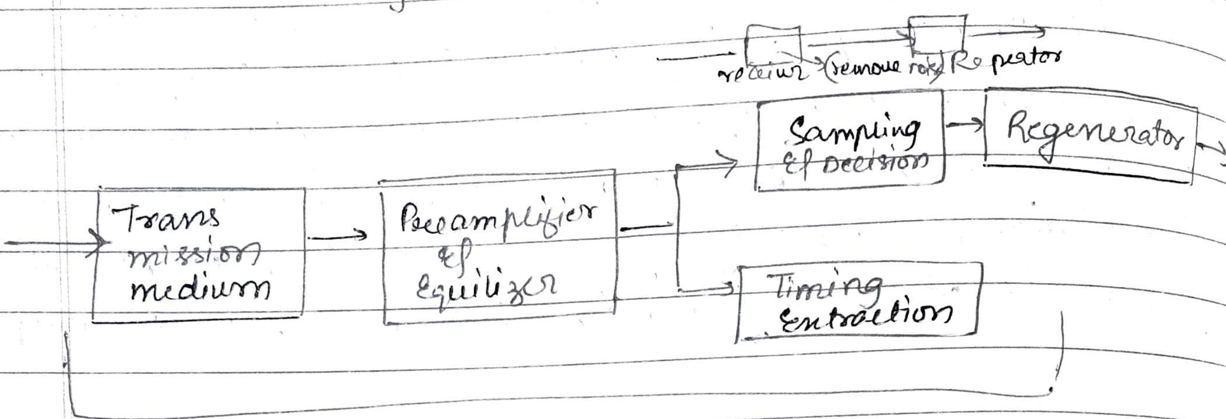
UNIT-III

Digital Receiver & Regenerative Repeater

* Digital Receiver & Regenerative Repeater

↓ receive the signal

↓ Repeat the received signal

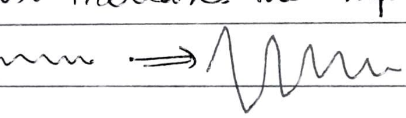


Receiver

1. To reshape the incoming pulse using an equilizer.

Signal $\xrightarrow{\text{(noise)}}$ Equilizer → shaping the pulses

& Pre-amplifier → just increases the amplitude



There are many types of equilizer, also, But, here we are using basic.

Timing Extraction → analysing time so that we can do samping of signal to know the instant & then regenerator regenerated.

(I) Equalization - Equalizer is used to compensate for the distortion, which was introduced when signal passed through communication channel.

I/P → Channel $H_c(f)$ → Equalizer → Delayed version of channel i/p

Equalizer is basically, helping in reducing the noise.

$$\boxed{H_c(f)\, H_{eq}(f) = C = Ke^{-j2\pi ft}}$$

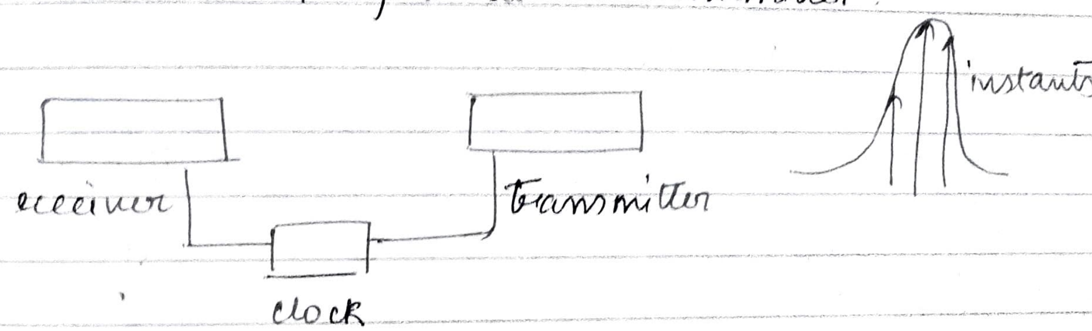
Practical Realization of an Equalizer :-

How many diff. equilizer we can make.

(1) Tapped Delay Time Filter
(2) Automatic Equalizer
(3) Preset Equalizer
(4) Adaptive Equilizer
(5) Decision Feedback Equalizer

Timing Extraction

It is needed to sample the recieved digital signal at precise instants. for this, clock signal at reciever must be synced with clock signal at the transmitter.



Methods of Synchronization

(i) Slaving the transmitter & reciever to a master timing source.
(ii) Self synchronization - Timing information is extracted automatically from the recieved signal.

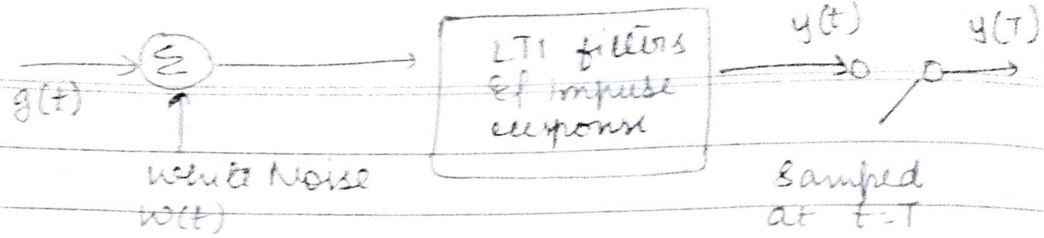
☆ Prediction Filter → (Pending)

* **Matched Filter**

Used for detection of a pulse signal of known waveform that is immersed in additive white noise.

