IT 4504
Section 1.0

Fundamentals of Digital Communications

Section 1.1

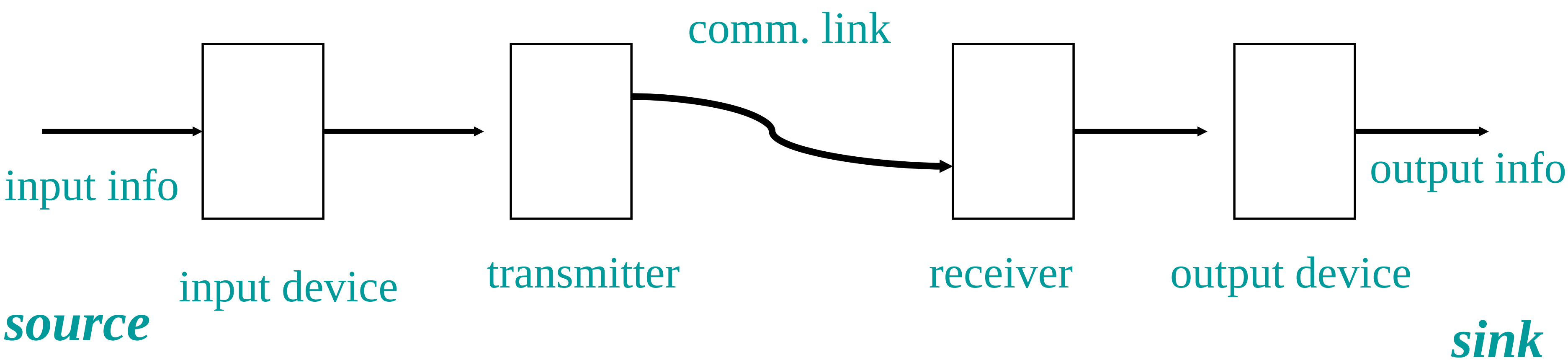
Introduction to Digital Communications

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.) by 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

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

Analog Signal:

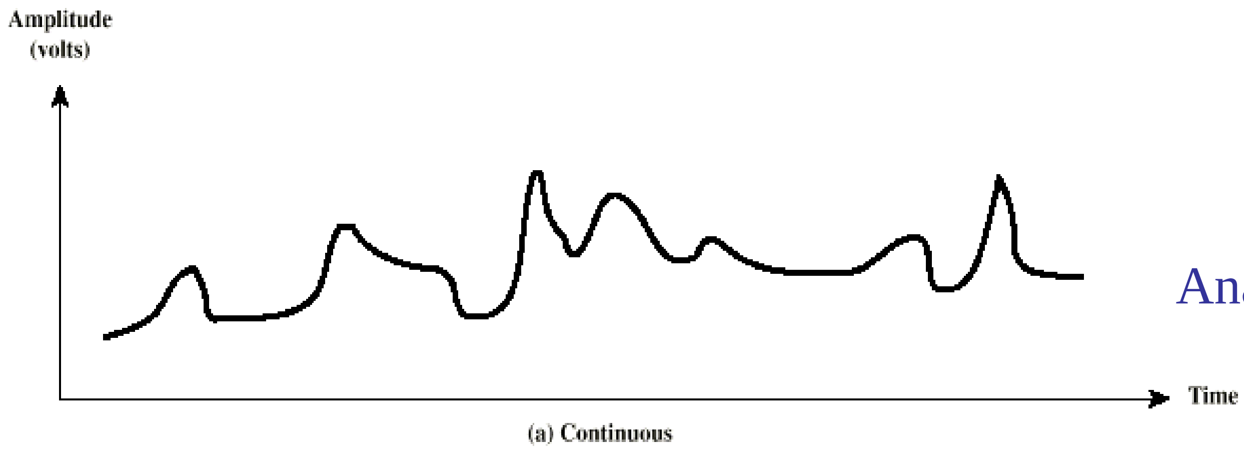
Represents data with continuously varying electromagnetic waves.

