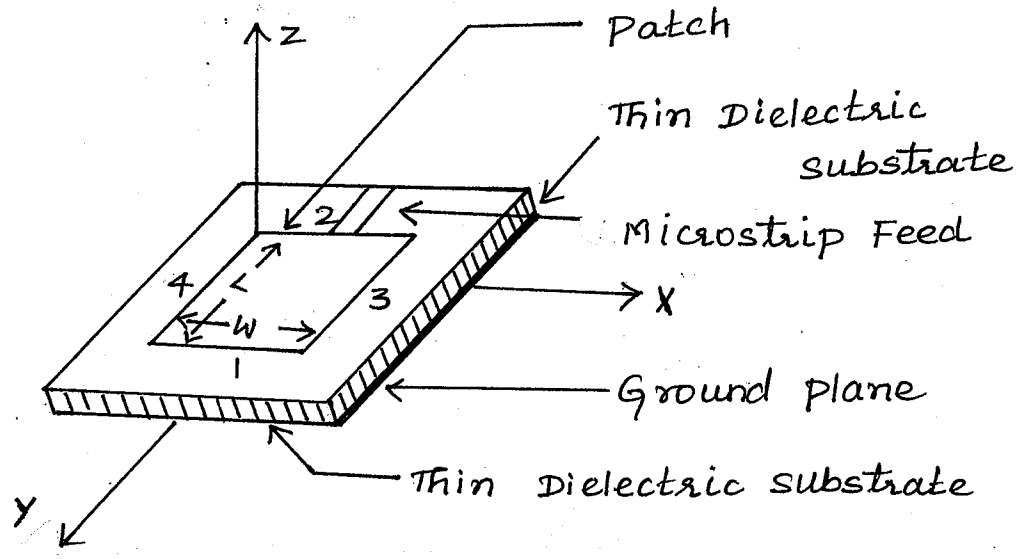
Microstrip Patch Antenna : (MSA)

* Microstrip antenna is also called as patch antenna or microstrip patch antenna or printed antenna.

* Microstrip antenna is directly printed on circuit board.

* There are different types of microstrip antennas but all types have common features.

1. Thin flat metallic region called Patch
2. Dielectric substrate
3. Ground Plane, Larger than Patch
4. Feed Network, supplies power to Antenna Network.



* A microstrip antenna consists a sandwich of 2 Parallel conducting layers separated by a single dielectric substrate as shown in above fig.

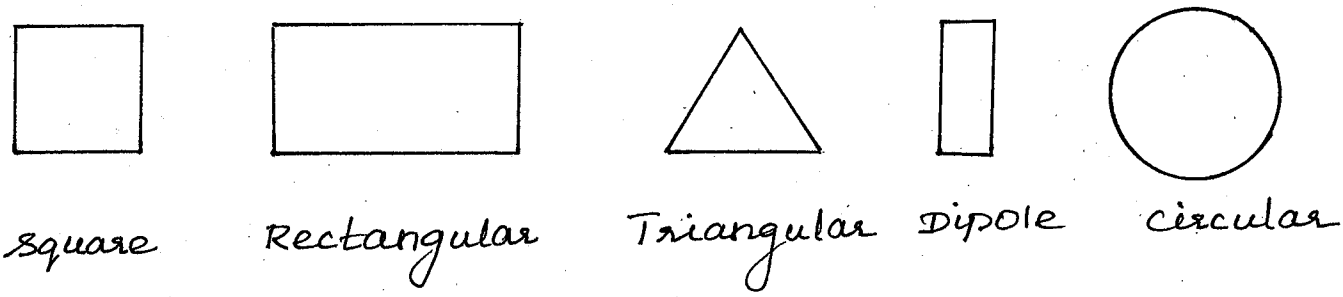
* The patch conductors are normally of copper coated with gold. The lower conductor functions as a

ground plane and the upper conductor may be a simple patch of any desired shape.

