

AM Transmission/AM Reception

Prepared By
Dr.Raju Sharma

Classification of Radio Transmitters

1. According to the type of modulation used.
2. According to the service involved.
3. According to the frequency range used.
4. According to the power used.

According to the type of modulation used

1. Amplitude Modulation Transmitters
2. Frequency Modulation Transmitters
3. Pulse Modulation Transmitters

Classification of Radio Transmitters

According to the service involved

1. Radio Broadcast Transmitters
2. Radio Telephony Transmitters
3. Radio Telegraph Transmitters
4. Television Transmitters
5. Radar Transmitters
6. Navigational Transmitters

Classification of Radio Transmitters

According to the type of Carrier frequency

1. Long Wave Transmitters
2. Medium Wave Transmitters
3. Short Wave Transmitters
4. V.H.F and U.H.F Transmitters
5. Microwave Transmitters

Classification of Radio Transmitters

According to the power used

- 1.Low level Modulated AM Transmitters
- 2.High level Modulated AM Transmitters

Types of AM Transmitters

1. Low level AM Transmitters
2. High level AM Transmitters

Block Diagram of Low level AM Transmitters

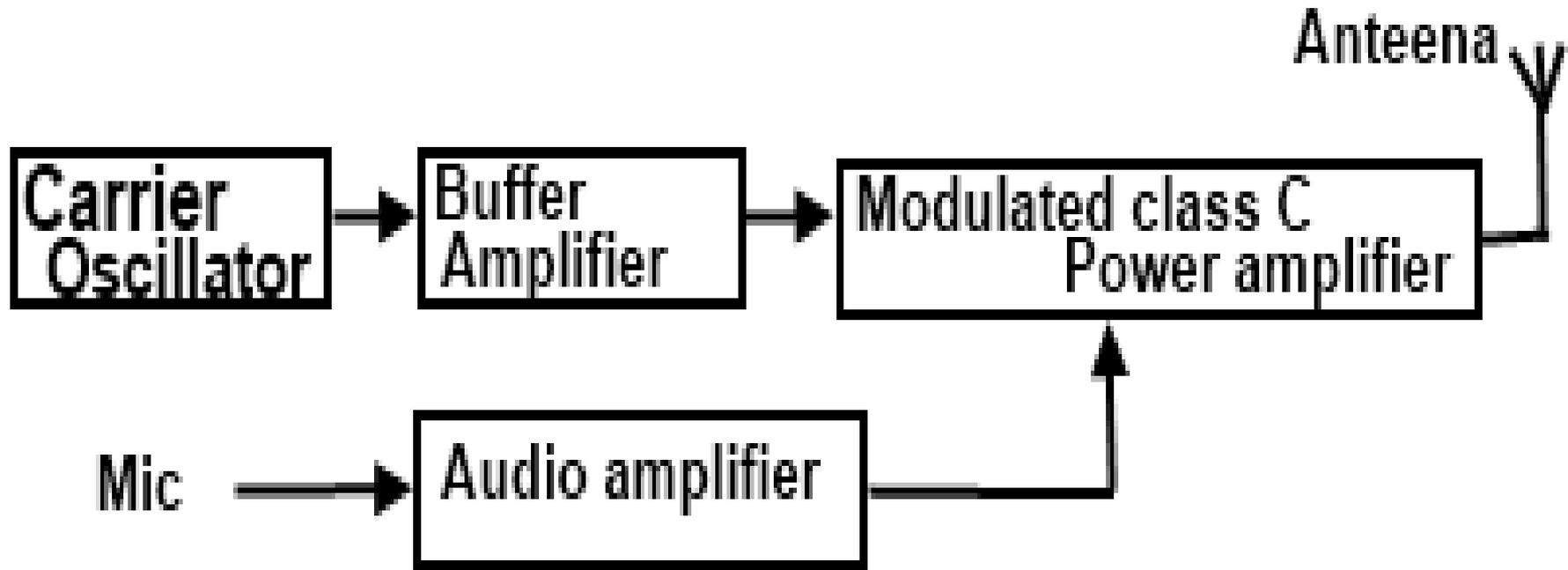


Figure (b) Block diagram of Low-level AM transmitter

Block Diagram of High level AM Transmitters

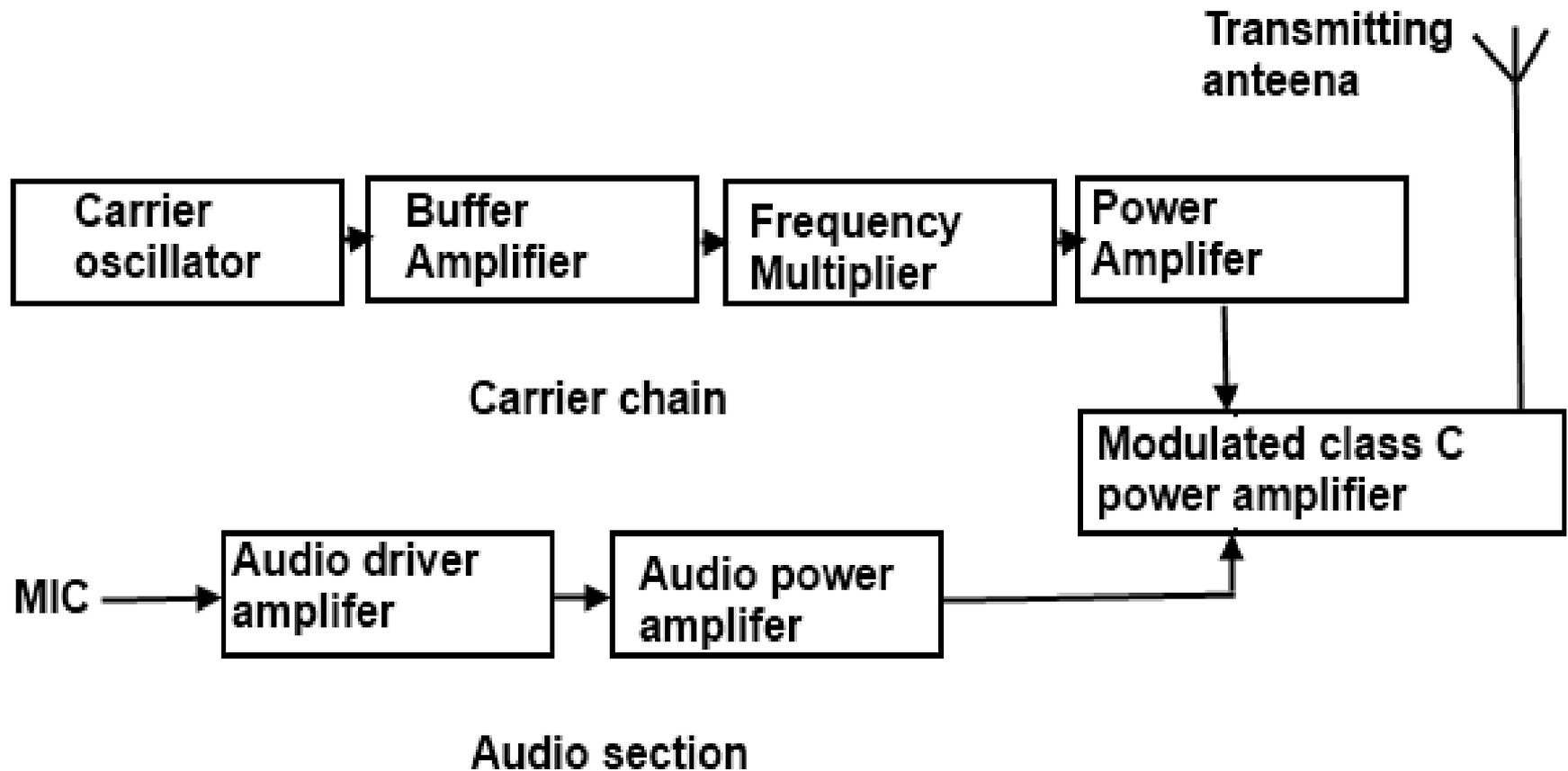


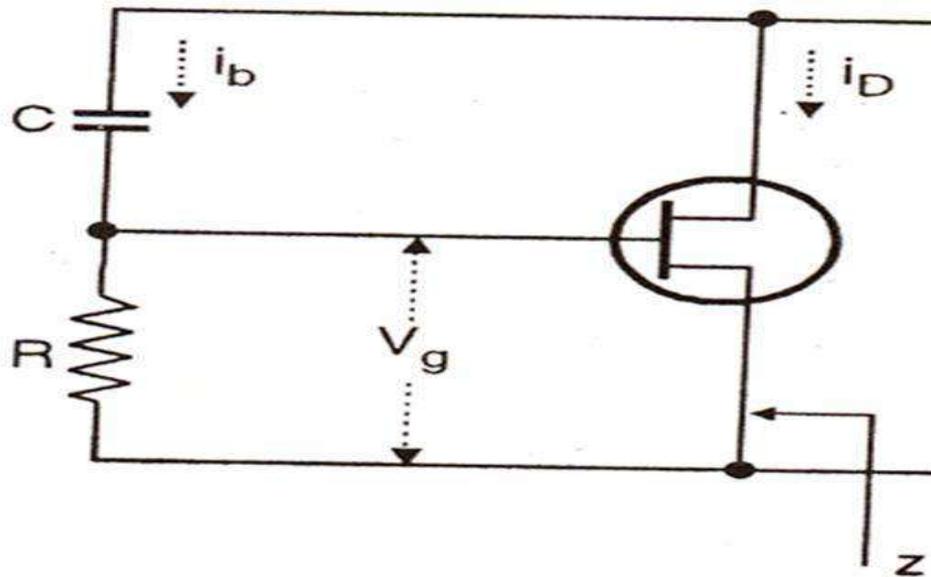
Figure (a) Block diagram of high level AM transmitter