Digital Signals:

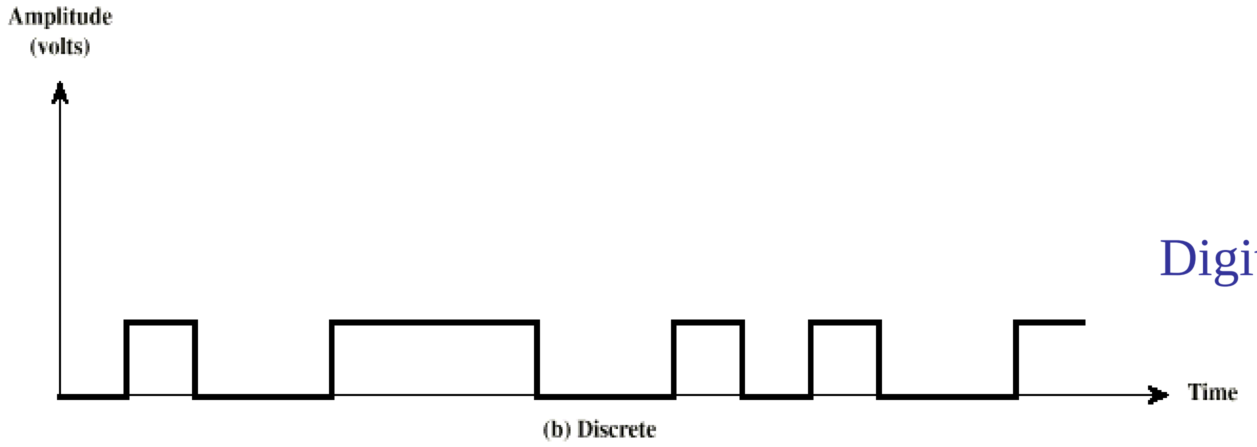
Represents data with sequence of voltage pulses.

- Continuous signal (Varies in a smooth way over time)
- Discrete signal (Maintains a constant level then changes to another constant level)
- Periodic signal (Pattern repeated over time)
- A periodic signal (Pattern not repeated over time)

Analog and Digital Signals



Analog waveform



Digital waveform

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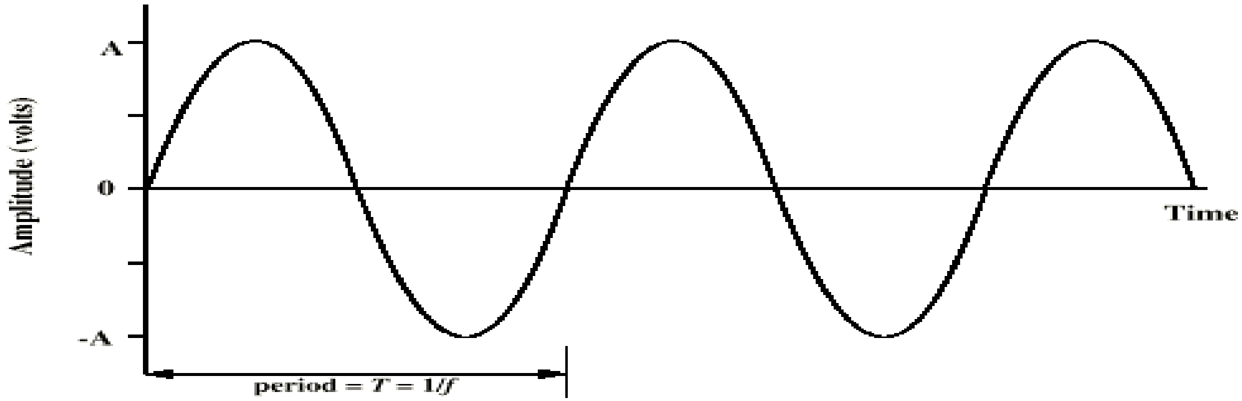
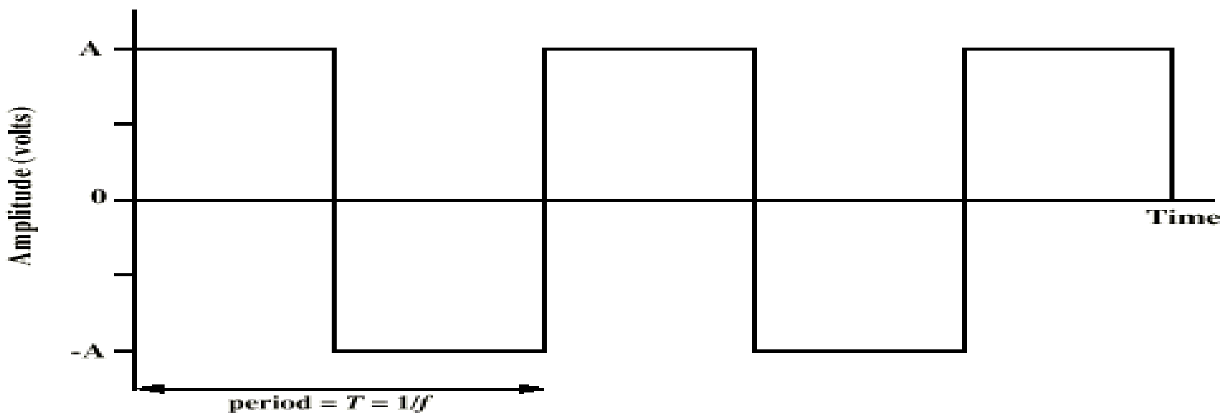
Sine Waves and Square Waves

