Module-4

Digital Modulation Techniques: Digital Modulation formats, Coherent binary modulation techniques, Probability of error derivation of PSK and FSK, M-ary modulations-QPSK, QAM, PSD for different digital modulation techniques, Non-coherent binary modulation techniques -DPSK

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Digital Modulation formats

- Modulation is defined as the process by which some characteristics of a carrier is varied in accordance with a modulating wave.
- In digital communications, the modulating wave consists of binary data or an M-ary encoded version of it.
- In M-ary signalling, the modulator produces one of an available set of $M=2^m$ distinct signals in response to m bits of source data at a time.
- Binary modulation is a special case of M-ary modulation with M=2.
- For modulation, it is customary to use a sinusoidal wave.
- There are 3 basic modulation techniques for the transmission of digital data.
  - Amplitude Shift Keying
  - Frequency Shift Keying
  - Phase Shift Keying

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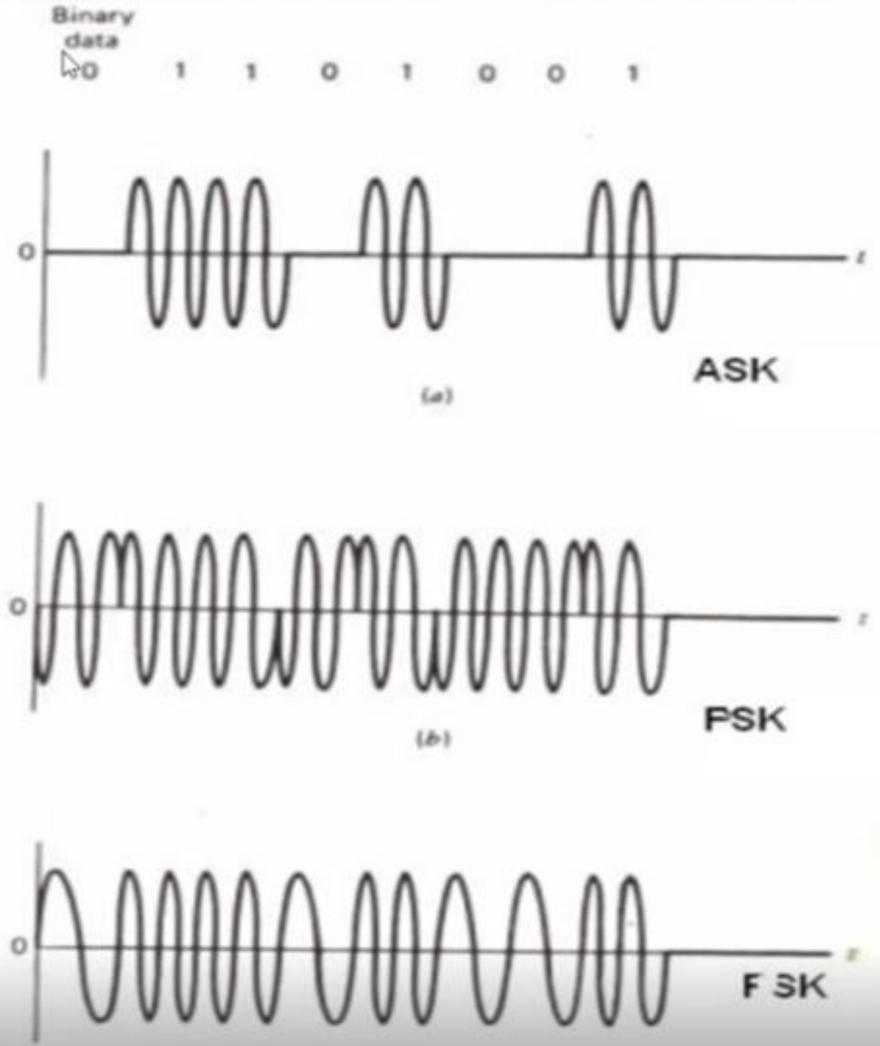

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- PSK and FSK have constant envelope. Therefore they are impervious to amplitude nonlinearities.
- Used in Microwave radio links and satellite channels.
- In practice, PSK and FSK signals are much more widely used than ASK signals.
- Note: Sometimes, a hybrid form of modulation is used.
- Example: changes in both amplitude and phase of the carrier are combined to produce amplitude-phase keying (APK).

