1. Define the following
   i) Parasitic array
   ii) Resonant and non-resonant antennas
   iii) Optimal horn design.

A: i) Parasitic Array:-

In order to overcome feeding problems of the antenna, sometimes, the elements of the array are fed through the radiation from the nearby element. The array of antennas in which the Parasitic elements get the power through electromagnetic coupling with the driven element which is in proximity with the Parasitic element is known as "Parasitic array"

The simplest form of the parasitic array consists one driven element and one Parasitic element. In multielement Parasitic array, there may be one or more driving elements and also one or more parasitic elements. So in general the multielement Parasitic array is the array with at least one driven element and one or more parasitic elements.

The common example for of the Parasitic array with linear half dipoles as elements of array is Yagi-Uda array or simply "Yagi antenna"

The amplitude and the Phase of the current Induced in the Parasitic element depends on the spacing between the driven element and Parasitic element. To make the radiation pattern unidirectional, the relative phase of the currents are changed by adjusting the spacing between the elements. This is called tuning of array

ii) Resonant and non-Resonant antennas

An antenna is said to be resonant if its input impedance is entirely real

ie., $Z_{in} = R + j(0)$

In this case the voltage and current are in phase at the antenna's terminals. This property makes the impedance matching of an antenna to a transmission line and receiver easier, as the imaginary part of the impedance doesnot need tuned out.

→ An antenna that has an approximatley constant input impedance over a wide range of frequencies is called a non-resonant antenna (or) wide band antenna.

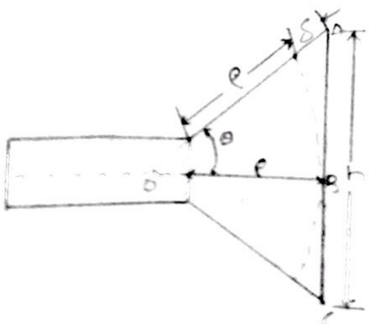
A diamond antenna is an example. It is the non resonant antenna

→ It is also known as aperiodic antenna (or) un-tuned antenna

iii) Optimal horn design:-

Horn antenna is widely used simplest form of microwave antenna.

The Horn antenna can be cosiderd as the waveguide with hallow pipe of different cross-sections which is flared or tapered into a large opening.



from the geometry

$\cos\theta = \frac{\ell}{\ell+\delta}$ also $\tan\theta = \frac{h/2}{\ell} = \frac{h}{2\ell}$

we can write

$$\boxed{\theta = \cos^{-1}\left[\frac{\ell}{\ell+\delta}\right] = \tan^{-1}\left[\frac{h}{2\ell}\right]} \quad -(1)$$

and By right angle triangle OBA

$$(P+\delta) = \sqrt{\ell^2+\left(\frac{h}{2}\right)^2}$$

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

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

As δ is factional, δ^2 is neglected

$$2\ell\delta = \frac{h^2}{4} \qquad \delta << \ell$$

$$\boxed{\ell = \frac{h^2}{8\delta}} \quad -(2)$$

(1) + (2) are design equations.

for optimal horn design.

→ optimal design takes care of how much flare angle to be choosen for given horn length in order to get <u>maximum directivity</u>

for rectangular horn

$$a_E = \sqrt{2\lambda(L+\delta E)}$$

$$a_H = \sqrt{3\lambda(L+\delta H)}$$

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

A_e : Effective aperture, m^2

A_P - Physical aperture, m^2

$\varepsilon_{ap} = \frac{A_e}{A_P}$ = aperture efficiency

2. List the various bands in RF spectrum

A. Radio frequency is the lowest portion in the electromagnetic spectrum familiar as a medium of analogue and modern digital wireless communication system. It spreads in the range of 3KHz-300GHz

