Q2 (a) What is meant by impedance matching? Explain single stub matching and give its drawbacks.

Answer:

<u>Impedance matching</u>

For maximum power transfer from the source to the load, the resistance of the load should be equal to that of the source i.e., $R_L = R_S$.

Also, the reactance of the load should be equal to that of the source but opposite in sign, i.e., + jx = - jx. This means that if the source is inductive, the load should be capacitive and vice versa.

When the above conditions are satisfied, we say that impedance matching has been achieved.

There are several methods to achieve impedance matching and the components used are referred to as impedance matching devices, or in transmission lines impedance matching lines.

<u>Stub Matching</u>

It is possible to connect sections of open or short circuited lines called stubs in shunt with the main line at some point or points to affect impedance matching. This method of achieving matching is known as stub matching and is used at higher microwave frequencies.

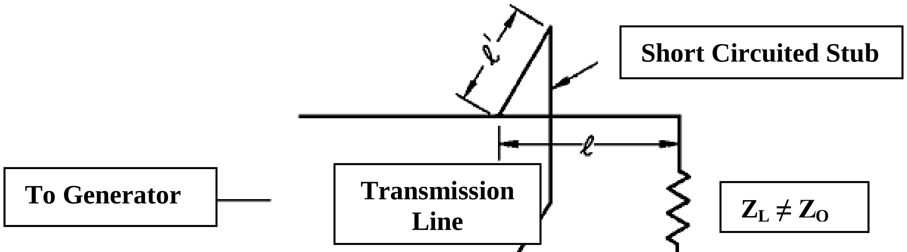
There are basically two stub matching techniques

(i) Single stub matching

(ii) Double stub matching.

<u>Single Stub Matching</u>

In this, a short circuited stub of length ℓ' is placed at distance ℓ from the receiving end impedance $Z_L \neq Z_O$ as shown in the figure below.



Single stub matching

At microwave frequencies, $Z_O = R_O$, a pure resistance and at a length L from the load, the impedance $R_1 + jX_1$ is such that $R_1 = R_O$.

The length (l') of the stub is given by the equation:

$$\ell' = \frac{\lambda}{2\pi}\tan^{-1}\left(\frac{Z_L Z_O}{Z_L - Z_O}\right)$$

and the position (l) of the stub required for matching is given by the equation:

$$\ell = \frac{\lambda}{2\pi}\tan^{-1}\sqrt{\frac{Z_l}{Z_O}}$$

Disadvantages of Single Stub matching

Single stub matching is useful only for a fixed frequency since any frequency change requires the location of the stub to be changed (Narrowband system).

Further, the matching is achieved by final adjustment of the stub by moving it along the line slightly.

The above is suitable for open wire lines but in coaxial lines it tends to be inaccurate.

The disadvantages of single stub matching are overcome by employing double stub matching.

(b) A 600Ω lossless transmission line is fed by a 50Ω generator. If the line is 200 m long and terminated by a load of 500Ω, determine in dBs:

(i) Reflection loss.
(ii) Transmission loss.
(iii) Return loss.

Answer:

Given that:

$Z_o = 600\Omega$, $Z_s = 50\Omega$ l = 200m and $Z_L = 500\Omega$

Therefore,

$$\rho = \frac{Z_L - Z_O}{Z_L + Z_O} = \frac{500-600}{500+600} = -\frac{100}{1100} = -\frac{1}{11}$$

$$\textbf{(i) Reflection loss} = 10\log_{10}\frac{1}{1-|\rho|^2} = 10\log_{10}\frac{1}{1-(1/121)}$$

$$= 10\log_{10}\frac{121}{120} = 0.036\text{dB}$$

(ii) Transmission loss = Attenuation loss + Reflection loss (dB)

Since the line is lossless, the attenuation loss = 0 dB

Therefore,

Transmission loss = 0 + 0.036 = **0.036 dB**

$$\textbf{(iii) Return loss} = 10\log_{10}\left(\frac{1}{11}\right) = -10.414 \text{ dB}$$

Q3 (a) By making use of Maxwells equations, show that a TEM wave cannot propagate in a waveguide.

