Modulation

It is a technique in which the characteristics or parameter of carrier signal (amplitude, phase, freq.) is changed according to the message signal. signals containing the information or intelligence are referred as modulating or base band signal. There are two types of modulation, Need of modulation

Comm^n system delivers the message signal from source to destination on due course of transmission the message signal so called base band signal is modulated and passed through the channel. For broadcast system (AM. FM & station) transmission medium or channel) is open space. The need of modulation are,

(1) Practicality of Antenna :- For free space medium, transmissing and receiving is done by antenna. For effective radiation and reception, transmitting antenna must have length quarter wavelength of frequency used. Eg; for AM broadcast system, the maximum audio frequency transmitted from a radio-station is 5kHz.

frequency $(f) = 5\text{ KHz}$

$$\text{Height of Antenna } (H) = \frac{\text{wavelength } (\lambda)}{4}$$

$$\text{Here, } \lambda = \frac{c}{f} = \frac{3\times10^8}{5\times10^3} = 6\times10^4 \text{ meter}$$

$$\therefore H = \frac{\lambda}{4} = \frac{6\times10^4}{4} = 1.5\times10^4 \text{ meter}$$

$$= 15\text{km}$$

which is not possible to construct or install. Therefore modulation is required. If the audio frequency is modulated to a radio carrier frequency of 3 MHz, the antenna height would be,

$$f = 3\text{MHz}$$

$$(H) = \frac{c}{4f}$$

$$= \frac{3\times10^8}{4\times3\times10^6}$$

$$= 25 \text{ meter}$$

(2) To remove interference

Frequency range of audio range is 20Hz to 20kHz. In radio broadcasting there are several radio station. If you transmit the signal without modulation, the signal will be mixed up and jammed which is called interference.

Hence in order to the various signal separate, it is necessary to transmit or shift then to different range of electromagnetic spectrum. Thus each station is allocated with band of ~~band of~~ frequency.

(3) Reduction of noise

Noise is the major limitation of any communication system. Efficient transmission through the medium only possible by reduction of noise. It can be minimize by several modulation techniques.

(4) To increase efficiency :- low frequency can't be radiated over long distance. So to increase the efficiency of radiation we require the modulation.

(5) Ease of multiplexing :- No. of base band signal can be modulated using different carrier frequency, they have their unique identity in due course of transmission. Therefore the no. of signals can be transmitted to a common transmission medium without interfering the other signal.

* Analog or continuous wave modulation

In Analog or Continuous wave modulation the carrier wave is continuous in nature.

1) Amplitude Modulation (A.M) :→

When the Amplitude of the carrier is varied in accordance with message signal, it is called Amplitude Modulation.

2) Angle Modulation :→

Angle modulation is defined as the process in which either the phase or frequency of carrier wave is varied in accordance to the message signal. It is further classified to

a) Phase Modulation (PM) :→

Phase modulation is that form of Angle modulation in which angular direction $\theta(t)$ is varied linearly with the message signal $m(t)$ as

$$\theta(t) = 2\pi f_c t + K_p m(t)$$

where K_p = phase sensitivity

The general expression of PM wave is

$$S_{PM}(t) = A_c \cos[2\pi f_c t + K_p m(t)]$$

b) Frequency Modulation (FM) :→

Frequency modulation is that form of Angle modulation in which instantaneous frequency $f_i(t)$ is varied lineary with message $m(t)$ as

$$f_i(t) = f_c + K_f m(t)$$

where f_c → Unmodulated carrier frequency

K_f → frequency sensitivity modulation

5.1 * Binary Digital Modulations :→

For long distance digital transmission it is necessary to generate band pass signal suited to the transmission medium.

This is achieved by varying the characterstics (Amplitude, Frequency, phase) of a carrier signal in accordance to the digital base band signal.

Basic Concepts in Digital Modulation is exactly same as of Analog Modulation apa-rt from the nature of modulating signal (message signal).

Binary Digital Modulation technique is the process that corresponds to switching or keying the amplitude, phase, frequency of the carrier between either of two possible values corresponding to binary symbols 0 and 1.

There are basically three different forms of digital modulation

1. Amplitude shift keying (ASK)
2. Frequency shift keying (FSK)
3. Phase shift keying (PSK)

and some modulation schemes that employ a combination of amplitude and phase modulation.

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1. Amplitude shift keying (ASK)

It is the earliest and Simplest forms of digital modulation used in wireless telegraphy. ASK is no longer used widely in digital Communication but serves as a useful model to understand the modulation concept.

In Amplitude shift keying system, binary symbol 1 is represented by $A_c \cos 2\pi f_c t$ for the duration 'T_b' and symbol 0 is represented by switching off the carrier for 'T_b' second. ASK signal is generated by simply turning the carrier of sinusoidal oscillator 'ON' and 'OFF' for the prescribed time or period. Therefore it is also named as "ON-OFF keying" (OOK).

Let the Sinusoidal carrier be

$$c(t) = A_c \cos 2\pi f_c t$$

The binary ASK signal $s(t)$ is

$$s(t) = A_c \cos 2\pi f_c t \qquad \text{Symbol 1}$$

$$s(t) = 0 \qquad \text{Symbol 0}$$

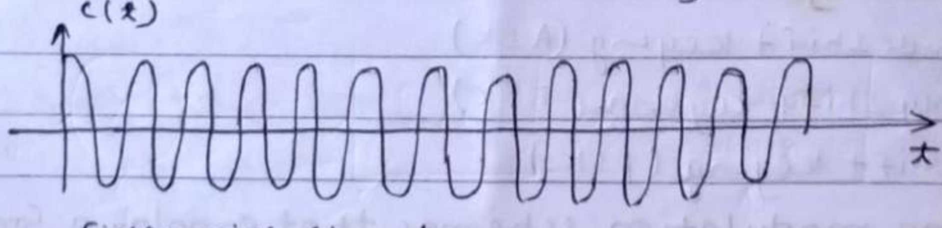

fig: carrier signal

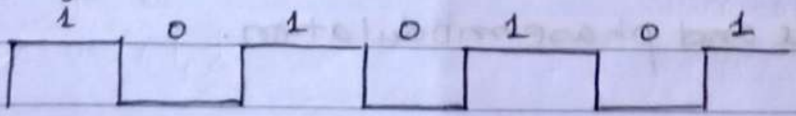

fig: unipolar Bit sequence

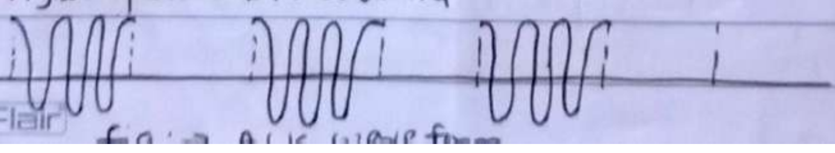

fig: ASK waveform

* Generation of ASK signal

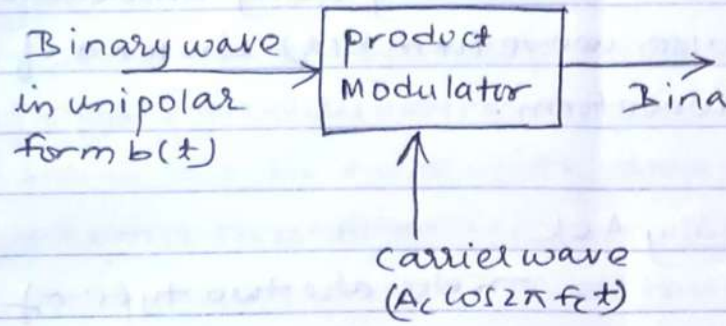

fig :→ Generation of binary ASK

Amplitude shift keying (ASK) modulated wave can be generated by applying Binary wave in unipolar form b(t) and sinusoidal carrier wave $c(t) = A_c \cos 2\pi f_c t$ to a product modulator (Balanced Modulator).

