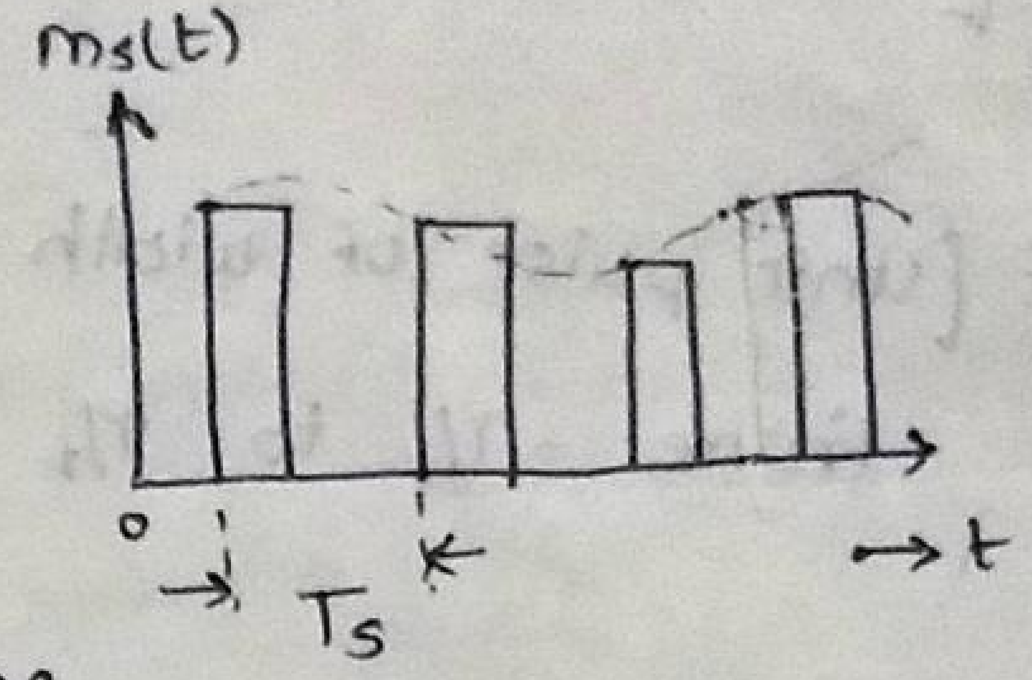
(3) By using instantaneous sampling, more no. of s/gs can be multiplexed since $\tau \to 0$, $N = \frac{T_s}{\tau}$.

② Flat-Top Sampling :-



The flat-topped samples constitute the samples in the form of pulses whose top portion is flat & within pulse interval at one instant of time only the pulse amplitude is equal to the base band s/g amplitude (i.e., it consists of pulses having constant amplitude value established by the sample value of the base band s/g at some point within the pulse interval)

Disadvantage :- In this type of sampling, the base band s/g m(t) can't be recovered exactly by simply passing the samples through an ideal LPF & at the Rxing end, when these samples are used to reconstruct the s/g, more distortion occurs.

Advantages :-
1) Simplifies the design of electronic cktry used to perform the sampling operation.
2) Design of flat topped samples is relatively easier & cost of implementation is less.