Answer:

Using Maxwell's equations, the general relationships of field components within a waveguide are given by:

$$E_x = \frac{-\gamma}{h^2}\frac{\delta E_z}{\delta x} - \frac{j\omega\mu}{h^2}\frac{\delta H_z}{\delta y} \qquad (1)$$

$$E_y = \frac{-\gamma}{h^2}\frac{\delta E_z}{\delta y} + \frac{j\omega\mu}{h^2}\frac{\delta H_z}{\delta x} \qquad (2)$$

$$H_x = \frac{-\gamma}{h^2}\frac{\delta H_z}{\delta x} + \frac{j\omega\varepsilon}{h^2}\frac{\delta E_z}{\delta y} \qquad (3)$$

$$H_y = \frac{-\gamma}{h^2}\frac{\delta H_z}{\delta y} - \frac{j\omega\varepsilon}{h^2}\frac{\delta E_z}{\delta x} \qquad (4)$$

The above equations give a general relationship for field components within a waveguide.
We know that for a TEM wave,

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

Substituting these values of $\mathbf{E_z}$ and $\mathbf{H_z}$ in the above equations, we find that all the field components along the x and y directions (namely $\mathbf{E_x}$, $\mathbf{E_y}$, $\mathbf{H_x}$, $\mathbf{H_y}$) vanish.
Thus, a TEM wave cannot exist inside a waveguide.

(b) Given a rectangular waveguide 3×1 cm operating at a frequency of 9 GHz in TE_{10} mode. Calculate the maximum power handling capacity of the waveguide if the maximum potential gradient of the signal is 3 kV/cm.

Answer:

$$\lambda = \frac{3\times10^{10}}{9\times10^{9}} = \frac{10}{3} = 3.33\text{cm}$$

$$\lambda_{c10} = 2a = 2\times3 = 6\text{cm}$$

$$\lambda_g = \frac{\lambda_o}{\sqrt{1-(\lambda_o/\lambda_c)^2}} = \frac{3.33}{\sqrt{1-(3.33/6)^2}} = 5\text{cm}$$

The power handling capacity of the rectangular waveguide is given by:

$$P = (6.63\times10^{-4})E^2_{max}ab\left(\frac{\lambda_o}{\lambda_g}\right)$$

$$= (6.63\times10^{-4})(3\times10^3)^2(3)(1)\left(\frac{3.33}{5}\right)$$

$$= 11.922 \text{ kW}$$

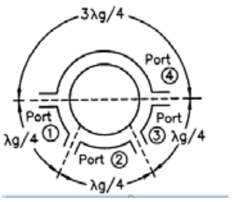
Q4 (a) Explain the functioning of a rat race junction. Also, write the scattering matrix of a rat race junction under ideal conditions i.e. neglecting leakage coupling values.

Answer:

Rat race junction

The rat race is a four port junction, the fourth port being added to a normal three port Tee.

A typical rat race junction is as shown.



The four arms/ports are connected in the form of an angular ring at proper intervals by means of series or parallel junctions.

These ports are separated by proper electrical lengths to sustain standing waves.

For proper operation, it is necessary that the mean circumference of the total race be 1.5 λ_g and that each of the four ports be separated from its neighbor by a distance of λ_g /4.

When power is fed into port 1, it splits equally (in clockwise and anti clockwise directions) into ports 2 and 4 and nothing enters port 3.

At ports 2 and 4, the powers combine in phase but at port 3 cancellations occur due to λ_g /2 path difference.

Similarly, any input applied at port 3 is equally divided between ports 2 and 4 but the output at port 1 will be zero.

The rat race can be used for combining two signals or dividing a single signal into two equal halves.

If two unequal signals are applied at port 1, an output proportional to their sum will emerge from ports 2 and 4 while a differential output will appear at port .

Scattering Matrix

The scattering matrix of a rat race junction (also called hybrid junction), under ideal conditions is:

$$[S] = \begin{bmatrix} 0 & S_{12} & 0 & S_{14} \\ S_{21} & 0 & S_{23} & 0 \\ 0 & S_{32} & 0 & S_{34} \\ S_{41} & 0 & S_{43} & 0 \end{bmatrix}$$

(b) A signal of power 32 mW is fed into one of the collinear ports of a lossless H-Plane Tee. Determine the powers in the remaining ports when other ports are terminated by means of matched loads.

Answer:

Let the collinear port be port 1 to which the signal of 30 mW is fed. The other ports then are port 2 (other collinear port) and port 3 (H-arm port) that are terminated in matched loads.

