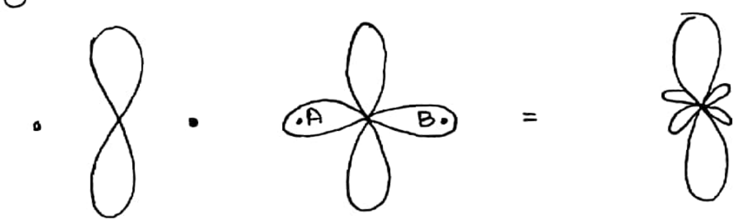
The resultant pattern is given by unit pattern, $\lambda/2$ Spacing (1)&(2) and (3)&(4) antennas and group pattern λ spacing of A& B is.



7/9/17

Unit-3 - VHF, UHF, Microwave antennas.

Introduction:-

→ VHF frequency range (30-300) MHz. (Very high)
Applications:- FM radio, ~~UHF~~.

→ UHF frequency range (300-3000) MHz (3GHz) - (Ultra high)
Applications:- GSM, GPRS, wi-fi, WLAN

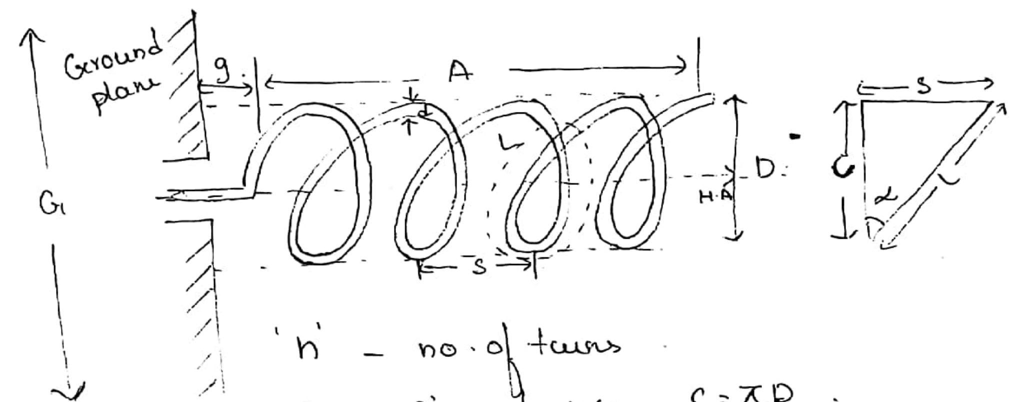
→ MW frequency range (300 MHz - 300 GHz)
Applications:- wi-fi, sattillite, Radar.

★ **VHF antenna:-** The antenna which is operated at VHF frequency.

★ **UHF antenna:-** The antenna which is operated at UHF frequency range.

★ **Microwave antenna:-** The antenna which is operate at microwave frequency range.

★ **Helical antenna:-**



'n' - no. of turns

C - circumference, $C = \pi D$.

$$L = \sqrt{S^2 + C^2}$$

$$\alpha = \tan^{-1}\left(\frac{S}{C}\right) = \tan^{-1}\left(\frac{S}{\pi D}\right)$$

G – length of ground plane.

d – width / thickness of conductor.

→ The helical antenna is consisting of helical loops

→ It is made up of conductor (copper) and it is associated with ground plane.

→ The ground plane is made up with conductor

→ The typical structure of helical antenna is as shown in above fig.

→ D – diameter of helix ; S – spacing b/w turns

L – length of one turn ; n – no. of turns ; A – axial length

d – diameter of helix conductor ; α – pitch angle.

$\boxed{A = nS}$. G – ground plane diameter

→ The length of one turn (L) is related to the pitch angle α i.e., as shown in fig 2

→ The pitch angle α is formed by a line tangent to the helix and plane normal ⊥ to the helix axis

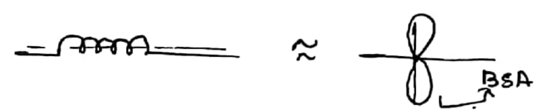
→ The pitch angle α is b/w 0 to 90°

<u>Properties</u> :- The radiation pattern and polarisation depends on diameter of the helix, pitch angle α, no. of turns, spacing b/w helical loops and wave length.

→ The helical antenna is excited under 2 modes

1st – normal mode 2nd – axial mode.

<u>Normal mode</u> :- In the normal mode operation maximum field is radiated in the plane normal to helical axis. i.e.,



→ This can be called as broadside mode

→ In this mode the dimension of helix is small compared with wavelength

→ In this case Beam width is small and the effic is low.

→ For the radiation pattern representation the field strengths are considered i.e., the far field for short dipole is E_θ

$$E_\theta = \frac{j60\pi I_0 \sin\theta}{r} \cdot \frac{S}{\lambda}$$

→ I_0 is retardent current and r is dist. b/w source and field points.

→ The far field of the small loop is E_ϕ

$$E_\phi = \frac{120\pi^2 I_0 \sin\theta}{r} \cdot \frac{A}{\lambda^2}$$

The area of the loop $A = \frac{\pi D^2}{4}$

The ratio of E_θ and E_ϕ is defined as axial ratio $AR = \frac{E_\theta}{E_\phi}$

<u>Condition – 1</u> :- If $E_\theta = 0$ then $AR = 0$, the elip. polarisation becomes linear polarisation i.e., horizontally connected

Condition 2 :- If $E_\phi = 0$ then $AR = \infty$, the elliptical polarisation becomes linear vertical polarisation.

$\therefore$ The axial ratio exists in b/w 0 & ∞

Condition 3 :- If $E_\theta = E_\phi$ then $AR = 1$, the eliptical polarisation becomes circular polarisation.

$$AR = \frac{E_\theta}{E_\phi} = \frac{\frac{j60\pi I_0 \sin\theta}{r}\frac{S}{\lambda}}{\frac{120\pi^2 I_0 \sin\theta}{r}\frac{A}{\lambda^2}} = \frac{S\lambda}{2\pi A} = \frac{2S\lambda}{4\pi^2 D^2}$$

$$A = \frac{\pi D^2}{4}$$

$$\frac{2S\lambda}{\pi^2 D^2} = 1 \Rightarrow S = \frac{\pi^2 D^2}{2\lambda} = \frac{C^2}{2\lambda}.$$

→ The normal mode is not used because of small beamwidth and less efficiency.

18/9/17 **Axial mode :-** (Design specifications)

In the case of axial mode the max. radiation direction is along the helical axis.

