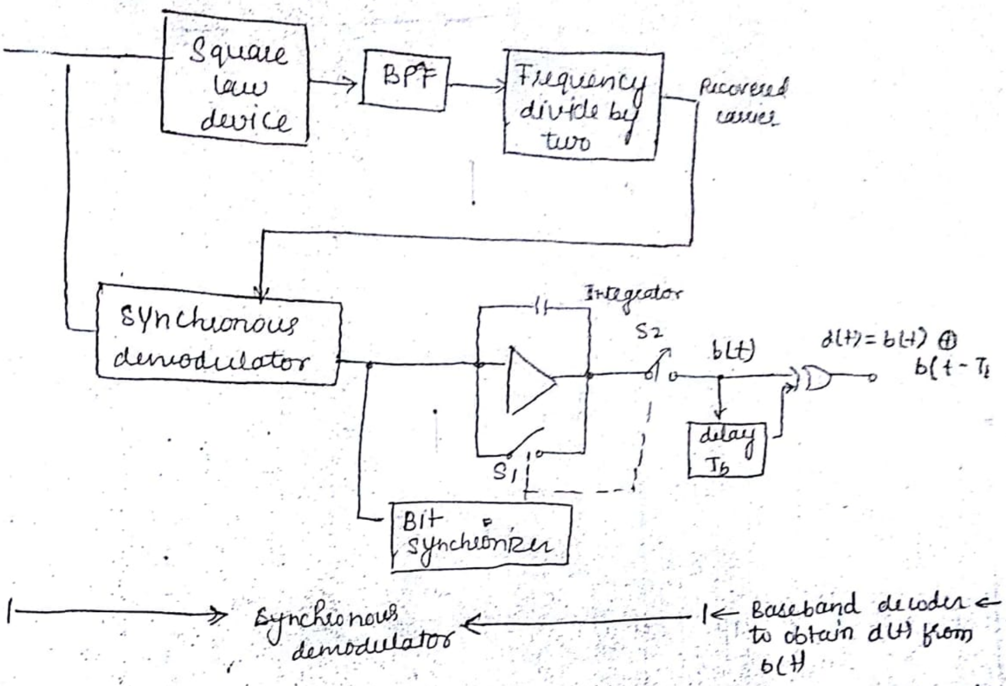
DEPSK (Differentially encoded PSK)

↳ The transmitter of a DEPSK is identical to DPSK transmitter but the receiver is different.



→ It shows that the signal is recovered from the received signal using ~~sch~~ synchronous demodulation technique.

→ Once the signal b(t) is recovered, it is applied to one input of an EX-OR gate. The signal b(t) is also applied to a time-delay ckt & the delayed signal $b(t-T_b)$ is applied to other input of EX-OR gate.

↳ If $b(t) = b(t-T_b)$, then output of EX-OR is 0

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

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

Advantages: ① synchronous detection reduces P(E) probability of error

② In DPSK demodulator, delay generating device operates at carrier frequency but in DEPSK, the delay device operate at baseband frequency. This reduces hardware cost

$b(k) =$ 0 1 1 0 1 1 0 0

$b(k-1)$ 0 1 1 0 1 1 0 0

$d(t) = b(k) \oplus b(k-1)$ 1 0 1 1 a 1 0

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(DPSK)

(Differential Phase Shift Keying)

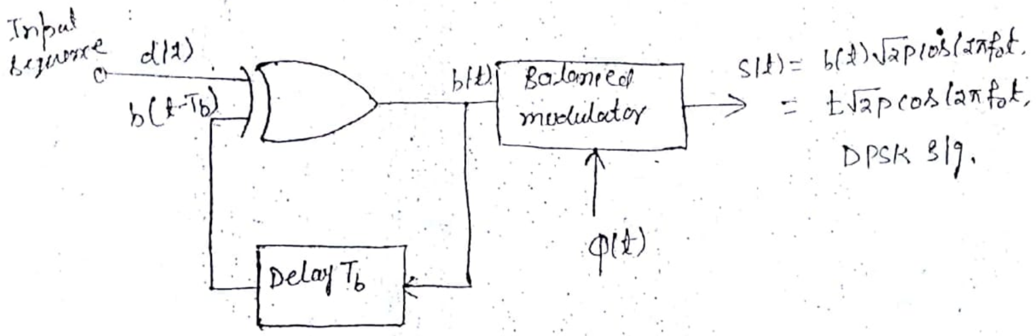
Principles:-

→ DPSK is differentially coherent modulation method.

→ DPSK does not need a synchronous (coherent) carrier at the demodulator.

→ The i/p sequence of binary bits is modified such that the next bit depends upon the previous bit.

DPSK Transmitter / Generator



$$s(t) = b(t)\sqrt{2P}\cos(2\pi f_0 t) = \pm\sqrt{2P}\cos(2\pi f_0 t),$$

DPSK s/g.