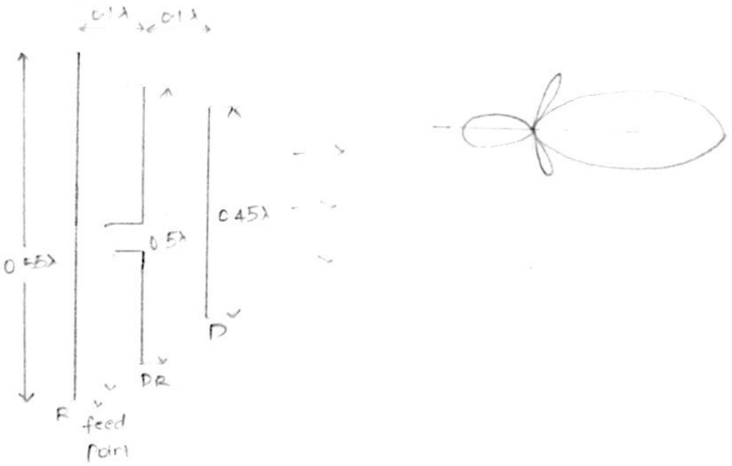
Designation	Abbrevation	frequency	wavelength	Applications
Very low frequency	VLF	3KHz-30KHz	10km-100km	Scientists use in seismic study by understand natural activities in earth's atmosphere.
Low frequency	LF	30-300kHz	1-10km	amateur radios, military applications submarines
medium frequency	MF	300K-3MHz	100m-1km	AM radio, navigation systems for ships, aircrafts, coast guards.
High frequency	HF	3-30MHz	10-100m	aviation industry, government systems weather broadcasting system
very high frequency	VHF	30-300MHz	1-10m	analog TV broadcasting FM broadcasting. MRI scanning
Ultra high frequency	UHF	300M-3GHz	10mm-1m	GPS, navigation, wifi bluetooth etc, mobile transmission
Super high frequency	SHF	3-30GHz	10-100mm	DTH service, microwave oven, mobile networks
Extremly High frequency	EHF	30-300GHz	1-10mm	radio astronomy, remote sensing.

3. Discuss the effect of reflector and director [illegible] next to a driven element.

A. A basic yagi-uda antenna consists of one driven element, a reflector and one director.

The driven element is a resonant half wave dipole.

Scientists found that highest gain is possible with the ~~director~~ reflector of lenegth equal to $\frac{\lambda}{2}$ located a distance $\frac{\lambda}{4}$ from driven element, along with director approximatly 10% less than $\frac{\lambda}{2}$ located at a distance $\frac{\lambda}{3}$ from driven element.

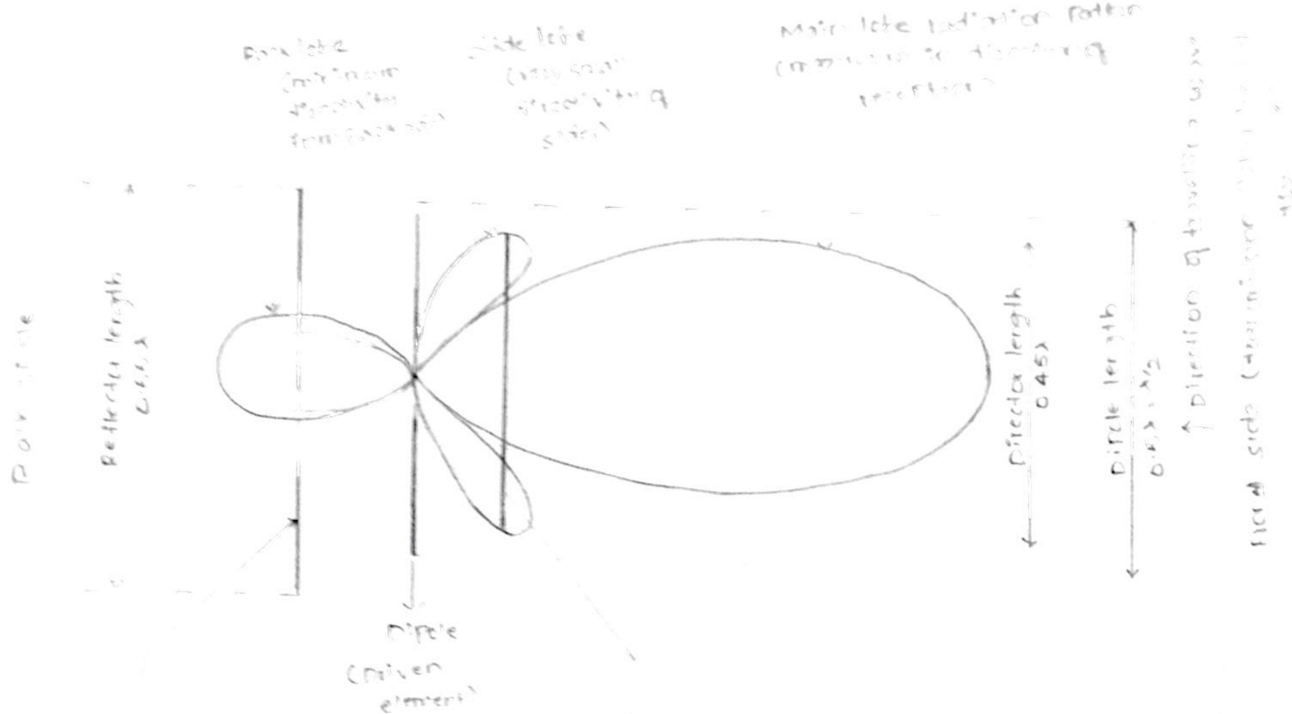


The parasitic element receives excitation through induced emf as current flows in the driven element.