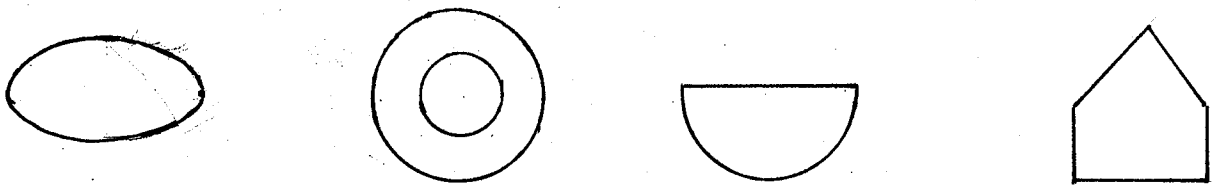
* The patch of microstrip antenna is of any continuous shape like square, rectangular, circular, triangular, hexagonal etc.

* out of these shapes, square, rectangular, dipole and circular are the most commonly used shapes for the patch because of ease in fabrication.

* The dielectric constant of the substrate should be low ($\epsilon_r \simeq 2.5$) in order to enhance the fringing fields which are responsible for most of the radiations from the patch.



Square Rectangular Triangular Dipole circular



Elliptical circular ring semidisk pentagon

Advantages :

1. compact planar structure
2. Low volume
3. Low weight
4. Low fabrication cost
5. Multiple polarisation is possible with simple changes in feed position.
6. can be easily bolted or Laminated to the metallic surface such as aircraft, missile or automotives.
7. Capable of dual and triple frequency Operation.

Disadvantages :-

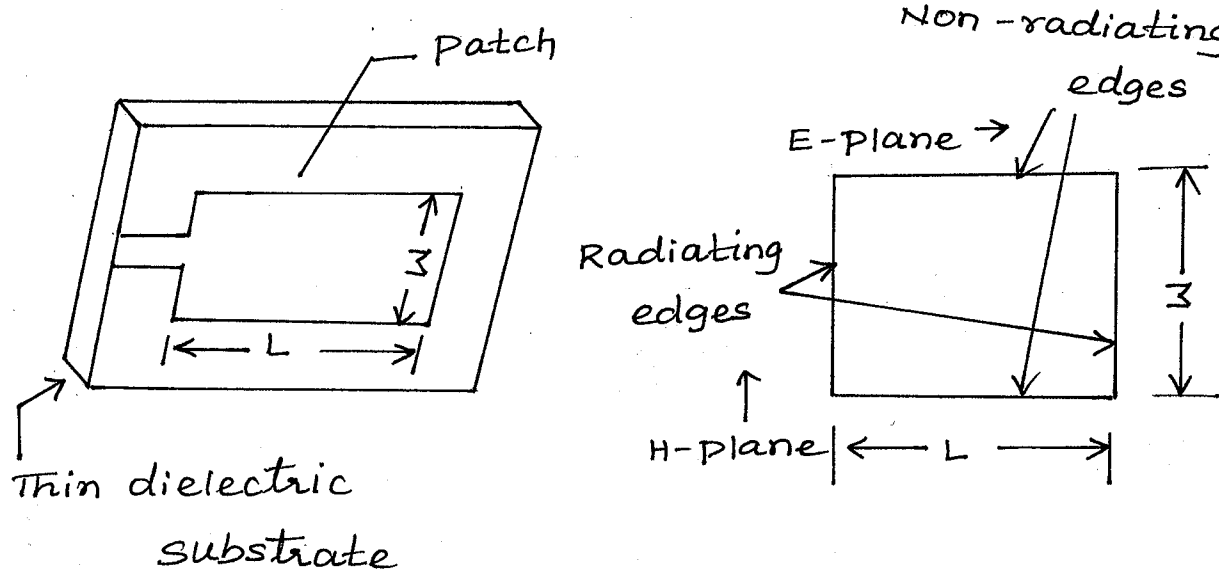
1. Very narrow Bandwidth
2. Low gain due to high loss
3. Radiation is half space only
4. Low Efficiency
5. poor end fire radiation
6. Low power handling capability
7. Bandwidth improves with substrate thickness

Applications :-

1. satellite and space communication.
2. Radar and altimeters
3. High speed space vehicles
4. Tanks and missile Telemetry
5. Feed element for complex antennas.

Mechanism of Radiation :

* The most commonly used microstrip antenna is rectangular microstrip antenna. such a rectangular microstrip antenna with a ground plane and dielectric is shown in figure below.

