Multiplexing

→ What is multiplexing? Discuss FDM and TDM.

Multiplexing: Multiplexing involves grouping of several channels in such a way as to transmit them simultaneously on the same physical transmission medium without mixing. At the receiving end demux is performed to seperate the channels. In the telephone networks, each channel provides a bandwidth of 300 - 3400 Hz for speech signals.

FDM (Frequency division multiplexing):

FDM is the process by which the total bandwidth available to the system is devided into a series of non overlapping frequency sub-bands that are then assigned to each communicating source and user pair.

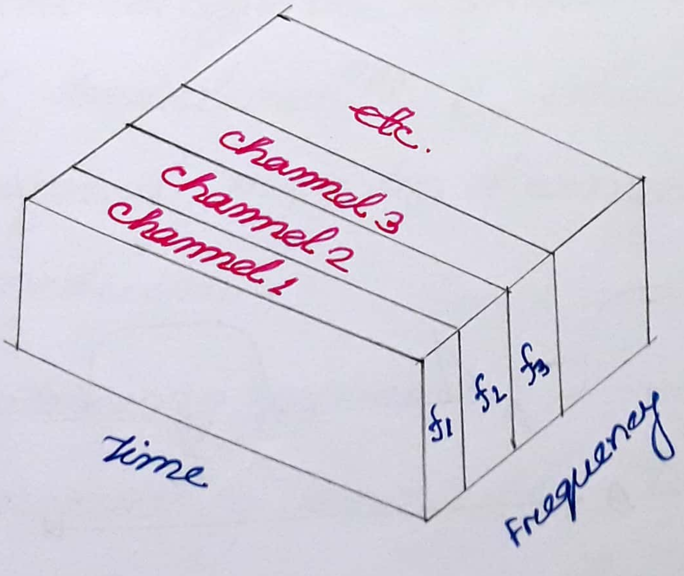

Fig: FDM (Frequency division Mux)

A familiar example of FDM is broadcast and cable television.

Multiplexing process:

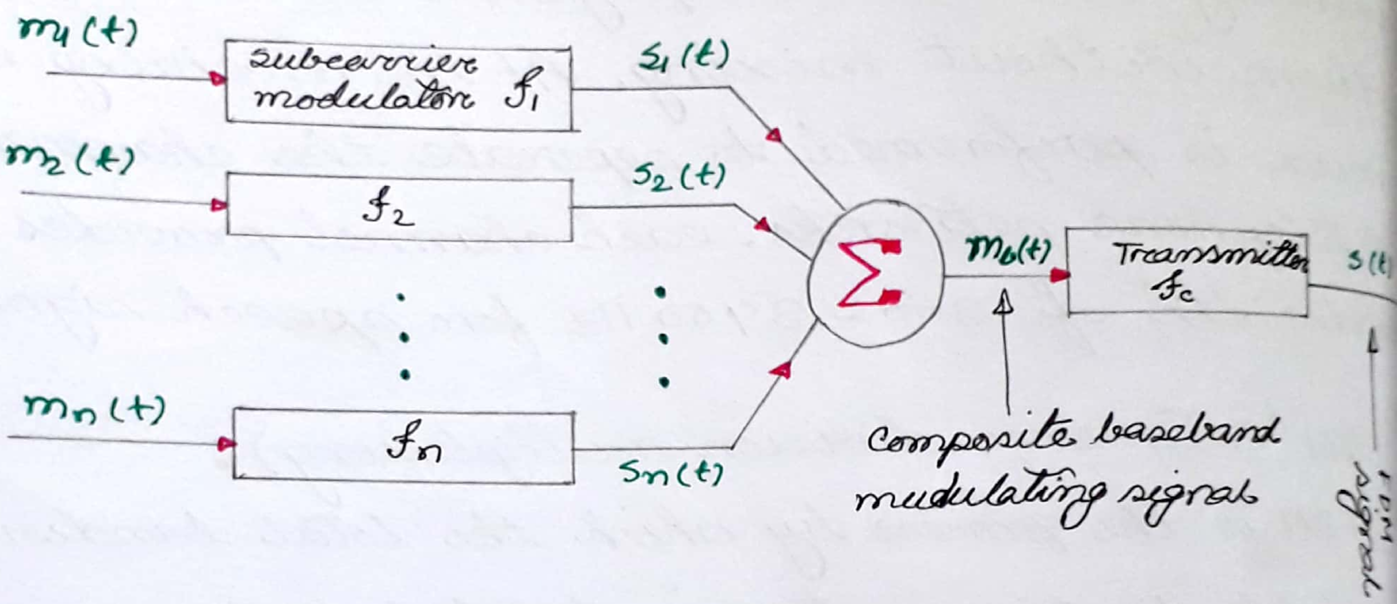

Fig : Transmitter

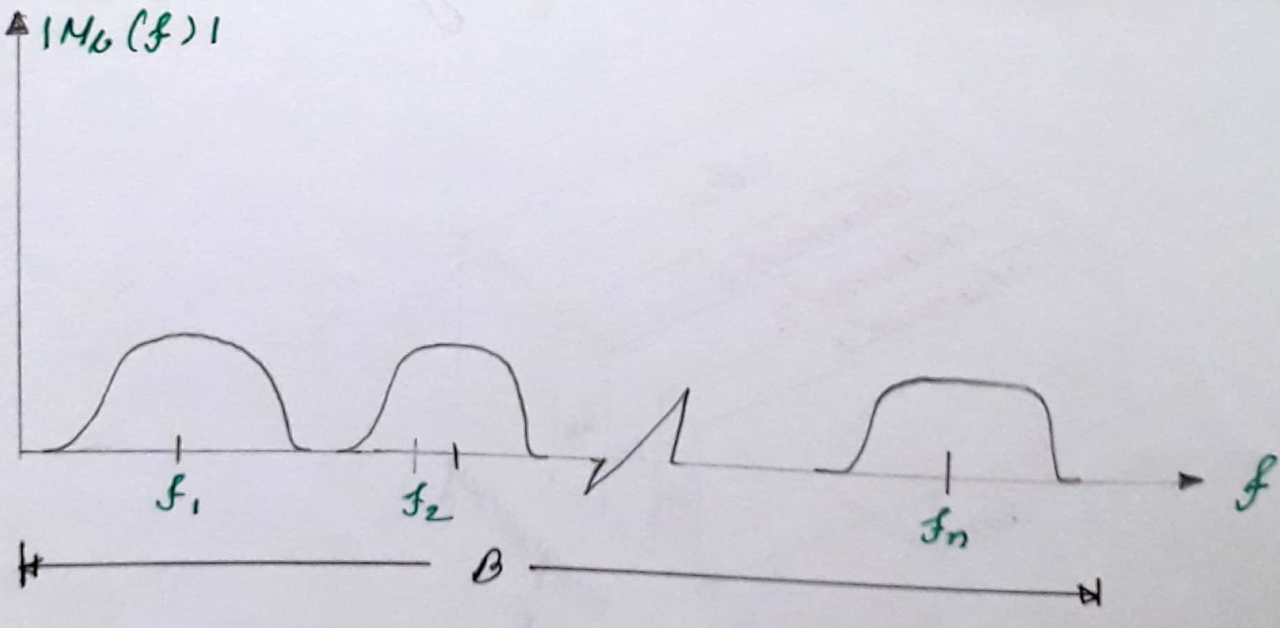

Fig: spectrum of baseband modulating signal.

