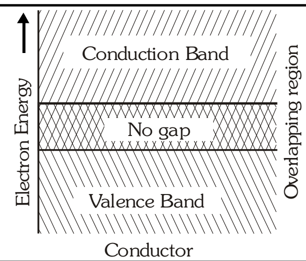
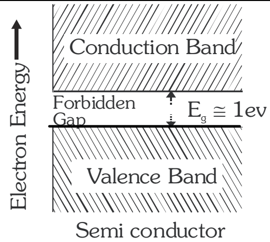
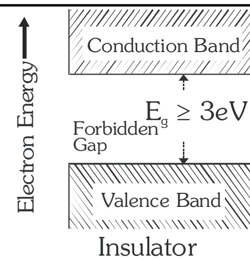
COMPARISON BETWEEN CONDUCTOR, SEMICONDUCTOR AND INSULATOR

Properties	Conductor	Semiconductor	Insulator
Resistivity	$10^{-2} - 10^{-8}$ Ωm	$10^{-5} - 10^{6}$ Ωm	$10^{11} - 10^{19}$ Ωm
Conductivity	$10^{2} - 10^{8}$ mho/m	$10^{-6} - 10^{5}$ mho/m	$10^{-19} - 10^{-11}$ mho/m
Temp. Coefficient of resistance (α)	Positive	Negative	Negative
Current	Due to free electrons	Due to electrons and holes	No current
Energy band diagram			
Forbidden energy gap	≅ 0eV	≅ 1eV	≥ 3eV
Example	Pt, Al, Cu, Ag	Ge, Si, GaAs, GaF_2	Wood, plastic, Diamond, Mica

- **Number of electrons reaching from valence band to conduction band :** $n = AT^{3/2}e^{-\frac{\Delta Eg}{2kT}}$
- **CLASSIFICATION OF SEMICONDUCTORS :**

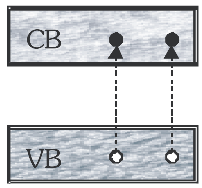
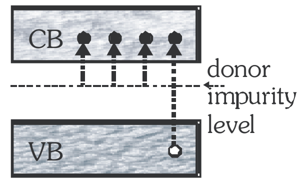
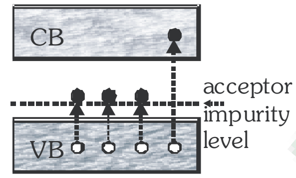
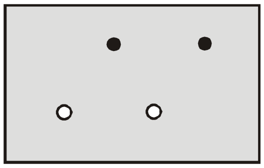
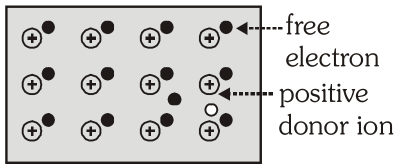
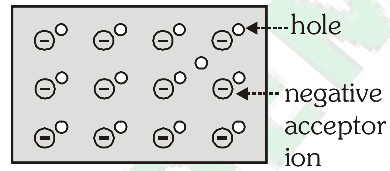
SEMICONDUCTOR

- Intrinsic semiconductor
  - (pure form of Ge, Si)
  - $n_e = n_h = n_i$
- Extrinsic semiconductor (doped semiconductor)
  - N-type: pentavalent impurity (P, As, Sb etc.) donor impurity (N_D) $n_e >> n_h$
  - P-type: trivalent impurity (Ga, B, In, Al) acceptor impurity (N_A) $n_h >> n_e$

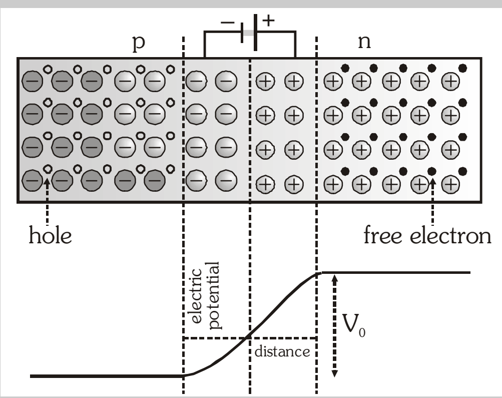
- **MASS-ACTION LAW** : $n_i^2 = n_e \times n_h$
  - ❒ For N-type semiconductor $n_e \simeq N_D$
  - ❒ For P-type semiconductor $n_h \simeq N_A$

CONDUCTION IN SEMICONDUCTOR

Intrinsic semiconductor	P - type	N - type
$n_e = n_h$ $J = ne\,[v_e + v_h]$ (Current density) $\sigma = \frac{1}{\rho} = en\,[\mu_e + \mu_h]$ (Conductivity)	$n_h >> n_e$ $J \cong e\,n_h v_h$ $\sigma = \frac{1}{\rho} \cong e\,n_h\,\mu_h$	$n_e >> n_h$ $J \cong e\,n_e v_e$ $\sigma = \frac{1}{\rho} \cong e\,n_e\,\mu_e$

