Band pass (Modulated) Data Communication System

Unit- 5

Binary Digital Modulations

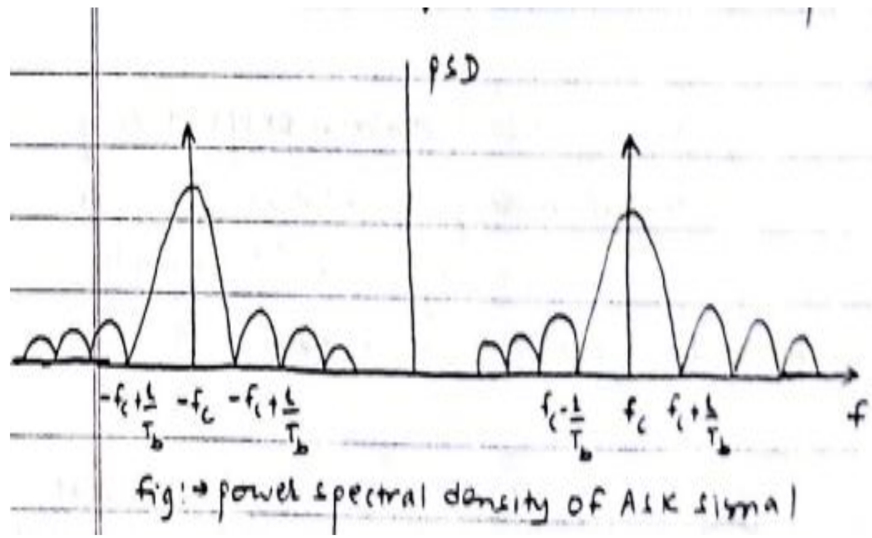
- Band pass signal is generated to transmit over transmission medium for digital communication.
- Characteristics or parameter(Amplitude, Phase, frequency) of carrier signal is changed w.r.t the digital baseband or message signal (binary signal 0 or 1) .
- Amplitude Shift Keying (ASK)
- Frequency Shift Keying (FSK)
- Phase Shift Keying (PSK)
- Other Modulation scheme employs combination of above mentioned modulation.

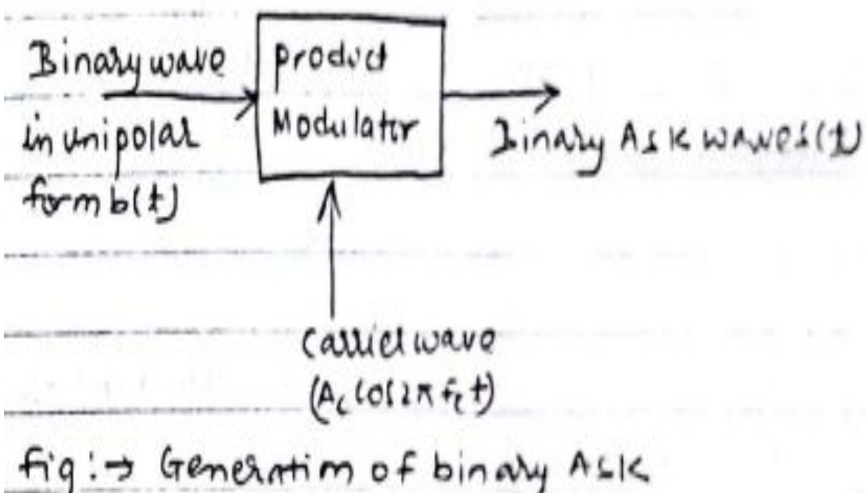
Amplitude Shift Keying(ASK)

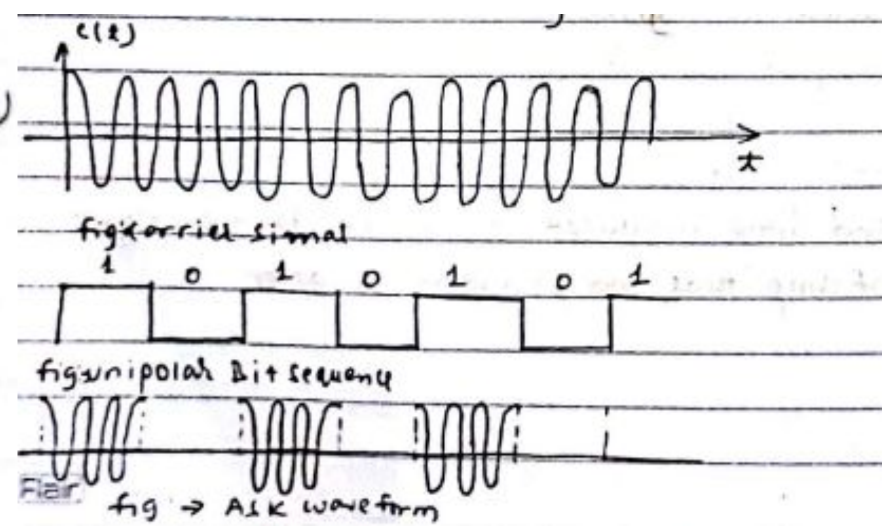
- Earliest and simplest form of modulation.
- Used in wireless telegraphy. No more used.
- Useful model to understand other modulation.
- In ASK, binary Symbol 1 is represented by $A_c \text{Cos} 2\pi f_c t$ for the duration T_b second.
- Symbol 0 is represented by switching OFF the carrier for duration T_b second .
- ASK is generated by simply turning the carrier of sinusoidal oscillator ON and OFF for the prescribed time period.
- Also known as ON- OFF Keying (OOK)

Amplitude Shift Keying (ASK)

- Let the sinusoidal carrier be $c(t) = A_c \text{Cos}2\pi f_c t$.
- The binary ASK signal is $S(t) = A_c \text{Cos}2\pi f_c t$ symbol 1
- $S(t) = 0$ symbol 0







Detection of ASK

- **Two types of detection of ASK**

1. Coherent or synchronous Detector:- It is also of two form

a. Phase synchronization:- Ensures the carrier wave generated at the carrier is locked in phase with respect to the transmitter.

b. Timing Synchronization:- Ensures proper timing of the decision making operation with respect to switching instant.

Detection of ASK

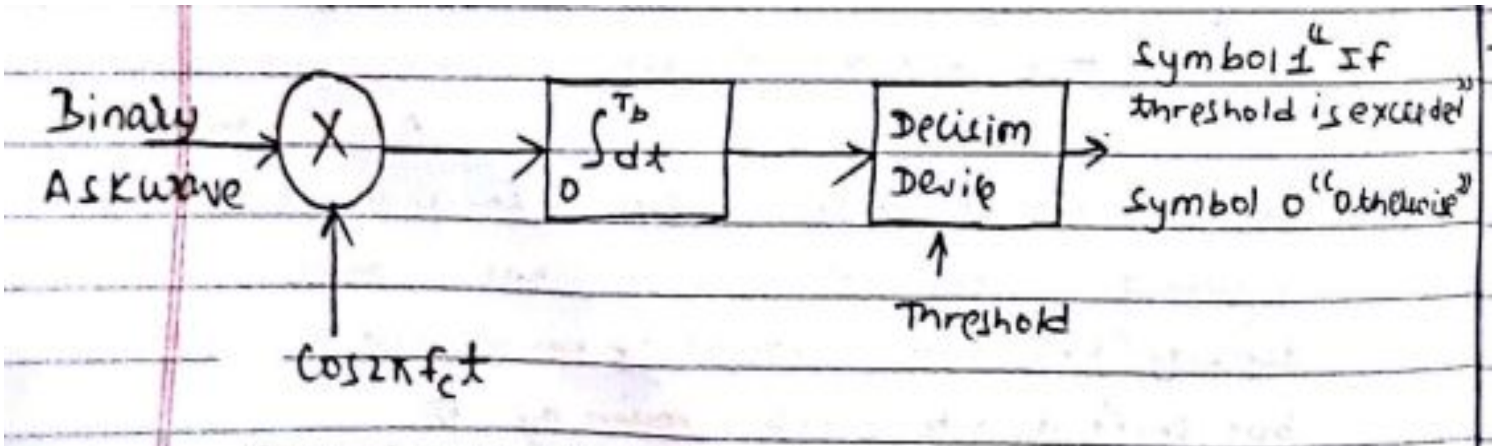
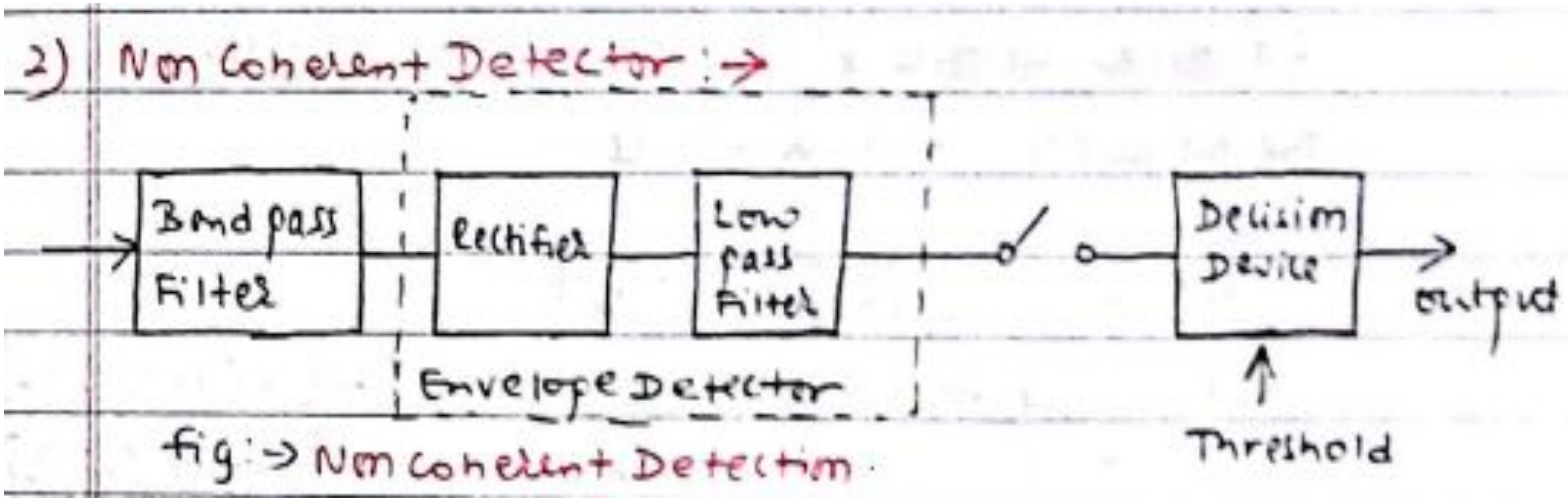