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Demodulation at the receiver:

Demodulation can be either
a)Coherent or
b) Noncoherent detection.

a) Coherent:

-Exact replicas of possible arriving signals are available at the receiver.

-Receiver is phase-locked to the transmitter.

- It is performed by cross-correlating the received signal with each one of the replicas, and then making a decision based on comparisions with preselected thresholds.

b) Non-coherent:

-Knowledge of the carrier wave's phase is not required.

-Complexity of the reciver is reduced.

-It exhibits an inferior error performance, compared to a coherent system.

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Coherent binary modulation techniques:

1. Coherent Binary ASK
2. Coherent Binary FSK
3. Coherent Binary PSK

- The choice among different scheme is made based on attaining as many of the following design goals.

1. Maximum data rate.
2. Maximum probobality of symbol error.
3. Minimum transmitted power.
4. Minimum channel bandwidth
5. Maximum resistance to interfering signals
6. Minimum circuit complexity.

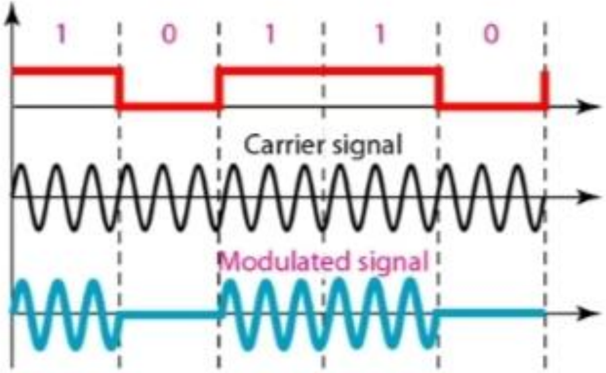
Coherent Binary ASK

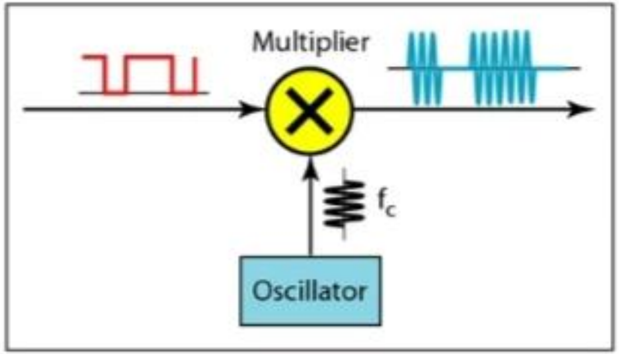
A binary ASK wave can be defined as

$S_t = A_c\, m(t)\, \cos 2\pi f_c t \;,\; 0 \le t \le T_b$

where A_c is amplitude of carrier, m(t) is digital information signal.

f_c is carrier frequency, T_b is bit duration.





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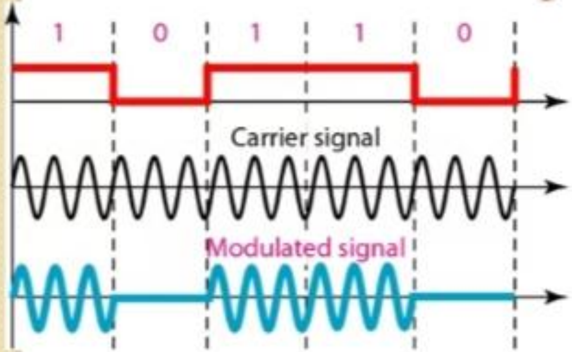
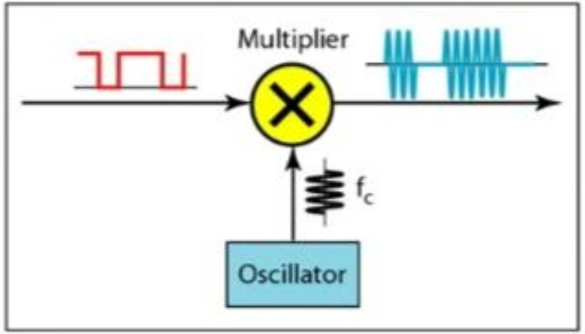
Coherent Binary ASK