It is similar to the EFA radiation

In this mode the polarization is almost circular. Based on the S & D the radiation pattern will be changed i.e., S & D decides the direction of Rad. pattern

The circumference of elipse must be 3/4 less than C/λ less than 4/3. The spacing b/w turns is $S = \lambda/4$

The ground plane diameter is $\lambda/2$

The pitch angle α is in b/w 12° & 18°

The terminal impedance of helix is above 100 Ω

→ The i/p impedance is $R = 140\frac{C}{\lambda}\,\Omega$

→ The gain & beamwidth depends on length of the helix

→ The half power beam width $= \frac{52\lambda}{(C/L)}$ C - circumference, L - length.

→ First null beam width $= \frac{115\lambda^{3/2}}{(C/\sqrt{L})}$

→ Directivity $D = \frac{15nC^2S}{\lambda^3}$ n - no. of turns.

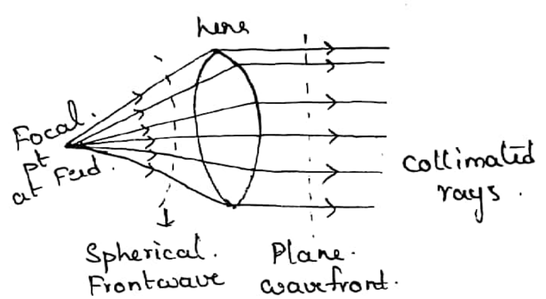
→ Axial ratio $= \frac{2n+1}{2n} = (AR)$

→ Gain (dB) $= 10\log\left[15\left(\frac{C}{\lambda}\right)^2\frac{L}{\lambda}\right]$.

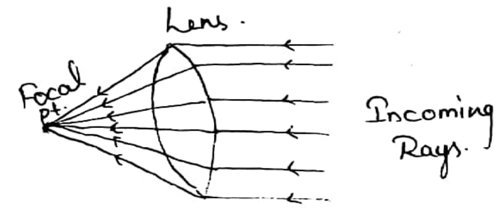
→ To achieve the axial mode radiation all the above parameters must be required.

12/9/17

★ **Lens Antenna :-**



(a) Transmitting mode.



(b) Receiving modes

→ The lens antenna consists of electromagnetic lens with a field

→ The operation of lens antenna is similar to the glass lens in optics

→ The lens antenna can be used in transmitting and recieving modes which is as shown in fig a & fig

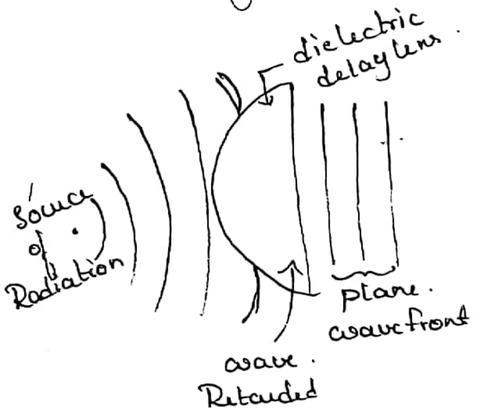
→ It collimate the electromagnetic waves (which prevents the EM waves from undesired directions).

→ The main application of lens antenna is to collimate incident divergent energy to prevent it from spreading in undesired directions.

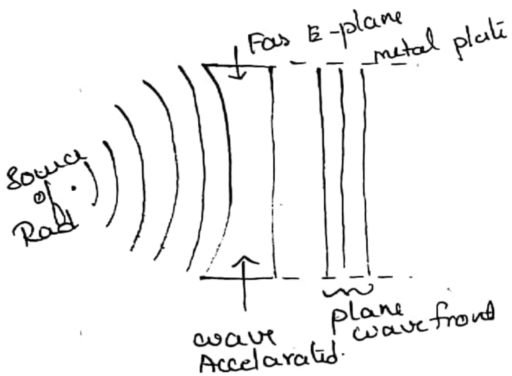
→ These antennas are used to transform the divergent energy into the plane waves by properly choosing lens material and geometry shape.

→ These antennas are used at very high freq.

→ The lense antennas are classified based on geometry shape and material used for lens construction. i.e., delay lense antenna & fast lens antenna



(a) Delay Lens antenna



(d) Fast Lens antenna

→ In delay lens antenna the electrical path length is increased by lens medium and the wave is retarded

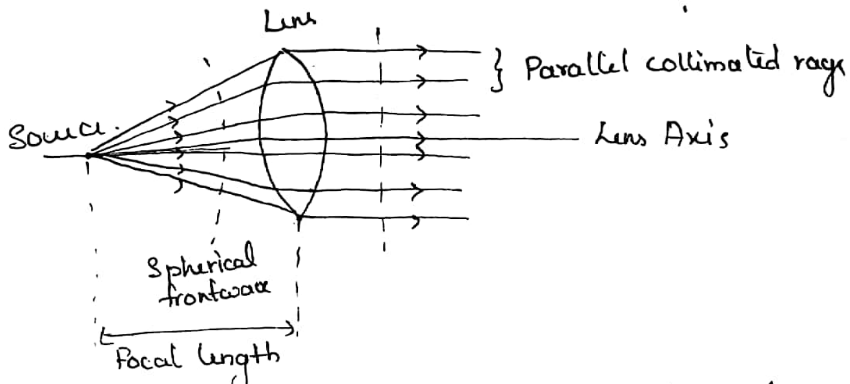
Ex:- Dielectric lens antenna and H-plane metal plate lens

→ In fast lens antenna, the electrical path length is decreased by lens medium and the wave is accelerated.

Ex:- E plane metal plate lenses

→ The dielectric lenses are furthuly clasified based on dielectric material.

Principle of lens antenna :-



→ Let us consider an optical convex plane lenses

→ If a point source is placed at the focal point of lens which is along the axis, with that the focal dist. is obtained on the lens axis

→ Due to the radiation from the source point we get spherical front wave.

→ When the rays travel to the lens, then the plane wave front of parallel rays is obtained (Due to the lens collimation)

→ The refraction is more at the edges that that centre.

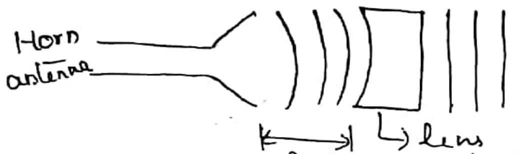
→ The dielectric lens antennas are used at radio (88-108)MHz.

→ If the spherical wavefront at left hand side is transformed into parallel rays then this operation treated as transmitting lens antenna

→ If the parallel rays are incoming from right hand side lens then these rays will converge at focal point in left hand side then it is treated as receiving lens antenna.