A yagi uda antenna uses both the reflector(R) and the director (D) elements in same antenna. The parasitic element back side of driven element is reflector. It is of larger length compared with remaining elements. The element in front of the driven element is director which is of lowest length in all three elements.

→ If the parasitic element greater than length $\frac{\lambda}{2}$ (i.e. reflector) then it is inductive in nature. Hence phase of the current in such element i.e. in reflector lags the induced voltage. Reflector adds the fields in the direction towards the driven element.

→ If the parasitic element less than length $\frac{\lambda}{2}$ (i.e. director) then it is capacitive in nature. Hence the current in director (away from the driven element) leads the induced voltage. The directors adds the fields of the driven element in the direction away from the driven element.



Reflector:

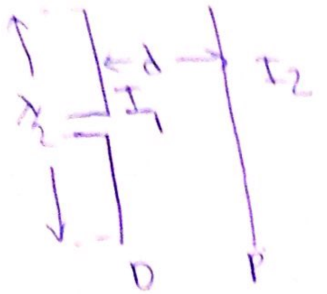
Reflects the signal coming from [illegible] side and totally attenuates the [illegible] signals [illegible]

Director:

Retransmits the signal collected from front side towards dipole. It attenuates the signal coming from sides and back side

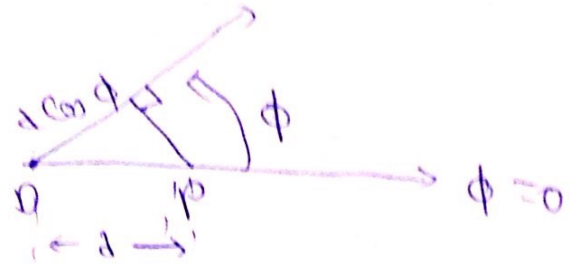
4. Discuss radiation from a 2 element parasitic array

A. Consider a 2 element parasitic array



D: Driven element

P: Parasitic element



Let both the elements be vertical and parallel to each other such that azimuth angle φ is a shown. Two elements are separated by distance d. Let I_1 be current in driven element D. Similarly I_2 be (element) current induced in parasitic P. The relation between voltages and currents can be written on the basis of circuit theory

$$V_1 = Z_{11} I_1 + Z_{12} I_2 \longrightarrow (1)$$

$$0 = Z_{21} I_1 + Z_{22} I_2 \longrightarrow (2)$$

Parasitic element P is not excited, the applied voltage V_2 is zero. V_1 is applied voltage at driven element D

The impedances Z_{11} and Z_{22} are self impedances of driven element D and parasitic element P. Impedances Z_{12} and Z_{21} is mutual impedance between two elements

$$Z_{12} = Z_{21} = Z_M$$

Let $Z_M = R_m + jX_M = R_{12} + jX_{12} = |Z_{12}| \angle \theta_M$

$$|Z_{12}| = \sqrt{R_{12}^2 + X_{12}^2}, \quad \theta_M = \tan^{-1}\left(\frac{X_{12}}{R_{12}}\right).$$

$$Z_{22} = R_{22} + jX_{22} = |Z_{22}| \angle \theta_2$$

$$|Z_{22}| = \sqrt{R_{22}^2 + X_{22}^2}, \quad \theta_2 = \tan^{-1}\left(\frac{X_{22}}{R_{22}}\right)$$

From eqn ②,

$$I_2 = \frac{-Z_{21}}{Z_{22}} I_1 = -\frac{Z_{12}}{Z_{22}} I_1 \quad (\because Z_{12} = Z_{21})$$

$$\therefore I_2 = \frac{-|Z_{12}| \angle \theta_M}{|Z_{22}| \angle \theta_2} I_1$$

$$I_2 = -I_1 \left[\left| \frac{Z_{12}}{Z_{22}} \right| \angle (\theta_M - \theta_2) \right]$$

$$\therefore I_2 = I_1 \left[\left| \frac{Z_{12}}{Z_{22}} \right| \angle \xi \right]$$

$$\xi = \pi + (\theta_M - \theta_2)$$

$$Z_1 = \frac{V_1}{I_1} = Z_{11} - \frac{Z_{12}^2}{Z_{22}}$$

$$Z_1 = Z_{11} - \frac{|Z_{12}^2| \angle 2\theta_M}{|Z_{22}| \angle \theta_2}.$$

Real part

$$R_1 = R_{11} - \left[\left| \frac{Z_{12}^2}{Z_{22}} \right| \cos(2\theta_M - \theta_2) \right]$$