Intrinsic Semiconductor	N-type (Pentavalent impurity)	P-type (Trivalent impurity)
		
		
Current due to electron and hole	Mainly due to electrons	Mainly due to holes
$n_e = n_h = n_i$	$n_h << n_e$ $(N_D \approx n_e)$	$n_h >> n_e$ $(N_A \approx n_h)$
$I = I_e + I_h$	$I \approx I_e$	$I \approx I_h$
Entirely neutral	Entirely neutral	Entirely neutral
Quantity of electrons and holes are equal	Majority Electrons Minority Holes	Majority Holes Minority - Electrons

P-N JUNCTION
(At equilibrium condition)

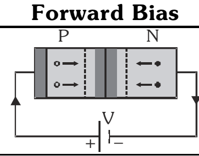
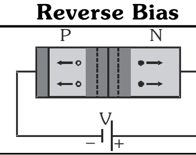
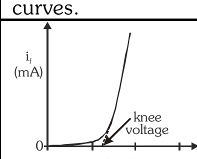
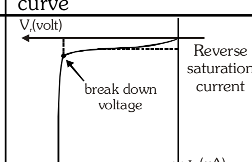


Direction of diffusion current : P to N side and drift current : N to P side

If there is no biasing then diffusion current = drift current. So total current is zero

In junction N side is at high potential relative to the P side. This potential difference tends to prevent the movement of electron from the N region into the P region. This potential difference called a **barrier potential**.

COMPARISON BETWEEN FORWARD BIAS AND REVERSE BIAS

	Forward Bias		Reverse Bias
			
1	Potential Barrier reduces	1	Potential Barrier increases.
2	Width of depletion layer decreases	2	Width of depletion layer increases.
3	P-N jn. provide very small resistance	3	P-N jn. provide high resistance
4	Forward current flows in the circuit	4	Very small current flows.
5	Order of forward current is milli ampere.	5	Order of current is micro ampere for Ge or Nano ampere for Si.
6	Current flows mainly due to majority carriers.	6	Current flows mainly due to minority carriers.
7	Forward characteristic curves.	7	Reverse characteristic curve
			
8	Forward Resistance : $R_f = \frac{\Delta V_f}{\Delta I_f} \cong 100\Omega$	8	Reverse Resistance : $R_r = \frac{\Delta V_r}{\Delta I_r} \cong 10^6\Omega$
9	Order of knee or cut in voltage	9	Breakdown voltage
	Ge→ 0.3 V		Ge → 25 V
	Si → 0.7 V		Si → 35 V
	Special point : Generally $\frac{R_r}{R_f} = 10^3 : 1$ for Ge		$\frac{R_r}{R_f} = 10^4 : 1$ for Si

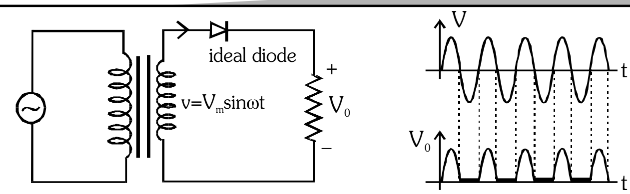
BREAKDOWN ARE OF TWO TYPES

Zener Break down	Avalanche Break down
Where covalent bonds of depletion layer, itself break, due to high electric field This phenomena take place in (i) P – N junction having "High doping" (ii) P – N junction having thin depletion layer Here P – N junction does not damage permanently "In D.C voltage stabilizer zener phenomena is used".	Here covalent bonds of depletion layers are broken by collision of "Minorities" which aquire high kinetic energy from high electric field This phenomena takes place in (i) P – N junction having "Low doping" (ii) P – N junction having thick depletion layer Here P – N junction damages permanentaly due to abruptly increment of minorities during repeatative collisions.

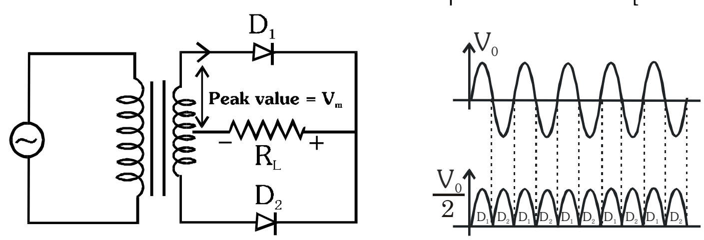
APPLICATION OF DIODE

- **Zener diode** : It is highly doped p-n junction diode used as a voltage regulator.
- **Photo diode** : A p-n junction diode use to detect light signals operated in reverse bias.
- **LED** : A p-n junction device that emits optical radiation under forward bias conditions
- **Solar cell** : Generates emf of its own due to the effect of sun radiations.

