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Transmission Line

* Fundamentals

→ These are used commonly for power distribution (at low freq.) and in communication (at high freq.).

→ The transmission line basically consists of two or more parallel conductors are used to connect source to load.

Types :- co-axial cable, parallel wire & microstrip line.

* Characteristics

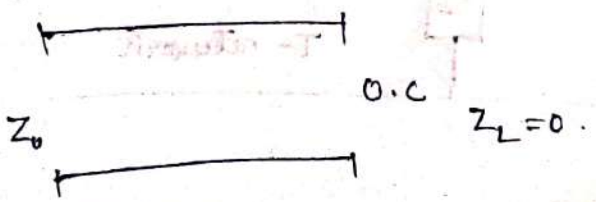
(i) Attenuation

(ii) Power handling capability

→ There should be minimum attenuation and maximum power handling capability.

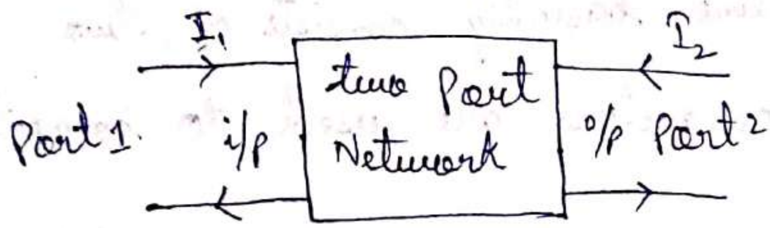
→ There are also two types transmission line based on load termination.

(a) Resonant Transmission Line ($Z_0 \neq Z_L$)

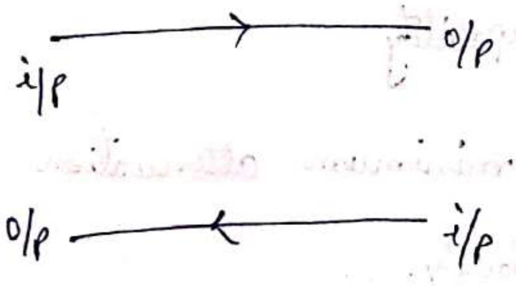


(b) Non - Resonant Transmission Line ($Z_0 = Z_L$)

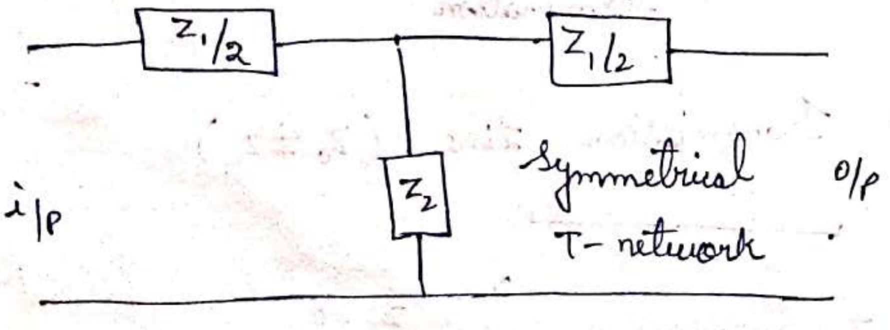
→ A Port is a Pair of terminals

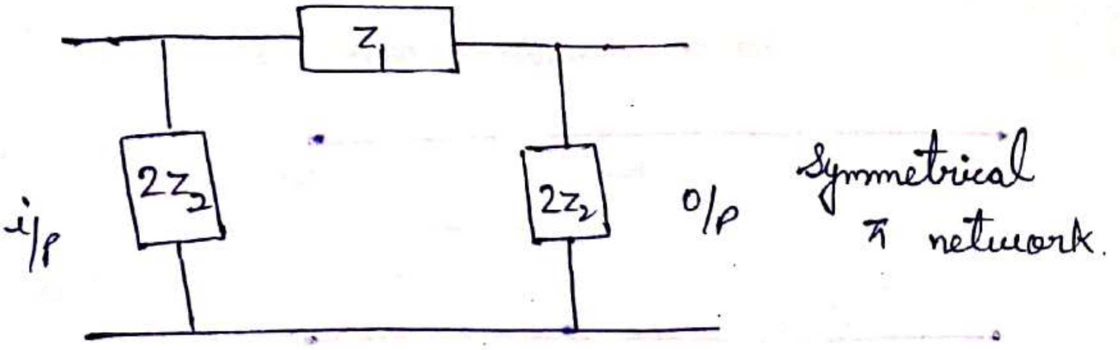


→ If i/p & o/p Ports are interchanged and electrical Properties of the network are not change then that network is symmetrical network.



→ Entering current = o/p current for symmetrical network.



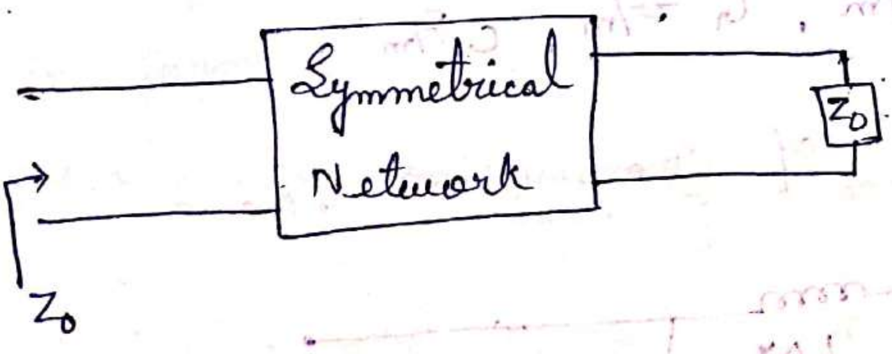


Symmetrical π network.

* Definition of characteristic impedance 'Z_0'

→ If infinite no of identical symmetrical network are connected in cascade then the impedance seen at i/p of the first network is called characteristics impedance 'Z_0'.

→ When a symmetrical network is terminated by characteristic impedance then the impedance seen at input of network is equals to characteristics impedance 'Z_0'.



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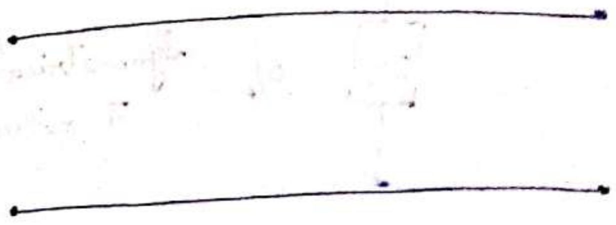


I/p end / (or)
transmitting end
(or)
source end
(or)
Sending end

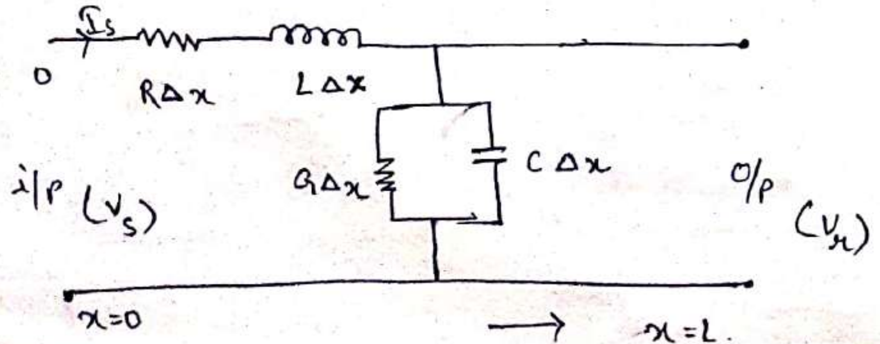
O/p end / (or)
Receiving end
(or)
Load end
(or)
Terminating end.

→ R, L, G, C are distributed throughout the transmission line. These are not physically present. So transmission lines are distributed network.

→ If R, L, G, C are distributed uniformally then transmission line is uniform transmission line.

→ R Ω/m, L H/m, G ℧/m, C F/m.

* Equivalent ckt of Transmission Line



x is length of transmission line.

* Transmission Line Equation

$$\boxed{\frac{\partial^2 V_s(x)}{\partial x^2} - \gamma^2 . V_s(x) = 0} \longrightarrow ①$$

$$\boxed{\frac{\partial^2 I_s(x)}{\partial x^2} - \gamma^2 . I_s(x) = 0} \longrightarrow ②$$

γ = Propagation constant

$$\boxed{\gamma = \alpha - j\beta}$$

$$\boxed{\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}}$$

where,

α = Attenuation constant = Re (γ)

β = Phase constant = Im (γ)

* Solutions of Transmission Line Equation

→ Solutions of these differential homogeneous equation are in form of :-

$$\boxed{V_s(x) = V_0^+ . e^{-\gamma x} + V_0^- . e^{\gamma x}} \longrightarrow ③$$

$$\boxed{I_s(x) = I_0^+ . e^{-\gamma x} + I_0^- . e^{\gamma x}} \longrightarrow ④$$

V_0^+, V_0^-, I_0^+, I_0^- are wave amplitude

V_0^+, I_0^+ travels are in (+)ve direction.

V_0^-, I_0^- travels in (-ve direction.

$$\boxed{V = V_S \cdot \cosh \gamma x - I_S \cdot Z_0 \sinh \gamma x.}$$

$$\boxed{I = I_S \cdot \cosh \gamma x - \frac{V_S}{Z_0} \cdot \sinh \gamma x.}$$

V and I are the voltage and current in terms of V_S and I_S at any position of transmission line. (At $x = 0$ to L).

* Characteristic Impedance

→ It is the ratio of Positively (negatively also), travelling voltage wave to current wave at any Point on transmission line.

$$\boxed{Z_0 = \frac{V_0^+}{I_0^+}} \text{ if Positively}$$

$$Z_0 = \frac{V_0^-}{-I_0^-} \quad [-I_0 \text{ due to reflection}]$$

$$\boxed{Z_0 = -\left(\frac{V_0^-}{I_0}\right)}$$

$$\boxed{Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}}$$

Question

A transmission line contains R, L, G, C Parameter where;
$R = 8\ \Omega/m$, $L = 8\ nH/m$, $G = 0.8\ m\ mho/m$, $C = 0.20\ PF$,
$f = 4\ GHz$.

Calculate

(a) characteristics impedance

(b) Propagation constant

Ans

Given data,

$R = 8\ \Omega/m$

$G = 0.8\ m\mho/m = 0.8 \times 10^{-3}\ \mho/m$

$L = 8\ nH/m = 8 \times 10^{-9}\ H/m$

$C = 0.20\ PF = 0.20 \times 10^{-12}\ F$

$f = 4\ GHz = 4 \times 10^{9}\ Hz.$

$\therefore\ \omega = 2\pi f$

$= 2\pi \times 4 \times 10^{9}$

$= 25.12 \times 10^{9}\ rad/s = 25.12\ G\ rad/sec.$

(a) characteristics impedance

$$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$= \sqrt{\frac{8 + j(25.12 \times 10^{9})(8 \times 10^{-9})}{0.8 \times 10^{-3} + j(25.12 \times 10^{9})(0.20 \times 10^{-12})}}$$

$$= \sqrt{\frac{8 + j200.96}{8 + 10^{-2} + j50 \times 10^{-12}}}$$

$$= \sqrt{\frac{201.2 \angle 87.7^\circ}{10^{-2} \times 50.6 \angle 80.9}}$$

$$= \sqrt{397.6 \angle 6.8^\circ} \quad = 19.99 \angle 3.4^\circ$$

(b) Propagation constant

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

$$= \sqrt{(201.2 \angle 87.7^\circ)(50.6 \times 10^{-2} \angle 80.9^\circ)}$$

$$= 100.9 \times 10^{-1} \angle 84.3^\circ$$

By calculator

$$(3 + j4) = 5 \angle 53.13^\circ \quad \text{or} \quad 3 + j4 = a + jb$$

$$= r \angle \theta \quad \left[r = \sqrt{a^2 + b^2} \right]$$

$$= \sqrt{3^2 + 4^2} = 5$$

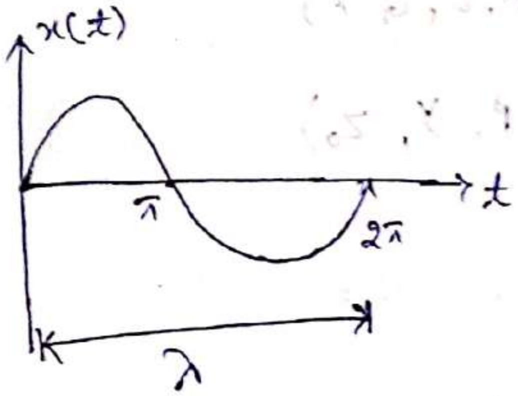
$$\theta = \tan^{-1}(b/a)$$

$$= \tan^{-1}(4/3)$$

$$= 53.13^\circ.$$

* Wavelength, Velocity of Propagation :-

→ A wavelength is distance travelled by the wave along line when the phase angle changes to 2π radians.



$\boxed{\lambda = \frac{2\pi}{\beta}}$, $\boxed{\text{Velocity } (v) = \frac{\omega}{\beta}}$

$\boxed{\text{Velocity } (V) = \frac{1}{\sqrt{LC}}}$

For any medium $\boxed{(v) = \frac{1}{\sqrt{\mu \cdot \epsilon}}}$

$\mu = \mu_0 \cdot \mu_r \; , \; \epsilon = \epsilon_0 \cdot \epsilon_r$

For air medium $\boxed{(v) = \frac{1}{\sqrt{\mu_0 \cdot \epsilon_0}}}$

$= 3 \times 10^8 \; m/s$

$\mu_0 = 4\pi \times 10^{-7} \; H/m.$

$\epsilon_0 = 8.814 \times 10^{-12} \; F/m.$

$\Rightarrow v = \omega/\beta = \frac{1}{\sqrt{LC}}$ (In transmission line).

$$\boxed{\beta = \omega . \sqrt{LC}}$$

* Relation between Primary and secondary Parameters

Primary Parameter (R, L, G, C).

Secondary Parameter ($\alpha, \beta, \gamma, Z_0$).

Case 1 : For loss less line

Defⁿ :- A transmission line is loss less when diaelectric medium between them is loss less and conductance is very high. ($\sigma_c = \infty$).

Condition :- R = G = 0 for loss less line

$$\therefore \boxed{Z_0 = \sqrt{L/C}}$$

$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)}$$

$$= \sqrt{(j\omega)^2 . LC}$$

Put R = G = 0 in above

$$= j\omega . \sqrt{LC}$$

$$\gamma = \alpha + j\beta$$

$$= j\omega . \sqrt{LC}$$

$= 0 + j\omega\sqrt{LC}$

$\alpha = 0, \beta = \omega\sqrt{LC}$

$$\boxed{V_p = \text{Phase velocity} = \frac{1}{\sqrt{LC}}}$$

Case 2 :- For distortion less line attenuation constant (α) is independent of frequency and phase constant is proportional to frequency.

Condition :- $\frac{R}{L} = \frac{G}{C}$

$R = \alpha . Z_0 \ \Omega/m$; $L = \frac{Z_0}{V_p} \ H/m$

$G = \frac{\alpha}{Z_0} \ \mho/m$; $C = \frac{1}{Z_0 . V_p} \ F/m.$

Delay $= \sqrt{LC}$ sec/m

$$\boxed{\alpha = R.\sqrt{\frac{C}{L}}} \quad \text{or} \quad \boxed{G\sqrt{\frac{L}{C}} = \alpha}$$

Ques

An airline has characteristic impedance of 70Ω & phase const. 3 rad/m at 100 MHz.

calculate

(i) Inductance/m

(ii) Capacitance/m.

Ans Assume an airline be loss less line ($\Rightarrow \sigma = 0$).

So $R = G = 0$ & $\alpha = 0$.

$Z_0 = \sqrt{\frac{L}{C}}$; $\beta = \omega\sqrt{LC}$

Given data,

$Z_0 = 70\,\Omega$, $\beta = 3$ rad/m.

$f = 100\ MHz = 100 \times 10^6\ Hz$

$\therefore Z_0 = \sqrt{L/c}$ $\quad \omega = 2\pi f = 2\pi \times 100 \times 10^6 = 200\pi \times 10^6\ Hz.$

$= \cancel{2\pi \times 100} \times 10^6 = \cancel{200\pi \times 10^6}\ Hz.$

$\Rightarrow 70 = \sqrt{L/c}$

$\Rightarrow \frac{L}{c}(70^2) = 4900$

$\Rightarrow L = 4900\,C.$

$\therefore \beta = \omega\sqrt{LC}$ $\quad \Rightarrow \sqrt{LC} = \frac{3}{200\pi \times 10^6}$

$\Rightarrow 3 = 200\pi \times 10^6 \sqrt{LC}$

$\Rightarrow 70\,C = \frac{3}{200\pi \times 10^6}$

$\Rightarrow C = \frac{3 \times 10^{-6}}{200 \times 3.14 \times 70} = 6.82 \times 10^{-5} \times 10^{-6}.$

$\Rightarrow C = 8.2 \times 10^{-12}\ F = 68.2\ pF/m.$

$\therefore L = 4900\,c = 4900 \times 68.2 \times 10^{-12}$

$= 334.2\ nH/m.$

* Reflection co-efficient of Transmission Line :-

If Z_L is load impedance of T.L, Z_0 is ch/as impedance of T.L then,

voltage reflection co-efficient (K_v).

$$\boxed{K_v = \frac{\text{Reflected voltage wave}}{\text{Incident voltage wave}}}$$

$$\boxed{K_v = \frac{Z_L - Z_0}{Z_L + Z_0}}$$

→ Similarly current reflection co-efficient (K_i).

$$\boxed{K_i = \frac{\text{Reflected current wave}}{\text{Incident current wave}}}$$

$$K_i = -(K_v)$$

$$\boxed{K_i = \frac{Z_0 - Z_L}{Z_L + Z_0}}$$

* Transmission co-efficient (T) :-

$$T = \frac{\text{Transmitted voltage wave}}{\text{Incident voltage wave}} = \boxed{\frac{V_{tr}}{V_{inc}}}$$

$$T = \frac{\text{Transmitted current wave}}{\text{Incident current wave}} = \boxed{\frac{I_{tr}}{I_{inc}}}$$

$$\boxed{T = 1 + K_v}$$

Transmission co-efficient (T) = 1 + Voltage Reflection co-efficient.

$$\boxed{T = \frac{2Z_L}{Z_L + Z_0}}$$

$$= 1 + K_v$$

$$= 1 + \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$= \frac{Z_L + Z_0 + Z_L - Z_0}{Z_L + Z_0} = \frac{2Z_L}{Z_L + Z_0}$$

Ques

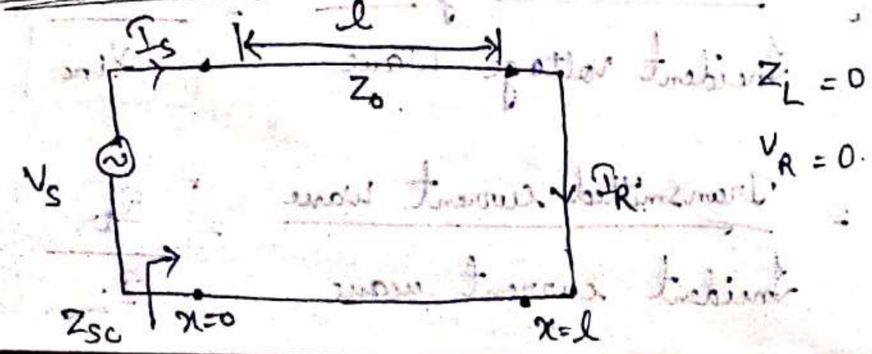
If the length of T.L. is $\frac{\lambda}{8}$, Find the electrical length.

Ans Electrical length = $\beta \cdot l$.

$$= \frac{2\pi}{\lambda} \cdot \frac{\lambda}{8}$$

$$= \frac{2\pi}{8} = \pi/4.$$

* Short circuit Line



$\rightarrow Z_{SC} = \frac{V_S}{I_S}$

→ when a finite length T.L is terminated by short circuit then that line is short ckt line.

$$V(\text{at } x=l) = V_R = 0$$

$$= V_S \cdot \cosh\gamma l - I_S \cdot Z_0 \cdot \sinh\gamma l.$$

$$\Rightarrow \boxed{\frac{V_S}{I_S} = Z_0 \cdot \tanh\gamma l.}$$

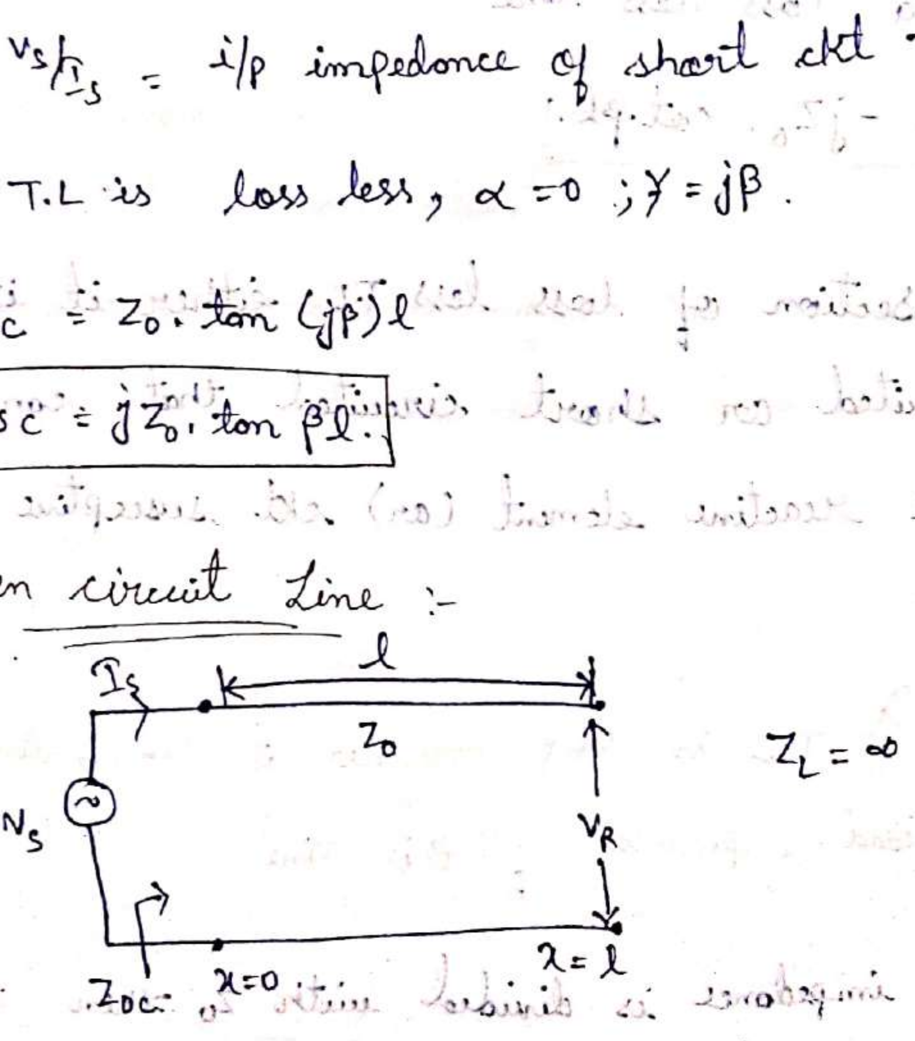
$Z_{SC} = V_S/I_S$ = i/p impedance of short ckt T.L.