Signal ↓ Noise + ISI (intersignal interference)

→ It will remove the noise.



Sampled at t = T (all samples are taken)

LTI → Linear time invariant

a b

a+k b+k

freq. domain: $\boxed{H(s)\,X(s) = Y(s)}$

x(t), h(t) Four T — Transfer Function — Inv. Four Transf → y(t)

* Reciever has knowledge of original signal g(t).

* Reciever has to detect g(t) from x(t).

$y(t) = g_o(t) + n(t)$ → noise

* ~~$y = g_o(t) + n(t)$~~.

$$V = \frac{|g_o(T)|^2}{E[n^2(t)]}$$ → inst. power in output signal

E = average ~~of noise filter~~

h(t) must be such that V is max

This ratio should be maximum

⇒ maximizing peak pulse signal to noise ratio

$g(t) \xrightarrow{FT} G(f)$

$\boxed{Y(s) = H(s)\,X(s)}$

H(f) Frequency response of filter

$FT(g_o(t)) = H(f)G(f)$

$$g_o(t) = \int_{-\infty}^{\infty} H(f)\,G(f)\,e^{-j2\pi ft}\,dt$$

At $t = T$

$$|g_o(T)|^2 = \left|\int_{-\infty}^{\infty} H(f)\,G(f)\,e^{-j2\pi ft}\,dt\right|^2$$

PSD (Power Spectral Density of the noise)

$S_N(f) = \frac{N_0}{2}|H(f)|^2$ as PSD of input noise $= \frac{N_0}{2}$ (white noise)

PSD of output noise n(t)

$$E[n^2(t)] = \int_{-\infty}^{\infty} S_n(f)\,df = \frac{N_0}{2}\int_{-\infty}^{\infty} |H(f)|^2 df$$

$$V = \frac{(g_0(T)^2)}{E(n^2(t))}$$

$$V = \frac{\left|\int_{-\infty}^{\infty} H(f)\,G(f)\,e^{-j2\pi f t}\,dt\right|^2}{\frac{N_0}{2}\int_{-\infty}^{\infty} |H(f)|^2 df}$$

using Schwart'z inequality

$$\left\{\int_{-\infty}^{\infty} \phi_1(x) K \phi_2(x) \le \int_{-\infty}^{\infty} \phi_1(x) \cdot \int_{-\infty}^{\infty} K\phi_2(x)\right\}$$

So, Numerator

$$\left|\int_{-\infty}^{\infty} H(f)\,G(f)\,e^{-j2\pi f t}\,df\right|^2 \le \int_{-\infty}^{\infty} |H(f)|^2 df \int_{-\infty}^{\infty} |G(f)|^2 df$$

use it

$$V \le \frac{\cancel{\int_{-\infty}^{\infty} |H(f)|^2 df} \int_{-\infty}^{\infty} |G(f)|^2 df}{\frac{N_0}{2}\cancel{\int_{-\infty}^{\infty} |H(f)|^2 df}}$$

G^* → conjugate of G

$$V \le \frac{2}{N_0}\int_{-\infty}^{\infty} |G(f)|^2 df$$

$G^*(f) = G(-f)$ → for real signal

we want max value

$$\boxed{V_{max} = \frac{2}{N_0}\int_{-\infty}^{\infty} |G(f)|^2 df}$$

Next, how we can use $h(t)$ to maximize V

$h(t) \rightarrow H(f)$

$$H_{optimum}(f) = K\,G^*(f)\,e^{-j2\pi f T}$$

Inverse Fouriour Transform

$$h_{optimum}(t) = K\int_{-\infty}^{\infty} G^*(f)\,e^{-j2\pi f(T-t)}\,df$$

$\boxed{h_{opt}(t) = K g(T-t)}$ — Time delay

Impulse response is matched to input signal

K = constant

Property of matched Filter

$$V = \frac{|g_0(T)|^2}{E(n^2(t))}$$ ← independent of g(t)

Derivations

$$\boxed{V = \frac{2E}{N_0}}$$ ← dimensionless

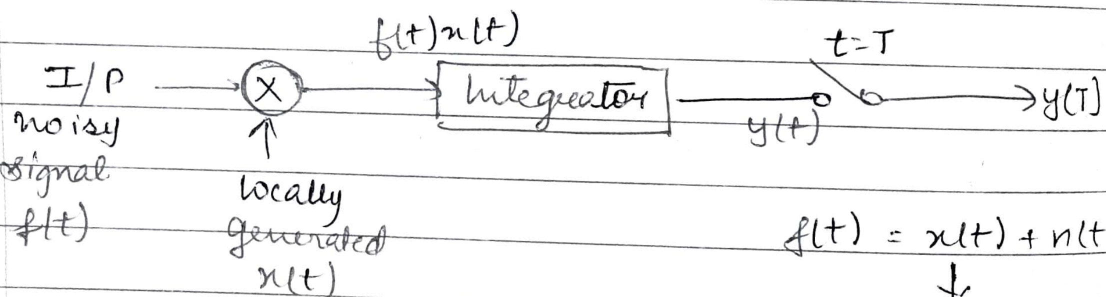
Average output noise power $= E[n^2(t)]$
$= K^2 N_0 E/2$

E = energy of signal

Correlator Signal

for XY

Correlation ⟶ how X is related to Y.