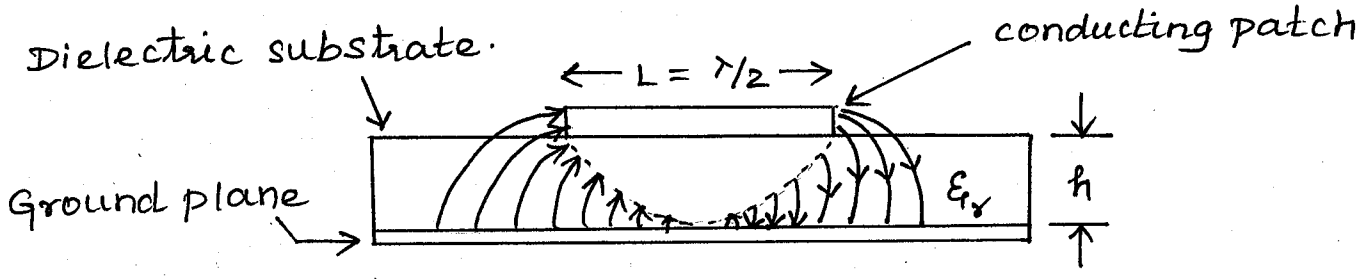


* The length of the patch is always greater than width of the patch. The edges with 'L' dimension causes resonance at its half wavelength frequency.

* The edges of L-dimension are radiating edges and the ends of W-dimension are non-radiating edges.

* The substrate thickness is 'h' and its permittivity is 'ε'. since the height of the substrate (h) is very small as compared to wavelength, there will be no field variation with z.

* When the patch length is half of wavelength ($L = \lambda/2$) the electric field produced below the edges of L-dimension are of opposite polarity as shown in fig below.



* The E-field lines emerge out and propagates in a direction normal to the substrate. Thus both the side lines are in same direction. As the fields are in same phase, both gets added together.

* The radiation intensity goes on decreasing as fields move away from edges and simultaneously 2 fields change phase also.

* For effective radiation of the microstrip antenna,

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

2. The dielectric substrate should be sufficiently thicker and with low dielectric constant.

3. The height of the substrate should be limited to a fraction of wavelength.

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

$$f_c = \frac{c}{2L\sqrt{\varepsilon_r}} \rightarrow (1)$$

* To obtain frequency of operation of a patch antenna accurately, we should consider 'w' dimension also.

$$f_c = \frac{c}{2\sqrt{\varepsilon_r}} \sqrt{\left(\frac{m}{w}\right)^2 + \left(\frac{n}{L}\right)^2} \rightarrow (2)$$

* For dominant mode ($m=0, n=1$) the freq. of operation expression reduces to

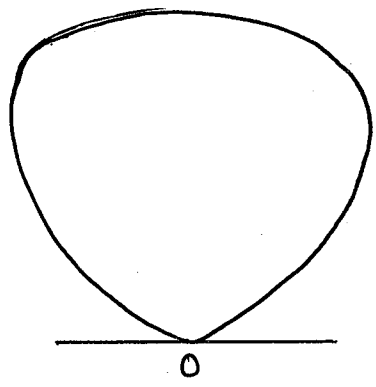
$$f_c = \frac{c}{2L\sqrt{\varepsilon_r}}$$

* The width 'w' of the patch is very important parameter as it controls the input impedance of an antenna. For a square patch antenna ($L=W$), the i/p impedance is 300 Ω.

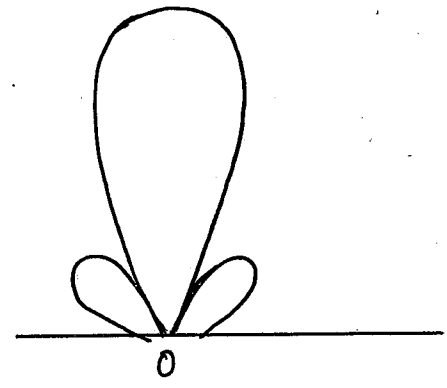
* When the width is increased the i/p impedance decreases. The width not only controls the i/p impedance but also controls the radiation pattern of a patch antenna.

Radiation Pattern of Microstrip Antenna :

The normalized radiation pattern for $L = W = \lambda/2$ in $\phi = 0°$ and $\phi = 90°$ plane are as shown below.