Spectrum for sampling methods :-

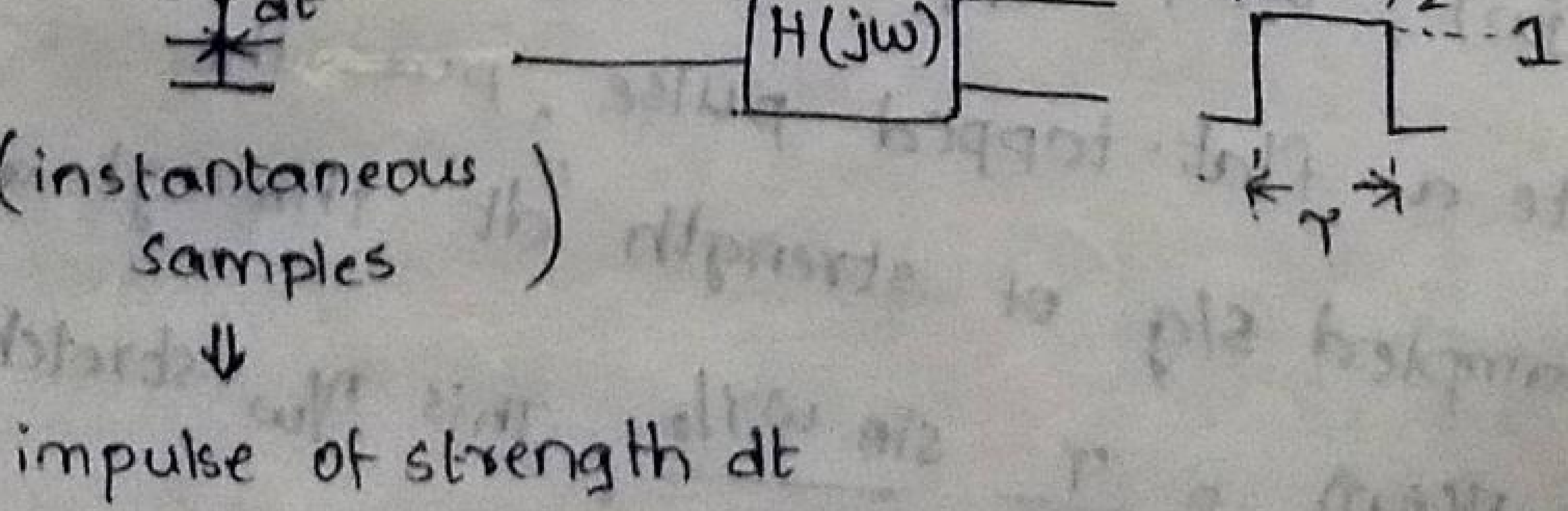


fig :- A n/w with transform H(jw) which converts a pulse of width dt into a rectangular pulse of same amplitude, but of duration τ.

H(jω) calculation :- $\left\{ V(f) = F[u(t)] = \int_{-\infty}^{\infty} e^{-j2\pi ft}\, dt \right\}$

F[impulse of strength dt at t = 0] = 1 × dt = dt $\downarrow$ strength $\left\{ F[\text{impulse}] = \int_{-\infty}^{\infty} e^{-j2\pi ft} dt \Big|_{t=0} = \int_{-\infty}^{\infty} e^{0} dt = 1 \right.$

F [unit pulse of width τ extending from $-\tau/2$ to $\tau/2$]

$$= \int_{-\tau/2}^{\tau/2} 1 \cdot e^{-j2\pi ft}\, dt$$

$$= \left[\frac{e^{-j2\pi ft}}{-j2\pi f} \right]_{-\tau/2}^{\tau/2}$$

$$= \frac{-2j \sin 2\pi f \tau/2}{-j2\pi f}$$

$$\frac{\sin \omega\tau/2}{\pi f \times \omega\tau/2} \times \omega\tau/2 \quad \left\{ \frac{\omega\tau}{2} = \frac{2\pi f\tau}{2} \right.$$

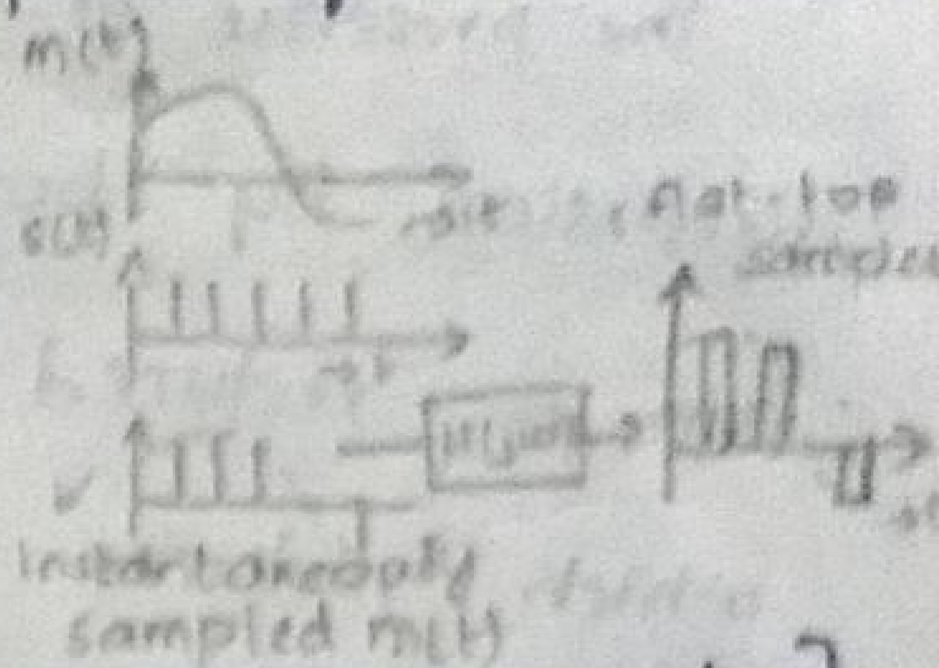
$$= \frac{\sin \omega\tau/2}{\omega\tau/2}\, \tau$$