R_{1Loss} be effective loss resistance

$$R_1 = R_{11} + R_{1Loss} - \left[\left| \frac{Z_{12}^2}{Z_{22}} \right| \cos(2\theta_M - \theta_2) \right]$$

Let P_{in} = input power.

$$P_{in} = I_1^2 R_1$$

$$I_1 = \sqrt{\frac{P_{in}}{R_1}}$$

$$I_1 = \sqrt{\frac{P_{in}}{\left[R_{11} + R_{Loss} - \left| \frac{Z_{12}^2}{Z_{22}} \right| \cos(2\theta_M - \theta_2) \right]}}$$

[illegible]

[illegible]

$d_r = \beta d = \left(\frac{2\pi}{\lambda}\right) d$

$$\therefore E(\phi) = k \left[I_1 + I_1 \left\{ \left| \frac{Z_{12}}{Z_{22}} \right| \angle \theta_1 \right\} \angle d_r \cos\phi \right]$$

$$\therefore E(\phi) = k I_1 \left[1 + \left| \frac{Z_{12}}{Z_{22}} \right| \angle \theta_1 + d_r \cos\phi \right]$$

$$\therefore E(\phi) = k \sqrt{\frac{P_{in}}{R_{11} + R_L - \left| \frac{Z_{12}^2}{Z_{22}} \right| \cos(2\theta_M - \theta_2)}} \left(1 + \left| \frac{Z_{12}}{Z_{22}} \right| \angle \theta_1 + d_r \cos\phi \right)$$

Assume that parasitic element is absent and same input power P_{in} is applied to $\frac{\lambda}{2}$ dipole driven element,

$$E_{HW}(\phi) = k I_0 = k \sqrt{\frac{P_{in}}{R_0 + R_{0Loss}}}$$

R_0 = self resistance of $\frac{\lambda}{2}$ dipole element alone

R_{0Loss} = Loss resistance of $\frac{\lambda}{2}$ dipole element alone.

$$\text{Gain} = G_f(\phi) \left[\frac{A}{HW} \right]$$

$$= \sqrt{\frac{R_{11} + R_{1Loss}}{R_{11} + R_{1Loss} - \left| \frac{Z_{12}^2}{Z_{22}} \right| \cos(2\theta_M - \theta_2)}} \left(1 + \left| \frac{Z_{12}}{Z_{22}} \right| \angle \theta_1 + d_r \cos\phi \right)$$

- When $\frac{\lambda}{2}$ parasitic element is larger than the resonant length, it Z_{22} is inductive in nature. Then such parasitic element acts as reflector ie, it adds the fields in the direction towards the driven element.

Similarly when $\frac{\lambda}{2}$ parasitic element is smaller than the resonant length, it Z_{22} is capacitive in nature. Then such parasitic element acts as director ie, it adds the fields in the direction away from the driven element

5 Design a 5 element Yagi Uda array required to operate at 160 MHz

A. $f = 160\ MHz$.

Length of dipole $D_R = \frac{143}{f(MHz)} = \frac{143}{160} = 0.893\ m$

Length of reflector $R = \frac{152}{f(MHz)} = \frac{152}{160} = 0.95\ m$

Length of director 1 $= \frac{137}{f(MHz)} = \frac{137}{160} = 0.85\ m$

Length of director 2 $= \frac{133}{f(MHz)} = \frac{133}{160} = 0.83\ m$

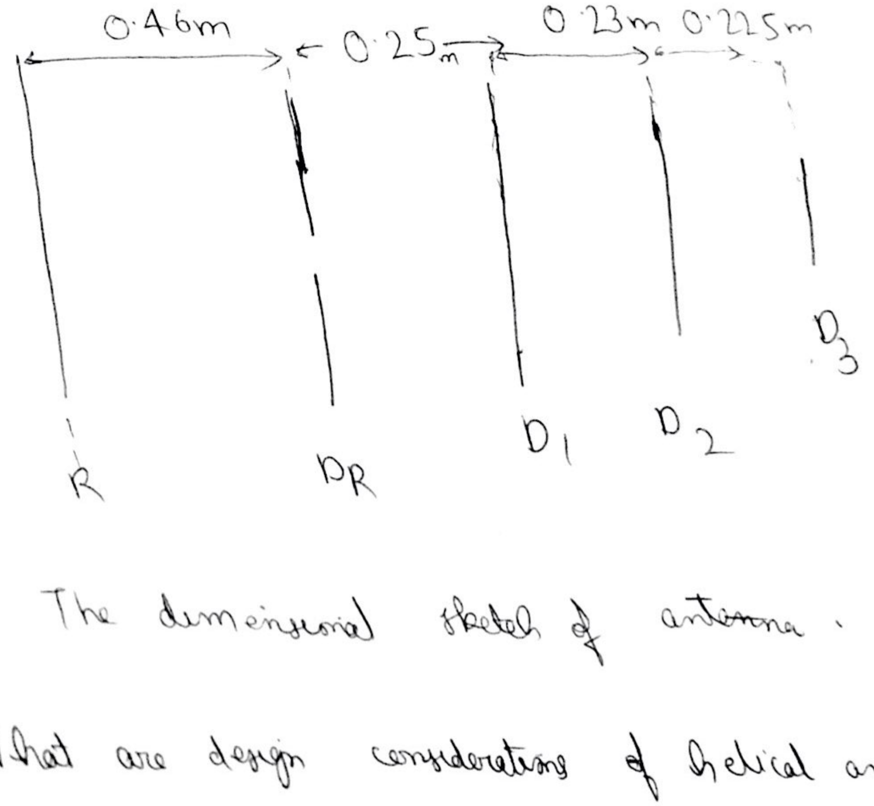
Length of director 3 $= \frac{130}{f(MHz)} = \frac{130}{160} = 0.8125\ m$