Therefore,

$a_2 = a_3 = 0$ and $a_1 = 30$ mW

The S-matrix for H-plane Tee is:

$$[S] = \begin{bmatrix} \frac{1}{2} & -\frac{1}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{1}{2} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \end{bmatrix}$$

or,

$$\begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & -\frac{1}{2} & \frac{1}{\sqrt{2}} \\ -\frac{1}{2} & \frac{1}{2} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} 30\ \text{mW} \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{aligned} b_1 &= \text{power at port 1} \\ &= \frac{1}{2}a_1 - \frac{1}{2}a_2 + \frac{1}{\sqrt{2}}a_3 = (\frac{1}{2})^2 |a_1| = \frac{1}{4} \times 32 \\ &= 8\text{mW} \end{aligned}$$

$$\begin{aligned} b_2 &= -\frac{1}{2}a_1 - \frac{1}{2}a_2 + \frac{1}{\sqrt{2}}a_3 = -(\frac{1}{2})^2 \times 32 \\ &= 8\text{mW} \end{aligned}$$

$$\begin{aligned} b_3 &= \frac{1}{\sqrt{2}}a_1 + \frac{1}{\sqrt{2}}a_2 - (\frac{1}{\sqrt{2}})^2 \times 32 \\ &= 16\text{mW} \end{aligned}$$

Q5 (a) What is a tunnel diode? Explain the volt-amp characteristics of a tunnel diode

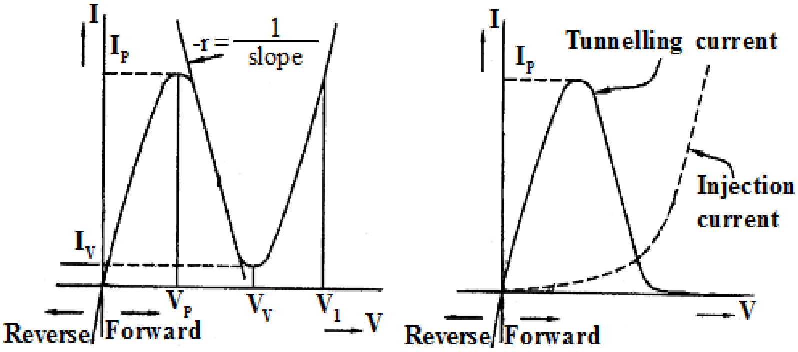
Answer:

TUNNEL DIODE (ESAKI DIODE)

A tunnel diode is a specially made p-n junction device which exhibits negative resistance over part of the forward bias characteristic.
It has extremely heavy doping on both sides of the junction and an abrupt transition from the p-side to the n-side.
The tunneling effect is a majority carrier effect and is consequently very fast. The tunnel diode is useful for oscillation or amplification purposes. Because of the thin junction and short transit time, it is also useful for microwave applications in fast switching circuits.

Volt-amp Characteristics of a Tunnel Diode

The volt-ampere characteristics of a tunnel diode are shown in the figure below:



(a) Sum of Tunnelling and Injection
(b) V-I characteristic of tunnel diode
I_P, V_P = Peak point parameters
I_V, V_V = Valley point parameters

The tunnel effect controls the current at very low values of forward bias where the normal or the injection current is very small.

The mechanism of tunneling is purely a quantum mechanical phenomenon.

An electron on one side of the barrier will have a certain probability of leaking through the barrier if the barrier is very thin.

If both p and n type materials of a junction are heavily doped, the depletion region becomes very narrow.

Another effect of heavy doping is to widen the donor level in the n material and the acceptor level in the p material respectively.

The fermi level also moves up into the conduction band in case of n material and moves down into the valence band in case of p material.

Under unbiased condition, there is just the same probability of electrons going from states in the conduction band on the n side to the states in the valence band on the p side. Net tunneling on the thin barrier is then zero.

As forward bias is applied, the energy levels on n side are raised relative to those on p side and consequently the electrons in the conduction band on n side see empty states just across the barrier and tunneling takes place.

This tunneling current will read a maximum value I_P at a forward bias V_P.

As the forward bias is further increased, the energy levels on n side are raised so high that only parts of the electrons in the conduction band see available energy levels across the barrier. Thus the tunneling current is reduced as the bias increases. This phenomenon, the suppression of tunneling, is responsible for the negative resistance part of the diode characteristic.

At a bias of V_V the tunneling is completely suppressed and the current, I_V, is entirely made up of the ordinary injection currents.