$\phi = 0°$



$\phi = 90°$

Parameters :-

1. Characteristic Impedance :

$$Z_0 = \frac{\eta}{n.\sqrt{\varepsilon_r}}$$

where, $n = \frac{W}{t}$; $W \rightarrow$ width, $t \rightarrow$ thickness

2. Beam Area :

Beam Area Ω_A is π sr.

$$\Omega_A = \pi$$

3. Directivity :

$$D = \frac{4\pi}{\Omega_A} \Rightarrow \frac{4\pi}{\pi} \Rightarrow 4 \text{ (or) } 6\text{dBi}$$

4. Radiation Resistance :

$$R_r = 90 \frac{\epsilon_r^2}{(\epsilon_r - 1)} \left(\frac{L}{W}\right)^2 \quad \Omega$$

5. Bandwidth :

$$BW = 3.77 \frac{(\epsilon_r - 1)}{\epsilon_r^2} \left(\frac{W}{L}\right) \left(\frac{t}{\lambda}\right)$$

6. Effective Aperture :

$$A_e = \frac{D\lambda^2}{4\pi} \Rightarrow \frac{4\lambda^2}{4\pi} = \frac{\lambda^2}{\pi}$$

7. Effective Height :

$$h_e = \sqrt{\frac{2 R_r A_e}{\eta}}$$

Feeding methods of Microstrip Antenna :-

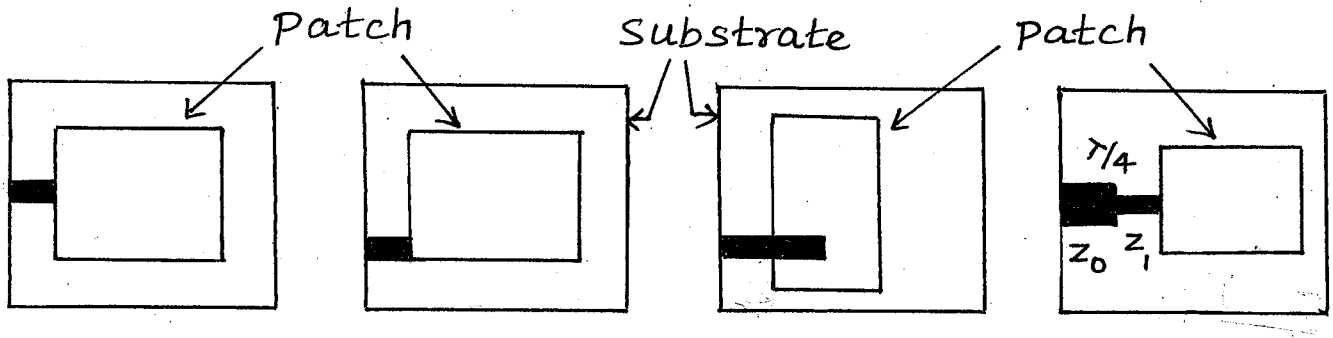
* The feeding techniques used in the microstrip antenna are divided into 2 types.

1. contacting Feed
2. Non- contacting Feed

1. contacting Feed :-

* In this method, the patch is directly fed with RF. power using the microstrip line or co-axial line.

* The most commonly used contacting feed methods are microstrip feed, co-axial feed as shown below.



centre Feed Offset Feed Inset Feed Quarter wave line Feed

a) Microstrip Feed :-

In this method, the feed line is directly connected to the edge of the patch on a substrate.

The width of the feed line is smaller compared with that of the patch.

The advantage of using microstrip feed is that the feed line can be etched directly on the same substrate.

i) centre Feed :-

The microstrip is etched exactly at the centre of the patch at the edge of patch.

ii) offset feed :-

The microstrip line is not at the centre of Patch but in general near the corner.

iii) inset Feed :-

The main drawback of feeding antenna at the centre or at the corner end is that current increases

from edge to the centre and hence the i/p impedance of antenna increases. To reduce the i/p impedance, the line extends inside the patch by appropriate distance from the edge so that proper impedance matching is done.

iv) Quarter wave line Feed :-

* In this method, the transmission line impedance is matched with the antenna impedance with the help of Quarter wave section of line with chara., Impedance Z_1'.