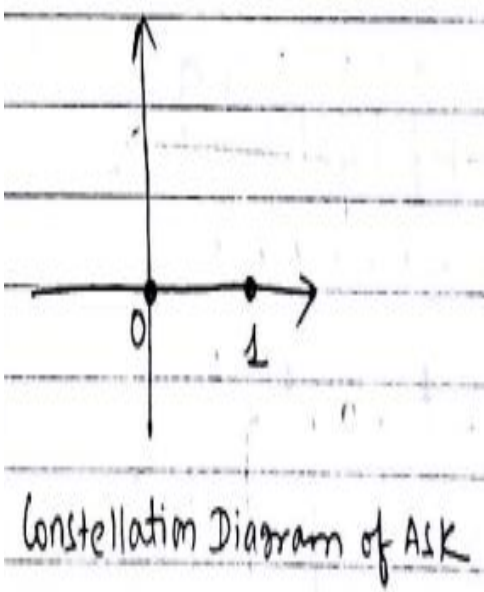
fig:→ Coherent Detection of ASK

- **Product modulator that receives ASK modulated wave.**
- **Sinusoidal carrier is generated by local oscillator is fed to product modulator.**
- **Output is fed to integrator which performs low pass filtering.**
- **It is than fed to decision device where comparison is done with the threshold.**
- **Symbol 1 as the output if it is greater than the threshold.**
- **Symbol 0 otherwise.**

Detection of ASK



- Binary ASK wave can be demodulated by Non Coherent Detector.
- It uses Envelope Detector.
- Envelope Detector consist of Rectifier and low pass filter.
- It is than fed to decision device where comparison is done with the threshold.
- Symbol 1 as the output if it is greater than the threshold.
- Symbol 0 otherwise.



Amplitude Shift Keying

- Carrier Signal, $C(t) = A_C \cos 2\pi f_c t$----------(1)
- $P_c = A_C^{\,2}/2$
- $A_c = \sqrt{(2P_c)}$
- $A_c = \sqrt{(2P_S)}$ P_S = Power dissipated per bit..
- m(t) is the binary data in uni polar form.
- Modulated ASK wave is
- $S(t) = m(t)\, C(t)$-------------(2)
- $S(t) = m(t)\, A_C \cos 2\pi f_c t$
- $S(t) = m(t) \sqrt{(2P_S)} \cos 2\pi f_c t$-----------(3)
- $S(t) = \sqrt{(2P_S)} \cos 2\pi f_c t$ For Symbol 1 (i.e $m(t) = 1$)
- $S(t) = 0$ For Symbol 0 (i.e $m(t) = 0$)
- $S(t) = m(t) \sqrt{(2P_S)}\, (e^{j2\pi fct} - e^{-j2\pi fct}) / 2$
- $S(t) = \sqrt{(2P_S)} / 2\ [m(t)\, e^{j2\pi fct} - m(t)\, e^{-j\,2\pi fct}]$
- Taking Fourier Transform (F.T)
- $S(f) = \sqrt{(2P_S)} / 2\ [\, M(f+f_c) + M(f-f_c)]$ ------ (4)

Amplitude Shift Keying

- **<u>Demodulation (Detection)</u>**
- $S'(t) = S(t)\, C(t)$--------------(1)
- $S'(t) = \sqrt{(2P_S)}\ m(t)\ \mathrm{Cos}2\pi f_c t * \mathrm{Cos}2\pi f_c t$
- $S'(t) = \sqrt{(2P_S)}\ m(t)\ \mathrm{Cos}^2 2\pi f_c t$
- $S'(t) = \sqrt{(2P_S)}\ m(t)\ (1+\mathrm{Cos}4\pi f_c t / 2)$
- $S'(t) = \sqrt{(2P_S)}\ m(t)/2 + \sqrt{(2P_S)}\ m(t)\mathrm{Cos}4\pi f_c t / 2)$

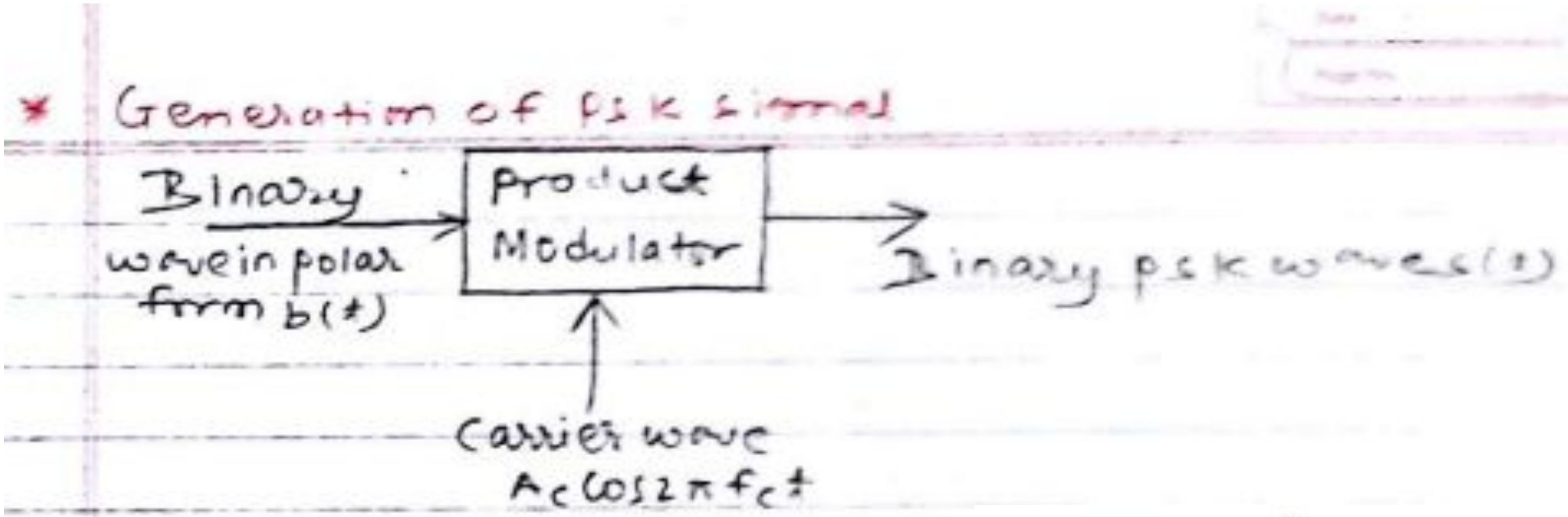
- Integrator does low pass filtering which will reject the high frequency term

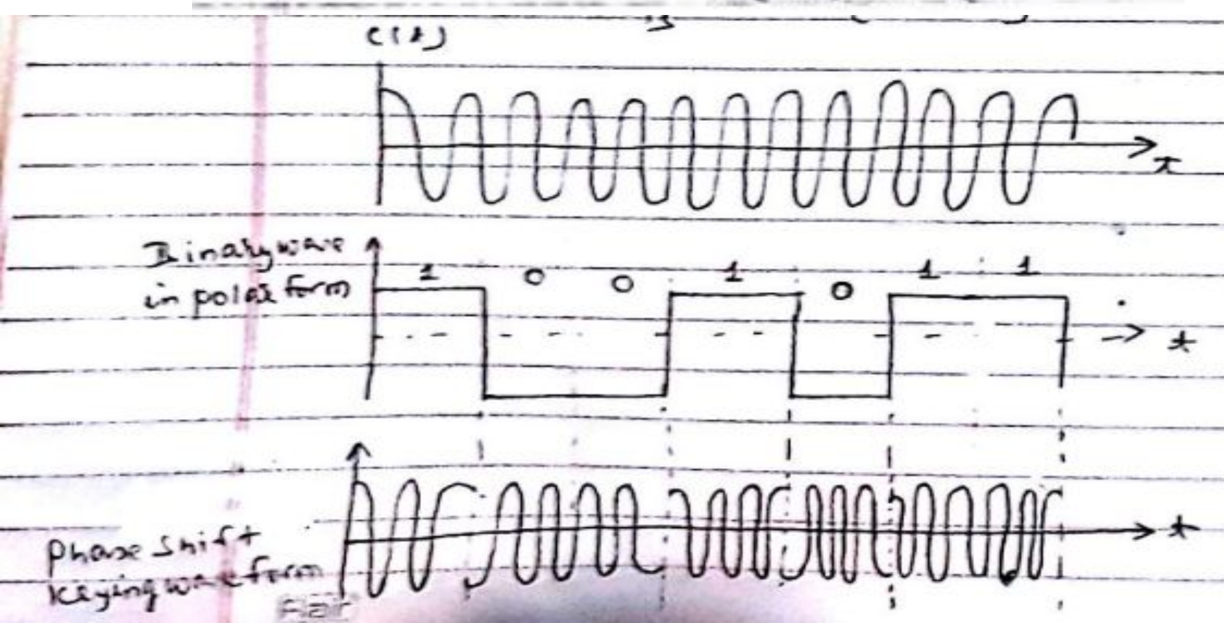
- $S'(t) = \sqrt{(2P_S)}\ m(t)/2$ -----(2) which is scaled original message signal.