$\therefore \dfrac{1}{H(j\omega)} = \dfrac{F[\text{impulse of strength dt at } t=0]}{F[\text{unit pulse of width } \tau \text{ extending from } -\tau/2 \text{ to } \tau/2]}$

$H(j\omega) = \dfrac{F[\text{unit pulse of width } \tau \text{ extending from } -\tau/2 \text{ to } \tau/2]}{F[\text{impulse of strength dt at } t=0]}$

$$\Rightarrow \boxed{H(j\omega) = \frac{\tau}{dt} \frac{\sin \omega\tau/2}{\omega\tau/2}} \qquad \left\{ H(j\omega) = \frac{F[o/p]}{F[i/p]} \right\}$$

Consider a base band s/g whose fourier transform is $F[m(t)] = M(j\omega)$, $0 \le f \le f_M$, since m(t) is band limited to f_M. To generate a flat-topped pulse, pass the instantaneously sampled s/g of strength 'dt' through a n/w having transfer fn $H(j\omega) = \dfrac{\tau}{dt} \dfrac{\sin \omega\tau/2}{\omega\tau/2}$. This n/w stretches impulse of strength 'dt' to form a unit pulse of width τ sec extending from $-\tau/2$ to $\tau/2$



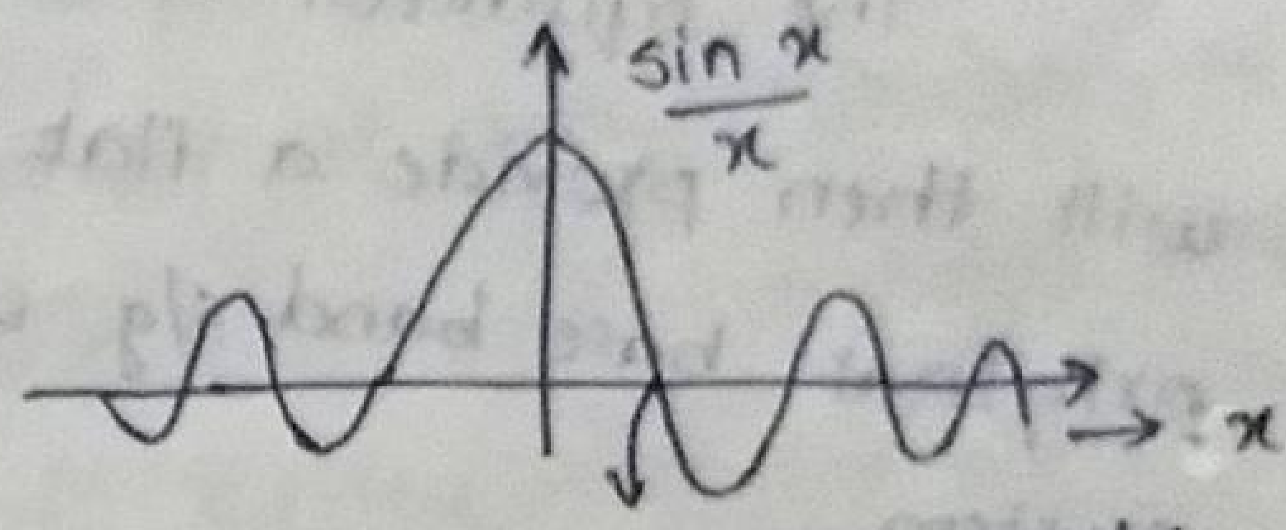
$\therefore F\left[\text{instantaneous samples}\right] = F\left[\frac{dt}{T_s}\right] F[m(t)]$

$= \frac{dt}{T_s} M(j\omega)$

$\therefore F\left[\text{flat topped sampled } m(t)\right] = H(j\omega)\, F\left[\text{instantaneous samples}\right]$

$= \frac{\tau}{T_s} M(j\omega) \frac{\sin \omega\tau/2}{\omega\tau/2}$

The term $\boxed{\frac{\sin \omega\tau/2}{\omega\tau/2}}$ is termed as aperture factor which is responsible for more distortion in flat topped samples.