The modulation causes the shift of the baseband signal spectrum.

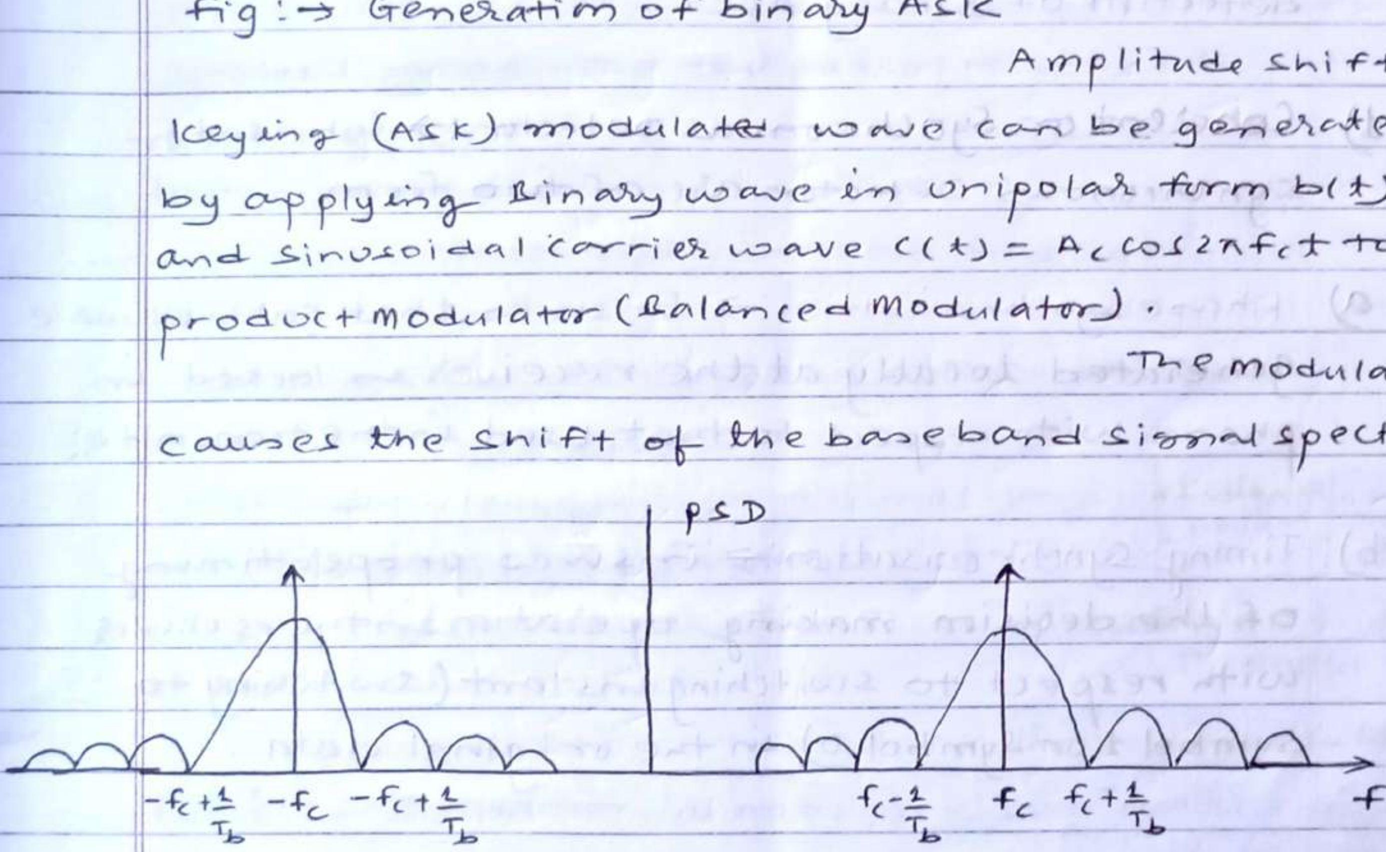

fig :→ power spectral density of ASK signal

Above spectrum shows that the ASK signal which is basically the product of the binary sequence and the carrier signal has a power spectral density (PSD) same as that of baseband 'on-off' signal but shifted in frequency domain by $\pm f_c$.

Bandwidth of ASK modulated signal is approximately $3/T_b$ Hz. However, bandwidth can be reduced by using smoothed version of the pulse waveform b(t) instead of rectangular pulse waveform.

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2) Phase shift keying (PSK) :→

In PSK system, a sinusoidal carrier is of fixed amplitude and frequency. The phase of the carrier is changed by 180° for the change in symbol.

If the unmodulated carrier wave is

$$c(t) = A_c \cos 2\pi f_c t$$

$$P_c = \frac{A_c^2}{2} \qquad A_c = \sqrt{2P_c} = \sqrt{2P_s}$$

$P_s \Rightarrow$ power dissipated per bit

For symbol 1

$$s(t) = \sqrt{2P_s}\cos 2\pi f_c t$$

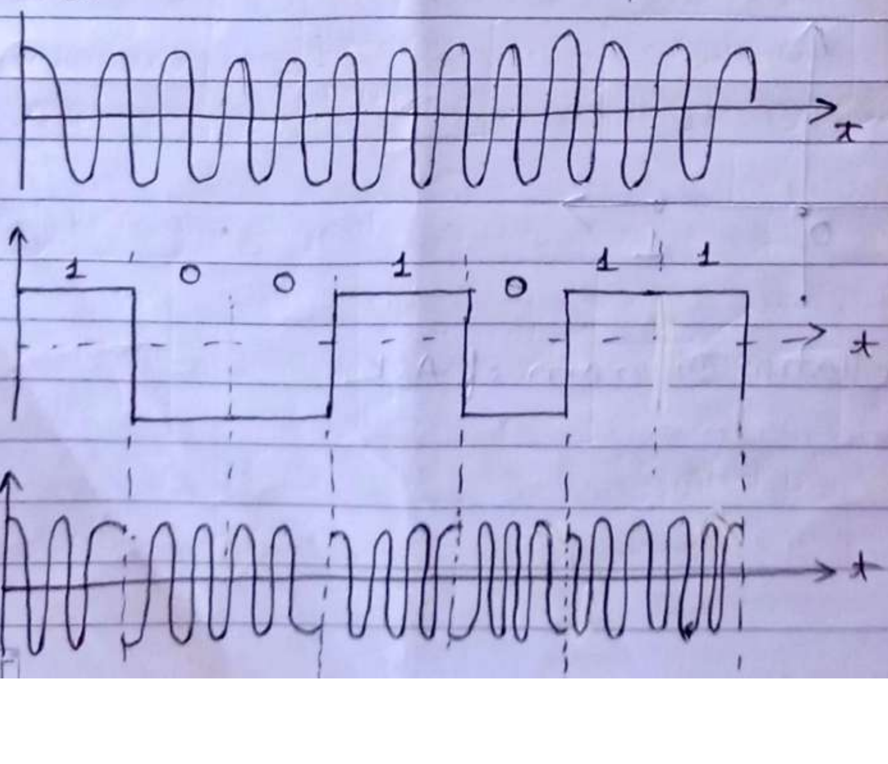
$$s(t) = \sqrt{2P_s}\left(\cos 2\pi f_c t + \pi\right) \quad \text{For symbol 0}$$