Fig Block diagram of DPSK generator or transmitter

Operation and waveform of Transmitter

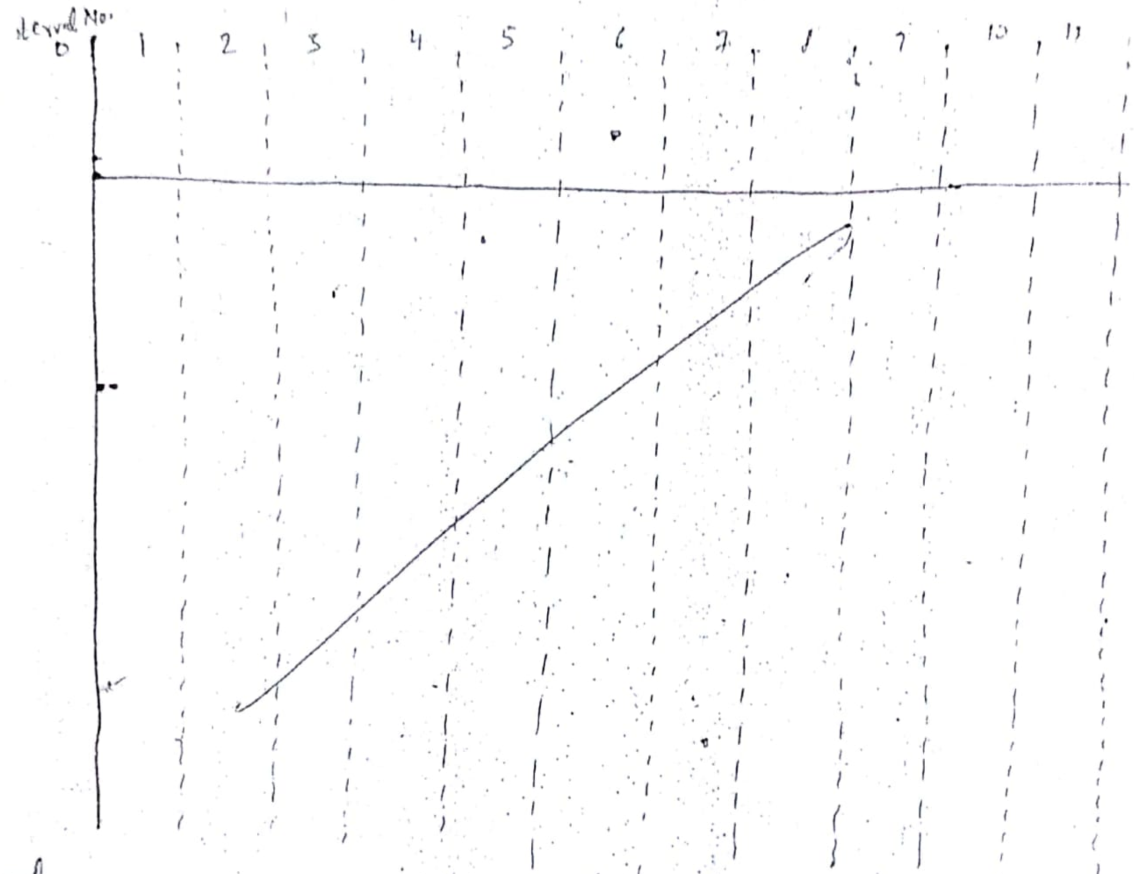
→ The i/p sequence is $d(t)$. O/P sequence is $b(t)$ and $b(t-T_b)$ is the previous O/P delayed by one bit period.

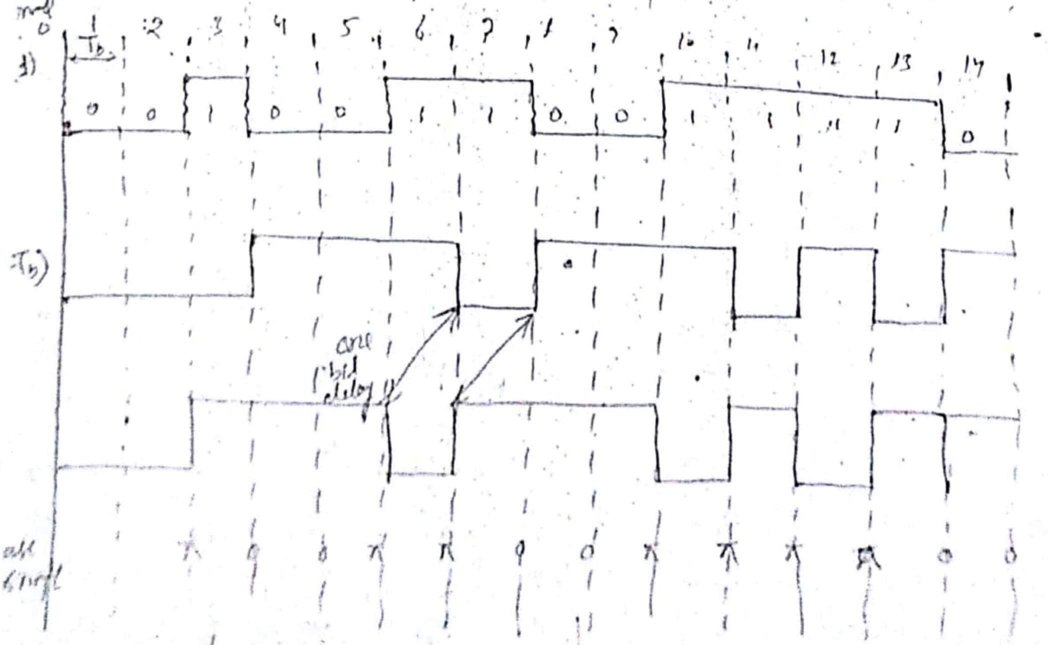
→ Depending upon values of ~~d(t)~~ $d(t)$ and $b(t-T_b)$ exclusive OR gate generates the o/p sequence $b(t)$.