A generic depiction of an FDM system is shown in figu-re. A number of analog or digital signals [$m_i(t)$, $i=1,n$] re to be multiplexed onto the same transmission edium. Each signal $m_i(t)$ is modulated onto a rrier f_i; because multiple carriers are to be sed, each is ~~reffered~~ referred to as a subcarrier. ny type of modulation may be used. The resulting nalog, modulated signals are then summed o produce a composite baseband signal $m_b(t)$. The pectrum of signal $m_i(t)$ is shifted to be centered n f_i. For this scheme to work, f_i must be chosen o that bandwidths of the various signals do not ignificantly overlap. Otherwise it will be impossibl o recover the original signals. The FDM signal $s(t)$ as a total bandwidth B, where $B > \sum_{i=1}^{n} B_i$. This s analog signal may be transmitted over a uitable medium.

Demultiplexing process:

At the receiving end, the FDM signal is demod-ulated to retrieve $m_b(t)$, which is then passed through n bandpass filters, each filter centered on f_i and having a bandwidth B_i . In this way the signal is again split into its component parts. Each component is then demodulated to recover the original signal.

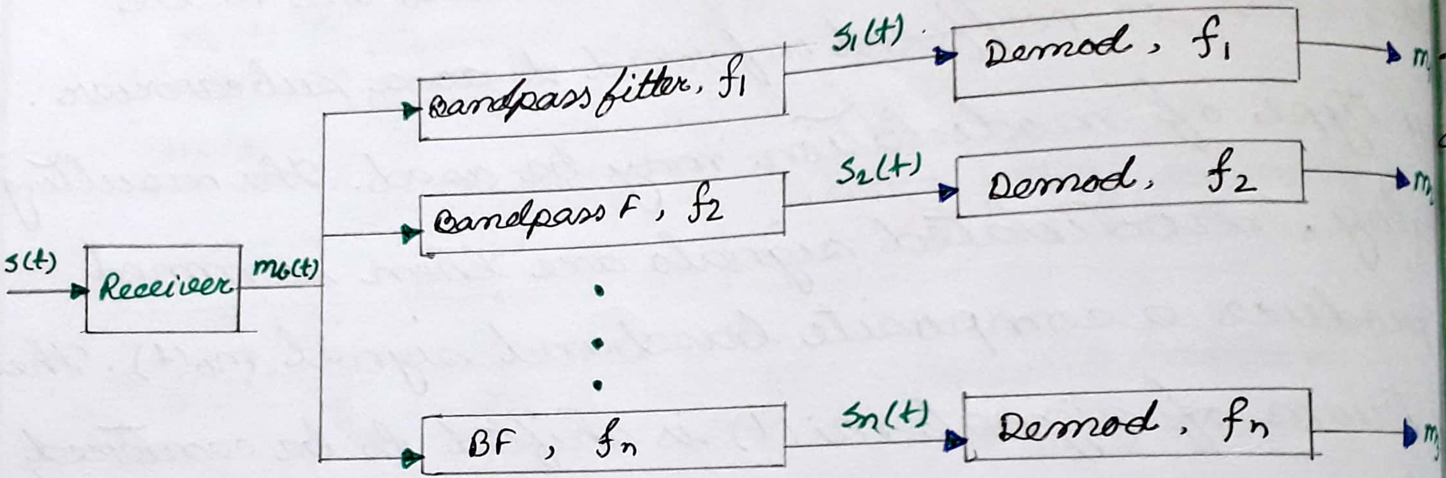

Fig: Receivers .

TDM (Time devision multiplexing):

TDM is a type of digital multiplexing in which two or more bit streams or signals are transferred apparently simultaneously as subchannels in one communication channel, but are physically taking turns on the channel. The time domain is devided into ~~several~~ several recurrent time slots of fixed length, one for ~~ea~~ each sub-channel.

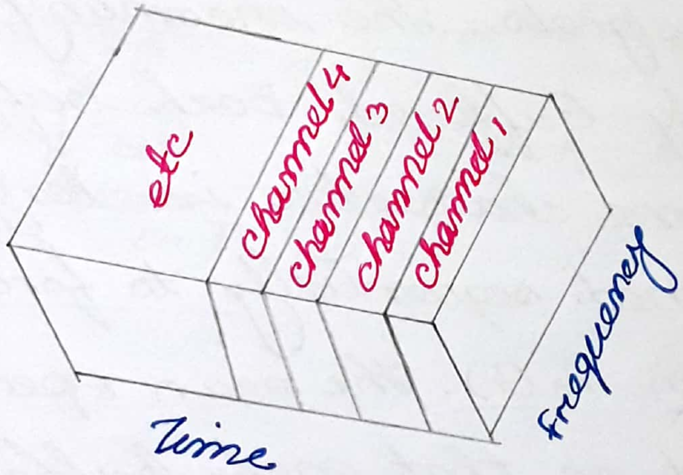

Fig: Time devision multiplexing.

Multiplexing process:

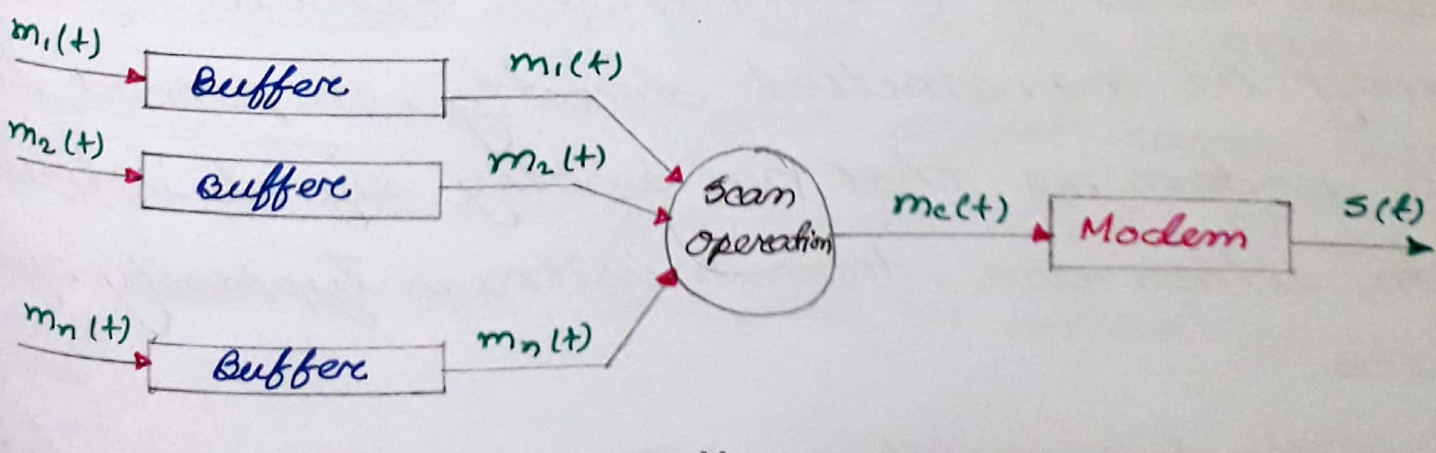

Fig: Transmitter.

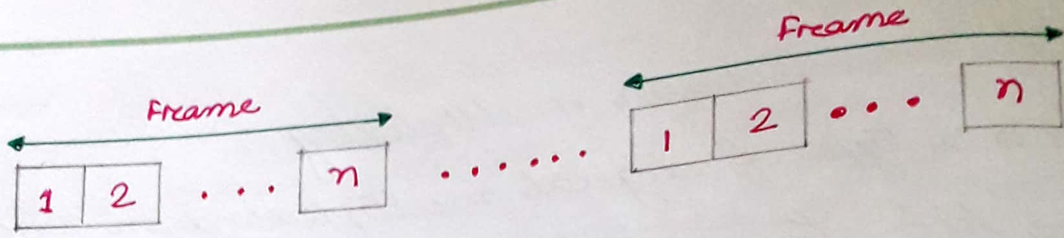

Fig: TDM frames

A generic depiction of a synchronous TDM system is provided in figure. A number of signals $[m_i(t), i = 1, n]$ are to be multiplexed onto the same transmission medium. The signals carry digital data and are generally digital signals. The incoming data of the source are briefly buffered. Each buffer is typically one bit or one character in length. The buffers are scanned sequentially to form a composite digital data stream $m_c(t)$. The scan operation is sufficiently rapid so that each buffer is emptied before more data can arrive. Thus, the data rate of $m_c(t)$ must at least equal the sum of the data rates of the $m_i(t)$. The digital signal $m_c(t)$ may be transmitted directly, or passed through a modem so that an analog signal is transmitted. In, either case, transmission is typically synchronous.

The transmitted data may have a format

like figure. The data are organised into frames. Each frame contains a cycle of time slots. In each frame one or more slots is dedicated to each data source. The sequence of t slots dedicated to one source, from frame to frame, is called a channel. The slot length is equal to the transmitter buffer length, typically a bit or character.

Demultiplexing process:

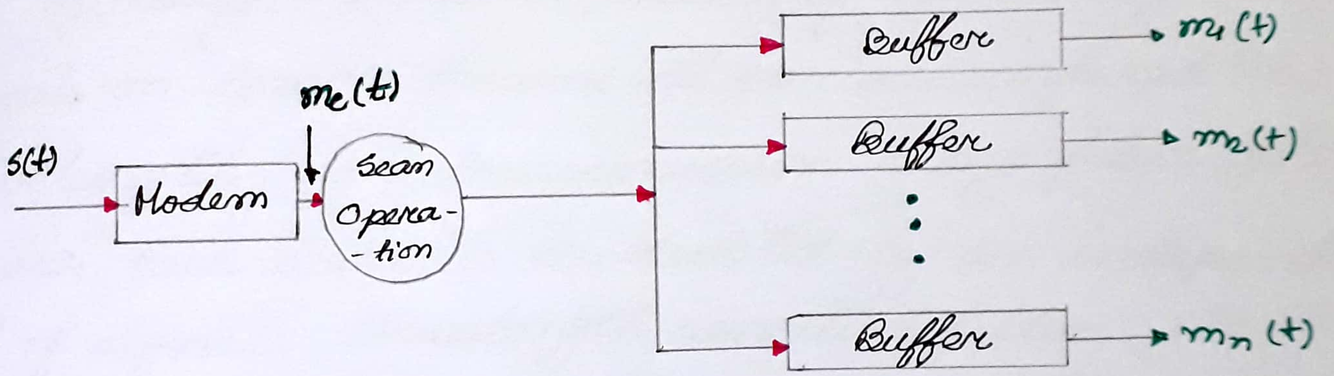

Fig: Receiver.

At the receiver, the interleaved data are ~~demodulated~~ demultiplexed and routed to the appropriate destination buffer. For each input source $m_i(t)$ there is an identical output source that will receive the input data at the same rate at which it was generated.

→ What is WDM? Write short note on WDM.

WDM: In fiber-optic communications, wave length division is a technology which multiplexes a number of optical carrier signals onto a single optical fiber by using different wavelengths of laser light. This technique enables bidirectional communications over one strand of ~~b~~ fiber as well as multiplication of capacity.

Actually WDM is a process of combining multiple signals on laser beams at various infared (IR) wavelengths for transmission along fiber optic media. Each laser is modulated by an independent set of signals. Wavelength sensitive filters, the IR ~~visible~~ analog of visible light coulour filters are used at the receiving end.

Process: Although WDM technology is very complex, the basic idea is very simple. We want to combine multiple light sources into one single light at the multiplexer and do the reverse at the demux. The combining and splitting of light sources are easily handled by the prism. Recall from basic physics that a prism bends a beam of light based

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on the angle of the incidence and the frequency and a prism also make the reverse process. By using this technique a multiplexer and demultiplexer work in WDM.

