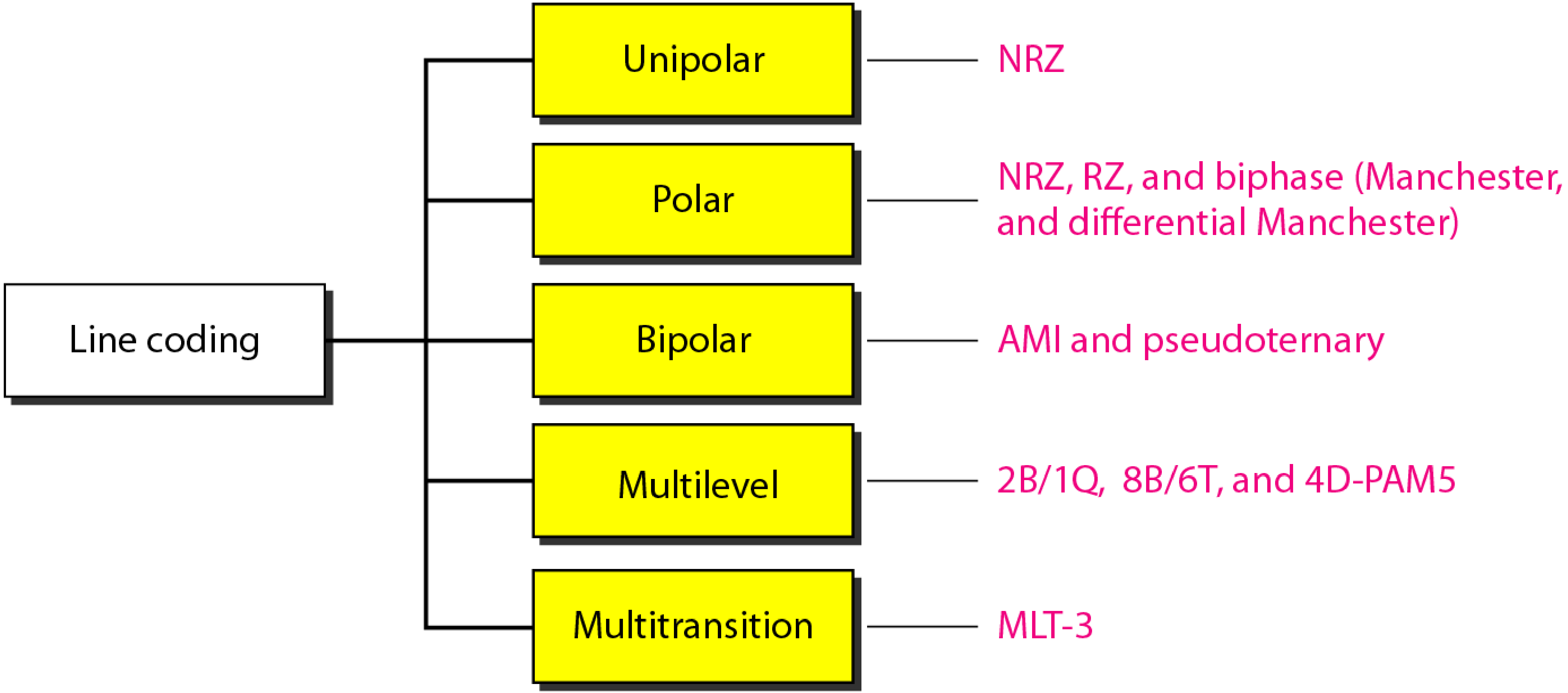
Line Coding Schemes



Line Coding Schemes

Digital Data a_k → **Line Coder** → Physical Waveform $x(t) = \sum_{k=-\infty}^{\infty} a_k \, p(t - kT_b)$

- The input to the line encoder is a sequence of values a_k that is a function of a data bit or an A D C output bit.
- The output of the line encoder is a waveform:

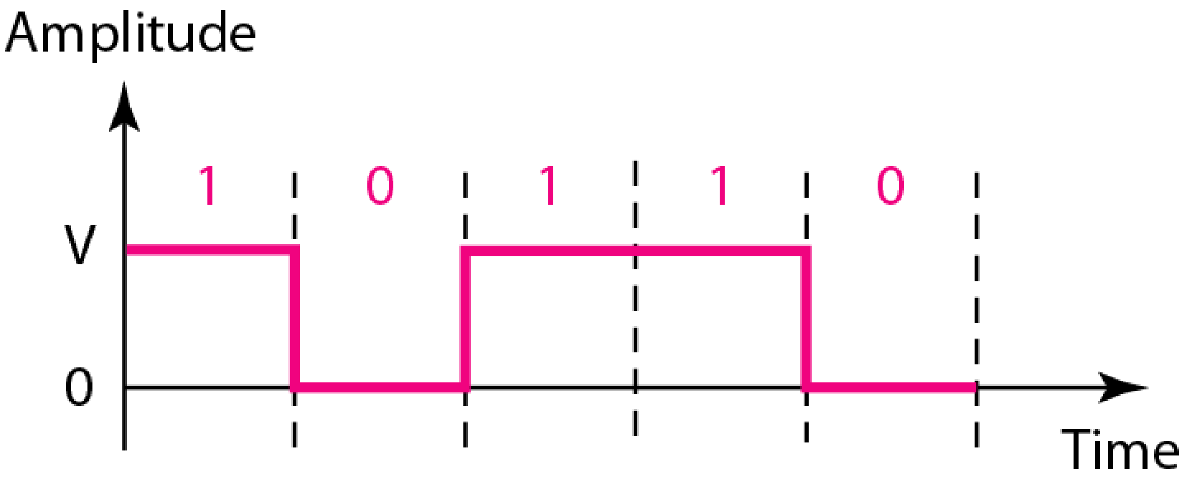
$$\boxed{x(t) = \sum_{k=-\infty}^{\infty} a_k \, p(t - kT_b)}$$

  - *Where p(t) is the Pulse Shape and Tb is the Bit Period*
  - *Tb =Ts/n for n bit quantizer (and no parity bits).*
  - *Rb =1/Tb=nfs for n bit quantizer (and no parity bits).*
- The operational details of this function are set by the particular type of ***line code*** that is being used.

Line Coding Schemes

Unipolar

- Unipolar encoding uses only one voltage level.
- All signal levels are on one side of the time axis - either above or below
- NRZ - Non Return to Zero scheme is an example of this code. The signal level does not return to zero during a symbol transmission.



$$\boxed{\frac{1}{2}V^2 + \frac{1}{2}(0)^2 = \frac{1}{2}V^2}$$

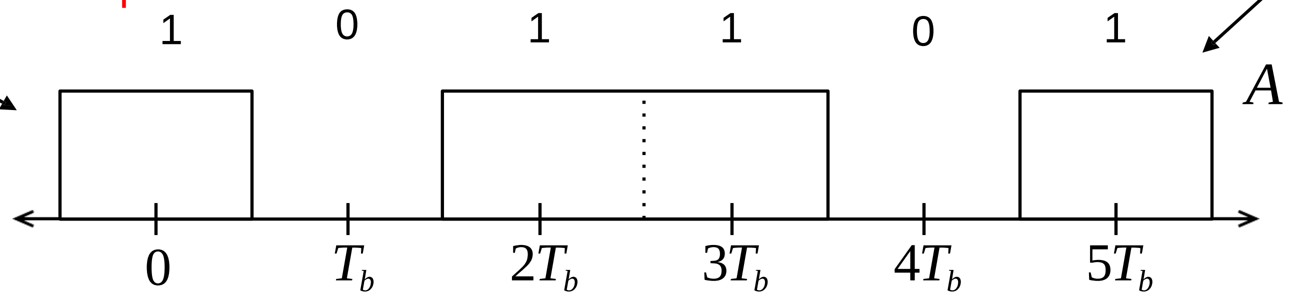
Normalized power

Line Coding Schemes

- Scheme is prone to baseline wandering and D C components.
- It has no synchronization or any error detection.
- It is simple but costly in power consumption.

