→ M-ary Phase shift keying (MPSK) :-

$$\boxed{\begin{array}{l} M = 2^N \\ T_s = N T_b \end{array}}$$

① For BPSK :- $M = 2 \Rightarrow 2 = 2^1$

$\Rightarrow N = 1$

& $T_s = T_b$

$\boxed{M = 2^N \quad \& \quad T_s = NT_b}$

where $M \rightarrow$ No. of symbols that can be Txed

$N \rightarrow$ No. of bits that can Txed simultaneously to represent a symbol.

$T_s \rightarrow$ symbol time

$T_b \rightarrow$ Bit duration

② For QPSK :- $M = 2^N \Rightarrow 4 = 2^2$

$\Rightarrow N = 2$

$T_s = 2T_b$

Note :-

1) For BPSK, two sinusoids differ in phase by $\frac{2\pi}{2} = \pi$ & symbol time $T_s = T_b$.

2) For QPSK, four sinusoids differ in phase by $\frac{2\pi}{4} = \pi/2$ & symbol time $T_s = 2T_b$

3) ∴ In general when N bits are lumped with symbol time $T_s = NT_b$ then $M (= 2^N)$ no. of s/gs are required with phase difference of $\frac{2\pi}{M}$

③ For MPSK :- $M = 2^N$; $T_s = NT_b$

MPSK s/g is represented as

$$\boxed{V_{MPSK}(t) = V_m(t) = \sqrt{2P_s} \cos (\omega_0 t + \phi_m)}$$

$$= \sqrt{2P_s} \left[\cos \omega_0 t \cos \phi_m - \sin \omega_0 t \sin \phi_m \right]$$

$$= P_e \cos \omega_0 t - P_o \sin \omega_0 t$$

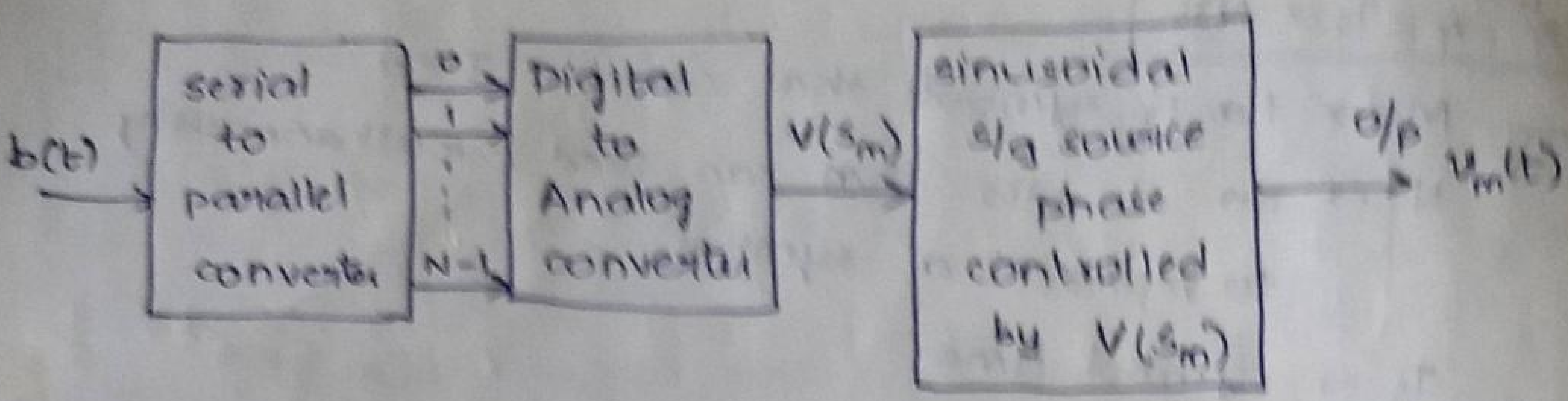
where $P_e = \sqrt{2P_s} \cos \phi_m$

$P_o = \sqrt{2P_s} \sin \phi_m$

$$\boxed{\phi_m = 2m \left(\frac{\pi}{M}\right) \text{ ; where } m = 0, 1, \ldots M-1}$$