$d(t)$	$b(t-T_b)$	$b(t)$
0 (−1V)	0 (−1V)	0 (−1V)
0 (−1V)	1 (1V)	1 (1V)
1 (1V)	0 (−1V)	1 (1V)
1 (1V)	1 (1V)	0 (−1V)

Table – Truth Table of exclusive OR gate.

→ An arbitrary sequence d(t) is taken. Depending on this sequence, b(t) and b(t − T_b) are found.





(Fig DPSK waveforms)

⇒ From the waveforms of Fig., it is clear that $b(t-T_b)$ is the delayed version of $b(t)$ by one bit period T_b. The exclusive OR operation is satisfied in any interval i.e in any interval $b(t)$ is given as,

$$\boxed{b(t) = d(t) \oplus b(t-T_b)}$$

Note

→ While drawing the waveforms the value of $b(t-T_b)$ is not known initially in the interval no. 1. Therefore it is assumed to be zero and then waveforms are drawn.

⇒ Important Conclusions from the waveforms

1 → O/P sequence $b(t)$ changes level at the beginning of each interval in which $d(t)=1$ and it does not changes level when $d(t)=0$ Observe that $d(3)=1$, hence level of $b(3)$ is changed at the beginning of interval 3. Similarly in intervals 10, 11, 12 and 13 $d(t)=1$ Hence $b(t)$ is changed at the starting of these intervals, In interval 8 and 9 $d(t)=0$. Hence $b(t)$ is not changed in these intervals.

2 - When $d(t)=0$, $b(t) = b(t-T_b)$
when $d(t)=1$, $b(t) = \overline{b(t-T_b)}$

3 - The sequence $b(t)$ modulates sinusoidal carrier.

4 - When $b(t)$ changes the level, phase of the carrier is changed since $b(t)$ changes the level only if $d(t)=1$; It shows that phase of the carrier is changed only if $d(t)=1$.

⇒ In DPSK phase of the carrier changes only on symbol '1'

:- Always two successive bits of d(t) are checked for any change of level. Hence one symbol has two bits.

Symbol duration (T) = Duration of two bits ($2T_b$)

$$\boxed{T = 2T_b}$$

In Fig. b(t) is applied to a balanced modulator. The balanced modulator is also supplied with a carrier $\sqrt{2P}(\cos(2\pi f_0 t)$

ie modulator o/p is

$$s(t) = b(t)\sqrt{2P}\cos(2\pi f_0 t)$$

$$= \pm\sqrt{2P}\cos(2\pi f_0 t)$$

DPSK Receiver :-

Fig. shows the method to recover the binary sequence from DPSK signal.

Operation

1 Phase shift in received s/g :-

During the transmission, the DPSK s/g undergoes some phase shift θ. Therefore the s/g received at the I/P of the receiver is,

$$\text{Received s/g} = b(t)\sqrt{2P}\cos(2\pi f_0 t + \theta) \quad \text{—①}$$

2- **Multiplier o/p :-** This s/g is multiplied with its delayed version by one bit. Therefore the o/p of the multiplier is,

$$\text{Multiplier o/p} = b(t)\, b(t-T_b)\,(2P)\cos(2\pi f_0 t+\theta)\cos[2\pi f_0(t-T_b$$

We know that,

$$\cos(A)\cos(B) = \frac{1}{2}\left[\cos(A-B)+\cos(A+B)\right]$$

now $A = 2\pi f_0 t+\theta$

$B = 2\pi f_0(t-T_b)+\theta$

$$\boxed{\text{Multiplier o/p} = b(t)\, b(t-T_b)\, P\left\{\cos 2\pi f_0 T_b + \cos\left[4\pi f_0\left(t-\frac{T_b}{2}\right)\right.\right.} \text{ — ⓐ}$$

f_0 = carrier frequency

T_b = one bit period. T_b contains integral no. of cycle

If T_b contains 'n' cycles of f_0 then

$$f_0 = n f_b$$

$$f_0 = \frac{n}{T_b}$$

$$\boxed{f_0 T_b = n} \text{ — Ⓑ}$$

Put Ⓑ in ⓐ

$$\text{Multiplier o/p} = b(t)\, b(t-T_b)\, P\left\{\cos 2\pi n + \cos\left[4\pi f_0\left(t-\frac{T_b}{2}\right)+\theta\right]\right.$$