$f(t) = x(t) + n(t)$
($x(t)$: replica of input signal)

$$\boxed{y(t) = \int_0^T f(t)\,x(t)\,dt}$$

$$y(T) = \int_0^T f(t)\,x(t)\,dt$$

$$y(T) = \int_0^T f(t)\,x(t)\,dt \qquad t=T$$

y(t) = Output of matched filter
$= f(t) * h(t) = \int_{-\infty}^{\infty} f(\tau)\,h(t-\tau)\,d\tau$

(Convolution Theoram Used)

Impulse response of matched filter $= h(t)$
$$= \frac{2K}{N_0}\,x(T-t)$$

$$y(t) = \int_{-\infty}^{\infty} f(\tau) \frac{2K}{N_0} x(T-t+\tau)\, d\tau$$

$$y(t) = \frac{2K}{N_0} \int_0^T f(\tau)\, x(T-T+\tau)\, d\tau$$

$$y(t) = \boxed{\frac{2K}{N_0} \int_0^T f(t)\, x(t)\, dt}$$

$\boxed{\frac{2K}{N_0} = 1}$ is also considered

Output of correlator & Matched filter are same but methods are different

Output of correlator = $y(T) = \int_0^T f(t)\, x(t)\, dt$

Output of Matched filter $y(T) = \frac{2K}{N_0} \int_0^T f(t)\, x(t)\, dt$

($\frac{2K}{N_0}$ can be normalised to 1)

* The matched filter and correlator provides same output inspite of being two distinct techniques.

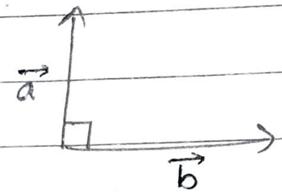
* There can be multiple correlator and each one of them are taking an local replica individually.

* Orthogonal Signals

Orthogonality: It is the property that allows transmission of more than one signal over a common channel with successful detection.

Orthogonal signal: Two signals are said to be orthogonal if they are mutually independent.

Orthogonal vectors:



$$\vec{a}\cdot\vec{b} = 0$$

For signals: $\int_{-\infty}^{\infty} x_1(t)\, x_2(t)\, dt = 0$ Non-periodic

$\int_{0}^{T} x_1(t)\, x_2(t)\, dt = 0$ periodic

Properties:

(i) Sine and cosine function with same phase of same frequency are orthogonal. $\int_0^T \sin(\omega t+\phi)\cos(\omega t+\phi) = 0$

(ii) If $x_1(t)$ and $x_2(t)$ are othogonal then:

$$\int_{-\infty}^{\infty} x_1(t)x_2(t)\,dt = 0 \quad \text{or} \quad \int_0^T x_1(t)x_2(t)\,dt = 0$$

and $y(t) = x_1(t) + x_2(t)$

$P_y = P_{x_1} + P_{x_2}$ ← Avg. Power

$E_y = E_{x_1} + E_{x_2}$ ← Total energy

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unit IV

Digital Modulation Techniques

Types:
(I) Coherent (ASK, FSK, PSK, QPSK, MSK, G-MSK)
(II) Non-coherent (DPSK, DEPSK)

Encoding Vs. Digital Modulation
Encoding : PCM, DPCM, DM, ADM, AD converter, DA converter
Modulation : signal is modulated using sinusoidal carrier
All the advantages of analog modulation are ~~sinusoidal~~ somewhat shared.

Modulat^n → Analog ∿∿ ; → Digital 010010 } both have same carrier wave i.e sinusoidal

Why to choose modulation over encoding?
Baseband signals : large power, low frequencies, coaxial cables, large antennas needed for ~~desired~~ distinct comm^n.

Digital signal $\xrightarrow[\text{(without modul}^n\text{)}]{}$ = Baseband signal (That's why not used in satellite)

Bandpass signals: Sent using satellite channel or microwave radio link.

digital sign $\xrightarrow[\text{modulated}]{}$ = received

Binary & M-ary
Binary : Any one of two possible signals 0 1
M-ary : Any one of M-ary signals 00, 01, 0001, ...

* Digital Modulation → Coherent → Binary / M-ary
→ Non-coherant

* Coherant - Phase synchronized carrier to be generated at the receiver to recover the information signal. Frequency and phase of this locally generated carrier must be synchronized with transmitter. Coherent (same f,φ) Schemes are complex but yeild better performance.

