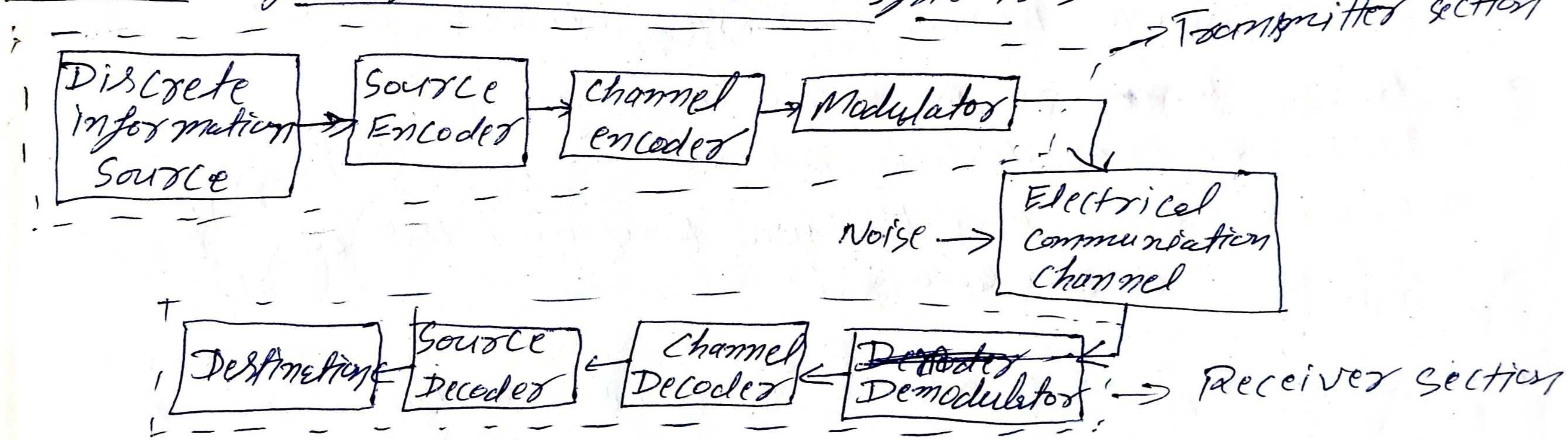
Digital communication system: Digital communication is that type of communication in which the message or information signal to be transmitted in digital in nature.

Elements of Digital communication system:



Information source:

Generates the message signal to be transmitted there are two types of information source.

(a) Analog information source.

(b) Discrete information source.

Source encoder* and Decoder** ⇒

* Converts the symbols produced by the information Source into digital form (i.e. sequence of 1's and 0's)
* Every binary '1' and '0' is called a bit and the group of bits is called a code word.

** Source decoder perform the reverse operation of source encoder.

* Important Parameters for source encoder are
  → Block size (max. distinct code word)
  → Code word length (No. of bits used to represent each code)(2^n bits).
  → data rate (o/p bits per second)

Channel encoder and Decoder ⇒

It is used to prevent the channel from noise.. channel may be wireless or wired. the prevention of channel from noise is done by adding an extra bit in the source encoder for making even parity. For example ⇒

Output of source encoder b_3 b_2 b_1	Bits to be added by the channel encoder for even parity (extra bit) b_0	Output of a channel encoder b_3 b_2 b_1 b_0
0 0 0	0	0 0 0 0
0 1 0	1	0 1 0 1
0 1 1	0	0 1 1 0

Source encoder* and Decoder**:⇒

* Converts the symbols produced by the information source into digital form (i.e. sequence of 1's and 0's)
* Every binary '1' and '0' is called a bit and the group of bits is called a code word.