Since $\cos 2\pi n = 1$

$$\text{Multiplier o/p} = b(t)\, b(t-T_b)\, P + b(t)\, b(t-T_b)\, P\cos\left[4\pi f_0\left(t-\frac{T_b}{2}\right)\right.$$

3 - Integrator :-

The above s/g is given to the integrator. In the kth bit interval, the integrator O/P can be written as,

Bandwidth of DPSK Signal

→ Since the one previous bit is always used to define the phase shift in next bit, the symbal can be said to have two bits. Therefore, one symbol duration (T) is equivalent to two bits duration ($2T_b$)

Symbal duration, $T = 2T_b$

B.W is given by

$$BW = \frac{2}{T}$$

$$= \frac{1}{T_b}$$

$$\boxed{BW = f_b}$$

Thus the minimum BW in DPSK is equal to f_b i.e max. baseband signal freq.

Advantages and Disadvantages of DPSK :-

Advantages 1) DPSK does not need carrier at its receiver. Hence the complicated circuitry for generation of local carrier is avoided.

2) The Bandwidth requirement of DPSK is reduced compared to that of BPSK.

Disadvantages :-

1) The probability of error or bit error rate of DPSK is higher than that of BPSK.

2) Since DPSK uses two successive bits for its reception, error in the first bit creats error in the second bit. Hence error

propagation in DPSK is more whereas in PSK single bit can go in error since detection of each bit is independent.

ii) Noise interference in DPSK is more.

In DPSK, previous bit is used to detect next bit. Therefore if error is present in previous bit. detection of next bit can also go wrong. Thus error is created in next bit also. Thus there is tendency of appearing errors in pairs in DPSK.

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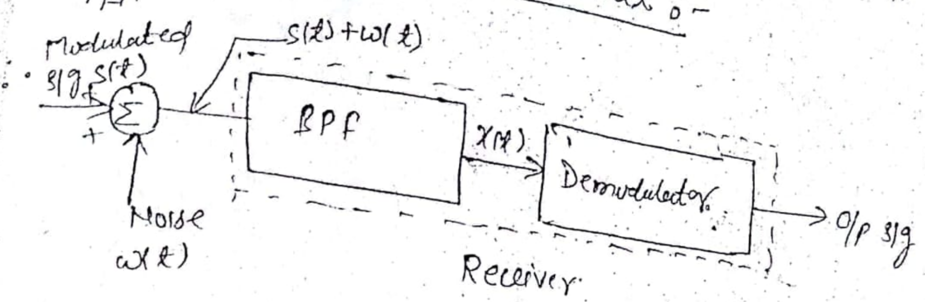
Receiver Model :-



→ s(t) is incoming modulated s/g and w(t) represents the front end receiver noise.

→ Received s/g is the addition of s(t) and w(t)

The combined s/g s(t)+w(t) is applied at the i/p of BPF.

→ The B.W of this filter is just sufficient to pass the s/g s(t) without any distortion.

→ The type of demodulator in the fig. depends on the type of modulation used.

→ Noise w(t) is assumed to be an additive white Gaussian noise. PSD (Power spectral density) of this noise is $N_0/2$ and it is constant, independent of freq.

→ The B.W of the Bandpass filter is exactly equal to the transmission B.W ~~Bep~~ B_T of the modulated s/g s(t).

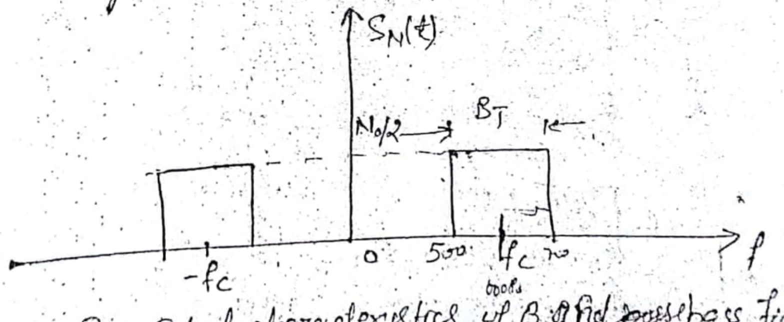


Fig. Ideal characteristics of B and bandpass filtered noise

Generally, $f_c >> B_T$, Hence

→ filtered noise $n(t)$ as a narrow band noise. So,

$n(t)$ can be represented in canonical form;

$$n(t) = n_I(t)\cos(2\pi f_c t) - n_Q(t)\sin(2\pi f_c t)$$

where $n_I(t)$ = in phase noise component.

$n_Q(t)$ = quadrature noise component.

→ O/P of BPF ; $x(t) = s(t) + n(t)$

↑ filtered noise (narrow band noise)

→ This s/g is then applied to the demodulator i/p.