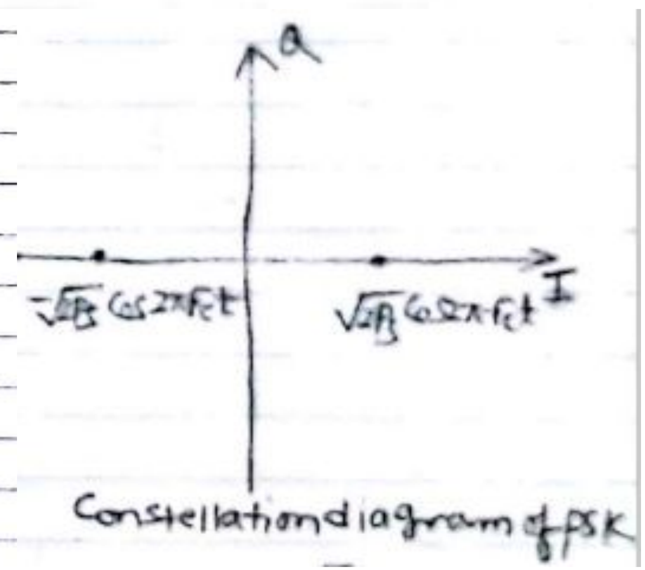
Phase Shift Keying (PSK)

- In PSK amplitude and frequency of carrier is unchanged (fixed) .
- The phase is varied or changed by 180^0 with the change in symbol.
- $C(t) = A_C \text{ Cos}2\pi f_c t$
- $P_c = A_C{}^2/2$
- $A_c = \sqrt{(2P_c)}$
- $A_c = \sqrt{(2P_S)}$ P_S = Power dissipated per bit.
- Modulated PSK wave is
- S(t) = m(t) C(t)-------------(2)
- $S(t) = m(t) A_C \text{ Cos}2\pi f_c t$
- $S(t) = m(t) \sqrt{(2P_S)} \text{ Cos}2\pi f_c t$-----------(3)
- $S(t) = \sqrt{(2P_S)} \text{ Cos}2\pi f_c t$ For Symbol 1 (i.e m(t) = 1)
- $S(t) = \sqrt{(2P_S)} \text{ Cos}(2\pi f_c t + \pi)$ For Symbol 0 (i.e m(t) = 0)
- $S(t) = -\sqrt{(2P_S)} \text{ Cos}2\pi f_c t$ For Symbol 0 (i.e m(t) = 0)

Phase Shift Keying (PSK)







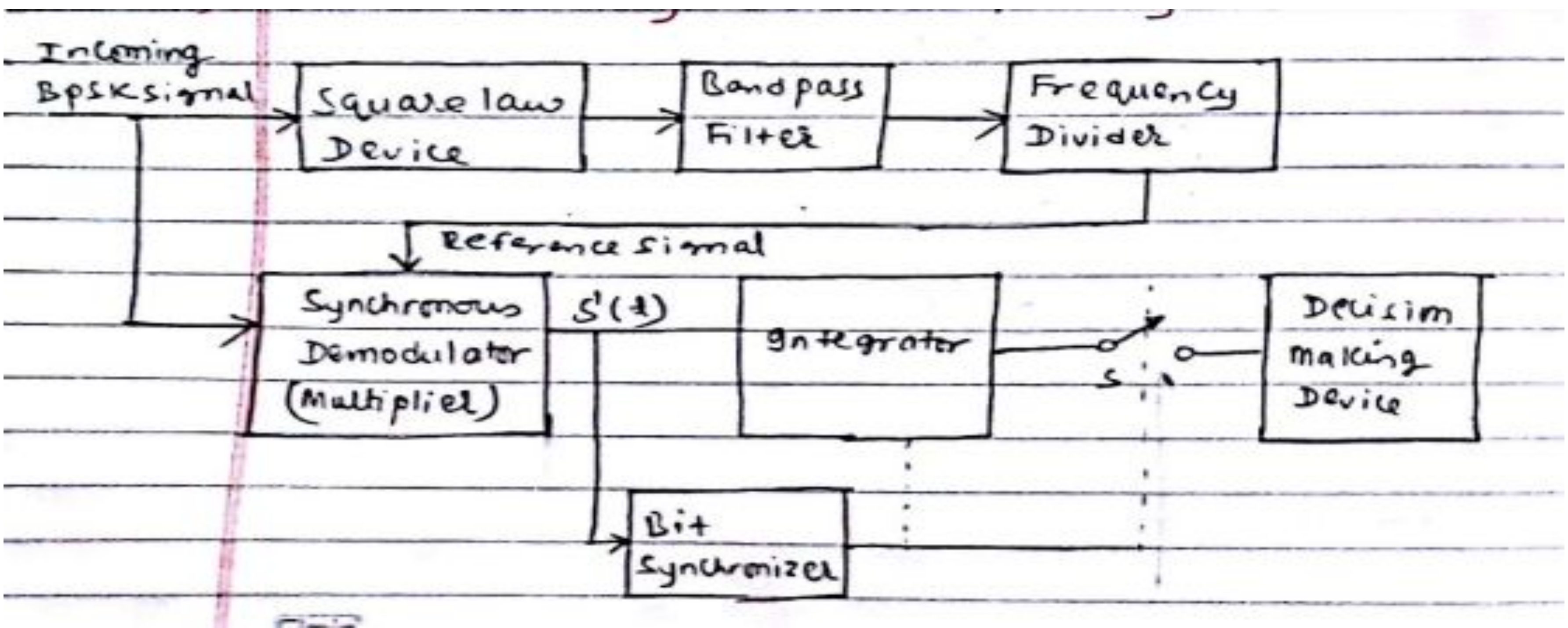
Phase Shift Keying (PSK)

- <u>Demodulation:-</u>

<u>1. Coherent or Synchronous Detector</u>:-

- Synchronous Demodulation of binary PSK wave is same as that of ASK wave demodulation.

2. Carrier Recovery Circuit in PSK System:-



Phase Shift Keying (PSK)

- **Demodulation:-**

Let the received BPSK signal is

- $S(t) = b(t)\ A_C \text{Cos}(2\pi f_c t+\Theta)$ Θ--- Phase change
- The received incoming signal is squared by square law device and the amplitude terms are neglected.
- $\text{Cos}^2(2\pi f_c t+\Theta)$
- $1+\text{Cos}2(2\pi f_c t+\Theta)/2$
- $1/2 + 1/2\ \text{Cos}(2\pi f_c t+\Theta)$ which is further passed through Band Pass filter removing scale 1/2 and is centered around $2f_c$.
- $\text{Cos}2(2\pi f_c t+\Theta)$ is fed to frequency divider by 2
- Reference signal $\text{Cos}(2\pi f_c t+\Theta)$ is passed to Synchronous demodulator

Phase Shift Keying (PSK)

- **<u>Demodulation:-</u>**

•Output of multiplier is

$S'(t)=S(t)\ Cos(2\pi f_c t+\Theta)$

$S'(t)=S(t)\ Cos(2\pi f_c t+\Theta)$

$S'(t)= b(t)\ A_C\ Cos(2\pi f_c t+\Theta)*Cos(2\pi f_c t+\Theta)$

$S'(t)= b(t)\ \sqrt{(2P_S)}\ Cos^2(2\pi f_c t+\Theta)$

$S'(t)= b(t)\ \sqrt{(2P_S)}\ [1+Cos2(2\pi f_c t+\Theta)] / 2$

$S'(t)= b(t)\ \sqrt{(P_S/2)}\ [1+Cos2(2\pi f_c t+\Theta)]$

•Output is supplied to the Integrator and Bit synchronizer.

•Integrator performs low pass filtering.

• Bit synchronizer is used to identify start and end of bit.

•Output of integrator is feed to the decision device which identifies Symbol 0 or Symbol 1.

Phase Shift Keying (PSK)

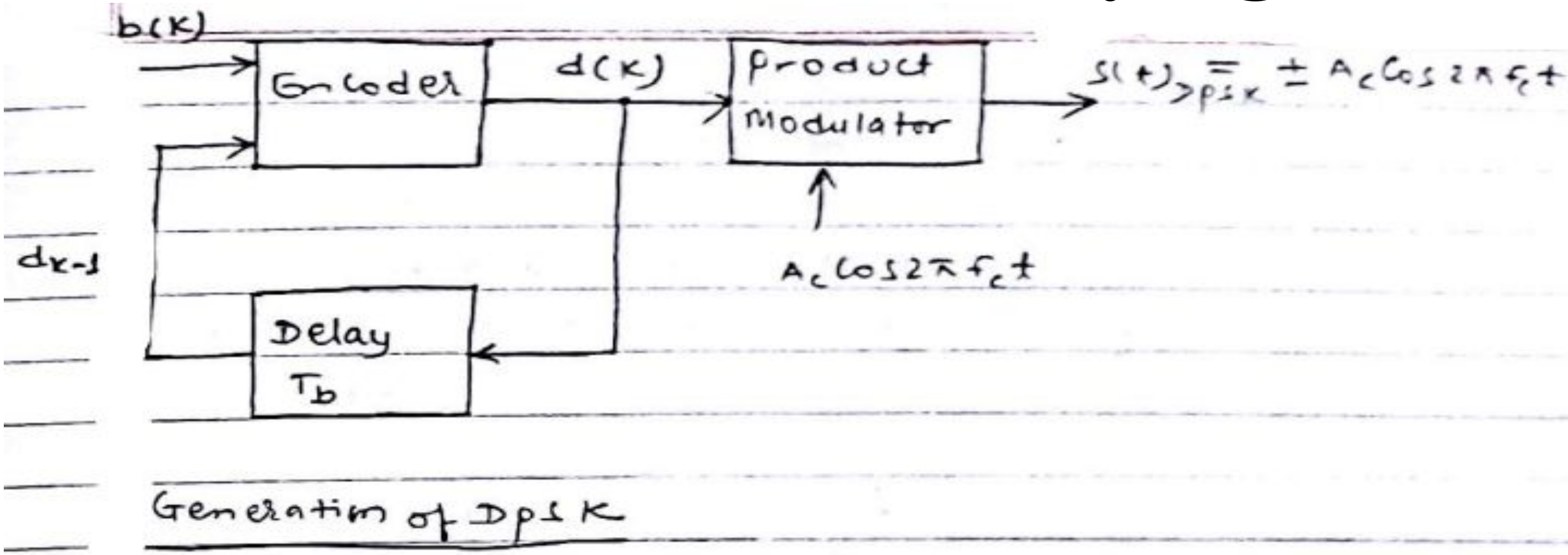
- ***<u>Advantage:-</u>***
- Most efficient digital modulation technique.
- PSK is used for the system that needs high bit rate.
- ***<u>Limitation:-</u>***
- Complication in Synchronization.
- Phase Ambiguity problem.

• Phase Shift Keying (PSK) cannot be detected non coherently.

•Envelope of PSK modulated wave is same for the Symbol 1 or Symbol 0.

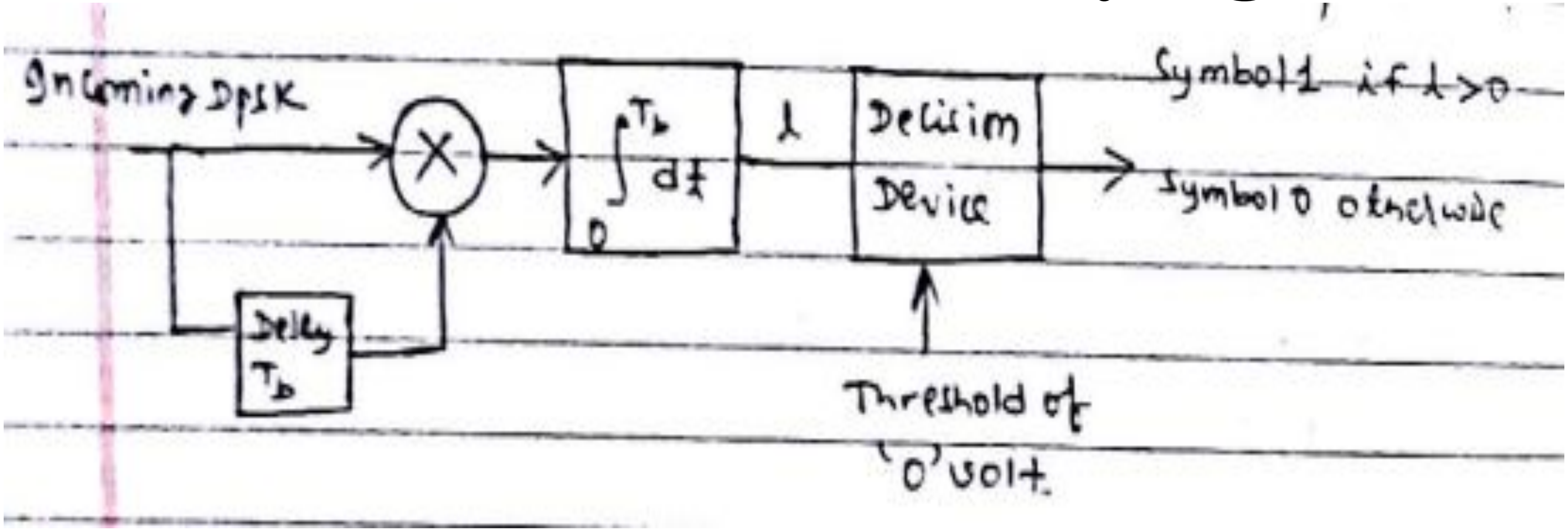
•To overcome this **Differential Phase Shift Keying(DPSK)** is introduced.

