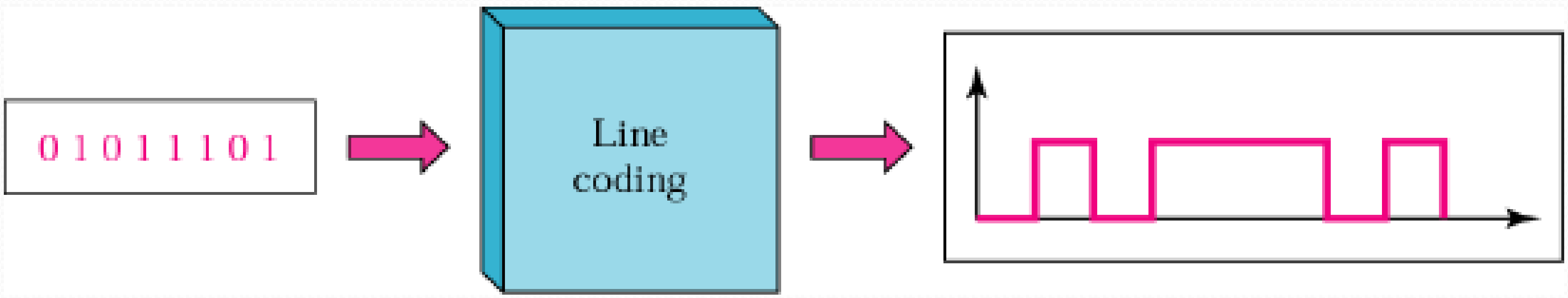
LINE CODING

Introduction

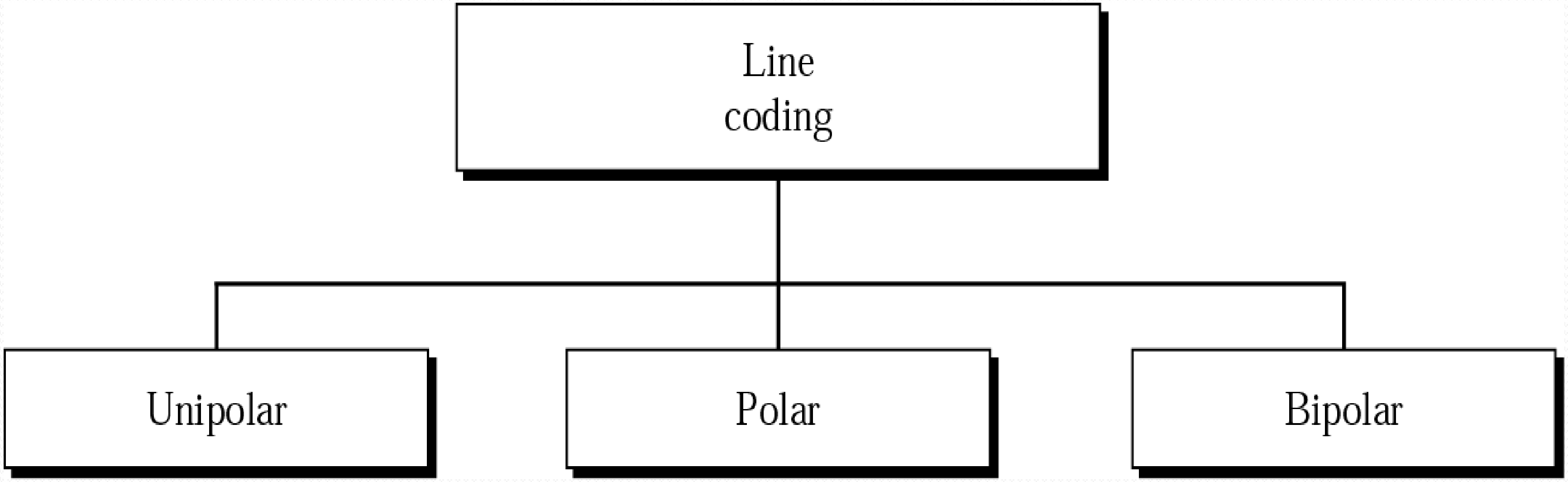
- Information is inherently discrete
- Has to be transmitted in terms of waveforms
- Process of converting the output of source encoder into electrical pulses for transmitting over physical channel.