Null freq : The freq at which spectral amplitude becomes zero is called null freq.

null points exists at multiples of π i.e., $\pi, 2\pi, 3\pi \ldots$

Determination of null freq : (f_0)

At $x = \omega\tau/2 = \pi$

$\Rightarrow 2\pi f_0 \tau/2 = \pi$

$\Rightarrow \boxed{f_0 = 1/\tau}$

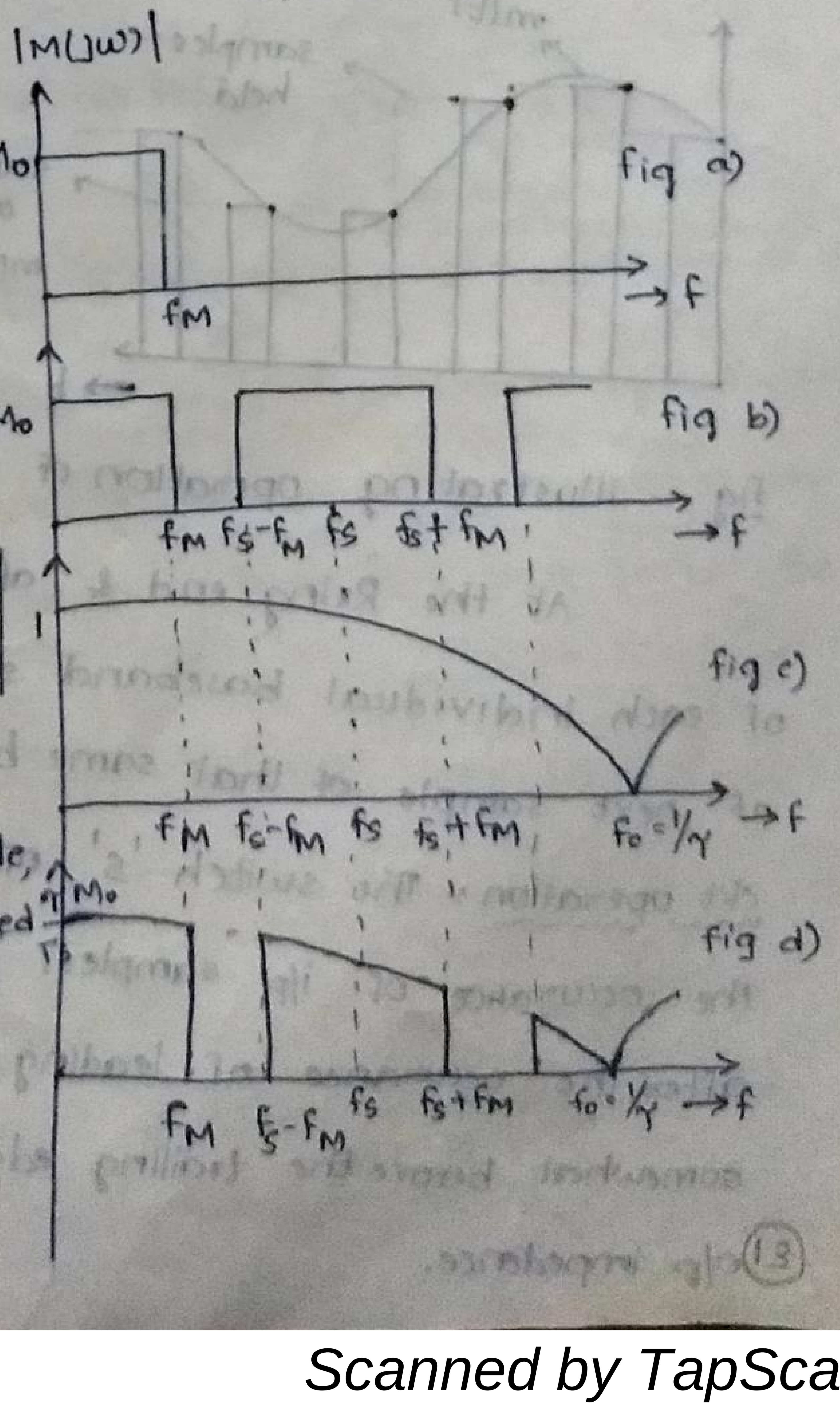


fig a) An idealized spectrum of base band s/g — magnitude,

fig b) Spectrum of s/g with instantaneous sampling — instantaneously sampled m(t)

fig c) The form of distortion factor (aperture effect) introduced by flat-topped samples

fig d) Spectrum of s/g with flat topped sampling. — magnitude, flat-topped sampled m(t)