→ If T.L is loss less, $\alpha = 0$; $\gamma = j\beta$.

$$\therefore Z_{SC} = Z_0 \cdot \tan(j\beta)l$$

$$\boxed{Z_{SC} = jZ_0 \cdot \tan\beta l.}$$

* <u>Open circuit Line</u> :-



→ when a finite length of T.L is open circuited at terminating end then it is called open ckt line.

→ The impedance seen at the i/p of the line is Z_{oc}.

∴ $\hat{I}$ (at $x = l$) $= \hat{I}_R = 0$

$$\hat{I}_s \cosh\gamma l - \frac{V_s}{Z_0}.\sinh\gamma l$$

$$\Rightarrow \frac{V_s}{\hat{I}_s} = Z_0 . \coth\gamma l.$$

$$\Rightarrow \boxed{Z_{oc} = Z_0 . \coth\gamma l.}$$

For a loss less line

$$\boxed{Z_{oc} = -jZ_0 . \cot\beta l.}$$

NOTE :- A section of loss less T.L either it is open circuited or short circuited that can act as a ckt reactive element (or) ckt susceptive element.

Ques

A loss less $\frac{\lambda}{8}$ T.L is sort circuited at terminating end. Find normalised impedance of this line.

Ans If any impedance is divided with Z_0 then that impedance is normalised impedance.

Here loss less T.L length $l = \lambda/8$.

Z_{sc} = i/p impedance of short ckt T.L.

$= jZ_0 \cdot \tan\beta l$.

$\therefore \frac{Z_{sc}}{Z_0} = j \tan \frac{2\pi}{\cancel{\lambda}} \cdot \frac{\cancel{\lambda}}{8} = j.1 = j$

⇒ Normalised Impedance = 1 = $|j|$.

This indicates an inductive reactance.

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$Z_{oc} \cdot Z_{sc} = Z_0^2$

Ques :-

A distortionless transmission line has $\alpha = 20$ mnP/m (milli Neper/mtr), Phase velocity $v_p = 0.6 \times 3 \times 10^8$ m/sec i.e., 0.6 times the velocity of light. Assume $Z_0 = 50\,\Omega$. Find the primary constants and delay in the T.L.

Ans

$\alpha = 20 \times 10^{-3}$ nP/m.

$v_p = 0.6 \times 3 \times 10^8$ m/sec

$Z_0 = 50\,\Omega$

$R = \alpha Z_0 = 20 \times 10^{-3}$ nP/m $\times 50\,\Omega$

$= 1\,\Omega$/m.

$G = \frac{\alpha}{Z_0} = \frac{20 \times 10^{-3} \text{ nP/m}}{50\,\Omega} = 0.4$ m℧/m.

$L = Z_0/v_p = \frac{50\,\Omega}{0.6 \times 3 \times 10^8 \text{ m/sec}} = 0.27$ μH/m.

$C = \frac{1}{Z_0 \cdot v_p} = \frac{1}{50\,\Omega \times 0.6 \times 3 \times 10^8 \text{ m/sec}} = 0.11$ G F/m.

* Input Impedance of a Transmission Line :-

If a transmission line has length 'l' and its characteristics impedance is Z_0 then i/p impedance of transmission line is :

$$\boxed{Z_{in} = Z_0 . \frac{Z_L + Z_0 \tanh \gamma l}{Z_0 + Z_L \tanh \gamma l.}} \longrightarrow ⑤$$

Z_L = load impedance i.e., the T.L is terminated at Z_L.

→ If T.L is lossless line $\alpha = 0$, $\gamma = j\beta$, then i/p impedance,

$$\boxed{Z_{in} = Z_0 . \frac{Z_L + jZ_0 . \tan \beta l}{Z_0 + jZ_L \tan \beta l}} \longrightarrow ⑥$$

NOTE :- When a T.L is terminated by $Z_L = Z_0$, then the impedance seen at any point in the T.L is Z_0, and the i/p impedance of T.L is also Z_0 whether the line is lossless (or) lossy, and irrespective of the length of the line.

* Properties of $\lambda/2$ line

Length of T.L $l = \lambda/2$, consider T.L is lossless.

$$Z_{in} = Z_0 . \frac{Z_L + jZ_0 \tan \beta l}{Z_0 + jZ_L \tan \beta l}$$

$$Z_{in} = Z_0 \cdot \frac{Z_L + jZ_0 \tan \frac{2\pi}{\lambda} \cdot \lambda/2}{Z_0 + jZ_L \tan 2\pi/\lambda \cdot \lambda/2}$$

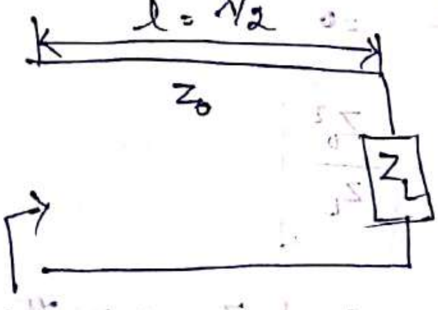
$$= Z_0 \frac{Z_L + jZ_0 \tan 0}{Z_0 + jZ_L \tan 0}$$

$$= Z_0 \cdot \frac{Z_L + 0}{Z_0 + 0}$$

$$\therefore \boxed{|Z_{in}| = |Z_L|}$$

i.e.,

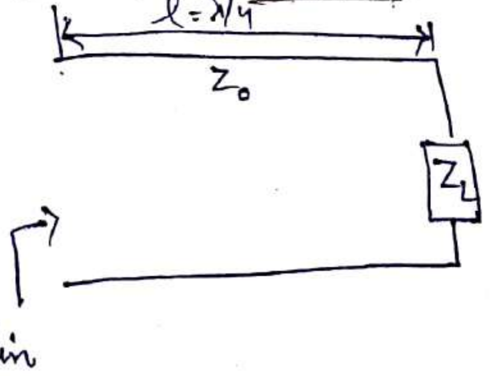
Input impedance of $\lambda/2$ line is same as load impedance.



$Z_{in} = Z_L$

→ Input impedance of $n\frac{\lambda}{2}$ line (length of T.L $l = n\lambda/2$), where $n = 1, 2, 3 \ldots$, is same as $\lambda/2$ line & it is equal to load impedance.

* Properties of $\lambda/4$ line



$$\tan\beta l = \tan\frac{2\pi}{\lambda}\cdot\frac{\lambda}{4}$$

$$= \tan\pi/2 = \infty \quad \text{(In radian).}$$

Let, the transmission line ($l = \lambda/4$) is lossless line.

$$Z_{in} = Z_0 \cdot \frac{Z_L + jZ_0 \cdot \tan\beta l}{Z_0 + jZ_L \tan\beta l}$$

$$= Z_0 \cdot \frac{\tan\beta l\left(Z_L/\tan\beta l + jZ_0\right)}{\tan\beta l\left(Z_0/\tan\beta l + jZ_L\right)}$$

$$\Rightarrow \frac{Z_L}{\tan\beta l} = \frac{Z_L}{\infty} = 0.$$

$$\Rightarrow Z_{in} = Z_0 \cdot \frac{jZ_0}{jZ_L} = \boxed{\frac{Z_0^2}{Z_L}}$$

→ If $Z_L = 0\,\Omega$ then $Z_{in} = \infty\,\Omega$ & $Z_L = \infty\,\Omega$, then $Z_{in} = 0\,\Omega$.

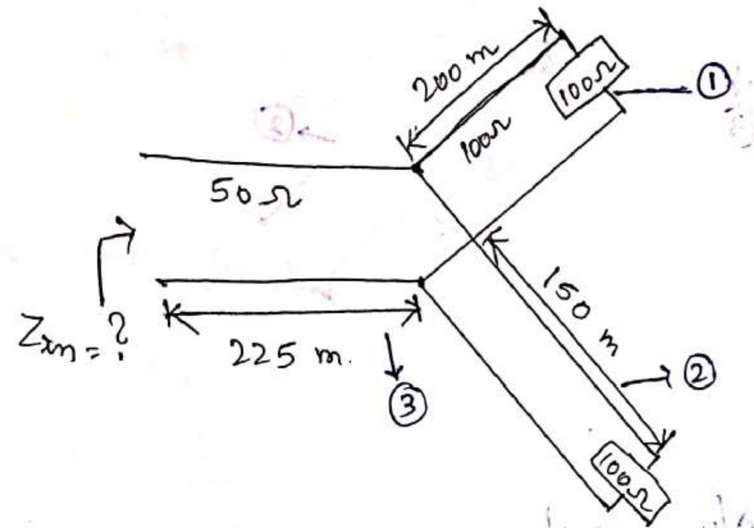
→ A quarter wave line ($l = \lambda/4$) also named as impedance T/F because it transforms high impedance to low impedance & vice versa.

→ The i/p impedance of a $n\lambda/4$ line (where n is add i.e., n = 1, 2, 3 ...) same as $\lambda/4$ line which is equal to $\frac{Z_0^2}{Z_L}$.

Ques

Find i/p impedance of the following T.L.

(i) Assume T.L are loss less lines.



Ans For line ①

$Z_0 = Z_L = 100\Omega$

$\Rightarrow Z_{in_1} = 100\Omega$.

For line ② ; $Z_0 = Z_L = 100\Omega$.

$\Rightarrow Z_{in_2} = 100\Omega$

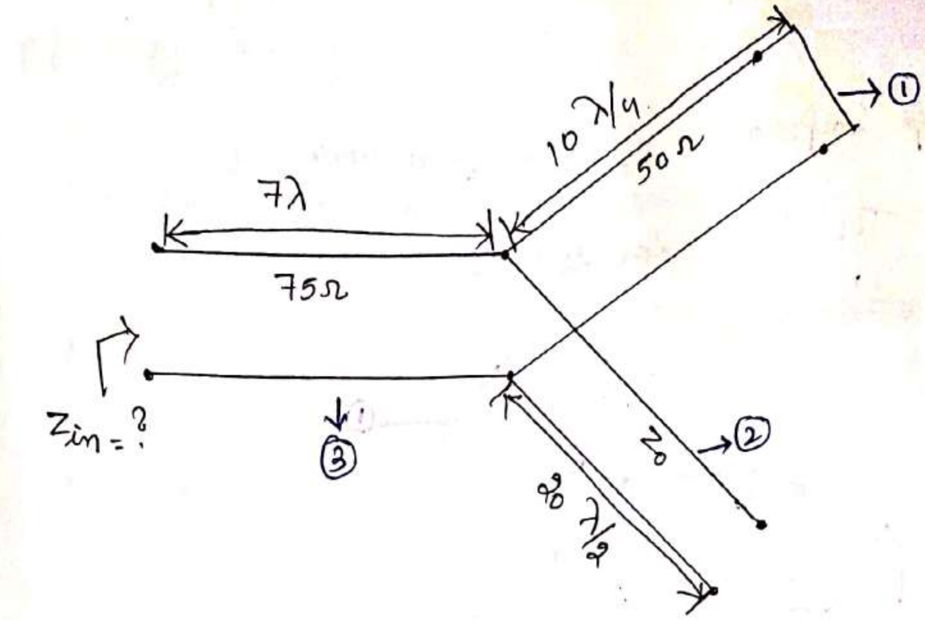
Line ① & line ② are parallel to each other, so their effective i/p impedance is

$$Z_{in} = Z_{in_1} \,//\, Z_{in_2}$$

$$= 100\Omega \,//\, 100\Omega = 50\Omega.$$

For line ③ $Z_0 = Z_L = Z_{in} = 50\Omega$.

(ii)



Ans For line ①

$l = 10\lambda/4 = 5\lambda/2.$

$Z_L = 0\,\Omega \Rightarrow Z_{in_1} = 0\,\Omega = Z_L$

For line ② $l = 20\lambda/2$ = ~~10λ~~

$Z_{L_2} = \infty\,\Omega \Rightarrow Z_{in_2} = Z_{L_2} = \infty\,\Omega$

Line ① & line ② are Parallel.

$Z_{in} = Z_{in_1} \parallel Z_{in_2}$

$= 0 \parallel \infty$

$= 0$

For line ③.

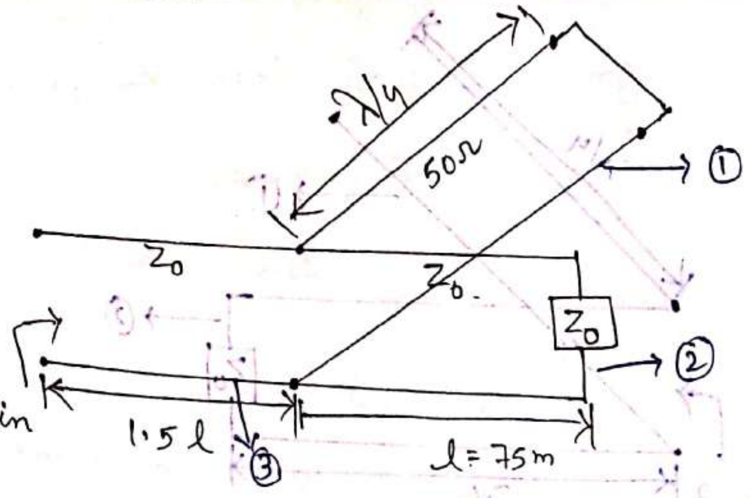
$l = 7\lambda = 14 \cdot \lambda/2$

$Z_{L_3} = 0\,\Omega$

$Z_{in} = Z_{L_3} = 0\,\Omega.$

For nλ/2 line, i/p impedance is load impedance.

(iii)



Ans

For line ① $l = \lambda/4$, $Z_{L_1} = 0\Omega$

$Z_{in_1} = \infty\ \Omega$

$$\left[\because Z_{in} = \frac{Z_0^2}{Z_L} = \frac{50^2}{0} = \infty\right]$$ For λ/4 line

For line ② $Z_{L_2} = Z_0 \Rightarrow Z_{in_2} = Z_0$

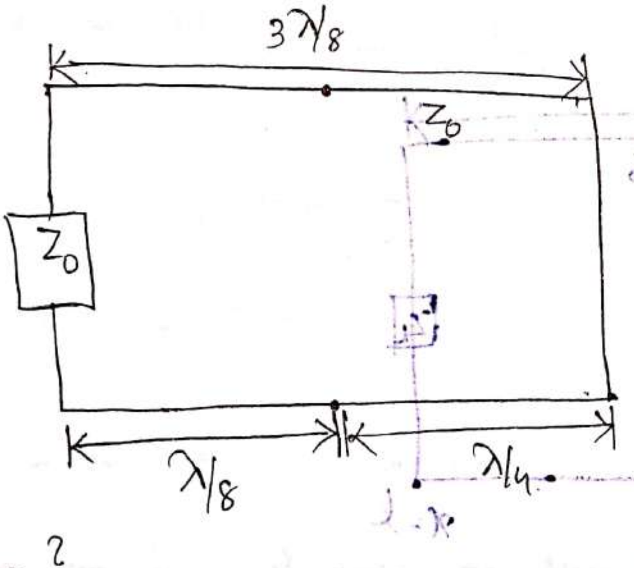
line ① // line ②

$$Z_{in} = Z_{in_1} \,//\, Z_{in_2}$$
$$= \infty \,//\, Z_0 = Z_0$$

For line ③ $Z_{L_3} = Z_0$

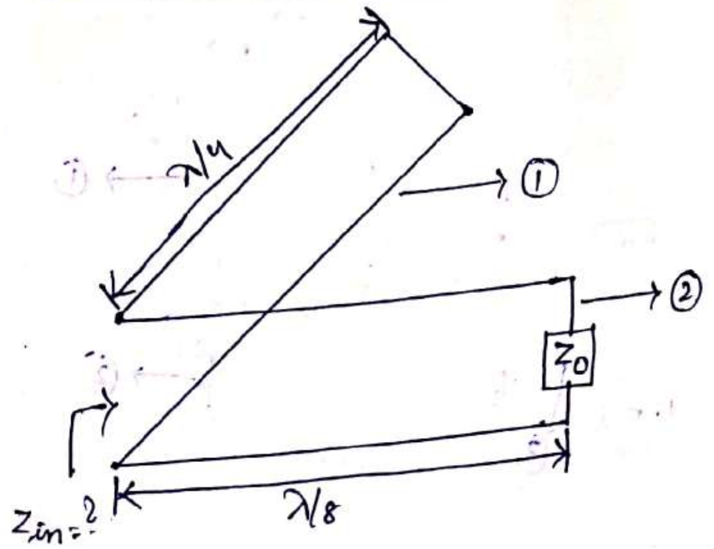
$\therefore\ Z_{in} = Z_{L_3} = Z_0$

(iv)



$Z_{in} = ?$

Ans



For line ①; $l = \lambda/4$, $Z_{L_1} = 0\,\Omega$

$$\Rightarrow Z_{in_1} = \infty \left[\because Z_{in} = \frac{Z_0^2}{Z_L}\right]$$

For line ②; $l = \lambda/4$, $Z_{L_2} = Z_0$.

$$\Rightarrow Z_{in_2} = Z_0.$$

Line ① // line ②

$$\begin{aligned} Z_{in} &= Z_{in_1} // Z_{in_2} \\ &= \infty // Z_0 \\ &= Z_0. \end{aligned}$$

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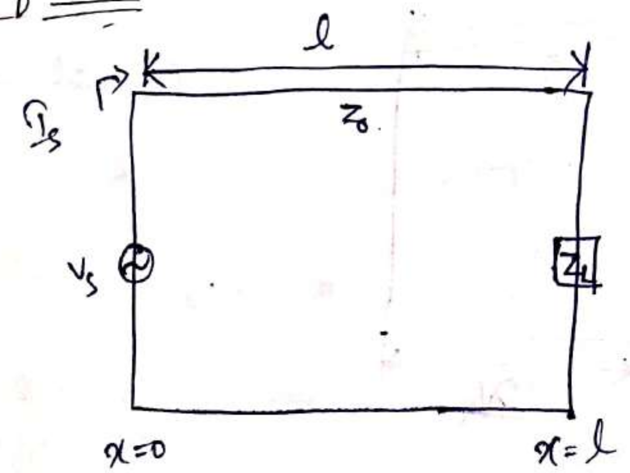
* Reflection



→ When $Z_L = Z_0$ at that time the impedance at any Point of the transmission line is same as Z_0. This is called impedance matching.

→ When $Z_L \neq Z_0$ at that time the impedance changes from Point to Point on the T.L. This is called impedance mismatching (or) impedance is discontinous (or) irregular (or) mismatch (or) non. uniform. Here reflection takes place.

→ The Voltage at any Point on T.L is vectorial sum of incident wave voltage & reflected wave voltage at some locations on T.L. If these two voltages add in phase at that time voltage maxima will be observed. $\boxed{V_{max} = |V_i| + |V_r|}$

→ But at some location on T.L these two voltages add in out of phase. So in voltage minima is observed in T.L. $\boxed{V_{min} = |V_i| - |V_r|}$

→ Therefore a voltage across T.L may swing between V_{max} to V_{min} and vice versa.

→ But when $Z_L = Z_0$, there are no maximas & no minimas in T.L. Because, no reflection takes place in T.L

→ Voltage standing wave ratio (V_{SWR}) or

$$\boxed{S = \frac{V_{max}}{V_{min}} = \frac{|V_i| + |V_r|}{|V_i| - |V_r|}}$$

$$= \frac{1 + \frac{V_r}{V_i}}{1 - \frac{V_r}{V_i}} = \frac{1 + |K|}{1 - |K|}$$

where,

K = reflection co-efficient $= \frac{V_r}{V_i}$

$$= \frac{Z_L - Z_0}{Z_L + Z_0}$$

$K \rightarrow |K| \angle\theta$

θ is phase angle of K.

$|K|_{max} = 1$; $|K|_{min} = 0$

$S_{min} = 1$; $S_{max} = \infty$

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→ The successive distance between two voltage ~~[illegible]~~ minimas (or) two maximas is $\lambda/2$

→ The successive distance between voltage minima to maxima (or) vice versa is $\lambda/4$.

Location of

$$\boxed{V_{max} \leftrightarrow Z_{max} \leftrightarrow I_{min}}$$

Location of

$$\boxed{V_{min} \leftrightarrow Z_{min} \leftrightarrow I_{max}}$$

* Location of V_{max} :-

$$2\beta y_{max} - \phi = 2n\pi$$

$n = 0$ for 1st maxima

$n = 1$ for 2nd maxima

⋮

so on.

* Location of V_{min} :-

$$2\beta y_{min} - \phi = (2n+1)\pi$$

$n = 0$ for 1st minima

$n = 1$ for 2nd minima

⋮

so on

$y \rightarrow$ Distance measured from load end.

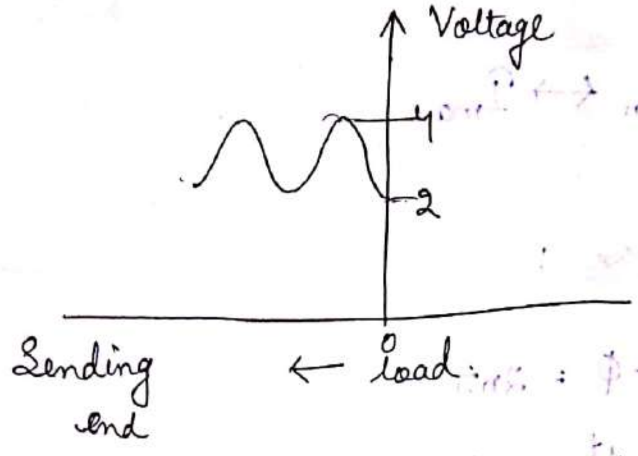
$$\boxed{Z_{max} = S \cdot Z_0} \; ; \; \boxed{Z_{min} = \frac{Z_0}{S}}$$

S = Standing wave ratio

Z_0 = characteristic impedance

Ques

A certain T.L is terminated by an unknown load impedance. The voltage standing wave pattern is shown in figure. Calculate SWR, reflection co-efficient & also find load impedance. Given that $Z_0 = 100\,\Omega$.



