK?

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