IT 4505
Section 1.0

Fundamentals of Digital Communications

Section 1.1

The Channel Mode

Section 1.1.1

Channel Characterization

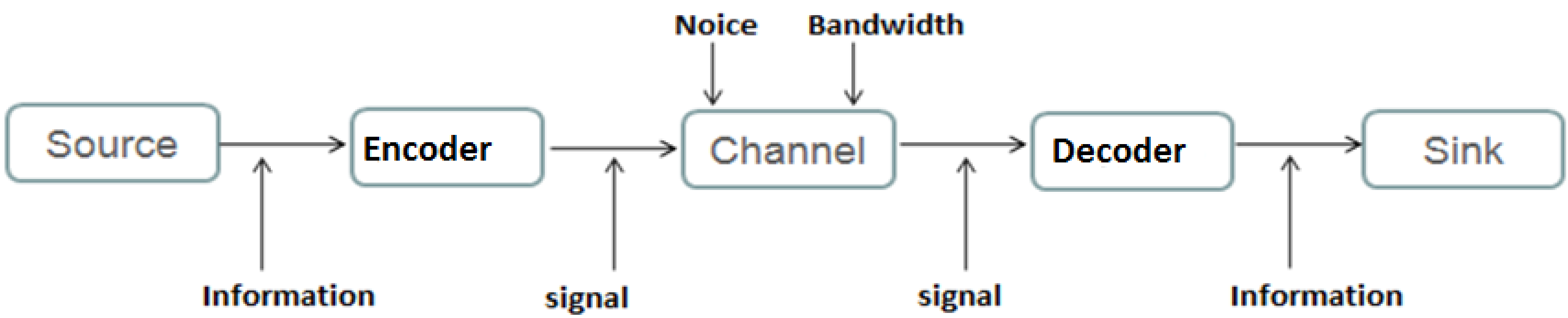
Data Communication

- Communication → exchange of information.

- To have a proper communication session needs:
  - At least 2 parties
  - Communication medium
  - Use of compatible standards (some common grounds)

Data Communication (Contd.)

- Basic building blocks of a data communication system:



E.g.:- e-mail, telephone conversation

Data Communication (Contd.)

Telecommunication:

Any process that permit passage from sender to one or more receivers of information of any nature (audible, visible, printed, etc.) through any electromagnetic system (electric, radio, optical).

Data Communication:

The part of telecommunication that is related to computer systems.

Transmission ➔ signal (wave) carry information through some media designated as a “Channel”.

Wave ➔ is generated by varying some physical property: voltage, current, intensity of light, etc.

Behavior can be modeled and analyzed mathematically. (Amplitude, Frequency, etc)

Analog and Digital Signals

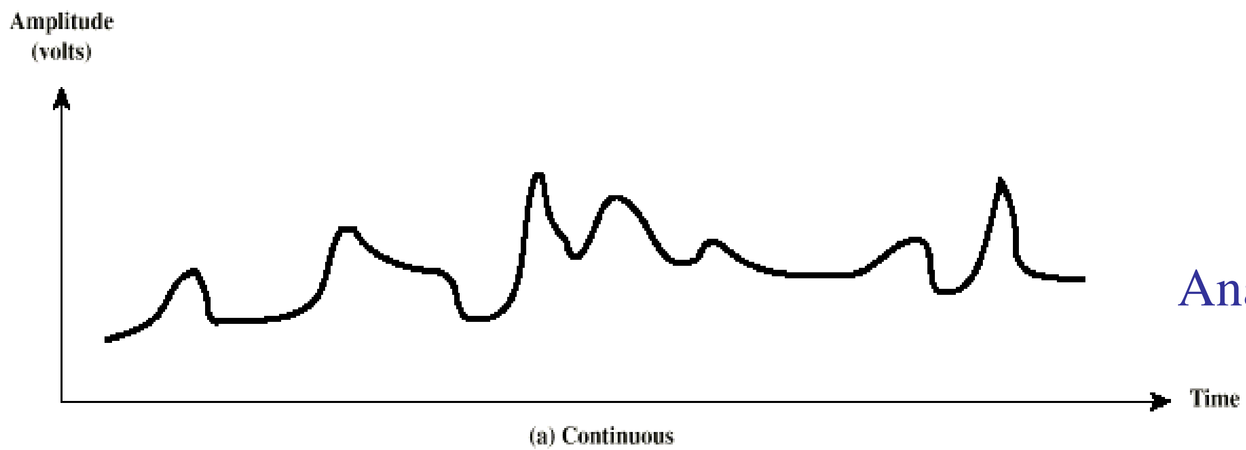
Analogue Signal:

Represents a continuously time varying electromagnetic waves.