In binary ASK system, symbol 1 & 0 are represented as

$$s(t) = \begin{cases} s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t & \text{for } 0 \le t \le T_b \quad \text{for symbol 1} \\ s_2(t) = 0 & \text{for } 0 \le t \le T_b \quad \text{for symbol 0} \end{cases}$$

Basis function $\Phi_1(t) = \sqrt{\frac{2}{T_b}} \cos 2\pi f_c t$

Binary ASK can be written as

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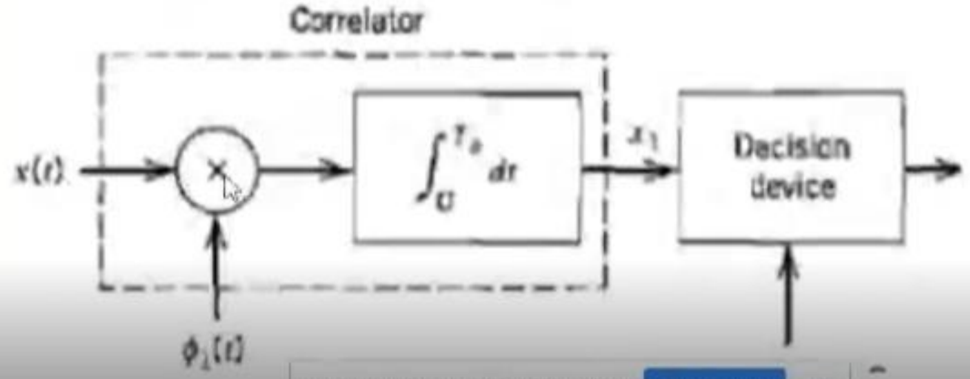
Coherent detection of ASK signal

- In demodulator, the received signal x(t) is cross correlated with local reference signal Φ_1 (t) .
- The output of correlator is applied to decision device.
- The correlator output x is compared with threshold λ.
- If $x > \lambda$ the receiver decides in favour of symbol 1.
- If $x < \lambda$ the receiver decides in favour of symbol 0.
- . In coherent detection the output of local oscillator is in perfect synchronisation with the carrier used in the transmitter



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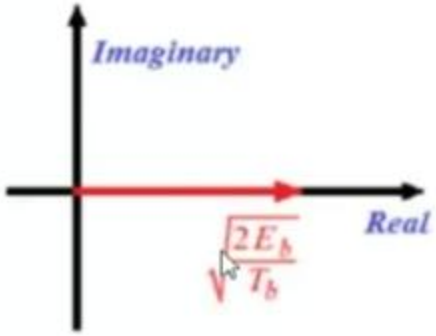
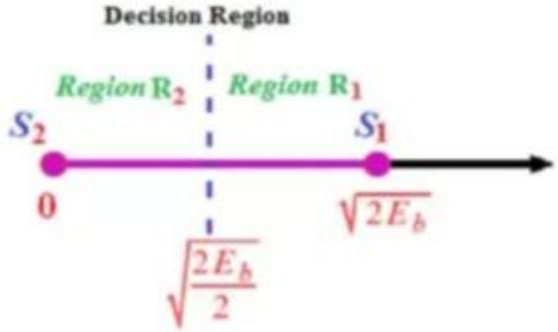
Signal Space and Constellation diagram for ASK

Signal Space:



$$s(t) = \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t + j\,0 \quad 0 \le t \le T_b$$

ASK Constellation Diagram



Coherent Binary PSK

In binary PSK system, symbol 1 & 0 are represented as

$$s(t) = \begin{cases} s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t & \text{for } 0 \le t \le T_b \quad \text{for symbol 1} \\ s_2(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t + \pi) & \text{for } 0 \le t \le T_b \quad \text{for symbol 0} \\ \quad = -\sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t & \end{cases}$$

Basis function $\Phi_1(t) = \sqrt{\frac{2}{Tb}} \cos 2\pi f_c t \qquad \text{for } 0 \le t \le T_b$