Necessary Characteristics of Line Code

- *Transmission bandwidth*
  - as small as possible
- *Power efficiency*
  - Tx power should be very low for a given B.W, BER
- *Error detection and correction capability*
- *Favorable power spectral density*
  - PSD=0 at f=0 (dc) because DC component does not contain any information; wastage of power
  - In Tx’n lines, ac couplers and transformers are used at different locations which don’t allow DC component to pass through (signal droop).
- *Self-synchronization*
  - Extraction of timing/ clock information should be possible from Rx-d signal
- *Transparency*
  - Faithful reception of data at Rx, independent of the pattern of 0’s and 1’s
  - Key: Long string of 0’s or 1’s often causes error in timing information

Types of Line Coding:



Unipolar Signaling:

•On-Off keying ie OOK

•Pulse 0: Absence of pulse

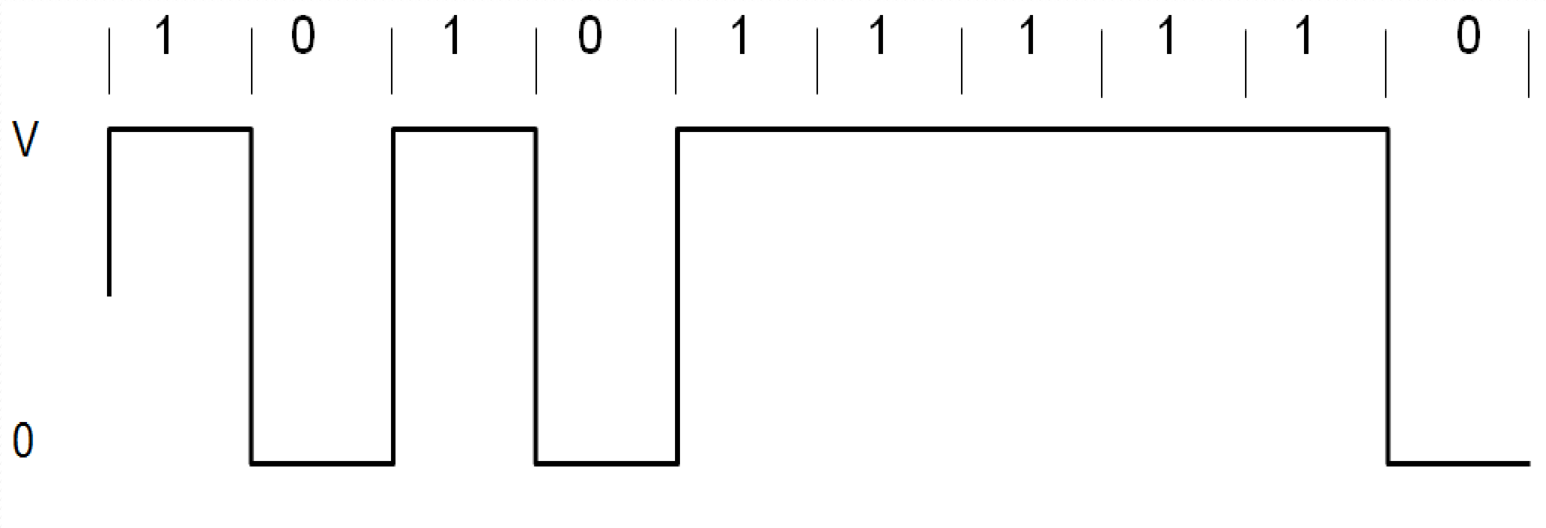
•Pulse1 : Presence of pulse

There are two common variations of unipolar signalling:

1. Non-Return to Zero (NRZ)
2. Return to Zero (RZ)

Unipolar Non-Return to Zero (NRZ):

•Duration of the MARK pulse (τ) is equal to the duration (T_o) of the symbol slot.



Advantages:

•Simplicity in implementation

• Doesn’t require a lot of bandwidth for transmission.

Disadvantages:

•Presence of DC level (indicated by spectral line at 0 Hz).