- FET Reactance Modulator –
- There are a number of devices whose reactance can be varied by the application of voltage. These include FET and BJT, varactor diode etc.
- If such a device is placed across the tank circuit of the L-C oscillator, then FM will be produced when the reactance of the device is varied by the modulating voltage.
- At the carrier frequency, the oscillator inductance is tuned by its own capacitance in parallel with the average reactance to the variable reactance device.

reactance FET FM Modulator

FET REACTANCE MODULATOR

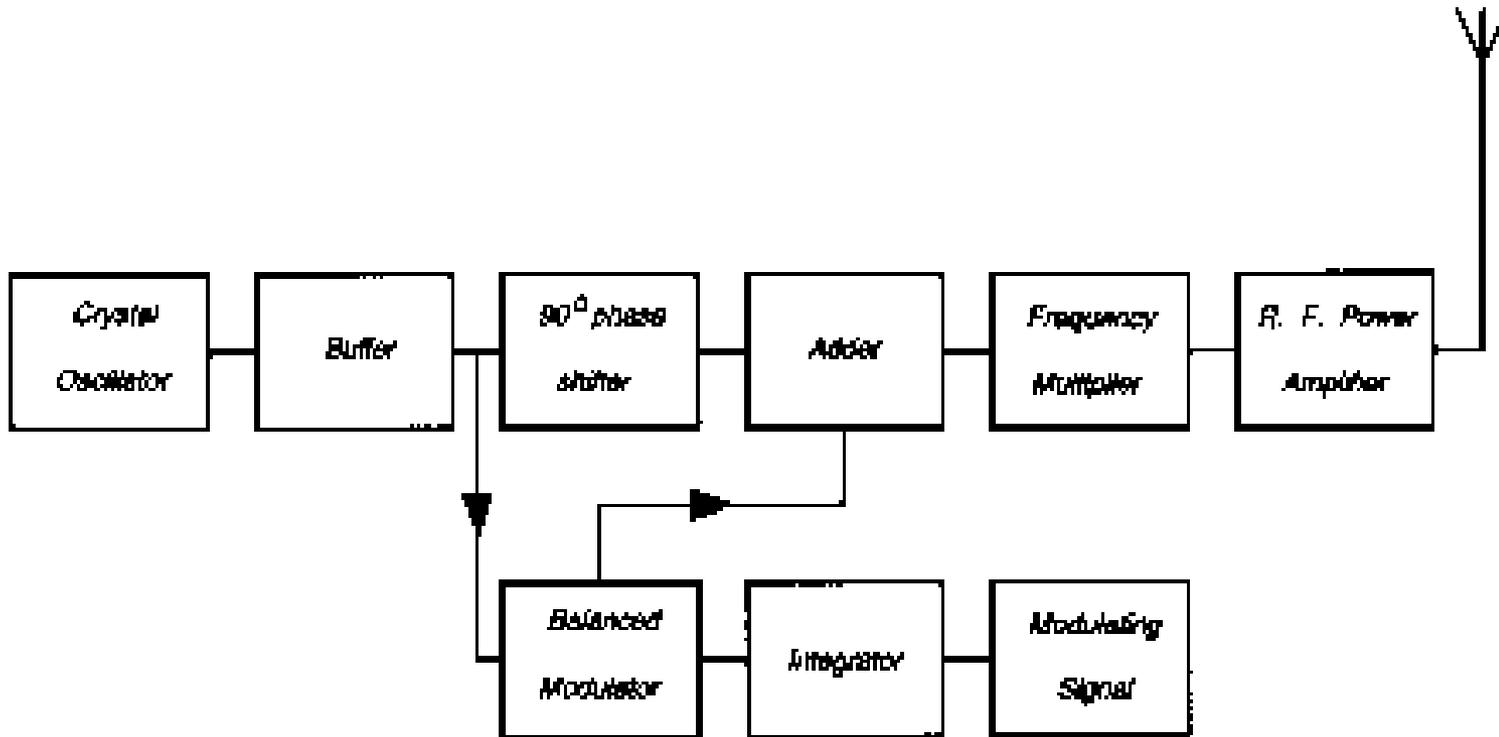
$$X_c \gg R$$



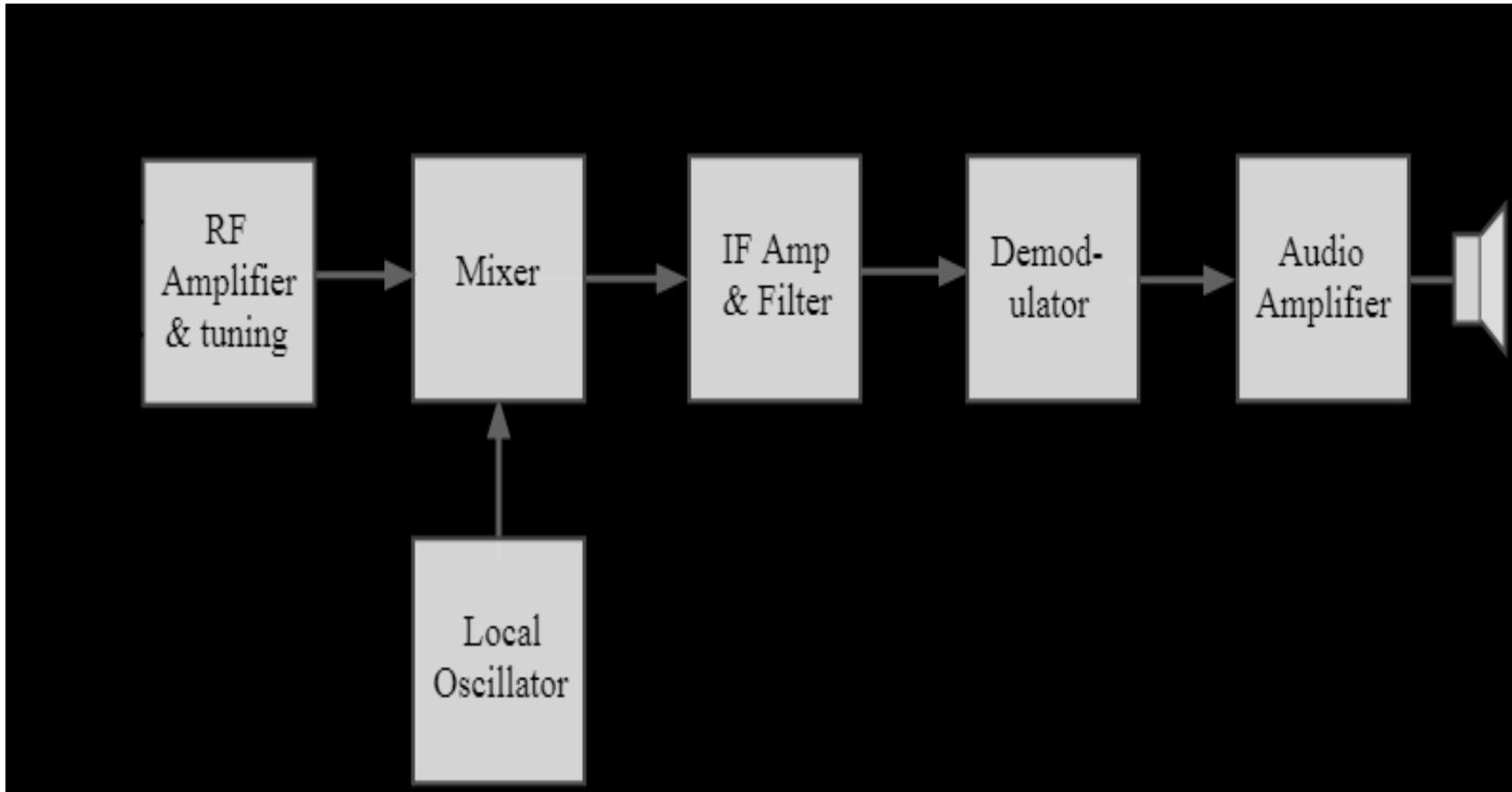
Armstrong FM Transmitter

- The direct methods cannot be used for the broadcast applications. Thus the alternative method i.e. indirect method called as the Armstrong method of FM generation is used.
- In this method the FM is obtained through phase modulation. A crystal oscillator can be used hence the frequency stability is very high.

BD of Armstrong FM transmitter



BD of Superhetrodyne AM Radio Receiver



- RF tuning & amplification: This RF stage within the overall block diagram for the receiver provides initial tuning to remove the image signal. It also provides some amplification. If noise performance for the receiver is important, then this stage will be designed for optimum noise performance. This RF amplifier circuit block will also increase the signal level so that the noise introduced by later stages is at a lower level in comparison to the wanted signal.
- Local oscillator: The local oscillator circuit block can take a variety of forms. Early receivers used free running local oscillators. Today most receivers use frequency synthesizers, normally based around phase locked loops. These provide much greater levels of stability and enable frequencies to be programmed in a variety of ways.

- Mixer: Both the local oscillator and incoming signal enter this block within the Superhetrodyne receiver. The wanted signal is converted to the intermediate frequency.
- IF amplifier & filter: This Superhetrodyne receiver block provides the majority of gain and selectivity. High performance filters like crystal filters may be used, although LC or ceramic filters may be used within domestic radios.