Differential Phase Shift Keying(DPSK)



- Non Coherent conversion of PSK. DPSK combines different encoding with Phase Shift Keying.
- It is modified scheme encoded in terms of signal transition.
- Symbol 0 represents transition whereas Symbol 1 no transition.
- Data Stream b(k) is fed to the encoder.
- Output of encoder d(k) is passed to Product Modulator to get DPSK.
- Output is fed back to the encoder.
- One extra bit 0 or 1 is added initial bit to predict transition.

Differential Phase Shift Keying(DPSK)



- Modulated DPSK is passed to product modulator directly and with the delay T_b.
- Phase difference between the phase of DPSK and shifted DPSK determines the phase comparator Output.
- Difference $\Phi = 0$, the integrator output is Positive(+).
- Difference $\Phi = \pi$, the integrator output is Negative(-).
- Integrator output is compared with Threshold (0v)
- Symbol 0 represents negative whereas Symbol 1 positive output.

Differential Phase Shift Keying(DPSK)

Binary Data b(K)		0	0	1	0	0	1	0	0	1	1	phase shift
Differentially encoded data d(t)	1	0	1	1	0	1	1	0	1	1	1	$d_k = b_k \oplus d_{k-1}$
Phase of DPSK	0	π	0	0	π	0	0	π	0	0	0	Transmitted
Shifted differentially encoded data (d_{k-1})		1	0	1	1	0	1	1	0	1	1	Received
Phase of shifted DPSK		0	π	0	0	π	0	0	π	0	0	
Phase comparision output		−	−	+	−	−	+	−	−	+	+	
Detected binary sequence		0	0	1	0	0	1	0	0	1	1	

Take extra bit 0

Binary Data b(K)		0	0	1	0	0	1	0	0	1	1	
Differentially encoded data d(K)	0	1	0	0	1	0	0	1	0	0	0	Tx
Phase of DPSK	π	0	π	π	0	π	π	0	π	π	π	
Shifted differentially encoded data d_{k-1}		0	1	0	0	1	0	0	1	0	0	Rx
Phase of shifted DPSK		π	0	π	π	0	π	π	0	π	π	
Phase comparision output		−	−	+	−	−	+	−	−	+	+	
Detected binary b(t)		0	0	1	0	0	1	0	0	1	1	

Frequency Shift Keying(FSK)

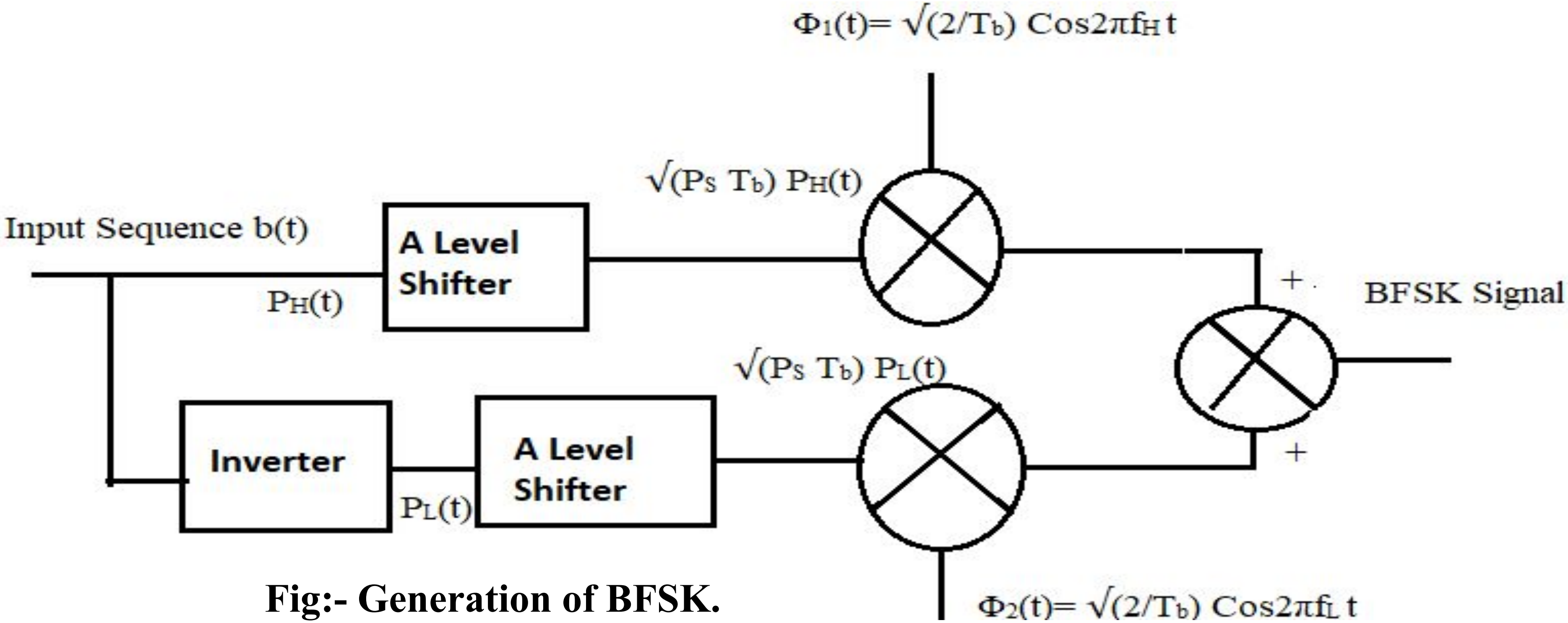


Fig:- Generation of BFSK.

- It has two level shifter whose one of the input is inverted.
- It has two product modulator with two carrier $\Phi_1(t)$, $\Phi_2(t)$.
- Output of product modulator is mixed or added up by summer.
- Generating BFSK signal.

Frequency Shift Keying(FSK)

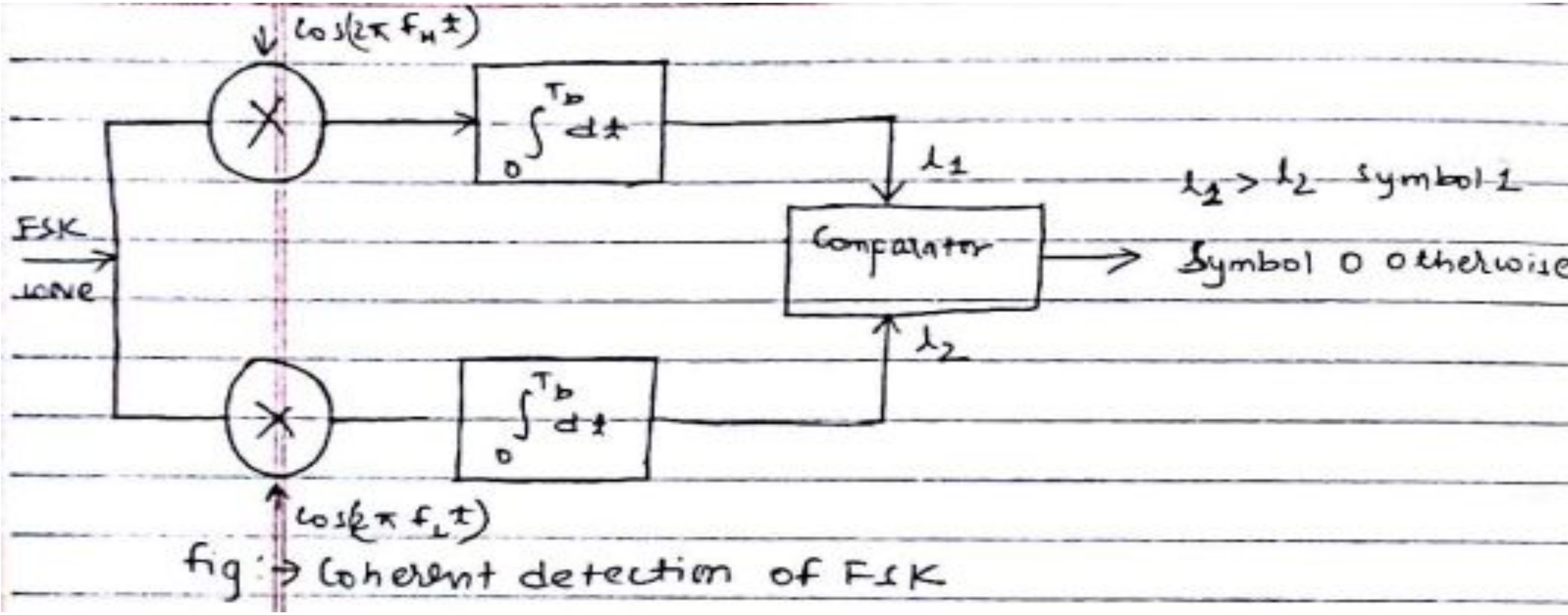


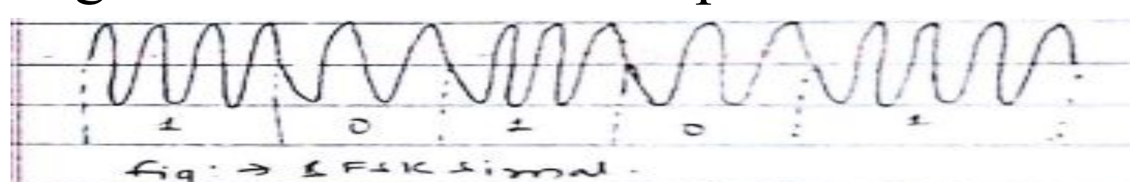
Fig:- Detection of BFSK.