Hard to recover symbol timing
when long string of 0s or 1s.

Note the DC component
This means wasted power!



Line Coding Schemes

- The unipolar nonreturn-to-zero line code is defined by the unipolar mapping:

$$a_k = \begin{cases} +A & \text{when } X_k = 1 \\ 0 & \text{when } X_k = 0 \end{cases}$$

- where X_k is the k^{th} data bit.
- In addition, the pulse shape for unipolar NRZ is:

$$p(t) = \Pi\left(\frac{t}{T_b}\right) \quad \text{NRZ pulse shape}$$

- Where T_b is the bit period.

Line Coding Schemes

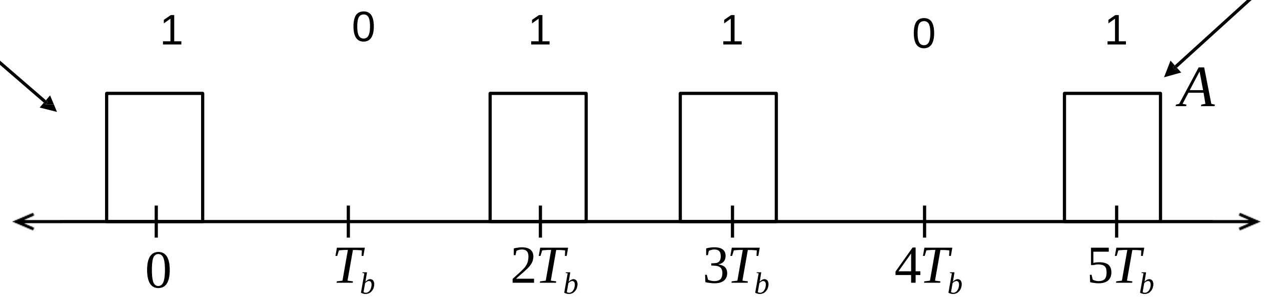
- The unipolar return-to-zero line code has the same symbol mapping but a different pulse shape than unipolar NRZ:

$$a_k = \begin{cases} +A & \text{when } X_k = 1 \\ 0 & \text{when } X_k = 0 \end{cases}$$

$$p(t) = \Pi\left(\frac{t}{T_b/2}\right) \quad \text{RZ pulse shape}$$

Pulse of half the duration of NRZ requires twice the bandwidth!

Long strings of 1's no longer a problem. However strings of 0's still problem.



Line Coding Schemes

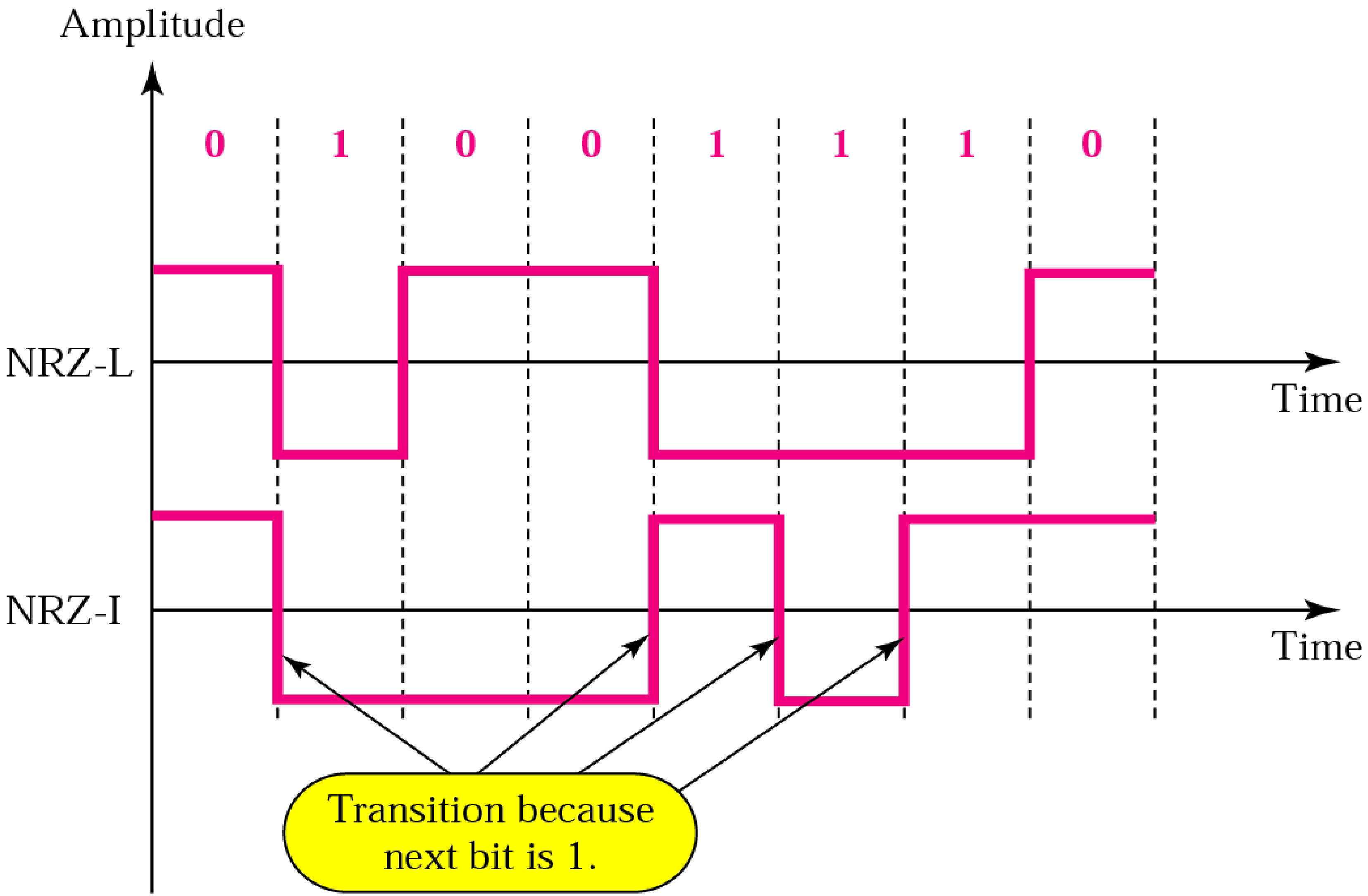
Polar codes

- Polar encoding uses two voltage levels (positive and negative).