Ans $V_{max} = 4$, $V_{min} = 2$

$$\therefore \ SWR\ (S) = \frac{V_{max}}{V_{min}} = 4/2 = 2.$$

At the load V_{min} [i.e., 2] is observed. So the load impedance is Z_{min}

$$\therefore \ Z_{min} = \frac{Z_0}{S} = \frac{100}{2} = 50 = Z_L.$$

* Reflection co-efficient

$$K = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{50-100}{50+100} = \frac{-50}{150}$$

$$= -1/3 = -0.33 = 0.33 \angle 180^\circ$$

$$|K| = \frac{S-1}{S+1} = \frac{2-1}{2+1} = 1/3 = 0.33.$$

At the load, V_{min} is observed i.e., at $y=0$ 1st V_{min} is observed ..

$$2\beta y_{min} - \phi = (2n+1)\pi$$

n = 0 for 1st minima

$\Rightarrow 2.\beta(0) - \phi = (2.0+1)\pi$

$\Rightarrow -\phi = \pi \Rightarrow \phi = -\pi \quad \Rightarrow \pi = -180 = 180^\circ$

* Impedance Matching :-

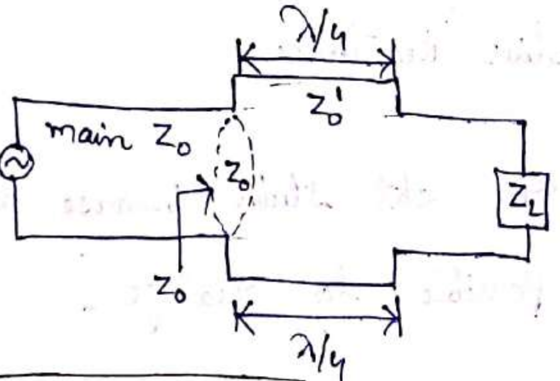
→ This technique is used for avoiding reflections.

→ Two types of impedance matching technique

(i) Quarter wave T/F.

(ii) Stub matching.

(i) Quarter Wave Transformer Matching :-



$$\boxed{Z_0' = \sqrt{Z_0 \cdot Z_L}}$$

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→ characteristics impedance of this quarter wave line (Z_0') is geometric mean of Z_0 & Z_L.

$$Z_0 = \frac{(Z_0')^2}{Z_L}$$

* Disadvantage:- When freq. of operation changes, length of quarter wave line has to be readjusted by disconnecting from the main line. So we use stub matching.

* Stub Matching :-

→ A section of a loss less T.L is either short circuited (or) open circuited can act as a ckt reactive element (or) circuit susceptible element and desired reactance (or) suspectance can be achieved by properly choosing length of T.L.

→ These are ~~a~~ used in impedance matching technique. Hence, the name is stub matching.

$X_L = \omega_L$ = Inductive Reactance

$X_C = \frac{1}{\omega_C}$ = capacitive Reactance

→ We don't prefer open ckt stubs because an ideal open ckt is not possible to realize.

→ For example :- When a T.L is open circuited, it is indirectly terminated by air impedance.

→ For free space air impedance is 120π (or) 377Ω.

(Or)

→ A section of T.L can be used in shunt (or) parallel with main line as impedance matching by inserting it between the load & source is known as stub.

→ The process of impedancing by the stub is called stub matching.

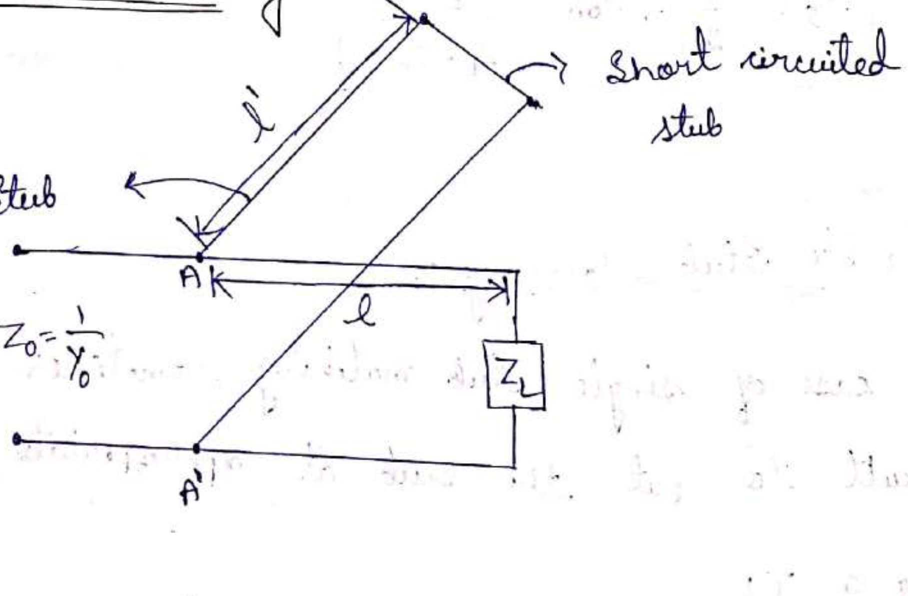
* Advantages :-

(i) Length of main T.L remains unchanged.

(ii) Z_0 of T.L remains constant.

(iii) At higher freq. the stub may be adjusted to a variable load & it is operated over a wide range of freq.

(i) Single Stub Matching :-



$$\underset{(Z)}{\text{Impedance}} = \frac{1}{\text{Admittance}(Y)}$$

$Z = R + jX_L$ = Resistance + j reactance

$Y = G + jb$ = conductance + j suspectance.

Here, in main T.L is $Z_L \mp Z_0$ then by inserting single stub we can match the impedance i.e., $Z_L = Z_0$.

→ Take 'l' is the distance from the load, where if we locate the stub then impedance matching occurs.

Then that distance.

$$\boxed{l = \frac{\lambda}{2\pi} \cdot \tan^{-1}\sqrt{\frac{Z_L}{Z_0}}}$$

→ Take 'l_s' is the length of stub that to be placed at a distance 'l' from the load for impedance matching $(Z_L = Z_0)$.

→ Then length of short circuit stub is

$$\boxed{l_s = \frac{\lambda}{2\pi} \cdot \tan^{-1} \frac{Z_L \cdot Z_0}{Z_L - Z_0}}$$

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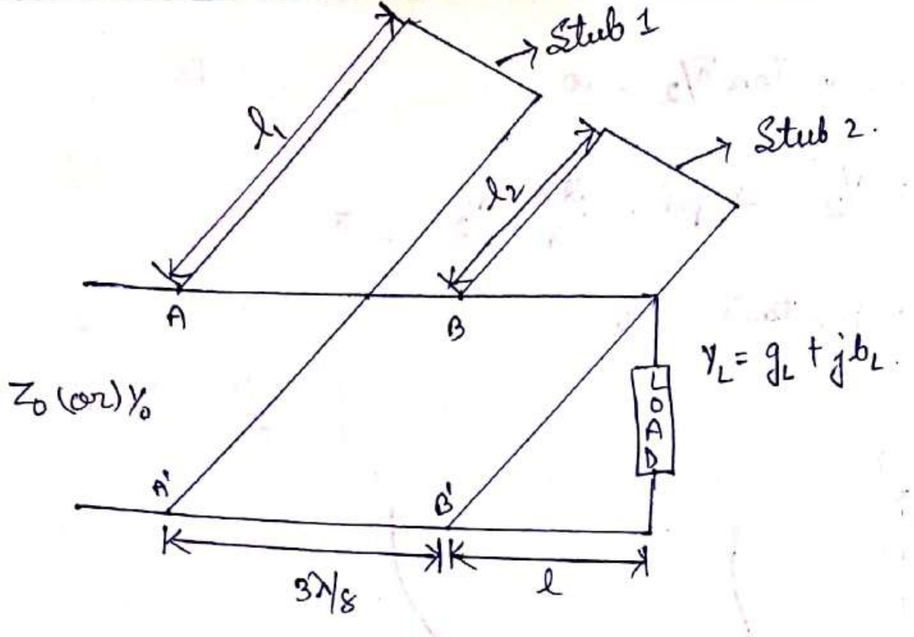
* Double Stub Matching :-

→ In case of single stub matching sometimes it is very difficult to put the stub at appropriate Position along a T.L.

→ So, in this situation double stub matching is Preferred.

→ In Double stub matching two stubs having length l_1 & l_2 are used & those are placed at a fixed Position AA' & BB' aparting a distance $3\lambda/8$.



→ The stub nearer to the load is adjusted to make the real part of resulting admittance at point AA' is equal to characteristic conductance of T.L = 1.

→ In the absence of 2nd stub at BB' (or) reflection co-efficient (Γ) is not fully negligible, in that case the stub at AA' is adjusted to produce the zero suspectance at AA'.

→ So in this way matching is done.

* Short circuit Line

$$\boxed{Z_{SC} = jZ_0 \cdot \tan \beta l}$$

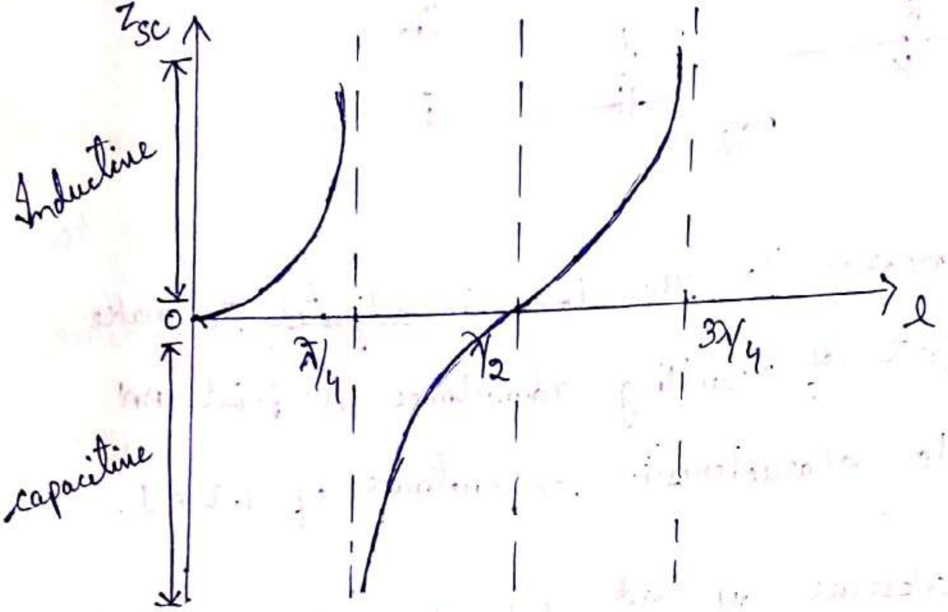
① If $l = \lambda/4$

$$\Rightarrow \beta l = \frac{2\pi}{\lambda} \cdot \lambda/4 = \pi/2.$$

$\Rightarrow Z_{SC} = jZ_0 . \tan \pi/2 = \infty.$

② If $l = \lambda/2 \Rightarrow \beta l = \frac{2\pi}{\lambda} . \lambda/2 = \pi.$

$\Rightarrow Z_{SC} = jZ_0 \tan \pi = 0$



→ In T.L, in loss less condition for length 'l' varies from 0 to $\lambda/4$, the short ckt i/p impedance is inductive in nature.

→ For length 'l' varies from $\lambda/4$ to $\lambda/2$ the short ckt i/p impedance is capacitive in nature.

* Open circuit Line :-

$$\boxed{Z_{OC} = -jZ_0 . \cot \beta l.}$$

① If $l = \lambda/4$

$\Rightarrow \beta l = \frac{2\pi}{\lambda} . \lambda/4 = \pi/2.$

⇒ $Z_{oc} = -jZ_0 \cot \pi/2$

$= -jZ_0\, 0$

$= 0$.

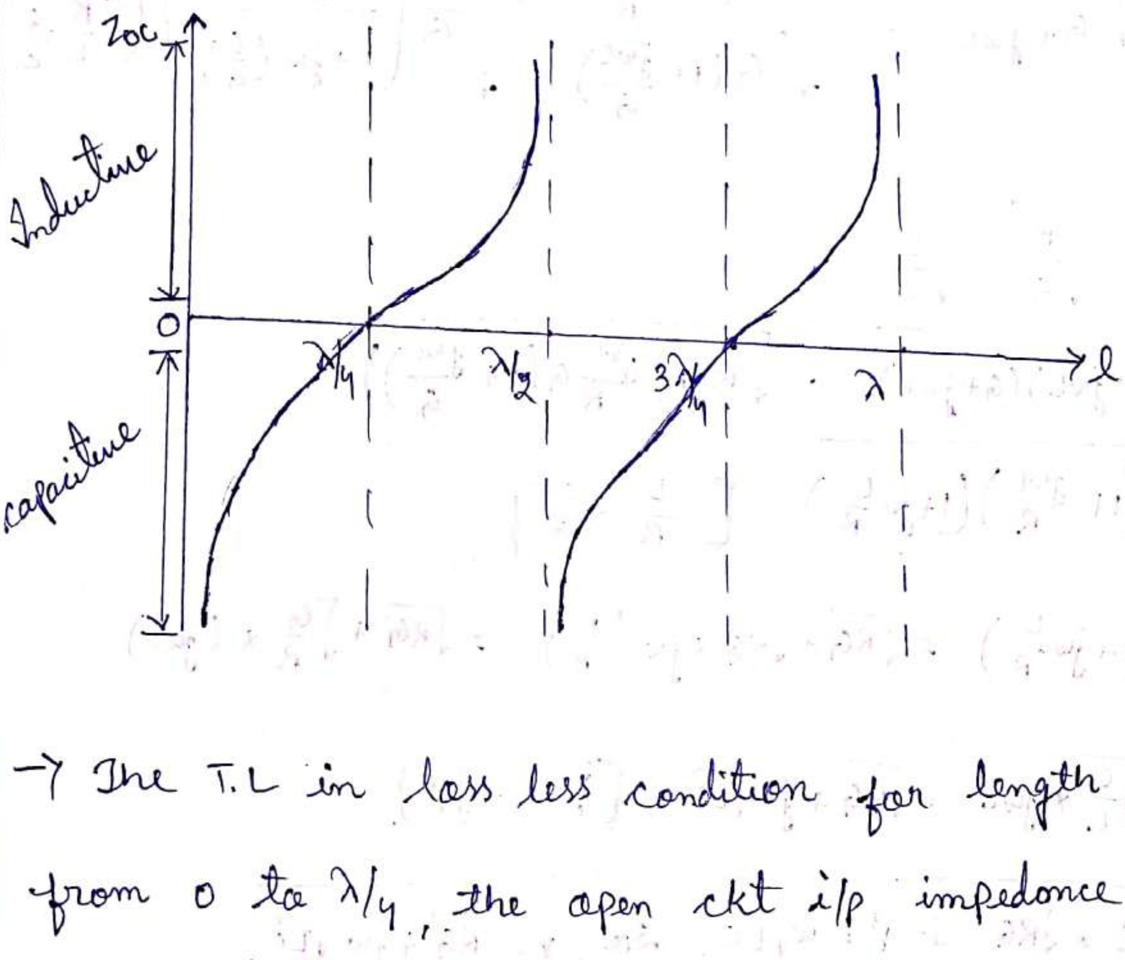
② If $l = \lambda/2$

⇒ $\beta l = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{2} = \pi$.

⇒ $Z_{oc} = -jZ_0 \cot \pi$

$= -jZ_0\, \infty$ $\left[\because \cot \pi = \frac{1}{\tan \pi} = \frac{1}{0} = \infty\right]$

$= \infty$.



→ The T.L in loss less condition for length 'l' varies from 0 to $\lambda/4$, the open ckt i/p impedance is capacitive in nature.

→ For length 'l' varies from $\lambda/4$ to $\lambda/2$, the open circuit i/p impedance is inductive in nature.

* Smith chart

→ In T.L equation, the solutions are complicated and computations are also difficult.

→ To overcome this problem, we use Smith chart.

* Relationship between Primary & secondary parameters

Case 2 :-

$$Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega L}} = \sqrt{\frac{R\left(1+\frac{j\omega L}{R}\right)}{G\left(1+\frac{j\omega C}{G}\right)}} = \sqrt{\frac{R}{G}\left(\frac{1+j\omega\left(\frac{C}{G}\right)}{1+j\omega\left(\frac{C}{G}\right)}\right)} \quad \left(\because \frac{R}{L} = \frac{G}{C}\right.$$

$$= \sqrt{\frac{R}{G}}$$

$$\therefore Z_0 = \sqrt{\frac{R}{G}} = \sqrt{\frac{L}{C}}$$

$$\therefore \nu = \sqrt{(R+j\omega L)(G+j\omega C)} = \sqrt{R\left(1+\frac{j\omega L}{R}\right)G\left(1+\frac{j\omega C}{G}\right)}$$

$$\therefore \nu = \sqrt{RG\left(1+\frac{j\omega L}{R}\right)\left(1+j\omega\frac{L}{R}\right)} \quad \left[\frac{L}{R} = \frac{C}{G}\right].$$

$$= \sqrt{RG}\left(1+j\omega\frac{L}{R}\right) = \sqrt{RG} + \sqrt{RG} \times j\omega\left(\frac{L}{R}\right) = \sqrt{RG} + \sqrt{\frac{G}{R}} \times (j\omega L)$$

$$= \sqrt{RG} + \sqrt{\frac{C}{L}} \times j\omega L = \sqrt{RG} + j\omega\sqrt{LC} \quad [\because \alpha + j\beta].$$

where, $\boxed{\alpha = \sqrt{RG} \ \& \ \beta = \omega\sqrt{LC}, \ \text{So}, \ v = \sqrt{RG} + j\omega\sqrt{LC}}$

$$\therefore v_p = \frac{\omega}{\beta} = \frac{\omega}{\omega\sqrt{LC}} = \frac{1}{\sqrt{LC}}$$

Case 3 At high frequency when ($R << \omega L$ & $G << \omega C$)

$$\therefore v = \sqrt{(R+j\omega L)(G+j\omega C)} = \sqrt{j\omega L\left(1+\frac{R}{j\omega L}\right)\left(1+\frac{G}{j\omega C}\right)j\omega C}$$

$= j\omega\sqrt{LC}\left(1+\frac{R}{j\omega L}\right)^{1/2}\left(1+\frac{G}{j\omega C}\right)^{1/2} = j\omega\sqrt{LC}\left(1+\frac{R}{j\omega L}\right)\left(1+\frac{1}{2}\times\left(\frac{G}{j\omega C}\right)\right)$

$= j\omega\sqrt{LC}\left(1+\frac{G}{2j\omega C}+\frac{R}{2j\omega L}+\frac{RG}{4j^2\omega^2 LC}\right)$ [∵ $\omega C >> G$ & $\omega L >> R$].

[∵ $(1+a_x)^n \simeq 1+nax$ when $|a|<1$, here $a = \frac{R}{j\omega L}$

$\Rightarrow a << 1$; $\omega L >> R$].

$= j\omega\sqrt{LC} + \frac{G}{2C}\sqrt{LC} + \frac{R}{2L}\times\sqrt{LC} = j\omega\sqrt{LC}+\frac{G}{2}\sqrt{\frac{L}{C}}+\frac{R}{2}\sqrt{\frac{C}{L}}$

$= \left[\frac{R}{2}\left(\sqrt{\frac{C}{L}}\right)+\frac{G}{2}\left(\sqrt{\frac{L}{C}}\right)\right]+j\omega\sqrt{LC} \simeq \alpha+j\beta$.

By similar process for $Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} = \frac{\sqrt{j\omega L}\left(\frac{R}{j\omega L}+1\right)^{1/2}}{\sqrt{j\omega C}\left(\frac{G}{j\omega C}+1\right)^{1/2}}$

$\Rightarrow Z_0\sqrt{\frac{L}{C}}\left(1+\frac{R}{2j\omega L}\right)\left(1-\frac{1}{2j\omega C}\right)$

$\therefore \alpha = \left(\frac{R}{2}\sqrt{\frac{C}{L}}+\sqrt{\frac{L}{C}}\frac{G}{2}\right.$ & $\beta = \omega\sqrt{LC}$

$\therefore u = \frac{\omega}{\beta} = \frac{1}{\sqrt{LC}}$

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1) An open wire T.L has the following primary constants

$R = 4 \Omega/Km$, $L = 2.5\ mH/Km$

$C = 0.009\ \mu f/Km$, $G = 0.29\ \mu mho/Km$

Frequency of operation = 1 KHz.

Find :- (a) Z_0

(b) Phase constant

(c) Attenuation const.

(d) Phase velocity

A) Given data

$R = 4 \Omega/Km$, $L = 2.5\ mH/Km = 2.5 \times 10^{-3}\ H/Km$

$C = 0.009\ \mu F/Km = 0.009 \times 10^{-6}\ F/Km$

$G = 0.29\ \mu \mho/Km = 0.29 \times 10^{-6}\ \mho/Km$

$f = 1\ KHz = 10^3\ Hz$.

$\omega = 2\pi f = (2\pi \times 10^3)\ rad/s$.

(a) $$Z_0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} = \sqrt{\frac{4 + j2\pi \times 10^3 \times 2.5 \times 10^{-3}}{0.29 \times 10^{-6} + j2\pi \times 10^3 \times 0.009 \times 10^{-6}}}$$

$$= \sqrt{\frac{4 + j22}{(0.29 + j56.5) \times 10^{-6}}} = 10^3 \sqrt{\frac{22.4 \angle 79.3^\circ}{56.5 \angle 90^\circ}}$$

$= 630 \angle 10.7^\circ\ \Omega$

$$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)}$$

$$= \sqrt{(4+j22)(0.29+j56.5)\times 10^{-6}}$$

$$= \sqrt{(22.4\angle 79.3)(10^{-6}\times 56.5\angle 90^\circ)} = 0.36\angle 84.65^\circ$$

$$= 0.36\cos 84.65^\circ + j\,0.36\sin 84.65$$

[$\alpha + j\beta$ form]

(b) β = Phase constant

$$= 0.36\sin 84.65^\circ = 0.358 \text{ rad/sec}$$

(c) $$\alpha = 0.36\cos 84.65^\circ$$

$$= 0.033 \text{ rad/sec.}$$

(d) Phase Velocity $= u = \frac{\omega}{\beta}$

$$= \frac{2\pi\times 10^3}{0.358} = 17.55 \text{ Km/sec}$$

Or

take

$$Z = R + j\omega L = (4 + j2\pi 10^3)\times(2.5\times 10^{-3})$$

$$= 4 + j22$$

$$= 22.4\angle 79.3^\circ$$

$$Y = G + j\omega C = (0.29\times 10^{-6}) + (j2\pi\times 10^3\times 0.009\times 10^{-6})$$

$$= (0.29 + j56.5)\times 10^{-6}$$

$$= 56.5\times 10^{-6}\angle 90^\circ$$

$$\therefore Z_0 = \sqrt{\frac{R+j\omega L}{G+j\omega C}} = \sqrt{\frac{Z}{Y}} = \sqrt{\frac{22.4\angle 79.3}{56.5\times 10^{-6}\angle 90^\circ}} = 630\angle -5.35^\circ$$

$\gamma = \sqrt{(R+j\omega L)(G+j\omega C)} = \sqrt{ZY}$

$= \sqrt{(22.4\angle 79.3^\circ)(56.5\times10^{-6}\angle 90^\circ)} = 0.037\angle 84.65^\circ$.

