CS221 - Data Communications: Introduction

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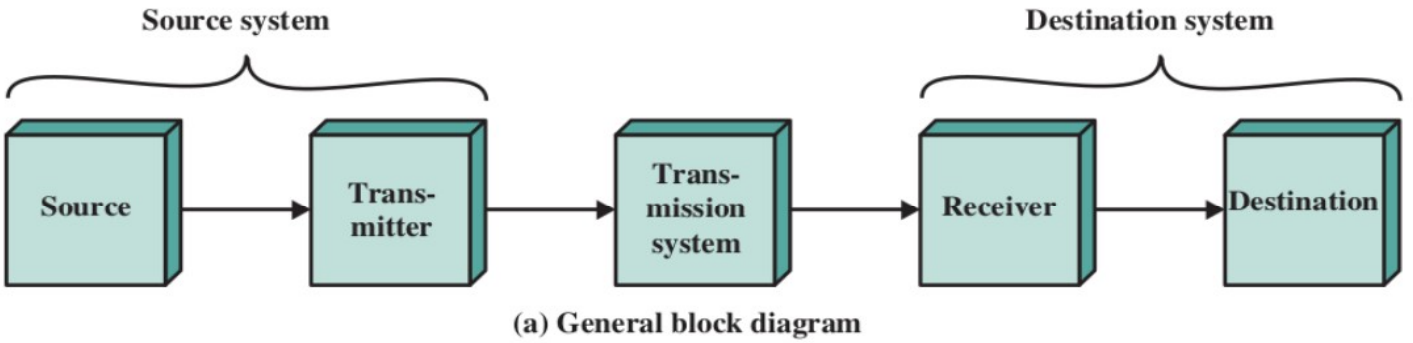
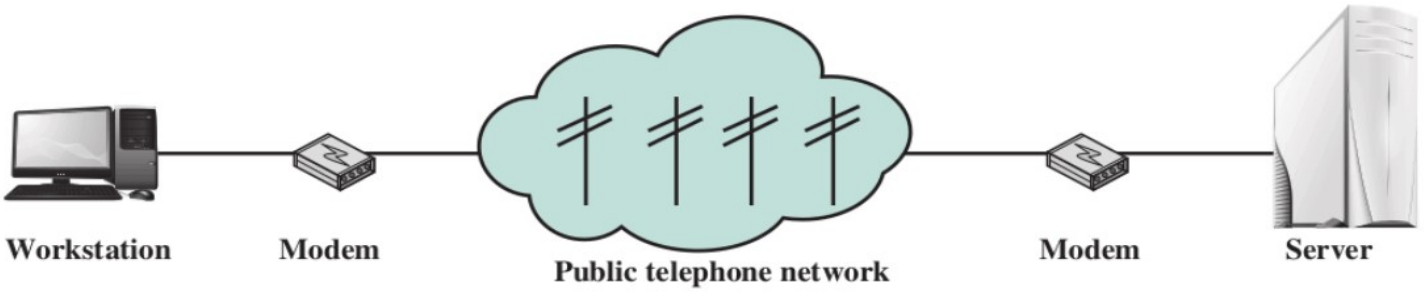
Communication model

The fundamental purpose of a communications system is the exchange of data between two parties.

