# 2. Data Transmission

## 2.1 Transmission Terminology (Simplex, Duplex)

The term transmission mode defines the direction of data flow between the communication devices. It can be simplex, half duplex or full duplex.

## Simplex, Half Duplex, Full Duplex Communications

In **simplex mode**, the communication is unidirectional. That is, only one of the two devices on a link can transmit and the other can only receive. Since the communication is unidirectional, there is no acknowledgement policy due to which there will be no any response from the receiver regarding any error in the data being received or even no confirmation to the safe and sound receipt of the transmitted signal. For example, traditional keyboards, monitors and printers involve simplex communication; the keyboard can only introduce input, and the printer or monitor can only accept output.

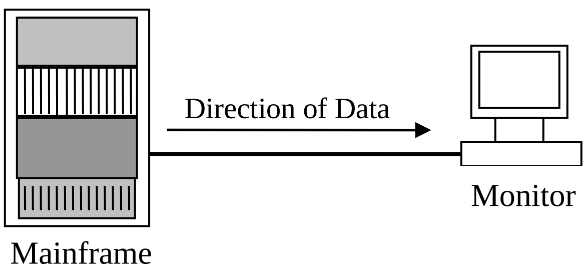
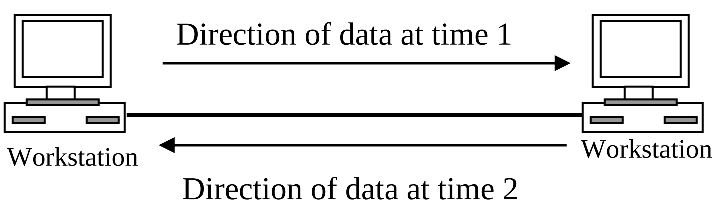



**Figure 2.1** Simplex Communication

In **Half Duplex mode,** each station can both transmit and receive, but not at the same time. That is, the communication is bidirectional but at alternate timings. It is also known as “two way alternate” communication mode. In this case, when one device is sending, the other can only receive and vice versa. Typically, once a party begins receiving a signal, it must wait for the transmitter to stop transmitting, before replying. The entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time. Walkie-talkie is a half duplex system.



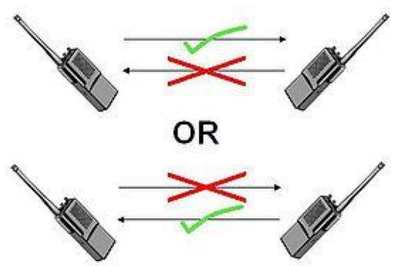
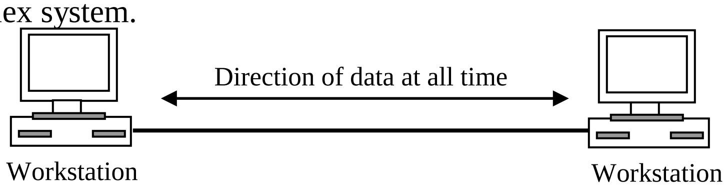




**Figure 2.2** Half Duplex Communication

In **Full Duplex mode,** both stations can transmit as well as receive simultaneously. That is, the communication is bidirectional that occurs simultaneously. In this case, signals going in either direction share the capacity of the link. This sharing can occur in two different ways; either the link must contain two physically separated transmission paths or channels, one for sending and the other for receiving, or the capacity of the channel is divided between signals traveling in both directions. Telephone network is a full duplex system.



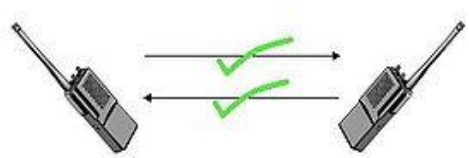



**Figure 2.3** Full Duplex Communication

Full-duplex Ethernet connections work by making simultaneous use of two physical pairs of twisted cable (which are inside the jacket), wherein one pair is used for receiving packets and one pair is used for sending packets (two pairs per direction for some types of Ethernet), to a directly connected device. This effectively makes the cable itself a collision-free environment and doubles the maximum data capacity that can be supported by the connection.