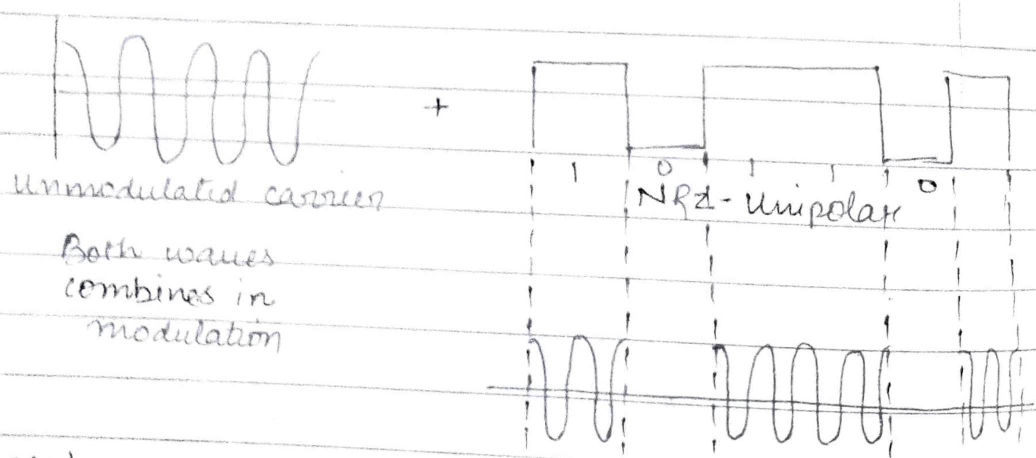
* Non-coherent - No requirement of such phase recognized carrier. less complex, low performance.

* Coherent

* Amplitude Shift Key (ASK)

Digital M → Analog / → Digital → Coher-Bin / Non-coh

→ Coherent and Binary (BASK)
→ Simplest digital modulation technique
→ Also called as ON-OFF Keying (OOK)



$s(t) = 0$ for symbol '0'

$s(t) = \sqrt{2P_s}\cos(2\pi f_c t)$ for symbol '1'.

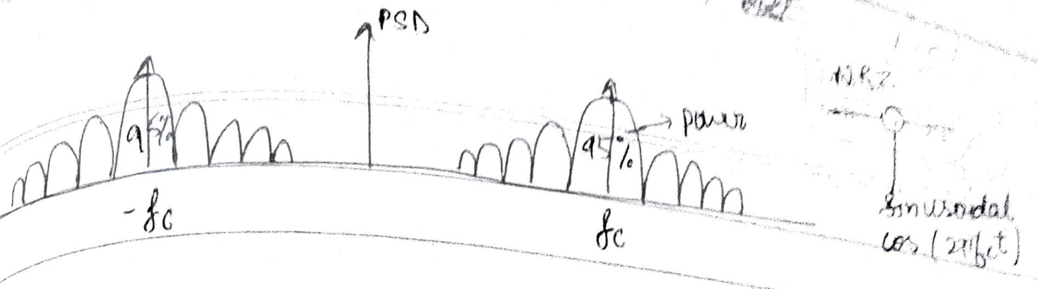
$= \sqrt{P_B T_B}\sqrt{2/T_b}\cos(2\pi f_c t) = \sqrt{P_B T_b}\,\phi_1(t)$

Signal will be present only at "1".

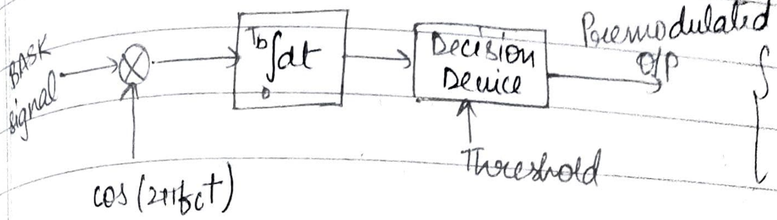
* NRZ Unipolar is used.

Characteristics :- 1. ASK signal can be generated by simply applying the incoming binary data and the sinusoidal carrier to the two inputs of products Modulator.

* Power Spectral Density



* BASK (Binary ASK) Reception: Coherent Detection of Binary ASK Signal



$$\begin{cases} 1 \text{ ; if threshold exceeded} \\ 0 \text{ , otherwise} \end{cases}$$

* phase and frequency is same as of carrier used in transmitter

Synchronization

Timing synchronization :- It enables proper timing of the decision making operation in the receiver with respect to switching instant (switching b/w 1 and 0) in the original binary data.

Advantages of using BASK:

* Simplicity
* Easy to generate and detect

Drawback

* Very sensitive to noise. To overcome this problem BFSK is used.

* Frequency Shift Keying (BFSK)

Frequency of sinusoidal carrier is shifted according to binary symbol. (Phase is unaffected)

Let the frequency shift be Ω.