Between the peak currents I_P and the valley current I_V, a negative dynamic resistance is obtained.

Beyond V_V, the current rises again because of the injection currents as in an ordinary p-n junction diode, reaching a value of I_P.

(b) An IMPATT diode has a drift length of 2 μm. Determine:

(i) Drift time of the carrier.

(ii) Operating frequency of the diode.

Answer:

$f = 1/2\tau = V_d / 2L$

V_d = carrier drift velocity

L = drift length

Taking $V_d = 10^5$ cm/sec

$$\textbf{Drift time}(\tau) = \frac{2\times10^{-6}}{10^5} = 2\times10^{-11}\ \textbf{sec}$$

$$\textbf{Operating frequency}(f) = \frac{1}{2\times2\times10^{-11}} = 0.25\times10^{11} = 25\text{GHz}$$

Q6 (a) Explain how a helical TWT achieves amplification. Give the applications of TWT and also explain how TWTs are different from klystron amplifiers.

Answer:

The travelling wave tube is a broad band amplifier which is different from klystron amplifier in the following ways:

Klystrons are essentially narrow band devices as they utilize cavity resonators to velocity modulate the electron beam over a narrow gap whereas TWT's are broad band devices in which there are no cavity resonators.

The interaction space in a TWT is extended and the electron beam exchanges energy with the RF wave over the full length of the tube.

The TWT makes use of a distributed interaction between an electron beam and a travelling wave.

To prolong the interaction between an electron beam and the RF field it is necessary to ensure that they are both traveling in the same direction with nearly the same velocity.

Thus, it differs from the klystron in which the electron beam travels and the

RF field remains stationary.

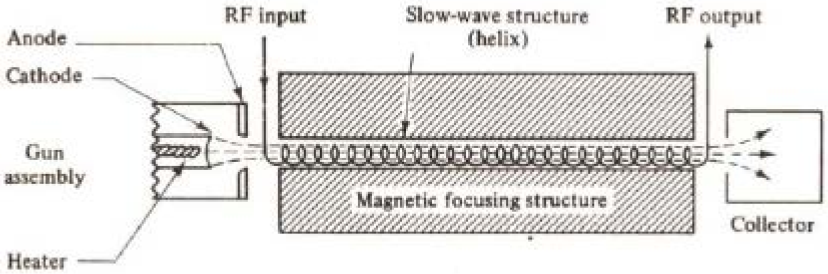
The electron beam travels with a velocity governed by the anode voltage (typically 0.1 V_c where V_c is the velocity of light in vacuum).

The RF field propagates with a velocity equal to velocity of light V_c.

The interaction between the RF field and the moving electron beam will take place only when the RF field is retarded by some means.

Normally slow .wave structures are utilized to retard the RF field, like helix or a waveguide arrangement.

The physical construction of a typical TWT' is shown in the figure below.



It has an electron gun which is used to produce a narrow constant velocity electron beam.

The electron beam is passed through the centre of a long axial helix.

A magnetic focusing field is provided to prevent the beam from spreading and to guide it through the center of the helix.

The helix is a loosely wound thin conducting helical wire which acts as a slow wave structure.

The signal to be amplified is applied to the end of the helix adjacent to the electron gun. The amplified signal appears at the output or other end of the helix under appropriate operating conditions.

When the applied RF signal propagates around the turns of the helix, it produces an electric field at the centre of the helix.

The RF field propagates with velocity of light.

The axial electric field due to RF signal travels with velocity of light multiplied by the ratio of helix pitch to helix circumference.

When the velocity of the electron beam travelling through the helix approximates the rate of advance of the axial field, then interaction takes place between them in such a way that on an average the electron beam delivers energy to the RF wave on the helix.

Thus, the signal wave grows and amplified output is obtained at the output of the TWT.

The axial phase velocity v_p is given by $v_p = v_c$ (Pitch/$2\pi r$) where r is the radius of the helix and is essentially constant over a range of frequencies.

This characteristic of helix slow wave structure enables TWTs to have broadband operation.

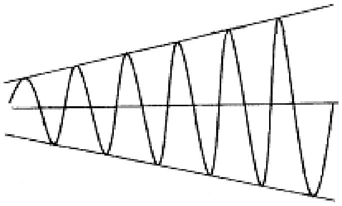
Since a helix provides the least change in v_p with frequency, it is preferred over other slow wave structures for TWTs.

As a result of energy transfer from the electron to the RF field in phase with the RF field at the axis, a second wave is induced on the helix. This produces an axial electric field that lags behind the original electric field by $\lambda/4$.

Bunching continues to take place.

The electrons in the bunch encounter retarding fields and deliver energy to the wave on the helix.

The output becomes larger than the input and amplification results. The energy increase in the RF is a continuous process as shown in the figure below.



Applications of TWT

1 Low noise RF amplifier in broad band microwave receivers.
2 Repeater amplifier in wide band communication links and long distance telephony (co-axial cables).
3 As power output tube in communication satellites (due to long life 50,000 hrs as compared to ¼ for other types)
4 CW high power TWTs are used in troposcatter communication links.
5 Used in airborne and shipborne pulsed high power radars as well as in ECM ground based radars.

(b) A reflex klystron is operated at 56 Hz with an anode voltage of 1000 V and cavity gap of 2 mm. Calculate the gap transit angle and the optimum length of the drift region. Assume N=$\mathbf{1\frac{3}{4}}$, V_R = -500 V.

Answer:

$$\mathbf{\left|V_R\right| = 6.74\times10^{-6}\times F\times lm\frac{\sqrt{V_o}}{N} - V_o}$$

or

$$\mathbf{500 = \frac{6.74\times10^{-6}Flm\sqrt{V_o}}{N} - V_o}$$

$$\mathbf{L = 2.463mm(length\ of\ drift\ region)}$$

$$\mathbf{Gap\ transit\ angle = \omega t_g = \frac{\omega_d}{u_o}}$$

$$\mathbf{d = 2\times10^{-3}m, u_o = 5.93\times10^5\sqrt{V_o} = 18.75\times10^6 m/s}$$

$$\mathbf{\omega = 5\times10^9 2\pi}$$

$$\mathbf{Transit\ angle(\theta_g) = \frac{2\pi\times5\times10^9\times2\times10^{-3}}{18.75\times10^6} = 3.351\ radians}$$

Q7 (a) What are crossfield devices? How does a magnetron sustain its oscillations using this crossfield? Assume π - mode for explaining the same.

Answer:

In crossed-field devices, the dc magnetic field and the dc electric field are perpendicular to each other.

In all crossed-field tubes, the dc magnetic field plays a direct role in the RF interaction process.

Crossed-field tubes derive their name from the fact that the dc electric field and the dc magnetic field are perpendicular to each other.

In a crossed-field tube, the electrons emitted by the cathode are accelerated by the electric field and gain velocity, but the greater their velocity, the more their path is bent by the magnetic field.

If an RF field is applied to the anode circuit, those electrons entering the circuit during the retarding field are decelerated and give up some of their energy to the RF field.

Consequently, their velocity is decreased, and these slower electrons will then travel the dc electric field far enough to regain essentially the- same velocity as before.

Because of the crossed-field interactions, only those electrons that have given up sufficient energy to the RF field can travel all the way to the anode.

This phenomenon would make the M -type devices relatively efficient. Those electrons entering the circuit during the accelerating field are accelerated by means of receiving enough energy from the RF field and are returned back toward the cathode.

This back-bombardment of the cathode produces heat in the cathode and decreases the operational efficiency.

The spacing between the anodes is so adjusted that it is equivalent to half cycle of the RF frequency and hence when the electrons reach the second anode the polarity of RF reverses. The electrons continue to slow down since the energy acquired by them in falling through the dc anode to cathode voltage in delivered to the RF oscillating wave. The electrons finally reach the anode after having slowed down almost to a dead spot having delivered the kinetic energy acquired by anode to cathode voltage.

In the presence of the cross field, let us consider one such favorable electron. The outward centrifugal force must equal the magnetic force on this electron.

i.e., $mv2/ r = eVB$

where, r = radius of cycloidal path.

Angular velocity, $\omega = v/r = eB/m$

Period of one revolution, $T = 2\pi/ \omega = 2\pi m / eB$

Therefore for oscillations to occur, the feedback should be in phase or integral multiples of 2π radians. If there are N-cavities, the phase should be

$$\phi = 2\pi n / N$$

Where, n = an integer indicating nth mode of oscillation. Magnetron oscillators are operated in the π - mode so that $\phi = \pi$. In the π mode the RF fields in successive cavities are in antiphase.

