WAVE PROPAGATION AND BROADBAND COMMUNICATIONENGINEERING(WP&BCE)

(Asperthelatestsyllabuspreparedbythe SCTE&VT, Bhubaneswar, Odisha)

FifthSemester

E&TC Engg.

Er.NIRANJAN SAHU

WAVE PROPAGATION AND BROADBANDCOMMUNICATION ENGINEERING

CHAPTER-WISEDISTRIBUTIONOFPERIODS&MARKS

Sl. No.	Chapter No.	Topics	Periodsas per syllabus	Periods actually needed	Expected marks
1	1	WAVEPROPAGATION AND ANTENNA	**12**	**14**	**20**
2	2	TRANSMISSIONLINES	**10**	**08**	**20**
3	3	TELEVISION ENGINEERING	**13**	**11**	**25**
4	4	MICROWAVE ENGINEERING	**15**	**13**	**30**
5	5	BROADBAND COMMUNICATION	**10**	**10**	**15**
Total			**60**	**56**	**110**

CHAPTER NO-01:

WAVEPROPAGATIONAND ANTENNA

LEARINGOBJECTIVES:

Effectsofenvironmentssuchasreflection,refraction, interference,diffraction, absorption and attenuation (Definition only)

Classification basedon Modes ofPropagation- Ground Wave, Ionosphere, Skywave Propagation, Space Wave Propagation.

Definition- Critical Frequency, Max. Useable Frequency, Skip Distance, Fading,

DuctPropagation&troposphereScatterPropagation,ActualHeighttAndVirtual Height,

RadiationMechanismofanAntenna-MaxwellEquation.

Definition – Antenna Gains, Directive Gain, Directivity, Effective Aperture,

Polarization,InputImpedance,Efficiency,RadiatorResistance,Bandwidth,Beam Width, Radiation Pattern.

Antenna-

TypesofAntenna:MonopoleAndDipoleAntennaAndOmnidirectional Antenna,

OperationoffollowingAntennawithAdvantage&Applications.

a. *DirectionalHighFrequencyAntenna:,Yagi&Rohmbus Only*
b. *UHF&MicrowaveAntenna.:DishAntenna(WithparabolicReflector)&Horn Antenna.*

BasicconceptsofSmartAntennas-ConceptandbenefitsofsmartAntennas

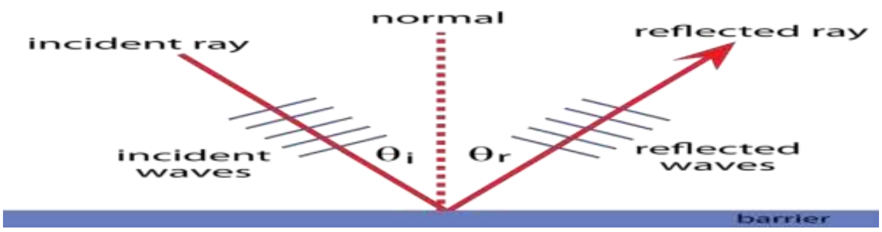
Introduction:

- **Wavepropagation** isanyofthewaysinwhich**waves**travel.
- Withrespecttothedirectionoftheoscillationrelativetothe **propagation**direction, we can distinguish propagations as
    1. Longitudinal **wave**and
    2. Transverse**waves**.
    3. Forelectromagnetic**waves**,**propagation**mayoccurinavacuumaswellas ina material medium.
- Inradioengineering,an **antenna**istheinterfacebetweenradio**wavespropagating** through space and electric currents moving in metal conductors, used with a transmitter or receiver.
- **In** wireless communication systems, signals are radiated **in** space as an electromagnetic**wave**byusingareceiving,transmitting **antenna**andafractionof this radiated power is intercepted by using a receiving **antenna**. An **antenna** is a device used for radiating or receiving radio**waves**.

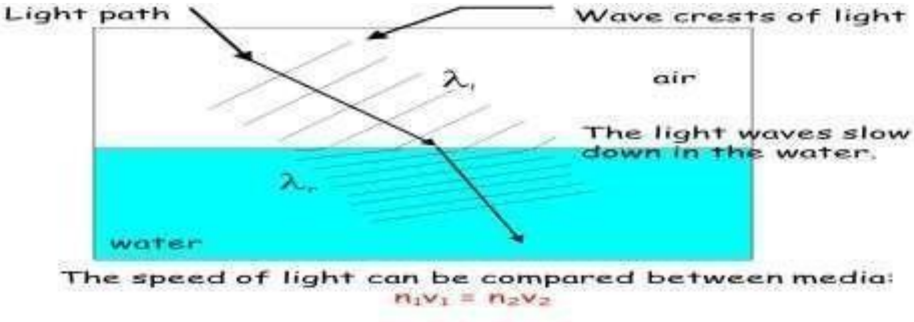
.Effectsofenvironmentssuch asreflection,refraction, interference, diffraction, absorption and attenuation (Definition only)

* A large number of copies of the useful signal at the reception are caused by the **effects** of environmental**impacts** onthe**propagation** ofelectromagnetic**waves** alongtheroute,such as reflection, refraction, interference, diffraction, absorption and attenuation.

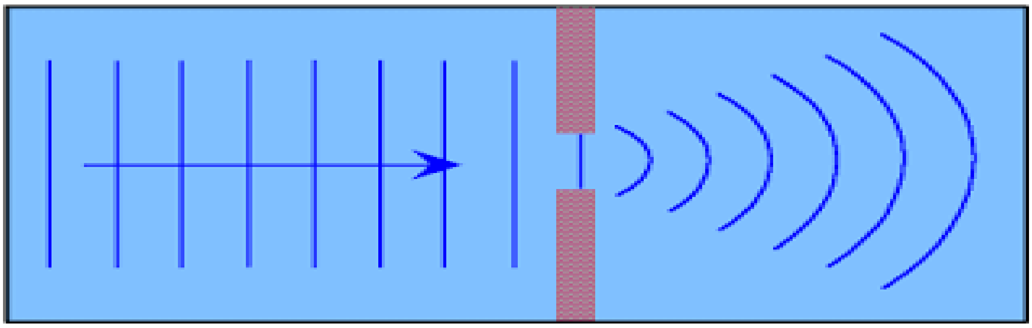
- **Reflection : Reflection of waves** is the change in the direction of a **wave** upon striking the interfacebetween two materials. When a **wave**strikes any interfacebetweenanytwomediumsthebouncingbackof**wave**istermedas **reflection ofwaves**.



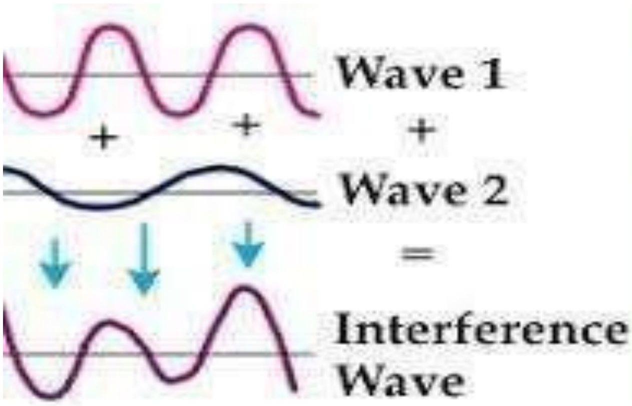
- **Refraction : Refraction** of **waves** involves a change in the direction of **waves** as theypassfromonemediumtoanother. **Refraction**,orthebendingofthepathofthe **waves**,isaccompaniedbyachangeinspeedandwavelengthofthe **waves**..Thus,if water **waves** are passing from deep water into shallow water, they will slowdown.



- **Diffraction : Diffraction of Wave** refers to various phenomena that occur when a waveencountersanobstacleoraslit.Itisdefinedasthebendingofwavesaroundthe cornersofanobstacle orthroughan apertureintotheregion of geometrical shadowof the obstacle/aperture.

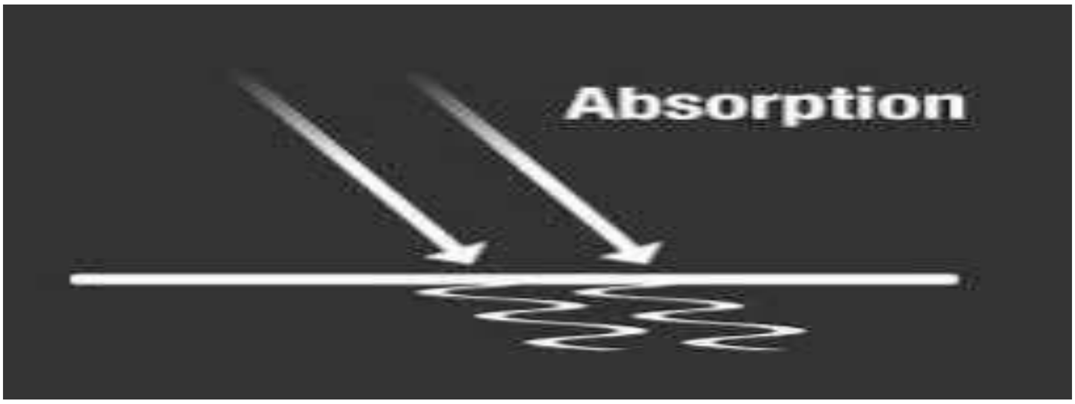


- **Interference:Waveinterference**isthephenomenonthatoccurswhentwo**waves** meet while traveling along the same medium. The **interference of waves** causes the mediumtotakeonashapethatresultsfromthoneteffectofthetwoindividual **waves** upon the particles of the medium.

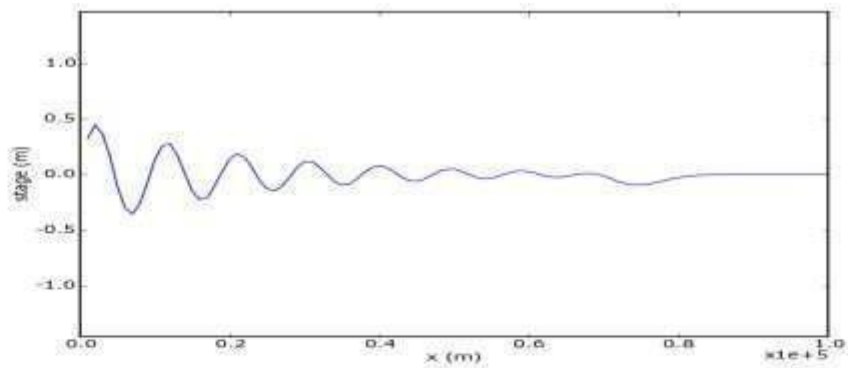



The interference of water waves coming from two sources.

- **Absorption : Electromagnetic** radiation travels in **wave** packets known as photonsthat consist of propagating electric and magnetic fields. These photons undergo**absorption**whentheytransferenergytoatomswithinasubstancetheyare strikinginstead of transmitting through or reflecting off ofit.



- **Attenuation : Attenuation** is a general term that refers to any reduction in the strengthofasignal.**Attenuation**occurswithanytypeofsignal,whetherdigitalor analog. Sometimes called loss, **attenuation** is a natural consequence of signal transmission over long distances.



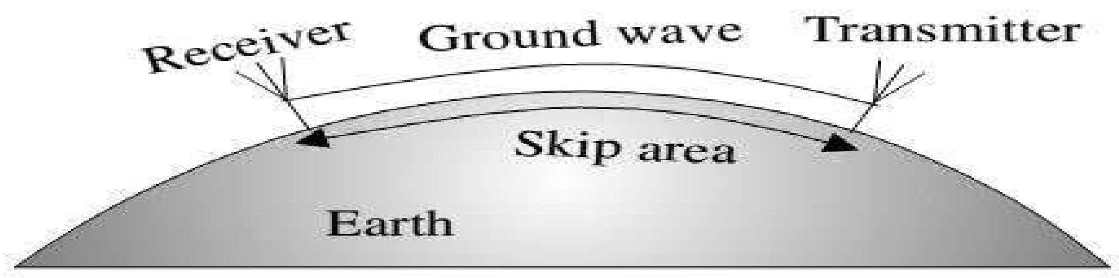
ClassificationbasedonModesofPropagation:

Basedon modesofpropagation,waves can beclassifiedinto followingfour types,

1) Groundwave
2) Ionosphere
3) Skywavepropagation
4) Spacewave propagation

GroundWavePropagation:

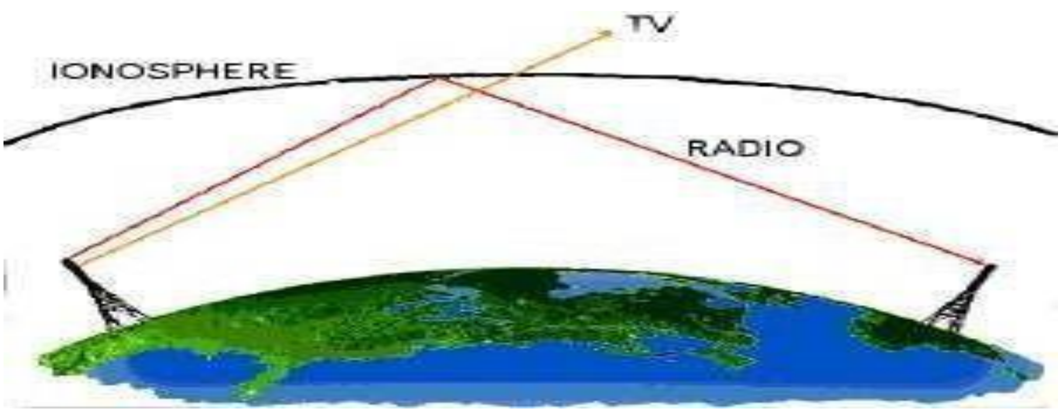
1) **GroundWavepropagation**isamethodofradiowavepropagationthatusesthearea between the surface of the earth and the ionosphere fortransmission.



2) Thegroundwavecanpropagateaconsiderabledistanceovertheearth'ssurface particularly in the low frequency and medium frequency portion of the radio spectrum.
3) Ground wave radio signal propagation is ideal for relatively short distance propagation on these frequencies during the daytime. Sky-wave ionospheric propagationisnotpossibleduringthedaybecauseoftheattenuationofthesignalson these frequencies caused by the D region in the ionosphere.
4) Inviewofthis,lower frequency radio communicationsstationsneed to relyonthe ground-wave propagation to achieve their coverage.
5) TheradiosignalspreadsoutfromthetransmitteralongthesurfaceoftheEarth. Instead of just travelling in a straight line the radio signals tend to follow the curvature of the Earth.
6) Thisisbecausecurrentsareinducedinthesurfaceoftheearthandthisactionslows down the wave-front in this region, causing the wave-front of the radio communications signal to tilt downwards towards the Earth.
7) Withthewave-fronttiltedinthisdirectionitisabletocurvearoundtheEarthandbe received well beyond the horizon.
8) The type of antenna and its polarization has a major effect on ground wave propagation.Verticalpolarizationissubjecttoconsiderablylessattenuationthan horizontally polarized signals.

IonosphereWavePropagation:

1) The**ionosphere**isaparticularlyimportantregionwithregardsto**radio**signal **propagation**and**radio**communicationsingeneral.

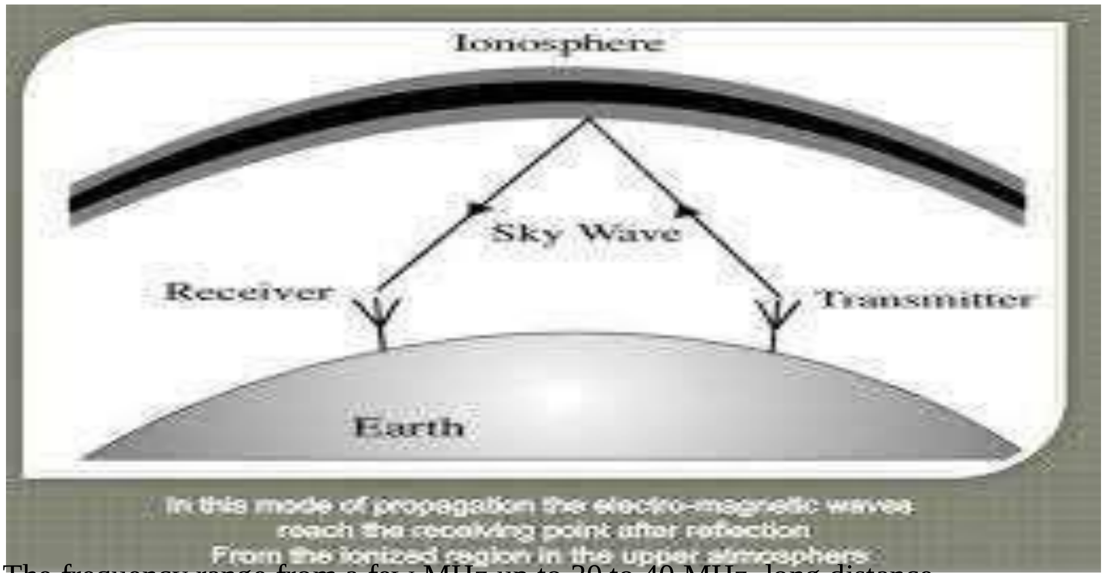


2) Whiletheions givethe**ionosphere**itsname,butitisthefreeelectronsthataffectthe **radiowaves**and**radio**communications.

3) As **radiowaves** enterEarth'satmospherefromspace.
4) Someof the **waves** areabsorbed **by** theelectrons inthe **ionosphere** whileothers **pass through** and are detectable to ground based observers.
5) Higher **frequencywaves** areableto **passthrough** theatmosphereentirelyandreach the ground.
6) The ionosphere exists between about 90 and 1000 km above the earth's surface. Radiationfromthesunionizesatomsandmoleculeshere,liberatingelectronsfrom molecules and creating a space of free electron and ions.
7) Subjected to an external electric field from a radio signal, these free ions will experiencea forceandbe pushedintomotion.However,sincethemassof theionsis muchlargerthanthemassoftheelectrons,ionicmotionsarerelativelysmallandwill be ignored.

SkyWavePropagation:

1) In radio communication, **skywave** or skip refers to the **propagation** of radio **waves** reflectedorrefracted backtowardEarthfromtheionosphere, an electricallycharged layer of the upper atmosphere.



2) The frequency range from a few MHz up to 30 to 40 MHz, long distance communication can be achieved by ionospheric reflection of radio **waves** back towardstheearth.Thismodeof **propagation** iscalled **skywavepropagation** andis used by short **wave** broadcast services.
3) Sinceitisnotlimitedbythecurvatureofthe Earth,skywavepropagationcanbeused to communicate beyond the horizon, at intercontinental distances.
4) Itismostlyusedintheshortwavefrequencybands.
5) Asaresultofskywavepropagation,asignalfrom adistant AMbroadcastingstation,a shortwave station, or – during sporadic E propagation conditions (principally during the summer months in both hemispheres) a distant VHF FM or TV station – can sometimes be received as clearly as local stations.
6) Mostlong-distanceshortwave(highfrequency)radiocommunication –between3and 30 MHz – is a result of sky wave propagation. Since the early 1920s amateur radio

operators(or"hams"),limitedtolowertransmitterpowerthanbroadcaststations, have taken advantage of sky wave for long-distance (or "DX") communication.

7) Theionosphereisaregionoftheupperatmosphere,fromabout80kmto1000kmin altitude, where neutral air isionized by solar photons and cosmic rays.
8) Whenhigh-frequency signalsentertheionosphere atalowanglethey arebentback towards the earth by the ionized layer.
9) Ifthepeakionizationisstrongenoughforthechosenfrequency,awavewillexitthe bottom of the layer earthwards – as if obliquely reflected from a mirror.
10) Earth'ssurface(groundorwater)thenreflectsthedescendingwavebackupagain towards the ionosphere.
11) When operating at frequencies just below the MUF, losses can be quite small, so the radiosignalmayeffectively"bounce"or"skip"betweentheearthandionospheretwo or more times (multi-hop propagation), even following the curvature of theearth.
12) Consequently, even signals of only a few Watts can sometimes be received many thousandsofmilesaway.Thisiswhatenablesshortwavebroadcaststotravelallover the world.
13) Iftheionizationisnotgreatenough,thewaveonlycurvesslightlydownwards,and subsequently upwards as the ionization peak is passed so that it exits the top of the layer only slightly displaced.

SpaceWavePropagation:

1) **Spacewavepropagation**isdefinedfortheradio**waves**thatoccurwithinthe20km of the atmosphere ie; troposphere, comprising of a direct and reflected **waves**.
2) These**waves** arealsoknownastropospheric**propagation**astheycantraveldirectly from the earth's surface to the troposphere surface of theearth.

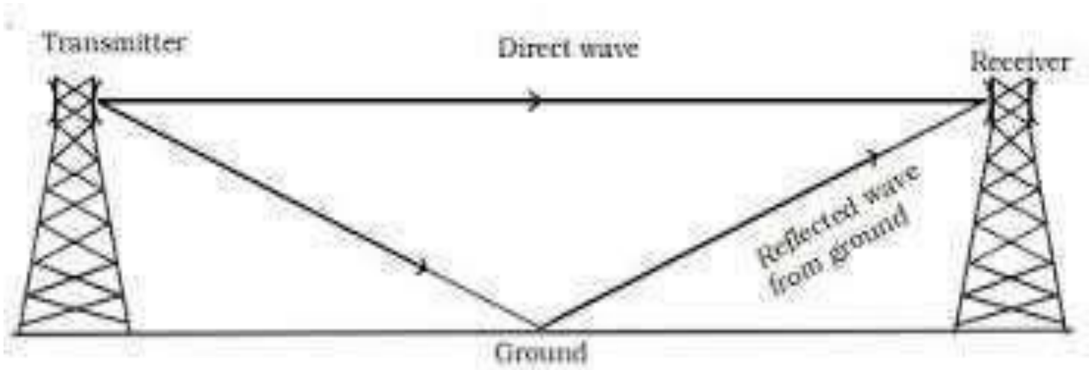


Fig Space wave propagation

3) Inordertopreventattenuationandlossofsignalstrength,theheightoftheantennas and distance between them can be given as:

$D_m=(2RH_t)^{-½}+(2RH_r)^{-½}$

Where,

D_m:distancebetweenthetwoantennas R:

radius of the earth

H_t:heightoftransmissionantenna

H_r: height of receiver antenna

Applicationsofspacewavepropagation

Itisusedinvariouscommunicationsystemslike

- Alineofsightcommunicationandsatellite communication
- Radarcommunication
- Microwavelinking

Spacewavepropagationlimitations

- Thesewaves areaffectedbythecurvatureoftheearth.
- The propagation of these waves happens along the line of sight distance which is definedasthedistancebetweenthetransmittingantennaandthereceivingantenna which is also known as the range of communication.

CriticalFrequency:

1. **Critical frequency** is the highest magnitude of **frequency** above which the **waves**penetratetheionosphereandbelowwhichthe**waves**arereflectedback from the ionosphere.
2. Itsvalueisnotfixedanditdependsupontheelectrondensityof the ionosphere.

MaximumUsableFrequency(MUF):

1. In radio transmission **maximum usable frequency** (MUF) is the **highest** radio **frequency** that can be used for transmission between two points via reflectionfromtheionosphere(**skywave**or"skip"**propagation**)ataspecified time, independent of transmitter power.

SkipDistance:

1. A**skipdistance**isthe**distance**aradio**wave**travels,usuallyincludingahop in the ionosphere.
2. A **skip distance** is a **distance** on the Earth's surface between the two points whereradio**waves**fromatransmitter,refracteddownwardsbydifferentlayers of the ionosphere, fall.

Fading:

1. Thedecreaseinthequalityofthesignalcan betermed as**fading**.
2. Thishappensbecauseofatmosphericeffectsorreflections duetomultipath.
3. **Fading** refersto thevariationof thesignalstrengthwithrespectto time/distance

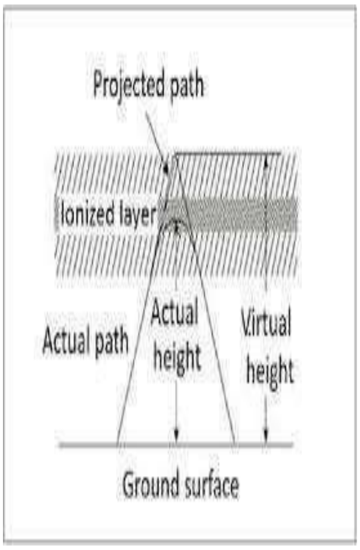
DuctPropagation:

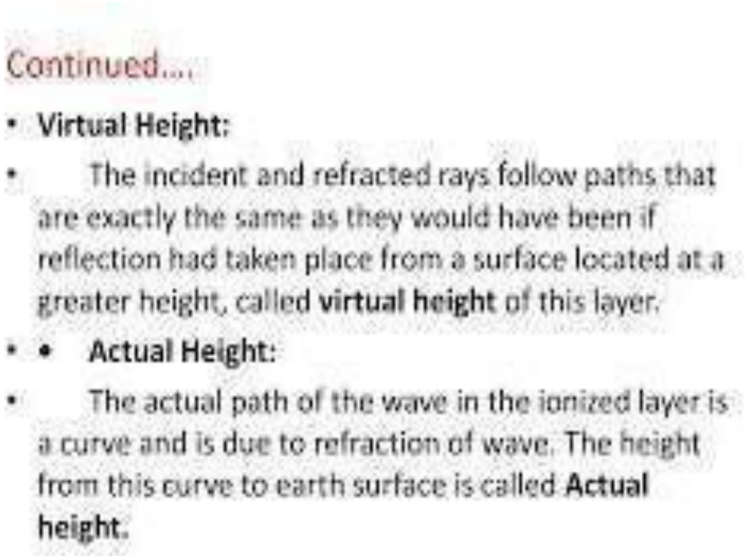
1. A layer of troposphere bounded above and below by layers that have differentrefractiveindex,whichconfinesandpropagatesanabnormallyhigh proportion of VHF (very high frequency) and UHF (ultrahigh frequency) radiation.
2. Thisresultsinfreaklong-distancecommunications andradarpickup ranges.

TroposphereScatterPropagation:

1. Thismethodofpropagationusesthetroposphericscatterphenomenon,where radiowavesatUHFandSHFfrequenciesarerandomlyscatteredastheypass through the upper layers of the troposphere.
2. Radiosignalsaretransmittedinanarrowbeamaimedjust abovethehorizon in the direction of the receiver station.

VirtualHeightAndActualHeight:





Radiationmechanismofanantenna-Maxwellequation:

Maxwell's Equations are a set of four vector-differential equations that govern all of electromagnetics (except at the quantum level, in which case we as antenna people don't care so much). They were first presented in a complete form by James Clerk Maxwell back in the 1800s. He didn't come up with them all on his own, but did add the displacement current term to Ampere's law which made them complete.

The four equations (written only in terms of **E** and **H**, the electric field and the magnetic field), are given below.

$$\nabla \cdot \mathbf{E} = \frac{\rho_v}{\varepsilon} \qquad \text{(Gauss' Law)}$$

$$\nabla \cdot \mathbf{H} = 0 \qquad \text{(Gauss' Law for Magnetism)}$$

$$\nabla \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t} \qquad \text{(Faraday's Law)}$$

$$\nabla \times \mathbf{H} = \mathbf{J} + \varepsilon \frac{\partial \mathbf{E}}{\partial t} \qquad \text{(Ampere's Law)}$$

In Gauss' law, ρ_v is the volume electric charge density, **J** is the electric current density (in Amps/meter-squared), ε is the permittivity and μ is the permeability.

AntennaGain :

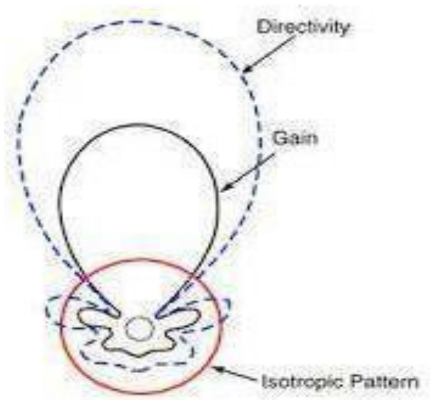
- Theterm**antennagain**definesthedegreetowhichan**antenna**concentratesradiated power in a given direction, or absorbs incident power from that direction, compared with a reference **antenna**.
- **Antenna gain** is usually defined as the ratio of the power produced by the **antenna** from a far-field source on the **antenna's** beam axis to the power produced by a hypotheticallosslessisotropic**antenna**,whichisequallysensitivetosignalsfromall directions.

DirectiveGain:

- The**directivegain** ordirectivityofanantennainagivendirectionistheratioofits radiation intensity in that direction to its mean radiation intensity .
- **Directivity**canbeextrapolatedfromtheratio**between** thepowerradiated**inthe** directionofthestrongestemissiontothetotalpowerradiatedbythe**antenna.**

Directivity:

- **Directivity**isafundamentalantennaparameter.It isameasureofhow'directional'an antenna's radiation pattern is.
- An antenna that radiates equally in all directions would have effectively zero directionality,andthe**directivity**ofthistypeofantennawould be1(or0dB).



EffectiveAperture:

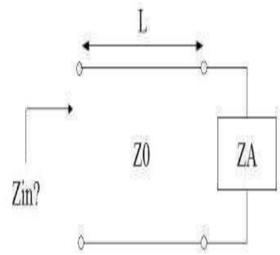
- In electromagneticsand antennatheory,antennaaperture, effectivearea,orreceiving cross section, is a measure of how effective an antenna is at receiving the power of electromagnetic radiation.
- Theeffectiveareasimplyrepresentshowmuchpoweriscapturedfromtheplane wave and delivered by the antenna.

Polarization:

- **Polarization**istheattributethatwaveoscillationshaveadefinitedirectionrelativeto the direction of propagation of the wave.
- EMwavesaretransverse wavesthatmaybe**polarized**.
- Thedirectionof**polarization**isdefinedtobethedirectionparalleltotheelectricfield of the EM wave.

InputImpedance:

- **Impedance**relatesthevoltageandcurrentatthe**input**tothe **antenna**.The real part of the **antenna impedance** represents power that is either radiated away or absorbed within the **antenna**. The imaginary part of the **impedance** represents power that isstored in the near field of the **antenna**.



EfficiencyOfAntenna:

- The**efficiency**ofan**antenna**isaratioofthepowerdeliveredto the**antenna**relative to the power radiated from the **antenna**.
- Ahigh**efficiencyantenna**hasmostofthepowerpresentatthe**antenna's**input radiated away.
- Beingaratio,**antennaefficiency**isanumberbetween0and1.

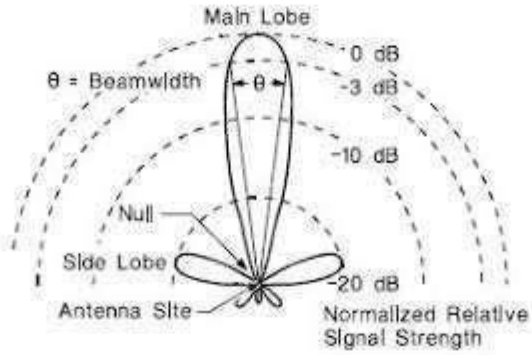
RadiationResistace :

- The radiation resistance can be defined as the value of resistance that would dissipate thesameamount ofpoweras radiated as radio waves by theantennawith theantenna input current passing through it.
- Radiationresistanceisthatpartofan antenna'sfeedpointelectricalresistancethatis caused by the radiation of electromagnetic waves from the antenna.

BandWidth:

- The**bandwidth**ofan**antenna**referstotherange offrequenciesoverwhichthe **antenna**canoperatecorrectly.
- The**antenna'sbandwidth** isthenumberofHzforwhichthe**antenna**willexhibitan SWR less than 2:1.
- The**bandwidth**canalsobedescribedintermsof percentageofthecenterfrequency of the **band**.

BeamWidth:



- **Beam widthis**thearea wheremostofthepower **is**radiated,which**is**thepeakpower.
- Halfpower**beamwidthis**theangleinwhichrelativepower**is**morethan50%ofthe peak power, in the effective radiated field of the **antenna**.
- Beamwidthisusuallybutnotalwaysexpressedindegreesandforthehorizontal plane.

RadiationPattern:

- Inthefieldof**antenna**designtheterm**radiationpattern**(or**antennapattern**orfar- field **pattern**) refers to the directional (angular) dependence of the strength of the radio waves from the **antenna** or other source.

TypesOfRadiationPattern:

- Pencil-beam**pattern** −Thebeamhasasharpdirectional pencilshaped**pattern**.
- Fan-beam**pattern**−The beamhasafan-shaped**pattern**.
- Shapedbeam**pattern**−Thebeam,whichisnon-uniformandpatternlessisknownas shaped beam.