→ Avg noise power can be obtained from fig. 2 as the area under $S_N(f)$ curve.

$$\text{Avg Noise Power} = 2 \times \frac{N_0}{2} \times B_T = N_0 B_T$$

Signal to Noise ratio at the demodulator i/p,

$$(SNR)_I = \frac{\text{Avg. power of } s(t)}{\text{Avg. power of filtered noise } n(t)}$$

$$(SNR)_O = \frac{\text{Avg power of demodulated msg s/g}}{\text{Avg power of the noise measured at the o/p of demodulator.}}$$

hannel SNR

$$(SNR)_C = \frac{\text{Avg s/g power at receiver i/p}}{\text{Avg noise power at receiver i/p.}}$$

Figure of merit :- to compare different CW modulation systems, we have to normalize the receiver performance by dividing the o/p s/g to noise ratio $(SNR)_o$ by the channel s/g to noise ratio (SNR_c).

$$\text{Figure of merit} = \frac{(SNR_o)}{(SNR_c)} = \frac{(SNR_o)}{(SNR_i)}$$

FOM can be less than greater than or equal to 1 depending on the type of modulation.

MSK (Minimum shift keying) Continuous phase shift-keying

→ Data stream $(b(t))$ is divided into an odd and even bit streams $b_o(t)$ and $b_e(t)$ as odd & even. Each bit in both these streams is held for two bit intervals i.e $T_s = 2T_b$ where T_s = symbol time.

→ The staggering process used in OQPSK is used in MSK. Hence the signal $b_o(t)$ and $b_e(t)$ do not change simuntaneousl They change one by one after every bit interval T_b.

→ Alongwith even & odd bit streams, two more waveforms are generated at MSK transmitter, which are ~~sin2πt~~ $\sin 2\pi (t/4T_b)$ and $\cos 2\pi (t/4T_b)$

→ Then the product of $b_e(t)$ and $\sin 2\pi(t/4T_b)$ and $b_o(t)$ with $\cos 2\pi(t/4T_b)$ are generated.

→ Expression

$$V_{MSK}(t) = \sqrt{2P_s}\,[b_e(t) \sin 2\pi(t/4T_b)] \cos\omega_c t + \sqrt{2P_s}\,[b_o(t) \cos 2\pi(t/4T_b)] \sin\omega_c t$$

In MSK, the quadrature carriers $\sin\omega_c t$ and $\cos\omega_c t$ are multiplied by 'smooth' waveform of $b_o(t)$ and $b_e(t)$

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M- ary Modulation

↳ We send one of the M possible signals such as $s_1(t), s_2(t)$ during each signaling interval of duration T-seconds. The number of possible signals is

$$M = 2^N$$

Adv → conserve channel B/W

Drawback → ① ↑ transmitted power
② ↑ error probability

Types → M-ary PSK
M-ary QAM
M-ary FSK

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① * M-ary PSK

↳ The M-ary PSK signals are obtained as under:-

1) group N-bits together to form N-bit symbol.
2) These symbols will extend over a period of NT_b where T_b is the duration of one-bit.
3) Due to the grouping of N-bits per symbol, we can have $2^N = M$ possible symbol.

④ These M-symbols are represented by sinusoidal signals of duration $T_s = NT_b$ which differ from one another by a phase $2\pi/M$ radians. M-ary PSK can be represented as:

$$V_{M\text{-ary PSK}} = \sqrt{2P_s}\,\cos(\omega_c t + \phi_m)$$

where $m = 0, 1 \ldots M-1$

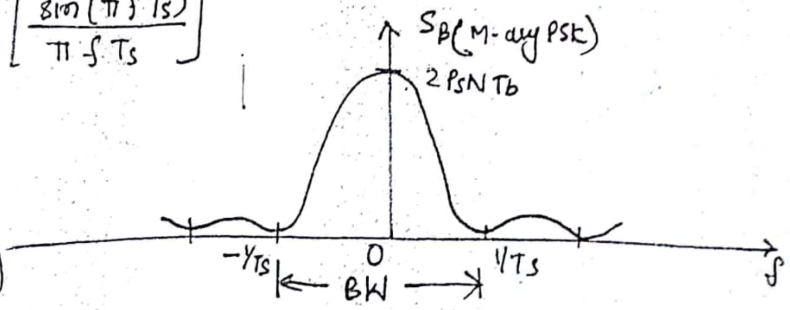
ϕ_m = symbol phase angle $= (2m+1)\frac{\pi}{M}$

