EC320 Communications Theory

Instructor: Dr. Heba A. Shaban

Lecture/Tutorial Guidance

- Lectures (Dr. Heba Shaban)
  - 2 hours per week
- Tutorials (Eng. Rana Rageh)
  - 2 hours per week

Assessment

- 7th week (30% weighting).
  - Two quiz (10% weighting)
  - 7th week exam (20% weighting)
- 12th week (20% weighting).
  - One quiz (5% weighting)
  - 12th week exam (15% weighting)
- Tutorial(10% weighting).
- Final exam (40% weighting).

Introduction and types of signals

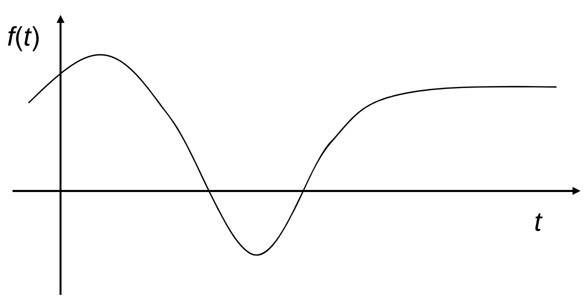
Signals section of the slides is based on EC321 course slides prepared by Dr. Amr El-Helw

What is a Signal?

- A signal is a pattern of variation of some form
- A signal is a varying quantity whose value can be measured and which conveys information.
- Examples of signal include:
  - Electrical signals
    - Voltages and currents in a circuit
  - Acoustic signals
    - Acoustic pressure (sound) over time
  - Mechanical signals
    - Velocity of a car over time
  - Video signals
    - Intensity level of a pixel (camera, video) over time

How is a Signal Represented?

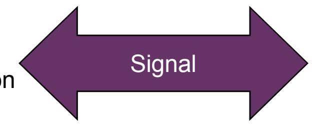
- Mathematically, signals are represented as a function of one or more **independent variables**.
- For instance a black & white video signal intensity is dependent on *x*, *y* coordinates and time *t* $f(x,y,t)$
- On this course, we shall be exclusively concerned with signals that are a function of a single variable: time/frequency



Signal Representation

Signals are functions of time. There are two ways by which we can represent the signal.

Time Domain Representation



Frequency Domain Representation

Why Use Frequency Representations When We Can Represent Any Signal With Time Functions?

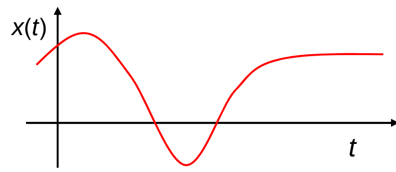
Signal Classification

- **Continuous & Discrete:** $x(t)$ & x_n
- **Digital & Analog**
- **Causal vs. Anti-causal vs. Non-causal**
- **Even vs. Odd**
- **Random & deterministic**
- **Periodic and Non-Periodic** (or Apperiodic)

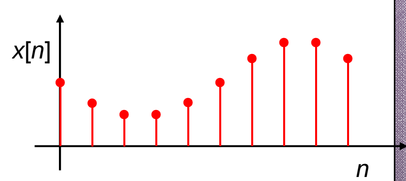
  periodic if: $x(t) = x(t + T)$ or $x_n = x_{n+N}$
- **Energy vs. Power**

Continuous & Discrete-Time Signals

- **Continuous-Time Signals**
  - Most signals in the real world are continuous time, as the scale is infinitesimally fine.
  - Denoted by $x(t)$, where the time interval can be bounded (finite) or infinite.

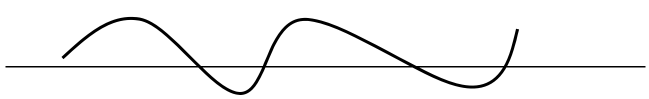


- **Discrete-Time Signals**
  - Some real world and many digital signals are discrete time, as they are sampled.
  - Contains information about the signal only at discrete points in time.
  - Denoted by $x[n]$, where n is an integer value that varies discretely.

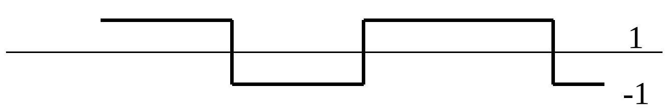


Analogue vs. Digital Signals

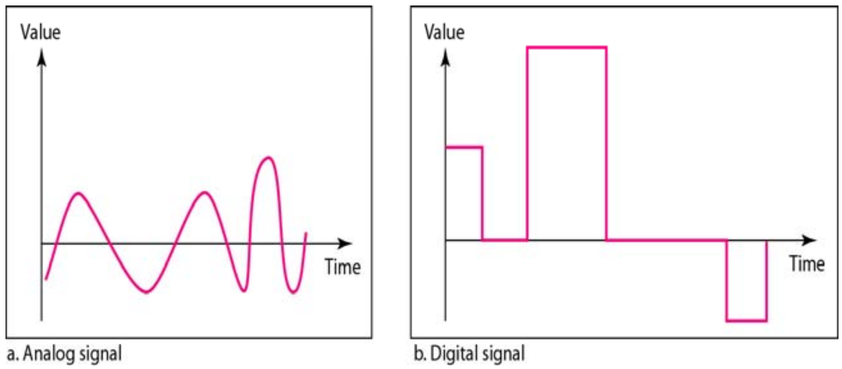
- Analog signals
  - Amplitude of analog signal can take any real or complex value at each time/sample.



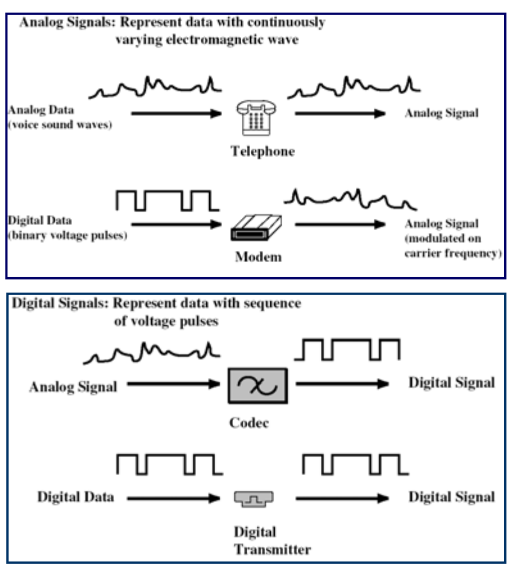
- Digital signals
  - They consist of pulses or digits with discrete levels or values. The value of each pulse is constant, but there is an abrupt change from one digit to the next.



Comparison of analog and digital signals

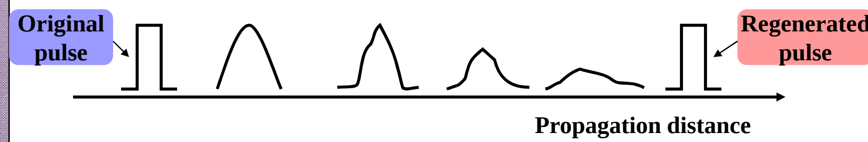


Analog and Digital Signals

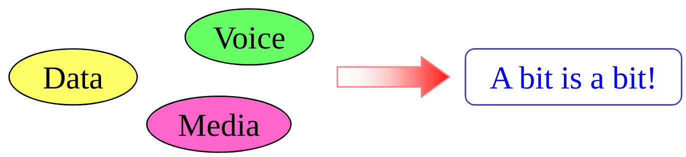


Analog and Digital Signals

- Advantages of digital signals in communication:
  - Regenerator receiver

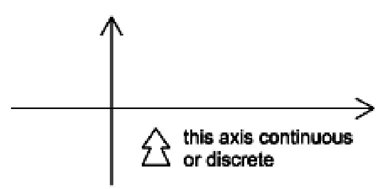


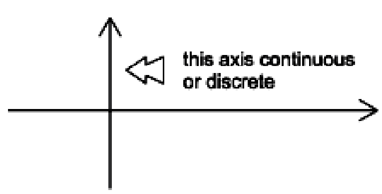
  - Different kinds of digital signal are treated identically.



- **Continuous vs. Discrete**

Continuous corresponds to a continuous x-axis, while discrete corresponds to a discrete x-axis.



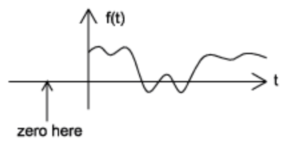


- **Analog vs. Digital**

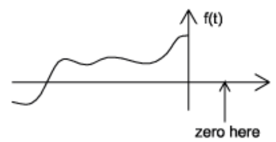
Analog corresponds to a continuous y-axis, while digital corresponds to a discrete y-axis.

Causal vs. Anticausal vs. Noncausal

- Causal signals are signals that are zero for all negative time, while anti-causal are signals that are zero for all positive time.

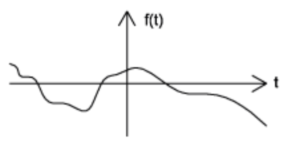


A causal signal



An anti-causal signal

- Non-causal signals are signals that have nonzero values in both positive and negative time

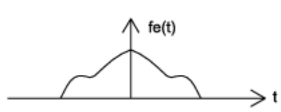


A noncausal signal

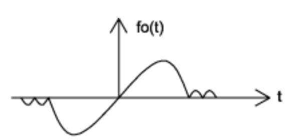
Even vs. Odd

- An even signal is any signal $f(t)$ such that $f(t) = f(-t)$. Even signals can be easily spotted as they are symmetric around the vertical axis.

- An odd signal, on the other hand, is a signal f such that $f(t) = -(f(-t))$. Odd signals can be easily spotted as they are symmetric around the horizontal axis.



An even signal

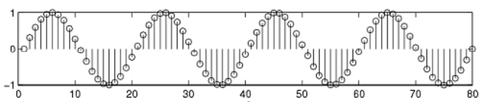


An odd signal

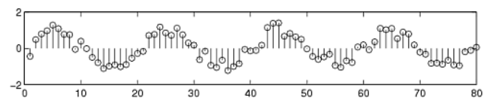
Deterministic vs. Random

A *deterministic signal* is a signal in which each value of the signal is fixed and can be determined by a mathematical expression, rule, or table. Because of this the future values of the signal can be calculated from past values with complete confidence.

On the other hand, a random signal has a lot of uncertainty about its behaviour. The future values of a random signal cannot be accurately predicted and can usually only be guessed based on the averages of sets of signals



Deterministic Signal

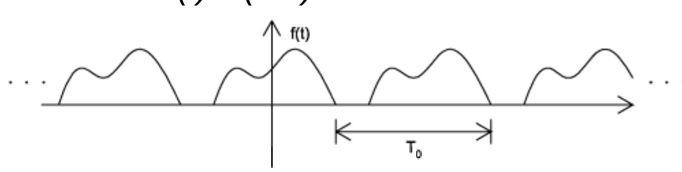


Random Signal

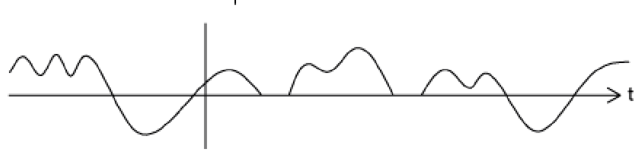
Periodic vs. Aperiodic

- Periodic signals repeat with some *period T*, while aperiodic, or non-periodic, signals do not.
- We can define a periodic function through the following mathematical expression, where *t* can be any number and *T* is a positive constant: $f(t) = f(T+t)$

Periodic signal



Aperiodic signal



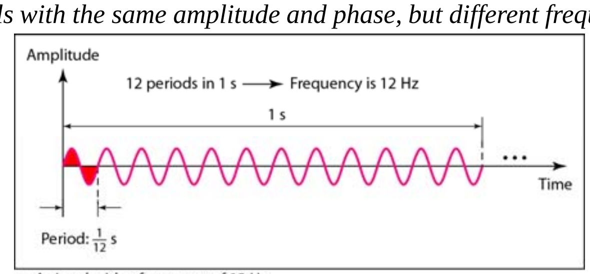
A sine wave (periodic wave example)

simple periodic signal

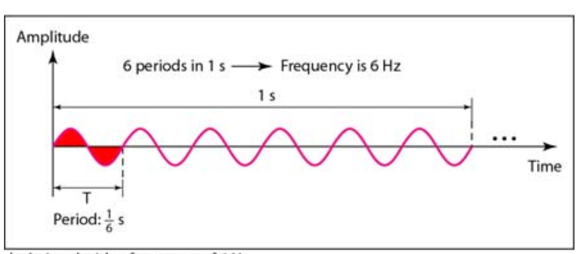
Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

Two signals with the same amplitude and phase, but different frequencies



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

Units of period and frequency

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

Energy vs. Power signal

- A signal is an energy signal if, and only if, it has nonzero but finite energy for all time:

$$E_x = \int_{-\infty}^{\infty} |x(t)|^2 dt \qquad (0 < E_x < \infty)$$

- A signal is a power signal if, and only if, it has finite but nonzero power for all time:

$$P_x = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} |x(t)|^2 dt \qquad (0 < P_x < \infty)$$

- General rule: Periodic signals are power signals, while signals that are non-periodic are energy signals.

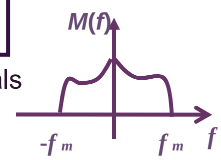
Introduction to Communication Systems

Communication Systems

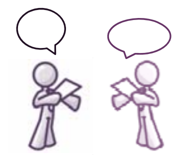
- The purpose of a communication system is to transmit information (***baseband***) signals located at one point (***source***) in space to another point (***destination***).
- The term ***baseband*** is used to designate the band of frequencies representing the original signal as delivered by the input transducer.
- For example, the voice signal from a microphone is a baseband signal, and contains frequencies in the range of 300-3400 Hz.

Why We Need Communication Systems

- Messages are in the form of baseband signals (low frequencies).

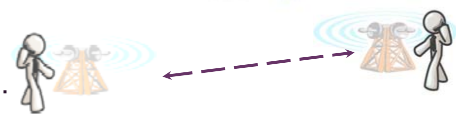


- Example human voice (speech)
  - Small distances.



  - Longer distances
    - Microphones and loudspeakers.

  - Very long distances??
    - Communication system.

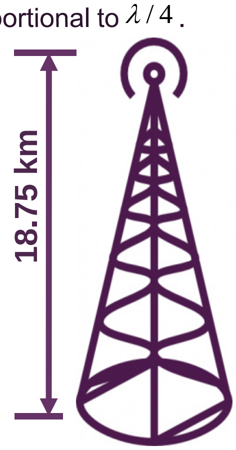


Why We Need Communication Systems

- Speech frequency 300-3400 Hz.
- Antenna length is directly proportional to $\lambda / 4$.

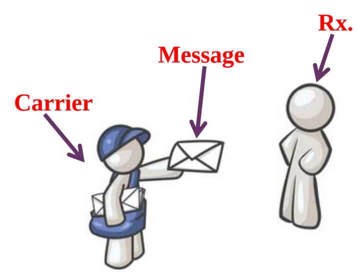
$$f = \frac{c}{\lambda}, c = 3*10^8 \mathrm{m/sec}$$

- Antenna length 18.75 km ??
- Need solutions…
- Higher frequencies??