→ MPSK Txer :-

At Txer, the bit string $b(t)$ is applied to serial to parallel converter which stores n-bits of a symbol. This converter o/p remains unchanged for a duration of NT_b of a symbol. Each



symbol time, the converter o/p is updated. This converter o/p is applied to DAC which generates an o/p voltage assuming one of $M = 2^N$ different values i.e, the DAC output is a voltage $V(S_m)$ which depends on various i/p symbols $(m = 0, 1, \ldots M-1)$. This voltage can be applied as a control i/p to the sinusoidal s/g source which is nothing but a phase controlled oscillator, the phase of this o/p can be changed once for every symbol time. The different carrier terms can be obtained using

$$v_m(t) = \sqrt{2P_s} \cos\left[\omega_0 t + \phi_m\right]$$

$$= P_e \cos \omega_0 t - P_o \sin \omega_0 t$$

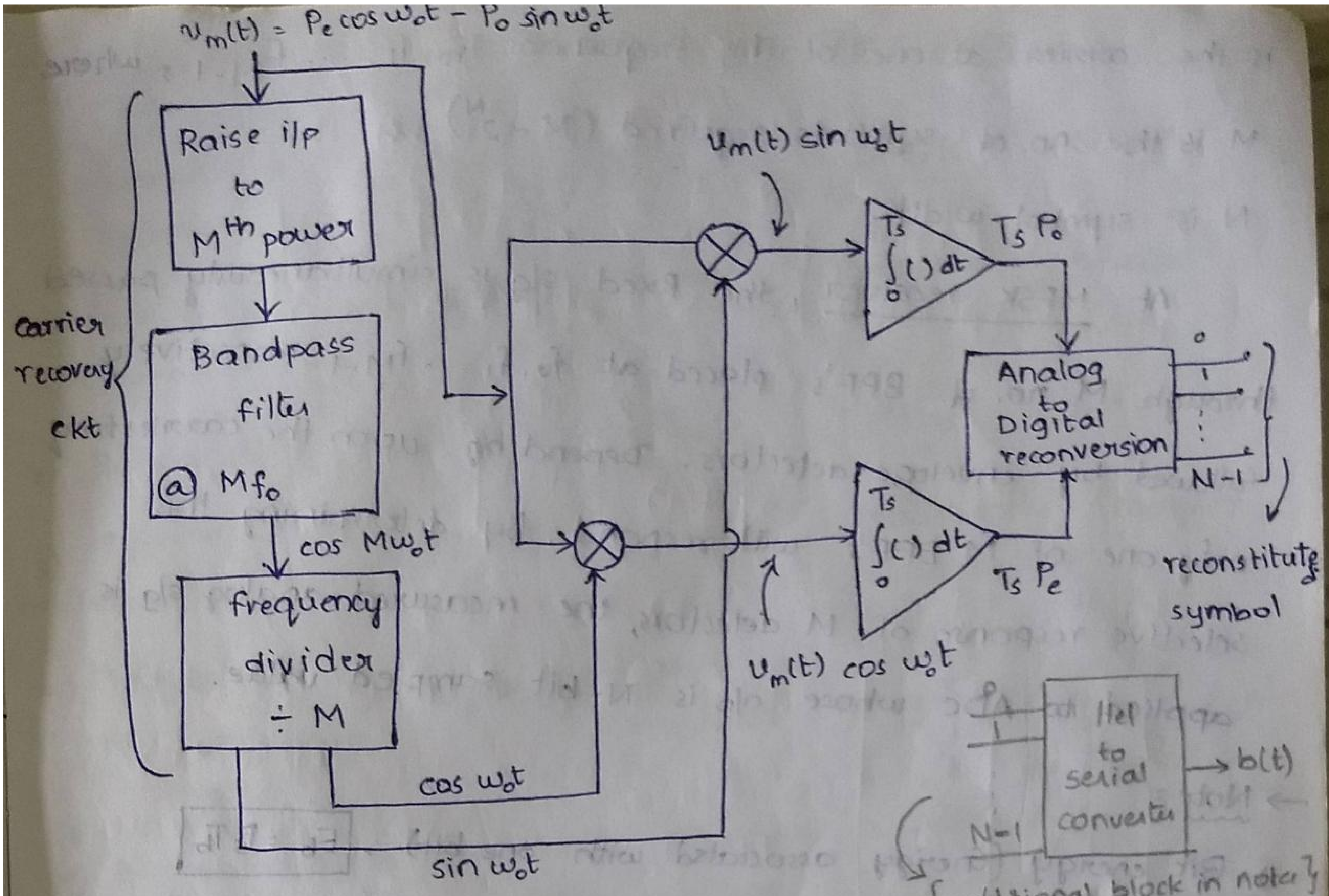
where $\phi_m = 2m\left(\frac{\pi}{M}\right)$ where $m = 0, 1 \ldots M-1$

& ϕ_m is the phase of the carrier.

