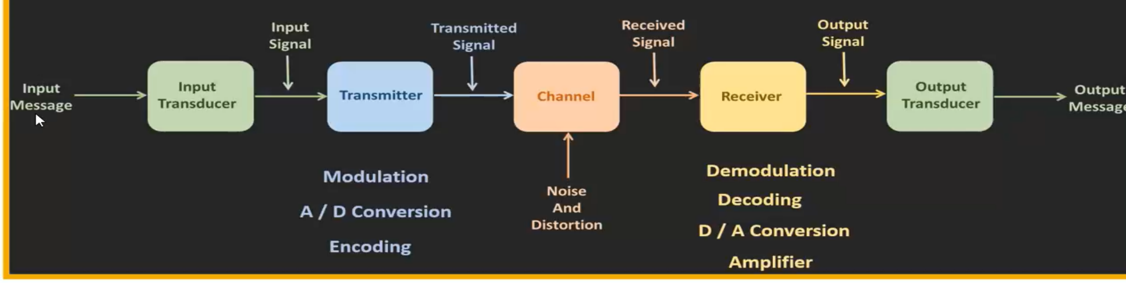
Analog and Digital Communication

Types of Signals

Block Diagram of Communication System



Classification of Signal

Continuous time and Discrete time signals

Analog and Digital signals

Periodic and Aperiodic signals

Energy and Power signals

Deterministic and Random signals

Classification of Signal

Continuous time Signal

If the signal is specified for every value in time then it is known as the Continuous time signal

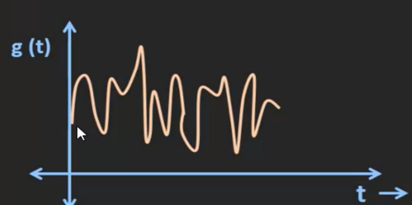


Fig. 1 (a)

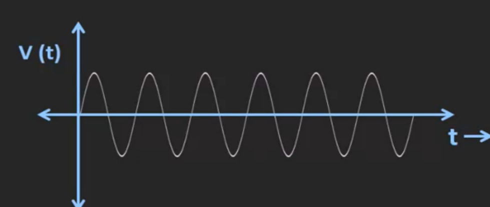


Fig. 1 (b)

Classification of Signal

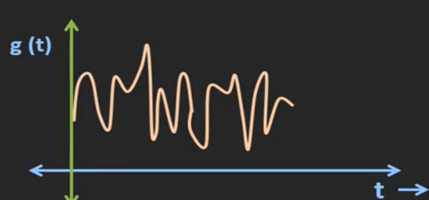
Discrete time Signal

If the signal is specified only for discrete time instances then it is called Discrete time signal.

Classification of Signal

Analog Signal

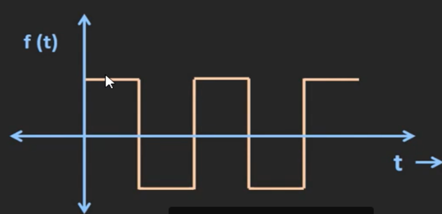
A signal whose amplitude can take any value in the continuous range is the analog signal.



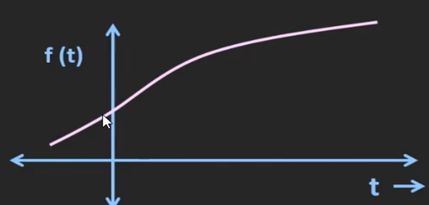
Classification of Signal

Digital Signal

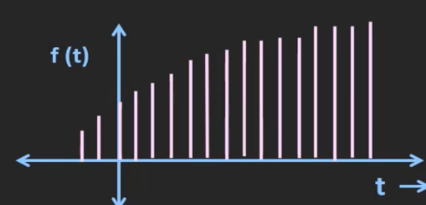
A signal whose amplitude can take only finite number of values is the digital signal.



Classification of Signal

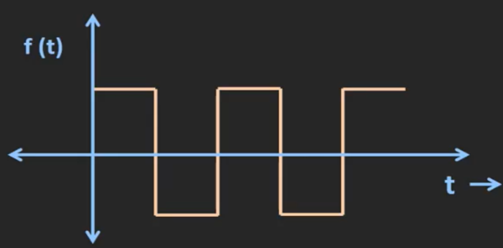


Analog and Continuous time signal

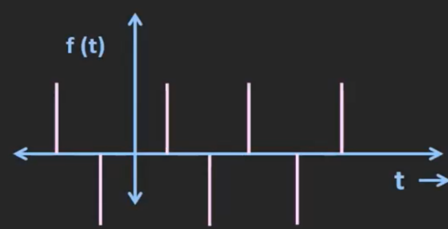


Analog and Discrete time signal

Classification of Signal



Digital and Continuous time signal

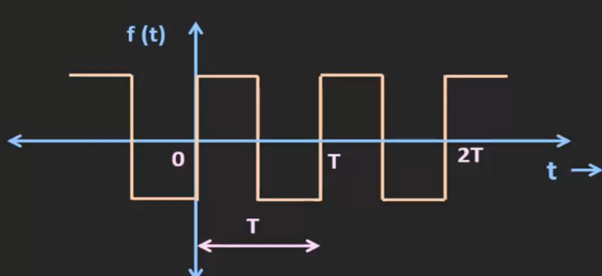


Digital and Discrete time signal

Classification of Signal

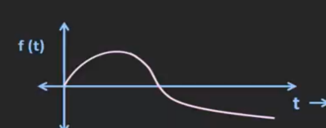
Periodic Signal

A signal which repeats itself after finite time T then it is called periodic signal.

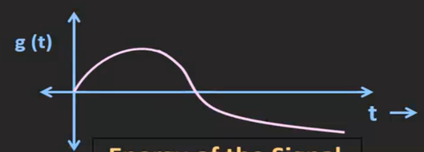


$$f(t) = f(t + T)$$

Aperiodic Signal



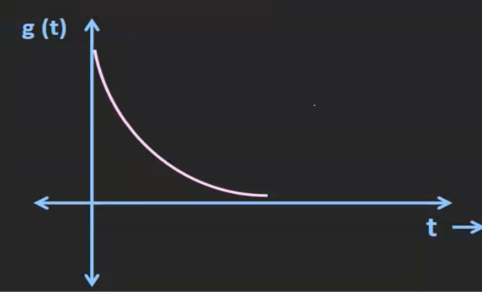
Strength of the Signal



Energy of the Signal

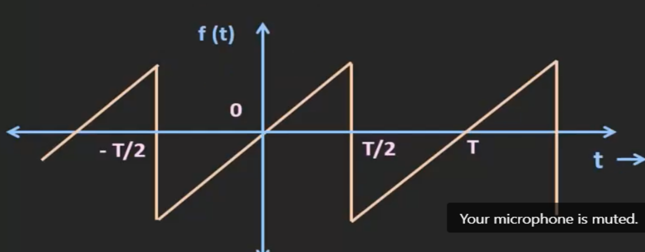
$$Eg = \int_{-\infty}^{\infty} g^2(t)\,dt$$

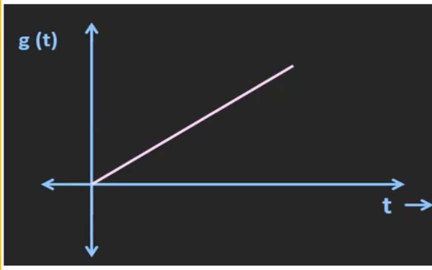
Strength of the Signal



Average Power of the Signal

$$Pg = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} g^2(t)\,dt$$





Classification of Signal

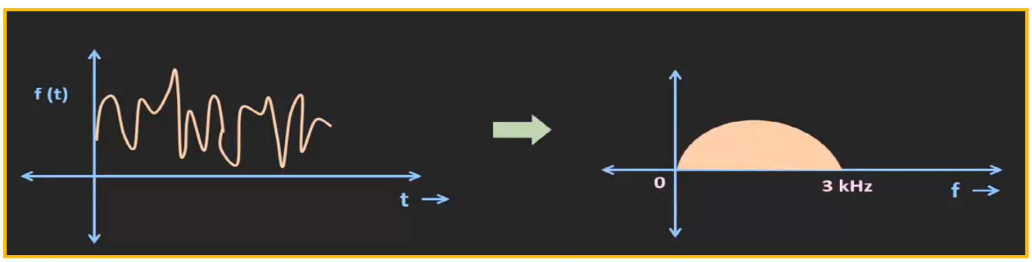
Deterministic Signal

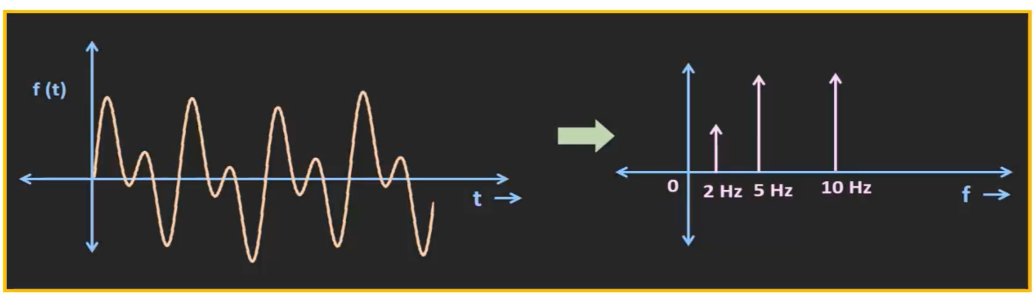
A signal whose physical description is known completely either in mathematical form or graphical form is known as the Deterministic Signal.

Random Signal

A signal which is known only in terms of the probabilistic description like mean, mean square value and distributions is known as the Random Signal.

Your microphone is muted.





Fourier Series

Fourier Series

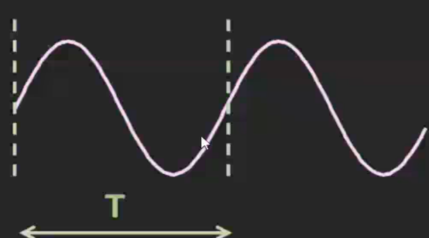
Any periodic signal can be represented by the linear combination of sine and cosines which are harmonically related to each other

Continuous Time Fourier Series (CTFS)

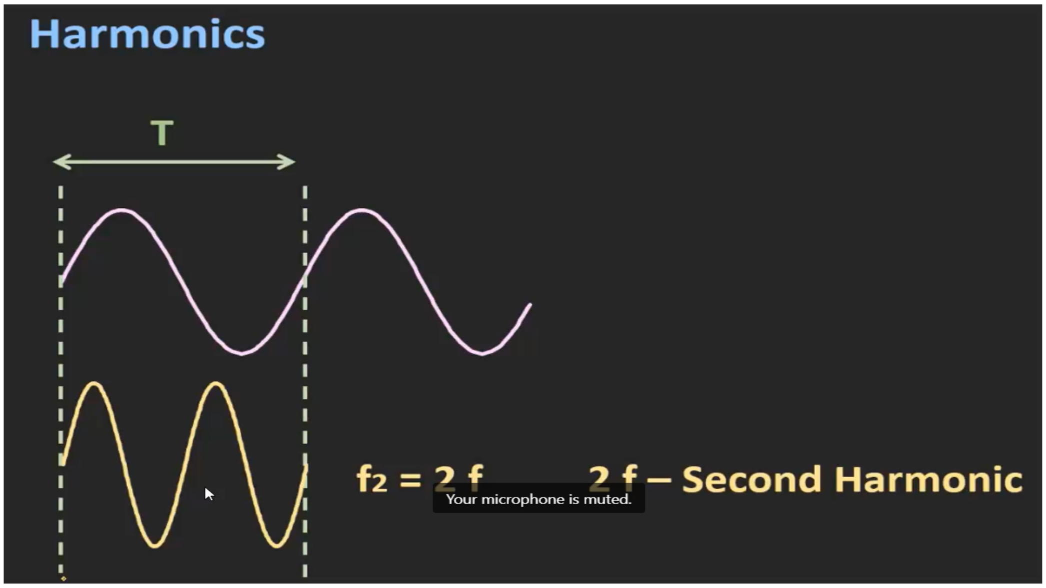
Discrete Time Fourier Series (DTFS)