Spacing between reflector and dipole = $\frac{[illegible]}{f(MHz)} = \frac{[illegible]}{160} = 4$[illegible]

Spacing between dipole and director 1 = $\frac{40}{f(MHz)} = \frac{40}{160} = 0.2$[illegible]

Spacing between director 1 and director 2 = $\frac{38}{f(MHz)} = \frac{38}{160} = 0.23m$

Spacing between director 2 and director 3 = $\frac{36}{f(MHz)} = \frac{36}{160} = 0.225m$



The dimensional sketch of antenna.

3. What are design considerations of helical antenna in normal mode of operation? Give analysis procedure

A. In this mode of helical antenna, radiation is maximum in broadway direction i.e Normal or perpendicular to axis of helix

This mode of radiation can be obtained if helix dimensions are made very small as compared with radiation N.S << λ. This mode of radiation, bandwidth of antenna becomes narrow and radiation efficiency becomes very less.

When pitch angle $\alpha = 0$, helix corresponds to a loop and when $\alpha = 90^0$ then it is linear dipole

Consider a helix in spherical co-ordinate system. It is approximated to be made of small loops and short dipoles arranged in series such that loop diameter equal to helix diameter D and length of short dipole equal to spacing between two helix S.

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

I = Retarded current, A

r = Distance at point, m

A = Area of loop (m2)

λ = Wavelength (m)

Short dipole

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

$S = dL$ = Length of dipole

$$A \cdot R = \left| \frac{E_\theta}{E_\phi} \right| = \frac{\left| j \frac{60\pi [I] \sin\theta}{r} \cdot \frac{S}{\lambda} \right|}{\left| j \frac{120\pi^2 [I] \sin\theta}{r} \frac{A}{\lambda^2} \right|}$$

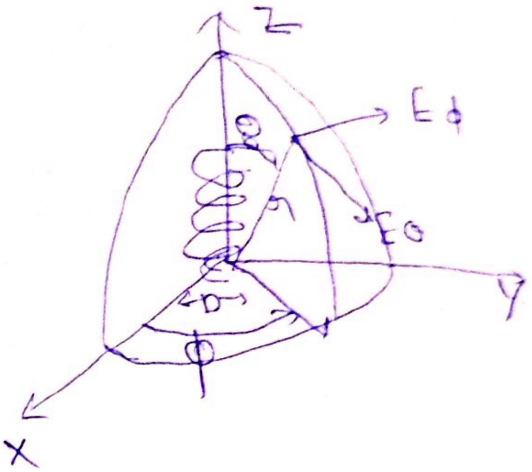
$$\therefore A \cdot R = \frac{2S\lambda}{\pi^2 D^2}$$

(i) $A \cdot R = 0$, elliptical polarization becomes linear horizontal polarization

(ii) $A \cdot R = \infty$, elliptical polarization becomes linear vertical polarization

(iii) $A \cdot R = 1$, elliptical (point) polarization becomes circular polarization

$$|E_\theta| = |E_\phi|$$



$$2S\lambda = \pi^2 D^2$$

$$\boxed{S = \frac{C^2}{2\lambda}}$$

C = Circumference = πD

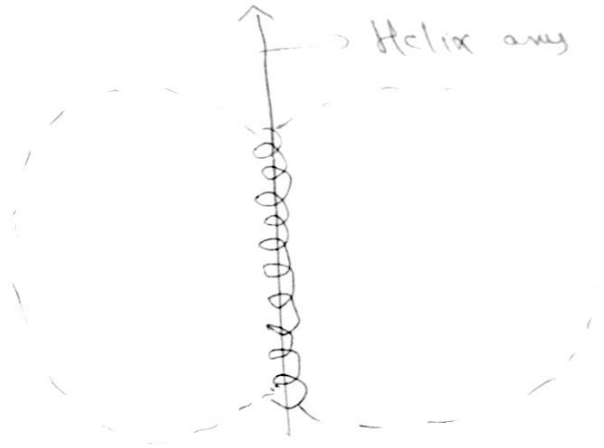
α = angle of pitch = $\tan^{-1}\left(\frac{S}{\pi D}\right)$