Therefore, The binary PSK signal is

$$s(t) = \sqrt{2P_s}\cos 2\pi f_c t \quad \text{Symbol 1}$$

$$= -\sqrt{2P_s}\cos 2\pi f_c t \quad \text{symbol 0}$$

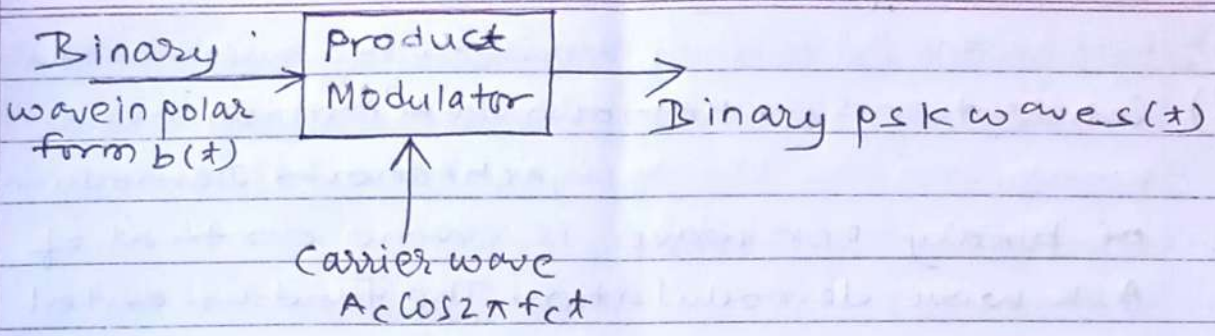
c(t)



Binary wave in polar form

Phase shift keying waveform

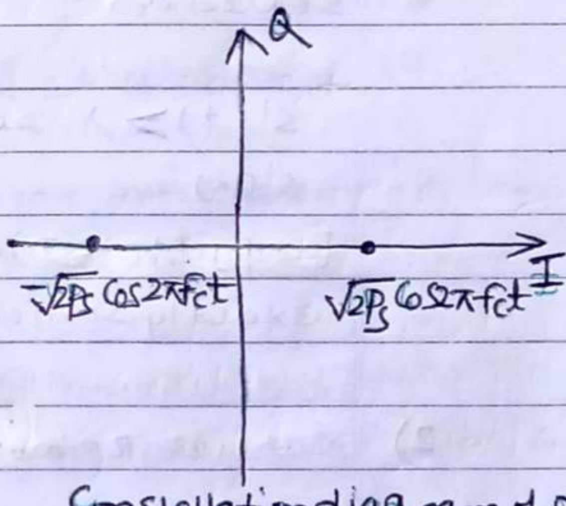
* Generation of PSK signal



Phase shift keying (PSK) modulated wave can be generated by applying Binary wave in polar form '$b(t)$' and sinusoidal carrier wave $c(t) = A_c \cos 2\pi f_c t$ to a product Modulator (Balanced Modulator.

$$s(t) = b(t)\, A_c \cos 2\pi f_c t$$

$$s(t) = \sqrt{2P_s}\, b(t) \cos 2\pi f_c t$$



Constellation diagram of PSK

$$P_s = \frac{E_b}{T_b}$$

similarly for symbol 1:

$$s(t) = \sqrt{2P_s} \cos 2\pi f_c t$$

$$\boxed{s(t) = \sqrt{2P_s} \cos 2\pi f_c t}$$

For symbol 0,

$$s(t) = \sqrt{2P_s} \cos(2\pi f_c t + \pi)$$

$$s(t) = -\sqrt{2P_s} \cos 2\pi f_c t$$

$$\boxed{s(t) = -\sqrt{2P_s} \cos 2\pi f_c t}$$

of start and end of the bit. The output of integrator is fed to Decision Making Device which decides the transmitted PSK signal is 0 or symbol 1.

* Advantage

1) Most efficient digital modulation technique.
2) PSK is used for the System that needs high bit rate.

* Limitation

1) Complication in synchronization.
2) Phase Ambiguity problem.

Phase Shift keying (PSK) Cannot be detected non coherently because the envelope of PSK modulated wave is same for both Symbol 1 and Symbol 0. To overcome this phase Synchronization effect Diffrential phase Shift keying (DPSK) was introduced.

* Diffrential Phase Shift Keying (DPSK)

It is also called the Non Coherent version of PSK. DPSK Combines diffrential encoding with phase Shift keying. It is modified scheme encoded interms of signal transition.

'Symbol 0' represents transition in a given binary sequence w.r.t previous encoded bit and 'Symbol 1' indicates no transition.

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* Frequency shift keying (FSK)

Also called Binary Frequency shift keying (BFSK). In Frequency shift keying the frequency of the carrier is varied according to the input binary symbol keeping the phase and amplitude unchanged.

In FSK it has two different frequency signals according to binary symbols. Let the frequency shift be Ω and $b(t)$ be the input binary data.

$$b(t) = 1 \quad \text{then} \quad S_H(t) = \sqrt{2P_s}\cos(2\pi f_c + \Omega)t$$

$$b(t) = 1 \quad \text{then} \quad S_H(t) = \sqrt{2P_s}\cos 2\pi\left(f_c + \frac{\Omega}{2\pi}\right)t \quad -(1)$$

$$b(t) = 0 \quad \text{then} \quad S_L(t) = \sqrt{2P_s}\cos(2\pi f_c - \Omega)t$$

$$b(t) = 0 \quad \text{then} \quad S_L(t) = \sqrt{2P_s}\cos 2\pi\left(f_c - \frac{\Omega}{2\pi}\right)t \quad -(2)$$

