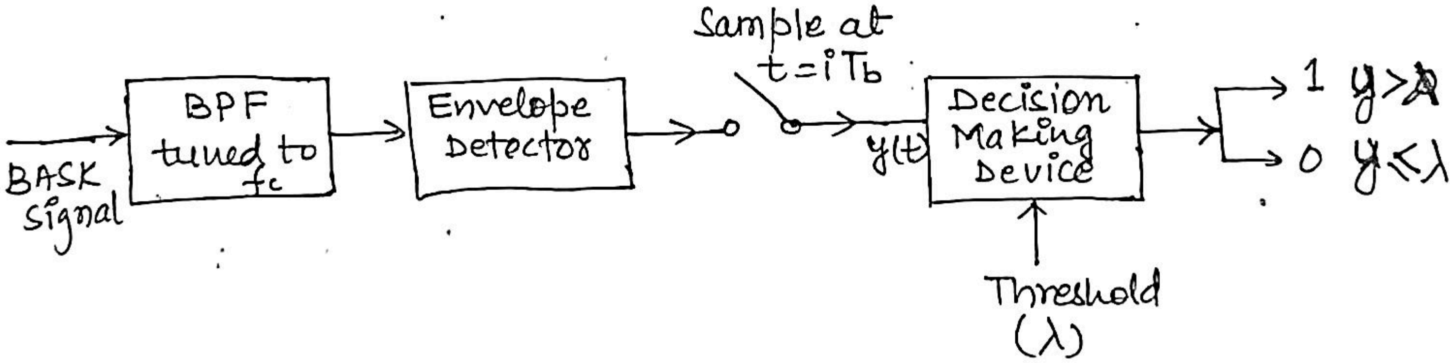
Noncoherent Digital Modulation Schemes

- Coherent receivers require knowledge of the carrier wave's phase reference to establish synchronism with their respective transmitters.

- However, in some communication environments, it is either impractical or too expensive to phase-synchronize a receiver to its transmitter. In situations of this kind, we use non-coherent detection.

Non-coherent Detection of BASK signals

- We see that the generation of BASK signals involves the use of a single sinusoidal carrier of frequency f_c for symbol 1 and switching OFF the transmission for symbol 0. Now, the system designer would have knowledge of two system parameters:
  (1) f_c (2) B_T, which is determined by the T_b.



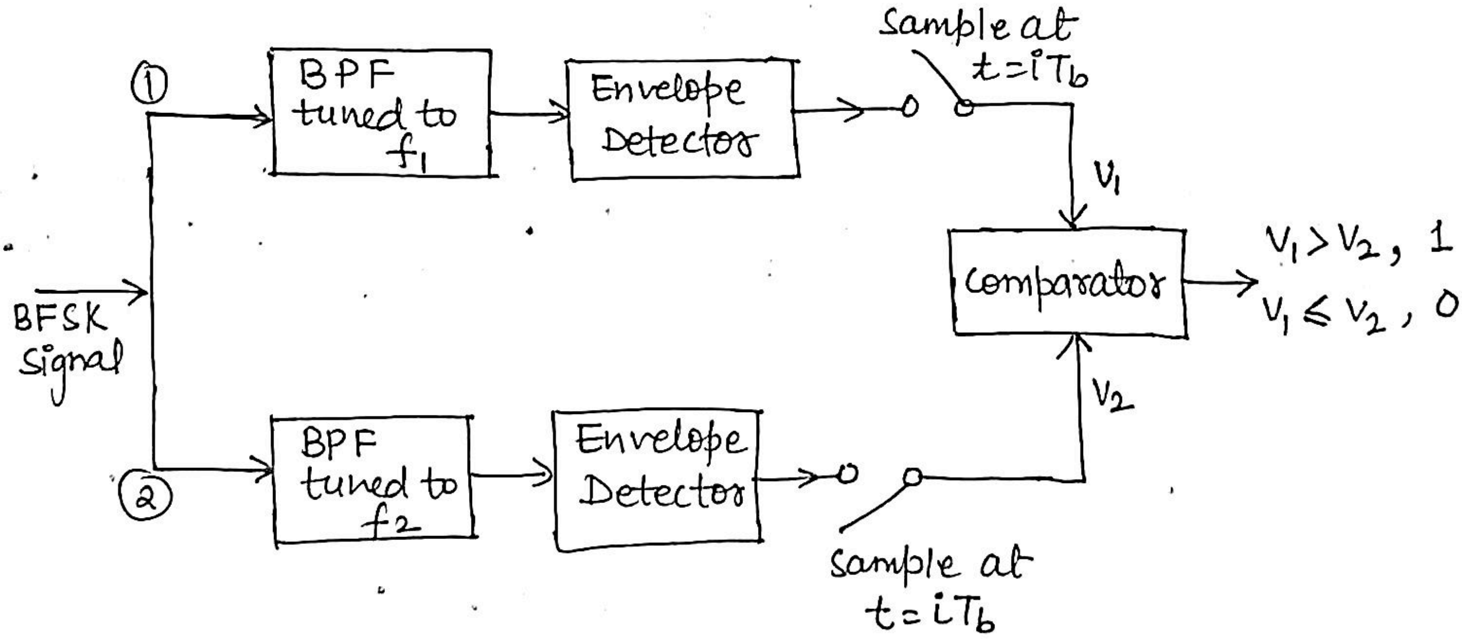
- The BPF is designed to have a mid-band frequency equal to the carrier frequency f_c and a bandwidth equal to the B_T of the BASK signal. Moreover, it is assumed that the ISI produced by the filter is negligible.