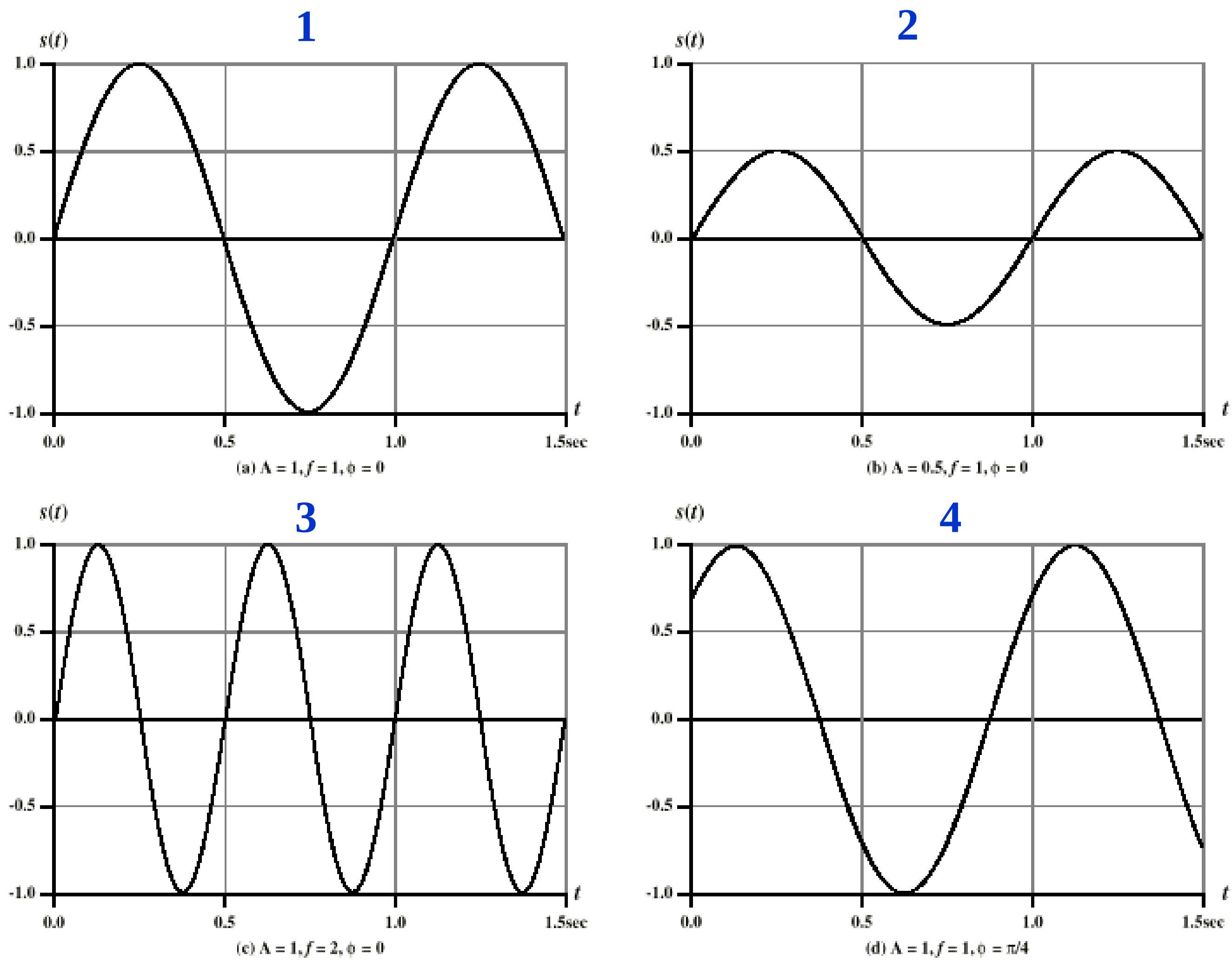


(a) Sine wave



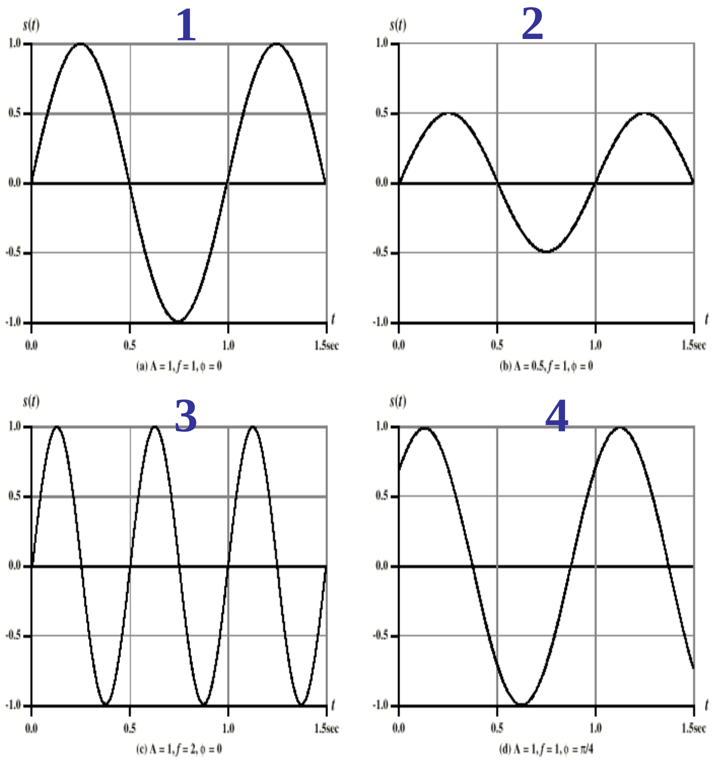
(b) Square wave

Amplitude, Frequency and Phase



Amplitude, Frequency and Phase

- 1 and 2 has the same frequency but 1 has a lager amplitude.
- 1 and 3 has the same amplitude but 3 has a higher frequency.
- 1 and 4 has the same amplitude and the frequency but they have phase difference of $\pi/4$.



Measuring signal power

Decibel

A measure of the relative strength of the two signals.

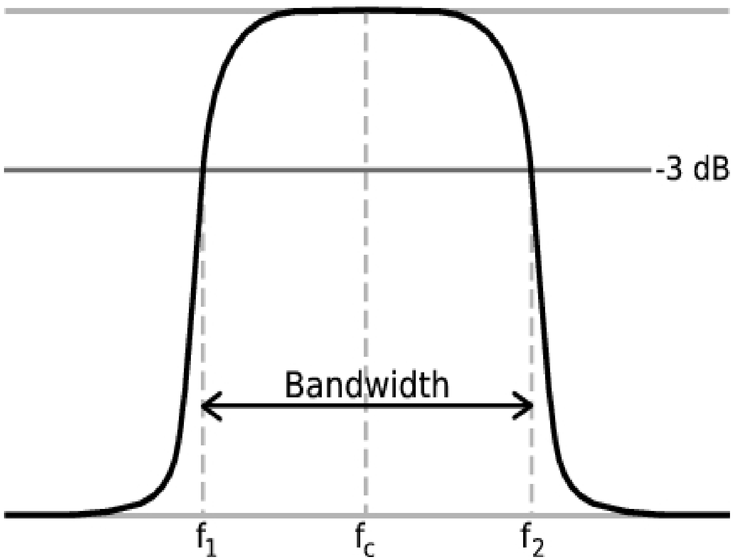
The number of decibels is 10 times the log of the ratio of the power of two signals or 20 times the log of the ratio of the voltage of threw two signals.

Section 1.2

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
- Absolute 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



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

Limited Bandwidth

- In general any digital waveform will have an infinite bandwidth. However, the transmission medium that is used will limit the bandwidth that can be transmitted. For any given medium ***greater the bandwidth, the greater the cost***.

- 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.

Limited Bandwidth (Contd..)

- There are 3 types of impairments :