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There for

$$f_H = f_c + \frac{\Omega}{2\pi} \quad \text{for symbol } 1$$

$$f_L = f_c - \frac{\Omega}{2\pi} \quad \text{for symbol } 0$$

* Generation of BFSK

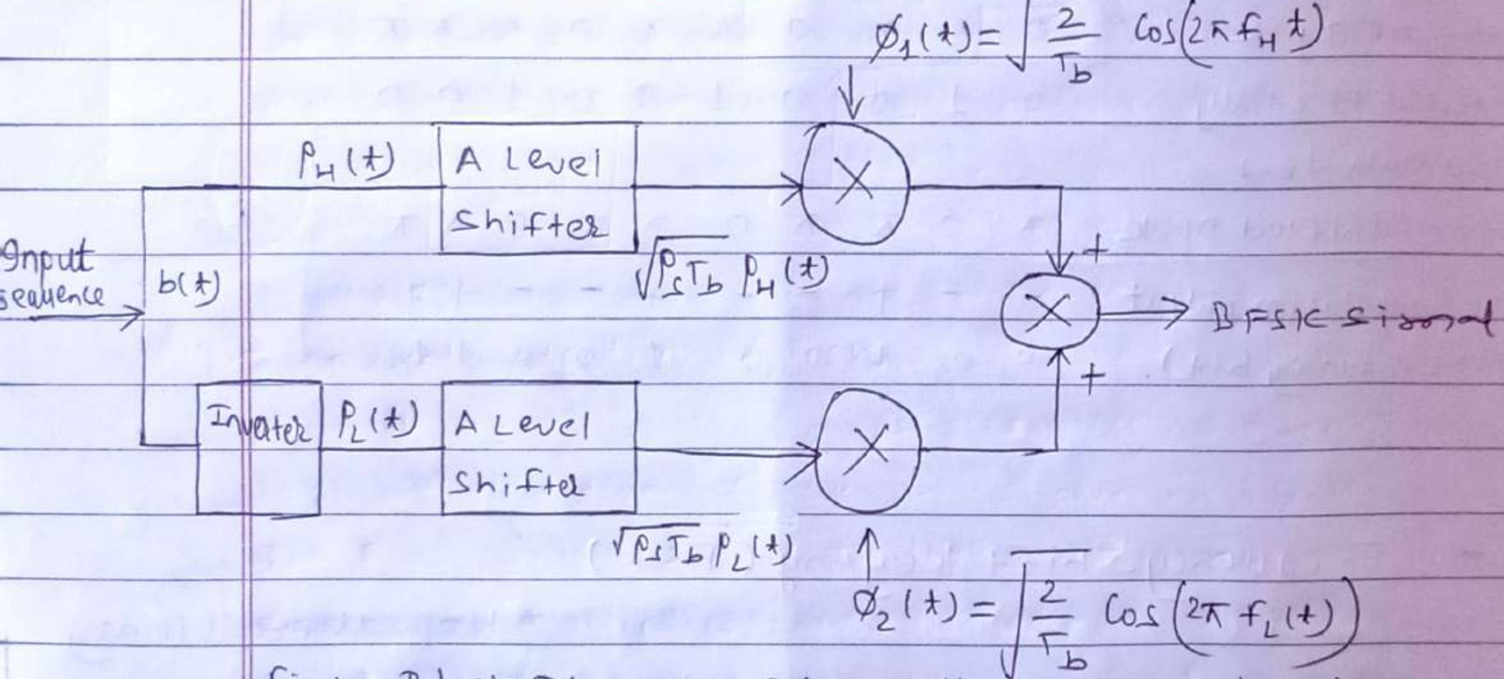

fig:→ Block Diagram of Generation of BFSK signal.

Above figure shows the block diagram of Frequency shift keying. The input sequence $b(t)$ is a binary signal. It has two level shifter. The input of the one shifter is inverted input given as $P_L(t)$ and the other shifter is $P_H(t)$ which shifts the level and fed to the product modulator with two carrier signal $\phi_1(t)$ and $\phi_2(t)$. The output of product modulator are added by the adder to generate Binary Frequency shift keying (BFSK) modulated signal.

For $b(t) = 0$ $\quad P_H(t) = 0$ & $P_L(t) = 1$ $\quad$ will be

For $b(t) = 1$ $\quad P_H(t) = 1$ & $P_L(t) = 0$

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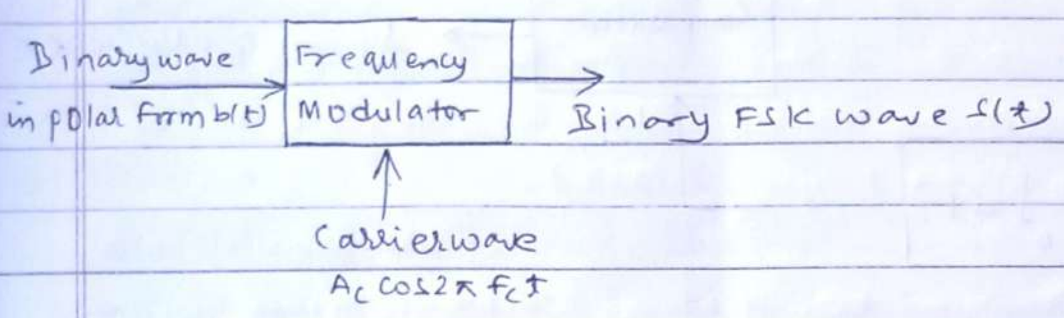
transmitted with modulated frequency f_H or f_L.

OR



FSK signal can be generated by applying the incoming binary data represented in polar form b(t) to a Frequency Modulator. Sinusoid carrier wave of constant amplitude and phase with varied frequency w.r.t binary input is fed to form FSK modulated wave.

The FSK wave are produced as the change of frequency of Frequency modulator output in corresponding fashion.

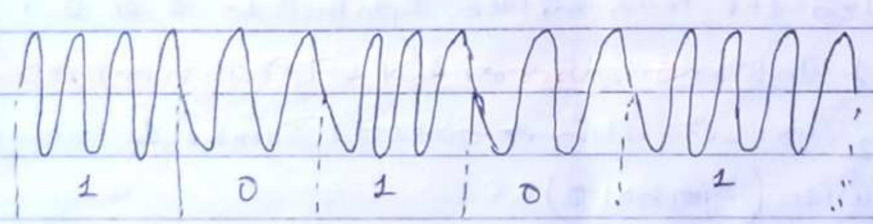


fig: → B FSK signal.

Sometimes Binary FSK is also said to be superposition of two binary ASK wave form.

* Quadriphase shift keying (QPSK)

Digital modulation discussed so far are inefficient as the channel bandwidth is not fully used.

The optimum utilization of bandwidth is possible by the modulation technique such as QPSK and Minimum shift keying (MSK).

QPSK also known as Quadrature phase shift keying is an extension of binary PSK where any one of M possible signal ($M=2^n$) can be transmitted during each interval of time 'T'.

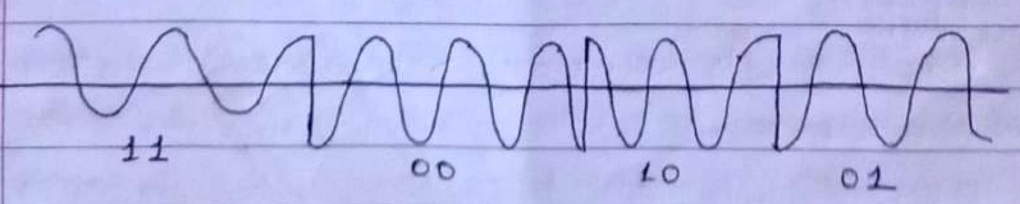
It is an M-ary encoding technique with four possible outcomes or condition ($n=2, M=4$) 00, 10, 11, 01. We represent four possible dibits with instantaneous phase $\phi(t)$ of $135^\circ, -45^\circ, 45^\circ, -135^\circ$.