Power spectral density

$$S_B = 2P_sT_s\left[\frac{\sin(\pi f T_s)}{\pi f T_s}\right]^2$$

↑
for QPSK

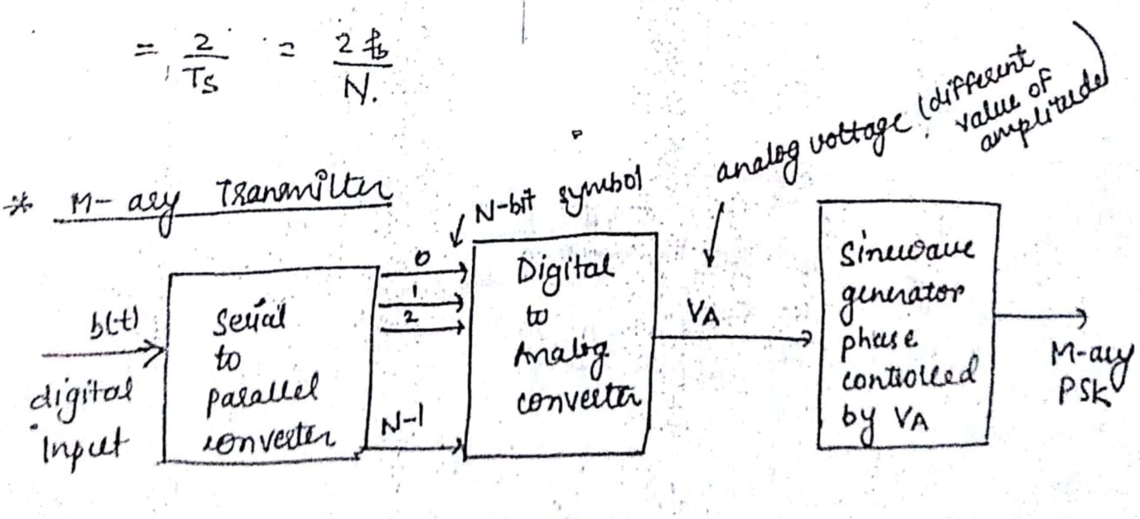
Put $T_s = NT_b$



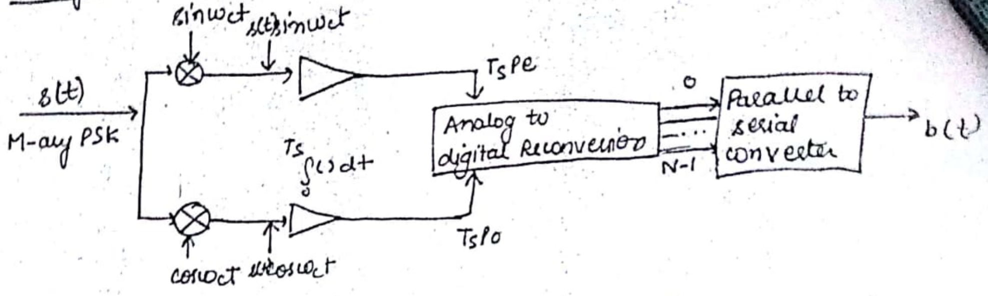
$$BW = \frac{1}{T_s} - \left(-\frac{1}{T_s}\right)$$

$$= \frac{2}{T_s} = \frac{2f_b}{N}.$$

* M-ary Transmitter



M-ary PSK Receiver



$$BW = \frac{2f_b}{N} = \frac{2F_b}{4} = \frac{f_b}{2}$$

Advantages ① BW reduces with increase in Number of bits per symbol (N).

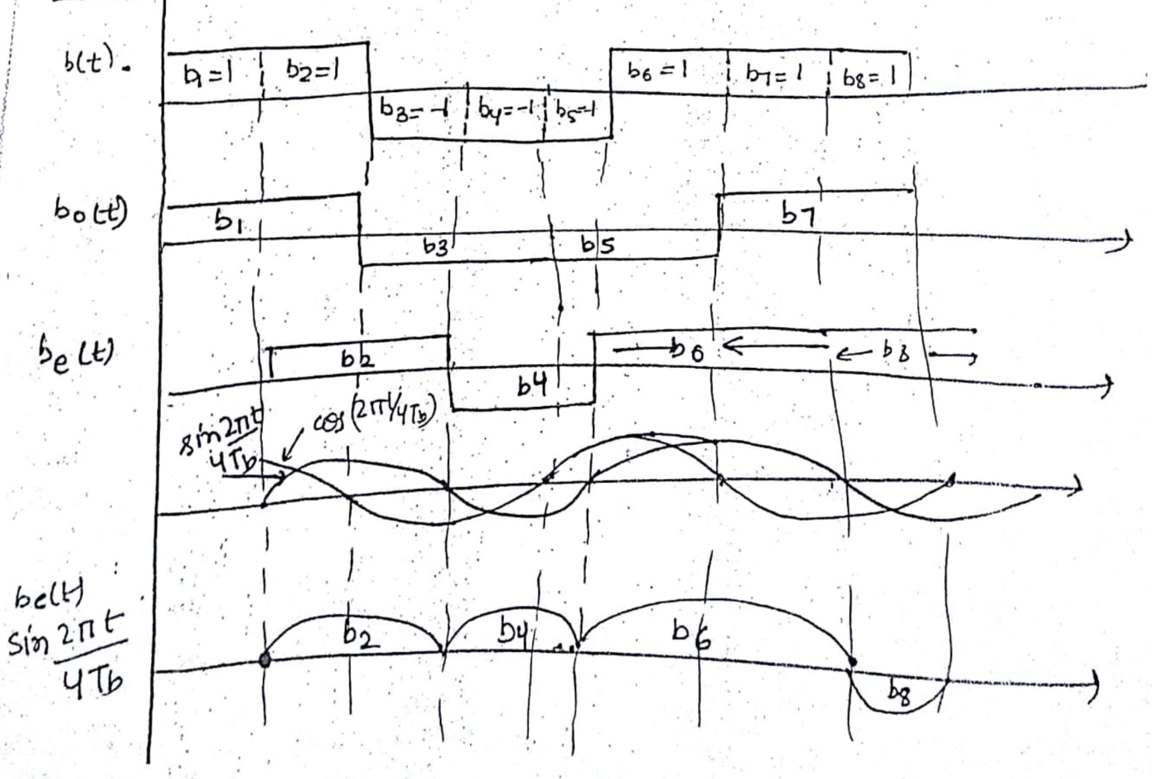
② Info travels as phase change & immune to amplitude changes.