→ MPSK Rxer:-

In MPSK Rxer, the synchronous carrier is generated similar to that of any other PSK system. The integrator o/p are voltages whose amplitudes are proportional to $T_s P_o$ & $T_s P_e$ respectively & change at symbol rate. These analog voltages are applied to ADC which reconstructs the digital N-bit s/g which constitutes the Txed s/g.

additional → { A ||el to serial converter is used to convert these N-bit symbols to form the actual data bit sequence b(t)



→ M-ary FSK (M-ary Frequency Shift Keying) system :-

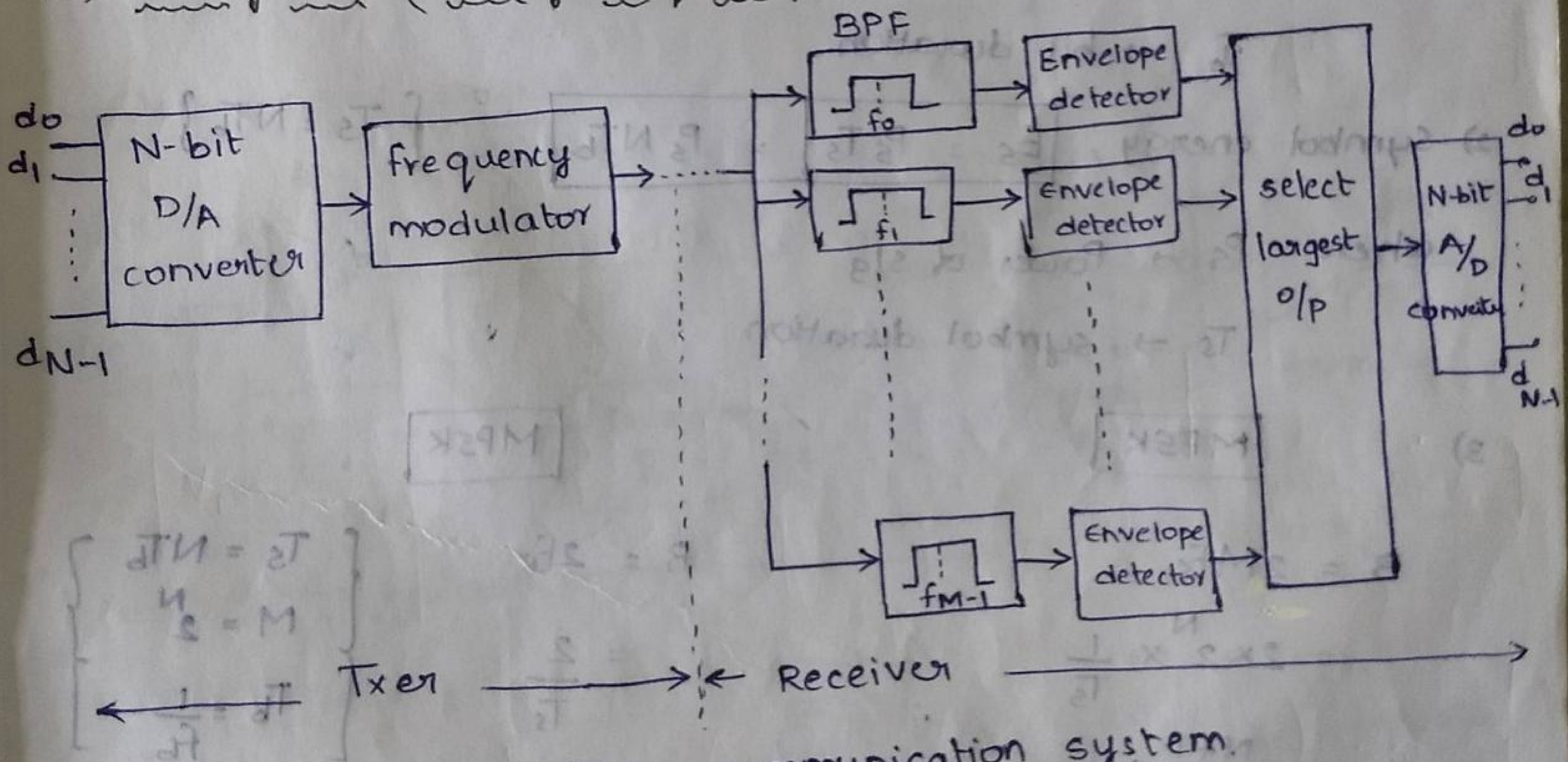


fig :- MFSK communication system.

In MFSK Txer, the N-bit symbol is presented for every symbol time of T_s to an N-bit DAC. The DAC o/p can be used as control voltage for a frequency modulator which generates the required carrier waveform. The o/p of freq modulator is the carrier at one of the frequencies $f_0, f_1 \dots f_{M-1}$, where

M is the no. of symbols required ($M = 2^N$) &

N is symbol width.

At MFSK receiver, the Rxed s/g is simultaneously passed through M no. of BPF's placed at $f_0, f_1 \dots f_{M-1}$ respectively followed by envelope detectors. Depending upon the carrier freq only one of M BPF's will respond. By determining this selective response of M detectors, the measured analog s/g is applied to ADC whose o/p is N-bit sampled value.