The angular velocity of the RF field in the interaction space is given by,

$$d\phi/ dt = \omega / \beta$$

The condition for maximum transfer of energy from the electrons to the RF field takes place when the cyclotron frequency of electron is equal to angular velocity of the RF wave.

i.e., $\omega / \beta = d\phi / dt$ or $\omega = \beta\, d\phi / dt = eB/m$

(b) A reflex klystron operates at the peak mode of n = 2 with V_o= 280 V, I_o = 22 mA and signal voltage V_1 = 30 V. Determine:

(i) The input power.
(ii) The output power.
(iii) The efficiency.

Answer:

$$\mathbf{Input\,power = V_o I_o = 280 \times 22 \times 10^{-3} = 6.16\,watts}$$

$$\mathbf{Output\,power = \frac{2V_o I_o \times J_1(X')}{2n\pi - \frac{\pi}{2}} = \frac{2 \times 6.16 \times 1.25}{2 \times 2 \times \pi - \frac{\pi}{2}}}$$

$$\mathbf{= \frac{15.4}{7\pi} \times 2 = 1.4\,watts}$$

$$\mathbf{Efficiency\,(\eta) = \frac{Output\,power}{Input\,power} \times 100 = \frac{1.40}{6.16} \times 100}$$

$$\mathbf{= 22.74\%}$$

Q8 (a) Describe striplines and microstrip lines in detail. Give the advantages / disadvantages of microstrip lines.

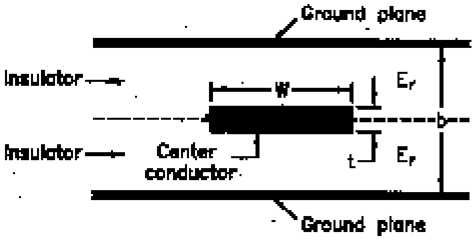
Answer:

Strip Lines

Strip lines are modifications of the two wire lines and coaxial lines.

These are basically planar transmission lines that are widely used at frequencies from 100 MHz to 100 GHz.

The figure below shows a cross-sectional view of the strip line structure.



Strip line transmission line.

A strip line consists of a central thin conducting strip of width ‘w’ which is greater than its thickness t, placed inside the low loss dielectric (E_r) substrate of thickness b/2 between two wide ground plates.

Usually the thicknesses of the metallic central conductor and the metallic ground planes are the same.

The dominant mode for the strip line is a TEM mode and the fields are confined within the transmission line with no radiation losses.

The width of the ground planes is at least five times greater than the spacing between the plates there by avoiding any vertical side walls at the two transverse ends.

There are practically no fringing fields after a certain distance from the edges of the centre conductor.

For b < λ/2, there will be no propagation in the transverse direction.

Disadvantages of Strip Lines

There are certain disadvantages of strip lines in that the circuit is not accessible during development for adjustment and tuning and also it is difficult to mount discrete and active components (like transistors, diodes, circulators, chip resistors, chip capacitors etc.).

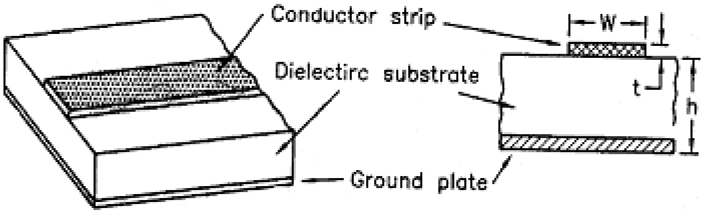
The characteristic impedance of strip line has been analyzed by a combination of analytical and empirical techniques.

The design equations are divided into high-impedance region and low-impedance region determined by the ratio of w to (b - t).

The impedance of a strip line in inversely proportional to the ratio of the width w of the inner conductor to the distance b between the ground planes.

Microstrip Line

Microstrip line is an unsymmetrical strip line that is nothing but a parallel plate transmission line having dielectric substrate, one face of which is metalized ground and the other (top) face has a thin conducting strip of certain width 'w' and thickness 't'. This is shown in the figure below.



The top ground plane is not present in a microstrip as compared to a stripline. Sometimes a cover plate is used for shielding purposes but it is kept much farther away than the ground plane so as not to affect the microstrip field lines.

The radiation loss of a microstrip line depends on the substrate thickness and dielectric constant as well as its geometry.

The quality factor Q of a microstrip line is very high which may be the requirement for high quality resonant MICs.

It is however limited by the radiation losses of the substrate and with low dielectric constant.

The Q of a microstrip line is given by: Q = 1/tan θ where θ is the dielectric loss tangent.

Advantages of microstrip lines over strip lines, co-axial lines and waveguides

1 Complete conductor pattern may be deposited and processed on a single dielectric substrate which is supported by a single metal ground plane. Thus fabrication costs would be substantially lower than stripline, co-axial or waveguide circuits.
2 Due to the planar nature of the microstrip structure, both packaged and unpackaged semiconductor chips can be conveniently attached to the microstrip element.
3 There is an easy access to the top surface, thereby making it easy to mount passive or active discrete devices and also for making minor adjustments after the circuit has been fabricated.
This also allows access for probing and measurement purposes.
4 Microstrip lines have a power handling capacity of a few –watts which is quite adequate for most microwave circuits.
Microstrip lines offer advantage of miniaturization but for long transmission lengths, they suffer from excessive attenuation per unit length.

Disadvantages of microstrip lines

1 Due to the openness of the microstrip structure, they have higher radiation losses or interference from nearby conductors.
These can be reduced by choosing thin substrates with high dielectric constants.
2 Because of the proximity of the air-dielectric air interface with the microstrip conductor at the interface, a discontinuity in the electric and magnetic fields is generated.
This results in a microstrip configuration that becomes a mixed dielectric transmission structure with un-pure TEM modes propagating.
This makes the analysis complicated.

(b) A strip line transmission line has a distance of 0.3175 cm between the ground planes. If the diameter of the equivalent circular conductor is 0.0539 cm, determine the characteristic impedance and velocity of propagation if the dielectric constant is 2.32 for the strip line material.

Answer:

b = 0.3175 cm, d = 0.0539 cm, $\in$ = 2.32

Therefore,

$$\textbf{Characteristic impedance}\,(Z_o) = \frac{60}{\sqrt{\in_r}}\ln\left[\frac{4\times 0.3175}{\pi\times 0.0539}\right]$$

$$= 79.38\Omega$$

$$\textbf{Velocity of propagation}\,(v) = \frac{c}{\sqrt{\in_r}} = \frac{3\times 10^8}{\sqrt{2.32}} = 1.97\times 10^8\,m/s$$

Q9 (a) Differentiate between discrete circuits, integrated circuits and monolithic microwave integrated circuits. What are the broad categories into which the basic materials used for MMIC fabrication are divided into? Write short notes on each of them. What are the disadvantages of MMICs?

Answer:

Electronic circuits are broadly classified into three categories based on the circuit technology.

Discrete Circuit

The circuit elements are separately manufactured and then interconnected by conducting wires.

The above results in a discrete circuit similar to well known transistor op amp based circuits.

Integrated Circuit (IC)

The IC consists of a single-crystal chip of semiconductor containing both active and passive elements and their inter connections.

ICs are manufactured either as a Small Scale Integrated (SSI) circuit (< 100 gates), Medium Scale Integrated (MSI) circuit (< 1000 gates), Large Scale Integrated (LSI) circuit (between 1000 and 10000 gates per chip), Very Large Scale Integrated (VLSI) circuit (> 10,000 gates) and Ultra Large Scale Integrated (ULSI) circuit (> 10 million components).

Monolithic Microwave Integrated Circuits (MMIC's)

A monolithic microwave integrated circuit is fabricated on a single crystal.

MMIC's are quite different from the conventional ICs in that conventional ICs contain very high packing densities, where as the packing density of a MMIC is typically low.

An MMIC consists of two or more integrated circuit types together with discrete elements and is referred to as a hybrid integrated circuit.

MMIC's are currently being used for a variety of applications including space and military taking into account the advances that have been made in the field of solid state microwave devices.

They present improved performance in view of the natural advantages offered by an integrated circuit.

A typical microwave integrated circuit for a discrete circuit shown in Fig. 4.48a

is fabricated as in Fig. 4.48b.

With the introduction ofMIC's and in particular hybrid MMIC's, three types of transmission systems have been utilized:

(i) Microstrip lines.
(ii) Lumped element circuits consisting of resistors and capacitors.
(iii) Thin film circuits.

The material used for MMIC's Fabrication are broadly divided into four categories which are:

1. Substrate material

   A substrate of MMIC is a piece of substance on which circuit elements are built.