•Contains low frequency components. Causes “Signal Droop”

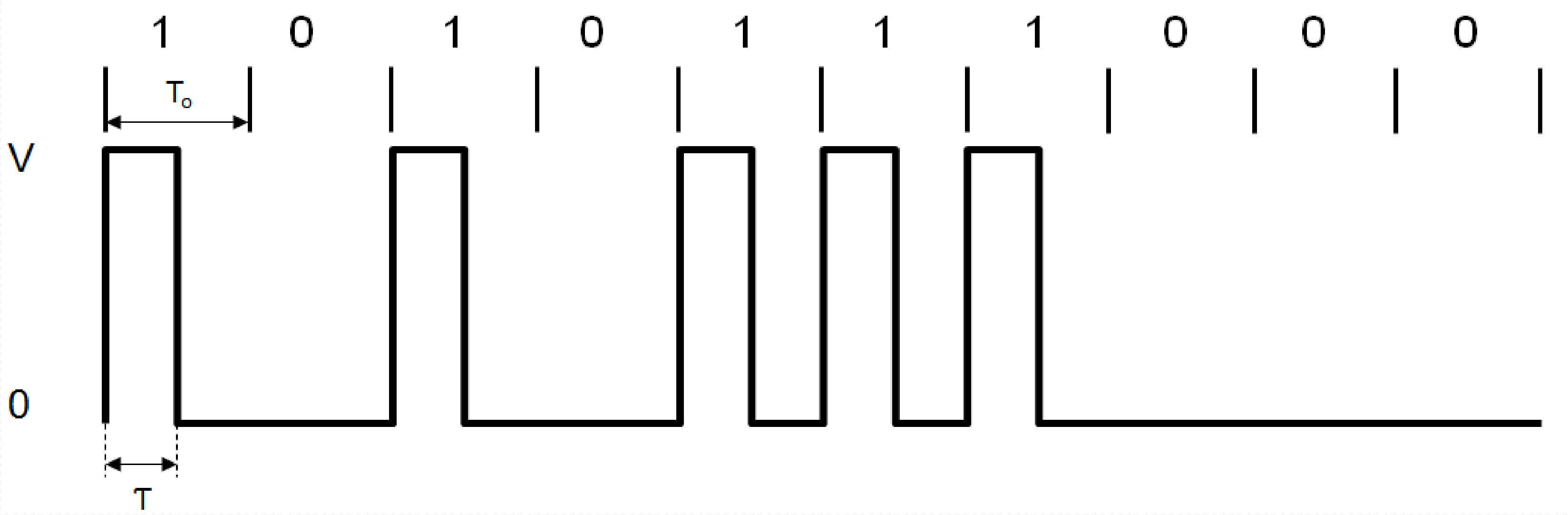
•Does not have any error correction capability.

•Does not posses any clocking component for ease of synchronisation.

•Is not Transparent. Long string of zeros causes loss of synchronisation.

Unipolar Return to Zero (RZ):

•MARK pulse (τ) is **less** than the duration (T_o) of the symbol slot.
•Fills only the first half of the time slot, returning to zero for the second half.



Advantages:

•Simplicity in implementation.

•Presence of a spectral line at symbol rate which can be used as symbol timing clock signal.

Disadvantages:

•Presence of DC level (indicated by spectral line at 0 Hz).

•Continuous part is non-zero at 0 Hz. Causes "Signal Droop".

•Does not have any error correction capability.

•Occupies twice as much bandwidth as Unipolar NRZ.