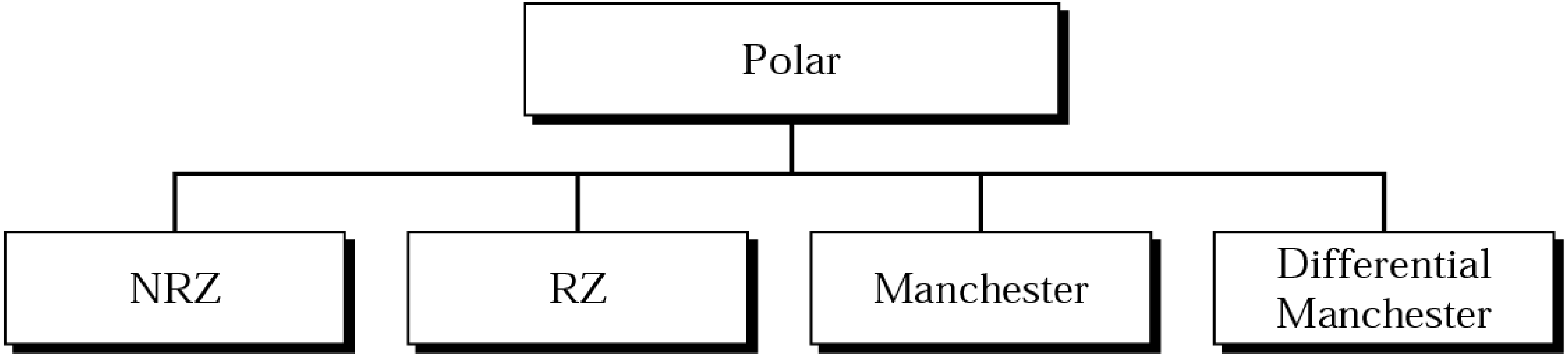
Variations of Polar Encodings

- In Nonreturn to Zero-level (NRZ-L) the level of the signal is dependent upon the state of the bit.
- In Nonreturn to Zero-Invert (NRZ-I) the signal is inverted if a bit '1' is encountered.

Line Coding Schemes



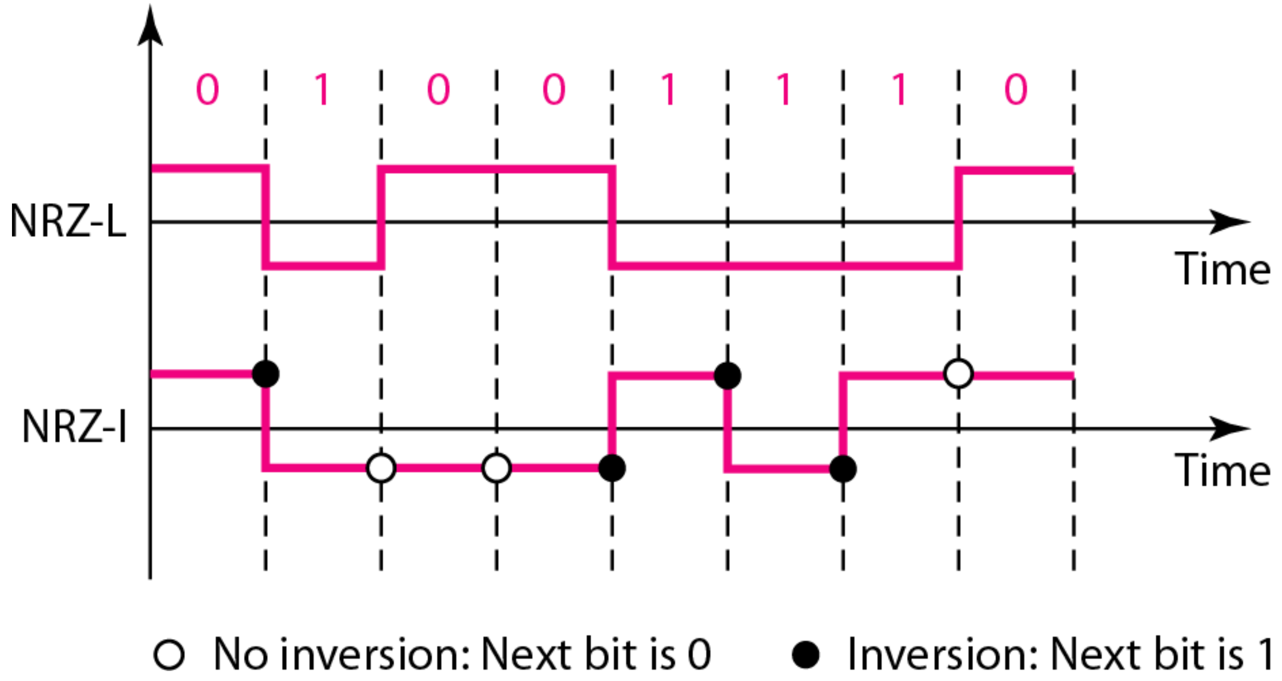
Line Coding Schemes

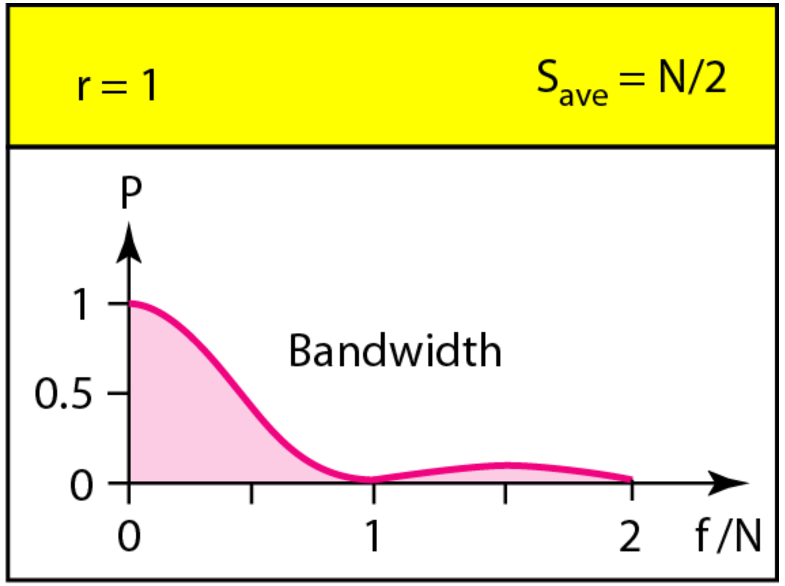


Line Coding Schemes

Polar - NRZ

- The voltages are on both sides of the time axis.
- Polar NRZ scheme can be implemented with two voltages. E.g. +V for 0 and -V for 1.





Line Coding Schemes

In NRZ-L the level of the voltage determines the value of the bit.
In NRZ-I the inversion or the lack of inversion determines the value of the bit.

Line Coding Schemes

NRZ-L and NRZ-I both have an average signal rate of N/2 Bd.

NRZ-L and NRZ-I both have a baseline wandering, it is worse for NRZ-L. Both have no self synchronization &no error detection. Both are relatively simple to implement.

Line Coding Schemes

- ***A system is using NRZ-I to transfer 1-Mbps data. What are the average signal rate and minimum bandwidth?***

- **<u>Solution:</u>**

Line Coding Schemes

- ***A system is using NRZ-I to transfer 1-Mbps data. What are the average signal rate and minimum bandwidth?***

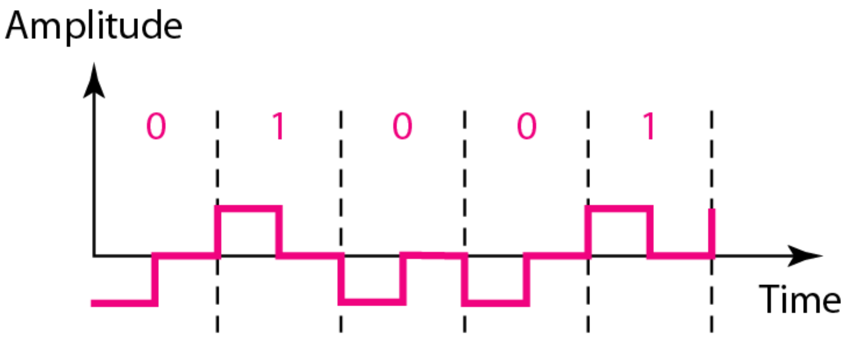
- **Solution:**
- The average signal rate is S= C x N x R = 1/2 x N x 1 = 500 kbaud.
- The minimum bandwidth for this average baud rate is B_{min} = S = 500 kHz.