- Demodulator: The Superhetrodyne receiver block diagram only shows one demodulator, but in reality radios may have one or more demodulators dependent upon the type of signals being receiver.
- Audio amplifier: Once demodulated, the recovered audio is applied to an audio amplifier block to be amplified to the required level for loudspeakers or headphones. Alternatively the recovered modulation may be used for other applications whereupon it is processed in the required way by a specific circuit block.

ANTENNA

- In radio, an antenna is the interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver.[1] In transmission, a radio transmitter supplies an electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce an electric current at its terminals, that is applied to a receiver to be amplified. Antennas are essential components of all radio equipment, and are used in radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, satellite communications and other devices.

DIPOLE

- The dipole is the prototypical antenna on which a large class of antennas are based. A basic dipole antenna consists of two conductors (usually metal rods or wires) arranged symmetrically, with one side of the balanced feedline from the transmitter or receiver attached to each.[18][21] The most common type, the half-wave dipole, consists of two resonant elements just under a quarter wavelength long. This antenna radiates maximally in directions perpendicular to the antenna's axis,

Yagi-Uda Antenna



ANTENNA ARRAY

- Array antennas consist of multiple antennas working as a single antenna. Typically they consist of arrays of identical driven elements, usually dipoles fed in phase, giving increased gain over that of a single dipole.
- Collinear - Consist of a number of dipoles in a vertical line. It is a high gain omnidirectional antenna, meaning more of the power is radiated in horizontal directions and less into the sky or ground and wasted. Gain of 8 to 10 dBi. Used as base station antennas for land mobile radio systems such as police, fire, ambulance, and taxi dispatchers, and sector antennas for cellular base stations.

The Electromagnetic Spectrum

Frequency Range	Band Designation
30-3000 Hz	ELF
3-30 kHz	VLF
30-300 kHz	LF
300-3000 kHz	MF
3-30 MHz	HF
30-300 MHz	VHF
300-3000 MHz	UHF
3-30 GHz	SHF
30-300 GHz	EHF

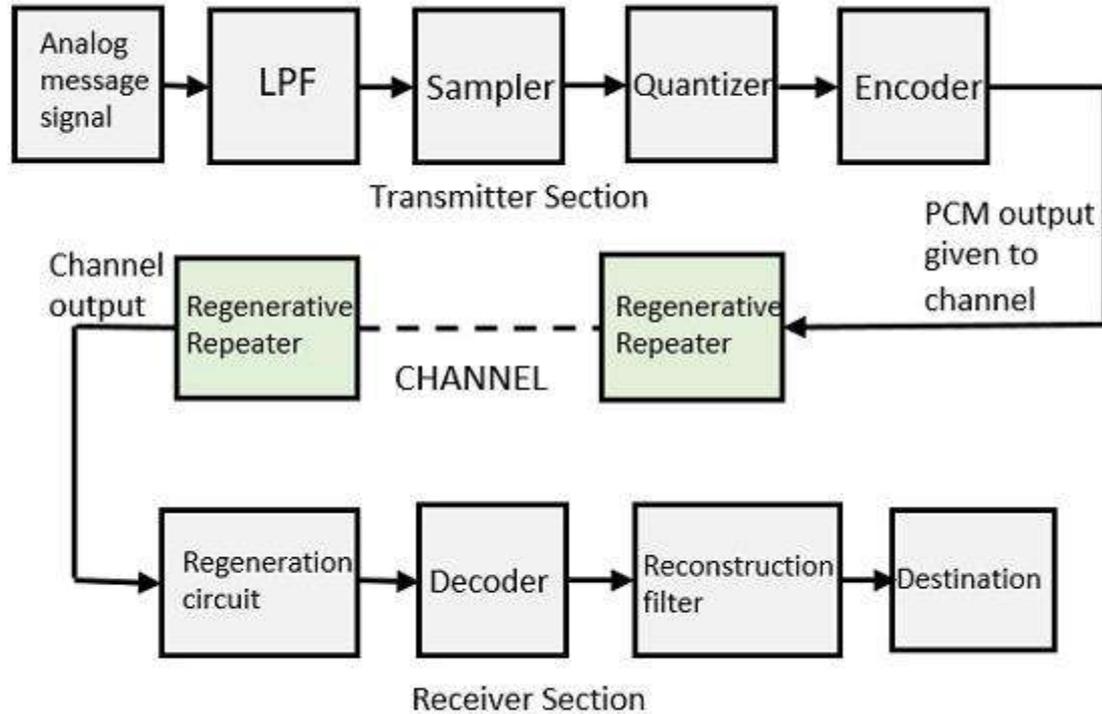
Ground Wave Propagation

- Radio waves in the VLF band propagate in a ground, or surface wave. The wave is connected at one end to the surface of the earth and to the ionosphere at the other. The ionosphere is the region above the troposphere (where the air is), from about 50 to 250 miles above the earth. It is a collection of ions, which are atoms that have some of their electrons stripped off leaving two or more electrically charged objects. The sun's rays cause the ions to form which slowly recombine. The propagation of radiowaves in the presence of ions is drastically different than in air, which is why the ionosphere plays an important role in most modes of propagation. Ground waves travel between two limits, the earth and the ionosphere,

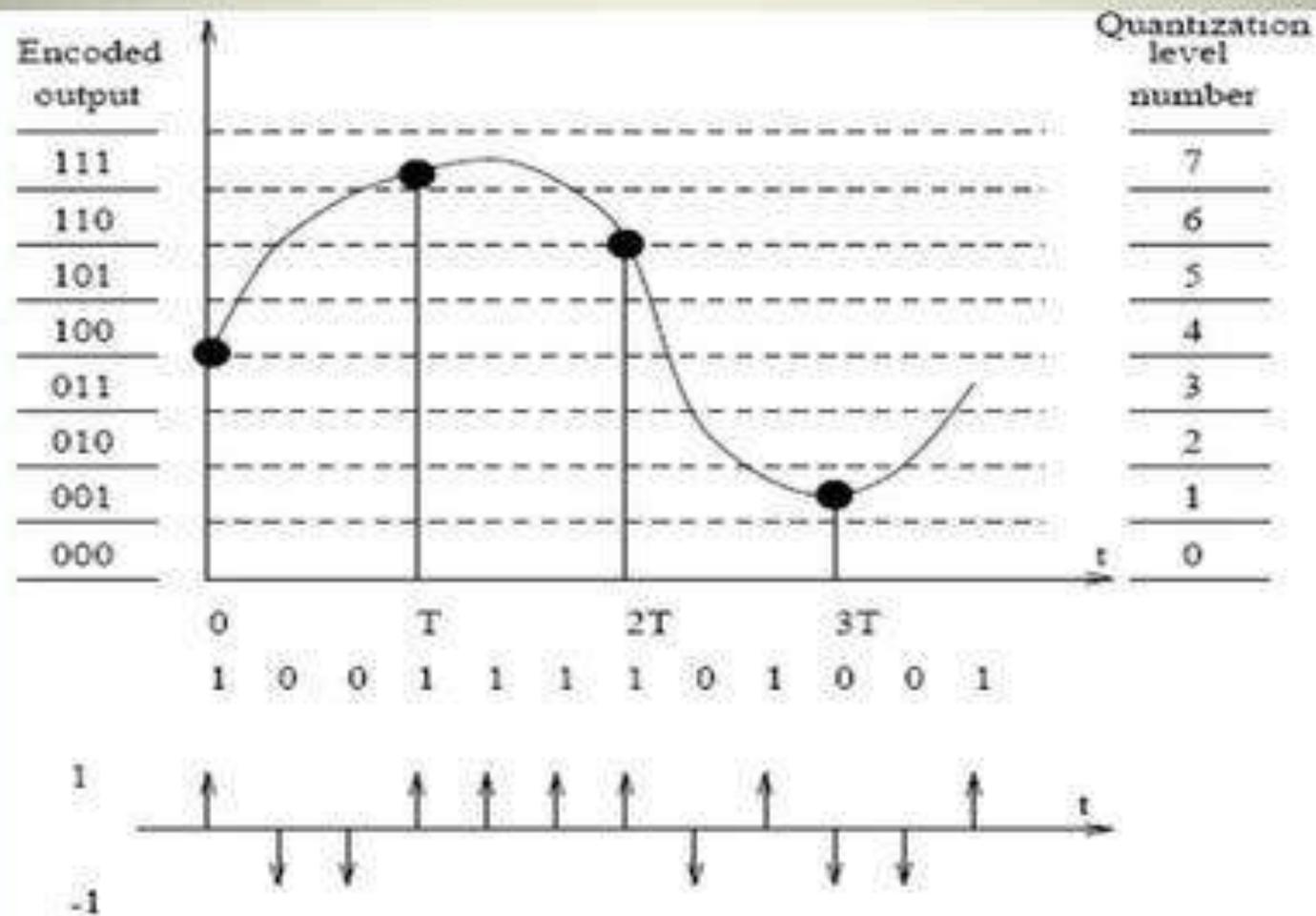
PCM

- Pulse code modulation (PCM) is a digital representation of an analog signal that takes samples of the amplitude of the analog signal at regular intervals. The sampled analog data is changed to, and then represented by, binary data. PCM requires a very accurate clock. The number of samples per second, ranging from 8,000 to 192,000, is usually several times the maximum frequency of the analog waveform in Hertz (Hz), or cycles per second, which ranges from 8 to 192 KHz.

Pulse Code Modulation



Pulse Code Modulation (PCM)



AM Transmission/AM Reception

Prepared By
Dr.Raju Sharma

Classification of Radio Transmitters

1. According to the type of modulation used.
2. According to the service involved.
3. According to the frequency range used.
4. According to the power used.