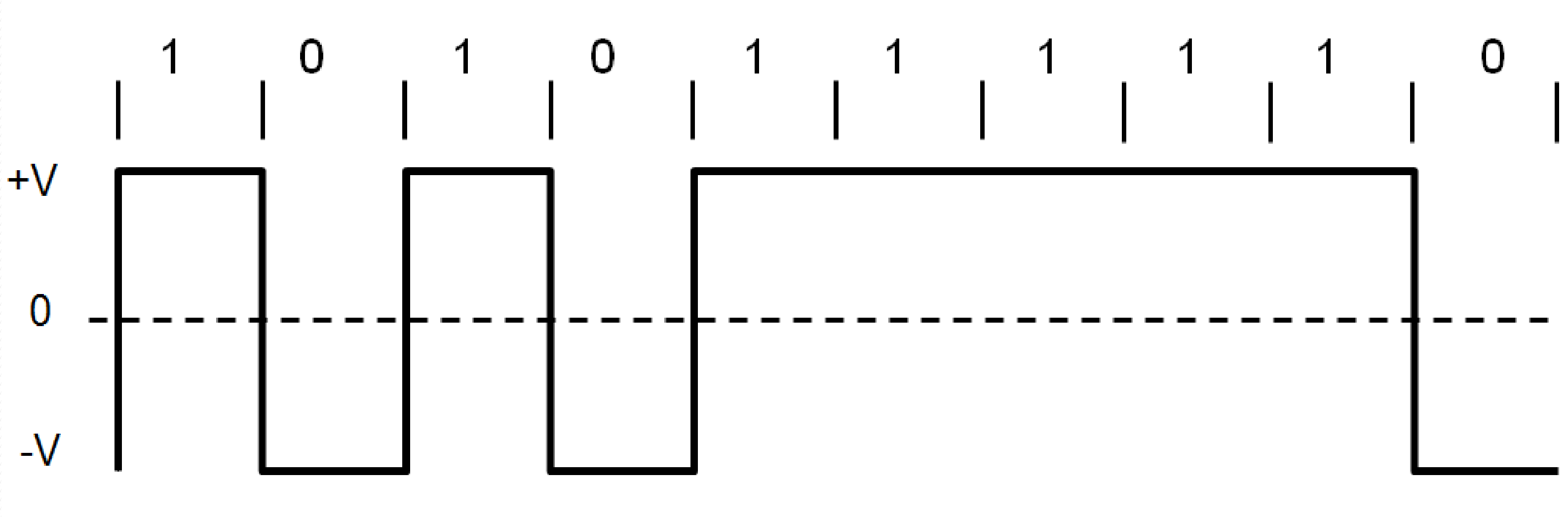
•Is not Transparent

Polar Signalling:

- Polar RZ
- Polar NRZ

Polar NRZ:

- A binary 1 is represented by a pulse $g_1(t)$
- A binary 0 by the opposite (or antipodal) pulse $g_0(t) = -g_1(t)$.



Advantages:

•Simplicity in implementation.

•No DC component.

Disadvantages:

•Continuous part is non-zero at 0 Hz. Causes “Signal Droop”.

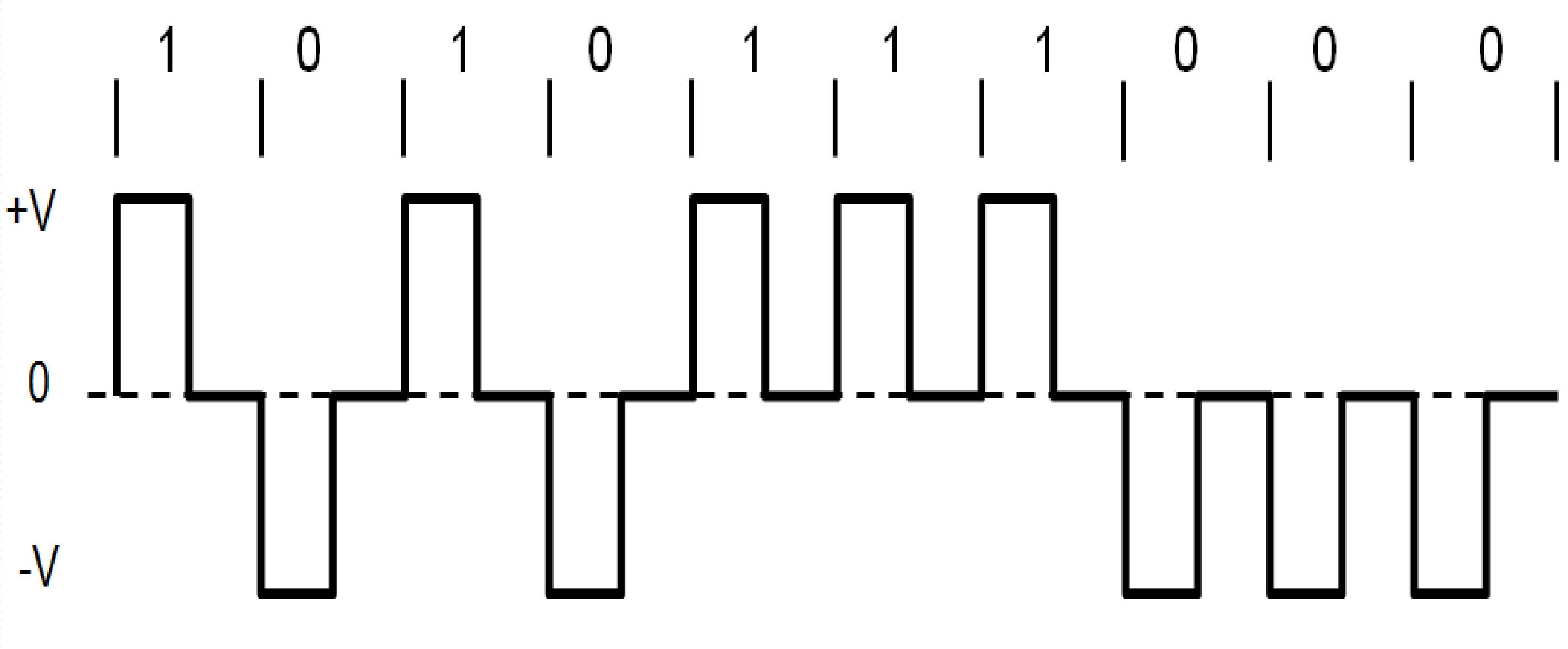
•Does not have any error correction capability.