Q2) A T.L has characteristic impedance of $(75+j0.01)\Omega$ & is terminated in load impedance of $(70+j50)\Omega$, compute

(a) The reflection co-efficient

(b) Transmission co-efficient

(c) Show that $T = 1+\Gamma$.

A) Given that,

$Z_L = (70+j50)\Omega$, $Z_0 = (75+j0.01)\Omega$.

(a) Reflection co-efficient means voltage reflection constant.

$\Gamma_V = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{(70+j50)-(75+j0.01)}{(70+j50)+(75+j0.01)}$

$= \frac{50.24\angle 95.71^\circ}{153.38\angle 19.03^\circ} = 0.33\angle 76.68^\circ = 0.08 + j0.32$

(b) Transmission co-efficient = T.

$T = \frac{2Z_L}{Z_L+Z_0} = \frac{2(70+j50)}{(70+j50)+(75+j0.01)}$

$= \frac{172\angle 35.54^\circ}{153.38\angle 19.03^\circ} = 1.12\angle 16.51^\circ = 1.08 + j0.32$.

(c) $T = 1+\Gamma$

$= 1 + (0.08+j0.32)$

$= 1.08 + j0.32$.

Q3) A. T.L has a $Z_0 = (50 + j0.01)\Omega$ & its terminated in a load impedance of $(73 - j42.5)\Omega$ calculate (a) Γ (b) SWR.

A) $Z_0 = 50 + j0.01\,\Omega$; $Z_L = 73 - j42.5\,\Omega$.

(a) $$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{(73 - j42.5) - (50 + j0.01)}{(73 - j42.5) + (50 + j0.01)}$$

$$= 0.377 \angle -42.7^\circ$$

(b) $$SWR = S = \frac{1 + |\Gamma|}{1 - |\Gamma|} = \frac{1 + 0.377}{1 - 0.377} = 2.21$$

Q4) A loss less T.L of $Z_0 = 100\Omega$ is terminated by an unknown impedance. The termination is found to be at a max. of Volt. standing wave & VSWR is 5. what is the value of terminated impedance?

A) Given, $Z_0 = 100\Omega$

$S = 5$, $Z_L = ?$

$$S = \frac{Z_L}{Z_0} \Bigg| (Z_{in})_{max} = SZ_0 \quad \Rightarrow Z_L = SZ_0$$ [$\because$ Z_L is found at max. of volt. standing wave].

when Z_L & Z_0 are real $S = \frac{Z_L}{Z_0}$ & will be a number only (no fractional).

Q5) A 50Ω lossless line connect a signal of 300 KHz to a load of 100Ω. If load power is 50 mW. Determine

(i) VSWR, (ii) V_{min} & V_{max}.

(iii) Position of V_{max} & V_{min}.

A) Given, $Z_0 = 50\Omega$, $Z_L = 100\Omega$.

$f = 300\,kHz = 300 \times 10^3\,Hz$.

Power $= P = 50mW = 50 \times 10^{-3}\,W$.

(a) $\Gamma = \dfrac{Z_L - Z_0}{Z_L + Z_0} = \dfrac{100 - 50}{100 + 50} = 1/3$.

$S = \dfrac{1 + |\Gamma|}{1 - |\Gamma|} = \dfrac{1 + 1/3}{1 - 1/3} = 4/3 \times 3/2 = 2$.

(b) $P = \dfrac{V^2_{max}}{Z_L} = 50 \times 10^{-3}$ (∵ v_{max} is located at the load $Z_L > Z_0$ & real).

$\Rightarrow V^2_{max} = 50 \times 10^{-3} Z_L$

$\Rightarrow V^2_{max} = 50 \times 10^{-3} \times 100$

⇒ V^2_{max} = [illegible].5 ⇒ $V_{max} = 2.24\,v$.

$S = \dfrac{V_{max}}{V_{min}} \Rightarrow V_{min} = \dfrac{V_{max}}{S}$

$\Rightarrow V_{min} = \dfrac{2.24}{2} = 1.12\,v$.

(c) V_{max} is located at the load (∵ $Z_L > Z_0$ & real).

V_{min} is located at $\lambda/4$ from load $= \frac{100}{4} = 50$ from load

$\left[\lambda = \dfrac{c}{f} = \dfrac{3 \times 10^8}{300 \times 10^3} = 10^3 m\right]$.

* Different Losses in Transmission Line

(i) Attenuation Loss :-

→ It happens due to absorption of signal/ in T.L. It is also called dielectric loss.

→ $$\boxed{\text{Loss} = 10 \log \left[\frac{E_i - E_r}{E_t}\right]}$$

where,

E_i = Energy of i/p signal

E_r = Energy of reflected signal

E_t = Total energy in incident signal.

→ Energy (E) $\propto$ (voltage)^2. $(V)^2$

$E_i \propto (V_i)^2 \qquad E_t \propto (V_t)^2$

$E_r \propto (V_r)^2$

$$\text{Loss} = 10 \log \left[\frac{|V_s^2| - |V_r^2|}{|V_s^2| - |V_r^2| e^{-2 \cdot \alpha \cdot l}}\right]$$

α = Attenuation co-efficient

$= 10 \log \left(e^{\alpha \cdot 2 \cdot l}\right) =$

$= 20\, \alpha \cdot l \,(\log e)$

$= 8.686\, \alpha l.$

(ii) Reflection Loss :-

→ It is present due to mismatch of T.L.

$$\boxed{L_{Ref} = 10 \log \left[\frac{E_i}{E_i - E_r}\right].}$$

$$= 10 \log \left[\frac{|V_i^2|}{|V_i^2| - |V_r^2|} \right]$$

$$= 10 \log \left[\frac{1}{1 - \left| \left(\frac{V_r}{V_i}\right)^2 \right|} \right]$$

$$= 10 \log \left[\frac{1}{1 - |K|^2} \right]$$; K = Reflection constant $\left(\frac{V_r}{V_i}\right)$.

(iii) Transmission Loss :-

→ It is associated with a loss in T.L.

$$\boxed{L_{tran} = 10 \log \left[\frac{E_i}{E_t} \right]}$$

$$= 10 \log \left[\frac{E_i}{E_i - E_r} \times \frac{E_i - E_r}{E_t} \right].$$

$$= 10 \log \left[\frac{E_i}{E_i - E_r} \right] + 10 \log \left[\frac{E_i - E_r}{E_t} \right]$$

$$= L_{ref} + L_{attenuation}$$

$$= 10 . \log \left[\frac{1}{1 - |K|^2} \right] + 8.686 \, \alpha l$$

(iv) Return Loss :-

→ It is associated with impedance mismatch to the point.

$$\boxed{L_{return} = 10 \log \left[\frac{E_i}{E_r} \right]}.$$

$$= 10 \log \left[\frac{|V_i|^2}{|V_r|^2} \right]$$

$$= 10 \log \left[\frac{1}{|K|^2} \right] = -20 \log |K|.$$

(v) Insertion Loss :-

→ It is associated with device insertion.

$$\boxed{L_{ins} = 10 \log\left[\frac{E_1}{E_2}\right]}$$

where,

E_1 = Energy received without device
E_2 = Energy received with device.

NOTE :-

→ Two wire line, coaxial cable, strip line etc are supporting Transverse Electro Magnetic (TEM) mode of wave propagation.

→ T.L supports TEM mode of wave propagation.

→ TEM mode wave propagation means both electric, magnetic field are $\perp^r$ to each other as well as they are also $\perp^r$ to direction of propagation.

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Microwave

→ Microwave means very small wave; wavelength of this wave is very small.

→ So, frequency is very high. Microwave frequency range is 0.3 GHz to 300 GHz.

1) Very Low frequency (VLF) = 3 KHz to 30 KHz

2) Low frequency (LF) = 30 KHz to 300 KHz.

3) Medium frequency (MF) = 300 KHz to 3MHz

4) High frequency (HF) = 3MHz to 30 MHz.

5) Very High frequency (VHF) = 30 MHz to 300 MHz

6) Ultra High frequency (UHF) = 300 MHz to 3 GHz

7) Super high frequency (SHF) = 3GHz to 30 GHz

8) Extra high frequency (EHF) = 30 GHz to 300 GHz.

L - Band = 1 GHz to 2 GHz
S - Band = 2 GHz to 4 GHz
C - Band = 4 GHz to 8 GHz
X - Band = 8 GHz to 12 GHz

* Advantages of Microwave :-

(i) Wide Bandwidth

Microwave signals have large bandwidth which makes it Possible to use Various multiplexing technique to transmit more information.

(ii) Improved Directive Properties

As frequency increases directivity increases & beam-width decrease which is required properties for a Antenna to get more gain.

(iii) Less Fading

Since low frequency signals becomes weaker for a long distance transmission i.e., called fading. But microwave signals are high frequency signal, so less fading occurs.

(iv) Reliability and Transparency

Microwave frequency signals are capable of freely propagating through ionized layers surrounding the earth where as it is not possible for less frequency signals.

* Disadvantages :-

-> Conventional resistors, inductors, capacitors can't be operated in very high freq. like microwave frequency range

-> The Simple LCR ckt behaves as complex ckt.

-> So lumped components are not used in this frequency that's why distributed ckt elements are used where T.L is the example of it which is used in microwave frequency.

-> Due to microwave signals are very high frequency signals, so snow, fog, rain, etc. affects more during transmission.

* Applications :-

(i) Telephone communication

(ii) In Radar Communication

(iii) Cable T.V

(iv) Satellite communication

(v) Used for heating purpose where very common example is microwave oven, etc.

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Waveguide

* Definition

-> It is a medium which contains a hollow metallic tube which guides the wave (or signal) in a proper direction from source to load.

-> It is operated in very high frequency, so it is capable of handling very large power.

-> Waveguide consists metallic tube with rectangular (or) circular cross section.

-> There is no loss due to radiation & dielectric losses are negligible, because waveguides are air filled (non-conducting, linear, homogenous, isotropic and charge free medium)

→ Tangential components of electric fields & normal component of magnetic field vanishes (i.e., 0) across the conductor interfaces.

→ Waveguides are cylindrical in structural & the preferred cross sections are rectangular, circular & elliptical.

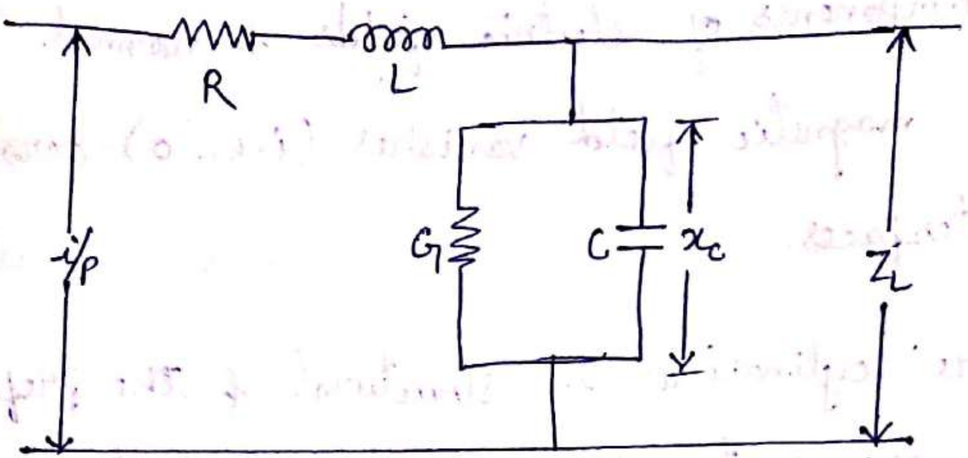
→ The wave is propagating through waveguide by reflection from the wall of waveguide.

Transmission Line (T.L)	Wave Guide (W.G)
→ It is operated in limited range of freq.	It is used in very high freq.
→ It can transmit dc signals also.	It operates after certain cutoff freq.
→ It acts as LPF.	It acts as HPF.
→ It supports TEM mode	It does not support TEM mode. But it supports TE, TM modes.
→ It is not capable of handling large powers as W.G	It is capable of handling large power.
→ Transmission loss is more	W.G has less loss.
→ Metal conductors are used	metal hollow tube is used to avoid loss.

Ques

How T.L acts as one type of low pass filter (LPF)?

Ans



→ T.L cannot be operated at high frequency due to skin effect.

Skin Effect

$x_c = \frac{1}{2\pi fc}$, At very high freq., $f \cong \infty$.

$\Rightarrow x_c = \frac{1}{\infty} = 0$.

→ The reactance path will be short circuited, so the signal pass through the short ckt path instead of passing to load, loss occurs.

→ But, T.L can be operated in some limited freq. (0 to f). So, it acts as LPF.

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* Modes In Rectangular Waveguide :-

→ The distinct field pattern is called mode - 4 types of modes available.

① TEM Mode (Transverse Electro-Magnetic Mode) :-

→ If the wave is propagating along z-direction then $E_Z = H_Z = 0$

→ There is no electric field & magnetic field along Z-direction.

② TE Mode (Transverse Electric Mode) :-

→ If the wave is propagating along z-direction, then in TE Mode ; $E_Z = 0$, but $H_Z \neq 0$.

→ That means there is no electric field component along z-direction.

③ TM Mode (Transverse Magnetic Mode) :-

→ In this mode there is no magnetic field component exist along direction of propagation of the wave. i.e., $H_Z = 0$ but $E_Z \neq 0$.

④ HE Mode (Hybride Mode) :-

→ Here neither electric (or) magnetic field component along propagationg direction are zero.

$$E_Z \neq 0, H_Z \neq 0.$$

→ Transverse Electromagnetic field is impossible to exist through waveguide having any crosssection.

→ TE_{mn} modes, TM_{mn} modes exists in waveguide.
where,
m & n are integers.

* TM_{mn} Waves :-

→ If the wave is propagating along z-direction in waveguide.

$$\longrightarrow (+z).$$

$$\boxed{\frac{E_x}{H_y} = \eta TM_{mn} = -\frac{E_y}{H_x}.}$$

ηTM_{mn} is characteristics wave impedance for TM_{mn} waves.

$$\boxed{E_x = E_{x0} \cdot \cos\left(\frac{m\pi}{a}\right)x \cdot \sin\left(\frac{n\pi}{b}\right)y \cdot e^{-\gamma z}}$$

$$\boxed{H_x = -\frac{E_y}{\eta TM_{mn}}}$$

a, b are rectangular waveguide dimensions:-

$$\boxed{E_y = E_{y0} \cdot \sin\left(\frac{m\pi}{a}\right)x \cdot \cos\left(\frac{n\pi}{b}\right)y \cdot e^{-\gamma z}}$$

$$\boxed{H_y = \frac{E_x}{\eta TM_{mn}}}$$

$$\boxed{E_z = E_{z0} \cdot \sin\left(\frac{m\pi}{a}\right)x \cdot \sin\left(\frac{n\pi}{b}\right)y \cdot e^{-\gamma z}}$$

$$\boxed{H_z = 0}$$

* TE_{mn} Waves :-

→ If the wave is propagating along z-direction in wave guide, then

$$\longrightarrow (+z).$$

$$\boxed{\frac{E_x}{H_y} = \eta TE_{mn} = -\frac{E_y}{H_x}}$$

ηTE_{mn} is characteristic wave impedance for TE_{mn} waves.

$$E_x = E_{x_0} \cos\left(\frac{m\pi}{a}\right)x \cdot \sin\left(\frac{n\pi}{b}\right)y \cdot e^{-\gamma z}$$

$$H_x = \frac{-E_y}{\eta TE_{mn}}$$

$$E_y = E_{y_0} \sin\left(\frac{m\pi}{a}\right)x \cdot \cos\left(\frac{n\pi}{b}\right)y \cdot e^{-\gamma z}$$

$$H_y = \frac{E_x}{\eta TE_{mn}}$$

$$E_z = 0$$

$$H_z = H_{z_0} \cos\left(\frac{m\pi}{a}\right)x \cdot \cos\left(\frac{n\pi}{b}\right)y \cdot e^{-\gamma z}$$

* Characteristics of TE_{mn} & TM_{mn} Waves :-

→ In the process of derivation we get the following equation :-

$$\boxed{\gamma = \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \omega^2 \mu\epsilon}}$$

$$\boxed{\gamma = \alpha + j\beta}$$

γ = Propagation constant

α = Attenuation constant

β = Phase shift constant

m, n: Integers

a, b: cross sectional dimensions

μ, ϵ : Medium properties → linear, homogenous, isotropic, charge free, non-conducting.

$\omega = 2\pi f$.

↳ freq. of wave which is progressing through the wave guide.

→ At high freq.

$$\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 < \omega^2 \mu \epsilon$$

So γ = propagation constant is imaginary

$= j\beta$.

$\alpha = 0$.

So wave propagation takes place along wave guide at high frequency.

→ So wave guide acts as high pass filter. We define a limiting freq. (or) cut off freq. beyond that propagation takes place.

$$\boxed{f_c = \frac{1}{2\pi\sqrt{\mu\epsilon}} \cdot \left[\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2\right]^{1/2}}$$

→ At $f = f_c$, $\gamma = 0$.

→ In free space $\mu = \mu_0$, $\epsilon = \epsilon_0$.

∴ velocity of wave in air

$$\boxed{v = \frac{1}{\sqrt{\mu_0 . \epsilon_0}}} = 3 \times 10^8 \, m/sec.$$

→ So, cut off freq. of a waveguide will depend upon physical properties of wave guide.

→ $$\boxed{\text{cut off wavelength } \lambda_c = \frac{2}{\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}}}$$

→ $\lambda = \frac{c}{f} = \frac{\text{Velocity}}{\text{freq.}}$ = wavelength.

→ For $f > f_c$ (or) $\lambda < \lambda_c$

Propagation is allowed through the waveguide.

→ For $f < f_c$ (or) $\lambda > \lambda_c$

Propagation is not allowed through the waveguide.

→ $\beta = \frac{2\pi}{\lambda}$ = Phase shift const.

→ Phase velocity $v_p = \omega/\beta$. , it is the velocity at which wave propagates in a wave guide.

$$\boxed{v_p = \frac{c}{\sqrt{1 - \left(\frac{f_c}{f}\right)^2}}}$$, c = light velocity.

→ Phase velocity (v_p) > c (light velocity), which violate Einstein's Relativity theory.

→ But signal wave in a wave guide does not travel in phase velocity. Actually signal travels in a group velocity (v_g).

* **Group Velocity** (v_g)

→ Group of signals travel in a waveguide in this velocity which is less than light velocity.

$$\boxed{v_g < c}$$

→ The velocity of modulation envelope is called group velocity.

$$\boxed{v_g = c \cdot \sqrt{1 - \left(\frac{F_c}{F}\right)^2}}$$

$$\boxed{v_p \times v_g = c^2}$$

$$\rightarrow \eta_{TE} = \frac{\eta}{\sqrt{1 - (f_c/f)^2}} \ \Omega$$

$$\rightarrow \eta_{TM} = \eta \cdot \sqrt{1 - \left(\frac{f_c}{f}\right)^2} \ \Omega.$$

η = Intrinsic impedance of the medium.

$= \sqrt{\mu/\epsilon}$

For air $\eta = \sqrt{\frac{\mu_0}{\epsilon_0}} = 377\ \Omega$ or 120π.

$$\rightarrow \boxed{\eta_{TE} \times \eta_{TM} = \eta^2}$$

→ At $f = f_c$, $\eta_{TE} = \infty$ & $\eta_{TM} = 0$.

→ Guided wave length

$$\lambda_g = \frac{\lambda_0}{\sqrt{1-(\lambda_0/\lambda_c)^2}}$$

where, λ_0 = wavelength in space

λ_c = cutoff wavelength

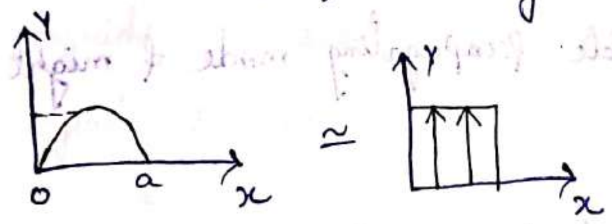
* Significance of m, n :-

m :- no. of half field variation along x.

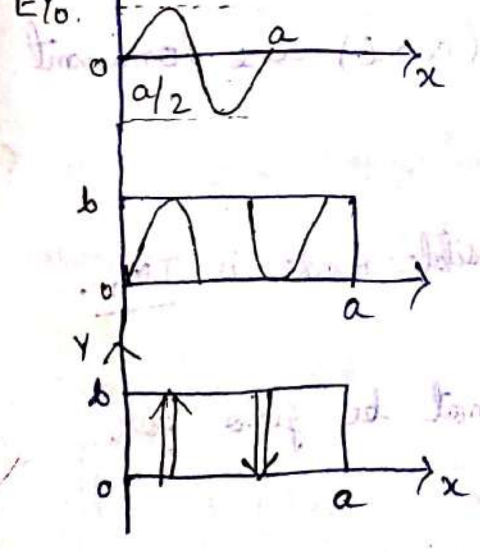
n :- no. of half field variation along y.

They indicates field variations in the transverse plane.

TE$_{10}$:- No. of half field along x is 1.

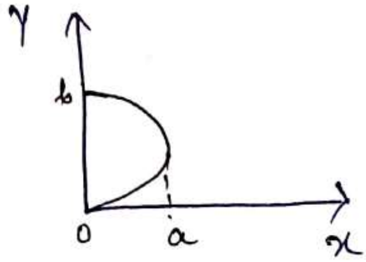


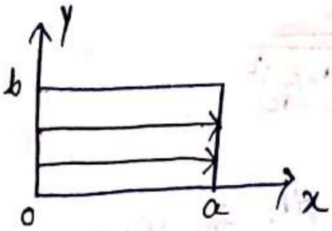
TE$_{20}$:- No. of half fields along x = 2.



TE_{01} :- $(m = 0, n = 1)$

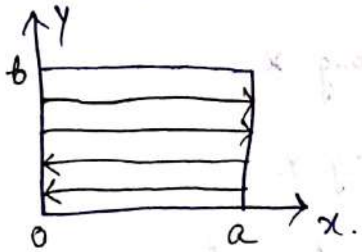
No. of half fields along Y-axis = 1.