According to the type of modulation used

1. Amplitude Modulation Transmitters
2. Frequency Modulation Transmitters
3. Pulse Modulation Transmitters

Classification of Radio Transmitters

According to the service involved

1. Radio Broadcast Transmitters
2. Radio Telephony Transmitters
3. Radio Telegraph Transmitters
4. Television Transmitters
5. Radar Transmitters
6. Navigational Transmitters

Classification of Radio Transmitters

According to the type of Carrier frequency

1. Long Wave Transmitters
2. Medium Wave Transmitters
3. Short Wave Transmitters
4. V.H.F and U.H.F Transmitters
5. Microwave Transmitters

Classification of Radio Transmitters

According to the power used

- 1.Low level Modulated AM Transmitters
- 2.High level Modulated AM Transmitters

Types of AM Transmitters

1. Low level AM Transmitters
2. High level AM Transmitters

Block Diagram of Low level AM Transmitters

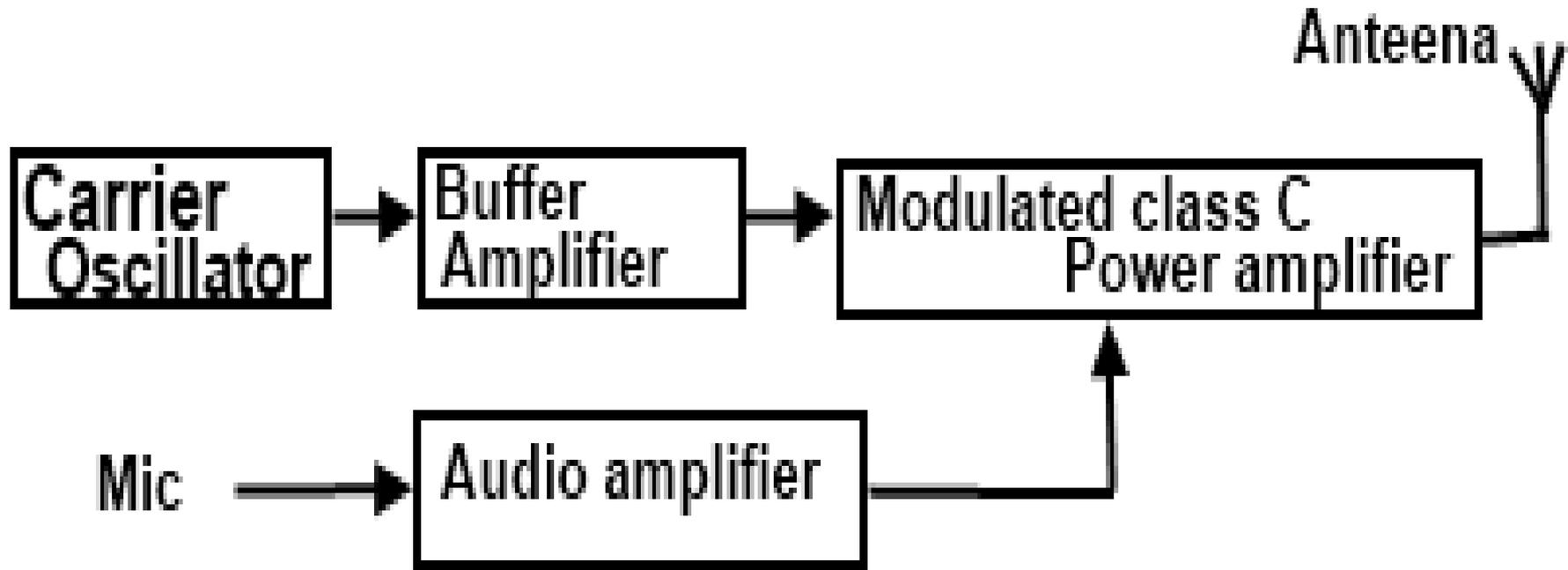


Figure (b) Block diagram of Low-level AM transmitter

Block Diagram of High level AM Transmitters

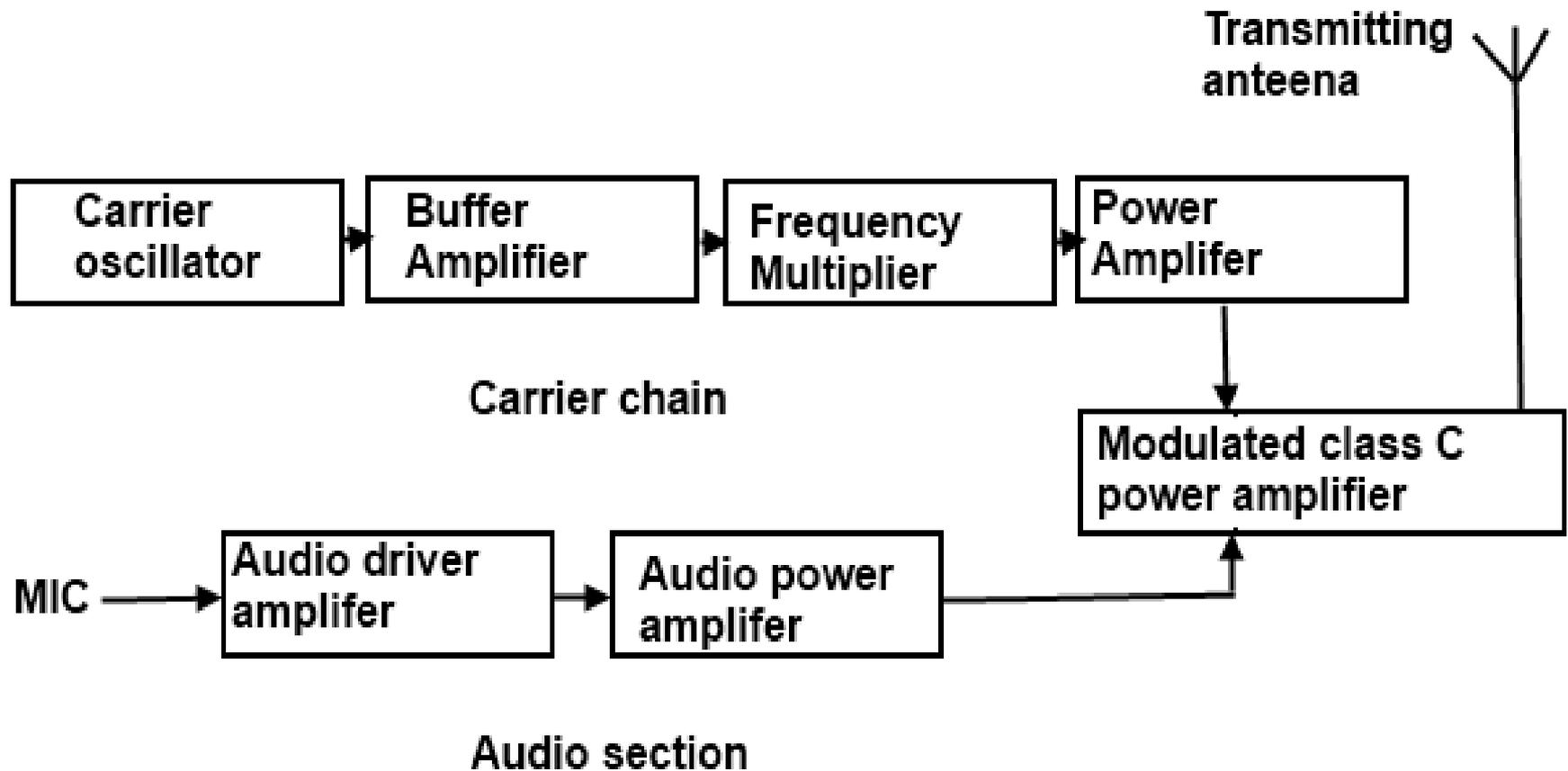


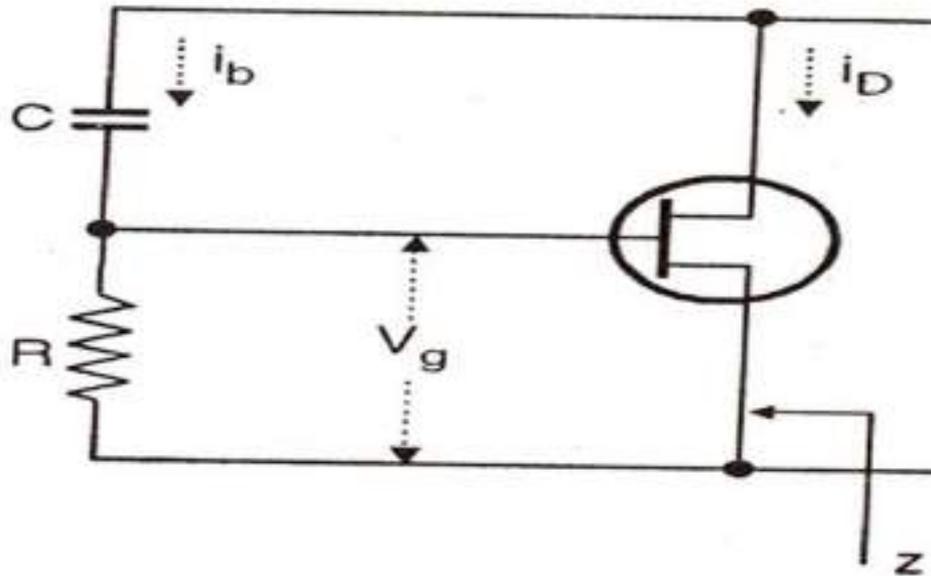
Figure (a) Block diagram of high level AM transmitter

- FET Reactance Modulator –
- There are a number of devices whose reactance can be varied by the application of voltage. These include FET and BJT, varactor diode etc.
- If such a device is placed across the tank circuit of the L-C oscillator, then FM will be produced when the reactance of the device is varied by the modulating voltage.
- At the carrier frequency, the oscillator inductance is tuned by its own capacitance in parallel with the average reactance to the variable reactance device.

reactance FET FM Modulator

FET REACTANCE MODULATOR

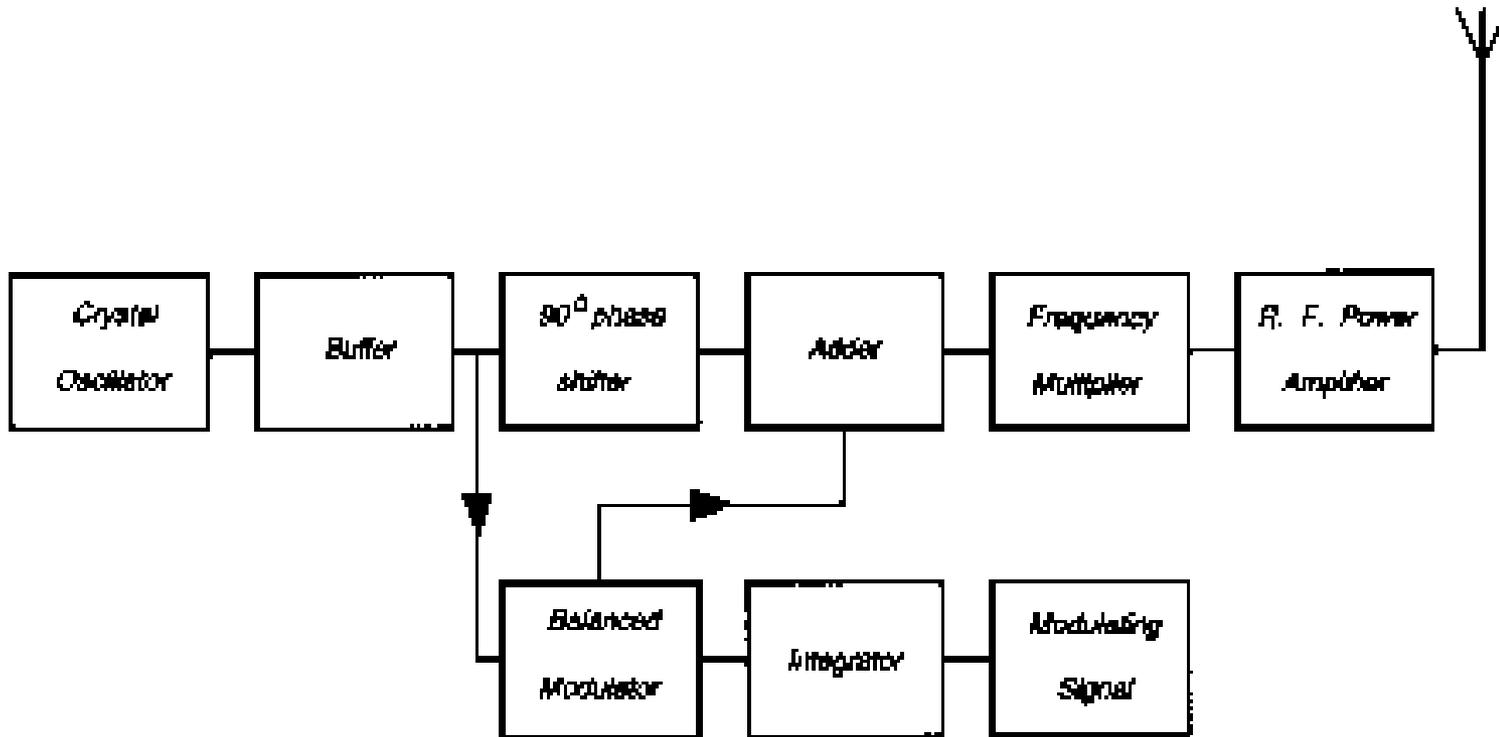
$$X_C \gg R$$



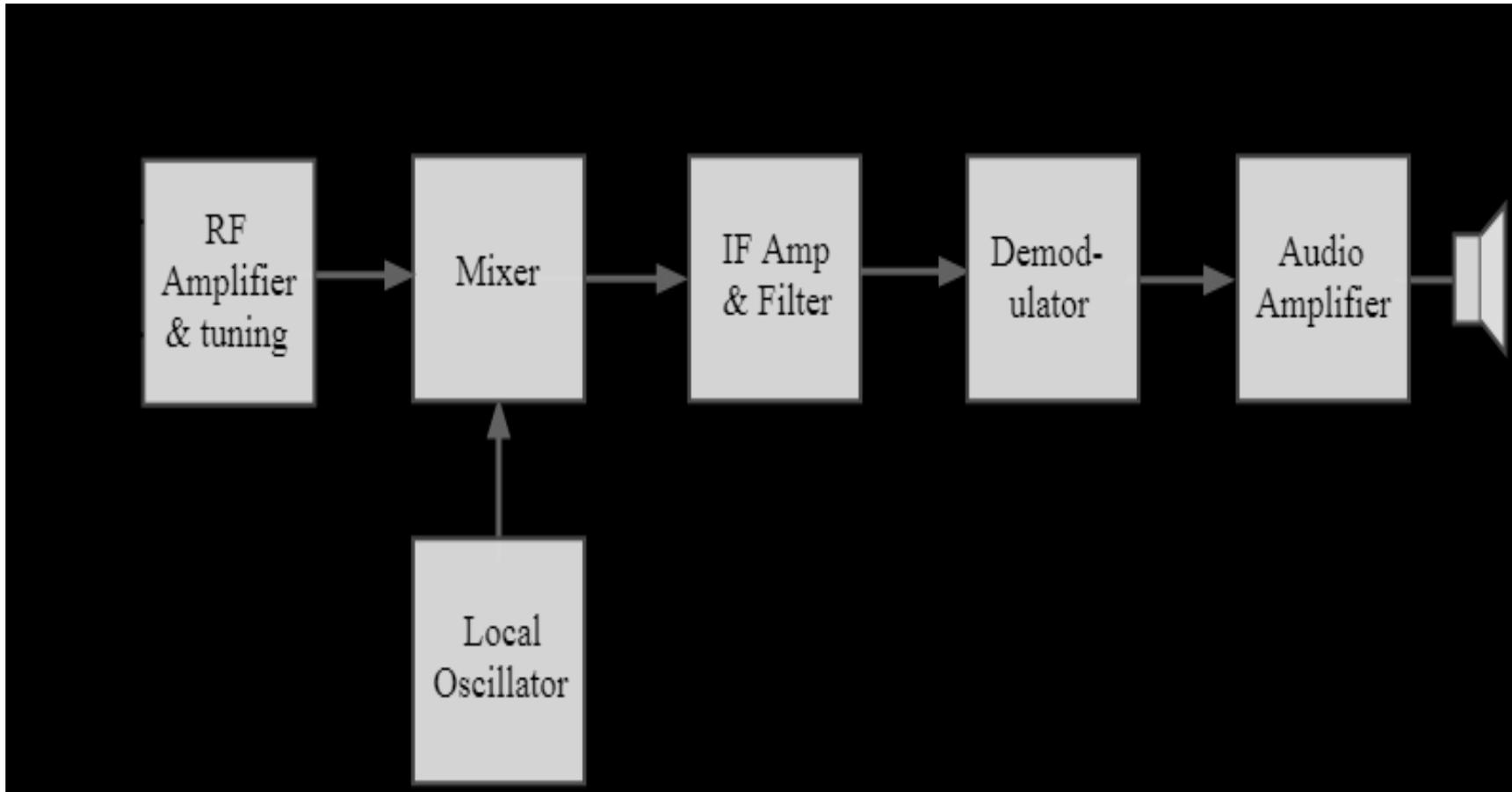
Armstrong FM Transmitter

- The direct methods cannot be used for the broadcast applications. Thus the alternative method i.e. indirect method called as the Armstrong method of FM generation is used.
- In this method the FM is obtained through phase modulation. A crystal oscillator can be used hence the frequency stability is very high.

BD of Armstrong FM transmitter



BD of Superhetrodyne AM Radio Receiver



- RF tuning & amplification: This RF stage within the overall block diagram for the receiver provides initial tuning to remove the image signal. It also provides some amplification. If noise performance for the receiver is important, then this stage will be designed for optimum noise performance. This RF amplifier circuit block will also increase the signal level so that the noise introduced by later stages is at a lower level in comparison to the wanted signal.
- Local oscillator: The local oscillator circuit block can take a variety of forms. Early receivers used free running local oscillators. Today most receivers use frequency synthesizers, normally based around phase locked loops. These provide much greater levels of stability and enable frequencies to be programmed in a variety of ways.

- Mixer: Both the local oscillator and incoming signal enter this block within the Superhetrodyne receiver. The wanted signal is converted to the intermediate frequency.
- IF amplifier & filter: This Superhetrodyne receiver block provides the majority of gain and selectivity. High performance filters like crystal filters may be used, although LC or ceramic filters may be used within domestic radios.

- Demodulator: The Superhetrodyne receiver block diagram only shows one demodulator, but in reality radios may have one or more demodulators dependent upon the type of signals being receiver.
- Audio amplifier: Once demodulated, the recovered audio is applied to an audio amplifier block to be amplified to the required level for loudspeakers or headphones. Alternatively the recovered modulation may be used for other applications whereupon it is processed in the required way by a specific circuit block.

ANTENNA

- In radio, an antenna is the interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver.[1] In transmission, a radio transmitter supplies an electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of an electromagnetic wave in order to produce an electric current at its terminals, that is applied to a receiver to be amplified. Antennas are essential components of all radio equipment, and are used in radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, satellite communications and other devices.

DIPOLE

- The dipole is the prototypical antenna on which a large class of antennas are based. A basic dipole antenna consists of two conductors (usually metal rods or wires) arranged symmetrically, with one side of the balanced feedline from the transmitter or receiver attached to each.[18][21] The most common type, the half-wave dipole, consists of two resonant elements just under a quarter wavelength long. This antenna radiates maximally in directions perpendicular to the antenna's axis,

Yagi-Uda Antenna



ANTENNA ARRAY

- Array antennas consist of multiple antennas working as a single antenna. Typically they consist of arrays of identical driven elements, usually dipoles fed in phase, giving increased gain over that of a single dipole.
- Collinear - Consist of a number of dipoles in a vertical line. It is a high gain omnidirectional antenna, meaning more of the power is radiated in horizontal directions and less into the sky or ground and wasted. Gain of 8 to 10 dBi. Used as base station antennas for land mobile radio systems such as police, fire, ambulance, and taxi dispatchers, and sector antennas for cellular base stations.

The Electromagnetic Spectrum

Frequency Range	Band Designation
30-3000 Hz	ELF
3-30 kHz	VLF
30-300 kHz	LF
300-3000 kHz	MF
3-30 MHz	HF
30-300 MHz	VHF
300-3000 MHz	UHF
3-30 GHz	SHF
30-300 GHz	EHF

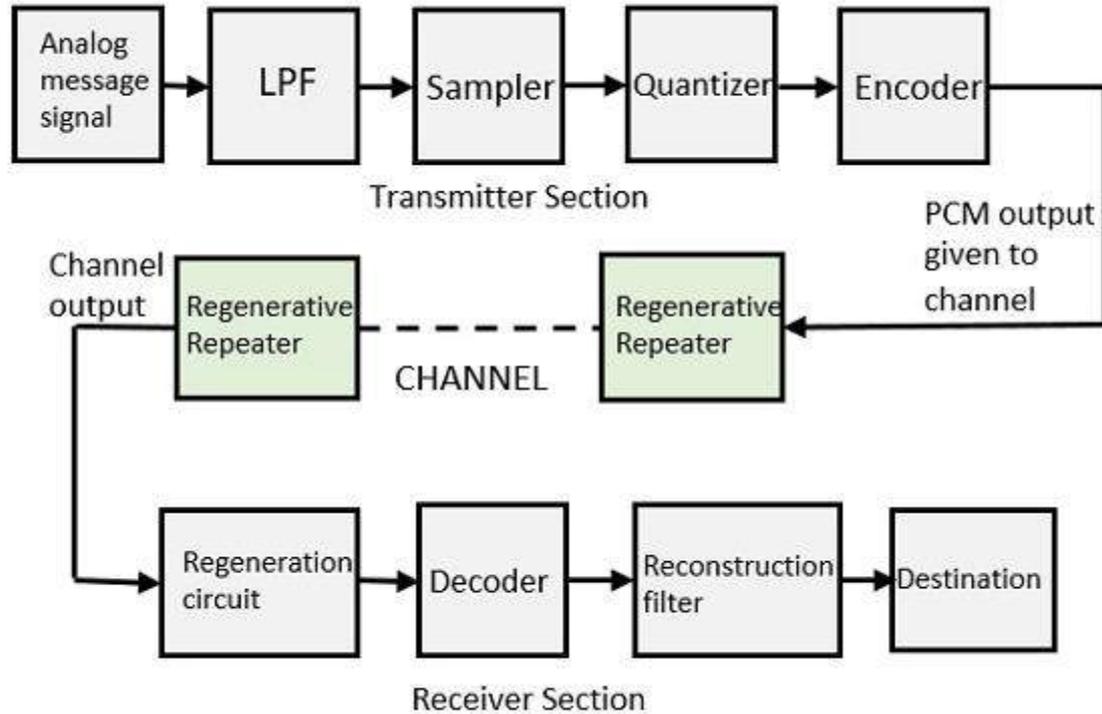
Ground Wave Propagation

- Radio waves in the VLF band propagate in a ground, or surface wave. The wave is connected at one end to the surface of the earth and to the ionosphere at the other. The ionosphere is the region above the troposphere (where the air is), from about 50 to 250 miles above the earth. It is a collection of ions, which are atoms that have some of their electrons stripped off leaving two or more electrically charged objects. The sun's rays cause the ions to form which slowly recombine. The propagation of radiowaves in the presence of ions is drastically different than in air, which is why the ionosphere plays an important role in most modes of propagation. Ground waves travel between two limits, the earth and the ionosphere,

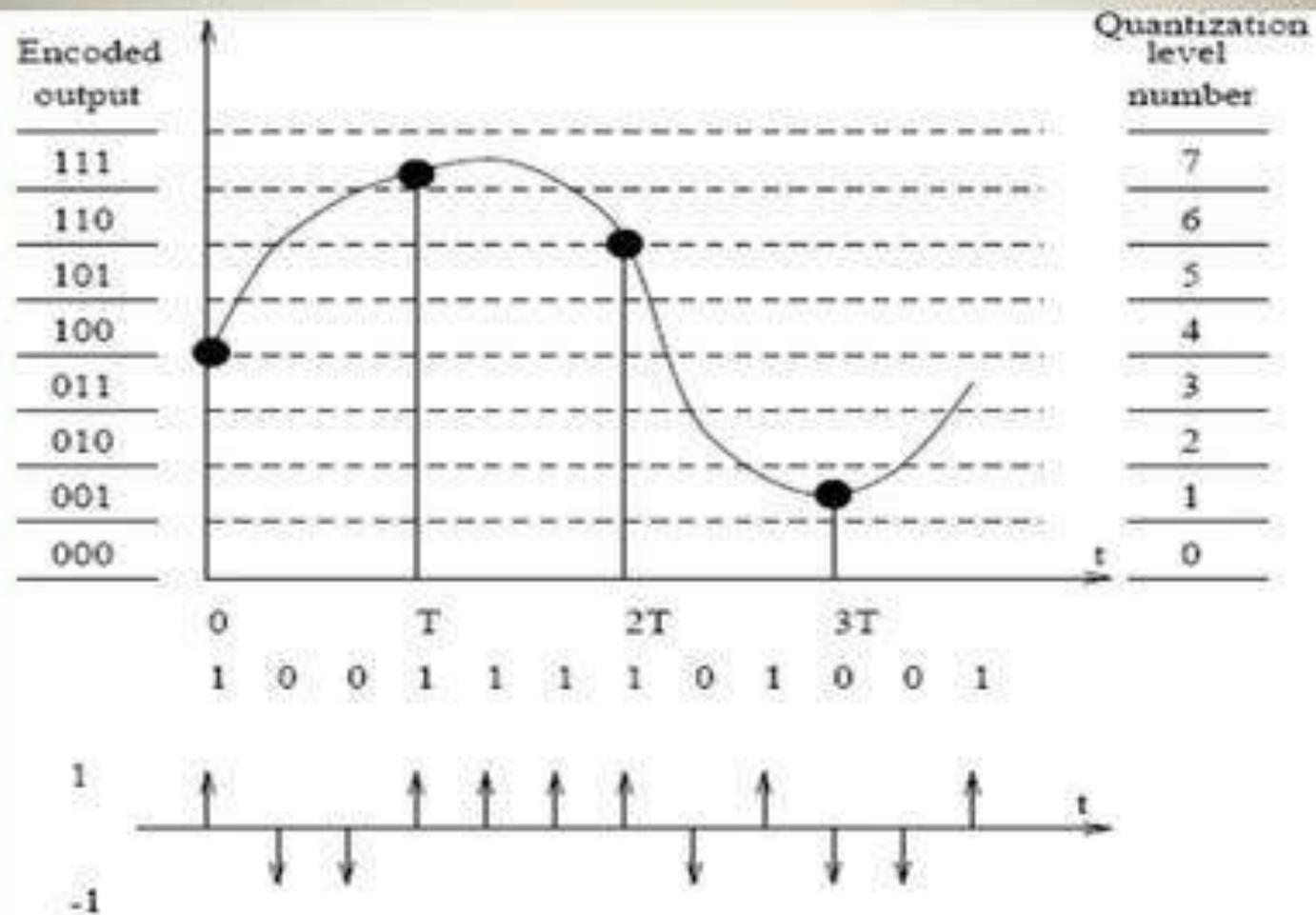
PCM

- Pulse code modulation (PCM) is a digital representation of an analog signal that takes samples of the amplitude of the analog signal at regular intervals. The sampled analog data is changed to, and then represented by, binary data. PCM requires a very accurate clock. The number of samples per second, ranging from 8,000 to 192,000, is usually several times the maximum frequency of the analog waveform in Hertz (Hz), or cycles per second, which ranges from 8 to 192 KHz.

