Chapter - 5 Suraj Basant Tulachan

Date / /

Page No.

* Bandpass (Modulated) Data Communication System: (4 hrs)

5.1 * Binary Digital Modulations :→

For long distance digital transmission it is necessary to generate bandpass 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 baseband signal.

Basic Concepts in Digital Modulation is exactly same as of Analog Modulation apart 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.

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

$s(t) = A_c \cos 2\pi f_c t$ Symbol 1

$s(t) = 0$ Symbol 0

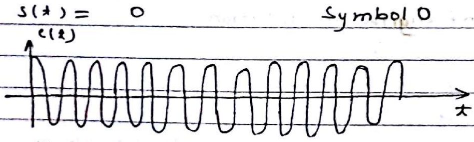


fig: carrier signal

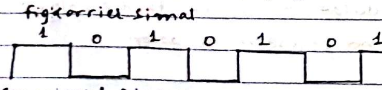


fig: unipolar Bit sequence

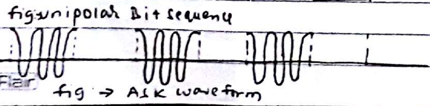


fig → ASK waveform

* Generation of ASK signal

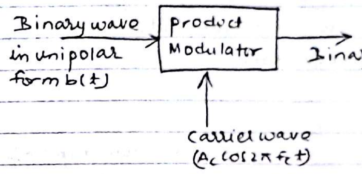


fig :→ Generation of binary ASK

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.

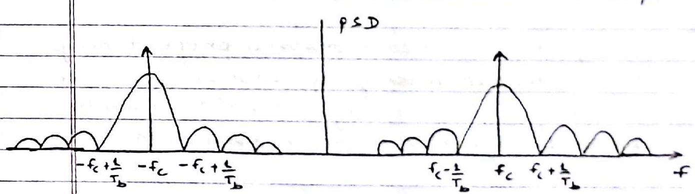


fig :→ power spectral density of ASK signal

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.

* Detection of Binary ASK

There are two type of detection of Binary ASK.

1) **Coherent or Synchronous Detector :⇒** Coherent or Synchronous Detector are of two form.

a) Phase Synchronisation :⇒ Ensures that carrier wave generated locally at the receiver is locked in phase with respect to that used in the transmitter

b) Timing Synchronisation :⇒ Ensures proper timing of the decision making operation in the receiver with respect to switching instant (switching to symbol 1 or symbol 0) in the original data.

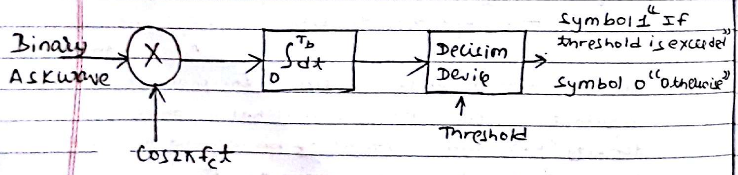


fig :⇒ Coherent Detection of ASK

Above figure shows the block diagram of coherent detection of ASK signal. It consist of product modulator where the incoming binary ASK wave is fed with the sinusoidal carrier generated by Local oscillator.

The output is then fed to the integrator where essential low pass filtering is performed. The output of the integrator is then passed to the Decision Device which compares with the threshold. 'Symbol 1' is decided if it exceeds than the threshold and 'Symbol 0' otherwise.

2) Non Coherent Detector :⇒

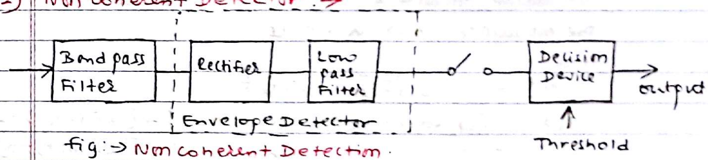


fig :⇒ Non Coherent Detection

Above figure shows the block diagram of Non Coherent Detector. Binary ASK can be demodulated non coherently by Envelope Detector. This greatly simplifies the design consideration needed in synchronous detection. It doesnot require a phase Coherent oscillator. This scheme involves some form of Rectification and Low pass filtering and put on Decision Device to decide for the incoming signal in 'Symbol 1' or 'Symbol 0' Compared to the threshold.

If noise is small, the Non coherent receiver is the best solution with regard to the performance and cost.