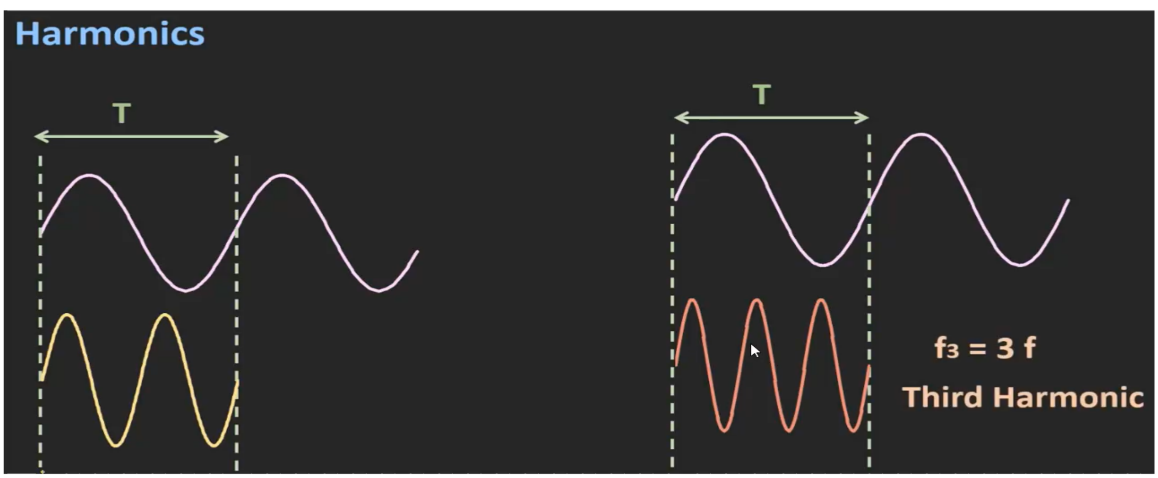
Harmonics

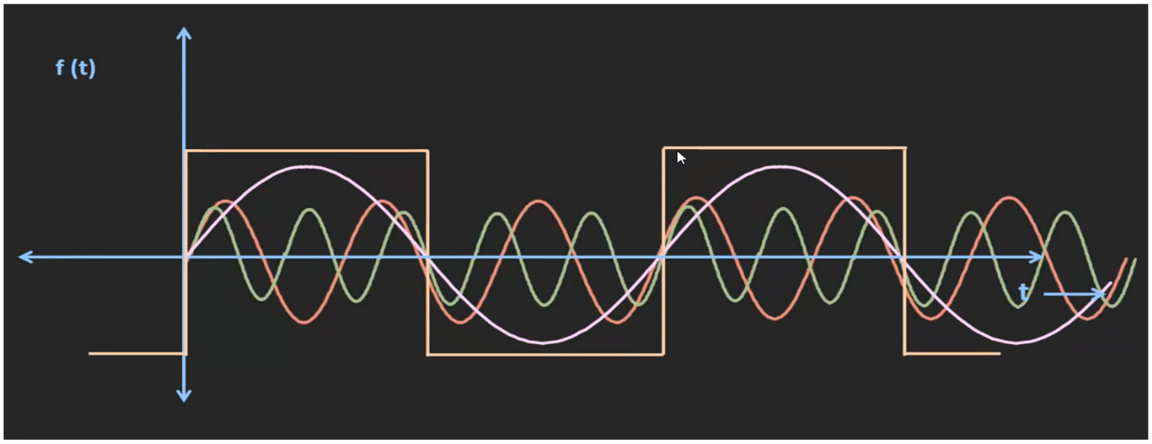
Integer Multiple of the fundamental Frequency



$f = \frac{1}{T}$ f – Fundamental Frequency


Harmonics
T
$f_2 = 2f$
2 f – Second Harmonic
Your microphone is muted.


Harmonics
T
T
$f_3 = 3f$
Third Harmonic



Fourier Series

Any periodic signal can be represented by the linear combination of sine and cosines which are harmonically related to each other

$$\boxed{g(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos(n\omega_0 t) + \sum_{n=1}^{\infty} b_n \sin(n\omega_0 t)}$$

$$\omega_0 = \frac{2\pi}{T}$$

$$a_0 = \frac{1}{T} \int_{To} g(t)dt$$

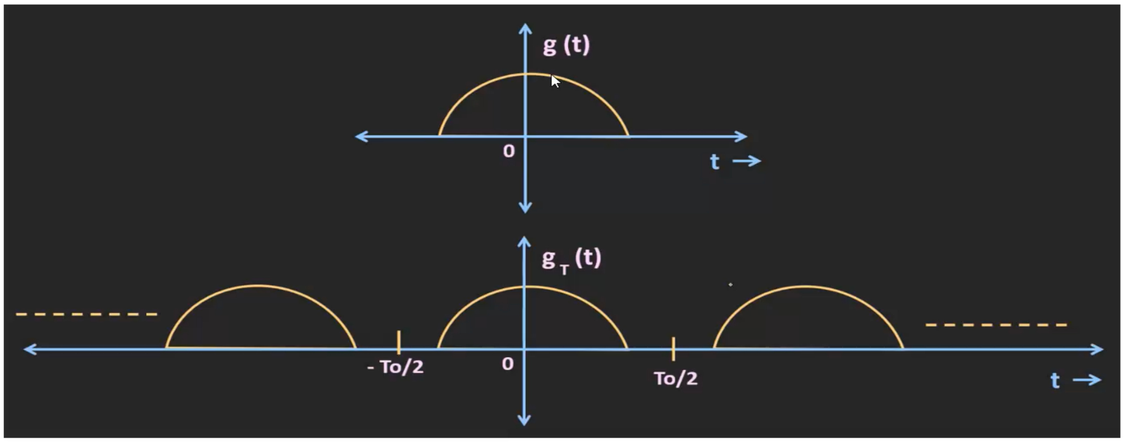
$$a_n = \frac{2}{T} \int_{To} g(t)\cos(n\omega_o t)dt$$

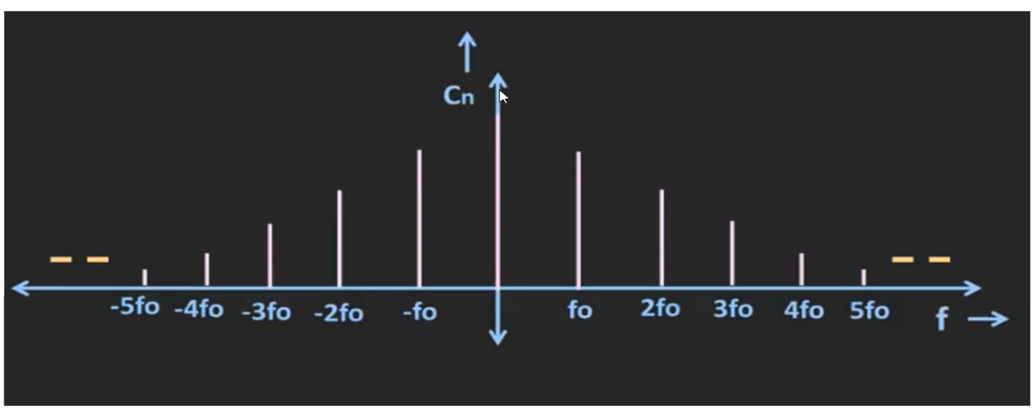
$$b_n = \frac{2}{T} \int_{To} g(t)\sin(n\omega_o t)dt$$

Exponential Fourier Series

Any periodic signal can be represented by the linear combination of complex exponentials.

$$\boxed{g(t) = \sum_{n=-\infty}^{\infty} C_n \, e^{jn\omega_o t}} \qquad \omega_o = \frac{2\pi}{T}$$


g (t)
0
t →
g_T (t)
- To/2
0
To/2
t →


Cn
-5fo -4fo -3fo -2fo -fo fo 2fo 3fo 4fo 5fo
f →

The Concept of Orthogonality

$$\int_{t_1}^{t_2} g(t)\, x(t)\, dt = 0$$

g (t) and x (t) are real signals

$$\int_{t_1}^{t_2} g(t)\, x^*(t)\, dt = 0 \quad \text{or} \quad \int_{t_1}^{t_2} g^*(t)\, x(t)\, dt = 0$$

g (t) and x (t) are complex signals

The Concept of Orthogonality

$x_1(t)$, $x_2(t)$, $x_3(t)$, $x_4(t)$, ----- $X_n(t)$

$g(t) = c_1 x_1(t) + c_2 x_2(t) + c_3 x_3(t) +$ ------ $+ C_n X_n(t)$

$$C_n = \frac{\int g(t)\, x_n^*(t)\, dt}{\int |x(t)|^2 dt}$$

$$g(t) = e^{jn\omega_0 t}$$

$$x(t) = e^{jm\omega_0 t}$$

$$\int_{t_1}^{t_2} g(t)\, x^*(t)\, dt = 0 \quad \text{or} \quad \int_{t_1}^{t_2} g^*(t)\, x(t)\, dt = 0$$

$$\int_0^T g(t)\, x^*(t)\, dt = 0 \Rightarrow \int_0^T e^{jn\omega_0 t} \times e^{-jm\omega_0 t}\, dt = 0$$

$$\Rightarrow \int_0^T e^{j(n-m)\omega_0 t}\, dt \qquad n \neq m$$

$$\left[\frac{e^{j(n-m)\omega_0 t}}{j(n-m)\omega_0} \right]_0^T$$

$$= \frac{1}{j(n-m)\omega_0} \times \left[e^{j(n-m)\frac{2\pi}{T} \times T} - 1 \right]$$

$$= 0$$

$$\int_0^T e^{jn\omega_0 t} \times e^{-jn\omega_0 t}\, dt = \int_0^T (1)\, dt = T \qquad n = m$$

$$n = -\infty \text{ to } \infty$$

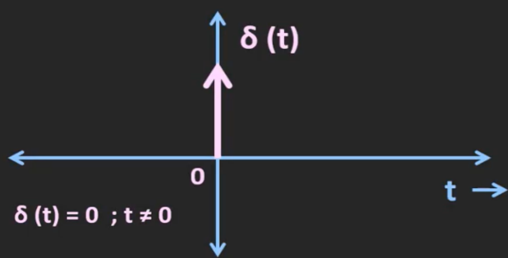
$$Cn = \frac{\int_T g(t)\, x_n^*(t)\, dt}{\int_T |x(t)|^2\, dt = T}$$

$$x_n(t) = e^{jn\omega_0 t}$$

$$\omega_0 = \frac{2\pi}{T}$$

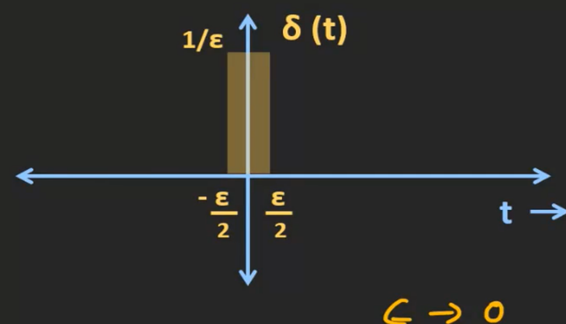
$$c_n = \frac{1}{T} \int_0^T g(t)\, e^{-jn\omega_0 t}\, dt$$