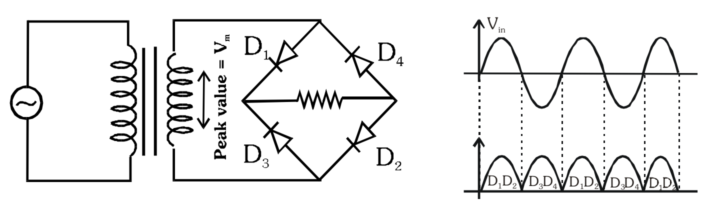
HALF WAVE RECTIFIER



CENTRE – TAP FULL WAVE RECTIFIER



FULL WAVE BRIDGE REACTIFIER



RIPPLE FACTOR : $r = \frac{I_{ac}}{I_{dc}}$

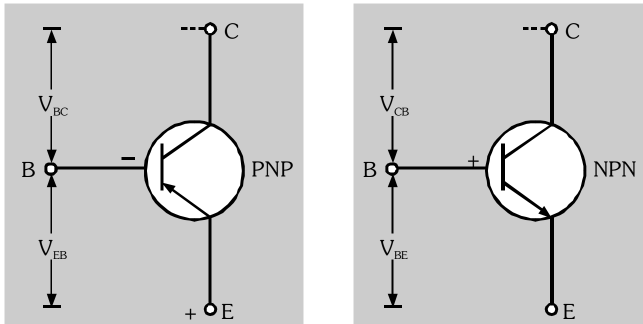
- For HWR r = 1.21
- For FWR r = 0.48

RECTIFIER EFFICIENCY: $\eta = \frac{P_{dc}}{P_{ac}} = \frac{I_{dc}^2 R_L}{I_{rms}^2 (R_F + R_L)}$

For HWR : $\eta\% = \frac{40.6}{1 + \frac{R_F}{R_L}}$ & FWR $\eta\% = \frac{81.2}{1 + \frac{R_F}{R_L}}$

FOR TRANSISTOR

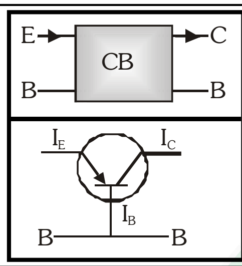
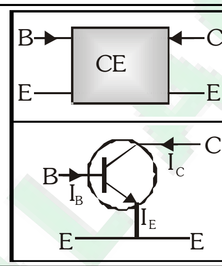
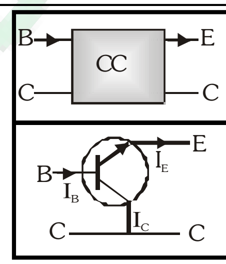
$I_E = I_B + I_C$



(a) (b)

COMPARATIVE STUDY OF TRANSISTOR CONFIGURATIONS

1. Common Base **(CB)** 2. Common Emitter **(CE)** 3. Common Collector **(CC)**

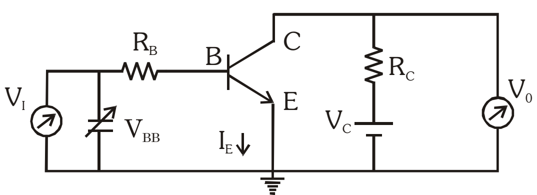
	CB	**CE**	**CC**
			
Input Resistance	Low (100 Ω)	High (750 Ω)	Very High ≅ 750 kΩ
Output resistance	Very High	High	Low
Current Gain	(A_I or α)	(A_I or β)	(A_I or γ)
	$\alpha = \frac{I_C}{I_E} < 1$	$\beta = \frac{I_C}{I_B} > 1$	$\gamma = \frac{I_E}{I_B} > 1$
Voltage Gain	$A_V = \frac{V_o}{V_i} = \frac{I_C R_L}{I_E R_i}$	$A_V = \frac{V_o}{V_i} = \frac{I_C R_L}{I_B R_i}$	$A_V = \frac{V_o}{V_i} = \frac{I_E R_L}{I_B R_i}$
	$A_v = \alpha \frac{R_L}{R_i} \cong 150$	$A_v = \beta \frac{R_L}{R_i} \cong 500$	$A_v = \gamma \frac{R_L}{R_i} < 1$
Power Gain	$A_p = \frac{P_o}{P_i} = \alpha^2 \frac{R_L}{R_i}$	$A_p = \frac{P_o}{P_i} = \beta^2 \frac{R_L}{R_i}$	$A_p = \frac{P_o}{P_i} = \gamma^2 \frac{R_L}{R_i}$
Phase difference (between output and input)	same phase	opposite phase	same phase
Application	For High Frequency	For Audible frequency	For Impedance Matching

TRANSISTOR CHARACTERISTICS

- **Input resistance (r_i)** $\left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE=constant}}$
- **Output resistance (r_0)** $\left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_{B=constant}}$
- **Relation between α and β :** $\beta = \frac{\alpha}{1-\alpha}$ **&** $\alpha = \frac{\beta}{1+\beta}$
- **Current amplification factor**
  - **For CE(n-p-n)** $\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE=constant}}$
  - **For CB (p-n-p)** $\alpha_{ac} = \left(\frac{\Delta I_C}{\Delta I_E}\right)_{V_{CB=constant}}$

TRANSISTOR IN CE CONFIGURATION

Appyling Kirchof's voltage Law



$V_i = V_{BB} = I_B R_B + V_{BE}$ ....(i)

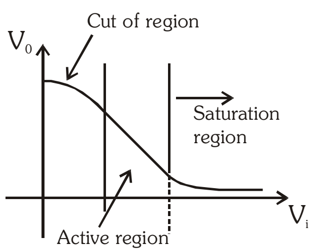
And $V_0 = V_{CE} = V_{CC} - I_C R_C$ ....(ii)

When V_i is less then Knee voltage, the trnasistor will be in cut off state and current I_C will be zero

So $\Delta V_i = R_B \Delta I_B + \Delta V_{BE}$ (ΔV_{BE} is negligible)

From equation (i) & (ii)

and $\Delta V_0 = -R_C \Delta I_C$ ($\because V_{CC}$ = constant)

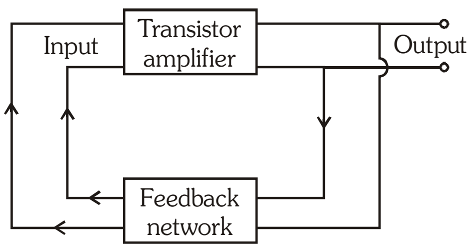


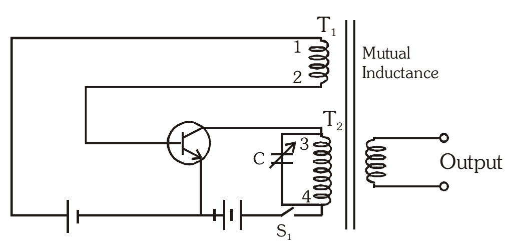
Voltage gain $A_V = \frac{\Delta V_0}{\Delta V_i}$

$\therefore$ Voltage gain $A_V = -\frac{R_C \Delta I_C}{R_B \Delta I_B}$

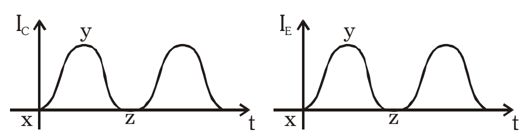
$A_V = -\beta_{ac} \frac{R_C}{R_B}$

Feeedback amplifier and transistor oscillator





Working



Initially surge of collector current (I_C) flows through T_2. This current increases from x to y. By inndductive coupling between coils T_2 and T_1 causes a current in emitter. It is the feedback from input to output. As soon as field becomes static and there will be not feed back. Without feedback, the emitter current begins to fall. So collector current decreases and it will further, untill transistor reaches at cut-off region. The whole process repeat it self. The frequency of tuned circuit at which oscillator will oscillate is $f = \frac{1}{2\pi\sqrt{LC}}$

APPLICATIONS OF TRANSISTORS

There are three regions of transistor operation:

- **Cut off region** * **Active region** * **Saturation region**
- **Transistor as Voltage amplifier**

  * To operate it as an amplifer we need to fix its operating voltage somewhere in active region where it increases the strength of input ac signal and produces an amplified output signal.

  * Voltage gain $A_V = \frac{V_0}{V_i} = -\beta_{ac}\frac{R_{out}}{R_{in}}$

  * Power gain $A_P = A_V \times \beta_{ac}$

- **Transistor as a Switch**

  A transistor can be used as a switch if it is operated in its cutoff and saturation states only.

- **Transisot as an Oscillator**

  An oscillator is a generator of an ac signal using positive feedback

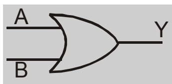
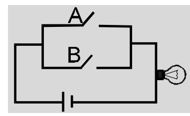
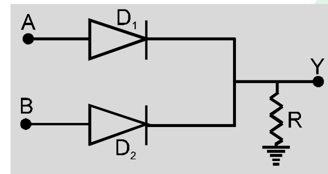
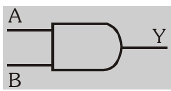
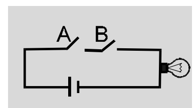
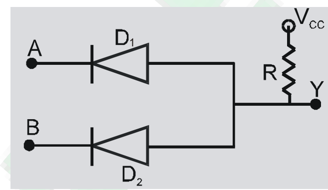
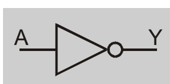
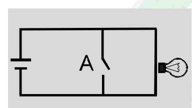
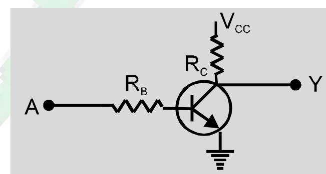
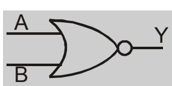
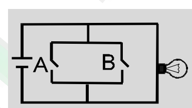
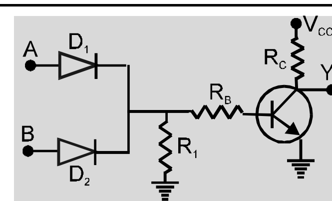
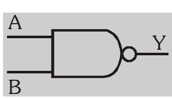
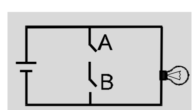
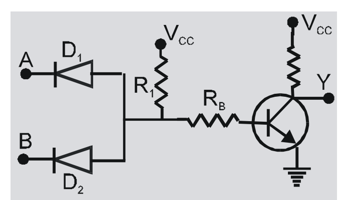
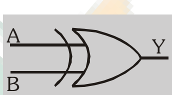
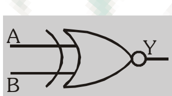
  Frequency of oscillations if $f = \frac{1}{2\pi\sqrt{LC}}$

