Ck : -2 -2 0 2 0 0 2

order Op : 0 0 1 0 1 1 0

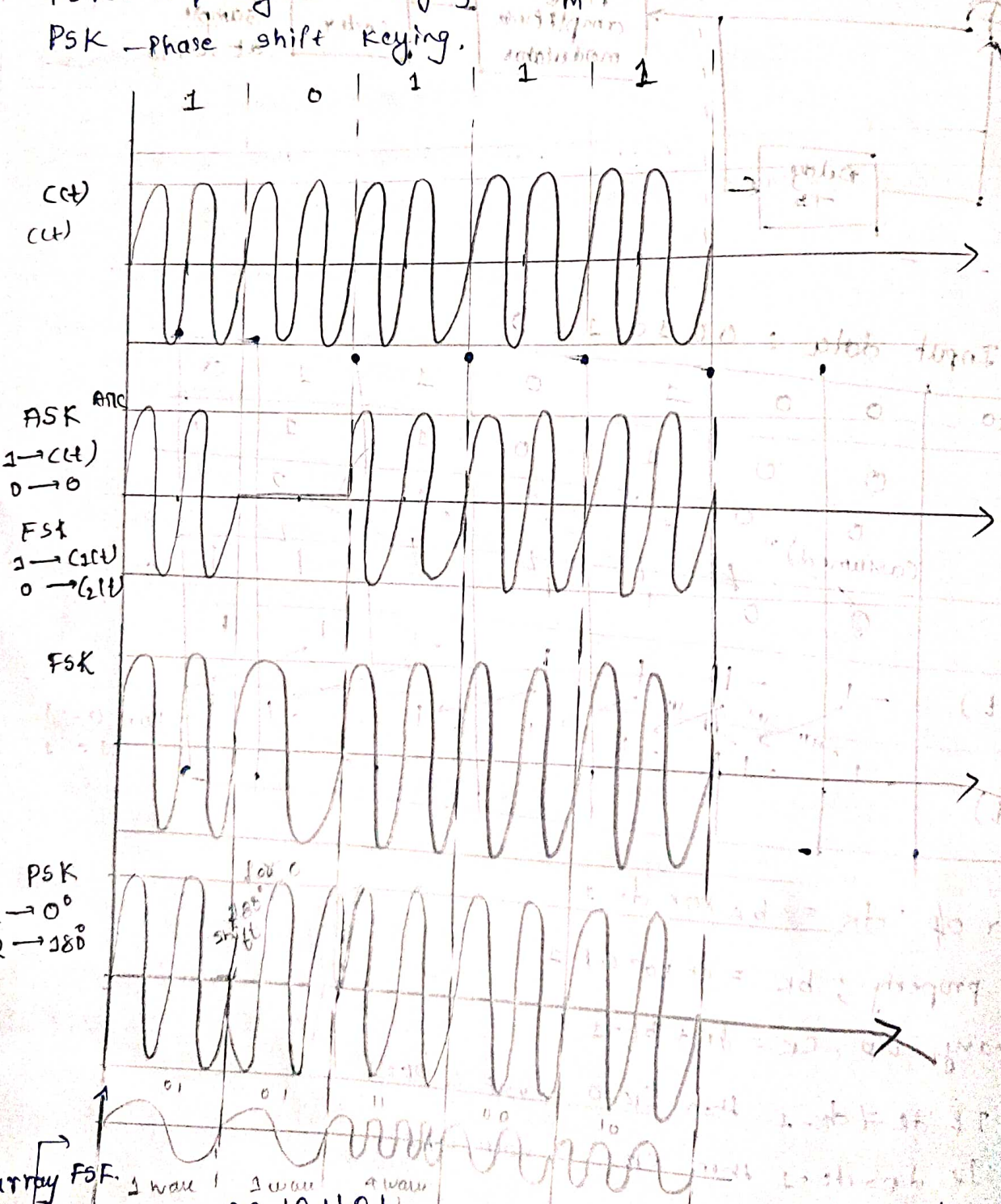
Advantage : • No Error propogation
• No polarity inversion Error.

16/01/2024

UNIT-3 Digital Modulation Techniques

ASK - Amplitude Shift Keying.
FSK - Frequency shift keying
PSK - phase shift keying.