The QPSK signal given as

$$s(t) = A_c \cos(2\pi f_c t + \phi(t))$$

$\phi(t) \rightarrow$ Instantaneous phase

$\phi(t) = -3\pi/4$	dibit 00	-135°
$= -\pi/4$	dibit 10	-45°
$= \pi/4$	dibit 11	45°
$= 3\pi/4$	dibit 01	135°



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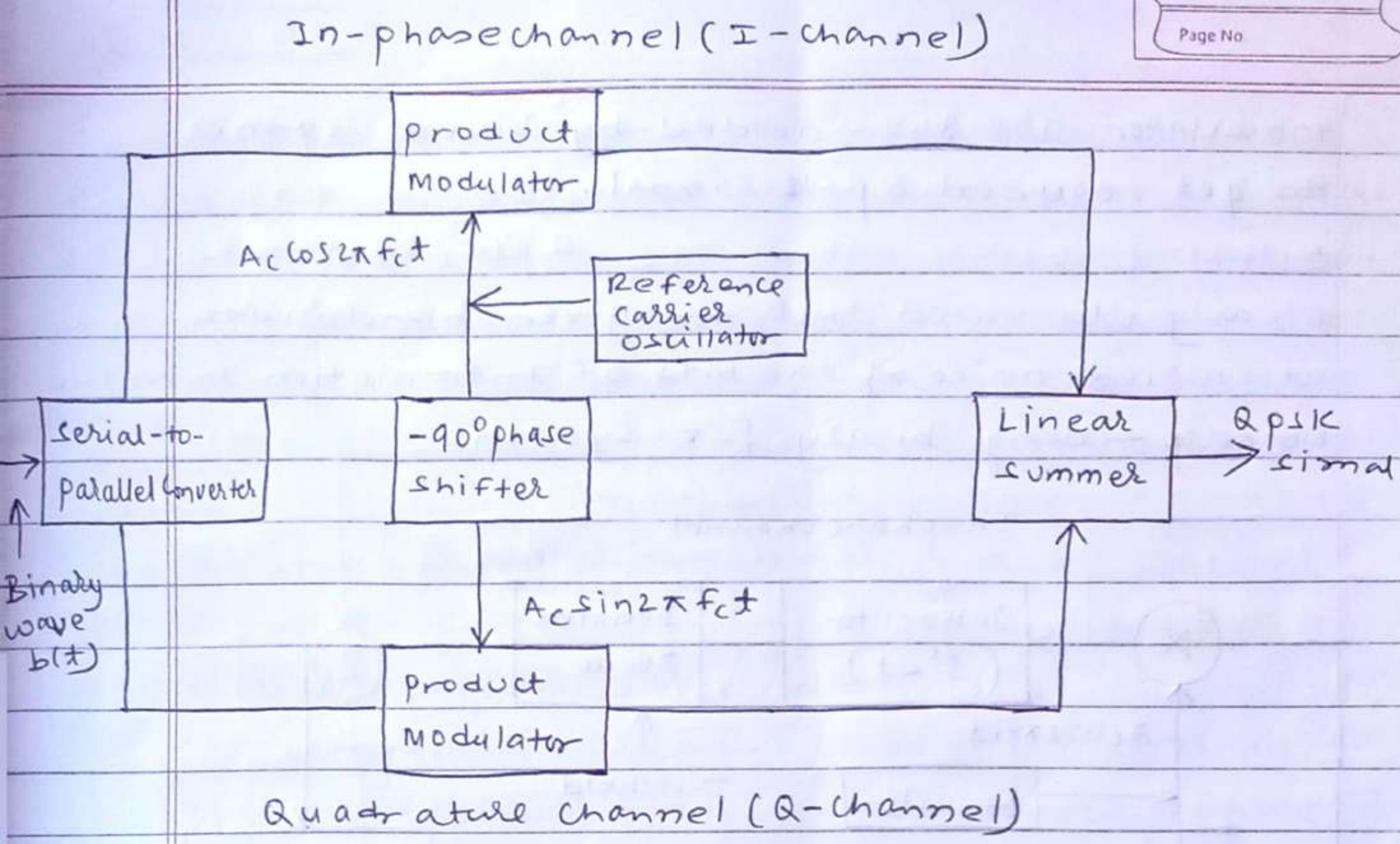


fig: → QPSK transmitter

Above figure shows the block diagram of QPSK transmitter. It consist of a serial to parallel converter, a pair of product modulators fed by '$A_c \cos 2\pi f_c t$' carrier signal and 90^0 phase shifted '$A_c \sin 2\pi f_c t$' carrier signal with a linear summer.

Here the serial to parallel converter represents each successive pair of bits (dibits) of the incoming binary data stream. It acts as a bit splitter where one bit is applied to the In-phase channel of the transmitter and the other bit to the Quadrature channel.

The Inphase bits (I-bit) are modulated with In-phase carrier signal '$A_c \cos 2\pi f_c t$' generated by Reference carrier oscillator and Quadrature phase bit (Q-bit) with phase shifted carrier signal '$A_c \sin 2\pi f_c t$'.

The output of product

modulator are then added by 'Linear summer'
to get required QPSK signal.

QPSK system
clearly illustrates that for given bandwidth
it carries twice of the bits of information than the
corresponding binary PSK system.

* Minimum shift Keying (MSK) :>

Minimum shift keying (MSK) is special form of Continuous-phase frequency shift keying (CPFSK) which over comes the limitation of QPSK.

Unlike QPSK has

1. Abrupt phase shift.
2. Have abrupt amplitude variation.
3. Inter channel interference is very high.

* Gaussian Minimum shift keying (GMSK)

GMSK is a modification of Minimum shift keying (MSK) highly used for cellular mobile Communication.

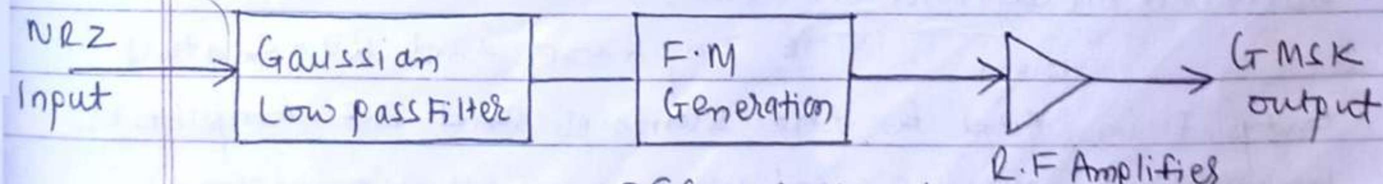


fig:> Block Diagram of Generation of GMSK using Direct FM Generation

GMSK modulated wave is obtained by passing NRZ binary input to the Gaussian Low pass Filter. output of LPF is then fed to the F.M transmitter along with R.F amplifier to produce GMSK signal.