Unit Impulse Function



$\delta(t) = 0 \;;\; t \neq 0$

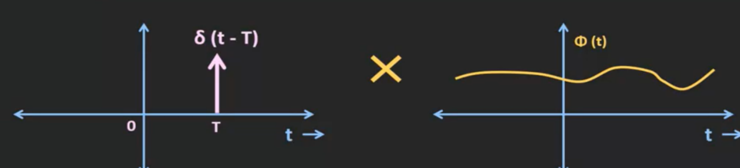
$$\int_{-\infty}^{\infty} \delta(t)\, dt = 1$$



Unit Impulse Function

$\delta(t) \times \phi(t) = \phi(0) \times \delta(t)$

Unit Impulse Function

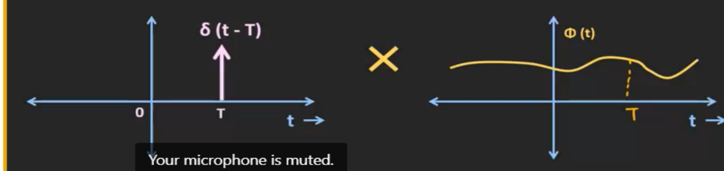


$\delta(t-T) \times \phi(t) = \phi(T) \times \delta(t-T)$

Unit Impulse Function

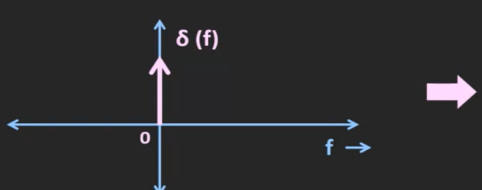
$$\int_{-\infty}^{\infty}\delta(t)\,\varphi(t)dt = \int_{-\infty}^{\infty}\delta(t)\,\varphi(0)dt = \varphi(0)\int_{-\infty}^{\infty}\delta(t)\,dt = \varphi(0)$$

Unit Impulse Function



$$\int_{-\infty}^{\infty}\delta(t-T)\,\varphi(t)dt = \int_{-\infty}^{\infty}\delta(t-T)\,\varphi(T)\,dt = \varphi(T)\int_{-\infty}^{\infty}\delta(t-T)\,dt = \varphi(T)$$

Unit Impulse Function

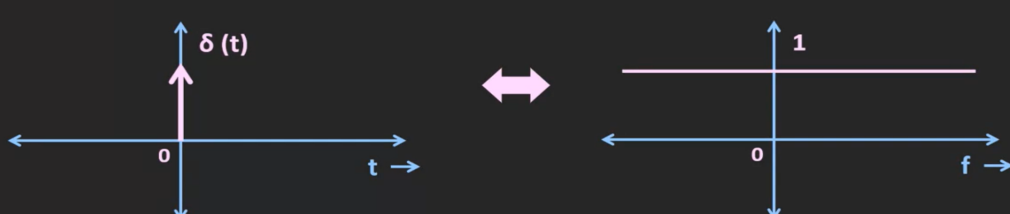


$$F^{-1}[\delta(f)]$$

$$\int_{-\infty}^{\infty}\delta(f)\times e^{j2\pi f t}\,df$$

$$= e^{0} = 1$$

Unit Impulse Function



Introduction of Electronic Communication

What is Electronic Communication?

"The systems and processes that are used to convey information from a source to a destination efficiently and reliably, especially by means of electricity or radio waves."

History

Milestones in the history of electronic communication.

When?	Where or Who?	What?
1837	Samuel Morse	Invention of the telegraph (patented in 1844).
1843	Alexander Bain	Invention of facsimile.
1866	United States and England	The first transatlantic telegraph cable laid.
1876	Alexander Bell	Invention of the telephone.
1877	Thomas Edison	Invention of the phonograph.
1879	George Eastman	Invention of photography.
1887	Heinrich Hertz (German)	Discovery of radio waves.
1887	Guglielmo Marconi (Italian)	Demonstration of "wireless" communications by radio waves.
1901	Marconi (Italian)	First transatlantic radio contact made.
1903	John Fleming	Invention of the two-electrode vacuum tube rectifier.
1906	Reginald Fessenden	Invention of amplitude modulation; first electronic voice communication demonstrated.
1906	Lee de Forest	Invention of the triode vacuum tube.
1914	Hiram P. Maxim	Founding of American Radio Relay League, the first amateur radio organization.
1920	KDKA Pittsburgh	First radio broadcast.
1923	Vladimir Zworykin	Invention and demonstration of television.
1933–1939	Edwin Armstrong	Invention of the superheterodyne receiver and frequency modulation.

History

Milestones in the history of electronic communication.

1939	United States	First use of two-way radio (walkie-talkies).
1940–1945	Britain, United States	Invention and perfection of radar (World War II).
1948	John von Neumann and others	Creation of the first stored program electronic digital computer.
1948	Bell Laboratories	Invention of transistor.
1953	RCA/NBC	First color TV broadcast.
1958–1959	Jack Kilby (Texas Instruments) and Robert Noyce (Fairchild)	Invention of integrated circuits.
1958–1962	United States	First communication satellite tested.
1961	United States	Citizens band radio first used.
1973–1976	Metcalfe	Ethernet and first LANs.
1975	United States	First personal computers.
1977	United States	First use of fiber-optic cable.
1982	United States	TCP/IP protocol adopted.
1982–1990	United States	Internet development and first use.
1983	United States	Cellular telephone networks.
1993	United States	First browser Mosaic.
1995	United States	Global Positioning System deployed.
1996–2001	Worldwide	First smartphones by BlackBerry, Nokia, Palm.
1997	United States	First wireless LANs.
2000	Worldwide	Third-generation digital cell phones.
2009	Worldwide	First fourth-generation LTE cellular networks.
2009	Worldwide	First 100 Gb/s fiber optical networks.