** Source decoder perform the reverse operation of source encoder.

* Important Parameters for source encoder are
  → Block size (max. distinct code word)
  → Code word length (No. of bits used to represent each code)(2^n bits).
  → data rate (o/p bits per second)

Channel encoder and Decoder:⇒

It is used to prevent the channel from noise.. channel may be wireless or wired. the Prevention of channel from noise is done by adding an extra bit in the source encoder for making even parity. For example⇒

Output of source encoder			Bits to be added by the channel encoder for even parity	Output of a channel encoder			
b_3	b_2	b_1	(extra bit) b_0	b_3	b_2	b_1	b_0
0	0	0	0	0	0	0	0
0	1	0	1	0	1	0	1
0	1	1	0	0	1	1	0

Digital Modulator & Demodulator :⇒

* A high frequency continuous sinosoidal wave is used as a carrier signal in digital modulation.
* the amplitude, phase, or frequency of carrier signal is varied in accordance with the input Binary sequence.

Channel:⇒ channel is used to transmit the data from one point to another point. channel may be wired or wireless. the main parameters of channel are as follows.

(a) Signal Attenuation.
(b) Noise
(c) Multipath distortion
(d) Amplitude and phase distortion.

Advantages of Digital Communication System:⇒

(a) Simpler and cheaper because of the advances made in IC technology.
(b) Speech, video and other data may be merged and transmitted over a common channel using multiplexing.
(c) Using data encryption, only permitted receivers may be allowed To detect the transmitted data.

(d) Due to channel coding, the error may be detected and corrected at the receivers.

Disadvantages of Digital comm. system:-

(a) Because of analog to digital conversion, the data rates becomes high, hence more transmission bandwidth is required for digital communication.

(b) Needs synchronization.

Line coding:- The digital data can be transferred by various lines codes such as ON-OFF, Polar, bipolar etc. This is called line coding.

Properties of line coding:-

(a) Transmission Bandwidth:- Must be as small as possible.

(b) Power efficiency:- Transmitted power for a line code should be as small as possible.

(c) - Error Detection and correction capability :⇒ It must be possible to detect and correct errors.

(d) ⇒ Adequate Timing content :⇒ It must be possible to extract timing or clock information from the signal.

(e) ⇒ Transparency :⇒ the wave form of the line code should be transparent to the digital data being transmitted.

(f) ⇒ The line code should protected the channel from noise and other ~~information~~ interference.

Formate of line code :⇒ (a) Unipolar RZ Format ⇒ (Return to zero)

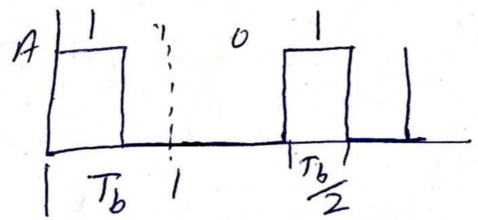
If symbol '1' is transmitted then

$$x(t) = \begin{cases} A & \text{for } 0 \le t \le \frac{T_b}{2} \\ 0 & \text{for } \frac{T_b}{2} \le t \le T \end{cases}$$

where T_b is the time period of waveform

For symbol '0' $x(t) = \{0 \text{ for } 0 \le t \le T_b\}$

Unipolar RZ



b) Unipolar NRZ Format:⇒

For symbol '1' $x(t) = \{ A$ for $0 \le t \le T_b \}$

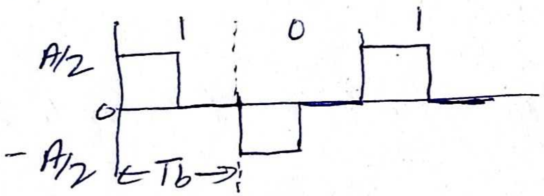
For symbol '0' $x(t) = \{ 0$ for $0 \le t \le T_b \}$

c) ⇒ Polar RZ format ⇒

For symbol '1' $x(t) = \begin{cases} A/2 & \text{for } 0 \le t \le T_b/2 \\ 0 & \text{for } T_b/2 \le t \le T \end{cases}$

For symbol '0' $x(t) = \begin{cases} -A/2 & \text{for } 0 \le t \le T_b/2 \\ 0 & \text{for } T_b/2 \le t \le T \end{cases}$