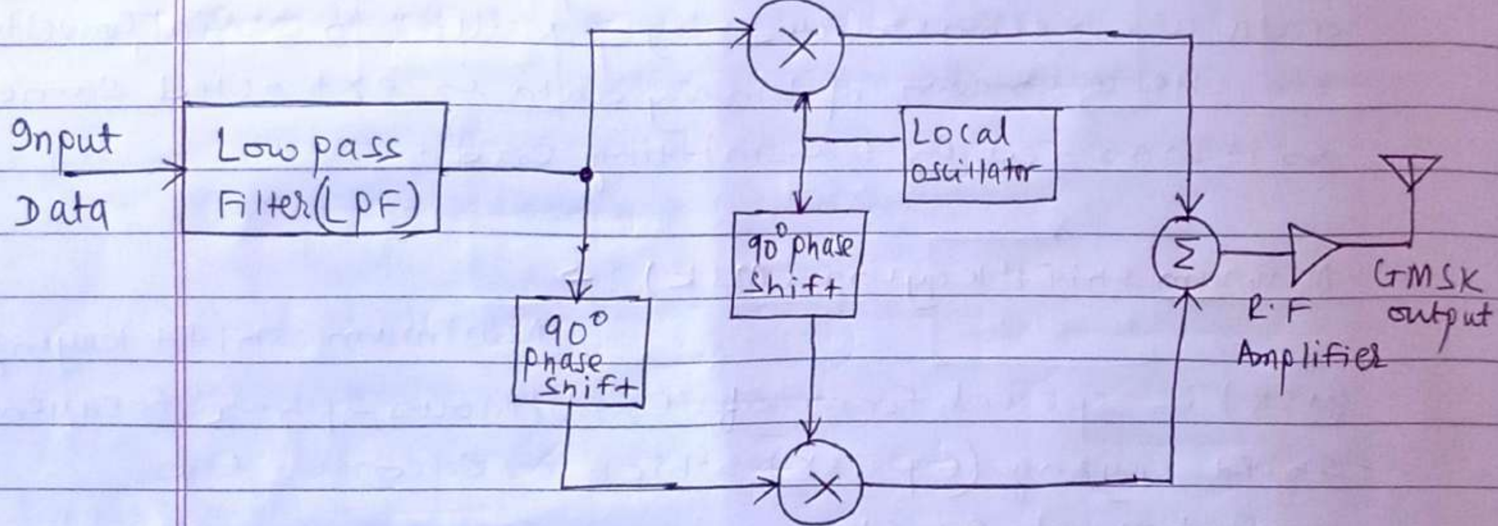


fig:→ GMSK Modulator.

Above figure shows the block diagram of GMSK Modulator Using Inphase and Quadrature balanced modulator.

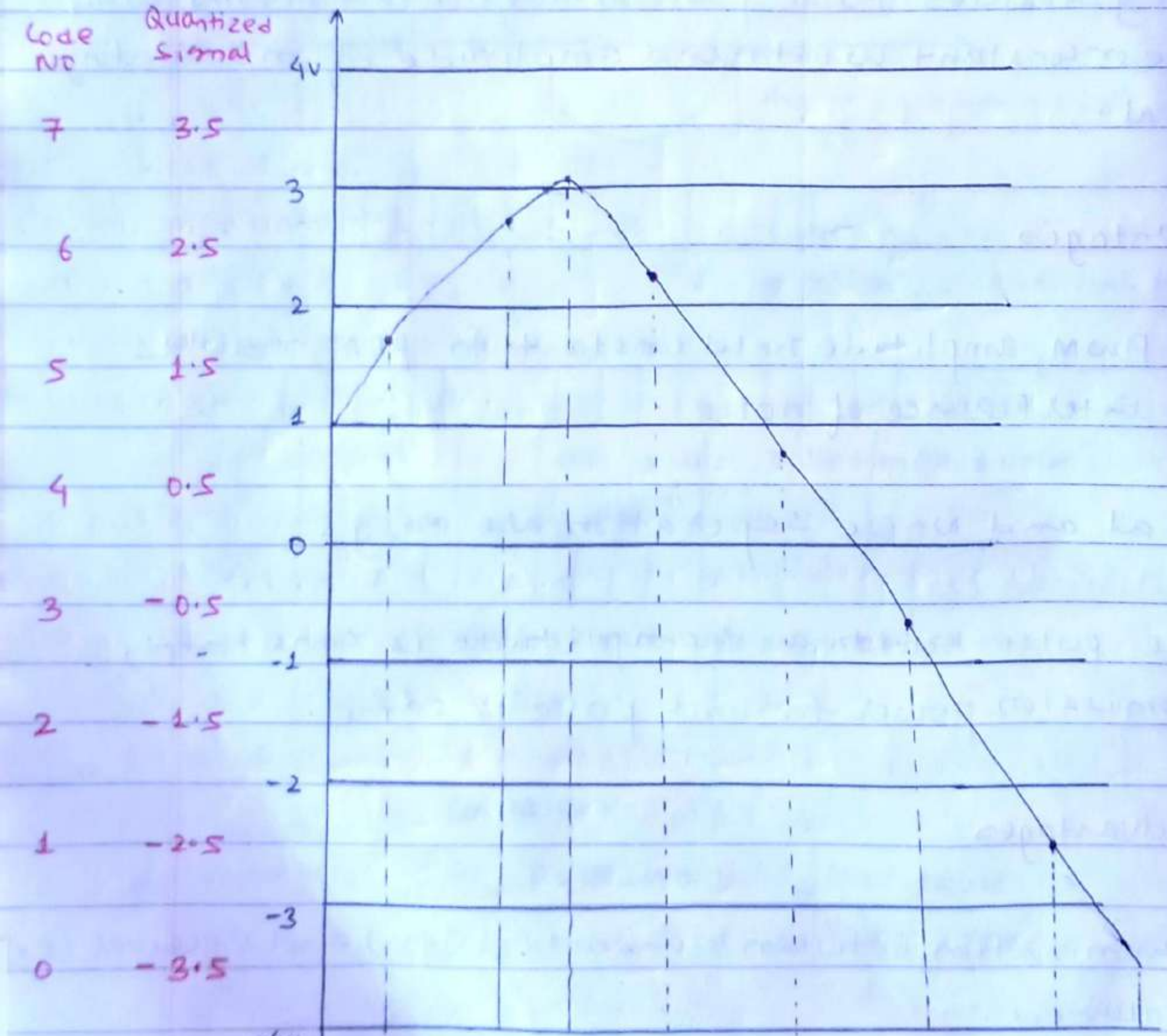
Here the input binary data is fed to the Low pass Filter (LPF) which seperates Inphase and Quadrature component. Appropirate Local oscillators are provided to generate carrier signal Inphase and 90° phase shifted fed to the balanced modulator.

The Inphase and Quadrature output is then fed to the summer to produce GMSK signal which is further amplified by R.F Amplifier and radiated through the GSM Antenna.

* pulse Code Modulation (pcm)

Till now we have studied Analog pulse modulation technique (i.e PAM, PWM and PPM).

Pulse code Modulation (PCM) is a digital pulse modulation technique in which analog signal is sampled and then converted into digital encoded signal which is represented by n-bit binary code.



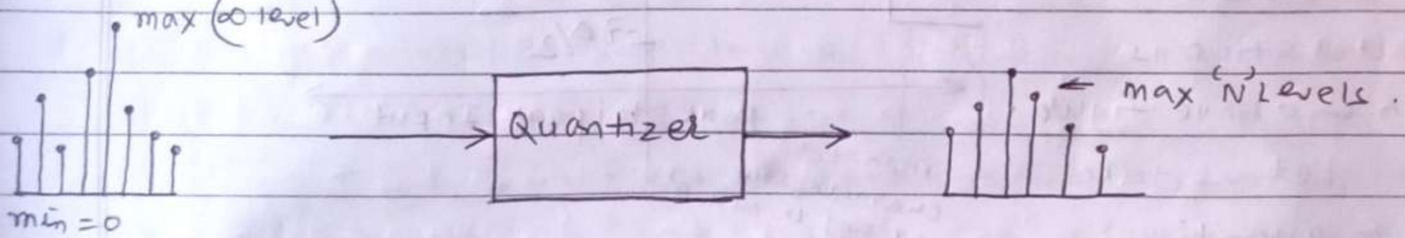
Sampled value →	1.6	2.6	3.1	2.3	0.7	-0.7	-2.5	-3.5
Near of Quantization level →	1.5	2.5	3.5	2.5	0.5	-0.5	-2.5	-3.5
Equivalent Code →	5	6	7	6	4	3	1	0
binary Code Equivalent →	101	110	111	110	100	011	001	000

Three basic and essential operation in pulse code Modulation (PCM) is

a Sampling
b Quantization
c Encoding

b Quantization :→

It is the process of representing analog sampled values by a finite set of levels. The sampling process converts a continuous time signal to a discrete time signal with a amplitude that can take any values from 0 to maximum level. It converts continuous amplitude sample to a finite set (discrete) amplitude values.



