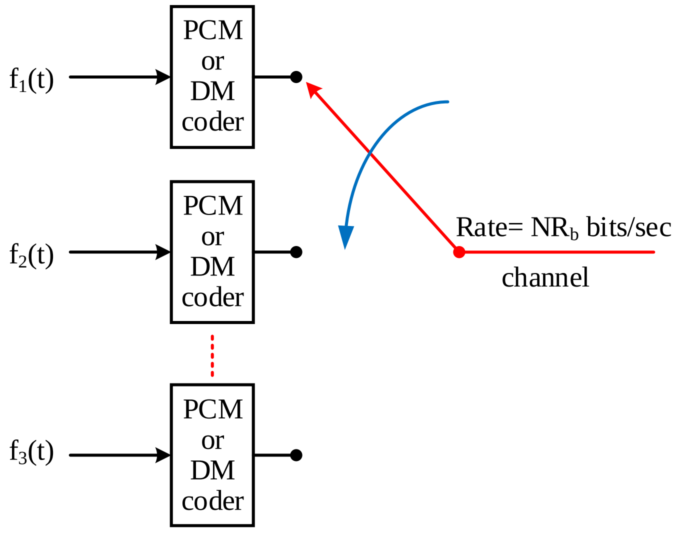
Bit Multiplexing:

Serial o/p of PCM or the o/p of DM for N messages had multiplexed and transmitted over one channel.

If R_b is the information rate of each source coder (nf_s for PCM & fs for DM) then the bit rate of channel will be NR_b if all messages have the same bit rate.



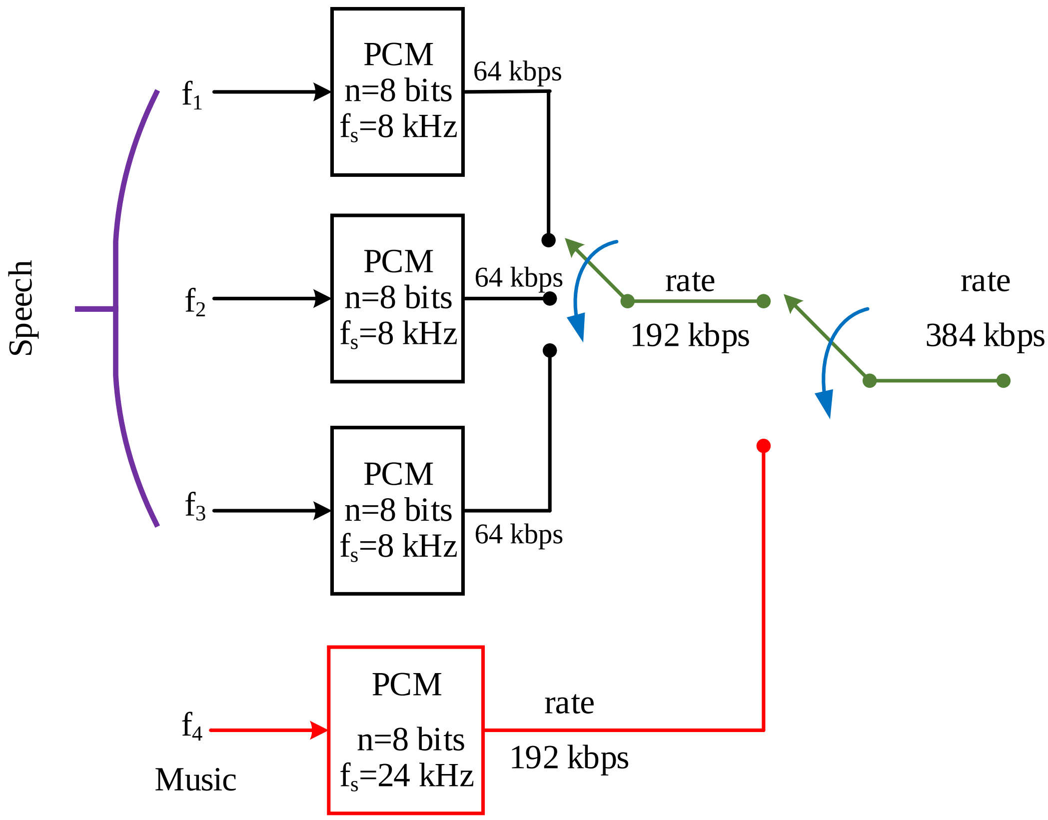
Note:

For none equal bit rate messages, and then sub-group multiplexing has done first before final TDM multiplexing.