Pulse Code Modulation



Pulse Code Modulation (PCM)



Wave Propagation



Prepared By
Dr.Raju Sharma

Introduction

- ❑ An antenna is an electrical conductor or system of conductors
 - Transmission - radiates electromagnetic energy into space
 - Reception - collects electromagnetic energy from space
- ❑ In two-way communication, the same antenna can be used for transmission and reception

Radiation Patterns

- ❑ Radiation pattern
 - Graphical representation of radiation properties of an antenna
 - Depicted as two-dimensional cross section
- ❑ Beam width (or half-power beam width)
 - Measure of directivity of antenna
- ❑ Reception pattern
 - Receiving antenna's equivalent to radiation pattern

Types of Antennas

- ❑ Isotropic antenna (idealized)
 - Radiates power equally in all directions
- ❑ Dipole antennas
 - Half-wave dipole antenna (or Hertz antenna)
 - Quarter-wave vertical antenna (or Marconi antenna)
- ❑ Parabolic Reflective Antenna

Antenna Gain

- Antenna gain
 - Power output, in a particular direction, compared to that produced in any direction by a perfect omnidirectional antenna (isotropic antenna)
- Effective area
 - Related to physical size and shape of antenna

Antenna Gain

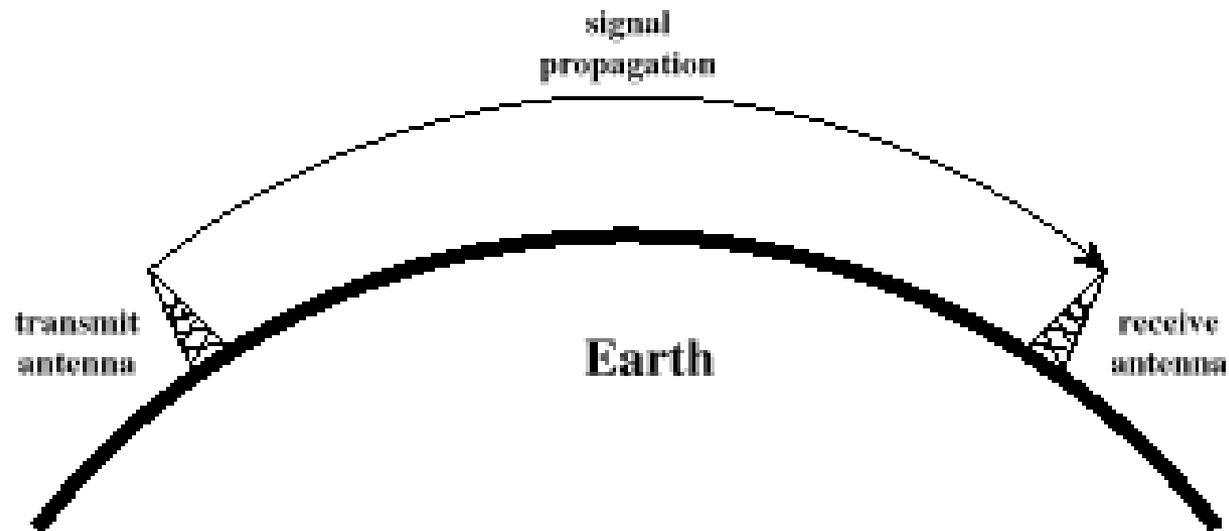
- Relationship between antenna gain and effective area

- $G = \text{antenna gain} = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$
- $A_e = \text{effective area}$
- $f = \text{carrier frequency}$
- $c = \text{speed of light } (\gg 3 \cdot 10^8 \text{ m/s})$
- $\lambda = \text{carrier wavelength}$

Propagation Modes

- Ground-wave propagation
- Sky-wave propagation
- Line-of-sight propagation

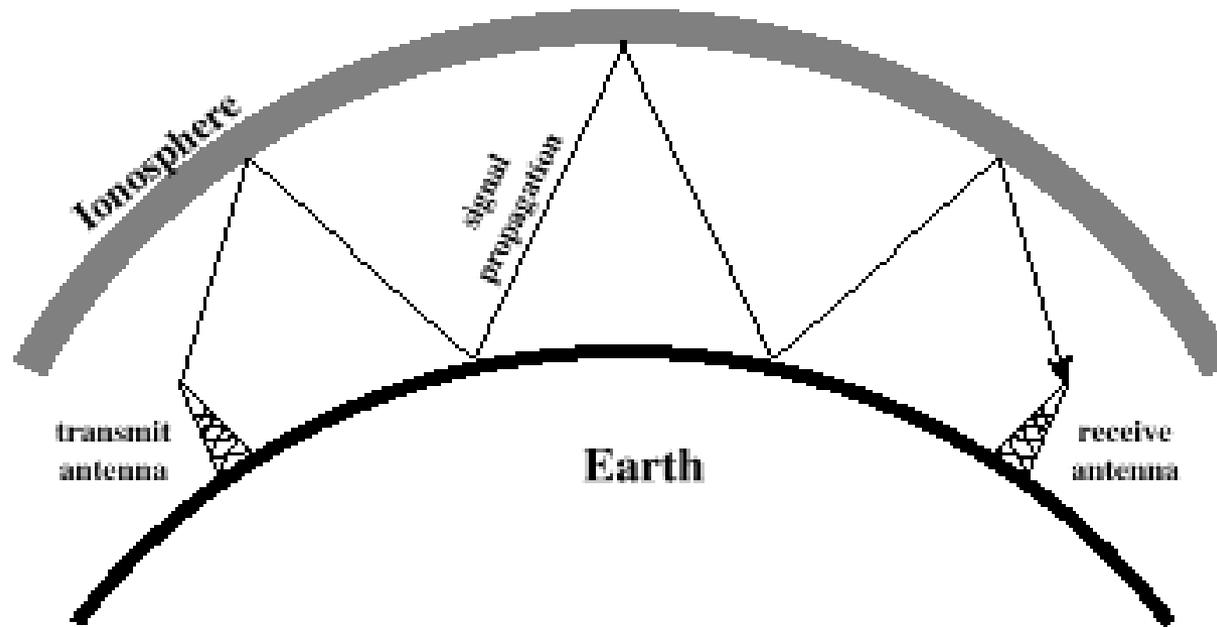
Ground Wave Propagation



Ground Wave Propagation

- Follows contour of the earth
- Can Propagate considerable distances
- Frequencies up to 2 MHz
- Example
 - AM radio

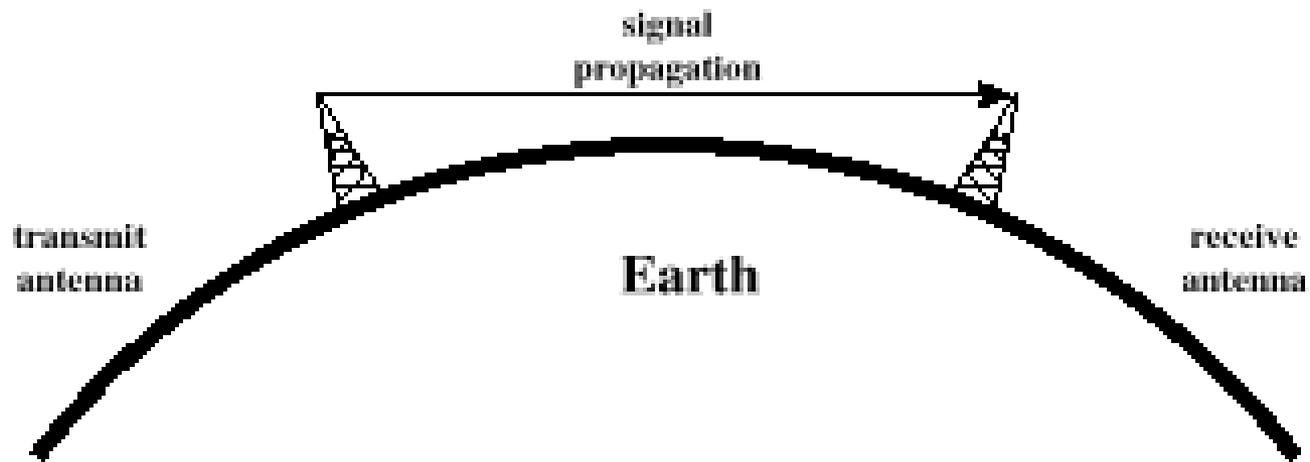
Sky Wave Propagation



Sky Wave Propagation

- ❑ Signal reflected from ionized layer of atmosphere back down to earth
- ❑ Signal can travel a number of hops, back and forth between ionosphere and earth's surface
- ❑ Reflection effect caused by refraction
- ❑ Examples
 - Amateur radio
 - CB radio

Line-of-Sight Propagation



Line-of-Sight Propagation

- ❑ Transmitting and receiving antennas must be within line of sight
 - Satellite communication – signal above 30 MHz not reflected by ionosphere
 - Ground communication – antennas within *effective* line of site due to refraction
- ❑ Refraction – bending of microwaves by the atmosphere
 - Velocity of electromagnetic wave is a function of the density of the medium
 - When wave changes medium, speed changes
 - Wave bends at the boundary between mediums

Line-of-Sight Equations

- Optical line of sight

$$d = 3.57\sqrt{h}$$

- Effective, or radio, line of sight

$$d = 3.57\sqrt{Kh}$$

- d = distance between antenna and horizon (km)
- h = antenna height (m)
- K = adjustment factor to account for refraction, rule of thumb $K = 4/3$

Line-of-Sight Equations

- Maximum distance between two antennas for LOS propagation:

$$3.57 \left(\sqrt{K h_1} + \sqrt{K h_2} \right)$$

- h_1 = height of antenna one
- h_2 = height of antenna two

LOS Wireless Transmission Impairments

- ❑ Attenuation and attenuation distortion
- ❑ Free space loss
- ❑ Noise
- ❑ Atmospheric absorption
- ❑ Multipath
- ❑ Refraction
- ❑ Thermal noise

Attenuation

- ❑ Strength of signal falls off with distance over transmission medium
- ❑ Attenuation factors for unguided media:
 - Received signal must have sufficient strength so that circuitry in the receiver can interpret the signal
 - Signal must maintain a level sufficiently higher than noise to be received without error
 - Attenuation is greater at higher frequencies, causing distortion