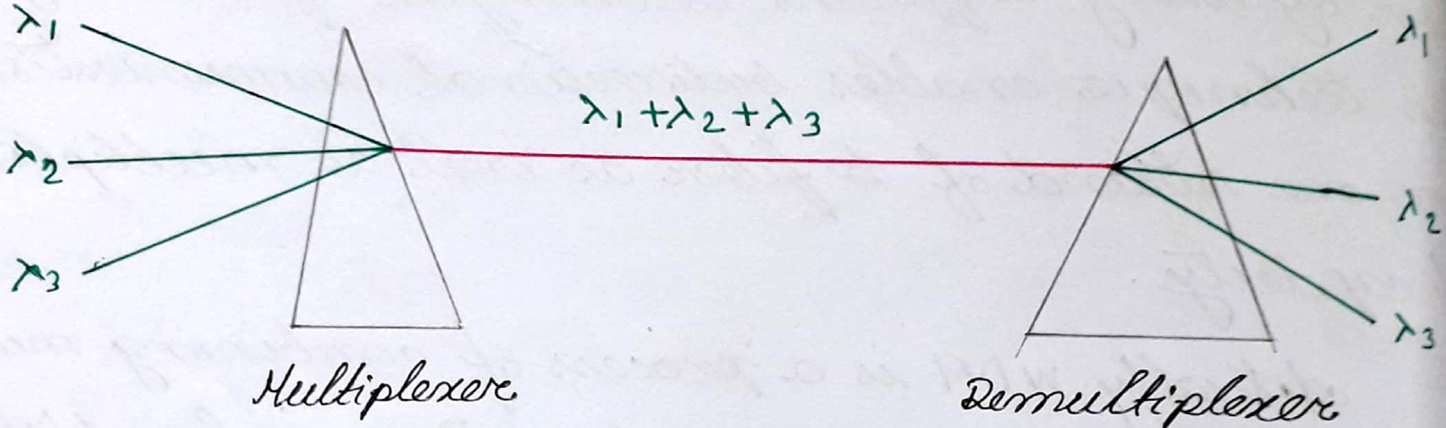

Fig: Prism in WDM multiplexing and demux

WDM is used in SONET network.

Example: We know,

$$\lambda = \frac{c}{f} = \frac{3\times10^8\ ms^{-1}}{f}$$

each λ is running at 40 Gbps

Let, $\lambda_1 = 1549.2nm$
$\lambda_2 = 1550.0nm$
$\lambda_3 = 1550.8nm$.

> 64λ multiplexer = 40 × 64 Gbps = 2560 Gbps/core

48 core = 2560 × 48 Gbps

= 122880 Gbps/link.

So we can send huge data in WDM process at a time.

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Multiple Access.

→ Discuss FDMA with examples?

FDMA: Frequency division multiple access is a channel access method used in multiple-access protocols as a channelization protocol. It gives users an individual allocation of one or several frequency bands or channels. Each station is allocated a band to send its data. Each station also uses a bandpass filter to confine the transmitter frequencies. To prevent station interferences, the allocated bands are separated from one another by small guard bands.

Example:

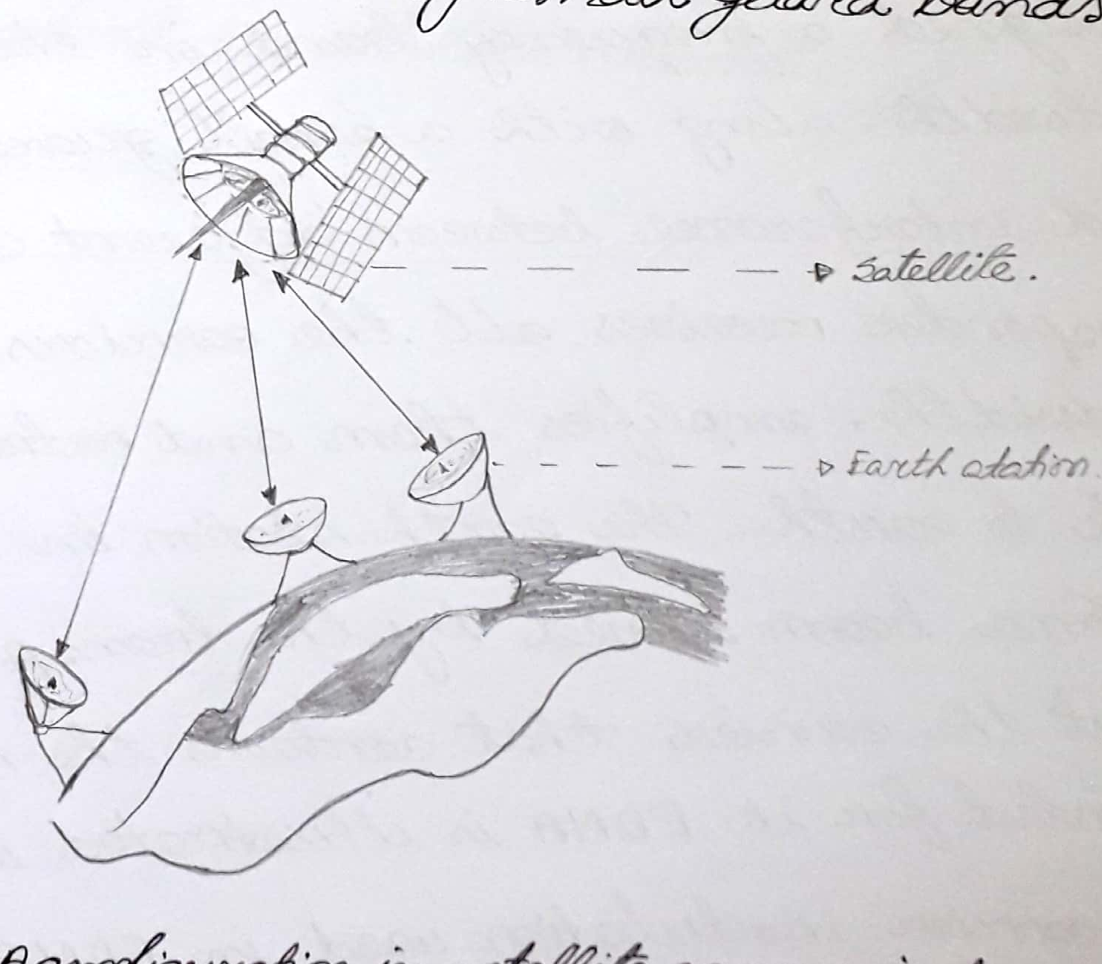

Fig: FDMA configuration in satellite communication.

Most common satellite systems are made up of trans-

-ponders (Nonregenerative). Non regenerative means that the uplink (earth to sat) transmission are simply amplified, frequency shifted and transmitted on the downlink (sat to earth) without any demodulation or signal processing.

FDMA has been used since the inception of satellite communication. Here each station in the community of earth stations that share transponder capacity transmits one or more carriers to the satellite transponder at different centre frequencies. Each carrier is assigned a frequency band in the transponder bandwidth, along with a small guard band to avoid interference between adjacent carriers. The transponder receives all the carriers in its bandwidth, amplifies them and retransmits them back to earth. The earth station in the satellite antenna beam served by the transponder can select the carrier that contains the message intended for it. FDMA is illustrated in figure. The carrier modulation used in FDMA is FM or PSK.