TE_{02} :- $(m = 0, n = 2)$

No. of half field variations along Y-axis = 2.



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* Dominant Mode :-

→ It is the lowest possible propagating mode & might have lowest cutoff freq.

→ In the dominant mode, it is possible to transfer maximum energy from sending end to receiving end.

→ In case of rectangular waveguide $(a > b)$ the dominant mode is TE_{10}.

→ For TM_{mn} mode, the lowest possible mode is TM_{11}.

→ For TM_{mn} mode, m & n values cannot be zero for rectangular waveguide.

* Degenerate Mode :-

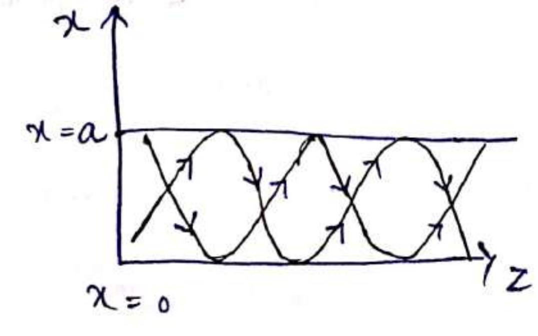
→ If two different modes are having same cutoff freq. then those modes.

→ Examples of degenerate modes are TE_{11}, TM_{11} & TE_{21}, TM_{21}. These modes are two different modes but having same cutoff freq. So these modes are degenerate mode.

→ The modes which are not possible in a wave-guide are called evenscont waves (or) evenscont modes.

→ Ex:- For rectangular wave guide TM_{10} is evenscont mode.

→ The waveguide is operated in dominant mode & this waveguide is used for x-band frequencies. The waveguide is air-filled.



→ The wave propagation through the waveguide is by means of total internal reflection between the walls.

→ Phase constant

$$\boxed{\beta = \beta' \sqrt{1 - \left({f_c}/{f} \right)^2}}, \quad \boxed{\beta' = \omega \sqrt{\mu \epsilon}}$$

where,

β = phase constant in presence of waveguide

β' = phase constant in absence of waveguide

f_c = cutoff frequency.

f = Operating frequency.

→ For rectangular waveguide in dominant mode TE_{10}, the cutoff freq. $f_c = \frac{c}{2a}$.

→ In dominant mode TE_{10}, the cutoff wavelength $\lambda_c = 2a$.

where,

c = Velocity of light = 3×10^8 m/sec

a = Length of waveguide...

Q1) A rectangular wave guide for which $a = 1.5$ cm, $b = 0.8$ cm, $\sigma = 0$ & $\mu_0 = \mu$ & $\epsilon = 4\epsilon_0$, $H_x = 2\sin\left(\frac{\pi x}{a}\right)\cos\left(\frac{3\pi}{b}\right)\sin\left(\pi \times 10^{11} t - \beta z\right)$ A/m

Determine

(a) The mode of operation

(b) The cutoff frequency

(c) The phase constant

(d) The propagation constant

(e) The intrinsic wave impedance (η).

A) $H_x = H_0 \sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)\sin\left(\omega t - \beta z\right)$.

where,

$m = 1$, $n = 3$ & $\omega = \pi \times 10^{11}$ rad/sec.

(a) Means waveguide is operating at TM_{13} or TE_{13} mode

(b) If we take TM_{13}

$$f_{c_{max}} = f_{c_{13}} = \frac{u'}{2}\sqrt{\frac{m^2}{a^2}+\frac{n^2}{b^2}}$$

$$\left[\therefore u' = \frac{1}{\sqrt{\mu\epsilon}} = \frac{1}{\sqrt{\mu_0 4\epsilon_0}} = \frac{1}{\sqrt{4}\sqrt{\mu_0\epsilon_0}} = \frac{c}{2}, \because c = \frac{1}{\sqrt{\mu_0\epsilon_0}}\right]$$

$$= \frac{\left(\frac{c}{2}\right)}{2}\sqrt{\left(\frac{1}{a^2}+\frac{9}{b^2}\right)} = \frac{3\times10^8}{4}\sqrt{\frac{1}{(1.5\times10^{-2})^2}+\frac{9}{(0.8\times10^{-2})^2}} = \underline{10.625\ GHz.}$$

(c) $\beta = \omega\sqrt{\mu\epsilon}\sqrt{1-(f_c/f)^2}$

$$\left[\because \omega = \pi\times10^{11} \Rightarrow f = 50\ GHz\ \&\ \mu\epsilon = \sqrt{\mu_0 4\epsilon_0} = 2\sqrt{\mu_0\epsilon_0} = \frac{2}{c} = \frac{2}{3\times10^8}\right].$$

$$= (\pi\times10^{11})\left(\frac{2}{3\times10^8}\right)\sqrt{1-\left(\frac{10.625\times10^9}{50\times10^9}\right)^2} = 2.046\ \cancel{K}rad/m.$$

(d) $\gamma = j\beta$

$= j2.046\times10^3$

(e) Intrinsic wave impedance

$$\eta_{TM_{13}} = \eta'\sqrt{1-(f_c/f)^2}$$

$$\left[\eta' = \sqrt{\frac{\mu}{\epsilon}} = \sqrt{\frac{\mu_0}{4\epsilon_0}} = \frac{1}{2}\sqrt{\frac{\mu_0}{\epsilon_0}} = \frac{1}{2}\times377\right]$$

$$= \frac{377}{2}\sqrt{1-\left(\frac{10.625\times10^9}{50\times10^9}\right)^2} = 184.19\ \Omega.$$

Q2) A standard air filled rectangular waveguide with dimensions a = 8.6 cm & b = 4.3 cm is fed by a 4 GHz carrier from co-axial cable. Determine if a TE_{10} mode will be propagated. If so, calculate phase velocity & group velocity.

A) TE_{10} mode $f_{c_{10}} = \frac{u'}{2}\sqrt{\frac{m^2}{a^2}+\frac{n^2}{b^2}}$ $[m=1, n=0]$...

$= \frac{u'}{2a} = \frac{c}{2a}$ [∵ $u' = c$, due to air filled guide].

$= \frac{3\times10^8\times10^2}{2\times8.6} = 1.74\ GHz.$

$f = 4\ GHz > f_c$ means TE_{10} mode will propagate

(∵ operating freq. should be greater than cut off freq).

Phase velocity $(v_p) = \frac{u'}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}} = \frac{3\times10^8}{\sqrt{1-\left(\frac{1.7}{4}\right)^2}} = 0.33\ G\ m/s.$

Group velocity $(v_g) = \frac{u'^2}{v_p}$ $\left[\because v_p \cdot v_g = v'^2\right]$

$= \frac{(3\times10^8)^2}{0.33\times10^9} = 0.27\ G\ m/s.$

Q3) A rectangular wave guide with dimension 3 cm × 2 cm operates in TM_{11} mode at 10 GHz. Determine characteristic wave impedance.

A) Given, $f = 10\ GHz$, $a = 3\ cm$, $b = 2\ cm$.

$TM_{11} = f_{c_{11}} = \frac{u'}{2}\sqrt{\left(\frac{m}{a}\right)^2+\left(\frac{n}{b}\right)^2}$ [assume air as dielectric $\Rightarrow u' = c$].

$= \frac{c}{2}\sqrt{\left(\frac{m^2}{a^2}\right)+\frac{n^2}{b^2}}$

$= \frac{3\times10^8}{2}\sqrt{\frac{1}{(3\times10^{-2})^2}+\frac{1}{(2\times10^{-2})^2}} = 9.01\ GHz.$

$\eta_{TM_{11}} = \eta\sqrt{1-\left(\frac{f_c}{f}\right)^2} = 377\sqrt{1-\left(\frac{9.01\times10^9}{10\times10^9}\right)^2} = 163.54\ \Omega.$

Q4) Determine the cutoff wavelength for dominant mode in a waveguide of 10 cm x 10 cm. For a 2.5 GHz signal Propagated in this waveguide in the dominant mode. Calculate the guide wavelength, groups & phase velocity?

A) For dominant mode TE_{10}.

(a) The cutoff length of wave $(\lambda_c) = 2a$.

$$\left[\because f_c = \frac{u'}{2a} = \frac{c}{2a}\ \{\because m=1, n=0\}\right.$$
$$\left.\Rightarrow \lambda_c = \frac{c}{f_c} = \frac{c}{c/2a} = 2a.\right]$$

$= 2\times10$ cm $= 20$ cm.

(b) λ_g (guide wavelength) $= \dfrac{\lambda_0}{\sqrt{1-\left(\frac{\lambda_0}{\lambda_c}\right)^2}}$ $\left[\because \lambda_0 = \frac{c}{f} = \frac{3\times10^8}{2.5\times10^9} = 0.12\text{ m} = 12\text{ cm}\right]$

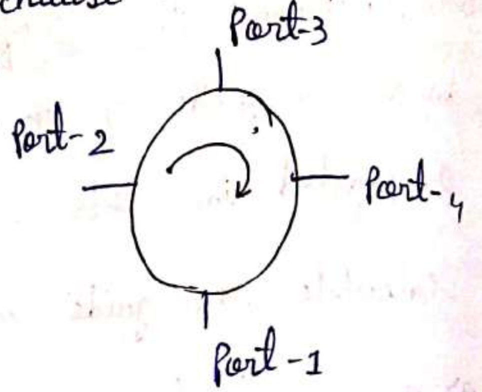
$$= \frac{12}{\sqrt{1-\left(\frac{12}{20}\right)^2}} = 15\text{ cm}.$$

(c) Phase velocity $(v_p) = \dfrac{c}{\sqrt{1-\left(\frac{\lambda_0}{\lambda_c}\right)^2}} = \dfrac{3\times10^8}{\sqrt{1-\left(\frac{12}{20}\right)^2}} = 3.75\times10^{10}$ cm/s.

v_g (group velocity) $= \dfrac{c^2}{v_p} = 2.4\times10^6$ cm/s. $[c^2 = v_p v_g]$.

* Circulator :-

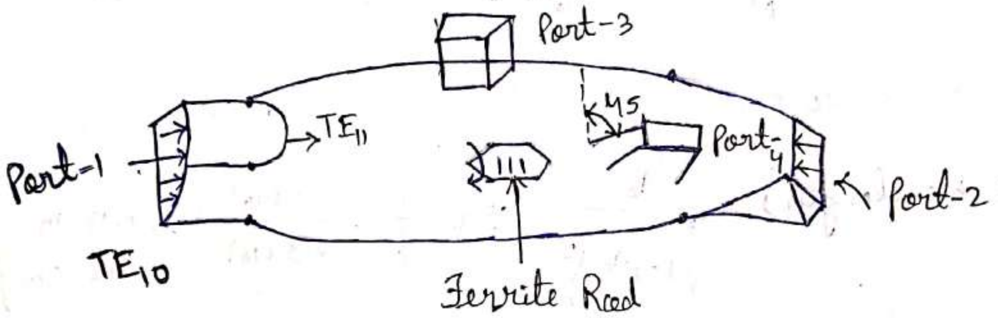
→ Here signal is circulated in clockwise direction.



→ If we apply signal at Port-1, O/p will be forwarded to Port-2 & at Port-3, Port-4 O/p = 0.

→ If we give i/p at Port-2, then O/p will circulate to Port-3 & at Port-4, Port-1 O/p = 0.

* Internal Structure of 4-Port circulator :-



→ If we apply i/p at Port-1 in TE_{10} mode, inside it is translated to circular waveguide & TE_{11} mode is O/p of Port-1.

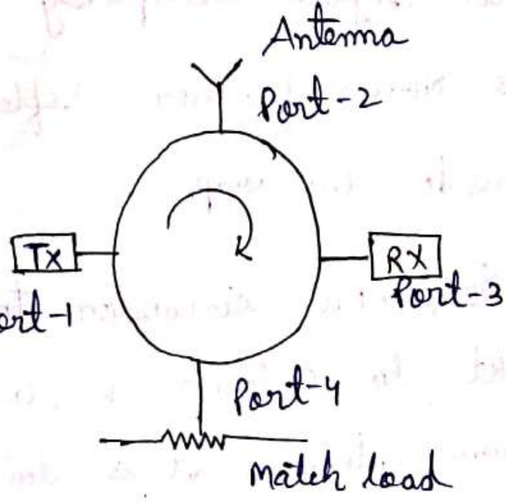
→ Orientation of Port-1 & Port-3 are out of Phase. So signal is not transferred to Port-3.

→ Ferrite Rod is in bet^n Port-3 & Port-4. It circulate the signal to 45° in clockwise direction.

→ At Port-2 o/p is available.

* Application of circulator :-

circulator as Duplexer :-



→ At Port-1 Tx (transmitter) is connected. At Port-2 Antenna is connected.

→ Duplexer aim is to use transmitting & receiving at single antenna.

→ Transmitting ckt. functions as Mega Watt (MW) in radar. Receiving ckt functions as Milli Watt (mW) in radar.

→ Transmitting ckt radiates extremely high Power to the antenna & receiving ckt receives extremely low power from the antenna.

→ So, it is very essential to isolate these two ckts & signal transmits at Port-1 & at Port-2 antenna receives.

→ Then from Port-2 signal is transmitted to Port-3. Due to mismatch in receiving ckt of antenna signal from Port-3 is propagated to Port-4.

-> If we provide match termination at Port-4 then that signal completely absorbed at match termination. So Now further reflections will not propagate inside the loop.

-> So, here circulator transfer signal from transmitter ckt. to antenna & receiver receives the signal from antenna. It is doing double job of isolation and duplexer.

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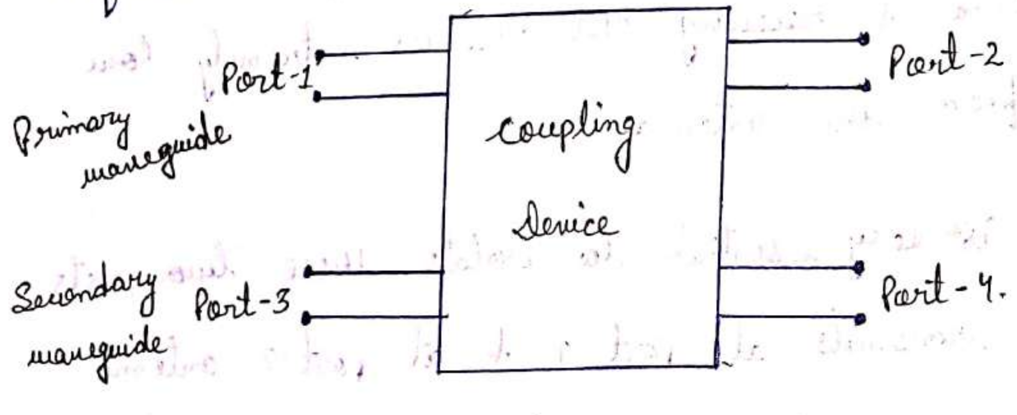
* Directional Coupler

-> It is 4-Port waveguide junction through which the i/p at one port directed to other port for o/p without reflection.



-> Construction

-> It consists of Primary & Secondary of total 2-wave guide.
Primary wave guide is Port-1 & Port-2
Secondary wave guide is Port-3 & Port-4.

→ All Ports are terminated in their characteristic impedances.

→ There is free transmission & no-reflection between Port-1 & port-2. But there is no direct transmission between Port-1 & Port-3 or Port 2 & Port-4, due to coupling is done in that system.

→ The o/p ports are port-3 & Port-4, but main port is Port-4

→ Characteristics

→ Directional coupler's characteristics is expressed in terms of coupling factor & directivity.

→ coupling factor is a measure of how much of incident power is sampled.

→ Directivity is measure of how well it distinguishes between forward & reverse travelling power.

$$\boxed{\text{Coupling factor } (C)_{dB} = 10 \log_{10}(P_1 | P_4)}$$

$$\boxed{\text{Directivity } (D)_{dB} = 10 \log_{10}(P_4 | P_3)}$$

where, P_1 → Power i/p to Port-1.

P_3 → Power o/p from Port-3

P_4 → Power o/p from Port-4 → actual o/p port.

→ So, if coupling factor & P_4 is known. We can calculate i/p power means P_1.

→ Similarly in directivity case if directivity & P_3 are known, So easily o/p Power P_4 can be calculated.

In ideal case

→ Directivity (D) is ∞ (⇒ for this case P_3 should be zero).

→ But practical value $D_{dB} = (30 \rightarrow 40)$ dB.

→ So for better directivity, P_3 should be less. That's why in case of 2-hole direction coupler here P_3 is less.

* Isolator (Ferrite Isolator)

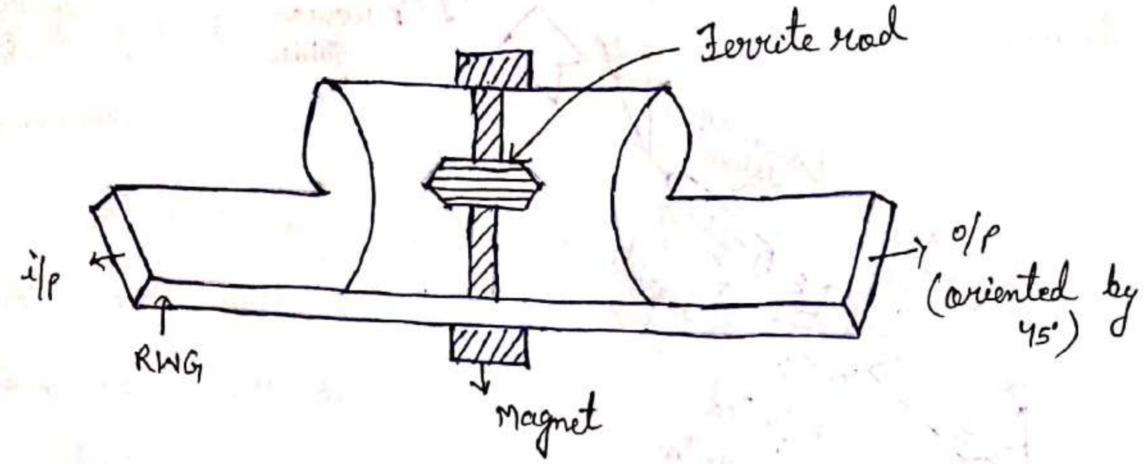
→ It is a device used to isolate one component from reflections of other components in T.L.

→ It absorbs the reflected energy in one direction & provides lossless transmission in opposite direction. So isolator is called uniline.

→ Generally isolator is used to improve the frequency stability of microwave generators like Klystron & magnetrons. In this case isolator is placed between generator & load. The reflection part from load is absorbed by isolator & i/p signal is transmitted from generator to load in other direction.

→ Due to absorption of reflection signal, it eliminates the interferrence of i/p signal frequency & refleition signal freq. So, it increases the freq. stability.

Construction



→ It consists of two rectongular waveguide at beginning and end side & a circular waveguide is middle Position between two rectongular wave guide.

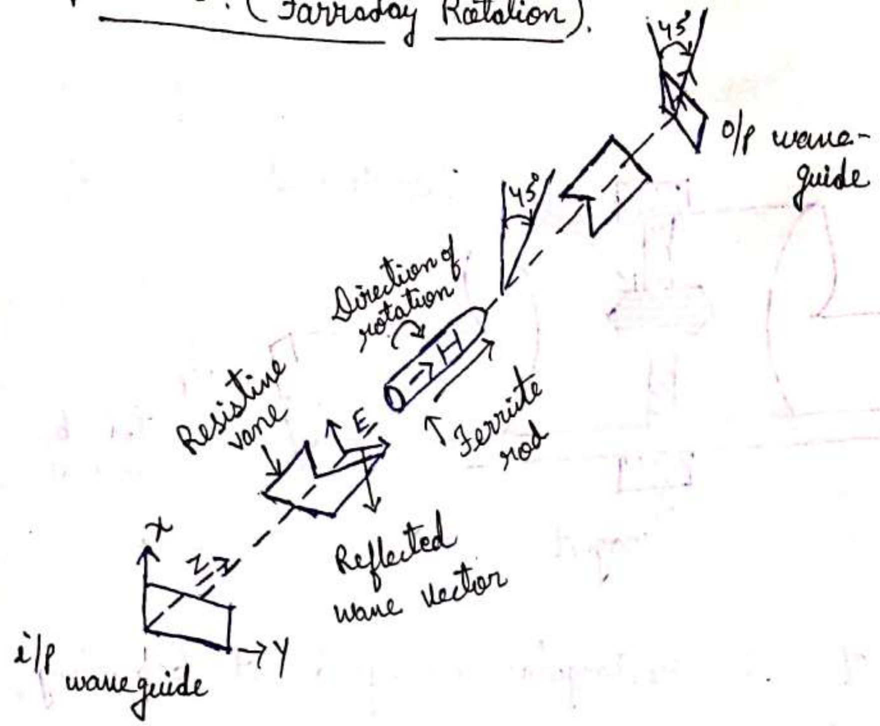
→ The rectongular waveguide supports TE_{10} dominating mode & the circular waveguide supports TE_{11} dominating mode.

→ A Pencil shaped ferrite rod is located inside the circular waveguide is surrounded by Permonent magnet.

→ So ferrite rod & magnet both have repulsion magnetic field. Due to repulsion any signal passes through its field direction changes some angle i.e, 45° taken generally as a standard value.

→ (Ferrites are example of $ZnFe_2O_3$ or $MnFe_2O_3$ are high resistive means insulator & these have magnetic properties due to 'Fe'. These ferrites are non-reciprocal devices because these support farrday rotation).

Operation : (Farraday Rotation).



→ All devices are on one axis.

→ When a signal enters to i/p waveguide at that time the $\vec{E}$ field is ⊥r to first i/p resistive vane.

→ But due to ferrite rod is affected by a permonent magnet due to magnetic property of ferrite in the rod. So the o/p of resistive vane is through ferrite rod is chonged to 45° Polarization (becouse of Faraday Rotation).

→ The chonged field is passed through to second resistive vane as normal becouse the second vane is set like such way that the resultont will be normal to it.

→ So, finally we will get 45° polarised signal at o/p of rectangular waveguide that means transmission occurs without attenuation.

→ But if some reflection occurs, so the reflected signal will be 45° changed towards left and to pass through ferrite rod. So result will be again 45° change means the signal will be parallel to its resistive vane which indicates absorption.