$$= \tan^{-1}\left(\frac{\frac{\pi^2 D^2}{2\lambda}}{\pi D}\right)$$

$\alpha = \tan^{-1}\left(\frac{C}{2\lambda}\right)$

C = Circumference = πD

The resultant radiation pattern for helical antenna in normal mode can be obtained by superposing field patterns of loop and dipole for circular polarization

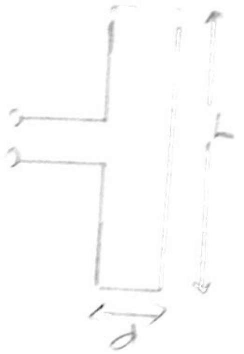


Normal mode circular polarization pattern for helical antenna

7. Find the input impedance of a 2 wire folded dipole antenna.

A) <u>Folded dipole antenna</u>:

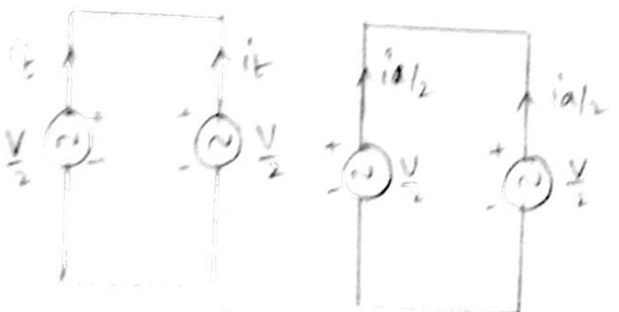
A folded dipole is a dipole antenna with the ends folded back around and connected to each other, forming a loop.



A folded dipole antenna of length L

<u>Derivation for input impedance of folded dipole antenna</u>:

Let us consider a folded dipole as shown in below figure. The equivalent circuit of two wire folded dipole of length $\lambda/2$ is shown in figure.



Transmission line equivalent ckt antenna mode equivalent ckt

The impedance in the transmission line equivalent ckt of the dipole is given as Z_t and in the antenna mode equivalent ckt, it is given as Z_a.

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from the above figure

We get, $I_t = \frac{V/2}{Z_t}$

$I_a = \frac{V/2}{Z_a}$

The total current is given by $I = I_t + \frac{I_a}{2}$

i.e $I = \frac{V/2}{Z_t} + \frac{V/2}{2Z_a}$ $\left(\because I_t = \frac{V/2}{Z_t} \text{ \& } I_a = \frac{V/2}{Z_a}\right)$

$$I = \frac{V}{2Z_t} + \frac{V}{4Z_a}$$

$$I = \frac{V}{2}\left[\frac{1}{Z_t} + \frac{1}{2Z_a}\right]$$

$$\frac{I}{V} = \frac{1}{2}\left[\frac{2Z_a + Z_t}{2Z_a Z_t}\right]$$

$$\frac{V}{I} = \frac{4 Z_a Z_t}{2Z_a + Z_t} \Rightarrow Z_{in}.$$

$$\therefore \boxed{Z_{in} = \frac{4Z_a Z_t}{2Z_a + Z_t}}$$

Considering a half wave dipole antenna, i.e,

$Z_t = \infty$

We get $Z_{in} = 4Z_a$.

$$\boxed{Z_{in} = 4 \times 73\Omega = 292\,\Omega}$$

$\therefore$ The input impedance of two wired folded dipole of length $\frac{\lambda}{2}$ is equal to 292Ω.

In general n wire folded dipole input impedance is given by

$$\boxed{Z_{in} = n^2 \times Z_a}$$

The above equation is true when the wire diameters are equal. When the radii are unequal Zin is given by the expression

$$\boxed{Z_{in} = Z_a\left[1+\frac{\log\frac{s}{r_1}}{\log\frac{s}{r_2}}\right]^2}$$

9) Explain about the design considerations of monofilar axial mode helical antenna.

A). <u>Helical antenna</u>:

Helical antenna basically a simple broadband VHF and UHF antenna which provides circular polarization. It consists of a thick copper wire wound in the form of a screw thread forming a helix.

Eventhough, a helix radiates in many modes, the modes of special interest are normal mode and axial mode. In normal mode, the radiation is maximum along the broadside to the helix axis under condition that the circumference of the helix is smaller with respect to one wavelength. Whereas in axial mode, the maximum radiation is along the helix axis under condition that ~~the~~ the circumference of the helix is of the order of one wavelength.