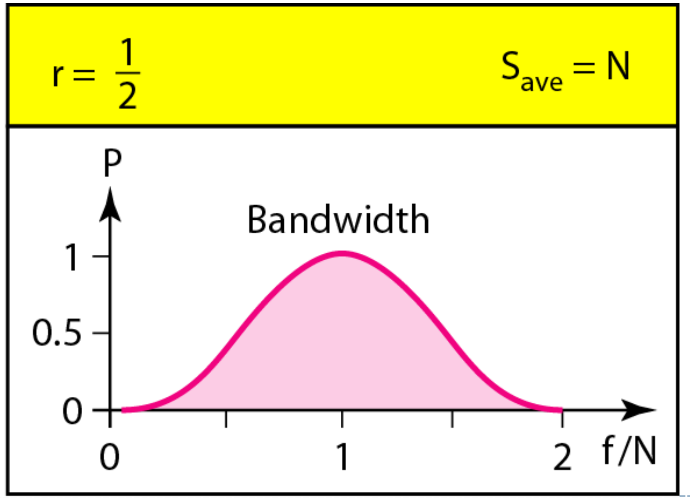
- Note c = 1/2 for the avg.case as worst case is 1 and best case is 0

Line Coding Schemes

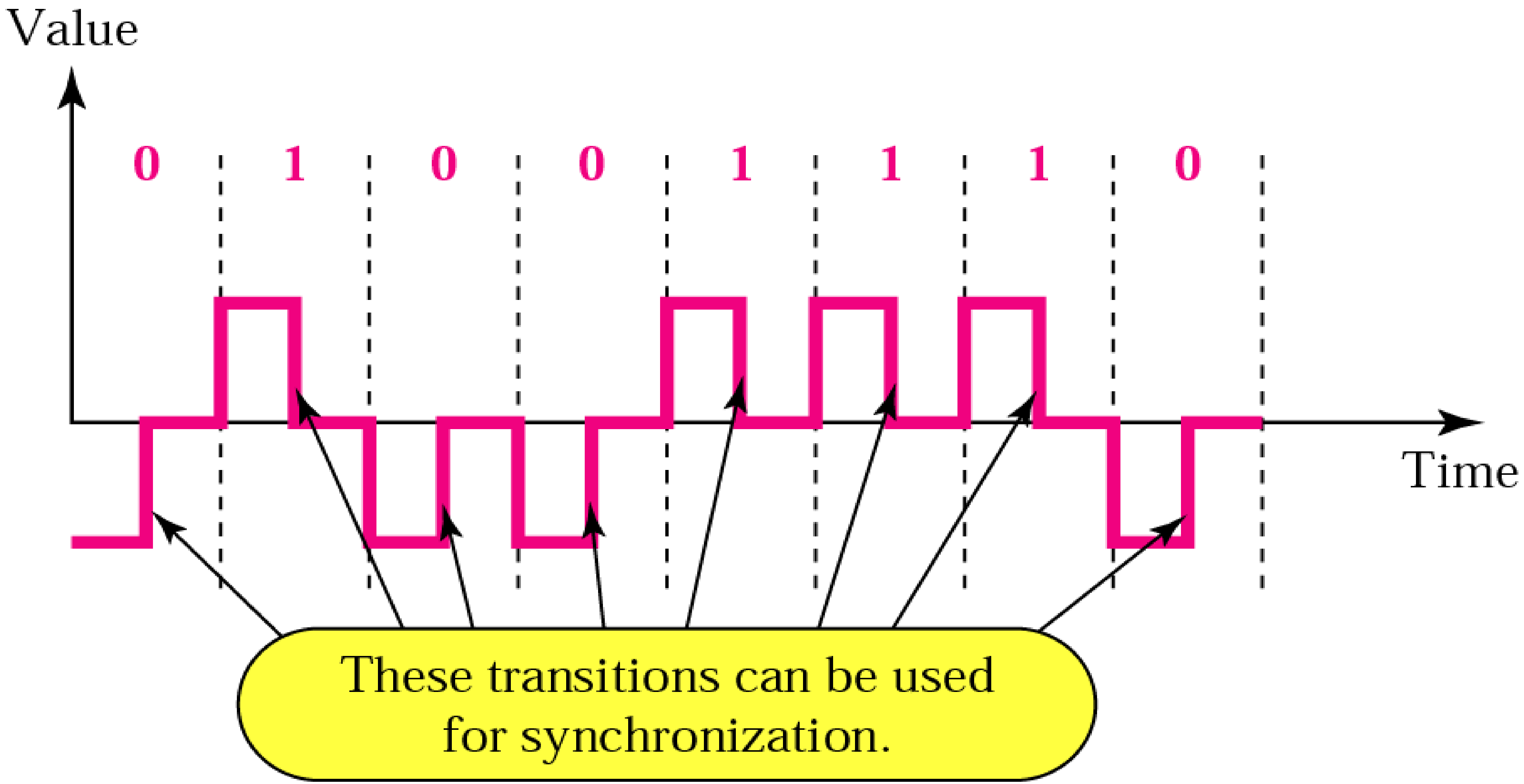
Polar – RZ

- The Return to Zero (RZ) scheme uses three voltage values. **+,0,-.**
- Each symbol has a transition in the middle.
- Either from high to zero or from low to zero.
- This scheme has more signal transitions (two per symbol) and therefore requires a wider bandwidth.





Line Coding Schemes



Line Coding Schemes

- No DC components or baseline wandering.
- Self synchronization - transition indicates symbol value.
- More complex as it uses three voltage level. It has no error detection capability.