- FSK is fed to the two Correlators.
- Correlator are supplied with carrier signal which is further passed to the integrators.
- Integrator provides necessary filtering action and are introduced to the comparator.
- $l_1 > l_2$ Symbol 1.
- Otherwise Symbol 0.

Frequency Shift Keying(FSK)

Fig:- Non Coherent Detection of BFSK.

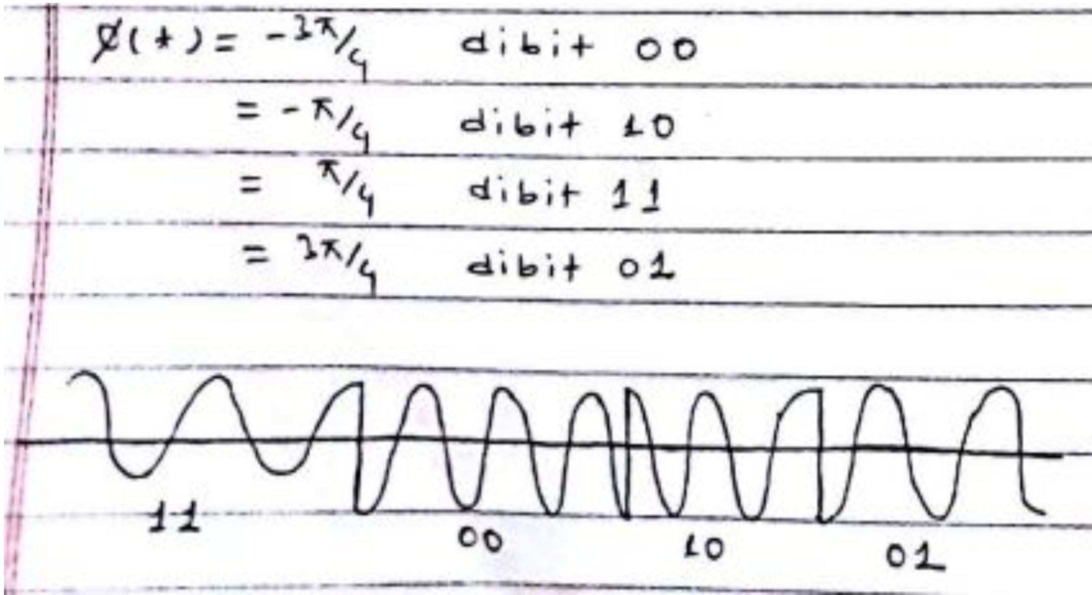
- Demodulation or Detection is done by Envelope Detector.
- BPF tuned to f_L and f_H
- Output of filter is fed to the Envelope Detector.
- Sampler performs sampling and introduced to comparator.
- If $f_H > f_L$ Symbol 1
- Symbol 0 Otherwise.



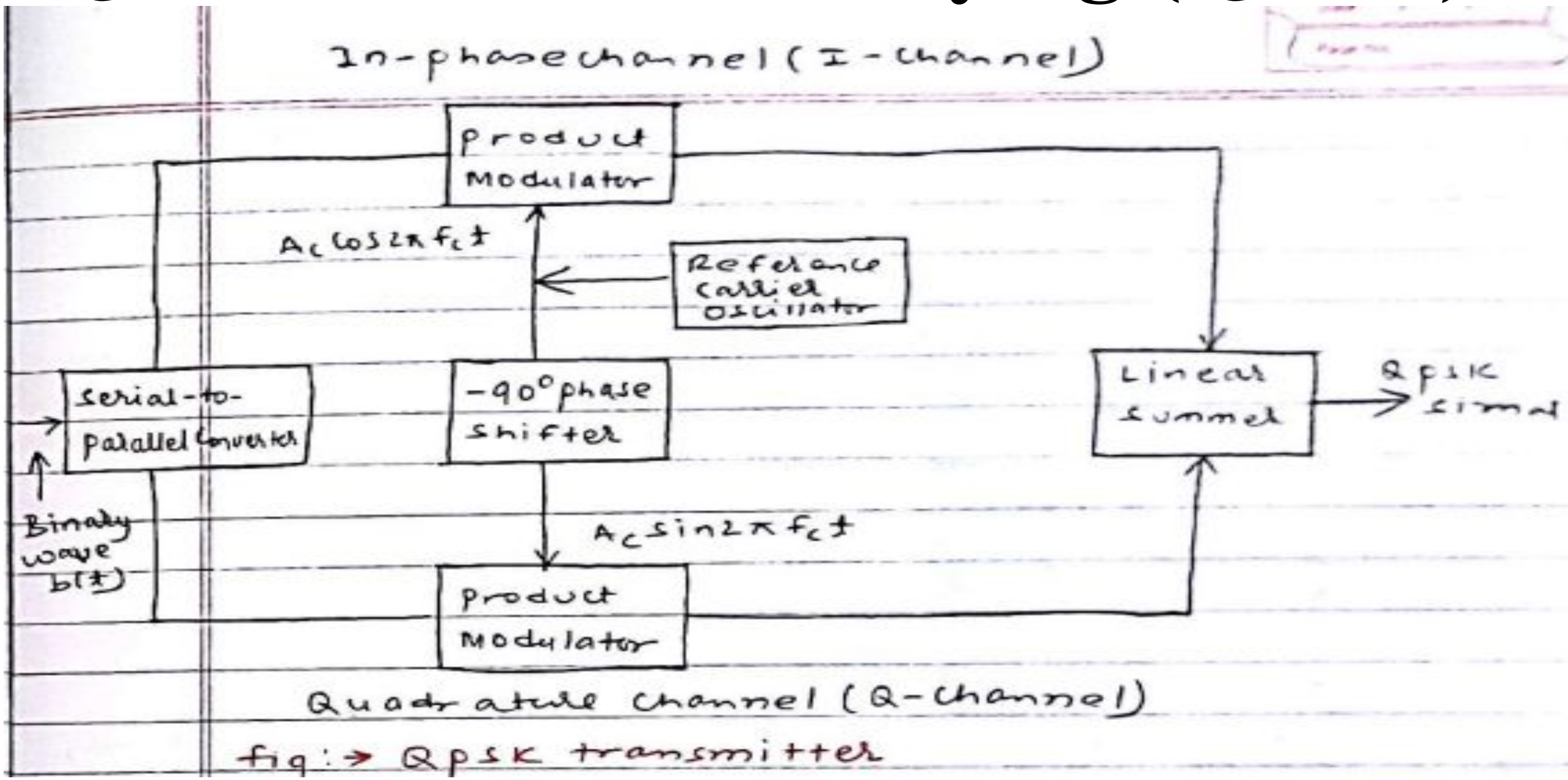
QuadriPhase Shift Keying (QPSK)

- For efficient utilization of bandwidth QPSK and MSK is introduced.
- ***<u>Quadrature Phase Shift Keying:-</u>***
- It is an extension of binary PSK.
- M possible signal ($M=2^n$) can be transmitted during each interval of time.
- M-ary encoding technique with four possible outcomes.
- Represented by four di bits (00, 01, 10,11) with instantaneous phase $+45^0$,-45^0, $+135^0$, -135^0

- QPSK Signal
- $S(t) = A_C \cos[2\pi f_c t + \Phi(t)]$
- $\Phi(t)$= Instantaneous Phase

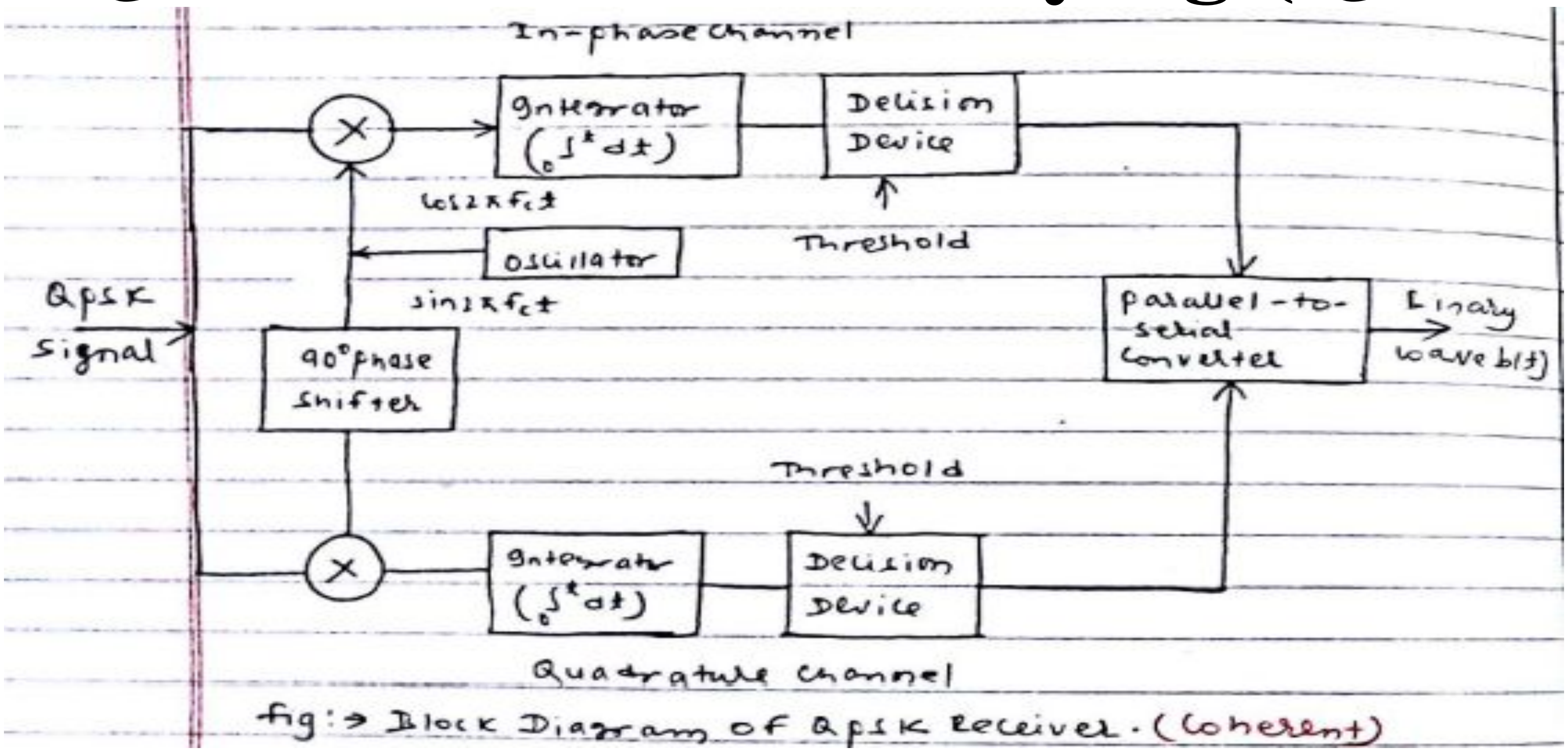


QuadriPhase Shift Keying (QPSK)