<u>Design consideration of monofilar axial mode helical antenna</u>:

Single thick wire in form of helical shape is called a monofilar.

The performance of helical antenna is based on resultant Bandwidth, Beamwidth, gain, Z_{in}, axial ratio (AR).

These parameters are functions of no. of turns (N) and spacing between turns s, operating frequency. They also depend on ground plane size and shape, helix conductor diameter, helix support structure feed arrangement.

→ Conductor diameter:

Helix conductor diameter varies between 0.005λ to 0.05λ.

→ Circumference: $0.8\lambda \leq C \leq 1.2\lambda$ (or) $\frac{3}{4} < C_\lambda < \frac{4}{3}$

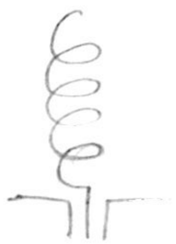
& pitch angle: $12° \leq \alpha \leq 14°$

$N \geq 4$

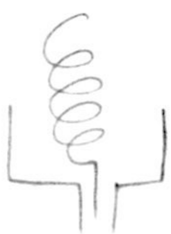
Where α is pitch angle and N is no. of turns.

→ We have the following possibilities with regard to the shape of ground plane

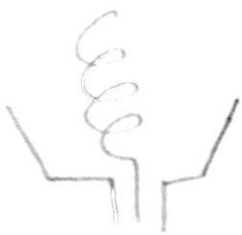
1) Flat ground:



2) Cup shaped ground:



3) General purpose flush mounted:



4) Aircraft Skin:

→ Helix support structure

We have following support structures

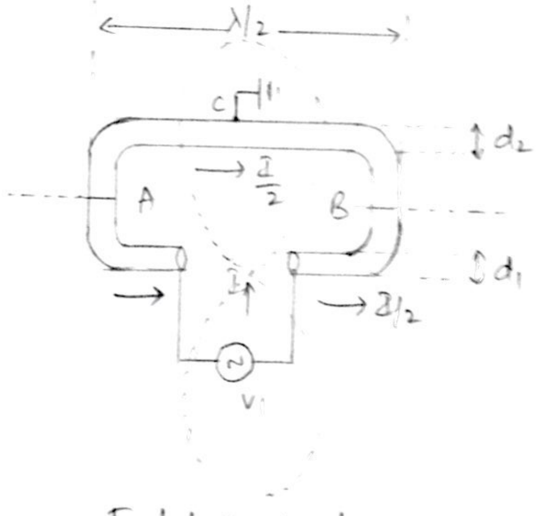
(i)  rods with radial insulators

(ii)  four peripheral dielectric rods

(iii) Dielectric tube 

8) Discuss the radiation characteristics of a folded dipole antenna. Compare that with the radiation characteristics with the half wave dipole.

A) The below figure shows the radiation pattern of a folded dipole.



Folded dipole and radiation pattern

1) It is basically a single antenna consisting two or three elements. The first element is fed directly while second and or third elements are coupled inductively at the ends.

2) The radiation pattern of the conventional half wave dipole and that of the folded dipole are exactly same. But the main difference between the two is that the input impedance of the folded dipole is much higher than that of the conventional half wave dipole. There are two more important factors which differ folded dipole from the conventional half wave dipole. They are directivity and bandwidth.

3) The radiation pattern of folded dipole antenna is same as that of the straight dipole.

4) In a straight dipole, the total current is I. But in folded dipole if current fed is I, then the current in each arm is $\frac{I}{2}$ with condition that both arms are of same dimension.

5) The input impedance of a folded dipole is 4 times that of straight dipole i.e $R_{rad} = 4(73) = 292\Omega$.

6) By using different diameters of two arms of folded dipole, the impedance can be transformed by factor ranging from 1.5 to 25.

7) The spacing between arms of the folded dipole is very small and it is of the order of $\lambda/100$.

Advantages of folded dipole antenna:

1) It has high input impedance.
2) It has greater bandwidth.
3) It acts as built in reactance compensation network.
4) Its construction is simple and cheaper.
5) It has better impedance matching characteristics.

Applications:

→ used as driven element in Yagi uda antenna.

→ Used as feed element for the antennas with very low and ~~are~~ very high terminal impedances.

10) Discuss radiation from a helical antenna operated in axial & normal modes. Give the Directivity and beamwidth expressions.

Ans

Radiation from helical Antenna:

A helical antenna operates in 2 modes.

(i) Normal mode of operation.

(ii) Axial mode of operation.