Antenna

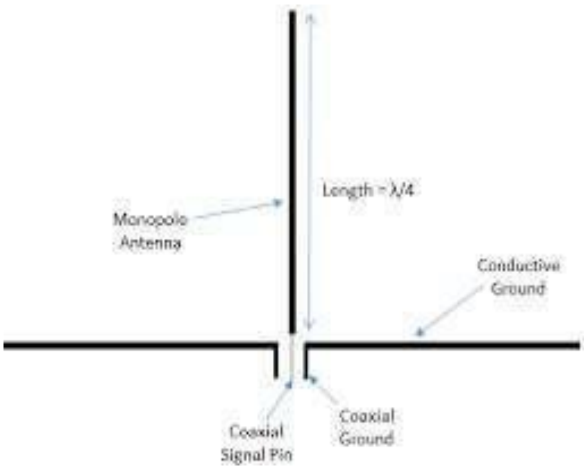
- Inradioengineering,anantennaistheinterfacebetweenradiowavespropagating through space and electric currents moving in metal conductors, used with a transmitter or receiver.

- **TypesOfAntenna:**Theseareoffollowingtypes,

  1. Mono pole
  2. Dipole antenna
  3. Omnidirectionalantenna

1.MonopoleAntenna:

- A**monopoleantenna**isaclassofradioantennaconsistingofastraightrod-shaped conductor, often mounted perpendicularly over some type of conductive surface, called a ground plane.



- Thedrivingsignal fromthetransmitteris applied, orforreceivingantennas theoutput signal to thereceiver is taken, between thelower end of the monopole and theground plane.
- Onesideoftheantennafeedlineis attached tothelowerend ofthemonopole,andthe other side is attached to the ground plane, which isoften theEarth.
- Thiscontrastswithadipoleantennawhichconsistsoftwoidenticalrodconductors, with the signal from the transmitter applied between the two halvesof theantenna.
- The monopole is often used as a resonant antenna; the rod functions as an open resonatorforradiowaves,oscillatingwithstandingwaves of voltageandcurrent along its length.

- Thereforethelengthoftheantennaisdetermined bythewavelengthoftheradio waves it is usedwith.
- Themostcommonformisthequarter-wavemonopole,inwhichtheantennais approximately one quarter of the wavelength of the radio waves.
- However in broadcasting monopole antennas 5/8 = 0.625 wavelength long are also popular,becauseatthislengthamonopoleradiatesamaximumamountofitspower in horizontal directions.
- ThemonopoleantennawasinventedIn1895byradiopioneerGuglielmoMarconi;for this reason it is sometimes called the Marconiantenna.
- Common types of monopole antenna are the whip, rubber ducky, helical, random wire,umbrella,inverted-LandT-antenna,inverted-F,mastradiator,andgroundplane antennas.
- Amonopolehasanomnidirectionalradiationpattern:itradiateswithequalpowerin all azimuthal directions perpendicular to the antenna.
- However,theradiatedpowervaries withelevation angle,withthe radiationdropping off to zero at the zenith of the antenna axis.
- Itradiatesverticallypolarizedradiowaves.

2.DipoleAntenna :

HalfWaveDipole:

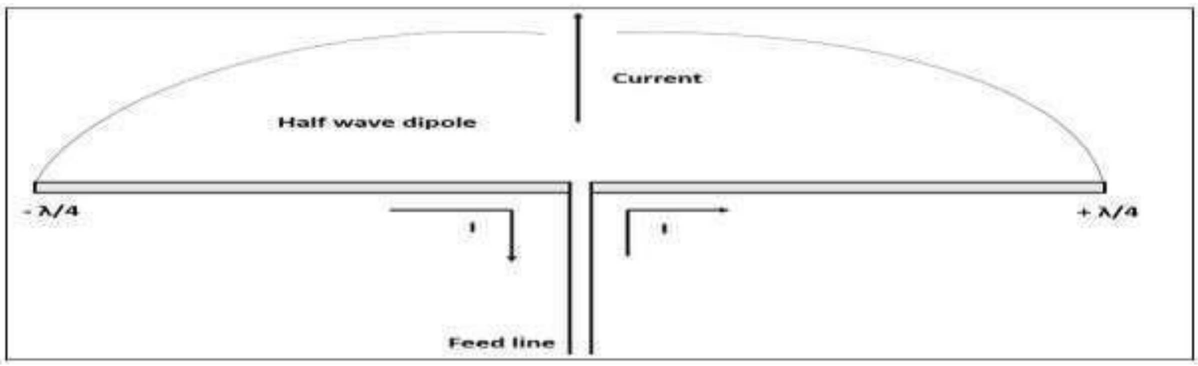
- A folded dipole is an antenna, with two conductors connected on both sides, and folded to form a cylindrical closed shape, to which feed is given at the center. The lengthofthedipoleishalfofthewavelength.Hence,itiscalledas**halfwavefolded dipole antenna**.

Frequencyrange

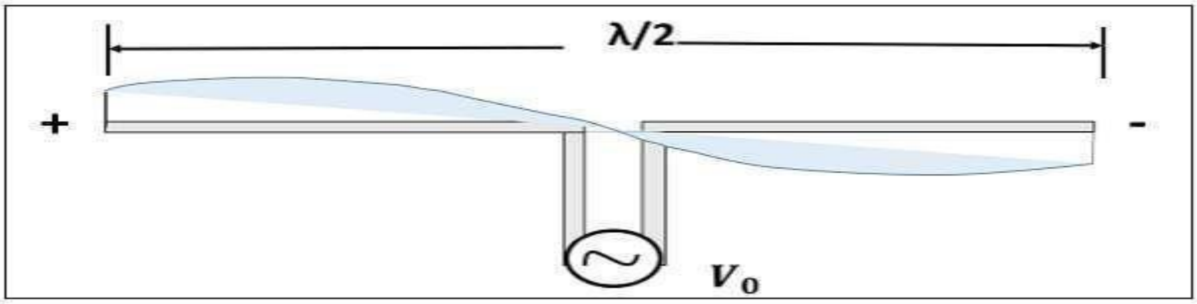
- Therangeoffrequencyinwhichhalfwavefolded dipoleoperatesisaround3KHzto 300GHz. This is mostly used in television receivers.

Construction&WorkingofHalf-waveFoldedDipole

- This antenna is commonly used with the array type antennas to increase the feed resistance.ThemostcommonlyusedoneiswithYagi-Udaantenna.Thefollowing figure shows a half-wave folded dipole antenna.



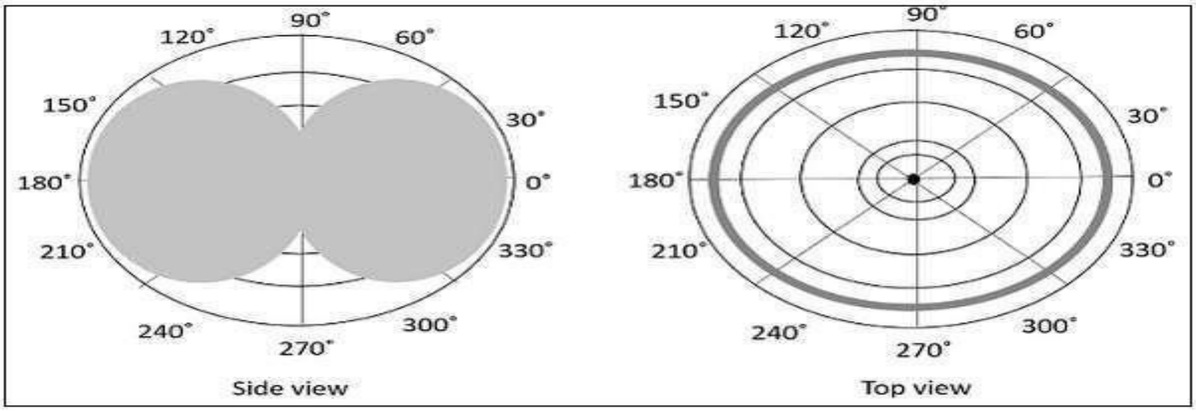
- Thisantennausesanextraconductingelement(awireorarod)whencomparedwith previous dipole antenna. This is continued by placing few conducting elements in parallel, with insulation in-between, in array type of antennas.
- Thefollowingfigureexplainstheworkingofahalf-wavefoldeddipoleantenna,when it is provided withexcitation.



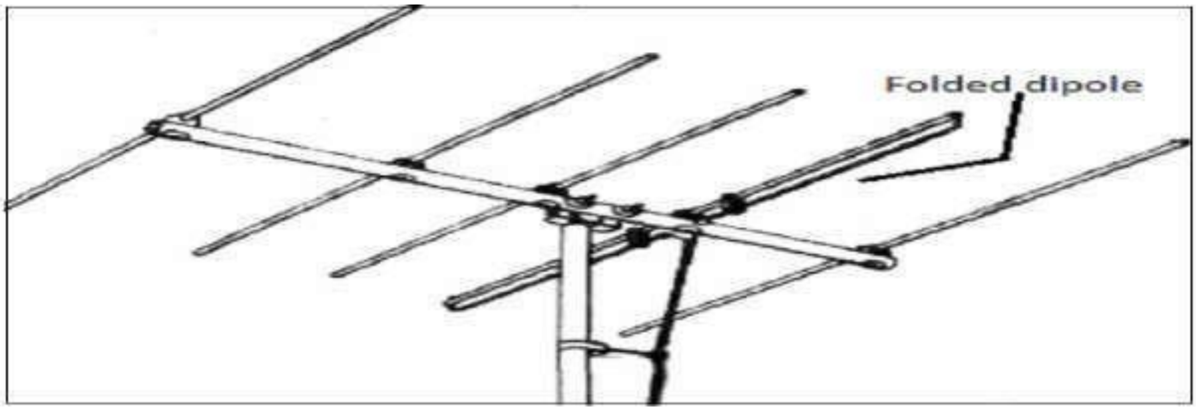
- Ifthe diameter ofthemain conductor and the folded dipolearesame, then therewill be four folded (two times of squared one) increase in the feed impedance of the antenna.
- This increase in feed impedance is the main reason for the popular usage of this foldeddipoleantenna.Dueofthetwin-lead,theimpedancewillbearound300Ω.

RadiationPattern

- Theradiationpatternofhalf-wavefoldeddipolesisthesameasthatofthehalf-wave dipole antennas.
- Thefollowingfigureshowstheradiationpatternofhalf-wavefoldeddipoleantenna, which is **Omni-directional** pattern.



- Half-wavefoldeddipoleantennasareusedwhereoptimumpowertransferis needed and where large impedances are needed.
- Thisfoldeddipoleisthemainelementin**Yagi-Udaantenna**.Thefollowingfigure shows a **Yagi-Uda antenna**, which we will study later.
- Themainelementusedhereisthisfoldeddipole, towhichtheantennafeedisgiven.
- Thisantennahasbeenusedextensivelyfortelevisionreceptionoverthelastfew decades.



Advantages

Thefollowing aretheadvantages ofhalf-wavefoldeddipoleantenna−

- Receptionofbalancedsignals.
- Receivesaparticularsignalfrom abandoffrequencieswithoutlosing thequality.
- Afoldeddipolemaximizes thesignalstrength.

Disadvantages

Thefollowingarethedisadvantages ofhalf-wave folded dipoleantenna −

- Displacementandadjustmentofantennaisahassle.
- Outdoormanagement canbedifficultwhen antennasizeincreases.

Applications

Thefollowingarethe applications of half-wavefoldeddipoleantenna−

- MainlyusedasafeederelementinYagiantenna,Parabolicantenna,turnstileantenna, log periodic antenna, phased and reflector arrays, etc.
- Generallyusedinradioreceivers.
- Mostcommonly usedinTVreceiverantennas

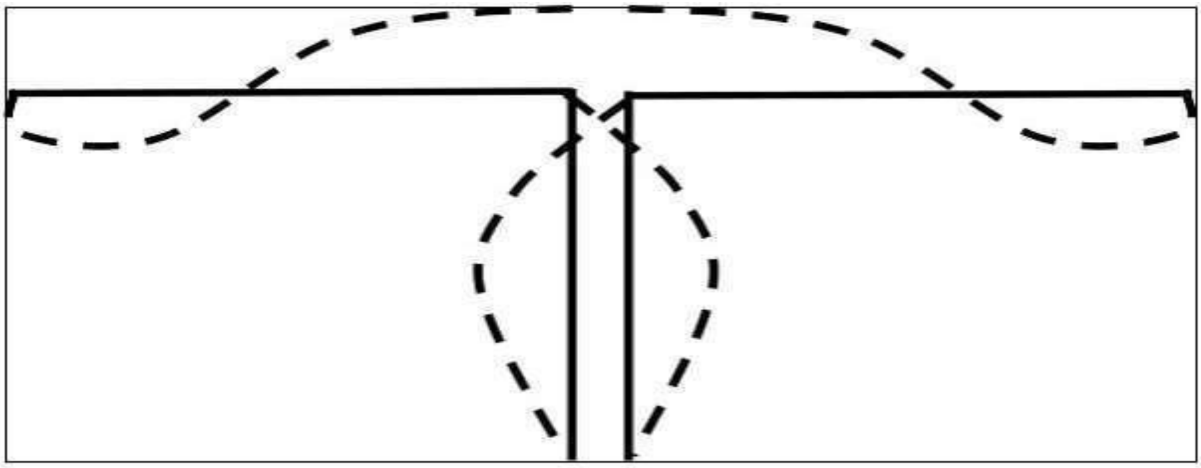
FullWaveDipole:

- Ifthelengthofthedipole,i.e.thetotalwire,equalsthefullwavelengthλ,thenitis called as **full wave dipole**.

Construction&WorkingofFull-waveDipole

- Thefull-wavedipolewithitsvoltageandcurrentdistribution isshownhere.Boththe positive and negative peaks of the wave induce positive and negative voltages respectively.

- However,astheinducedvoltagescancelouteachother,thereisnoquestionof radiation.
- Thebelowfigureshowsthevoltagedistributionoffull-wavedipolewhoselengthis λ. It isseen that two half-wave dipoles are joined to make a full-wave dipole.



Thevoltage pattern when induces its positive charges and negative charges at the same time, cancelouteachotherasshowninthefigure.Theinducedchargesmakenofurtherattemptof radiation since they are cancelled. The output radiation will be zero for a fullwave transmission dipole.

RadiationPattern

Asthereisnoradiationpattern,nodirectivityandnogain,theFullwavedipoleisseldom used as an antenna. Which means, though the antenna radiates, it is just some heat dissipation, which is a wastage of power.

Disadvantages

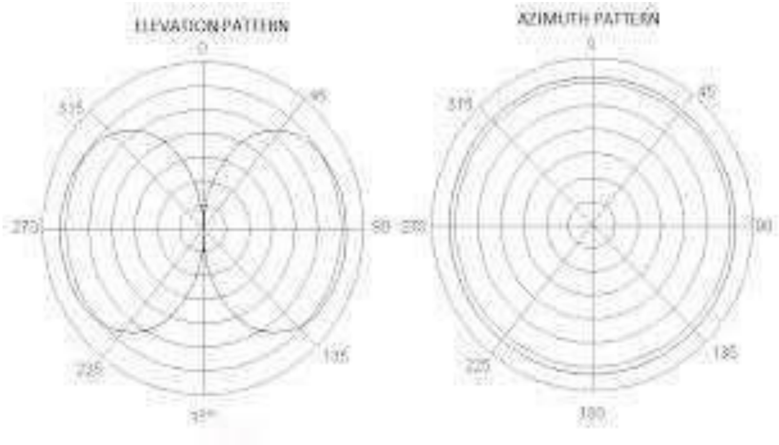
Thefollowing arethedisadvantages offull-wavedipoleantenna.

- Heatdissipation
- Wastageof power
- Noradiationpattern
- Nodirectivityandnogain

Duetothesedrawbacks,thefull-wavedipoleisseldom used.

3.Omni-DirectionalAntenna:

- An**omnidirectional antenna** isaclassofantennawhichradiates equal radio power in all directions perpendicular to an axis (azimuthal directions), with power varying with angle to the axis (elevation angle), declining to zero on theaxis.



- Whengraphedinthreedimensionsthisradiationpatternisoftendescribed as doughnut-shaped.
- Notethatthisisdifferentfromanisotropicantenna,whichradiatesequalpowerinall directions, having a spherical radiation pattern.
- Omnidirectional antennas oriented vertically are widely used for nondirectional antennasonthesurfaceoftheEarthbecausetheyradiateequallyinallhorizontal directions, while the power radiated drops off with elevation angle so little radio energy is aimed into the sky or down toward the earth and wasted.
- Omnidirectional antennas are widely used for radio broadcasting antennas, and in mobiledevicesthatuseradiosuchascellphones,FMradios,walkie-talkies,wireless computer networks, cordless phones, GPS, as well as for base stations that communicate with mobile radios, such as police and taxi dispatchers and aircraft communications.
- Commontypesoflow-gainomnidirectionalantennasarethewhipantenna,"Rubber Ducky" antenna, ground plane antenna, vertically oriented dipole antenna, discone antenna, mast radiator, horizontal loop antenna (sometimes known colloquially as a 'circular aerial' because of the shape) and the haloantenna.
- Higher-gain omnidirectional antennas can also be built. "Higher gain" in this case meansthattheantennaradiateslessenergyathigherandlowerelevationanglesand more in the horizontal directions.
- High-gainomnidirectionalantennasaregenerallyrealizedusingcollineardipole arrays.
- Omnidirectional radiation patterns are produced by the simplest practical antennas, monopoleanddipoleantennas,consistingofoneortwostraightrodconductorsona common axis. Antenna gain (G) is defined as antenna efficiency (e) multiplied by antennadirectivity(D)whichisexpressedmathematicallyas: $G = eD$.
- Ausefulrelationshipbetweenomnidirectionalradiationpatterndirectivity(D)in decibels and half-power beamwidth (HPBW) based on the assumption ofa $\sin(b\theta)/b\theta$ patternshapeis:

$$D \approx 10 \log_{10} \left(\frac{101.5}{\mathrm{HPBW} - 0.00272\,\mathrm{HPBW}^2} \right) \ \mathrm{dB}.$$

OperationsoffollowingAntennaswithadvantageandapplications.

(A)DirectionalHighFrequencyAntenna:

Yagi-UdaAntenna

Yagi-UdaantennaisthemostcommonlyusedtypeofantennaforTV receptionoverthelast few decades. It is the most popular and easy-to-use type of antenna with better performance, which is famous for its high gain and directivity

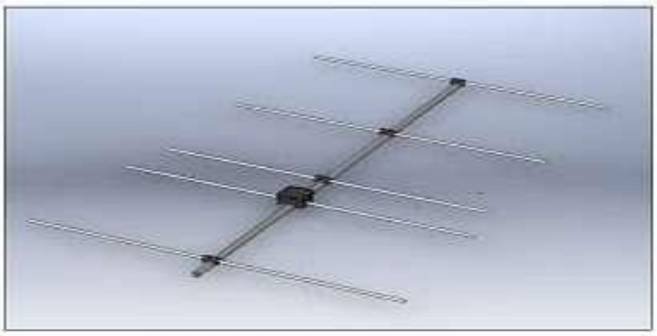
Frequencyrange

ThefrequencyrangeinwhichtheYagi-Udaantennasoperateisaround**30MHzto 3GHz** whichbelong tothe **VHF**and **UHF**bands.

ConstructionofYagi-UdaAntenna

AYagi-Udaantennawasseenontopofalmosteveryhouseduringthepastdecades.The parasitic elements and the dipole together form this Yagi-Uda antenna.

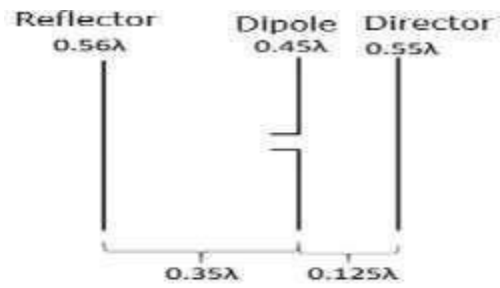
The figure shows a **Yagi-Uda antenna**. It is seen that there are many directors placed to increasethedirectivityoftheantenna.Thefeederisthefoldeddipole.Thereflectoristhe lengthy element, which is at the end of the structure.



The figure depicts a clear form of the Yagi-Uda antenna. The center rod like structure on whichtheelementsaremountediscalledas**boom**.Theelementtowhichathickblackhead is connected is the **driven element** to which the transmission line is connected internally, through that black stud. The single element present at the back of the driven element is the **reflector**, which reflects all the energy towards the direction of the radiation pattern. The other elements, before the driven element, are the **directors**, which direct the beam towards the desired angle.

Designing

Forthisantennatobedesigned,thefollowingdesignspecifications shouldbefollowed.



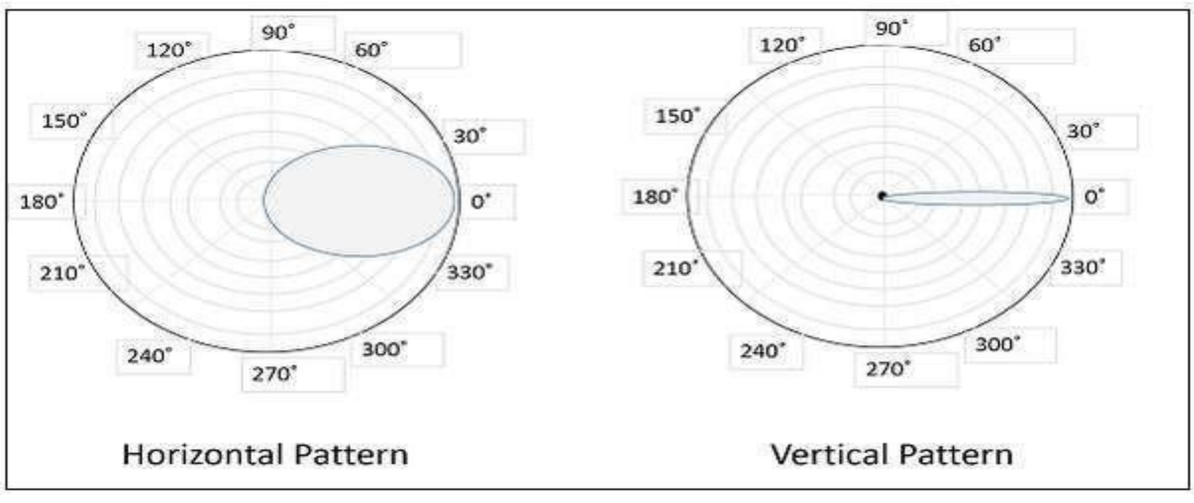
They are −

ELEMENT	SPECIFICATION
Length of the Driven Element	0.458λ to 0.5λ
Length of the Reflector	0.55λ to 0.58λ
Length of the Director 1	0.45λ
Length of the Director 2	0.40λ
Length of the Director 3	0.35λ
Spacing between Directors	0.2λ
Reflector to dipole spacing	0.35λ
Dipole to Director spacing	0.125λ

Ifthespecifications given abovearefollowed,onecan designanYagi-Udaantenna.

RadiationPattern

ThedirectionalpatternoftheYagi-Udaantennais **highlydirective**asshowninthefigure given below.



Theminorlobesaresuppressedandthedirectivityofthemajorlobeisincreasedbythe addition of directors to the antenna.

Advantages

Thefollowing aretheadvantages ofYagi-Udaantennas −

- Highgainisachieved.
- Highdirectivity isachieved.
- Easeofhandlingandmaintenance.
- Lessamount ofpoweriswasted.
- Broadercoverageoffrequencies.

Disadvantages

Thefollowingarethedisadvantagesof Yagi-Udaantennas−

- Pronetonoise.
- Pronetoatmosphericeffects.

Applications

Thefollowingaretheapplications ofYagi-Udaantennas −

- MostlyusedforTVreception.
- Usedwhereasingle-frequencyapplication isneeded.

RhombicAntenna

The**RhombicAntenna**isanequilateralparallelogramshapedantenna.Generally,ithastwo opposite acute angles. The tilt angle, θ is approximately equal to 90° minus the angle of major lobe. Rhombic antenna works under the principle of travelling wave radiator. It is arranged in the form of a rhombus or diamond shape and suspended horizontally above the surface of the earth.

FrequencyRange

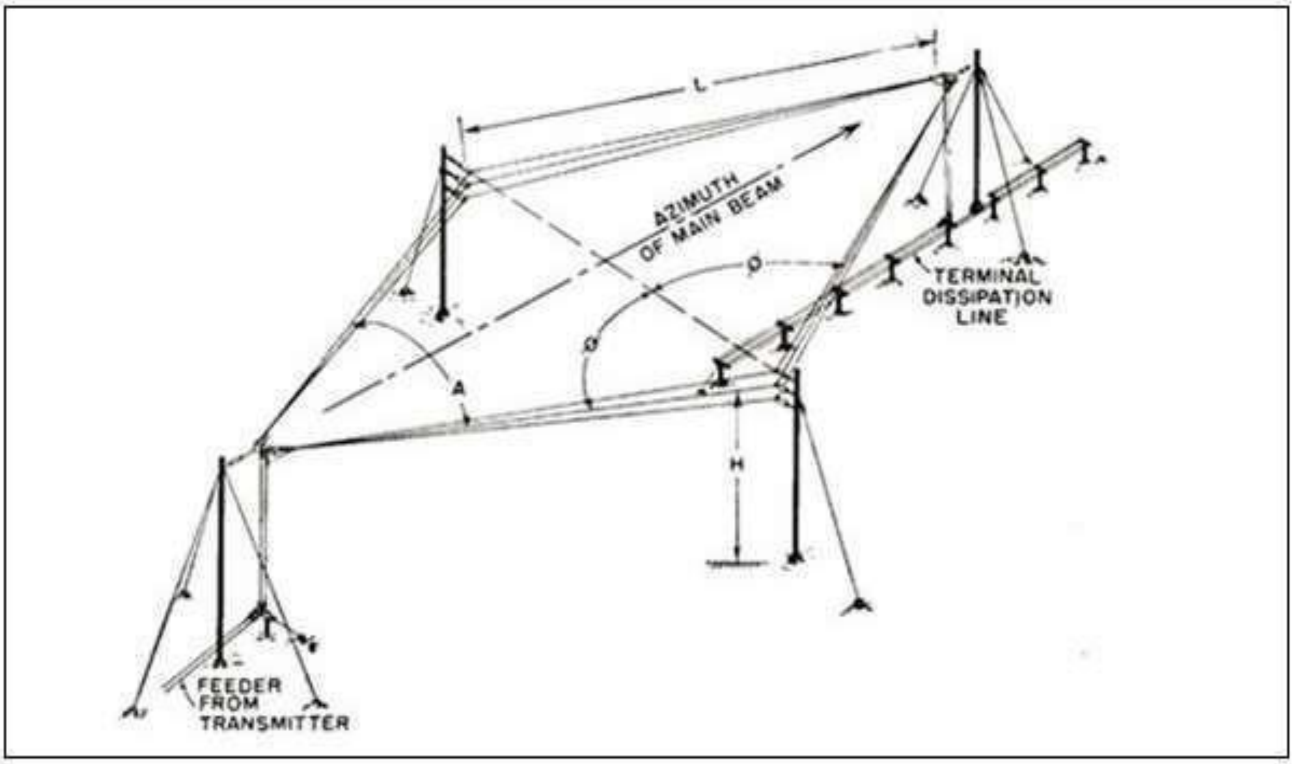
Thefrequency rangeofoperationofaRhombicantennaisaround **3MHzto300MHz**.This antenna works in **HF** and **VHF** ranges.

ConstructionofRhombicAntenna

RhombicantennacanberegardedastwoV-shapedantennasconnectedend-to-endtoform obtuse angles. Due to its simplicity and ease of construction, it has many uses −

- InHFtransmissionandreception
- Commercialpoint-to-pointcommunication

Theconstruction oftherhombicantennais in the form arhombus, as shownin thefigure.



Thetwosidesofrhombusareconsidered astheconductorsofatwo-wiretransmissionline. When this system is properly designed, there is a concentration of radiation along the main axis of radiation. In practice, half of the power is dissipated in the terminating resistance of the antenna. The rest of the power is radiated. The wasted power contributes to the minor lobes.

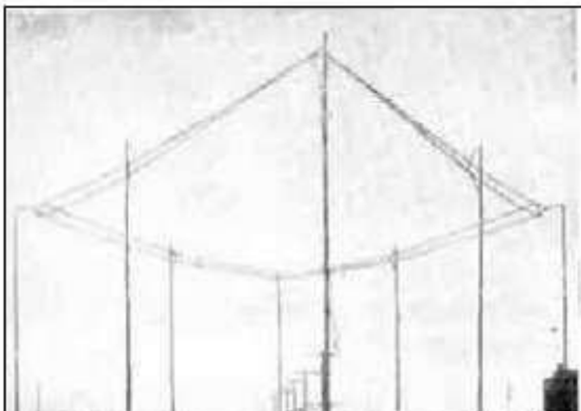


Figure 1

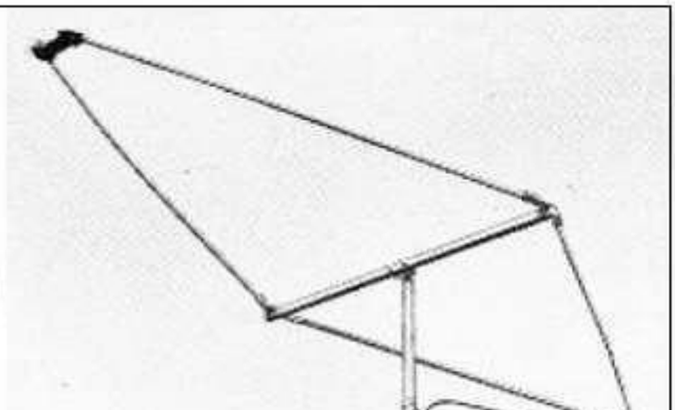


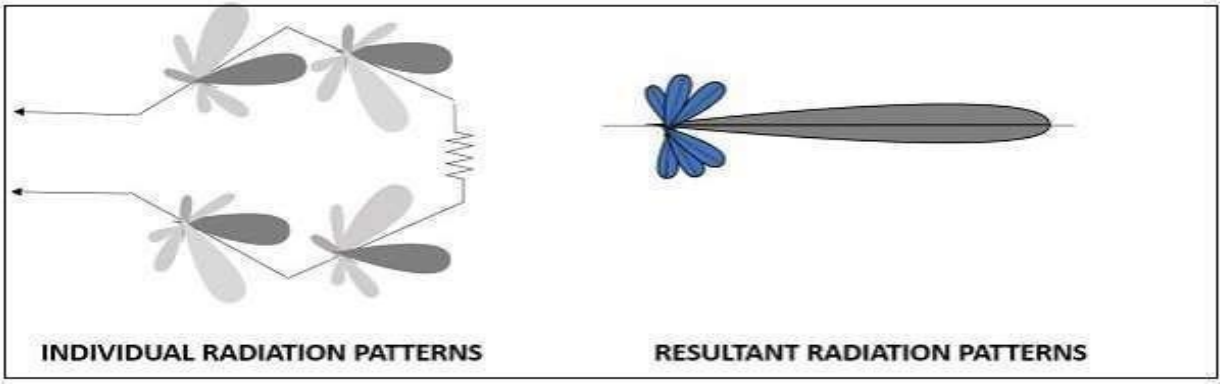
Figure 2

Figure1showstheconstructionof**rhombicantenna**forpoint-to-pointcommunicationin oldendays.Figure2showsthe**rhombicUHFantenna**forTVreception,usedthesedays.

Themaximumgainfromarhombicantennaisalongthedirectionofthemainaxis,which passes through the feed point to terminate in free space. The polarization obtained from a horizontal rhombic antenna is in the plane of rhombus, which is horizontal.

RadiationPattern

The radiation pattern of the rhombic antenna is shown in the following figure. The resultant patternisthecumulativeeffectoftheradiationat allfourlegsofthe antenna.Thispattern is **uni-directional**, while itcan bemadebi-directional by removing the terminating resistance.



Themaindisadvantageofrhombicantennaisthattheportionsoftheradiation,whichdonot combine with the main lobe, result in considerable side lobes having both horizontal and vertical polarization.

Advantages

Thefollowing aretheadvantagesof Rhombicantenna −

- Inputimpedanceandradiationpatternarerelativelyconstant
- Multiplerhombicantennascanbeconnected
- Simpleandeffective transmission

Disadvantages

Thefollowing arethe disadvantagesof Rhombicantenna−

- Wastageofpower interminatingresistor
- Requirementoflargespace
- Reduedtransmissionefficiency

Applications

Thefollowing aretheapplicationsof Rhombicantenna−

- UsedinHF communications
- UsedinLongdistanceskywave propagations
- Usedinpoint-to-pointcommunications

(B)UHFAndMicrowaveAntenna:

DishAntenna(ParabolicReflector)

ParabolicReflectors areMicrowaveantennas.Forbetterunderstandingoftheseantennas, the concept of parabolic reflector has to be discussed.