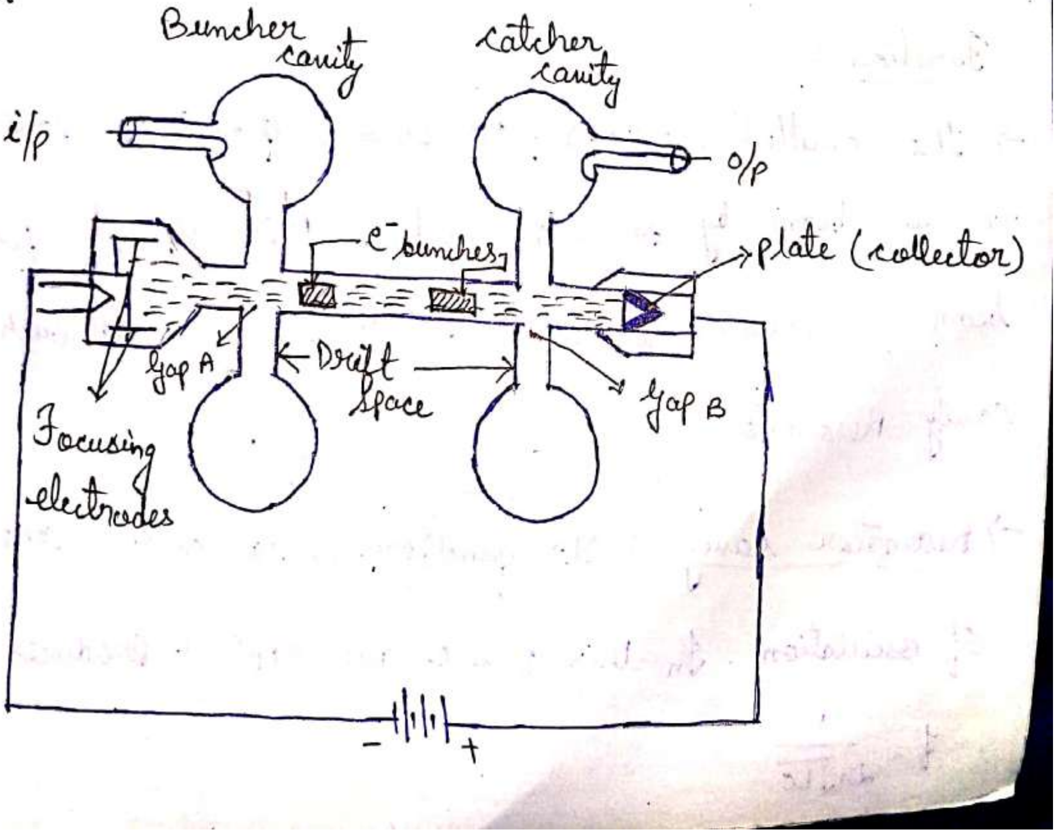
→ Because when any signal passes parallel to resistive vane that signal will be absorbed by that vane. So, no interference will be occured means reflection signal will no interfere with incident signal.

→ Attenuator :- These are devices which are used for reducing the microwave power (or for controlling power).

* Klystron (Two-Cavity Klystron)

→ It is a microwave vacuum tube using cavity resonator to produce velocity modulation of election beam & to produce amplification.

Construction



Operation

(i) Filoment :- Its function is to heat the cathode.

(ii) Cathode :- Its function is to emit electrons (after heated by filoment).

(iii) Focusing Anode :- Its function is to pass the electrons into a narrow beam.

(iv) Buncher Cavity

→ It is the i/p cavity at which electrons are bunched & passed towards right.

→ Also microwave signal is given at the i/p path of ~~cab~~ cavity.

(v) Catcher Cavity :- It is the o/p cavity at which the o/p is taken which is at the end side of tube.

(vi) Plate (collector) :- It is connected to +ve voltage side & its function is to collect the electrons.

Function :

→ The emitted electrons (are from cathode) are passed to a narrow beam by focusing anode. This sharply focused beam of electrons is then forced to pass through 1st cavity Resonator.

→ Resonator cavity :- Its function is to control the freq. of oscillation. In this L & C are kept & produces a freq.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

→ The microwave Signal is given at i/p side of buncher cavity. Due to this signal there is the +ve half cycle & -ve half cycle.

→ During +ve half cycle the focused e⁻ speed up & in -ve half cycle slow down. This speeding & slowing Process is called Velocity modulation. And this Process is happened at i/p cavity, so this cavity is called buncher cavity.

→ These bunched e⁻ are attracted by +ve plate because the Plate is connected +ve terminal voltage.

→ So this attraction results in to pass the e⁻ through the o/p path in 2nd cavity. So this cavity is called catcher cavity.

→ But another RF field is maintained at catcher cavity, So these bunch e⁻ of RF signal increases. As more speeded bunch e⁻ interact, they release energy & more amplification occurs at catcher cavity.

→ Means more amplified energy is extracted from this cavity outlet & e⁻ after releasing energy attracted to +ve plate & complete a path. So 2-cavity Klystron is called an Amplifier.

* Magnetron Oscillator

Basics :-

-> It is high Power Vacuum tube.

-> It is multi-cavity device.

-> Frequency is from 0.6 GHz to 30 GHz.

-> It works with fix frequency constructively.

-> It is available with 8 to 20 cavity.

-> It works self exited microwave Oscillator.

Advantages

-> The magnetron is high power microwave generator.

-> With antennas it can be easily installed.

-> The magnetron is a fairly efficient device.

Disadvantages

-> It is costly device.

-> Device cannot tune wide range of frequency.

-> Resonance is based on dimension & it is fix.

Operational steps of Magnetron:-

-> Generation of e^- from cathode.

-> Velocity modulation.

-> Formation of e^- bunch.

-> Reducing (or) transferring energy.

* Travelling Wave Tube (TWT) :-

Basics :-

-> It is a specialized vacuum tube i.e., used in electronics to amplify audio freq. signals in microwave range.

-> It belongs to category of linear beam tubes, such as Klystron.

-> Two major categories of TWT are :- Helix TWT, coupled cavity TWT.

-> The major advantage of TWT w.r.t other microwave tube is to amplify a wide range of frequencies.

-> TWT accounts 50% of microwave total tubes.

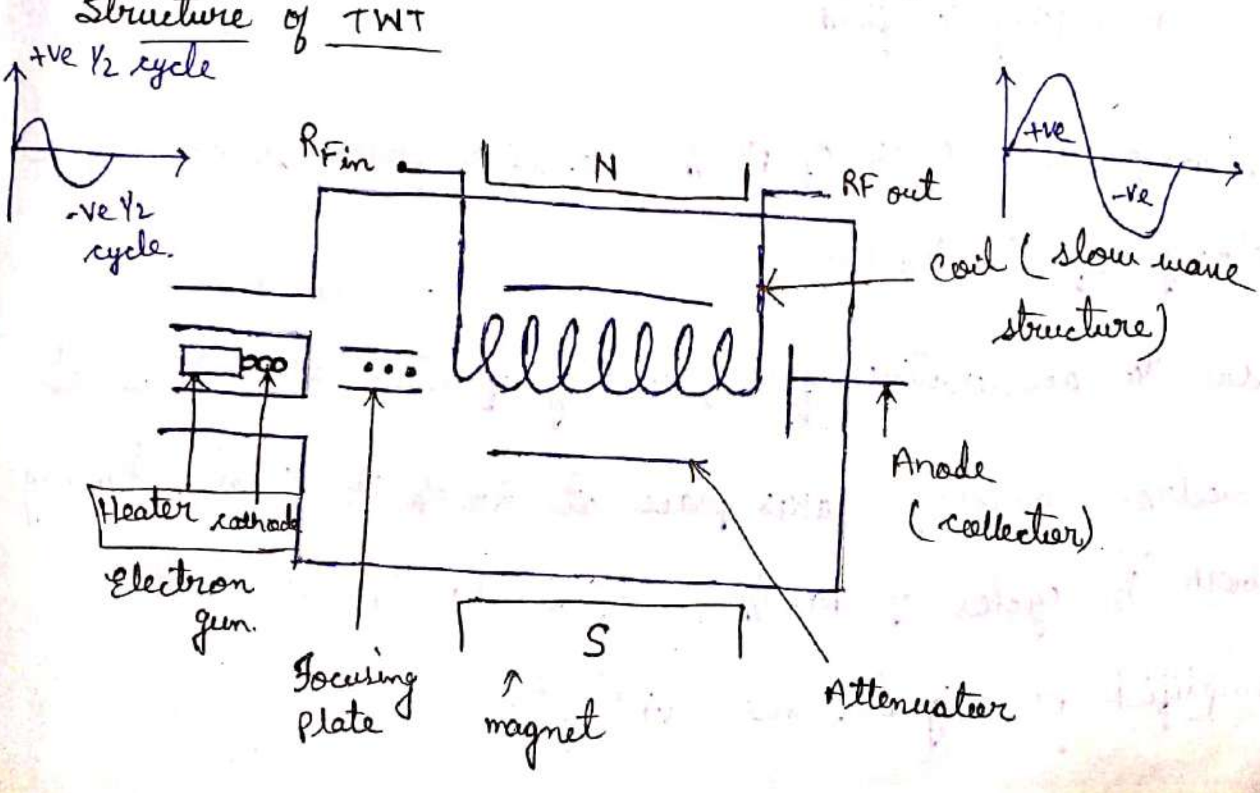
Operational Parameters of TWT

-> It's operating freq. range is from 300 MHz to 50 GHz.

-> Power gain 40 to 70 dB. Generally 60 dB.

-> o/p Power ranges from few watt to megawatts.

Structure of TWT



→ Anode collects e^- and cathode generates e^-. -ve terminal of battery is connected to e^- gun & +ve terminal of battery is connected to anode.

→ Focusing plates focuses the electrons i.e., generated by e^- gun.

→ Electrons travels through coil, attenuator bounds the focusing e^- through coil.

→ Magnet generates magnetic field i.e., used to amplify RF i/p signal & amplified signal is collected at RF o/p terminal.

→ When we give RF i/p, during +ve ½ cycle the e^- get accelerated.

→ Magnetic field directions from north to south.

→ In +ve ½ cycle the force on e^- is accelerative force

i.e., $F = q\,(V \times B)$.

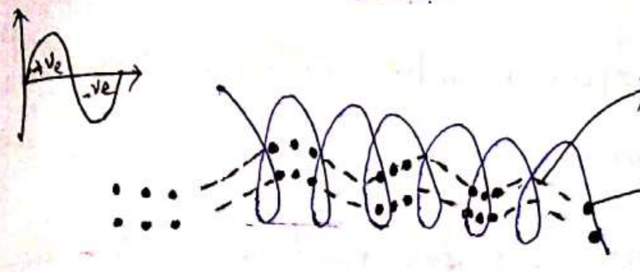
where,
V = Velocity of e^-
q = charge of e^-
B = Magnetic field

→ During -ve ½ cycle of RF i/p, resistive force is on e^-, so Velocity of e^- decreases.

→ Due to accelerative force, velocity of e^- increases.

→ Electron bunching takes place at RF o/p terminal. During both ½ cycles of RF i/p. So, at RF o/p terminal amplified AC signal, we will get.

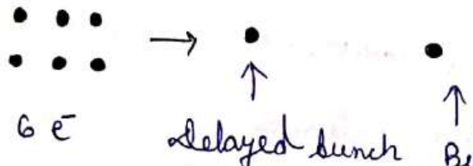
Top View



Path length increased

e^- bunch occurs. o/p at this point is amplified version.

-> While travelling the e^-, the distance between the e^- decreas



ed.

-> These bunching e^- results amplification at RF o/p.

-> Because of e^- path length increases, so it is makes slow wave structure.

-> Electron motion completely based on force & that force drives the e^- from cathode to anode.

Applications

-> It is used in o/p tube in radar. Generally in pulse radar system.

-> It is used in microwave amplifier

-> It is used in microwave high power generator

-> It is used in satellite communication.

Application of Magnetron Oscillator

-> In radar

-> In heating (microwave oven)

-> In lighting (Sulphur lamp)

-> Microwave generator.

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Antenna

→ The antennas which are operated under microwave frequencies are called microwave antennas.

→ An antenna is a transducer used for matching the T_x-line (or wave guide) to surrounding medium & vice versa.

→ The types of antenna are as follows :-

(i) Microstrip Antenna	(iv) Helical Antenna
(ii) Lense Antenna	(v) Slot Antenna
(iii) Horn Antenna	(vi) Parabolic reflector Antenna.

→ Horn antenna & Parabolic antenna are used in microwave freq.

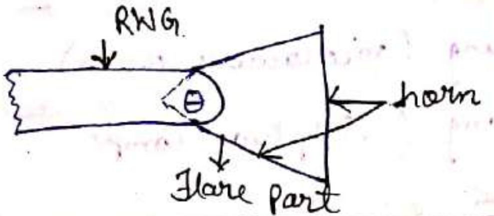
* Horn Antenna

→ The most widely used microwave antenna is horn antenna

→ It is nothing but a flared wave guide. The horn exhibits gain & directivity.

→ Generally the signal is transmitted through T.L or W.G. But W.G in high freq. cases is efficient. So rectangular W.G is used.

→ But problem is a rectangular W.G as radiator has poor impedance matching with space (or medium). This mismatch causes standing waves & reflection which indicates powerloss of original signal.



→ This mismatch con be overcome by flaring the end of rectongular wave guide. This flaring portion is called horn.

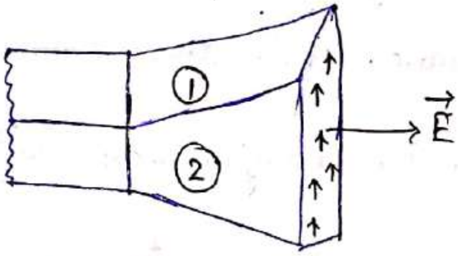
→ The more and gradual the flare (horn), the better impedance match or lower the loss. So horn antenna exhibits excellent gain & directivity.

→ The types of Horn antenna are as follows:-
(i) Sectoral horn
(ii) Pyramidal horn.
(iii) Conical horn.

Sectoral horn :- When the flaring is done only in one direction then it is called sectoral horn. It is of two type namely. sectoral E-plane & sectoral H-plane.

Sectoral E-plane horn :-

→ [a_e → Aperature of E-plane horn. Aperature Area (A_p) = (height) (breadth)].



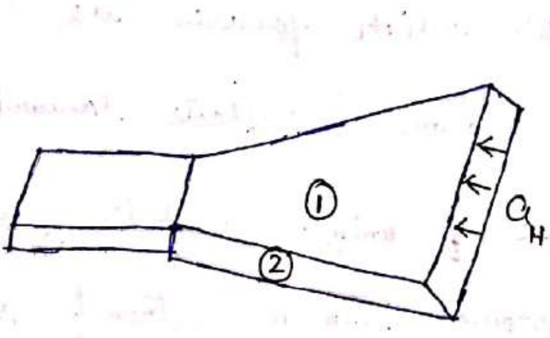
→ In this side (2) is flared only. The flaring is done in direction of $\vec{E}$ field.

Sectoral H-plane horn

→ a_H → Aperature of H-plane of horn.

→ In this side (1) is flared.

→ The flaring is done in direction of $\vec{H}$ field.

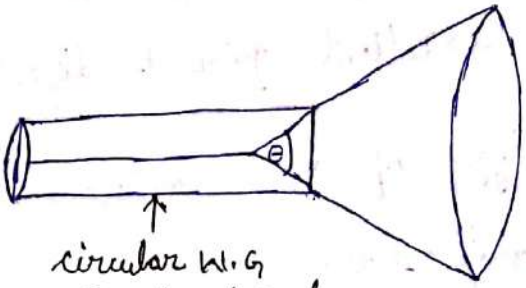


Pyramidal Horn Antenna

→ When flaring is done along both walls of W.G is called Pyramidal horn antenna.

Conical Horn Antenna

→ When one side (end Portion) is flared of circular W.G is called conical horn antenna.



circular W.G
θ → flared angle.

* Parabolic Reflector Antenna

→ When a horn antenna is in conjunction with Parabolic reflector is called Parabolic Reflector Antenna.

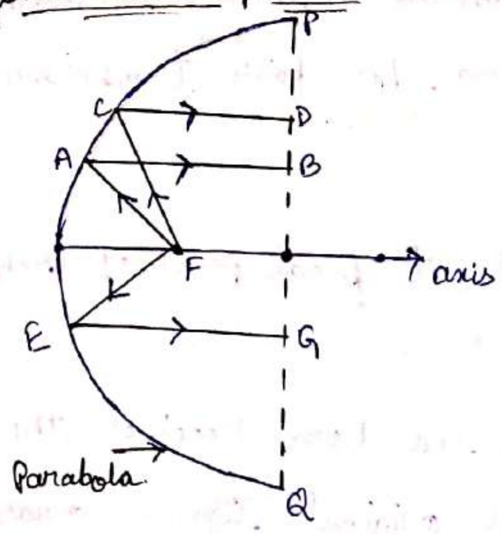
→ Horn antennas are used in many microwave (μw) application, but many times more Power gain & more directivity are desirable. And this can be easily obtained by using a horn in conjunction with Parabolic reflector.

→ A Parabolic reflector is a large dish-shaped structure made of metal.

→ The energy is radiated by the horn is pointed to the reflector which focuses the radiated energy into a narrow beam & reflects towards its destination.

→ Because of unique Parabolic shape the electromagnetic waves are narrowed into a extremely small beam which indicates extremely high gains.

Systems and operation

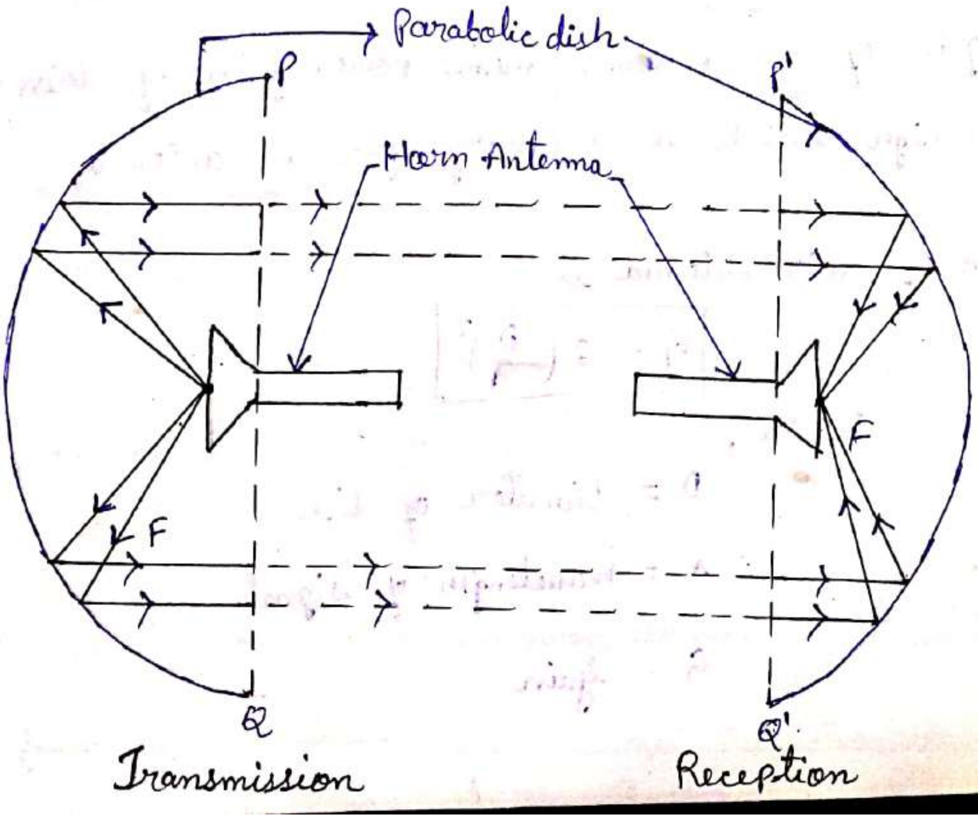


- 'F' point → focal point of parabola.
- 'PQ' → end line (end points) of parabola.
- Parabola's unique characteristic is distance between focal point to parabola and to vertical dashed line are same.

  i.e., $(FA + AB) = (FC + CD) = (FE + EG)$

- This system of effects results the electromagnetic waves to pass a narrow beam.

Operation



→ The figure shows how a parabolic reflector is used in conjuction with horn antenna, for both transmission and reception.

→ The horn antenna is placed at focal point of each side (T_x & R_x side).

→ In T_x side (transmitting side) the horn receives the original signal & radiates that original signal towards reflector which bounces the signal wave & passes them in to parallel narrow beam.

→ When used for receiving, the reflector picks up the electromagnetic signal which are from T_x - Antenna & bounces the signal towards antenna at focal point at (R_x-side).

→ Practically it is seen that the result is an extremely high gain & it is narrow beamwidth antenna.

→ The gain of the Antenna means Power gain of this antenna is very high which is necessary for an antenna.

Gain of this antenna is

$$\boxed{G = 6\left(\frac{D}{\lambda}\right)^2}$$

where,

D = Diameter of dish

λ = Wavelength of signal

G = Gain

Gain when expressed in dB (decibel)

$$\boxed{G_{dB} = 10 \log_{10}(G)}$$

uses:-

-> In satellite communication

-> One example dish TV & (DTH)

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* Rhombic Antenna

Basics

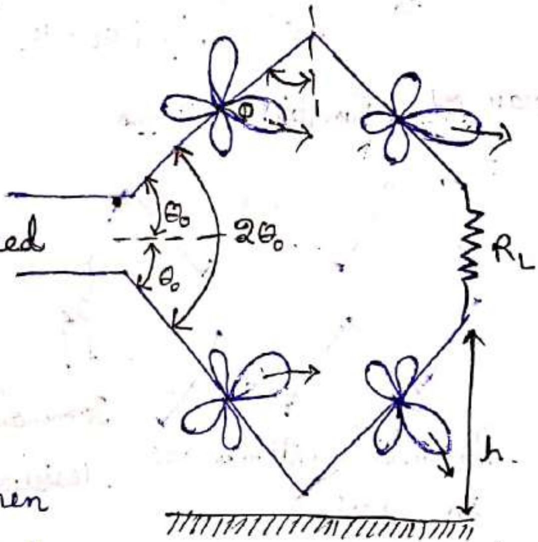
-> It's name comes from its diamond shaped layout.

-> It is array of four inter-connected long wire antennas.

-> It is also called as double V antenna.

-> It needs 600 Ω to 800 Ω terminator resistance to minimize reflection loss.

Structure of Rhombic Antenna



Φ = Tilt Angle

$2\theta_0$ = Apex angle.

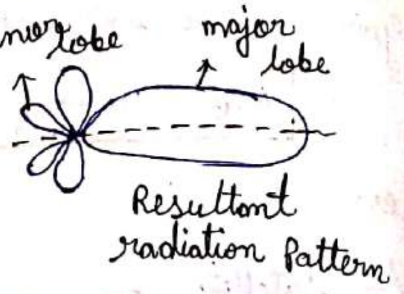
-> If we have very long wire then we will not use R_L

-> But if we have limited wire then we will use R_L to minimize reflection loss.