15/9/17 **Feed system of lens antenna :-**

1. The feed of the lens antenna is similar to the parabolic reflector.
2. These are fed with horn antennas i.e.,



For the better performance of lens antenna dimensions of horn antenna is equal to the focal length

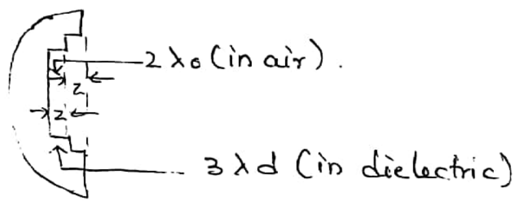
★ **Zoning of lens :-** Removing the sections of lens is called zoning. By using this method, the weight of lens antenna can be reduced.

★ **Types of zoning :-** There is no performance changes due to the zoning and also freq also not changed.

1) Curved surface zoning :-
2) plane surface zoning :-

The zone step (thickness) is denoted by z.

The thickness in the dielectric is longer than that in air.



The pitch angle α is in b/w ...

The thickness 'z' in dielectric is 3λd.

And 'z' in air is 2λo (3λd > 2λo)

Here λd & λo are wavelengths in dielectric and air resp.

→ For one wavelength difference (dielectric & air)

i.e., $\frac{z}{\lambda d} - \frac{z}{\lambda o} = 1$.

Here the refractive index $\eta = \frac{\lambda o}{\lambda d}$.

$$\Rightarrow \frac{z}{\left(\frac{\lambda o}{\eta}\right)} - \frac{z}{\lambda o} = 1$$

$$\boxed{z = \frac{\lambda o}{(\eta - 1)}}$$

2) **Curved surface zoning :-**

If the zoning is done along the curved surface of the lens then it is called curved surface zoning which is as shown in above fig

→ It is mechanically stronger
→ It has less weight
→ The power dissipation is low.

Plane surface zoning :- If zoning is done along the plane surface of lens it is called PSZ.

→ It is mechanically weaker
→ It has relatively more weight
→ It has relatively more power dissipation.

★ Tolerances of lens antenna :-

In dielectric lens antenna the path length diff caused by → deviations in thickness.
→ variations in index of refraction.

Let us assume that max. allocoable variation in both parameters (t & η) to be $\frac{\lambda_0}{32}$ then the thickness tolerance is given by: $\frac{\Delta t}{\lambda_d} - \frac{\Delta t}{\lambda_0} = \frac{1}{32}$.

$$\eta = \frac{\lambda_0}{\lambda_d}.$$

$$\frac{\Delta t}{\left(\frac{\lambda_0}{\eta}\right)} - \frac{\Delta t}{\lambda_0} = \frac{1}{32}.$$

$$\Delta t = \frac{\lambda_0}{32(\eta - 1)} \approx \frac{0.03\lambda_0}{\eta - 1} \quad — (1)$$

For the tolerance of η we can write $\Delta\eta t = \frac{\lambda_0}{32}$

$$\Delta\eta = \frac{\lambda_0}{32t} = \frac{1}{32(t/\lambda_0)} = \frac{1}{32\, t_\lambda} \quad — (2)$$

Here $t_\lambda = \frac{t}{\lambda_0}$

thickness in freespace/air.

Divide (2) by η.

$$\frac{\Delta\eta}{\eta} = \frac{0.03}{\eta t_\lambda} = \frac{3}{\eta t_\lambda}\ \%.$$

In case of E plane metal plate ; the path length may be effected by the thickness of lens and spacing b/w lens plates (b).

i.e., the thickness tolerance is given by:

$$\cancel{\frac{\Delta t}{\lambda_d}} / \cancel{\frac{\Delta t}{\lambda_0}} \neq \cancel{\frac{1}{32}}.$$

$$\Delta t = \frac{0.03\,\lambda_0}{1-\eta}.$$

→ For the tolerance of the spacing b/w lines is given by

$$\frac{\Delta b}{b} = \frac{3\eta}{(1-\eta^2)t_\lambda}\ \%$$

★ Advantages of lens antenna :-

→ To reduce the weight of lens antenna.
→ Due to the feed point there is no effect.

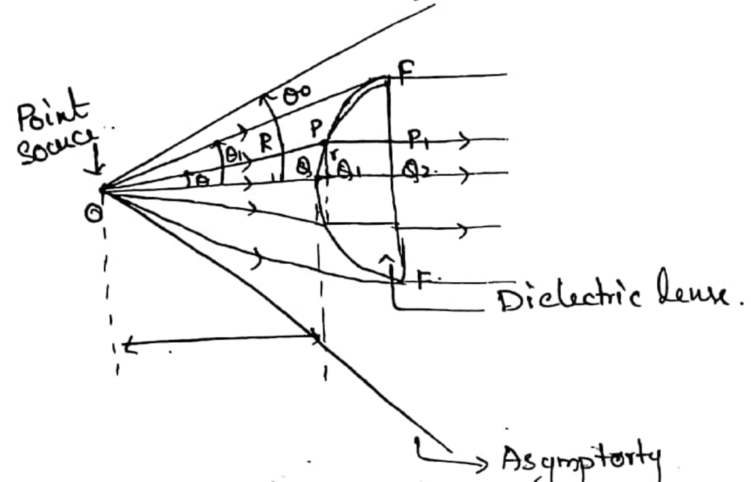
★ Disadvantages :-

→ Designing of lens antenna is complicated
→ It is expensive.

★ Applications :-

→ They are used as microwave antennas.
→ It is used for freq above 300MHz.
→ For the larger BW requirement the unsteppe dielectric lens are used.
→ For narrow BW requirement the stepped diele lens are used.

Dielectric lenses — Principle of Equality of path length.



$OP = R$, $OQ = L$, $OPP_1 = OQQ_1Q_2$ (&), $OP = OQ_1$ } SFW → PFW → (desired direction)

→ The dielectric lens is similar to the optical lens by using ray analysis method.

→ Let us consider an isotropic point source which is placed at focal point 'O'.

→ Then isotropic pt source is acting as primary antenna it produces spherical front waves, but we require plane front wave (in desired direction)

→ To convert the spherical front wave into plane front wave, the electrical path length of all the rays must be same & equal this is called principle of equality of path length

→ Let L is the focal length

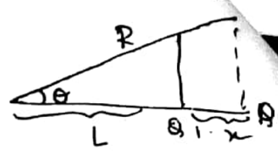
→ According to the above principle the electrical path length ~~of~~ $OPP_1 = OQQ_1Q_2$ &

$OP = OQ_1$

The pitch angle α is in b/w ...

i.e., it can be written as

$$OP = OQ + \underbrace{QQ_1}_{x}$$



$$\frac{R}{\lambda_0} = \frac{L}{\lambda_0} + \frac{(R\cos\theta - L)}{\lambda_d} \quad \text{--- (1)}$$

Here $OP = R$, λ_0 = wave length in free space

λ_d = wave length in dielectric.

$$R = L + (R\cos\theta - L)\frac{\lambda_0}{\lambda_d} \quad \text{--- (2)}$$

→ In general the refractive index η is ratio of velocity of space to velocity of dielectric.

$$\eta = \frac{C_0}{V_d} = \frac{C}{V_d}$$

$$\lambda = \frac{c}{f} \Rightarrow c = f\lambda$$

$$\eta = \frac{f\lambda_0}{f\lambda_d} = \frac{\lambda_0}{\lambda_d}$$

$$R = L + (R\cos\theta - L)(\eta)$$

$$R = L + R\eta\cos\theta - L\eta$$

$$R(1-\eta\cos\theta) = L(1-\eta)$$

$$\boxed{R = \frac{L(1-\eta)}{(1-\eta\cos\theta)}}$$

→ The above eq. represents the shape of the lens and it is like hyperbola.

22/9/17 The electric field in horizontal plane at a distance 'x' is given by $E_\phi(\theta) = k' I_1[\cos(\alpha d\cos\theta) - \cos(\alpha d\sin\theta)]$ ...

I_1 = Current in each element

k' = constant

d = dist. from driven element to the corner

→ The terminal voltage at the centre of driven element is given by.

$V_1 = I_1Z_{11} + I_1Z_{12} - I_1Z_{13} - I_1Z_{14}$.

Z_{11} – mutual impedance.

$Z_{12} = Z_{13} = Z_{14}$ = mutal impedance.

$V_1 = (Z_{11} + Z_{12} - 2Z_{14})$.

If the power P is supplied to the driven element then the power to each image is $P = I_1^2 R$,

$I_1 = \sqrt{\frac{P}{R}}$, $I_1 = \sqrt{\frac{P}{(R_{11}+R_{12}-2R_{14})}}$

from eq (1) $E\phi(\theta) = k'\sqrt{\frac{P}{R_{11}+R_{12}-2R_{14}}}\left[\cos(\alpha d\cos\theta) - \cos(\alpha d\sin\theta)\right]$ — (2)

If the reflector is removed then no image can exist i.e., $R_{12} = R_{14} = 0$ then eq (2) becomes

$E\phi(\theta)_{\lambda/2} = k'\sqrt{\frac{P}{R_{11}}}$ — (3)

→ Feild pattern consists of 4 lobes (1 is real & 3 are imaginary.

→ The gain is obtained by $E\phi(\theta)$ but at the reference of $\lambda/2$ ⇒ $G = \frac{E\phi(\theta)}{E\phi(\theta)_{\lambda/2}}$.

→ The maximum radiation occurs in the direction of in $\theta = 0°$

$G = \frac{E\phi(\theta)}{E\phi(\theta)_{\lambda/2}} = G(\theta=0) = \sqrt{\frac{R_{11}}{R_{11}+R_{12}-2R_{14}}}\left[\cos(\alpha d\cos\theta) - \cos(\alpha d\sin\theta)\right]$

★ Design eq. for square corner effect :

(i) $l = 2d$ — (1)

l = side length of reflector sheet.

d = dist. b/w feild & Vertex

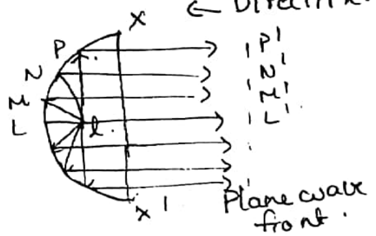
$DA = \sqrt{l^2 + l^2} = \sqrt{2}\,l = 1.41\,l$ (from eq (1))

$= 1.41 \times 2d$.

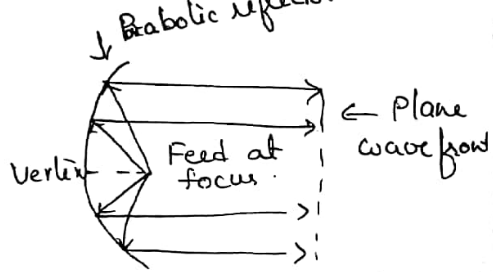
↓

Dimension of aperture.

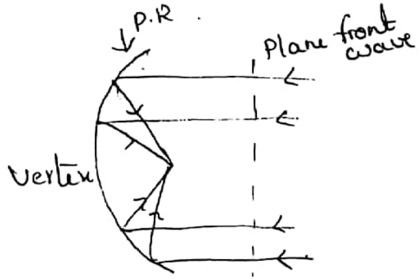
★ Parabolic Reflector :-



a) Geometry of (P-R).



b) P-R at transmitter end



c) P-R at receiver end.

Operation :-

→ To improve the overall radiation characteristic of reflector antenna, the parabolic structure is us

→ The parabola is obtained by locus of point wh moves the distance from fixed point is called focus. The dist. from st. line is called directrix which is as shown in fig. (a)

L, L' is axis of parabola.
Lf is focal length.
L is vertex
F is focus point.
x' L x is parabola
x x' – directrix
Lf / xx' – aperture of parabola.

→ When the point source is placed at focal point then the rays reflected by the parabolic reflector & it forms the parallel wavefront or plane wave front which is as shown in fig (b)

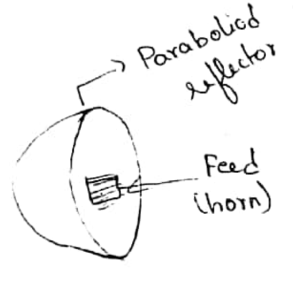
→ This principle is treated as transmitting mode of parabolic reflector.

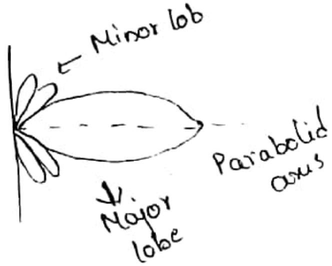
→ Similarly when the beam of parallel rays are incident on a parabolic reflector is called an aperture

→ All the rays are inphase.

→ The power gain of parabolide is a function of ratio b/w diameter of aperture (i.e., d/λ)

Paraboloid:-





OP = OQ

→ The parabolide is 3-D structure and obtained by rotating the parabola around axis that is called parabolide reflector or Dish antenna

→ When the point source is placed at focus then the wave are incident on reflector & then reflected back & it forms plane front waves from the spherical front waves.

→ The radiation pattern of paraboloid is as shown above.

→ The radiation pattern consists of very sharp major lobe (pencile shaped) & small minor lobes

→ The primary antenna (field) is a non directional antenna (isotropic antenna)

→ The performance of parabolid reflector depends on the radiation characteristics of primary antenna & field point & its sides.

→ Consider the power gain of parabolide with circular mouth or aperture wrt dipole i.e., gain of the parabolide is $\boxed{\frac{4\pi A_0}{\lambda^2} = G_p}$

where A_0 = captured area
$= k \cdot A$ → actual area
(k → const)

$k = 0.65$ for halfwave dipole.

$$G_p = \frac{4\pi k \cdot A}{\lambda^2} = 6\left(\frac{d}{\lambda}\right)^2$$

$$\left(\because A = \pi\left(\frac{d}{2}\right)^2\right)$$

23/9/17

$$G_p = 6\left(\frac{d}{\lambda}\right)^2$$

The maximum power gain of paraboliod depends on the ratio of diameter of the parabolid to the wavelength & appertue ratio.

If the field antenna is isotropic then the parabolic produces beam of radiation.

Assume that a large circular appertue then the 1st null beam width $FNBW = \frac{140\lambda}{d}^{\circ}$. d - diameter of paraboloid.

If appertue is rectangular then $FNBW = \frac{115\lambda}{L}$.

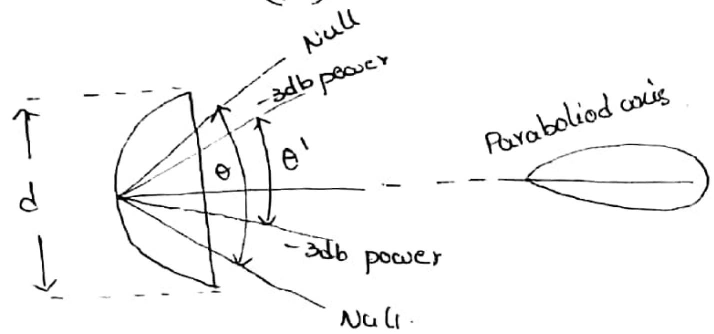
L - length of rectangular appertue.

HPBW for circular appertue is $\frac{58\lambda}{d}$

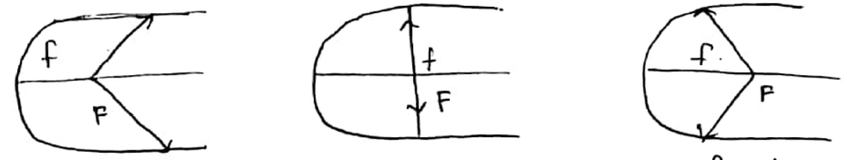
The directivity $D_{cir} = \frac{4\pi A_e}{\lambda^2}$

$$A_e = \pi\left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$$

$$D_{cir} = 9.87\left(\frac{d}{\lambda}\right)^2$$



f/d, Spill over, Back lobe



$f < \frac{d}{4}$ (a) $f = \frac{d}{4}$ (b) $f > \frac{d}{4}$ (c)

f → focal length
F → focal point.

In parabolic reflector, the ratio of f to d is important parameter while designing Parabolic refle

The paraboloid can be designed to obtain pencil shaped radiation beam by keeping d fixed and changing the focal length 'f'.

(i) focal point inside the appertue of paraboloid
(ii) focal pt. along the plane of one mouth of parab
(iii) focal pt. beyond the open mouth of parabola.

When f is very small the focal point lies insi the open mouth of paraboliod as shown in a

When f lies on the plane of open mouth of paraboliod by the geometry, the f is onefourth of diameter d and this condition gives the max gai pencil shaped radiation as shown in b

When f is too large the focal point lies be the one mouth of paraboliod as shown in c and in this case to get the radiation pattern i difficult.

Practically, some of the rays are not fully captured [by] the reflector, such non captured rays forms the spill over.

In addition to spill over few radiations are orginated from the primary radiators and which [are] added to desired parallel beam. this is called b[ack] lobe radiation.

★ Types of paraboliod reflectors :-

→ Truncated paraboliod.

→ Parabolic right cylinder.

→ Pill box / cheese antenna.

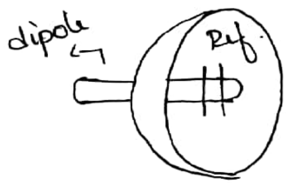
★ Feed system for parabolic reflectors :-

In this case the feed is acted as primary reflector & primary antenna

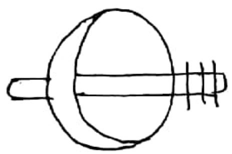
The feed radiator is placed at focal pt. the[y] is classified as 3 types

→ Dipole with plane reflector.

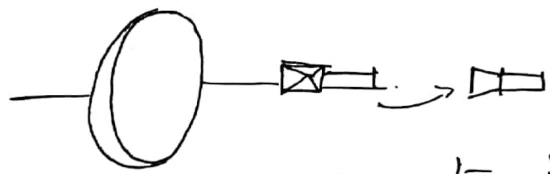
→



→ Endfire array of dipole.

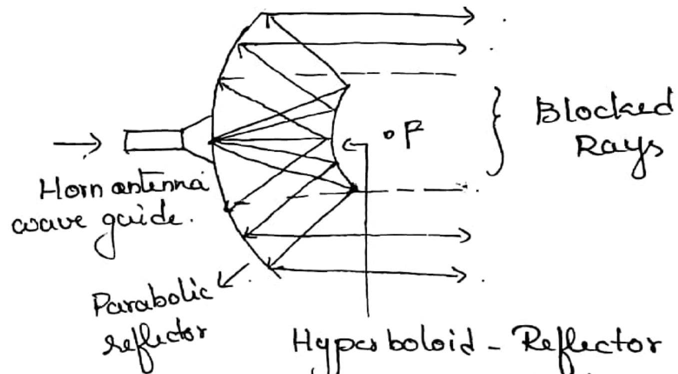


→ Horn antenna with wave guide.



The most widely used feed system is horn antenna with wave guide. This horn antennas are feed points of (i) Cassegrain feed system (ii) Offset feed system.

★ Cassegrain feed system :-



The feed system is diff in Cassegrain feed system than others

In general the feed point is located at the focus but in this case the feed radiator is placed at vertex of parabolic reflector.

This system uses hyperboloid reflector & sub reflector as shown in above fig.

the pitch angle ...

; The feed radiator uses a horn antenna and it at the sub reflector

The geometry of cassegrain is as shown above. When the feed radiator & horn antenna radiates towards the cassegrain, it radiates all the radiations towards the parabolic reflector and this rays are collimated.

advantages :-

→ It reduces the minor lobe radiations.

→ The system has ability to place a feed at convenient place.

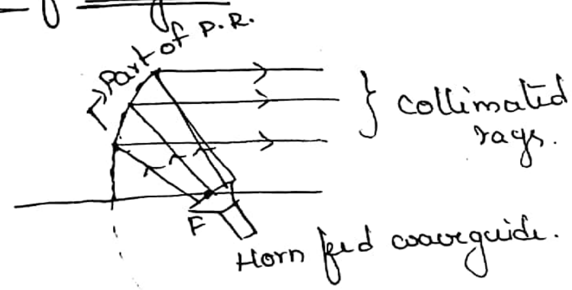
→ In this case the beam can be broadened & extracted by adjusting the reflector surfaces.

Disadvantages :-

→ Large parabola is expensive.

→ There is a region of block rays infront of Cassegrain reflector (for large dimensions of P.R it is not effective)

★ **Offset feed system :-**



To avoid the effect of blocked rays the offset feed system is used which is as shown above. Here feed is placed at focus.

With this system all the rays are properly collimated without formation of the region of blocked rays.

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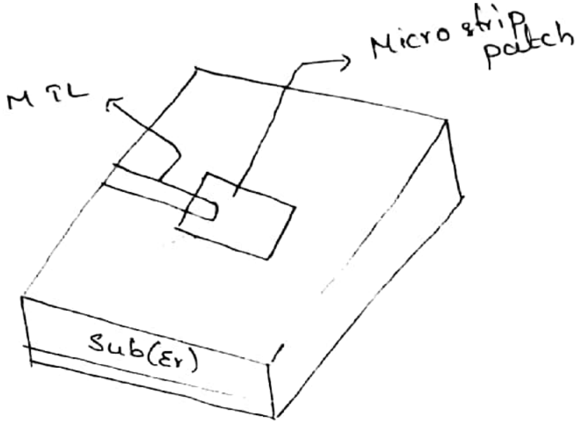
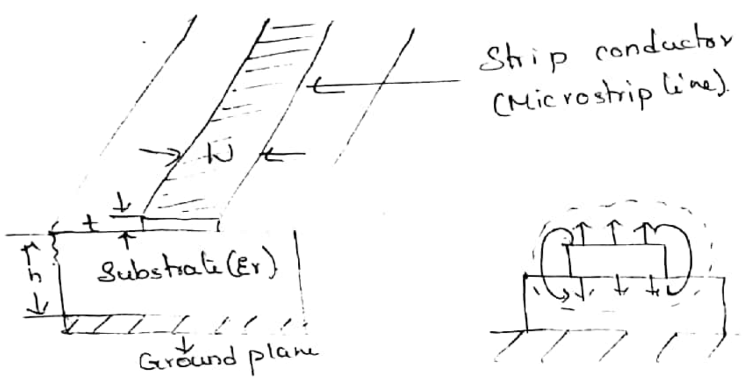
Unit-IV – Microstrip Transmission Lines, Microstrip Antennas & Antenna Measurements.

★ Microstrip transmission line :-





Transmission Line :- A device used to transfer the energy from one point to another point efficiently.

Need :-

→ Easy to fabricate

→ Simple to matching by controlling the feed position

→ low spurious radiation.

→ It can be easily placed on the substrate layer.

→ It has more flexibility and compactness than the coaxial line.

→ It is one type of planar transmission line.

→ A micro stripe line consists of single ground plane, open strip conductor (feed line) seperated by dielectric substrate as shown in above fig.

→ It has feed lines in b/w strip conductor and ground plane

→ It is operated under Quasi TEM mode

→ while designing, we consider only basic valid formulas for calculating the phase velocity (v_p), characteristic impedance (Z_0), effective dielectric constant (ε_{eff}) and losses of the lines

→ phase velocity is defined as $v_p = \frac{c}{\sqrt{\varepsilon_{eff}}}$

→ Because of the fringing, the ε_{eff} is less than the relative permitivity (ε_r) (or) greater than 1,

$$1 < \varepsilon_{eff} < \varepsilon_r$$

the pitch angu ...

→ The ϵ_{eff} is dependent on h & w

→ effective Dielectric constant is defined as

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{(\epsilon_r - 1)}{2} \frac{1}{\sqrt{1 + 12\left(\frac{h}{w}\right)}}$$

→ The characteristic impedance of microstrip transmission line is given by.

$$Z_0 = \begin{cases} \frac{60}{\sqrt{\epsilon_{eff}}} \ln\left(\frac{8h}{w} + \frac{w}{h}\right), & \text{for } \frac{w}{h} \le 1. \\ \frac{120\pi}{\sqrt{\epsilon_{eff}}\left[\frac{w}{h} + 1.393 + 0.667 \ln\left[\frac{w}{h} + 1.444\right]\right]}, & \text{for } \frac{w}{h} > 1 \end{cases}$$

$$\frac{w}{h} = \begin{cases} \frac{8e^{A}}{e^{2A} - 2}, & \text{for } \frac{w}{h} < 2. \\ \frac{2}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\epsilon_r - 1}{2\epsilon_r}\left[\ln(B-1) + 0.39 - \frac{0.61}{\epsilon_r}\right]\right\} & \text{for } \frac{w}{h} \ge 2 \end{cases}$$

→ Z_0 is low for wide strip and high for narrow strip width of the strip is inversely proportional to Z_0

→ For design purpose, if ϵ_r and Z_0 are known then the ratio of w and h can be calculated

→

$$A = \frac{Z_0}{60}\sqrt{\frac{\epsilon_r - 1}{2}} + \frac{\epsilon_r - 1}{\epsilon_r + 1}\left(0.23 + \frac{0.11}{\epsilon_r}\right); \quad B = \frac{60\pi^2}{Z_0\sqrt{\epsilon_r}}$$