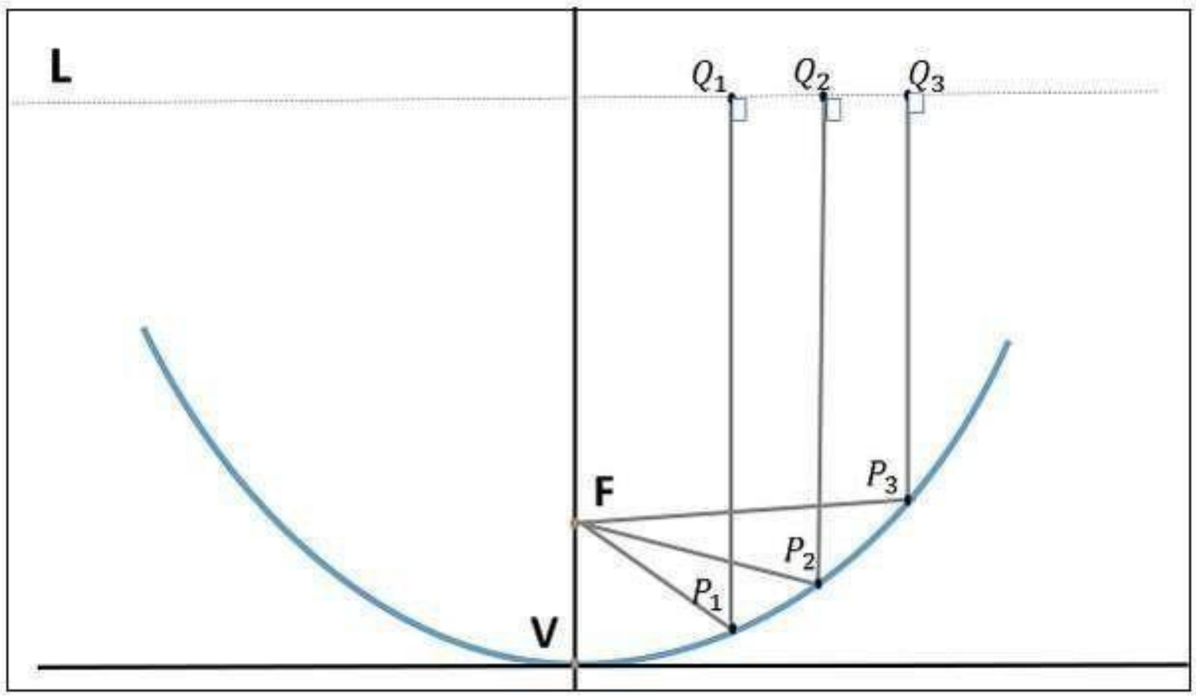
FrequencyRange

Thefrequency rangeusedfortheapplicationofParabolicreflectorantennasis **above1MHz**. These antennas are widely used for radio and wireless applications.

PrincipleofOperation

Thestandarddefinitionofaparabolais-Locusofapoint,whichmovesinsuchawaythatits distance from the fixed point (called **focus**) plus its distance from a straight line (called **directrix**) is constant.

Thefollowingfigureshowsthegeometryofparabolicreflector.Thepoint **F**isthefocus(feed is given) and **V** is the vertex. The line joining F and V is the axis of symmetry. PQ are the reflected rays where **L** represents the line directrix on which the reflected points lie (to say that they are being collinear). Hence, as per the above definition, the distance between F and L lie constant with respect to the waves beingfocussed.



The reflected wave forms a colllimated wave front, out of the parabolic shape. The ratio of focallengthtoaperturesize(ie., f/D)knownas **"foverDratio"**isanimportantparameterof parabolic reflector. Its value varies from **0.25 to 0.50**.

Thelawofreflectionstatesthattheangleofincidenceandtheangleofreflectionareequal. This law when used along with a parabola, helps the beam focus. The shape of the

parabolawhenusedforthepurposeofreflectionofwaves,exhibitssomepropertiesofthe parabola, which are helpful for building an antenna, using the waves reflected.

PropertiesofParabola

- Allthewavesoriginatingfromfocus,reflectsbacktotheparabolicaxis.Hence,all the waves reaching the aperture are in phase.
- Asthewavesareinphase,thebeamofradiationalongtheparabolicaxiswillbe strong and concentrated.

Advantages

Thefollowingaretheadvantagesof Parabolicreflectorantenna−

- Reductionofminorlobes
- Wastageofpowerisreduced
- Equivalentfocallengthisachieved
- Feedcanbeplacedinanylocation,accordingtoourconvenience
- Adjustmentofbeam (narrowing orwidening)isdonebyadjusting thereflecting surfaces

Disadvantage

Thefollowingisthedisadvantageof aParabolicreflectorantenna−

- Someofthepowerthatgetsreflectedfromtheparabolicreflectorisobstructed.This becomes a problem with small dimension paraboloid.

Applications

Thefollowingaretheapplications ofParabolicreflectorantenna−

- Thecassegrainfeedparabolicreflectorismainlyusedinsatellitecommunications.
- Alsousedinwirelesstelecommunicationsystems.

HornAntenna

To improve the radiation efficiency and directivity of the beam, the wave guide should be provided with an extended aperture to make the abrupt discontinuity of the wave into a gradualtransformation.Sothatalltheenergyintheforwarddirectiongetsradiated.Thiscan be termed as **Flaring**. Now, this can be done using a horn antenna.

FrequencyRange

Theoperationalfrequencyrangeofahornantennaisaround **300MHzto30GHz**.This antenna works in **UHF** and **SHF** frequency ranges.

Construction&WorkingofHornAntenna

Theenergyofthebeam whenslowlytransforminto radiation,thelossesarereduced andthe focussing of the beam improves. A **Horn antenna** may be considered as a **flared out wave guide**, by which the directivity is improved and the diffraction is reduced.

Thereareseveralhornconfigurationsoutofwhich, threeconfigurationsaremostcommonly used.

Sectoralhorn

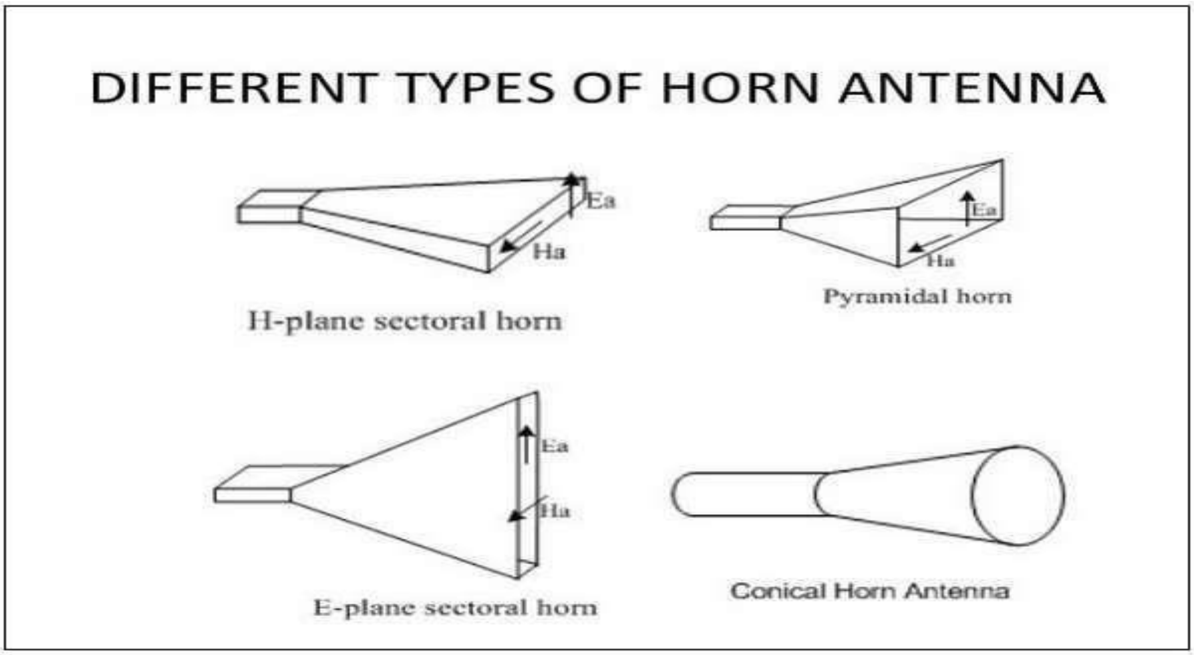
Thistypeofhornantenna,flaresoutinonlyonedirection.FlaringinthedirectionofElectric vector produces the **sectorial E-plane horn**. Similarly, flaring in the direction of Magnetic vector, produces the **sectorial H-plane horn**.

Pyramidalhorn

Thistypeofhornantennahas flaringonboth sides. Ifflaringisdone onboththeE&H walls ofa rectangular waveguide, then **pyramidal horn antenna** is produced. This antennahas the shape of a truncated pyramid.

Conicalhorn

Whenthewallsofacircularwaveguideareflared,itisknownasa **conicalhorn**.Thisisa logical termination of a circular wave guide.



Theabovefigures show thetypesofhornconfigurations,which werediscussed earlier.

Flaring helps to match the antenna impedance with the free space impedance for better radiation. It avoids standing wave ratio and provides greater directivity and narrower beam width.Theflaredwaveguidecanbetechnically termedas**ElectromagneticHornRadiator**.

Flareangle,**Φ**ofthehornantennaisanimportant factortobeconsidered. Ifthisistoosmall, then the resulting wave will be spherical instead of plane and the radiated beam will not be directive. Hence, the flare angle should have an optimum value and is closely related to its length.

Combinations

Hornantennas,mayalsobecombinedwithparabolicreflectorantennastoformspecialtype of horn antennas. These are −

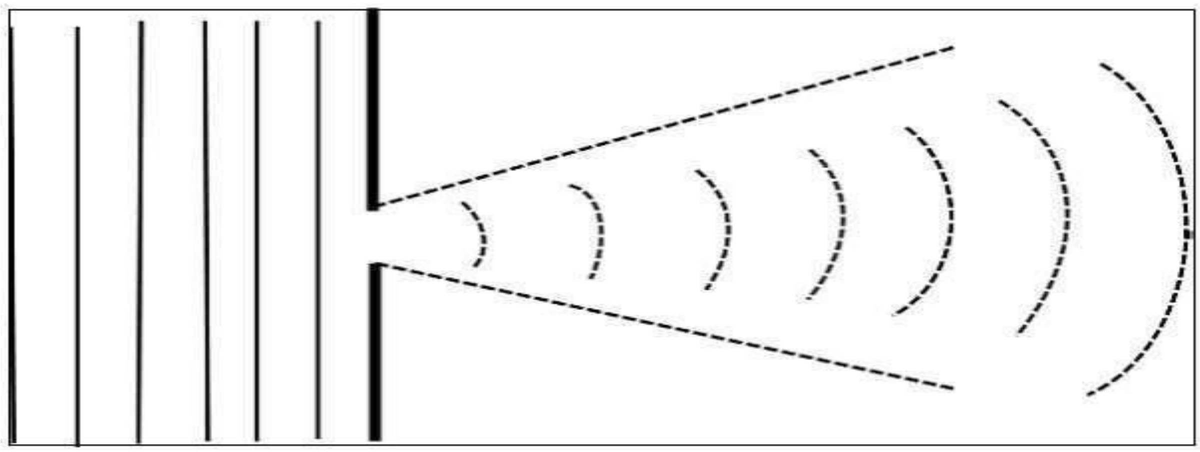
- Cass-hornantenna
- Hog-hornortriplyfoldedhornreflector

In **Cass-horn antenna**, radio waves are collected by the large bottom surface, which is parabolicallycurvedandreflectedupwardat45°angle.Afterhittingtopsurface,theyare reflected to the focal point. The gain and beam width of these are just like parabolic reflectors.

In **hog-horn** antenna, a parabolic cylinder is joined to pyramidal horn, where the beam reachesapexofthehorn.Itformsalow-noisemicrowaveantenna.Themainadvantageof hog-horn antenna is that its receiving point does not move, though the antenna is rotated about its axis.

RadiationPattern

Theradiationpatternofahornantennaisa SphericalWavefront.Thefollowingfigureshows the **radiation pattern** of horn antenna. The wave radiates from the aperture, minimizing the diffraction of waves. The flaring keeps the beam focussed. The radiated beam has high directivity.



Advantages

Thefollowing aretheadvantages ofHornantenna −

- Smallminorlobesareformed
- Impedancematchingisgood
- Greaterdirectivity
- Narrowerbeamwidth
- Standingwavesareavoided

Disadvantages

Thefollowing arethedisadvantages of Hornantenna−

- Designingofflareangle, decidesthedirectivity
- Flareangleandlength oftheflareshould notbeverysmall

Applications

Thefollowing aretheapplicationsofHorn antenna−

- Usedforastronomicalstudies
- Usedinmicrowaveapplications

BasicConceptsofSmartAntennas:

- **Smart antennas** (also known as adaptive array **antennas**, digital **antenna** arrays, multiple **antennas** and, recently, MIMO) are **antenna** arrays with **smart** signal processingalgorithmsusedtoidentifyspatialsignalsignaturessuchasthedirectionof arrival (DOA) of the signal, and use them to calculate beam forming vectors.
- An antenna, when individually can radiate an amount of energy, in a particular direction,resultinginbettertransmission,howitwouldbeiffewmoreelementsare added it, to produce more efficient output. It is exactly this idea, which led to the invention of **Antenna arrays**.
- Anantennaarraycanbe betterunderstoodbyobservingthefollowingimages. Observe how the antenna arrays are connected.
- An**antennaarray**isaradiatingsystem,whichconsistsofindividualradiatorsand elements.
- Eachofthis radiator, whilefunctioning hasitsown inductionfield. Theelementsare placed so closely that each one lies in the neighbouring one’s induction field.
- Therefore,the radiation patternproduced bythem, wouldbethe vector sum ofthe individual ones.
- Thespacingbetweentheelementsandthelengthoftheelementsaccording tothe wavelength are also to be kept in mind while designing theseantennas.
- Theantennasradiateindividuallyandwhileinarray,theradiationofalltheelements sum up, to form the radiation beam, which has high gain, high directivity and better performance, with minimum losses.

Advantages

Thefollowingaretheadvantagesof usingantennaarrays−

- Thesignal strength increases
- Highdirectivity isobtained
- Minorlobesarereducedmuch
- HighSignal-to-noiseratioisachieved
- Highgain isobtained
- Powerwastageisreduced
- Betterperformanceisobtained

Disadvantages

Thefollowingarethedisadvantagesof arrayantennas −

- Resistivelosses areincreased
- Mountingandmaintenanceisdifficult
- Hugeexternalspaceisrequired

Applications

Thefollowingaretheapplications ofarray antennas−

- Usedinsatellitecommunications
- Usedinwirelesscommunications
- Usedinmilitaryradar communications
- Usedintheastronomical study

TypesofArrays

Thebasictypesof arraysare−

- Collineararray
- Broadsidearray
- Endfirearray
- Parasiticarray
- Yagi-Udaarray
- Log-peroidicarray
- Turnstilearray
- Super-turnstilearray

ShortQuestionsWithAnswers

1. Define an antenna.

Antenna is a transition device or a transducer between a guided wave and a free space waveor vice versa. Antenna is also said to be an impedance transforming device.

2. What is meant by radiation pattern?

Radiation pattern is the relative distribution of radiated power as a function of distance in space .It is a graph which shows the variation in actual field strength of the EM wave at all points which are at equal distance from the antenna. The energy radiated in a particular direction by an antenna is measured in terms of FIELD STRENGTH.(E Volts/m)

3. Define Radiation intensity?

The power radiated from an antenna per unit solid angle is called the radiation intensity U (watts per steradian or per square degree). The radiation intensity is independent of distance.

4. Define Beam efficiency?

The total beam area (WA) consists of the main beam area (WM) plus the minor lobe area (Wm) . Thus WA = WM+ Wm . The ratio of the main beam area to the total beam area is called beam efficiency. Beam efficiency = SM = WM / WA.

5.Define Directivity?

The directivity of an antenna is equal to the ratio of the maximum power density P(q,f)max to its average value over a sphere as observed in the far field of an antenna. D = P(q,f)max / P(q,f)av. Directivity from Pattern. D = 4p / WA. . Directivity from beam area(WA).

6.What are the different types of aperture.?

i) Effective aperture. ii). Scattering aperture. iii) Loss aperture. iv) collecting aperture.
v). Physical aperture.

7.Define different types of aperture.?

Effective aperture(Ae). It is the area over which the power is extrated from the incident wave and delivered to the load is called effective aperture. Scattering aperture(As.) It is the ratio of the reradiated power to the power density of the incident wave. Loss aperture. (Ae). It is the area of the antenna which dissipates power as heat. Collecting aperture. (Ae). It is the addition of above three apertures. Physical aperture. (Ap). This aperture is a measure of the physical size of the antenna.

8. Define Aperture efficiency?

The ratio of the effective aperture to the physical aperture is the aperture efficiency. i.e Aperture efficiency = hap = Ae / Ap (dimensionless).

9. What is meant by effective height?

The effective height h of an antenna is the parameter related to the aperture.It may be defined as the ratio of the induced voltage to the incident field.i.e H= V / E.

10. What are the field zone?

The fields around an antenna may be divided into two principal regions. i. Near field zone (Fresnel zone) ii. Far field zone (Fraunhofer zone)

LongQuestions

1. Writeshortnoteoneffectsofenvironmentinwavepropagation.
2. WriteshortnoteonSkywavepropagation.
3. DefineandderiveequationforRadiationmechanismofAntenna.
4. DefinedipoleAntenna.ExplainfullwavedipoleAntennaindetail.
5. ExplainhowYagi-UdaAntennaperformitsoperation?

CHAPTER NO-02:

TRANSMISSION LINES

LEARINGOBJECTIVES:

FundamentalsOfTransmissionLines
Equivalentcircuitoftransmissionline&RFequivalentcircuit
Characteristicsimpedance,methodsofcalculations&simple numerical.
LossesInTransmissionLine
Standingwave–SWR,VSWR,Reflectioncoefficient,simple numerical.
Quarterwave&halfwavelengthLine
Impedancematching&Stubs–single&double
PrimaryAndSecondaryConstantsOfX-MissionLine

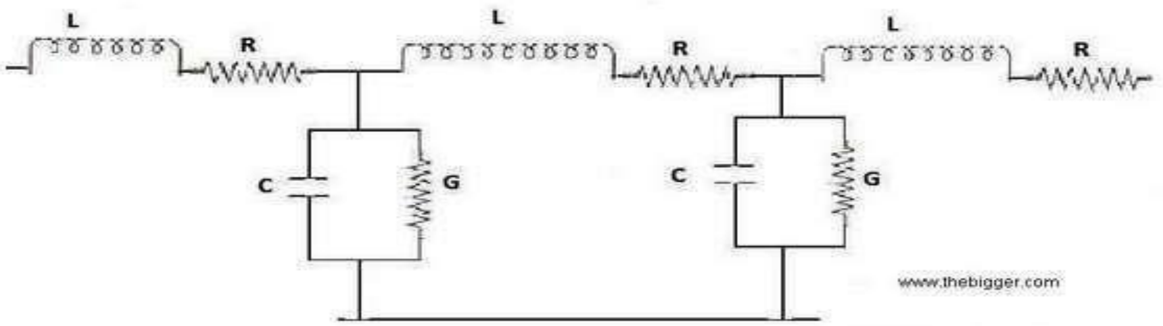
FundamentalsOfTransmissionLines:

- In radio-frequency engineering, a **transmission line** is a specialized cable or other structuredesignedtoconductalternatingcurrentofradiofrequency,thatis,currents with a frequency high enough that their wave nature mustbe taken into account.
- Transmission lines are used for purposes such as connecting radio transmitters and receivers with their antennas (they are then called feed lines or feeders), distributing cabletelevisionsignals,trunklinesroutingcallsbetweentelephoneswitchingcentres, computer network connections and high speed computer data buses.
- Thesearebasicallyofthetypessuchasparallelline(ladderline),coaxialcable, stripline, and microstrip.
- Ordinary electrical cables suffice to carry low frequency alternating current (AC), suchasmainspower,whichreversesdirection100to120timespersecond,andaudio signals.
- However,theycannotbeusedtocarrycurrentsintheradiofrequencyrange,above about 30 kHz, because the energy tends to radiate off the cable as radio waves, causing power losses.
- Radiofrequencycurrents alsotendtoreflectfromdiscontinuitiesinthecablesuchas connectors and joints, and travel back down the cable toward the source. These reflections act as bottlenecks, preventing the signal power from reaching the destination.
- Transmissionlinesusespecializedconstruction,andimpedancematching,tocarry electromagnetic signals with minimal reflections and power losses.
- The distinguishing feature of most transmission lines is that they have uniform cross sectionaldimensionsalongtheirlength,givingthemauniform *impedance*,calledthe characteristic impedance, to prevent reflections.
- Typesoftransmissionlineincludeparallelline(ladderline,twistedpair),coaxial cable, and planar transmission lines such as strip line and micro strip.
- Thehigherthefrequency of electromagneticwavesmovingthroughagivencableor medium, the shorter the wavelength of the waves.
- Transmissionlinesbecomenecessarywhenthetransmittedfrequency'swavelengthis sufficiently short that the length of the cable becomes a significant part of a wavelength.
- At microwave frequencies and above, power losses in transmission lines become excessive, andwaveguidesareusedinstead,whichfunction as"pipes"toconfineand guide the electromagnetic waves.
- Somesources definewaveguidesas atypeoftransmissionline;however,thisarticle will not include them.
- Atevenhigherfrequencies,intheterahertz,infraredandvisibleranges,waveguides in turn become lossy, and optical methods, (such as lenses and mirrors), are used to guide electromagnetic waves.

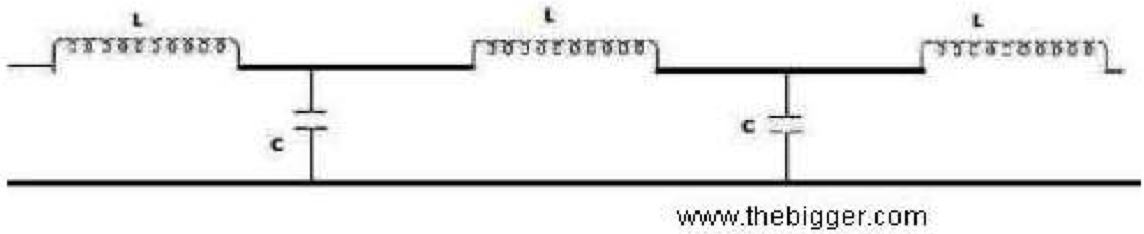
2.2Equivalentcircuitoftransmissionline&RFequivalentcircuit :

<u>EquivalentCircuit:</u>

- Weknowthattheconductorsarepresentinatwowireline.Dielectricsarealso present between them.
- Itisalsoclearthatconductorscanbeofanylength.Conductorsalsohavesome diameter.
- Ifboththelength anddiameterareassociatedwith theconductorthen resistanceand inductance must be presentthere.
- Ifwiresareseparatedfromeachotherbyplacingthedielectricbetweenthemthenthe leakage of charge will take place, because the dielectric that we are using is an insulating material which can’t be a perfect insulator.
- Thiscanbeexplainedwellbyintroducingtheconceptofshuntconductance.Itis denoted by G.



- Allthequantitiesi.e.Resistance,CapacitanceandShuntconductancearecalculated with respect to the length of the conductor.
- Theinductiveresistancehasagreatervaluethanthatofresistancewithrespecttothe radio frequencies.
- Ontheotherhandthevalueofthecapacitivesusceptenceisalsomuchmorethanthat of the shunt capacitance.
- Theseallthequantitiesareworkingalongthelengthofline.So,ifweignorebothR and G then we can consider the circuit as lossless.
- Thecircuit drawnbelowisformedaftersimplifyingthecircuit shownabove.



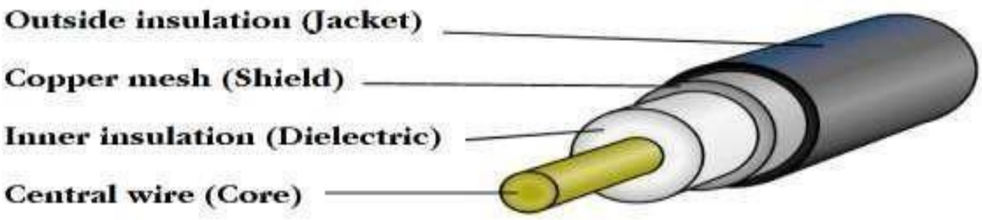
RFEquivalentCircuit:

- The transmitter that generates the RF power to drive the antenna is usually located at somedistancefromtheantennaterminals.Theconnectinglinkbetweenthetwoisthe RF transmission line.
- ItspurposeistocarryRFpowerfromoneplacetoanother,andtodothisas efficiently as possible.

- Fromthereceiverside,theantennaisresponsibleforpickingupanyradiosignalsin the air, and passing them to the receiver with the minimum amount of distortion so that the radio has its best chance to decode the signal.
- Forthesereasons,theRFcablehasaveryimportantroleinradiosystems:itmust maintain the integrity of the signals in both direction.
- Therearetwomaincategoriesoftransmissionlines:cablesandwaveguides.

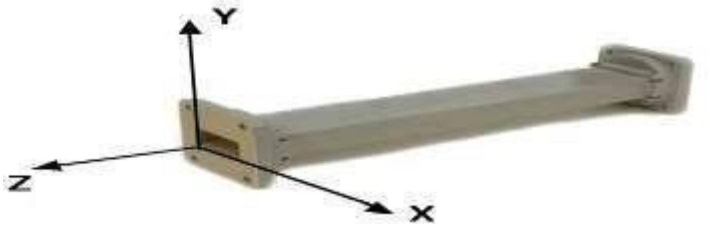
Cables:

- RFcablesare,forfrequencieshigherthanHF,almostexclusivelycoaxialcables(or "coax" for short, derived from the words "of common axis").
- Coax cables have a core wire, surrounded by a non-conductive material (which is calleddielectric or insulation),andthen surroundedbyan encompassingshielding which is often made of braided wires.
- Thedielectrickeepsthecoreandtheshieldingapart.Finally,thecoaxisprotectedby an outer shielding which will generally be a PVC material.
- TheinnerconductorcarriestheRFsignalandtheoutershieldistheretokeeptheRF signal from radiating to the atmosphere and to stop outside signals from interfering with the signal carried by the core.
- Another interesting fact is that the electrical signal always travels along the outer layerofthecentralconductor:thelargerthecentral conductor,thebettersignalwill flow. This is called the “skin effect”.



Waveguides:

- Above2GHz,thewavelengthisshortenoughtoallowpractical,efficientenergy transfer by different means.
- Awaveguideisaconductingtubethroughwhichenergyistransmittedintheformof electromagnetic waves.
- Thetubeactsasaboundarythatconfinesthewavesintheenclosedspace.Theskin effect prevents any electromagnetic effects from being evident outside theguide.
- Theelectromagneticfieldsarepropagatedthroughthewaveguidebymeansof reflections against its inner walls, which are considered perfect conductors.
- Theintensityof thefieldsisgreatestatthecenteralongtheXdimension,andmust diminish to zero at the end walls because the existence of any field parallel to the walls at the surface would cause an infinite current to flowina perfect conductor.
- Waveguides,ofcourse,cannotcarryRFinthisfashion.TheX,YandZdimensions of a rectangular waveguide can be seen in the following figure:



- There are an infinite number ofways in which the electric and magnetic fields can arrangethemselvesinawaveguideforfrequenciesabovethelowcutofffrequency.
- Eachofthesefieldconfigurationsiscalledamode.Themodesmaybeseparatedinto two general groups.
- One group, designated TM (Transverse Magnetic), has the magnetic field entirely transversetothedirectionofpropagation,buthas acomponentoftheelectricfieldin the direction of propagation.
- Theothertype,designatedTE(TransverseElectric)hastheelectricfieldentirely transverse,buthasacomponentofmagneticfieldinthedirectionofpropagation.
- TMwavesaresometimescalledEwaves,andTEwavesaresometimescalledH waves, but the TM and TE designations are preferred.

Characteristicsimpedance,methodsofcalculations& simple numerical :

- Transmission system behavior differs at low and high frequencies, and the different behaviorsareusuallydescribedintermsoflumped-constantanddistributed-constant systems.
- Lumped-constantcircuitsinvolvecomponents(coils,resistors,capacitors,etc.)whose physical dimensions are much less than the wavelength of the propagating electromagnetic wave and which can be located at discrete points.
- When circuit components and connecting wires are of dimensions comparable to a wavelengthofthepropagatingelectromagneticwave,thenthecircuitcomponentsand the wires effectively become distributed constants.
- We may then think of a line as begin composed of a series of small inductors and capacitors,whereeachcoil istheinductanceofanextremelysmallsectionofwire, and the capacitance is that existing between the same two sections.
- Each series inductor acts to limit the rate at which current can charge the following shunt capacitor, and in so doing it establishes a very important property of a transmissionline,its**characteristicimpedance**.Thisisabbreviatedbyconventionas **Z0**.
- Thevalueof athecharacteristicimpedanceisequalto L/Cinaperfectline,onein which the conductors have no resistance and there is no leakage between them.
- LandCarerespectivelytheinductanceandcapacitanceperunitoflengthofline.
- Theinductancedecreaseswithincreasingconductordiameter,andthecapacitance decreases with increasing spacing between the conductors.
- Hencealinewithcloselyspacedlargeconductorshasalowcharacteristicimpedance, while one with widely spaced thin conductors has a high one.
- Typicalcoaxiallinescanhavecharacteristicimpedance'srangingfrom30Ωto100 Ω, but most common impedance values for coaxial cables are 50 Ω and 75 Ω.

- Physicalconstraintsonpracticalwirediametersandspacing limitZ_0valuestothese ranges. The 50Ω RG-58 cable was developed during World War II to connect antennas which had an impedance of 50 Ω.
- Alineterminatedinapurelyresistiveloadequaltothecharacteristiclineimpedance is said to be matched.
- Inamatchedtransmissionline,thepoweristransferredoutwardfromthesourceuntil it reaches the load, where it is completelyabsorbed.
- Thuswitheitheraninfinitelylonglineoramatchedone,theimpedancepresentedto the source of power is the same, regardless of the line length: it is equal to the characteristic impedance of the line.
- Thecurrent insuchalineisgivenby theappliedvoltagedividedby thecharacteristic impedance, according to Ohm's law.If the terminating resistance R is not equal to Z_0, thenthelineissaid to bemismatched. ThemoretheR differs from Z_0, the greater the mismatch.
- The power reaching R is not totally absorbed, as it was when R was equal to Z_0, becauseRrequiresavoltagetocurrentratiothatisdifferentfromtheonetraveling along the line.
- TheresultisthatRabsorbsonlypartofthepowerreachingit,theincidentordirect power.
- Theremaindergoesback alongthelinetowardthesource,anditisknowsasthe reflected power.
- The greater the mismatch, the larger the percentage of the incident power that is reflected.IntheextremecasewhenR iszero(ashortcircuit)orinfinity(anopen circuit), all of thepower reaching the end ofthe lineis reflected back toward the source.
- Theratioofthereflectedvoltageatagivenpointonatransmissionlinetotheincident voltage is called the voltage reflection coefficient.
- Thevoltagereflectioncoefficient isalsoequaltotheratiooftheincidentand reflected currents.

$$\rho = \frac{E_r}{E_i} = \frac{I_r}{I_i}$$

- Where ρ isthereflectioncoefficient,$E_r$isthereflectedvoltage,$E_i$istheincident voltage, I_r is the reflected current, I_i is the incidentcurrent.
- The reflection coefficient is determined by the relationship between the line's characteristicimpedanceandtheactualloadattheendoftheline.Inmostcases,the load is not entirely resistive.
- It is a complex impedance, consisting of a resistance in series with a reactance. The reflectioncoefficientisthusacomplexquantity,havingbothamplitudeandphase.It can be designated with the letter ρ or with the letter Γ.
- TherelationshipbetweenRa,theloadresistance,Xa,theloadreactance,Z_0,theline characteristic impedance with real part $R_0$and reactive part $X_0$and the complex reflection coefficient is given by:

$$\rho = \frac{Z_a - Z_0}{Z_a + Z_0} = \frac{(R_a \pm jX_a) - (R_0 \pm jX_0)}{(R_a \pm jX_a) + (R_0 \pm jX_0)}$$

- For most transmission lines the characteristic impedance is almost completely resistive,meaningthatZ0=R0andX0=0.Themagnitudeofthe complexreflection coefficient then simplifies to

$$|\rho| = \sqrt{\frac{(R_a - R_0)^2 + X_a^{\ 2}}{(R_a + R_0)^2 + X_a^{\ 2}}}$$

Example:ifthecharacteristicimpedanceofacoaxiallineis50Ωandtheloadimpedance is 140 Ω in series with a capacitive reactance of €-190 Ω, the magnitude of the reflection coefficient is

$$|\rho| = \sqrt{\frac{(140-50)^2 + 190^2}{(140+50)^2 + 190^2}} = 0.782$$

LossesInTransmissionLine:

Theenergylossesthat happen incaseoftransmissionlines areshown below:

1. **ConductorHeating**
2. **DielectricHeating**
3. **RadiationLosses**

Itisobservedthattheradiationlossin parallelwirelinesismuchmorethanthatofthe coaxial cables.

Conductorheating: Theheatingrateofaconductorisdirectlyproportionaltothe square ofthe current. It is inversely proportional to the characteristic impedance (Z_o). Conductor heating will also increase with the increase in frequency.