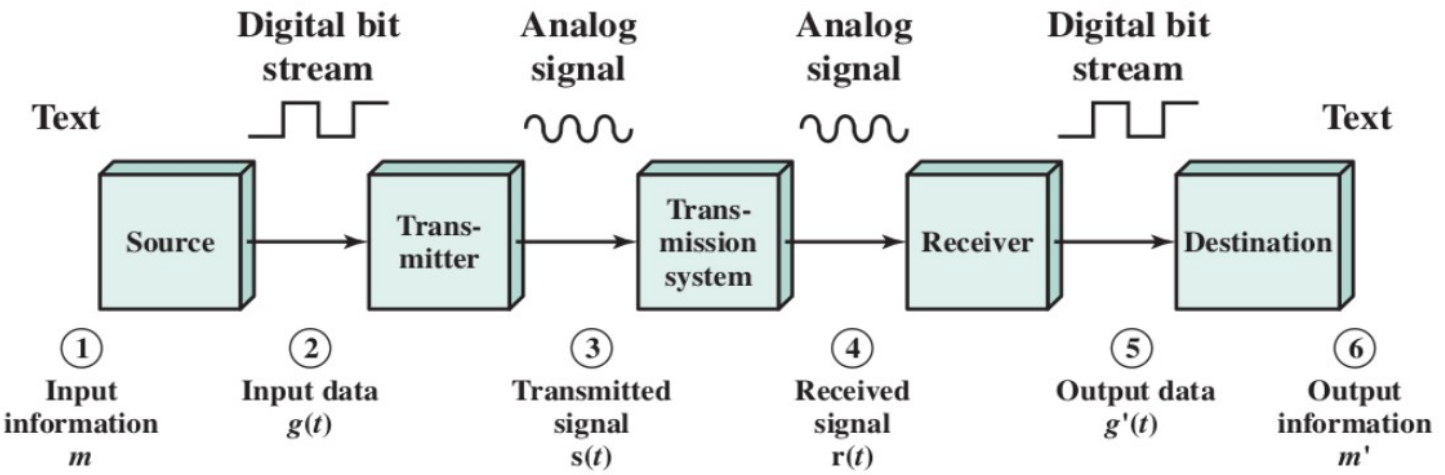


(a) General block diagram



(b) Example

A data communication model

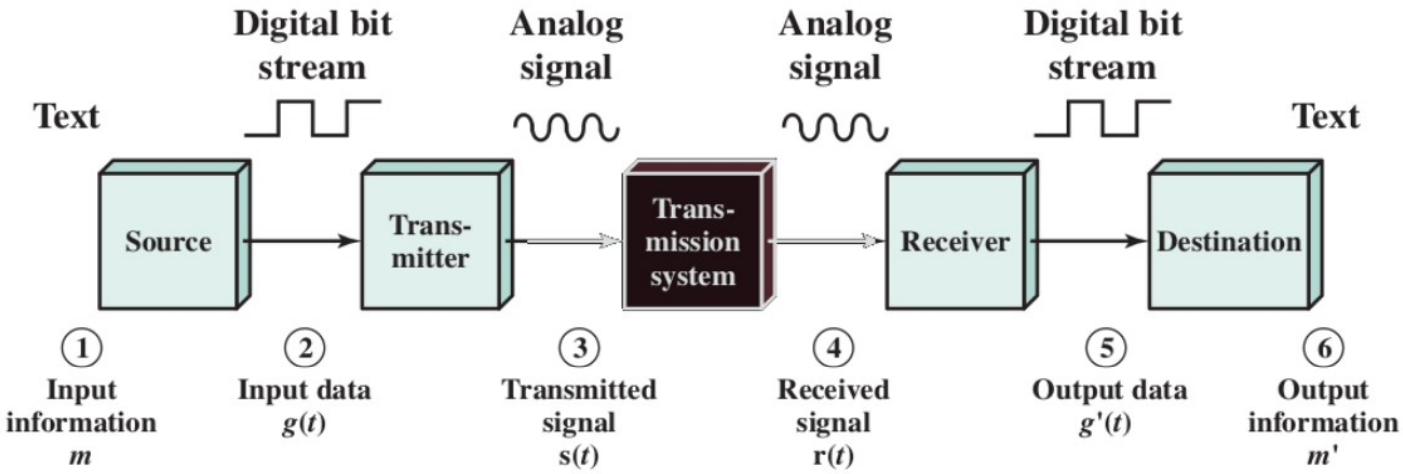


- m : message
- g(t): sequence of voltage shifts, representing bits
- s(t): transmitted signal
- r(t): received signal, different from s(t)
- g'(t): Estimate of the receiver, of the original signal s(t) based on r(t) and knowledge of the medium
- m' : usually the same as m

A telephone conversation

- m: sound waves
- s(t): transmitted signal - m converted to electrical signals, transmitted without modification over the telephone line
- r(t): received signal - not identical to s(t)
- m': r(t) is converted to m' without any error correction or improvement of sound quality

Data transmission



We need to successfully transmit data. That depends on

- the quality of signal transmitted
- characteristics of the transmission medium

Let us try to understand both of the above

Transmission terminology

Tranmission media

- guided , where waves are guided along a physical path. Ex: twister paid, coaxial cable, optical fibre.
- unguided/wireless, where means are available to transmit electromagnetic waves, but do not guide them. Examples ?