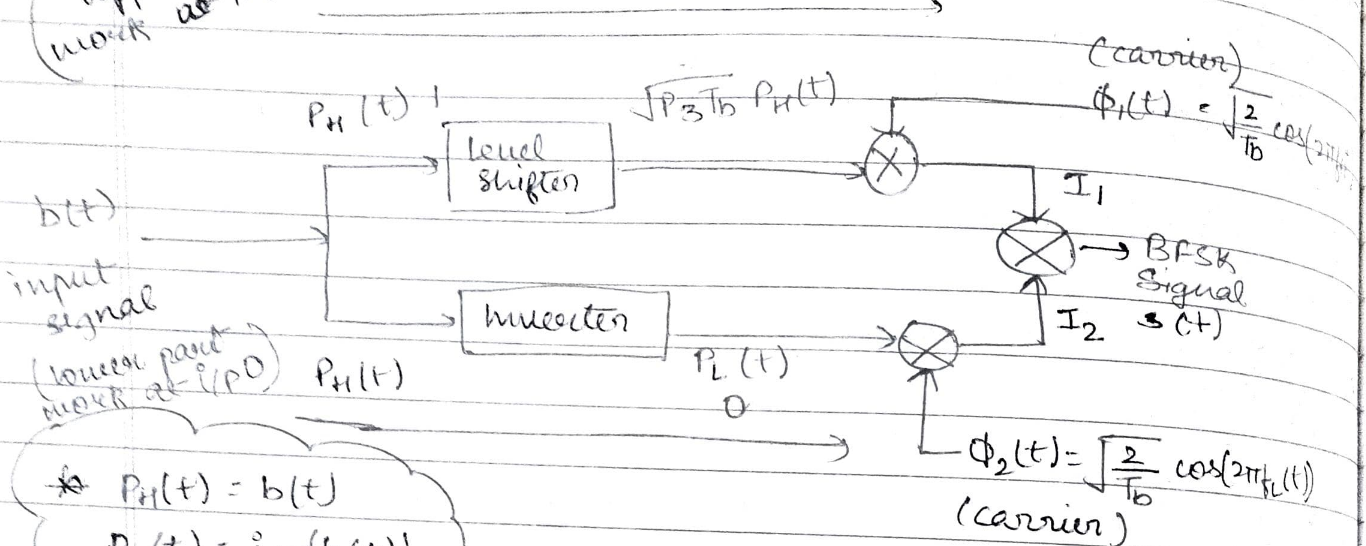
$f_H = f_c + \dfrac{\Omega}{2\pi}$ for symbol 1

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

b(t) input	d(t)
1	+1
0	-1

$$s(t) = \sqrt{2P_s}\cos\left[(2\pi f_0 + d(t)R)t\right]$$
$$\sqrt{2P_s}\cos\left[2\pi\left(f_0 + \frac{d(t)}{2\pi}R\right)t\right]$$

If $d(t) = 1$ then f_H
$d(t) = -1$ then f_L



* $P_H(t) = b(t)$
$P_L(t) = inv(b(t))$

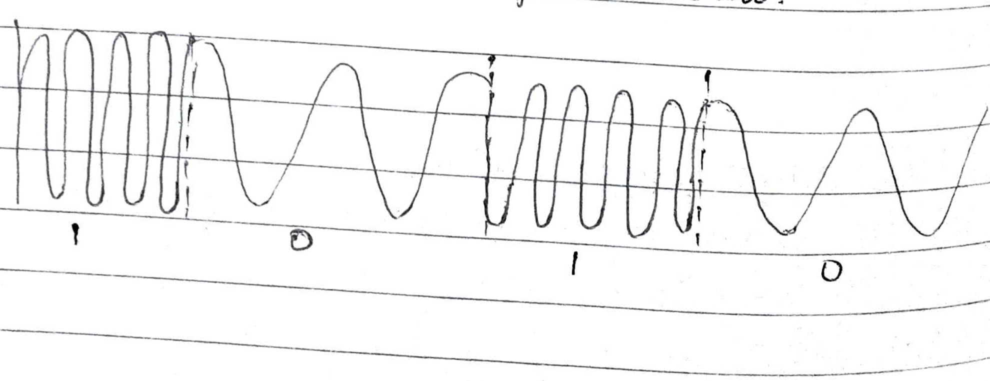
BFSK = $I_1 + I_2$

Level shifter :

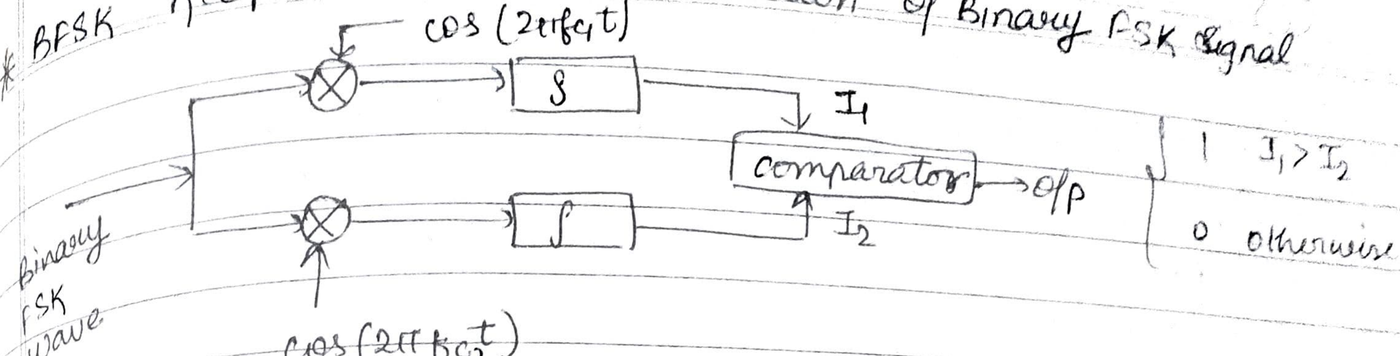
Output $\begin{cases} \sqrt{P_s T_b} & \text{for } +1 \\ 0 & \text{for } 0 \end{cases}$

* $\phi_1(t)$ and ϕ_2 are orthogonal.
* Output from both multipliers is not possible at a time becoz of inverter. If inverter will be active, level shifter will be deactivated & vice-versa.