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

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

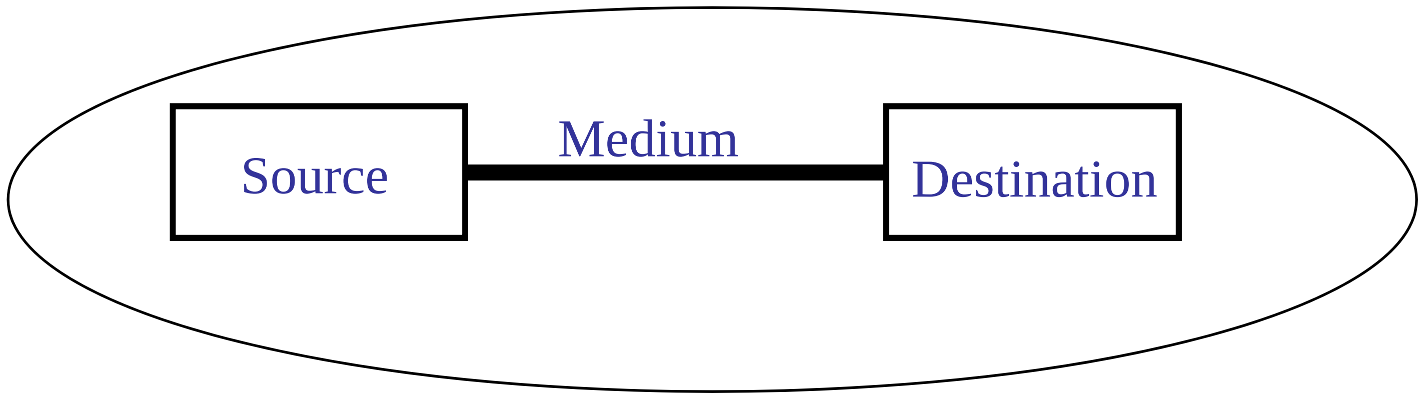
  Noise – unwanted energy from sources other than the transmitter (thermal noise, cross talk, impulse, etc)

Section 1.3

Data Rate limits in Channels

Channel & Info. Rate

Channel – a logical concept

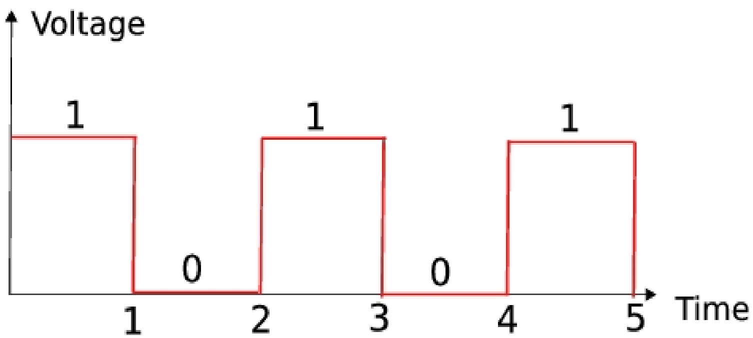


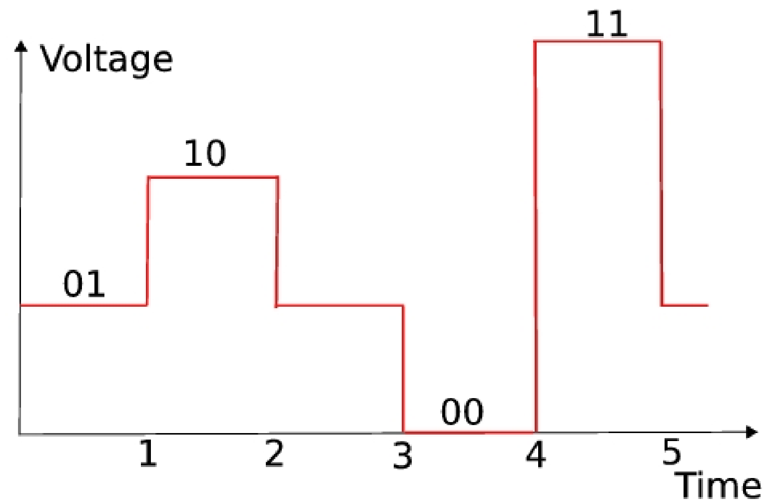
If T is the min. time to transfer one symbol of set of symbols that has p different symbols, then the capacity of the channel:

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

$$data\ rate = \frac{1}{T}\log_2(P)\ \ bits/\sec$$

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

Nyquist Theorem

In 1924 Nyquist proved → any arbitrary signal run through a low ***pass filter*** of bandwidth **W**, the filtered signal can be ***completely*** reconstructed by making ***only*** **2W** samples/sec. (*The sampling freq. of the analog signal must be at least twice max. freq. component of the analog signal*)

Sampling the channel at a rate faster than 2W is pointless.

That is 1/T=2W. Therefore the max. rate

$$\mathbf{C = 2W \log_2 (P) \text{ bits/sec (or bps)}}$$

However this equation is ***valid*** for an ***ideal noise free channel***. But in practice the channels degrades the signals in various means.

Shannon Limit

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 = $10 \log_{10} (S/N)$ - this is a linear quantity

C = W log2 {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

End of Section 1.0