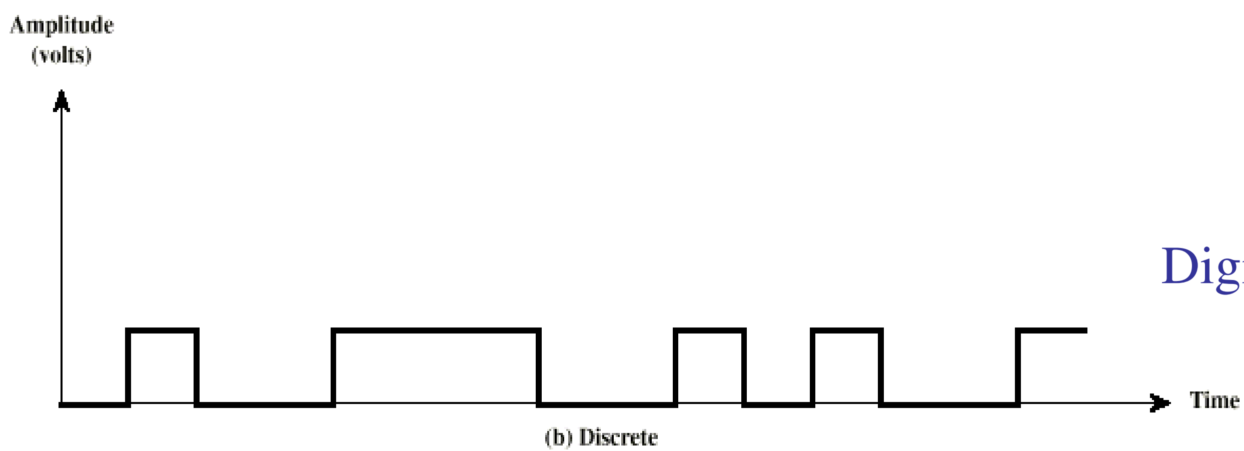
Digital Signals:

Represents a sequence of discrete electromagnetic variations in time.