Ex 6-7

Setup multiplexing scheme using TDM for 3 speech messages, each sampled at 8 kHz and PCM quantized into 8 bits/sample identifying the bit rate at each part of the multiplexing processes.

Solution:



Transmission of Digital signals:

There are two ways to transmit the digital signals, these are:

a) Baseband transmission and,

b) Sinusoidal modulation (digital carrier system).

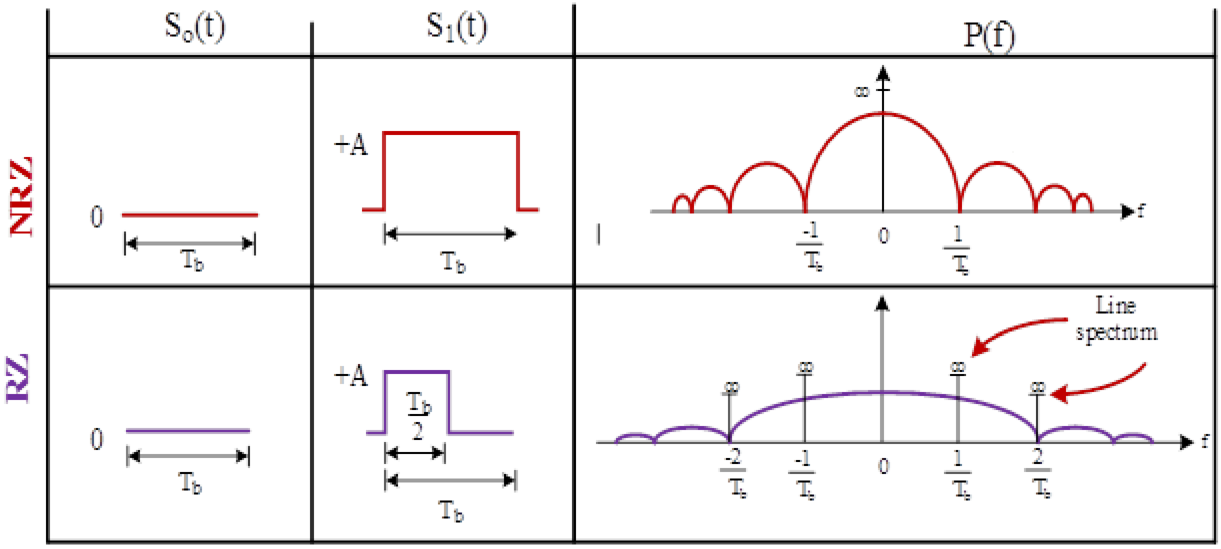
For binary data, it is assumed that logic "0" is transmitted as the waveform $S_o(t)$ and logic "1" as the waveform $S_1(t)$ over a bit duration $T_b = 1/R_b$, where R_b is the bitrate (bps). Also it is assumed that $P(0_T) = P(1_T) = {}^1/_2$.

a) Baseband Transmission:

These are used for short or medium distance communication. The signals are transmitted without carrier modulation (frequency shifting).

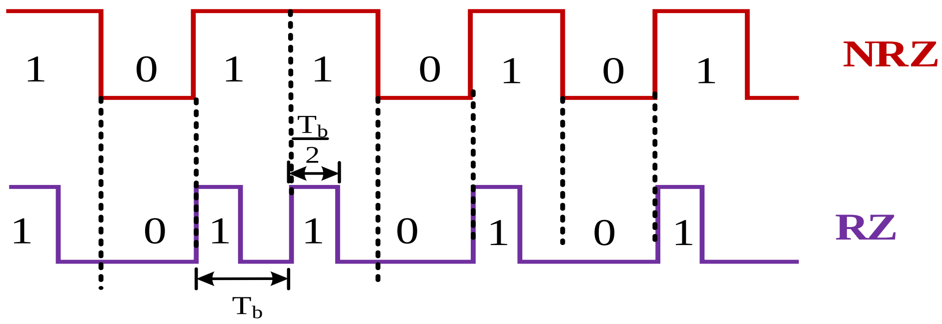
1- Unipolar Transmission:

The waveform and power spectral density are summarized below:



RZ = Returned to Zero

NRZ= Non Returned to Zero



Notes:

1- The unipolar Return to zero (RZ) format increases the power at data rate, but double the bandwidth.

2- The spectrum of the unipolar RZ contains line spectrum at $0, \mp R_b, \mp 2R_b, \mp 3R_b, \ldots$. in addition to continuous spectrum due to nonzero dc power

3- When large number of zeros or ones exists, synchronization problem will occur.

