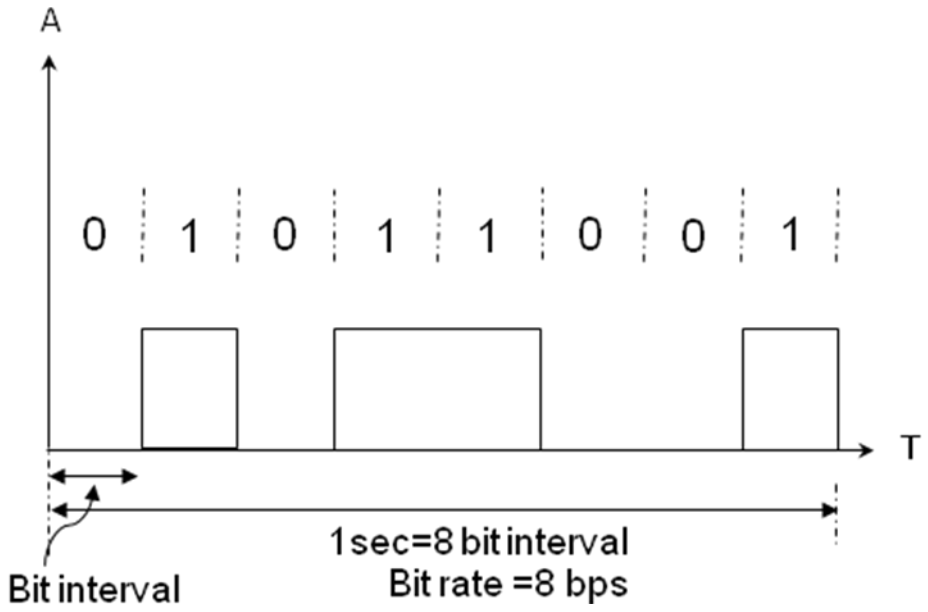
Digital Signals and Digital Transmission

In addition to being represented by an analogue signal, data also be represented by digital signal. For example, 1 can be encoded as positive voltage and 0 as a zero voltage as shown:



A digital signal can be decomposed into an infinite number of simple sine waves called harmonics, each with a different amplitude, frequency, and phase. This means that when we send a digital signal along a transmission medium, we are sending an infinite number of simple signals.

To receive and extract replica of the digital signal, all of the frequency components must be faithfully transferred through transmission medium. If some of the components are not passed through the medium (such as a cable) always has a distortion. If we send only components whose amplitudes are significant, we can still recreate the digital signal with reasonable accuracy at the receiver.

Example:

To see the effect of band width, let's take the ASCII code for letter (b) which is (01100010). The time required to transmit the character depends on both the encoding method and the signaling speed:

Suppose that bit rate = ? bps.

Time required to transmit 8 bits = T = $\frac{8}{?}$ $(\frac{bit}{bit/\sec})$ = $\frac{8}{?}\sec$