Mathematical part

If carrier signal is $A_c \cos 2\pi f_c t$

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

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

$$A_c = \sqrt{2P_s} \qquad P_s \Rightarrow \text{power dissipated per bit}$$

If $m(t)$ is the binary data in unipolar form the Modulated ASK wave is

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

$$s(t) = \sqrt{2P_s}\cos 2\pi f_c t \quad \text{for symbol 1 [If } m(t)=1]$$
$$= 0 \quad \text{for symbol 0 [If } m(t)=0]$$

$$s(t) = \frac{m(t)}{2}\sqrt{2P_s}\left(e^{j2\pi f_c t} + e^{-j2\pi f_c t}\right)$$

$$s(t) = \frac{\sqrt{2P_s}}{2}\left[m(t)e^{j2\pi f_c t} + m(t)e^{-j2\pi f_c t}\right]$$

Taking F.T we get

$$\boxed{S(f) = \frac{\sqrt{2P_s}}{2}\left[M(f+f_c) + M(f-f_c)\right]}$$

* Demodulation (Detection)

If $s'(t)$ is the message signal extracted from the demodulation.

$$s'(t) = s(t)\, c(t) \quad \cos 2\pi f_c t$$

$$s'(t) = \sqrt{2P_s}\, m(t) \cos 2\pi f_c t$$

$$s'(t) = \sqrt{2P_s}\, m(t) \cos^2 2\pi f_c t$$

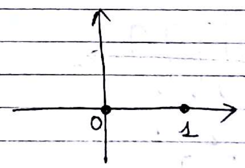
$$s'(t) = \sqrt{2P_s}\, m(t)\left(\frac{1+\cos 4\pi f_c t}{2}\right)$$

$$s'(t) = \frac{\sqrt{2P_s}}{2} m(t) + \frac{\sqrt{2P_s}\, m(t)}{2}\cos 4\pi f_c t$$

After Integrator which performs low pass filtering

$$s'(t) = \frac{\sqrt{2P_s}}{2} m(t)$$ which is scaled original message signal.

Decision is then made if it is "symbol 1" or "symbol 0".



Constellation Diagram of ASK

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

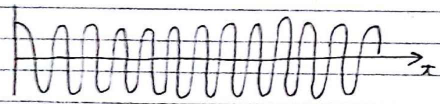
$$s(t) = \sqrt{2P_s}\cos 2\pi f_c t$$

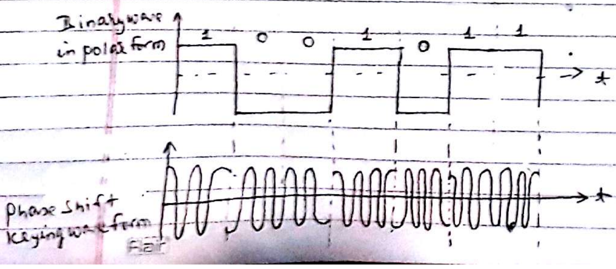
~~$s(t) = \sqrt{2P_s}(\cos 2\pi f_c t + \pi)$ For symbol 0~~

Therefore, The binary PSK signal is

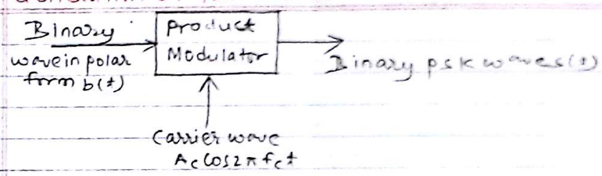
$$s(t) = \sqrt{2P_s}\cos 2\pi f_c t \quad \text{Symbol 1}$$

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





* 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.

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

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

similarly for symbol 1

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

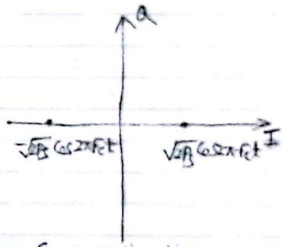
$$\boxed{s(t) = \sqrt{2P_s}\cos 2\pi f_c t}$$

For symbol 0,

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

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

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



Constellation diagram of PSK

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

* Detection of Binary PSK wave

1) **Coherent or Synchronous Detector :→**

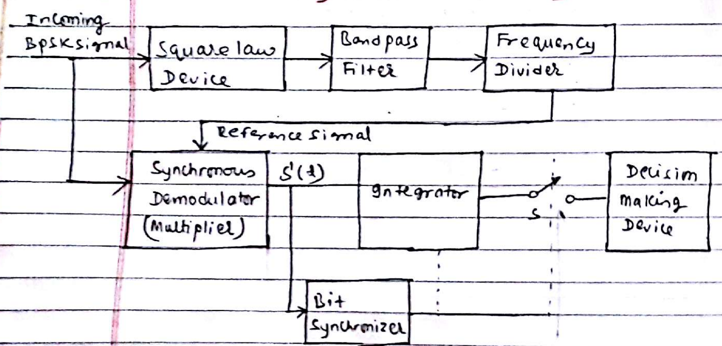
Synchronous Demodulation of binary PSK wave is same as that of ASK wave demodulation. The fundamental difference is the choice of threshold level (λ). In this case threshold level is '$\lambda = 0V$'.