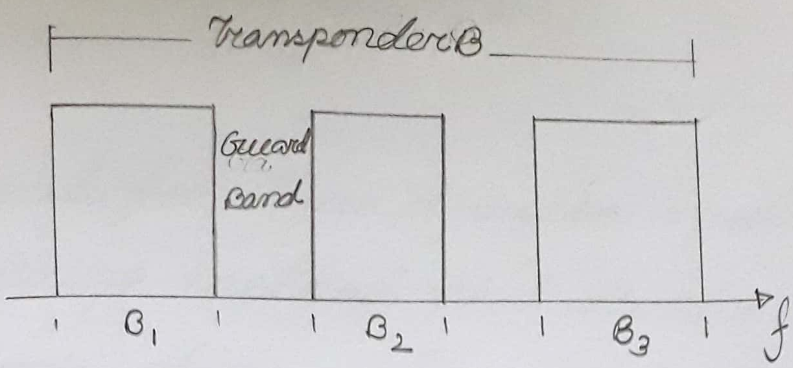

Fig: Concept of FDMA.

The major advantage of FDMA is that filters can be used to seperate signals. It channels require no synchronization or central timing. each ~~co~~ channel is almost independent of all other channels.

Discuss TDMA with examples?

TDMA:

TDMA stands for time division multiple access. [It is] a multiplexing method that divides network connections into time slices, where each device on the TDMA network connection gets one or more time slices during which it can transmit or receive data. The carrier modulation used in TDMA is always a digital modulation scheme.

Example:

In TDMA the earth stations that share the satellite transponder use a carrier at the same centre frequency for transmission on a time division basis. Earth stations are allowed to transmit traffic bursts in a

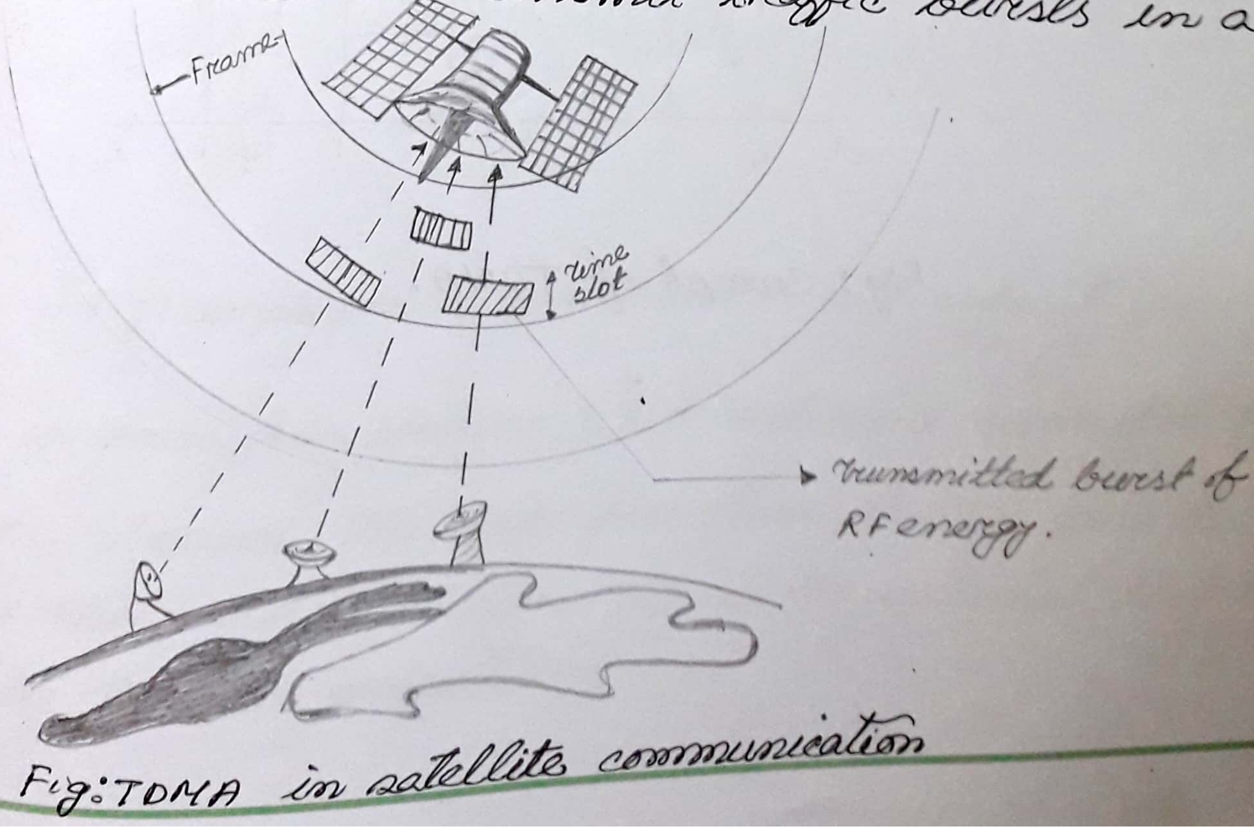

Fig: TDMA in satellite communication

periodic time frame called the TDMA frame.

During the burst, an earth station has the entire transponder bandwidth available to it for transmission the transmit by tyming of the bursts is carefully synchronized so that all the bursts arriving at the transponder are closely spaced in time but do not overlap. The satellite transponder receives one bursts at a time, amplifies it, and retransmits it back to earth. Thus every earth station in the satellite beam served by the transponder can receive the entire burst stream and extract the bursts intended for it. TDMA is illustrated in figure:

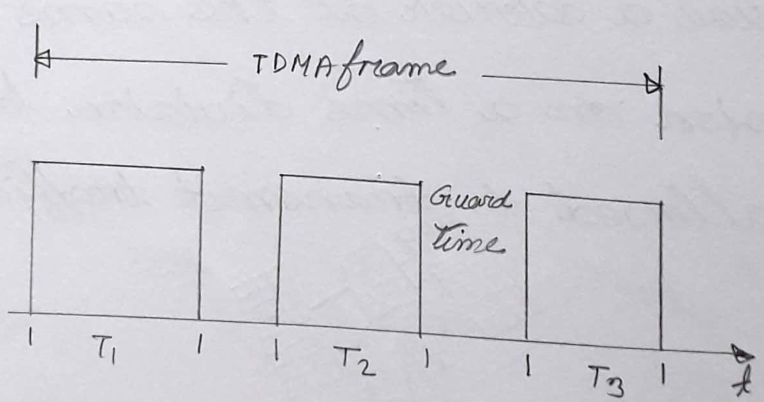

Fig: Concept of TDMA.

→ What is CDMA? Discuss CDMA with encoding and decoding?

CDMA:

Code division multiple access (CDMA) is a form of multiplexing and a method of multiple access that divides up a radio channel not by time, nor by frequency, but instead by using different pseudorandom code sequences for each user. It is a form of "spread-spectrum" signalling.