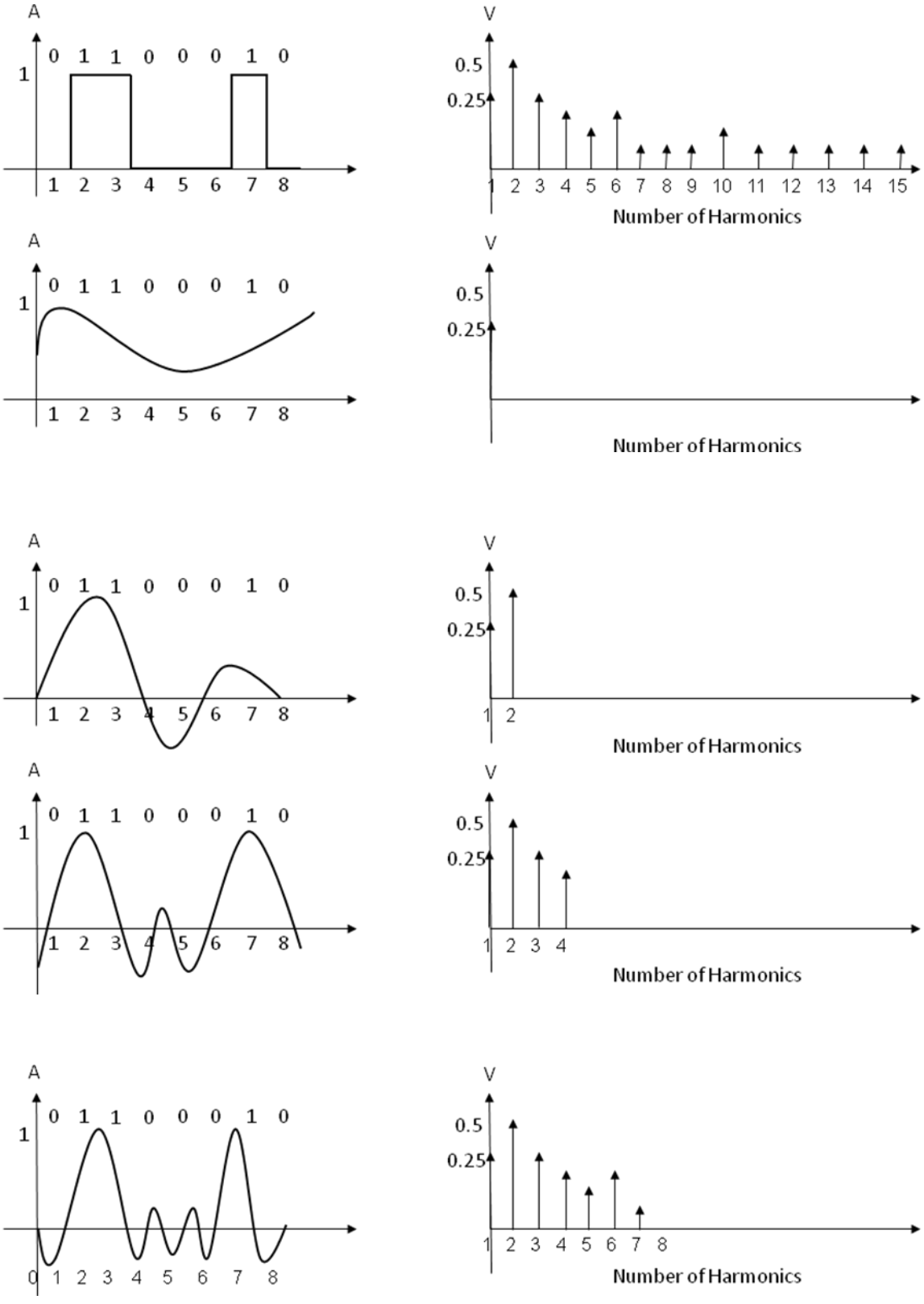
Frequency of first harmonic = $f_1 = \frac{1}{T} = \frac{?}{8}$ Hz

If we take telephone line, then the cutoff frequency = f_c = 3000 Hz.

The number of highest harmonic passed through = $\frac{fc}{f1} = \frac{3000}{?/8} = \frac{24000}{?}$.

If bit rate = ?= 9600 bps then the highest harmonic passed through telephone line = $\frac{24000}{9600} = 2.5$

This means that only two harmonics are appeared, as shown in figure below. We can say that limiting the band width limits the data rate, even for perfect channels.


A
1
0 1 1 0 0 0 1 0
1 2 3 4 5 6 7 8
V
0.5
0.25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Number of Harmonics
A
1
0 1 1 0 0 0 1 0
1 2 3 4 5 6 7 8
V
0.5
0.25
Number of Harmonics
A
1
0 1 1 0 0 0 1 0
1 2 3 4 5 6 7 8
V
0.5
0.25
1 2
Number of Harmonics
A
1
0 1 1 0 0 0 1 0
1 2 3 4 5 6 7 8
V
0.5
0.25
1 2 3 4
Number of Harmonics
A
1
0 1 1 0 0 0 1 0
0 1 2 3 4 5 6 7 8
V
0.5
0.25
1 2 3 4 5 6 7 8
Number of Harmonics

The following table explains the relation between data rate and harmonics:

Data rate Bps	T (msec) 8/bps	First harmonic(Hz) $f_1=\frac{1}{T}$	Harmonic sent=$\frac{fc}{f1}=\frac{3000}{f1}$ (if telephone line is used)
300	26.67	37.5	80
600	13.33	75	40
1200	6.67	150	20
2400	3.33	300	10
4800	1.67	600	5
9600	0.83	1200	2
19200	0.42	2400	1
38400	0.21	4800	0

Maximum Data Rate of Channel

Nyquist Theorem:

- ✓ For noiseless channel:

Max. data rate = $2H \log_2 V$ bit/sec.

Where :

H → bandwidth

V → signal levels; binary signal has 2 levels

Shannon result for noisy channel:

Max. number of data rate (bit/sec)= $H \log_2 (1+ \frac{S}{N})$

Where:

H $\rightarrow$ Bandwidth

$\frac{S}{N}$ $\rightarrow$ Signal to noise ratio.