Therefore PSK modulated wave passed through series of blocks are scaled as

$s'(t) > \lambda$ Decision is made '1' and '0' else.

[Copy Block Diagram & mathematical illustration exactly same as Synchronous Detection of ASK]

2) **Carrier Recovery Circuit in PSK system :→**



block diagram of

Above figure shows the carrier Recovery circuit for demodulation or detection of phase shift keying (PSK) signal.

Let the received BPSK signal is

$s(t) = b(t) A_c \cos(2\pi f_c t + \theta)$ $\theta \rightarrow$ phase change

$\theta \rightarrow$ depends on the time delay from transmitter and receiver. The received is squared by square law Device and the amplitude terms are neglected.

$$\cos^2(2\pi f_c t + \theta) = \frac{1 + \cos 2(2\pi f_c t + \theta)}{2}$$

$$= \frac{1}{2} + \frac{1}{2}\cos 2(2\pi f_c t + \theta)$$ which is further

passed through Band pass filter removing scale '1/2' as it is centred around '$2f_c$'

$\cos 2(2\pi f_c t + \theta)$ is fed to frequency divider by '2' and $\cos(2\pi f_c t + \theta)$ is passed to synchronous demodulator.

$\therefore$ Output of Multiplier is

$$s'(t) = s(t) \cdot \cos(2\pi f_c t + \theta)$$

$$s'(t) = b(t) A_c \cos(2\pi f_c t + \theta) \cdot \cos(2\pi f_c t + \theta)$$

$$s'(t) = b(t)\sqrt{2P_s}\cos^2(2\pi f_c t + \theta) = b(t)\sqrt{2P_s}\left[\frac{1 + \cos 2(2\pi f_c t + \theta)}{2}\right]$$

$$\boxed{s'(t) = b(t)\sqrt{P_s/2}\left[1 + \cos 2(2\pi f_c t + \theta)\right]}$$ are applied

to the Integrator and bit synchronizer. Integrator integrates and perform low pass filtering operation over one bit period (T_b) and Bit synchronizer takes care

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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** digital

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

* **Limitation**

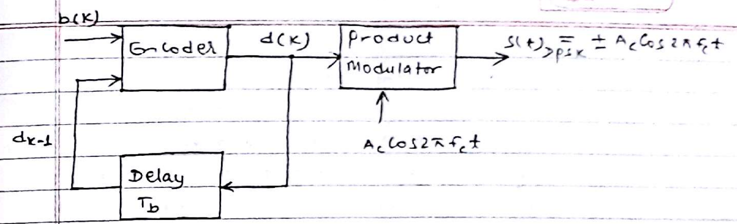
1) Complication in synchronization.
2) Phase Ambiguity problem.

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 in terms of signal transition.

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



Generation of DPSK

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

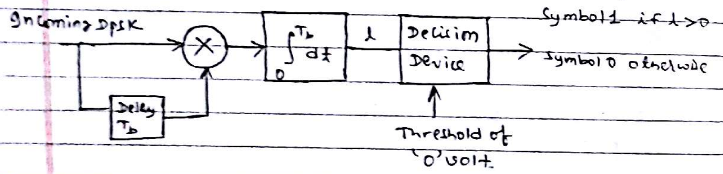
The output of the Encoder is applied to the product modulator with the carrier signal ($A_c \cos 2\pi f_c t$) generating DPSK signal.

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

Binary Data b(K)		0	0	1	0	0	1	0	0	1	1	phase shift
Diffrentially encoded data d(k)	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 diffrentially 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	

* Row 3 → phase of generated DPSK has been shown in third row.

For detection of DPSK the modulated signal is applied to one of the input of the multiplier and delayed version by the time interval 'T_b' as another input.



* Row 5 → Delayed version of phase (phase shifted)

Now the phase difference between the phase of the DPSK and phase of shifted DPSK determines the sign of the phase comparator output. When difference $\phi = 0$, the integrator output is positive and negative when $\phi = \pi$ which is given by 'Row 6'.

By comparing the integrator output with a decision level of 0V, the decision device can reconstruct the binary sequence 'symbol 0' for negative output and 'symbol 1' for positive output.

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
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
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

T_x

R_x

* 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.