Idea:

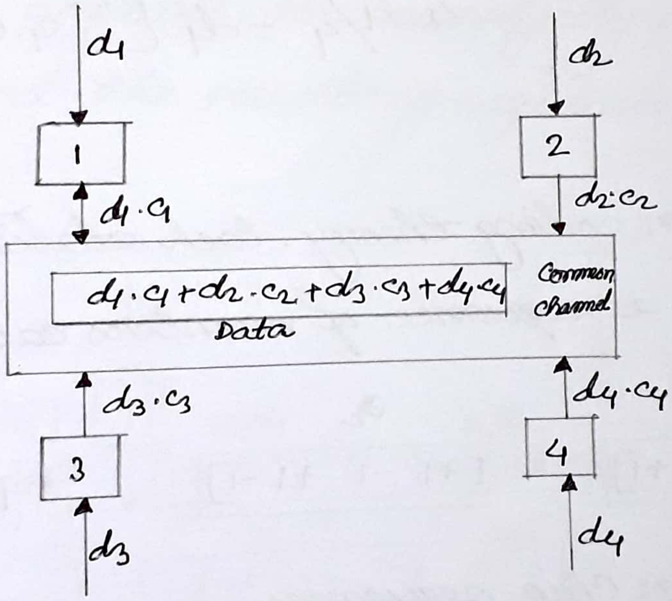

Fig: Simple idea of communication with code.

Assume we have four stations, 1, 2, 3 and 4 are connected to the same channel. The data for these stations are d_1, d_2, d_3, d_4. and the codes are c_1, c_2, c_3, c_4. We assumed that the assigned code has two properties:

- If we multiply each code by another, we get 0.
- If " " " " " itself, we get 4.

Station 1 multiplies its data by its code to get $d_1 \cdot c_1$, for station 2, $d_2 \cdot c_2$ and so on.

Now, station 4 ~~have to~~ receives the station 1' data. So it multiplies by station 1 code and divide by 4 to find the data.

$\therefore$ data of station 1 $= (c_1 \cdot d_1 + c_2 d_2 + c_3 d_3 + c_4 d_4) \cdot c_1 / 4$

$= 4 d_1 / 4 = d_1$ [$\because c_1 \cdot c_1 = 4$; $c_1 \cdot c_2 = 0$]

Chips:

CDMA is based on coding theory. Each station is assigned a code, which is a sequence of numbers called chips.

c_1: [+1 +1 +1 +1]

c_2: [+1 -1 +1 -1]

c_3: [+1 +1 -1 +1]

fig: Chip sequences

Data representation:

We follow these rules for encoding: If a station needs to send a 0 bit, it encodes it as -1; if it needs to send 1 bit, it encodes it as $+1$.

Encoding and decoding :

As a simple example, we show how four stations share the link during a 1-bit interval. The procedure can easily be repeated for additional intervals. We assume that stations 1 and 2 are sending 0 bit and 4 sending 1. station 3 is silent. The data at the sender site is translated into -1, -1, 0, +1. Each station multiplies the corresponding number by its chip, which is unique for each station. The result is a new sequence which is sent to the channel. For simplicity, we assume that all stations send the resulting sequence at the same time.

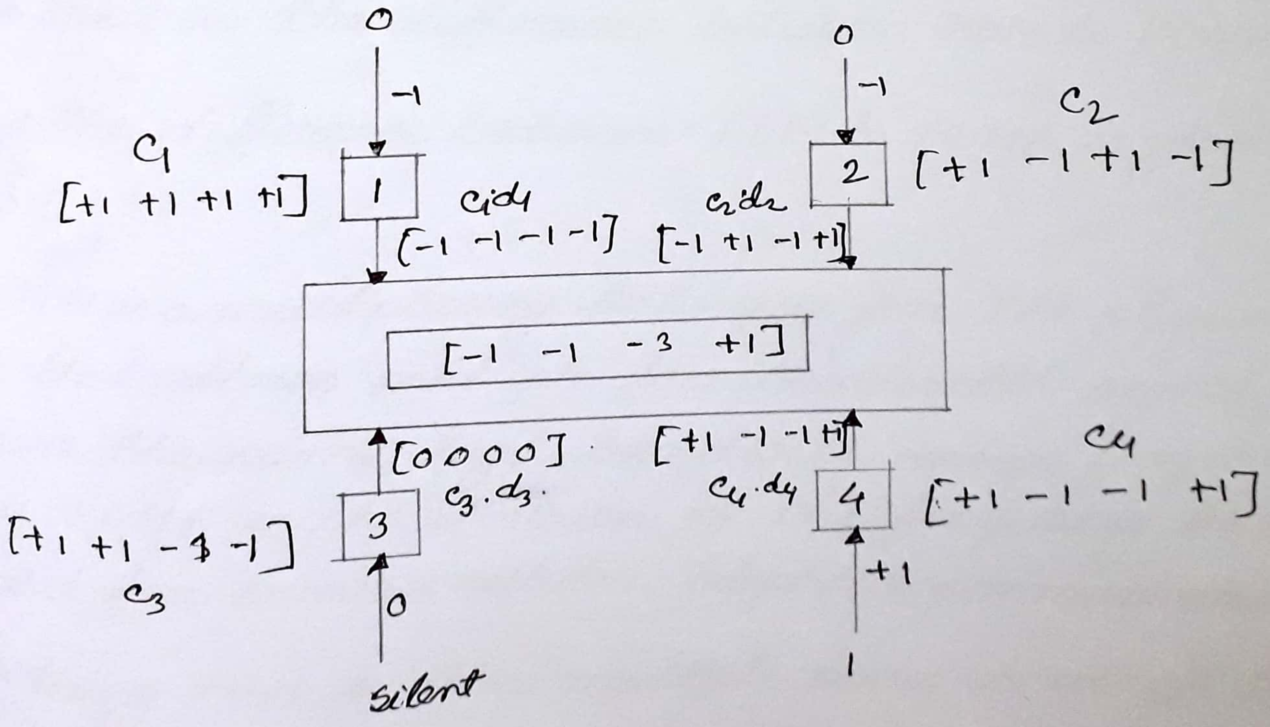

Fig : Sharing channel in CDMA.

Now imagine station 3, which we said silent, is listening to station 2. station 3 multiplies the total data on the channel by the code for station 2. which is [+1 -1 +1 -1] to get,

$$[-1 \ -1 \ -3 \ +1] \cdot [+1 \ -1 \ +1 \ -1] = -4/4 = -1 \text{ bit } 1.$$

→ What is the difference between TDM to TDMA?

Ans: The difference between TDM and TDMA is given below:

→ In TDM, all multiplexed data channels come from the same transmitter, which means that clock and carrier frequencies do not change. But in TDMA, each frame contains a number of independent transmissions i.e. signals multiplexed from different sources.

