PET ENGINEERING COLLEGE

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

UNIT – 2

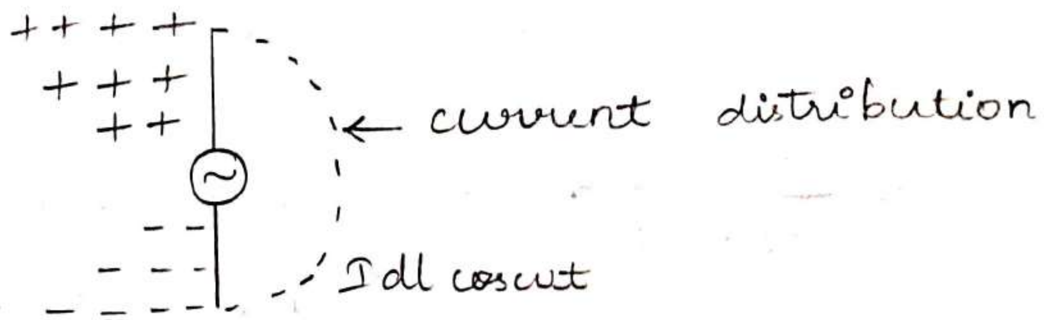
RADIATION MECHANISM AND DESIGN ASPECTS

CLASS	**: S7 ECE**
SUBJECT CODE	**: EC8701**
SUBJECT NAME	**: ANTENNA AND MICROWAVE ENGINEERING**
REGULATION	**: 2017**

1) Linear Wire Antennas (Short dipole Antenna):

Consider a thin wire antenna in which current is fed at the center and the current distribution is maximum at the end.

The current in the wire is given as, $Idl \cos\omega t$.



The magnetic vector potential, A_z in given direction is given by,

$$A_z = \frac{\mu [I]}{4\pi r}$$

$[I] \Rightarrow$ Retarded current

$$A_z = \frac{\mu I dl \cos\omega(t - r/c)}{4\pi r}$$

r/c is the vector potential retarded in time.

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Magnetic flux density, $B = \nabla \times A$

$A \rightarrow$ Magnetic vector potential

$$\nabla \times A = \frac{1}{r^2 \sin\theta} \begin{vmatrix} a_r & r a_\theta & r\sin\theta\, a_\phi \\ \partial/\partial r & \partial/\partial\theta & \partial/\partial\phi \\ A_r & r A_\theta & r\sin\theta\, A_\phi \end{vmatrix}$$

$$\frac{\partial}{\partial\phi} = 0, \quad A_\phi = 0.$$

$$\nabla \times A = \frac{1}{r^2 \sin\theta} \begin{vmatrix} a_r & r a_\theta & r\sin\theta\, a_\phi \\ \partial/\partial r & \partial/\partial\theta & 0 \\ A_r & r A_\theta & 0 \end{vmatrix}$$

$$= \frac{1}{r^2 \sin\theta} \left[a_r(0) - r a_\theta(0) + r\sin\theta\, a_\phi \left(\frac{\partial}{\partial r} r A_\theta - \frac{\partial}{\partial\theta} A_r \right) \right]$$

$$= \frac{1}{r^2 \sin\theta} \times \left[r\sin\theta\, a_\phi \left(\frac{\partial}{\partial r} r A_\theta - \frac{\partial}{\partial\theta} A_r \right) \right]$$

$$A_\theta = A \cdot a_\theta$$
$$= A_z \, a_z \, a_\theta$$
$$A_\theta = A_z(-\sin\theta) \quad a_z \cdot a_\theta = -\sin\theta \text{ (See Table in back side)}$$
$$A_r = A \cdot a_r$$
$$= A_z \cdot a_z \cdot a_r \quad a_z \cdot a_r = \cos\theta \text{ (Table)}$$
$$A_r = A_z(\cos\theta)$$
$$\nabla \times A = \frac{1}{r^2\sin\theta}\left[r\sin\theta \, a_\phi\left(\frac{\partial}{\partial r} r(-A_z\sin\theta) - \frac{\partial}{\partial\theta} A_z\cos\theta\right)\right]$$
$$= \frac{1}{r} a_\phi \left[\frac{\partial}{\partial r}(r(-A_z\sin\theta)) - \frac{\partial}{\partial\theta}(A_z\cos\theta)\right]$$
$$A_z = \frac{\mu I dl \cos\omega(t - r/c)}{4\pi r}$$
$$\nabla \times A = \frac{1}{r} a_\phi \left[\frac{\partial}{\partial r}\left(r\left(\frac{-\mu}{4\pi r} I dl \cos\omega(t - r/c)\right)\sin\theta\right) - \frac{\partial}{\partial\theta}\frac{\mu}{4\pi r} I dl \cos\omega(t - r/c)\cos\theta\right]$$
$$= \frac{1}{r} a_\phi \left[\frac{-\mu}{4\pi} I dl \sin\theta\left(\frac{\partial}{\partial r}\cos\omega(t - r/c)\right) - \frac{\mu}{4\pi r} I dl \cos\omega(t - r/c)\left(\frac{d}{d\theta}\cos\theta\right)\right]$$

$\cos(\omega t - \frac{\omega r}{c})$

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$$\nabla \times A = -\frac{1}{r} a_\phi \frac{\mu}{4\pi} I dl \left[\sin\theta\left(\frac{\omega}{c}[\sin\omega(t - r/c)]\right) + \frac{1}{r}\cos\omega(t - r/c)(-\sin\theta)\right]$$

$$\nabla \times A = \frac{-1}{r} a_\phi \frac{\mu}{4\pi} Idl \sin\theta \left[\frac{\omega}{c} \sin\omega(t - r/c) - \frac{1}{r} \cos\omega(t - r/c) \right]$$

$r \to$ high

$$\nabla \times A = -\cancel{\frac{1}{r}} a_\phi \frac{\mu}{4\pi} Idl \sin\theta \left[\frac{\omega}{cr} \sin\omega(t - r/c) - \frac{1}{r^2} \cos\omega(t - r/c) \right]$$