•Does not posses any clocking component for ease of synchronisation.

•Is not transparent.

Polar RZ:

- A binary 1: A pulse $g_1(t)$
- A binary 0: The opposite (or antipodal) pulse $g_0(t) = -g_1(t)$.
- Fills only the first half of the time slot, returning to zero for the second half.



Advantages:

- Simplicity in implementation.
- No DC component.

Disadvantages:

- Continuous part is non-zero at 0 Hz. Causes “Signal Droop”.
- Does not have any error correction capability.
- Occupies twice as much bandwidth as Polar NRZ.

Bipolar Signalling:

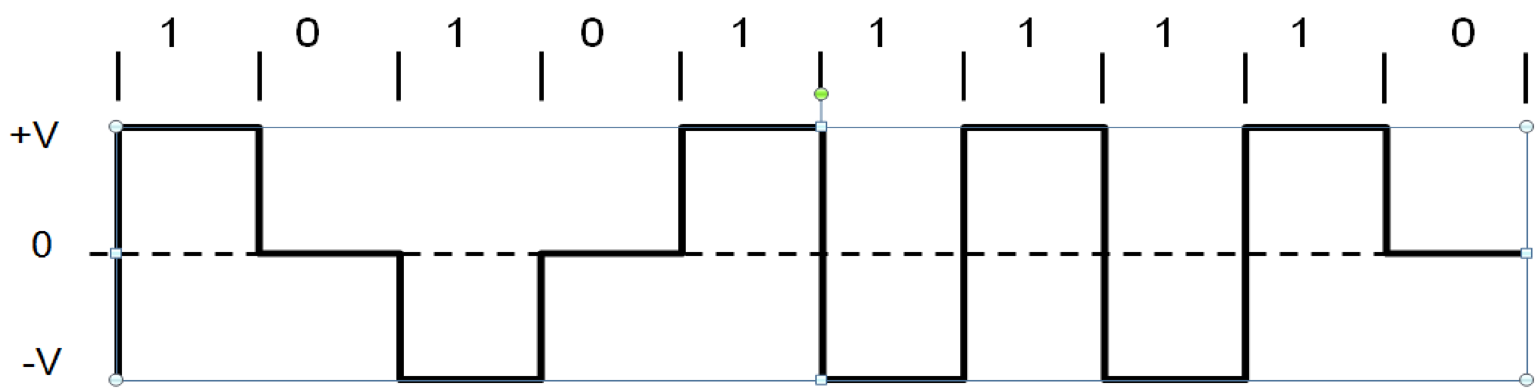
•Alternate mark inversion (AMI)

•Uses three voltage levels (+V, 0, -V)