BFSK signal $\longrightarrow$



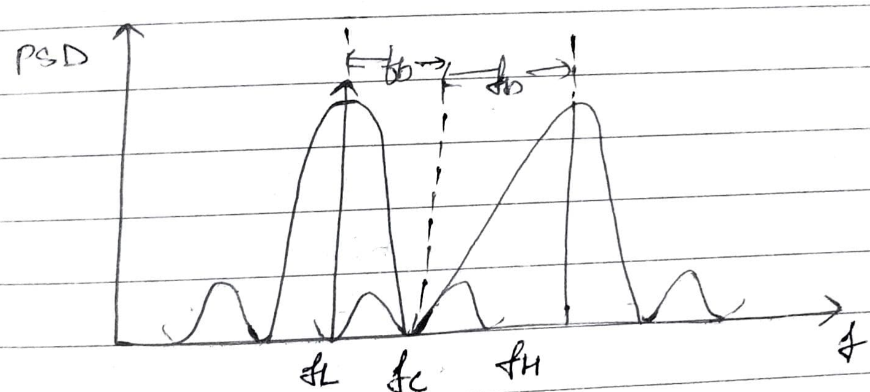
* BFSK Reception : Coherent Detection of Binary FSK Signal



(phase & freq will be similar to the carrier wave at transmitter)

* Receiver is also called correlator receiver.
* Phase & timing synchronization is needed (coz it is of coherent modulation).

* PSD of BFSK



BW = $4f_b$ as width of lobe is $2f_b$

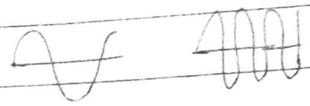
* BW (BFSK) = 2×BW (BPSK)

Advantages
(1) Not that difficult to implement.
(2) Better noise immunity than ASK.

Disadvantages
(1) High bandwidth requirement which is overcame by BPSK.

ASK

BFSK



(freq. changes)

BPSK (phase changed)

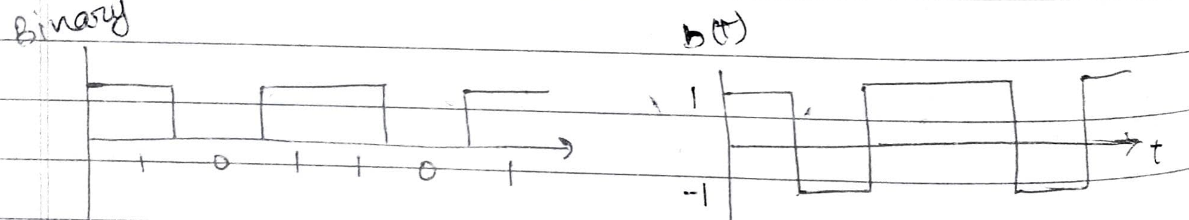
* Binary Phase Shift Keying (BPSK)

* Most efficient of ASK, FSK and PSK
* Bipolar NRZ is used
* Phase of sinusoidal carrier is changed according to data bit to be transmitted (Phase is changed by 180 degrees)

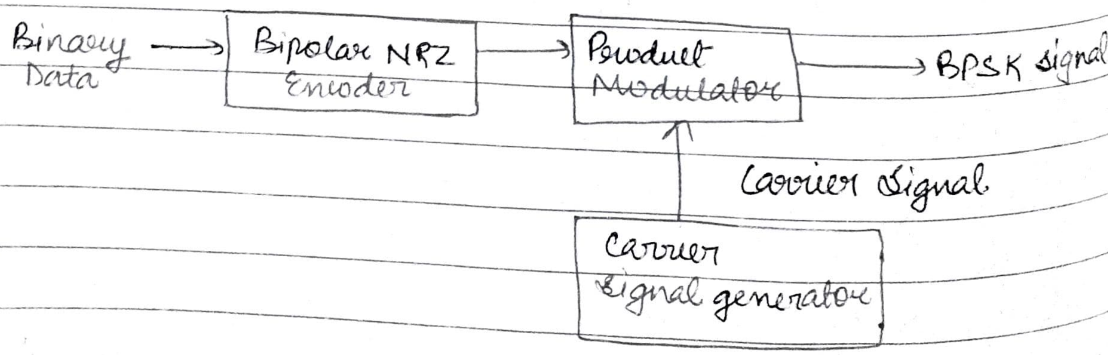
$$\boxed{s(t) = b(t)\sqrt{2P}\cos(2\pi f_c t)}$$

where $b(t) = +1$ when binary 1 is to be transmitted

$= -1$ when binary 0 is to be transmitted



* Generation of BPSK Signal

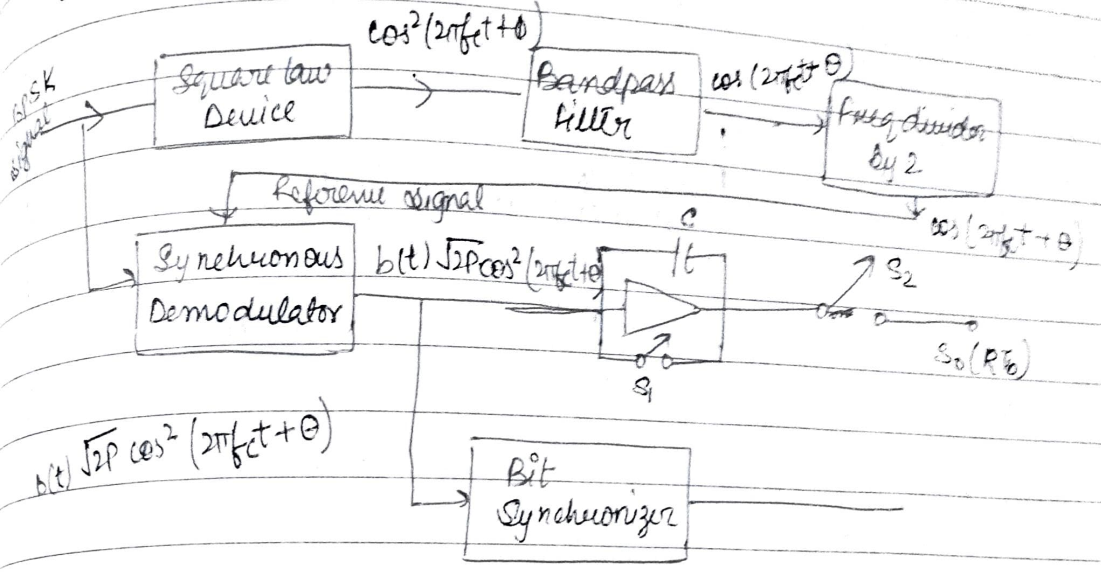


* Receiver for BPSK

Signal at input end of receiver : $S(t) = b(t)\sqrt{2P}\cos(2\pi f_c t + \theta)$

where θ = phase shift

BPSK signal input.



Square law Device : To separate the carrier from received signal

Bandpass filter : $\cos^2(2\pi f_c t+\theta)$

using $\cos^2\theta = \frac{1+\cos 2\theta}{2}$

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

BPF removes this 1/2 .

Frequency divider : $\cos^2 2(2\pi f_c t+\theta) \longrightarrow \cos(2\pi f_c t+\theta)$

Synchronous Demodulator : $b(t)\sqrt{2P}\cos(2\pi f_c t+\theta) \times \cos(2\pi f_c t+\theta)$

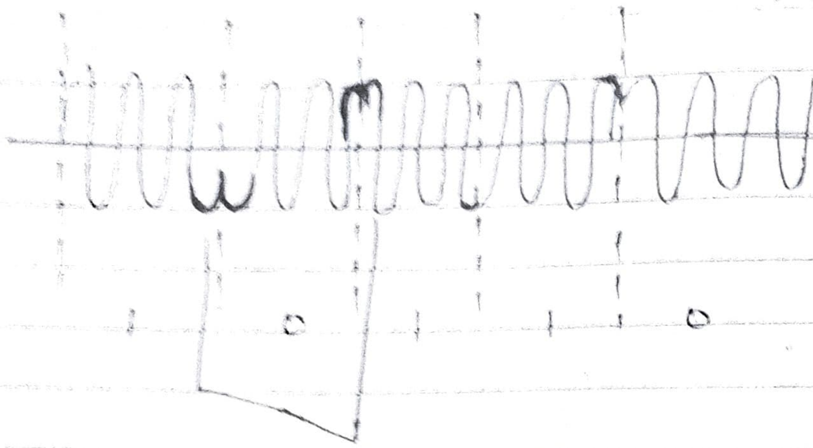
$$= b(t)\sqrt{2P}\cos^2(2\pi f_c t+\theta)$$

$$= b(t)\sqrt{2P} \times \frac{1}{2}[1+\cos 2(2\pi f_c t+\theta)]$$

$$= \boxed{b(t)\frac{\sqrt{P}}{\sqrt{2}}[1+\cos 2(2\pi f_c t+\theta)]}$$

Integrator : Integrates the signal

Synchronizer : Takes care of starting and ending point of bit



Phase shifts whenever bit changed

$$s_0(KT_b) = b(KT_b)\sqrt{\frac{P}{2}}\,T_b \qquad (\text{For } K^{th} \text{ bit})$$

Output is generated in receiver depending upon $b(KT_b)$.

Advantages :

(i) Lower bandwidth than BFSK.

(ii) Best performance among BASK, BFSK, BPSK → best

(iii) Very good noise immunity.

Drawback :

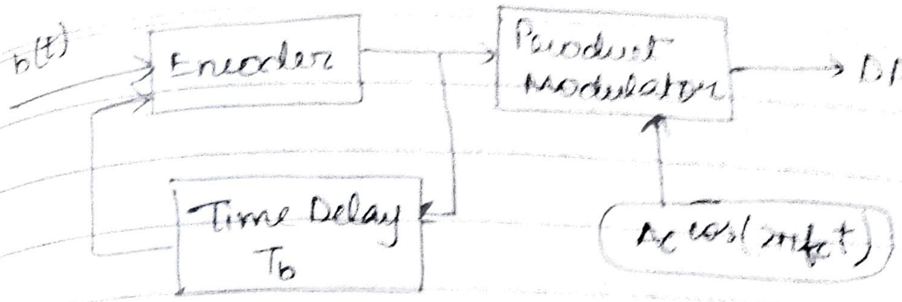
(i) Square signal is same for $b(t)$ and $-b(t)$ (i.e $b^2(t)$)

So, this problem is resolved by DPSK.