The presence of aperture factor is the reason for getting distortion. By choosing null freq f_0 as $f_0 >> f_M$, the distortion can be reduced. But since $f_0 = 1/\tau$, if f_0 is large, τ reduces which reduces the strength of Txed s/g. $\left\{ S_0(t) = \frac{\tau}{T_s} m(t) \right\}$

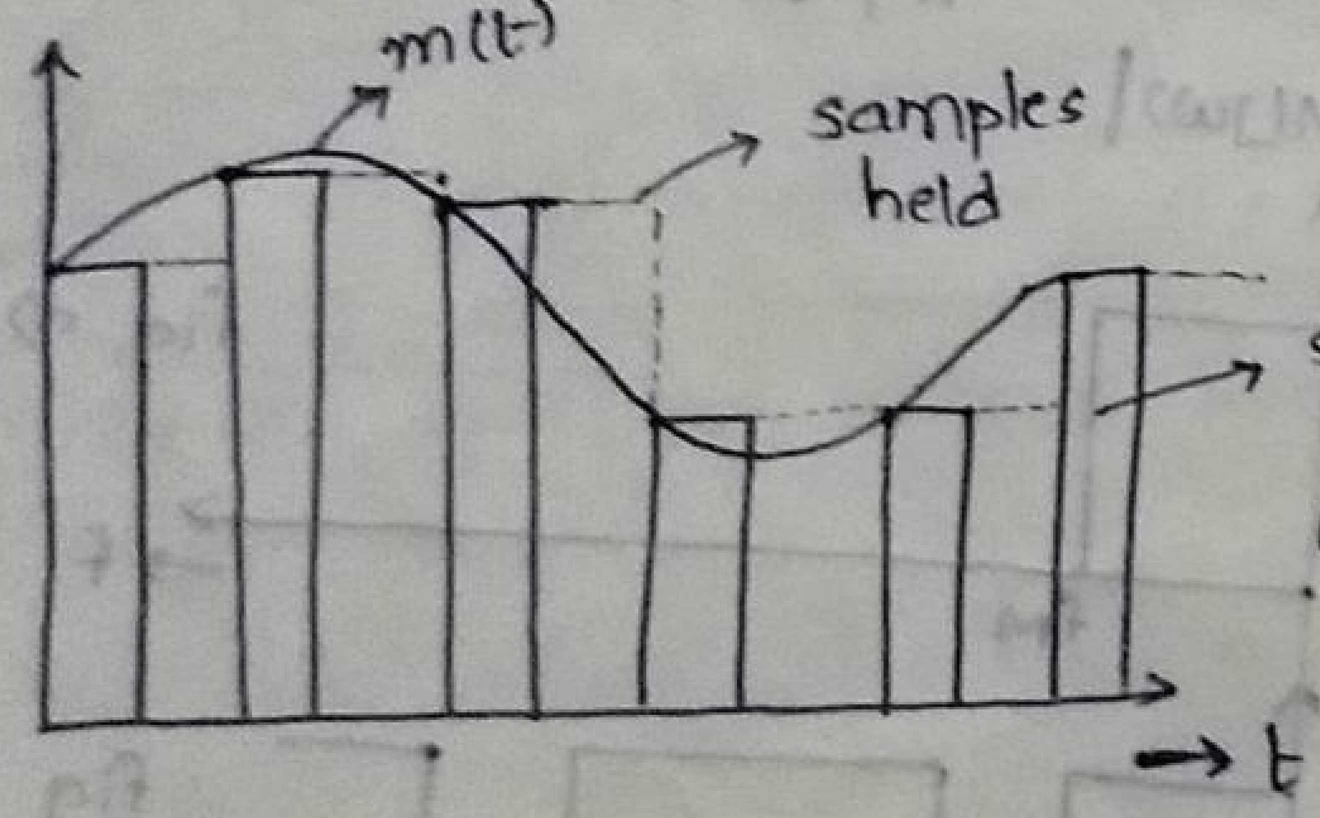
Equalizer :-

Alternately pass the s/g through an equalizer whose transfer fn is freq dependent in the form of $\frac{x}{\sin x}$ and is placed in cascade with o/p LPF.

The equalizer in combination with the aperture effect will then provide a flat overall transfer characteristic b/w original base band s/g & the o/p at the Rxing end of the system.