4- The error probability of unipolar NRZ

$$P_e = Q\left(\sqrt{\frac{SNR}{2}}\right) \quad \text{in AWGN.}$$

- $Q(x)$ is called **Marcum function or Error Function**. It is tabulated for x<3 or can be approximated for large x as:

$$Q(x) \approx \frac{1}{\sqrt{2\pi}x}\left(1-\frac{0.7}{x^2}\right)e^{-\frac{x^2}{2}} \quad ,x > 2$$

Ex 6-8

Calculate average power a signal has unipolar NRZ format

Solution

The average power for unipolar NRZ is:

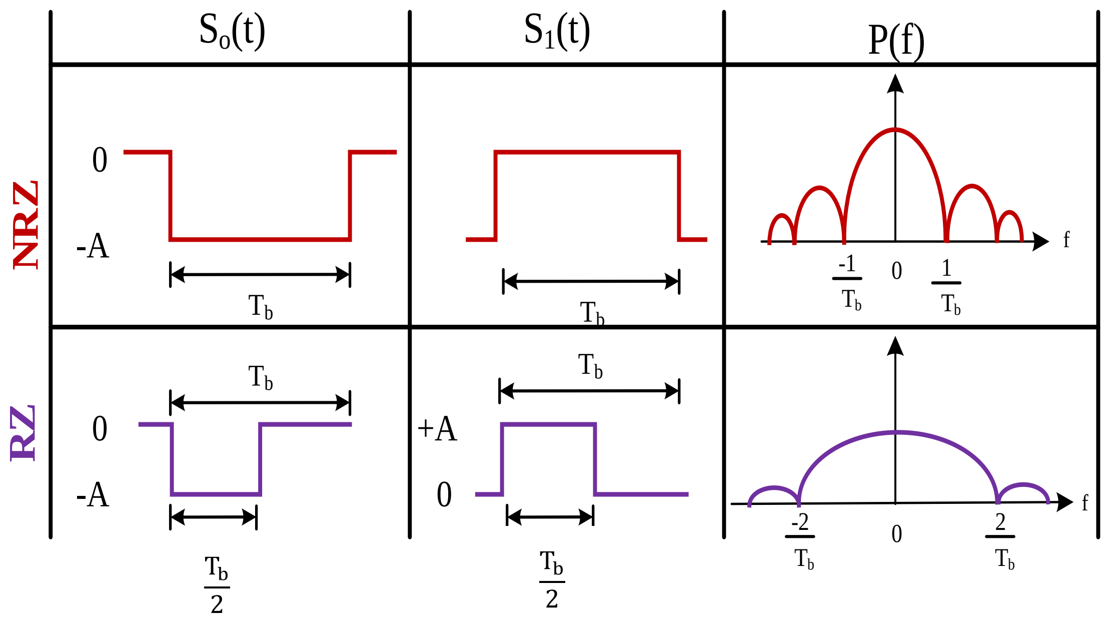
$$P = \frac{1}{2}A^2 + \frac{1}{2}(0)^2 = \frac{A^2}{2}\,\text{volt}^2$$

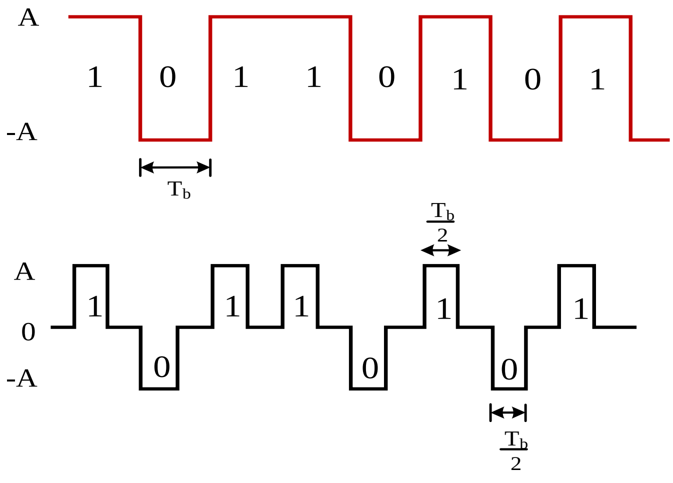
H.W

Repeat the previous example for unipolar RZ format

2- Bipolar transmission:

The waveform and power spectral density has summarized below:





Notes:

1- BW of bipolar RZ is greater than BW of bipolar NRZ.

2- Bipolar RZ has significant frequency content at $\boldsymbol{f} = \boldsymbol{R_b} = \frac{\mathbf{1}}{\boldsymbol{T_b}}$= clock of the data.