Binary PSK can be written as

$$s(t) = \begin{cases} s_1(t) = \sqrt{E_b}\,\Phi_1(t) & \text{for } 0 \le t \le T_b \quad \text{for symbol 1} \\ s_2(t) = -\sqrt{E_b}\,\Phi_1(t) & \text{for } 0 \le t \le T_b \quad \text{for symbol 0} \end{cases}$$

A coherent binary PSK system is characterized by one-dimensional signal space. (N=1), and with two message points(M=2)

The coordinates o message points equal

$$s_{11} = \int_0^{T_b} s_1(t)\,\Phi_1(t)\,dt = +\sqrt{E_b} \qquad s_{21} = \int^{T_b} s_2(t)\,\Phi_1(t)\,dt = -\sqrt{E_b}$$

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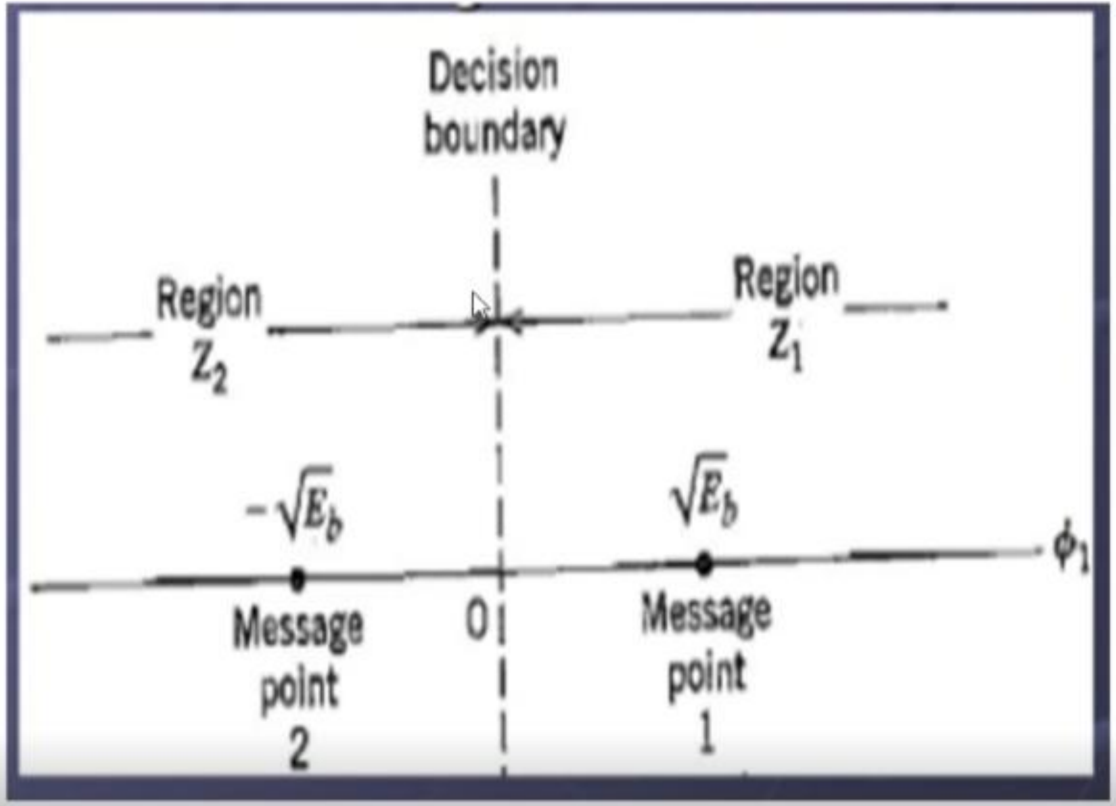
Signal space diagram for coherent binary PSK system