- **Relation between α, β and γ :**

  $\beta = \frac{\alpha}{1-\alpha}$, $\gamma = 1+\beta$, $\gamma = \frac{1}{1-\alpha}$

KUSAL ACADEMY

SUMMARY OF LOGIC GATES

Names	Symbol	Boolean Expression	Truth table	Electrical analogue	Circuit diagram (Practical Realisation)
OR		$Y = A + B$	A B Y 0 0 0 0 1 1 1 0 1 1 1 1		
AND		$Y = A.\ B$	A B Y 0 0 0 0 1 0 1 0 0 1 1 1		
NOT or Inverter		$Y = \bar{A}$	A Y 0 1 1 0		
NOR (OR +NOT)		$Y = \overline{A + B}$	A B Y 0 0 1 0 1 0 1 0 0 1 1 0		
NAND (AND+NOT)		$Y = \overline{A.B}$	A B Y 0 0 1 0 1 1 1 0 1 1 1 0		
XOR (Exclusive OR)		$Y = A \oplus B$ or $Y = \bar{A}.B + A\bar{B}$	A B Y 0 0 0 0 1 1 1 0 1 1 1 0		
XNOR (Exclusive NOR)		$Y = A \odot B$ or $Y = A.B + \bar{A}.\bar{B}$ or $Y = \overline{A \oplus B}$	A B Y 0 0 1 0 1 0 1 0 0 1 1 1		

DE MORGAN'S THEOREM

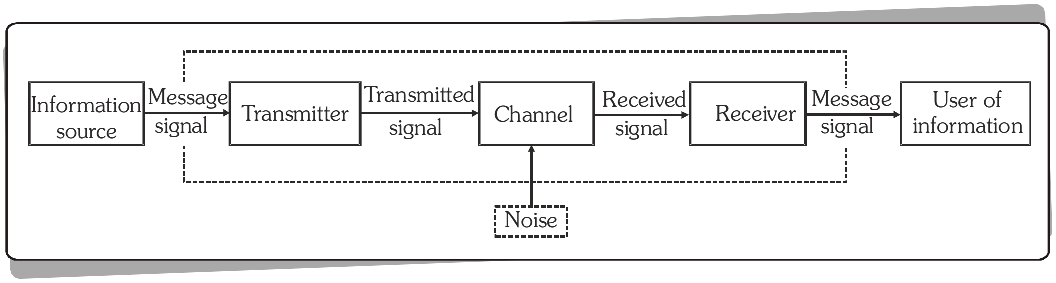
$\overline{A+B} = \bar{A}\bullet\bar{B}, \quad \overline{A\bullet B} = \bar{A}+\bar{B}$

OR	AND	NOT
$A + 0 = A$	$A.\ 0 = 0$	$A + \bar{A} = 1$
$A + 1 = 1$	$A.\ 1 = A$	$A \cdot \bar{A} = 0$
$A + A = A$	$A\ .\ A = A$	$\bar{\bar{A}} \cdot A = A$

Communication System

Faithful transmission of information from one place to another place is called communication.

BASIC COMPONENTS OF A COMMUNICATION SYSTEM



- **Transmitter :** Transmitter converts the message signal produced by information source into a form (e.g. electrical signal) that is suitable for transmission through the channel to the receiver.
- **Communication channel** : Communication channel is a medium (transmission line, an optical fibre or free space etc) which connects a receiver and a transmitter. It carries the modulated wave from the transmitter to the receiver.
- **Receiver** : It receives and decode the signal into original form.

IMPORTANT TERMS USED IN COMMUNICATION

- **Transducer.** Transducer is the device that converts one form of energy into another. Microphone, photo detectors and piezoelectric sensors are types of transducer.
- **Signal** Signal is the information converted in electrical form. Signals can be analog or digital. Sound and picture signals in TV are analog.

  It is defined as a single–valued function of time which has a unique value at every instant of time.