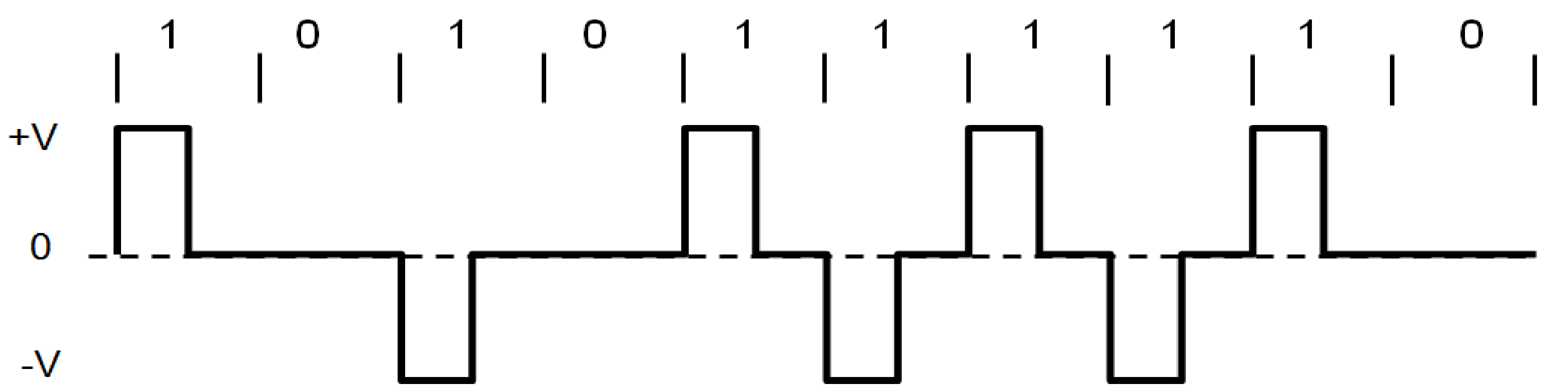
•0: Absence of a pulse

•1: Alternating voltage levels of +V and –V

Bipolar NRZ:



Bipolar RZ:



Advantages:

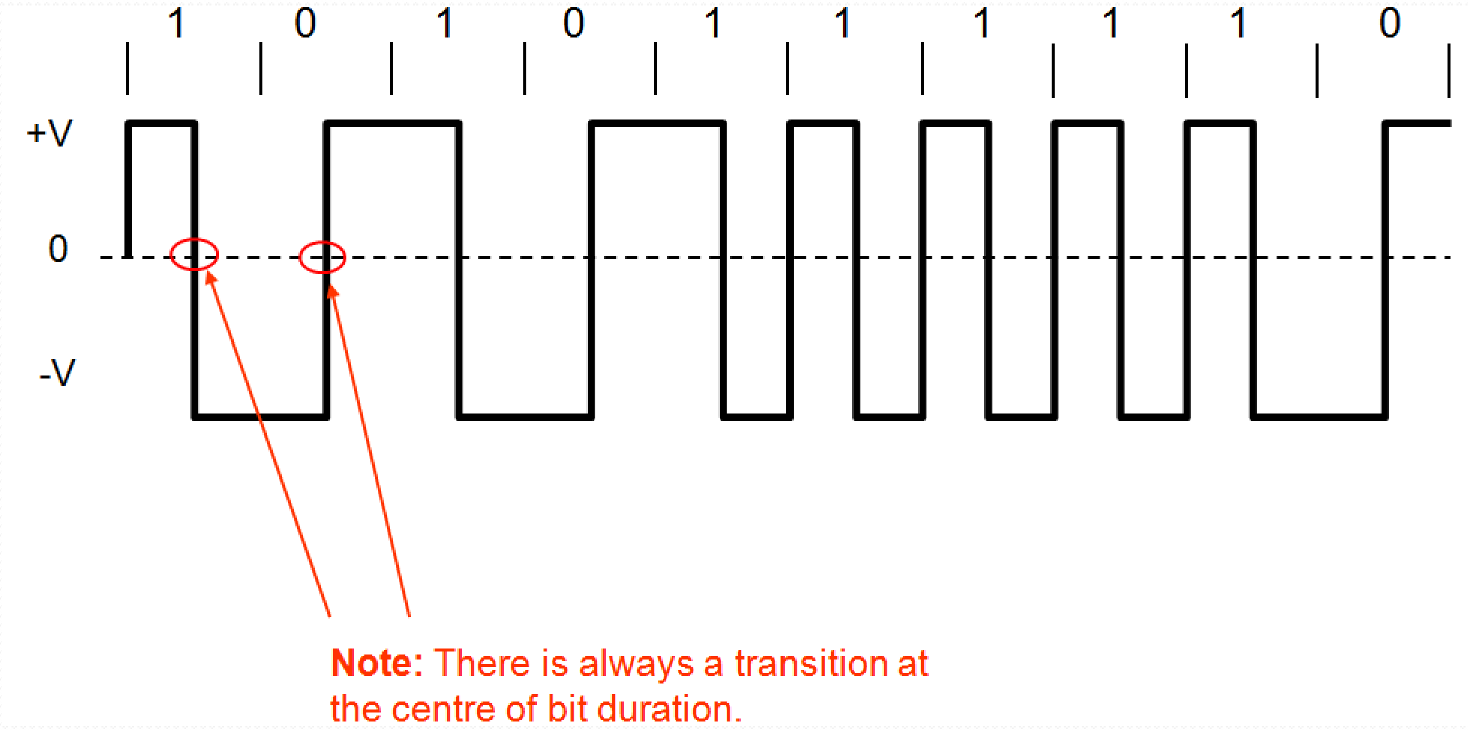
- No DC component.
- Occupies less bandwidth than unipolar and polar NRZ schemes.
- Does not suffer from signal droop (suitable for transmission over AC coupled lines).
- Possesses single error detection capability.