There are two types of Quantization. They are

i Uniform Quantization.
ii Non Uniform Quantization.

i. Uniform Quantization :→

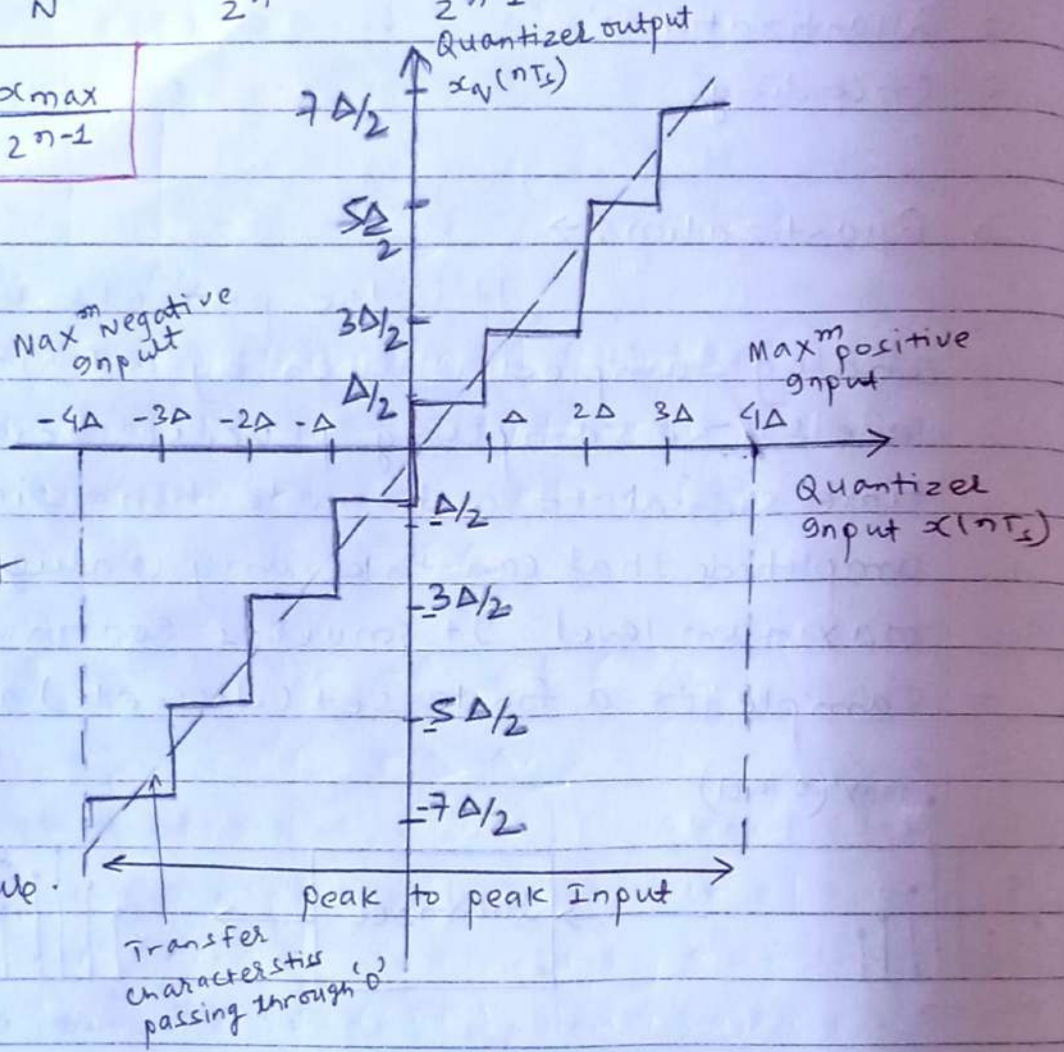
In uniform Quantization the range of input sample is $[-x_{max}, +x_{max}]$ and the number of Quantization level (Q-level) is $N = 2^n$, where n is the number of bits per source sample. Then the step size (Δ) or the length

Quantization Error (q_e)

of the Q-level.

$$\Delta = \frac{2x_{max}}{N} = \frac{2x_{max}}{2^n} = \frac{x_{max}}{2^{n-1}}$$

$$\boxed{\Delta = \frac{x_{max}}{2^{n-1}}}$$



* working principle of Quantizer.

Considering midrise type uniform Quantizer. The transfer characterstics is shown in above figure.

Let us take input to quantizer $x(nT_s)$ from -4Δ to 4Δ, where Δ is stepsize. The fixed digital level or Quantizer output is given at

$x(nT_s) = \pm\Delta \quad x_q(nT_s) = \pm\Delta/2$

$x(nT_s) = \pm 2\Delta \quad x_q(nT_s) = \pm 3\Delta/2$

$x(nT_s) = \pm 3\Delta \quad x_q(nT_s) = \pm 5\Delta/2$

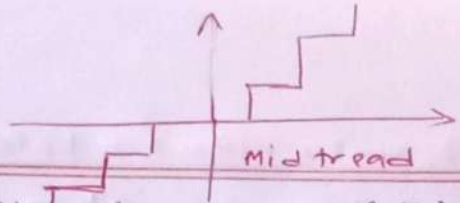
$x(nT_s) = \pm 4\Delta \quad x_q(nT_s) = \pm 7\Delta/2$

Therefore Quantization Error is expressed as

$$E = x_q(nT_s) - x(nT_s)$$

$\boxed{E = \pm\Delta/2}$. Maximum Quantization Error is given by

$$\boxed{E_{max} = \left|\frac{\Delta}{2}\right|}$$



Therefore Quantization Error (E) is the difference between the input signal level $x(nT_s)$ and the level of quantized version $x_q(nT_s)$.

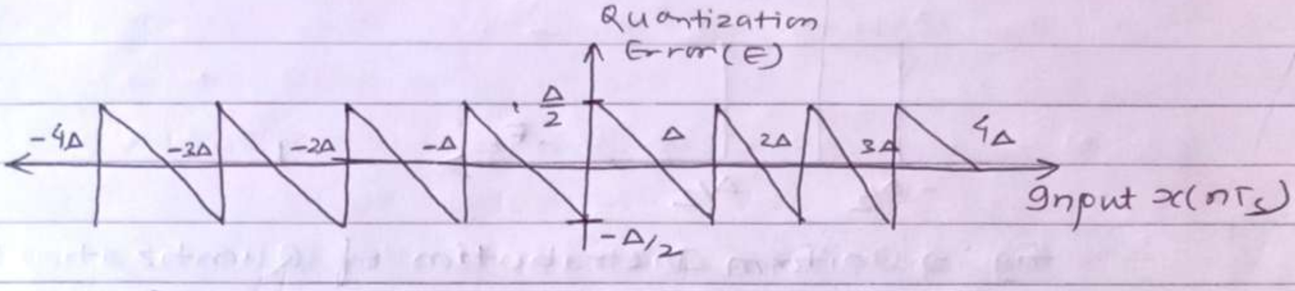


fig:→ Variation of Quantization Error.