Direct link: Transmission path between two devices in which signals propagate directly from transmitter to receiver with no intermediate devices, other than amplifiers or repeaters

Question

Can there be a direct link used for data communication between two devices through air?

(A) Yes

(B) No

Transmission terminology contd.

A *guided* transmission medium is **point-to-point** if

- it provides a direct link between two devices and
- those are the only two devices sharing the medium

multipoint if more than two devices share the same medium. Examples?

Transmission terminology contd.

A transmission may be

- **simplex**: signals are transmitted in only one direction; one station is transmitter and the other is receiver Ex: baby monitors, surveillance cameras
- **half-duplex**: both stations may transmit, but only one at a time Ex: A walkie-talkie
- **full-duplex**: both stations may transmit simultaneously Ex: A mobile phone

Note: These are definitions as per the American National Standards Institute (ANSI).

Question

The kind of transmission that a wireless microphone uses is:

(A) simplex

(B) half-duplex

(C) full-duplex

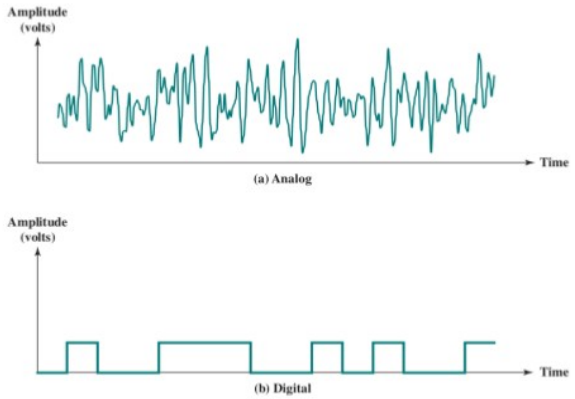
Analog and digital signals

Electromagnetic signals are used to transmit data. Signals could be analog or digital.

- A signal $s(t)$ is continuous if

$$\lim_{t \to a} s(t) = s(a)$$

  for all a. In an **analog signal**, the signal intenstity varies in a continuous fashion over time.
- In a **digital signal**, the signal intensity maintains a constant level for some period of time and then abruptly changes to another constant level, in a discrete fashion