- Under these conditions, we find that in response to the incoming BASK signal, the BPF produces a pulsed sinusoid for symbol 1 and no output for symbol 0.

- Next, the envelope detector traces the envelope of the filtered version of the BASK signal.
- Finally, the decision-making device working in conjunction with the sampler, regenerates the original binary data stream by comparing the sampled envelope-detector output against a preset threshold every T_b seconds.
- If the received signal exceeds the threshold, the receiver decides in favor of symbol 1; otherwise, it decides in favor of symbol 0.

Non-coherent Detection of BFSK Signals

$$s(t) = \begin{cases} \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_1 t, & \text{for symbol } 1 \\ \sqrt{\frac{2E_b}{T_b}} \cos 2\pi f_2 t, & \text{for symbol } 0 \end{cases}$$



- Path 1 uses a BPF of mid-band frequency f_1. The filtered version of the incoming BFSK signal is envelope-detected and then sampled at time $t = iT_b$, $i = 0, \pm 1, \pm 2, \ldots$, to produce the output V_1.

- Path 2 uses a BPF of mid-band frequency f_2. ~~At~~ The filtered version of the BFSK signal is envelope-detected and then sampled at time $t = iT_b$, $i = 0, \pm 1, \pm 2, \ldots$, to produce a different output V_2.

- The two BPFs have the same BW, equal to the B_T of the BFSK signal.

- The outputs V_1 and V_2 are applied to a comparator, where decisions on the composition of the BFSK signal are repeated every T_b second.

- The comparator decides in favor of symbol 1, if $V_1 > V_2$ at the specified bit-timing instant; otherwise, the decision is made in favor of symbol 0.

Binary Phase shift Keying (BPSK)

- Phase of the carrier signal (Analog carrier) is varied in accordance with the instantaneous values of modulating signal (Binary Data).

- For example, when encoding bits, the phase could be 0° for encoding a bit '0' and 180° for encoding a bit '1'.