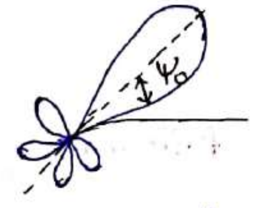
Radiation Pattern

-> It is due to long wires is given above. By addition of those four wire radiations, resultant radiation is formed.

→ If we place rhombic antenna nearer to ground with height h, then resultant radiation will shift by an angle ψ_0.



Design of Rhombic antenna



ψ_0 = Direction of major lobe

→ To obtain major lobe direction ψ_0, we need to calculate height.

$$\boxed{\frac{h_m}{\lambda_0} = \frac{m}{4\cos'(90-\psi_0)}},$$ where h_m is min. height for $m = 1$.

→ For a symmetrical rhombus all leg lengths are equal.

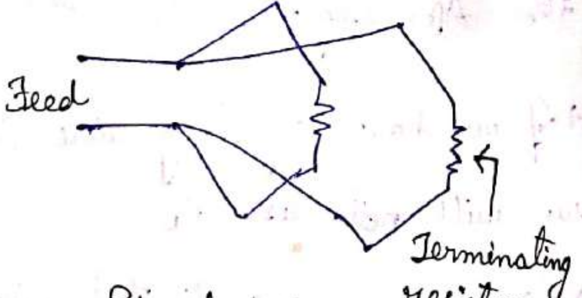
$$\frac{l}{\lambda_0} = \frac{0.371}{1-\sin(90-\psi_0)\cos\theta_0}$$

where, $2\theta_0$ = Apex angle.

$$\theta_0 = \cos^{-1}[\sin(90-\psi_0)]$$

Array of Rhombic Antenna :-

Rhombic antenna are in Series



Rhombic antenna are in Parallel.

Advantages

→ Simple & cheap

→ Vertical radiation is low, hence it is suitable for long distance F-layer propagation.

→ Short wave antennas of this type require low height.

→ Small variation of i/p impedance that results of wide range frequencies.

Disadvantages

→ It occupy large space.

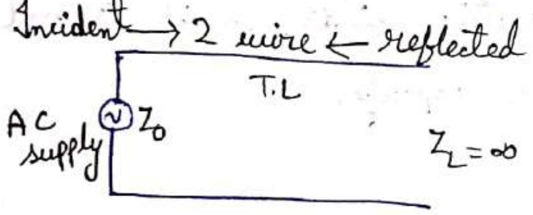
→ It has minor lobes that reduce transmission efficiency.

→ Half power is wasted in terminating resistor.

* Dipole Antenna :-

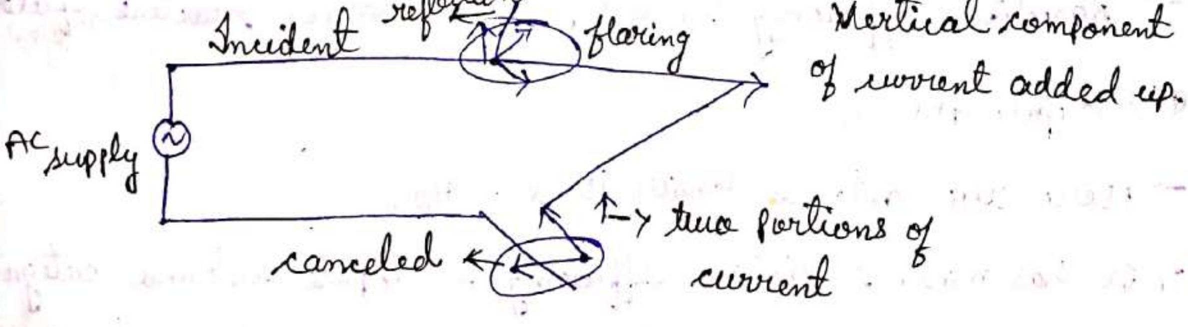
case-1

→ In a normal, T.L when $Z_L = \infty$ i.e., T.L is opened then reflection occurs i.e., max. reflection & min. radiation occurs.



case 2

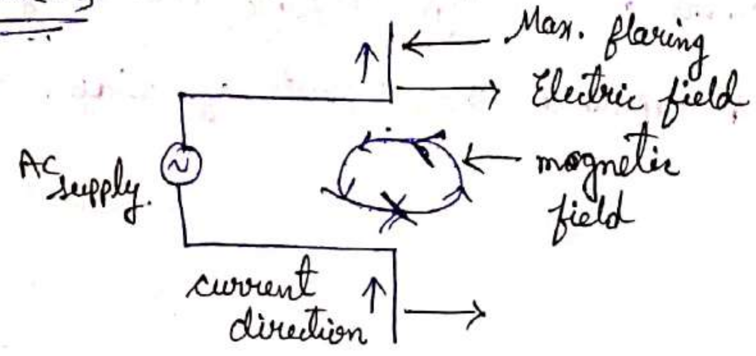
→ when we start increasing flaring in T.L then reflected signal decreases & T.L start to radiate.



→ Here, incident & reflected signal will not get cancelled completely.

→ So, the partial vertical component of signal is radiated in the space.

Case-3



→ Flaring in T.L is dipole antenna.

→ At max. flaring, max. radiation happen.

Types of Dipole Antenna

(i) Hertzian Dipole (Infinitisinal small dipole) :-

→ Here length of dipole antenna is $l < \lambda/50$.

→ Min. use, higher loss, radiation efficiency is less.

→ It has larger region of reactive fields, so it is not commercial used in larger capacity.

(ii) Small Dipole Antenna

→ Here, the antenna length is $\lambda/50 < l < \lambda/10$.

→ Less use, higher losses.

→ Radiation efficiency is less, it has larger reactive field.

(iii) Dipole Antenna

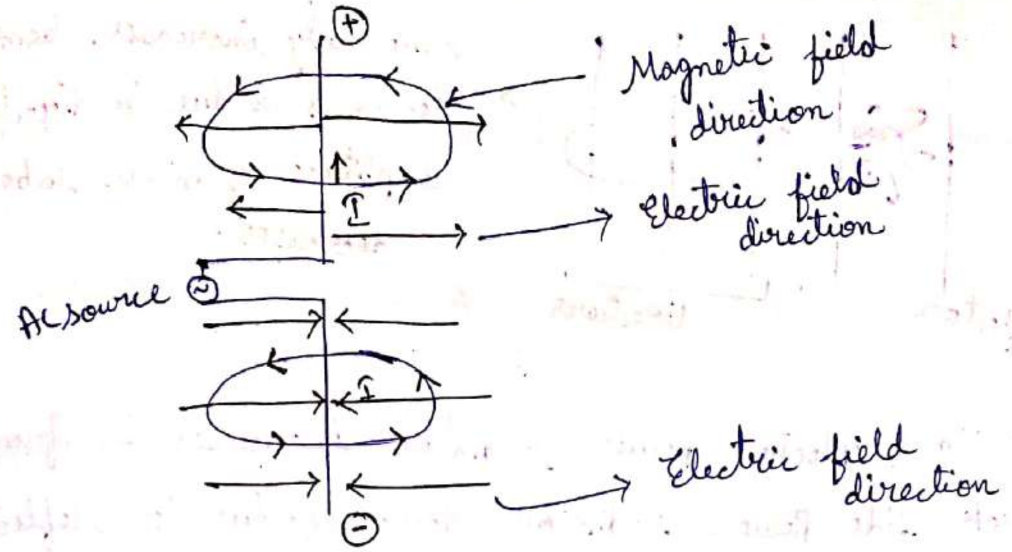
→ Here the antenna length is $l = \lambda/2$.

→ It has max. radiation efficiency in dipole antenna category.

* Electric & Magnetic field in Dipole Antenna :-

→ Electric field is away from +ve dipole & E-field direction is in to -ve dipole.

→ Magnetic field is circulating along the dipole antenna.



→ For -ve 1/2 cycle of AC signal, the direction of E-field & M-field will be reverse.

* Yagi Uda Antenna

Basics

→ It is directional antenna. It has operating frequency <10MHz.

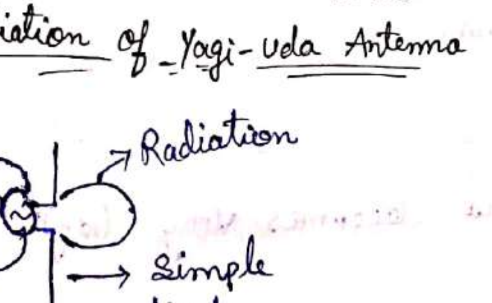
→ It can be used for 40 to 60 Km distance.

→ It has two types of elments :-

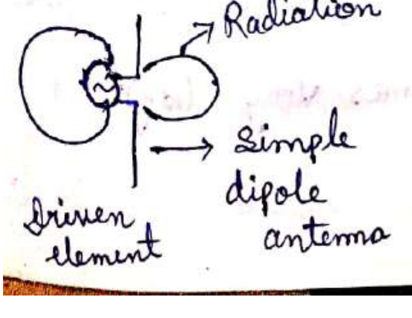
i) Active element [driven element] :- it is connected to power supply.

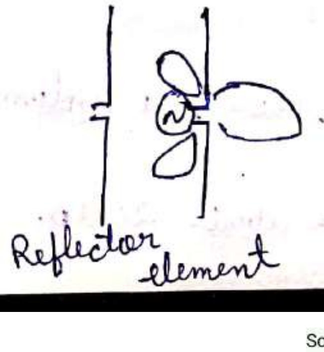
ii) Parasitic element [reflector, directors]:- it is not " " "

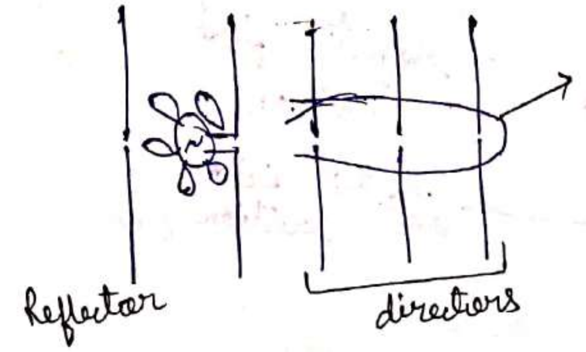
→ Structure of Yagi Uda Antenna :-



Radiation of Yagi-Uda Antenna







Directivity increases, beam wid decreases & due to directors, amplitude of minor lobe decreases.

→ Due to reflector power radiation increases in front sid In back side power radiation decreases, due to reflector back side radiated field reflected.

Designing of 3-element Yagi-Uda Antenna :-

→ Length of active element.

$$L_a = \frac{478}{f(MHz)} \text{ (feet).}$$

→ Length of reflector element

$$L_R = \frac{492}{f(MHz)} \text{ (feet)}$$

→ Length of director element.

$$L_D = \frac{461.2}{f(MHz)} \text{ (feet).}$$

→ Spacing between elements should be .0.25λ.

Advantages of Yagi-Uda Antenna :-

→ High gain about 9.dB, high front to back ratio.

→ Cheap, it is light weight antenna.

Disadvantages

→ For high gain level the antenna becomes very long.

→ Gain limitation is about 20 dB.

h Applications

→ It is used in HF (3-30 MHz), VHF (30-300MHz), UHF (300-3000 MHz)

→ Home TV receiver.

→ For point to point communication.

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* Directivity

→ It refers to the ability of an antenna to send or receive signals over a narrow ~~hoz~~ horizontal direction range.

→ It means how much it directional in physical orientation towards the signal source.

* Beam Width

→ It refers to angle of radiation pattern over which transmitter's energy is transmitted or received.

→ The measure of an antenna's directivity is beam width.

→ The angle formation by the two 3-dB down point from centre of graph is beam width.

→ Less beam width ⇒ more gain ⇒ more directivity

* Duct propagation (Super Refraction) (SR)

→ The VHF, UHF & microwaves are neither reflected by Ionosphere nor propagated along earth's surface. But due to the refraction of such high freq. waves in the troposphere, the transmission occurs much beyond of LOS surface.

→ Due to water, vapour, temp. the refraction occurs i.e., S.R

* Critical Frequency

→ The sky wave propagation due to reflection from Ionosphere Occurs in HF range of frequencies.

→ As the freq. is increased at same point, the wave is not reflected by Ionosphere & instead it pierces through the Ionosphere.

→ This freq. known as Critical freq. (f_c), where, is $f_c = \sqrt{N_{max}}$ & N_{max} is max. e^- density in m^{-3} which varies with time.

* MUF

→ It stands for Max. Usable Freq.

→ It is highest freq., that is bent back by Ionosphere layer & depends on angle of incident ray.

→ $f_{muf} = (9\sqrt{N}) \sec \theta$; where, N → e^- density; θ → angle made by incident ray in ionised layer.

* Fading

→ If the intensity (strength) of received signal decreases when the transmitted signal travels in different by covering long distance to reach at receiver is called fading.

→ Fading depends upon wind flow, temp., humidity of air, etc.

→ Types of fading are namely of interference, selective, absorption, skip & Polarization.

* Propagation

→ The propagation of microwave signal means travelling of EM waves from transmitter to receiver through channel. (i.e., may be free space).

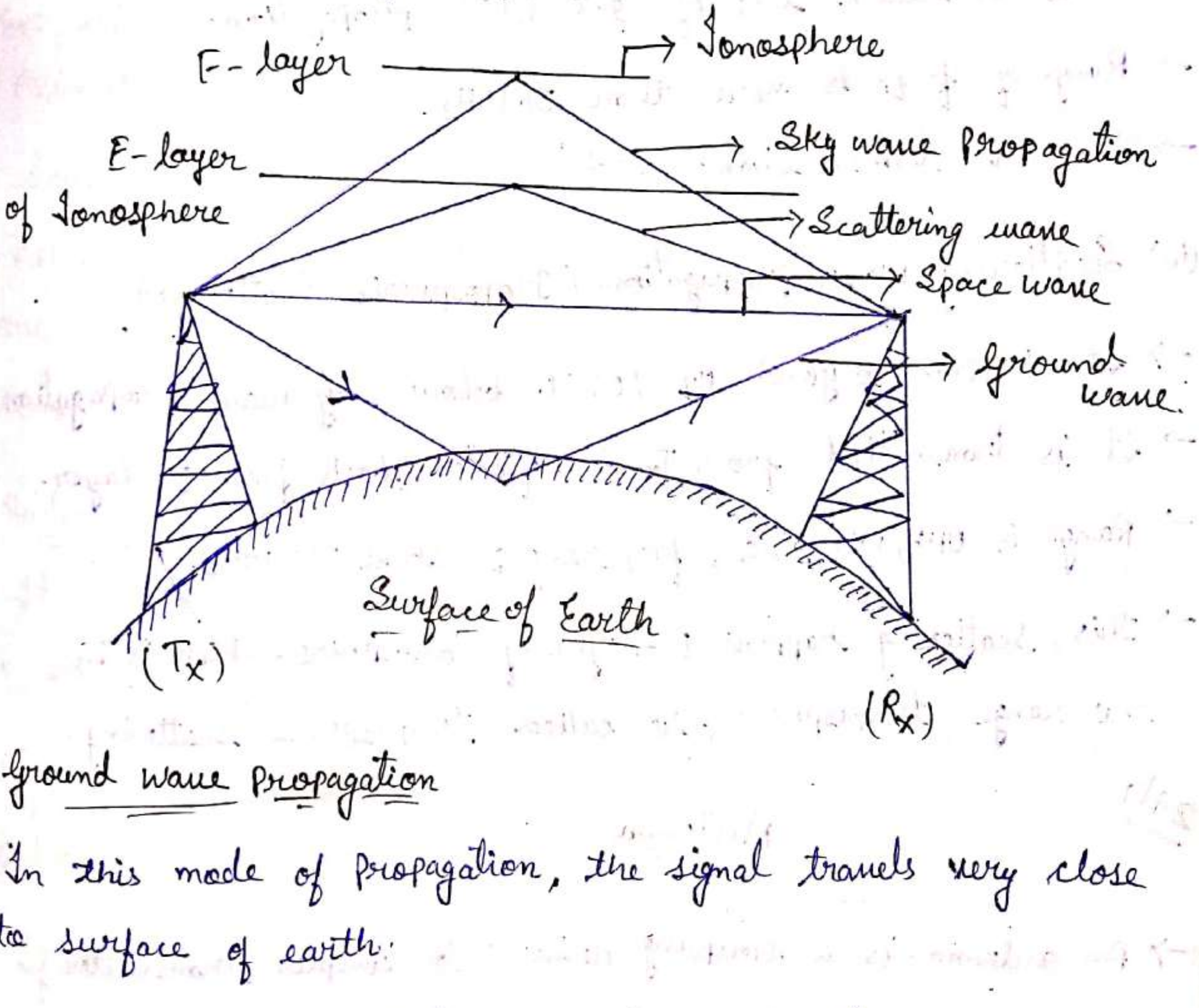
→ Types of propagation are namely :-

(i) Ground Wave Propagation

(ii) Sky-wave Propagation

(iii) Space wave propagation

(iv) Scatter wave propagation



(i) Ground wave Propagation

→ In this mode of propagation, the signal travels very close to surface of earth.

→ The ground wave actually follows the curvature of earth & travel long distances beyond the horizon.

→ Freq. range is 30 KHz - 3 MHz

→ Ex:- All medium broadcasting, telephone communication.

(ii) Sky-Wave Propagation :-

→ In this mode the waves are reflected back from transmitting antenna to receiving antenna through F - layer of ionosphere.

→ Rang of freq. is 3 MHz - 30 MHz.

→ Ex :- Point to point communication of large distance radio communication and short wave radio communication.

(iii) Space Wave Propagation (LOS)

→ The wave Propagates from T_x to R_x in direct path wave. So it is called line of sight (LOS) propagation.

→ Range of freq. is more than 30 MHz.

→ Ex :- TV transmission.

(iv) Scattering Wave propagation (Tropospheric Scattering)

→ It happens beyond of LOS & below sky wave propagation.

→ It is transmitted from T_x & reflected back from E - layer.

→ Range is UHF, VHF, μw, freq rang is above 300 MHz.

→ This scattering happens E - layer of ionosphere which is in the range triopospher, so called troposphere scattering.

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Antenna

→ An antenna is a coupling device. It couples transmitter to space & space to receiver.

→ It radiates & receives EM waves. It is a tuned element and passive element.

* Isotropic Radiator :-

→ It is a fictious antenna (or) impractical antenna. It is capable of radiating uniformly in all directions.

Ex:- Point source.

* Omnidirectional Antenna :-

→ This antenna is capable of radiating uniformly in Azimuthal plane & having non-uniform radiation in the elevation plane.

Ex:- Dipole Antenna

Azimuthal Angle (0° to 180°); Elevation angle (0° to 360°).

* Directional Radiator

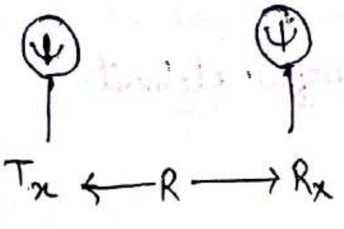
→ All practical antennas are directional radiators i.e., they are capable of radiating & receiving EM waves through some particular direction.

* Radiation Pattern :-

→ It is the locus of received field strength (or) power at a fixed far distance as a function of space co-ordinates.

→ If received quantity is field strength then it is called field strength pattern.

→ If the received quantity is power then it is called power pattern.



→ If $R > \frac{2D^2}{\lambda}$, then this zone is Fraunhofer far field zone.

→ In this zone the radiated fields are active field & it is used for radiation purpose.

→ If $R < \frac{2D^2}{\lambda}$, then it is called Fraunhofer near field zone

→ In this zone the fields are reactive fields & it is not used for radiation purpose.

λ = operating wavelength

D = diameter of antenna

→ All the antennas are intended to be operated in the Fraunhofer far field zone only.

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* Average Radiation Density :-

→ It is defined as average power radiated per unit area.

$$P_{avg} = P_{rad} = \frac{1}{2} \times \vec{ES} \times \vec{HS}^{*} \ \text{W/m}^2 .$$

→ This is avg Poynting vector. $\vec{ES}$, $\vec{HS}$ are phasor form of the electric field ($\vec{E}$ field) & Magnetic field ($\vec{H}$ field).

* Average Radiated Power (W_{rad}) :-

→ It is an average power radiated by an antenna.

$$W_{rad} = \oint_{s} P_{avg} \cdot ds \text{ watt.}$$

$\vec{ds}$ is the vector differential surface element.

* Average Radiation Intensity ($\vec{U}$) :-

→ It is defined as average power radiated per unit solid angle.

$\vec{U} = r^2 \cdot \vec{P}_{avg}$ W/steradian.

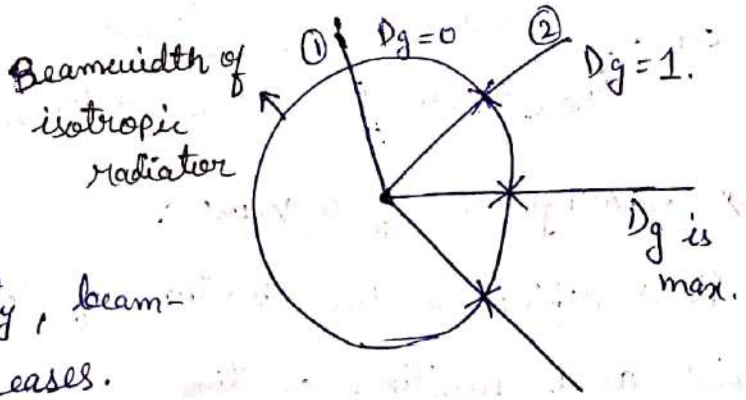
* Directive Gain (D_g) :-

→ It is in a given direction is the ratio of radiation intensity of the practical antenna whose directive gain (D_g) you want to calculate to the radiation intensity of the reference antenna.

$$D_g = \frac{\text{Radiation Intensity of the practical Antenna whose } D_g \text{ you want to calculate}}{\text{Radiation Intensity of reference antenna.}}$$

→ This reference antenna is being choosen as isotropic radiator.

→ Isotropic radiator directive gain is zero.



→ By increasing directivity, beam-width of antenna decreases.

→ For larger directivity we require narrow beam width. For smaller directivity we require larger beam width.

→ For Broadcast application an antenna has low directivity.

→ For point to point communication the antenna must have very high directivity.

$$\boxed{D_g = 4\pi \cdot \frac{U_{max}}{W_{rad}}}$$

→ $\boxed{\text{Power gain } (G_P) = 4\pi \cdot \frac{U}{W_{in}}}$

W_{in} = Power in to the antenna

$W_{in} = W_{rad} + W_{loss}$

- I^2R loss (Power loss)
- Reflection loss
- Dielectric loss.