Disadvantages:

- Does not posses any clocking component for ease of synchronisation.
- Is not Transparent.

Manchester Signalling:

- The duration of the bit is divided into two halves
- A ‘One’ is +ve in 1^{st} half and -ve in 2^{nd} half.
- A ‘Zero’ is -ve in 1^{st} half and +ve in 2^{nd} half.



Advantages:

•No DC component.

•Does not suffer from signal droop (suitable for transmission over AC coupled lines).

•Easy to synchronise.

•Is Transparent.

Disadvantages:

•Because of the greater number of transitions it occupies a significantly large bandwidth.

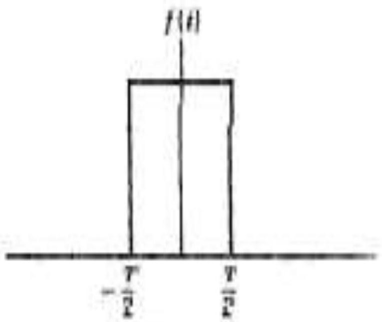
•Does not have error detection capability.

Power Spectral Density:

•The function which gives distribution of power of a signal at various frequencies in frequency domain.

•PSD is the Fourier Transform of autocorrelation

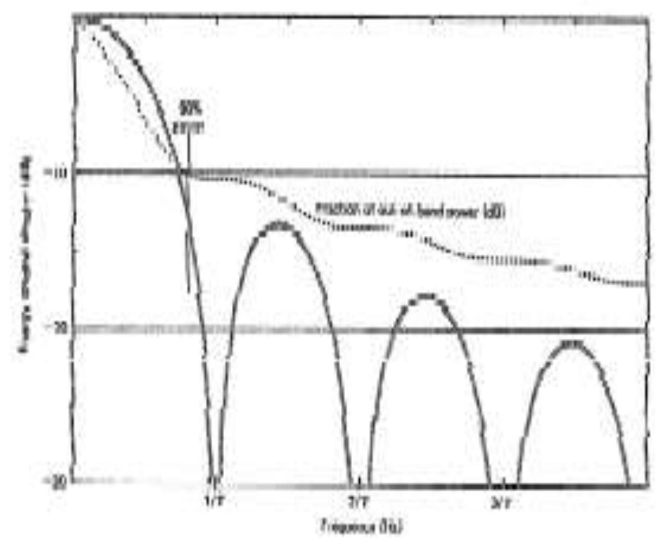
•Rectangular pulse and its spectrum



$$f(t) = \begin{cases} 1 & |t| \leq \frac{T}{2} \\ 0 & \text{otherwise} \end{cases}$$

$$F(w) = (T)\frac{\sin(wT/2)}{wT/2}$$

where w = radian frequency $2\pi f$,
T = duation of a signal interval.