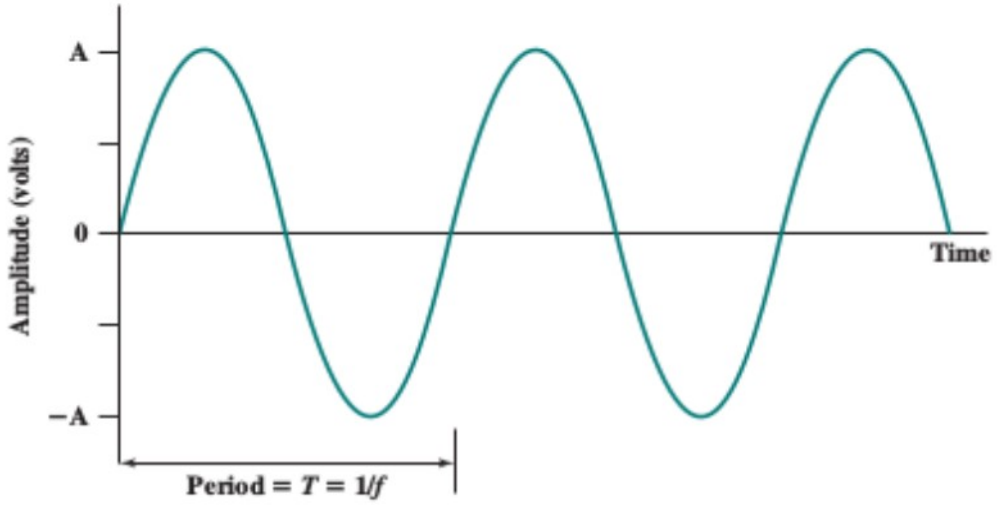


Periodic and aperiodic signals

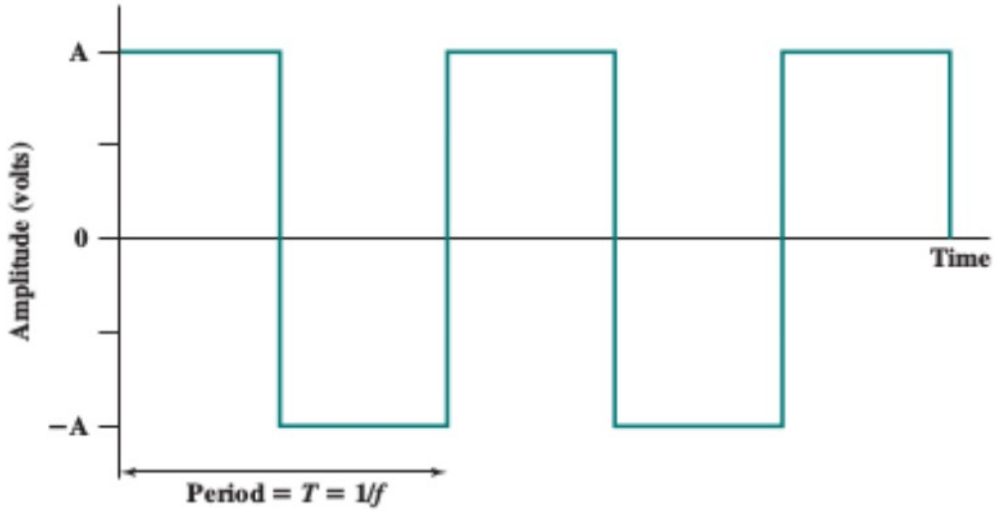
- A signal is periodic if and only if
  $s(t + T) = s(t)$ where $-\infty < t < +\infty$
  where the constant T is the period of the signal
  (T is the smallest value that satisfies the equation)
- In a **periodic signal** the same signal pattern repeats over time
- If a signal is not periodic, it is aperiodic

The sine wave is the fundamental periodic signal.
Represented by peak amplitude (A), frequency (f), and phase (ϕ).

Examples of periodic signals



(a) Sine wave



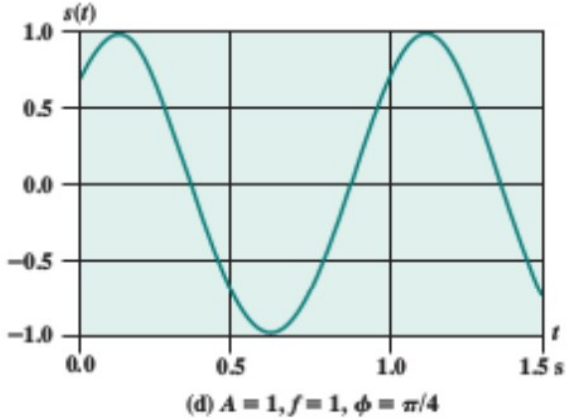
(b) Square wave

Periodic signals

- **peak amplitude** is the maximum value or strength of the signal over time — measured in volts.
- **frequency** is the rate at which the signal repeats — measured in Hertz
- **period** (T) of a signal is the amount of time it takes for one repetition; therefore, $T = 1/f$, where f is the frequency

