CHAPTER 5

Wireless Modulation Techniques

- Modulation is a process of encoding information from a message source in a manner suitable for transmission.
- Modulation converts information or message signal frequency to one that is suitable for transmission through a medium like radio waves, wires etc.
- A device that performs modulation is known as modulator and a device that performs the inverse operation of modulation is known as demodulator.
- A device that can do both operations is a modem (modulator-demodulator).
- Two types of techniques of modulation: analog modulation and digital modulation.
- The information bearing signal is referred to as the modulating signal, and the output of the modulation procession is referred to as the modulated signal.

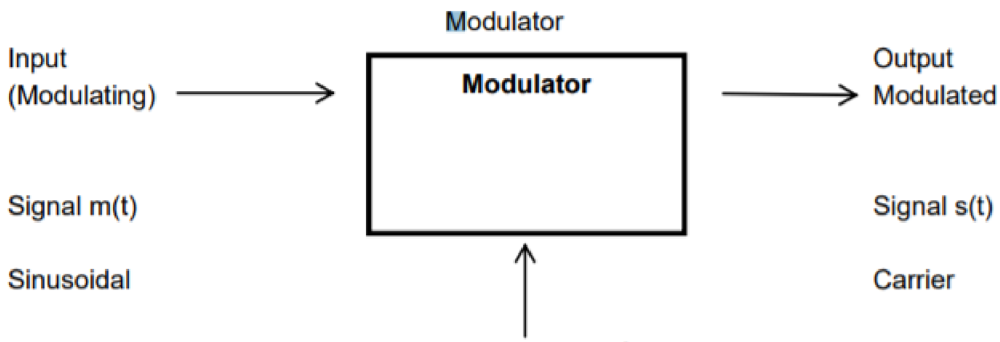
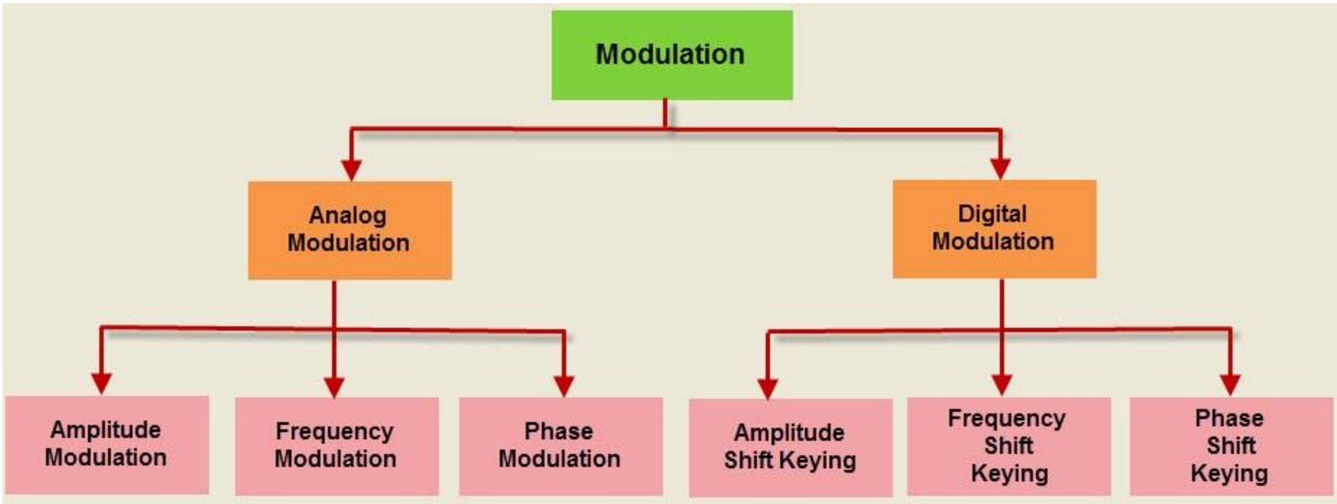


Figure 11.1: Block Diagram of Modulator

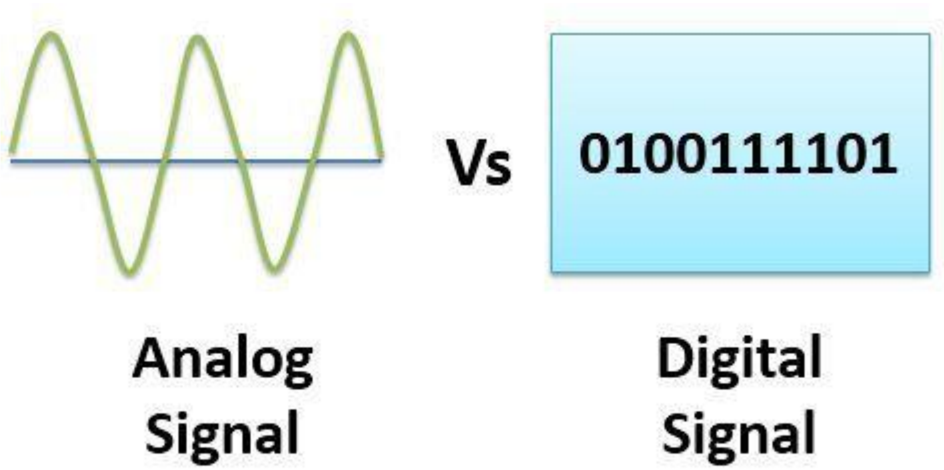
- Figure above shows the block diagram of a modulator supplied with a sinusoidal carrier.
- The modulating signal, acting as input, is denoted by m(t).
- The modulated signal, acting as output, is denoted by s(t).
- The input-output relation of the modulator is governed by the manner in which the output s(t) depends on the input m(t).

Benefits of Modulation

- More bandwidth available at higher carrier frequency.
- Antenna size is on the order of signal's wavelength.
- The shift the spectral content of a message signal so that it lies inside the operating frequency band of wireless communication channels such as cellular networks.



- Basically, the modulation is of following two types:
  - Analog Modulation
  - Digital Modulation

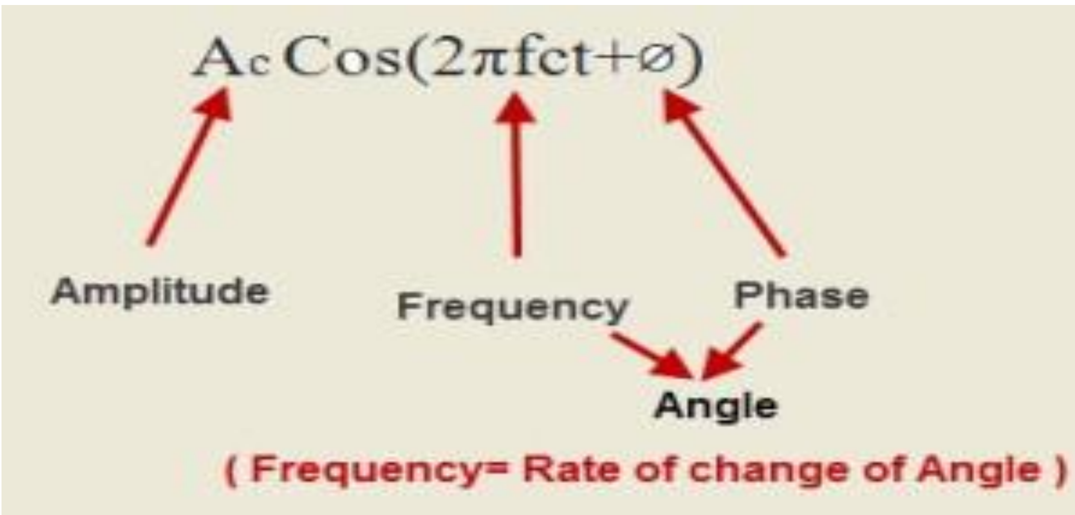


- The main difference between analog modulation and digital modulation is in the manner that they transmit data. With analog modulation, the input needs to be in the analog format, while digital modulation needs the data in a digital format.

BASIS FOR COMPARISON	ANALOG SIGNAL	DIGITAL SIGNAL
Basic	An analog signal is a continuous wave that changes over a time period.	A digital signal is a discrete wave that carries information in binary form.
Representation	An analog signal is represented by a sine wave.	A digital signal is represented by square waves.
Description	An analog signal is described by the amplitude, period or frequency, and phase.	A digital signal is described by bit rate and bit intervals.
Range	Analog signal has no fixed range.	Digital signal has a finite numbers i.e. 0 and 1.
Distortion	An analog signal is more prone to distortion.	A digital signal is less prone to distortion.
Transmit	An analog signal transmit data in the form of a wave.	A digital signal carries data in the binary form i.e. 0 nad 1.
Example	The human voice is the best example of an analog signal.	Signals used for transmission in a computer are the digital signal.