→ Note :

1) Bit energy (Energy associated with one bit), $\boxed{E_b = P_s T_b}$

where P_s → Power of s/g

T_b → bit duration

2) Symbol energy, $\boxed{E_s = P_s T_s} = \boxed{P_s N T_b}$ $\{T_s = NT_b\}$

where P_s → Power of s/g

T_s → symbol duration

3)

MFSK	MPSK
$B = 2MF_s$	$B = 2F_s$
$= 2 \times 2^N \times \frac{1}{T_s}$	$= \frac{2}{T_s}$
$= 2^{N+1} \frac{1}{NT_b}$	$= \frac{2}{NT_b}$
$\Rightarrow \boxed{B = \frac{2^{N+1}}{N} f_b}$	$\boxed{B = \frac{2}{N} f_b}$

$$\left[\begin{array}{l} T_s = NT_b \\ M = 2^N \\ T_b = \frac{1}{f_b} \end{array}\right]$$

∴ MFSK requires more bandwidth than that of MPSK.

→ Comparison of Digital Modulation Techniques :-

parameter to be compared	BPSK	DPSK	BFSK	QPSK
1) variable characteristics	phase	phase	frequency	phase
2) Bandwidth	$2f_b$	$2f_b$	$4f_b$	f_b
3) system complexity	complex	simple	Moderately complex	complex
4) Requirement of synchronous carrier	Required	Not required	Not required	Required
5) Bit determination at Rxer	Based on single bit interval	Based on two successive bit durations	Based on 1 bit interval	Based on 2 bit intervals

Scanned by TapScanner

→ Describe the Txed s/g for 16 PSK to Tx the data bit sequence $b(t) = 1011010011110$. consider digital precise i/p data rate is 10 Kbps, avg energy per bit is 0.02 units & carrier freq of 1 MHz

Ans] $\boxed{16\ PSK} \Rightarrow M = 16 = 2^N \Rightarrow \boxed{16 = 2^4}$

$N = 4$

$\therefore\ b(t) = \underbrace{1\ 0\ 1\ 1}_{S_{11}} \ \vdots\ \underbrace{0\ 1\ 0\ 0}_{S_4} \ \vdots\ \underbrace{1\ 1\ 1\ 0}_{S_{14}}$

<u>Given</u> :- i/p data rate, $f_b = 10$ kbps

$f_o = 10^6$ Hz $\Rightarrow T_b = \frac{1}{10\times10^3} = 10^{-4}$ sec

$E_b = 0.02$ units

$E_b = P_s T_b \Rightarrow 0.02 = P_s\, 10^{-4}$

$\Rightarrow P_s = 0.02 \times 10^4$

$= 200$ watts.

$V_{MPSK}(t) = \sqrt{2P_s}\cos(\omega_0 t + \phi_m)$

where $\phi_m = 2m\left(\frac{\pi}{M}\right)$ & $m = 0, 1 \ldots M-1$

Here $M = 16$, so $m = 0, 1 \ldots 15$

Tx bits	m	ϕ_m		
1011	11	$2\times 11\left(\frac{\pi}{16}\right)$	$= 22\pi/16$	$= 11\pi/8$
0100	4	$2\times 4\,(\pi/16)$	$= 8\pi/16$	$= \pi/2$
1110	14	$2\times 14\,(\pi/16)$	$= 14\pi/8$	$= 7\pi/4$

$\therefore S_{11} : V_{16PSK}(t) = \sqrt{2\times 200}\cos\left[2\pi\times10^6 t + 11\pi/8\right]$

$= 20\cos(2\pi\times10^6 t + 11\pi/8)$

$S_4 : V_{16PSK}(t) = 20\cos(2\pi\times10^6 t + \pi/2)$

$S_{14} : V_{16PSK}(t) = 20\cos(2\pi\times10^6 t + 7\pi/4)$

→ An 8-ary PSK is used to modulate the bit stream $d(t) = 001010011010$. Find the phase of the carrie needed to be Txed for 8 PSK system & indicate the phase angle during every symbol time for the given bit sequence b(t)

Ans] $\boxed{\text{8-ary PSK}}$ $\Rightarrow 8 = 2^3$

$\Rightarrow N = 3$

d(t)	0 0 1	0 1 0	0 1 1	0 1 0
	S_1	S_2	S_3	S_2

$V_{MPSK}(t) = \sqrt{2P_s} \cos(\omega_0 t + \phi_m)$ where $\phi_m = 2m\frac{\pi}{M}$

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

m	Tx bits	ϕ_m
1	0 0 1	$2 \times \pi/8 = \pi/4$
2	0 1 0	$2 \times 2 \times \pi/8 = \pi/2$
3	0 1 1	$2 \times 3 \times \pi/8 = 3\pi/4$

$\therefore$ Phase angle of carrier for the given sequence

$= \pi/4, \quad \pi/2, \quad 3\pi/4, \quad \pi/2$

$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$

(0 0 1) (0 1 0) (0 1 1) (0 1 0)