There are several benefits to using full-duplex over half-duplex. First, time is not wasted, since no frames need to be retransmitted, as there are no collisions. Second, the full data capacity is available in both directions because the send and receive functions are separated. Third, stations (or nodes) do not have to wait until others complete their transmission, since there is only one transmitter for each twisted pair.

## 2.2 Bandwidth and Frequency

Frequency is a measure of the number of occurrences of a repeating event per unit time. It is the rate of change of signal with respect to time. If the value of a signal changes over a short span of time, its frequency is high and if it changes over a long span of time, its frequency is low. It is expressed in hertz(HZ).

*Frequency Range*

| **Frequency** | **Band Name** | **Application** |
|---|---|---|
| 3 – 30 Hz | Super Low Frequency – SLF | Communications with Submarines |
| 30 - 300 HZ | Ultra Low Frequency - ULF | Communication in mines |
| 50Hz | Alternating Current | Power Supply |
| 3 – 30 KHz | Very Low Frequency - VLF | Military Communicaitons, Wireless heartmonitors |
| 30 – 300 KHz | Low Frequency - LF | Navigation, timesignals, AM-longwave transmissions |
| 0.3 to 3 MHz | Medium Frequency – MF | AM transmission |
| 3 – 30 MHz | High Frequency - HF | Short wave transmission |
| 30 – 300 MHz | Very High Frequency – VHF | FM radio and television broadcasts |

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The bandwidth of a frequency is simply the difference between upper and lower frequencies. However, bandwidth can be defined as follows:

i.) In computer networks, bandwidth is often used as a synonym for data transfer rate - the amount of data that can be carried from one point to another in a given time period (usually a second). This kind of bandwidth is usually expressed in bits (of data) per second (bps). Occasionally, it's expressed as bytes per second (Bps). In general, a link with a high bandwidth is one that may be able to carry enough information.

ii.) In electronic communication, bandwidth is the width of the range (or band) of frequencies that an electronic signal uses on a given transmission medium. In this usage, bandwidth is expressed in terms of the difference between the highest-frequency signal component and the lowest-frequency signal component. Since the frequency of a signal is measured in hertz(the number of cycles of change per second), a given bandwidth is the difference in hertz between the highest frequency the signal uses and the lowest frequency it uses. A typical voice signal has a bandwidth of approximately three kilohertz (3 kHz); an analog television (TV) broadcast video signal has a bandwidth of six megahertz (6 MHz) -- some 2,000 times as wide as the voice signal.