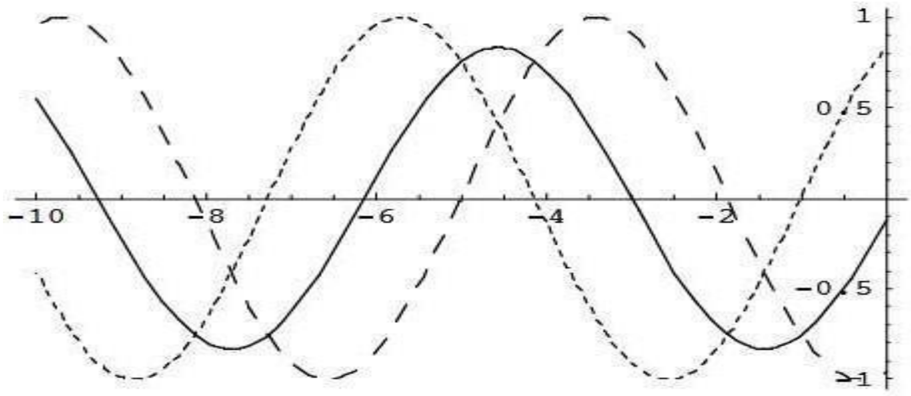
Radiation Loss: The transmission lines act as antennas when the separation distance betweenthe conductors is very small as compared to their wavelength. Then the conductor startsradiatingenergy.Aswewillincreasethefrequencytheradiationlosswillalsoincrease.

Dielectric heating: It directly depends upon the voltage flowing across the dielectric. Similarto conductor heating, it is also inversely proportional to the characteristic impedance oftheline. Inthiscasethelossalsoincreaseswiththeincreaseinfrequency.Ifweuseairas the dielectric medium then the loss will be almost zero.

Standingwave–SWR,VSWR,Reflectioncoefficient, simple numerical. :

- IfRaisequaltoR0andifXaiszero,theformulaforreflectioncoefficient(mentioned above) is also zero: this is the case of the matchedline.
- On the otherhand, if Ra is equal to zero, meaning that the load has no resistive part, then the reflection coefficient is equal to 1 regardless of the value of R0. Thismeans thatall theforwardpowerisreflected,sincetheloadiscompletelyreactive.

- As a consequence of reflection, a standing wave may be visualized as an interference betweentheincidentsignalEi atagivenfrequency,traveling intheforwarddirection, and the signal Er, at the same frequency, traveling in the reverse direction.
- Attheload,therelationshipbetweentheamplitudesofErandEiandthephaseangle between them are uniquely determined by the load impedance.
- Thephaseanglebetween ErandEi,however,willvaryalongthelineasafunctionof the distance from the load.
- Awaveiscreatedthatoscillatesinamplitudebutnevermoveslaterally.Thatiswhyit is called standing wave. In the following figure, the Er, Ei and the standing wave can be seen. The dashed lines are the Er and the Ei, while the non dashed one represents the standing wave.



- At a position 180° from the load (1/2λ), the voltage and current must have the same values they do at the load. At a position 90° from the load (/14λ), the voltage and currentmustbeinverted:ifthevoltageislowestandthecurrentishighestattheload, thenat90°fromtheloadthevoltagereachesitshighestvalueandthecurrentreaches its lowest value at the same point.
- Notethattheconditionsat90°alsoexistat270°, andtheonesat180°arevalidat everypointmultipleof180°.In amatchedline, allofthepowerthatistransferred along the line is absorbed in the load if the load is equal to the characteristic impedance.Noneofthepowerisreflectedbacktowardthesource.Asaresult,no standing waves will be developed along the line. The voltage along the line is constant, so the matched line is also said to beflat.
- The ratio of the maximum voltage, resulting from the interaction of incident and reflected voltages along the line, to the minimum voltage is defined as the **Voltage Standing-WaveRadio(VSWR)orsimplyStanding-WaveRadio(SWR).**Theratio of the maximum current to the minimum current is the same as the VSWR, so either current or voltage can be measured to determine the standing-wave ratio.

$$SWR = \frac{E_{max}}{E_{min}} = \frac{I_{max}}{I_{min}}$$

- In the case where the load contains no reactance, the SWR is equal to the ratio between the load resistance R and the characteristic impedance of the line. The standing-waveratioisan indexofmanyof thepropertiesofamismatchedline.The SWR is related to the magnitude of the complex reflection coefficient by the following equation

$$SWR = \frac{1+|\rho|}{1-|\rho|}$$

- wherewecanseethatwith€ρ=0wegetSWR=1,sowehavemaximumtransmission, and with €ρ=1we get SWR=€∞, so we have no transmission. And the reflection coefficient magnitude may be defined from a measurement of SWR as

$$|\rho| = \frac{SWR-1}{SWR+1}$$

- We may also express the reflection coefficient in terms of forward and reflected power,quantitiesthatcanbeeasilymeasuredusingadirectionalRFwattmeter.The reflection coefficient may be computed as

$$\rho = \sqrt{\frac{P_r}{P_f}}$$

- wherePfisthepowerintheforwardwaveandPristhepowerinthereflectedwave. We can use this equation to calculate the SWR from a measurement of the forward and reflected power

$$SWR = \frac{1+|\rho|}{1-|\rho|} = \frac{1+\sqrt{\frac{P_r}{P_f}}}{1-\sqrt{\frac{P_r}{P_f}}}$$

- The relation between the Return Lossexpresses in dB, which is theamplitude of the reflectedwavetotheamplitudeoftheincidentwave,andthereflectioncoefficientis given by:

$$\text{Return Loss (dB)} = -20\log(\rho)$$

- Therelation betweenthepowerratioandthereflectioncoefficientisgivenby:

$$\frac{P_r}{P_f} = 100\rho^2$$

- Forexample,ifwemeasureareturnlossof15dB,thenwecancalculatethe reflection coefficient as 0.178 and thus the SWR as 1.43.

Quarterwave&halfwavelengthLine:

- RF is reflected from the end of a transmission line that is not terminated in its characteristicimpedance. Asaconsequence,theimpedancemeasuredattheinputof the transmission may or may not be the same as the load impedance. Before examiningthegeneral caseofatransmissionofan arbitraryelectrical length,wewill look at two special cases:
  1. Halfwavelengthlines
  2. Quarterwavelengthlines.

1.HalfWavelengthLines:

A half wavelength transmission line is one whose electrical length is one half wavelength long, or a multiple of one half wavelength. When a $\lambda/2$ line whose characteristic impedance is Z_0 is terminated in a load impedance Z_L , the input impedance is always Z_L , regardless of the value of Z_L . To see why this is so, consider an RF sine wave of frequency f and wavelength λ traveling from input to the load. If $V_0\cos(2\pi[(x/\lambda)+ft])$ and $I_0\cos(2\pi[(x/\lambda)+ft])$ are the voltage and current on the transmission line, then at the input, x = 0, and the input impedance is:

$$Z_S = V_0\cos(2\pi ft) / I_0\cos(2\pi ft)$$

At the load, $x = \lambda/2$, and the load impedance of the line is:

$$Z_L = V_0\cos(\pi+2\pi ft) / I_0\cos(\pi+2\pi ft)$$

From elementary trigonometry, we know that $\cos(\pi+2\pi ft) = \cos(2\pi ft)$. Substituting this into the above expression gives:

$$Z_L = V_0\cos(2\pi ft) / I_0\cos(2\pi ft) = Z_S$$

Notice that this is true for any value of Z_0 , Z_S and Z_L.

This property of half wave lines has a very useful consequence

A transmission line may be reduced or increased in length by a half wavelength (or a multiple) and the input impedance remains the same.

Here is an example showing how a half wavelength line could be used:

An FM broadcast antenna has an impedance of 50 ohms. The transmitter requires a 50 ohm load. The only transmission line available is low loss 75 ohm coaxial cable (type RG-6), whose velocity factor is 0.75. If the antenna is located 400 feet above the transmitter and the operating frequency is 89.1 MHz, what is the minimum length of 75 ohm cable required that will connect the transmitter and antenna and provide a 50 ohm input impedance?

Solution:

Since the transmission line has a characteristic impedance of 75 ohms and the load impedance is 50 ohms, the only way to get a 50 ohm input impedance is to select a length of linethatisamultipleofahalfwavelengthlong. In fact,weneedtodeterminethemultipleof a half wavelength at 89.1 MHz that is closest to and larger than the required line length of 400ft.WebeginbycomputingtheelectricallengthofRG-6coaxialtransmission line:

$$l_{ELECTRICAL} = \frac{lf}{984V_F} = \frac{200*98.1}{984*0.75} = \frac{19620}{738} = 26.59\lambda$$

Itisnecessary tomaketheline0.41λlonger,resultinginanoveralllengthof27λ,whichisa multiple of 0.5λ. Note that we cannot take 0.19λoff the line to get 26.5λ, because the line would then be too short. Now we determine the physical length of line equivalent to 0.41λ

$$\frac{984V_F l_{ELECTRICAL}}{f} = l = \frac{984*0.75*.41}{98.1} = \frac{302.6}{98.1} = 3.084\,ft = 3\,ft\,1in.$$

The required length of line is 400 + 3.084 = 403.084 ft = 403 ft 1 in

A half wave line can also be used in place of a resonant LC circuit. The input impedance of anopencircuitedhalfwavelineisinfinite.IfRFofaslightlylowerfrequencyisapplied,the electrical length of the line decreases below a half wavelength and the input impedance is inductive. If the frequency is increased, the input impedance is capacitive. Thus the open circuited half wave line acts like a parallel LC circuit. By similar reasoning, one can show that a shorted half wave line acts like a series resonant circuit. The table below shows the relationship between a half wave line and a resonant LC circuit.

Half Wave Line Termination	$f < f_0$	$f = f_0$	$f > f_0$	Type of LC Circuit
open circuit	Z_S is inductive $L_{ELECT} < \lambda/2$	Z_S is infinite $L_{ELECT} = \lambda/2$	Z_S is capacitive $L_{ELECT} > \lambda/2$	Parallel LC
short circuit	Z_S is capacitive $L_{ELECT} < \lambda/2$	Z_S is zero $L_{ELECT} = \lambda/2$	Z_S is inductive $L_{ELECT} > \lambda/2$	Series LC

Atveryhighfrequencies,whereitisdifficulttoconstructLCcircuitswithcapacitorsand inductors, they may be constructed from lengths of transmission line.

2. Quarter Wavelength Lines:

A quarter wavelength transmission line is one whose electrical length is one quarter wavelengthlong,oranoddmultipleofaquarterwavelengthlong.Theinput,loadand characteristicimpedances of aquarter wavelinearerelatedby thefollowing equation:

$$Z_S = Z_0^2 / Z_L$$

where:
Z_S is the input impedance
Z_0 is the characteristic impedance of the transmission line
Z_L is the load impedance

Quarter wave lines are generally used to transform an impedance from one value to another. Hereisan example:AVHFloopantennausedto receiveweathermapsfromsatelliteshasan impedance of 110 ohms at 137 MHz. This antenna will be used with a receiver whose input impedance is 50 ohms.

a) Whatistheimpedanceofthequarterwavematchingsection?

b) Ifacablewitha0.75velocity factorisusedforthematching section,whatisitslength?

a) We begin with $Z_S = Z_0^2 / Z_L$. This equation can be rewritten as:

$$Z_0^2 = Z_L Z_S$$

$$Z_0^2 = 110*50 = 5500$$

$$Z_0 = \text{sqrt}(5500) = 74 \text{ ohms}$$

b) To determine the actual length we use the following formula:

(984*VF*0.25)/f = length

where VF = the velocity factor and f is the frequency in MHz. If we do the math, we discover that the matching section is 15 inches long.

AquarterwavelinecanalsobeusedinplaceofaresonantLCcircuit.Theinputimpedance of an open circuited quarter wave line is zero (short circuit).

IfRFofaslightlylowerfrequencyisapplied,theelectricallengthofthelinedecreasesbelow a half wavelength and the input impedance is capacitive.

If the frequency is increased, the input impedance is inductive. Thus the open circuited quarterwavelineactslikeaseriesLCcircuit.Bysimilarreasoning,onecanshowthataopen circuited quarter wave line acts like a parallel resonant circuit.

ThetablebelowshowstherelationshipbetweenaquarterwavelineandaresonantLC circuit.

Quarter Wave Line Termination	f < f_0	f = f_0	f > f_0	Type of LC Circuit
open circuit	Z_S is capacitive $L_{ELECT} < \lambda/2$	Z_S is zero $L_{ELECT} = \lambda/2$	Z_S is inductive $L_{ELECT} > \lambda/2$	Series LC
short circuit	Z_S is inductive $L_{ELECT} < \lambda/2$	Z_S is infinite $L_{ELECT} = \lambda/2$	Z_S is capacitive $L_{ELECT} > \lambda/2$	Parallel LC

Impedancematching&Stubs–single&double:

Stub tuning is an impedance matching technique, when an open-circuited or short-circuited transmissionlineisconnectedtothemaintransmissionline.Astubisusuallymadeaspartof circuit which allows the avoidance of lumped elements. Co–planar waveguides or slot lines are usually connected to a stub in series; microstrips in parallel.

Parallel stubtuningisdepictedin Figure1.Theparameter dischosen,soadmittanceis $Y = Y_0 + jB$,and susceptance $-jB$.

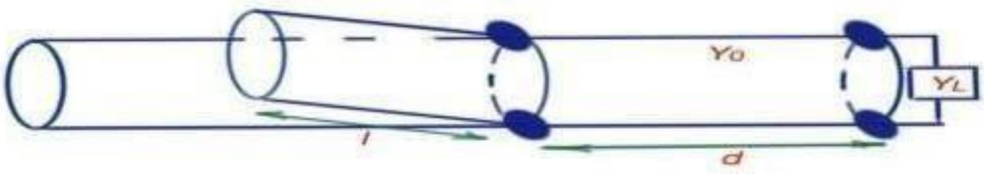


Figure 1.

Seriesstubtuningisdepictedin Figure2.Theparameterdischosensotheimpedance is $Z = Z_0 + jX$, where reactance is $-jX$.

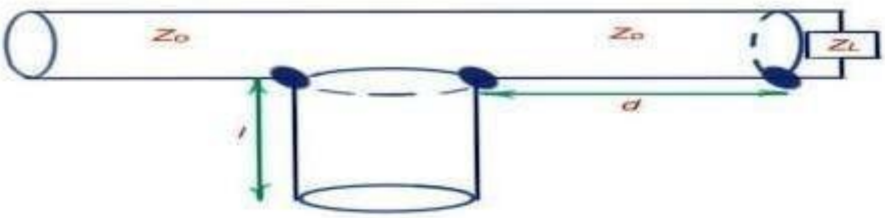


Figure 2.

Admittanceandimpedancearerelated with $Y = \frac{1}{X}$.

Byvaryingtheparameterdistancetotheload,wecanachievethedesiredvaluesofreactance and susceptance.

Forthistypeofimpedance,matchingparametersandareimportant.Hereistheanalytical solution.

$Z_L = R_L + jX_L$ is a load impedance.

Then, the distance between stub and load can be found as:

$$\frac{d}{\lambda} = \begin{cases} \frac{1}{2\pi}\tan^{-1}\frac{Z_L \pm \sqrt{R_L\frac{(Z_0-R_L)^2+X_L{}^2}{Z_0}}}{R_L-Z_0}, \ if \frac{Z_L \pm \sqrt{R_L\frac{(Z_0-R_L)^2+X_L{}^2}{Z_0}}}{R_L-Z_0} > 0 \\ \frac{1}{2\pi}(1+\tan^{-1}\frac{Z_L \pm \sqrt{R_L\frac{(Z_0-R_L)^2+X_L{}^2}{Z_0}}}{R_L-Z_0}), \ if \ \frac{Z_L \pm \sqrt{R_L\frac{(Z_0-R_L)^2+X_L{}^2}{Z_0}}}{R_L-Z_0} < 0 \end{cases}$$

The stub length equations are more complex (stub can be opened or short cutted):

$$\frac{l_{open}}{\lambda} = -\frac{1}{2\pi}\tan^{-1}(\frac{B}{Y_0}), \ where \ B = \frac{R_L{}^2 a-(Z_0-X_L a)(Z_0+X_L a)}{Z_0(R_L{}^2+[X_L+Z_0 a]^2)}, \ a = \frac{Z_L \pm \sqrt{R_L\frac{(Z_0-R_L)^2+X_L{}^2}{Z_0}}}{R_L-Z_0}$$

$$\frac{l_{short}}{\lambda} = \frac{1}{2\pi}\tan^{-1}(\frac{Y_0}{B}), \ where \ B = \frac{R_L{}^2 a-(Z_0-X_L a)(Z_0+X_L a)}{Z_0(R_L{}^2+[X_L+Z_0 a]^2)}, \ and \ a = \frac{Z_L \pm \sqrt{R_L\frac{(Z_0-R_L)^2+X^2{}_L}{Z_0}}}{R_L-Z_0}$$

When we have a series connection of stubs, the analytical solution will be the following:

$Y_L = G_L + jB_L$ is a load admittance.

The distance between load and stub is

$$\frac{d}{\lambda} = \begin{cases} \frac{1}{2\pi}\tan^{-1}(\frac{B_L \pm \sqrt{\frac{G_L}{Y_0}(Y_0-G_L)^2+\frac{G_L B_L{}^2}{Y_0}}}{G_L-Y_0}), \ if \ \frac{B_L \pm \sqrt{\frac{G_L}{Y_0}(Y_0-G_L)^2+\frac{G_L B_L{}^2}{Y_0}}}{G_L-Y_0} > 0 \\ \frac{1}{2\pi}(\pi+\tan^{-1}(\frac{B_L \pm \sqrt{\frac{G_L}{Y_0}(Y_0-G_L)^2+\frac{G_L}{Y_0}B^2{}_L}}{G_L-Y_0})), \ if \ \frac{B_L \pm \sqrt{\frac{G_L}{Y_0}(Y_0-G_L)^2+\frac{G_L}{Y_0}B^2{}_L}}{G_L-Y_0} < 0 \end{cases}$$

The stubs lengths are (for short cut and open stub):

$$\frac{l_{open}}{\lambda} = \frac{1}{2\pi}\tan^{-1}\frac{Z_0}{X}, \ where \ X = \frac{G_L{}^2 a-(Y_0-cB_L)(B_L+cY_0)}{Y_0(G_L{}^2+(B_L+Y_0 c)^2)} \ and \ c = \frac{B_L \pm \sqrt{\frac{G_L}{Y_0}(Y_0-G_L)^2+\frac{G_L}{Y_0}B_L{}^2}}{G_L-Y_0}$$

$$\frac{l_{short}}{\lambda} = -\frac{1}{2\pi}\tan^{-1}\frac{X}{Z_0}, \ where \ X = \frac{G_L{}^2 a-(Y_0-cB_L)(B_L+cY_0)}{Y_0(G_L{}^2+(B_L+Y_0 c)^2)} \ and \ c = \frac{B_L \pm \sqrt{\frac{G_L}{Y_0}(Y_0-G_L)^2+\frac{G_L}{Y_0}B_L{}^2}}{G_L-Y_0}.$$

Double-stubmatchingisatypeofmatchingwheretwostubsareshuntedtomain transmission line on a fixed distance.

Thistypeoftuningismorefavourable fromapracticalpointofview.Doublestubtuningis schematically depicted in Figure 3.

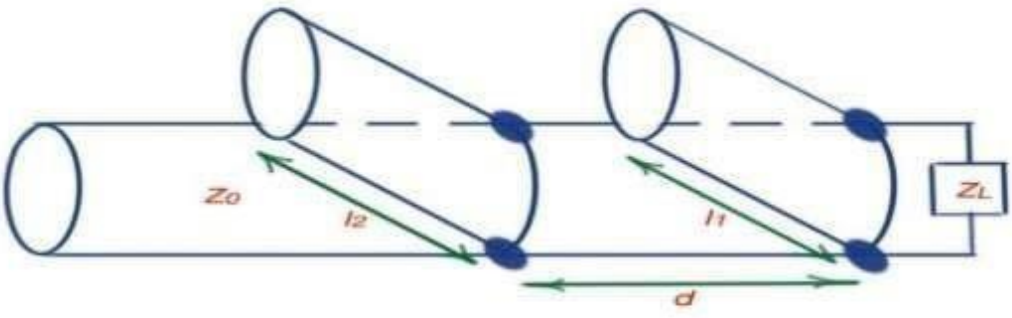


Figure 3.

Here two stubs are shunted to the main transmission line in a fixed position. Here is an analytical solution for double stub tuning.

Admittance of the first stub $Y_1 = G_L + j(B_L + B_1)$, where load admittance $Y_L = G_L + jB_L$. Then for admittance of a second stub we have: $Y_2 = Y_0 \dfrac{G_L + j(B_L + B_1 + Y_0 \tan\beta d)}{Y_0 + j(\tan\beta d)(G_L + jB_1 + jB_L)}$,

here $G_L = Y_0 \dfrac{1+(\tan\beta d)^2}{2(\tan\beta d)^2}\left[1 \pm \sqrt{1 - \dfrac{4(\tan\beta d)^2 (Y_0 - B_L \tan\beta d + B_1 \tan\beta d)^2}{Y_0^2 (1+\tan\beta d^2)^2}}\right]$.

The lengths of stubs are:

$$\frac{l_{1open}}{\lambda} = \frac{1}{2\pi}\tan^{-1}\left(\frac{B_1}{Y_0}\right),\ \frac{l_{2open}}{\lambda} = \frac{1}{2\pi}\tan^{-1}\left(\frac{B_2}{Y_0}\right),\ \frac{l_{1short}}{\lambda} = -\frac{1}{2\pi}\tan\left(\frac{Y_0}{B_1}\right),\ \frac{l_{2short}}{\lambda} = -\frac{1}{2\pi}\tan\left(\frac{Y_0}{B_2}\right).$$

Here $B_1 = -B_L + \dfrac{Y_0 \pm \sqrt{Y_0 G_L (1+(\tan\beta d)^2) - G_L^{\,2} (\tan\beta d)^2}}{\tan\beta d}$, and

$$B_2 = \frac{G_L Y_0 \pm Y_0 \sqrt{Y_0 G_L (1+(\tan\beta d)^2) - G_L^{\,2} (\tan\beta d)^2}}{G_L \tan\beta d}.$$

PrimaryAndSecondaryConstantsOfX-MissionLine:

Primary Parameters or constants

Resistance (R):

- It is series resistance due to internal resistance of the conductor.
- It is uniformly distributed along the line.
- It depends on the conductivity and cross sectional area of the conductor.
- At high frequencies, it depends on skin depth.
- It is measured as loop resistance per unit length of the line.

Primary Parameters or constants

Inductance (L):

- It is series inductance due to magnetic flux density produced around a conductor of a transmission line.
- It is uniformly distributed along the line.
- The flux linkages per unit current gives the inductance of the transmission line.
- It is measured as loop inductance per unit length of the transmission line.
- Units: H/m

Primary Parameters or constants

Capacitance (C):

- Two parallel conductors or coaxial conductors of a transmission line separated by distance 'd' acts as a capacitor.
- Thus a shunt capacitance formed due to the electric field between the conductors.
- It is uniformly distributed along the line.
- It is measured as shunt capacitance per unit length of the transmission line.

Primary Parameters or constants

Conductance (G):

- A shunt conductance due to leakage current between the conductors of a transmission line.
- Since, the dielectric or insulation material around the conductors is not perfect, a small amount of current flows through the dielectric material.
- It is uniformly distributed along the line.
- It is measured as shunt conductance per unit length of the transmission line.

Secondary Parameters or constants

Propagation constant (γ):

- The propagation constant of a sinusoidal electromagnetic wave is a measure of the change undergone by the amplitude and phase of the wave as it propagates in a transmission line.
- It is also the square root of the product of series impedance and shunt admittance.

Propagation constant (γ) = $\sqrt{(R + j\omega L)(G + j\omega C)}$

Where, $(R + j\omega L)$ = Z→ series impedance

$(G + j\omega C)$ = Y → Shunt admittance

$$\therefore \gamma = \sqrt{Z\,Y}$$

Secondary Parameters or constants

Characteristic impedance(Z_0):

- It is the ratio of magnitude of voltage and current in an infinite transmission line at zero reflection wave condition.
- It is also the square root of the ratio of series impedance to shunt admittance.

- Characteristic impedance (Z_0) = $\sqrt{\frac{R+j\omega L}{G+j\omega C}}$

Where, $(R + j\omega L)$ = Z→ series impedance

$(G + j\omega C)$ = Y → Shunt admittance

$$\therefore Z_0 = \sqrt{\frac{Z}{Y}}$$

PossibleShortTypeQuestionsWithAnswers

1. **Definethelineparameters?**

Ans-TheparametersofatransmissionlineareResistance(R),Inductance(L), Capacitance (C),Conductance (G).

2. **Whatarethesecondaryconstantsofaline?Whytheline parameters are calleddistributed elements?**

Ans- The secondary constants of a line are: Characteristic Impedance Propagation Constant SincethelineconstantsR,L,C,Garedistributedthroughtheentirelengthof the line, they are calledas distributed elements. They are also called as primary constants.

3. **DefineCharacteristicimpedance**

Ans-Characteristicimpedanceistheimpedancemeasuredatthesendingendoftheline. It is given by

$Z0 = \sqrt{Z/Y}$,where
$Z = R + j\omega L$ is the series impedance
$Y = G + j\omega C$ is the shunt admittance

4. **DefinePropagationconstant**

Ans-Propagation constant isdefined asthenaturallogarithm oftheratio ofthesending end currentor voltage to the receiving end current or voltage of the line. It gives the mannerinthewaveis propagated along alineandspecifiesthevariationofvoltageand current in theline as a function of distance. Propagation constant is a complex quantity and is expressed as

$\gamma = \alpha + j\beta$

The real part is called the attenuation constant α whereas the imaginary part of propagation constantis called the phase constant β

5. **Whatisafiniteline?Writedownthesignificanceofthisline?**

Ans- An infinite line is a line in which the length of the transmission line is infinite. A finiteline,whichisterminatedinitscharacteristicimpedance,istermedasinfiniteline. Soforaninfiniteline,theinputimpedanceisequivalenttothecharacteristicimpedance.

6. **Howfrequencydistortionoccursinaline?**

Ans- When asignal having many frequency components are transmitted alongthe line, allthefrequencieswillnothaveequalattenuationandhencethereceivedendwaveform willnotbeidenticalwiththeinputwaveformatthesendingendbecauseeachfrequency is having different attenuation. This type of distortion is called frequency distortion.

7. **Whatis delay distortion?**

Ans-Whenasignalhavingmanyfrequencycomponentsaretransmittedalongthe line, all the frequencies will not have same time of transmission, some frequencies being delayedmorethanothers. So the received end waveform will not be identical with the input waveform at the sendingend because some frequency components will be delayed more than those of other frequencies. This type of distortion is called phase or delay distortion.

8. Mentiondifferenttypesoflossesin Transmission line.(w-20)

Ans-

- copperloss,
- DielectricLoss,
- RadiationorInductionLoss.

<u>PossibleLongQuestions</u>

1. ExplainequivalentcircuitofTransmissionlineandRFequivalent circuit.(w-20)
2. ExplainaboutdifferentlossesinTransmissionLine.
3. Whatisimpedancematching?Explainsinglestubmatchingindetail.
4. Discussabouttheprimaryandsecondaryconstantsoftransmission line.(w-20)

CHAPTERNUMBER-03:
TELEVISION ENGINEERING.

LEARINGOBJECTIVES:

Define-Aspect ratio, Rectangular Switching. Flicker, Horizontal Resolution,Videobandwidth,Interlacedscanning,Compositevideosignal, Synchronization pulses

TVTransmitter–Blockdiagram&functionofeachblock.

MonochromeTVReceiver-Blockdiagram&functionofeachblock.

ColourTVsignals(LuminanceSignal&ChrominanceSignal,(I& Q,U & V Signals).

TypesofTelevisionsbyTechnology-

Discusstheprincipleofoperation-LCDdisplay,LargeScreen

CATVsystems&Types&networks

DigitalTVTechnology-DigitalTVSignals,TransmissionofdigitalTV signals & Digital TV receiver Video programme processor unit.

Define-Aspectratio,RectangularSwitching.Flicker,Horizontal Resolution,Videobandwidth,Interlacedscanning,Compositevide o signal,Synchronization pulses

Aspect ratio : Aspectratio can bedefinedasthe ratioofwidthtoheightofthe picture frame. For television, it is standardized as 4:3.

Rectangular Switching : TV's aspect ratio is the width and height (**W:H**) of your TV screen. So, if the shape of your TV is:

- **Squareshape:**4:3aspectratio.UsuallytraditionalTVswithStandardDefinition (SD).
- **Rectangleshape:**16:9aspectratio.UsuallycurrentHighDefinition (HD)TVs.

YourTV can affect the aspect ratio, but there are otherthings that can affect it, too -likeTV boxes, videogames,and DVD players.Anything that is connectedto and shownon yourTV has its own aspect ratio.

Flicker: Theresultof24picturespersecondinmotionpicturesandthatofscanning 25 frames per second in televisionpicturesisenoughtomakeanillusionof continuity. But, they are not rapid enough to permit thebrightnessofonepicture or frame to blend smoothly in the next through thetimewhenthescreenis blanked between successive frames. This develops in a definite flicker of lightthat isvery irritating to the observer when the screen is made alternately bright anddark.

HorizontalResolution: Theability of thesystemtoresolvemaximumnumber of picture elements along the scanning lines determines horizontal resolution.

Video bandwidth : Inbroadcast**television**systems,VF**bandwidth**,**videobandwidth** or more formally **video** frequency **bandwidth** is the range of frequencies between 0 and the highest frequency used to transmit a live **television** image. The maximum frequency can be found by multiplying three figures; the number of frames per second, number of lines per frame and maximum number of sine periods per line.

Interlaced scanning : Interlaced scan is a display signal type in which one-half of the horizontal pixel rows are refreshed in one cycle and the other half in the next, meaning that two complete scans are required to display the screen image. The *i* in a TV signal specificationsuchas1080istandsfor*interlacedscanning*.Thenumberindicatesthenumber of horizontal lines in a raster.

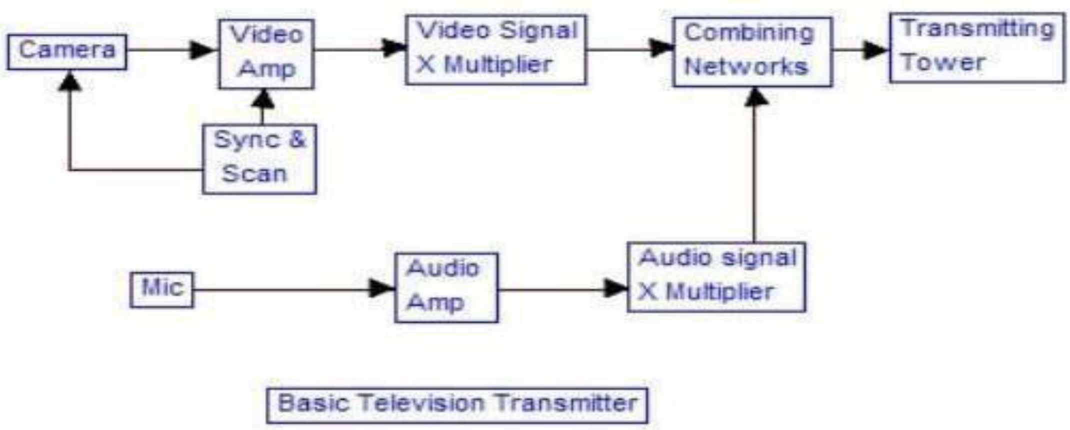
Composite video signal :A single-frequency sine wave is not useful in data communications. We need to send a **composite signal**, a **signal** made of many simple sine waves.AccordingtoFourieranalysis,any**compositesignal**isacombinationofsimplesine waves with different frequencies, amplitudes, and phases.

Synchronization pulses : In general, synchronizations is the process in which the signalsaretransmittedandreceivedinaccordancewiththeclock **pulses**.In**synchronization** of **Television** transmitter, a sharp **pulse** is sent between each video signal line so that to maintain the impeccable transmitter-receiver **synchronization**.

TVTransmitter–Blockdiagram&functionofeachblock.

Theblockdiagramcanbebroadlydividedintotwoseparatesection,viz., onethat-Generates an electronic signal (called video signal) corresponding to the actual picture and then usesthis video signal to modulate an R-F carrier so as to be applied to the transmitting antenna for transmission, other that generates an electronic signal (called audio signal) containing sound information and then uses this signal to modulate another RF carrier and then applied to the transmitting antenna for transmission.

Blockdiagramoftelevisiontransmitter



[ThebasictelevisionBroadcasttransmitterblockdiagramfigure(a)]

Theblockdiagramcanbebroadlydividedintotwoseparatesection,viz.,onethat -Generates an electronic signal (called video signal) corresponding to the actual picture and then uses thisvideosignaltomodulateanR-Fcarriersoastobeappliedtothetransmittingantennafor transmission, other that generates an electronic signal (called audio signal) containing sound information and then uses this signal to modulate another RF carrier and then applied to the transmitting antenna for transmission.