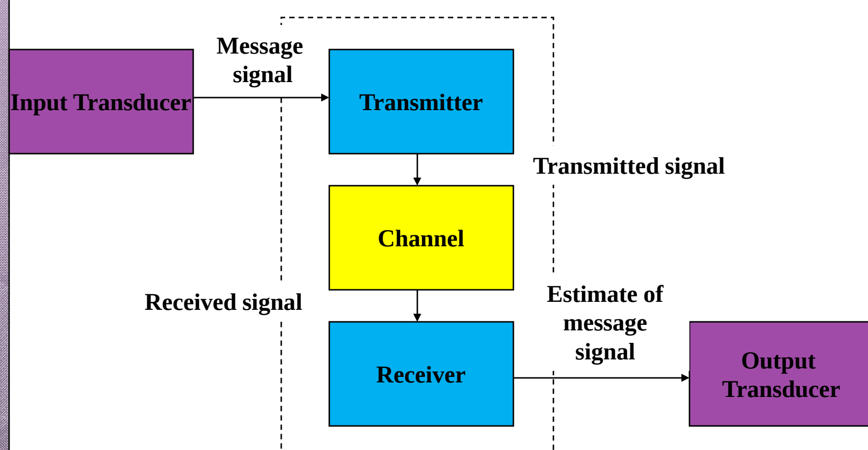


Concept of Modulation

- Have baseband signal.
- Have carrier signal (typically high frequency).
- Modulate carrier with message.
- Demodulate signal (remove carrier at the receiver (Rx.).
- Restore original signal.



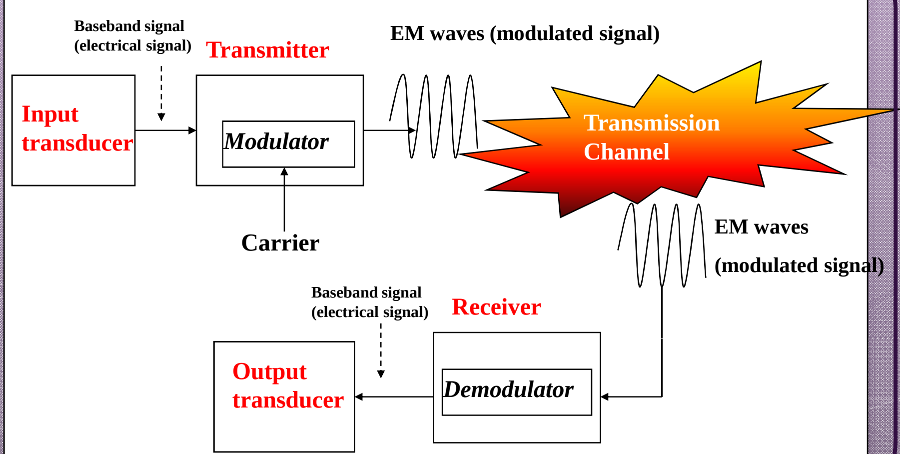
Generic Communication System



Components of Communication Systems

- ***Input transducer:*** The device that converts a physical signal from source to an electrical, mechanical or electromagnetic signal more suitable for communication.
- ***Transmitter:*** The device that sends the transduced signal.
- ***Transmission channel:*** The physical medium on which the signal is carried.
- ***Receiver:*** The device that recovers the transmitted signal from the channel.
- ***Output transducer:*** The device that converts the received signal back into a useful quantity.

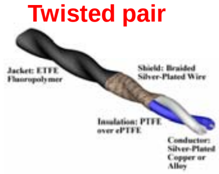
Basic Analog Communication System



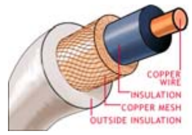
Transmission Channels

- Wire-line channel

Twisted pair



Coaxial cable

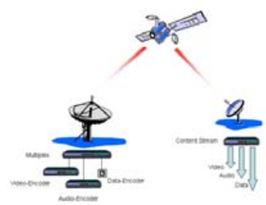


Fiber optics

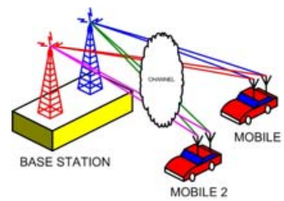
- Wireless Communication channel

Wireless networks

Satellite comm.



Mobile comm.



Types of Analog Modulation

Amplitude Modulation (AM)

- Amplitude modulation is the process of ***varying the amplitude of a carrier wave in proportion to the amplitude of a baseband signal.*** The frequency of the carrier remains constant

Frequency Modulation (FM)

- Frequency modulation is the process of ***varying the frequency of a carrier wave in proportion to the amplitude of a baseband signal.*** The amplitude of the carrier remains constant

Phase Modulation (PM)

- Phase modulation is the process of ***varying the phase of a carrier wave in proportion to the amplitude of a baseband signal.*** The amplitude of the carrier also remains constant.


Any Questions?