→ TDM imply partitioning bandwidth of the channel connecting two nodes into finite set of time slots. TDMA imply partitioning the bandwidth of a channel shared by many nodes, where each node gets to access its dedicated time slot.

→ What is the difference between FDM to FDMA?

Ans: The difference between FDM to FDMA is given below:

→ FDM is a multiplexing technique for the physical layer that allows multiple low bandwidth signals to share the same high bandwith ~~range~~ frequency range. FDMA is the division of the frequency band allocated for wireless cellular telephone communication.

→ Using FDM to allow multiple users to utilize the same bandwidth is called FDMA.

→ FDM uses a physical multiplexer, while FDMA does not.

→ FDM is multiplexing process where FDMA is multiple access process.

→ FDM is generally is used in general communication such as cable transmission. FDMA generally is used in satellite communication.

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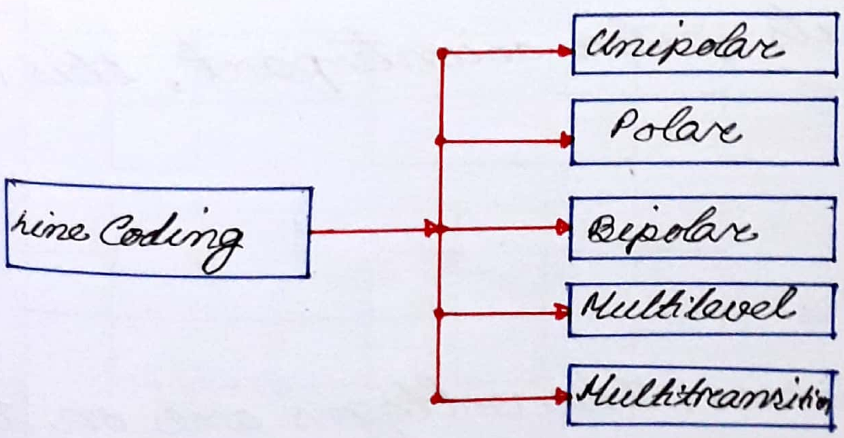
LINE CODING

• Line coding:

Line coding is the process of converting digital data [to] digital signals. We assume that data, in the form [of] text, numbers, graphical images, audio or video, [are] stored in computer memory as sequences as bits. [Line] coding converts a sequence of bits to a digital [sig]nal. At the sender, digital data are encoded [in]to a digital signal; at the receiver, the digital [da]ta are recreated by decoding the digital signal.

• Line coding schemes:

We can roughly divide line coding schemes [in]to five broad categories. They are:

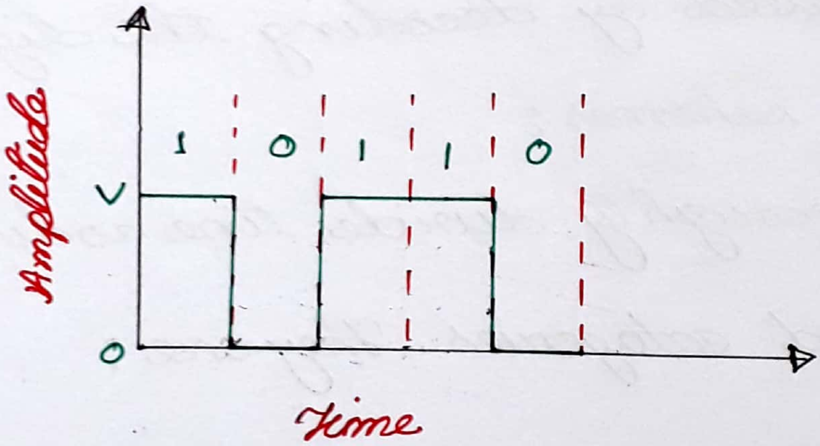


• Unipolar scheme:

In a unipolar scheme, all the signal levels are on [o]ne side of the time axis, either above or below.

Unipolar → NRZ.

• **NRZ:** NRZ (Non-Return-to zero) traditionally, a unipolar scheme was designed as a non-return-to-zero scheme in which the +ve voltage defines bit 1 and the zero voltage defines bit 0. It is called NRZ cause the signal does not return to zero at the middle of the bit.



compared with its polar counterpart, this scheme is very costly.

• **Polar schemes:**

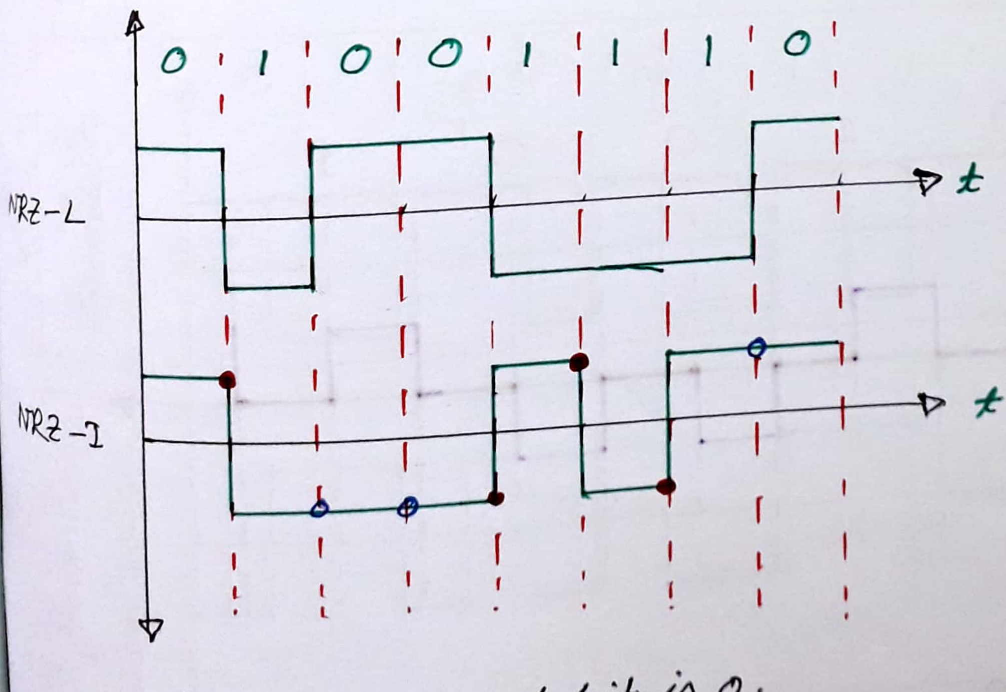
In polar schemes, the voltages are on the both sides of the Time axis. For example, the voltage level for 0 can be +ve and the voltage level for 1 can be negative.

Polar → NRZ, RZ, and biphase (Manchester, Differential Manchester).