→ Max. Power gain.

$$\boxed{G_0 = 4\pi \cdot \frac{U_{max}}{W_{in}}}$$

* Total Efficiency of an antenna :-

$$e_t = \frac{\text{Gain}}{\text{Directivity}} \quad ; \quad \text{Directivity} = \frac{\text{Gain}}{\text{Efficiency}}$$

$$e_t = \frac{R_{rad}}{R_{rad} + R_{loss}} \quad ; \quad = \frac{W_{rad}}{W_{rad} + W_{loss}}$$

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* Polarization of a Wave :-

→ It is defined as the direction of electric field at a given point as a function of time.

Polarization

- Linear Polarization.
  - Horizontal
  - Vertical
  - Theta
- circular
- Elliptical

* Linear Polarization :-

→ $\vec{E}$ field remain along a straight line as a function of time at some point in the medium.

→ When wave travels in z-direction both $\vec{E_s}$ & $\vec{H_s}$ lying in x-y plane.

If (i) $E_{ys} = 0$ & E_{xs} is present [x-Polarised or Horizontal]

(ii) $E_{xs} = 0$ & E_{ys} is present [y-Polarised or vertical polarised].

(iii) E_{xs} & E_{ys} is present & in phase [θ-polarised ; $\theta = \tan^{-1}\frac{E_y}{E_x}$]

* Circular Polarization :-

→ In this polarization $\vec{E}$ (Electric field) traces a circle.

→ Here, Electric field ($\vec{E}$) has 2 components E_{xs} & E_{ys} have equal magnitude & a 90° phase difference.

→ The locus of the resultant $\vec{E}$ field is a circle & the wave is a circle & the wave is circularly polarized.

$$E_{xs}^2 + E_{ys}^2 = E_K^2$$

where,

K represents the direction of propagation & it is generally in z-direction.

* Elliptical Polarization :-

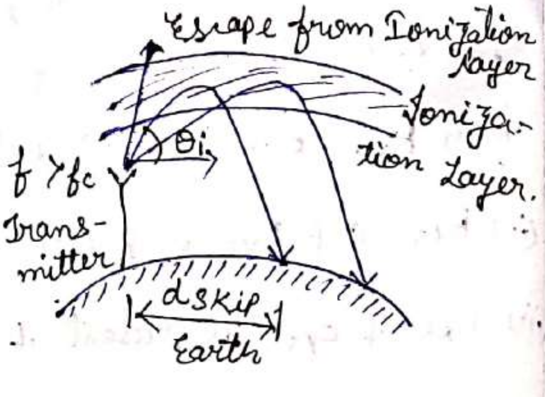
→ Here, $\vec{E}$ has 2 components E_{xs} & E_{ys} are not equal in magnitude & they differ by 90° phase, then the tip of the resultant electric vector traces an ellipse. The wave is said to be elliptically polarized.

$$\frac{E_{xs}^2}{a^2} + \frac{E_{ys}^2}{b^2} = 1$$

* Skip Distance

→ It is the shortest distance from a transmitter measured along earth's surface at which sky wave has fixed frequency ($f > f_c$) will be returned to the earth.

→ A θ_i angle of radiation the signal comes to the earth by reflecting in ionization layer.



→ So we can say the sky wave propagation is possible for greater than skip distance.

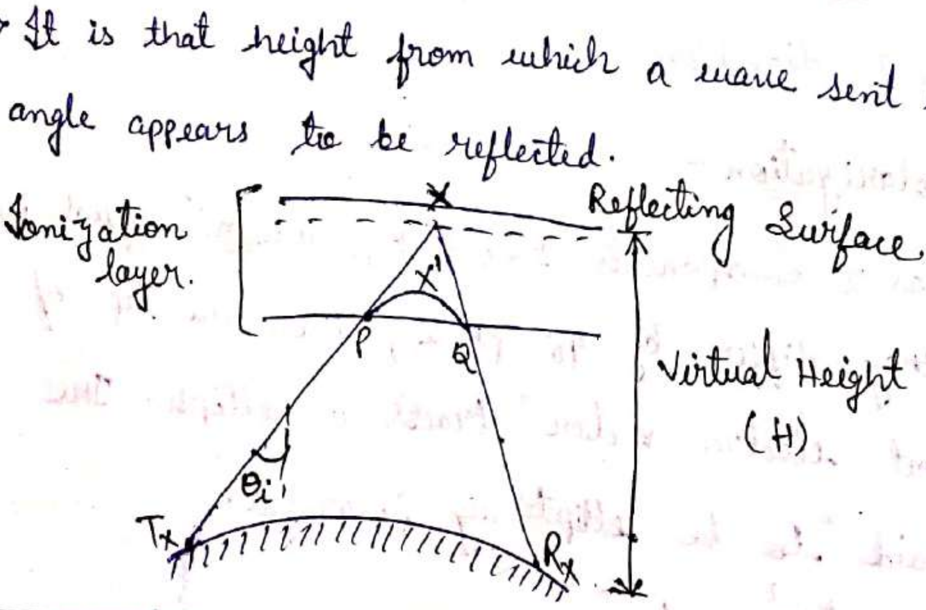
→ Equation of MUF & critical freq. is

$$\Rightarrow f_{muf} = f_c \sqrt{1+\left(\frac{d}{2H}\right)^2}$$

$$\Rightarrow d_{skip} = 2H \cdot \sqrt{\left(\frac{f_{muf}}{f_c}\right)^2 - 1}$$

* Virtual Height :-

→ It is that height from which a wave sent up at an angle appears to be reflected.



-> Due to gradual change in refractive index actual path is $T_x - P - X' - Q - R_x$. And virtual path is $T_x - P - X - Q - R_x$.

-> The height associated with virtual path is virtual height.

-> To measure the virtual height, the instrument used is ionospheric sound is also called as Ionosonde.

-> The transmitter antenna sends vertically upward radio-wave of pulse duration 150 μs.

-> The receiver antenna (R_x) is placed close to transmitter antenna (T_x) & receives reflected signal.

-> If the duration of transmitter (T_x) & receiver (R_x) signal difference is T, then distance = velocity × time,

$$\Rightarrow 2H = C \times T \quad \Rightarrow H = \frac{C \times T}{2}$$

↓

(Sending distance H, receiving distance is H by reflection. So total distance is 2H).

* <u>Actual Height</u> :-

-> The height associated with actual path is actual height.

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Television.

* SMPS :-

→ SMPS stands for Switch Mode Power Supply.

→ It is a device which provides power to any electrical load and involves some kind of switching action.

→ Previously linear power supplies become very bulky with increase in its current ratings. So, we need something which will allow us to handle large amount of currents without taking a lot of space. So we use SMPS as a solution for that.

→ SMPs works on a very high frequencies as compared to linear power supplies & as the size of transformer reduces with increase in frequency, the overall size of an SMPS become very small as compared to linear power supplies.

→ There are basically five blocks in SMPS namely :-

(i) Input rectifier & filter.

(ii) Chopper (It is used to convert DC signal to Pulsnating DC).

(iii) Transformer (It steps down the volt. to required level).

(iv) Output rectifier and filter (constant DC o/p voltage is obtained).

(v) Feedback circuit (This circuit has to maintain the o/p voltage to a desired value).

* Working of SMPS

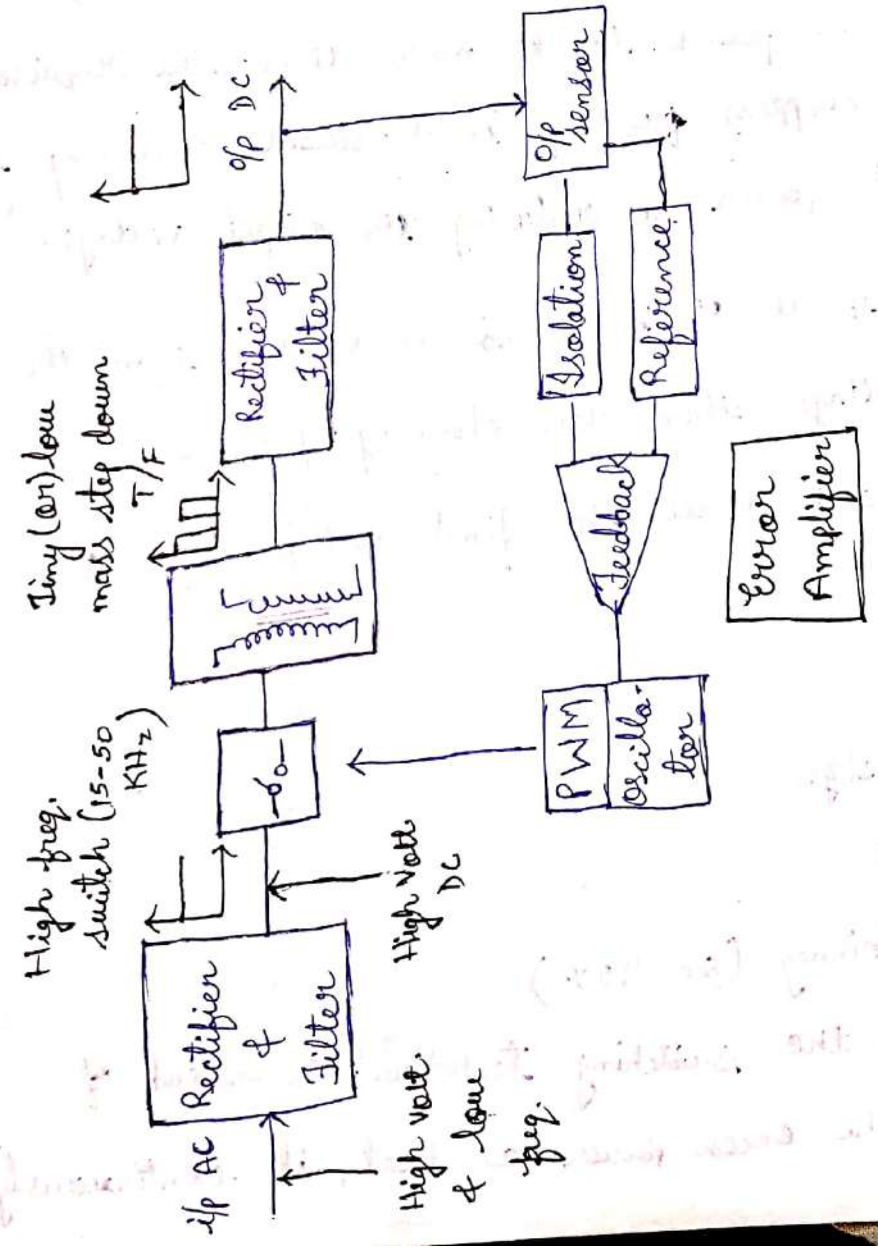
→ SMPS works on high frequencies.

→ We need to increase the frequency of 50 Hz i/p.

→ So, we have to convert the ac i/p to d.c first & then chop it at high frequency to get the pulsating dc o/p which is then applied to rectifiers & filters.

→ Feedback helps to maintain the level of o/p signal.

* Block Diagram of SMPS :-



→ Isolation unit is used to separate the high current from damaging the primary side circuitory.

→ Transformer steps down the pulsnating DC signal and it is applied to o/p rectifier & filter circuit to get a constant DC o/p.

* Feedback circuit

→ Output sensor of the feedback unit senses the o/p voltage and then compares with reference voltage. The error voltage is used to control the chopping frequency.

→ If the o/p is found to be more than the required value, the chopping frequency is decreased, reducing the total output power so reducing the output voltage.

→ Similarly if the o/p is found to be less than the required voltage then the chopping frequency is increased, and hence the final voltage level is maintained.

* Advantages :-

(i) Small in size

(ii) Less noise.

(iii) High efficiency (80-95%)

SMPS uses the switching technique, so instead of dissipating the excess power as heat, it continuously switches its i/p to control the o/p power contribute to linear power supplies. This increases overall efficiency of SMPS.

* Disadvantage :-

-> SMPS has high complexity as it involves so many stages of operation.

-> It operates at high freq. which causes generation of EMI that can damage the sensitive instruments.

Antenna

* Total efficiency of an antenna (e_t) :-

-> $e_t = \frac{W_{rad}}{W_{in}} = \frac{\text{gain } (G_0)}{\text{directivity } (D_0)}$

$\Rightarrow$ Directivity $= \frac{\text{gain}}{\text{efficiency}}$; D_0 = directivity $= 4\pi \cdot \frac{U_{max}}{W_{rad}}$

$$\text{Efficiency } (e_t) = \frac{W_{rad}}{W_{rad} + W_{loss}} = \frac{R_{rad}}{R_{rad} + R_{loss}}$$

* Effective Aperature Area (A_e) :-

-> It refers to physical size of the antenna. Large antennas will have larger aperature area & vice versa.

-> If the antenna dimensions are less than λ, thin they are called small antennas & vice versa.

$$A_e = \frac{\text{Average Power received}}{\text{Avg. Power density of the incident wave}}$$

$$A_e = \frac{\text{Watt}}{(\text{Watt}/\text{mtr})^2} \therefore = \text{mtr}^2$$

$$\boxed{A_e = \frac{\lambda^2}{4\pi} \cdot D_g}$$

→ A_e ↑ (increase), D_0 ↑, Beamwidth(↓), A_e ↓, D_0 ↓, Beamwidth(↑)

* Hertzian Dipole:-

$$H \text{ (magnetic field)} = \frac{I.\beta.l.\sin\theta}{4\pi r}$$

E (Electric field) = $\eta . H$ [$\because \eta$ = Impedance]

Radiation Resistance $(R_{rad}) = 80.\pi^2 \left(\frac{l}{\lambda}\right)^2$

Radiated Power $(W_{rad}) = 80.\pi^2 (1/\lambda)^2 . I^2_{eff}$

I_{eff} = Effective current of antenna
$= I/\sqrt{2}$

* Intrinsic / Input Impedance :-

→ It is the ratio of electric field (E) to magnetic field (H)

$$\eta = \frac{E}{H} \text{ in } \Omega \text{ or } \sqrt{\frac{\mu}{\epsilon}}, \text{ for free space.}$$

→ If the wave is moving along Z-direction then,

$$\frac{E_x}{H_y} = \eta = -\frac{E_y}{H_x}$$

$$\frac{E_x}{H_y} = -\eta = -\frac{E_y}{H_x} \text{ (for -ve Z direction)}$$

→ If the wave is moving along x-direction then,

$$\frac{E_y}{H_z} = \eta = -\frac{E_x}{H_y}$$

$$\frac{E_y}{H_z} = -\eta = -\frac{E_x}{H_y}$$ (If the wave move & along -ve z-direction).

→ If the wave is moving along y-direction then,

$$\frac{E_z}{H_x} = \eta = -\frac{E_x}{H_z}$$

$$\frac{E_z}{H_x} = -\eta = -\frac{E_x}{H_z}$$ (for -ve y-direction).

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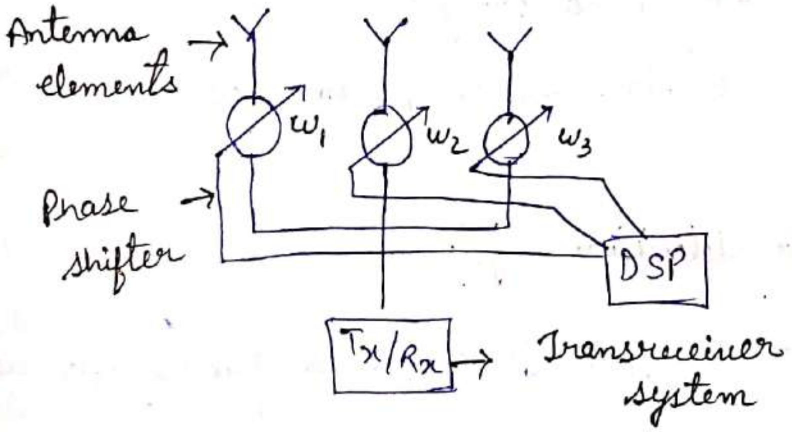
* Smart Antenna

→ It is the combination of antenna phased array and DSP processors.

Structure of Smart Antenna



→ Phase of the phase shifter is controlled by DSP Processor. By controlling the phase of phase shifter antenna is steered.

→ Antenna elements radiates in desired direction only. It has minimum interference. Each antenna element is connected with Phase shifter & then it is connected with transreceiver system. Smart antenna has higher gain in desired direction.

Definition :- A smart antenna system combines multiple antenna elements with signal processing capability to optimize the radiation and/or reception pattern automatically in response to the signal environment.

Benefits :-

(i) It has higher gain for the desired signal.

(ii) Interference Rejection.

(iii) Increase system capacity.

Applications :-

(i) It is used in acoustic signal processing.

(ii) It is used in tracking of RADAR.

(iii) It is used in radio astronominy.

(iv) It is used in cellular system, radio telescopes.

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* Introduction to Television system :-

→ The word television has its origin in two greek words 'tele' & 'vision'. Tele means 'at distance' & vision means 'seeing'.

→ Earlier selenium photosensitive cells were used for converting light from pictures into electrical signals. (i.e., Conversion of optical signal to electrical signal).

→ First camera tube is iconoscope. In 1935 TV broadcasting started. In 1959 TV came to India.

* Evolution of TV :-

Black & white TV → color TV → plasma TV → 3D TV → HD TV.

* Aspect Ratio :-

→ Width to height ratio of a picture frame is called aspect ratio. Width is kept longer than height because of the following facts:-

i) Horizontal dimension of a scene is generally more than its vertical dimension.

ii) Eyes can move with more ease & comfort in the horizontal plane than in vertical.

(iii) The fovea, the surface of max. senstivity & resolution at the centre of the retina in the eye has greater width than height. Hence, the longer width of the image ensures more efficient use at the fovea.

(iv) As a result of intensive subjective tests by the cinema People, aspect ratio of 4:3 was found to be most pleasing aesthetically & less fatiguing to the eyes.

* Details & Resolution :-

→ Closely spaced small objects (or) small distinct features in a Picture form details.

→ Smaller the objects (or) features visible distinctly, higher is the resolution of the details (or) finer are the details being seen.

→ The ability to see the fine details in a Picture is called resolution.

* Flicker :-

→ Time of Persistence of vision is more for darkness than for bright light. This results in a phenomenon called flicker.

→ It means dark intervals between bright Pictures become visible for a very short time & appear as a flicker.

* Scanning :-

→ Optical information is converted into electrical form and transmitted element by element, one at a time in a sequential manner to cover the entire scene to be televised.

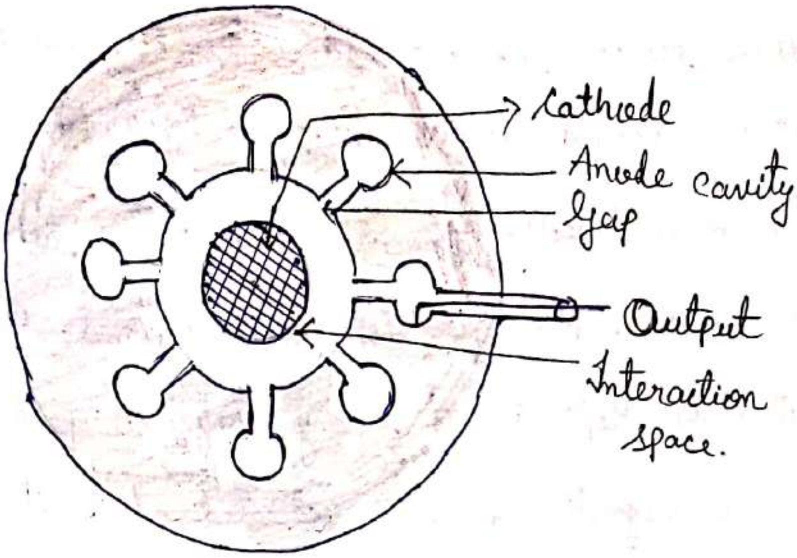
→ Scanning is done at very fast rate.

→ It is repeated a no. of times per second to create an illusion of simultaneous Pick up.

* Magnetron :-

→ It is a combination of a simple diode vacuum tube with built in cavity resonators & an extremely Powerful magnet.

Construction



-> A Magnetron is a called a cross field device, because there is a magnet outside of the magnetron.

-> Due to e^- move, there is a electric field. But the magnetic field & electric field acts in Perpendicular.

-> The two fields crossed each other so it is called cross field device.

$$F = \bar{B} \times e\bar{v} = Bev \sin\theta$$

$$\Rightarrow F = B_{ev} \quad [\text{when } \theta = 90^\circ \text{ means perpendicular}]$$

$\sin\theta = 1$; B → Mag. field.

-> There are even no. of cavities. Every portion is indicated as cathode, e^- path, interaction space, outlet. The o/p is taken from one of the cavities.

-> Cathode :- Its function is to emit e^-. Here ~~its~~ cathode is a circular cathode.

-> Interaction space :- At which e^- moves & magnetic & electric fields act.

Operation

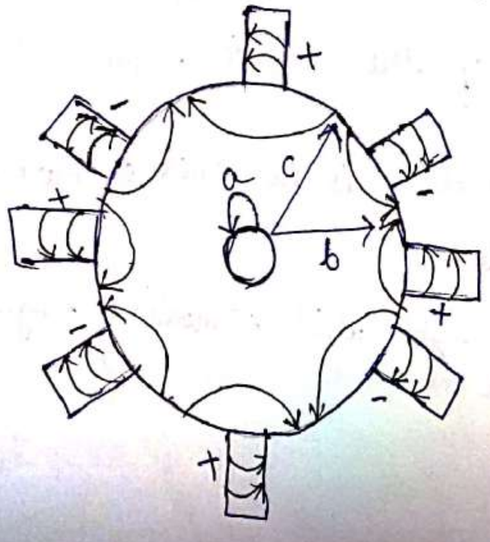
-> When heated the cathode emits e^-. So the e^- wont to move towards +ve anode. Due to anode is connected DC supply

-> If e^- move directly towards the anode, anode current will flow. But it is not happened. ~~But~~ Because the system is kept in a strong magnetic field, when e^- move also a magnetic field is created but it is small compare to outside magnetic field. So repulsion occurs.

-> Due to this repulsion the e^- moves in a (curved path) or circular path instead of directly towards the anode.

-> The magnetic field for which e^- return back to cathode without reaching the anode for which anode current is zero, that magnetic field is called critical magnetic field. (B_c).

-> For zero anode current applied magnetic field (B) should be greater than B_c.



→ Input is applied to one anode cavity. It is circulated to other cavities by making 180° phase shift.

→ There is +ve & −ve polarity for each cavity. $\vec{E}$ is always +ve to −ve potential.

→ For 'b' e^- $\vec{E}$ & e^- movement direction same means velocity of e^- increases. But 'c' e^- $\vec{E}$ & e^- movement opposite means velocity of e^- decreases.

→ So velocity modulation occurs & e^- move up & down & releases energy as a result oscillation occurs.

→ So from one cavity the oscillated e^- are taken. That's why magnetron is called oscillator.