Analog and Digital Signals

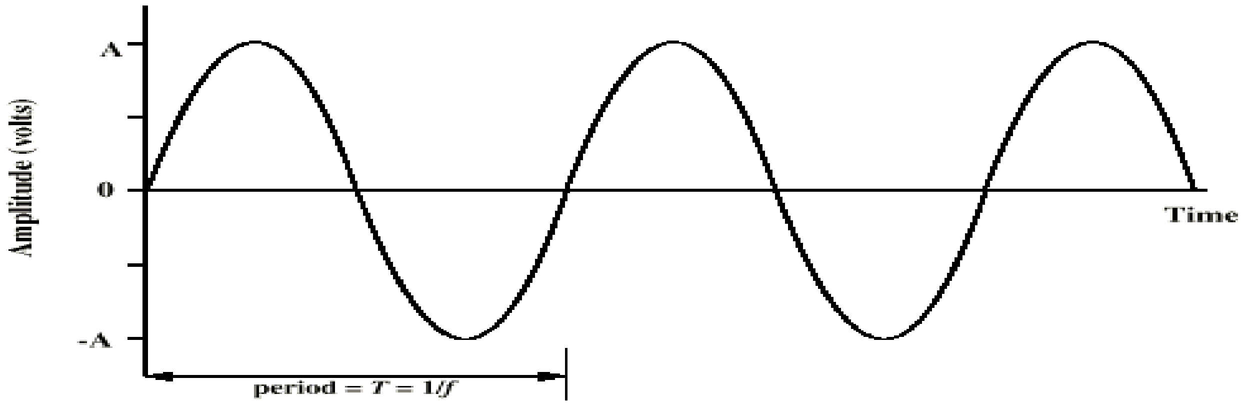


Analogue Signal

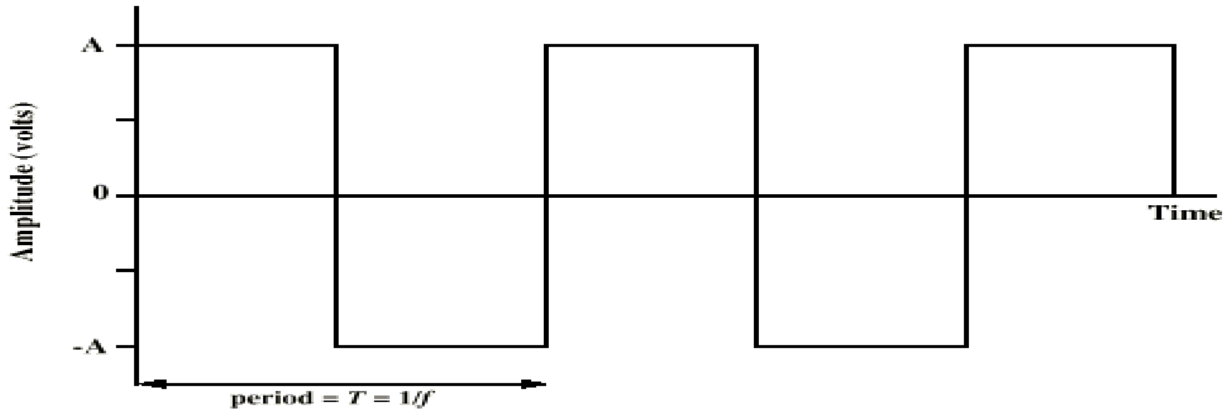


Digital Signal

Sine Waves and Square Waves

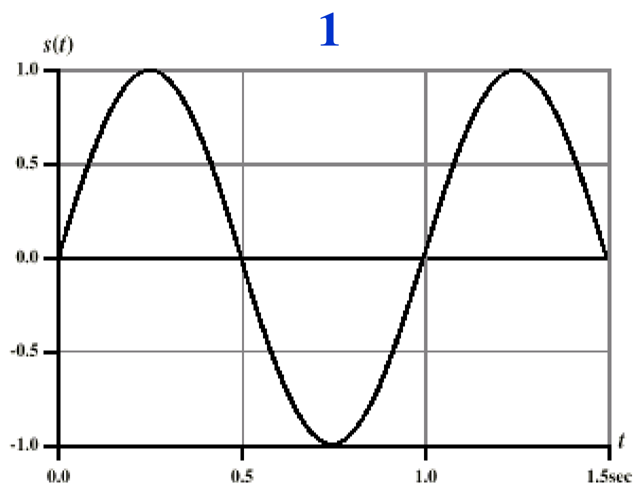


(a) Sine wave

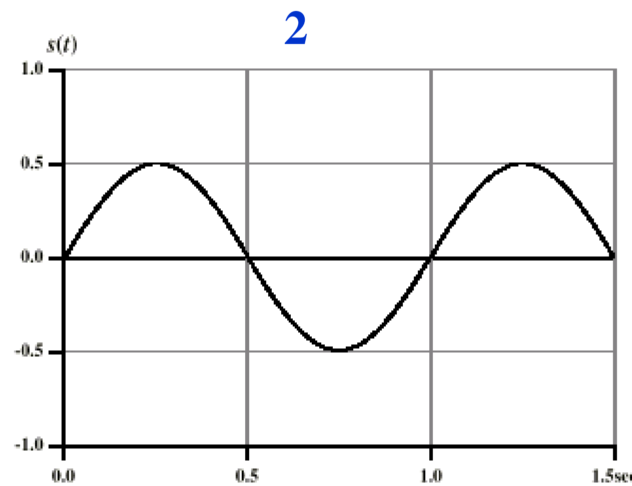


(b) Square wave

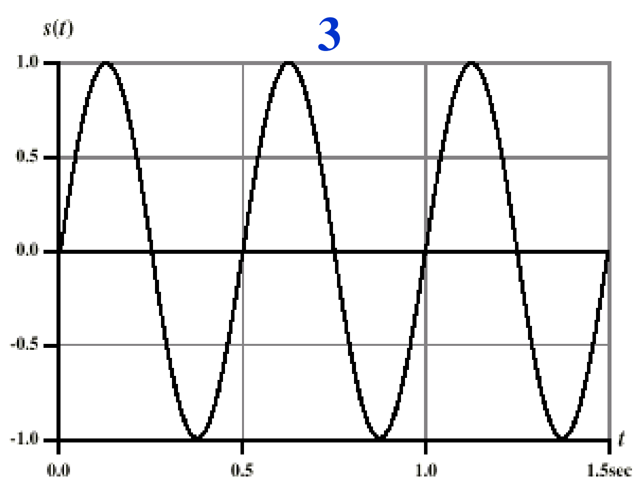
Amplitude, Frequency and Phase



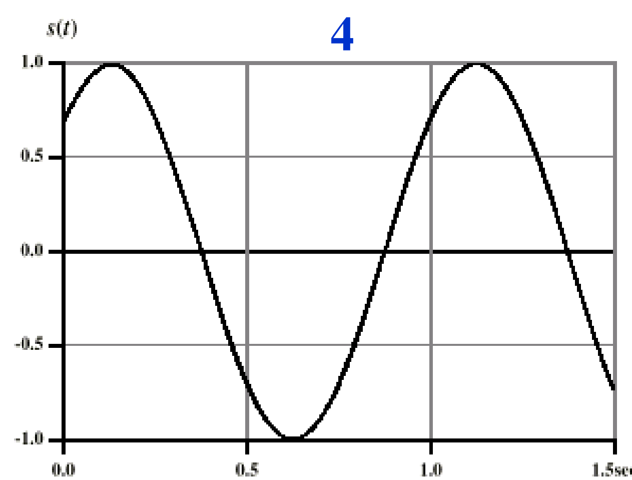
(a) A = 1, f = 1, ϕ = 0



(b) A = 0.5, f = 1, ϕ = 0



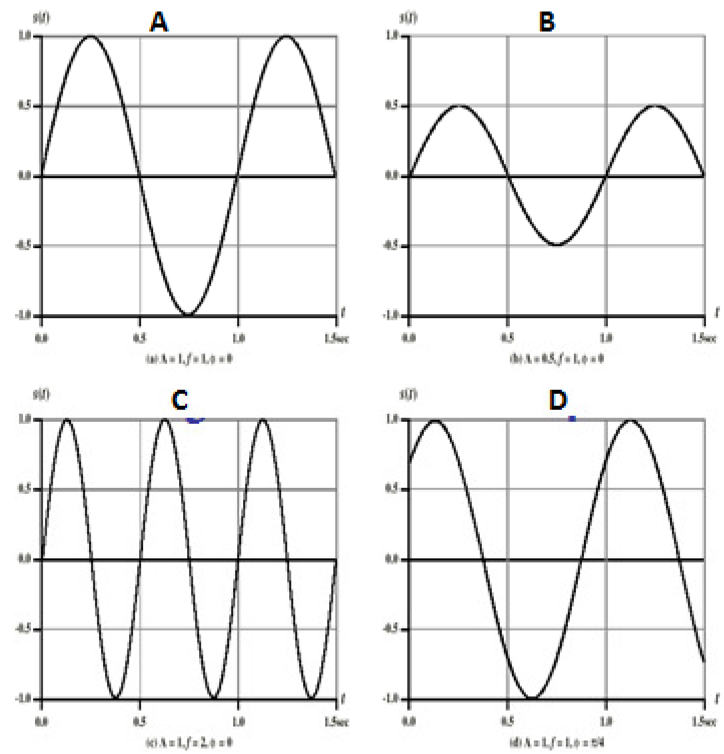
(c) A = 1, f = 2, ϕ = 0



(d) A = 1, f = 1, ϕ = π/4