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

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

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

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

There for

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

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

* Generation of BFSK

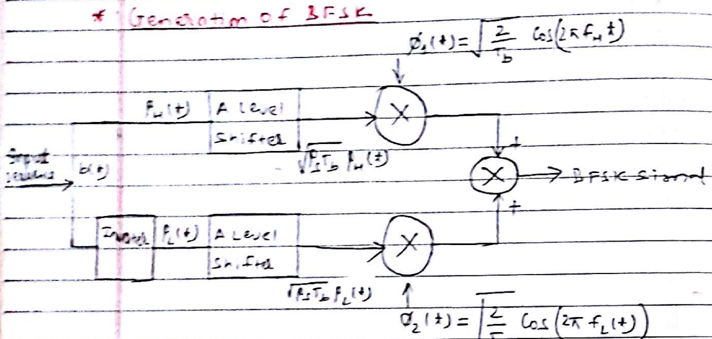


fig → Block Diagram of Generation of BFSK signal.

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.

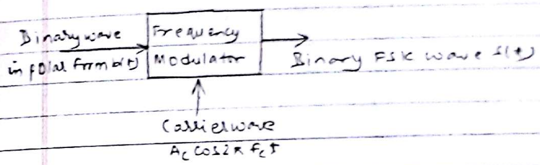
For $b(t) = 0$ $P_H(t) = 0$ & $P_L(t) = 1$ will be

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

modulated

transmitted with 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.

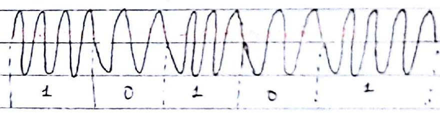


fig: → BFSK signal.

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

* Detection of FSK signal

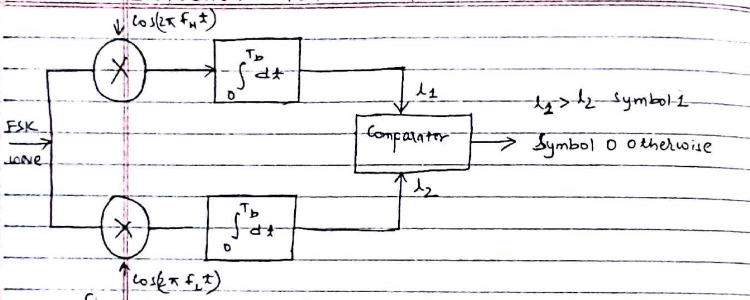


fig :→ Coherent detection of FSK

The block diagram of coherent detection of FSK is shown in above figure. The FSK wave is fed to two Correlators. Correlators consist of multiplier where the two carrier frequency are introduced which are further passed through the Integrators.

The Integrator provides necessary filtering action and are fed to the Comparator which decides the transmitted symbol is 1 or 0.

The output of Integrator

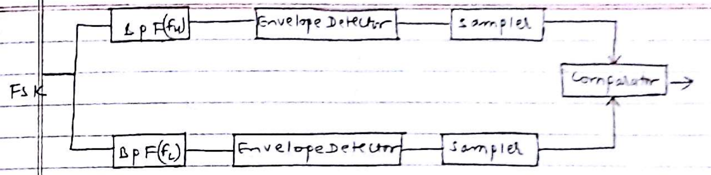
$l_1 > l_2$ resembles or detects Symbol 1

& otherwise (Symbol 0)

2) Non-Coherent detection of FSK :→

Below figure shows the block diagram of Non-Coherent detection of FSK.

The demodulation or detection of FSK wave is done by Envelope detector where



the FSK signal is applied to two band pass filter tuned to f_H and f_L. Each filter is followed by Envelope detector and are sampled by sampler. The output of the sampler are then compared which decides in favour of Symbol 1 or Symbol 0

If $f_H > f_L$ Symbol 1 & Otherwise (symbol 0).

* 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°, -45°, 45°, -135°.

The QPSK signal given as

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

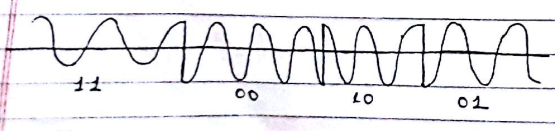
$\phi(t) \rightarrow$ Instantaneous phase