• NRZ: In polar NRZ encoding, we use two levels of voltage amplitude. We can have two versions of polar NRZ: NRZ-L and NRZ-I.

NRZ-L, the level of the voltage determines the value of the bit.

NRZ-I, the change or lack of of change in the level of the voltage determines the value of the bit. If there is no change the bit is 0, and for change the value of bit is 1.



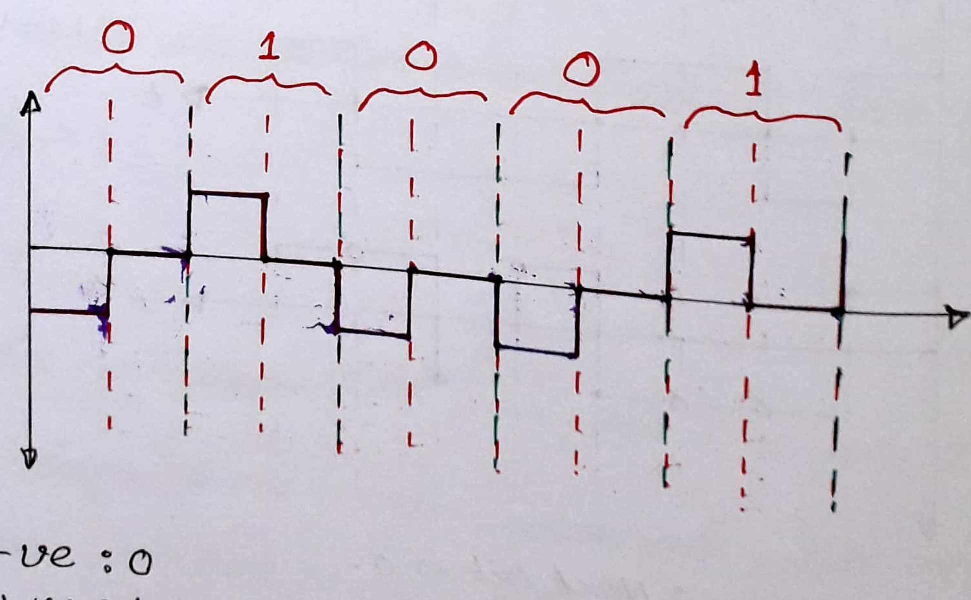
0: +ve.
1: -ve.

○ No inversion: Next bit is 0.

• Inversion: Next bit is 1.

• **RZ :** Return to zero, the main problem with NRZ encoding occurs when the sender and receiver clock are not synchronized. The receiver does not know when one bit has ended and the next bit is starting. One solution is the return-to-zero scheme, which uses three values: +ve, −ve and zero. In RZ the signal changes not between bits but during the bit.

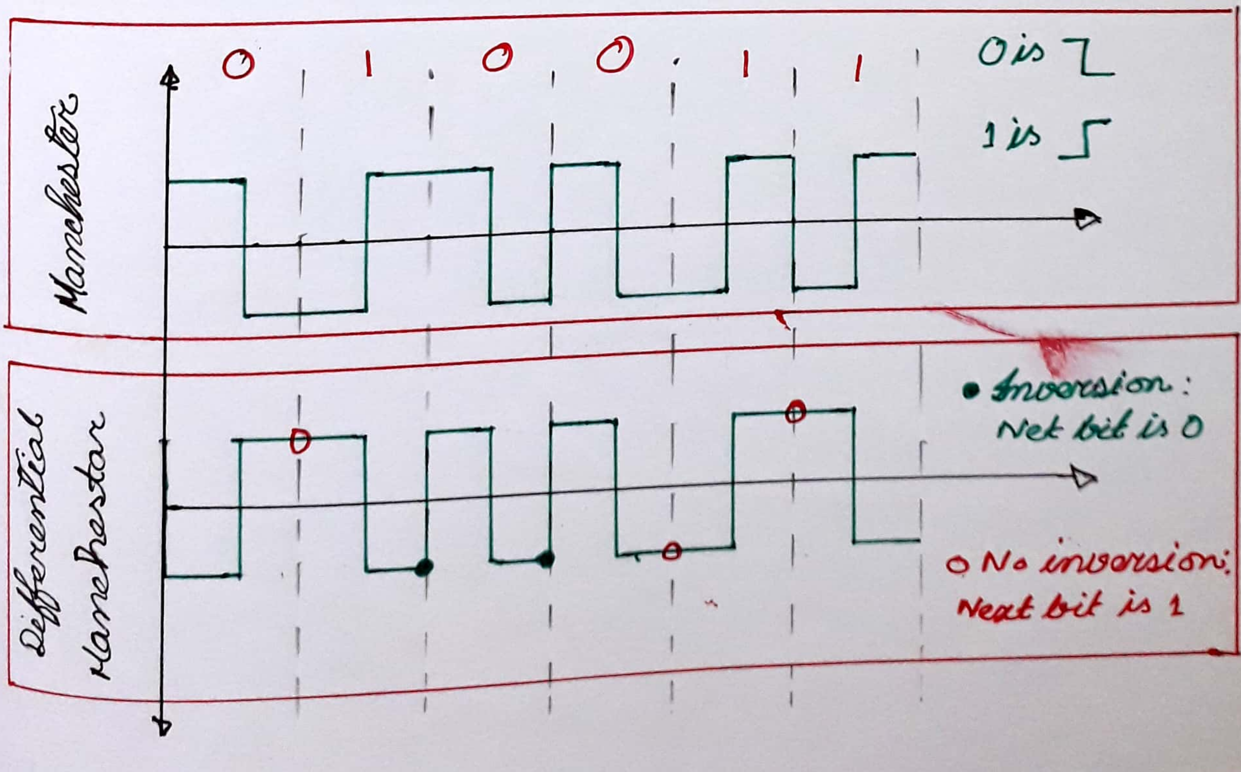
In figure we see that the signal goes to zero in the middle of each bit. It remains until the begining of the next bit. The main disadvantages of RZ encoding is that it requires two signal changes to encode a bit and therefore occupies greater bandwidth.



−ve : 0
+ve : 1

• Biphase : Manchestar and Differential Manchestar. The idea of RZ and the idea of NRZ-L are combined into the Manchestar scheme. In Manchestar encoding the duration of the bit is devided into two halves. The voltage remain at one level during the first half and moves to the other level during the second half. The transition at the middle of the bit provides synchronization. RZ + NRZ-L.

Differential manchestar, on the otherhand, combines the RZ and NRZ-I. There is always a transition at the middle of the bit, but the bit values are determined at the begining of the bit. If the next bit is 0, there is a transition, if the next bit is 1, there is none. RZ + NRZ-I



- Bipolar : AMI and Pseudoternary.
- Multilevel : 2B/1Q, 8B/6T, and 4D-PAM5.
- Multitransition : MLT-3

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