Amplitude, Frequency and Phase

- A and B have the same frequency but A has a lager amplitude.
- A and C have the same amplitude but C has a higher frequency.
- A and D have the same amplitude and the frequency but they have a phase difference of $\pi/4$.



Measuring signal power

Decibel

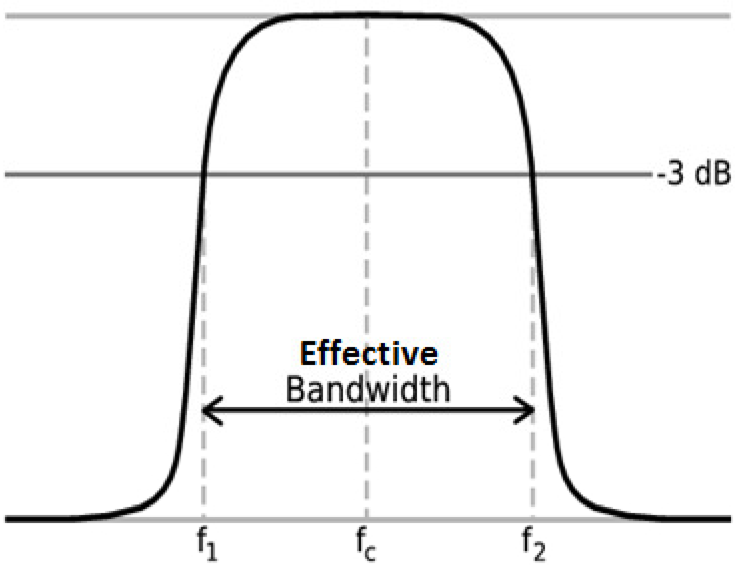
A logarithmic measure of the relative strength of two signals. The number of decibels is 10 times the log of the ratio of the power of two signals or 20 times the log of the ratio of the voltage of threw two signals.