$\phi(t) = -3\pi/4$ dibit 00

$= -\pi/4$ dibit 10

$= \pi/4$ dibit 11

$= 3\pi/4$ dibit 01



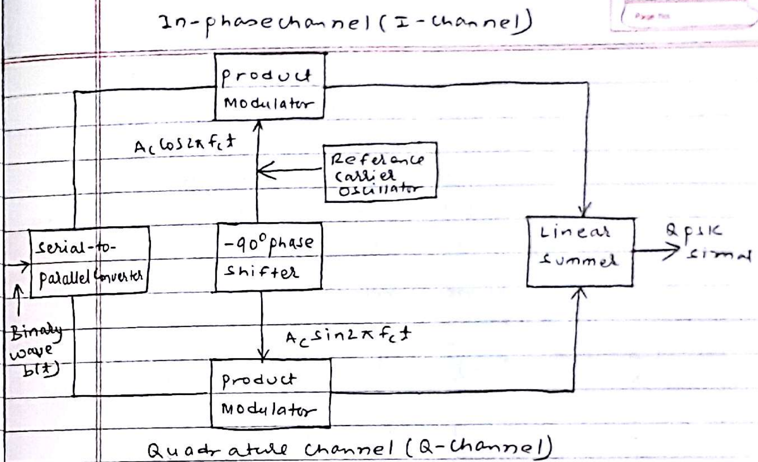


fig:→ QPSK transmitter

Above figure shows the block diagram of QPSK transmitter. It consist of a serial to parallel converter, a pair of product modulator fed by '$A_c \cos 2\pi f_c t$' carrier signal and 90° 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.

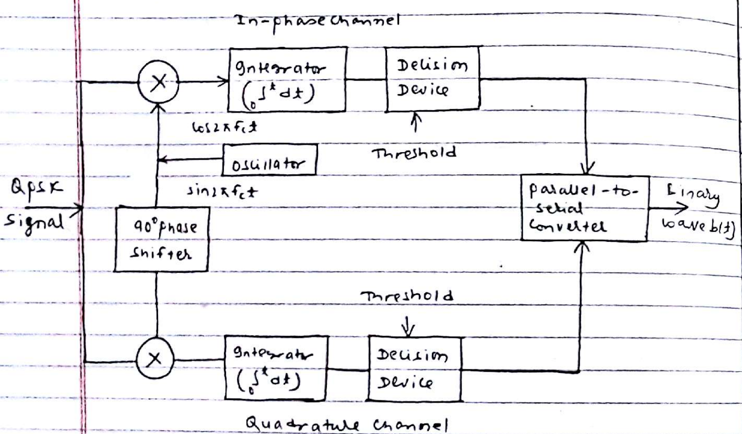


fig:→ Block Diagram of QPSK Receiver. (Coherent)

QPSK signal can be detected by using pair of correlators (multiplier followed by integrator) in parallel.

The upper side or path of correlator computes the modulated Inphase bit and the lower side or path, the modulated Quadrature phase bit. The balanced modulator are fed with inphase carrier and phase shifted carrier $\sin 2\pi f_c t$ which is then passed through the integrator. The output of integrator is fed to the decision device where the comparision is done with the given threshold. phase is decided out of four phase and the binary data are reconstructed by parallel to serial converter. Hence, stream of binary data is extracted same as it was fed in transmitting end.

* 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.

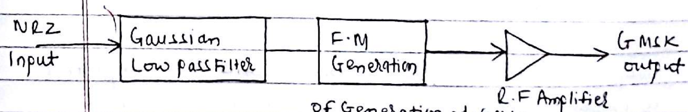


fig:→ Block Diagram of Generation of GMSK using Direct FM Generation

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.

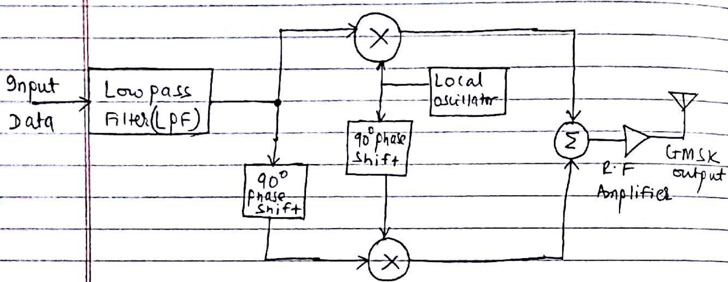
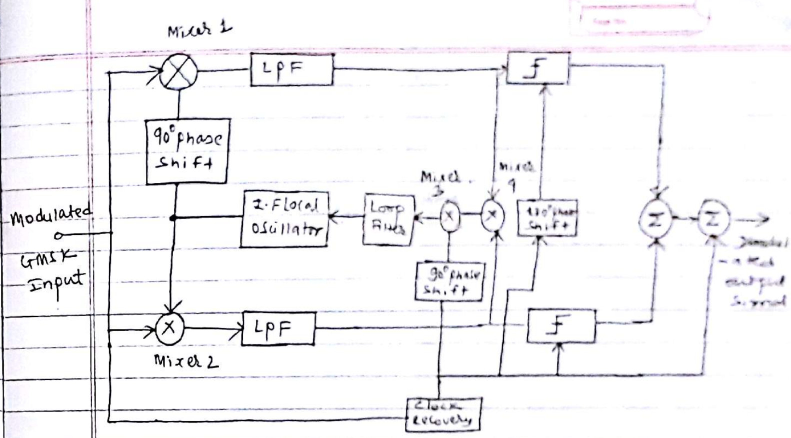


fig:→ GMSK Modulator.