Example:

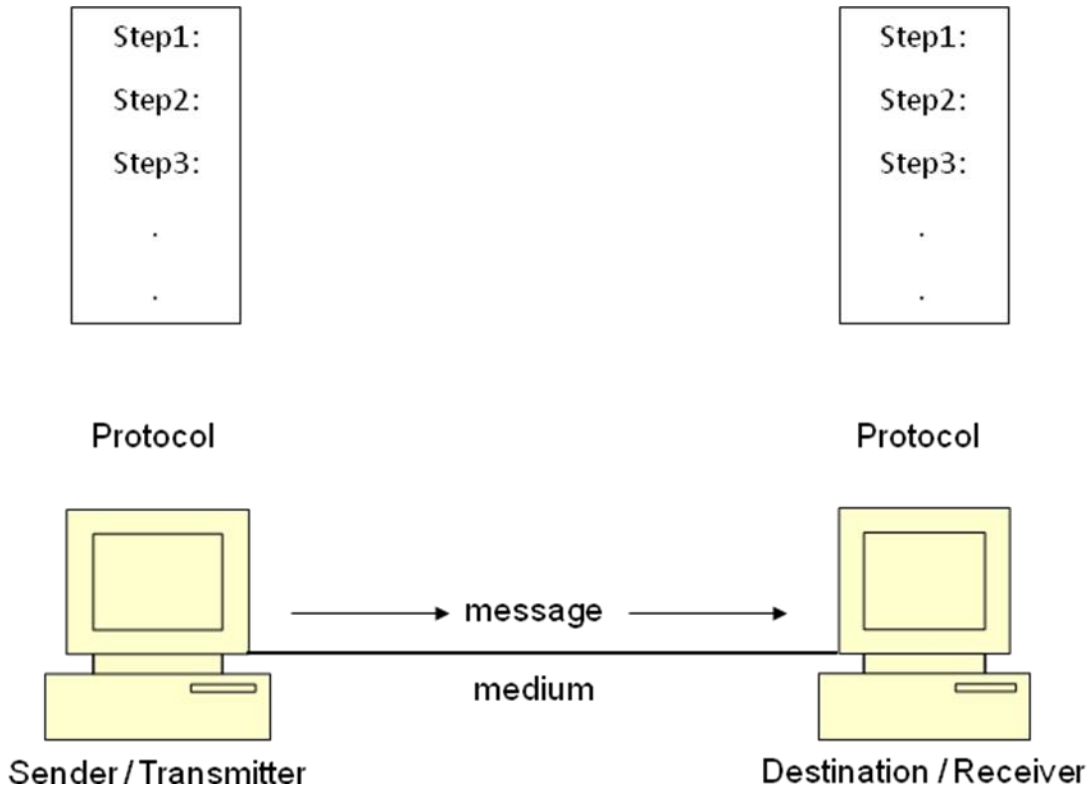
If a binary signal is sent over 3 KHz channel whose signal to noise ratio is 30 dB. What is the maximum achievable data rate?

Max. number of data rate=H $\log_2 (1+ \frac{S}{N})$

dB=10 $\log_{10} \frac{S}{N}$, 30=10 $\log_{10} \frac{S}{N}$, $10^3 = \frac{S}{N}$ =1000

Maximum number of data rate=3000 $\log_2(1+1000)$=29884.3 bps

Data Communication System Components:



1-Message: is the information (data) to be communicated.

2-Sender: is the device that sends the data message.