→ Problems (2) [2, 3]

→ signal Recovery through holding :-



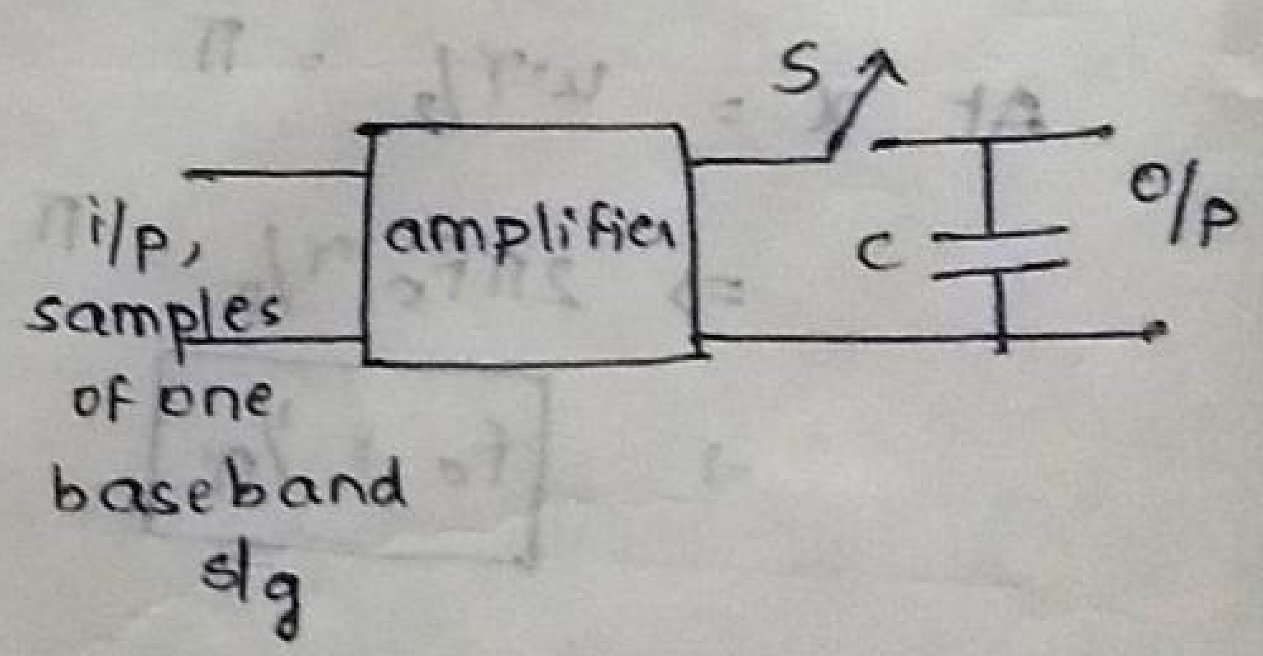


fig :- Illustrating operation of holding

At the Rxing end & after demultiplexing, sample value of each individual baseband s/g is held until the occurance of next sample of that same base band s/g.

ckt operation :- The switch 's' operates in synchronism with the occurance of i/p samples. This switch closes somewhat after the occurance of leading edge of a sample pulse & opens somewhat before the trailing edge. The amplifier has a low o/p impedence.