$r \to$ high, $\frac{1}{r} \to$ low, $\frac{1}{r^2} \to$ very very low

$\therefore \frac{1}{r^2}$ term is neglected

$\nabla \times A = B$ & $B = \mu H$

So, sub $\nabla \times A = \mu H$

$$\mu H = -a_\phi \frac{\mu}{4\pi} Idl \sin\theta \left[\frac{\omega}{cr} \sin\omega(t - r/c) \right]$$

$$\mu H = \mu (H_r a_r + H_\theta a_\theta + H_\phi a_\phi)$$

$$\mu H_\phi a_\phi = \left\{ -\frac{\mu}{4\pi} Idl \sin\theta \left[\frac{\omega}{cr} \sin\omega(t - r/c) \right] \right\} a_\phi$$

$$H_\phi = -\frac{1}{4\pi} Idl \sin\theta \left[\frac{\omega}{cr} \sin\omega(t - r/c) \right]$$

$$\boxed{|H_\phi| = \frac{1}{4\pi} Idl \sin\theta \left[\frac{\omega}{cr} \sin\omega(t - r/c) \right]}$$

Intrinsic impedence, $\eta = \frac{E_\theta}{H_\phi}$

$E_\theta = \eta H_\phi$

$E_\theta = 120\pi \cdot H_\phi \quad (\eta = 120\pi)$

$$E_\theta = 120\pi \left[\frac{1}{4\pi} \sin\theta \, I dl \left(\frac{\omega}{cr} \sin\omega \left(t - r/c \right) \right) \right]$$

$$\boxed{E_\theta = 30 \, I dl \sin\theta \left[\frac{\omega}{cr} \sin\omega \left(t - r/c \right) \right]}$$

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Sub $\Rightarrow \dfrac{\omega}{c} = \dfrac{2\pi}{\lambda}$.

$v = \dfrac{\omega}{\beta}$

$c = \dfrac{\omega}{\beta}$

$\lambda = \dfrac{c}{f}$

$c = \lambda f$

$\beta = \dfrac{\omega}{c} = \dfrac{2\pi f}{\lambda f}$

$\beta = \dfrac{\omega}{c} = \dfrac{2\pi}{\lambda}$

$$E_\theta = 30 \frac{I dl \sin\theta}{r} \left[\frac{2\pi}{\lambda} \sin\omega \left(t - r/c \right) \right]$$

$$E_\theta = \frac{60\pi \, I dl \sin\theta}{\lambda r} \left[\sin\omega \left(t - r/c \right) \right]$$

Sub. $[I] = \sin I dl \sin\omega \left(t - \frac{r}{c} \right)$

$$\boxed{E_\theta = \frac{60\pi}{\lambda r} \sin\theta . [I]}$$

Total radiated power,

$$P_{rad} = 80\pi^2 \left(\frac{I_{rms}^2 \, dl^2}{\lambda^2} \right)$$

$$P = I^2 R$$

$$P_{rad} = I_{rms}^2 \, R_{rad}$$

$P_{rad} \rightarrow$ Radiated power

$I_{rms} \rightarrow$ RMS current.

$R_{rad} \rightarrow$ Radiation Resistance.

$$R_{rad} = \frac{P_{rad}}{I_{rms}^2} = \frac{80\pi^2 \left(\frac{I_{rms}^2 \, dl^2}{\lambda^2} \right)}{I_{rms}^2}$$

$$R_{rad} = 80\pi^2 \frac{dl^2}{\lambda^2} \text{ ohm } (\Omega)$$

Advantages:

* Ease of construction due to small size.
* Power dissipation efficiency is higher.

Disadvantages:

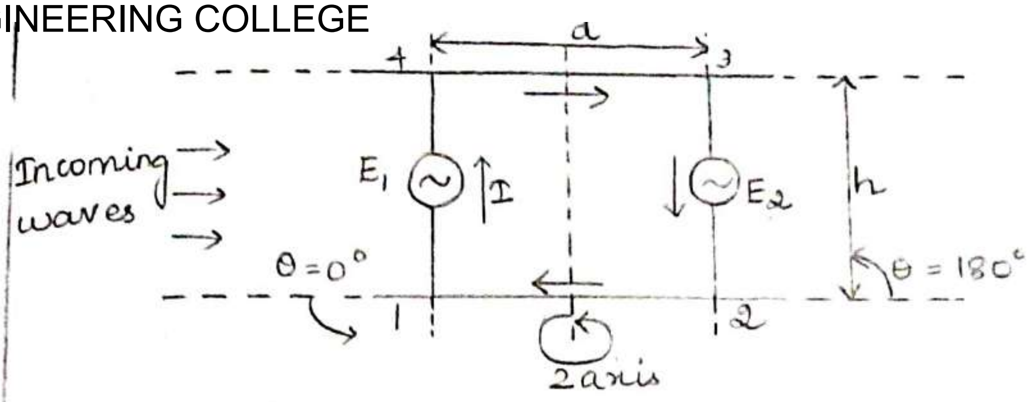
* High resistive loss
* High power dissipation
* Low signal to Noise ratio (SNR)
* Radiation is low and not so efficient

Applications:

* Used in narrowband applications
* Used as an antenna for tunner circuits.

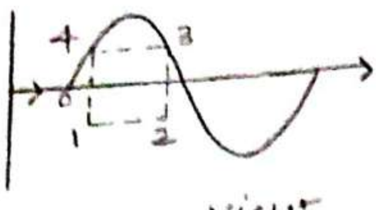
2) Loop Antenna:

7 [A loop antenna is a radiating coil of any shape with one or more turns carrying RF current]

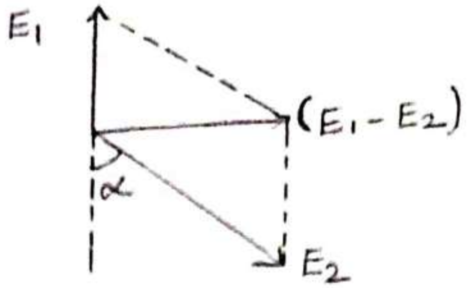


The horizontal arms and the vertical arms of the loop antenna acts as horizontal antennas and vertical antennas respectively. Consider that the loop is placed such that its plane is at right angles in the direction of wave travel. If the incoming waves are vertical polarized, then the voltages will be reduced in two vertical arm of the loop. These voltages are shown same in magnitude, but they are opposite in phase, so they are cancelled out each other. Therefore there is no output when the incoming signals is perpendicular to the loop antenna.