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.



Above figure shows the block diagram of GMSK detection process with appropirate clock recovery circuit. The input modulated signal is given to two Mixer.

The carrier signal generated by I.F local oscillator is given directly to the mixer 2 and 90° phase shifted to the mixer 1.

The output of the mixer is then fed to the low pass Filter (LPF) and the orthogonal coherent detectors are used to extract the GMSK demodulated output signal.

* Advantages of GMSK :->

1) GMSK has good power Efficiency
2) GMSK has good spectral Efficiency
3) GMSK has less Intersymobol Interference (ISI).
4) GMSK is best for wireless Communication.

* GMSK Transmission System

The fundamental

Problem of MSK is that the spectrum is not compact enough to occupy R.F channel

Bandwidth. Wireless data transmission requires efficient use of the R.F Channel Bandwidth, which is achieved by using Gaussian Filter in MSK.

Below figure shows the spectral density of MSK and GMSK of different Bit Duration (B.T).

Less Bit Duration (B.T) has better ISI tolerance.

Here the Bit duration refers the channel spacing where B.T = 0.3 has more tighter channel spacing then B.T = 0.5 making spectrum to be more compact. Two main system Cellular Digital packet data (CDPD) and Mobitex System use GMSK modulation.

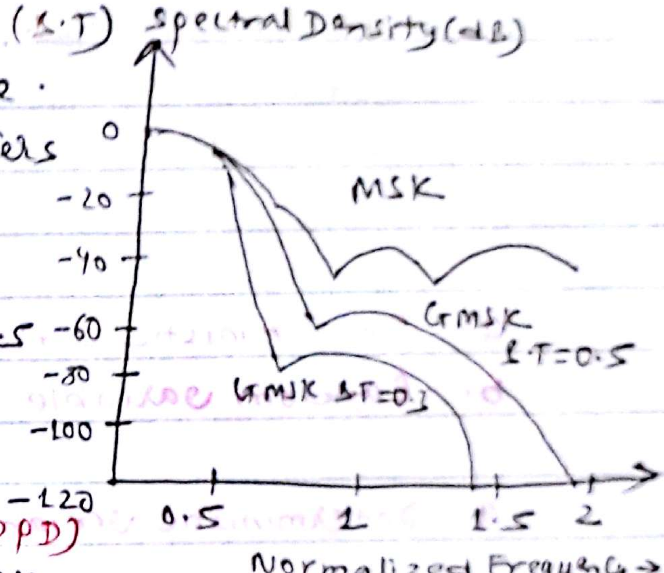


Fig:→ Spectral Density of MSK and GMSK

CPDD has bit duration B.T = 0.5 with 30KHz channel spacing with data rate of 19.2 kbps.

Mobitex System has bit duration of B.T = 0.3 which has tighter channel spacing of 12.5 KHz and data rate of 8 kbps.

Note → Offset QPSK (OQPSK) overcomes the limitation of Abrupt phase shift of QPSK which introduces attenuation. QPSK represented by two bit and four states experiences 180° phase shift per state can be minimized in OQPSK by 90° phase shift. Therefore OQPSK overcomes the abrupt change and hence attenuation is decreased.

Flair

* M-ary data communication system

In binary signalling there are two levels of output but in case of M-ary signalling there are M-level of output i.e output may have one of the M possible level.

* Signaling Rate :→

If M symbols emitted are equiprobable and statistically independent then the source entropy

$$H = \sum_{i=1}^{N} P_i \log_2 (1/P_i)$$

where $P_i = 1/M$ and $\sum_{i=1}^{M} P_i = 1$

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

Information Rate $R = rH$ r = Symbol Rate

Information Rate for M-ary data communication system is

$$R = r \log_2 M$$

For $M = 4$, $\log_2 4 = 2$

$$\boxed{R = 2r}$$

* Advantage of M-ary Data Communication System

For M-ary data communication system, data rate in M-ary signalling is $\log_2 M$ times faster than data rate in binary signalling.

Flair

* Comparision betn M-ary signalling and Binary signalling.