1. **Analog Modulation**

- In analog modulation, analog signal (Sinusoidal signal) is used as a carrier signal that modulates the messages signal or data signal.
- The general function Sinusoidal wave is shown in the figure below, in which three parameters can be altered to get modulation – they are amplitude, frequency and phase.
- So, the types of analog modulation are:
    - Amplitude Modulation (AM)
    - Frequency Modulation (FM)
    - Phase Modulation (PM)



- Recall that any wave has three basic properties:
  1) Amplitude – the height of the wave
  2) Frequency – a number of waves passing through in a given second
  3) Phase – where the phase is at any given moment.

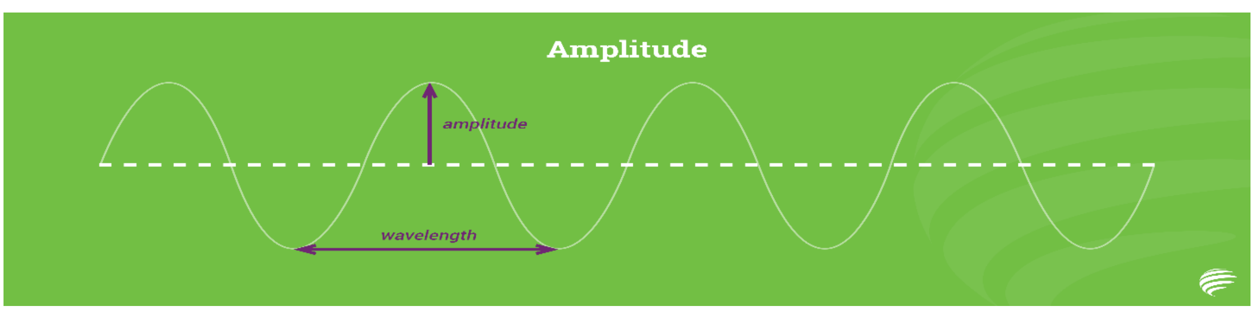


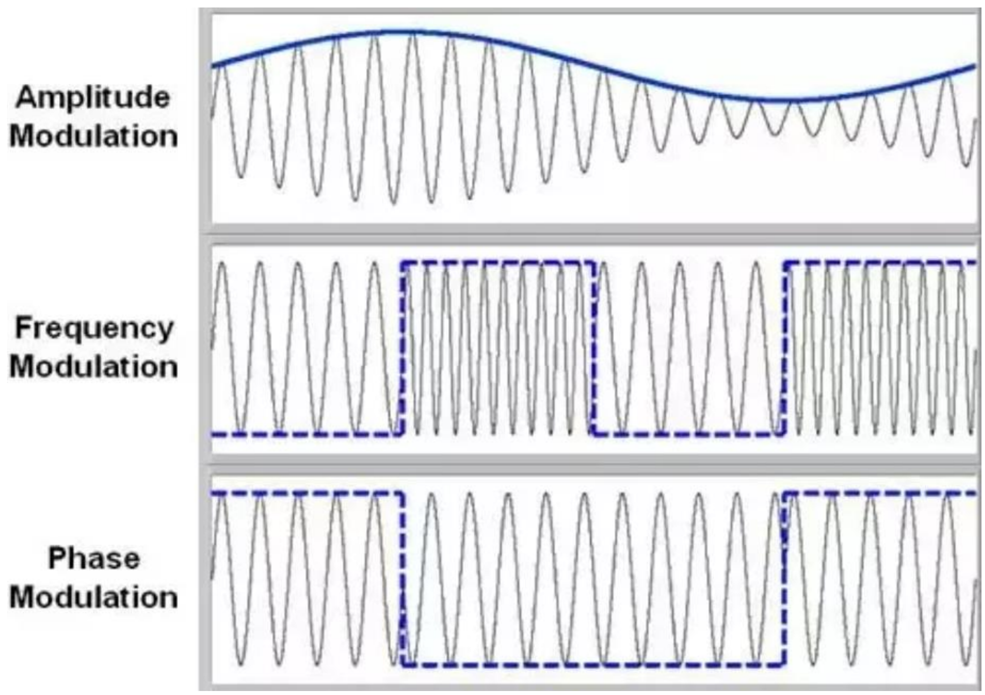
Figure: Types of Analog Modulation

1. **Amplitude Modulation**
   In this modulation, the amplitude of the carrier signal varies in accordance with the message signal, and other factors like phase and frequency remain constant.

2. **Frequency Modulation**
   In this type of modulation, the frequency of the carrier signal varies in accordance with the message signal and other parameters like amplitude and phase remain constant.

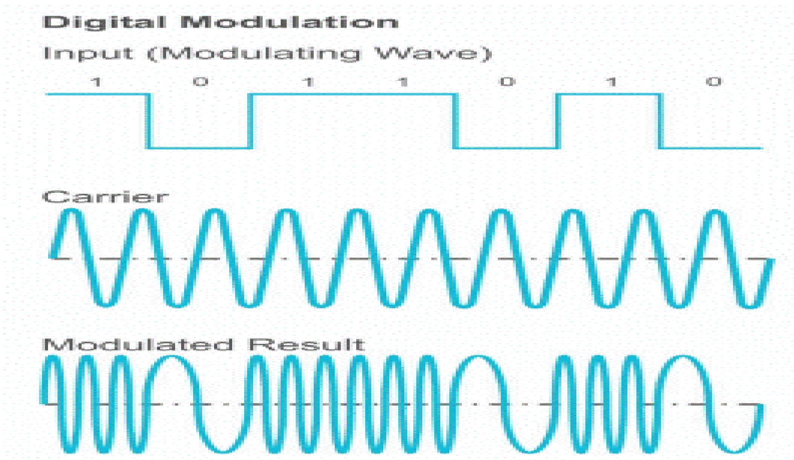
3. **Phase Modulation**

- In this type of modulation, the phase of the carrier signal varies in accordance with the message signal.

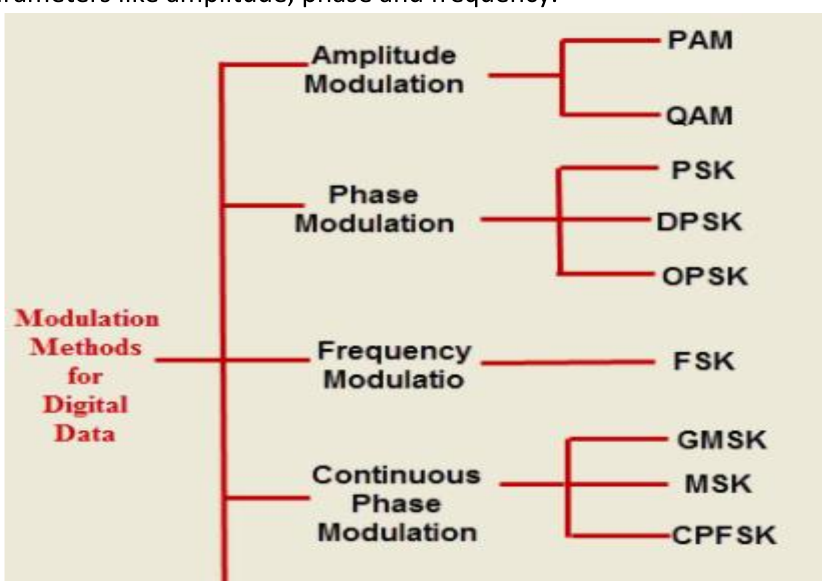


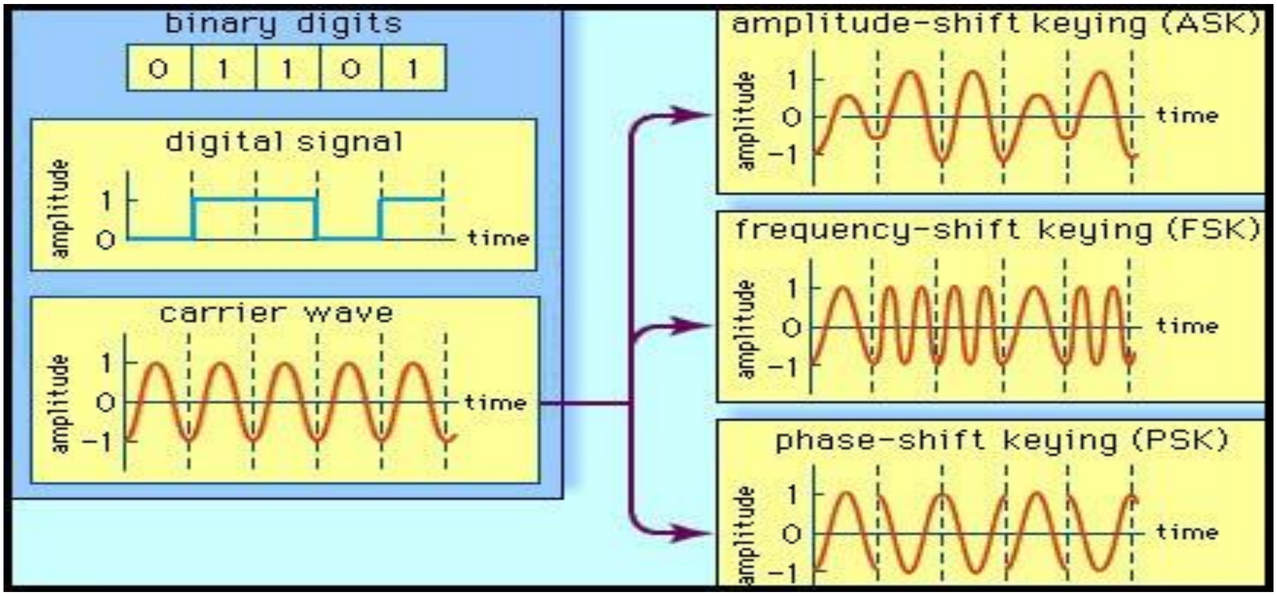
Digital Modulation

- For a better quality and efficient communication, digital modulation technique is employed.
- The main advantages of the digital modulation over analog modulation include available bandwidth, high noise immunity and permissible power.
- In digital modulation, a message signal is converted from analog to digital message, and then modulated by using a carrier wave.



- Similar to the analog system, the type of the digital modulation is decided by the variation of the carrier wave parameters like amplitude, phase and frequency.





BPSK (Binary Phase Shift Keying)

QPSK (Quadrature Phase Shift Keying)

- Quadrature Phase Shift Keying (QPSK) is a form of Phase Shift Keying in which two bits are modulated at once, selecting one of four possible carrier phase shifts (0, 90, 180, or 270).
- QPSK allows the signal to carry twice as much information as ordinary PSK using the same bandwidth.

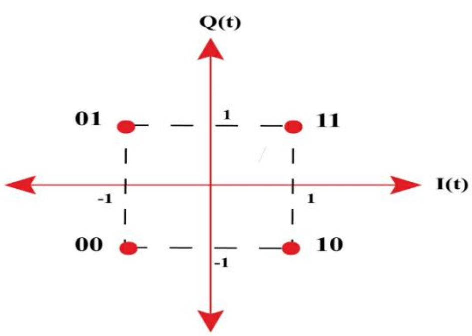
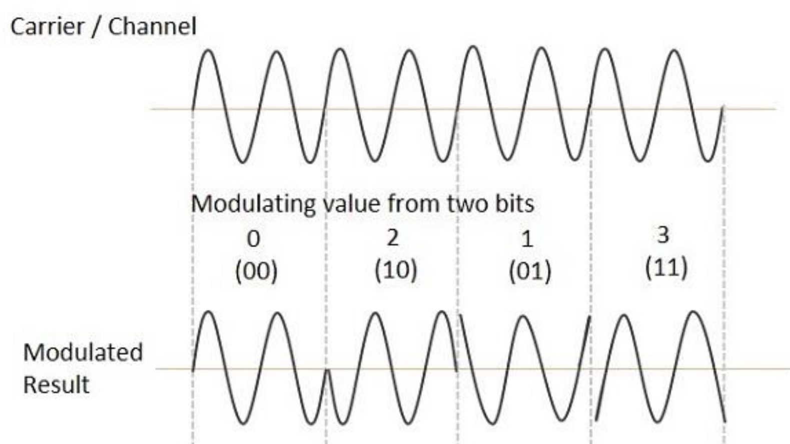
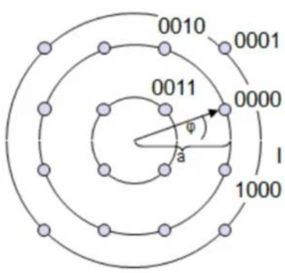


Figure 7.6 QPSK Constellation Diagram

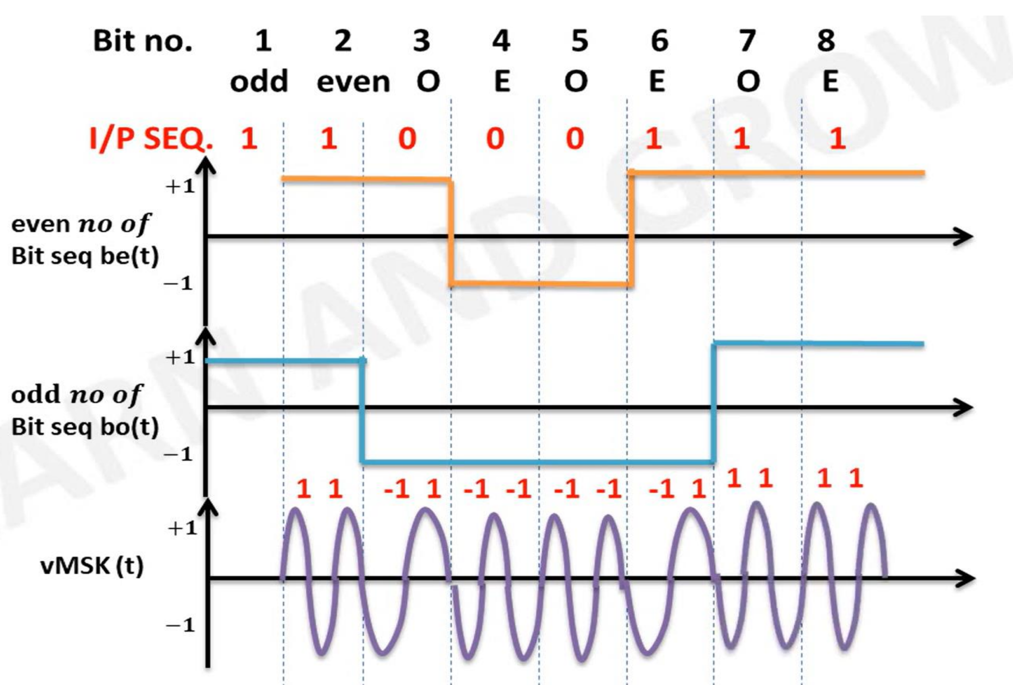


QAM (Quadrature Amplitude Modulation)

- QAM is defined as the modulation technique which is the combination of phase and amplitude modulation of a carrier wave into a single channel.
- In other words, QAM transmits information by changing both the amplitude and phase of a carrier wave, thereby doubling the effective bandwidth.
  - Quadrature Amplitude Modulation (QAM): combines amplitude and phase modulation
  - it is possible to code n bits using one symbol
  - 2^n discrete levels, n=2 identical to QPSK
  - Bit error rate increases with n, but less errors compared to comparable PSK schemes



Example: 16-QAM (4 bits = 1 symbol)
Symbols 0011 and 0001 have the same phase φ, but different amplitudes.
0000 & 1000 have different phases but the same amplitude.



- While higher order modulation rates are able to offer much faster data rates and higher levels of spectral efficiency for the radio communications system, this comes at a price. The higher order modulation schemes are considerably less resilient to noise and interference.