* It acts as a quarter wave transformer and the i/p impedance at the Quarter wave section beginning is

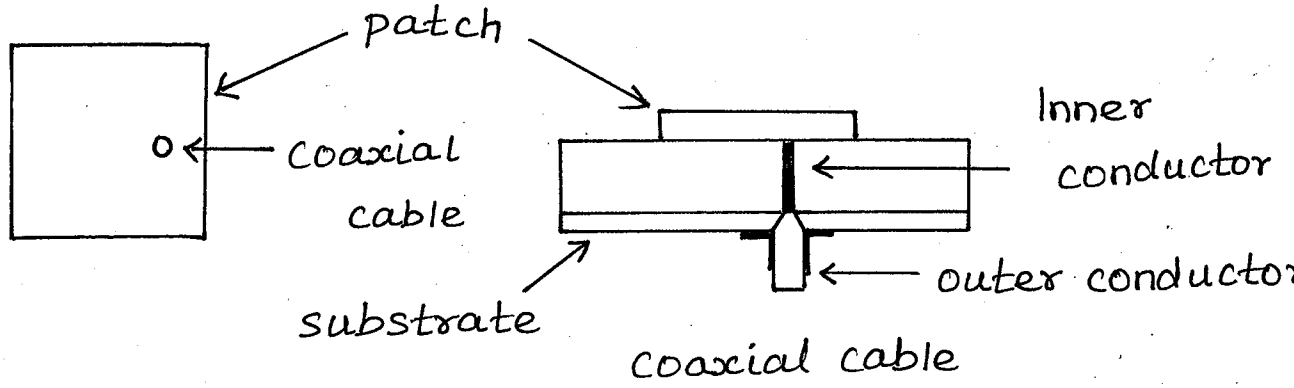
$$Z_0 = Z_1^2 / Z_A$$

b) co-axial Feed :-

* This technique is also called probe feed.

* In this method, the inner conductor is extended up to radiating patch through the substrate and it is soldered to the metallic patch. while the outer conductor is connected to the ground plane.

* For impedance matching, i/p impedance of the microstrip antenna can be adjusted by properly selecting feed position.



* The main advantage of this technique is that the co-axial feed can be placed at any location inside patch to achieve impedance matching.

* The disadvantage of this method is that the bandwidth is very narrow. Moreover a hole is to be drilled through substrate.

2) Non-contacting Feed :-

* In this method the patch is not directly fed with RF power but instead the RF power is transfered to the path from the feed line through electromagnetic coupling.

a) Aperture coupled Feed :-

* This technique uses an electromagnetic coupling between a patch and a microstrip line.

* The feed circuit is isolated from the antenna by a conducting plane with aperture or hole located

below the patch at the centre.

* The amount of coupling varies with size, shape and location of aperture. Due to the isolation of the radiating pitch and feed line, the spurious radiations are lowered.

* In general, top substrate near patch is thick and having low dielectric constant while the bottom substrate near microstrip line is thin and having greater dielectric constant.

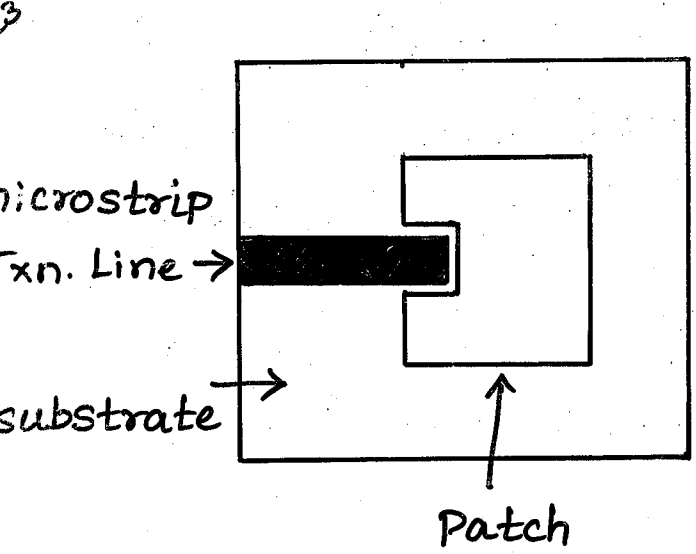
* The major disadvantage is that 2 dielectric layers need to be properly aligned during fabrication.