Line Coding Schemes

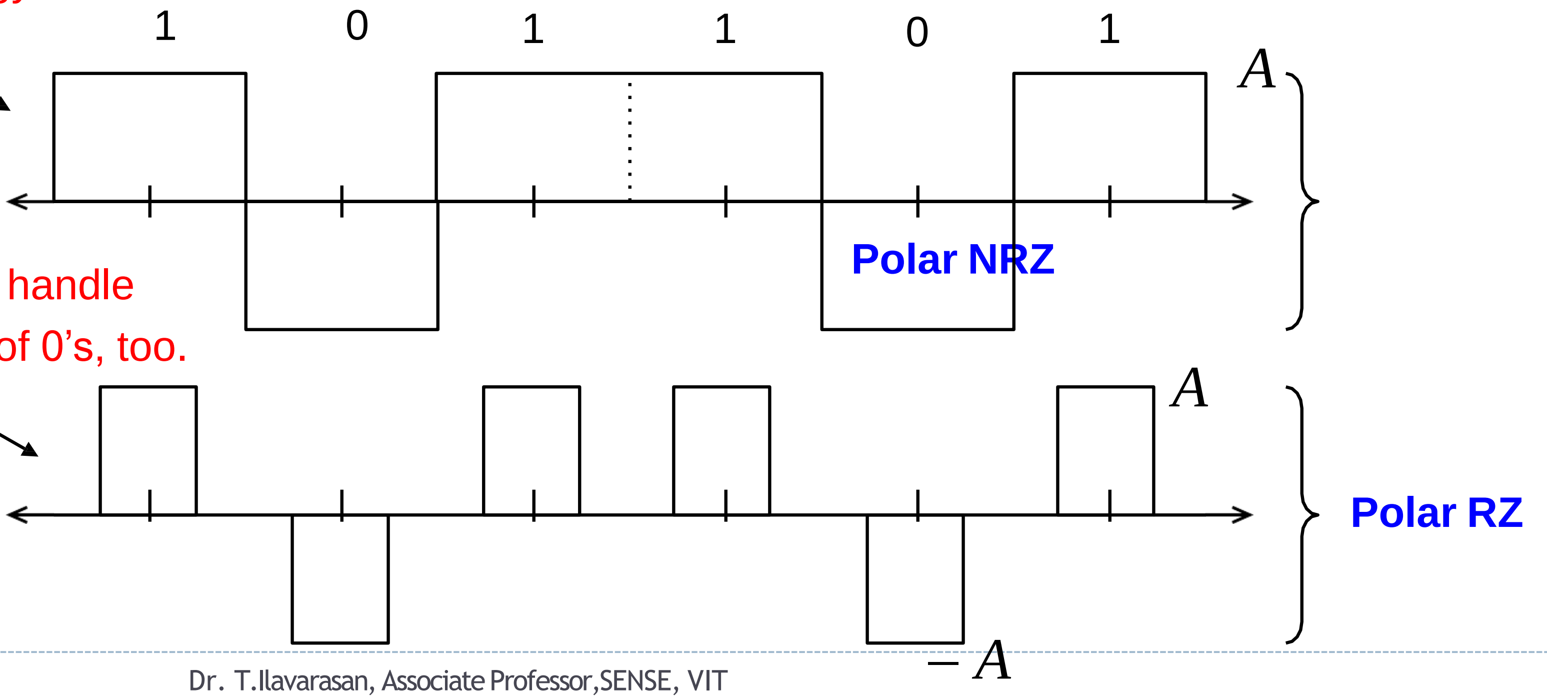
- Polar line codes use the antipodal mapping:
  - Polar NRZ uses NRZ pulse shape.
  - Polar RZ uses RZ pulse shape.

$$a_k = \begin{cases} +A & \text{when } X_k = 1 \\ -A & \text{when } X_k = 0 \end{cases}$$

$$x(t) = \sum_{k=-\infty}^{\infty} a_k \, p(t - kT_b)$$

No DC component,
so more energy efficient.

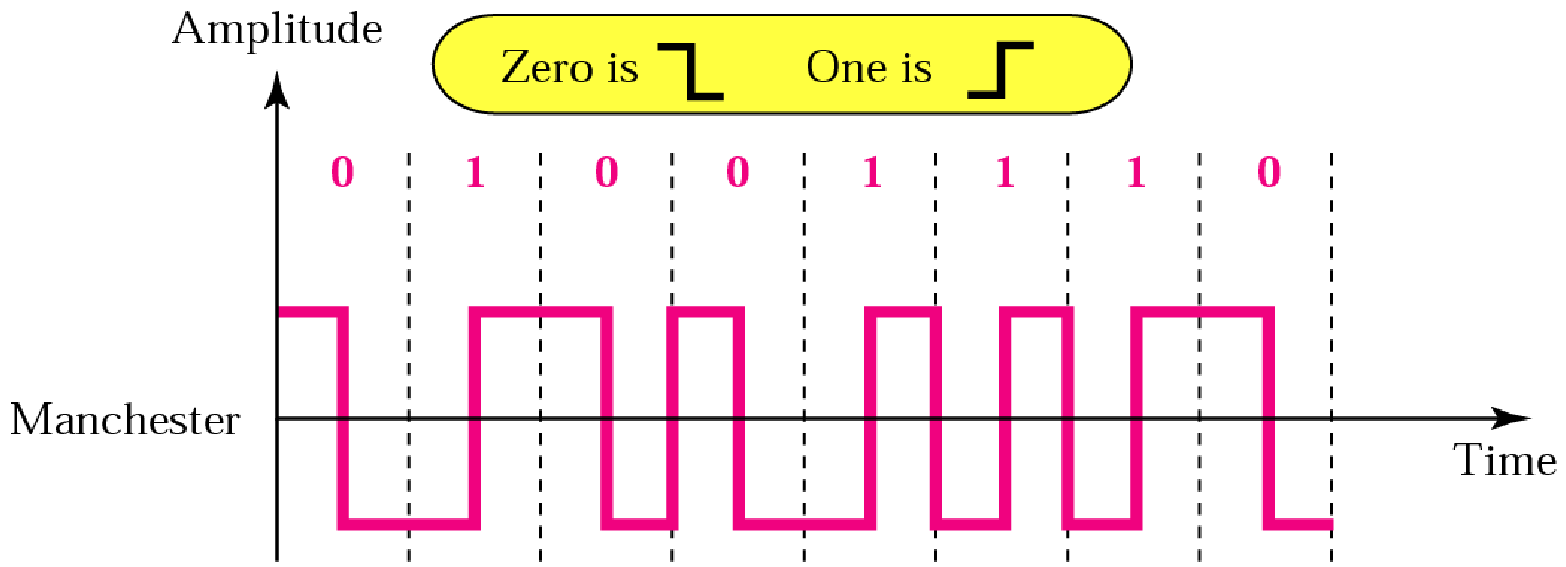
Now we can handle
long strings of 0's, too.



Line Coding Schemes

Polar - Biphase:Manchester

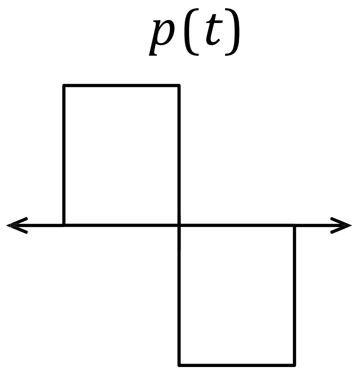
- Manchester coding consists of combining the NRZ-L and RZ schemes.
- Every symbol has a level transition in the middle: from high to low or low to high.
- The transition at the middle of the bit is used for synchronization and bit representation.