Periodic signals - phase

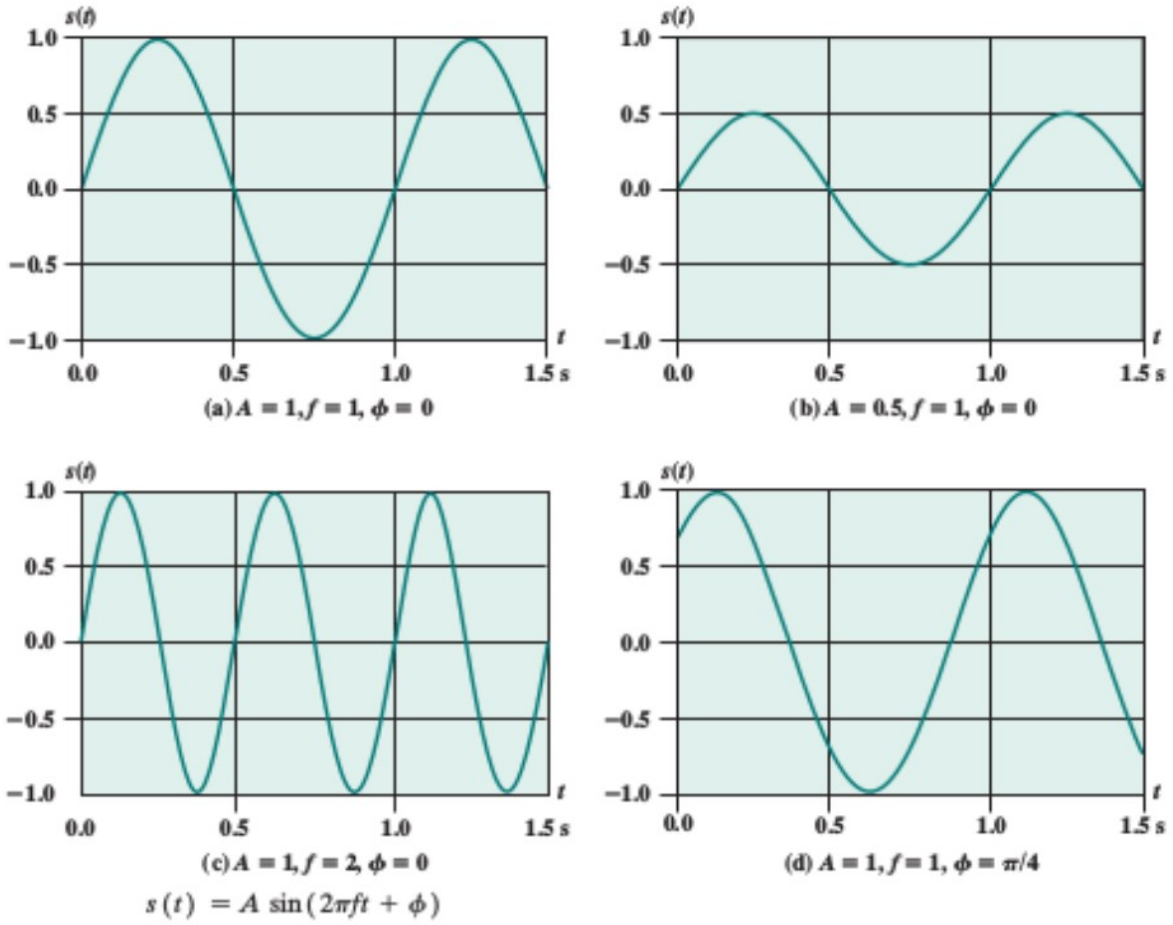
Phase is a measure of the relative position in time within a single period of a signal



(d) $A = 1, f = 1, \phi = \pi/4$

Formally, phase is the fractional part t/T of the period T through which t has advanced relative to an arbitrary origin.
The origin is usually taken as the last previous passage through zero from the negative to the positive direction.
The function $s(t) = A\ sin(2\pi ft + \phi)$ is called a **sinusoid**

$s(t) = A\sin(2\pi ft + \phi)$

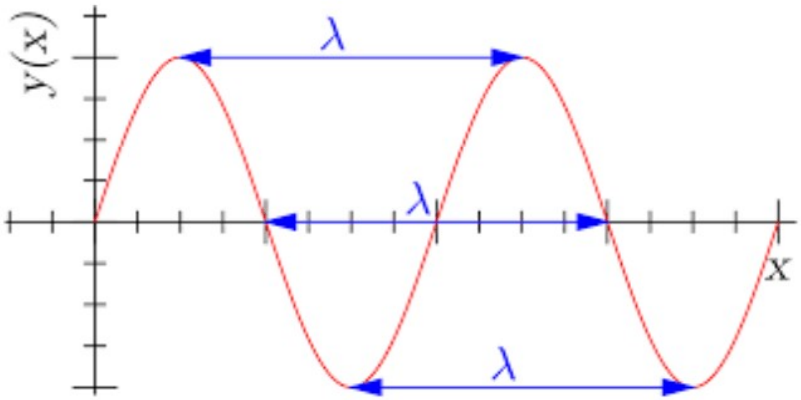


Horizontal axis as space instead of time

- X-axis can be space and y-axis the amplitude of the signal
- As the distance from the source increases, the signal attenuates (amplitude reduces)
- The effect of attenuation is ignored in the previous diagrams.
- A wave from a radio transmitter or from a loud speaker is sinusoidal tranmission.
- At a given time, the amplitude of such a wave varies sinusoidally with distance.