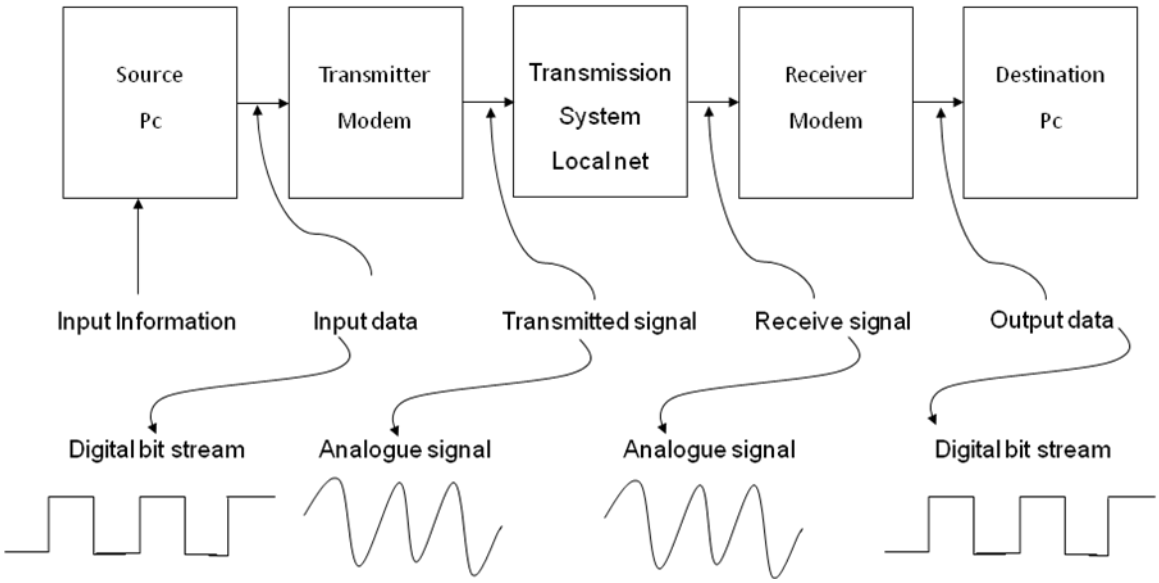
3-Receiver: is the device that receives the data message.

4-Medium: is the physical path by which a message travels from sender to receiver.

5-Protocol: is a set of rules that govern data communication. It represents an agreement between the communicating devices. Without protocol, two devices may be connected but not communicating, just as a person speaking French cannot be understood by a person who speaks only Japanese.

Note: The term telecommunications, which includes telephony, telegraphy, and television, means communication at a distance (tele: is Greek word for far).

Simplified Data Communications Model:



Modulation:

Modulation is a process where two input signals (a constant carrier frequency signal and a variable signal that carries information) are combined to produce a unique output signal.

Modulation Methods:

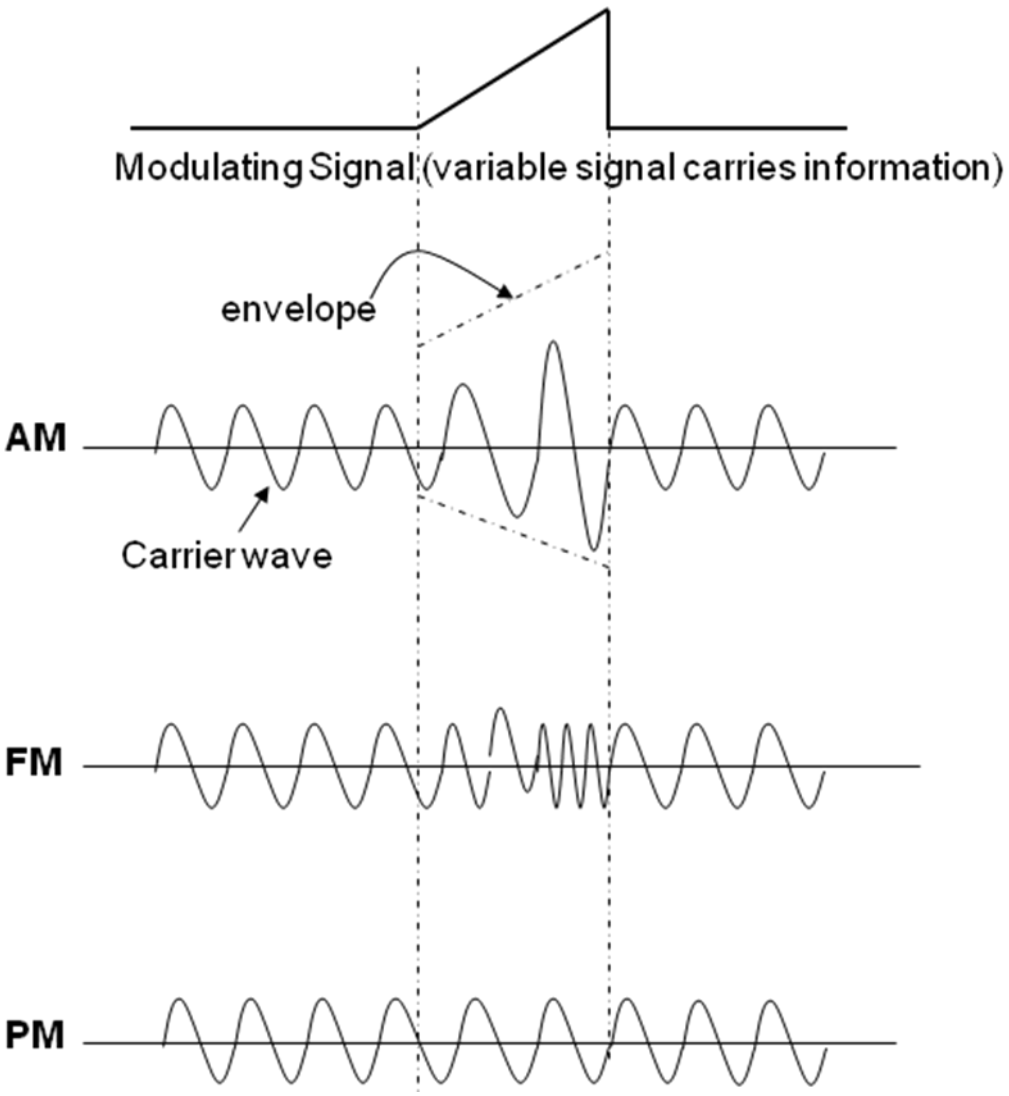
1- Analogue Modulation:

This type of modulation includes:

a- Amplitude Modulation: (AM).

b- Frequency Modulation (FM).

c- Phase Modulation (PM).



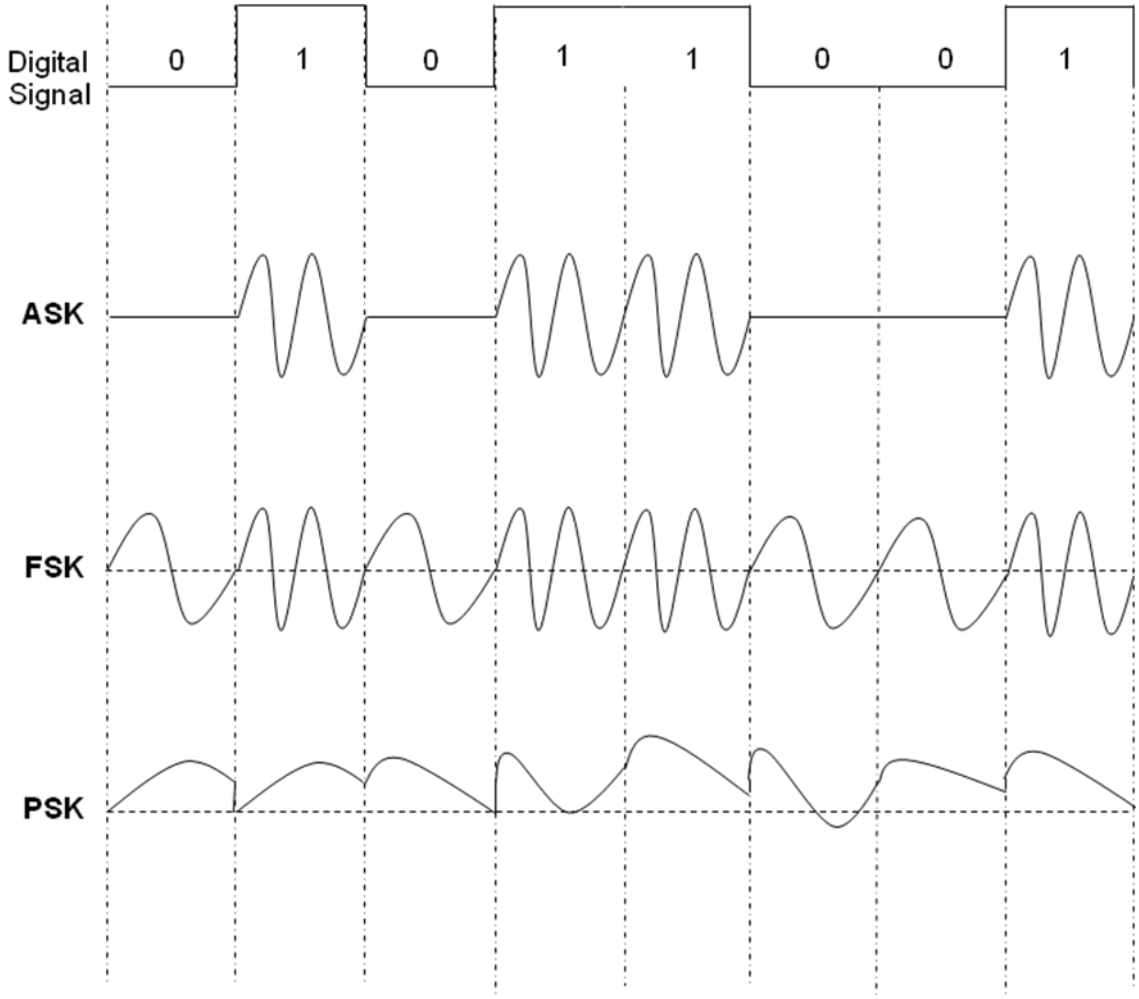
2- **Digital Modulation**:

This type of modulation includes:

a- **A**mplitude **S**hift **K**eying (**ASK**).

b- **F**requency **S**hift **K**eying (**FSK**).

c- **P**hase **S**hift **K**eying (**PSK**).



Modem (<u>M</u>odulator – <u>Dem</u>odulator):

It is a device that accepts serial bits as input and produces a modulated carrier as output (or vice versa). The modem is inserted between the (digital) computer and the (analogue) telephone system (wire).

If an ideal transmission medium existed, there would be no need for modems. i.e., the receiver and transmitter would be connected by ideal medium and the received pulse would be identical to the transmitted pulse and the life of communication would be very simple. But, such transmission medium is not existed, and modems are used for two reasons:

1- Because the telephone interface to the subscriber is mostly analogue, the digital signal from the computer must be modulated, that means changed into an analogue signal before it is sent over the telephone line.

2- large Fourier components) and thus are subject to strong attenuation and delay distortion.

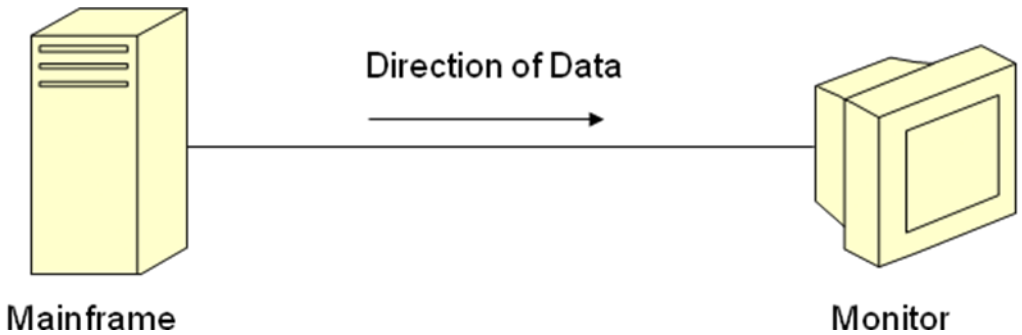
A personal computer modem can be either internal card or an external unit, which is then connected with a cable to the computer's serial port.

Transmission Mode:

The term transmission mode is used to define the direction of signal flow between two linked devices. There are three types of transmission modes:

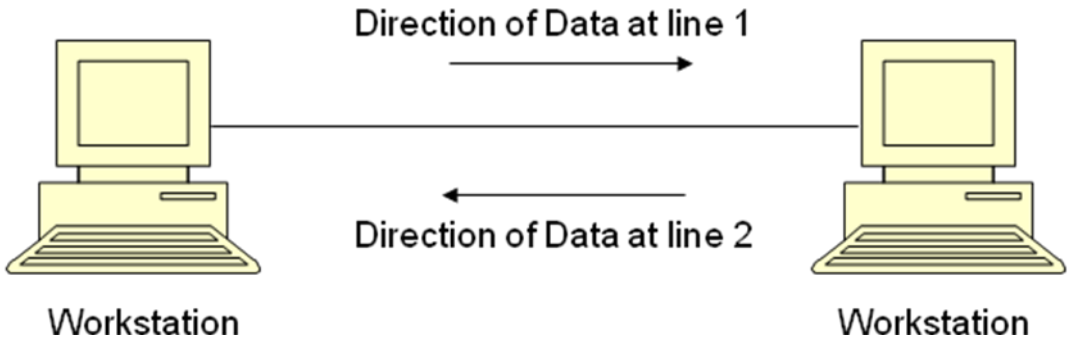
1- Simplex:

In simplex mode, the communication is unidirectional. Only one of the two stations on the link can transmit; the other can only receive.



2- Half (Semi) Duplex:

In half duplex mode, each station can both transmit and receive but not at the same time.



3-Full Duplex:

In full duplex mode (also called Duplex), both stations can both transmit and receive simultaneously.