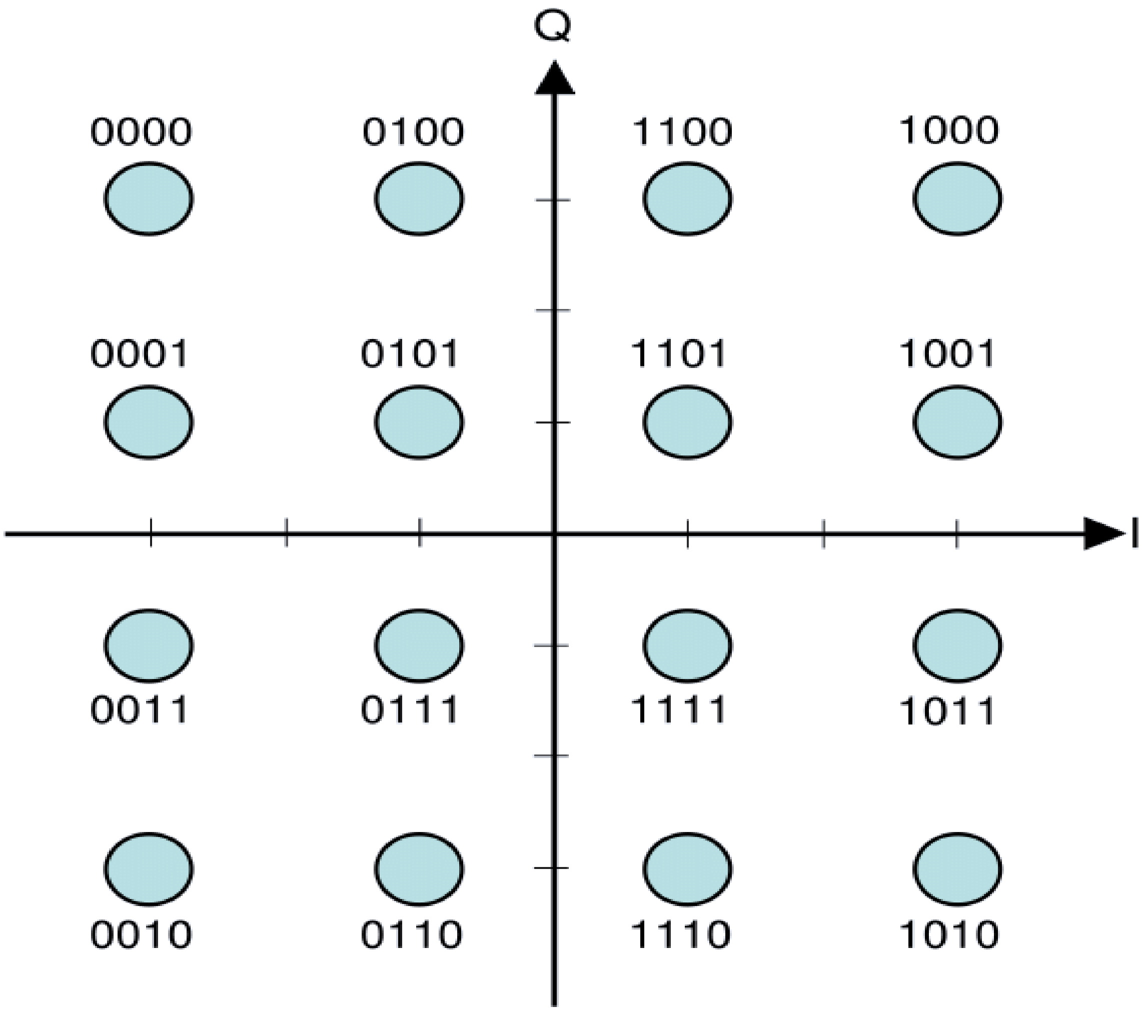
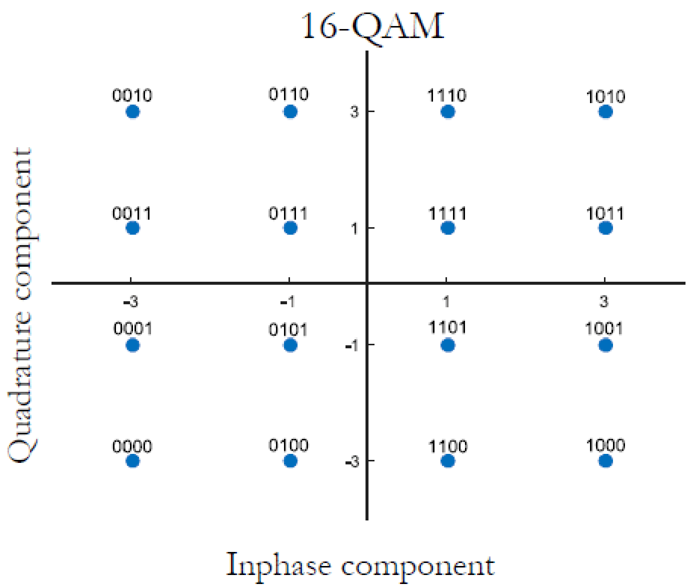
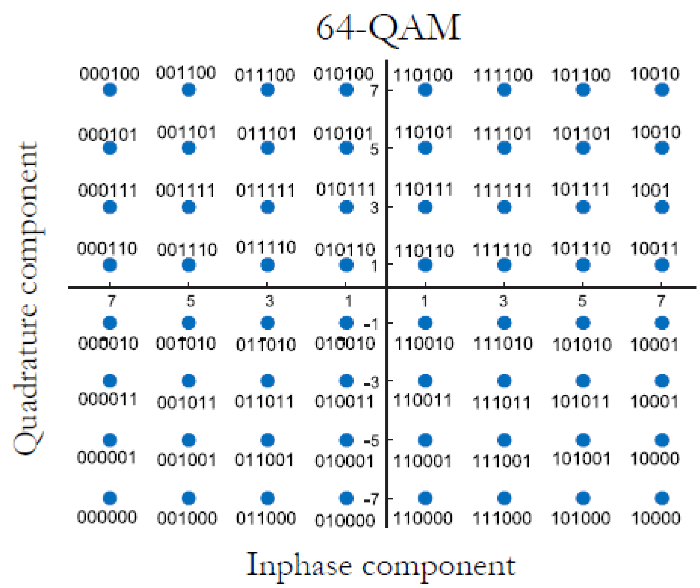


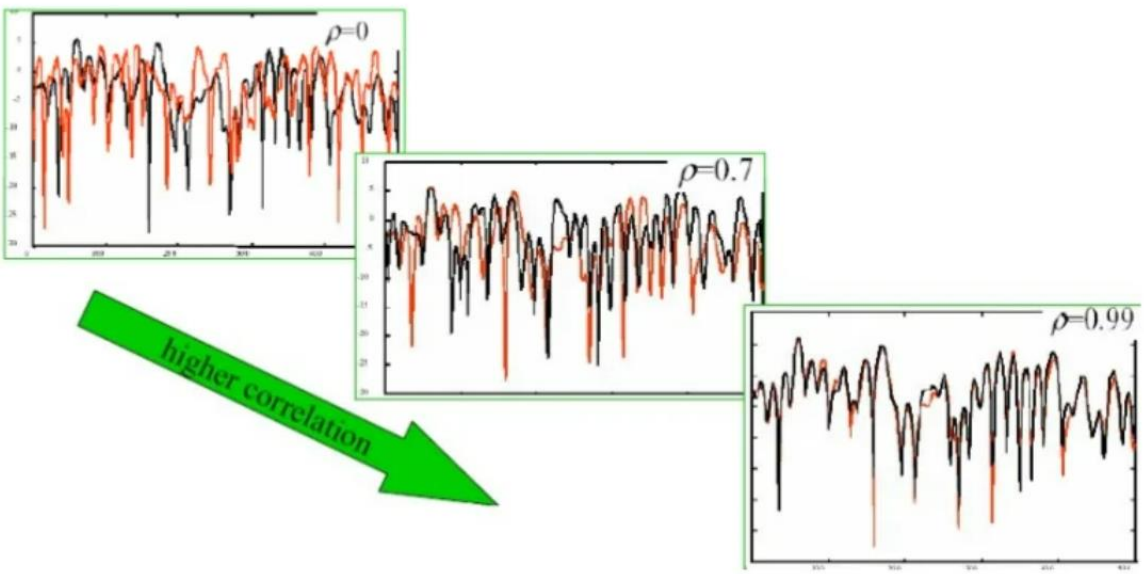
Figure: 16QAM Constellation Diagram


16-QAM
0010 0110 1110 1010
0011 0111 1111 1011
0001 0101 1101 1001
0000 0100 1100 1000
-3 -1 1 3
3 1 -1 -3
Quadrature component
Inphase component


64-QAM
000100 001100 011100 010100 110100 111100 101100 10010
000101 001101 011101 010101 110101 111101 101101 10010
000111 001111 011111 010111 110111 111111 101111 1001
000110 001110 011110 010110 110110 111110 101110 10011
000010 001010 011010 010010 110010 111010 101010 10001
000011 001011 011011 010011 110011 111011 101011 10001
000001 001001 011001 010001 110001 111001 101001 10000
000000 001000 011000 010000 110000 111000 101000 10000
7 5 3 1 1 3 5 7
7 5 3 1 -1 -3 -5 -7
Quadrature component
Inphase component

Diversity Techniques in Wireless Communications

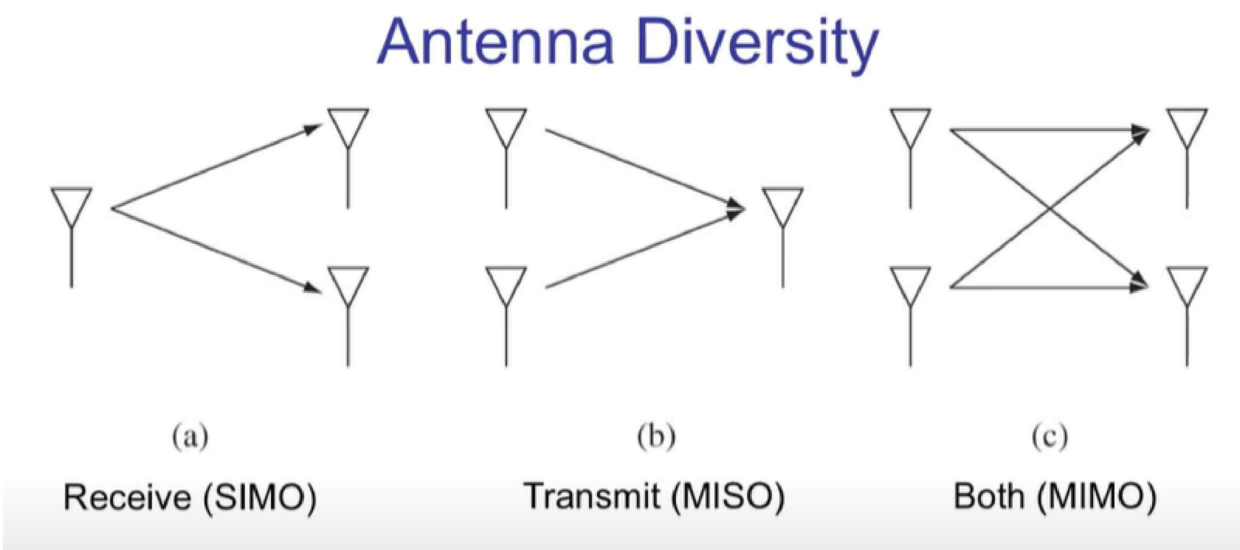
- Diversity techniques are used in wireless communication systems to primarily to improve performance over a fading radio channel.
- In such a system, the receiver is provided with multiple copies of the same information signal which are transmitted over two or more communication channels.
- The signal is transmitted and received through multiple paths.
- Receiver diversity improves reception quality by using multiple antennas with a preferably low correlation factor between each other.
- Requirements for diversity
  1. Multiple Branches
  2. Low correlation between branches