History

Claude Shannon (1948)

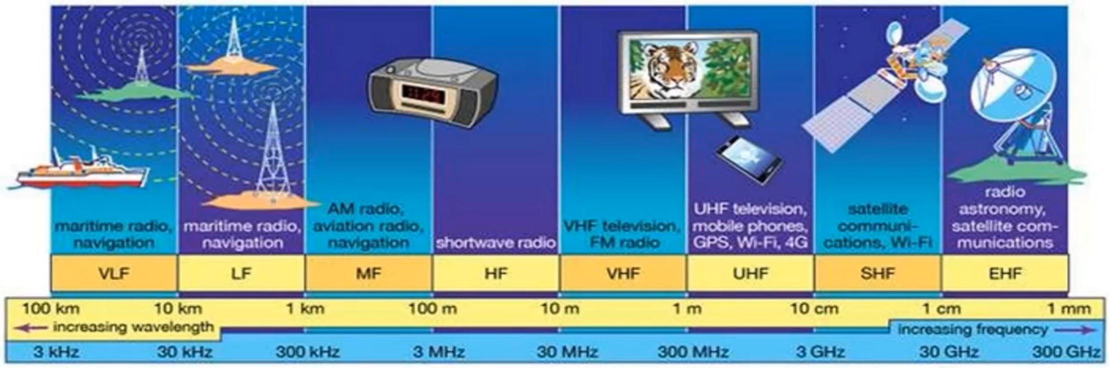
"A Mathematical Theory of Communication", *Bell System Technical Journal*. 1948

Information Theory

Fundamental limits of source compression rate and channel transmission rate

Analog communication ⇒ Digital communication

Frequency Spectrum



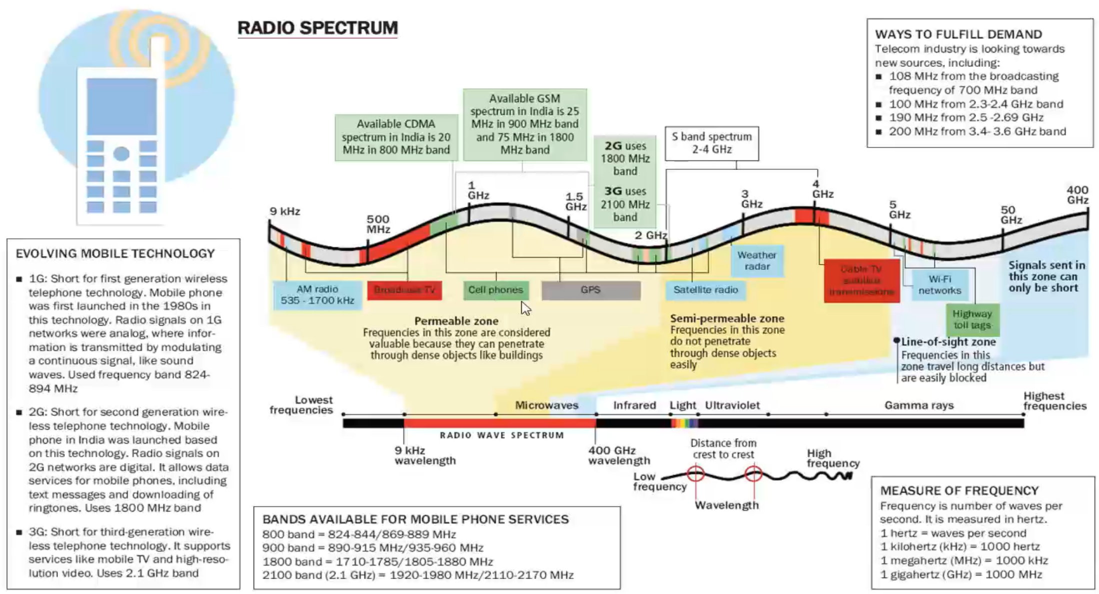
Frequency Spectrum

Radio Frequency Spectrum: Ranges

Designation	Abbreviation	Frequencies	Wavelengths
Very Low Frequency	VLF	3 kHz - 30 kHz	100 km - 10 km
Low Frequency	LF	30 kHz - 300 kHz	10 km - 1 km
Medium Frequency	MF	300 kHz - 3 MHz	1 km - 100 m
High Frequency	HF	3 MHz - 30 MHz	100 m - 10 m
Very High Frequency	VHF	30 MHz - 300 MHz	10 m - 1 m
Ultra High Frequency	UHF	300 MHz - 3 GHz	1 m - 100 mm
Super High Frequency	SHF	3 GHz - 30 GHz	100 mm - 10 mm
Extremely High Frequency	EHF	30 GHz - 300 GHz	10 mm - 1 mm

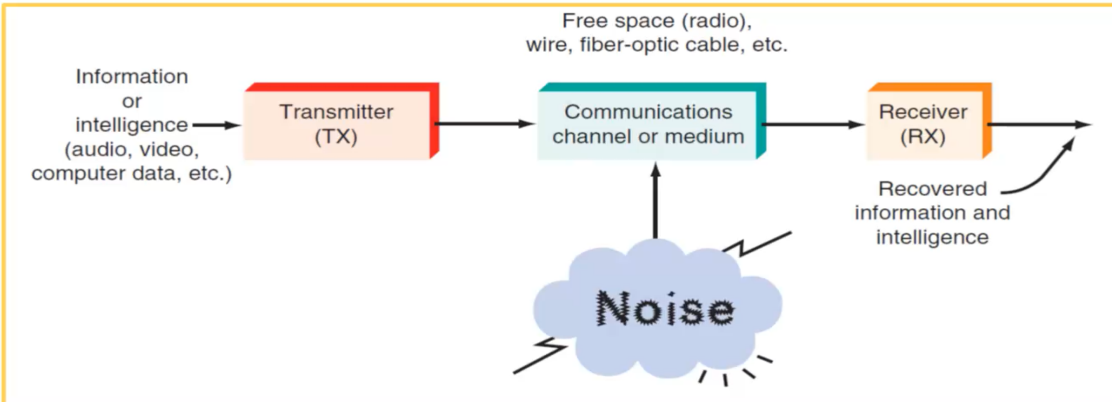
	Frequency	Common Uses
VLF	3-30 kHz	underwater communications
LF	30-300 kHz	AM radio
MF	300-3000 kHz	AM radio
HF	3-30 MHz	AM radio, long distance aviation communications
VHF	30-300 MHz	FM radio, television, short range avaiation communications, weather radio
UHF	300-3000 MHz	television, mobile phones, wireless networks, Bluetooth, satellite radio, GPS
SHF	3-30 GHz	satellite television and radio, radar systems, radio astronomy
EHF	30-300 GHz	radio astronomy, full body scanners