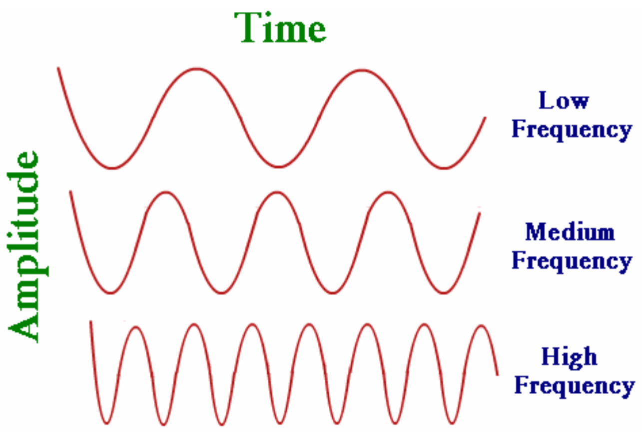



Fig. 1. Frequency

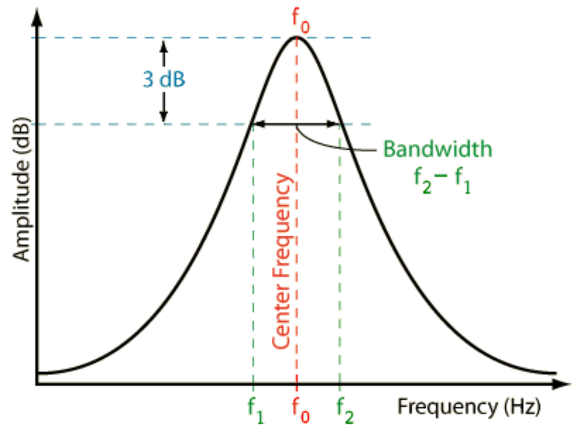



Fig. 2. Bandwidth

## 2.3 Serial and parallel transmission

Considering wired transmission, the major concern during transmission of data from one device to another is the data stream. That is, whether we send the data 1 bit at a time or we group bits into larger groups. The transmission of binary data across a link can be accomplished either in parallel or serial mode. In parallel mode, multiple bits are sent with each clock tick while 1 bit is sent with each clock tick in serial mode.

## Parallel Transmission:

Binary data consists of 1s and 0s and these bits can be organized into groups of *n* bits each. In fact computers produce and consume data in groups of  bits. Then by grouping the bits, we can send *n* bits of data at a time instead of a single bit. This is called **Parallel Transmission.** Thus the mechanism of grouping of bits and sending *n* bits at a time is called parallel transmission. Each bit in parallel transmission has its own wire, and all *n* bits of one group can be transmitted with each clock pulse from one device to another. This is the simultaneous transmission of multiple bits.

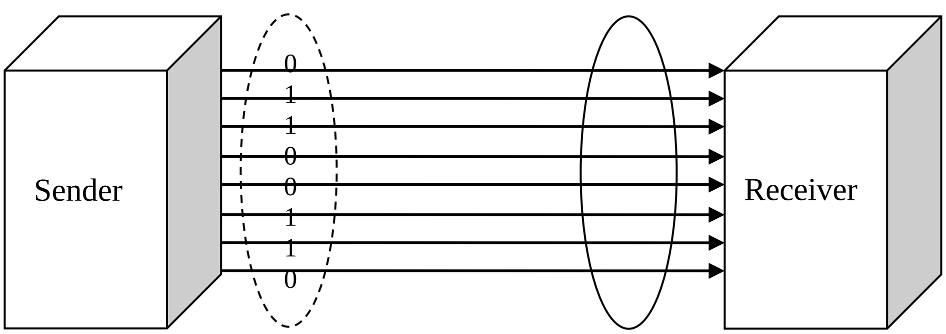



**Figure 2.4** Parallel Transmission

In the figure above, there are eight transmission lines bundled together for parallel transmission. Here the bits across each wire are transmitted together, i.e. *n*=8.

The advantage of parallel transmission is speed, since *n* bits can be transferred at once.

However, it is disadvantageous in terms of cost at it requires *n* communication lines to transmit the data stream and is thus preferred for short distances only.

Also that, parallel ports suffer extremely from **inter-symbol interference** (ISI) and noise, and therefore the data can be corrupted over long distances. Also, because the wires in a parallel system have small amounts of capacitance and mutual inductance, the bandwidth of parallel wires is much lower than the bandwidth of serial wires.

Example of parallel mode transmission include connections between a computer and a printer (parallel printer port and cable), IDE( **integrated development environment)** harddisk connectors, etc.

## Serial Transmission:

Unlike the parallel transmission in which *n* bits are transmitted at once, only one bit is transmitted at a time in **serial transmission**. During transmission, one bit follows the other, due to which we only need single communication channel rather than *n* channels.

The primary advantage of serial over parallel transmission is that, it only requires a single communication channel which further reduces the cost of transmission over parallel by a factor of *n*. But it is a fact that communication within devices is parallel, so conversion devices are required at the interface between the sender and the line (parallel-to-serial) and between the line & the receiver (serial-to-parallel). Compared to parallel transmission, it is slower as one bit is transferred at each clock tick, however, is preferred for longer communication.

Examples of serial mode transmission include connections between a computer and a modem using the RS-232 **protocol**. Other examples are USB(Universal Serial Bus), SATA (Serial Advanced Technology Attachment) and PCI(**Peripheral Component Interconnect)** Express cards.