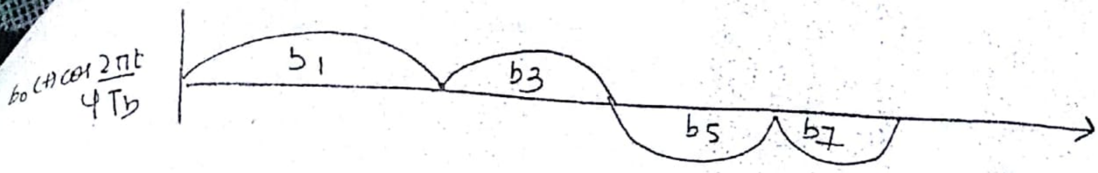
Disadvantages

① P(e) increases with increase in number of bits N per symbol

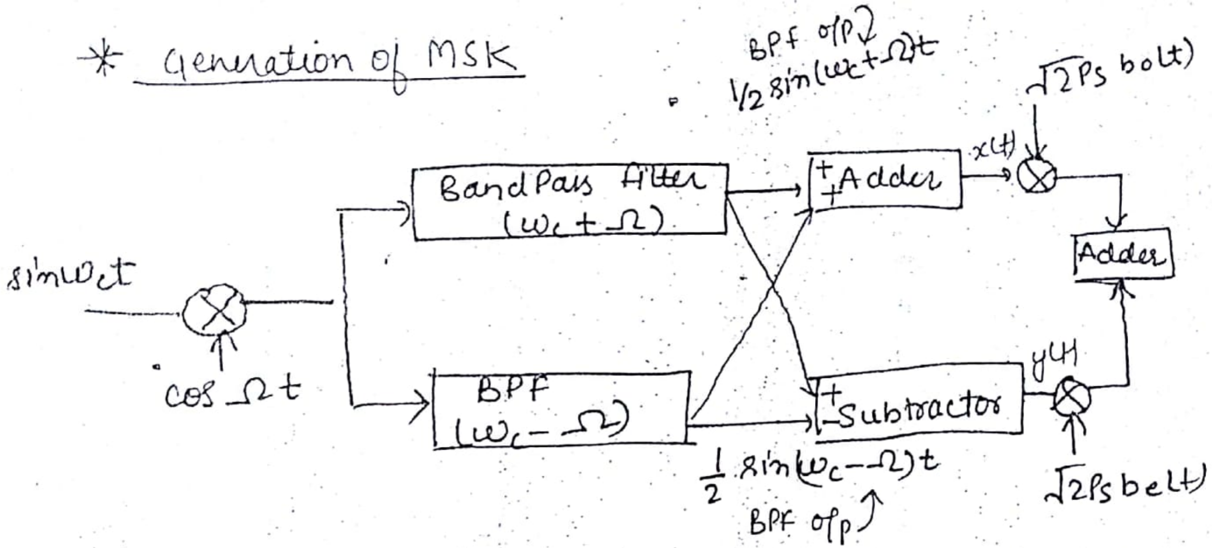
② Tx & Rx are complex

* MSK (shaped QPSK) (MSK is continuous FSK)





* Generation of MSK



output at both adder & subtractor

$$x(t) = \frac{1}{2}\sin(\omega_c+\Omega)t + \frac{1}{2}\sin(\omega_c-\Omega)t$$

$$= \sin\omega_c t \cos \Omega t$$

$$y(t) = \cos\omega_c t \sin \Omega t$$

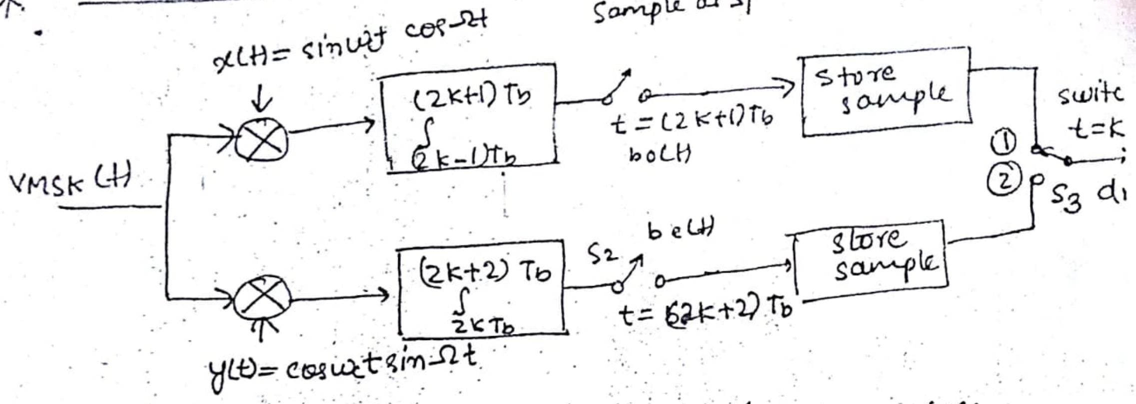
$$V_{msk}(t) = \sqrt{2P_s}\, b_o(t) \sin\omega_c t \cos\Omega t + \sqrt{2P_s}\, b_e(t) \cos\omega_c t \sin.$$