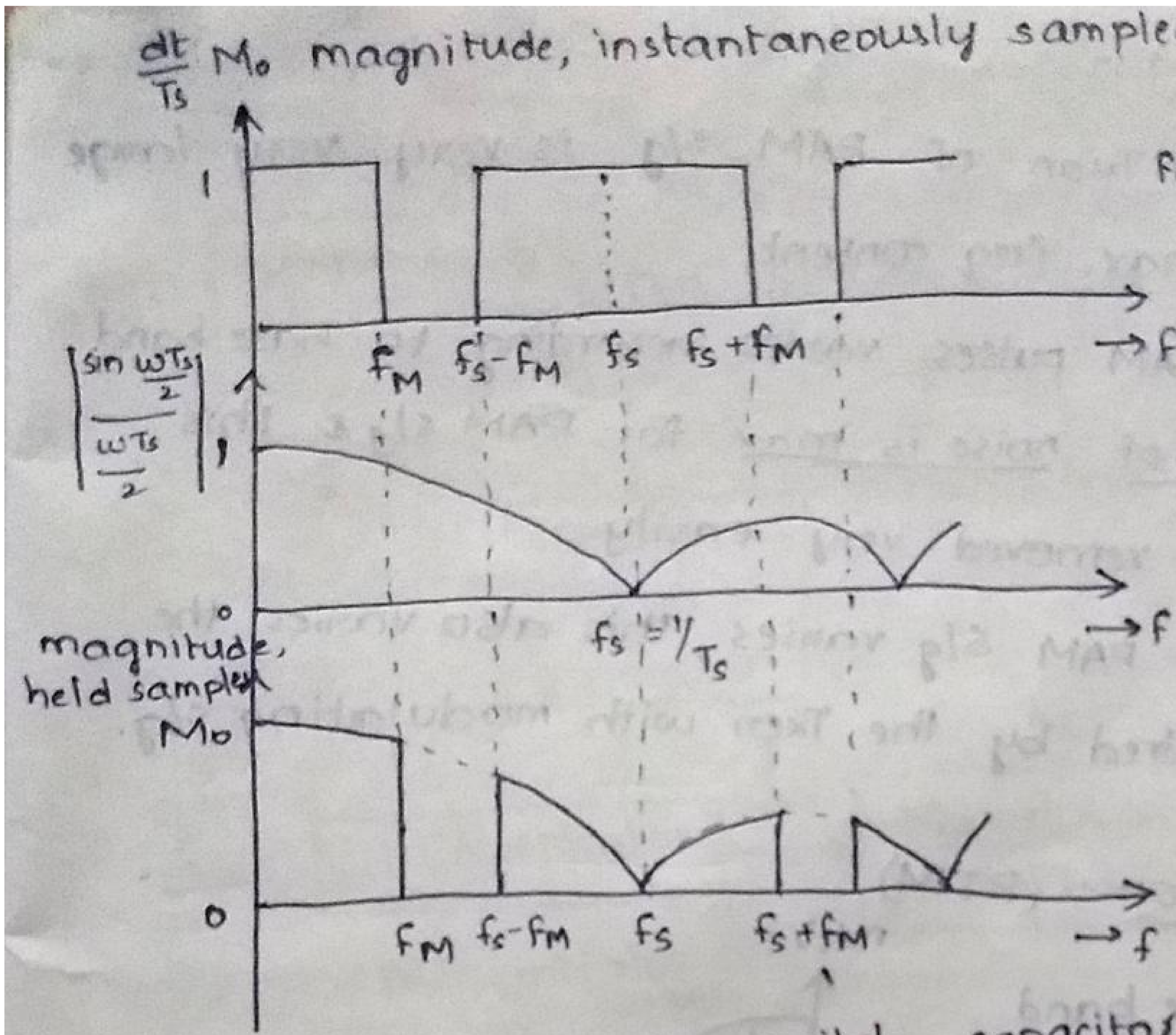


fig a) Spectrum of instantaneously sampled s/g m(t)

fig b) Magnitude of aperture effect factor

fig c) Spectrum of sampled & held s/g.

At the closing of the switch, capacitor 'c' charges abruptly to a voltage proportional to the sample value & the capacitor holds this voltage until the operation is repeated for the next sample.

let the base band s/g m(t) has spectral density

$$F[m(t)] = M(j\omega)$$

$$F[m(t), \text{sampled \& held}] = \frac{\sin \omega T_s/2}{\frac{\omega T_s}{2}} M(j\omega), \quad 0 \le f \le f_M$$

i.e., flat topped samples stretched to T_s

$$= \frac{T_s}{\tau} F[\text{flat topped samples at } \tau = T_s]$$

The sampled & held s/g has a magnitude larger by a factor $\frac{T_s}{\tau}$ than the s/g of sample duration τ. Thus this method is an alternate method of recovery of base band s/g that raises the level of o/p s/g.

Advantages of PAM :-

1) Easy to implement.

2) Greater peak power compared to AM & FM

3) In PAM, pulses are of uniform duration & equally spaced.

∴ Rxer synchronization is not a problem.