Radio Spectrum



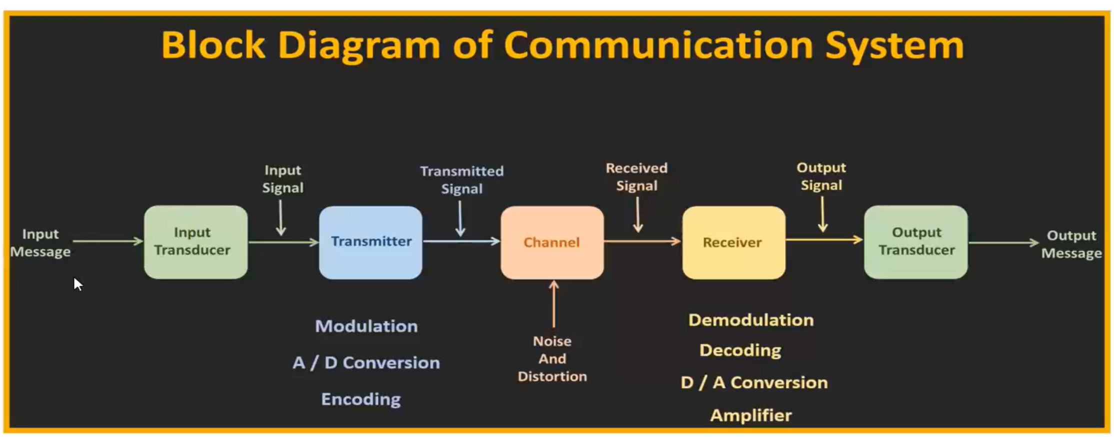
Basic Communication

General Model of all Communication Systems



A general model of all communication systems.

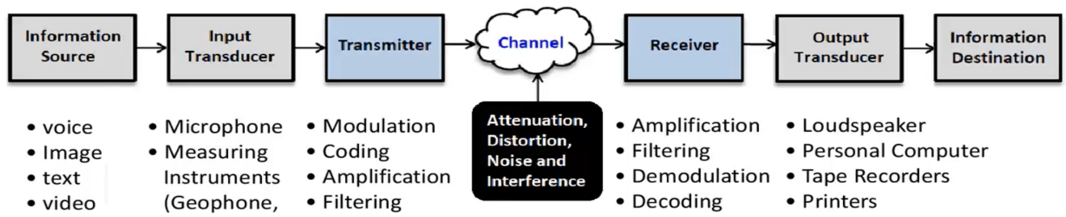
Extended Block Diagram



Basic Elements of a Communication System

Basic Elements of a Communication System

- Free space
- Wireline
- Twisted Pair
- Coaxial Cable
- Optical Fiber etc.



- voice
- Image
- text
- video

etc.

- Microphone
- Measuring Instruments (Geophone, Hydrophone)
- Video Camera

etc

- Modulation
- Coding
- Amplification
- Filtering

- Amplification
- Filtering
- Demodulation
- Decoding

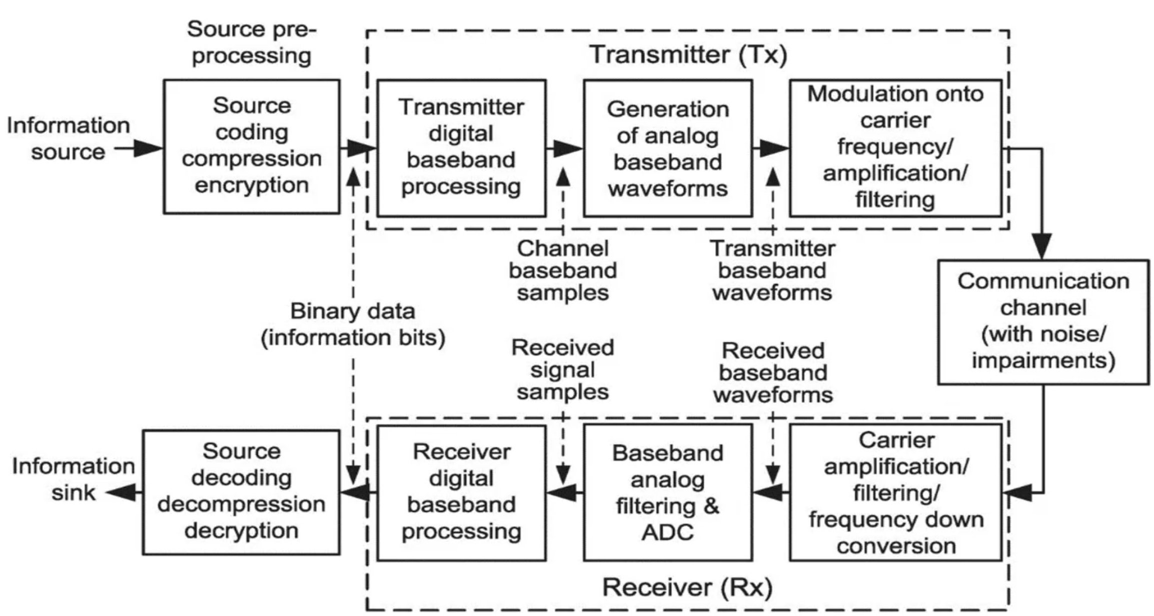
- Loudspeaker
- Personal Computer
- Tape Recorders
- Printers

etc.