Polar RZ

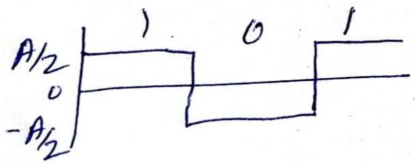


D) ⇒ Polar NRZ Format:-

For symbol '1' $x(t) = \{ A/2$ for $0 \le t \le T_b \}$

For symbol '0' $x(t) = \{ -A/2$ for $0 \le t \le T_b \}$

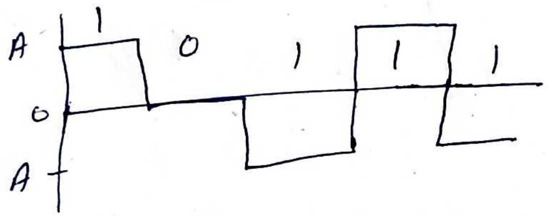
Polar NRZ



(E) Bipolar NRZ Format :- (Alternate Mark Inversion i.e. AMI)

* Successive '1' are represented by pulses with alternate polarity.
* '0' are represented by No Pulse.

Bipolar NRZ

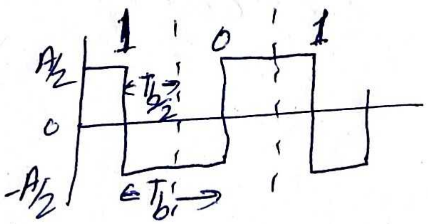


(F) Split Phase Manchester :-

for symbol '1' $x(t) = \begin{cases} A/2 & \text{for } 0 \leq t < T_b/2 \\ -A/2 & \text{for } T_b/2 \leq t < T_b \end{cases}$

for symbol '0' $x(t) = \begin{cases} -A/2 & \text{for } 0 \leq t < T_b/2 \\ A/2 & \text{for } T_b/2 \leq t < T_b \end{cases}$

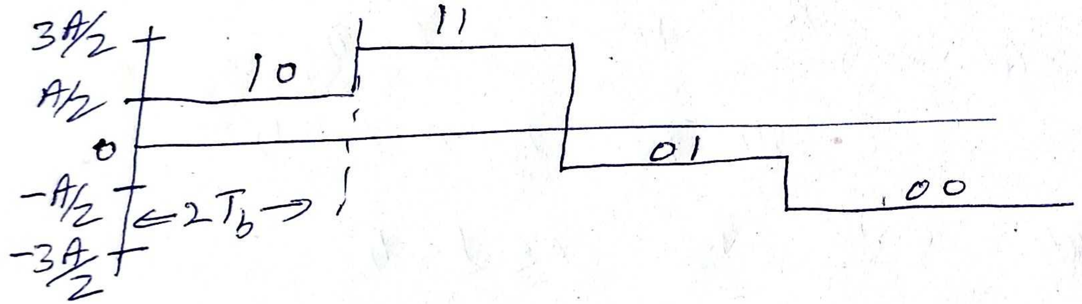
Split phase Manchester



(G) Quaternary NRZ format → It is used to reduced the Bandwidth. Here the combination of two bits are transmitted. It is also known as polar Quaternary format.