PSD Derivation:

- We now need to derive the time autocorrelation of a power signal x(t)

$$R_x(\tau) = \lim_{T_p \to \infty} \frac{1}{T_p} \int_{-T_p/2}^{T_p/2} x(t)x(t+\tau)dt$$

- Since x(t) consists of impulses, $R_x(\tau)$ is found by

$$R_x(\tau) = \frac{1}{T} \sum_{n=-\infty}^{\infty} R_n \delta(\tau - nT)$$

where $$R_n = \lim_{N \to \infty} \frac{1}{N} \sum_k a_k a_{k+n}$$

- Recognizing $R_n = R_{-n}$ for real signals, we have

$$S_x(w) = \frac{1}{T} \left(R_0 + 2 \sum_{n=1}^{\infty} R_n \cos nwT \right)$$

•Since the pulse filter has the spectrum of $F(w) \leftrightarrow f(t)$, we have

$$\begin{aligned} S_y(w) &= |F(w)|^2 S_x(w) \\ &= |F(w)|^2 \left(\sum_{n=-\infty}^{\infty} R_n e^{-jnwT_b} \right) \\ &= \frac{|F(w)|^2}{T} \left(R_0 + 2 \sum_{n=1}^{\infty} R_n \cos nwT \right) \end{aligned}$$

• Now, we can use this to find the PSD of various line codes.

PSD of Polar Signalling:

- In polar signalling,

Binary "1" is transmitted by a pulse f(t)

Binary "0" is transmitted by a pulse –f(t)

- In this case, a_k is equally likely to be 1 or -1 and a_k^2 is always 1.

$$R_0 = \lim_{N\to\infty} \frac{1}{N} \sum_k a_k^2 = \lim_{N\to\infty} \frac{1}{N}(N) = 1$$

Where, There are N pulses and $a_k^2=1$ for each one.

The summation on the right-hand side of the above equation is N.

- Moreover, both a_k and a_{k+1} are either 1 or -1. So, $a_k a_{k+1}$ is either 1 or -1.

They are equally likely to be 1 or -1 on the average, out of N terms the product $a_k a_{k+1}$ is equal to 1 for N/2 terms and is equal to -1 for the remaining N/2 terms.

$$R_1 = \lim_{N\to\infty} \frac{1}{N}\left[\frac{N}{2}(1) + \frac{N}{2}(-1)\right] = 0$$

$$R_n = 0 \qquad n \geq 1$$

$$S_y(w) = \frac{|F(w)|^2}{T} R_0 = \frac{|F(w)|^2}{T}$$

$$S_y(w) = \frac{T}{2}\text{sinc}^2\left(\frac{wT}{2}\right)$$

PSD of Bipolar Signalling:

•To calculate the PSD, we have

$$R_n = \lim_{N\to\infty} \frac{1}{N} \sum_k a_k a_{k+n} \qquad R_0 = \lim_{N\to\infty} \frac{1}{N} \sum_k a_k^2$$

•On the average, half of the a_k's are 0, and the remaining half are either 1 or -1, with $a_k^2=1$. Therefore,

$$R_0 = \lim_{N\to\infty} \frac{1}{N} \left[\frac{N}{2}(\pm 1)^2 + \frac{N}{2}(0)^2\right] = \frac{1}{2}$$

- To compute R1, we consider the pulse strength product $a_k a_{k+1}$.

  -Four possible equally likely sequences of two bits:11,10,01,00.

  -Since bit 0 encoded by no puls $(a_k=0)$, the product $a_k a_{k+1}=0$ for the last three of these sequences. This means that, on the average, 3N/4 combinations have $a_k a_{k+1}=0$ and only N/4 combinations have non zero $a_k a_{k+1}$. Because of the bipolar rule, the bit sequence 11 can only be encoded by two consecutive pulse of opposite polarities. This means the product $a_k a_{k+1}= -1$ for the N/4 combinations.

$$R_1 = \lim_{N\to\infty} \frac{1}{N}\left[\frac{N}{4}(-1)+\frac{N}{4}(0)\right] = -\frac{1}{4}$$

PSD of Lines Codes: