UNIT II

APERTURE AND SLOT ANTENNAS

Radiation from rectangular apertures, Uniform and Tapered aperture, Horn antenna , Reflector antenna , Aperture blockage , Feeding structures , Slot antennas ,Microstrip antennas – Radiation mechanism – Application ,Numerical tool for antenna analysis

2.1 RADIATION FROM RECTANGULAR APERTURE

A rectangular aperture of dimensions 2a along x and 2b along y and located in the z = 0 plane shown in fig. We will assume that the field in the aperture is uniform and is given by

$$\begin{aligned} \mathbf{E}_a &= E_0\mathbf{a}_x \qquad |x| \le a \qquad |y| \le b \\ &= 0 \qquad \text{otherwise} \end{aligned}$$

We then have

$$\begin{aligned} \mathbf{f}_t &= E_0\mathbf{a}_x \int_{-a}^{a}\int_{-b}^{b} e^{jk_x x + jk_y y}\, dy\, dx \\ &= 4abE_0\mathbf{a}_x \frac{\sin k_x a}{k_x a}\frac{\sin k_y b}{k_y b} \\ &= 4abE_0\mathbf{a}_x \frac{\sin(k_0 a \sin\theta\cos\phi)}{k_0 a \sin\theta\cos\phi}\frac{\sin(k_0 b\sin\theta\sin\phi)}{k_0 b\sin\theta\sin\phi} \\ &= 4abE_0\mathbf{a}_x \frac{\sin u}{u}\frac{\sin v}{v} \end{aligned}$$

$$\text{where} \quad u = k_0 a \sin\theta \cos\phi, \quad v = k_0 b \sin\theta \sin\phi.$$

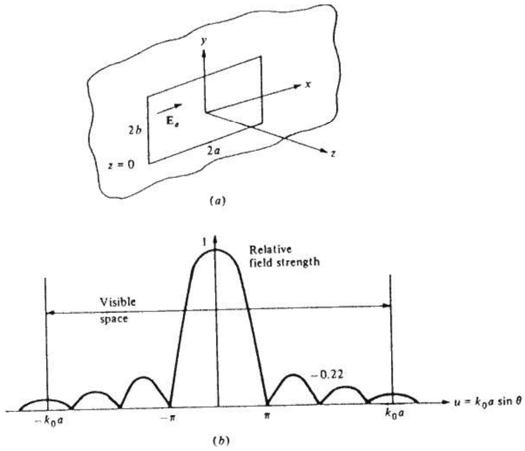

Fig 2.1 : (a) Rectangular aperture with a uniform field (b)Radiation field pattern

The electric field is given by

$$\mathbf{E}(\mathbf{r}) = \frac{jk_0 4abE_0}{2\pi r} e^{-jk_0 r} \frac{\sin u}{u} \frac{\sin v}{v} (\mathbf{a}_\theta \cos\phi - \mathbf{a}_\phi \sin\phi \cos\theta)$$

….(a)

The expression is similar to the broad side array and indeed the radiation patterns are nearly identical in the visible region of uv space , which extends over $|u| \le k_0 a$ and $|v| \le k_o b$. For an array the pattern repeats periodically, while for an aperture the side lobe pattern continuous to decrease as u and v move into the invisible region. For a large array the range of u and v to cover visible space is small enough that the $\sin u/2 \sin v/2$ term in the denominator of the array factor can be replaced by $v/4$, in which case the pattern for a uniform two – dimensional array of dipoles becomes identical with the pattern from a uniformly illuminated aperture. Note , however , that for an array we defined u to be equal to $k_0 d\ sin\theta \cos\phi$. where d is the element spacing. A one-to-one correspondence with the aperture problem would require defining u as $k_0 \left[\frac{N+1}{2}\right] d \sin\theta\ \cos\phi$ for the array. But this is simply a change in scale for u and does change the pattern. The above remarks also apply to the variable v.

In a principal plane , say $\phi = 0$, we have

$$\mathbf{E} = jk_0 \frac{e^{-jk_0 r}}{2\pi r} \mathbf{a}_\theta 4abE_0 \frac{\sin(k_0 a \sin\theta)}{k_0 a \sin\theta}$$

The main diffraction lobe has an angular width $\Delta\theta$ is given by

$$\mathrm{BW} = \Delta\theta = 2\sin^{-1}\frac{\pi}{k_0 a} = 2\sin^{-1}\frac{\lambda_0}{2a} \approx \frac{\lambda_0}{a} \qquad \text{for } a \gg \lambda_0$$

Thus the diffraction lobe has an angular width inversely proportional to the aperture width measured in wavelengths, which was also found to be the case for an array.

2.2 UNIFORM APERTURE FIELD WITH A LINEANR PHASE VARIATION

We will now reconsider the rectangular aperture problem shown in Fig.but assume that the aperture Field has a linear phase variation; that is

$$\mathbf{E}_a = E_0 \mathbf{a}_x e^{-j\alpha x - j\beta y} \qquad |x| \le a \qquad |y| \le b$$

For this aperture distribution

$$\mathbf{f}_t = E_0 \mathbf{a}_x \int_{-a}^{a} \int_{-b}^{b} e^{j(k_x-\alpha)x + j(k_y-\beta)y}\, dy\, dx$$

which shows that the only modification in the pattern is that brought about by replacing k_x and k_y by $k_x - \alpha$ and $k_y - \beta$. Hence if we call $\alpha a = u_0, \beta b = v_0$, we obtain by direct analogy with equation (a).

$$\mathbf{E}(\mathbf{r}) = \frac{jk_0 4abE_0}{2\pi r} e^{-jk_0 r} \frac{\sin(u-u_0)}{u-u_0} \frac{\sin(v-v_0)}{v-v_0} (\mathbf{a}_\theta \cos\phi - \mathbf{a}_\phi \sin\phi\cos\theta)$$

In uv space the pattern is the same as before, except for a shift of the maximum from $u = v = 0$ to $u = u_0, v = v_0$. In physical space this means that the radiation lobe is no longer along the z axis but instead occurs at the angles specified by

$$k_0 a \sin\theta\cos\phi = u_0 = \alpha a$$
$$k_0 b \sin\theta\sin\phi = v_0 = \beta b$$

These relations can also be expressed in the form

$$\tan \phi = \frac{\beta}{\alpha}$$

$$\sin \theta = \frac{(\alpha^2 + \beta^2)^{1/2}}{k_0}$$

The beam can be scanned or positioned in any desired direction by controlling the linear phase variation of the aperture field in a manner analogous to what was found for the two-dimensional array.

If $\beta = 0$, then the direction of maximum radiation is in the $\phi = 0$ or xz plane at an angle $\theta = \theta_0$ given by $\sin^{-}\left(\frac{\alpha}{k_0}\right) = \sin^{-1}\left(\frac{\alpha\lambda_0}{2\pi}\right)$. The beam nulls occur where $u - u_0 = \pm\pi$ or at $u = u_0 \pm \pi = k_0 a \sin\theta \approx k_o a[\sin\theta_0 + cos\theta_0(\theta - \theta_0)]$ upon using a Taylor series expansion of $sin\theta$ about θ_0, the position of the maximum as given by k_0 a$\sin\theta_0 = u_0$. The beam width between nulls is thus given by

$$\mathrm{BW} = 2(\theta - \theta_0) = \frac{2\pi}{k_0 a \cos\theta_0} = \frac{\lambda_0}{a \cos\theta_0}$$

We find that when the beam is scanned away from **the normal to the** aperture the beam width is increased inversely with the i educed or projected width of the aperture in the direction of the main lobe. This same result was also found for the array.

2.3 TAPERED APERTURE FIELD

In manly applications of antennas it is desired to have very low side-lobe. levels in order to reduce interference effects, A. strong interfering signal incident on a receiving antenna in a direction corresponding to a side lobe will interact with a weaker desired signal incident along the direction of the main lobe. It is often necessary to reduce the side-lobe level to 30 dB or inure below the main lobe. For a rectangular aperture with a uniform field the first side lobe is down by only 13 dB. For a uniformly itluminaled circular aperture the. first side lobe is about 17.6dB below the main lobe, which is only a modest amount better, in the study of arrays it was found that the side-lobe level could be reduced by tapering the element excitations toward the ends of the array. This **Barrie** technique works with apertures as well. A tapered aperture-field distribution will generally result in a reduction of the side-lobe level. The penalty paid is an increase in the beam width and a reduction in the directivity brought about by a reduced efficiency of utilization of the available aperture area.

In order to illustrate the. effect of a tapered aperture field we will consider the rectangular aperture with a triangular aperture-field distribution of the form

$$\mathbf{E} = E_0 \mathbf{a}_x \left(1 - \frac{|x|}{a}\right) \qquad |x| \le a \qquad |y| \le b$$

For this aperture field

$$\mathbf{f}_t = E_0 \mathbf{a}_x \int_{-a}^{a} \int_{-b}^{b} \left(1 - \frac{|x|}{a}\right) e^{jk_x x + jk_y y}\, dy\, dx$$

$$= 4bE_0 \mathbf{a}_x \frac{\sin k_y b}{k_y b} \int_0^a \left(1 - \frac{x}{a}\right) \cos k_x x\, dx$$

$$= 4bE_0 \mathbf{a}_x \frac{\sin k_y b}{k_y b} \frac{1 - \cos k_x a}{k_x^2 a}$$

$$= 2abE_0 \mathbf{a}_x \frac{\sin k_y b}{k_y b} \left[\frac{\sin k_x (a/2)}{k_x (a/2)}\right]^2$$

The radiated electric field is thus

$$\mathbf{E}(\mathbf{r}) = \frac{jk_0 abE_0}{\pi r} e^{-jk_0 r} \frac{\sin v}{v} \left(\frac{\sin u/2}{u/2}\right)^2 \cdot (\mathbf{a}_\theta \cos\phi - \mathbf{a}_\phi \sin\phi \cos\theta)$$

We note that the maximum field strength at $u = v = 0$ is $abE_0k_0/r\pi$ in place of $2abE_0k_0/r\pi$ for a uniformly illuminated aperture. This reduction is due to using a triangular aperture field. The pattern function along u now involves the square of $\left(sin\frac{u}{2}\right)/(u/2)$ in place of the function $(sin\, u)/u$ and this means that the beam width between nulls has been doubled, but at the same time the first side lobe has been reduced from 13 to 26 dB below the main lobe. It is clear from this example that tapering the aperture field can have a pronounced effect on the side-lobe level. The radiation pattern along u has double zeros and is similar to the array with triangular current distribution.

Although the Fourier transform theory provides a convenient formulation for calculating the radiated field from a known aperture field on a plane surface, it cannot he applied directly to the case of an aperture cut in a curved surface such as on a cylinder or sphere.

2.4 HORN ANTENNA:

- ✓ The horn antenna is most widely used simplest form of the microwave antenna.
- ✓ As it is widely used at microwave frequencies 3 GHz to 30 GHz, it may be considered as an aperture antenna.
- ✓ The horn antenna serves as a feed element for large radio astronomy, communication dishes and satellite tracking throughout out the world.
- ✓ The horn antenna is most useful for broad band signals.

Horn Antenna as a wave guide:

- ✓ A horn antenna may be regarded as a flared out or opened out waveguide. When one end of the waveguide is excited and the other end is kept open, it radiates in open space in all directions.
- ✓ The radiation is much greater through waveguide than the two wire transmission line.

Limitations of waveguide:

- ✓ In the waveguide, a small amount of power in the incident wave is radiated and the large amount of power is reflected back by the open circuit end.
- ✓ Also the impedance matching with the free space is not perfect.
- ✓ At the edges of the waveguide, diffraction takes place which results in poor radiation.
- ✓ Also the radiation pattern is non-directive.

Termination of wave guide as a horn:

- ✓ In order to overcome the above mentioned limitations, the mouth of the waveguide is **flared or opened** out such that is assumes shape like horn. This electromagnetic horn produces **uniform phase front** with a larger aperture as compared with waveguide.

Advantages of terminating the waveguide into electromagnetic horn:

- ✓ Properly shaped gradual transition takes place.
- ✓ Proper impedance matching with free space occur.

- ✓ Total power incident will be radiated in forward direction and therefore the radiation is increased
- ✓ As the edges are flared out the diffraction at the edges reduces and thus directivity improves.

TYPES OF HORN ANTENNA:

Based on the flaring and type of waveguide there are four basic types of the horn antennas, they are

I. **E** plane sectoral horn
II. **H** plane sectoral horn
III. Pyramidal horn

} Rectangular horn antenna since it is fed with rectangular waveguide

IV. Conical horn
V. Biconical horn

} Circular horn antenna since it is fed with circular waveguide

- ✓ Sectoral horn is obtained if the flaring is done in one direction only.
- ✓ If the flaring is done along both the walls of the rectangular waveguide in the direction of both the electric and magnetic field vectors, then the horn obtained is called pyramidal horn.

(I) E-plane sectoral horn:

E-plane sectoral horn is obtained when the flaring is done in the direction of the electric field vector as shown in the fig 2.2(a).

(II) H-plane sectoral horn:

In this type, the flaring is a done in the direction of the magnetic field vector as shown in fig 3.10(b).

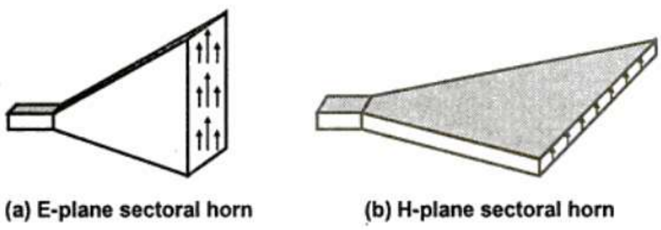

Fig : 2.2 Rectangular sectoral horns

- ✓ In both the cases, the arrows indicate direction of the electric field. The lengths of the arrows indicate approximate magnitude of the field intensity.

(III) Pyramidal horn:

- ✓ When the flaring is done along both the walls of the rectangular waveguide in the direction of both the magnetic field vectors, the horn obtained is called **pyramidal horn**.

- ✓ It is most widely used electromagnetic horn since it has characteristics as a combination of both **E**-plane and **H**-plane sectoral horns as shown in fig2.3.

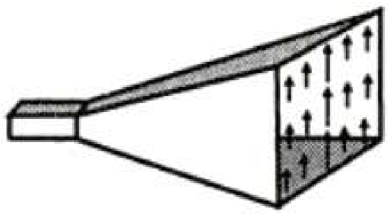

Fig 2.3 Pyramidal horn

(IV) Conical horn and biconical horn:

Here in this type flaring is done uniformly along the walls of a circular waveguide as shown in fig 2.4 (a) and fig 2.4 (b).

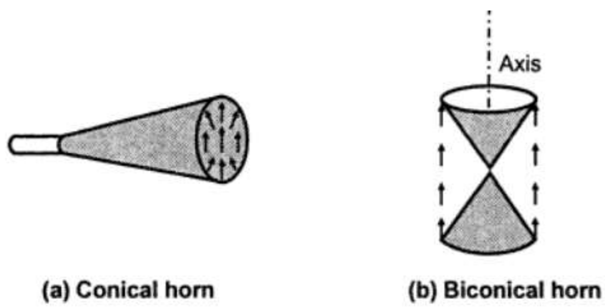

Fig 2.4 Circular horn antennas

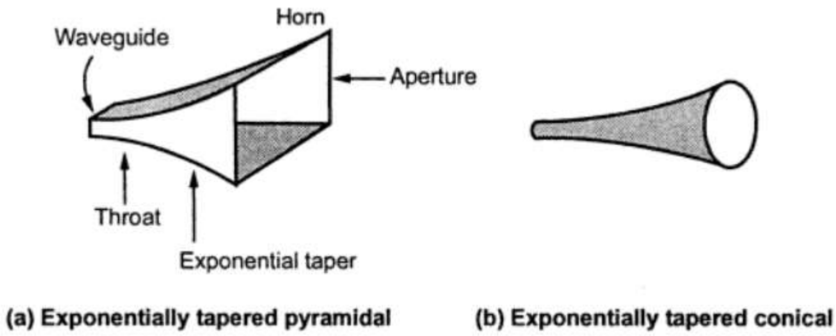

Fig2.4 : Exponentially tapered horn antennas

Principles of horn antenna:

- ✓ The fields inside the waveguide propagate in the same manner as in free space. But the main difference is that the waves are constrained by the walls of the waveguide from being spherically spreading.
- ✓ According to huygene's principle, each point on a primary wavefront can be considered to be a new source of a secondary spherical wave and the secondary wavefront can be constructed as the envelope of these secondary spherical waves.

  Thus according to this principle, the fields also spread laterally and thus we can get spherical wavefront.
- ✓ At the end of the waveguide, the guided propagation changes to free space propagation. so this region is generally called **transition region.**
- ✓ Since the waveguide impedance and free space impedance do not match, the flaring of the walls of the waveguide must be done so that impedance matching is achieved along with the concentrated radiation pattern with high directivity and narrow beam width.

DESIGN OF HORN ANTENNA:

Consider a E-plane sectoral horn of length 'L' and aperture height 'h' with flaring along 'θ' as shown in fig 2.5.

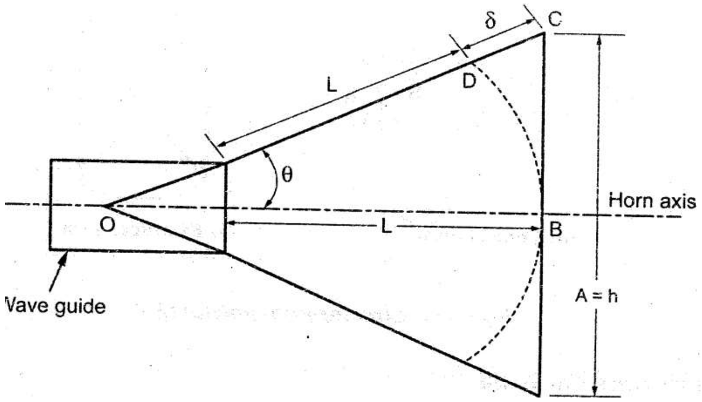

Fig :2.5 Geometry of E-plane sectoral horn

The function of the electromagnetic horn is to produce a uniform phase front with a larger aperture in comparison to waveguide. Because of this, the directivity is greater. Consider an imaginary apex'0' of horn as shown in fig 2.5. Assume that there exists a line source which radiates cylindrical waves. The constant or uniform wave fronts are cylindrical as the waves propagate in the direction radially outwards. At any point on the aperture the phase is different than at origin. The reason for the difference in phase is that the wave traces different distances from apex to the aperture.

Let 'δ' be the difference in the path of travel.

From the geometry of fig 3.13.

$$\text{Cos } \theta = \frac{L}{L+\delta}$$

And $$\tan \theta = \frac{h/2}{L} = \frac{h}{2L}$$

$$\theta = \tan^{-1}\left(\frac{h}{2L}\right) = \cos^{-1}\left(\frac{L}{L+\delta}\right) \quad \text{.....(a)}$$

From the right angled triangle OBC,

$$(L+\delta)^2 = L^2 + \left(\frac{h}{2}\right)^2$$

$$L^2 + \delta^2 + 2L\delta = L^2 + \frac{h2}{4}$$

If 'δ' is small, then δ^2 can be neglected.

$$\therefore \ 2L\delta = \frac{h^2}{4}$$

$$L = \frac{h2}{8\delta} \quad .....(b)$$

Equations (a) and (b) gives the design equations of the horn antenna. If flare angle is small, then the aperture area for a specified length 'L' becomes small. Thus at the mouth of the horn, uniform phase distribution occurs which results in increased directivity and decreased beam width. The angle represented in equation (3.48) is known as optimum aperture angle. In general for the practical horn antennas, the flare angle, varies from 40° to 15° which gives beam width=66°, directivity=40° for L=6λ . for the same flare angle, beam width=23° and directivity =120 for L=50λ.

For a horn of optimum flare angle, the half power beam width can be approximated as

$$\theta_H = \frac{67°\lambda}{a_H}$$

And $$\theta_E = \frac{56°\lambda}{a_E}$$

Assuming no loss, the directivity is given in terms of the effective aperture of the horn as

$$D = \frac{4\pi\ Ae}{\lambda^2} = \frac{4\pi\varepsilon_{ap}\ Ap}{\lambda^2}$$

Where, A_e = Effective aperture in m^2

A_p = Physical aperture in m^2

$\varepsilon_{ap} = \frac{Ae}{Ap}$ = Aperture efficiency

For a rectangular horn as shown in fig 2.6.

$$A_p = a_E \,.\, a_H$$

Where, a_E= E - plane aperture in meter

a_H = H - plane aperture in meter

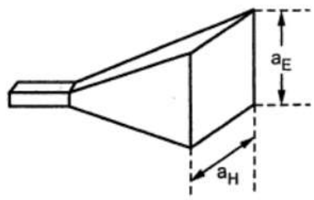

Fig 2.6 : Dimension of the aperture

For example if

$$a_E = a_H = \lambda = 1\text{m}$$

And $\varepsilon_{ap} = 0.6$, then the directivity of the rectangular horn is given by

$$D = \frac{4\pi(0.6)\, a_P}{\lambda^2} = \frac{7.5\, A_p}{\lambda^2}$$

$$D_{(\text{in db})} = 10 \log_{10} \frac{7.5\, A_p}{\lambda^2}$$

Similarly for a conical horn,

$$A_p = \pi r^2$$

Where r = Radius of aperture in metre.

Then the approximate formula for the directivity of a conical horn antenna will be same as given in equations but the calculation of physical aperture will be different.

ADVANTAGES OF HORN ANTENNA:

- ✓ The directivity of the pyramidal horn and conical horn is highest as they have more than one flare angle.
- ✓ It can be operated over a wide range of high frequency as there is no resonant element in the antenna.

APPLICATION OF HORN ANTENNA:

- ✓ Used in microwave applications.
- ✓ Used as feeder in parabolic reflector.
- ✓ Used in short range radar system.

2.5 REFLECTOR ANTENNA:

- ✓ Reflector type of Antennas or **Reflector** are widely used to **modify the radiation pattern of a radiating element.** For example, backward radiation from an antenna may be eliminated with a plane sheet reflector of large enough dimensions.
- ✓ By means of a reflector of suitable size and shape, a beam of desired characteristics may be produced.
- ✓ The reflector antennas are effectively used for space communications.
- ✓ The antenna which is used to excite the reflector antenna is called secondary antenna. The most common feeds are dipole, horn and slot.

- ✓ The reflector antennas are of several types.
  They are
  - **I.** Plane reflector or flat sheet reflector.
  - **II.** Corner reflector.
  - **III.** Parabolic reflector.
  - **IV.** Hyperbolic reflector.
  - **V.** Elliptical reflector.
  - **VI.** Circular reflector.

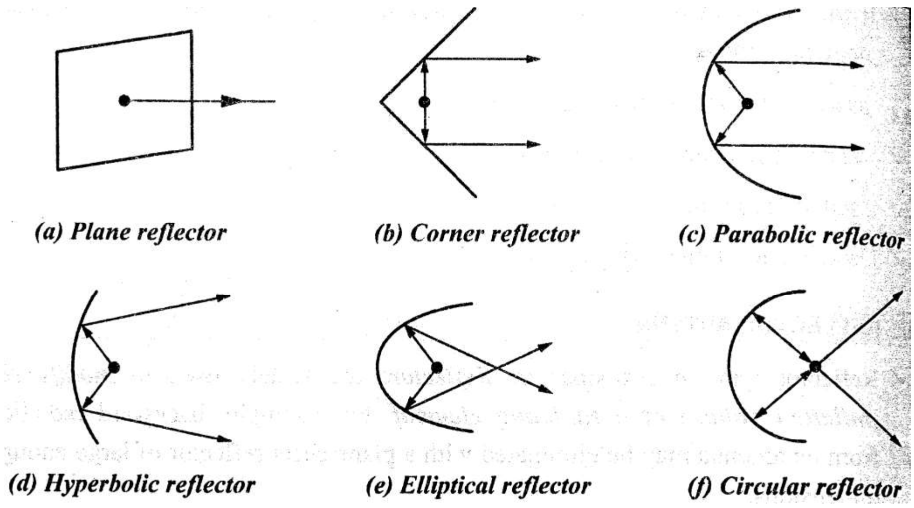

Fig 2.7: Various structures of reflectors

2.5.1 FLAT SHEET REFLECTOR (OR) PLANE REFLECTOR:

- ✓ The plane reflector is the simplest form of the reflector antenna.
- ✓ The main advantage of the plane reflector is that dipole (feed) backward radiations are reduced and the gain in the forward direction increases.
- ✓ Gain can be increased further by reducing the spacing between the feed and the sheet reflector. However bandwidth is narrow for small spacing.
- ✓ The plane reflectors areas shown in fig. 2.8
- ✓ To increase the directivity of the antenna, a large flat sheet can be kept as plane reflector in front of a half wave dipole as shown in the fig 2.8(a)
- ✓ The desirable properties of the sheet reflector may be largely preserved with the reflector reduced in size as shown in fig 2.8(b).
- ✓ The flat sheet reflector are relatively insensitive to small frequency changes. Therefore thin reflector element as shown in fig 2.8© can be increase directivity.
- ✓ The increase directivity further, array of two half wave dipole are used in front of a flat plane reflector as shown in the fig 2.8(d).

- ✓ Polarization of the radiating source (feed) and its position with respect to the reflector are important. By means of this radiation properties of the overall antenna (reflector with feed) such as radiation pattern, directivity, impedance etc, can be controlled.

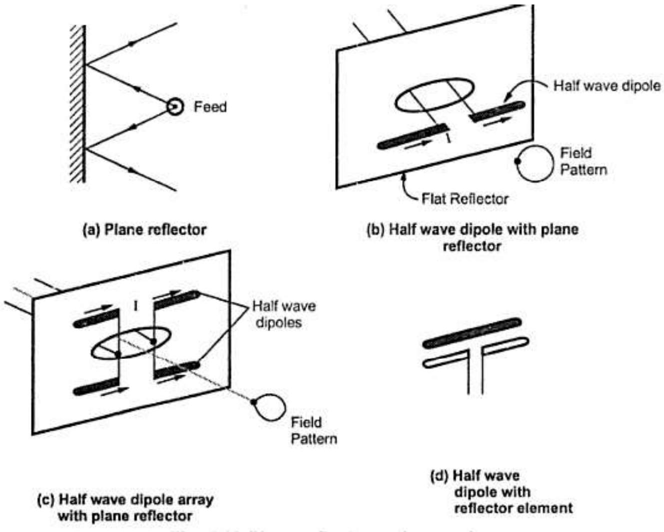

Fig 2.8 : Plane reflector and examples

- ✓ Then problem of an antenna at a distance 'S' from a perfectly conducting plane sheet reflector of infinite extent is readily handled by the method of images . In this method, the **reflector** is replaced by an **image of the antenna** at a distance 2 S from the antenna..
- ✓ This situation is identical with a horizontal antenna above ground.
- ✓ The gain in terms of field intensity of a $\frac{\lambda}{2}$ dipole antenna at a distance 'S' from an infinite plane reflector plane reflector is given by the expression.

$$G_f\ (\phi) = 2\sqrt{\frac{R_{11}+R_L}{R_{11}+R_{L-}R_{12}}}\ |\sin(S, \cos\phi)|$$

where $S_r = \frac{2\pi S}{\lambda}$

and S = distance between flat sheet reflector and feed.

- ✓ The field patterns $\frac{\lambda}{2}$ of antennas at distances S= $\frac{\lambda}{4}$, $\frac{\lambda}{8}$ and from the flat sheet reflector are as shown in fig. 3.18. These patterns are calculated from the above equation for the case R_L=0.

- ✓ The gain as a function of the spacing 'S' is shown in the fig .for assumed antenna loss resistance R_L=0,1 and 5Ω. These curves are calculated from the above equation for $\phi = 0$. it is clear that bandwidth is narrow and gain is more for small spacings.

When the reflecting sheet is reduced in size, the analysis can be done by considering three principal angular regions.

Region 1(above or in front of the sheet): In this region, the radiated field is given by the resultant of the direct field of the dipole and the reflected field from the sheet.

Region 2(above and below at the sides of the sheet): In this region, there is only the direct field from the dipole. This region is in the shadow of the reflected field.

Region 3(below or behind the sheet): In this region, the sheet acts as a shield, producing a full shadow. Here in this region, there is only diffracted field and there is no direct or reflected fields.

2.5.2 CORNER REFLECTORS:

- ✓ This disadvantage of plane reflector is that there is radiation in back and side directions.
- ✓ In order to overcome this limitations, the shape of the plane reflector is modified in which two plane reflectors are joined to form a corner with some angle. The reflector thus formed is known as corner reflector.
- ✓ The angle at which two plane reflectors are joined is called **included angle**(α).
- ✓ $\alpha = 90°$ For most of the practical applications.
- ✓ A vertical corner reflector with field pattern along main axis is shown in fig 3.21(a).
- ✓ The analysis of the corner reflector is carried out under the assumption that the two interesting planes are perfectly conducting and infinite.
- ✓ The system efficiency depends on the spacing between the vertex of the corner reflector and the fed element 'd'.
- ✓ If decreases, 'd' must be increased to desired efficiency.
- ✓ The feed element is either a dipole or array of collinear dipoles. Biconical or cylindrical dipoles may be used to increase the bandwidth.

A corner reflector with a driven antenna is called **active corner reflector antenna** or simply corner reflector antenna.

A corner reflector without any driven element is called **passive corner reflector antenna** (retro), and it is shown in fig 2.9(b).

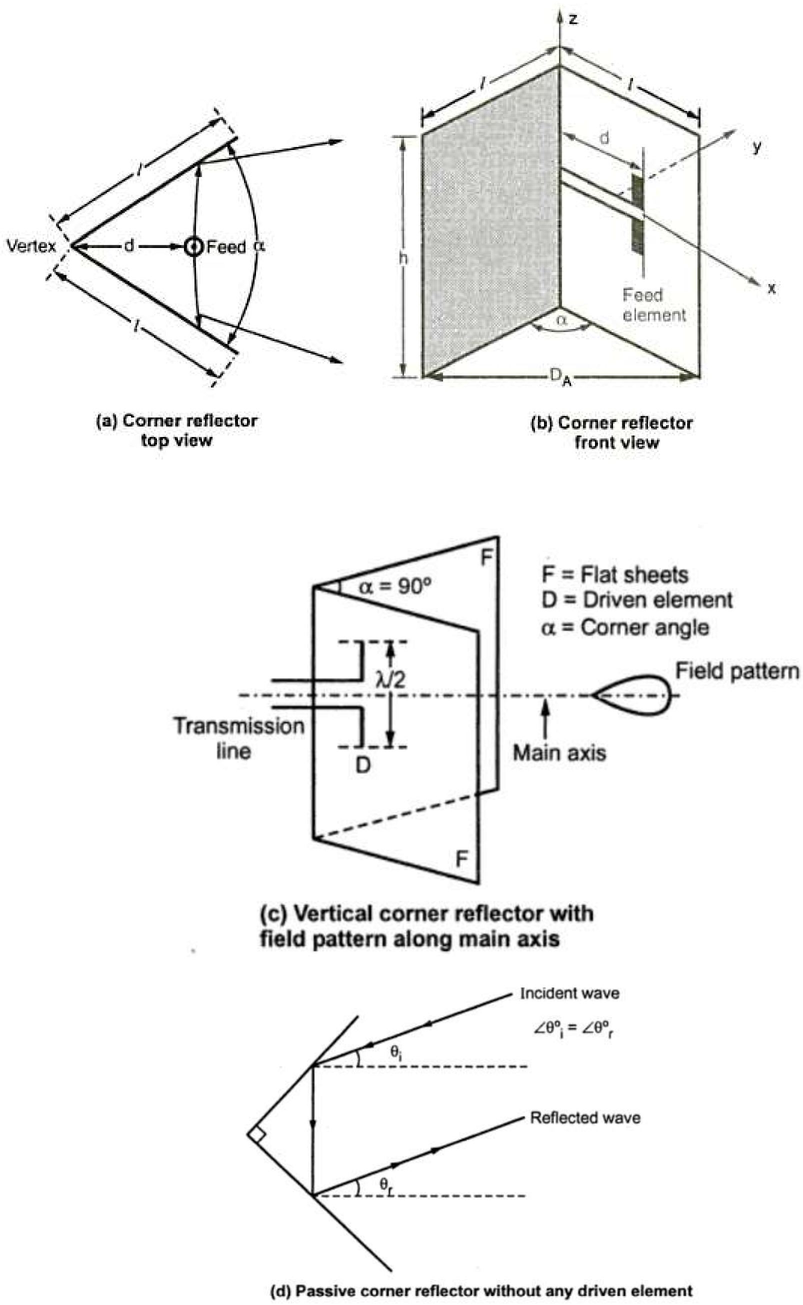

Fig :2.9 . Active and Passive corner reflector antenna

Design of corner reflector :

Let D_A = Dimension of the aperture of the corner reflector

And d = spacing between the vertex of the reflector and the feed element

- ✓ D_A is selected between one and two wavelengths ($\lambda < D_A < 2\lambda$).
- ✓ 'd' is selected as a fraction of wavelength ($\frac{\lambda}{3} < d < \frac{2\lambda}{3}$)
- ✓ The length of the reflector (l) = 2d for $\alpha = 90°, l > d.$
- ✓ Height of the reflector (h) is generally selected as about 1.2 to 1.5 times greater than the total length of the feed element.
- ✓ The radiation resistance is the function of 'd'. if 'd' is **too large**, the unwanted multiple lobes are produced and hence the **directivity** of the antenna is lost.
- ✓ If 'd' is **very small,** the radiation resistance decreases. The losses in the system increase as the decreased radiation resistance becomes comparable with the loss resistance of the antenna. Thus antenna is treated as inefficient antenna. Therefore for every corner reflector, there exists an optimum value of 'd'.
- ✓ In general *l = 2d*

  And $D_A = \sqrt{l^2} + \sqrt{l^2} = \sqrt{2l^2} = \sqrt{2}l$ = **1.414 l**

  But $l = 2d.$

  ∴ D_A = *1.414 (2d)* = ***2.828 d***

  Thus $l = 2d$

  And D_A = *1.414 l = 2.828 d*

  are the design equations of corner reflector.

ANALYSIS OF CORNER REFLECTOR BY METHOD OF IMAGES:

- ✓ The method of image can be applied to analyze the corner reflector antenna for angles $\alpha = \frac{180°}{n}$ where 'n' is any positive integer.
- ✓ By applying the image principle, we can show that the field produced between the two reflector planes is same as the field resulted from an array of 2N current elements spaced equidistant on a circular path
- ✓ The number of images, polarity and position is controlled by the included angle and polarization of the feed element.
- ✓ The pattern of multiple images for different values of with perpendicular polarization of the feed element is shown in the fig 2.10.

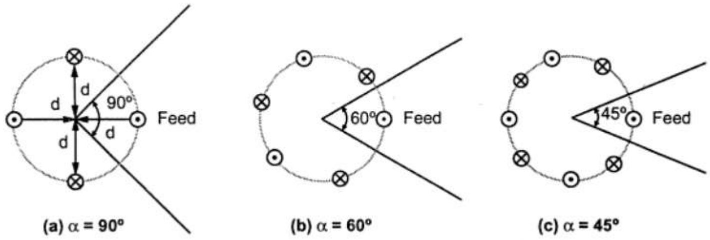

Fig 2.10 : Multiple images for different values of 'α'

$\alpha = \frac{\pi}{n}$ or $\frac{180°}{n}$

If n =1 , $\alpha = \frac{\pi}{1}$ rad or 180° → flat sheet or plane reflector

If n =2 , $\alpha = \frac{\pi}{2}$ rad or 90° → square corner reflector

If n =3 , $\alpha = \frac{\pi}{3}$ rad or 60° → Corner reflector with corner angle $\alpha = 60°$

If n =4, $\alpha = \frac{\pi}{4}$ rad or 45° → Corner reflector with corner angle $\alpha = 45°$

METHOD OF IMAGES FOR SQURE CORNER REFLECTOR:

Consider a square corner reflector with corner angle $\alpha = 90°$. This reflector consists of one driven element (feed) represented by 'D'. This is shown by point (1) in fig 3.23 (a) corresponding to one driven element, three images are represented by points (2),(3) and(4) as shown in fig 2.11(a). The driven element along with all three images carry current of same magnitude. The phase of currents in (1) and (2) are same. The phase of currents in (3) and (4) are also same but 180° out of phase with respect to the current in (1) and (2).

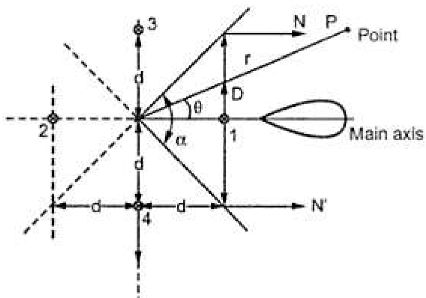

Fig 2.11(a) Square corner reflector with one driven element and three images

- At point 'p' which is at large distance 'r' from the antenna, the field intensity is

$$E_{\phi}(\theta) = K' \, L_1 \, [\cos(\alpha \, d \cos\theta - \cos(\alpha \, d \sin\theta)] \quad \ldots\ldots(a)$$

Where I_1 = current in each element

K' = constant incorporating distance r

D = distance of driven element from the corner along the main axis.

- The terminal voltage at the center of driven element is given by

$$V_1 = I_1 Z_{11} + I_1 Z_{12} - I_1 Z_{13} - I_1 Z_{14}$$

Where Z_{11} = self impedance of driven element [$\frac{\lambda}{2}$ dipole] = 73Ω

Z_{12} = Mutual impedance between elements(1) and (2)

Z_{13} = Z14 = Mutual impedance between elements (1) and (3) and elements (1) and (4)

$$V_1 = (Z_{11} + Z_{12} - 2Z_{14}) \, I_1 \quad \ldots\ldots(b) \quad (\therefore Z_{13} = Z_{14})$$

- If 'p' is power supplied to the driven element, then the power input to each image also remains the same.

- Now power can be expressed interns of current I_1 as

$$P = I_1^2 \, . \, R$$

$$I_1 = \sqrt{\frac{p}{R}}$$

$$I_1 = \sqrt{\frac{P}{R_{11} + R_{12-2R_{14}}}} \quad \ldots\ldots..(c)$$

Equation (b) is written by considering resistive part of all the impedances substituting equation(c) in equation (a), we get

$$E_{\phi}(\theta) = K' \sqrt{\frac{P}{R_{11} + R_{12-2R_{14}}}} \, [\cos(\alpha \, d \cos\theta) - \cos(\alpha \, d \sin\theta)] \quad \ldots\ldots(d)$$

- If reflector is removed, then no images element can exist. Therefore $R_{12} = R_{14} = 0$. Now only half wave dipole (driven element) remains. Therefore electric field due to isolated field due to isolated dipole antenna is given by

$$E_{\phi} \; (\theta)\lambda/2 = K' \sqrt{\frac{p}{R_{11}}} \quad \ldots\ldots..(e)$$

- Now gain in the direction is obtained by dividing equation (d) by equation (e), we get

$$G(\theta) = \frac{E_\phi(\theta)}{E_\phi\ (\theta)\lambda/2}$$

$$= \sqrt{\frac{R_{11}}{R_{11}+R_{12}-2R_{14}}}\ [\cos(\alpha\ d\cos\theta) - \cos(\alpha\ d\sin\theta)] \ldots\ldots(f)$$

- ✓ Here $\sqrt{\frac{R_{11}}{R_{11}+R_{12}-2R_{14}}}$ is called coupling factor and $[\cos(\alpha\ d\cos\theta) - \cos(\alpha\ d\sin\theta)]$ is called pattern factor.

- ✓ From equation (f), it is clear that the field pattern depends on angle θ and spacing 'd'.

- ✓ The field pattern consists of 4 lobes; out of these four lobes only one is real while the others are its images as shown in fig 2.11(b).

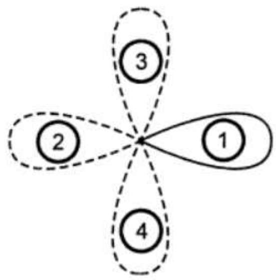

Fig 2.11(b) : Field pattern of driven element and its image elements

- ✓ But we know that for corner reflector, the maximum radiation is in the direction $\theta = 0°$. Hence substituting $\theta = 0°$ in equation(f), we get

$$G_0 = G(\theta = 0) = \sqrt{\frac{R_{11}}{R_{11}+R_{12}-2R_{14}}}\ [\cos(\alpha d) - 1]$$

- ✓ Now this same method can be extended to analyze the corner reflectors with corner angles $\alpha = 60°, \alpha = 45°$, etc.

- ✓ These analysis are carried out under the assumption that the reflecting sheets are perfectly conducting with infinite size.

ADVANTAGES OF CORNER REFLECTOR ANTENNA:

- ✓ The square- corner reflector is a simple, practical wide band antenna producing substantial gains (11 to 14 dBi).

- ✓ The field strength of the square corner reflector is four times that of the field strength of the half wave dipole in the free space because all the image elements add the direct signal from the driven element.

- ✓ The power radiated by the driven antenna of the corner reflector is 1.7 times than that reflected by half wave dipole in the free space.

2.5.3 PARABOLIC REFLECTOR:

- ✓ The parabolic structure is used to improve the overall radiation characteristics of the reflector antenna.

Principle of parabolic reflector:

- ✓ A parabola is a locus of a point which moves in such a way that the distance of the point say 'p' from focus (fixed point 'F') plus the distance from the straight line (directrix) is constant as shown in the fig 2.12 (a)

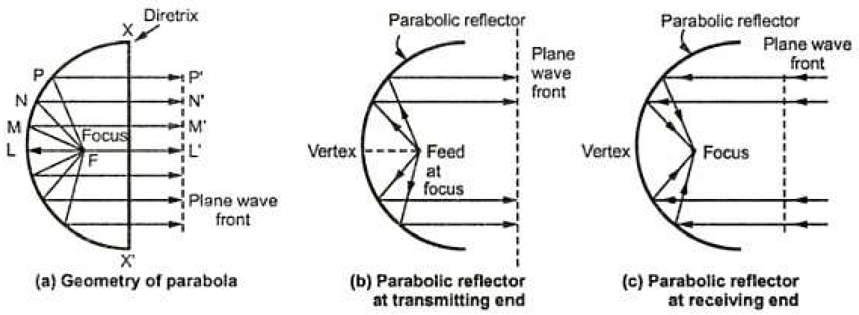

Fig 2.12Parabolic reflector principle

The parabola is a two dimensional plane curve,

OF	= focal length
F	= Focus
O	= Vertex
OO'	= Axis of parabola

- ✓ The open mouth(D) of the parabola is known as the aperture.

- ✓ The ratio of focal length to aperture is known as **" f over D ratio"** and it is an important characteristics of parabolic reflector(f/D varies from 0.25 to 0.50)

- ✓ By the geometrical optics, when the point source(feed) is placed at the focus, then the rays reflected by the parabolic reflector from parallel wavefront as shown in the fig 2.12(a). all the reflected rays are in phase since the time taken by the reflected rays to travel a distance upto the directrix of the parabola is same. This principle is used in the transmitting antenna.

- ✓ Similarly, when the beam of parallel rays is incident on a parabolic reflector, then the radiations focus at the focal point as shown in the fig 2.12(b). this principle is used in the receiving antenna
- ✓ Hence the geometrical properties of parabola provide excellent **microwave reflectors** that lead to the production of concentrated beam of radiation.

- ✓ In fact, the parabola converts a spherical wave front coming from the focus into a plane the mouth of the parabola. The part of the radiation from the focus which is not striking the parabolic curve as spherical wave appears as minor lobes. Obviously this is a waste of power.

PARABOLOID (OR) PARABOLOIDAL REFLECTOR (OR) MICROWAVE DISH:

- ✓ A parabola is a two dimensional plane curve.
- ✓ In practical applications, a three dimensional structure of the parabolic reflector is used.
- ✓ This three dimensional structure can be obtained by rotating the parabola around its axis and it is called parabolid.
- ✓ The parabolid and its radiation pattern is as shown in fig 2.13. the radiation pattern consists of very sharp major lobe and smaller minor lobes.
- ✓ As the mouth of the parabolid is circular n shape, the parallel beam produced are of the circular cross-section

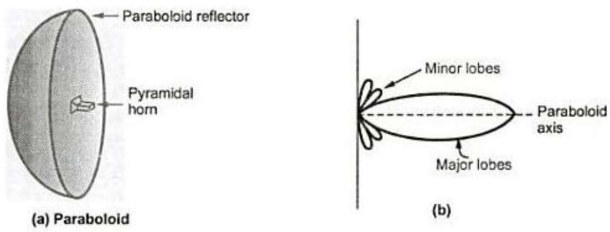

Fig 2.13 : Paraboloid with pyramidal horn as feed

DESIGN OF PARABOLID:

- ✓ The power gain of the circular aperture parabolid with half wave dipole feed is given by

$$G_p = \frac{4\pi A_0}{\lambda^2}$$

Where, A_0= Capture area

= k . A (k=0.65 for dipole)

Where, k = Constant dependent on feed antenna used.

- ✓ Capture area A_0 is less than the actual area A of the mouth.
- ✓ Hence the power gain is given by

$$G_p = \frac{4\pi(KA)}{\lambda^2} = \frac{4\pi \times 0.65A}{\lambda^2}$$

- ✓ The actual area of circular aperture with diameter d is given by

$$G_p = \frac{4\pi \times 0.65}{\lambda^2} \times \frac{\pi d^2}{4} = \frac{\pi^2\, 0.65\, d^2}{\lambda^2}$$

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

Where $\frac{d}{\lambda}$ = aperture ratio of the parabolid

- ✓ The equation (d) clearly indicates that the power gain of the parabolid depends on the ratio of diameter(***d***) of the circular aperture to the wavelength in free space.
- ✓ Hence the effective radiated power(ERP) is the product of the input power fed and the power gain GP.

For example,

If $\lambda = 0.02\, m$

d = 1 m

f = 1.5 GHZ

And input power fed to the parabolid=1 watt

Then, $G_p = 6\,(\frac{1}{0.02})^2 = 15000$

ERP = G_p × input power fed

15000 × 1 walt = 15000 watts

= 15 kW

Therefore by using parabolid, large gain with narrow beam width can be achieved. For effective use, the diameter of the circular aperture is kept minimum 10 λ.

- ✓ If the feed antenna (primary antenna) is isotropic, produces beam of radiation. Assuming large circular aperture, the beam width between first null can be expressed as

$$\text{BWFN} = \frac{140\lambda}{d} \text{ degrees}$$

Where d = Diameter of the circular aperture in terms of λ in m.

λ= free space wavelength in metre.

- ✓ Similarly BWFN for uniformly illuminated rectangular aperture is given by

  BWFN $=\frac{115\lambda}{L}$ degrees

  Where, L = Length of rectangular aperture is terms of $\lambda\lambda$

- ✓ The **half power beam width**(HPBW) for large **circular aperture** can be expressed as

  HPBW $= \frac{58\lambda}{D}$ degree

- ✓ Similarly the directivity of the uniformly illuminated aperture is given by

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

- ✓ For circular aperture

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

Hence we can write

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

$$\therefore D = \pi^2 \left(\frac{d}{2}\right)^2 \approx 9.87 \left(\frac{d}{2}\right)^2$$

F/D RATIO, SPILL OVER, BACK LOBE OF PARABOLOID F/D RATIO:

F/d Ratio:

- ✓ In parabolid reflector, the ratio f/d is an important design constraint

  Where, f = focal length

  D= diameter of the aperture

- ✓ The parabolid can be designed to obtain pencil shape radiation beam by keeping the diameter of the aperture fixed and changing the focal length f .The three possible cases are as follows:
  1. Focal point inside the aperture of parabolid.
  2. Focal point along the plane of open mouth of parabolid.
  3. Focal point beyond the open mouth of parabolid.

- ✓ When the focal length is very small, obviously the focal point lies **inside** the open mouth of parabolid as shown in the fig 2.14(a). here in this case, it is very difficult to obtain uniform illumination because it involves illumination over a wide angle.

- ✓ When the focal point lies on the plane of the parabolid as shown in fig 2.14(b), then the focal length 'f' is one fourth of the open mouth diameter 'd'. this condition gives pencil shaped radiation with maximum gain which is equal in horizontal an vertical plane.

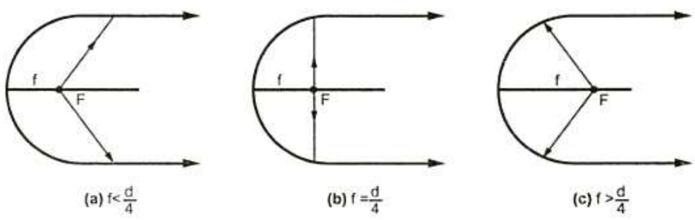

Fig 2.14 : Effect of variation of focal length 'f' keeping diameter of aperture 'd' fixed in paraboloid

- ✓ When the focal length is too large, the focal point lies beyond the open mouth of the parabolid as shown in fig 2.14(c). here it is difficult to direct all the radiations from the source on the reflector.

SPILL OVER:

- ✓ The most widely used antenna for microwave is the parabolid reflector antenna or microwave dish.
- ✓ It consists of a primary antenna such as **dipole** or **horn** situated at the **focal point** of a paraboloidal reflector.
- ✓ Basically the mouth or aperture of the paraboloid is circular. But the reflector contour when projected onto any plane containing the focal point 'F' and the vertex 'O' forms are parabola .
- ✓ The important practical implication of this property is that reflector can focus parallel rays at the **focal point** 'F'(for receiving antenna) or it can focus parallel beam from radiations organizing from the focal point. Practically it is observed that some of the rays are not fully captured by the reflector and such non-captured rays from **spill over.**

BACK LOBE:

While receiving spill over, the noise pick up increases which is troublesome. In addition to this, few radiations originated from the primary radiators are observed in forward direction. Such radiations get added with desired parallel beam. This is called **back lobe radiation** as it originates from the back lobe of primary radiator.

Obviously the back lobe radiations are unwanted as they considerably affect the reflected beam.

TYPES OF PARABOLOID REFLECTORS:

Depending upon the use, the paraboloid is modified into various types of the structurs. Some of the important types of the paraboloid are as follows.

a) **Truncated parabolid or cut paraboloid:**
This type is formed by cutting some of the paraboloid to meet the requirements are shown in fig 2.15.

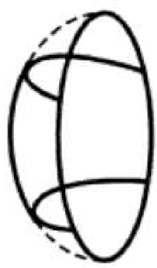

Fig :2.15 Truncated paraboloid or cut paraboloid

b) **Parabolic right cylinder:**
This structure is obtained by moving the parabola side ways. A plane sheet is curved to parabolic shape in one dimension.

This parabolic structure has focal line instead of a focal point and similarly vertex line instead of a vertex as shown in fig 2.16. here in this type of reflector, the energy is collimated at a line which is parallel to the axis through the focal point of the reflector. In practical, linear dipole (or) linear array(or) a slotted waveguide is used as primary antenna.

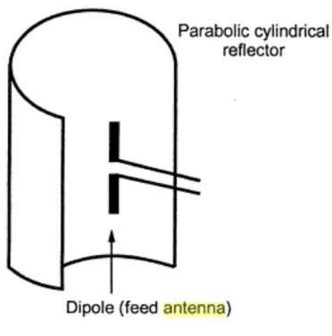

Fig :2.16 Parabolic right cylinder

c) Pill box or cheese antenna:

This is a short parabolic right cylinder enclosed by parallel plates as shown in the fig 2.17. this antenna is useful in producing wide beam in one of the planes while narrow in other.

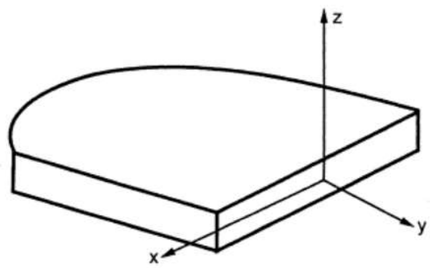

Fig 2.17 : Pill box paraboloid

2.5.4 FEED SYSTEMS FOR PARABOLIC REFLECTORS:

We know that parabolic reflector antenna consists of two parts namely

i. A source of radiation placed at the focus called **primary radiator**(or) feed

ii. The reflector called **secondary radiator.**

- ✓ The feed is said to be ideal feed if it radiates entire energy towards the reflector. Therefore, the entire surface of the reflector is illuminated and no energy is radiated in any unwanted direction.
- ✓ Practically, there are number of possible feeds to the parabolic reflector antenna.
- ✓ The secondary radiator used is a paraboloid most of the times.
- ✓ The simplest type of the feed that can be used is a dipole antenna. But it is not a suitable feed for the parabolic reflector antenna. Instead of only one dipole a feed consisting dipole with parasitic reflectors can be used as a feed system.
- ✓ In some cases, an end fire array of dipoles is used as feed radiator as shown in fig 2.17(b).
- ✓ The **most widely used feed** system in the parabolic reflector antenna is **horn antenna.** The horn antenna is fed with a waveguide.
- ✓ In all cases, the feed or primary radiator is placed at the focus to obtain maximum beam pattern. If the feed is moving along a line perpendicular to the main axis, then the beam deteriorates.
- ✓ Two important feed systems are
    i. Cassegrain feed system
    ii. Offset feed system

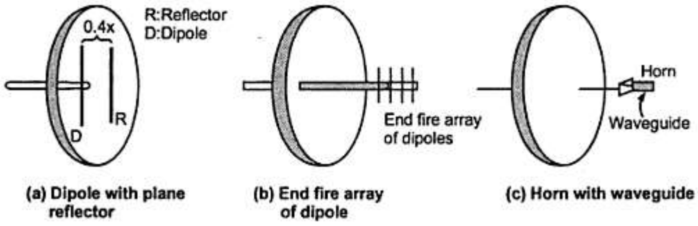

Fig 2.17 .Feed systems

(i) CASEGRAIN FEED SYSTEM:

- ✓ This system of feeding paraboloid reflector is named after a mathematician prof.Cassegrain.
- ✓ In this system, the feed 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 hyperbolid reflector is called **cassegrain secondary reflector** or **subflector.**
- ✓ The primary radiator used is generally a horn antenna.
- ✓ It aims to radiator at the sub-reflector.
- ✓ The geometry of the cassegrain feed system is as shown in the fig 2.18.

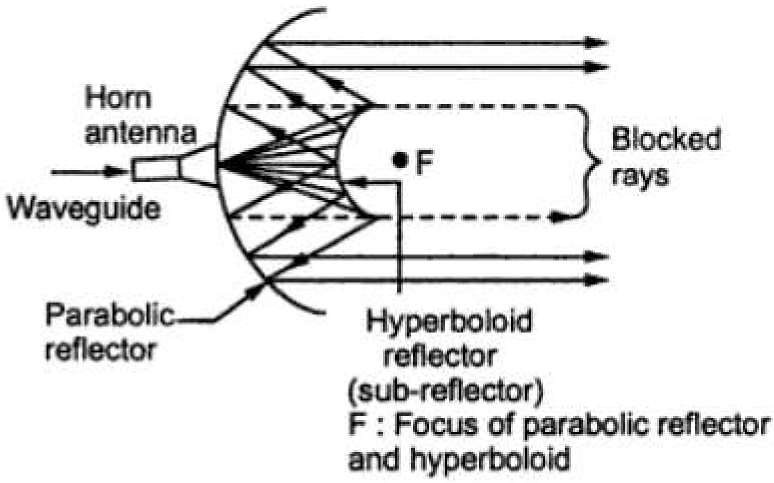

Fig 2.18 Cassegrain feed system

- ✓ When the primary radiator(horn antenna) radiates towards the cassegrain (subreflector), it reradiates all the radiations. Due to this, the parabolic reflector gets illuminated similar to the feed radiator placed at the focus.
- ✓ Then the parabolic reflector colliminates all the radiations as previous feed systems.

ADVANTAGES OF CASSEGRAIN FEED SYSTEM:

- ✓ It reduces the spill over and therefore minor lobe radiations.
- ✓ With this system, focal length greater than the physical focal length can be achieved.
- ✓ The system has ability to place a feed at convenient place.
- ✓ Using this system, beam can be broadened by adjusting one of the reflector surfaces.

DISADVANTAGES OF CASSEGRAIN FEED SYSTEM:

From fig 2.18, it is clear that there is a region of blocked rays in front of cassegrain reflector. This is not very serious problem in case of a parabolic reflector or larger dimensions.

(ii) OFFSET FEED SYSTEM

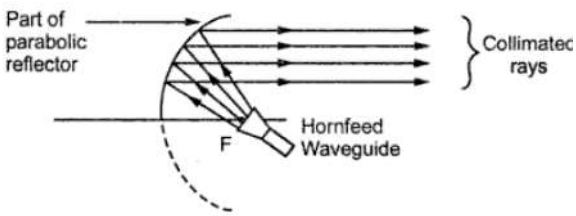

Fig 2.19 : Offset feed system

To overcome the aperture blocking effect due to the dependence of the secondary reflector dimensions on the distance between feed and sub-reflector, the offset feed system as shown in the fig 2.19 is used.

Here the feed radiator is placed at the focus as shown in the fig 2.19. with this system, all the rays are perfectly collimated without formation of the region of blocked rays.

APPLICAIOTN OF PARABOLIC REFLECTOR:

- ✓ Microwave communication.
- ✓ Radio astronomy.
- ✓ Satellite transmission and reception.

2.6 SLOT ANTENNAS:

Slot Antenna is a opening cut in a sheet of conductor which is energized via a co-axial cable or waveguide. It is best suitable radiator at frequencies above 300MHz. the shape, size and operating frequency of the slot determines the radiation pattern.

Concept:

Whenever a high frequency field exists across a very narrow slot in an infinite conducting sheet, the energy is radiated through slot.

Construction:

- ✓ Consider an infinite conducting sheet as shown in the fig2.20(a).
- ✓ A slot of length $\lambda/2$ in this conducting sheet.
- ✓ The flat strip taken out of the slot can be treated as short dipole as shown in the fig 2.20 (b)

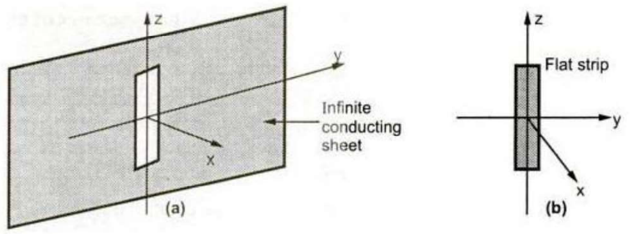

Fig 2.20 : Metallic conducting sheet and complementary flat strip

- ✓ When the flat strip and the slot are combined together, we get the complete original infinite conducting sheet.
- ✓ The infinite conducting sheet with slot and the flat strip of same dimension as that of the slot are said to be **complementary.**
- ✓ In general , the slot antenna is fed either by a generator or transmission line connected across it.[In case of the wave guides, the slot antenna is fed with the guided waves incident on slot].

Working principles:

- ✓ Now let us consider that the slot antenna is fed transmission line connected across points A and B as shown in fig 2.21

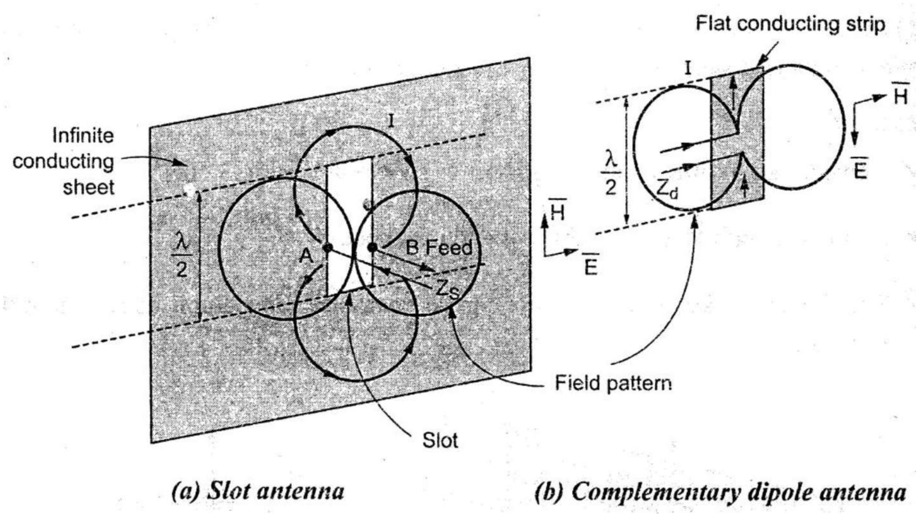

Fig 2.21: Slot and complementary dipole antenna

- ✓ Radiation takes place due to the current flowing in the conducting sheet.
- ✓ The complementary of the slot antenna is the dipole as shown in fig 2.21
- ✓ The metal and air regions of the slot are interchanged for the dipole, the place where the metal is present in the slot is replaced by air in the dipole and vice versa.
- ✓ According to G. booker's theory, the field pattern of the slot is exactly identical in shape as that of the half wave dipole as shown in fig 2.21(a) and 2.21(b). But the only difference is the electric field is Ē vertically polarized for dipole and horizontally polarized for dipole and horizontally polarized for slot.

If Z_s = terminal impedance of the slot.
Z_d = terminal impedance of the dipole

then Z_s and Z_d are related to each other in terms of intrinsic impedance of the free space η_0

$$Z_d \,.\, Z_s = \eta_0^2 = \frac{(377)2}{4} = 35530 \qquad (\because \eta_0 = 120\pi\ \Omega)$$

Hence the terminal impedance of the slot antenna is given by

$$Z_s = \frac{35530}{Z_d} \text{ or } Z_s = 35530 Y_d$$

Where, Z_d = 73+ j 42.5 ohms.

- ✓ This means that the slot impedance is proportional to the admittance of the dipole Y_d. That is if the slot requires inductance for a impedance match, the complementary dipole requires capacitance.

- ✓ *If the properties of the dipole are known , then the properties of the complementary slot can be easily predicted. The slot and the dipole are said to be completely complementary if the sheet containing the slot is large and perfectly conducting.*
- ✓ Thus the field pattern produced slot in a conducting sheet is exactly identical to that produced by a thin flat wire antenna. The distribution of **current** in the **thin flat** wire antenna is same as the distribution of **electric field** across the **slot**. But there are few differences between the two.

I. Polarization is different is both the antennas as we said earlier.
II. The radiations from the back side of the slot antenna and the complementary antenna are of opposite polarity.

METHOD OF FEEDING SLOT ANTENNA:

- ✓ Practically the slot antenna is fed with a co-axial transmission line. The outer conductor of the co-axial transmission line is bonded to the metal sheet as shown in the fig2.22(a)
- ✓ In general, the terminal impedance of $\lambda/2$ slot in a conducting large sheet is very large(approximately 500 Ω) while the characteristic impedance of the transmission line is much smaller.(50 Ω) Thus under such conditions, off-center feed as shown in the fig3.8(b) is used to provide proper impedance matching.

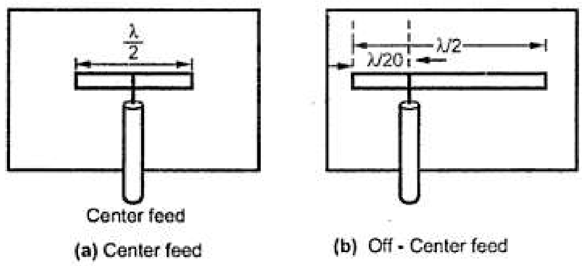

Fig 2.22 Feeding of slot antenna

VARIOUS SHAPES OF SLOT ANTENNA:

- ✓ At very high frequencies, a slot antenna with a slot cut in a conducting cylinder is most widely used. This longitudinal slot in infinitely long cylinder as shown in fig 2.23(a) produces circular radiation when the diameter of the cylinder is very small.

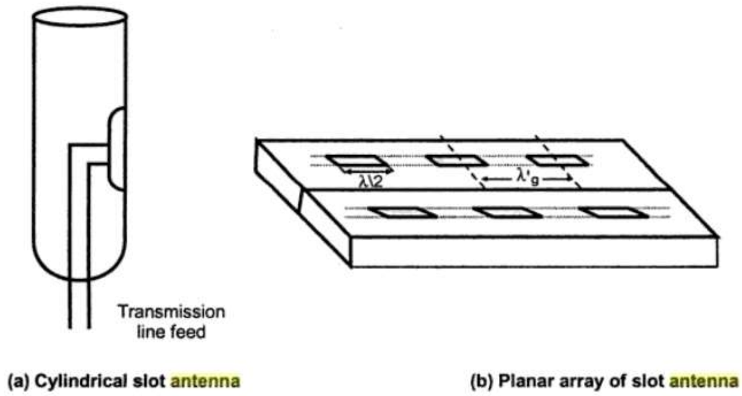

Fig 2.23 : Shapes of slot

- ✓ The gain and directivity properties of the basic slot antenna can be improved by using a broadside array of slots as shown in fig2.23 (b). here the centers of successive slots are spaced half wavelength apart and placed on opposite side of central line as shown in the fig2.23 (b). actually all the slots radiates in same phase but there is a reversal of polarity of the central line.
- ✓ The shape of the slot may be either rectangular or circular.

- ✓ The slot with circular or annular shape is called annular slot antenna. The annular slot antenna is as shown in the fig 2.23(c).

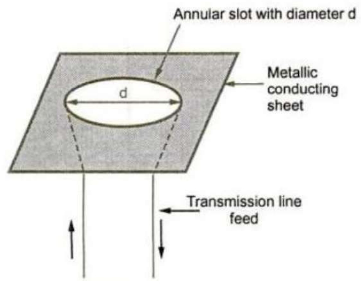

Fig : 2.23 (c) Annular slot antenna

- ✓ The shape of the slot need not be rectangular (or) circular. The slot may be of any convenient shape. But the analysis is easy with rectangular or circular slot.

APPLICATIONS OF SLOT ANTENNA:

- ✓ cylindrical slot antenna has found considerable application for TV broad casting of the horizontally polarized wave with an omni directional pattern.

(Here vertical-plane directivity may be increased by using stacked collinear slots in the long vertical cylinder).

2.7 MICROSTRIP ANTENNAS

The Antenna which is made of metal patches placed on dielectric and ted by microstrip (or) coplanar transmission line is called microstrip Antenna (or) Patch Antenna, This Antenna is mostly used with poor polarization purity and very narrow bandwidth. As it is low profile antenna it is affected by the spurious feed radiations.

Construction

- The microstrip antenna consists of a very thin metallic strip or patch placed over a substrate.
- The thickness of the microstrip is very small (t $<<\lambda_0$)as compared to the free space wavelength λ_0,
- The substrate is placed only a small fraction of free space wavelength above the ground plane. This height (h) is very small (h << λ_0) as compared to the free space wavelength λ_0, and typically it is 0.003 λ_0, $< 0.05\lambda_0$,
- The substrate in between the patch and ground plane is a dielectric sheet. By properly selecting field configuration by choosing the mode of excitation beneath the patch, the pattern maximum normal to the patch can he achieved.
- Typically the length of the patch is selected in between ($\frac{\lambda_0}{3} < L < \frac{\lambda_0}{2}$ as shown in the Fig 2.24 .

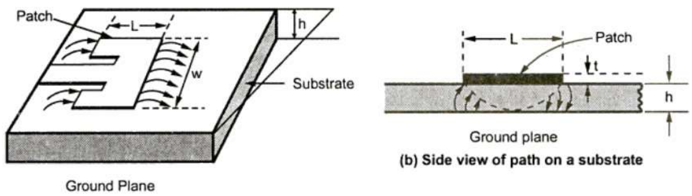

Fig 2.24. Construction of microstrip antenna

CHARACTERISTICS OF MICRQSTRIP ANTENNA

- In general, the number of different dielectric substrates can he used in the microstrip antenna. The value of the dielectric constant typically varies in the range of $2.2 \leq \varepsilon_r \leq 12$ for the microstrip antenna.
- The dielectric constant for the thick substrate is at the lower end of the range. It provides larger bandwidth, better efficiency and loosely bound fields, hence the thick substrates are most desirable.
- On the other hand, the dielectric constants are higher for the thin substrates. The thin substrates are useful to get smaller size of the antenna. Such antenna are suitable in the microwave circuitry as they require lightly bound fields to minimize unwanted radiations. But as compared to the thick substrate microstrip antenna, the losses are greater in the thin substrate microstrip antenna, they are less efficient and relatively narrower bandwidths.

TYPES OF PATCH IN MICROSTRIP ANTENNA

In microstrip antenna, the radiating elements *i.e.,* patch and the feed lines are generally photoetched on the dielectric substrate. The shapes of the radiating element (or) patch are as shown in the Fig,2.25.

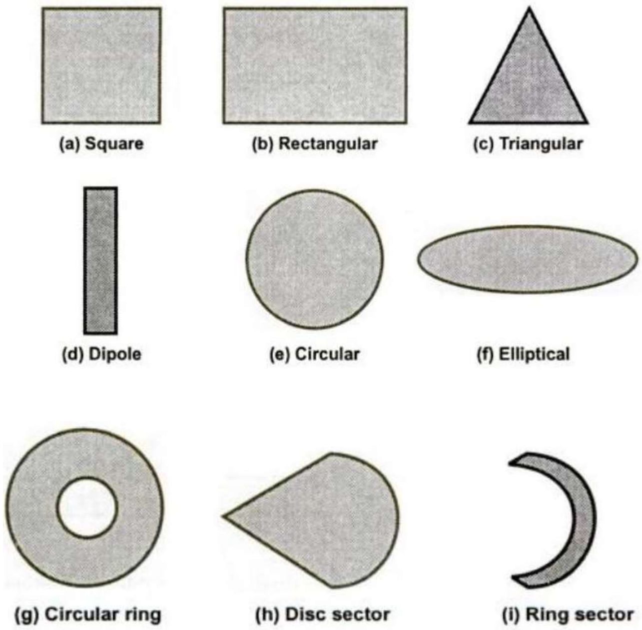

Fig 2.25 : Different shapes of patch in microstrip patch antenna

Out of the these shapes, square, rectangular, triangular, dipole and circular are the most commonly used shapes for the patch because of ease in fabrication. Besides this, these shapes are useful for low cross polarization radiation. Also the radiation pattern can be easily analyzed. The microstrip dipole or strip is more important and useful shape as it has inherent property of large bandwidth and can be easily fabricated with less space. To obtain linear and circular polarization, either a single element or an array of micro strip antennas car be used. To achieve greater directivities, arrays of microstrip elements with single or multiple feeds are used.

FEEDING METHODS IN MICRQSTRIP ANTENNAS

Similar Lo other types, the microstrip antenna can be fed with many configurations. But most widely used feed configurations are

(i) microstrip line feed
(ii) probe feed

(iii) aperture coupled feed
(iv) proximity coupled feed.

Microstrip feed line is nothing but a conducting strip. The width of the feed line is very much smaller as compared with the width of the patch. The microstrip feed line is easy to fabricate, Even though it is simple to model, the spurious feed radiation increases with increase in the thickness. Thus the bandwidth is limited.

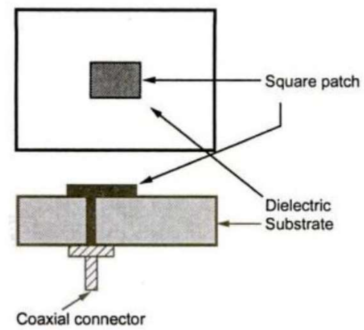

Fig 2.26 Probe feed system

In case of probe feed configuration, the outer conductor is connected to the ground plane, while the inner conductor is attached io a patch as shown in the Fig.2.26. As compared to the microstrip line feed, the spurious radiations are lower. Even though it is very easy to fabricate, the bandwidth is further narrower.

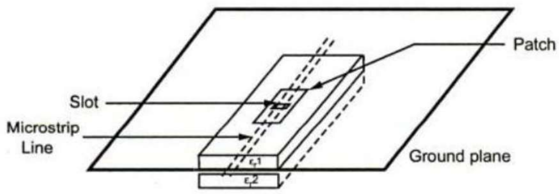

Fig 2.27 Aperture couple feed

The common limitation of the microstrip feed fine and probe feed is that both posses the inherent asymmetries, due to which cross polarized radiation is produced as higher modes are generated by the two systems. To overcome this, aperture coupled feed systems are used. In the aperture coupled feed system two substrates are used. The two substrates are separated by ground plane as shown in the Fig.2.27.

The microstrip feed line is fabricated on the lower substrate. The energy of this fine is coupled to the patch through the slot on ground plane. Generally for bottom thin substrate low dielectric material is used. This feed system minimizes the spurious radiations and interference for the pattern formation as the feed and radiating elements are isolated from each other.

The proximity coupled feed is another non-contacting feed system. Out of the four feed systems, it has largest bandwidth. Its fabrication is somewhat difficult as compared to other three systems,

APPLICATIONS OF MICROSTRIP ANTENNA

- ✓ Increased use in wireless applications due to their low-profile structure.
- ✓ Extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers, etc.
- ✓ Used in telemetry communication antennas on missiles.
- ✓ Successfully used in satellite communication.

ADVANTAGES OF MICROSTRIP ANTENNA

- ✓ Lightweight and low volume.
- ✓ Low fabrication cost, hence can be manufactured in large quantities.
- ✓ Low profile planar configuration which can be easily made conformal to host surface.
- ✓ Supports both, linear as well as circular polarization.
- ✓ Can be easily integrated with microwave integrated circuits.
- ✓ Capable of dual and triple frequency operations.
- ✓ Mechanically robust when mounted on rigid surfaces.

DISADVANTAGES OF MICROSTRIP ANTENNA

- ✓ Narrow bandwidth.
- ✓ Low efficiency .
- ✓ Low gain
- ✓ Extraneous radiation from feeds and junctions .
- ✓ Poor end fire radiator except tapered slot antennas.
- ✓ Low power handling capacity. .
- ✓ Surface wave excitation. .
- ✓ Poor polarization purity.

2.8 RADIATION MECHANISM FOR ANTENNA

Let us consider a voltage source connected to a two-conductor transmission line which is connected to an antenna. This is shown in Figure

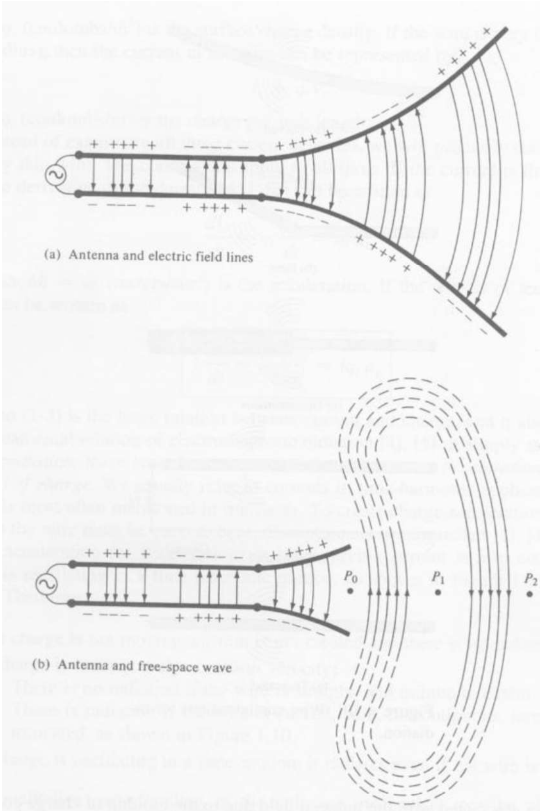

Fig : 2.28 Source, transmission line, antenna, and detachment of electric field lines

Applying a voltage across the two-conductor transmission line creates an electric field between the conductors. The electric field has associated with it electric lines of force which are tangent to the electric field at each point and their strength is proportional to the electric field intensity. The electric lines of force have a tendency to act on the free electrons (easily detachable from the atoms) associated with each conductor and force them to be displaced. The movement of the charges creates a current that in turn creates a magnetic field intensity. Associated with the magnetic field intensity are magnetic lines of force which are tangent to the magnetic field.

We have accepted that electric field lines start on positive charges and end on negative charges. They also can start on a positive charge and end at infinity, start at infinity and end on a negative charge, or form closed loops neither starting or ending on any charge. Magnetic field lines always form closed loops encircling current-carrying conductors because there are no magnetic charges. In some mathematical formulations, it is often convenient to introduce magnetic charges and magnetic currents to draw a parallel between solutions involving electric and magnetic sources.

The electric field lines drawn between the two conductors help to exhibit the distribution of charge. If we assume that the voltage source is sinusoidal, we expect the electric field between the conductors to also be sinusoidal with a period equal to that of the applied source. The relative magnitude of the electric field intensity is indicated by the density (bunching) of the lines of force with the arrows showing the relative direction (positive or negative). The creation of time-varying electric and magnetic fields between the conductors forms electromagnetic waves which travel along the transmission line, as shown in Figure2.28 (a). The electromagnetic waves enter the antenna and have associated with them electric charges and corresponding currents. If we remove part of the antenna structure, as shown in Figure 2.28 (b), free- carrying conductors because there are no magnetic charges. In some mathematical formulations, it is often convenient to introduce magnetic charges and magnetic currents to draw a parallel between solutions involving electric and magnetic sources.

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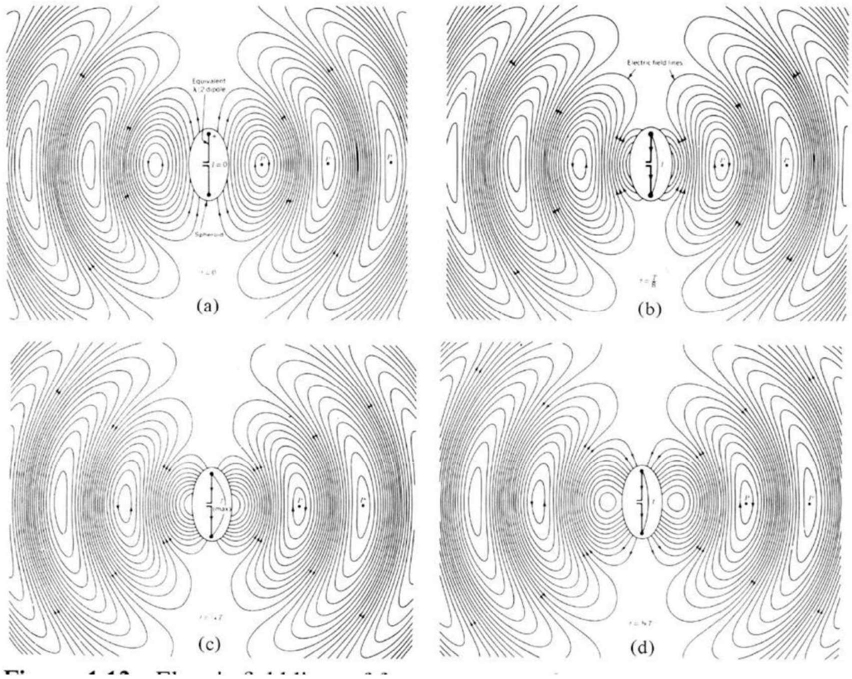

Next, let us attempt to explain the mechanism by which the electric lines of force are detached from the antenna to form the free-space waves. This will again be illustrated by an example of a small dipole antenna where the time of travel is negligible. This is only necessary to give a better physical interpretation of the detachment of the lines of force. Although a somewhat simplified mechanism, it does allow one to visualize the creation of the free-space waves. Figure 1.14(a) displays the lines of force created between the arms of a small center-fed dipole in the first quarter of the period during which time the charge has reached its maximum value (assuming a sinusoidal time variation) and the lines have traveled outwardly a radial distance $\lambda/4$. For this example, let us assume that the number of lines formed are three. During the next quarter of the period, the original three lines travel an additional $\lambda/4$. (a total of $\lambda/2$.from the initial point) and the charge density on the conductors begins to diminish. This can be thought of as being accomplished by introducing opposite charges which at the end of the first half of the period have neutralized the charges on the conductors. The lines of force created by the opposite charges are three and travel a distance $\lambda/4$ .during the second quarter of the first half, and they are shown dashed in Figure1.14(b)

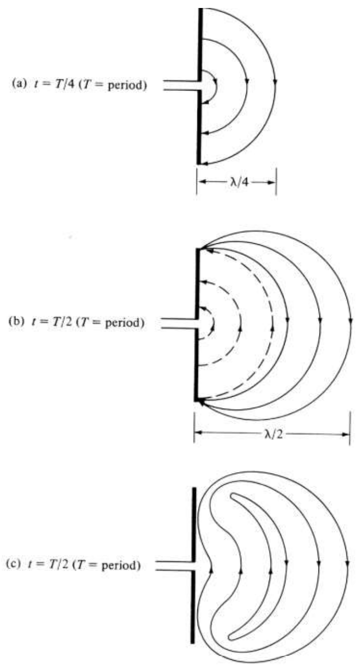

Fig2.29 : Formation and detachment of electric field lines for short dipole.

The end result is that there are three lines of force pointed upward in the first $\lambda/4$ distance and the same number of lines directed downward in the second $/4$. Since there is no net charge on the antenna, then the lines of force must have been forced to detach themselves from the conductors and to unite together to form closed loops. This is shown in fig 2.29 (c). In the remaining second half of the period , the same procedure is followed but in the opposite direction. After that, the process is repeated and continues indefinitely and electric patterns.