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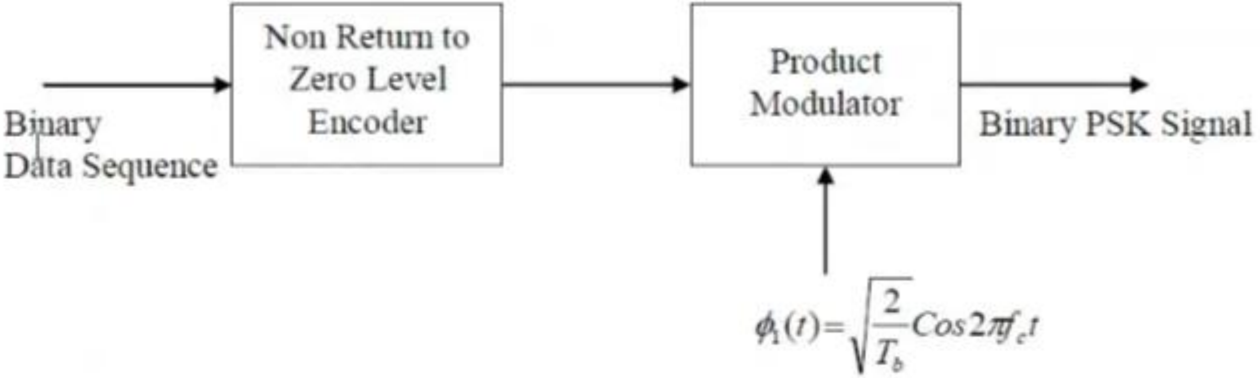
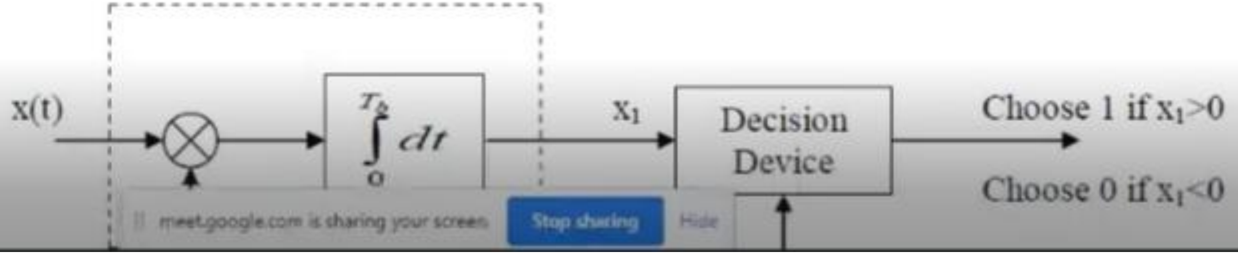
PHASE SHIFT KEYING(PSK):



Fig(a) Block diagram of BPSK transmitter



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$$\phi_1(t)=\sqrt{\frac{2}{T_b}}Cos2\pi f_c t$$

Fig(a) Block diagram of BPSK transmitter

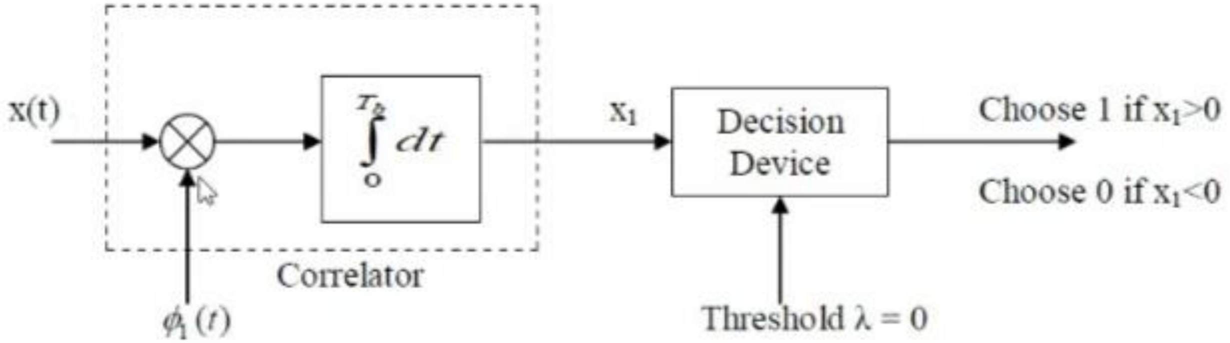

Fig (b) Coherent binary PSK receiver

In a Coherent binary PSK system the pair of signals $S_1(t)$ and $S_2(t)$ are used to represent binary symbol '1' and '0' respectively.