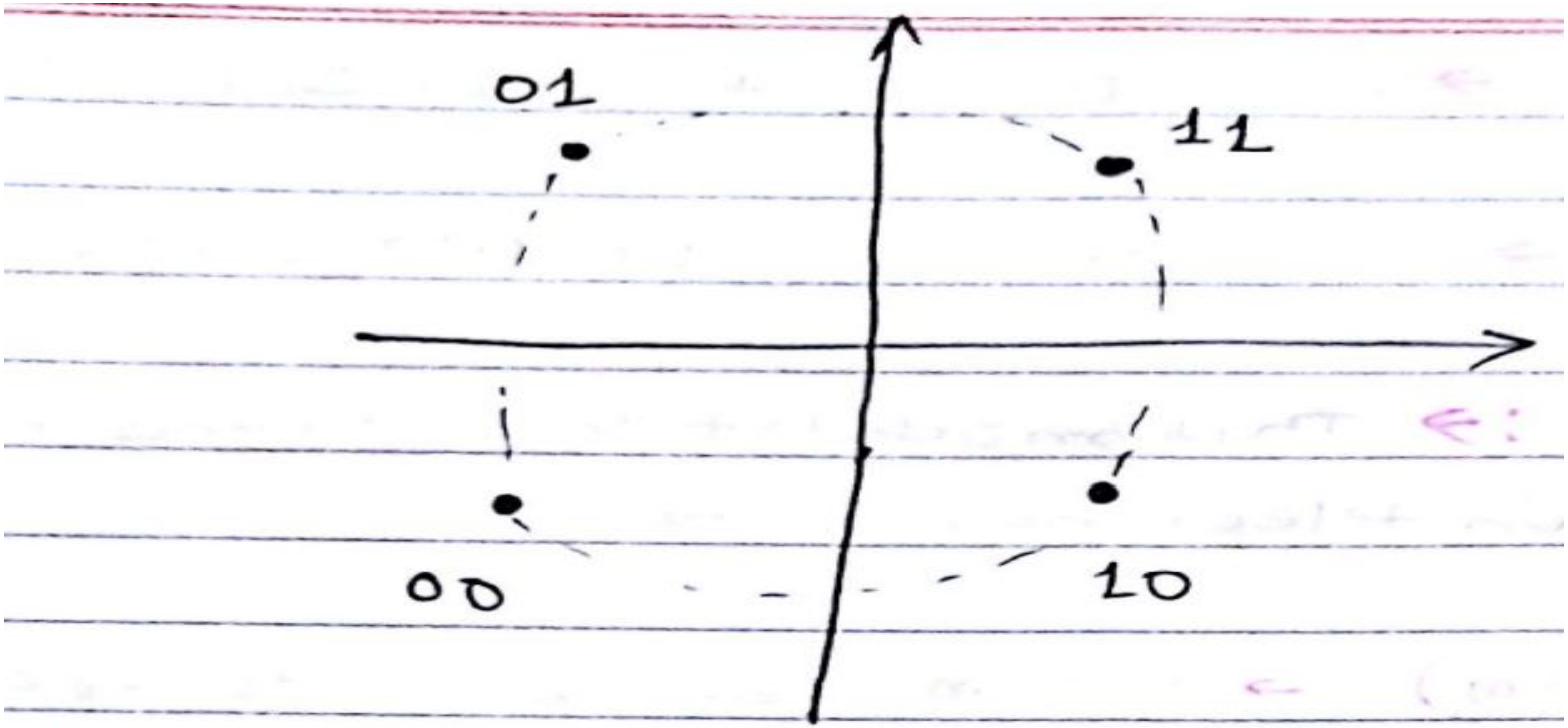
- It consist of serial to parallel converter.
- Pair of product modulator where the serial to parallel converter splits the bit.
- One bit passes to I- Channel Product modulator with carrier signal A_C $\text{Cos}2\pi f_c t$.
- Other bit passes to Q-channel product modulator with carrier signal A_C $\text{Sin}2\pi f_c t$.
- Modulated signal are than added in Linear Summer to generate QPSK Signal.

QuadriPhase Shift Keying (QPSK)



- QPSK Signal is detected by using pair of Correlators.
- Upper part computes the modulated In phase bit whereas lower part computes the modulated Quadrature bit.
- Balanced modulator with carrier signal $\cos 2\pi f_c t$ is fed to Integrator and Decision device.
- Balanced modulator with carrier signal $\sin 2\pi f_c t$ is fed to Integrator and Decision device.
- Comparison with Threshold decides four phases which is further transferred to binary bits by Parallel to Serial Converter.

QuadriPhase Shift Keying (QPSK)



• Constellation Diagram of QPSK

Offset QPSK (OQPSK) :-

- Abrupt phase shift in QPSK introduces attenuation.
- OQPSK overcomes abrupt phase shift.

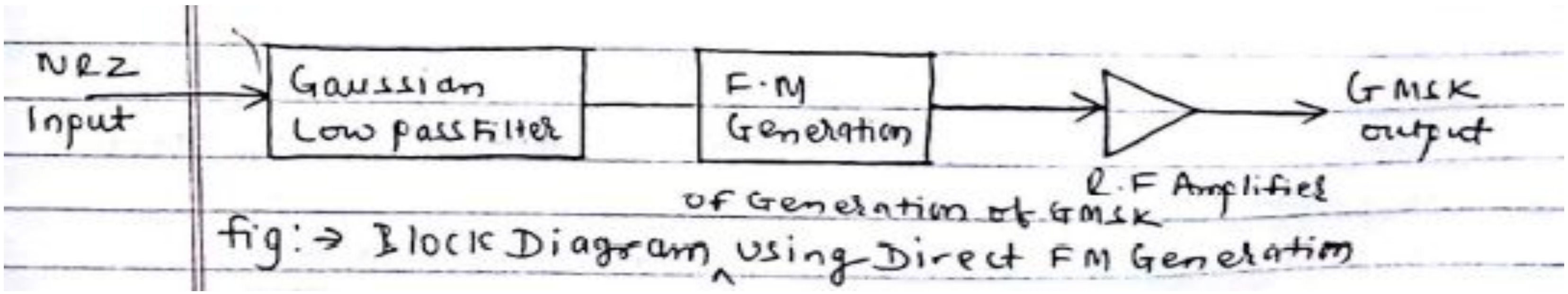
Minimum Shift Keying (MSK)

- **Limitation of Quadrature Phase Shift Keying**
- Abrupt Phase Shift Keying.
- Abrupt amplitude Variation.
- Inter channel interference is very high.

- Minimum Shift Keying(MSK) is a special form of Continuous Phase Frequency Shift Keying (CPFSK) which overcomes the limitation of QPSK.

Gaussian Minimum Shift Keying(GMSK)

- Modification of MSK: Highly used in cellular mobile Communication.



- NRZ binary input is fed to Gaussian Low Pass Filter.
- Output of LPF is fed to F.M transmitter.
- Output of F.M transmitter is fed to R.F Amplifier to produce GMSK Output.

Gaussian Minimum Shift Keying(GMSK)

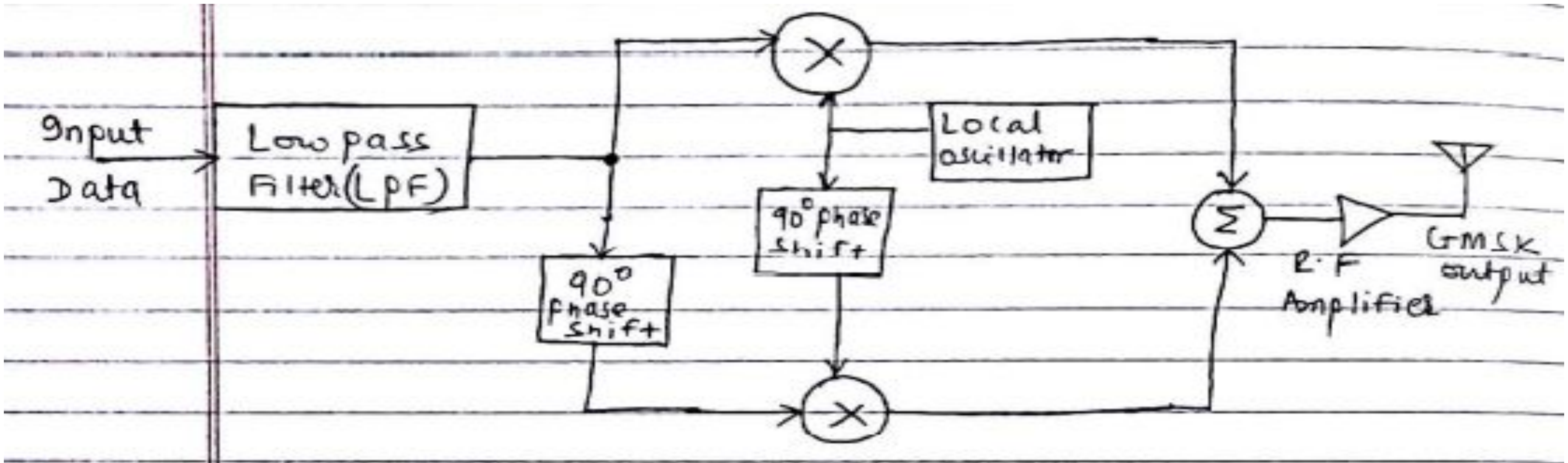
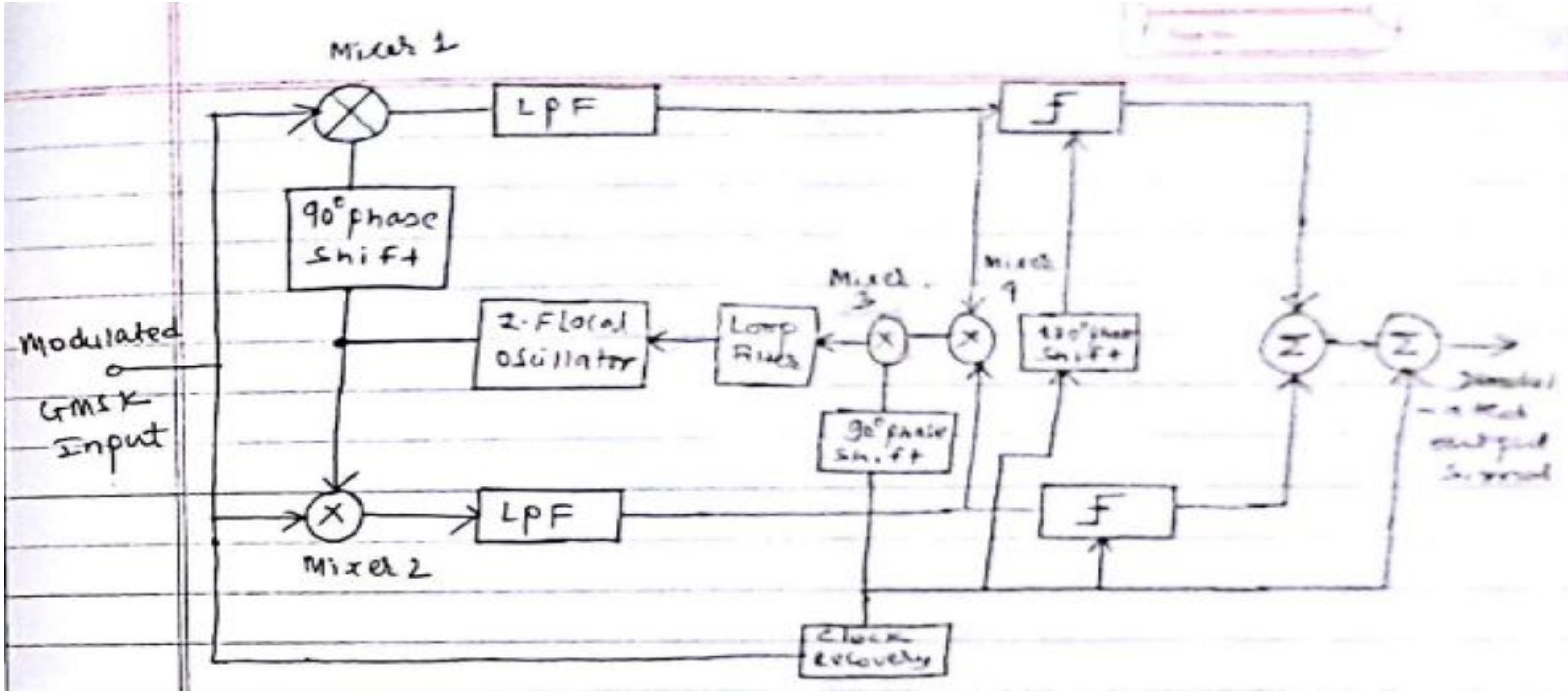