Now consider that the loop is rotated by -90° such that the plane of the loop antenna with the direction of incoming waves



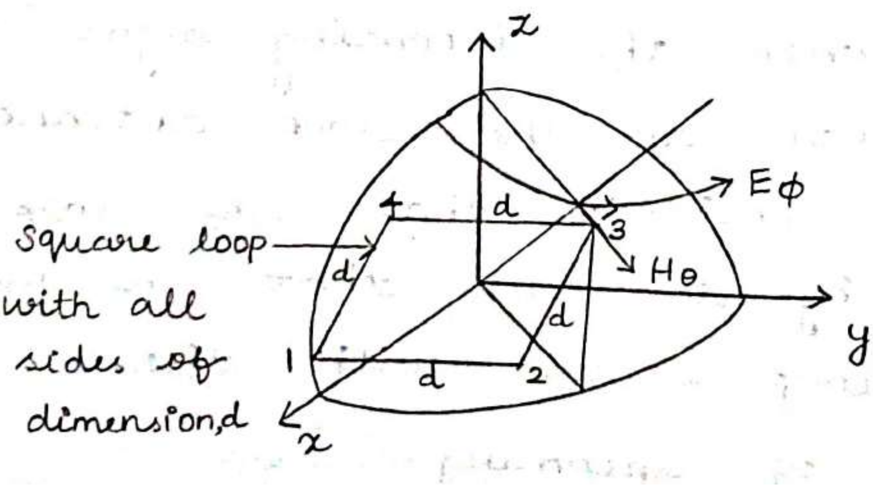
Perspective view



Phase representation of two emf's

Note the distance between the transmitter and the vertical antenna is no more same, the two emf's induced respectively in the vertical arms will also be of same amplitude but of different phase. Hence the resultant emf induced along the vertical axis will be E.

Thus we can conclude that the induced emf is maximum only when the plane of the loop is in the direction of incoming waves. This condition can be successfully used in the direction finding of the unknown transmitter



Path difference:

Path difference $= d\cos(90-\theta)$ (interms of meter)

Path difference $= \frac{d}{\lambda}\cos(90-\theta)$ (interms of wavelength)

Phase angle, ψ = 2π x Path difference

$= 2\pi \times \frac{d}{\lambda}\cos(90-\theta)$

$= \beta d.\sin\theta$ $\quad \beta = \frac{2\pi}{\lambda}$

$\cos(90-\theta) = \sin\theta$

Let Eo be the magnitude of electric field due to dipole.

There are 4 dipoles in the loop antenna. Two antenna in vertical direction and another two antenna in horizontal direction.

Always horizontal arms outputs are same and the outputs is Null.

The electric field,

$$E\phi = E_o e^{-j\psi/2} - E_o e^{+j\psi/2}$$

$2j\sin\theta = e^{j\theta} - e^{-j\theta}$

$$= E_o\left(e^{-j\psi/2} - e^{+j\psi/2}\right)$$

$$= E_o\left(-2j\sin(\psi/2)\right)$$

Sub, $\psi = \beta d \sin\theta$

$$E\phi = E_0 \left[-2j \sin\left(\frac{\beta d \sin\theta}{2}\right)\right]$$

Electric field due to dipole

$$E_0 = \underbrace{j\left(\frac{60\pi [I] \sin\theta}{\lambda r}\right)L}$$

From short dipole derivation

$\theta = 90°$

$$E_0 = \frac{j 60\pi [I] L}{\lambda r}$$

Sub E_0 in $E\phi$

$$E\phi = \frac{j60\pi [I] L}{\lambda r} \left\{-2j \sin\left(\frac{\beta d \sin\theta}{2}\right)\right\}$$

$\sin\alpha = \alpha$ (when α is small)

Therefore $\sin\left(\frac{\beta d \sin\theta}{2}\right) = \frac{\beta d \sin\theta}{2}$

$$E\phi = \frac{j60\pi [I] L}{\lambda r}\left[-2j \frac{\beta d \sin\theta}{2}\right]$$

$$\beta = \frac{2\pi}{\lambda}$$

$$E\phi = \frac{j60\pi [I] L}{\lambda r}\left[-j \beta \frac{2\pi}{\lambda} d \sin\theta\right]$$

$$E\phi = \frac{120\pi^2 [I] L d \sin\theta}{\lambda^2 r}$$

$L \times d$ = Area of rectangle = A

$$\boxed{E\phi = \frac{120\pi^2 [I] A \sin\theta}{\lambda^2 r}}$$

Intrinsic impedence, $\eta = \frac{E\phi}{H\theta}$

$$H\theta = \frac{E\phi}{\eta}$$

$$H\theta = \frac{E\phi}{120\pi} \quad (\eta = 120\pi)$$

$$H\theta = \frac{120\pi^2 [I] A \sin\theta}{\lambda^2 r \, 120\pi}$$

$$\boxed{H\theta = \frac{\pi [I] A \sin\theta}{\lambda^2 r}}$$

Radiation resistance of loop antenna,

$$\boxed{R_{rad} = \frac{320\pi^4 A^2 N^2}{\lambda^4} \ \Omega}$$

There are two, errors usually occurs on loop antenna

1) vertical error
2) Night error

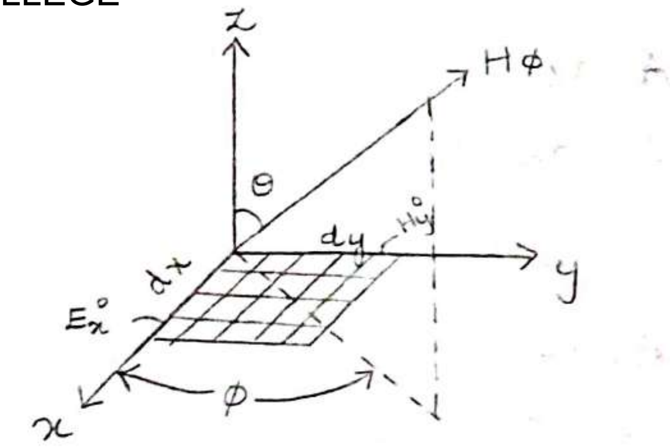
Vertical Error ⇒ Normally when the signal is perpendicular to the loop antenna, the resultant o/p is zero. But if there is any error in this condition, it termed as vertical error.

Night error ⇒ Null position is the position where the horizontally polarized and vertically polarized signals are zero. Due to the inosphere there will be the output at the horizontal arms even in Null position. This error commonly occured at night due to the impact of inosphere is called night error.

3) Apperture Antennas:

Aperture antennas are high frequency antenna and it take the form of wave guide.

V.V ⊗ 2m Huygen's principle states that each particle in any wave front acts as a new source of disturbance sending out secondary waves and the secondary waves combine to form a wave front



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The element of wave front having electric field strength, Ex and magnetic field strength, Hy are related as, $H_y = \frac{E_x}{\eta}$.

It can be treated as secondary source & can be replaced by electric and magnetic sheets.

The density of current sheets

Electric current sheet, $J_x = -H_y^\circ = -E_x^\circ/\eta$

Magnetic current sheet, $M_y = -E_x^\circ$

The value of magnetic vector potential, $A_x = \frac{\mu (J_x dy) dx\, e^{-j\beta r}}{4\pi r}$.

The electric field due to electric current sheets,

$$E^e = -j\omega A$$

$$E_\theta^e = -j\omega A_\theta \,, \quad H_\phi^e = \frac{E_\theta^e}{\eta}$$

$$E_\phi^e = -j\omega A_\phi \,, \quad H_\theta^e = -\frac{E_\phi^e}{\eta}$$

$$A_\theta = A \cdot a_\theta$$

$$= A_x \, a_x \cdot a_\theta$$

$$\boxed{A_\theta = A_x \left(\cos\theta \cos\phi\right)}$$

$$A_\phi = A \cdot a_\phi$$

$$= A_x \, a_x \cdot a_\phi$$

$$\boxed{A_\phi = A_x \left(-\sin\phi\right)}$$

The value of magnetic electric vector potential,

$$F_y = \frac{\varepsilon \left(M_y \, d_{yx}\right) d_y \, e^{-j\beta r}}{4\pi r}$$

The magnetic field due to magnetic current sheets.

$$H^{m} = -j\omega F$$

$$H_\theta^{m} = -j\omega F_\theta \, , \quad E_\phi^{m} = H_\theta^{m} \cdot \eta$$

$$H_\phi^{m} = -j\omega F_\phi \, , \quad E_\theta^{m} = -H_\phi^{m} \cdot \eta$$

$$F_\theta = F \cdot a_\theta$$

$$= F_y \cdot a_y \cdot a_\theta$$

$$\boxed{F_\theta = F_y \left(\cos\theta \sin\phi\right)}$$

$$F_\phi = F \cdot a_\phi$$

$$= F_y \cdot a_y \cdot a_\phi$$

$$\boxed{F_\phi = F_y \left(\cos\phi\right)}$$

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Total Electric field,

$$E_\theta = E_\theta^e + E_\theta^m$$

$$= -j\omega A_\theta + (-H_\phi^m \cdot \eta).$$

$$= -j\omega (A_x \cos\theta \cos\phi) - (-j\omega F_\phi \cdot \eta)$$

$$= -j\omega A_x \cos\theta \cos\phi + j\omega F_y \cos\phi \cdot \eta.$$

$$= -j\omega \times \frac{\mu (J_x dy) dx \, e^{-j\beta r}}{4\pi r} \cos\theta \cos\phi +$$

$$j\omega \times \frac{\varepsilon (M_y dx) dy \, e^{-j\beta r}}{4\pi r} \cdot \eta \cos\phi$$

$$E_\theta = \frac{j\omega e^{-j\beta r} \cos\phi}{4\pi r} \left[-\mu (J_x dy) dx \cancel{\cos\theta} + \eta \cdot \varepsilon (M_y dx) dy \right]$$

$$E_\theta = \frac{j\omega e^{-j\beta r} \cos\phi \, dx dy}{4\pi r} \left[\eta \varepsilon M_y - \mu J_x \cos\theta \right]$$

Sub $J_x = \frac{-E_x^\circ}{\eta}$, $M_y = -E_x^\circ$ in E_θ

$$E_\theta = \frac{j\omega e^{-j\beta r}}{4\pi r} \cos\phi \, dx dy \left[\eta \varepsilon (-E_x^\circ) + \mu \frac{E_x^\circ}{\eta} \cos\theta \right]$$

$$\mu/\eta = \frac{\mu}{\sqrt{\mu/\varepsilon}} = \frac{\mu \sqrt{\varepsilon}}{\sqrt{\mu}} = \sqrt{\mu\varepsilon} = \frac{1}{c}$$

$$\left[\therefore c = \frac{1}{\sqrt{\mu\varepsilon}} \right]$$

$$\eta \varepsilon = \varepsilon \sqrt{\mu/\varepsilon} = \frac{\varepsilon \sqrt{\mu}}{\sqrt{\varepsilon}} = \sqrt{\mu\varepsilon} = \frac{1}{c}$$

$$E_\theta = \frac{j\omega e^{-j\beta r}}{4\pi r} \cos\phi \, dx dy \left[-\frac{E_x^\circ}{c} + \frac{E_x^\circ}{c} \cos\theta \right]$$

$$\boxed{E_\theta = \frac{-j\omega e^{-j\beta r}}{4\pi r c} E_x^{\circ} \cos\phi \, dx dy \left[1 - \cos\theta\right]}$$

$$E_\phi = E_\phi^{e} + E_\phi^{m}$$

$$= -j\omega A_\phi + H_\theta^{m} \cdot \eta$$

$$= -j\omega A_\phi - j\omega F_\theta \cdot \eta$$

$$= -j\omega A_x(-\sin\phi) - j\omega F_y(\cos\theta \sin\phi)\eta$$

$$= j\omega A_x \sin\phi - j\omega F_y \cos\theta \sin\phi \cdot \eta.$$

$$= j\omega \frac{\mu(J_x dy) dx e^{-j\beta r}}{4\pi r} \sin\phi - \cos\theta \sin\phi . j\omega \frac{\varepsilon(M_y dx) dy e^{-j\beta r}}{4\pi r} \cdot \eta$$

$$= \frac{j\omega e^{-j\beta r}}{4\pi r} dx dy \sin\phi \left[\mu J_x - \eta \varepsilon M_y \cos\theta\right]$$

$$= \frac{j\omega e^{-j\beta r}}{4\pi r} \sin\phi \, dx dy \left[-\mu \frac{E_x^{\circ}}{\eta} + \eta \varepsilon E_x^{\circ} \cos\theta\right]$$

$$\left[\because J_x = -\frac{E_x^{\circ}}{\eta}, M_y = -E_x^{\circ}\right]$$

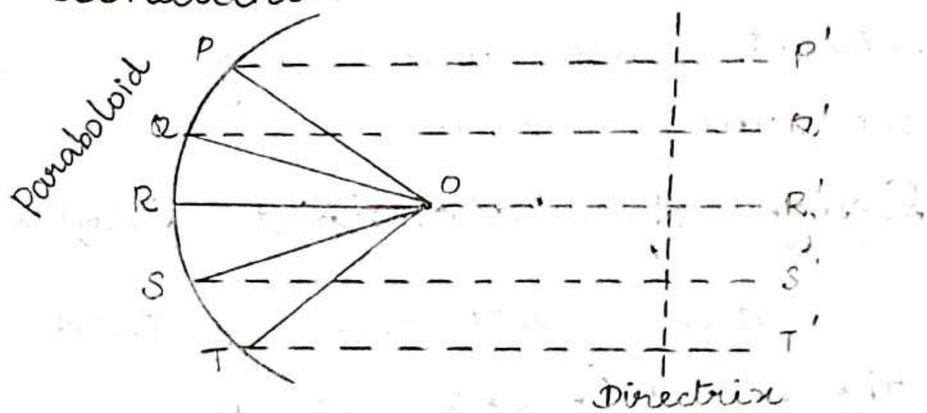
$$= \frac{j\omega e^{-j\beta r}}{4\pi r} \sin\phi \, dx dy \left[\frac{-E_x^{\circ}}{c} + \frac{E_x^{\circ}}{c} \cos\theta\right]$$

$$\left[\because \mu/\eta = \frac{1}{c}, \eta\varepsilon = \frac{1}{c}\right]$$

$$\boxed{E_\phi = \frac{-j\omega e^{-j\beta r}}{4\pi r c} E_x^{\circ} \sin\phi \, dx dy \left[1 - \cos\theta\right]}$$

Parabolic reflectors:

* To improve the overall radiation of the reflector antenna, the parabolic structure is used.
* Basically the distance from the focus to the paraboloid plus the distance from the paraboloid to the straight line is called directive and it is constant.



$OP+PP'$, $OQ+QQ'$, $OR+RR'$, $OS+SS'$, $OT+TT'$ are constants.

* The open end of parabolic reflector is called aperture
* The waves reflected from the aperture of the parabolic reflector is uniform phase front and thus very strong and concentrated beam is obtained along the axis.
* Feed is placed at the force point, while transmitting purpose. Signal from the feed illuminates.

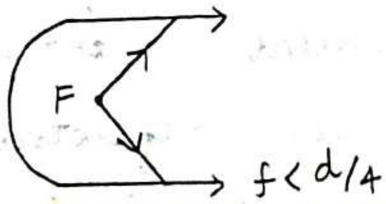
the parabola and a very high concentrated beam gets reflected from the parabola.

* When it is used for receiving of signals, the signal illuminates the paraboloid reflector and these signal are made to focus on the focal point where the feed is present which collect all the signal and give to the receiver.

Design of Paraboloid Reflector:

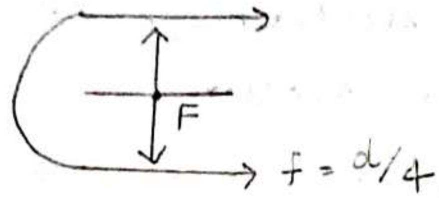
Feed can be placed in three different ways.

1) Focal point inside the aperture of paraboloid:



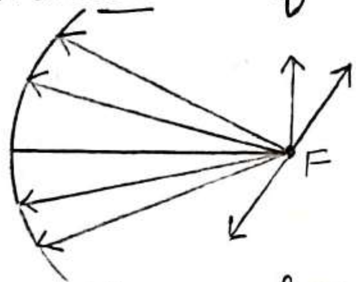
When focal length is at the distance less than one-fourth the mouth of aperture, it is difficult to obtain uniform illumination over a wide angle.

2) Focal point along the plane of open mouth of paraboloid:



When focal length is at the distance of $d/4$ it produces maximum gain pencil shaped radiation equal in horizontal and vertical plane.

3) Focal point beyond the open mouth of paraboloid:

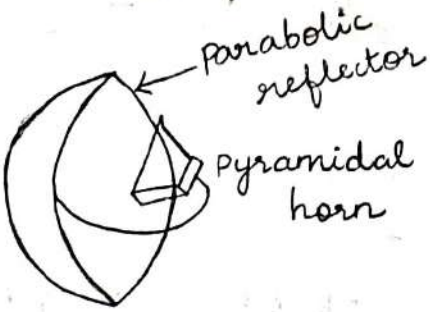


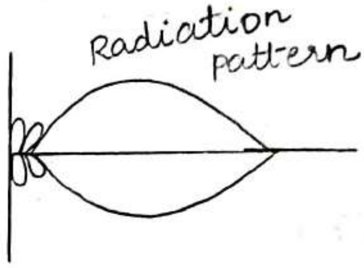
When the focal length is too large the focal point is beyond the open mouth of paraboloid. It is difficult to direct all the radiation on the reflection.

Due to the feed on focus at $f > \frac{d}{4}$, some of the rays gets escapes out of the reflector and constitute a loss called spillover.

Sometimes, instead of the wave moving in forward direction towards reflector, it moves from the feed to the straight, line which is in in opposite direction to the reflection, this is called backlobe radiation.

Parabolic reflector can be obtained by rotating the parabola around its axis and are called paraboloid. The radiation pattern consists of majorlobe which is very sharp and smaller minor lobes.





Power gain of reflector,

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

The actual area of circular aperture

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

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

$$= \frac{\pi^2 \times 0.65 \times d^2}{\lambda^2} \Rightarrow G_p = 6\left(\frac{d}{\lambda}\right)^2$$

The ratio $\left(\frac{d}{\lambda}\right)$ is called aperture ratio of paraboloid.

For large circular aperture,

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

where,

BWFN - Bandwidth first null.

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

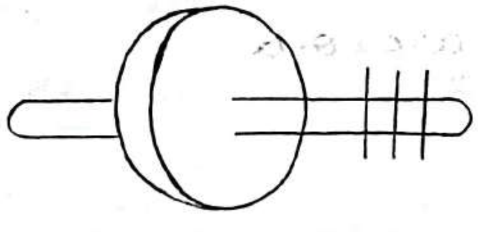
$$A_e = \pi\left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4}$$

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

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

Feed Systems:

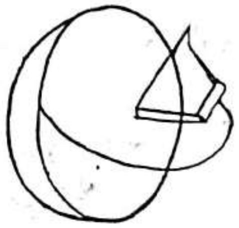
1) Array of dipole as feed:



The dipole are spaced in such a way that end fire pattern of an array illuminates reflector.

2) Horn - Antenna as feed:

Most widely used feed system is horn antenna. The horn antenna is fed with waveguide. If circular polarisation is required a rectangular horn is used.

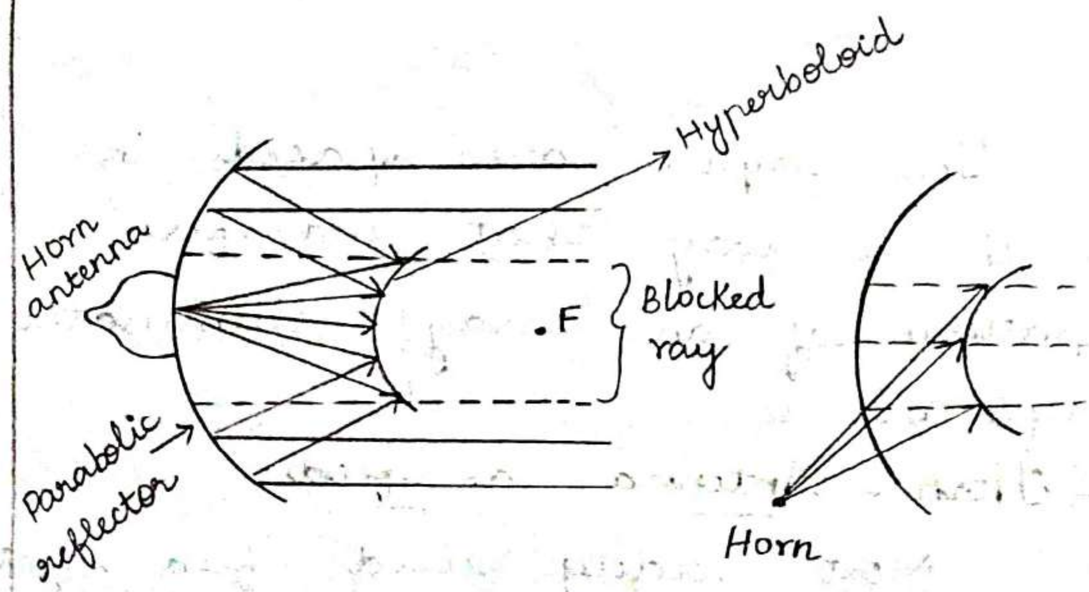


3) Cassegrain feed system:

This system uses a hyperboloid reflector placed such that one of the foci coincides with the focus of the paraboloid reflector.

It consists of main reflector, sub reflector and a feed.

Horn antenna radiates towards the subreflector which is the hyperbola placed at the focus of parabola.



Then the subreflector re-radiates the radiation towards the main reflector. From the main reflector collimated beam radiates out.

Advantages of cassegain feed:

* It reduces the spill over.
* System has ability to place a feed at convenient point.
* With this system greater focal length can be achieved.
* It provides high gain.

Disadvantages of cassegain feed:

Some rays are blocked by hyperboloid which is not serious problem incase of larger dimension paraboloid. But for small dimension of paraboloid is the major drawback of cassegrain feed system.

Microstrip Antenna:

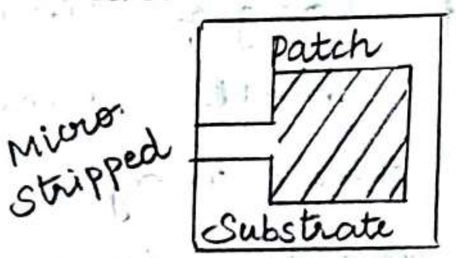
* A microstrip antenna is nothing but a metallic patch suspended over a ground plane.
* They were constructed on a

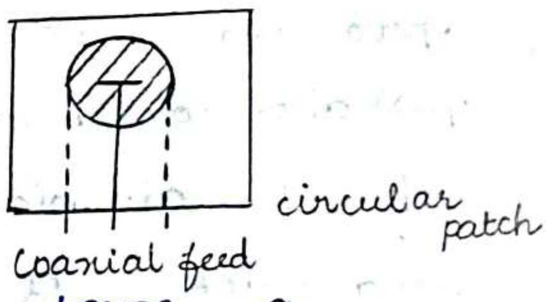
similar to lithography in which patterns are printed on a substrate.

* To protect the microstrip antenna from any damages the total assembly is enclosed in plastic enclosure.

* The microstrip antenna are of any shape like square, rectangular etc.

* The square patch produces pencil shaped beam pattern, the rectangular patch produces fan shaped beam pattern. The current distribution.





* In the basic form a microstrip antenna, on one side of the dielectric substrate is the radiating patch while on the other side is ground plane.

* Generally, the patch is half wavelength to achieve better performance.

* The current flows in the direction of field line so that the the electric field follows the current. The wave radiated by the microstrip antenna is linearly polarised wave.

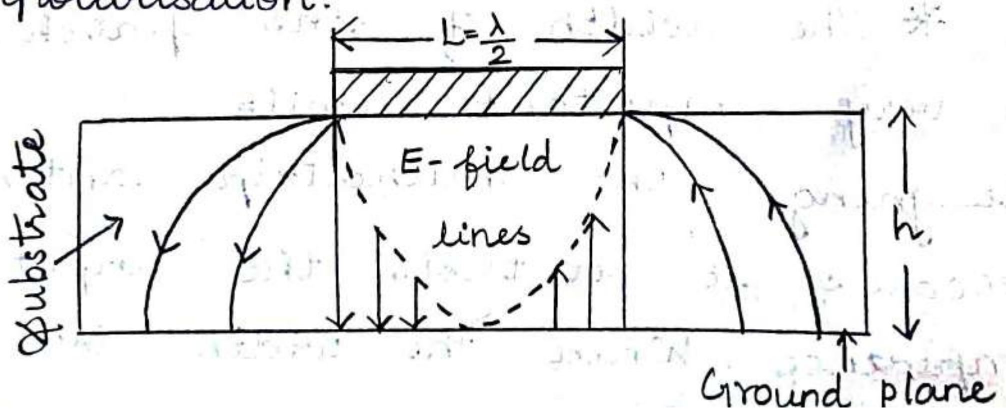
Rectangular Microstrip Patch Antenna:

* The most commonly used microstrip antenna is rectangular MSA.

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

* At the end of L dimension there are radiating edges which gives single polarisation.

* At the end of W dimension there are non-radiating edges with less radiation which gives cross polarisation.



* When the patch length is equal to half wavelength, the electric field produced below the patch are of opposite polarity.

* These E-field lines energes and propagated in a direction normal to the substrate.

* For effective radiation of microstrip antenna consider,

⇒ The metallic path should have / equal to half wavelength.

⇒ The dielectric substrate is enough thicker with low dielectric constant.

⇒ The height of the substrate should be a fraction of wavelength

* The critical frequency of operation is given as,

$$f_c = \frac{1}{2L\sqrt{\varepsilon_r \varepsilon_0 \mu_0}}$$

* The width of the patch is very important, while designing the microstrip antenna because it controls the input impedance. When the width increase

the input impedance decreases.

* The width also controls the radiation patterns.

Advantages of MSA:

* Smaller in size, light weight antennas which occupies less volume.
* MSA can be easily bolted or laminated to the metallic surface such as aircroll, missile.
* MSA is a mechanically robust antenna.
* MSA is versatile can be designed to produce variety of pattern and polarisation.
* It is reliable, since entire array up with a single copper clad.

Disadvantages of MSA:

* Used in aircrafts, space crafts, mobile radio, communication devices.
* The MSA's low gain and low efficiency antenna.
* The MSA is have narrow bandwidth of operation. They have lower power handling capacity.
* The size of microstrip antenna is inversely proportional

to frequency, they can be used only to very high frequencies only.

* The MSA's are poor end fire radiations.

Applications:

* Used in aircrafts, space crafts, mobile radio, communication devices.

* Feed antenna of microstrip antenna are,

⇒ Contacting feed: Patch is directly fed with RF power using microstrip line or coaxial line.

⇒ Non-contacting feed: Patch is directly fed with RF power instead power is transferred to the patch through electromagnetic coupling.

⇒ Centrefeed: The microstrip line is etched exactly at the centre of the patch.

⇒ Offsetfeed: The microstrip line is etched at the ~~center~~ corner of patch

Frequency Independent Antenna :

* A frequency independent antenna may be defined as the antenna for which the impedance and radiation pattern remain constant as a function

of the frequency.

* In order to be frequency independent the antenna should expand or contract in proportion to the wavelength

* It's practically impossible Hence log periodic antenna came into existence.

Logarithm (log) Periodic Antenna :

* The geometry of log periodic antenna is chosen such that electrical properties must repeat periodically with the logarithm of frequency

* It is fed at the narrow end The lengths and spacings are graduated in such a way that certain dimensions of adjacent elements bear a constant ratio in each other.

* The dipole length increases in such a way that included angle, α is constant. The scale factor or design

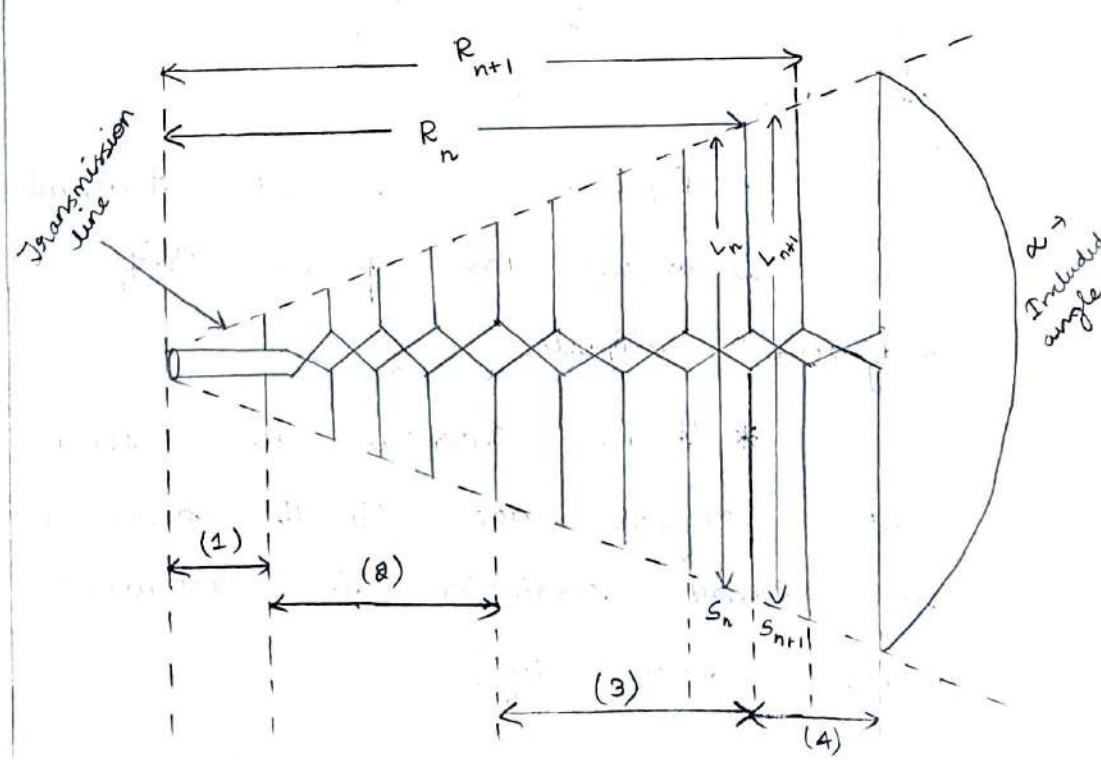
... designated by τ whose value is less than 1.

* The dipole lengths and spacing are related as,

$$\frac{R_1}{R_2} = \frac{R_2}{R_3} = \cdots = \frac{R_n}{R_{n+1}} = \tau = \frac{L_1}{L_2} = \frac{L_2}{L_3} = \cdots = \frac{L_n}{L_{n+1}}$$

$$\frac{R_n}{R_{n+1}} = \frac{L_n}{L_{n+1}} = \tau$$ (Periodicity factor or design ratio or scale factor)

$$\frac{S_{n+1}}{S_n} = \frac{L_{n+1}}{L_n} = K = \left(\frac{1}{\tau}\right) \; ; \; K > 1$$



→ Unloaded transmission line region
→ Loaded transmission line region } Inactive region ($L < \lambda/2$)
→ Active region ($L = \lambda/2$)
→ Reflective region ($L > \lambda/2$)

* The analysis of log periodic array can be done by considering 3 regions of antenna.