Coherent Binary FSK

In binary FSK system, symbol 1 & 0 are distinguished from each other by transmitting one of two sinusoidal waves that differ in frequency by a fixed amount.

$$s_i(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_c t & \text{for } 0 \leq t \leq T_b \\ 0 & \text{elsewhere} \end{cases} \quad \text{where } i=1,2.$$

Transmitted frequency equals $f_i = \dfrac{n_c + i}{T_b}$ for some fixed integer n_c and i=1,2

$$\Phi_i(t) = \begin{cases} \sqrt{\frac{2}{T_b}} \cos 2\pi f_c t & \text{for } 0 \leq t \leq T_b \\ 0 & \text{elsewhere} \end{cases}$$

$$s_{ij} = \int_0^{T_b} s_i(t)\, \Phi_j(t)\, dt = \begin{cases} \sqrt{E_i} & i=j \\ 0 & i \neq j \end{cases}$$

efficient modulation scheme and several forms of M-ary FSK modulation are becoming popular for spread spectrum communications and other wireless applications. In this lesson, our discussion will be limited to binary frequency shift keying (BFSK).

Two carrier frequencies are used for binary frequency shift keying modulation. One frequency is called the 'mark' frequency (f_2) and the other as the space frequency (f_1). By convention, the 'mark' frequency indicates the higher of the two carriers used. If T_b indicates the duration of one information bit, the two time-limited signals can be expressed as :

$$s_i(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_i t, & 0 \le t \le T_b, i = 1, 2 \\ 0, & \text{elsewhere.} \end{cases} \qquad 5.23.2$$

The binary scheme uses two carriers and for special relationship between the two frequencies one can also define two orthonormal basis functions as shown below.

$$\varphi_j(t) = \sqrt{\frac{2}{T_b}} \cos 2\pi f_j t \quad ; \quad 0 \le t \le T_b \text{ and } j = 1,2 \qquad 5.23.3$$

Generation and Detection:-

m(t)

Binary

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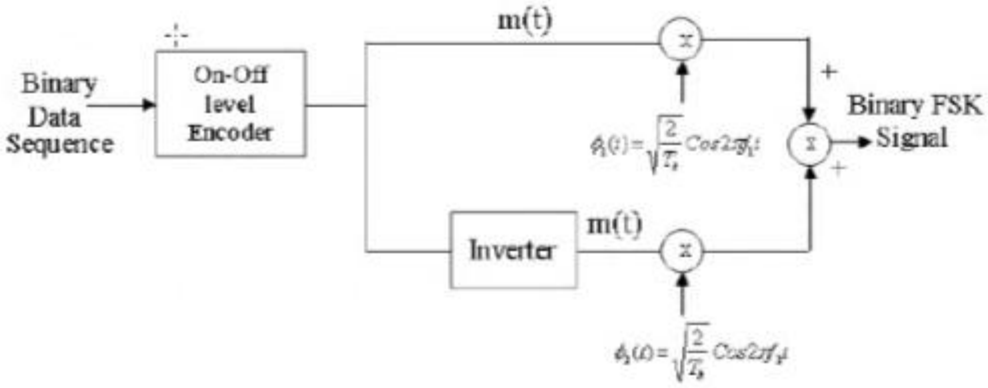
<u>Generation and Detection:-</u>