Free Space Loss

- Free space loss, ideal isotropic antenna

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

- P_t = signal power at transmitting antenna
 - P_r = signal power at receiving antenna
 - λ = carrier wavelength
 - d = propagation distance between antennas
 - c = speed of light ($\approx 3 \times 10^8$ m/s)
- where d and λ are in the same units (e.g., meters)

Free Space Loss

- Free space loss equation can be recast:

$$\begin{aligned}L_{dB} &= 10\log\frac{P_t}{P_r} = 20\log\left(\frac{4\pi d}{\lambda}\right) \\ &= -20\log(\lambda) + 20\log(d) + 21.98 \text{ dB} \\ &= 20\log\left(\frac{4\pi f d}{c}\right) = 20\log(f) + 20\log(d) - 147.56 \text{ dB}\end{aligned}$$

Free Space Loss

- Free space loss accounting for gain of other antennas

$$\frac{P_r}{P_t} = \frac{(4\pi)^2 (d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

- G_t = gain of transmitting antenna
- G_r = gain of receiving antenna
- A_t = effective area of transmitting antenna
- A_r = effective area of receiving antenna

Free Space Loss

- Free space loss accounting for gain of other antennas can be recast as

$$\begin{aligned}L_{dB} &= 20\log(\lambda) + 20\log(d) - 10\log(A_t A_r) \\ &= -20\log(f) + 20\log(d) - 10\log(A_t A_r) + 169.54\text{dB}\end{aligned}$$

Categories of Noise

- ❑ Thermal Noise
- ❑ Intermodulation noise
- ❑ Crosstalk
- ❑ Impulse Noise

Thermal Noise

- ❑ Thermal noise due to agitation of electrons
- ❑ Present in all electronic devices and transmission media
- ❑ Cannot be eliminated
- ❑ Function of temperature
- ❑ Particularly significant for satellite communication

Thermal Noise

- Amount of thermal noise to be found in a bandwidth of 1Hz in any device or conductor is:

- $N_0 = kT$ (W/Hz)
- N_0 = noise power density in watts per 1/Hz of bandwidth
- k = Boltzmann's constant = 1.3803×10^{-23} J/K
- T = temperature, in kelvins (absolute temperature)

Thermal Noise

- Noise is assumed to be independent of frequency
- Thermal noise present in a bandwidth of B Hertz (in watts):

or, in decibel-watts

$$N = kTB$$

$$\begin{aligned} N &= 10 \log k + 10 \log T + 10 \log B \\ &= -228.6 \text{ dBW} + 10 \log T + 10 \log B \end{aligned}$$

Noise Terminology

- ❑ Intermodulation noise – occurs if signals with different frequencies share the same medium
 - Interference caused by a signal produced at a frequency that is the sum or difference of original frequencies
- ❑ Crosstalk – unwanted coupling between signal paths
- ❑ Impulse noise – irregular pulses or noise spikes
 - Short duration and of relatively high amplitude
 - Caused by external electromagnetic disturbances, or faults and flaws in the communications system

Expression E_b/N_0

- Ratio of signal energy per bit to noise power density per Hertz

$$\frac{E_b}{N_0} = \frac{S / R}{N_0} = \frac{S}{kTR}$$

- The bit error rate for digital data is a function of E_b/N_0
 - Given a value for E_b/N_0 to achieve a desired error rate, parameters of this formula can be selected
 - As bit rate R increases, transmitted signal power must increase to maintain required E_b/N_0

Other Impairments

- ❑ Atmospheric absorption – water vapor and oxygen contribute to attenuation
- ❑ Multipath – obstacles reflect signals so that multiple copies with varying delays are received
- ❑ Refraction – bending of radio waves as they propagate through the atmosphere

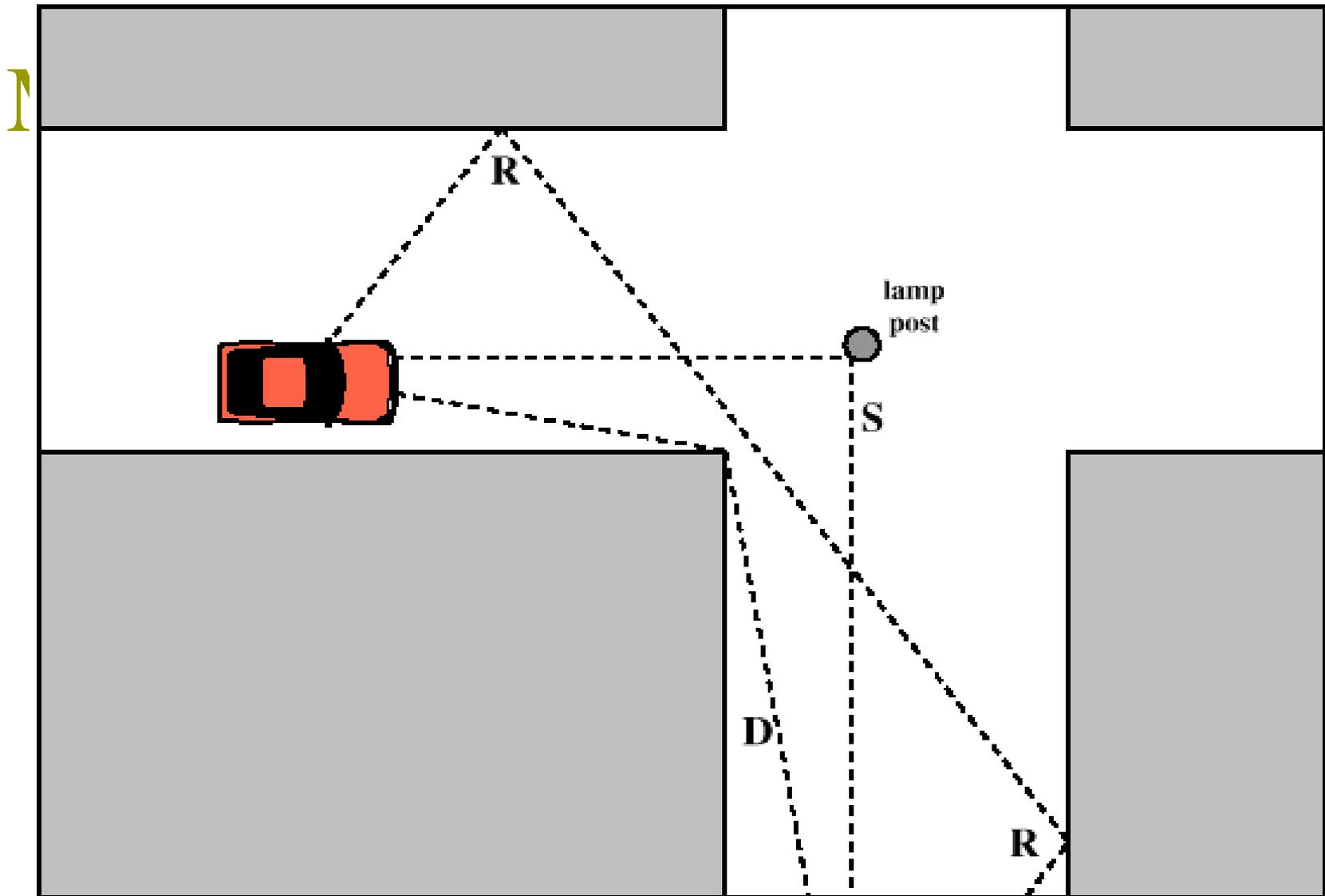


Figure 5.10 Sketch of Three Important Propagation Mechanisms: Reflection (R), Scattering (S), Diffraction (D) [ANDE95]

Multipath Propagation

- ❑ Reflection - occurs when signal encounters a surface that is large relative to the wavelength of the signal
- ❑ Diffraction - occurs at the edge of an impenetrable body that is large compared to wavelength of radio wave
- ❑ Scattering – occurs when incoming signal hits an object whose size is in the order of the wavelength of the signal or less

The Effects of Multipath Propagation

- ❑ Multiple copies of a signal may arrive at different phases
 - If phases add destructively, the signal level relative to noise declines, making detection more difficult
- ❑ Intersymbol interference (ISI)
 - One or more delayed copies of a pulse may arrive at the same time as the primary pulse for a subsequent bit

Types of Fading

- ❑ Fast fading
- ❑ Slow fading
- ❑ Flat fading
- ❑ Selective fading
- ❑ Rayleigh fading
- ❑ Rician fading

Error Compensation Mechanisms

- ❑ Forward error correction
- ❑ Adaptive equalization
- ❑ Diversity techniques

Forward Error Correction

- ❑ Transmitter adds error-correcting code to data block
 - Code is a function of the data bits
- ❑ Receiver calculates error-correcting code from incoming data bits
 - If calculated code matches incoming code, no error occurred
 - If error-correcting codes don't match, receiver attempts to determine bits in error and correct

Adaptive Equalization

- ❑ Can be applied to transmissions that carry analog or digital information
 - Analog voice or video
 - Digital data, digitized voice or video
- ❑ Used to combat intersymbol interference
- ❑ Involves gathering dispersed symbol energy back into its original time interval
- ❑ Techniques
 - Lumped analog circuits
 - Sophisticated digital signal processing algorithms

Diversity Techniques

- ❑ Diversity is based on the fact that individual channels experience independent fading events
- ❑ Space diversity – techniques involving physical transmission path
- ❑ Frequency diversity – techniques where the signal is spread out over a larger frequency bandwidth or carried on multiple frequency carriers
- ❑ Time diversity – techniques aimed at spreading the data out over time