  - **Analog Signal :–** A continuously varying signal (Voltage or Current) is called an analog signal. A decimal number with system base 10 is used to deal with analog signal.
  - **Digital Signal :–** A signal that can have only discrete stepwise values is called a digital signal. A binary number system with base 2 is used to deal with digital signals. (See Fig. 1)
- **Noise :** There are unwanted signals that tend to disturb the transmission and processing of message signals. The source of noise can be inside or outside the system.
- **Attenuation :** It is the loss of strength of a signals while propagating through a medium. It is like damping of oscillations.
- **Amplification :** It is the process of increasing the amplitude (and therefore the strength) of a signal using an electronic circuit called the amplifier. Amplification is absolutely necessary to compensate for the attenuation of the signal in communication systems.
- **Range :** It is the largest distance between the source and the destination upto which the signal is received with sufficient strength.
- **Repeater :** A repeater acts as a receiver and a transmitter. A repeater picks up the signal which is coming from the transmitter, amplifies and retransmits it with a change in carrier frequency. Repeaters are necessary to extend the range of a communication system as shown in figure A communication satellite is basically a repeater station in space. (See Fig. 2)

Fig.1

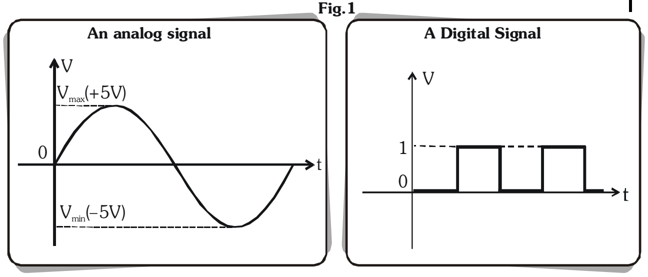
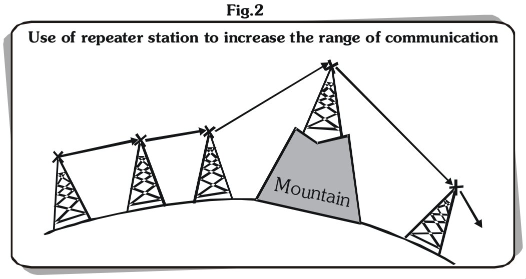


Fig.2



BANDWIDTH

BANDWIDTH OF SIGNALS

Different signals used in a communication system such as voice, music, picture, computer data etc. all have different ranges of frequency. The difference of maximum and minimum frequency in the range of each signal is called bandwidth of that signal. Bandwidth can be of message signal as well as of transmission medium.

(i) Bandwidth for analog signals :

Bandwidth for some analog signals are listed below

Signal	Frequency range	Bandwidth required
Speech	300-3100 Hz	3100-300 =2800 Hz
Music	High frequencies produced by musical instrument audible range =20 Hz - 20 kHz	20 kHz
Picture	—	4.2 MHz
TV	Contains both voice and picture	6 MHz

(ii) Bandwidth for digital signal :

Basically digital signals are rectangular waves and these can be splited into a superposition of sinusoidal waves of frequencies ν_0, $2\nu_0$, $3\nu_0$, $4\nu_0$, $n\nu_0$, where n is an integer extending to infinity. This implies that the infinite band width is required to reproduce the rectangular waves. However, for practical purposes, higher harmonics are neglected for limiting the bandwidth

BANDWIDTH OF TRANSMISSION MEDIUM

Different types of transmission media offer different band width of which some are listed below

	Service	Frequency range	Remarks
1	Wire (most common : Coaxial Cable)	750 MHz (Bandwidth)	Normally operated below 18 GHz
2	Free space (radio waves)	540 kHz-4.2 GHz	
	(i) Standard AM	540 kHz to 30 MHz	
	(ii) FM	88-108 MHz	
	(iii) Television	54-72 MHz 76-88 MHz 174-216 MHz 420-890 MHz	VHF (Very high frequencies) TV UHF (Ultra hight frequency) TV
	(iv) Cellular mobile radio	896-901 MHz 840-935 MHz	Mobile to base Station Base station to mobile
	(v) Satellite Communication	5.925-6.425 GHz 3.7 - 4.2 GHz	Uplinking Downlinking
3	Optical communication using fibres	1THz-1000 THz (microwaves- ultra violet)	One single optical fibre offers bandwidth > 100 GHz

GROUND WAVE PROPAGATION

(a) The radio waves which travel through atmosphere following the surface of earth are known as ground waves or surface waves and their propagation is called ground wave propagation or surface wave propagation. These waves are vertically polarised in order to prevent short-circuiting of the electric component. The electrical field due to the wave induce charges in the earth's surface. As the wave travels, the induced charges in the earth also travel along it. This constitutes a current in the earth's surface. As the ground wave passes over the surface of the earth, it is weakened as a result of energy absorbed by the earth. Due to these losses the ground waves are not suited for very long range communication. Further these losses are higher for high frequency. Hence, ground wave propagation can be sustained only at low frequencies (500 kHz to 1500 kHz).

(b) The ground wave transmission becomes weaker with increase in frequency because more absorption of ground waves takes place at higher frequency during propagation through atmosphere.

(c) The ground wave propagation is suitable for low and medium frequency i.e. upto 2 MHz only.