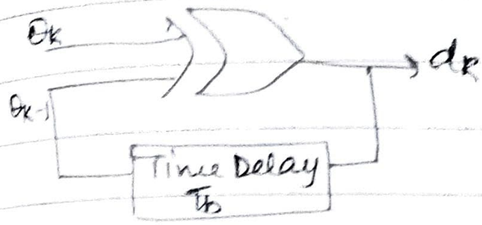
* Non-coherent

* Differential Phase Shift Keying (DPSK)

Differential : Procedure of encoding the data differentially. In the receiver, previously received bits are used to detect the present bits. (predictⁿ of next bit using previous bit)

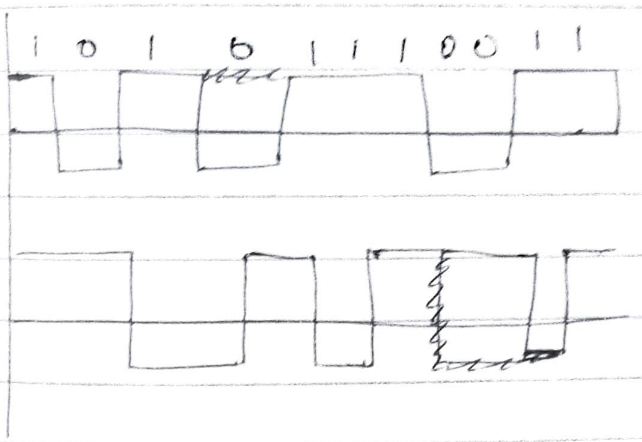


Encoder (exclusive-OR-Gate)

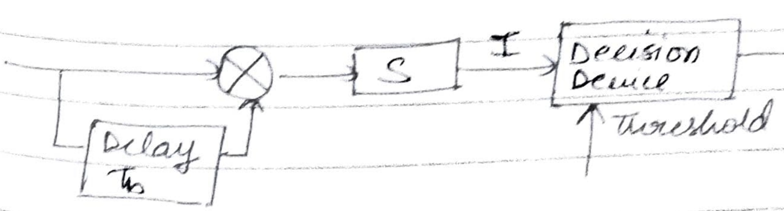


0	0	0
0	1	1
1	0	1
1	1	0

Next bit 0 No change
Next bit 1 change



Receiver of DPSK



1 I>0
0 otherwise

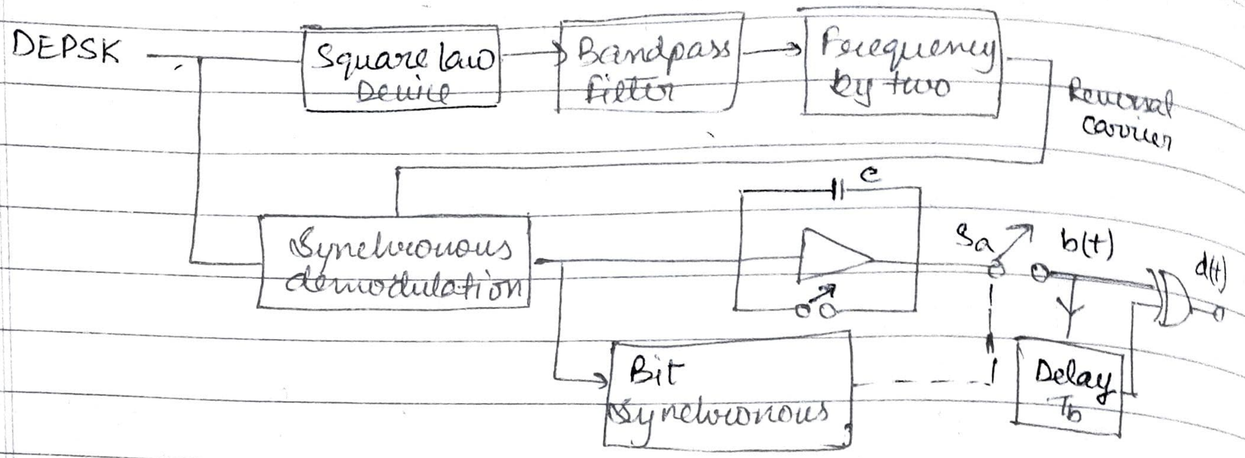
Advantages: No carrier at receiver, less bandwidth than BPSK.

Disadvantages: POE (probability of error) is higher, Noise interference is more.

DPSK & DEPSK

both have same transmitter & modulation but different receiver

* Differentially Encoded PSK (DEPSK)



$$d(t) = 0 \quad \text{if } b(t) = b(t-T_b)$$
$$d(t) = 1 \quad \text{if } b(t) = b(t-T_b)$$

Advantages: Uses coherent type of detection unlike DPSK, therefore POE is less.

Disadvantages: Complex receiver.

* coherent receivers are better.