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FSK transmitter

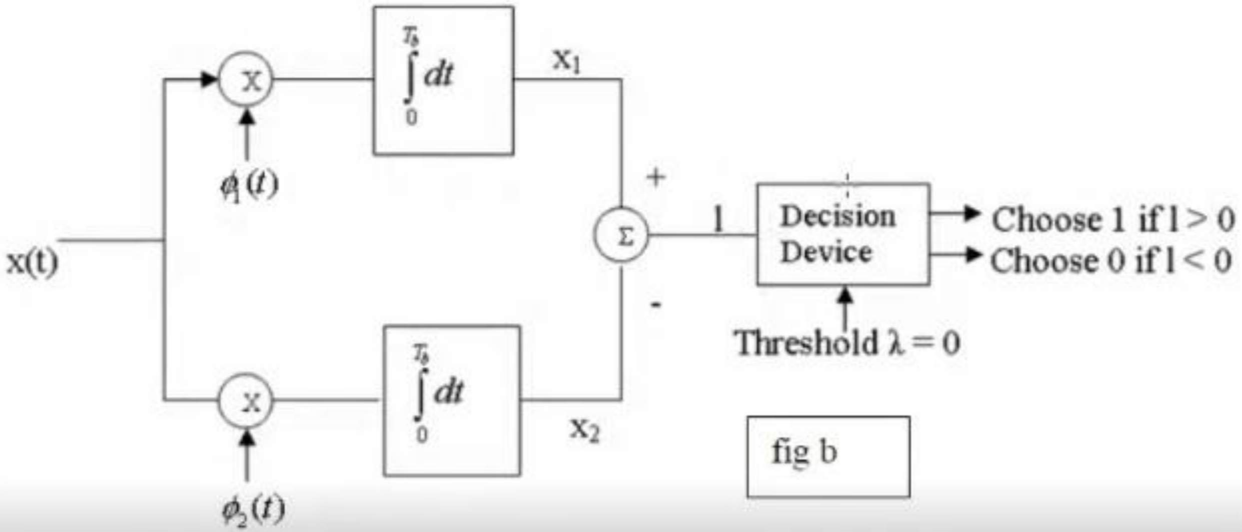

fig b

FSK receiver

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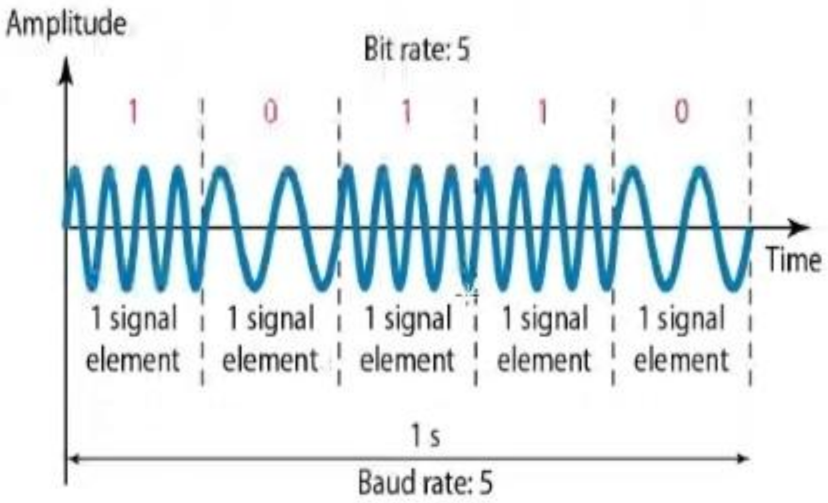
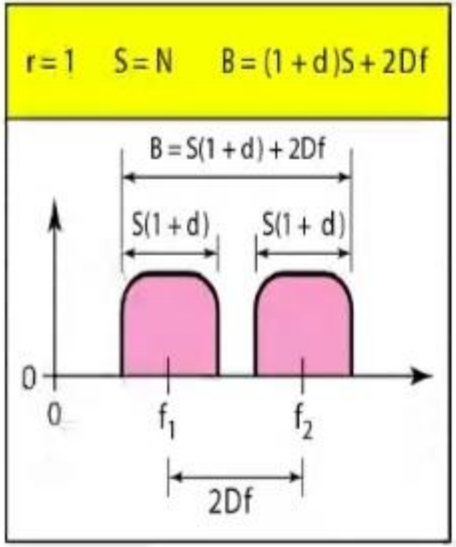
- Limiting factor: Physical capabilities of the carrier
- Not susceptible to noise as much as ASK





- Applications
  - On voice-grade lines, used up to 1200bps
  - Used for high-frequency (3 to 30 MHz) radio transmission
  - used at higher frequencies on LANs that use coaxial cable.