The ideal characteristics of substrate material are high dielectric constant (> 9), low dissipation factor or loss tangent, constant dielectric constant over the positive temperature and frequency range of interest, high- purity, surface smoothness, resistivity, dielectric strength, thermal conductivity and constant thickness.

The selection of a substrate material depends on the required circuit dissipation, the circuit function and the type of circuit to be used.

Alumina, Beryllia, Ferrite/garnet, GaAS, glass, rutile are used as substrate materials.

2. Conductor material

   The ideal characteristic of a conductor material are high conductivity, low temperature coefficient of resistance, good adhesion to the substrate, etchability, solderability and capability to be easily deposited or electroplated.

   Alumina, copper, gold and silver are mainly used as conductor materials.

3. Dielectric films

   To realize blockers, capacitors and couple line structures, dielectric materials are used.

   The typical dielectric materials are: Al2Oa, SiO, SiO2, SiaN4 and Ta20s. The desirable properties of dielectric materials re good reproductivity, ability to undergo processes without developing pin holes, low RF dielectric loss and ability to withstand high voltages.

4. Resistive films

   For realizing bias networks, terminations, and attenuators, resistive materials are employed.

   The desirable properties of resistive materials are good stability, low temperature coefficient of resistance, adequate dissipation capability and sheet resistivity's in the range of 10 to 1000 Ω per square.

   The typical resistive materials are: Cr, Cr-SiO, NiCr, Ta and Ti.

Disadvantages of MIC's

There are various difficulties both in design as well as in usage ofMIC's.

Some of them are:

1. Once a MIC is fabricated, there is no provision for adjusting any circuit parameters. This requires accurate design values so that any adjustment later on is avoided.
2. Accurate design of circuits pose problem for precise characterization of semiconductor devices requiring computer aided design so that the performance of the MIC can be known before it is actually made.
3. Low values of Q are associated with microstrip resonators (of the order of 100) compared to those of waveguide resonators (of the order of 1000). This forces stable high frequency oscillators using microstrip configuration to have lower Q's. This problem can be overcome by using dielectric disc resonation, which provide high Q.

4. MIC's have lower power handling capability as compared to waveguide circuits.

(b) Write a short note on Hybrid Microwave Integrated Circuits (HMICs)

Answer:

Hybrid Microwave Integrated Circuits (HMICs):

Where solid state devices and passive elements (both lumped and distributed) are bonded to its dielectric substrate. The passive elements are fabricated using thick or thin film technology.

(a) **Standard Hybrid MIC’s:** Standard hybrid MIC’s use a single-level metallization for conductors & transmission lines with discrete circuit elements (such as transistors, inductors, capacitors, etc.) bonded to the substrate. This type of MIC use a very mature single-layer metallization technique to form RF components. A typical standard hybrid MIC is shown in the figure.

(b) Miniature Hybrid MIC’s: use multi-level processes in which passive elements (inductors, capacitors, resistors, transmission lines, etc.) are batch deposited on the substrate whereas the semiconductor devices (transistors, diodes, etc.) are bonded on the substrate surface.

•These circuits are smaller than hybrid MIC’s but are larger than MMIC’s; therefore miniature hybrid circuit technology can be also called quasi-monolithic.

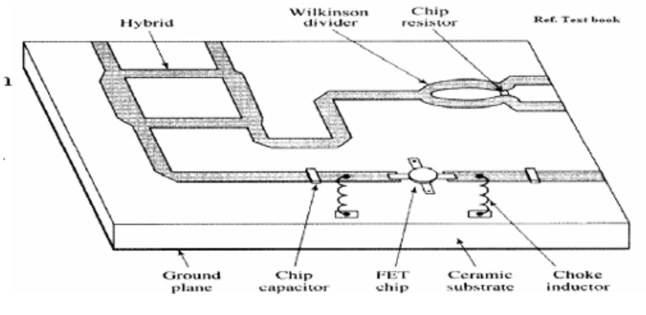
•The advantages of miniature hybrid compared to standard hybrid circuits are:

(i) Smaller size,

(ii) Lighter weight,

(iii) Lower loss.

•But as frequency is increased thinner substrates are required, resulting in smaller sized circuits; for example, 1-20 GHz require substrate thickness of 0.635-0.254 mm



Text Book

Microwave Devices and Circuits, Samuel Y. Liao, 3rd Edition, Prentice-Hall of India, New Delhi, 2006