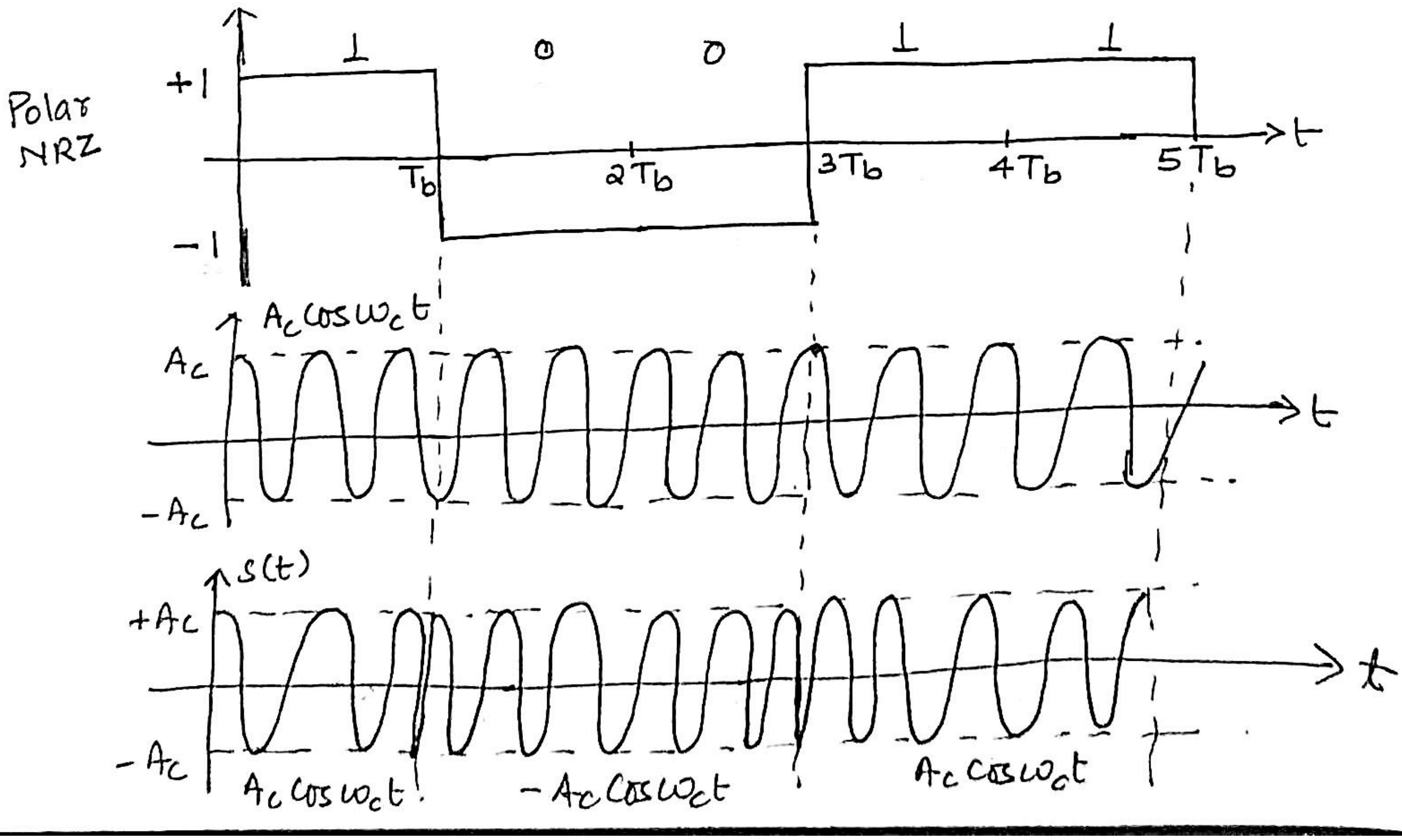
Also '0' $\longrightarrow -90°$
'1' $\longrightarrow +90°$

Essence $\Rightarrow$ representations for '0' and '1' are a total of 180° apart.

- Such PSK systems in which the carrier can assume only two different phase angles are known as BPSK.

Bit 1 $\longrightarrow s_1(t) = s(t) = A_c \cos \omega_c t$
Bit 0 $\longrightarrow s_2(t) = -s(t) = A_c \cos(\omega_c t + 180°)$

$$s(t) = \begin{cases} A_c \cos \omega_c t & ; \text{ for bit '1'} \\ -A_c \cos \omega_c t & ; \text{ for bit '0'} \end{cases}$$



Energy Per Bit (E_b)

(a) Transmission of '1' $\quad s(t) = A_c \cos w_c t = s_1(t)$

$$E_b = \int_0^{T_b} A_c^2 \cos^2 w_c t \, dt = \frac{A_c^2}{2} T_b \Rightarrow A_c = \sqrt{\frac{2E_b}{T_b}}$$

$$s(t) = s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos w_c t$$

(b) Transmission of '0' $\quad s(t) = s_2(t) = -A_c \cos w_c t$

$$E_b = \int_0^{T_b} [-A_c \cos w_c t]^2 dt = \frac{A_c^2}{2} T_b \Rightarrow A_c = \sqrt{\frac{2E_b}{T_b}}$$

$$s(t) = s_2(t) = -\sqrt{\frac{2E_b}{T_b}} \cos w_c t$$

Now, applying GSOP on $s_1(t)$ and $s_2(t)$.

$$\phi_1(t) = \frac{s_1(t)}{\sqrt{E_b}} = \sqrt{\frac{2}{T_b}} \cos w_c t \qquad 0 \le t \le T_b$$