Classification of Diversity

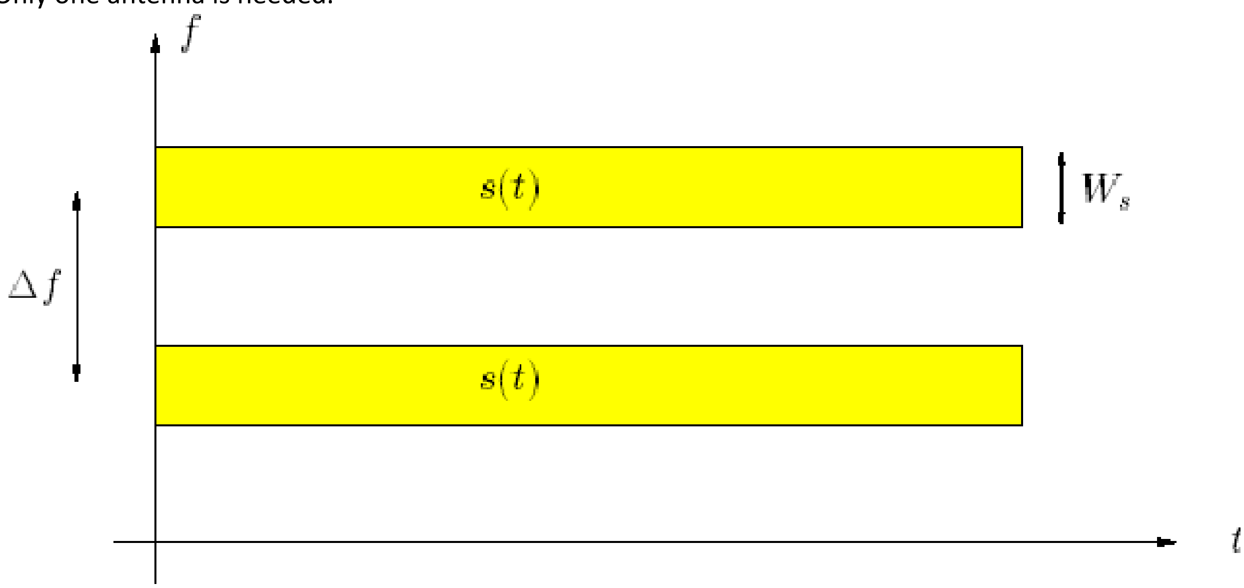
1. Space Diversity

- A space diversity means using different physical paths for the signal, at a single frequency.
- It is especially used in urban and indoor environments where there is no clear line-of—sight (LOS) between transmitter and receiver.
- The signal is reflected along multiple paths before finally being received.
- Each of these bounces can introduce phase shifts, time delays, attenuations, and distortions that can destructively interfere with one another at the aperture of the receiving antenna.
- Space diversity is also called antenna diversity or spatial diversity.
- Space diversity is especially effective at mitigating these multipath situations. This is because multiple antennas offer a receiver several observations of the same signal.



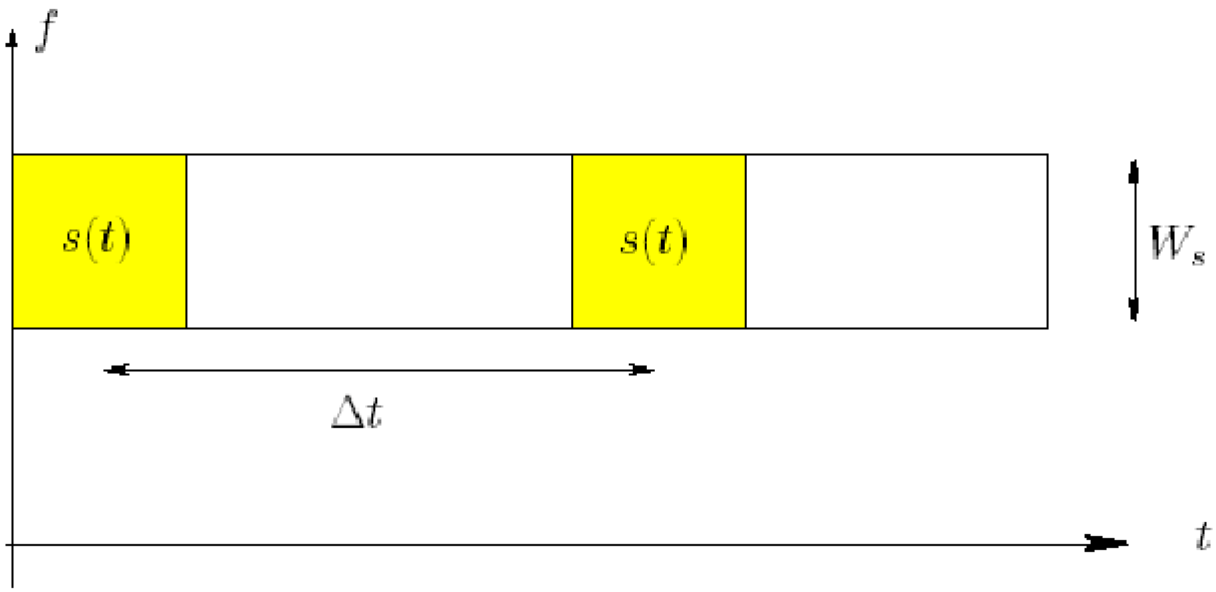
2. Frequency Diversity

- Frequency diversity is implemented by transmitting same information on more than one carrier frequency.
- The separation between the carriers should be at least the coherent bandwidth (delf)c.
- Different copies undergo independent fading.
- Only one antenna is needed.



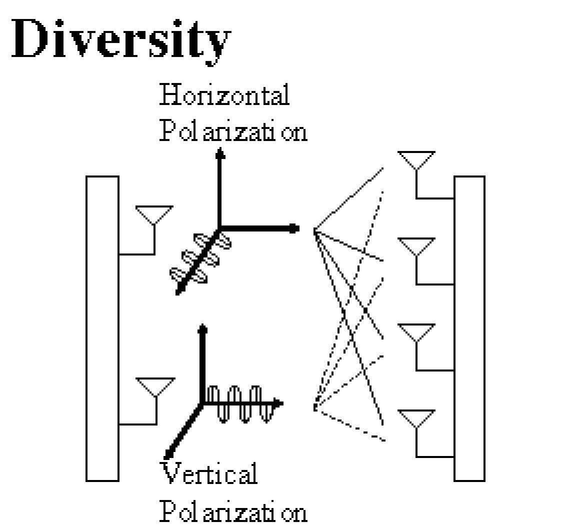
3. Time Diversity

- Repeatedly transmits information at the time spacing that exceeds the coherence time of the channel.
- The interval between transmission of same symbol should be at least the coherence time (delt)c.
- Different copies undergo independent fading.
- Only one antenna is needed.