$$\boxed{V_{msk} = \sqrt{P_s}\, C_H(t) \sin\omega_H(t) + \sqrt{2P_s}\, C_L(t) \sin\omega_L t}$$

$$C_H(t) = \frac{b_o(t) + b_e(t)}{2}, \quad \omega_H = \omega_c + \Omega$$

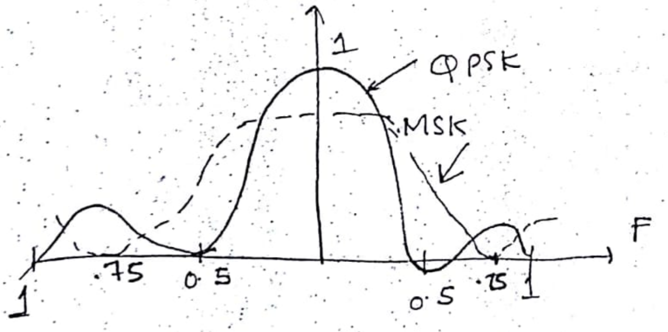
$$C_L = \frac{b_o(t) - b_e(t)}{2}, \quad \omega_L = \omega_c - \Omega$$

* MSK Receiver



→ $x(t)$ and $y(t)$ are regenerated at receiver.

→ Switch S_3 at the output will then switch between the positions 1 & 2 at bit rate.



Normalised PSD

* BW of MSK is higher than that of QPSK

MSK Power spectral density $S_b(f) = \frac{32 E_b}{\pi^2}\left[\frac{\cos(2\pi f T_b)}{1-(4fT_b)}\right]$

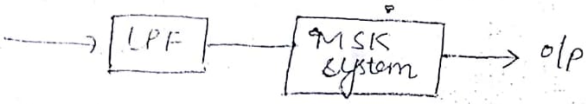
BW = width of main lobe $= 0.75f_b + 0.75f_b$
$= 1.5f_b$

*

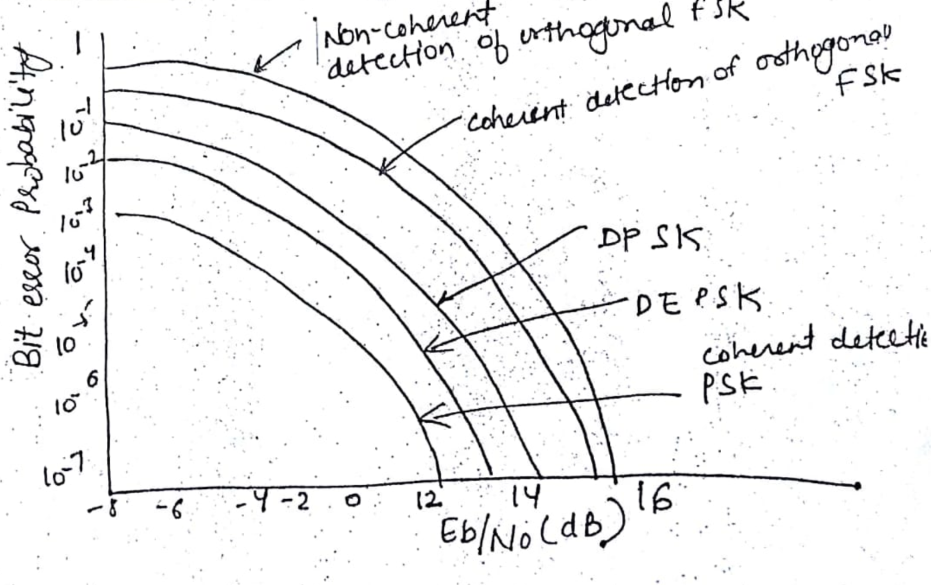
* Gaussian MSK

↳ Adjacent channel interference occurs in MSK. This makes MSK unsuitable for multiuser applications.

↳ The performance of MSK system can be improved by making its baseband spectrum more compact. This can be achieved by using a premodulation LPF.



* Performance comparison of digital modulation schemes



Coherent BPSK $= \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{E_b/N_0}\right)$

Coherent BFSK $= \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{E_b/2N_0}\right)$

DPSK $= \frac{1}{2}\,e^{-(E_b/2N_0)}$

Non coherent FSK $= \frac{1}{2}\,e^{-(E_b/N_0)}$

QPSK $= \mathrm{erfc}\left(\sqrt{E_b/N_0}\right) - \frac{1}{4}\,\mathrm{erfc}^2\left(\sqrt{E_b/N_0}\right)$

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