~~Similarly.~~ $\quad N < M \quad \underline{M=2} \quad s_2(t) = -s_1(t)$

$\cancel{\phi_2(t) = -\sqrt{\frac{2}{T_b}} \cos w_c t} \quad \cancel{0 \le t \le T_b}$

Projection of $s_1(t)$ on $\phi_1(t)$ $\qquad \begin{bmatrix} i = 1, 2 \\ j = 1 \end{bmatrix}$

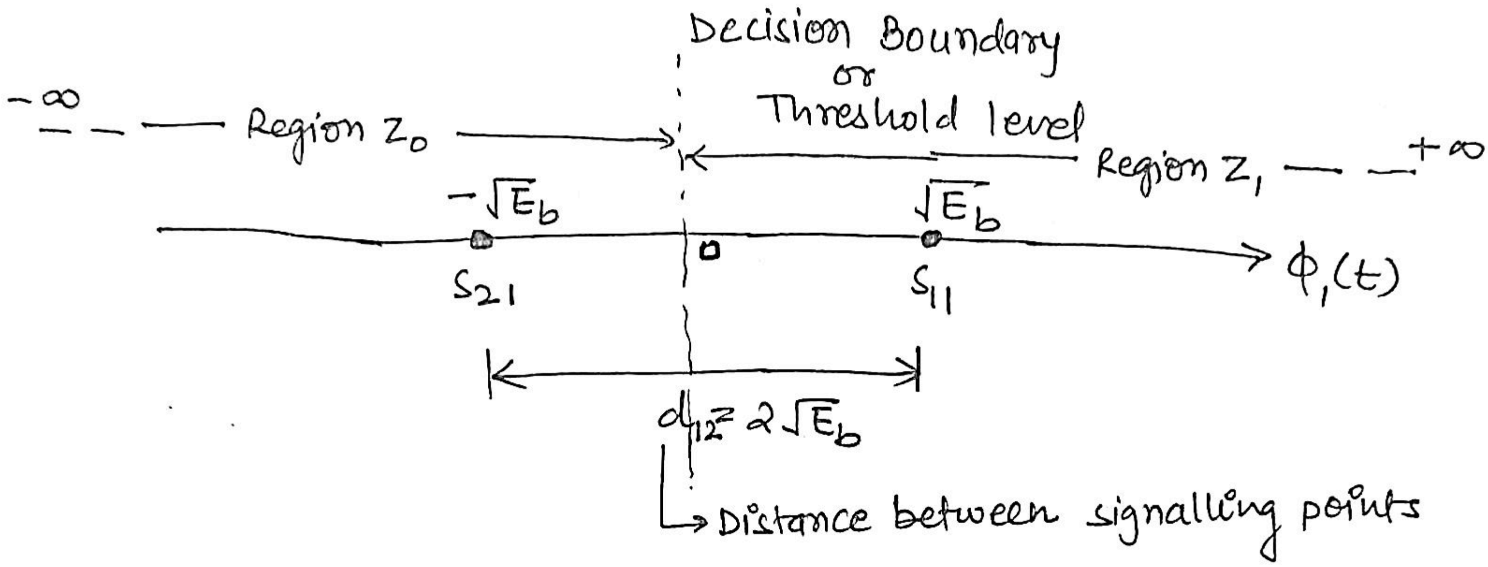
$$s_{11} = \int_0^{T_b} s_1(t)\, \phi_1(t)\, dt = +\sqrt{E_b} \qquad s_{ij} = \int_0^{T_b} s_i(t)\, \phi_j(t)\, dt$$

Projection of $s_2(t)$ on $\phi_1(t)$

$$s_{21} = \int_0^{T_b} s_2(t)\, \phi_1(t)\, dt = -\sqrt{E_b}$$

The message point corresponding to $s_1(t)$ is located at $s_{11} = \sqrt{E_b}$ and $s_2(t)$ at $s_{21} = -\sqrt{E_b}$.