(d) The ground wave propagation is generally used for local band broadcasting and is commonly called medium wave.

(e) The maximum range of ground or surface wave propagation depends on two factors :

(i) The frequency of the radio waves and (ii) Power of the transmitter

SKY WAVE PROPAGATION

(a) The sky waves are the radio waves of frequency between 2 MHz to 30 MHz.

(b) The ionospheric layer acts as a reflector for a certain range of frequencies (3 to 30 MHz). Therefore it is also called has ionospheric propagation or short wave propagation. Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape.

(c) The highest frequency of radio waves which when sent straight (i.e. normally) towards the layer of ionosphere gets reflected from ionosphere and returns to the earth is called critical frequency. It is given by $\boxed{f_c = 9\sqrt{N_{max}}}$, where N is the number density of electron/m^3.

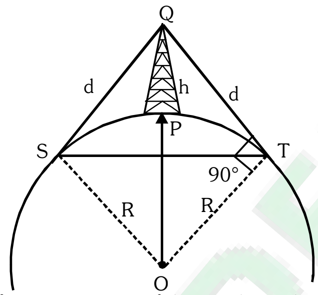
SPACE WAVE PROPAGATION

(a) The space waves are the radio waves of very high frequency (i.e. between 30 MHz. to 300 MHz or more).

(b) The space waves can travel through atmosphere from transmitter antenna to receiver antenna either directly or after reflection from ground in the earth's troposphere region. That is why the space wave propagation is also called as tropospherical propagation or line of sight propagation.

(c) The range of communication of space wave propagation can be increased by increasing the heights of transmitting and receiving antenna.

(d) **Height of transmitting Antenna :**
The transmitted waves, travelling in a straight line, directly reach the received end and are then picked up by the receiving antenna as shown in figure.



Due to finite curvature of the earth, such waves cannot be seen beyond the tangent points S and T.

$$(R+h)^2 = R^2 + d^2$$

As R>>h, So $h^2 + 2Rh = d^2 \Rightarrow d = \sqrt{2Rh}$

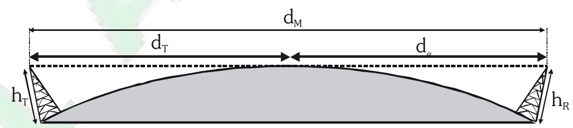
Area covered for TV transmission :

$$A = \pi d^2 = 2\pi Rh$$

Population covered=population density × area covered

If height of receiving antenna is also given in the question then the maximum line of sight

$$d_M = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$



Line of sight communication by space waves

where ;

R=radius of earth (approximately 6400 km)

h_T = height of transmitting antenna

h_R = height of receiving antenna

MODULATION

The phenomenon of superposition of information signal over a high frequency carrier wave is called modulation. In this process, amplitude, frequency or phase angle of a high frequency carrier wave is modified in accordance with the instantaneous value of the low frequency information.

- **Modulation**
  - **Continuous wave Modulation**
    - **AM** (Amplitude Modulation)
    - **FM** (Frequency Modulation)
    - **PM** (Phase Modulation)
  - **Pulse Wave Modulation**
    - **PAM** (Pulse Amplitude Modulation)
    - **PTM** (Pulse Time Modulation)
      - **PWM** (Pulse Width Modulation)
      - **PPM** (Pulse Position Modulation)
    - **PCM** (Pulse Code Modulation)

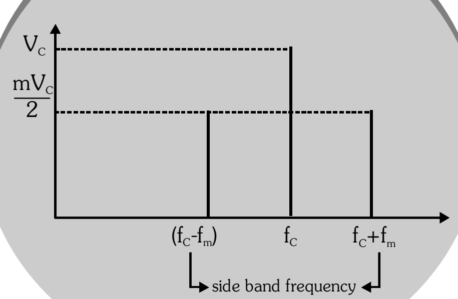
NEED FOR MODULATION

(i) To avoid interference: If many modulating signals travel directly through the same transmission channel, they will interfere with each other and result in distortion.

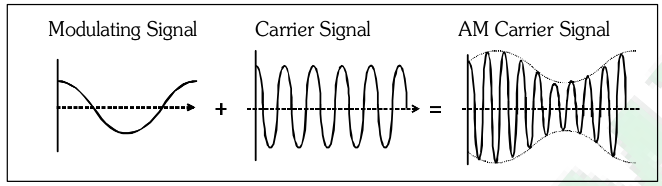
(ii) To design antennas of practical size : The minimum height of antenna (not of antenna tower) should be $\lambda/4$ where λ is wavelength of modulating signal. This minimum size becomes impracticale because the frequency of the modulating signal can be upto 5 kHz which corresponds to a wavelength of $3 \times 10^8/5 \times 10^3 = 60$ km. This will require an antenna of the minimum height of $\lambda/4 = 15$ km. This size of an antenna is not practical.

