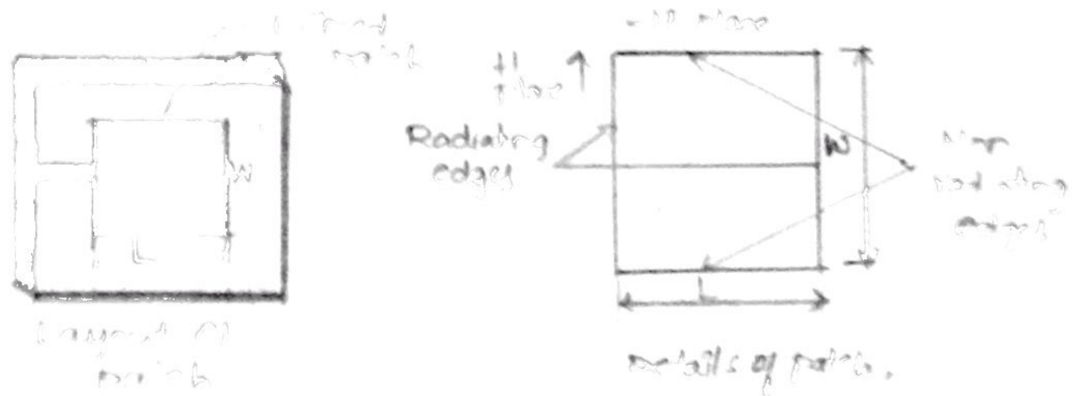
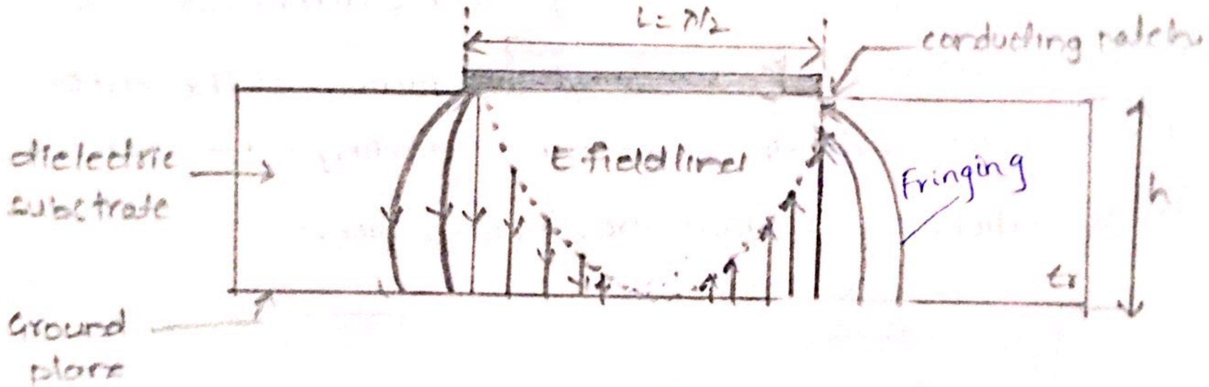
1) Explain about radiation from a rectangular patch antenna

The most commonly used microstrip antenna is rectangular microstrip antenna. Such a rectangular MSA with a ground plane and dielectric is shown in fig

The dimension L (i.e. length) of a patch is always greater than dimension W of a patch. The edges with L dimensions causes resonance at its half wavelength frequency. At the end of W-dimension; then there are non-radiating edge with very less radiation which give cross polarization.



When the patch length is half of wave length (i.e., $L = \lambda/2$); the electric field produced below the edges of L-dimensions are of opposite polarity. These E-field lines emerge out and propagated in a direction normal to the substrate. Thus both the slide's lines are in same direction. As the fields are in same phase both get added together. The radiation intensity goes on decreasing as fields move away from the edges and simultaneously two fields change phase also. At two angles particularly the fields called fringing fields are exactly out of phase and cancel each other. Hence the radiation intensity of the MSA depends on the direction of viewing.



For effective radiation of the microstrip antenna:

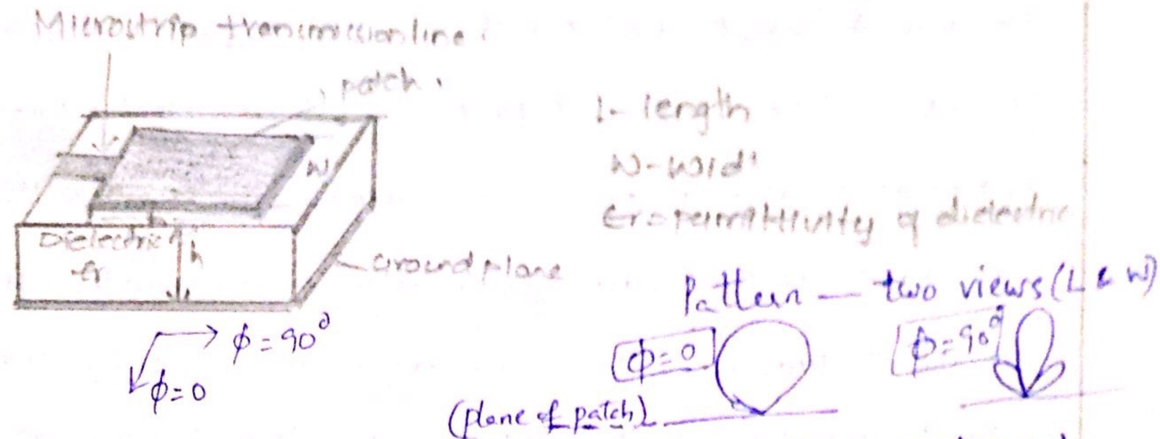
(i) The structure has to be half wavelength resonator ($L = \lambda/2$)

(ii) The dielectric substrate should be sufficiently thicker and with low dielectric constant.

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

let us consider a rectangular microstrip antenna fed by a microstrip antenna transmission line as shown in the fig.

The fringing effect increases the length of path effectively by ΔL on either sides



The critical or centre frequency of operation of an antenna is approximately given by.

$$f_c \cong \frac{c}{2L\sqrt{\epsilon_r}} \quad \text{where } c = \text{velocity of light} = \frac{1}{\sqrt{\epsilon_0 \mu_0}}$$

$$f_c = \frac{1}{2L\sqrt{(\epsilon_0 \epsilon_r)\mu_0}} \quad -①$$

To obtain frequency of operation of a patch antenna accurately we should consider dimension W also. So the expression for the frequency of operation of patch antenna considering L and W is given by.

$$f_{r,nm} = \frac{c}{2\sqrt{\epsilon_{reff}}}\left[\left\{\frac{n}{L+2\Delta L}\right\}^2 + \left\{\frac{m}{W+2\Delta W}\right\}^2\right]^{1/2} \quad -②$$

For a dominant mode (with $n=1, m=0$) the frequency of operation expression reduces to simply

$$f_{r,nm} = \frac{c}{2(L+2\Delta L)\sqrt{\epsilon_{reff}}} \quad -③$$

The width w of the patch is very important parameter as it controls the input impedance of an antenna. For a typical square shape patch antenna (L = W) the input impedance is typically 300 Ω. When the width is increased, the input impedance decreases. The width not only controls the input impedance but also controls the radiation pattern of a patch antenna.

2. What are the advantages and limitations of microstrip antenna?

The special class of antennas that are becoming more popular in recent years is microstrip antenna. The microstrip antenna is also called as patch antenna or printed antenna or microstrip patch antenna. The microstrip antenna is generally preferred where thickness and conformability to the surface are the main requirements. As the MSA are directly printed onto the circuit boards in the modern era of mobile phone market there is no other best option than microstrip antennas.

Advantages of Microstrip Antenna (MSA's).

The important advantages of the microstrip antenna are as follows:

1) The microstrip antennas are the low profile antennas. They

are of smaller size, light weight antennas which occupy very less volume.

2) They are easily conformable to non planar surface. They can be easily bolted or laminated to the metallic surface such as an aircraft, missile or automotive as they are designed to operate from the ground plane on the back of a printed circuit board.

3) As the fabrication process involved in manufacturing the microstrip antenna is simple the complete production process is easy and very cheap. Due to low cost advantage, mass production of the MSA is easily achievable using modern advanced printing circuit technologies.

4) By mounting the MSA on a rigid surface, we get mechanically robust antenna.

5) The MSA is the most suitable option where thickness and conformability to the surface of a platform are the main requirements.

6) The main advantage of MSA is that it is possible to have dual (or) tripple frequency operations.

Limitations of Microstrip Antenna :-

As compared with the conventional antennas, the microstrip antennas have following limitations.

(i) The MSAs low gain and low efficiency antennas.

(ii) The MSAs have narrow bandwidth of operation. Moreover they have lower power handling capacity.

(iii) The size of microstrip antenna is inversely proportional to frequency, they can be used only for very high frequencies only. Because for low frequencies, the size of MSA is impractical.

(iv) Increasing bandwidth by using any suitable method increases the complexity of design of the MSA.

v) The MSAs are poor end fire radiators.

Besides these limitations, the MSAs are most widely used in many applications such as aircraft, spacecrafts, mobile radio communication devices because of many important characteristics and advantages.

Write down the design equations of MSA (rectangular)

Ans: $$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

$$\frac{\Delta L}{h} = 0.412\,\frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

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

$$f_r = \frac{1}{2\sqrt{\mu_0 \epsilon_0}\,(L + 2\Delta L)\sqrt{\epsilon_{reff}}}$$

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ECE-I
15261A0426

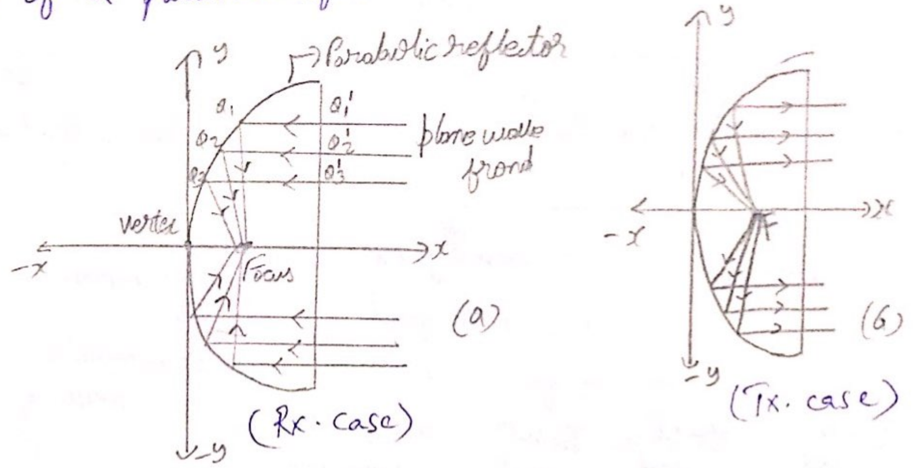
AWP Assignment

7. Give the geometry and principle of operation of parabolic reflector antenna. What is the significance of f/d ratio in parabolic reflector antennas?

A. To improve the overall radiation characteristics of the reflector antenna, the parabolic structure is oftenly used.

Parabolic reflectors are used at microwave frequencies between 300 - 3000 MHZ.

Geometry of a parabolic reflector :-



$$FQ_1 + Q_1Q_1' = FQ_2 + Q_2Q_2' = FQ_3 + Q_3Q_3' = K \text{ (constant)}$$

when the point source is placed at focus (or) focal point, then the rays reflected by parabolic reflector from parallel wave front shown in fig (b) This principle used in transmitting antenna

when parallel rays are incident on a parabolic reflector, then the radiations focus at focal point. This principle is used in receiving antenna.

f/d ratio:- The ratio of focal length to dish diameter is referred as f/d ratio. The f/d ratio considered by the antenna designer also calculate depths of the dish. The f/d ratio lies between 0.25 and 0.5

A high f/d ratio will have a shallow contour and for low f/d ratio it represents a deep bowl.

8. What are the various feeding methods of MSA?

A. Microstrip antenna have a variety of feed methods and they are classified as -

Feed methods
- Contacting feeds
  - microstrip feed
    - Centre feed
    - offset feed
    - Inset feed
    - Quarter waveline feed.
  - coaxial probe (or) probe feed
- Non-contacting feeds
  - Aperture coupling (or) electromagnetic coupling
  - Proximity coupling (or) Indirect feed

1) Contacting feed:- The patch is directly fed with RF Power using connecting element such as microstripline

A) microstrip feed:- The feed line is directly connected to edge of a patch on substrate. The width of feed is very less than the patch. This method provides planar structure and thus same substrate can be used for etching of feed line.

i) Centre feed:- The microstrip line is etched exactly at the centre of of the patch at the edge of patch.

ii) offset feed:- The microstrip line is not at centre of patch but at general near to the corner of patch.

iii) Inset feed:- To reduce the increase in Input Impedance of antenna, the line extends inside the patch by appropriate distance from edge so, the proper impedance matching is done.

(v) Quarter-wave line feed:- In this the transmission line Impedance is match with the antenna Impedance with help of quarter wave section of line with characteristic Impedance Z_1.

$$Z_{in} = Z_0 = Z_1^2 / Z_a$$

B. Coaxial feed:- ~~This uses an electromagnetic coupling between a patch and a microstrip line~~ - the inner conductor of coaxial cable is soldered to the microstrip patch by drilling hole in it leaving connector protruding outside substrate.

2. Non-Contacting feed method:- In this RF power is fed with help of electro magnetic coupling between the feed line and Radiating Path.

a) Aperture coupled feed:- The feed line is placed between two dielectric substrates and antenna patch is inserted at top substrate.

The coupling aperture transmits energy to the antenna and provides low cross polarization as it is placed under Patch. The amount of coupling depends on shape, size & location of aperture.

b) Proximity Coupled method:- Same as inset feed method, but the difference is, the probe feed is trimmed down in such a way that it does not come in contact with the patch and it is stopped first before the patch antenna.

Structural diagram is required in each case!

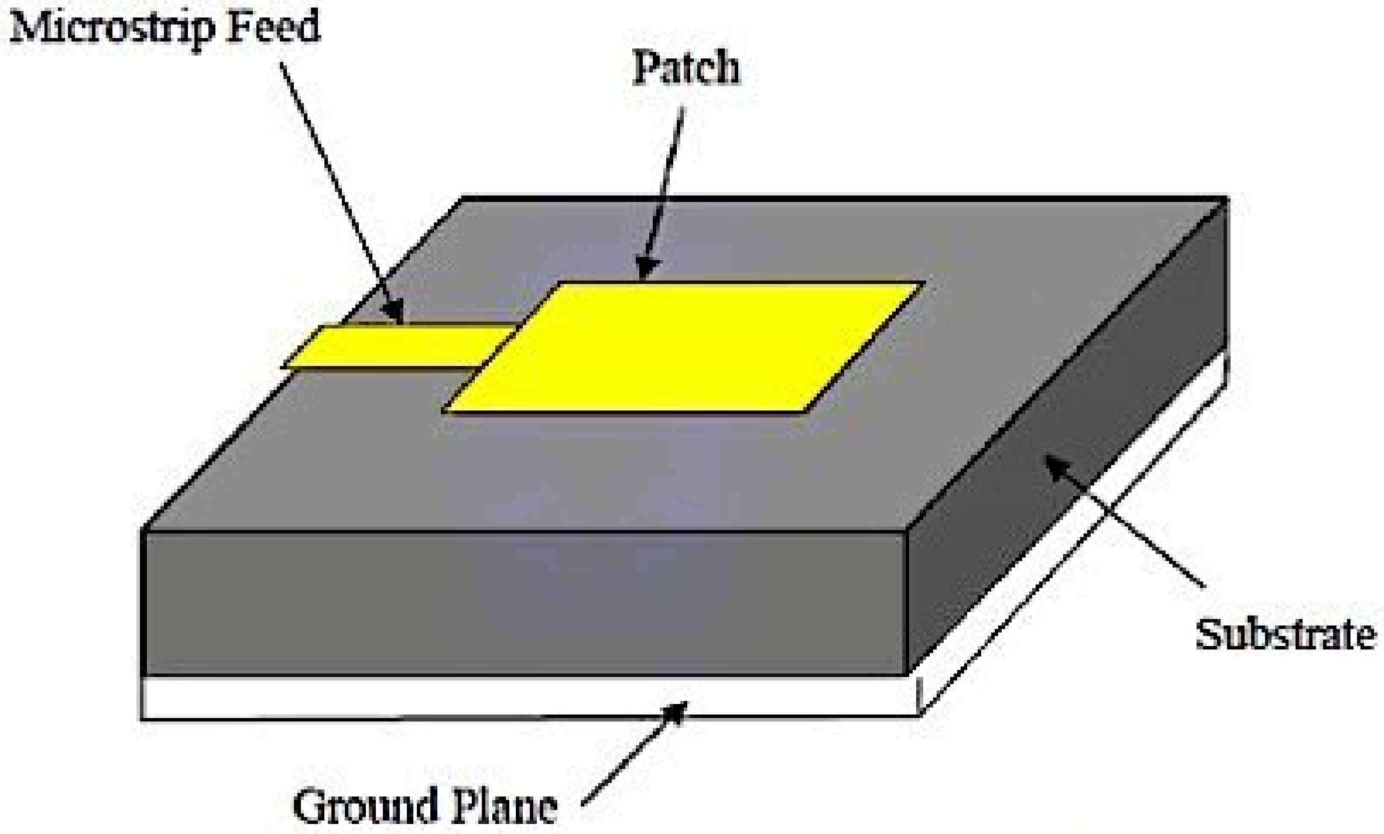
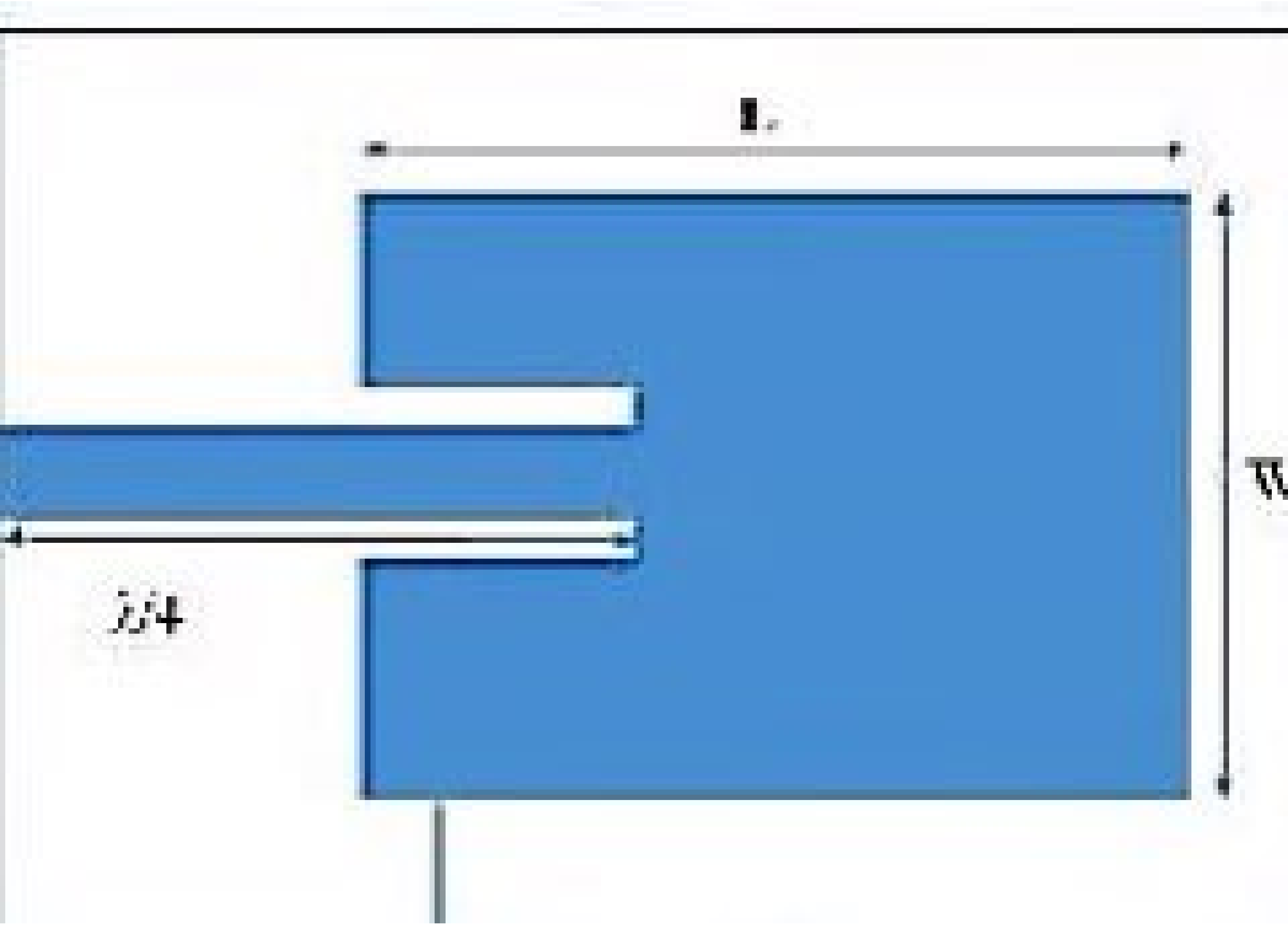
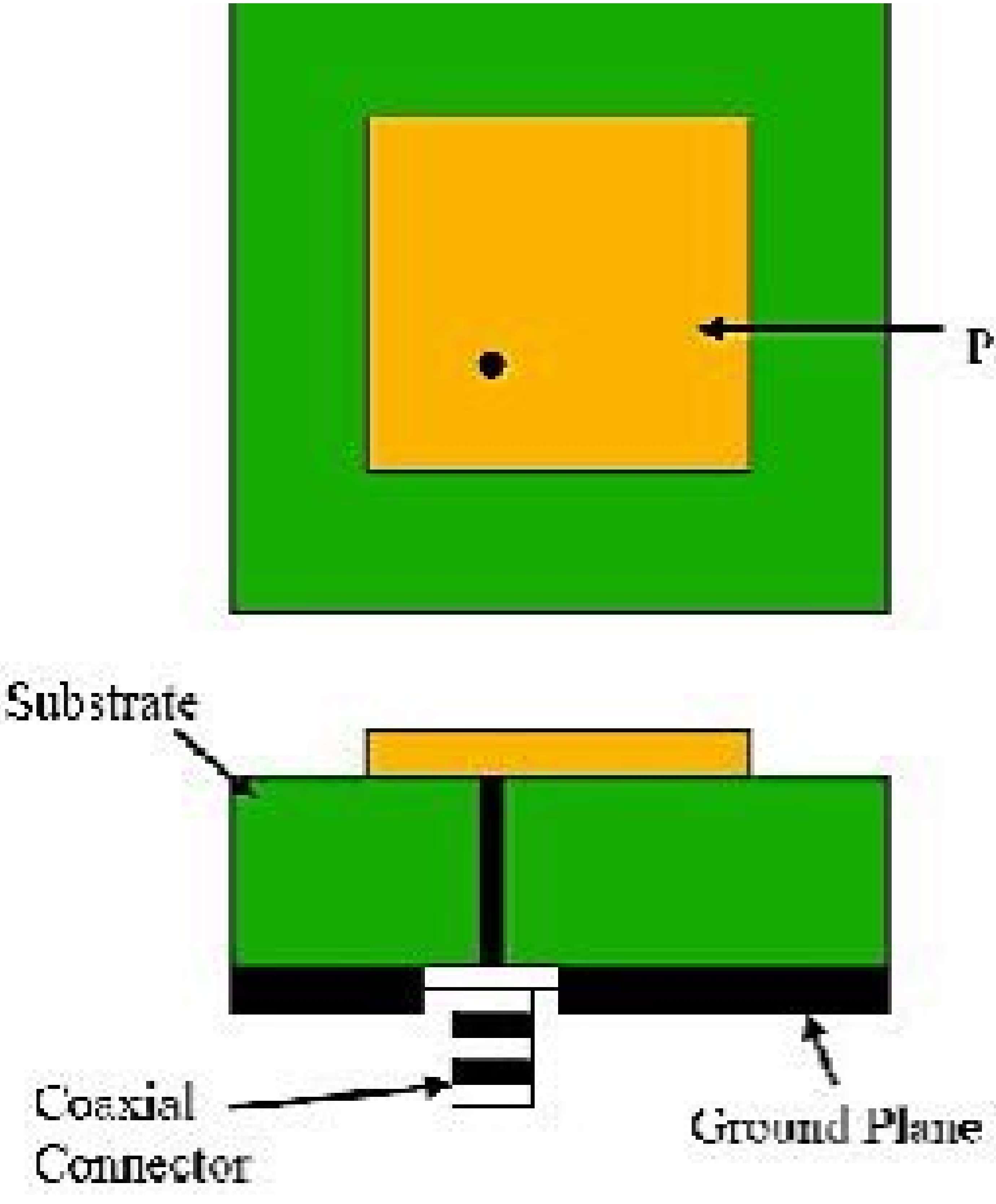
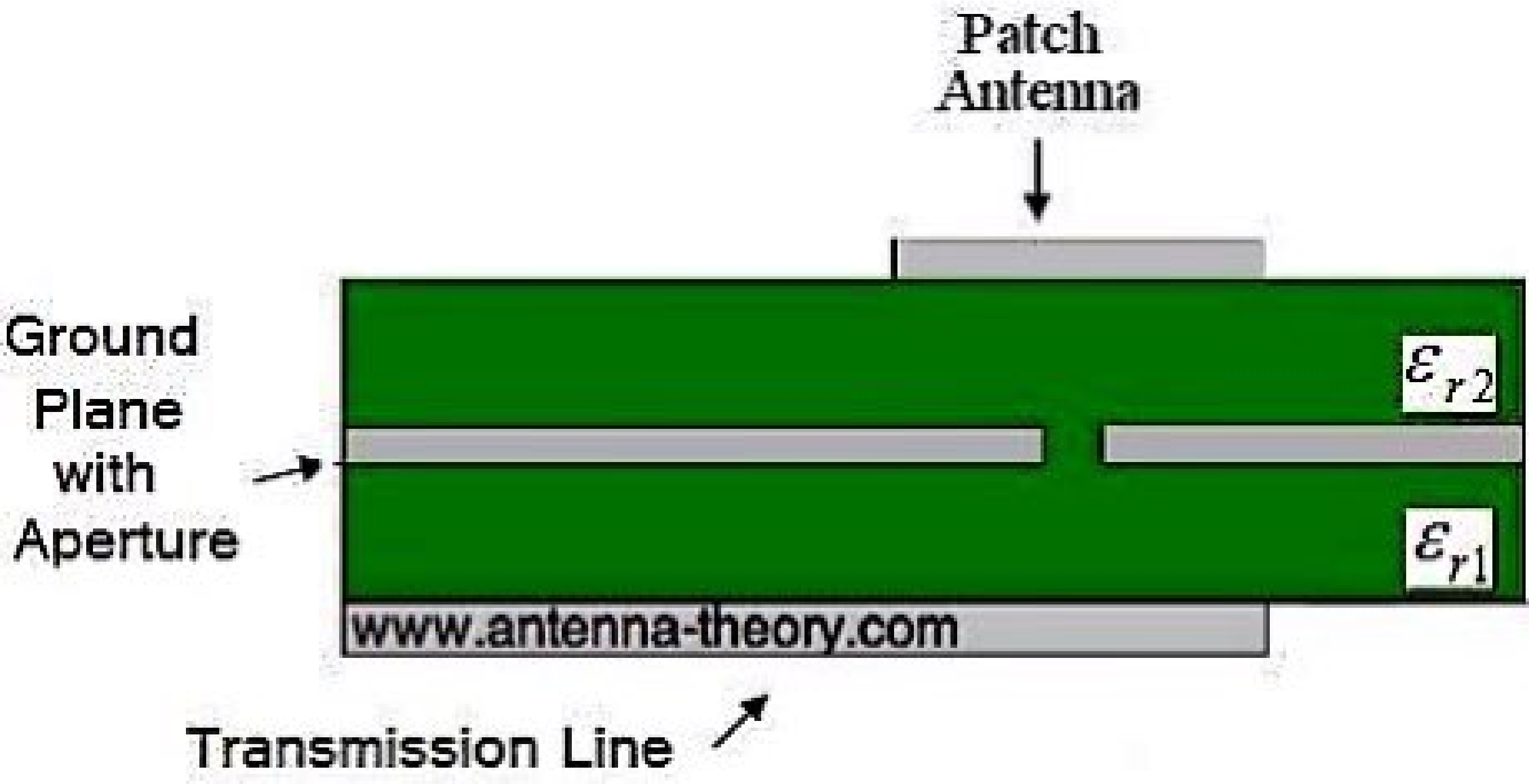


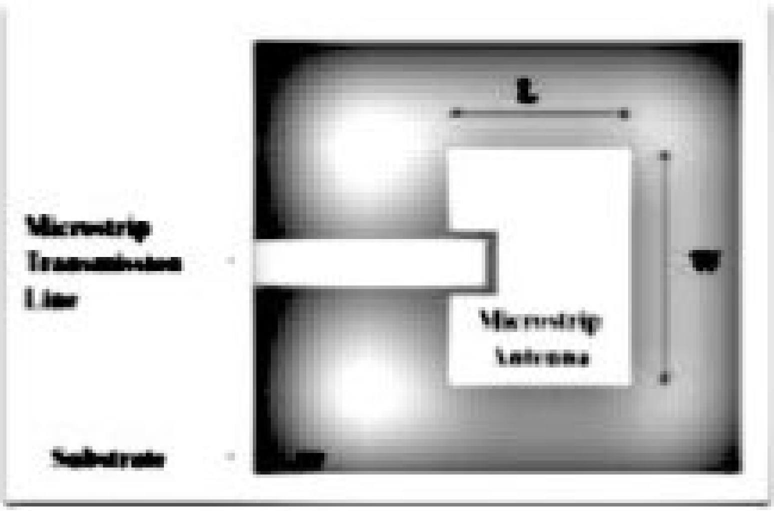
Figure 1: Micro strip Line Feed/Edge fed.

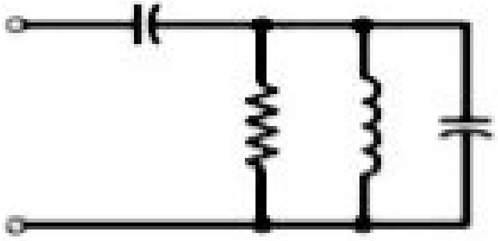

L
W
λ/4


Patch
Substrate
Coaxial
Connector
Ground Plane


Patch
Antenna
Ground
Plane
with
Aperture
ε_{r2}
ε_{r1}
www.antenna-theory.com
Transmission Line

Proximity Coupled Feed





Equivalent circuits

Comparing the different feed techniques :-

Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with impedance matching)	2-5%	2-5%	2-5%	13%

9. Design a parabolic reflector antenna require to give a gain of 33dB operate at 4GHZ. find corresponding half power beam width?

A. Given, gain = 33dB

$f = 4 GHZ = 4 \times 10^9 Hz$

$G_{P(dB)} = 10 \log_{10}(G_P)$

$\Rightarrow 33 = 10 \log_{10} G_P$

$\Rightarrow G_P = 1995.2623$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{4 \times 10^9}$

$\Rightarrow \lambda = 0.075m$

$G_P = \frac{0.065 \pi^2 d^2}{\lambda^2}$

$\Rightarrow d^2 = \frac{\lambda^2 G_P}{0.065 \pi^2} = 17.512$

$\Rightarrow d = 4.184 m$

$\Rightarrow$ The paraboloid reflector is of 4.184 m diameter

$FNBW = \frac{140\lambda}{d} = \frac{140 \times 0.075}{4.184}$

$\Rightarrow FNBW = 2.509°$

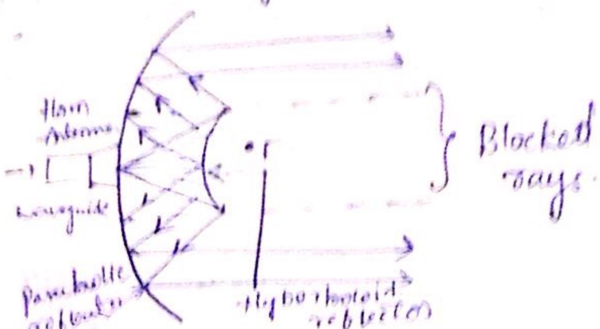
$HPBW = \frac{58\lambda}{d} = \frac{58 \times 0.075}{4.184}$

$\Rightarrow HPBW = 1.0396°$

(Q) 10 Discuss the Various feeding methods used in parabolic Reflector Antennas.

Various feeding Methods used in parabolic Reflector Antenna is.

1) Cassegrain Feed System
2) Offset Feed System.