fig:-> GMSK Modulator.

- Consist of In-Phase and Quadrature Balanced Modulator.
- Input Data is fed to the LPF which separates Inphase and Quadrature Component.
- Local oscillator generates In-phase carrier signal and 90 phase shifted Carrier Signal fed to the Balanced Modulator.
- Output of Balanced Modulator is mixed in Summer.
- The output of Summer is further Amplified and radiated through GSM Antnenna.

Gaussian Minimum Shift Keying(GMSK)



- Clock Recovery Circuit
- Input modulated signal is given to two mixer.
- Carrier signal directly given to Mixer 1 and 90 phase shift to Mixer 2.
- Output of LPF is fed to Orthogonal Coherent detector to extract original Signal.

Gaussian Minimum Shift Keying(GMSK)

- ***Advantages:-***
- Good Power Efficiency.
- Good Spectral Efficiency.
- Less ISI.
- Best for Wireless Communication.
- ***GMSK Transmission System:-***
- In MSK, spectrum is not compact enough to occupy R.F channel Bandwidth.
- It is done by using Gaussian filter which will efficiently use the bandwidth. (***GMSK***)

Gaussian Minimum Shift Keying(GMSK)

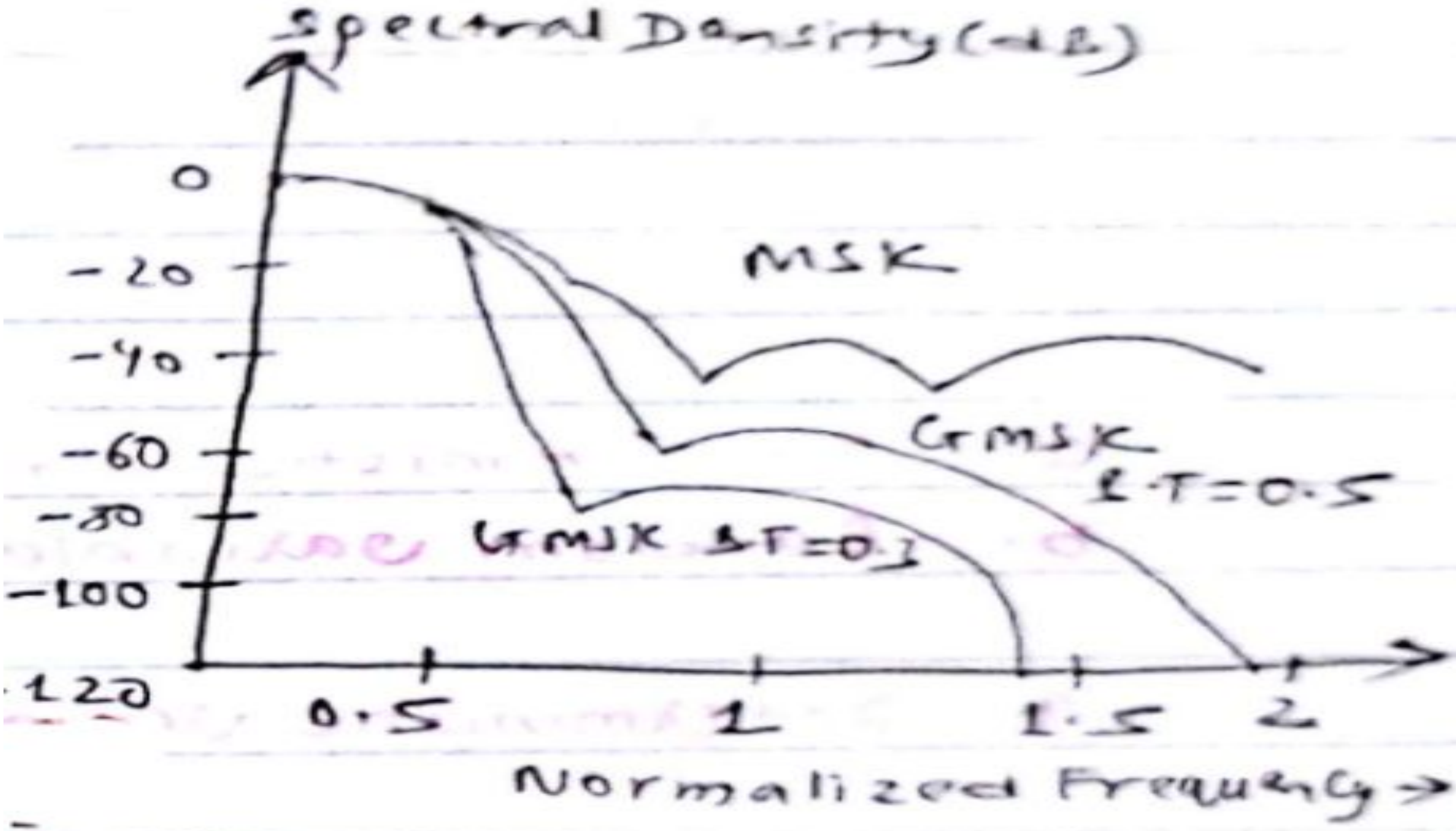


Fig:→ Spectral Density of MSK and GMSK

Gaussian Minimum Shift Keying(GMSK)

- Bit duration (B.T) is channel spacing.

- Less Bit duration(B.T) will have better ISI tolerance and compact Spectrum.

- Cellular Digital Packet Data (CDPD) uses GMSK with bit duration B.T= 0.5 of 30 KHz channel spacing data rate of 19.2 Kbps.

- Mobitex uses GMSK with bit duration B.T= 0.3 tighter channel spacing 12.5 KHz channel spacing data rate of 8 Kbps.

M-ary Data Communication System

- M-ary Signaling has M-level of output.
- Output may be one of the M possible level.
- ***Signaling Rate:-***
- If M symbols emitted are equi probable and statistically independent then source entropy

$$H = \sum_{i=1}^{N} p_i \log_2\left(\frac{1}{p_i}\right)$$

where $p_i = \frac{1}{M}$ and $\sum_{i=1}^{M} p_i = 1$

$$\boxed{H = \log_2 M}$$

- Information Rate (R) = r H
- r = Symbol Rate
- Information Rate for M-ary Data communication system is $R = r \text{ Log}_2 M$
- For M = 4, $\text{Log}_2 4 = 2$, R = 2r

Comparison between Binary & M-ary Signaling

Binary Signaling System	M-ary Signaling System
Signal is of two possible amplitude level.	Signal is of M possible amplitude level.
Signaling rate $1/T_b$ for T_b is bit duration.	Signaling rate 1/T for T is bit duration.
Transmits data slower than M-ary	Transmits data $\log_2 M$ faster than binary.
Less Power is required	More power is required

Quadrature Amplitude Modulation

- Quadrature Amplitude Modulation (QAM) overcomes the limitation of ASK and PSK.
- Amplitude and Phase of the carrier signal is changed w.r.t message signal.
- It is the combination of both Amplitude Shift Keying and Phase Shift Keying.