BPSK
QPSK
M



4array FSK. 1 way 1 way 4 way

01 01 11 00 10 11 01

00 → C1 → 2 assume
01 → C2 → 1 these
10 → C3 → 3
11 → C4 → 4

4array PSK
0°
90°
180°
270°

17/01/2024

Coherent system	Noncoherent.
Utilizes a reference phase for signal detection.	Operates without a reference phase for signal detection.
Requires accurate phase synchronization for signal processing	Does not rely on precise phase information.
Coherent system performs better in the presence of fading & noise.	More robust in situations with rapidly changing channels.
Typically more complex due to the need for phase synchronization.	Simpler in design as it doesn't require accurate phase tracking.
can achieve lower error rates under optimal condition	may have higher error rates, especially in challenging environments.
Common in high performance communication systems.	Used in scenarios where simplicity and robustness are prioritized over absolute performance.

ASK
ASK
Array ASK
} ASK

B = Binary,
Q = Quadrature,
M = M-level.

Amplitude shift ~~Array~~ Keying.

Basically Binary Amplitude Shift Keying:

Symbols '1' and '0'

$$s_1(t) = \sqrt{\frac{2E_b}{T_b}} \cos(2\pi f_c t)$$

$$s_2(t) = 0.$$

It can be represented by the orthonormal basis function as,

$$s_1(t) = \sqrt{E_b}\,\phi_1(t)$$

$$s_2(t) = 0\,\phi_1(t).$$

$\phi(t)$ = Orthonormal basis function.

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

also written as,

$$s_1(t) = s_{11}\phi_1(t).$$

$$s_2(t) = s_{21}\phi_1(t).$$

where,

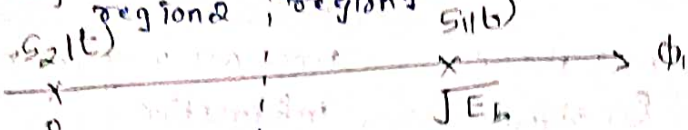
$s_{11} = \sqrt{E_b}$, $s_{21} = 0$.

Constellation dimension = No. of orthonormal basis function.

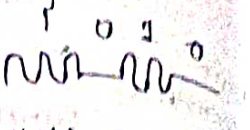
here " = 1.

∴ 1 dimension.

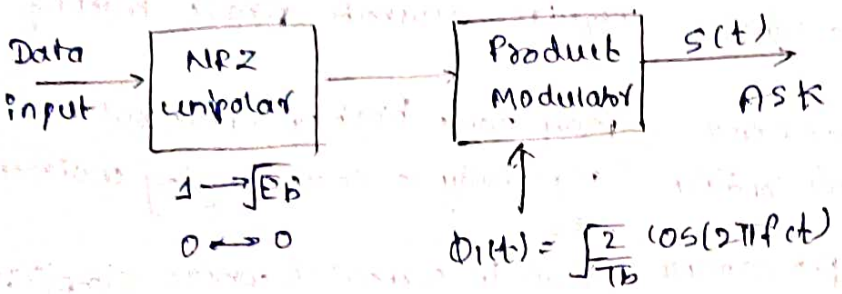
Constellation diagram - we can design the receiver from this diagram.



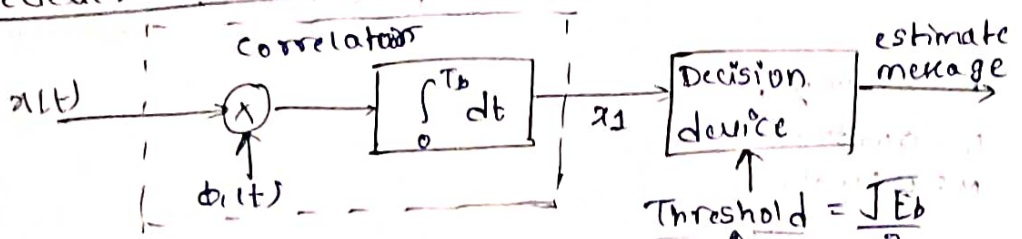
Threshold = $\frac{\sqrt{E_b}}{2}$



Transmitter of ASK



Reciever of ASK.