4. Polarization Diversity

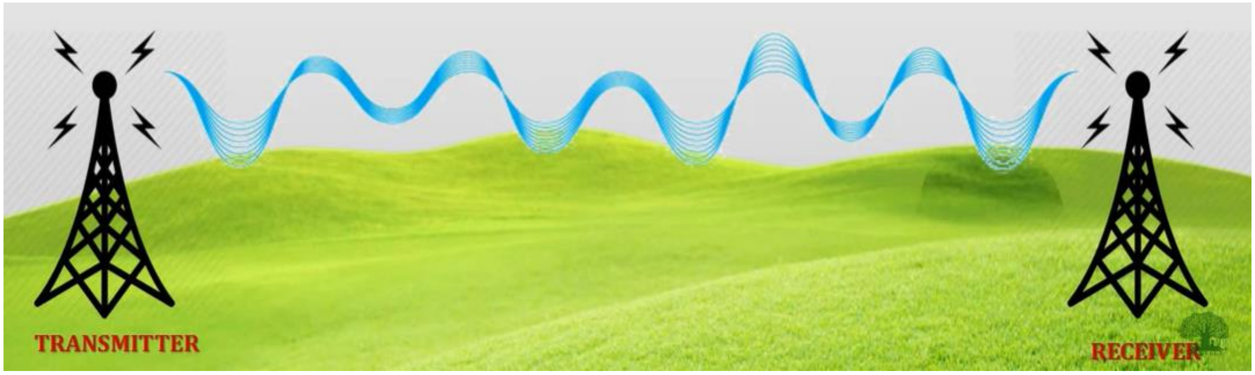
- Uses antennas of different polarizations i.e. horizontal and vertical.
- The antennas take advantage of the multiple propagation characteristics to receive separate uncorrelated signals.



ıre 2: Polarization Diversity

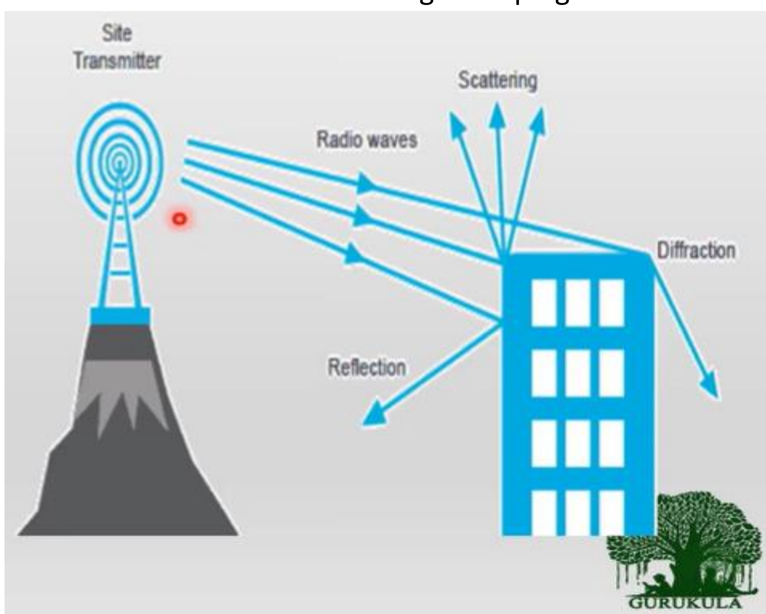
Wireless Propagation Mechanisms

- Channel is a medium through which the signal is transferred from one point to another.
- Propagation is the tendency of Electromagnetic Wave to travel from one place to another place.



Propagation Mechanisms- Effects

- When a signal hits the obstacle there are three possible effects that would happen to the signal based on the surface on which the signal impinges:



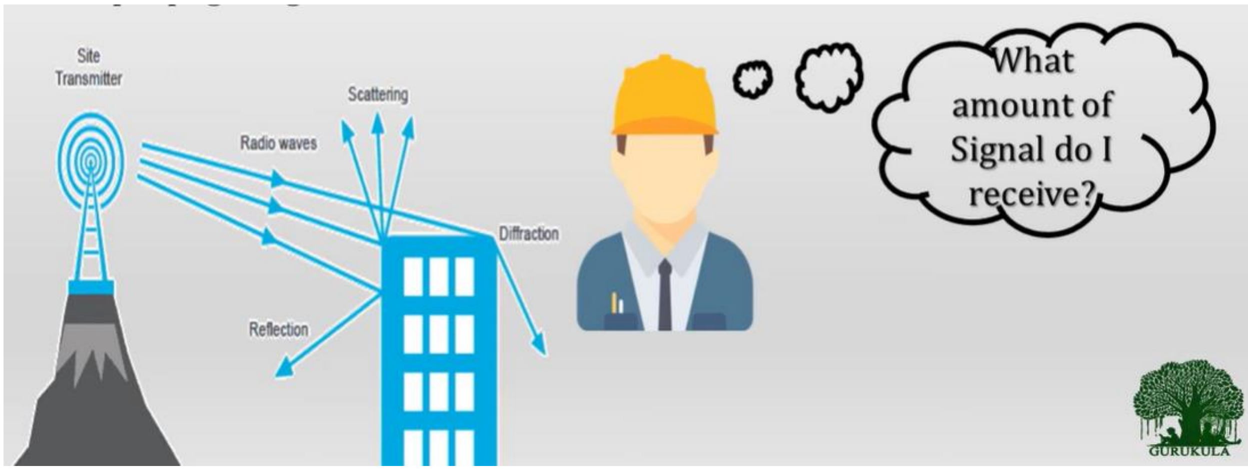
They are:

1. **Reflection**
   - Reflection occurs when the propagating wave impinges on a smooth objects that has a very large wavelength when compared to the wavelength of the wave. Eg:. Earth and buildings.
2. **Diffraction**
   - Diffraction occurs when there are sharp edges between the transmitter and the receiver. The diffracted wave spreads all over the space and creates bending of signal.

3. **Scattering**
   - Scattering occurs when the propagating wave impinges on a rough surface or irregular surfaces that have more number of obstacles per unit volume.

Need of Propagation Model

- All these propagation mechanisms have different effects on the propagating radio waves.



Method of Estimation of Received Signal

- Basically there are two ways to predict the amount of received signal after propagation at the receiver side.

EMPERICAL METHOD

An **empirical method** involves the use of objective, quantitative observation in a systematically controlled, replicable situation, in order to test or refine a theory.

PROPAGATION MODEL

mathematical formulation for the characterization of radio wave propagation as a function of frequency, distance and other conditions.

Propagation Models - Merits

- With Propagation models it is **easy to design, simulate and Plan the wireless systems.**
- Propagation models **reflect the properties of** the propagation **channel**
- Since the wireless channel characteristics are dynamic in nature **one single model cannot be defined** for estimating the wireless systems.
- Modelling a radio channel **decides the coverage area, modulation schemes to be used** to optimize communication parameters

Noise in Communication System

Introduction

"How do you want to send data/information to someone who is far from you?"

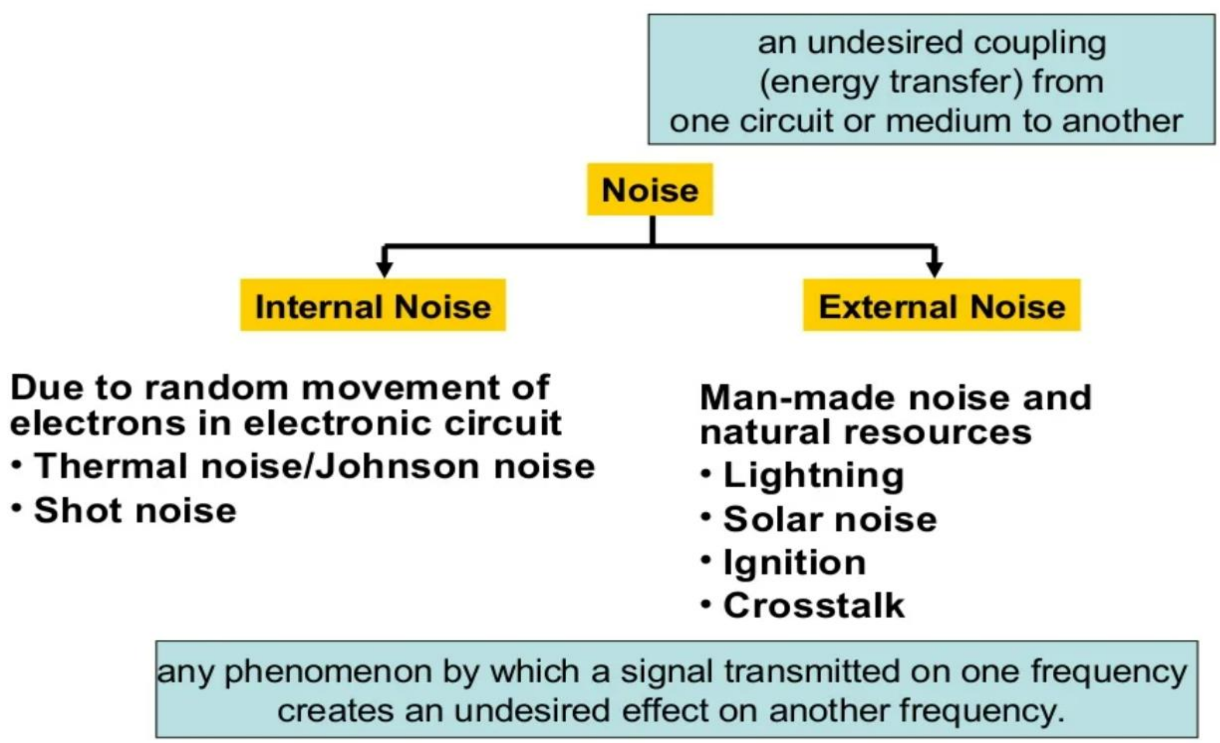
"If the information that you want to send is your voice, how to make sure that what your words are understood by your friend?"