Losses:-

→ The attenuation due to conduction loss is

$$\alpha_c \approx \frac{8.686 R_s}{w Z_0}.$$

→ The attenuation due to dielectric loss is

$$\alpha_d \approx \frac{27.3(\epsilon_{eff} - 1)\epsilon_r}{(\epsilon_r - 1)\epsilon_{eff}} \frac{\tan\theta}{\lambda}$$

$$\alpha = \alpha_c + \alpha_d.$$

→ Quality factor is given by (Q)

$$\frac{1}{Q_t} = \underbrace{\frac{1}{Q_{rad}}}_{\text{due to rad}} + \underbrace{\frac{1}{Q_c}}_{\text{due to conductor}} + \underbrace{\frac{1}{Q_d}}_{\text{due to dielectric}} + \underbrace{\frac{1}{Q_{sw}}}_{\text{due to surface w}}$$

★ **Microstrip Antenna / patch antenna characteri**

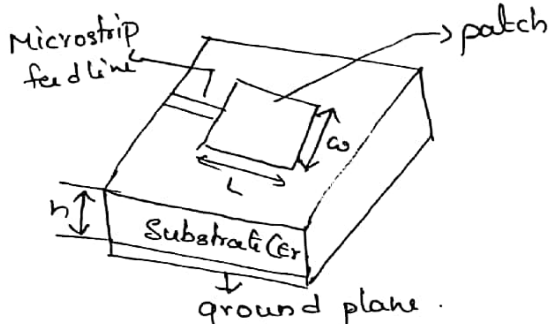
→ The microstrip (MPA) patch antennas are ve popular in recent year.

→ The microstrip antennas are also called a patch antennas (or) printed antennas

→ It consists of very thin metal strip.

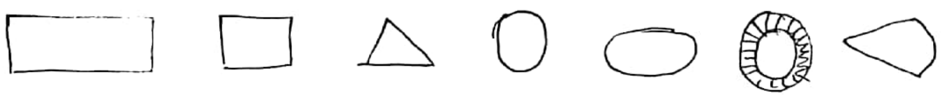
→ The microstrip antenna is placed over a substrate with the ground plane which is shown below

→ Microstrip conductor is normally copper or gold.



→ The lower conductor functions as ground plane.

→ The upper conductor is simply patched with various structure i.e., rectangular, square, triangle, circular, elliptical, ring sector and ring which are shown below



→ Investigation of microstrip antenna started in 1970's by Robert and it is further extended as printed antennas with various materials as substrate.

→ Out of these structures of patch, the rectangular square and triangle are most used because of easy fabrication.

→ The radiation pattern can be easily analysed

→ It occupies less space.

→ To achieve more directivity, the array of patch are used.

→ The wave radiated by microstrip patch antenna is linearly polarized wave.

Advantages:-

→ Microstrip antenna are low profile antennas small in size, light volume, less volume, compact planar structure.

→ It is mechanically robust.

→ It is versatile.

→ Fabrication of microstrip is easy.

→ It is directly placed on surface of the aircraft and missiles and it is used to generate variety of patterns and polarizations.

Disadvantages:-

→ It has very narrow BW.

→ Low gain.

→ Low power handling capability.

→ Poor endfire radiations.

→ Large in size at VHF and UHF.

Applications:-

→ MPA are used in satellite communication RADAR and space communication.

→ Biomedical applications

→ Remote sensing and navigation.

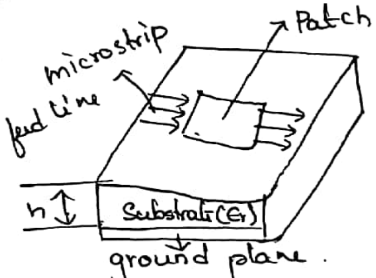
→ Military.

→ Commercial like WLAN, mobile N/w's, YMAX GPS.

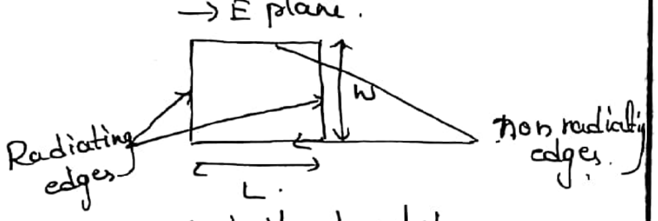
→ Most commonly used MPA is rectangular MP

The pitch angle

→ The rectangular microstrip antenna with ground plane and the substrate is shown ~~above~~ below.



Layout of RMPA



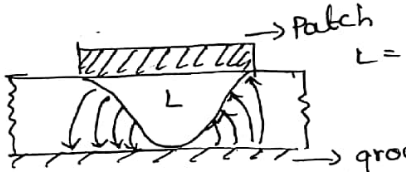
Details of patch.

→ Dimension of L is always greater than width of the patch

→ Edges with L dimension causes resonance at its half wavelength freq.

→ At the end of 'w' dimension. there are no radiating edges (very less radiation)

→ When the patch length 'L' is equal to the half of wavelength then electric field produced below the edges of 'L' dimension and which are opposite polarity as shown below.



→ The field lines are normal to the substrate.

→ Both side lines which are in same direction in same phase are added together.

→ The radiation intensity goes on decreasing as fields move away from the edge and the phases also changes (out of phase) and they cancel each other.

→ For effective radiation of the microstrip antenna

(i) The structure has to be length of the patch is half of the wavelength.

(ii) The substrate with low dielectric constant.

(iii) The height of substrate should be limited to a fraction of wavelength.

→ Let us consider a rectangular microstrip patch antenna fed by microstrip line which is as shown in above figure.

→ The effective dielectric constant is $\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left(1+12\frac{h}{w}\right)^{-1/2}$ — (1)

ϵ_r - Dielectric constant

h - height of substrate

w - width of patch.

→ The center frequency of operation of antenna is approx. given by $f_r = \frac{c}{2L\sqrt{\epsilon_r}}$; $c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$.

f_r - resonant freq.

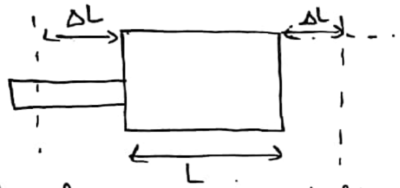
L - length of patch

→ To obtain the frequency of operation of the pa[tch] accurately we should consider width of the patch c[...]

→ The width of patch controls the impedance mat[ching] and radiation pattern.