Message Combination	Signal Amplitude
0 0	$-3A/2$
0 1	$-A/2$
1 0	$A/2$
1 1	$3A/2$

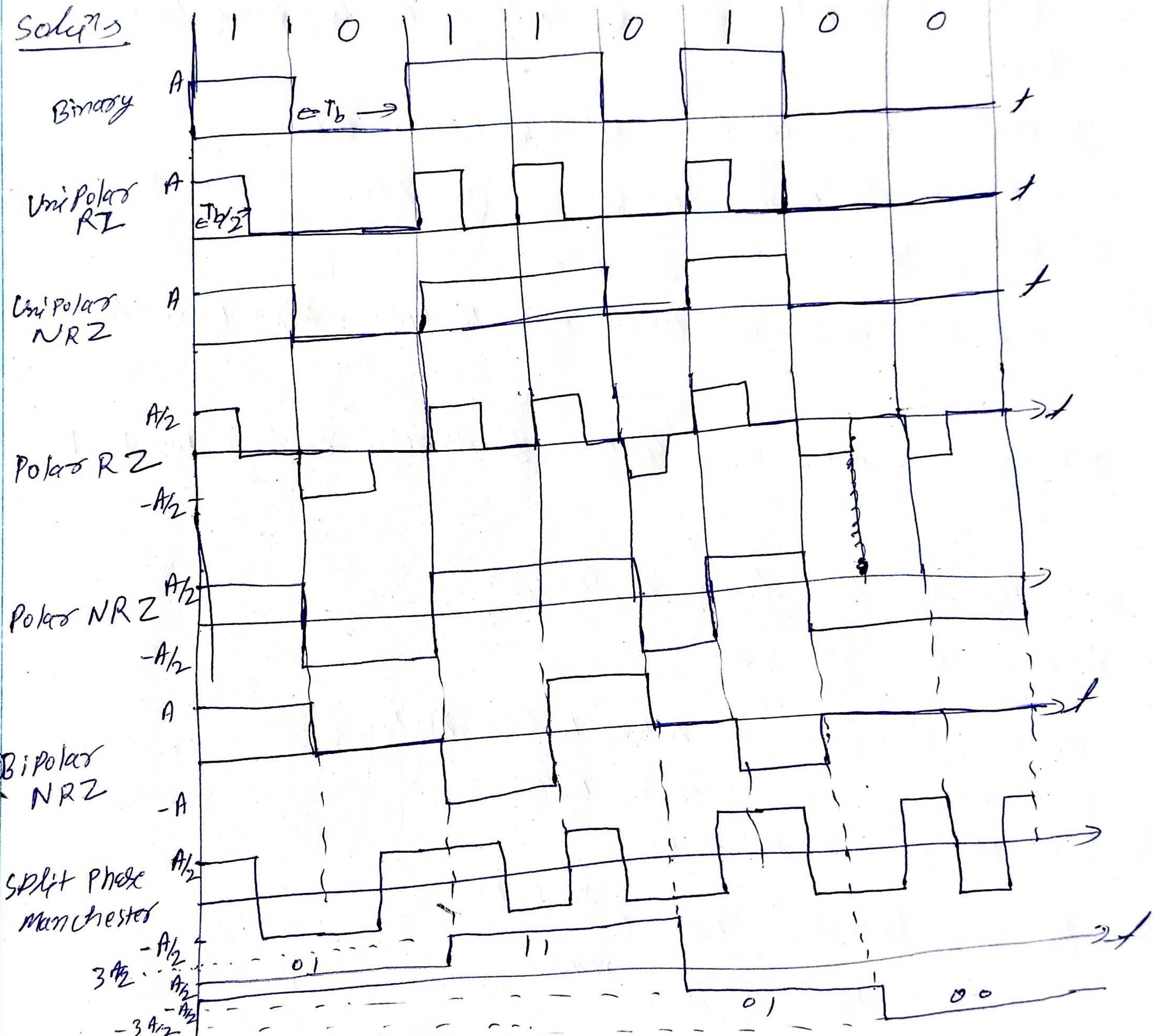
For duration of $2T_b$



Q → Draw the line coding of given sequence.

1 0 1 1 0 1 0 0

Sol^n



1 0 1 1 0 1 0 0
Binary
A
Tb
t
Uni Polar RZ
Tb/2
Uni Polar NRZ
Polar RZ
A/2
-A/2
Polar NRZ
Bipolar NRZ
-A
Split Phase Manchester
3A/2
-3A/2
01
11
01
00

M-Ary coding:-

* In Polar quaternary NRZ type of coding, we combine two successive bits.
* In M-ary coding we combine 'K' successive bits.
* For $K=2$, $2^2=4$ distinct levels are possible. this is called 4-ary coding.
* For $K=3$, $2^3=8$ distinct levels are possible. this is called 8 ary coding.
* Polar quaternary NRZ is also a type of M-ary coding For $K=1$

Imp→

Power spectral density of line codes:→

(a) PSD for NRZ Unipolar format:-

Step-1 ⇒ find fourier transform of NRZ Pulse $X(f)$.