"What is the source and technology available surround you that can help?"

Noise

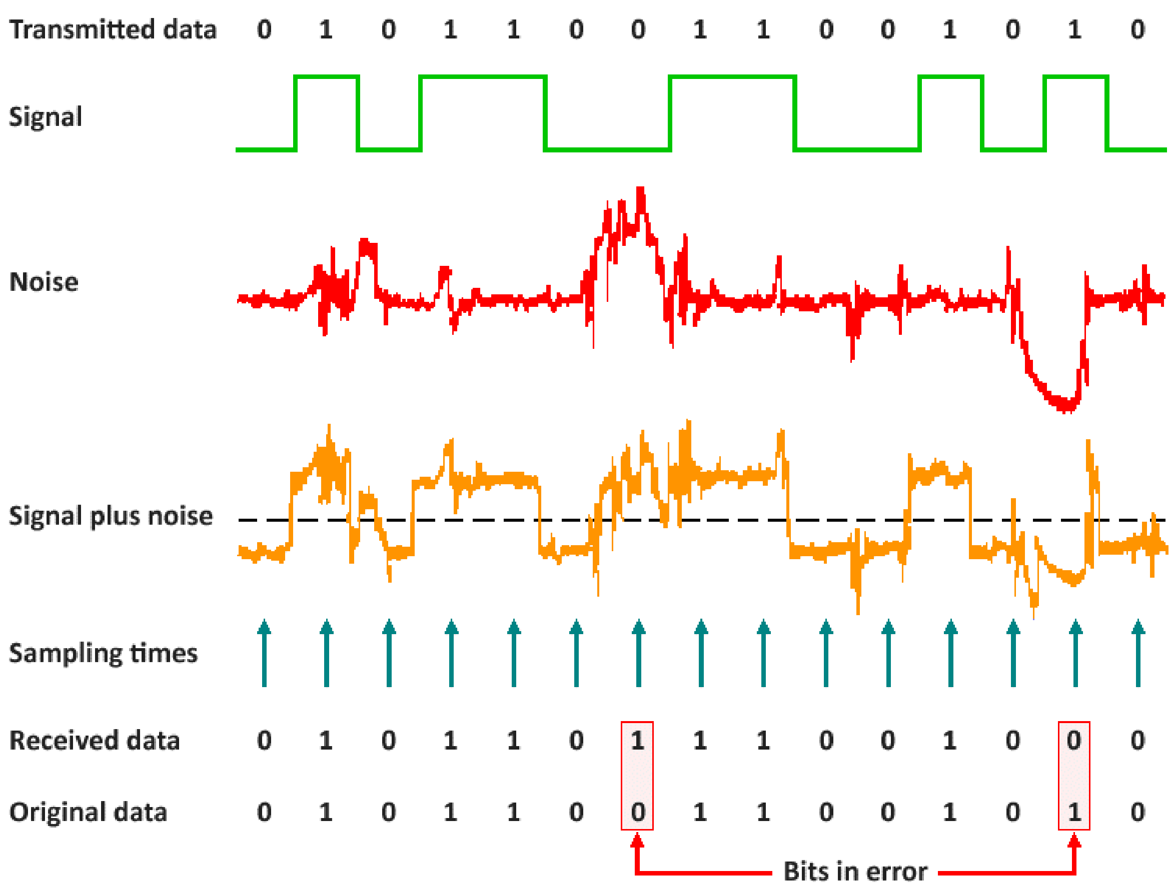
- **Practically, we cannot avoid the existence of unwanted signal together with the modulated signal transmitted by the transmitter.**
- **This unwanted signal is called noise.**
- **Noise is a random signal that exists in a communication system.**
- **Random signal cannot be represented with a simple equation.**
- **The existence of noise will degrade the level of quality of the received signal at the receiver.**

Types of noise



Noise Effect

- Degrade system performance for both analog and digital systems.
- The receiver cannot understand the sender.
- The receiver cannot function as it should be.
- Reduce the efficiency of communication system.



RSRP and RSRQ Measurement in LTE and 5G

- RSRP and RSRQ are key measures of signal level and quality for modern LTE networks. In cellular networks, when a mobile moves from cell to cell and performs cell selection/reselection and handover, it has to measure the signal strength/quality of the neighbor cells.
- In LTE network, a UE measures two parameters on reference signal: RSRP (Reference Signal Received Power) and RSRQ (Reference Signal Received Quality).
- In LTE network, a UE measures two parameters on reference signal:

1. **RSSI – Received Signal Strength Indicator:** In telecommunications, received signal strength indicator (RSSI) is a measurement of the power present in a received radio signal.

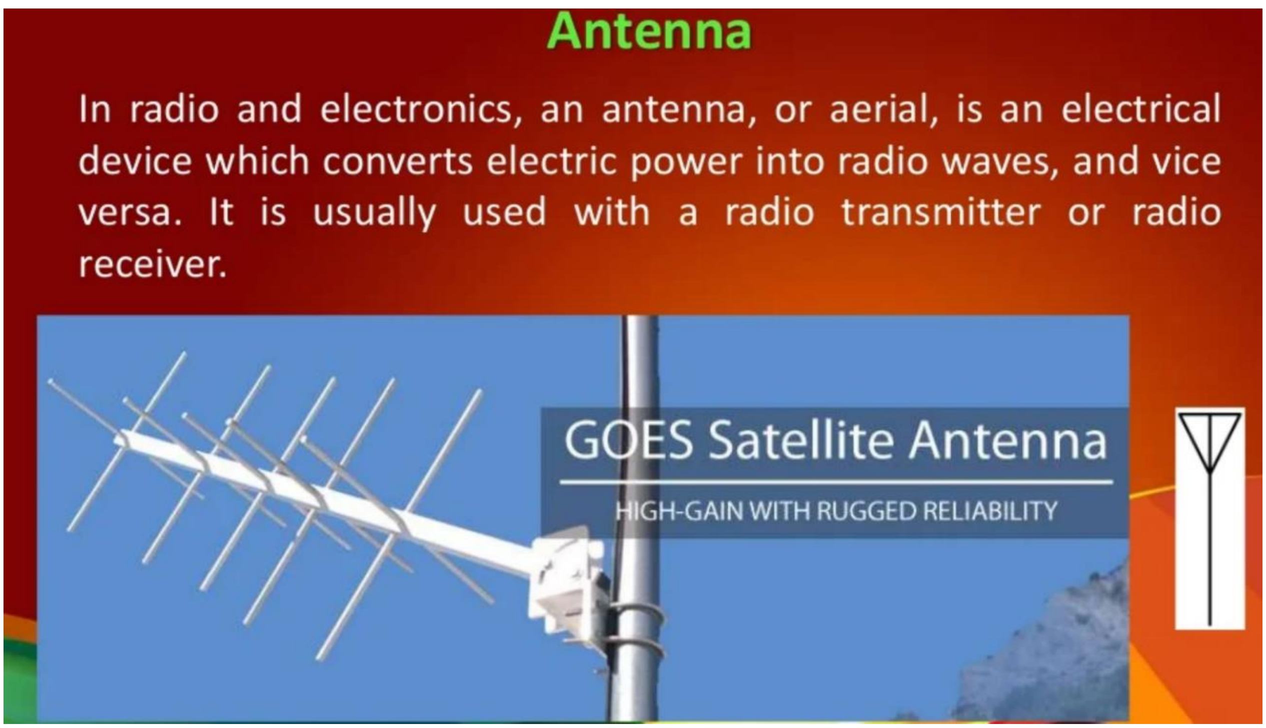
2. **RSRP – Reference Signal Received Power:** A modem determines which tower to connect to on the basis of a value called RSRP (Reference Signal Received Power). This is the measured power of the LTE reference signals spread across the broadband and narrowband portions of the spectrum.