→ If width increases i/p impedance decreases

→ To obtain the effective radiation of the patch the patch length is extended by ΔL on each side i.e.,



The practical approx. relation of the above fig. is

$$\frac{\Delta L}{h} = 0.412 \frac{(\varepsilon_{eff} + 0.3)\left(\frac{\omega}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{\omega}{h} + 0.81\right)} \quad — (2)$$

→ For the effective radiation the length becomes L_{eff}, and dielectric constant becomes ε_{eff}.

$$L_{eff} = L + 2\Delta L$$

$$\therefore f_r = \frac{c}{2(L+2\Delta L)(\sqrt{\varepsilon_{eff}})}$$

★ **Design procedure :-**

It gives the practical designing of rectangular microstrip antenna.

Specification of ε_r, f_r, h :-

Determine the width and length of patch

(1) For an efficient radiator the width ω leads the good radiation efficiency i.e., $\omega = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$

(2) Determine the effective dielectric constant from (1)

(3) Once width of ω is found determine the extended length of ΔL from (2)

(4) Determine the length $L = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L$.

$f \rightarrow \frac{c}{2L\sqrt{\varepsilon_r}}$, $L = \frac{c}{2f_r\sqrt{\varepsilon_r}}$.

Radiation pattern of microstrip antenna :-

The expression of E field component E_θ & E_ϕ are given by.

$$E_\theta = \frac{\sin[(\beta\omega \sin\theta \sin\phi)/2]}{[(\beta\omega \sin\theta \sin\phi)/2]} \cos\left[\left(\frac{\beta L}{2}\right)\sin\theta\cos\phi\right]\cos\phi$$

$$E_\phi = -\frac{\sin[(\beta\omega \sin\theta \sin\phi)/2]}{[(\beta\omega \sin\theta \sin\phi)/2]} \cos\left[\left(\frac{\beta L}{2}\right)\sin\theta\cos\phi\right]\sin\phi$$

θ & ϕ are elevation and azimuthal angle of radiation pattern. Here $\beta = \frac{2\pi}{\lambda}$

Resultant electric field at any point $E(\theta,\phi) = \sqrt{E_\theta^2 + E_\phi^2}$

Normalized radiation pattern for $L = \omega = \frac{\lambda}{2}$. $\phi = 0°$ & $\phi = 90°$ planes are shown in fig (a) fig (b) resp.

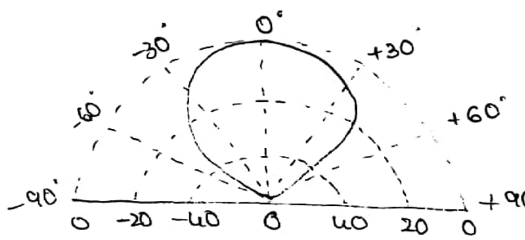


fig. Radiation pattern at $\phi = 0°$

the pitch angle ...

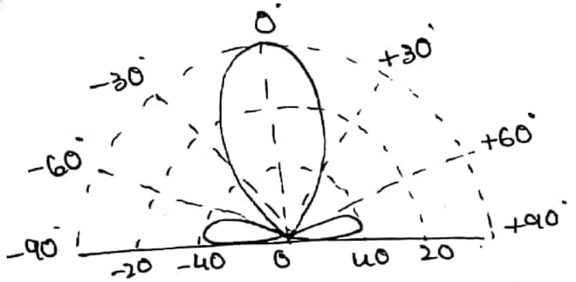


fig. radiation pattern at $\phi = 90'$

Ex. Design a rectangular microstrip antenna using a substrate (RT duroid 5880) with dielectric constant of $\epsilon_r = 2.2$, high of substrate $h = 0.1588$ cm, so as to resonate at freq 10 GHz. Find the w & L.

$$w = \frac{c}{2 f_r} \sqrt{\frac{2}{\epsilon_r + 1}}$$

$$= \frac{3 \times 10^{10}}{2 \times (10 \times 10^9)} \sqrt{\frac{2}{2.2+1}}$$

$$= 1.186 \text{ cm}$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{-1/2}$$

$$= \frac{2.2+1}{2} + \frac{2.2-1}{2}\left(1 + 12\left(\frac{0.1588}{1.186}\right)\right)^{-1/2}$$

$$\epsilon_{eff} = 1.972$$

→ The extended length of patch ΔL

$$\Delta L = 0.1588(0.412) \frac{(1.972 + 0.3)\left(\frac{1.18}{0.158} + 0.26\right)}{(1.972 - 0.258)\left(\frac{1.18}{0.15} + 0.8\right)}$$

$$= 0.081 \text{ cm}$$

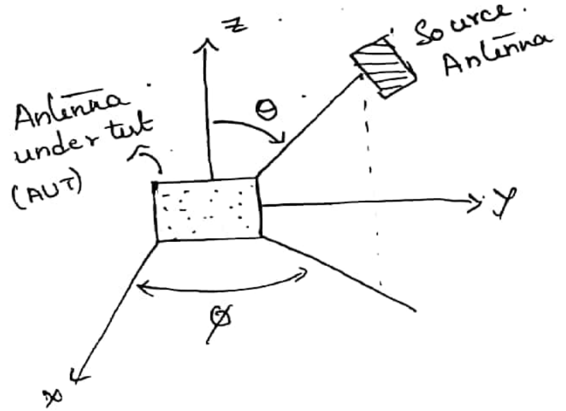
The actual length $L = \frac{c}{2 f_r \sqrt{\epsilon_{eff}}} - 2\Delta L$

$$= 0.906 \text{ cm}$$

Finally $L_{eff} = L + 2\Delta L = 1.068$ cm

7/10/17

Antenna measurements :-



→ Basic Concept.
→ procedure
→ Reciprocity
→ Near & far field.
→ Coordinate s/m.
→ Source of errors.

* **Radiation pattern measurement**

1. Calculate the width and length of the microstrip line for a 50 Ω characteristic impedance at a 90° phase shift at 2.5 GHz. The ~~surface~~ substrate thickness $h = 0.127\,cm$ with $\epsilon_r = 2.2$

$$\frac{w}{h} = \frac{2}{\pi}\left\{ - \right\} \qquad \frac{w}{h} \geq 2$$

$$= 3.081.$$

$$w = 3.081h.$$

$$\beta l = 90^\circ$$

$$\beta_0 \sqrt{\epsilon_{eff}}\, l = 90^\circ$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{-1/2}$$

$$\beta_0 = \frac{2\pi}{\lambda}, \quad \lambda = \frac{c}{f}.$$

$$\frac{2\pi}{\lambda}\sqrt{\epsilon_{eff}}\, l = \pi/2.$$

$$l = \_\_\_\_ = 2.19\,cm$$