However only one antenna is used for transmission of the video as well as audio signals. Thusthesemodulatedsignalshavetobecombinedtogetherinsomeappropriatenetwork.In additiontherearetheraccessories also.Forinstance,videoas wellasaudiosignalshaveto be amplified to the desired degree before they modulate their respective RF carriers.

This function is performed by video and audio amplifiers. The block picture signal transmitter and audio signal transmitter shown in figure(a) may consist of modulators as the essential component; Video signal transmitter employs an AM transmitter as amplitude-modulationisusedforvideosignalswhereasaudiosignaltransmitteremploysFMmodulator as frequency modulation is used for sound information. Scanning circuits are used to mike the electron beam scan the actual picture to produce the corresponding video signal. The scanning by electron beam is in the receiver too. The beam scans the picture tube to reproducethe original picturefrom thevideo signal and this scanning at thereceivermust be matched properly to the scanning at the transmitter. It is for this reason that synchronizing Circuits are used at the transmitter as well as receiver.

CompleteTVtransmitterBlockDiagram

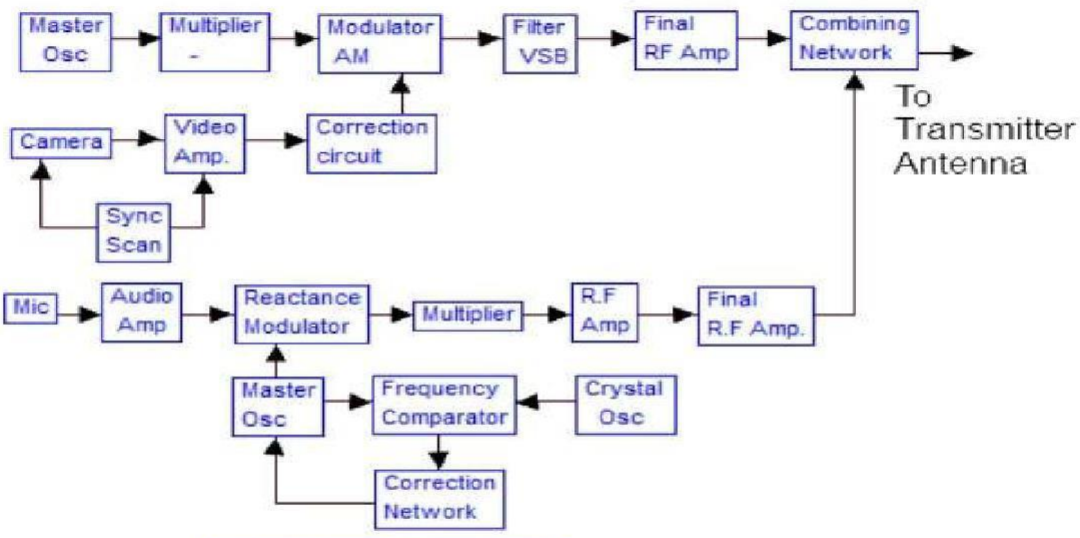


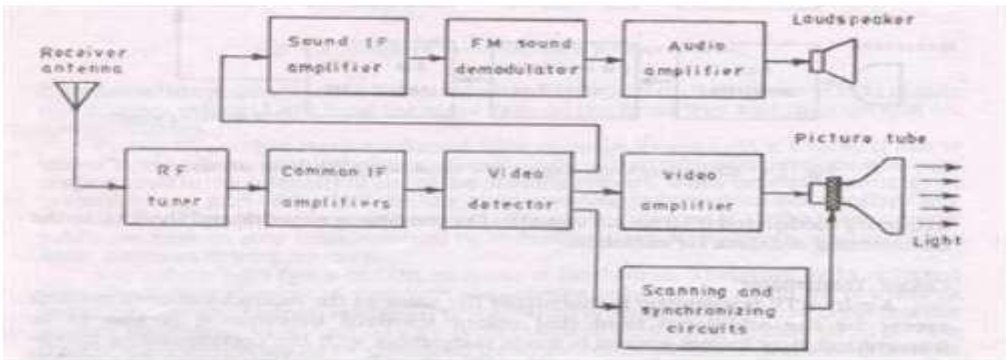
Fig (b) Complete T.V transmitter

Figure (b) depicts the complete block diagram of a Television Broadcast Transmitter. The important block have already been discussed individually in the preceding sections. that makes understanding of the diagram shown here much more simple. A brief explanation is givenahead.Theblockdiagramcanbebroadlydividedintotwo-sections,viz.,anamplitude modulated transmitter and a frequency modulated transmitter. Former is used for video modulation whereas latter is used for audio modulation.

Masteroscillatorinbothgeneratesan RFcarrierfrequency.Generally,amasteroscillator generates a sub multiple of carrier and then drives harmonic generators (frequency multipliers) to achieve correct value carrier. Harmonic generators are nothing but class C tuned amplifiers whose output tuned circuit is to tuned to some harmonic of the input signal. In actual practice, master oscillator and harmonic generator are s crated or isolated by a buffer stage to av214Joactrrig of the harmonic generator on the oscillator output. The carrier isthenfedto anamplitudemodulatorinvideotransmitterandafrequency modulatorinaudio transmitter. Into-the modulator, the modulation signal is also fed with proper amplitude. Since low-level modulation is employed, the modulating signal is amplified by linear amplifiers up-to the desired degree required for transmission. Video and audio signals on separatecarriersarethen combinedtogethersoastobefedtothetransmittingantennaason signal.

3.3:MonochromeTVReceiver-Blockdiagram&functionofeachblock.

Block diagram of television receiver



TelevisionReceiver

A radio receiver designed to amplify and convert the video and audio radio- frequency signals of a television broadcast that have been picked up by a television antenna; the receiver reproduces the visual image broadcast and the accompanying sound. Television receiversaredesigned forcolororblack-and-whiteoperation; bothnonportableandportable modelsareproduced.ThosemanufacturedintheUSSRarecapableofreceivingsignalsfrom television stations transmitting in specifically assigned portions of thevery-high-frequency (VHF) band (48.5–100 megahertz and 174– 230 megahertz; 12 channels) and ultra high-frequency (UHF) band (470– 638 megahertz; several tens ofchannels).

Television receivers must simultaneously amplify and convert video and audio radio-frequency signals. They are usually designed with a super heterodyne circuit, and versions differinthemethodsusedtoextractandamplifytheaudiosignal.Theprincipalcomponents of a television receiver are shown in Figure1.

Thetunerselectsthesignalsofthedesired channelandconvertsthemtoalowerfrequency within the inter mediate-frequency pass band. The signal-processing circuits include an intermediate-frequency amplifier for the video signal, an amplitude detector, a video amplifier for the brightness signal, and, incolor receivers, a color- processing circuit for the chrominance signal. The processing circuit produces a brightness signal and a color-difference signal, which are fed to the control electrodes of a kinescope; an audio signal, which is fed to the audio channel; and horizontal and vertical synchronizing pulses (or a composite television signal), which are fed to a scanning generator. In the color television systemusedintheUSSR,thecolor-processingcircuitforthechrominancesignalconsistsof a band-pass amplifier, in which the chrominance signal is extracted, channels for the direct and delayed signals, an electronic switching device, two frequency detectors for the color-difference signals, a matrix circuit, and amplifiers for the three color-difference signals. The color processing circuit has provisions for the extraction and decoding of the chrominance signal and for line selection, as well as chrominance disconnect circuits that operate when black-and-white transmissions are received.

The scanning generators include horizontal and vertical scanning circuits that produce sawtoothcurrentsinthehorizontalandverticalscanningcoilsofthedeflectionsystem.

Thehighvoltageforfeedingthesecondanodeofthekinescopeisderivedfromaspecialhigh voltage winding of the line transformer or by rectifying pulses from the transformer; the volt age for the focusing electrode is similarly derived.

The kinescope’s interface includes static and dynamic white balance controls, switches for exting uishingthe electron guns, and regulators for focusing the beams. The demagnetizing circuit for a color kinescopecreates a damped alternating current in a demagnetizing loop that circlesthekinescopescreen.Thecurrentdemagnetizestheshadowmaskandtuberim,which are made of steel. The audio section consists of an amplifier for the difference frequency, which in the USSR is 6.5 megahertz, a frequency detector for the audio signal, and a low- frequency amplifier from which the audio signal is fed to a high- quality acoustical system, usually composed of several loudspeakers. Thepower-supply section converts mains voltage into the supply voltages for all components of the television set, including the kinescope and vacuum tube heaters.

ColourTVsignals(LuminanceSignal&Chrominance Signal,(I & Q,U & V Signals).

<u>Luminance</u>

Lumaistheweightedsumofgamma-compressedR′G′B′componentsofacolorvideo—the *prime symbols ′* denote gamma compression. The word was proposed to prevent confusion between luma as implemented in video engineering and relative luminance as used in color science (i.e. as defined by CIE). Relative luminance is formed as a weighted sum of *linear* RGB components, not gamma-compressed ones.

While luma is more often encountered, relative luminance is sometimes used in video engineeringwhenreferringtothebrightnessofamonitor.Theformulausedtocalculate relative luminance uses coefficients based on the CIE color matching functions and the relevant standard chromaticities of red, green, and blue.

The I **signal** represents hues from the orange-cyan colour axis, and the **Q signal** represents hues along the magenta-yellow colour axis. The human eye is much less sensitive to spatial detailincolour,andthusthechrominanceinformationisallocatedmuchlessbandwidth than the **luminance** information.

Chrominance

Chrominance(*chroma*or*C*forshort)isthesignalusedinvideosystemstoconveythecolor information of the picture, separately from the accompanying luma signal (or Y' for short).

Chrominanceisusuallyrepresented astwocolor-differencecomponents:U=B′−Y′ (blue−luma)andV=R′ −Y′(red−luma).Each ofthesedifferencecomponentsmayhave scale factors and offsets applied to it, as specified by the applicable video standard.

Incompositevideosignals,theUandVsignalsmodulateacolorsubcarriersignal,andthe result is referred to as the chrominance signal; the phase and amplitude of this modulated chrominance signal correspond approximately to the hue and saturation of the color. In digital-video and still-image color spaces such as Y′CbCr, the luma and chrominance components are digital sample values.

SeparatingRGBcolorsignalsintolumaandchrominanceallowsthebandwidthofeachtobe determinedseparately.Typically,thechrominancebandwidthisreducedinanalogcomposite video by reducing the bandwidth of a modulated color subcarrier, and in digital systems by chroma subsampling.

TypesofTelevisionsbyTechnology-

BasedonTelevisionTechnology,therearebasically6typesofTVsavailableinthe market,such as:

1. cathode-raytubeTVs:

- DirectViewTVsarearebrandingoftheclassic,century-longdominance of the cathode-ray tube TVs. Most TV manufacturers have ceased production on thesemodels in most countries in favor of newer technologies.
- Forgaming,especiallyoldergaming, havingadirectviewTVmaybeimportant.
- Many classic video games were developed specifically for the cathode-ray tubetechnology. Older games played on newer TVs can look torn or lag in ways thataren’t a problem with direct view TVs.

2. PlasmaDisplayPanels:

- Beginning in the 1990s, plasma display panel TVs became the first flat screen alternativeto cathode-ray tubetechnology.Plasmadisplaysaredesignedas acellular grid with pixels that contain plasma, an ionized gas that responds to electricfields.
- The plasma layer is flanked by electrodes, with glass panels in the front and rear. PlasmaTVsusesimilarphosphorscreensascathode-raytubeTVs,makingthecolor depth similar in both technologies.

- However, plasma screen technology has considerable faster frame response over cathode-raytubes,refreshingupto600timesasecond(600Hz).PlasmaTVsarealso easily scalable — the first flat, bigscreen systems were all plasma displays.
- Whileanimprovementinmanywaysovercathode-raytubes,plasmaTVswerestill bulky,andtheywereandaresusceptibleto“burn-in,”orimageretention,overtime.

3. DigitalLightProcessing(DLP):

- DigitalLightProcessing(DLP)TVswereinventedbyTexas Instrumentsinthe 1980s, using a completely novel technological approach.
- DLPs use an optical semiconductor chip with over 1 million mirrors that process digitalsignalsbytiltingtovaryingdegrees,reflectinglightindeferentdirectionsto create an image.
- The resulting smooth viewing experience has several advantages over cathode-ray tube and plasma TVs, including longer lifespans, lighter weight, and 3Dprojection compatibility.
- However,newertechnologiesthatarethinner,quieter,havefasterresponserates,and use less energy have also caused the shutdown of DLP TV production as of2012.

4. LiquidCrystalDisplay(LCD):

- Liquid Crystal Display TVs are by far the most common TV type available today. First conceived in the 1960s, LCD technology uses a unique state of matter called liquidcrystals.Inthisstate,moleculesarefluidbutretainaspecificcrystalstructure such that they are all oriented the sameway.
- ForLCDs,eachpixelofthedisplaycontainsseveralpreciselyorientedliquidcrystal molecules that are aligned between two electrodes and two polarizing filters. When the screen is inert, no light can passthrough.
- Butwhenanelectricfieldisapplied,theliquidcrystalsrotatetoadegreedependent on the voltage applied, which lets a corresponding amount of light pass through the screen at that pixel.
- So, by applying different voltages to different pixels across the screen, an image can beviewed.MostLCDTVstodayarebacklitwithLEDlights,andaresometimesjust referred to as LED TVs.
- LCDshavebeenusedforalmostallscreensproducedinthelastdecade(2010s), including, among others, computers, clocks, smartphones, and watches.
- This is in part due to the versatility of the LCD technology, allowing screen sizes rangingfromsmallwatchesallthewayuptoverylargeTVs.AndunlikepreviousTV technologies, LCD screens are all flat and lightweight.

5. OrganicLight-EmittingDiode(OLED)Display:

- Anorganiclight-emittingdiode(OLED)display containsanorganiccompoundthat emits light in response to electricity.

- Theorganiccompound, whichcanbesmallmoleculesorpolymers,issituated between two electrodes, at least one of which is transparent for viewing the fluorescent compound clearly.
- UnlikeLCDs,no backlightingisrequiredsincethecompounditselfislight-emitting, so OLEDs can display deeperblacks than LCD screens and generally display greater contrast ratios in ambient light.
- They can also be even thinner and lighter than LCDs because filter layers are not required. Whiletherearemanyadvantages of OLEDtechnologyand OLEDTVshave started slowly to replace LCD TVs over the last decade, the take over isn't nearly as fast or sure of victory as the transition from cathode-ray tubes to LCDs for our television viewing.
- And that's because, even with all the excitement in and potential of the technology, there are still some significant drawbacks. The biggest problem with OLEDs is a finitelifespanonthelightemittingfluorescentmaterials,resultinginamuchshorter lifespan than LCDs.

6. <u>QuantumLight-EmittingDiode(QLED):</u>

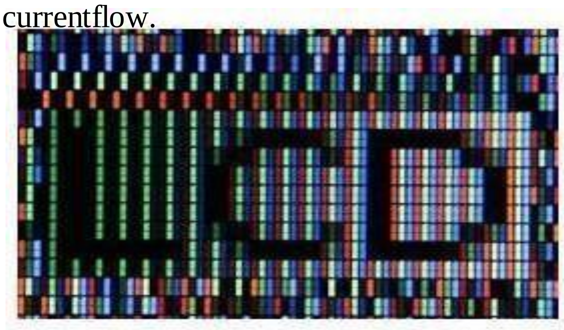
- Justafewyearsold,quantumlight-emittingdiode(QLED)displaysarethenext generation of LCD displays.
- TinynanoparticlescalledquantumdotsareemendedintheLCDdisplay,which dramatically improves color and brightness.
- OLEDsstillhavebettercontrastratiosoverQLEDs,butQLEDscreenscanbelarger, last longer, and are not susceptible to burn-in. Plus, QLED TVs are more affordable than OLED TVs, ranging between LCDs and OLEDs in price.

Discusstheprincipleofoperation-LCDdisplay,LargeScreen -

Display.LCDdisplay

A liquid crystal display or LCD draws its definition from its name itself. It is a combination oftwostatesofmatter,thesolidandtheliquid.LCDusesaliquidcrystalto produceavisible image. Liquid crystal displays are super-thin technology display screens that are generally used in laptop computer screens, TVs, cell phones, and portable video games. LCD's technologies allow displays to be much thinner when compared to a cathode ray tube(CRT) technology.

Liquid crystal display is composed of several layers which include two polarized panel filters and electrodes. LCD technology is used for displaying the image in a notebook or someotherelectronicdeviceslikeminicomputers.Lightisprojectedfromalensonalayer of liquid crystal. This combinationofcoloredlightwiththegrayscaleimageofthecrystal(formedaselectric currentflow.



An LCD

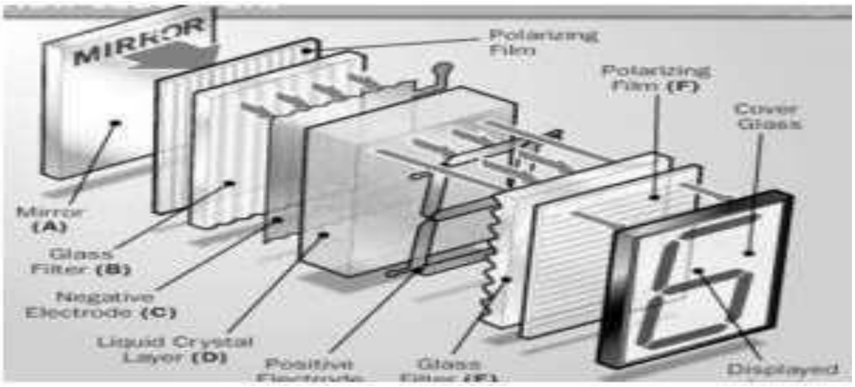
AnLCDiseithermadeupofanactivematrixdisplaygridorapassivedisplaygrid.Mostof the Smartphone's with LCD technology uses active matrix display, but some of the older displays still make use of the passive display grid designs. Most of the electronic devices mainlydependonliquidcrystaldisplaytechnologyfortheirdisplay.Theliquidhasaunique advantage of having low power consumption than the [LED](LED)or cathode ray tube.

Theliquidcrystaldisplayscreenworksontheprincipleofblockinglightratherthan emitting light. LCDs require a backlight as they do not emit light them. We always usedevices which are made up of LCD's displays which are replacing the use of cathode ray tube. Cathode ray tube draws more power compared to LCDs and is also heavier and bigger.

HowLCDsareConstructed?

Simplefactsthat shouldbeconsideredwhile makingan LCD:

1. Thebasicstructureofthe LCDshould becontrolled bychanging theappliedcurrent.
2. Wemust usepolarizedlight.
3. Theliquidcrystalshouldablebetocontrolbothoftheoperationstotransmitor can also able to change the polarized light.



As mentioned above that we need totake two polarized glass pieces filterin the making of the liquid crystal. The glass which does not have a polarized film on the surface of it must be rubbedwithaspecialpolymerthatwillcreatemicroscopicgroovesonthesurfaceofthe polarizedglassfilter.Thegroovesmustbeinthesamedirectionasthepolarizedfilm.

Now we have to add a coating of pneumatic liquid phase crystal on one of the polarizing filters of the polarized glass. The microscopic channel causes the first layer molecule to align with filter orientation. When the right angle appears at the first layer piece, we should add a second piece of glass with the polarized film. The first filter will be naturally polarized as the light strikes it at the starting stage.

Thus the light travels through each layer and guided to the next with the help of a molecule. Themolecule tends to change its planeof vibration of the light to match itsangle. When the lightreachesthefarend oftheliquidcrystalsubstance,itvibratesatthesameangleasthatof the final layer of the molecule vibrates. The light is allowed to enter into the device only if the second layer of the polarized glass matches with the final layer of the molecule.

HowLCDs Work?

The principle behind the LCDs is that when an electrical current is applied tothe liquid crystal molecule, the molecule tends to untwist. This causes the angle oflight which is passing through the molecule of the polarized glass and also causes a change in the angle of the top polarizing filter. As a result, a little light is allowed to pass the polarized glass through a particular area of the LCD.

Thus that particular area will become dark compared to others. The LCD works on the principle of blocking light. While constructing the LCDs, a reflected mirror is arranged at the back. An electrode plane is made of indium-tin-oxide which is kept on top and a polarized glass with a polarizing film is also added on the bottom of the device. The complete region of the LCD has to be enclosed by a common electrode and above it should be the liquid crystal matter.

Next comes the second piece of glass with an electrode in the form of the rectangle on the bottom and, on top, another polarizing film. It mustbe considered that both the pieces are kept at the right angles. When there is no current, the light passes through the front of theLCD it will be reflected by the mirror and bounced back. As the electrode is connected to a battery the current from it will cause the liquid crystals between the common-plane electrode and the electrode shaped like a rectangle to untwist. Thus the light is blocked from passing through. That particular rectangular area appears blank.

CATVsystems&Types&networks

Thetelevisioncableindustryhasbecomeamajorserviceproviderbyallowingdatatransport over upgraded CATV cable networks. The cable industry has had many plans for delivering unique services to its subscribers. High-resolution digital video has been part of the plan, as well as TV set-top boxes that provide interactive game interfaces, WebTV, and other features. Cable data networks make this possible.

Cable data networks are one of several residential broadband schemes. Other schemes includeDSL(DigitalSubscriberLine),satellitesystemssuchasHughesNetworkSystem's DirecPC, and wireless data systems discussed under "Wireless Broadband Access Technologies." In fact, MMDS (Multichannel Multipoint Distribution Services) has been called a "wireless cable data network" solution because of its multipoint characteristics.

CableNetworkProviderServices

Cable operators can add various types of Internet-related services to enhance their networks. For example, caching ensures that the benefits of high-speed Internet access available to cablenetworksubscribersisnotlostwhenaccessingslowerlinksandserversontheInternet. For example, a number of users in the system may frequently access a server that is connected to the Internet via a 56K modem link. The cable operator can cache this informationonitslocalserverstomaketheinformationimmediatelyavailable tosubscribers.

IP telephony support allows users to makevoice telephone calls over the cable network. This requiresacablemodemthatprovidesintegratedMTA(multimediaterminaladapter)support, which basically means it has a telephone jack and a computer connector. IP telephony over cable networks supports multiple phone and simultaneous calls, which are set up as virtual circuits. Additional virtual circuits can be created at any time, with available bandwidth and the number of handsets/headsets being the only restriction. Incoming calls are set up as another virtual circuit. At the cable operator end, an IP-to-PSTN (public-switched telephone network) gateway converts and routes IP-based telephone calls into the traditional telephone system.

Cable operators are working to provide a number of services to their customers, including audioandvideoserversthatcanserveupmusicandmovies.Abigplayeris@Home,acable- specific ISP, meaning that it provides content to cable companies throughout the United States. Cable companies such as Cox Communications deploy @Home Network as part of their interactive content for homes and workplaces. Cox is an equity partner in At Home Corporation, along with Comcast Corporation and Tele-Communications.

Corporateusersshouldkeepinmindthatcablenetworksareprimarilygearedtowardhome users, not companies that want to build high-speed remote office connections, extranets, or other high-usage links. Many cable operators may discourage large organizations from connecting to their cable system.

StandardsDevelopment

Cablestandardsaredesignedtoprovideinteroperabilitybetweencablemodemsandhead-end gear. Subscribers should be able to buy off-the-shelf cable modems that are guaranteed to connectoverthecablenetworkwithequipmentinstalledatthecableoperatorssite.Standards benefit both subscribers and operators by making connection easier and promoting new applications. The most important standards are outlined here:

- **DOCSIS (Data over Cable Interface Specification):** DOCSISistheresultofwork done by MCNS (Multimedia Cable Network System Partners Ltd.). This standard has become the most interesting and important, and is covered under the "DOCSIS"heading.
- **DAVIC (Digital Audio Visual Council):** DAVIC was a non-profit group that promoteddigitalaudio-visualapplicationsandservicesbasedonspecificationswhich maximized interoperability across countries and applications/services. DAVIC developed a digital video broadcast reference model that is popular in Europe and preferred by the European Cable Communications Association (ECCA), a European cable industry organization. DAVIC is oriented toward delivering digital video to

homeusers,whileDOCSISisbetterpositionedfordatadelivery.DAVICcompleted its work and closed in 2000.

- **IEEE 802.14 Working Group:** This group is defining the physical layer and a MAC (Medium Access Control) layer protocol for HFC networks. The architecture specifies an HFC cable plant with a radius of 80 kilometers from the head end. The group's goal is to develop a specification for delivering Ethernet traffic over the network.ATMnetworkingwasalso consideredforthedeliveryofmultimediatraffic. There has been some conflict between the work done by this IEEE group and the work done by MCNS, but MCNS is implementing part of the IEEE's physical layer work. Still, a paper about cable standards at the CATV Cyberlab claims that "the IEEE 802.14 effort was a failure." In fact, MCNS began work on DOCSIS because the IEEE was not working fast enough on its specification.
- **IETF IP over Cable Data Network (IPCDN) Working Group:** The IPCDN is defining how IP can be delivered over thecable network. Most of its work is centered on DOCSIS and addresses higher levels than the IEEE 802.14 Working Group, which is concentrating on physical and data link layer protocols. IPCDN is defining a specification to map both IPv4 and IPv6 into the HFC access networks. The group is interested in multicast, broadcast, address mapping and resolution (for IPv4), and neighbordiscovery(forIPv6).IPCDNisalsoworkingonbandwidthmanagementand guarantees using RSVP, security using IPSec, and management using SNMP.

DigitalTVTechnology-DigitalTVSignals,Transmissionof digital TV signals & Digital TV receiver Video programme processor unit.

Digital television (**DTV**) is the transmission of television audiovisual signals using digital encoding, in contrast to the earlier analog television technology which used analog signals. At the time of its development it was considered an innovative advancement and represented the first significant evolution in television technology since color television in the 1950s.Modern digital television is transmitted in high definition (HDTV) with greater resolution than analog TV. It typically uses a widescreen aspect ratio (commonly 16:9) in contrast to the narrower format of analog TV. It makes more economical use of scarce radio spectrumspace;itcantransmituptosevenchannelsinthesamebandwidthasasingleanalog channel,and provides many new features that analog television cannot. A transition from analog to digital broadcasting began around 2000.

Differentdigitaltelevisionbroadcastingstandardshavebeenadoptedindifferentpartsofthe world; below are the more widely used standards:

DigitalVideoBroadcasting(DVB)

Advanced Television System Committee (ATSC)

Integrated Services Digital Broadcasting (ISDB)

DigitalTerrestrialMultimediaBroadcasting(DTMB)

Digital Multimedia Broadcasting (DMB)

Formatsandbandwidth

Digital television's roots havebeen tied very closely to the availability of inexpensive, high performance computers. It was not until the 1990s that digital TV became a real possibility.Digitaltelevisionwaspreviouslynotpracticallyfeasibleduetotheimpractically high bandwidth requirements of uncompressed digital video,requiring around 200 Mbit/s (25 MB/s) bit-rate for a standard-definition television (SDTV) signal,and over 1 Gbit/s for high-definition television (HDTV).

Digitaltelevisionsupportsmanydifferentpictureformatsdefinedbythebroadcasttelevision systems which are a combination of size and aspect ratio (width to height ratio).

With digital terrestrial television (DTT) broadcasting, the range of formats can be broadly dividedintotwocategories:highdefinitiontelevision(HDTV)forthetransmissionofhigh-definition video and standard-definition television (SDTV). These terms by themselves are not very precise, and many subtle intermediate cases exist.

One of several different HDTV formats that can be transmitted over DTV is: 1280 × 720 pixelsinprogressivescanmode(abbreviated*720p*)or1920×1080pixelsininterlacedvideo mode (*1080i*). Each of these uses a 16:9 aspect ratio. HDTV cannot be transmitted over analog television channels because of channel capacity issues.

Receivingdigitalsignal

There are several different ways to receive digital television. One of the oldest means of receiving DTV (and TV in general) is from terrestrial transmitters using an antenna (known as an *aerial* in some countries). This way is known as Digital terrestrial television (DTT). WithDTT,viewersarelimitedtochannelsthathaveaterrestrialtransmitterinrangeoftheir antenna.

Other ways have been devised to receive digital television. Among the most familiar to people are digital cable and digital satellite. In some countries where transmissions of TV signals are normally achieved by microwaves, digital MMDS is used. Other standards, such asDigitalmultimediabroadcasting(DMB)andDVB-H,havebeendevisedtoallowhandheld devices such as mobile phones to receive TV signals. Another way is IPTV, that is receiving TV via Internet Protocol, relying on digital subscriber line (DSL) or optical cable line. Finally,analternativewayistoreceivedigitalTVsignalsviatheopenInternet(Internet television), whether from a central streaming service or a P2P (peer-to-peer) system.

PossibleShortTypeQuestionsWithAnswers

1. **Mentionthemajorfunctionofthecamera tube?**

Ans-Themajorfunctionofthecameratubeisto convertanopticalimage into electricalsignals.

2. **Definevisualacuity?**

Ans-Visualacuitycanbedefined astheabilityofhumaneyetoresolvefinerdetailsin a picture.

3. **Defineaspectratio?(w-20)**

Ans-Aspectratiocanbedefinedastheratioof widthtoheightofthepictureframe. For television, itis standardized as 4:3.

4. **Defineluminousflux?**

Ans- Luminous flux can be defined as the radiated luminous power or power ofvisiblelightexpressedinterms ofits effectontheaverageornormalhuman eye.

5. **Defineluminance?**

Ans-Luminancecanbedefinedasthequantityoflightintensityemittedpersquare centimeter of anilluminated area.

6. **Whatarerodsand cones?**

Ans- The retina of the human eye consists of light sensitive cellular structures of two kindsnamelyrodsandcones.Therodssenseprimarilythebrightnesslevelsincluding very faint impressions.The cones aremainly responsible for colourperception.There are 65 lakhs cones and about 10 crores rodsconnected to the brain through 8 lakhs optic nerve fibres.

7. **Whyisscanningnecessaryintelevisionsystem?**

Ans-Scanning is the important process carried out in a television system inorder to obtain continuous frames andprovidesmotionofpicture.Thesceneisscannedbothin the horizontal and vertical directions simultaneously in a rabid rate. As a result sufficient number of complete picture offrames per second is obtained to give the illusion of continuous motion.

8. **Howwillyousolvetheflickeringproblem?**

Ans- The flickering problem is solved in motion pictures by showing each picture twice.Hence48views ofthe scene are shownpersecond althoughthey are stillthe same 24 pictures frames per second. As a result of the increased.

9. DefineFlickerandResolutionOfTV.?(w-20)

Ans-Flickeriswheneachframeisonlydisplayedforashorttimewith black frames inserted between.

Resolutionisthetotalnumberofpixelsavailableonadisplayscreen or total pixels contained within the processed picture,

<u>PossibleLongQuestions</u>

1. Explainthefunctionofeachblockofa TVTransmitter.(w-20)
2. Explainthefunctionofeachblockofa TVReciever.
3. BrieflyexplainaboutthecolorTVsignals.
4. ExplaindifferenttypesofTVaccordingtoits technology.
5. ExplainprincipleofoperationofLCD.(w-20)
6. WithNeatDiagram,explainthe compositevideosignal.(w-20

CHAPTERNUMBER-04:

MICROWAVE ENGINEERING

LEARINGOBJECTIVES:

Definemicrowavewaveguides.

Operationofrectangularwaveguidesanditsadvantages.

PropagationofEMwavethroughwaveguidewithTE&TM modes.

Circularwaveguide.

OperationalCavityResonator

WorkingofDirectionalCoupler,Isolators&Circulators.

MicrowaveTubes-PrincipleofOperationofTwoCavityKlystron

Principleofoperationoftravellingwavetubes

PrincipleofoperationofCyclotron.

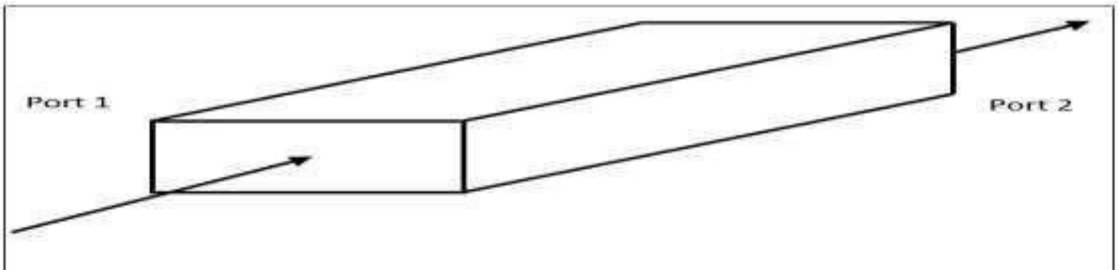
PrincipleofoperationsofTunnelDiode&GunnDiode.

DefineMicrowaveWaveGuides.-

Microwavespropagatethroughmicrowavecircuits,componentsanddevices,whichactasa part of Microwave transmission lines, broadly called as Waveguides.

Ahollowmetallictubeofuniformcross-sectionfortransmittingelectromagneticwavesby successive reflections from the inner walls of the tube is called as a **Waveguide**.

Thefollowing figureshows anexampleof awaveguide.



A two-port rectangular waveguide

Awaveguideisgenerallypreferredinmicrowavecommunications.Waveguideisaspecial form of transmission line, which is a hollow metal tube. Unlike a transmission line, a waveguide has no center conductor.

ThemaincharacteristicsofaWaveguideare−

- Thetubewallprovidesdistributedinductance.
- Theemptyspacebetweenthe tubewalls providedistributedcapacitance.
- Thesearebulky and expensive.

AdvantagesofWaveguides

FollowingarefewadvantagesofWaveguides.

- Waveguidesareeasytomanufacture.
- Theycanhandleverylargepower*inkilowatts*.
- Powerlossisverynegligibleinwaveguides.
- Theyofferverylowloss*lowvalueofalpha−attenuation*.
- Whenmicrowaveenergytravelsthroughwaveguide,itexperienceslowerlossesthan a coaxial cable.

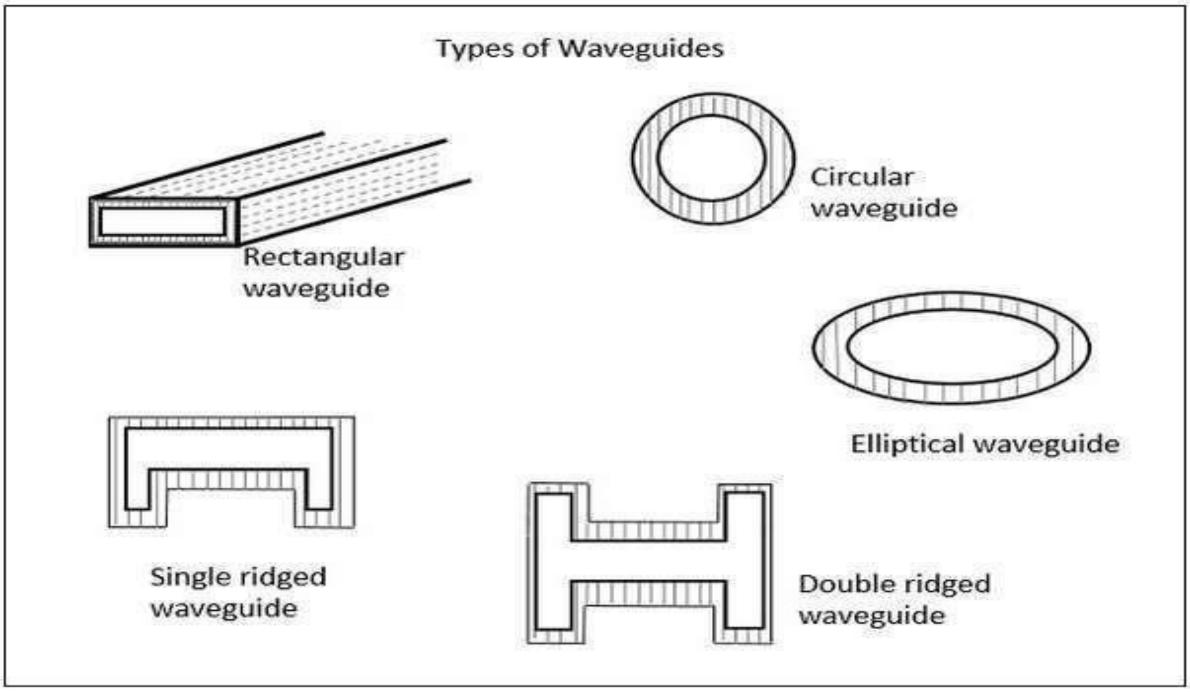
TypesofWaveguides

Therearefivetypes ofwaveguides.

- Rectangularwaveguide
- Circularwaveguide
- Ellipticalwaveguide

- Single-ridgedwaveguide
- Double-ridgedwaveguide

Thefollowing figures show thetypes ofwaveguides.

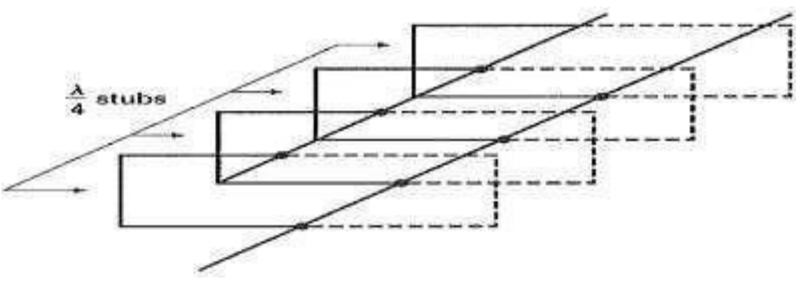


Thetypesofwaveguidesshownabovearehollowinthecenterandmadeupofcopperwalls. These have a thin lining of Au or Ag on the inner surface.

Operationofrectangularwaveguidesanditsadvantage.

Rectangular Waveguides – As we know already that the term skin effect indicated that the majority of the current flow (at very high frequencies) will occur mostly along the surface of the conductor and very little at the center. This phenomenon has led to the development of hollow, conductors known as waveguides.

To simplify the understanding of the waveguide action, which explained how the quarter-wave shorted stub appeared as a parallel resonant circuit (Hi Z) to the source. This fact can be used in the analysis of a wave guide; i.e., a transmission line can be transformed into a waveguide by connecting multiple quarter-wave shorted stubs (Figure 1). These multiple connections represent a Hi Z to the source and offer minimum attenuation of a signal.



In a similar way, a pipe with any sort of cross section could be used as a waveguide, but the simplest cross sections are preferred. Waveguides with constant rectangular or circular cross sections are normally employed, although other shapes may be used from time to time for specialpurposes.Withregulartransmissionlinesandwaveguides,thesimplestshapesare the ones easiest to manufacture, and the ones whose properties are simplest to evaluate.

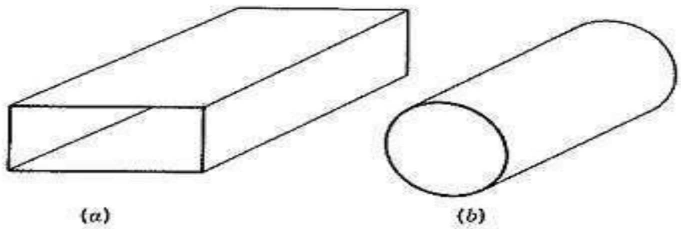


FIGURE 10-2 Waveguides. (*a*) Rectangular; (*b*) circular.

Arectangularwaveguidesisshownin Figure10-2,asis acircularwaveguideforcomparison. In a typical system, there may be an antenna at one end of a waveguide and a receiver or transmitterat theother end. Theantennagenerates electromagneticwaves, which travel down the waveguide to be eventually received by the load.

The walls of the guide are conductors, and therefore reflections from them take place. It is of the utmost importance to realize that conduction of energy lakes place not through the walls, whosefunction is only toconfinethis energy,butthrough thedielectricfilling thewaveguide, which is usually air. In discussing the behavior and properties ofwaveguides, it is necessary to speak of electric and magnetic fields, as in wave propagation, instead of voltages and currents, as in transmission lines. This is the only possible approach, but it does make the behavior of waveguides more complex to grasp.

AdvantagesofRectangularWaveguides:

The first thing that strikes us about the appearance of a (circular) waveguide is that it looks like a coaxial line with the insides removed. This illustrates the advantages that waveguides possess. Since it is easier to leave out the inner conductor than to put it in, waveguides are simpler to manufacture than coaxial lines. Similarly, because there is neither an inner conductor nor the supporting dielectric in a waveguide, flashover is less .likely. Therefore the power-handling ability of waveguides is improved, and is about 10 times as high as for coaxial air-dielectric rigid cables of similar dimension (and much more when compared with flexible solid-dielectric cable).

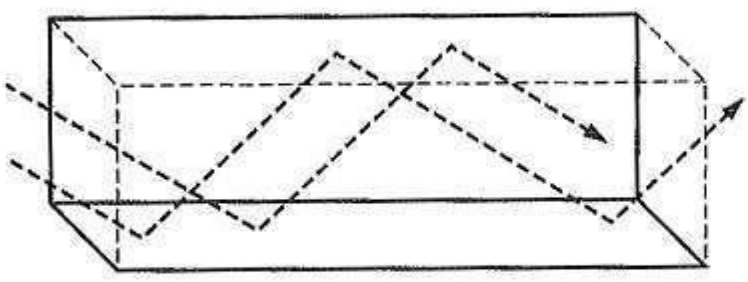


FIGURE 10-3 Method of wave propagation in a waveguide.

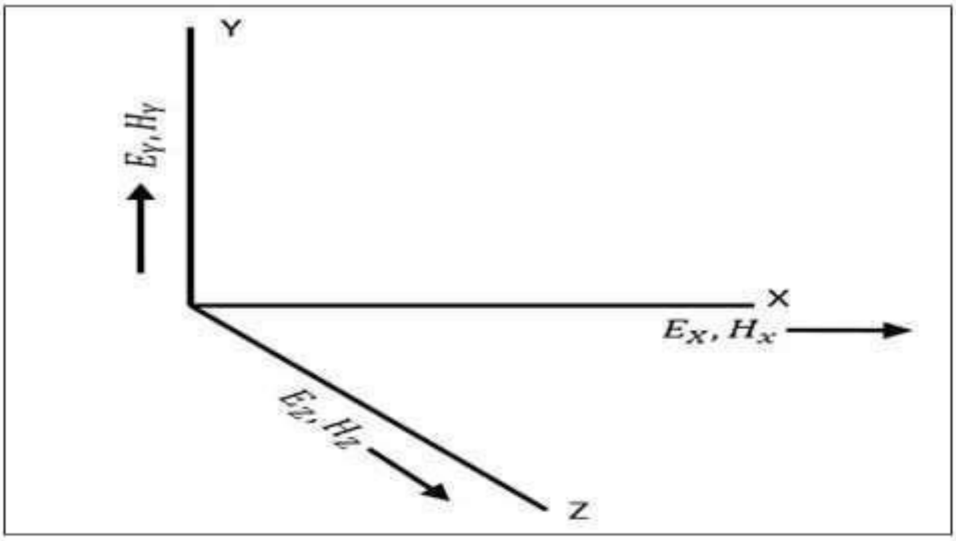
There is nothing but air in a waveguide, and since propagation is by reflection from the walls instead of conduction along them, power losses in waveguides are lower than in comparable transmission lines (see Figure 10-3). A 41-min air-dielectric cable has an attenuation of 4.0 dB/100 m at 3 GHz (which is very good for a coaxial line). This rises to 10.8 dB/100 m for a similar foam-dielectric flexible cable, whereas the figure for the copper WR284 waveguide is only 1.9 dB/ 100 m.

Everything else being equal, waveguides have advantages over coaxial lines in mechanical simplicity and a much higher maximum operating frequency (325 GHz as compared with 18 GHz) because of the different method of propagation.

PropagationofEMwavethroughwaveguidewithTE&TMmodes.

A wave has both electric and magnetic fields. All transverse components of electric and magneticfieldsaredeterminedfromtheaxialcomponentsofelectricandmagneticfield,in the z direction. This allows mode formations, such as TE, TM, TEM and Hybrid in microwaves. Let us have a look at the types of modes.

Thedirectionoftheelectricandthemagneticfieldcomponentsalongthreemutually perpendicular directions x, y, and z are as shown in the following figure.



TypesofModes

Themodesofpropagationofmicrowavesare−

TEMTransverseElectromagneticWave

Inthismode,boththeelectricandmagneticfields arepurelytransverse to thedirectionof propagation. There are no components in 'Z'direction.

$$E_z = 0 \text{ and } H_z = 0$$

TETransverseElectricWave

Inthismode,theelectricfieldispurelytransversetothedirectionofpropagation,whereas the magnetic field is not.

$$E_z=0 \text{ and } H_z\neq 0$$

TMTransverseMagneticWave

Inthismode,themagneticfieldispurelytransversetothedirectionofpropagation,whereas the electric field is not.

$$E_z\neq 0 \text{ and } H_z=0$$

HEHybrid Wave

Inthismode,neithertheelectricnorthemagneticfieldispurelytransversetothedirectionof propagation.

$$E_z\neq 0 \text{ and } H_z\neq 0$$

Multi conductor lines normally support TEM mode of propagation, as the theory of transmissionlinesisapplicabletoonlythosesystemofconductorsthathaveagoandreturn path, i.e., those which can support a TEM wave.

Waveguides are single conductor lines that allow TE and TM modes but not TEM mode. OpenconductorguidessupportHybridwaves.Thetypesoftransmissionlinesarediscussed in the next chapter.

Circularwaveguide.

A waveguide is a hollow metal tube (rectangular or circular in cross section) that transmits electromagneticenergyfromoneplacetoanother.Awaveguidewithacircularcross-section is called as **Circular Waveguide**. It supports both transverse electric (TE) and transverse magnetic(TM)modes.TE11isthedominantmodeinacircular waveguidei.e.,asignalin this mode propagates with the minimum degradation.

Thecircularwaveguideiseasiertomanufacturethanrectangularwaveguidesandisrelatively easy to install. It is usually used to connect a horn antenna with a reflector in tracking radars and for long-distance waveguide transmission above 10 GHz.

The cut-off frequency of a circular waveguide is inversely proportional to its radius. See the formulabelow -ris theradiusofthecircularwaveguideand Cisthespeed of light.Circular waveguide cut off frequency can be calculated by the following formula,

Formula:

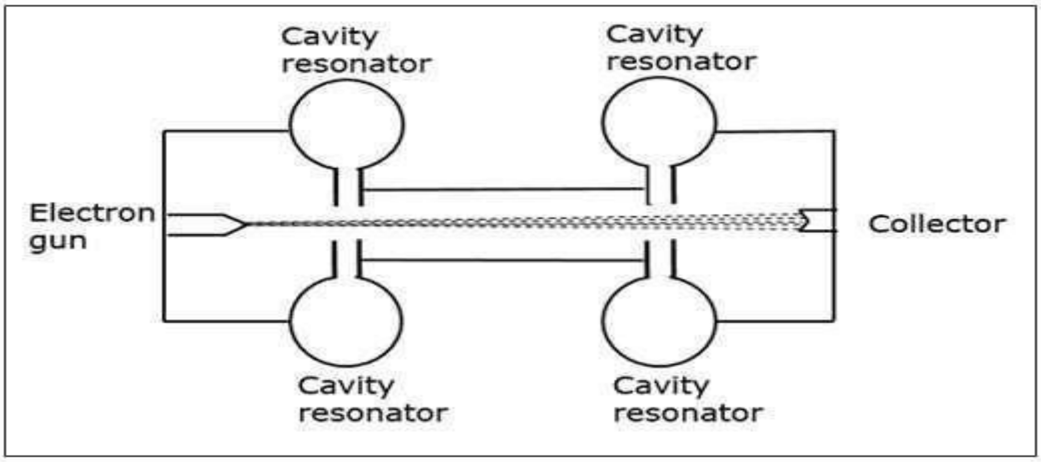
$$f_c = \frac{1.8412 \times C}{2 \times \pi \times r}$$

Basedonfrequencybands,therearefixedwaveguidesizesforcircular waveguides.

OperationalCavityresonator.(CavityKlystron)

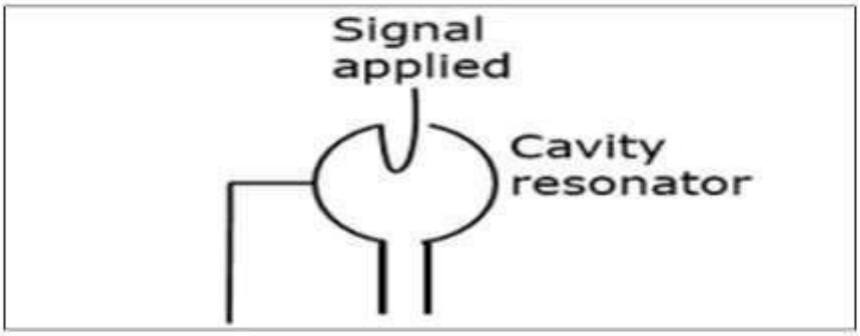
ForthegenerationandamplificationofMicrowaves,thereisaneedofsomespecialtubes called as **Microwave tubes**. Of them all, **Klystron** is an important one.

TheessentialelementsofKlystronareelectronbeamsandcavityresonators.Electronbeams are produced from a source and the cavity klystrons are employed to amplify the signals. A collector is present at the end to collect the electrons. The whole set up is as shown in the following figure.



Theelectronsemittedbythecathodeareacceleratedtowardsthefirstresonator.Thecollector at the end is at the same potential as the resonator. Hence, usually the electrons have a constant speed in the gap between the cavity resonators.

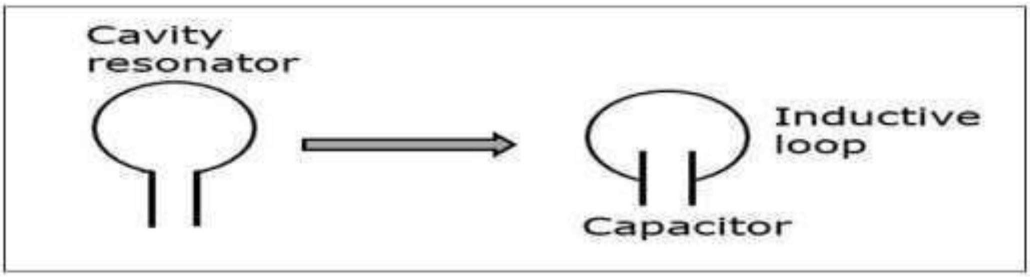
Initially,thefirstcavityresonatorissuppliedwithaweakhighfrequencysignal,whichhasto be amplified. The signal will initiate an electromagnetic field inside the cavity. This signal is passed through a coaxial cable as shown in the following figure.



Due to this field, the electrons that pass through the cavity resonator are modulated. On arrivingatthesecondresonator,theelectronsareinducedwithanotherEMFatthesame frequency. This field is strong enough to extract a large signal from the second cavity.

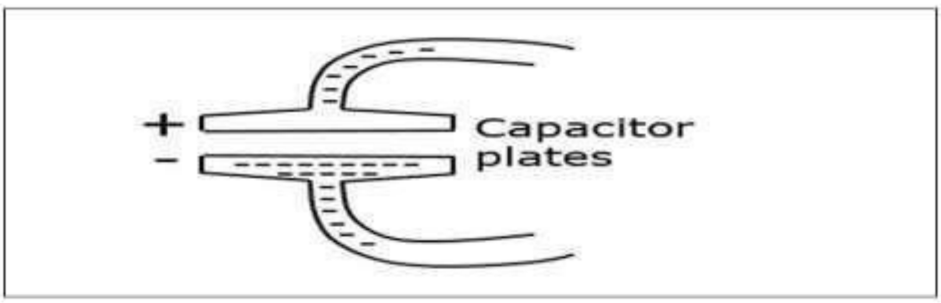
CavityResonator

Firstletustrytounderstandtheconstructionaldetailsandtheworkingofacavityresonator. The following figure indicates the cavity resonator.



A simple resonant circuit which consists of a capacitor and an inductive loop can be comparedwiththiscavityresonator.Aconductorhasfreeelectrons. Ifachargeisappliedto thecapacitortogetitchargedtoavoltageofthispolarity,manyelectronsareremovedfrom the upper plate and introduced into the lower plate.

The plate that has more electron deposition will be the cathode and the plate which has lesser numberofelectronsbecomestheanode.Thefollowingfigureshowsthechargedepositionon the capacitor.



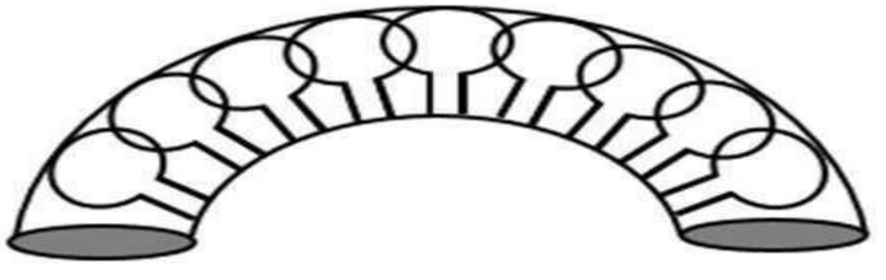
The electric field lines are directed from the positive charge towards the negative. If the capacitor is charged with reversepolarity, then the direction ofthe field is also reversed. The displacement of electrons in the tube, constitutes an alternating current. This alternating currentgivesrisetoalternatingmagneticfield,whichisoutofphasewiththeelectricfieldof the capacitor.

When the magnetic field is at its maximum strength, the electric field is zero and after a while,theelectricfieldbecomesmaximumwhilethemagneticfieldisatzero.Thisexchange of strength happens for a cycle.

ClosedResonator

Thesmallerthevalueofthecapacitorandtheinductivityoftheloop,the higherwillbethe oscillation or the resonant frequency. As the inductance of the loop is very small, high frequency can be obtained.

To produce higher frequency signal, the inductance can be further reduced by placing more inductiveloopsinparallelasshowninthefollowingfigure.Thisresultsintheformationofa closed resonator having very high frequencies.



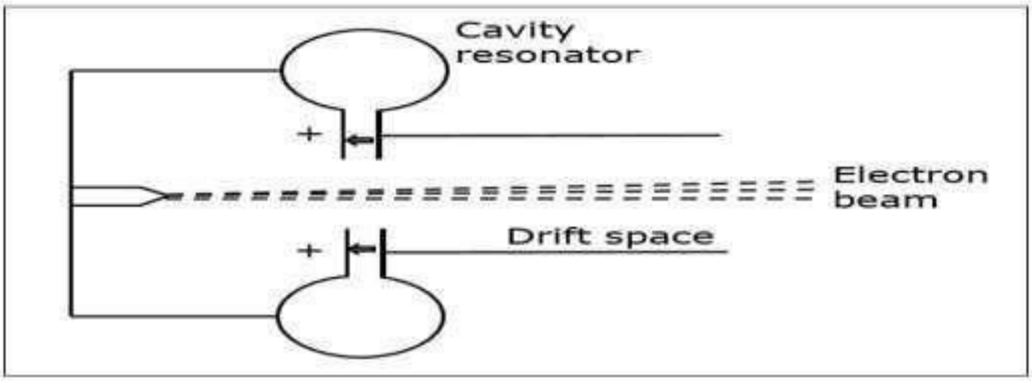
Cross-section of Cavity Resonator

In a closed resonator, the electric and magnetic fields are confined to the interior of the cavity.Thefirstresonatorofthecavityisexcited bytheexternalsignalto beamplified.This signal must have a frequency at which the cavity can resonate. The current in this coaxial cable sets up a magnetic field, by which an electric field originates.

WorkingofKlystron

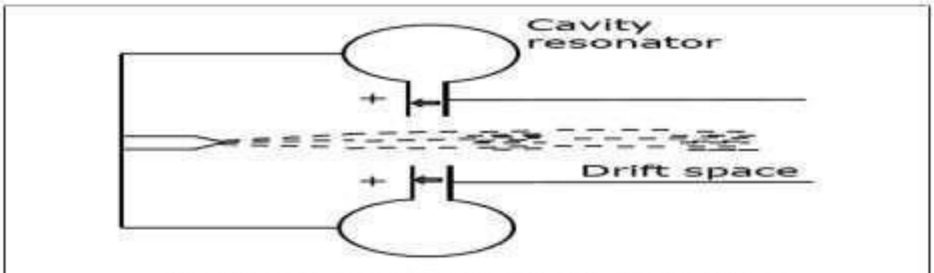
Tounderstandthemodulationoftheelectronbeam,enteringthefirstcavity,let'sconsiderthe electric field. The electric field on the resonator keeps on changing its direction of the induced field. Depending on this, the electrons coming out of the electron gun, get their pace controlled.

As the electrons are negatively charged, they are accelerated if moved opposite to the directionoftheelectricfield.Also,iftheelectronsmoveinthesamedirectionoftheelectric field, they get decelerated. This electric field keeps on changing, therefore the electrons are accelerated and decelerated depending upon the change of the field. The following figure indicates the electron flow when the field is in the opposite direction.



Whilemoving,theseelectronsenterthefieldfreespacecalledasthe **driftspace**betweenthe resonators with varying speeds, which create electron bunches. These bunches are created due to the variation in the speed of travel.

Thesebunchesenterthesecondresonator,withafrequencycorrespondingtothefrequencyat whichthefirstresonatoroscillates.Asallthecavityresonatorsareidentical,themovementof electrons makes the second resonator to oscillate. The following figure shows the formation of electron bunches



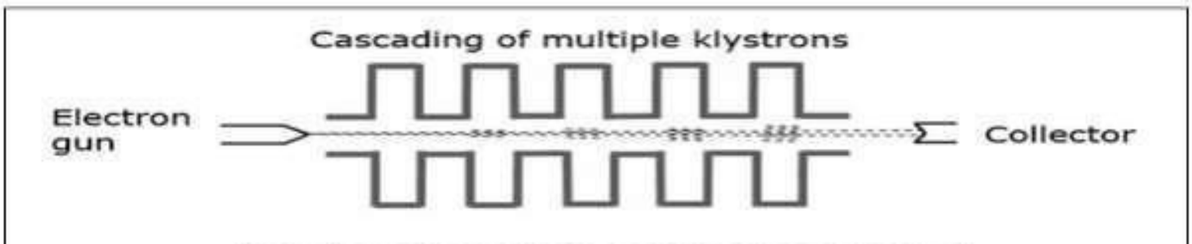
Formation of electron bunches

Theinducedmagneticfieldinthesecondresonatorinducessomecurrentinthecoaxialcable, initiating the output signal. The kinetic energy of the electrons in the second cavity is almost equal to the ones in the first cavity and so no energy is taken from the cavity.

Theelectronswhilepassingthroughthesecondcavity,fewofthemareacceleratedwhile bunches of electrons are decelerated. Hence, all the kinetic energy is converted into electromagnetic energy to produce the output signal.

Amplificationofsuchtwo-cavityKlystronislowandhencemulti-cavityKlystronsareused. The

following figure depicts an example of multi-cavity Klystron amplifier.



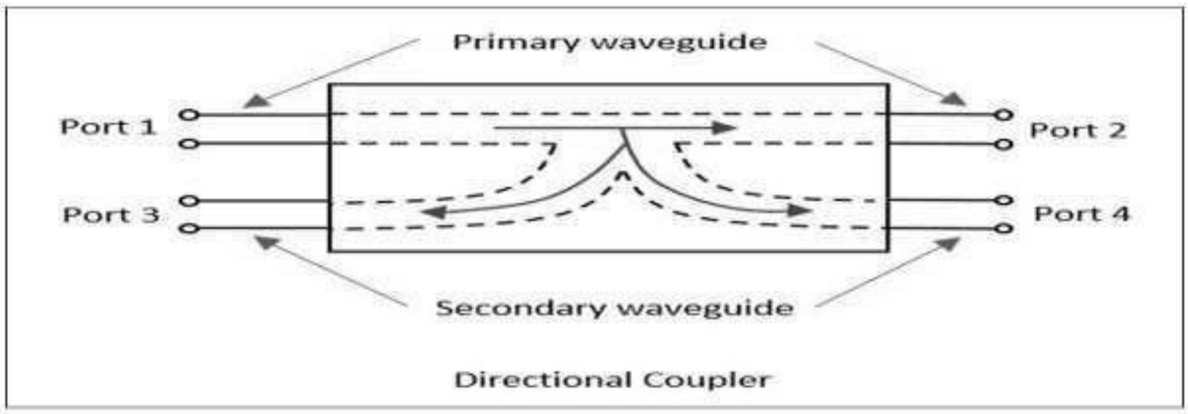
With thesignal applied in thefirst cavity, weget weak bunches in thesecond cavity. These willsetupafieldinthethirdcavity,which producesmoreconcentratedbunchesand soon. Hence, the amplification is larger.

WorkingofDirectionalcoupler,Isolators&Circulator.

Directionalcoupler:

A **Directional coupler** is a device that samples a small amount of Microwave power for measurementpurposes.Thepowermeasurementsincludeincidentpower,reflectedpower, VSWR values, etc.

Directional Coupler is a 4-port waveguide junction consisting of a primary main waveguide andasecondaryauxiliarywaveguide.The followingfigureshows theimageofadirectional coupler.



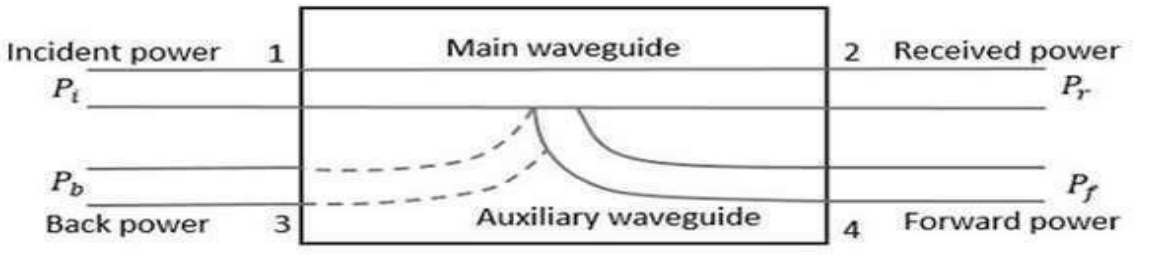
Directionalcouplerisusedtocoupletheicrowavepowerwhichmaybeunidirectionalor bi-directional.

PropertiesofDirectionalCouplers

Thepropertiesofanideal directionalcouplerareasfollows.

- Alltheterminations arematchedtotheports.
- WhenthepowertravelsfromPort1toPort2,someportionofitgetscoupledto Port 4 but not to Port 3.
- Asitisalsoabi-directionalcoupler,whenthepowertravelsfromPort2toPort1, some portion of it gets coupled to Port 3 but not to Port 4.
- IfthepowerisincidentthroughPort3,aportionofitiscoupledtoPort2,butnotto Port 1.
- IfthepowerisincidentthroughPort4,aportionofitiscoupledtoPort1,butnotto Port 2.
- Port1 and3aredecoupled asarePort2 andPort4.

Ideally, the output of Port 3 should be zero. However, practically, a small amount of power called**backpower**isobserved atPort3.Thefollowingfigureindicates thepowerflowin a directional coupler.



Directional Coupler indicating powers

Where

- P_i=Incident poweratPort1
- P_r=ReceivedpoweratPort2
- P_f=ForwardcoupledpoweratPort4
- P_b=BackpoweratPort3

Followingaretheparametersusedtodefinetheperformanceof adirectionalcoupler.

CouplingFactor$C$

TheCouplingfactorofadirectionalcoupleristheratioofincidentpowertotheforward power, measured in dB.

$$C=10\log_{10}\frac{P_i}{P_f}dB$$

Directivity$D$

TheDirectivityofadirectionalcoupleristheratiooforwardpowertothebackpower, measured in dB.

$$D=10\log_{10}\frac{P_f}{P_b}dB$$

Isolation

Itdefinesthedirectivepropertiesofadirectionalcoupler.Itistheratioofincidentpowerto the back power, measured in dB.

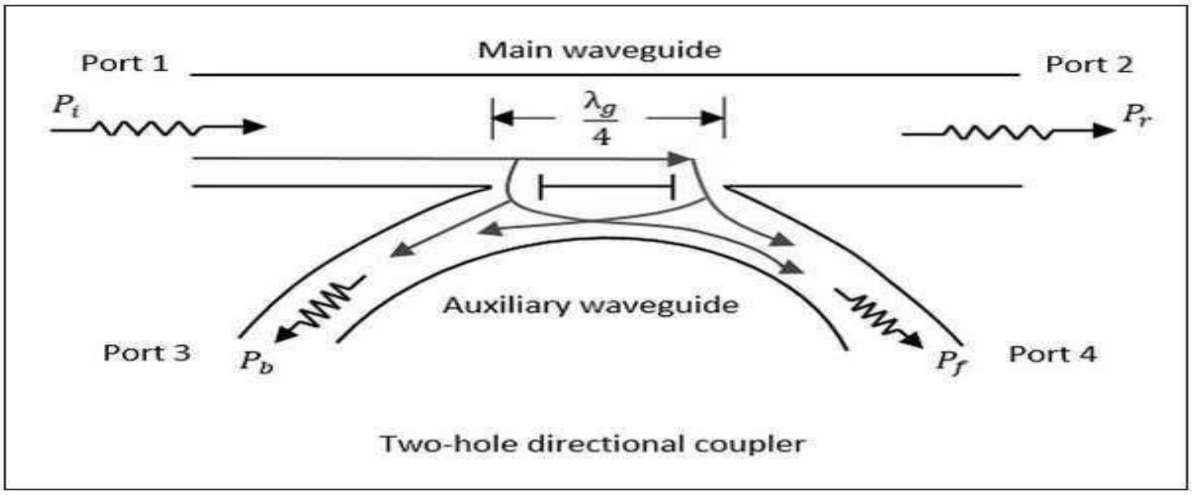
$$I=10\log_{10}\frac{P_i}{P_b}dB$$

IsolationindB=Couplingfactor+Directivity

Two-HoleDirectionalCoupler

Thisisadirectionalcouplerwithsamemainandauxiliarywaveguides,butwith twosmall holes that are common between them. These holes are $\lambda_g/4$

distanceapartwhereλgistheguidewavelength.Thefollowingfigureshowstheimageofa two-hole directional coupler.