(iii) Effective Power Radiated by an Antenna : A theoretical study of radiation from a linear antenna (length ℓ) shows that the power radiated is proportional to (frequency)^2 i.e. $(\ell/\lambda)^2$. For a good transmission, we need high powers and hence this also points out to the need of using high frequency transmission.

FREQUENCY SPECTRUM OF AM WAVE



AMPLITUDE MODULATION



Modulation factor, $m = \dfrac{\text{amplitude of modulating wave}}{\text{amplitude of normal carrier wave}}$

If $v_m = V_m \cos\omega_m t$ and $v_c = V_c \cos\omega_c t$ then $m = \dfrac{V_m}{V_c}$

- As amplitude of the carrier wave varies at signal frequency f_m so the amplitude of AM wave = $V_C + mV_C \cos\omega_m t$ & frequency of AM wave = $\dfrac{\omega_c}{2\pi}$

Therefore $v = [V_c(1+m)\cos\omega_m t]\cos\omega_c t$

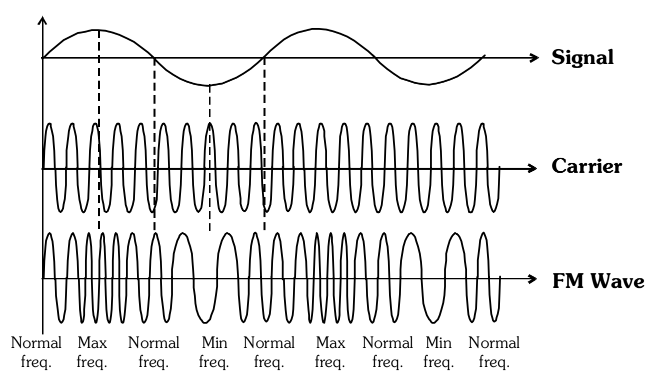
$$\Rightarrow v = V_C \cos\omega_c t + \frac{mV_C}{2}\cos(\omega_C + \omega_m)t + \frac{mV_C}{2}\cos(\omega_C - \omega_m)t$$

POWER IN AM WAVE

- Power of carrier wave : $P_C = \dfrac{V_C^2}{2R}$ where R = resistance of antenna in which power is dissipated.
- Total power of side bands : $P_{sidebands} = 2 \times \dfrac{1}{2R}\left(\dfrac{mV_C}{2}\right)^2 = \dfrac{m^2}{2}P_C$
- Total power of AM wave = $P_C\left(1 + \dfrac{m^2}{2}\right)$
- Fraction of total power carried by sidebands = $\dfrac{m^2}{2+m^2}$

FREQUENCY MODULATION (FM)

When the frequency of carries wave is changed in accordance with the instantaneous value of the modulating signal, it is called frequency modulation.



MODULATION FACTOR OR INDEX AND CARRIER SWING (CS)

- ***Modulation factor***: $m = \dfrac{\text{max. frequency deviation}}{\text{Modulating frequency}} = \dfrac{\Delta f}{f_m}$

  $\Delta f = f_{max.} - f_c = f_c - f_{min.}$; $v_{FM} = V_C\cos[\omega_C t + m_f \cos\omega_m t]$
- ***Carrier Swing (CS)***

  The total variation in frequency from the lowest to the highest is called the carrier swing $\Rightarrow$ CS = $2 \times \Delta f$
- ***Side Bands***

  FM wave consists of an infinite number of side frequency components on each side of the carrier frequency f_C, $f_C \pm f_m$, $f_C \pm 2f_m$, $f_C \pm 3f_m$, & so on.

	Amplitude Modulation		Frequency Modulation
1	The amplitude of FM wave is constant, whatever be the modulation index.	1	The amplitude of AM signal varies depending on modulation index.
2	It require much wider channel (Band width) [7 to 15 times] as compared to AM.	2	Band width* is very small (One of the biggest advantage).
3	Transmitters are complex and hence expensive.	3	Relatively simple and cheap.
4	Area of reception is small since it is limited to line of sight. (This limits the FM mobile communication over a wide area)	4	Area of reception is Large.
5	Noise can be easily minimised amplitude variation can be eliminated by using limiter.	5	It is difficult to eliminate effect of noise.
6	Power contained in the FM wave is useful. Hence full transmitted power is useful.	6	Most of the power which contained in carrier is not useful. Therefore carrier power transmitted is a waste.
7	The average power is the same as the carrier wave.	7	The average power in modulated wave is greater than carrier power.
8	No restriction is placed on modulation index (m).	8	Maximum m = 1, otherwise over modulation (m > 1) would result in distortion.
9	It is possible to operate several independent transmitter on same frequency.	9	It is not possible to operate without interference.

MODEM

The name modem is a contraction of the terms Modulator and Demodulator. Modem is a device which can modulate as well as demodulate the signal.

FAX (Facsimile Telegraphy)

FAX is abbreviation for facsimile which means exact reproduction. The electronic reproduction of a document at a distance place is called Fax.

DETECTION OF AMPLITUDE MODULATION WAVE