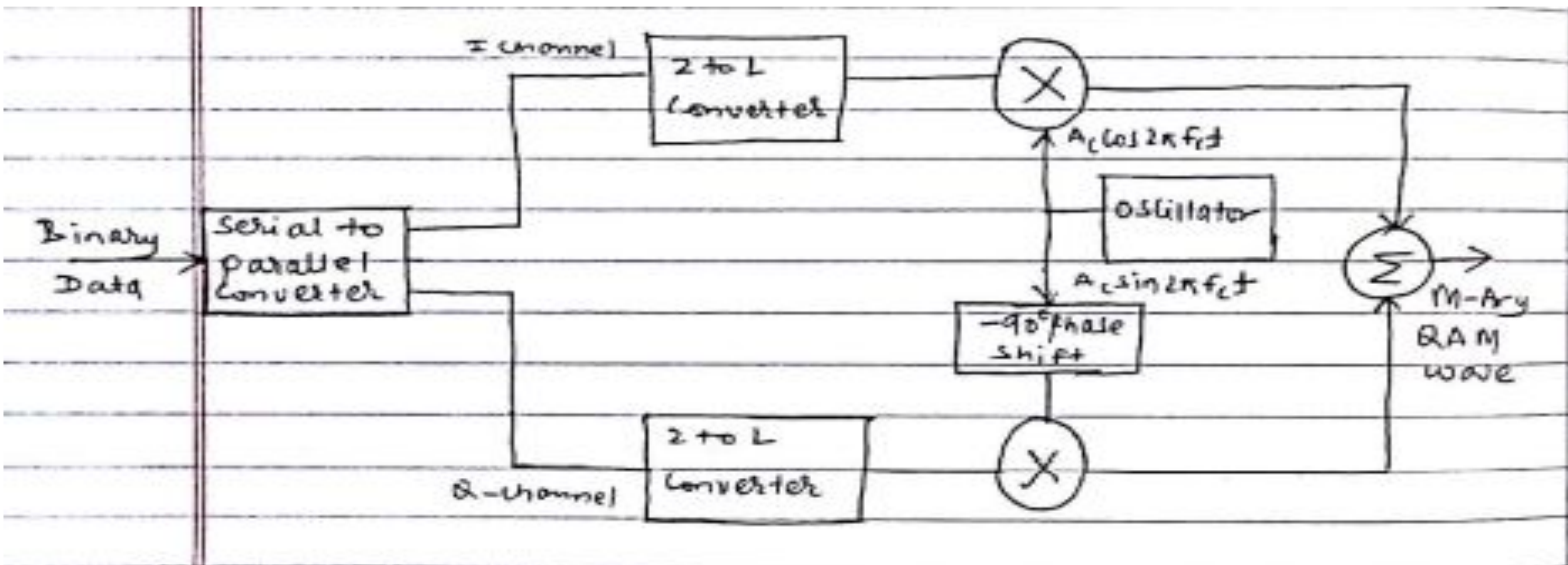
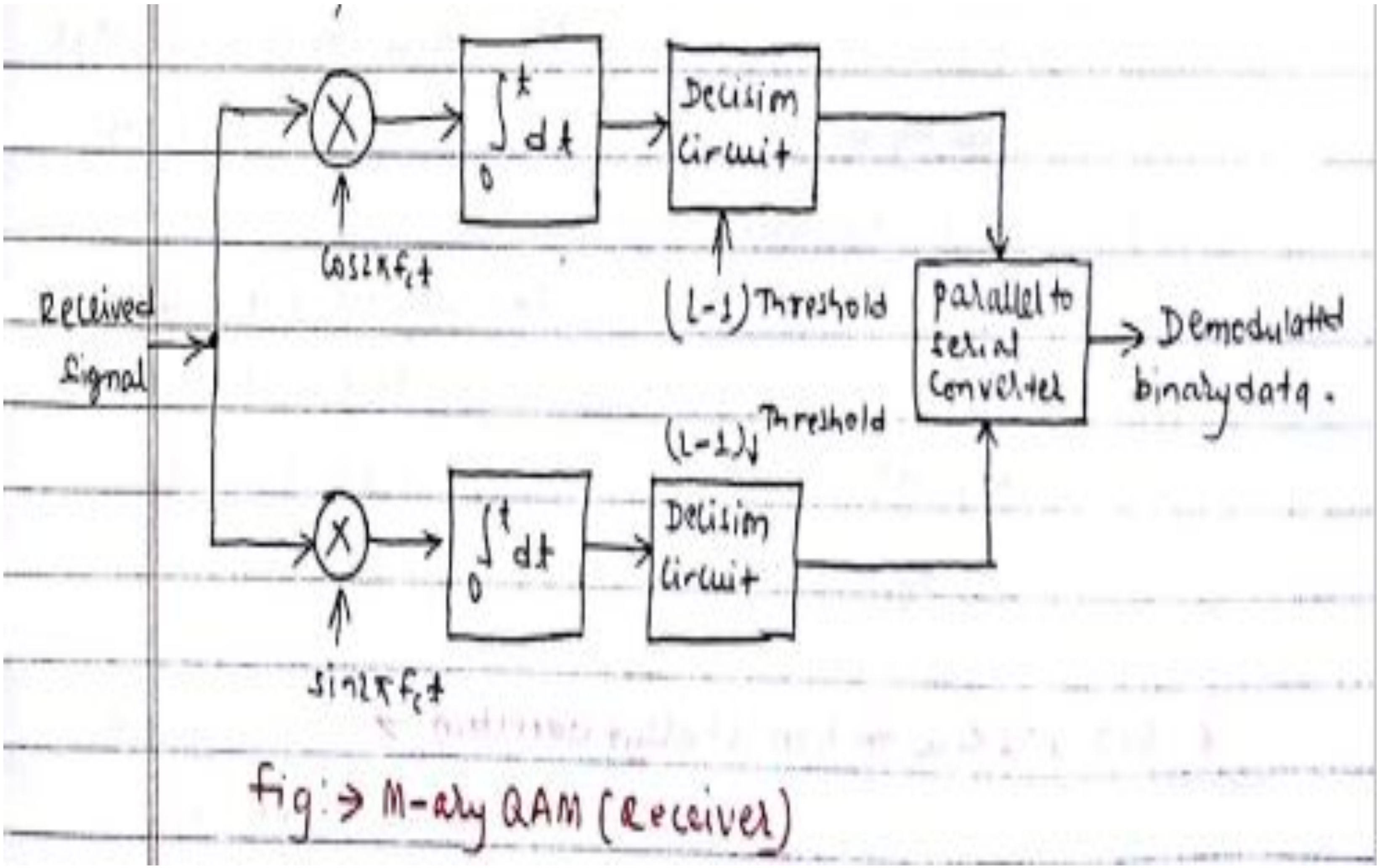
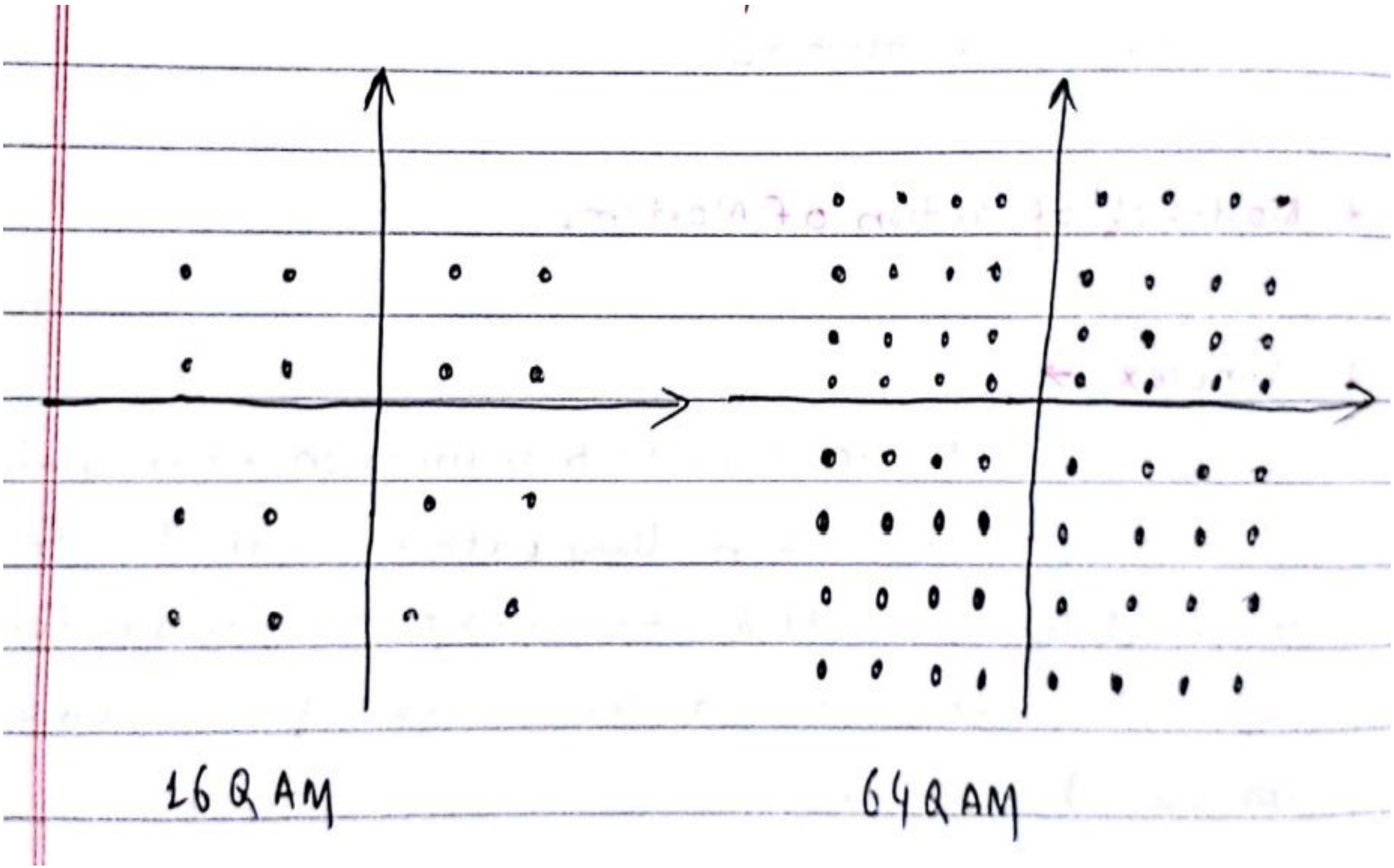


fig:→ M-ary QAM (Transmitter)

Quadrature Amplitude Modulation



Quardrature Amplitude Modulation



MODEM & its Application

- Known as Data Transceiver.

- Modulator- Demodulator used to transmit/receive digital data over voice grade public telephone lines.

- MODEM used to connect terminals located in remote places to a central computer.

- ***<u>Modulation Types according to the Use:-</u>***

MODEM & its Application

- ***<u>Binary FSK with Non Coherent Detection:-</u>***
- Simple and economic.
- FSK MODEMS operates at frequency 1300 to 2100 Hz.
- Has speed1200 bps.
- ***<u>Four Phase DPSK:-</u>***
- Operates at 1300 Hz. Speed 2400 bps.
- ***<u>Eight Phase DPSK:-</u>***
- Operates at 1800 Hz. Speed 4800 bps.
- ***<u>M-ary PSK & DPSK:-</u>***
- Susceptible to phase jitter in telephone channel.
- ***<u>M-ary QAM(16-QAM):-</u>***
- Speed 9600 bps. Implements adaptive equalization to compensate distortions.

Modes of Operation of MODEM

- ***Simplex:-***
- One direction only and no signaling path is available.
- One way Communication. No error Correction and retransmission of data.
- ***Half Duplex:-***
- Transmission in both direction but one at time.
- ***Full Duplex:-***
- Data Transfer in both direction at a same time.

Band pass (Modulated) Data Communication System

Thank you