Section 1.1.2

Channel Effects on Transmission

Frequency Spectrum & Bandwidth

- Frequency is the number of repetitions of the period (cycles) per second and is measured in Hz. Distance between 2 consecutive maxima – wavelength
- Spectrum
  - range of frequencies contained in signal
- Bandwidth
  - width of spectrum
- Effective bandwidth
  - Often just bandwidth
  - Narrow band of frequencies containing most of the energy – frequency range between the two half power (-3dB) points



$$10 \log\left(\frac{1}{2}\right) \approx -3$$

Channel Bandwidth

- In general any discrete waveform will have an infinite bandwidth. However, the transmission medium or the channel used will limit the bandwidth of the signal that can be transmitted. For any given medium ***greater the bandwidth, the greater the cost of transmission***.

- Therefore, the economics and practical reasons allow only a ***limited bandwidth*** for the digital information to be sent. The limit is ***determined by*** the bandwidth of the equipment and the media. These limitations give rise to transmission impairments.

Channel Effects

- There are 3 types of channel effects :

  Attenuation – loss of signal power as it travels over a distance. Depends on medium. Attenuation is an increasing function of signal frequency.

  Delay distortion – different propagation speeds at different frequencies. Only in guided media.

  Noise – unwanted additive energy from sources other than the information source (thermal noise, cross talk, impulse, etc)

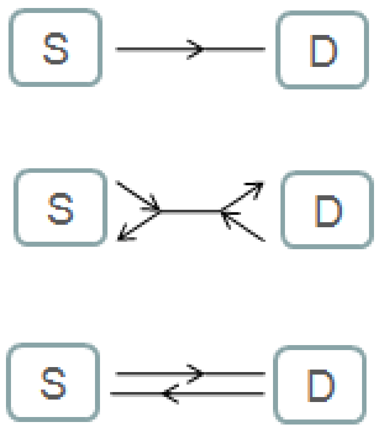
Section 1.1.3

Channel Properties

Data Rate

- The speed with which data can be transmitted from one device to another.
- Any transmission system has a limited band of frequencies
- This limits the data rate that can be carried on the transmission medium