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Ther ... al signal space with two messages

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$s_1(t)$ and $s_2(t)$, [N=2 , m=2] they are represented,

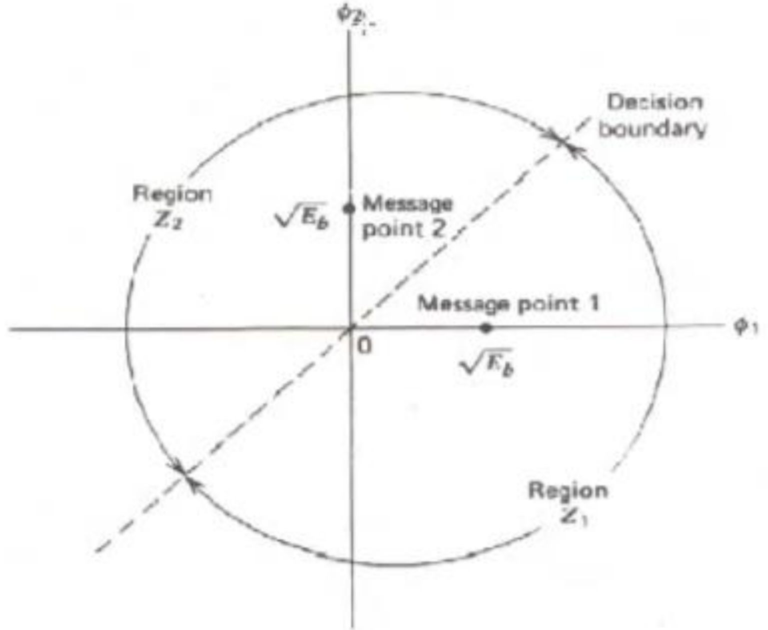

Fig. Signal Space diagram of Coherent binary FSK system.

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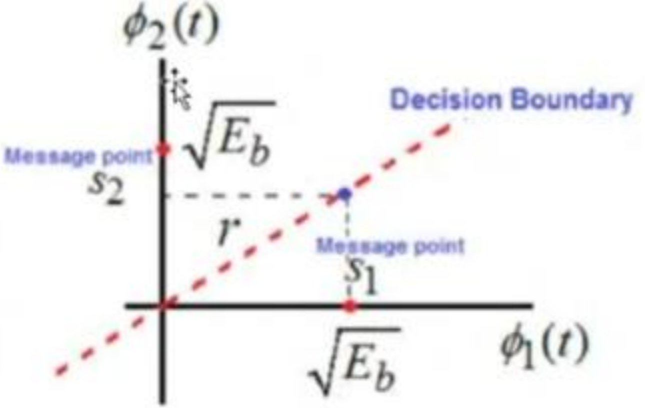
Signal space diagram for coherent binary FSK system



Probability of error derivation of PSK

From fig ①: decision region associated with symbol 1 or $s_1(t)$ is given by

$$Z_1 : 0 < x_1 < 1$$

where x_1 is observation scalar

$$x_1 = \int_0^{T_b} x(t)\,\phi_1(t)\,dt \rightarrow (1)$$

$x(t)$ is received signal

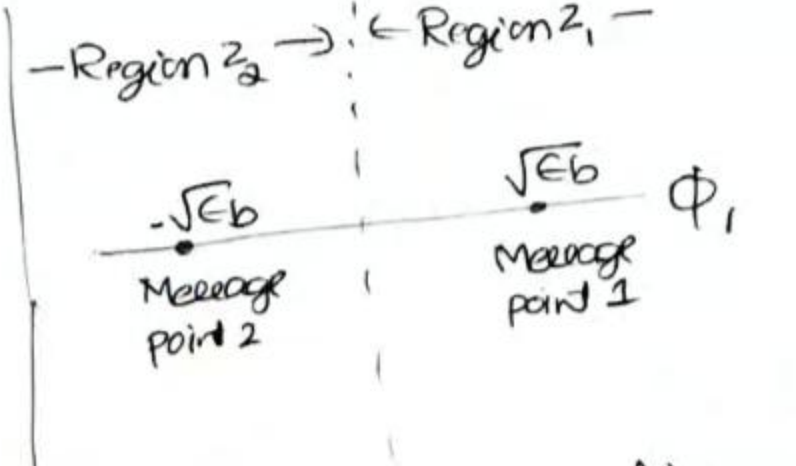


fig ①: Signal space diagram

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channel are defined