→ Disadvantages of PAM :-

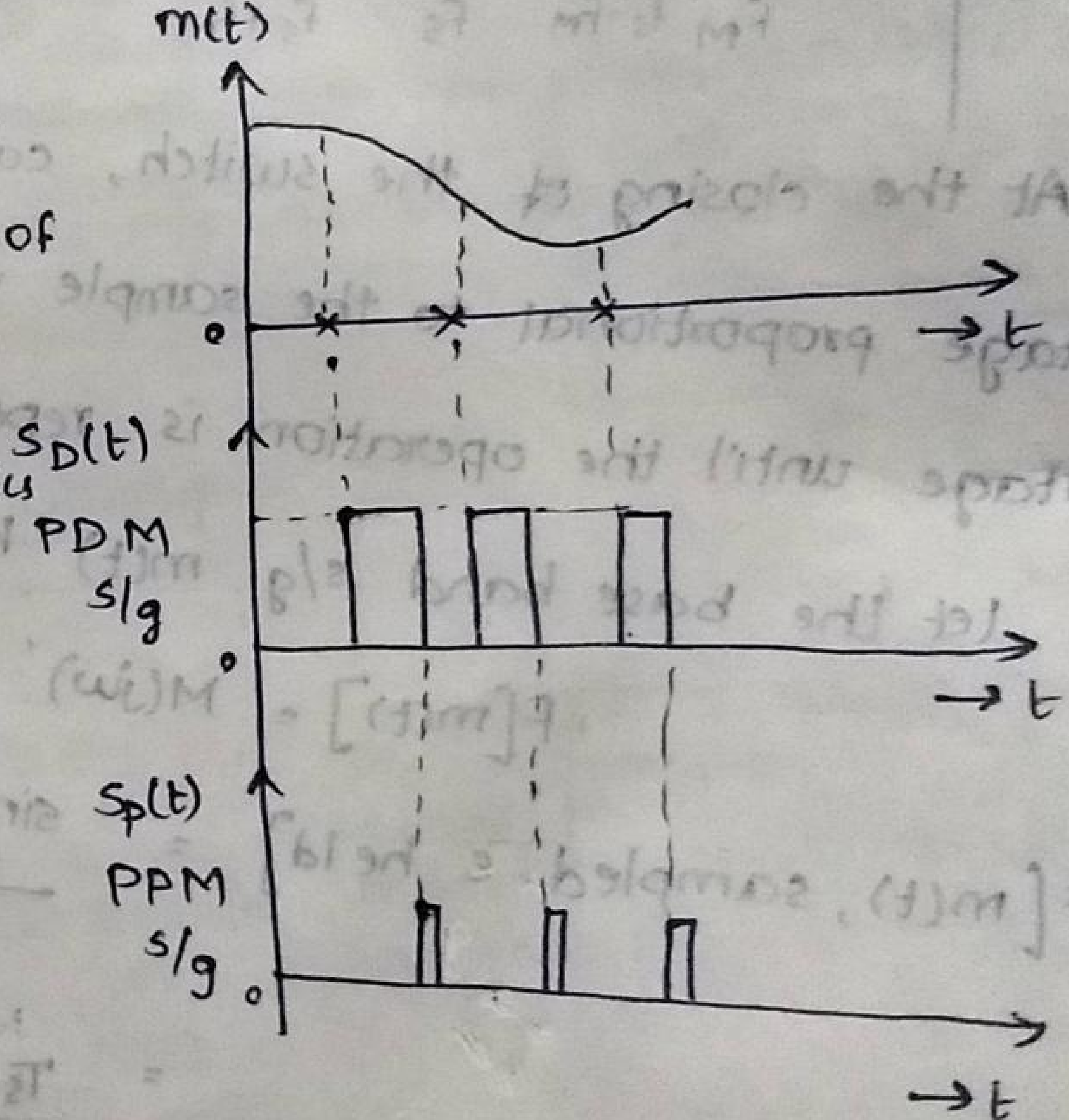
1) The BW needed for Txion of PAM s/g is very very large compared to the max. freq content.

2) The amplitude of PAM pulses varies according to base band s/g. ∴ Interference of noise is max for PAM s/g & this noise cannot be removed very easily.

3) Since the amp. of PAM s/g varies, this also varies the peak power required by the Txer with modulating s/g.

→ Pulse Time Modulation :- (PTM)

In PAM, the base band s/g modulates the amplitude of sampling s/g, but in PTM one of the time characteristics (such as width, position) of the sampling s/g is varied according to the s/g amplitude at that instant.



PTM is of 2 types :-

- 1) PWM / PDM / PLM
- 2) PPM

PWM : Pulse width modulation
PDM : Pulse Duration Modulation
PLM : Pulse Length Modulation

In PDM system, the duration of sampled pulse is proportional to sample value of base band s/g amplitude, whereas PPM system generates pulses of constant amplitude & width whose position is varied according to the base band amplitude at each sampling point.