It further can occur in one of the two ways – synchronous or asynchronous.

### i. Synchronous Transmission

In **synchronous transmission**, the bit stream is combined into longer "frames", which may contain multiple bytes. These frames are then sent continuously with or without data to be transmitted. That is, each byte is transmitted without a gap between it and the next one. In other words, data are transmitted as an unbroken string of 1s and 0s, and the receiver separates that string into the bytes or characters to reconstruct the information.

Thus in synchronous transmission, bits are sent one after another without start/stop bits or gaps and the receiver is responsible to group the bits. However, timing is very important.

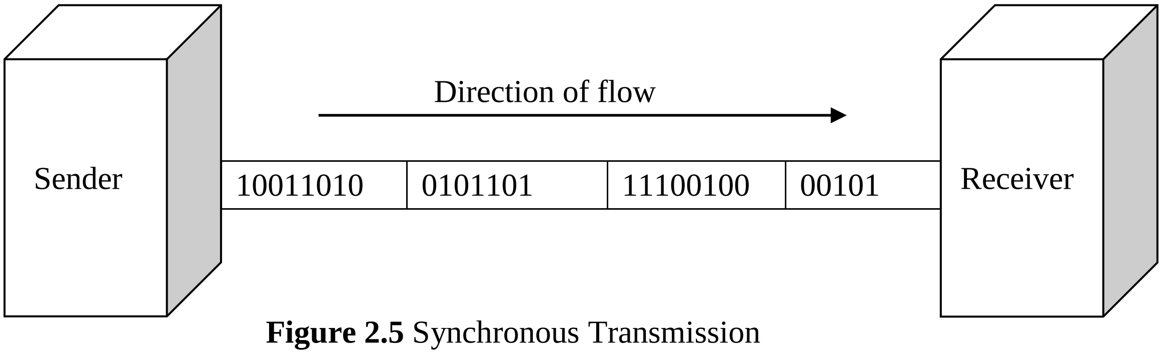



**Figure 2.5** Synchronous Transmission

Its advantage is speed. Since there are no extra bits or gaps in the bit stream, it requires no mechanism to introduce extra bits at the sending end and also does not require to remove at the receiving end which makes it faster than the asynchronous transmission.

It is useful for high speed applications.

## ii. Asynchronous Transmission

In asynchronous transmission, groups of bits are sent as independent units with start/stop flags and no data link synchronization, to allow for arbitrary size gaps between frames. Here, the timing of a signal is not important; rather, the information is received and translated by agreed-upon patterns. The receiving device can receive the information as long as the pattern is followed without any regard to the rhythm of the data being sent. The patterns are based on grouping the bit stream into bytes and each group, usually 8 bits, is sent along the link as a unit.

Since there is no synchronization, the receiver can not use timing to predict when the next group will arrive. So to alert the receiver to the arrival of a new group, an extra bit is added to the beginning of each byte, usually a 0 bit called the **start bit.** Further, to let the receiver know that the byte is finished, 1 or more additional bits are appended to the end of the byte, usually 1s, called **stop bits.** Thus, each byte is increased in size to at least 10 bits (out of which 8 are information and 2 or more are signals to the receiver). In addition to this, the transmission of each byte may be followed by a gap of varying duration which can be represented either by an idle channel or by a stream of additional stop bits.

At the byte level, the sender and receiver do not have to be synchronized but within each byte, the receiver must still be synchronized with the incoming bit stream, which is required only for the duration of a single byte. When the receiver detects a start bit, it sets a timer and begins counting bits as they come in. After *n* bits, the receiver looks for a stop bit. As soon as it detects the stop bit, it waits until it detects the next start bit.

Since there is addition of stop/start bits and also the gaps are inserted into the bit stream, it makes asynchronous transmission slower.

It is cheap and effective.

Preferred for low-speed communication.

For example, the connection of a keyboard to a computer is a natural application for asynchronous transmission.