A two-hole directional coupler is designed to meet the ideal requirement of directional coupler,whichistoavoidbackpower.SomeofthepowerwhiletravellingbetweenPort1 and Port 2, escapes through the holes 1 and 2.

Themagnitudeofthepowerdependsuponthedimensionsoftheholes.Thisleakage powerat both the holes are in phase at hole 2, adding up the power contributing to the forward power $\mathbf{P_f}$. However, it is out of phase at hole 1, cancelling each other and preventing the back power to occur.

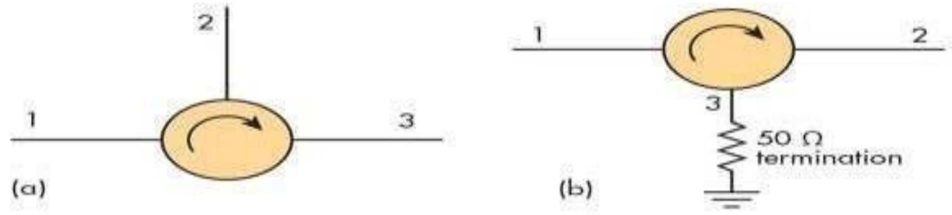
Hence,thedirectivityofadirectionalcoupler improves.

<u>CirculatorsAndIsolators:</u>

These essential devices help direct the flow of microwave signals in RF equipment and systems.Circulatorsandisolatorsarethree-portpassiveelectronicdevicesthathelpdirectthe flow of microwave signals in RF equipment and systems. A port is defined as a connection point for either an input signal, output signal, or termination. *Figure 1a* shows the standard schematic symbol for a circulator. The arrow indicates the unidirectional flow any signals from port to port.

HowaCirculatorWorks

Figure1ashows acirculator,whereany portcan bean input oran output.Asignal applied to port1willbe passed toport2withminimumattenuation.Asignalinputto port2willpassto port 3, but not back to port 1. An input to port 3 will pass to port 1, but not in reverse to port 2.Theamount ofinsertion lossfrom port to portistypicallyin the0.2-to0.75-dB range

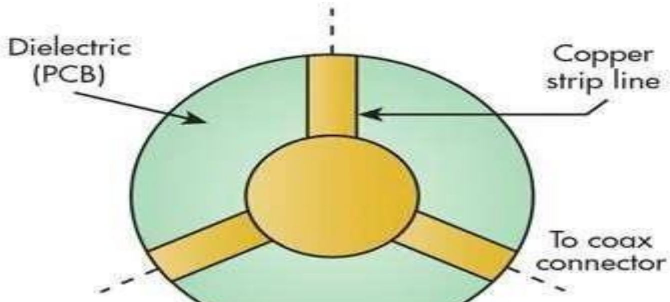


1. Shown are (a) the common schematic symbol of a circulator and (b) the schematic symbol of an isolator.

Ifone of theports is terminated in a resistance equal to the impedance of theport, usually 50 â„¦,thecirculatorbecomesanisolator*(Fig.1b)*.Aninputsignalatport1willpasstoandexit port 2 if port 2 is properly matched to 50 â„¦. If there is a mismatch at port 2, any reflected signal will be passed to port 3 and absorbed by the load. This protects or isolates port 1 from port 2 in the reverse direction.

Construction

AcirculatoristypicallyaY-shapedsectionofmicrostriporstriplinetransmissionlineona printed circuit board or other dielectric *(Fig. 2)*. The line impedance is 50 â„¦. The ports, spaced 120 deg. apart, are commonly terminated with SMA or N-type coaxial connectors.

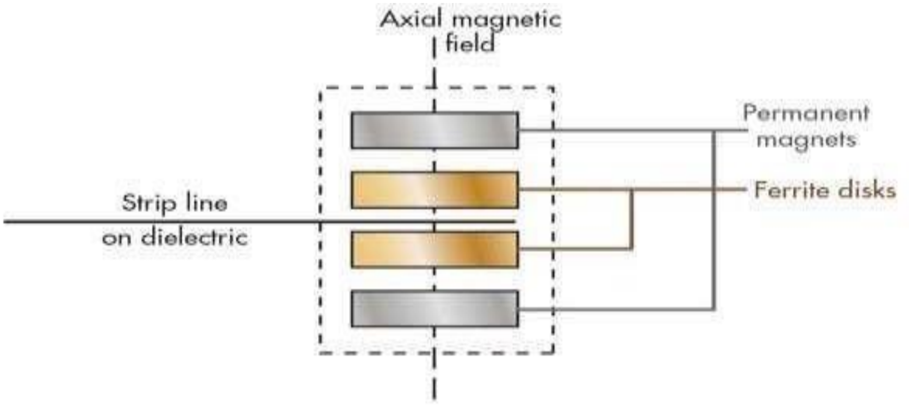


2. The Y-shaped strip line circuit is the heart of the circulator.

The Y-junction assembly is then sandwiched between two layers of ferrite material *(Fig. 3)*. Twostrongpermanentmagnetsarepositionedoneithersideoftheferritedisks.Themagnets send a strong magnetic field axially through the ferrite disks. The ferrite material supports and focuses the magnetic field around the Y-junction. The axial magnetic field is called the bias.

Whenasignalisapplied tooneoftheports,anelectromagneticfieldisset upinthestripline. This field then interacts with the applied bias magnetic field, causing the signal to rotate in one direction to the next adjacent port.

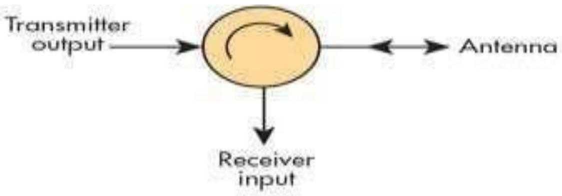
TheassemblymadeupoftheY-junctionandtheferritedisksformsadielectricresonatorthat has a resonant frequency. The circulator is not operated at this frequency. Operation takes place in regions above or below the resonant frequency of the device, where attenuation is minimal.



3. This common construction of a circulator shows a Y strip line, ferrite disks, and magnets. There is no spacing between actual disk components as shown here.

Applications

The most common application of a circulator is as a duplexer. A duplexer allows the transmitter and receiver in a radio or radar unit to share a common antenna *(Fig. 4)*. The transmitter output is applied to port 1 and will pass to port 2, wherethe antennais connected. Thereceiverinputisconnectedtoport3.Asignal receivedbytheantennaispassedtoport3, but not back to port 1. The transmitter output is not passed to the receiver input. The key effect is to prevent the typically high transmitter power from damaging the receiver input circuits.



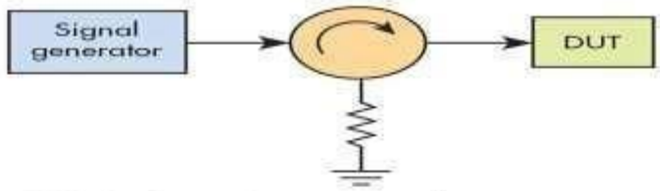
4. This circulator connected as a duplexer allows a transmitter and receiver to share a common antenna.

A common use of an isolator is shown in *Fig. 5*. The isolator is connected between a signal generatorandsomedeviceundertest(DUT).Ifall impedancesarematched, thesignalpasses freely to the DUT. If thereis a mismatch at theDUTor ifthe DUTis disconnected, it creates a high-voltage standing wave ratio (VSWR), causing a large reflected signal. The circulator absorbs this signal, protecting the usually expensive signal generator.

The attenuation of an isolator in the reverse direction is typically in the 20-dB range. If greaterattenuationisneeded,twoisolatorscanbecascadedasshownin*Fig.6*.Theresultisa four-port device that can boost attenuation to about 40 dB or so. Such four-port units are available as a single product rather than two individual isolators.

Specifications

Whenspecifyingorbuyingacirculatororisolator,themostimportantcharacteristicsto consider are:



5. This isolator is connected to protect a signal generator in a test setup.

Microwavetubes-PrincipleofoperationaloftwoCavityKlystron.

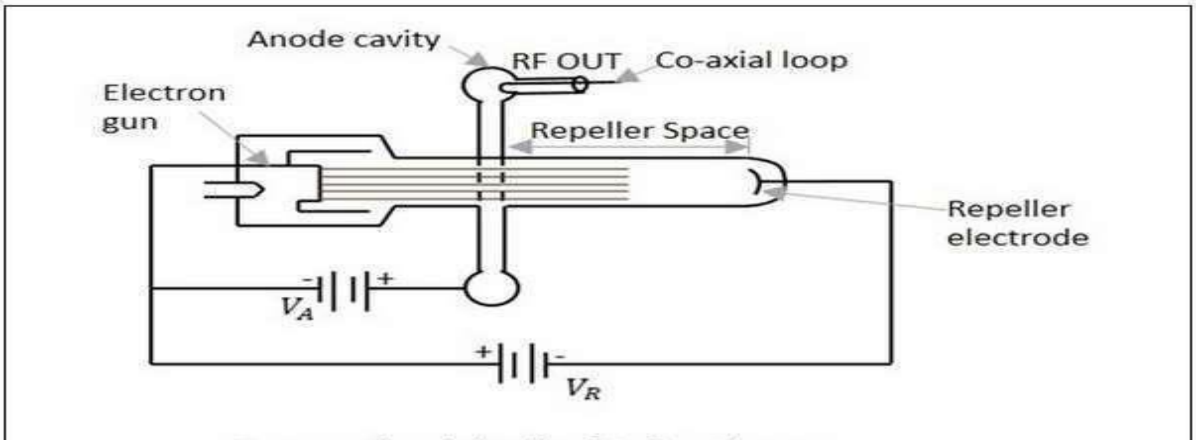
ReflexKlystron:

Thismicrowavegenerator,isaKlystronthatworksonreflectionsandoscillationsinasingle cavity, which has a variable frequency.

ReflexKlystronconsistsofanelectrongun,acathodefilament,ananodecavity,andan electrode at the cathode potential. It provides low power and has low efficiency.

ConstructionofReflexKlystron

Theelectrongunemitstheelectronbeam,whichpassesthroughthegapintheanodecavity. These electrons travel towards the Repeller electrode, which is at high negative potential.
Due to the high negative field, the electrons repel back to the anode cavity. In their return journey,theelectronsgivemoreenergytothegapandtheseoscillationsaresustained.The constructional details of this reflex klystron is as shown in the following figure.



Constructional details of Reflex Klystron

Itisassumedthatoscillationsalreadyexistinthetubeandtheyaresustainedbyitsoperation. The electrons while passing through the anode cavity, gain some velocity.

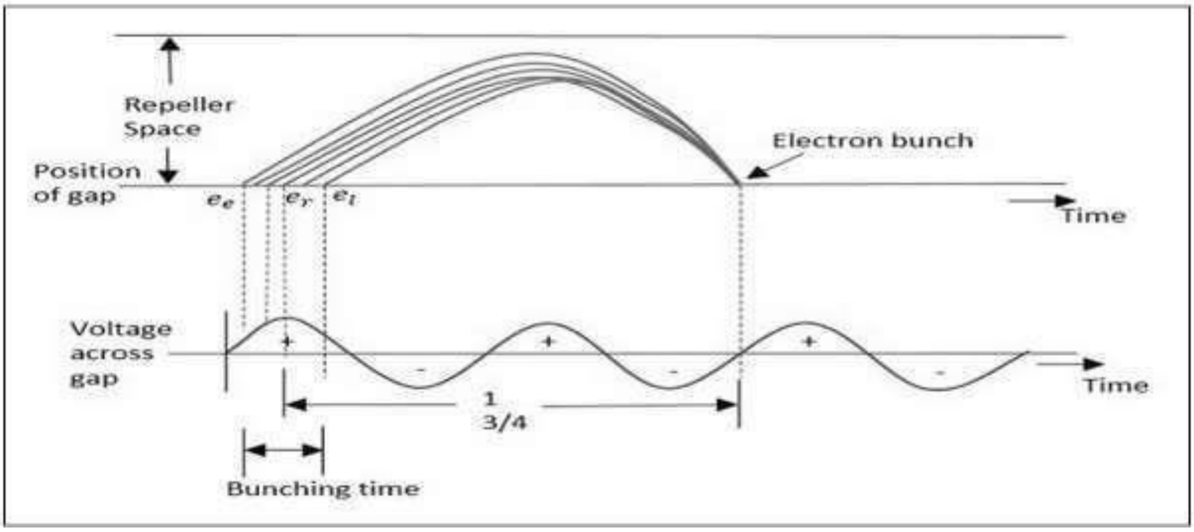
OperationofReflexKlystron

TheoperationofReflexKlystronisunderstoodbysomeassumptions.Theelectronbeamis accelerated towards the anode cavity.

Let us assume that a reference electron $\mathbf{e_r}$ crosses the anode cavity but has no extra velocity and it repels back after reaching the Repeller electrode, with the same velocity. Another electron,let'ssay$\mathbf{e_e}$whichhasstartedearlierthanthisreferenceelectron,reachestheRepeller first, but returns slowly, reaching at the same time as the reference electron.

Wehaveanotherelectron,thelateelectron$\mathbf{e_l}$,whichstartslaterthanboth $\mathbf{e_r}$and$\mathbf{e_e}$,however, it moves with greater velocity while returning back, reaching at the same time as er and ee.

Now, these three electrons, namely $\mathbf{e_r}$, $\mathbf{e_e}$ and $\mathbf{e_l}$ reach the gap at thesametime,forming an **electronbunch**.Thistraveltimeiscalledas **transittime**,whichshouldhaveanoptimum value. The following figure illustrates this.



Theanode cavity acceleratestheelectrons while going and gains their energy by retarding themduringthereturnjourney.Whenthegapvoltageisatmaximumpositive,thisletsthe maximum negative electrons to retard.

Theoptimum transittimeisrepresentedas

$$T = n + 3/4 \, where n is an integer$$ This

transit time depends upon the Repeller and anode voltages.

Applications of Reflex Klystron

ReflexKlystronisusedinapplicationswherevariablefrequencyisdesirable, suchas−

- Radioreceivers
- Portablemicrowavelinks
- Parametricamplifiers
- Localoscillatorsofmicrowavereceivers
- Asasignalsourcewherevariablefrequencyisdesirableinmicrowavegenerators.

PrincipleofOperationsofTravellingWaveTubes:

Travelling wave tubes are broadband microwave devices which have no cavity resonators like Klystrons. Amplification is done through the prolonged interaction between an electronbeam and Radio Frequency *RF* field.

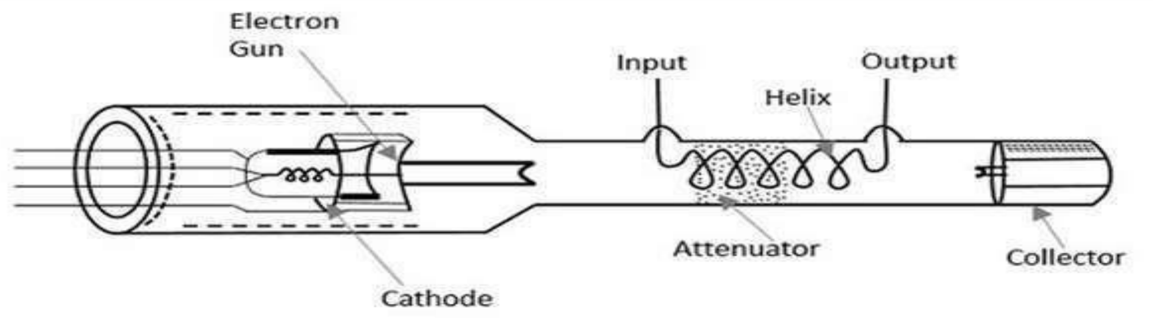
ConstructionofTravellingWaveTube

Travelling wavetubeis a cylindrical structurewhich contains an electrongun from a cathode tube.Ithasanodeplates, helixandacollector.RFinputissenttooneendofthehelixandthe output is drawn from the other end of the helix.

An electron gun focusses an electron beam with the velocity of light. A magnetic field guides the beam to focus, without scattering. The RF field also propagates with the velocity of light whichisretardedbyahelix.Helixactsasaslowwavestructure.AppliedRFfieldpropagated in helix, produces an electric field at the center of the helix.

The resultant electric field due to applied RF signal, travels with the velocity of light multipliedbytheratioofhelixpitchtohelixcircumference.Thevelocityofelectronbeam, travelling through the helix, induces energy to the RF waves on the helix.

Thefollowingfigureexplainstheconstructional featuresof atravellingwave tube.



Physical construction of TWT

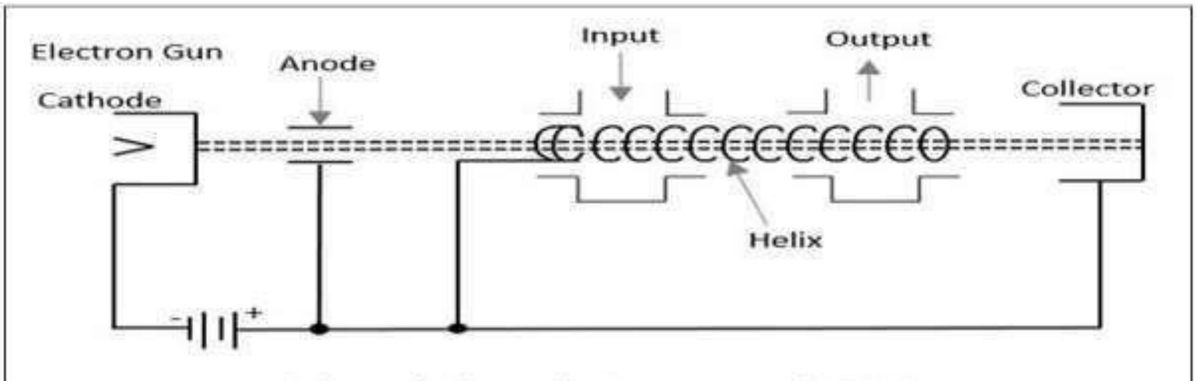
Thus,theamplifiedoutputisobtainedattheoutputofTWT.TheaxialphasevelocityV_p

isrepresentedas

$$V_p = V_c(Pitch/2\pi r)$$

Where**r**is theradiusofthehelix. Asthehelixprovidesleast changeinV_p

phasevelocity,itispreferredoverotherslowwavestructuresforTWT.InTWT,theelectron gun focuses the electron beam, in the gap between the anode plates, to the helix, which is then collected at the collector. The following figure explains the electrode arrangements in a travelling wave tube.



Schematic Electrode Arrangement in TWT

OperationofTravellingWaveTube

Theanodeplates,when atzeropotential,whichmeans whentheaxialelectricfieldisata node,theelectronbeam velocityremainsunaffected.Whenthe waveontheaxialelectric field is at positive antinode, the electron from the electron beam moves in the opposite direction. This electron being accelerated, tries to catch up with the late electron, which encounters the node of the RF axial field.

At the point, where the RF axial field is at negative antinode, the electron referred earlier, triestoovertakeduetothenegativefieldeffect.Theelectronsreceivemodulatedvelocity.As a cumulative result, a second wave is induced in the helix. The output becomes larger than the input and results in amplification.

ApplicationsofTravellingWaveTube

Therearemany applicationsof atravellingwavetube.

- TWTisusedinmicrowavereceiversasalownoiseRFamplifier.
- TWTsarealsousedinwide-bandcommunicationlinksandco-axialcablesasrepeater amplifiers or intermediate amplifiers to amplify low signals.
- TWTshavealongtubelife,duetowhichtheyareusedaspoweroutputtubesin communication satellites.
- ContinuouswavehighpowerTWTsareusedinTroposcatterlinks,becauseof large power and large bandwidths, to scatter to large distances.
- TWTsareusedinhighpowerpulsedradarsand groundbasedradars.

PrincipleofOperationsofCyclotron:

Cyclotronisadeviceusedtoacceleratechargedparticlestohighenergies.Itwasdevisedby Lawrence.

Principle : Cyclotron works on the principle that a charged particle moving normal to a magnetic field experiences magnetic lorentz force due to which the particle moves in a circular path.

Construction:

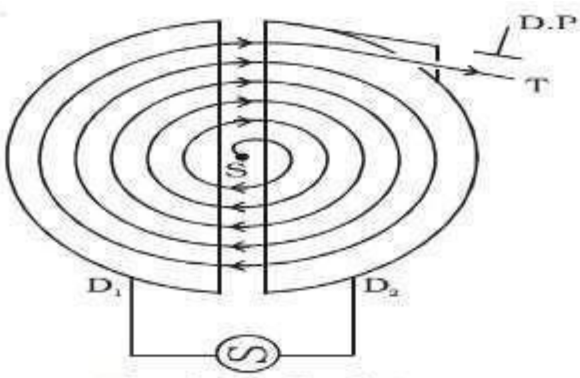


Fig 3.21 Cyclotron

It consists of a hollow metal cylinder divided into two sections D1 and D2 called Dees, enclosedinanevacuatedchamber(Fig3.21).TheDeesarekeptseparatedandasourceof ionsisplacedatthecentreinthegapbetweentheDees.They areplacedbetweenthepole piecesofastrongelectromagnet.Themagneticfieldactsperpendiculartotheplaneof the Dees. The Dees are connected to a high frequency oscillator.

Working:

When a positive ion of charge q and mass m is emitted from the source, it is accelerated towards the Dee having a negative potential at that instant of time. Due to the normal magnetic field, the ion experiences magnetic lorentz force and movesin a circular path. By the time the ion arrives at the gap between the Dees, the polarity of the Dees gets reversed. Hence the particle is once again accelerated and moves into the other Dee with a greater velocity along a circle of greater radius. Thus the particle moves in a spiral path of increasing radiusand when itcomes neartheedge, itistaken outwiththe helpof adeflectorplate(D.P). The particle with high energy is now allowed to hitthe target T.

Bqv =(vm2)/ r

v/r =Bq /m =constant ...(1)

Thetimetakentodescribeasemi-circle t =

π r / v ...(2)

Substitutingequation(1)in(2), t

= π m/ Bq . .. (3)

Itisclearfromequation(3)thatthetimetakenby theionto describeasemi-circleis independent of

(i)theradius(r)ofthepathand(ii)thevelocity(*v*)oftheparticle

Hence,periodofrotationT=2t

T=2 πm /Bq =constant ...(4)

So,inauniformmagneticfield,theiontraversesallthecirclesinexactlythesametime.The frequency of rotation of the particle,

v=1 /T=Bq /2 πm .. (5)

Ifthehighfrequencyoscillatorisadjustedtoproduceoscillationsoffrequencyasgivenin equation (5), resonance occurs.

Cyclotronisusedtoaccelerateprotons,deutrons andα– particles.

$$Bq\upsilon = \frac{m\upsilon^2}{r}$$

$$\frac{\upsilon}{r} = \frac{Bq}{m} = \text{constant} \qquad ...(1)$$

$$t = \frac{\pi r}{\upsilon} \qquad ...(2)$$

$$t = \frac{\pi m}{Bq} \qquad ...(3)$$

$$T = \frac{2\pi m}{Bq} = \text{constant} \qquad ...(4)$$

$$\upsilon = \frac{1}{T} = \frac{Bq}{2\pi m} \qquad ...(5)$$

Limitations

a. MaintainingauniformmagneticfieldoveralargeareaoftheDeesis difficult.

b. Athighvelocities,relativisticvariationof massof theparticleupsetsthe resonance condition.

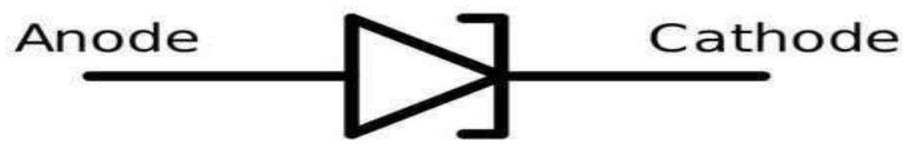
c. Athighfrequencies,relativisticvariationofmassoftheelectronis appreciable and hence electrons cannot beaccelerated by cyclotron.

PrincipleofOperationsofTunnelDiode&Gunndiode:

<u>Tunnel diode :</u> A Tunnel Diode is also known as Eskari diode and it is a highly doped semiconductor that is capable of very fast operation. Leo Esaki invented the Tunnel diode in August 1957. The Germanium materialis basically used tomake tunnel diodes. They can also be made from gallium arsenide and silicon materials. Actually, they are usedin frequency detectors and converters. The Tunnel diode exhibits negative resistance in their operating range. Therefore, it can be used as an amplifier, oscillators and in any switching circuits.

WhatisaTunnel Diode?

Tunnel Diode is the P-N junction device thatexhibitsnegative resistance.When the voltageis increased than the current flowing through it decreases. It works on the principle of the Tunneling effect. Metal-Insulator-Metal (MIM) diode is another type of Tunnel diode, but its present application appears to be limited to research environments due to inherit sensitivities, its applications considered to be very limited to research environments. There is one more diode called **Metal-Insulator-Insulator-Metal (MIIM) diode** which includes an additional insulator layer. The tunnel diode is a two-terminal device with n-type semiconductor as the cathode and p-type semiconductor as an anode. The tunnel diode circuit symbol is as shown below.



Tunnel Diode

TunnelDiodeWorkingPhenomenon

Based on the classical mechanics' theory, a particle must acquire energy which is equal to the potential energy barrier height, if it has to move from one side of the barrier to the other. Otherwise, energy has to be supplied from some external source, so the N-sided electrons of the junction can jump over the junction barrier to reach the P-side of the junction. Ifthe barrier is thin such asin tunnel diode, according to the Schrodinger equation implies thatthere is a large amount of probability and then an electron will penetrate through the barrier. This process will happen without any energy loss on the part of the electron. The behavior of the quantum mechanical indicates tunneling. The high-impurity **P-N junction devices** are called as tunnel-diodes. The tunneling phenomenon provides a majority carrier effect.

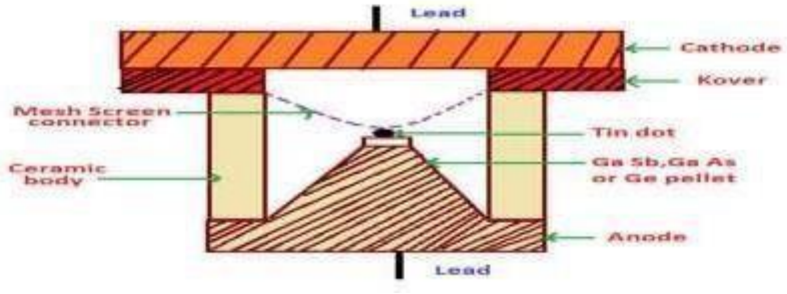
Pɑexp(-A*E_b*W)

Where,

'E'istheenergyofthebarrier,
'P'istheprobabilitythattheparticlecrossesthebarrier, 'W' is
the width of the barrier

ConstructionofTunnelDiode

The diode has a ceramic body and a hermetically sealing lid on top. A small tin dot is alloyed or soldered to a heavily doped pellet of n-type Ge. The pellet is soldered to anode contact which is used for heat dissipation. The tin-dot is connected to the cathode contact via a mesh screen is used to reduce the inductance.



OperationanditsCharacteristics

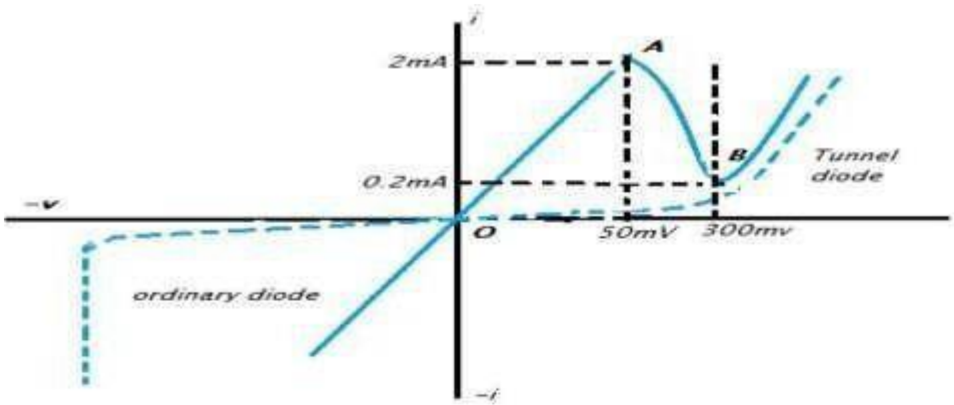
The operation of the tunnel diode mainly includes two biasing methods such as forward and reverse

ForwardBias Condition

Under the forward bias condition, as voltage increases, then-current decreases and thus become increasingly misaligned, known as negative resistance. An increase in voltage will lead to operating as a normal diode where the conduction of electrons travels across the P-N junction diode. The negative resistance region is the most important operating region for a Tunnel diode. The Tunnel diode and normal P-N junction diode characteristics are different from each other.

ReverseBiasCondition

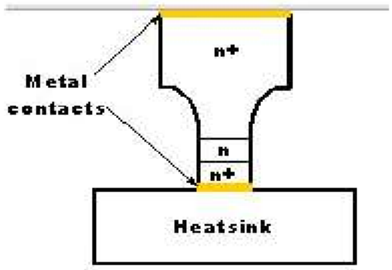
Under the reverse condition, the tunnel diode acts as a back diode or backward diode. With zero offset voltage, it can act as a fast rectifier. In reverse bias condition, the empty states on the n-side aligned with the filled states on the p-side. In the reverse direction, the electrons will tunnel through a potential barrier. Because of its high doping concentrations, tunneldiode acts as an excellent conductor.



Theforward resistance is very small because of its tunneling effect. An increase in voltage will lead to an increase in the current until it reaches peak current. But if the voltage increased beyond the peak voltage then current will decrease automatically. This negative resistanceregionprevailstillthevalleypoint.Thecurrentthroughthediodeisminimumat valley point. The tunnel diode acts as a normal diode if it is beyond the valley point.

GUNNDIODE:

A Gunn Diode is considered as a type of diode even thoughit does not contain any typicalPN diode junction like the other diodes, but it consists of two electrodes. This diode is also called as a Transferred Electronic Device. This diode is a negative differential resistance device,whichisfrequently used asalow-power oscillatorto generatemicrowaves. Itconsists ofonlyN-typesemiconductorinwhichelectronsarethemajoritychargecarriers.Togenerate short radio waves such as microwaves, it utilizes the Gunn Effect.



Gunn Diode Structure

The central region shown in the figure is an active region, which is properly doped N-type GaAsandepitaxiallayerwithathicknessofaround8to10micrometers.Theactiveregionis sandwiched between the two regions having the Ohmic contacts. A heat sink is provided to avoid overheating and premature failure of the diode and to maintain thermal limits.

For the construction of these diodes, only N-type material is used, which is due to the transferred electron effect applicable only to N-type materials and is not applicable to the P-typematerials.Thefrequencycanbevariedbyvaryingthethicknessoftheactivelayerwhile doping.

GUNNEffect:

It was invented by John Battiscombe Gunn in 1960s; after his experiments on GaAs (Gallium Arsenide), he observed a noise in his experiments' results and owed this to the generation of electrical oscillations at microwave frequencies by a steady electric field with a magnitude greater than the threshold value. It was named as Gunn Effect after this had been discovered by John Battiscombe Gunn.

The Gunn Effect can be defined as generation of microwave power (power with microwave frequencies of around a few GHz) whenever the voltage applied to a semiconductor device exceeds the critical voltage value or threshold voltage value.

GUNNDiodeWorking:

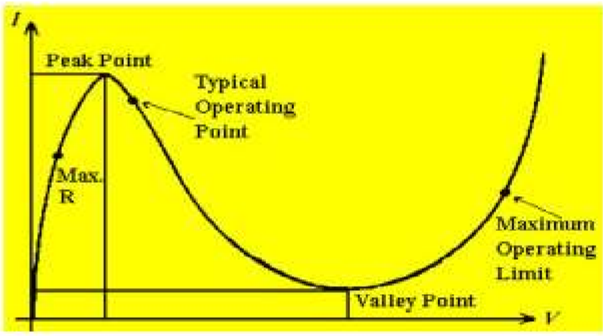
This diode is made of a single piece of N-type semiconductorsuch as Gallium Arsenide and InP (Indium Phosphide). GaAs and some other semiconductor materials have one extra-energy band in their electronic band structure instead of having only two energy bands, viz. valence band and conduction band like normal semiconductor materials. These GaAs and some othersemiconductor materials consist of three energy bands, and this extra third band is empty at initial stage.

If a voltage is applied tothis device, then most of the applied voltage appears across the active region. The electrons from the conduction band having negligible electrical resistivity are transferred into the third band because these electrons are scattered bytheapplied voltage. The third band of GaAs has mobility which is less than that of the conductionband.

Because of this, an increase in the forward voltage increases the field strength (for field strengths where applied voltage is greater than the threshold voltage value), then the number of electrons reaching the state at which the effective mass increases by decreasing their velocity, and thus, the current will decrease.

Thus, if the field strength is increased, then the drift velocity will decrease; this creates a negative incremental resistance region in V-I relationship. Thus, increase in the voltage will increase the resistance by creating a slice at the cathode and reaches the anode. But, to maintain a constant voltage, a new slice is created at the cathode. Similarly, if the voltage decreases, then the resistance will decrease by extinguishing any existing slice.

GUNNDiodeCharacteristics:



Thecurrent-voltagerelationshipcharacteristicsofaGunn diodeareshownintheabovegraph with its negative resistance region. These characteristics are similar to the characteristics of the tunnel diode.

As shown in the above graph, initially the current starts increasing in this diode, but after reaching a certain voltage level (ata specified voltage value called as threshold voltage value), the current decreases before increasing again. The region where the current falls is termed as a negative resistance region, and due to this it oscillates. In this negative resistance region, this diode acts as both oscillator and amplifier, as in this region, the diode is enabledto amplify signals.

PossibleShortTypeQuestionsWithAnswers

1. **Whatistransmissionmatrix?**

Ans- When anumberof microwavedevices are connected in cascade.Each junctionis representedbyatransmission matrixwhich gives theoutputquantities interms ofinput quantities.

2. **DefineVSWR.**

Ans-Voltagestandingwaveratioisdefinedastheratioofmaximumvoltagetothe minimum vottageVSWR=Vmax/Vmin.

3. **WhatistheprincipleofMicrowavephaseshifter?**

Ans-Whenawavepropagatesonaline,aphasedifferenceprevailsbetweenanytwo arbitary pointsalong its paths.The phase difference between two points.

4. **WhatarethedifferenttypesofDirectional coupler?**

Ans-Twoholedirectionalcoupler,Threeholedirectionalcoupler,Fourholedirectional coupler

5. **Whatarehybrid couplers?**

Ans-Hybridcouplersareinterdigitatedmicrostripcouplersconsistingoffourparallel striplines withalternate lines tied together,It has four ports.This type of coupler is called Lange hybrid coupler.

6. **Givethedrawbacksofklystronamplifiers.**

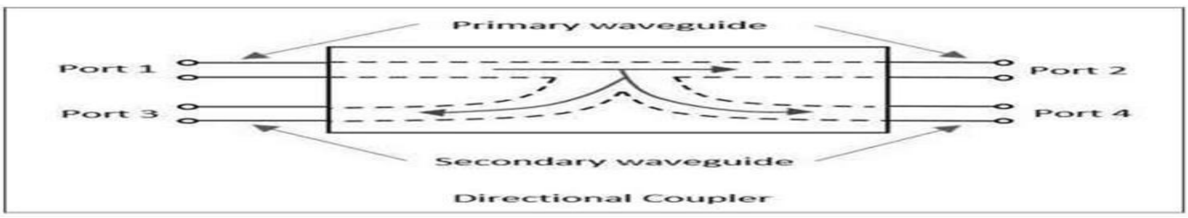
Ans-1.Astheoscillatorfrequencychangesthenresonatorfrequencyalsochanges and the feedbackpath phase shift must be readjusted for a positive feedback.
2. The multicavityklystron amplifierssuffer fromthe noise causedbecause bunching isnevercompleteandelectronsarriveatrandomatcatchercavity. Hence it is not used in receivers.

7. **What is the purpose of slow wave structures used in TWT amplifiers?**

Ans- Slow wave structures are special circuits that are used in microwave tubes to reduce wave velocity in a certain direction so that the electron beam and the signal wavecaninteract.InTWT, sincethebeamcanbeacceleratedonlytovelocitiesthat are about a fraction of the velocity of light,slow wave structures are used.

8. **Drawdirectionalcouplerandwriteitsports.(w-20)**

Ans-



PossibleLongTypeQuestions

1. Explainoperationofrectangularwaveguideandwriteitsadvantages.
2. DiscusspropagationofEMwavethroughwaveguidewithTEandTMmodes.
3. WriteshortnoteonCavityKlystronandwriteitsapplications.(w-20)
4. ExplainoperationofIsolatorandCirculator.(w-20)
5. ExplainbrieflyaboutReflexKlystron.
6. WriteshortnoteonTravellingWaveTube.
7. Explainindetailtheprincipleofoperationof TravellingWaveTubeswithaneat diagram.(w-20)

CHAPTER NUMBER-05 :BROADBANDCOMMUNICATION

LEARINGOBJECTIVES:

1. *Broadbandcommunicationsystem-FundamentalofComponentsand Network*
2. *Cablebroadbanddatanetwork-architecture,importance&futureof broadband telecommunication internet based network*
3. *SONET(SynchronousOpticalNetwork)-signalframecomponents topologies advantages and disadvantages*
4. *ISDNDevices,interfaces,services,Architecture,Applications*
5. *BISDN-interfaces&terminals,protocolarchitectureapplications*

Broadbandcommunicationsystem-Fundamentalof Components and Network architecture :

Broadband communications is usually considered to be any technology with transmission rates abovethe fastest speed available over atelephoneline. Broadband transmission systems typicallyprovidechannelsfordatatransmissionsindifferentdirectionsandbymanydifferent users. For example, the coaxial CATV system is a broadband system that delivers multiple television channels over the same cable. In addition, it can handle data transmissions (primarily Internet access for home users) in an entirely different frequency spectrum.

Typicalbroadbandcommunicationsystems includethe following:

- **ISDN (Integrated Services Digital Network)** ISDNisimplementedoverexisting coppertelephonecables.Thebasicratevarietyprovidestwochannels of64-Kbit/sec throughput that can be bonded to form a 128-Kbit/sec data channel. Primary rate ISDN provides additional bandwidth in increments of 64 Kbits/sec.
- **ATM (Asynchronous Transfer Mode)** Anotherhigh-bandwidthserviceavailable from the carriers. The carriers use of ATM benefits everyone, but medium to large companies can install ATM equipment on-site to connect directly into carrier ATM networksand gain allthe benefitsof thosesystems.Seethe "ATM"heading formore information.
- **Frame Relay** A data networking and voice service offered by the carriers that is widelyavailable.LikeATM,framerelayisprimarilyusedforcorporaterather than home connections.
- **Leasedlines**and**TCarriers** LeasedT1linesprovidededicatedthroughputof 1.544 Mbits/sec over two-pair twisted wire. Existing telephone cable is usually adequate.T3providesapproximately45-Mbit/secthroughput.FractionalT1canbe leased in increments of 64 Kbits/sec.
- **DSL (Digital Subscriber Line)** DSL is a whole family of high-bandwidth digital servicesthatthetelephonecompaniesofferovercoppertelephonecable.Depending on the service, rates can reach into the multimegabit/sec rates.
- **Cable (CATV) Data Networks** The cable TV system is a well-established broadband network that now makes its system available for data links and Internet access. Nearly 100 million homes in the U.S. have cable access, and it is estimated that70to75percentofthosehomeswillbeabletosupportInternetaccessintheyear 2000.
- **Wireless Communications** A variety of wireless broadband services are now available or under development, including satellite-based systems and terrestrial-based systems that are essentially fixed cellular systems. Broadband wireless uses microwaveandmillimeterwavetechnologytotransmitsignalsfrombasestationsto customers.

DSL, cable, and broadband wireless will largely solve the problem of providing high bandwidthtohomeusers.Thisistheso-called"lastmile,"althoughlastmilehastraditionally referredtothecopperlocalloopthatconnectshomestolocaltelephonecentraloffices.Inthis respect, CATV and broadband wireless have never had a last-mile problem. DSL solves the last-mile problem in the local loop.

Another aspect of most of these broadband technologies (although not directly related to the definitionofbroadband)isthattheyprovidedirect accesstotheInternet. Thereisno need to dial up and hopeyou getaconnection. Youarealways connected,in thesameway that your TV is always connected to the CATV network.

Asbandwidthincreases,customerswillgainaccesstohigherqualitiesofserviceforvoice, video, and data using packet-based Internet technologies. Global Internet-based telephone calls and videoconferences will become more commonplace, as will distance learning and high-resolution imaging as applied in areas like telemedicine.

An interesting technology that can provide broadband service is HALO (High Altitude Long Operation),whichisaschemetoputhigh-flyingplanesorballoonsabovemajormetropolitan areas. Angel technologies is promoting HALO in the form of a 28-GHz LMDS system that typically uses three planes as aerial base stations. Data rates are in the 10-Mbit/sec range. SkystationInternationalusesballoonsthatprovide1-Mbit/secto12-Mbit/sectransferrates. The systems connect with ISP and carriers so that users can access the global telecommunications infrastructure.

Cable broadband data network- architecture, importance&futureofbroadbandtelecommunication internet based network.

CablenetworksdeliverInternetaccessthroughasharedarchitecturethatisdistinctfromDSL or fiber to the premise (FTTP) networks.

Cablebroadbandnetworksutilizestatisticalmultiplexingtoshareafixedamountofnetwork capacity across a group of users. The network'sarchitecture isa hybrid of fiber and coaxial cable, utilizing frequency division duplexingto divide upstream and downstream transmissions.

Approximately 750 MHz to 1 GHz of spectrum is typically available on cable networks to be shared across all services, including television, broadband, and voice.Upstream traffic uses thelowerportionofthefrequencyduplexcablesystem,between5MHzand42MHzusually, and downstream traffic uses the remaining upper portion of the available frequencies.

Theamountofspectrumonthecablesystemdedicatedtobroadbanddepends,inpart,onthe requirements of the other,While the 750 MHz –1 GHz may be a typical range, there are systems that operateat lower levels of spectrum (e.g., down to 450 MHz).

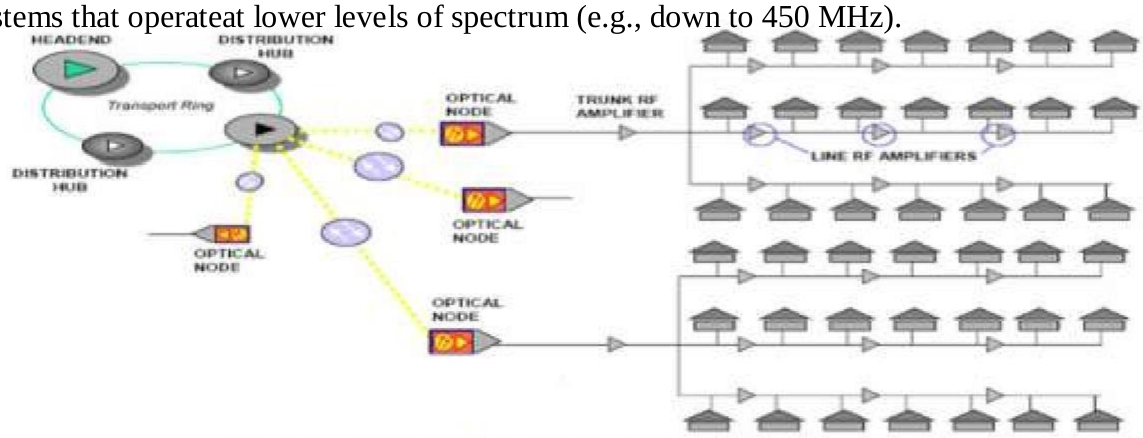


Figure 1: Cable Network Architecture

Cablebroadbandtechnology,knownasDataOverCableServiceInterfaceSpecificationor DOCSIS® technology, is specified by CableLabs on behalf of the global cable industry. DOCSIStechnology addressesboththephysicallayerandmediaaccess control(MAC)layer of cable broadband services. DOCSIS technology was initially specified in 1997; several revisionstothespecificationhavebeenmadeovertimetoenablehigher-performingservices. Today, DOCSIS 3.0technologyis the most widely deployed cable broadband technology.

Inatypicalcablenetwork,fiberopticsconnect theheadendtoaneighborhoodhub,andthen to an optical node. Coaxial cable then extends beyond the node to the end customers, of whichthere are generally between 50 and 500households. Beyond the node, the coaxial network may utilize amplifiers to extend the range of thesignal. These 50 to 500households on the node share the capacity provided by DOCSIS technology. This architecture is depicted in the above diagram.

Importance:

Broadband is important for rural health care providers interested in meaningfully using electronichealthrecords,asmanyofthecapabilitiesofhealthIT,suchastelehealthand electronic exchange of health care information, require broadband capability.

It is an **important** tool for businesses. It enables companies to communicate effectively withcustomersanddeliverhighstandardsofcustomerservice. **Telecommunications**isa key element in allowing employees to collaborate easily from wherever they are located, remote or local.

Therangeoftelecommunicationsapplicationsisbroadandincludestelephonyandvideo conferencing, facsimile, broadcast and interactive television, instant messaging, e-mail, distributed collaboration, a host of Web- and Internet-based **communication**, and data transmission.

It Satisfies Our Basic Needs. Information technology and the ability to connect and communicate is a fundamental part of how our **society** operates. In today's digital ecosystem,**telecommunication**hasbecomethefoundationforbusinesses,governments, communities, and families to seamlessly connect and share information.

It'sVitalforSecurity:Fromasecurityperspective,telecommunicationisoneofthemost crucial infrastructures for protection. From natural disaster initiatives to military needs, there's a wide spectrum of institutions that depend on telecom to provide safety.

Future:

- Informationsharing over theInternetwill besoeffortlesslyinterwovenintodailylife that it will become invisible, flowing like electricity, often through machine intermediaries.
- ThespreadoftheInternetwillenhanceglobalconnectivitythatfosters more planetary relationships and less ignorance.
- TheInternet ofThings,artificialintelligence, and bigdatawill makepeople more aware of their world and their own behaviour.
- Augmented reality and wearable devices will be implemented to monitor and give quickfeedbackondailylife,especiallytiedtopersonalhealth.Politicalawarenessand actionwillbefacilitatedandmorepeacefulchangeandpublicuprisingslikethe Arab Spring will emerge.

- Thespreadofthe'Ubernet'willdiminishthemeaningofborders,andnew'nations' of those with shared interests may emerge and exist beyond the capacity of current nation-states to control.
- TheInternetwill become'theInternets'asaccess,systems,andprinciples are renegotiated.
- AnInternet-enabledrevolutionineducationwillspreadmoreopportunities,withless money spent on real estate and teachers.

SONET(Synchronous Optical Network)-signal frame componentstopologiesadvantagesanddisadvantages:

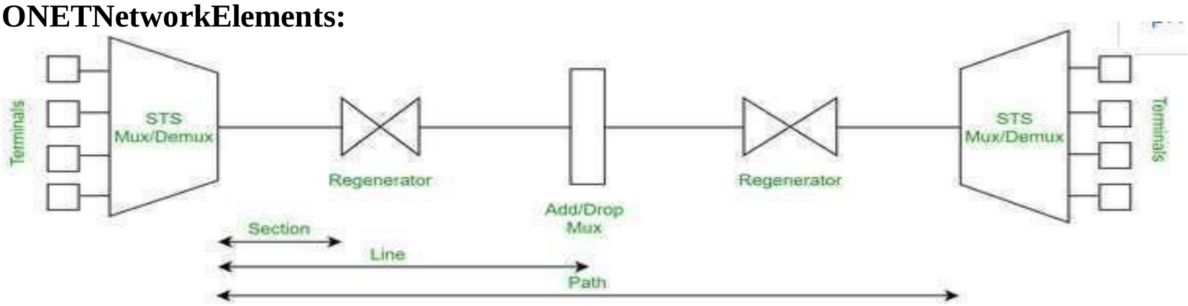
SONET stands for Synchronous Optical Network. SONET is a communication protocol, developed by Bellcore – that is used to transmit a large amount of data over relatively large distancesusingopticalfibre.WithSONET,multipledigitaldatastreamsaretransferedatthe same time over the optical fibre.

KeyPoints:

- DevelopedbyBellcore
- UsedinNorthAmerica
- StandardizedbyANSI(AmericanNationalStandardsInstitute)
- SimilartoSDH(SynchronousDigitalHierarchy) whichisused inEuropeandJapan.

WhySONETiscalledaSynchronousNetwork?
Asingleclock(PrimaryReferenceClock,PRC)handlesthetimingoftransmissionofsignals & equipments across the entire network.

SONETNetworkElements:



1. **STSMultiplexer:**
   - Performsmultipleximgofsignals
   - Convertselectrical signaltoopticalsignal
2. **STS Demultiplexer:**
   - Performsdemultiplexingof signals
   - Convertsopticalsignaltoelectricalsignal
3. **Regenerator:**

   - Itisarepeater,thattakesanopticalsignalandregenerates(increasesthe strength) it.

4.Add/DropMultiplexer:

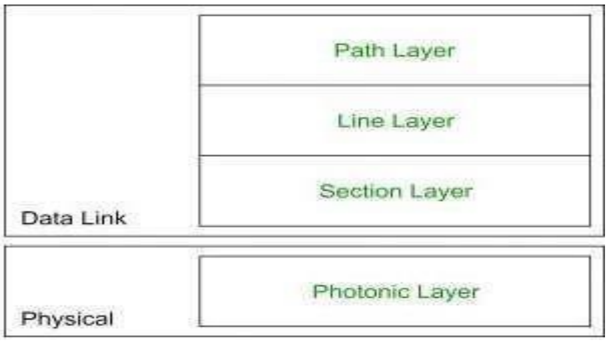
- Itallowstoaddsignalscomingfromdifferentsourcesintoagivenpathor remove a signal.

WhySONETis used?
SONETisusedtoconvertelectricalsignalintoopticalsignalsothatitcantravellonger distances.

SONETConnections:

- **Section:**Portion ofnetworkconnectingtwoneighbouringdevices.
- **Line:**Portion of networkconnecting twoneighbouringmultiplexers.
- **Path:**End-to-endportion ofthenetwork.

SONETLayers:



SONETincludesfourfunctionallayers:

1. **PathLayer:**
   - Itisresponsibleforthemovementofsignalfromitsopticalsourcetoits optical destination.
   - STSMux/Demuxprovidespathlayerfunctions.
2. **LineLayer:**
   - Itisresponsibleforthemovement ofsignalacrossaphysicalline.
   - STSMux/Demux andAdd/DropMuxprovidesLinelayerfunctions.
3. **SectionLayer:**
   - Itisresponsibleforthemovement ofsignalacrossaphysicalsection.
   - Eachdeviceofnetworkprovidessectionlayer functions.
4. **PhotonicLayer:**
   - ItcorrespondstothephysicallayeroftheOSImodel.
   - Itincludesphysicalspecificationsfortheopticalfibrechannel(presenceof light = 1 and absence of light = 0).

AdvantagesofSONET:

- Transmitsdatatolarge distances
- Lowelectromagneticinterference
- Highdatarates
- LargeBandwidth

DisadvantagesofSONET:

- Nointeroperablestandard.
- Tributaryservicesrequire**SONET**mux services.
- Lowcosteffectiveforlowchannelnumbers.
- **SONET**/SDH**network**managementsystemnotwellequippedtohandletheDWDM method and management.
- Bandwidthefficiencyisaproblemathigher capacity.
- Moreoverheadisrequired.

Applicationsof**SONET**

- **SONET**isthebestperforming,data-efficientandmostwidelyusedcommunication standard for large telecom **networks**.
- Ithasemerged asafoundationfortelecom**networks** acrosstheglobe.
- **SONET** hasanextremelyhigh datarateof**operation**.

ISDNDevices,interfaces,services,Architecture,Applications

ISDNorIntegratedServicesDigitalNetworkisaninternationalstandardforendtoend digital transmission of voice, data and signalling.

ISDNcanoperateovercopperbasedsystemsandallowsthetransmissionofdigitaldataover the telecommunications networks, typically ordinary copper based systems and providing higher data speeds and better quality than analogue transmission.

TheISDNspecificationsprovideasetofprotocolsthatenablethesetup,maintenanceand completion of calls.

ISDNisacircuit-switchedtelephonenetworkthatcarriespacketsdataovercopperlinesand enabled existing copper wire based landline technology to be used to carry digital services.

AlthoughISDNhasbeen inuseformanyyears,anditisbeingretiredinsomeareas,itisstill widely used and some legacy services still make considerable use of it.

ISDNdevelopment

TheconceptforISDNwasdevelopedwhentheanaloguePOTS,plainoldtelephonesystems were the only real telecommunications systems available.

Withcomputertechnologydevelopingfastandthe Interneteraabouttodawn,companies needed the ability to communicate using data rather than analogue technology.

Thefirst ideas for packet data systems had been developed int he 1960s, but with there being littleneedfordataexchangebetweendifferent companiesand sites,itwas notintegratedinto the customer facing side of the business. Telecommunications remained firmly analogue and circuit switched.

Astechnologydeveloped,theInternationalTelecommunicationsUnion,ITUrecommended the introduction ISDN, and only slowly did companies start to take up the new offering.

Asdigitaltechnology,andalsotheInternetstartedtomakeitsmark,morecompaniestookup the idea of ISDN, with even some homes where home offices were required, looking at the use of ISDN.

ISDN performed very well when compared to the dial up modems that were used in the 1990s, but as DSL technology took hold, and speeds rose, ISDN became less attractive. Nevertheless, many legacy systems were used, and in some countries it offered the best performance and remained in use formany years. Accordingly many customers who used ISDNfortheirbusinesstelephonesystemsarenowmigratingtoVoIPasthisoffers ahigh degree of capability when compared to analogue systems and even ISDN.

ISDNadvantages

ISDN,IntegratedServicesDigitalNetwork,providesanumberofsignificantadvantagesover analogue systems.

Inisbasicformitenablestwo simultaneoustelephonecallstobemadeoverthesameline simultaneously.

Fastercallconnection.Ittypicallytakesasecondtomakeconnectionsratherthanthemuch longer delays experienced using purely analogue based systems.

Datacanbesentmorereliablyandfasterthanwiththeanaloguesystems. Noise,

distortion, echoes and crosstalk are virtually eliminated.

Thedigitalstreamcancarryanyformofdatafromvoicetofaxesandinternetwebpagesto data files - this gives the name 'integrated services'

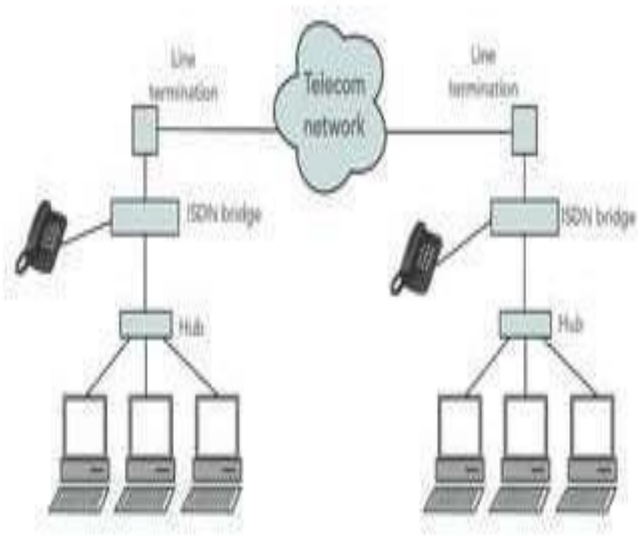
ISDNUsage

ISDN is in use around the world, but with the introduction of ADSL it is facing strong competition.ThetechnologynevergainedmuchmarketshareintheUSA,althoughitusedin other countries.

InJapanitbecamereasonablypopularinthelate1990salthoughitisnowindeclinewiththe advent of ADSL. The system was also introduced in Europe where providers such as BT, France Telecom and Deutsche Telekom introduced services.

With most companies now opting for DSL, or fibre connections, ISDN is used in some countrieswherethesystemhavenotmigratedoverfullyyet. Itcan alsobeusedasabackup in case the DSL or other digital systems fail.

ISDNnetworkarchitecture



ISDN network concept

ISDNconfigurations

AlthoughtheISDNoperationisrelativelystraightforward,it utilisesanumberofchannels and interfaces.

Therearetwotypes ofchannelthat arefoundwithin ISDN:

- ***BorBearerchannels:***Thebearerchannelsareusedtocarrythepayloaddata which may be voice and / or data
- ***DorDeltachannels:***TheDchannelsareintendedforsignallingandcontrol, although it may also be used for data under somecircumstances.

AdditionallytherearetwolevelsofISDNaccessthatmaybeprovided.Theseareknownas BRI and PRI.

BRI (Basic Rate Interface) - This consists of two B channels, each of which provides a bandwidthof64kbpsundermostcircumstances.OneDchannelwithabandwidthof16kbps is also provided. Together this configuration is often referred to as 2B+D.

Thebasicratelinesconnecttothenetworkusing astandardtwistedpairofcopperwires.The data can then be transmitted simultaneously in both directions to provide full duplex operation. The data stream is carried as two B channels as mentioned above, each of which carry64kbps(8kbytes persecond).Thisdatais interleavedwiththeDchanneldataandthis isusedforcallmanagement:settingup,clearingdownofcalls,andsomeadditionaldatato maintain synchronisation and monitoring of the line.

The network end of the line is referred to as the 'Line Termination' (LT) while the user end acts as a termination for the network and is referred to as the 'Network Termination' (NT). Within Europe and Australia, the NT physically exists as a small connection box usually attached to a wall etc, and it converts the two wire line (U interface) coming in from the network to four wires (S/T interface or S bus). The S/T interface allows up to eight items or 'terminal equipments' to be connected, although only two may be used at any time. The terminal equipments may be telephones, computers, etc, and they are connected in what is termed a point to point configuration. In Europe the ISDN line provides up to about 1 watt of power that enables the NT to be run, and also enables a basic ISDN phone to be used for emergency calls. In North America a slightly different approach may be adopted in that the terminalequipmentmaybedirectlyconnectedtothenetworkinapointtopointconfiguration as this saves the cost of a networktermination unit, but it restricts theflexibility. Additionally power is not normally provided.

PRI (Primary Rate Interface) - This configuration carries a greater number of channels than the Basic Rate Interface and has a D channel with a bandwidth of 64 kbps. The number of B channels varies according to the location. Within Europe and Australia a configuration of 30B+D has been adopted providing an aggregate data rate of 2.048 Mbps (E1). For North AmericaandJapan,aconfigurationof23B+1Dhasbeenadopted.Thisprovidesan aggregate data rate of 1.544 Mbps (T1).

The primary rate connections utilise four wires - a pair for each direction. They are normally 120 ohm balanced lines using twisted pair cable. Primary rate connections always use apoint to point configuration.

PrimaryratelinesarewidelyusedtoconnecttoPrivateBrancheXchanges(PBX)inanoffice etc. Typically this may be used to provide a number of POTS (Plain Old Telephone System) or basic rate ISDN lines to the users.

ISDNoperation

Calldataistransmittedoverthedata(B)channels,withthesignalling(D)channelsusedfor call setup and management. Once a call is set up, there is a simple 64 kbit/s synchronous bidirectional data channel between the end parties, lasting until the call is terminated.

Therecanbeasmanycallsastherearedatachannels,tothesameordifferentend-points. Bearer channels may also be multiplexed into what may be considered single, higher- bandwidth channels via a process called B channel bonding.

TheDchannelcan alsobeusedforsendingandreceivingX.25datapackets,andconnection to X.25 packet network. In practice, this was never widely implemented.

Although ISDN is has been overtaken by technologies such as ADSL it is nevertheless still widely used in many areas, particularly where existing services need to be maintained, or wherecompatibilityneedstobeguaranteed.WhenitisbeingphasedoutVoIPphonesystems areoften taking over as they offer the advantages of adigitally based business phone system.

BISDN-interfaces&terminals,protocolarchitectureapplications:

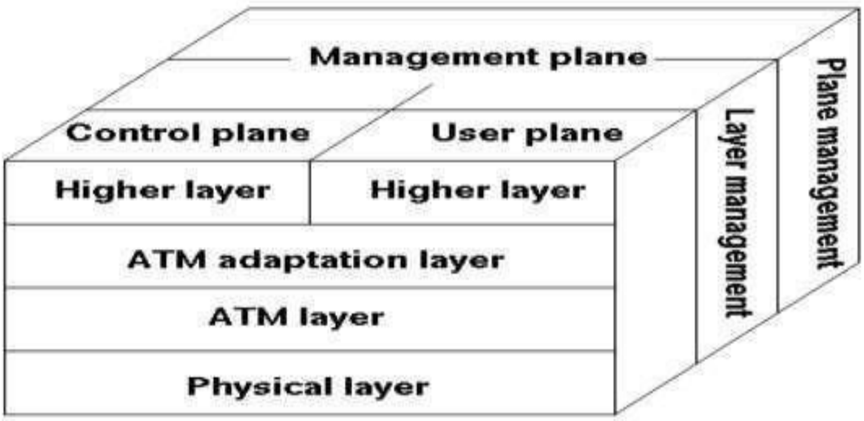
- Thenext generation of ISDN technology with promised bandwidth from 150 megabitspersecondupwardsufficienttocarryvideophonecallsandmovies.
- BISDNwillbecarriedoverfiberopticcablingratherthanwireandunderlying protocol will be asynchronous transfer mode.
- DifferentimplementationsareplannedintheUSAwhichwillemploysynchronous optical networks and Europe which will be SDH
- OneofthefundamentalprincipleofBISDNistooffer subscribersalargevarietyof services such as video telephony,video high volume file transfer,HDTV and many more.
- The fixed length cells allows the prediction of the size of the buffers to be used and hencebitscouldbetransmittedatanyconvenientrateunlikethefixedrate (64kbps) specified by ISDN

<u>GeneralStructure:</u>

- The assembly of several 64kbps channels could be achieved with ordinary ISDNby setting upseveral 64kbpscalls to thesame destinationon aprimary rate interface and concatenating the channels at the terminal.
- Theproblemisthatauniformdelayisnotguaranteed;sincechannelsdonot followthesamepaththroughthenetwork;thereisadifferentframedelayfor each channel and sometimes a satellite link is involved for one or more channels.
- Therearetwo solutionsfortheproblem:
- TheTerminalSolution:Byusingtheappropriatebuffersattheterminals,the delaysineachchannelcanbepaddedtobeequal. Inordertoestablishthese delays the terminals should do a prior investigation. An assumption that is usually made is that relative delays will not change during a call.
- TheNetworkSolution:Inthiscasetheexchangeprocessorswouldensurethat all channels are kept within a single time division multiplex and therefore follow a common route.

Broadband ISDN Protocol

The suggested arhitecture for the B-ISDN protocol is depicted in figure below.



PossibleShortTypeQuestionswithAnswers

1. **DefineNyquistrate**.

Ans-Letthesignalbebandlimitedto„W"Hz.
ThenNyquistrateisgivenas,*Nyquistrate=2Wsamples/sec*
Aliasingwillnottakeplaceifsamplingrateisgreaterthan Nyquist rate.

2. **Whatismeantbyaliasingeffect?**

Ans- Aliasing effect takes place when sampling frequency is less than Nyquist rate.Under such condition, he spectrum of the sampled signal overlaps with itself. Hencehigherfrequenciestaketheformoflower frequencies.Thisinterferenceofthe frequency components iscalled as aliasing effect.

3. **StateSamplingtheorem.**

Ans- A bandlimited signal of finite energy, which has no frequency components higherthanWHz,maybecompletelyrecoveredfromtheknowledgeofitssamples taken at the rate of 2W samples persecond.

4. **HowthemessagecanberecoveredfromPAM?**

Ans-ThemessagecanberecoveredfromPAMbypassingthePAMsignal .through reconstruction filter integrates amplitude of PAM pulses. Amplitude reconstructionsignalisdonetoremoveamplitudediscontinuitiesduetopulses.

5. **Whatdouunderstandfromadaptivecoding?**

Ans- In adaptive coding, the quantization step size and prediction filter coefficients arechangedasperpropertiesofinputsignal.Thisreducesthequantizationerrorand number of bits to represent thesample value. Adaptive coding is used for speech coding at low bits rates.

6. **Whatismeantbyadaptivedelta modulation?**

Ans- In adaptivedelta modulation, the step sizeis adjusted as per the slopeof the inputsignal.Stepsizeis madehighif slopeof theinputsignalishigh.This avoids slope overload distortion.

7. **WritethefullformofISDNandBISDN.(w-20)**

Ans-ISDN-IntegratedServicesDigitalNetwork.
BISDN-BroadbandIntegratedServicesDigitalNetwork

PossibleLongTypeQuestions

1. ExplainfundamentalsofBroadbandCommunication.
2. ExplainArchitecture,FutureofBroadbandcommunicationsystem.(w-20)
3. WriteshortnoteonSONET.(w-20)
4. WriteshortnoteonISDN.
5. Writeshortnoteon BISDN.

REFERENCE:

Table

Sl.no.	NameofBook/Source	Nameofthe Author	Nameofthe Publication
01	ElectronicsCommunication	G.Kennedy	MGH
02	Television&videoengineering	A.M.Dhake	TataMcGrawHill
03	BroadbandCommunicationSystem	Akujuobi &Sadiku	PHI
04	AntennasandWavePropagation	D.Kraus,Ahmed S Khan	TMG
05	Microwave&RadioEngg.	M.Kulkarni	UmmeshPublication
06	MicrowaveEngineering	MonojilMitra	DhanpatRai&Co.
07	BroadbandCommunication	Balajikumar	-----
08	IntroductiontoBroadband Communication System	Chapman&Hall	
09	MicrowaveEngineering	G.S.N.Raju	IKI