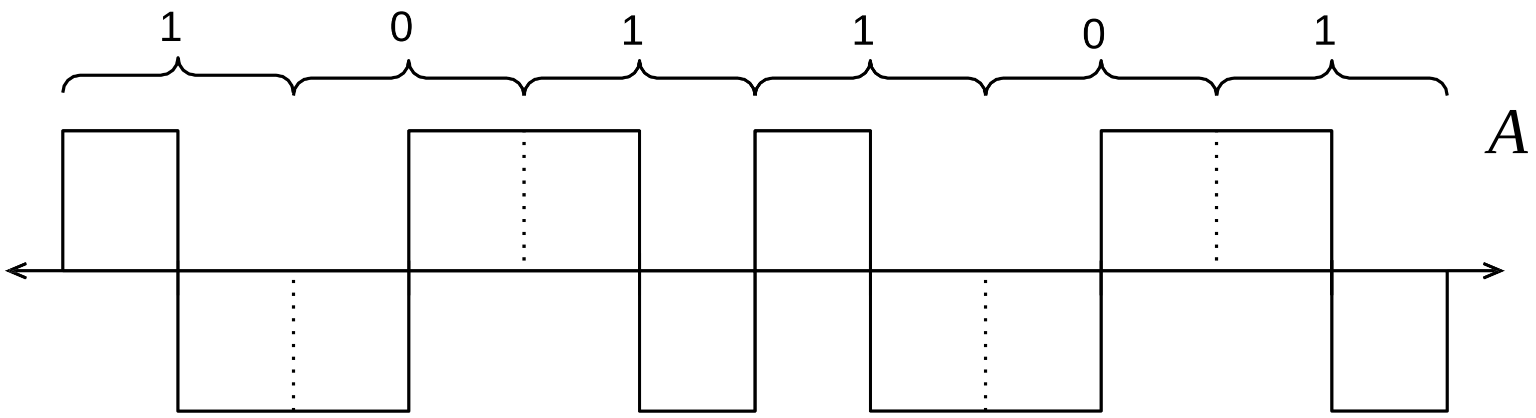


Line Coding Schemes

- ***Manchester line codes*** use the antipodal mapping and the following ***split-phase*** pulse shape:

$$p(t) = \Pi\left(\frac{t + T_b/4}{T_b/2}\right) - \Pi\left(\frac{t - T_b/4}{T_b/2}\right)$$