1) Inactive Region ($L < \lambda/2$)

* Antenna elements are short ont resonant length i.e., $L \leq \lambda/2$
* Elements present high Capacitance impedance.
* Element current is small and leads base Voltage by 90°
* Element spacing in wavelength is also small.
* By transposition of transmission line introduces 180° phase shift between adjacent dipoles.
* Hence currents in elements of these region are small and hence the small radiation in backward direction (towards left).

2) Active Region $(L = \lambda/2)$:

* Dipole lengths are approximately resonant length i.e., $L = \lambda/2$

* Impedance offered by the dipoles are resistive.

* Elements currents are large and inphase with base voltage. The spacing between two elements are now sufficiently large, causing the phase in a particular elements to lead approximately by 90°

* By the time field radiated from element $\overset{L_{n+1}}{\cancel{R_{n+1}}}$, reaches $\overset{L_n}{\cancel{R_n}}$ the phase of $\overset{L_n}{\cancel{R_n}}$ advances by 90° and its field add to the field of $\overset{L_{n+1}}{\cancel{R_{n+1}}}$ elements, in phase producing a large resultant field towards left

* Hence there is strong radiation towards left in backward direction and a little radiation towards right.

3) Inactive Reflective Region $(L > \lambda/2)$:

* Dipole lengths are longer than the resonant length.

* Impedance becomes inductive because $L > \lambda/2$, causing currents in the elements to lag the base voltage

* The base voltage supplied by transmission line is now very much small as almost all the energy transmitted down the line has been attracted and radiated by active region. This region presents a large reactive impedance to the line and thus any small amount of incident wave from active region is reflected back towards backward direction.

Design of log periodic Antenna :

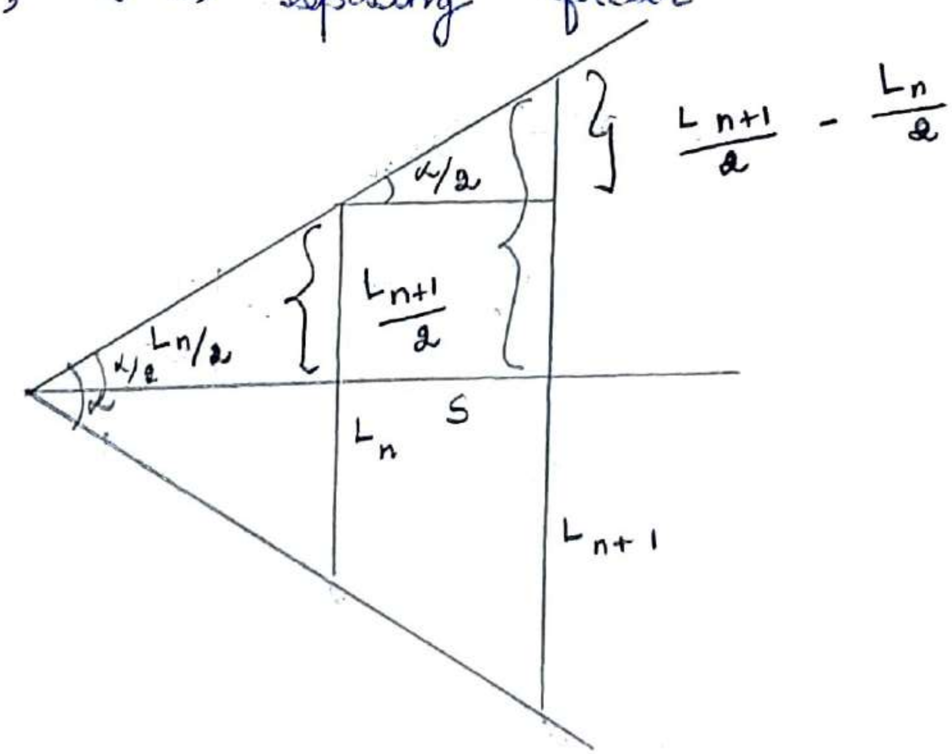
Log periodic dipole array consist of a sequence of side by side parallel linear dipole array.

$$\frac{L_{n+1}}{L_n} = \frac{L_n}{L_{n-1}} = \frac{S_{n+1}}{S_n} = \frac{1}{\tau} = k \,;$$

$$L_{n+1} = \lambda/2$$

$$\sigma = \frac{S_n}{2L_n}$$

Where, $\sigma \rightarrow$ spacing factor



From this triangle

$$\tan \alpha/2 = \frac{\left(\frac{L_{n+1}}{2}\right) - \left(\frac{L_n}{2}\right)}{S}$$

$$\tan \alpha/2 = \frac{L_{n+1} - L_n}{2S}$$

$$= L_{n+1} \left[\frac{1 - L_n/L_{n+1}}{2S} \right]$$

Substitute, $\frac{L_n}{L_{n+1}} = \frac{1}{K} = \tau$

$$\tan \alpha/2 = L_{n+1} \left[\frac{1-\tau}{2S} \right]$$

$$\therefore L_{n+1} = \lambda/2$$

$$\tan \alpha/2 = \frac{\lambda}{2} \left[\frac{1-\tau}{2S} \right]$$

$$\tan \alpha/2 = \frac{1-\tau}{(S/\lambda) \times 4}$$

$$\therefore \sigma = \frac{S}{2L_n} \Rightarrow \frac{S}{2 \times \lambda/2} = \frac{S}{\lambda}$$

$$\tan \alpha/2 = \frac{1-\tau}{4\sigma}$$

$$\alpha/2 = \tan^{-1}\left(\frac{1-\tau}{4\sigma}\right)$$

$$\alpha = 2\tan^{-1}\left(\frac{1-\tau}{4\sigma}\right)$$

Where, $\alpha \rightarrow$ Apex angle / Included angle

$\sigma \rightarrow$ Spacing factor

$\tau \rightarrow$ Scale factor

General Characteristics :

* Log periodic antenna is excited from the shorter length side. for one active region and at the centre of two active region. They are fed by a balanced two wire transmission line.

* For unidirectional log periodic antenna, the radiation pattern is towards the left.

* For bidirectional log periodic antenna, the maximum radiation is in broadside direction.

* Transmission line inactive region must have proper characteristic impedance with small amount of radiation.

* In active region, maximum radiation in backward and zero radiation in forward direction.

* In reflective region there should be rapid decay of current.

Uses of log periodic antenna :

* It is used in the field of HF communication where multi-band steerable and fixed antennas are used.

* It is used for Television reception even upto the frequency of UHF band.

* It is suited for all roun

monitoring