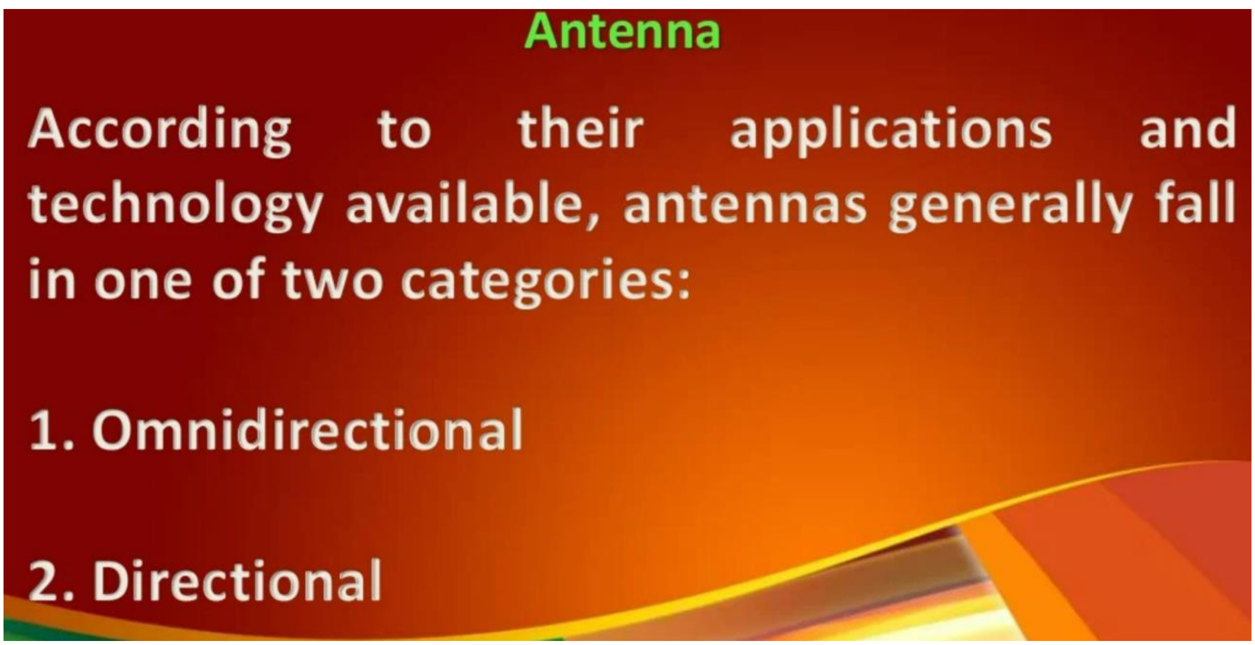
3. **RSRQ – Reference Signal Received Quality:** The LTE specification defines a second value, RSRQ (Reference Signal Received Quality), as the ratio of the carrier power to the interference power: essentially this is a signal-noise ratio measured using a standard signal.

4. **SINR - Signal to Interference & Noise Ratio:** It measures signal quality: the strength of the wanted signal compared to the unwanted interference and noise.

		RSRP (dBm)	RSRQ (dB)	SINR (dB)
RF Conditions	Excellent	>=-80	>=-10	>=20
	Good	-80 to -90	-10 to -15	13 to 20
	Mid Cell	-90 to -100	-15 to -20	0 to 13
	Cell Edge	<=-100	<-20	<=0

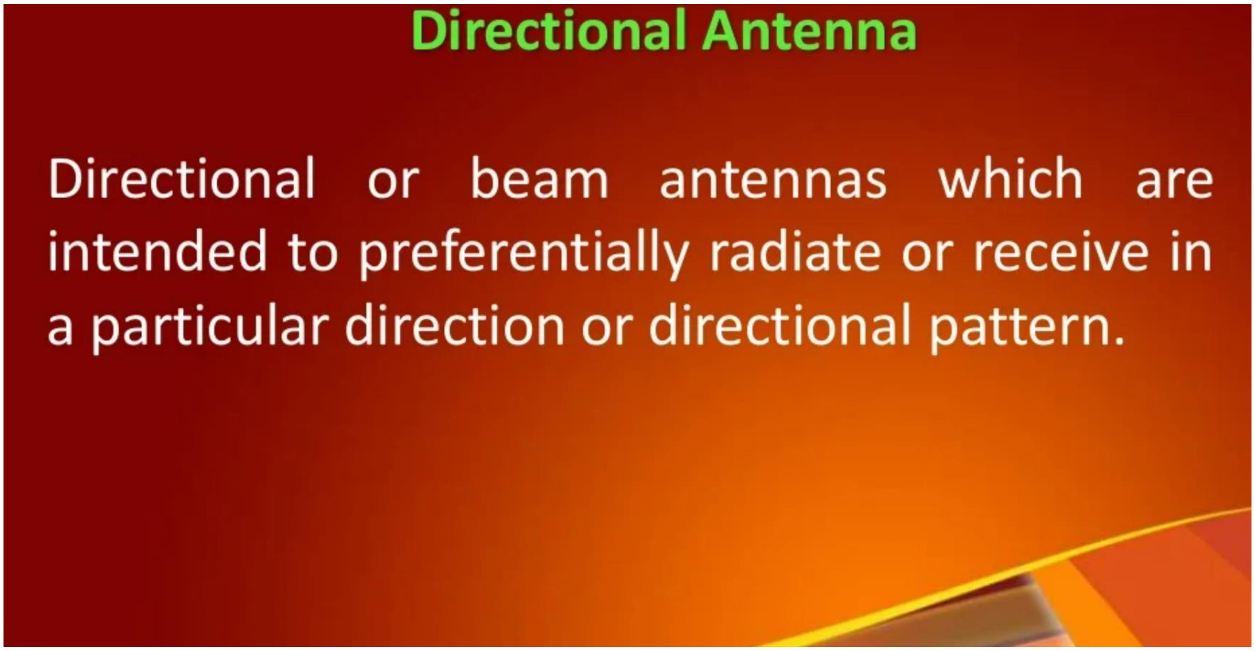
Antenna System

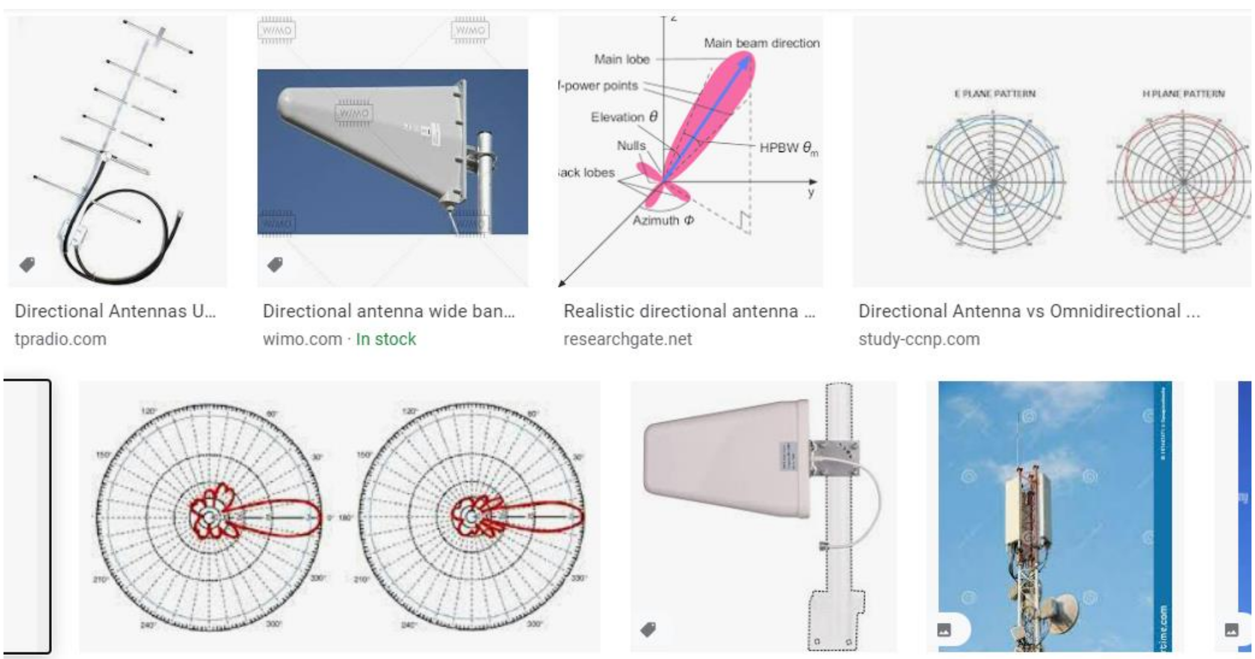



Antenna
According to their applications and technology available, antennas generally fall in one of two categories:
1. Omnidirectional
2. Directional

Omnidirectional Antenna

only weakly directional antennas which receive or radiate more or less in all directions. These are employed when the relative position of the other station is unknown or arbitrary. They are also used at lower frequencies where a directional antenna would be too large, or simply to cut costs in applications where a directional antenna isn't required.


Directional Antenna
Directional or beam antennas which are intended to preferentially radiate or receive in a particular direction or directional pattern.


Main beam direction
Main lobe
Elevation θ
Nulls
HPBW θ_m
Azimuth Φ
E PLANE PATTERN
H PLANE PATTERN
Directional Antennas U...
tpradio.com
Directional antenna wide ban...
wimo.com · In stock
Realistic directional antenna ...
researchgate.net
Directional Antenna vs Omnidirectional ...
study-ccnp.com