Information flow over Channel



Simplex – One way only

Half Duplex – One way at a time

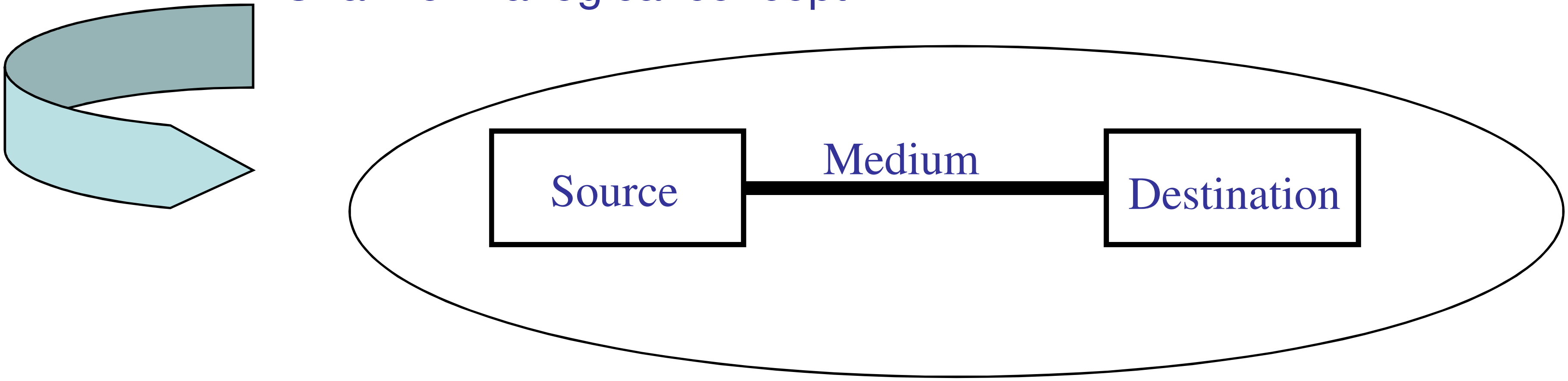
Full Duplex – Both ways simultaneously

Section 1.1.4

Data Rate limits in Channels

Channel & Info. Rate

Channel – a logical concept

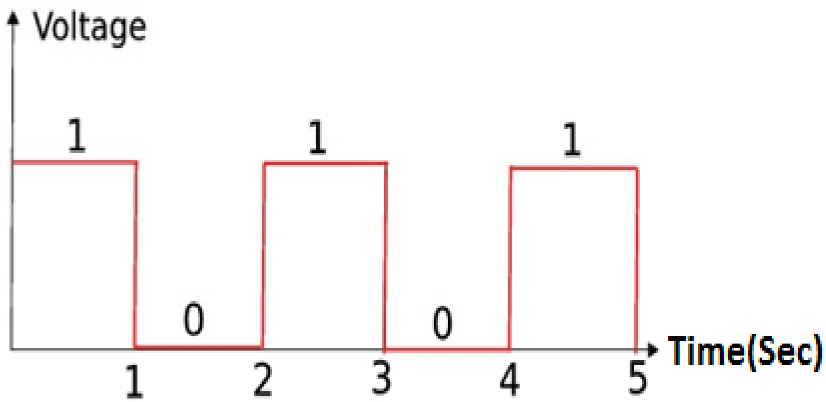


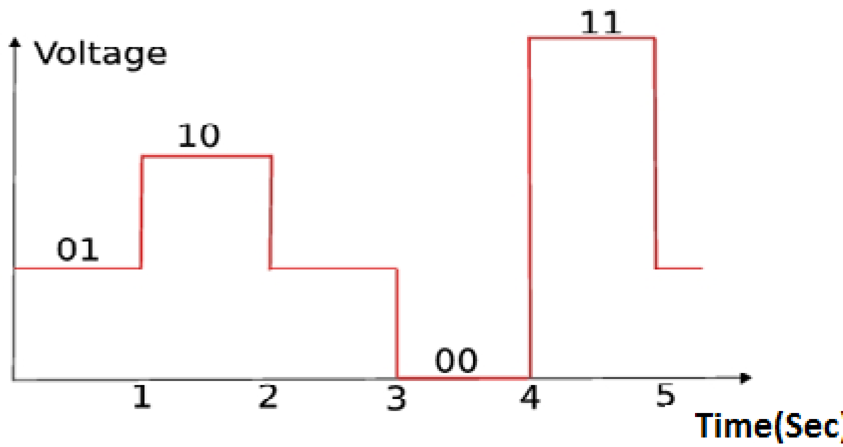
If T is the min. time to transfer one symbol of a set of symbols with p different symbols, then the capacity of the channel with no noise is:

$$baud\ rate = \frac{1}{T}\ symbols/sec$$

$$data\ rate = \frac{1}{T} log_2(P) \frac{bits}{\text{sec}} \text{ with } \frac{bits}{\text{sec}} = \left(\frac{bits}{symbol}\right)\left(\frac{symbol}{sec}\right)$$

Data and Baud Rate





Baud rate = 1 symbol per second

Date rate = 1 bit per second

Baud rate = 1 symbol per second

Date rate = 2 bit per second

Section 1.1.5

Nyquist’s Theorem

Nyquist Theorem

In 1924 Nyquist proved that any sampled and discretised (analogue) signal can be recovered by passing it through a low pass filter, if the sampling rate is at least twice the maximum frequency of the original signal.

Now, if W is the bandwidth of the channel, it is also the maximum frequency of a signal that can go through the channel .

Therefore , sampling rate = 2W sample/sec.

$$\frac{1}{T} = 2W$$

$$data\,rate(channel) = \frac{1}{T}\, log_2(P) \frac{bit}{sec}$$

$$= 2W\, log_2(P)\ bps$$

Section 1.1.6

Shannon's Theorem

Shannon's Theorem

The amount of thermal (Gaussian) noise present is measured by the ratio of the signal power (**S**) to the noise power (**N**) and is called the "***signal-to-noise***" ratio. Normally expressed in decibels (dB).

Signal-to-Noise Ratio = $10 \log_{10} (S/N)$

Shannon's Theorem state:

$C = W \log_2 \{1 + S/N\}$ bps

SNR (dB)	$\log_2 \{1 + S/N\}$
100	36.54
30	9.96
20	6.65
10	3.46
1	1.18