3- The spectrum has **almost zero DC power** (exactly zero when P(0)=P (1))

4- The synchronization problem is minimized in bipolar RZ format.

5- Error probability of NRZ bipolar $P_e = Q(\sqrt{SNR})$ for AWGN channel.

Ex 6-9

Calculate average power of a signal has bipolar RZ format

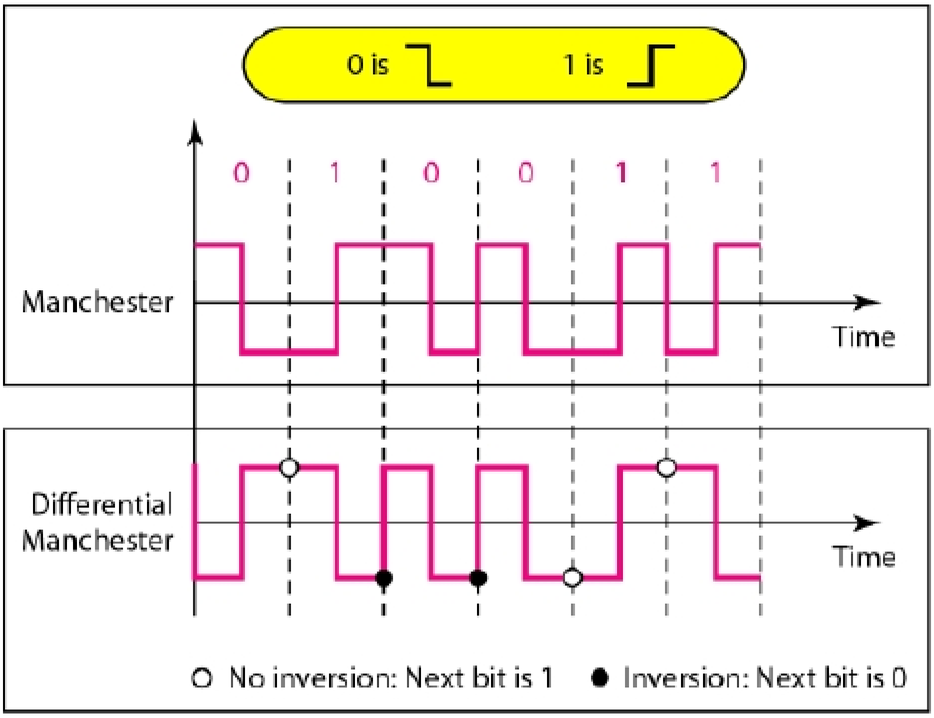
Solution

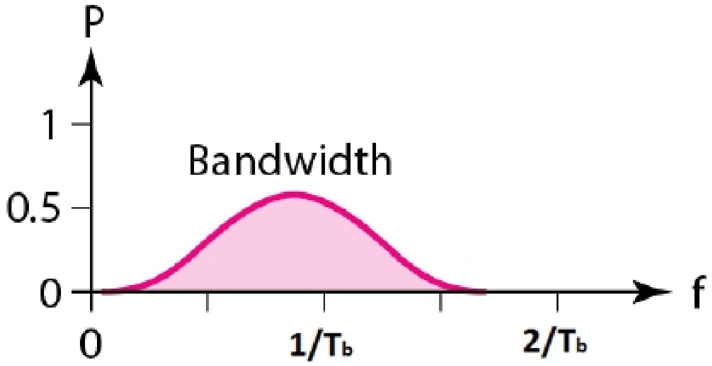
The average power for bipolar RZ is: $P = \frac{1}{2}(\frac{A^2}{2}) + \frac{1}{2}(\frac{A^2}{2}) = \frac{A^2}{2}$ volt^2

H.W

Repeat the previous example for bipolar NRZ format

3- Biphase and Differential Manchester (Split phase)





Notes:

- The duration of the bit is divided into two halves. The voltage remains at one level during the first half and moves to the other level in the second half. The transition at the middle of the bit provides **good synchronization**.
- The Manchester code has **no dc power**, high power at data rate, less bandwidth than bipolar RZ.
- It is less complex than Bipolar RZ since it uses only two voltage levels ±A.

4- Alternate Mark Inversion (AMI) RZ code

- Positive and negative pulses (of equal magnitude) are used for symbol 1, and no pulse is used for symbol 0. In either case the pulse retunes to0 before the end of bit interval.
- The BW here is almost less than Manchester code and the DC power is almost zero. However, the power is max. at half the data rate.

Ex 6-10

Encode the binary data 10110001 using the following transmission codes:

Unipolar (RZ/NRZ), Bipolar (RZ/NRZ), AMI and Manchester.

Solution