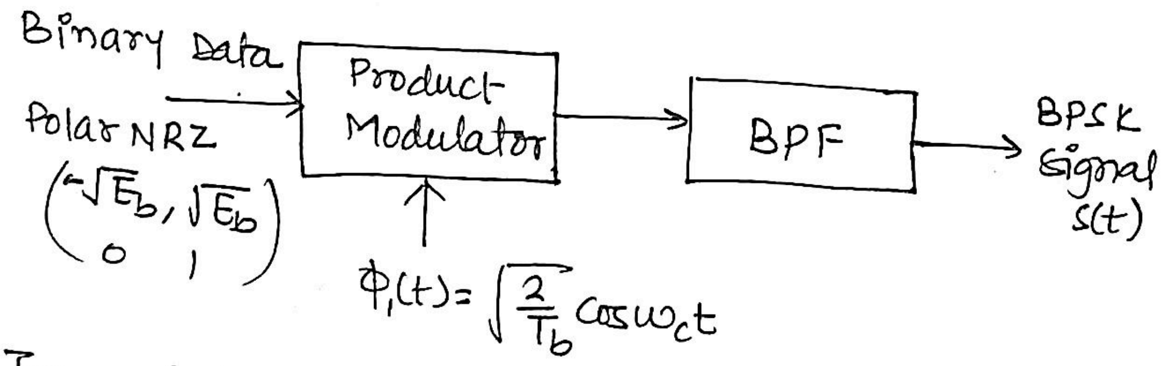
Constellation Diagram



Desision region $Z_1 \approx$ symbol $1 \approx (0$ to $+\infty)$

Decision region $Z_2 \approx$ symbol $0 \approx (-\infty$ to $0)$

Modulation of BPSK



Transmission Bandwidth $\Rightarrow$ The spectrum of BPSK is same as BASK. Therefore, BW of BPSK is same as BASK.

Ideal: $B_T = 2R_b = \frac{2}{T_b}$

Practical: $B_T = (1+\alpha)R_b = (1+\alpha)\frac{1}{T_b}$

for $\alpha = 0$ $(B_T)_{min} = R_b = 1/T_b$

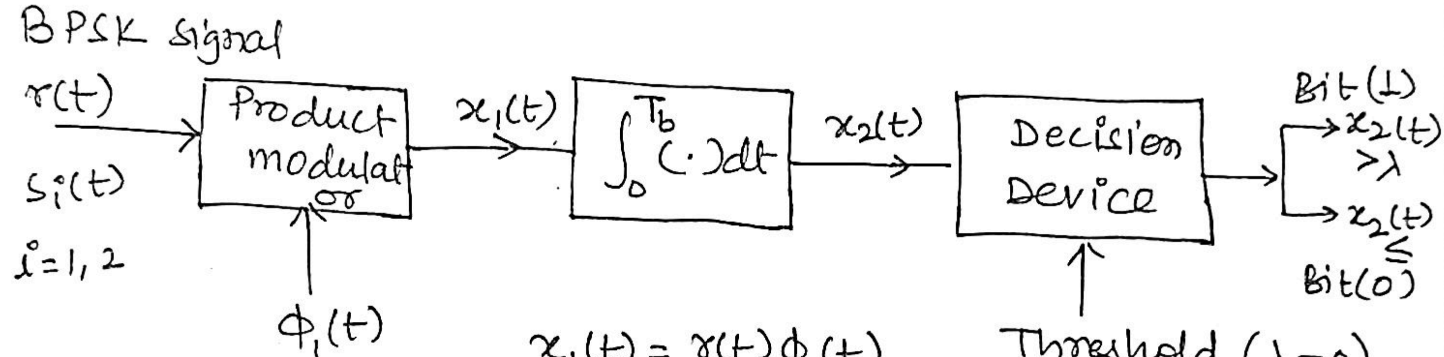
for $\alpha = 1$ $(B_T)_{max} = 2R_b = 2/T_b$

Applications:-

(1) In digital communications
(2) It was also used in telephone modems with data rate 2400 and 4800 bps.
(3) WLAN IEEE802.11b (1 Mbps)

Demodulation of BPSK

(Coherent Demodulator)



$x_1(t) = r(t)\phi_1(t)$

$x_2(t) = \int_0^{T_b} x_1(t)\,dt$

if $r(t) = s_1(t)$

$x_1(t) = s_1(t)\phi_1(t)$

$x_2(t) = \int_0^{T_b} s_1(t)\phi_1(t)\,dt$

$= s_{11} = \sqrt{E_b}$

$x_2(t) > \lambda$

Bit '1' Received.

if $r(t) = s_2(t)$

$x_1(t) = s_2(t)\phi_1(t)$

$x_2(t) = \int_0^{T_b} s_2(t)\phi_1(t)\,dt$

$= s_{21} = -\sqrt{E_b}$

$x_2(t) \leq \lambda$

bit '0' is received