From above illustration, we can know that the Quantization Error/Noise are reduced with the increase of level 'N' which in turn reduces the step size.

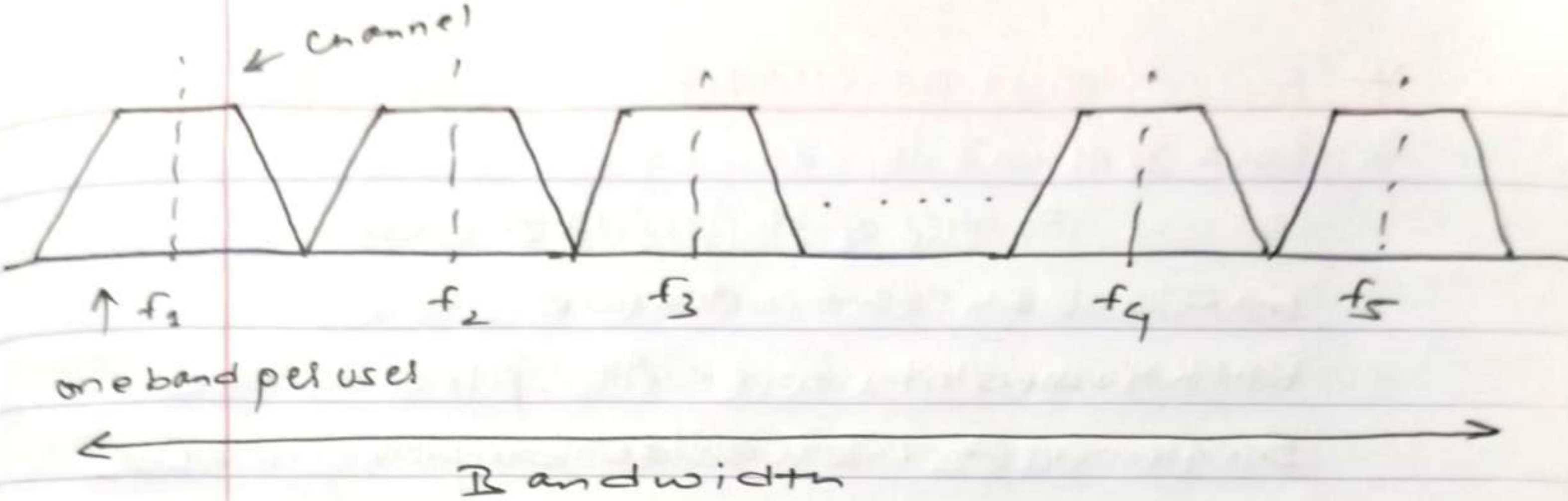
* Fundamental of Communication Access Technology

Access methods are multiplexing techniques that provide Communication services to multiple user in single bandwidth wired or wireless medium. Access method allow many user to share these limited channel. There are three types of Access or multiplexing method. They are

1. Frequency Division Multiple Access
2. Time Division Multiple Access.
3. Code Division Multiple Access.
4. Spatial Division Multiple Access.

1. Frequency Division Multiple Access :→

Frequency Division Multiple Access (FDMA) is the process of dividing bandwidth into multiple individual bands. Each bands is allocated to the single user. Therefore FDMA divides shared medium bandwidth into individual channel. Therefore a number of user can transmit information Simultaneously. Gaurd band are placed



eg:→ cable television, optical fiber, Analog telephone

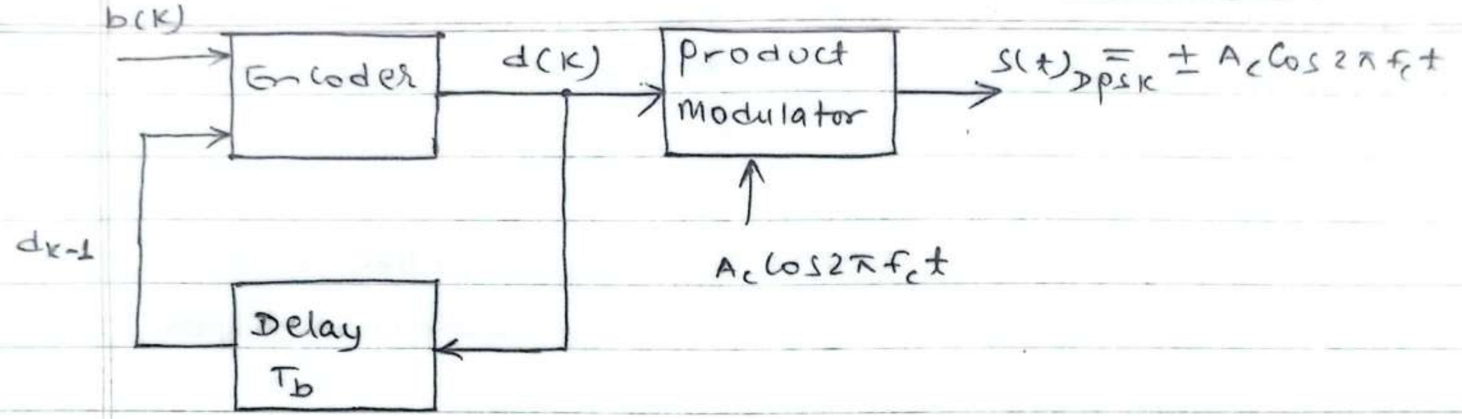
in adjacent frequency band to avoid interference.

2. Time Division Multiple Access (TDMA):→ Time Division Multiple Access is the process of dividing bandwidth into the distinct Timeslots Each timeslots are allocated to the single user. It allows multiple user to share the same channel in a effective way to increase the capacity of the Network.

3. Code Division Multiple Access (CDMA):→ Code Division Multiple Access (CDMA) is the process of sharing the same frequency channel by assigning Unique orthogonal codes rather than dividing in timeslots in TDMA and fre-quency in FDMA. CDMA offers high capacity supporting more users than TDMA and FDMA. It is more secured.

4) Spatial Divison Multiple Access (SDMA):→ Spatial Division Multiple Access (SDMA) is the process of creating spatial channels for multiple user on the same frequency by using

Smart Antennas. SDMA employs arrays of Antenna directing towards the specific user boosting up of System capacity and spectral efficiency. It is based on wireless technology.



Generation of DPSK

Above figure shows the block diagram of DPSK where data stream b(K) is applied to the Encoder.

The output of the Encoder is applied to the product modulator with the carrier signal ($A_c \cos 2\pi f_c t$) generating DPSK signal.

Similarly the output is also fed back to Encoder by delaying duration of 'T_b'. In this modulation technique an extra bit (1 or 0) is added as an initial bit and the transistion is predicted. 'Symbol 0' represents transition and 'Symbol 1' no transition which is clearly illustrated below