Relationship between the two sine waves

Wavelength λ: The distance occupied by a single cycle
or
the distance between two points of corresponding phase of two consecutive cycles.



If v is the velocity of the signal, the distance occupied by a single cycle $\lambda = vT$, where T is the period. Equivalently, $\lambda f = v$.
So far, we have discussed the concepts in the **time domain**.

Figure Source: Wikipedia

Electromagnetic spectrum

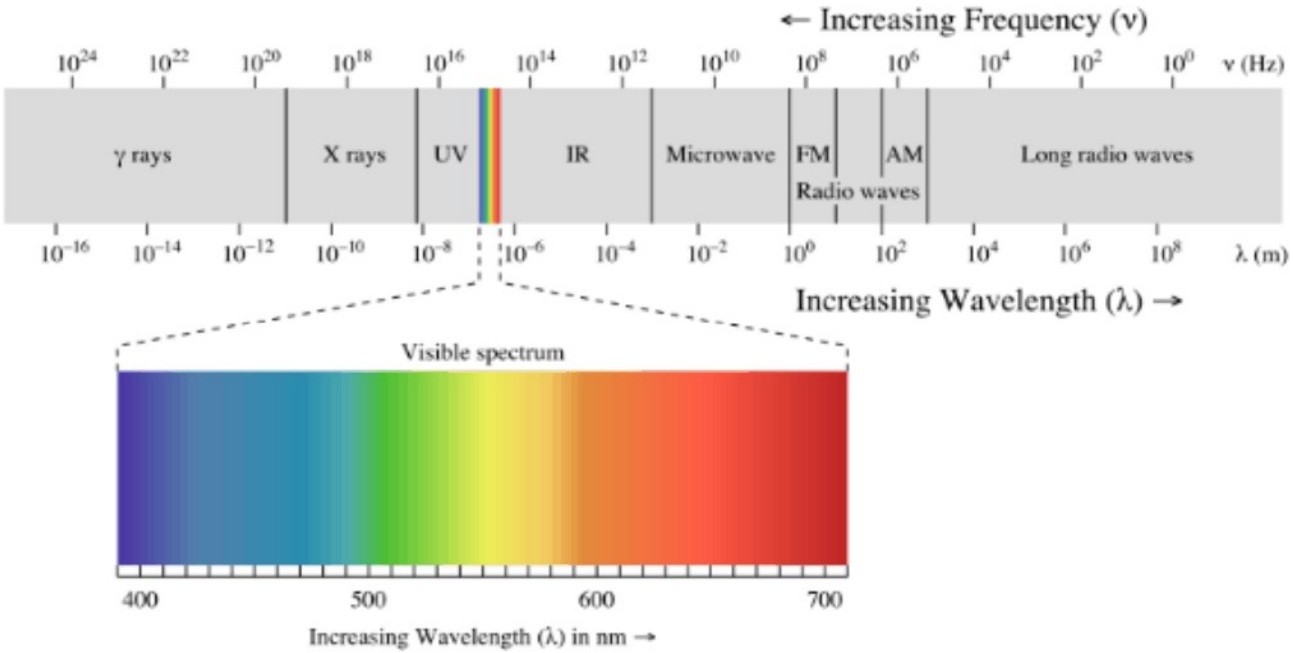


Figure Source: Wikipedia

Electromagnetic signals

The propagation speed of electromagnetic signals depends on 1) the medium of the signal 2) the frequency of the signal
The speed of light in vacuum is $3 * 10^8$ m/s. It is lower in air and further lower in a cable.

Unit	*Equivalent*	*Unit*	*Equivalent*
Seconds (s)	1 s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	Kilohertz (kHz)	10^3 Hz
Microseconds (μs)	10^{-6} s	Megahertz (MHz)	10^6 Hz
Nanoseconds (ns)	10^{-9} s	Gigahertz (GHz)	10^9 Hz
Picoseconds (ps)	10^{-12} s	Terahertz (THz)	10^{12} Hz

Wavelength of electromagnetic signals is measured in **microns**, represented as μ. $1\ \mu = 10^{-6}\ m$.

Homework Exercise

Sunlight takes approximately 8 minutes to reach the earth. What is the distance between the sun and the earth?