	Binary Signaling System	M-ary Signaling System
1.	output of pulse generator consist of binary pulse i.e pulse with one of two possible amplitude level.	1. output of pulse generator takes one of M possible amplitude level with $M > 2$
2	signalling rate of the system is $1/T_b$ if T_b is bit duration	2. signalling rate of system is $\frac{1}{T}$ if 'T' is symbol duration.
3.	It transmits data slower than M-ary.	3. It transmits data at rate of $\log_2 M$ times faster than binary.
4.	Less power is required.	More power is required.

Flair

* Quadrature Amplitude Modulation (QAM) System.

Quadrature Amplitude Modulation is the digital modulation technique that combines both Amplitude shift keying (ASK) and phase shift keying (PSK) together.

Both Amplitude and phase of transmitter is varied with respect to message signal which is in binary form (0,1).

QAM addresses both the limitation of A.S.K and P.S.K. M-ary QAM is classified as 8-QAM and 16 QAM.

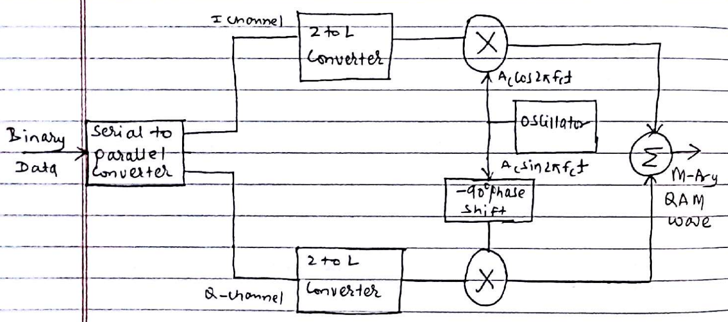


fig:→ M-ary QAM (Transmitter)

Above figure shows the block diagram of M-ary QAM. It consist of serial to parallel converter which is passed through the 2 to L level converter in I-channel and Q-channel.

The output of 2 to L level converter is passed through the product modulator and passed to the Linear summer to produce M-ary QAM signal.

Here the serial to parallel converter accepts a binary sequence of bit rate $\boxed{R_b = \frac{1}{T_b}}$ and produces two parallel binary sequence whose bit rate are $\frac{R_b}{2}$. The 2 to L level converter converts $(L = \sqrt{M})$ polar L-level signal.

For 8-QAM

$N = 3, \quad M = 2^N = 2^3 = 8$ possible output phase and amplitude.

For 16-QAM

$N = 4, \quad M = 2^N = 2^4 = 16$ possible output phase and amplitude.

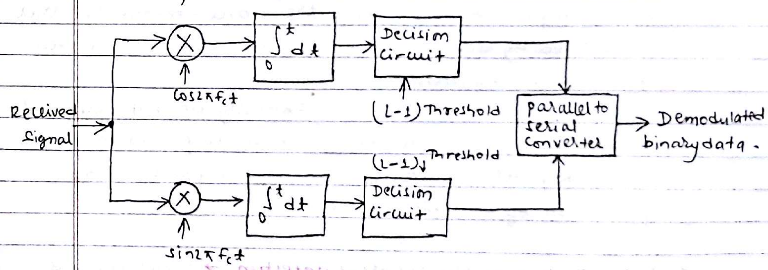


fig:→ M-ary QAM (Receiver)

Above block diagram shows the M-ary QAM receiver which is passed through product modulator of I-channel & Q-channel. The output is then passed through the integrator circuit which performs filtering action. The output of integrator is passed through the Decision circuit which is compared to (L-1) threshold producing demodulated signal. The extracted binary data are then converted in serial form by parallel to serial converter performing complete demodulation of QAM signal.

* **Modems and its applications**

MODEM is commonly known as Data Transceiver. MODEM also known as Modulator-Demodulator is an electronic device that is used to transmit/receive digital data over voice-grade public telephone lines.

Telephone channel which is analog in nature fits the voice-frequency carrier modulated by data transmitter and is demodulated or extracted by data receiver.

Initially MODEM were used to connect terminals located in remote places to a central computer. The modulation type depends on the application of interest.

* Binary FSK with Non coherent detection :→ Simplicity and economy are more important than bandwidth efficiency. FSK MODEMs operates at 1200 bps operating at frequency 1200 to 2100 HZ.

Telephone channel :→ 300-3400 HZ voice frequency

* Four phase DPSK :→ with carrier at 1200 HZ with speed of 2400 bps.
* Eight phase DPSK :→ with carrier at 1800 HZ with speed of 4800 bps.
* M-ary PSK & DPSK :→ This modulation scheme is susceptible to phase jitter in telephone channel.