1) Cassegrain Feed System :-

This System of feeding paraboloid reflector is named after a mathematician prof. Cassegrain. This System is different than the systems we discussed earlier. In all the feed systems discussed earlier, the feed is located at the focus. But in Cassegrain feed System, the feed radiator is placed at the Vertex of the parabolic reflector, instead of placing it at the focus. This System uses a hyperboloid reflector placed such that its one of the foci Coincides with the focus of the parabolic reflector. this Hyperboloid reflector is called Cassegrain Secondary reflector or Sub-reflector. The primary Radiator or feed radiator used is generally of a horn antenna. It aims at the Sub-reflector Then the parabolic reflector Collimates all the radiations as previous feed system

Advantages of Cassegrain Feed system:-

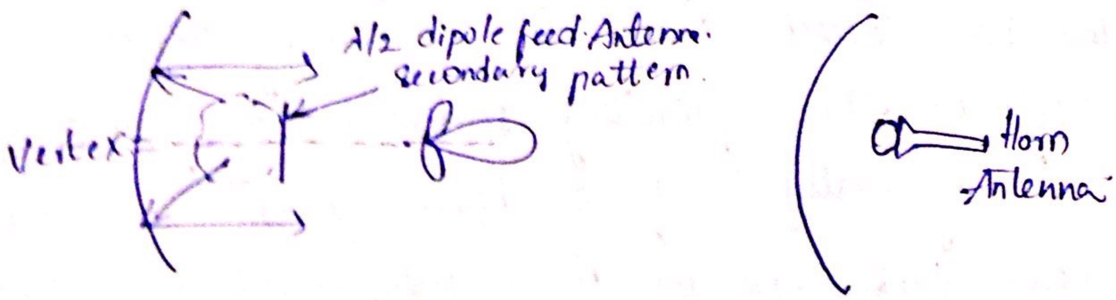
1) It Reduces the Spill over & thus minor lobe Radiations
2) The System has ability to place a feed at Convenient place.
3) using this system, beam Can be broadened by adjusting one of the Reflector Surfaces.

Disadvantages

→ Some of the radiation from the parabolic reflector are Obstracted & blocked by the hyperboloid reflector Creating region of blocked Arrays.
→ Small Dimension parabolic reflector it is the main drawback of the Cassegrain feed system.

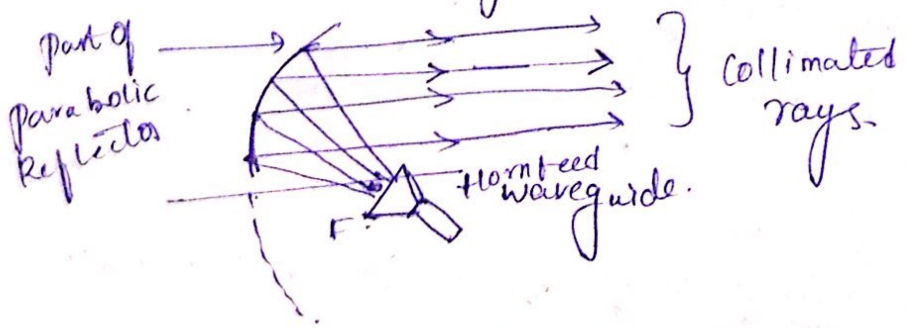
Offset Feed Systems:-

By suitably selecting primary Antenna, Correct directional pattern for any arrangement Can be Obtained. The Paraboloidal reflector Can be fed using λ/2 Antenna with a small Ground plane or a horn Antenna as shown in fig.



Parabolic Reflector with offset feed.

In both cases reflected wave from paraboloidal ref-
-lector causes mismatching and interaction at
primary Antenna. Also the primary Antenna blocks
central portion of the aperture which p'es.
minor lobe effectively. To overcome the Aperture
blocking effect due to the dependence of the
secondary reflector dimension on the distance between
feed & Sub- Reflector, the offset feed system as
Show in fig



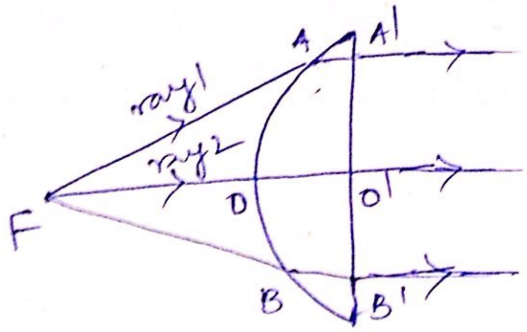
Here feed radiator is placed at the focus as
shown in fig. with this system all the rays
are properly collimated without formation of
the region of blocked rays.

(Q) 11 Explain fermat's principle? What is the principle of operation of a delay lens Antenna?

Fermat's principle:-

(A) In optics, fermat's principle or the principle of least time, named after french mathematician pierre de fermat, is the principle that the path taken between two points by a ray of light is the path that can be transversed in the least time. This principle is sometimes taken as the definition of a ray of light.

A delay lens is one in which electrical path length is ~~decreased~~ increased by the lens medium and the wave is decelerated.



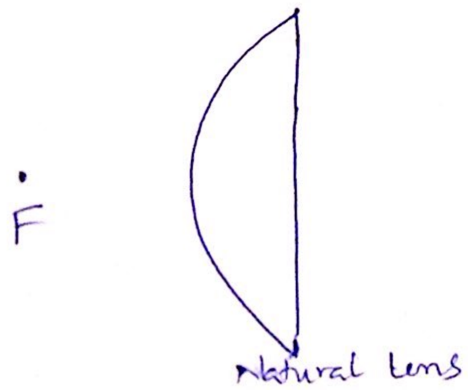
Collimation

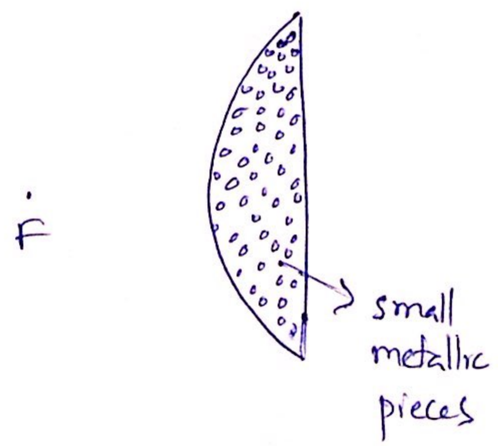
Ray 1, in the diagram, which travels longer distance in air must be given less deceleration. So we cut the lens in a way that it spends lesser time inside. Ray 2 travels least distance in air. So it must spend most time inside the lens for getting maximum deceleration.

Q12. Distinguish between Natural & Artifical dielectric lens Antenna?

(A)

Natural	Artifical.
1) Natural dielectric lenses have More weight	1) Artifical dielectric lenses have less weight
2) Natural dielectric lenses are made up of molecular Particles	2) Artifical dielectric lenses are made up of discrete metal particles
3) It Does not have any Resonant effect	3) It have Resonant effect.
4) lens action done at microscopic level	4) done at macroscopic level





13. What is a fast lens? What are the different types of fast lenses?

A. A fast lens antenna is the antenna in which electrical path length is decreased by the lens medium and the wave is accelerated.

Example. is E-plane metal plate lenses.

H-plane metal plate lens

Types of fast lenses -

~~① Dielectric lens antenna~~

② Metal plate lens antenna.

14. What is meant by zoning? What are their advantages?

A. Lens, antennas are suitable for frequencies above 3000 MHz. If the frequency is less than 3000 MHz, lens antennas have more thickness. The thickness of lens antennas can be reduced with the help of zoning.

Thickness (t) is given by $\boxed{t = \frac{\lambda}{\mu - 1}}$ where t = Thickness

λ = Free space wavelength

μ = Refractive index $= \left(\frac{c}{v}\right)$

Zoning is classified into two types

(i) Curved surface zoning

(ii) Plane surface zoning

a) Curved Surface Zoning -

1. In curved surface zoning stepping or zoning is done to the curved surface of lens antenna.
2. Thickness of curved surface zoned lens is $t = \frac{\lambda}{\mu - 1}$
3. Curved surface zoned lens is mechanically stronger than the plane surface zoned lens,
4. Curved surface zoning lens antennas have less weight and less power dissipation.

b) Plane Surface Zoning

1. In plane surface zoning stepping or zoning is plane surface
2. Thickness of plane surface zoned lens is, $t = \frac{\lambda}{\mu - 1}$
3. Plane surface zoned lens is less strong.
4. Here the power dissipation is more.

- Curved surface zoning is preferable compared to the plane surface zoning.

Advantages of Zoning

1. This process reduces the weight of lens considerably.
2. The zoned dielectric lens antenna ensures that signals are in phase after emergence, despite difference in appearance.
3. The zoned lens is having less power dissipation.

Disadvantages

The zoned lens antennas are frequency sensitive i.e, they are dependent on wavelength λ.

15. Write about tolerences applicable in lens antennas.

A. In general, in dielectric lens antenna, the path length differences are caused because of,

(i) Deviations in thickness from the ideal contour,

(ii) Variations in the index of refraction

Let us assume that maximum allowable variations in both the parameters to be $\frac{\lambda_0}{32}$ rms. Then the thickness tolerance is given by,

$$\frac{\Delta t}{\lambda_d} = \frac{\Delta t}{\lambda_0} = \frac{1}{32}$$

But, n = Index of refraction = $\frac{\lambda_0}{\lambda d}$

$$\therefore \frac{\Delta t}{(\lambda_0/n)} - \frac{\Delta t}{\lambda_0} = \frac{1}{32}$$

$$\frac{n\Delta t}{\lambda_0} - \frac{\Delta t}{\lambda_0} = \frac{1}{32}$$

$$\boxed{\Delta t = \frac{\lambda_0}{32(n-1)} \cong \frac{0.03\lambda_0}{n-1}} \quad \text{—— (1)}$$

Thus for $n = 1.5$,

$$\Delta t = 0.06\lambda_0$$

Now for the tolerance of n, we can write,

$$\Delta n t = \frac{\lambda_0}{32}$$

i.e. $$\Delta n = \frac{\lambda_0}{32t} = \frac{1}{32\left(\frac{t}{\lambda}\right)} = \frac{1}{32 t_\lambda} = \frac{0.03}{t_\lambda} \quad \text{—— (2)}$$

where $t_\lambda = \frac{t}{\lambda}$ = Thickness of lens in free space wavelength λ_0.

Dividing equation (2) by n, we get,

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

In case of E-plane metal plate lens, the path length may be affected by the thickness of lens and spacing 'b' between lens plate. So again assuming maximum allowable variation of $\frac{\lambda_0}{32}$, the thickness tolerance is given by,

$$\boxed{\Delta t = \frac{\lambda_0}{32(1-n)} = \frac{0.03\lambda_0}{1-n}}$$

then for the tolerance on the spacing b between plates is given by.

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

As compared to large reflector antenna, for the lens antenna, relatively large amount of warping or twisting is tolerated. As the thickness tolerance of a lens is with reference to the thickness of the lens, it not necessary to the contour of lens should be maintained to this accuracy which is the most important advantage of such antennas.