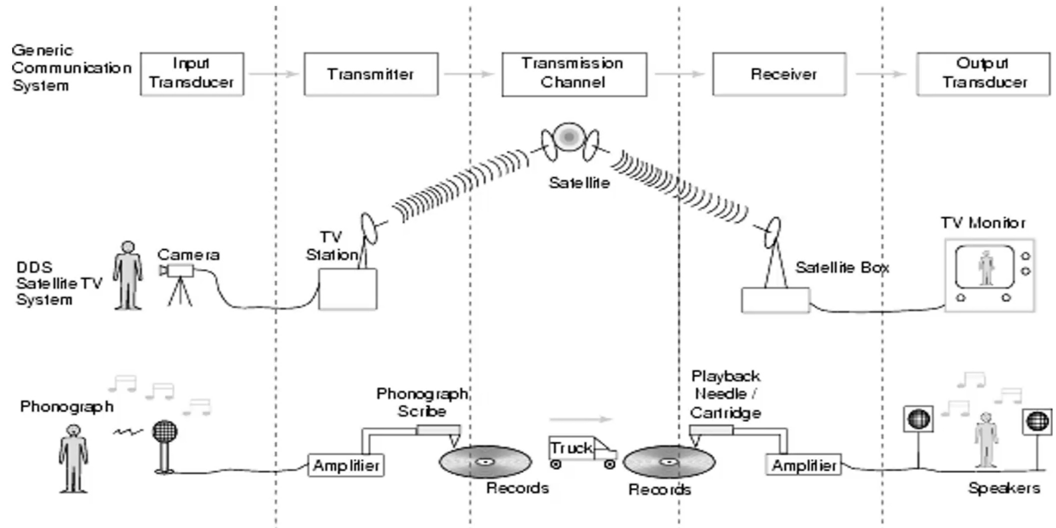
Channel Limitations :

- Propagation Loss
- Frequency Selectivity
- Time Variation
- Nonlinearity
- Multiplexing or Shared usages
- Noise
- Interference

Block Diagram of Complex Comm. System



Basic View of Communication System



Receivers & Transceivers

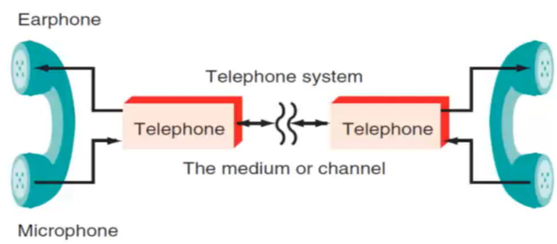
Receivers

A *receiver* is a collection of electronic components and circuits that accepts the transmitted message from the channel and converts it back to a form understandable by humans. Receivers contain amplifiers, oscillators, mixers, tuned circuits and filters, and a demodulator or detector that recovers the original intelligence signal from the modulated carrier. The output is the original signal, which is then read out or displayed. It may be a voice signal sent to a speaker, a video signal that is fed to an LCD screen for display, or binary data that is received by a computer and then printed out or displayed on a video monitor.

Transceivers

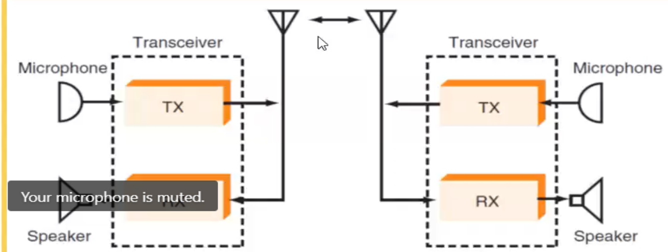
Most electronic communication is two-way, and so both parties must have both a transmitter and a receiver. As a result, most communication equipment incorporates circuits that both send and receive. These units are commonly referred to as *transceivers*. All the transmitter and receiver circuits are packaged within a single housing and usually share some common circuits such as the power supply. Telephones, handheld radios, cellular telephones, and computer modems are examples of transceivers.

Types of Electronic Communication



(*a*) Full duplex (simultaneous, two-way)

Duplex communication
(a) Full duplex (simultaneous two-way).
(b) Half duplex (one way at a time).



(*b*) Half duplex (one way at a time)

Attenuation & Noise

Attenuation

Signal *attenuation,* or degradation, is inevitable no matter what the medium of transmission. Attenuation is proportional to the square of the distance between the transmitter and receiver. Media are also frequency-selective, in that a given medium will act as a low-pass filter to a transmitted signal, distorting digital pulses in addition to greatly reducing signal amplitude over long distances. Thus considerable signal amplification, in both the transmitter and the receiver, is required for successful transmission. Any medium also slows signal propagation to a speed slower than the speed of light.

Noise

Noise is mentioned here because it is the bane of all electronic communications. Its effect is experienced in the receiver part of any communications system. For that reason, we cover noise at that more appropriate time in Chapter . While some noise can be filtered out, the general way to minimize noise is to use components that contribute less noise and to lower their temperatures. The measure of noise is usually expressed in terms of the signal-to-noise (S/N) ratio (SNR), which is the signal power divided by the noise power and can be stated numerically or in terms of decibels (dB). Obviously, a very high SNR is preferred for best performance.

Types of Electronic Communication

Simplex

The simplest way in which electronic communication is conducted is one-way communications, normally referred to as *simplex communication.* Examples are shown in Fig. The most common forms of simplex communication are radio and TV broadcasting. Another example of one-way communication is transmission to a remotely controlled vehicle like a toy car or an unmanned aerial vehicle (UAV or drone).

Full Duplex

The bulk of electronic communication is two-way, or *duplex communication.* Typical duplex applications are shown in Fig. For example, people communicating with one another over the telephone can talk and listen simultaneously, as Fig. (*a*) illustrates. This is called *full duplex communication.*

Half Duplex

The form of two-way communication in which only one party transmits at a time is known as *half duplex communication* [see Fig. (*b*)]. The communication is two-way, but the direction alternates: the communicating parties take turns transmitting and receiving. Most radio transmissions, such as those used in the military, fire, police, aircraft, marine, and other services, are half duplex communication. Citizens band (CB), Family Radio, and amateur radio communication are also half duplex.