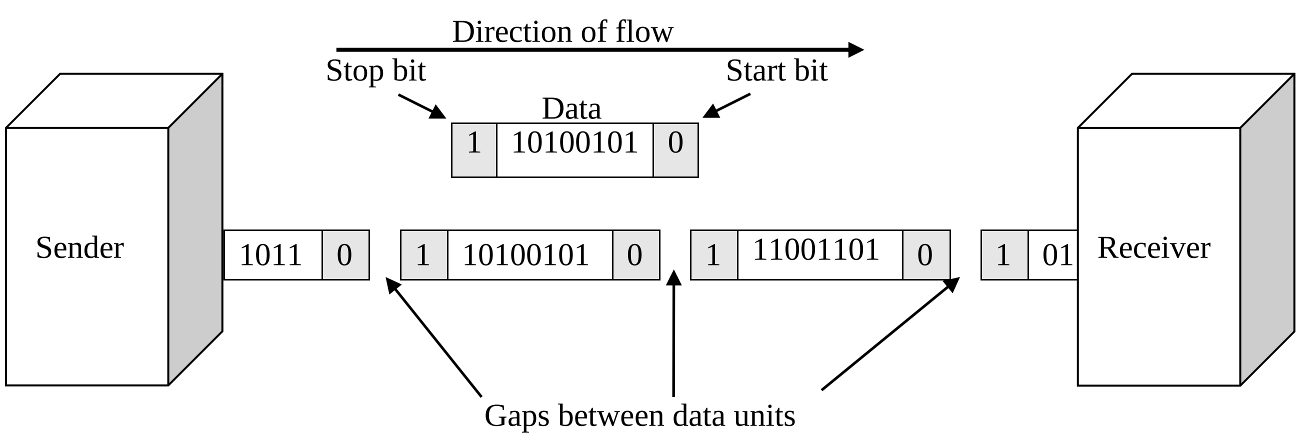
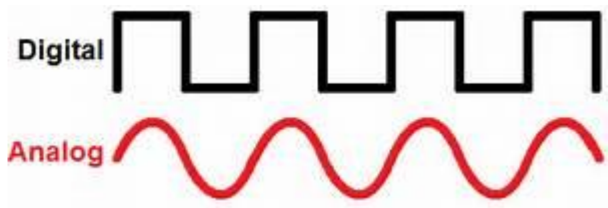



**Figure 2.5** Asynchronous Transmission

## 2.4 Analog and Digital Transmissions

Analog signal is a continuous signal which represents physical measurements. The information carried by analog signal is translated into electric pulses of varying amplitude. It is denoted by sine waves. Whereas, Digital signal is a discrete signal represented in digital form. The information carried by digital signal is translated into binary format (i.e.0 or 1) where each bit represents two distinct amplitudes. It is denoted by square waves.




**Analog transmission** is a method of conveying voice, data, image, signal, or video information. It uses a continuous signal varying in amplitude, phase, or another property that is in proportion to a specific characteristic of a variable. Analog transmission could mean that the transmission is a transfer of an analog source signal which uses an analog modulation method (or a variance of one or more properties of high frequency periodic waveform, also known as a carrier signal). FM and AM are examples of such a modulation. The transmission could also use no modulation at all. It is most notably an information signal that is constantly varying. Human voice in air, analog electronic devices are some of the examples. The analog signal is subjected to deterioration by noise during transmission and write/read cycle. The signals are more likely to get affected reducing the accuracy. This kind of transmission costs less.

**Digital transmission** is a transfer of data over a point to point (or point to multipoint) transmission medium –such as copper wires, optical fibers, wireless communications media, or storage media in digital form. The data that is to be transferred is often represented as an electro-magnetic signal (such as a microwave). Digital transmission transfers messages discretely. These messages are represented by a sequence of pulses. However, these messages can also be represented by a limited set of wave forms that always vary. Either way, they are represented using a digital modulation method. Computers, CDs, DVDs, and other digital electronic devices are some of its examples. The digital signals can be noise-immune without deterioration during transmission and write/read cycle. It is less affected since noise response are analog in nature. This kind of transmission is costlier.