$x_1 > \frac{\sqrt{E_b}}{2}$ ⇒ Symbol 1.

$x_1 < \frac{\sqrt{E_b}}{2}$ ⇒ Symbol 0.

Probability of Error for ASK -

Let us assume symbol '1' is transmitted.

Error occurs if x_1 value is between $\frac{\sqrt{E_b}}{2}$ to $-\infty$

i.e. $-\infty < x_1 < \frac{\sqrt{E_b}}{2}$.

$$x_1 = \int_0^{T_b} x(t)\,\phi_1(t)\,dt$$ — received signal.

Probability Error,

$$P_{10} = \int_{-\infty}^{\frac{\sqrt{E_b}}{2}} f_{x_1}(x_1 \mid 1)\,dx_1$$ — (x_1 is received when transmitted is sent to 1).

$$f_{x_1} = \frac{1}{\sqrt{2\pi\,\mathrm{Var}(x_1)}} \exp\left(-\frac{1}{2\,\mathrm{Var}(x_1)}(x_1 - m_{x_1})^2\right).$$

$m_{x1} = s_{11}$

$\sigma_{x1}^2 = \frac{N_0}{2}$

$$f_{x_1}(x_1/1) = \frac{1}{\sqrt{\pi N_0}} \exp\left(-\frac{1}{N_0}(x_1 - s_{11})^2\right)$$

$$f_{x_1}(x_1/1) = \frac{1}{\sqrt{\pi N_0}} \exp\left(-\frac{1}{N_0}(x_1 - \sqrt{E_b})^2\right)$$

$$P_{10} = \int_{-\infty}^{\sqrt{E_b}/2} \frac{1}{\sqrt{\pi N_0}} \exp\left(-\frac{1}{N_0}(x_1 - \sqrt{E_b})^2\right) dx_1.$$

$-\frac{z^2}{2}$ — a function $\int e^{-\frac{z^2}{2}}$

Let $z = \sqrt{\frac{2}{N_0}}(x_1 - \sqrt{E_b})$

$dz = \sqrt{\frac{2}{N_0}}\, dx_1 \Rightarrow dx_1 = \sqrt{\frac{N_0}{2}}\, dz$

$x_1 \longrightarrow -\infty \quad z \longrightarrow -\infty.$

$x_1 \longrightarrow \frac{\sqrt{E_b}}{2} \quad z \longrightarrow -\sqrt{\frac{E_b}{2N_0}}$

$$P_{10} = \int_{-\infty}^{-\sqrt{\frac{E_b}{2N_0}}} \frac{1}{\sqrt{\pi N_0}} \exp\left(-\frac{z^2}{2}\right) \cdot \sqrt{\frac{N_0}{2}}\, dz.$$

x

$z = \sqrt{\frac{2}{N_0}}\left(\frac{\sqrt{E_b} - 2\sqrt{E_b}}{2}\right)$

$\frac{\sqrt{2}}{\sqrt{N_0}}\left(-\frac{\sqrt{E_b}}{2}\right)$

$-\sqrt{\frac{E_b \times 2}{4 \times N_0}}$

$z = -\sqrt{\frac{E_b}{2N_0}}.$

$$P_{10} = \frac{1}{\sqrt{2\pi}} \int_{\frac{\sqrt{E_b}}{\sqrt{2N_0}}}^{\infty} \exp\left(-\frac{z^2}{2}\right) dz.$$

WKT $Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp\left(-\frac{z^2}{2}\right) dz.$

$$\boxed{P_{10} = Q\left(\sqrt{\frac{E_b}{2N_0}}\right).}$$

(1 was sent & was estimated)

likely $P_{01} = Q\left(\sqrt{\frac{E_b}{2N_0}}\right)$

$P_e = \frac{1}{2} P_1 P_{10} + P_0 P_{01}$

Symbols are transmitted with equal probability.

$\therefore P_e = \frac{1}{2} P_{10} + \frac{1}{2} P_{01}.$

$$\boxed{P_e = Q\left(\sqrt{\frac{E_b}{2N_0}}\right)}$$ formula for probability of error of ASK.