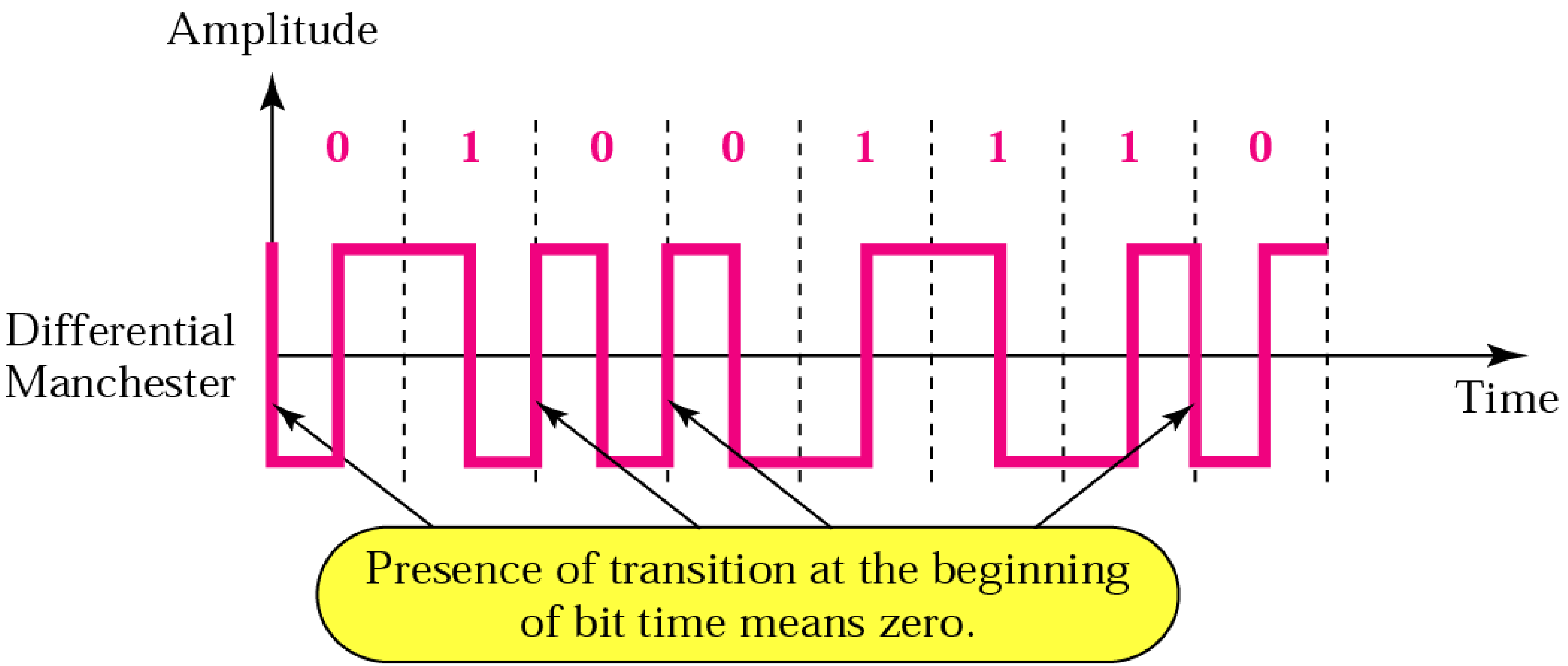




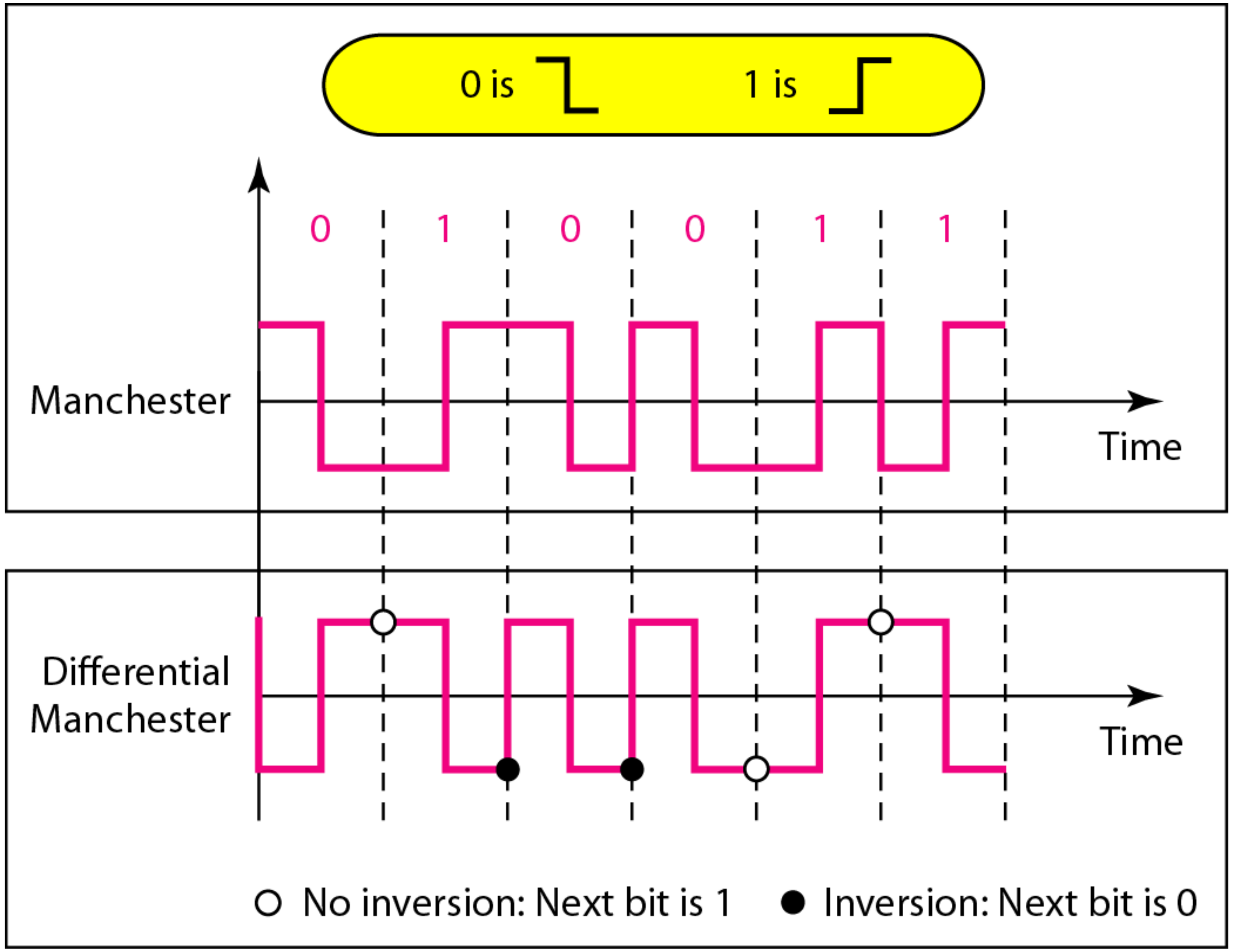
Polar - Biphase:Differential Manchester

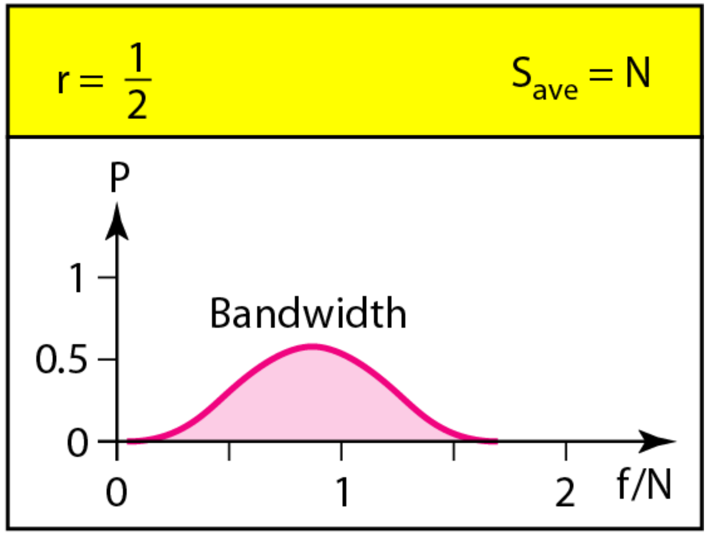
- Differential Manchester coding consists of combining the NRZ-I and RZ schemes.
- Every symbol has a level transition in the middle.
- But the level at the beginning of the symbol is determined by the symbol value.
- One symbol causes a level change the other does not.
- In differential Manchester encoding, the transition at the middle of the bit is used only for synchronization.
- The bit representation is defined by the inversion or noninversion at the beginning of the bit.

Line Coding Schemes



Line Coding Schemes





Dr. T.Ilavarasan, Associate Professor,SENSE, VIT

Line Coding Schemes

In Manchester and differential Manchester encoding, the transition at the middle of the bit is used for synchronization.

Line Coding Schemes

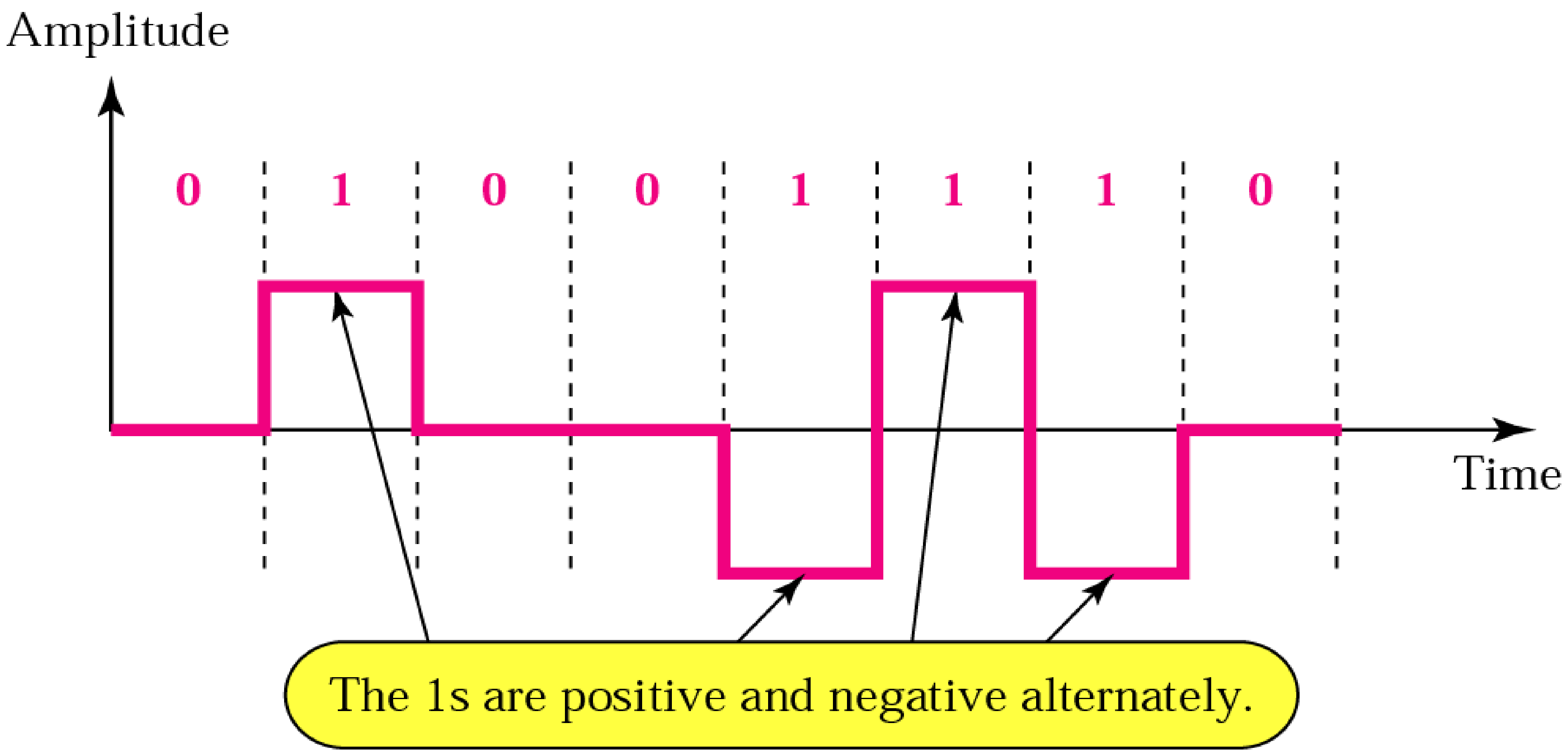
The minimum bandwidth of Manchester and differential Manchester is 2 times that of NRZ. The is no DC component and no baseline wandering. None of these codes has error detection.