## 2.5 Transmission Impairments

Signals are transmitted through transmission media, which are not always perfect due to which there occurs impairments (harm) in the signal. That is, the signal being originally transmitted from the starting end varies with the signal received at the other end. Then for analog signals, these impairments can degrade the signal quality and for digital signals, bit errors may be introduced; a binary 1 is transformed to 0 and vice versa. It occurs, usually, because of attenuation, distortion and noise attached to the signal.

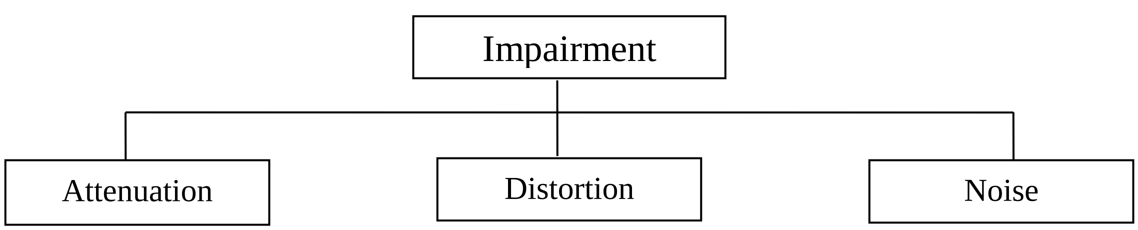



**Fig. 2.6** Impairment Types

## Noise and Interface

During data transmission, the received signal will consist of the transmitted signal, modified by the various distortions imposed by the transmission system, along with some additional unwanted signals that are inserted somewhere between transmission and reception. The latter unwanted signals are referred to as noise. There are mainly four types of such noise i.e., thermal noise, intermodulation noise, crosstalk, and impulse noise.

**Thermal noise** is due to the thermal agitation of electrons and is present in all electronic devices and transmission media. It exists as a function of temperature. It is uniformly distributed across the bandwidths typically used in communication systems and hence often referred to as **white noise.** It cannot be eliminated and is significant for satellite communication.

**Intermodulation noise** occurs when signals at different frequencies share the same transmission medium. The effect of intermodulation noise is that it produces signals at a frequency that is the sum or difference or multiple of the two original frequencies.

**Impulse noise** is caused by spikes on power line or other causes. It is non-continuous, consisting of irregular pulses, or noise spikes of short duration and of relatively high amplitude The impulse noise causes much impairments in digital data communication than in analog ones.

**Crosstalk** is the effect of one wire on the other. It is an unwanted coupling between the two wires that are close to each other. For example, while using the telephone, besides the intended communicators, we also hear other conversation due to crosstalk.

## Delay Distortion :

Distortion is defined as the change in form or shape of a signal. It occurs in a composite signal that is made up of signals with different frequencies. Since each signal component has its own propagation speed through a medium, each has its own delay in arriving at the final destination.

***Delay distortion*** occurs because the velocity of propagation of a signal through a guided medium varies with frequency. For a bandlimited signal, the velocity tends to be highest near the center frequency and fall off toward the two edges of the band. Thus, various frequency components of a signal will arrive at the receiver at different times, resulting in phase shifts between the different frequencies. It is particularly critical for digital data.

## Attenuation :

Attenuation refers to the loss of strength of signal. It is the loss of energy. When a signal, simple or complex travels through a medium, it loses some of its energy so that it can overcome the resistance of the medium. During data transmission over distance through medium, the wires carrying electrical signals get warm, that is, some of the electrical energy in the signal is converted into heat which results into degradation in signal strength. Analog signals are much prone to attenuation than the digital signals.

For guided media, the reduction in strength, or attenuation, is generally exponential and thus is typically expressed as a constant number of decibels per unit distance and for unguided media, it is a more complex function of distance and the makeup of the atmosphere.

In order to compensate this loss, amplifiers are used to amplify the signal.