Step-2 → Find auto correlation of unipolar $R_a(n)$

Step-3 ⇒ Calculate PSD of $x(t)$ given by.

Winer Knintchine ⇒ $$S(f) = \frac{1}{T}|X(f)|^2 \sum_{n=-\infty}^{\infty} R_a(n)\, e^{-j2\pi f n T}$$

where $H(f) = \int_{-\infty}^{\infty} x(t)\, e^{-j2\pi f t}\, dt$

For example: Calculate NRZ Pulse fourier transform:-

Step-I ⇒ Find fourier transform by

$$X(f) = \int_{-\infty}^{\infty} x(t)\, e^{-j2\pi f t}\, dt$$

$$= \int_{-T_b/2}^{T_b/2} (1)\, e^{-j2\pi f t}\, dt = \left[\frac{e^{-j2\pi f t}}{-j2\pi f}\right]_{-T_b/2}^{T_b/2}$$

$$= -\frac{1}{j2\pi f}\left[e^{-j2\pi f T_b/2} - e^{j2\pi f T_b/2}\right]$$

$$= \frac{1}{j2\pi f}\left[e^{j2\pi f T_b/2} - e^{-j2\pi f T_b/2}\right]$$

$$= \frac{1}{\pi f}\left[\frac{e^{j\pi f T_b} - e^{-j\pi f T_b}}{2j}\right]$$

we know that $\boxed{\sin\theta = \frac{e^{j\theta} - e^{-j\theta}}{2j}}$

$$X(f) = \frac{1}{\pi f}\sin(\pi f T_b)$$

we know that the sinc funⁿ $\boxed{\text{sinc}(x) = \frac{\sin(\pi x)}{\pi x}}$

$$X(f) = T_b \frac{\sin(\pi f T_b)}{\pi f T_b}$$

$$\boxed{X(f) = T_b\, \text{sinc}(f T_b)}$$

Now Step-II → Calculation of Auto correlation funⁿ.

for Unipolar NRZ format

$$A_K = \begin{cases} A & \text{Symbol } 1 \\ 0 & \text{Symbol } 0 \end{cases}$$

Probability of occurrence. $P(A_K = 0) = P(A_K = A) = \frac{1}{2}$

Auto correlation of A_K with A_K is given as.

$$R_A(n) = E[A_K \cdot A_{K-n}]$$

for $n = 0$; $R_A(0) = E[A_K A_K] = E[A_K^2]$

we know the mean value of discrete random variable is

$$m_x = E(X) = \overline{X} = \sum_{i=1}^{n} x_i P(x_i)$$

and $E(X^2) = \sum_{i=1}^{n} x_i^2 P(x_i)$ — ①

formation of tables

A_K	A_K	Amplitude A_K	A_K	A_K^2	$P(x_i)$
0	0	0	0	0	1/2
1	1	A	A	A^2	1/2

from equⁿ ① $E(X^2) = 0 \times \frac{1}{2} + A^2 \times \frac{1}{2} = \frac{A^2}{2}$

$$E(A_K^2) = \frac{A^2}{2}$$

Now for $n \neq 0$ $R_x(n) = E[A_K \cdot A_{K-n}]$

formation of table.

A_K	A_{K-n}	Amplitude A_K	Amplitude A_{K-n}	$A_K \cdot A_{K-n}$	$P(A_K \cdot A_{K-n})$
0	0	0	0	0	1/4
0	1	0	A	0	1/4
1	0	A	0	0	1/4
1	1	A	A	A^2	1/4

Now $E[A_K \cdot A_{K-n}] = \sum_{i=0}^{n} x_i^2 P x_i$

$$= 0^2 \cdot \frac{1}{4} + 0^2 \cdot \frac{1}{4} + 0^2 \cdot \frac{1}{4} + A^2 \cdot \frac{1}{4}$$

$$E[A_K \cdot A_{K-n}] = \frac{A^2}{4}$$

$$R_x(n) = \begin{cases} A^2/2 & \text{for } n = 0 \\ A^2/4 & \text{for } n \neq 0 \end{cases}$$