Line Coding Schemes

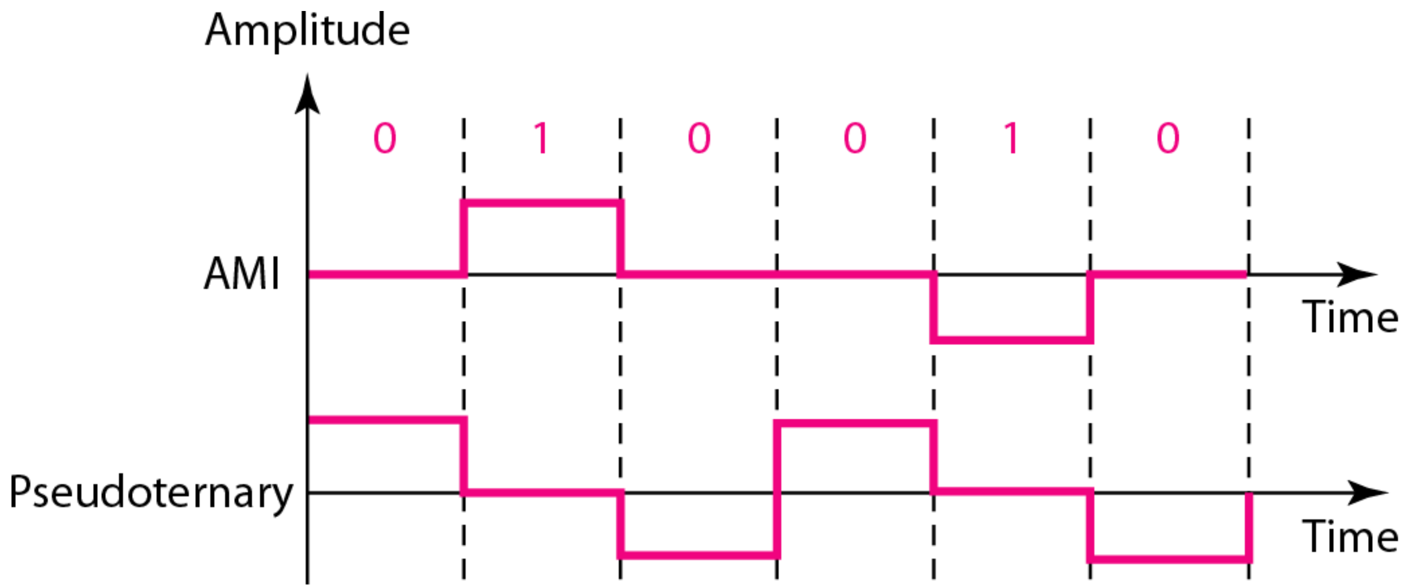
Bipolar -AMI and Pseudoternary

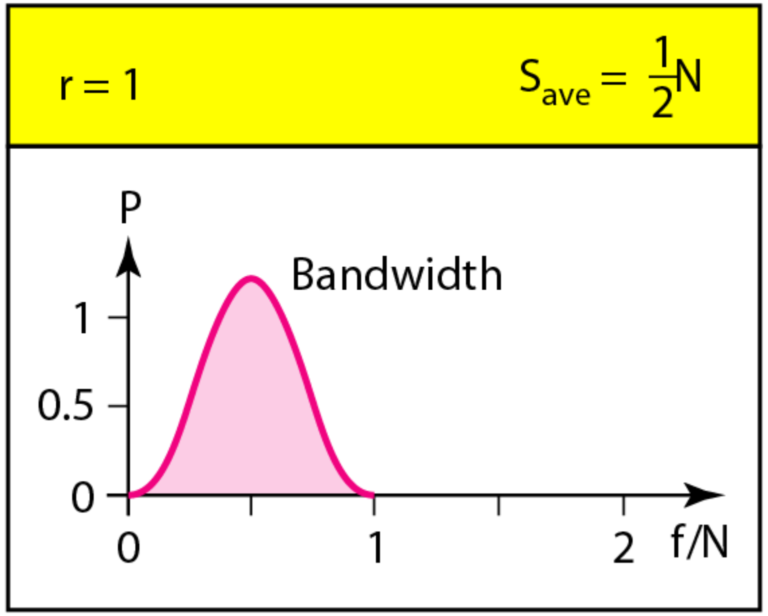
- Code uses 3 voltage levels: - +, 0, -, to represent the symbols (note not transitions to zero as in RZ).
- Voltage level for one symbol is at "0" and the other alternates between + & -.
- Bipolar **Alternate Mark Inversion (AMI)** - the "0" symbol is represented by zero voltage and the "1" symbol alternates between +V and -V.
- **Pseudoternary** is the reverse of AMI.

Line Coding Schemes



Line Coding Schemes





Line Coding Schemes

- It is a better alternative to NRZ.
- Has no DC component or baseline wandering.
- Has no self synchronization because long runs of "0"s results in no signal transitions.
- No error detection.

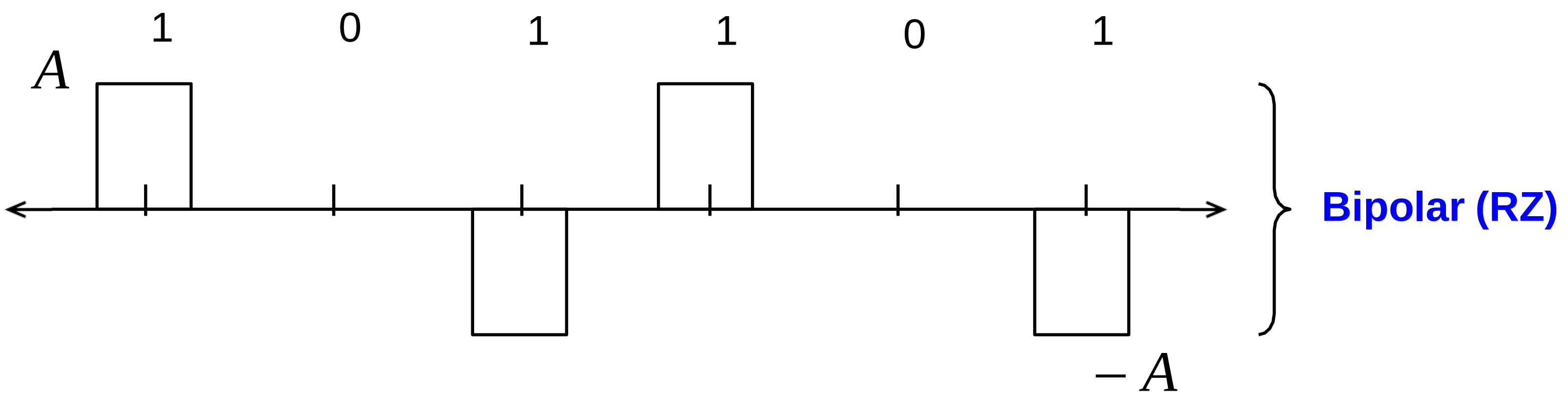
Line Coding Schemes

- With bipolar line codes a space is mapped to zero and a mark is alternately mapped to -A and +A:

$$a_k = \begin{cases} 0 & \text{when } X_k = 0 \\ -A & \text{when } X_k = 1 \text{ and last mark } \rightarrow \ +A \\ +A & \text{when } X_k = 1 \text{ and last mark } \rightarrow \ -A \end{cases}$$

$$\boxed{x(t) = \sum_{k=-\infty}^{\infty} a_k \, p(t - kT_b)}$$

- Also called pseudoternary signalling and alternate mark inversion (AMI).
- Either RZ or NRZ pulse shape can be used.



Comparison of Line Codes

Self-synchronization:

- Manchester codes have built in timing information because they always have a zero crossing in the center of the pulse.
- Polar RZ codes tend to be good because the signal level always goes to zero for the second half of the pulse.
- NRZ signals are not good for self-synchronization.

Error probability:

- Polar codes perform better (are more energy efficient) than Unipolar or Bipolar codes.

Channel characteristics:

- We need to find the PSD of the line codes to answer this .