* Also, due to 2 substrates, the overall thickness increases.

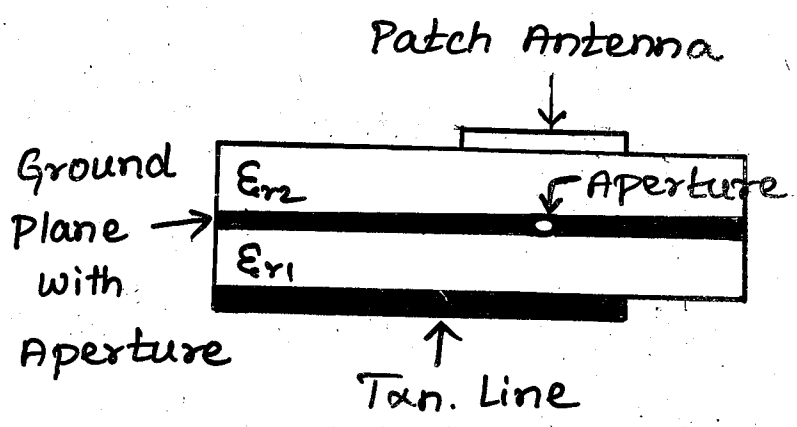
b) Proximit coupled Feed (Indirect Feed)

* In this method, a strip line is etched inside the patch but it does not touch the patch.

* The gap between microstrip line and the radiating probe provides a capacitance but it can cancel the inductance added by the increasing length of the coaxial cable in the co-axial feed method.



a) Proximit coupled feed

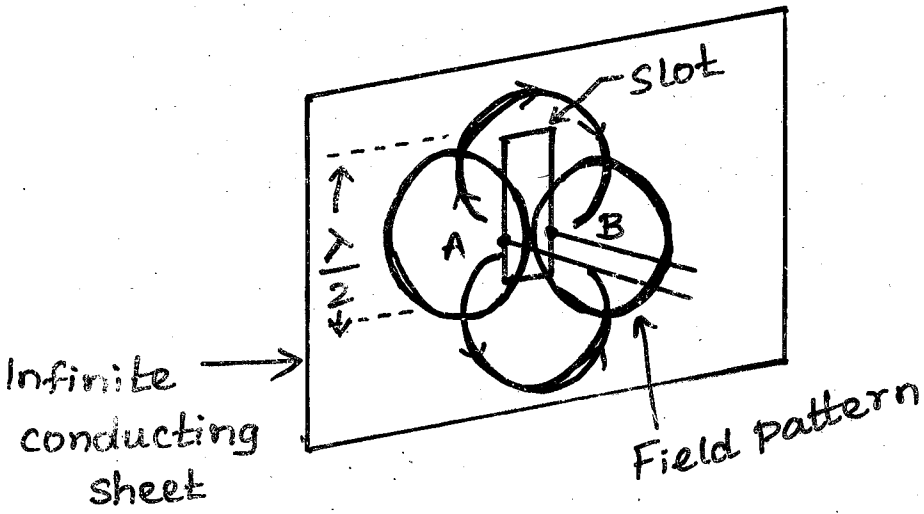


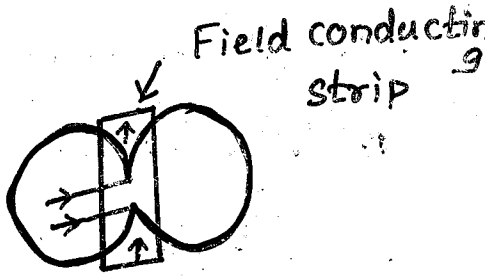
b) Aperture coupled Feed

SLOT ANTENNA

* slot antenna is a radiating element formed by a slot in a metallic surface

* It is excited by a coaxial cable or waveguide.





* slot and complementary dipole Antenna

* If the slot is properly energised, radiation occurs from both sides of the sheet.

* If $\lambda/2$ slot is cut in a large metal sheet and a Txn. line is connected to the Point AB, the structure radiates