Now Step-III ⇒ PSD of unipolar NRZ

$$S(f) = \frac{1}{T_b} |X(f)|^2 \sum_{n=-\infty}^{\infty} R_x(n) e^{-j2\pi f n T_b}$$

Now Put the value of $X(f)$ and $R_n(n)$

~~S(f) = 1/T_b~~

$$S(f) = \frac{1}{T_b}\left[T_b^2 \operatorname{sinc}^2(fT_b)\right]\left[\sum_{n=0} \frac{A^2}{2} e^{-j2\pi f n T_b} + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} \frac{A^2}{4} e^{-j2\pi f n T_b}\right]$$

$$S(f) = \frac{A^2 T_b}{2} \operatorname{sinc}^2(fT_b) + \frac{T_b A^2}{4} \operatorname{sinc}^2(fT_b)\left[\sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} e^{-j2\pi f n T_b}\right]$$

$$S(f) = \frac{A^2 T_b}{2} \operatorname{sinc}^2(fT_b) + \frac{T_b A^2}{4} \operatorname{sinc}^2(fT_b)\left[\sum_{n=-\infty}^{\infty} e^{-j2\pi f n T_b} - 1\right]$$

$$= \frac{A^2 T_b}{2} \operatorname{sinc}^2(fT_b) - \frac{T_b A^2}{4} \operatorname{sinc}^2(fT_b) + \frac{T_b A^2}{4} \operatorname{sinc}^2(fT_b) \sum_{n=-\infty}^{\infty} e^{-j2\pi f n T_b}$$

$$= A^2 T_b \operatorname{sinc}^2(fT_b)\left[\frac{1}{2} - \frac{1}{4}\right] + \frac{T_b A^2}{4} \operatorname{sinc}^2(fT_b) \sum_{n=-\infty}^{\infty} e^{-j2\pi f n T_b}$$

$$S(f) = \frac{A^2 T_b}{4} \operatorname{sinc}^2(fT_b) + \frac{A^2 T_b}{4} \operatorname{sinc}^2(fT_b) \sum_{n=-\infty}^{\infty} e^{-j2\pi f n T_b}$$

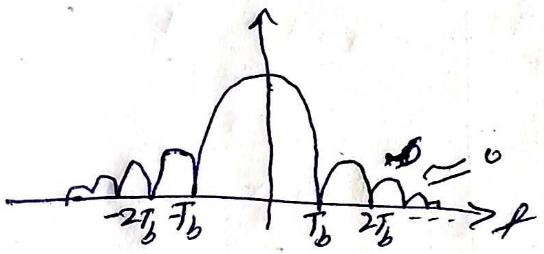
Now As Per Poisson's formula :-

$$\sum_{n=-\infty}^{\infty} e^{-j2\pi f n T_b} = \frac{1}{T_b} \sum_{m=-\infty}^{\infty} \delta\left(f - \frac{m}{T_b}\right)$$

$$S(f) = \frac{A^2 T_b}{4} \operatorname{sinc}^2(fT_b) + \frac{A^2}{4} \operatorname{sinc}^2(fT_b) \sum_{m=-\infty}^{\infty} \delta\left(f - \frac{m}{T_b}\right)$$

$$S(f) = \frac{A^2 T_b}{4} \sin^2(f T_b) + \frac{A^2}{4}\delta(f)$$

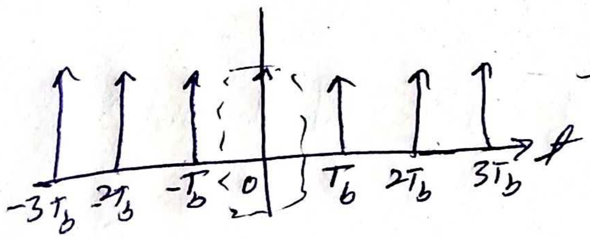
↑ D.C. term which causes distortion in signal.



sinc fun

$\sin^2(fT_b) = 1$ at $f = 0$ otherwise zero(0).

after multiplecation of this fun we get only output at zero.



impulse fun