* M-ary QAM (16-QAM) :→ This Modem permits speed with 9600 bps and implements adaptive equalization to compensate distortions.

* **Modes of operation of Modems**

1. Simplex :→

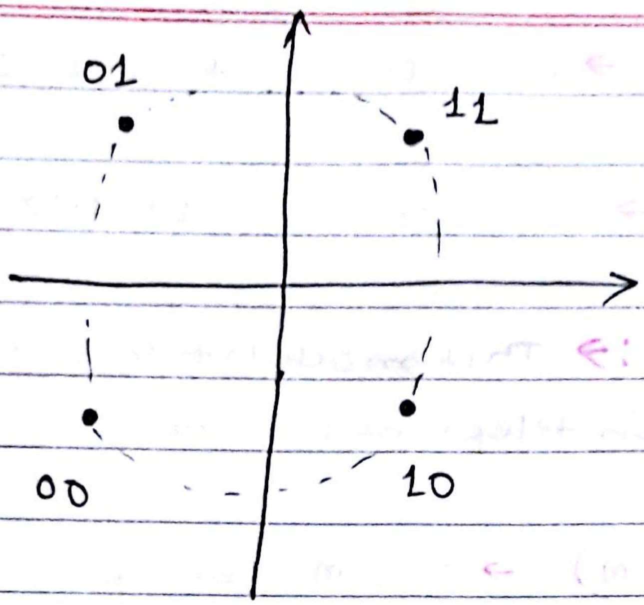
In this mode data transmission is only in one direction and no signalling path is available from receiver to transmitter. There is no mechanism for error correction and retransmission of data in simplex mode. It has limited use.

2. Half Duplex :→

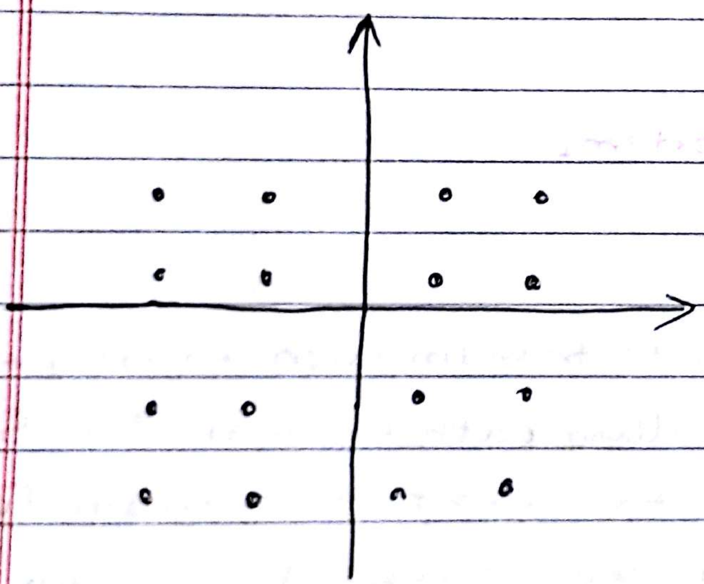
In this mode data transmission is in both direction but is transmitted one way at a time. Speed is reduced in this mode.

3. Full Duplex :→

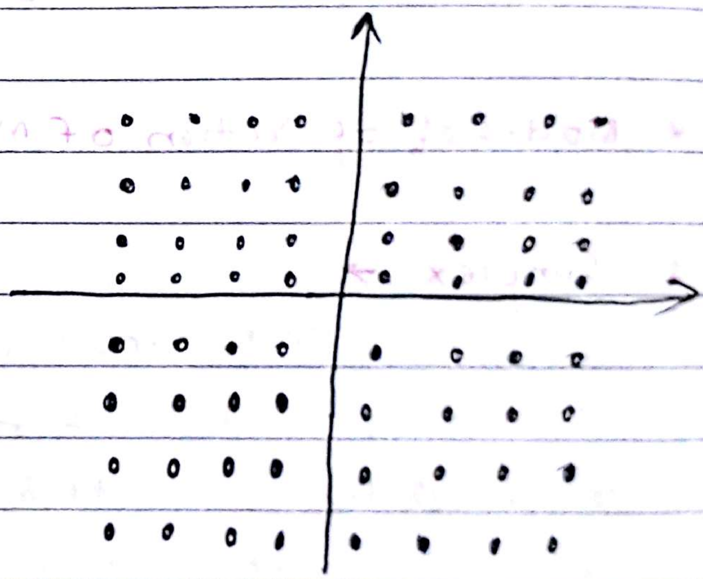
In this mode data transfer is in both direction at same time. It requires two independent channel.



Constellation Diagram of QPSK



16 QAM



64 QAM