(i) Normal mode of operation:

In this mode of helical antenna, the radiation is maximum in broadway direction i.e, perpendicular (normal) to the axis of helix, hence this mode is called Normal mode of operation.

When the axial length $(n-1)S$ of helix is much less than one wave length $(n-1)S << \lambda$, at the frequency of operation, the antenna gives maximum radiation in the direction normal to the axis of helix defined as Normal mode.

→ Radiation pattern of helical antenna (normal to helix axis)

we approximate helix using small loops and short dipoles.

$$\text{axial ratio} = \frac{E_\theta}{E_\phi} = \frac{\text{major axis}}{\text{minor axis}}$$

E_θ = 'E' field due to short dipole

E_ϕ = 'E' field due to small loop

Now, we get elliptical polarization. This mode of operation has more disadvantages than advantages.

i.e, ~~Efficie~~ Efficiency is low, ~~Band~~

Beamwidth is narrow due to transistion & diffused Capacitance.

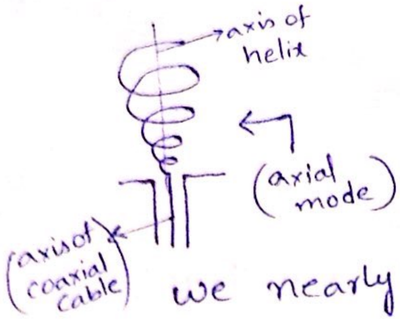
axial ratio is high.

(ii) Axial Mode of Operation:

The helical antenna radiating field maximum ~~is~~ along the axis of helix is called axial mode (or) end fire mode helical antenna.

when the axial length is close to one wavelength at the frequency of operation.

Resultant radiation has main lobe along axis of helix.



→ Radiation pattern in axial mode of helical antenna.

we nearly get circularly polarized output.

and axial ratio $= \frac{E_\theta}{E_\phi} = \frac{2n+1}{2n}$ ($n \to$ no. of turns)

Helix have either right handed circular polarization (clockwise) or left handed circular polarization (anticlockwise).

It has wide bandwidth $\left(\frac{f_H}{f_L} \simeq 1.8\right)$

FNBW =

D =

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11) Explain how a horn can act as radiating element. Mention the various types of horn. write its merits and demerits.

Ans Types of horn antenna:

Horn antennas are classified as rectangular horn antennas and circular horn antennas.

~~Base~~

Horn antenna

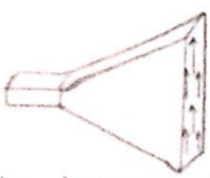
- Rectangular horn antenna.
  - fed with rectangular waveguide
  - (Depending on flaring in rectangular horn antenna)
    - Sectoral horn
      - It is obtained if the flaring is done in one direction only.
        - E-plane sectoral horn
        - H-plane sectoral horn
    - Pyramidal horn
      - flare out is done in both planes.
- Circular horn antenna
  - fed with circular waveguide.
    - Conical horn
    - Biconical horn

(Conical horn)

Biconical horn

(Pyramidal horn)

E-plane sectoral horn



(E plane sectoral horn)

E field planes are circular and visible from side view.

H-plane sectoral horn

(H-plane sectoral horn)

H field lines are circular and visible from only top view and bottom view.

Merits of horn antenna

1) Moderate directivity

2) Low standing wave ratio

3) broad bandwidth , simple construction.

4) Since they have no resonent elements, they can operate over a wide range of frequencies , a wide bandwidth.

Demerits of horn antenna

1) The gain of horn antenna is subjected to major fluctuations particularly at low frequencies

~~2) VSWR in the lower frequency~~ range is unfavorable ~~with values of between 2 and~~ 3.

2) Moderate gain and it is not applicable in UHF, VHF.

Horn antenna as radiating element:

The horn antenna is considered as waveguid with hollow pipe of different cross section which is flared into large opening.

When one end of the waveguide is excited while the flared (other) end is kept open, it radiates in open space in all directions.

Under condition of proper impedance matching (proper flare out) Total power incident will be radiated in forward direction. Thus radiation is increased. (As the edges are flared out, the diffraction at edges reduces thus directivity improves)

12) i) write the design equations of pyramidal horn. What is an optimal horn?

ii) A pyramidal horn antenna has aperture dimensions of 7λ and 4λ in H and E planes respectively. Complete the design if it is supposed to give a gain of 17 dB. Also find HPBW in both the planes., $\delta E = 0.25\lambda$, $\delta H = 0.375\lambda$

Ans i) Design equation of pyramidal horn

$$D = \frac{4\pi A_e}{\lambda^2} \Rightarrow D = \frac{7.5 A_p}{\lambda^2} \qquad (A_p = a_E a_H)$$

$$A_e = K A_p \qquad K = \text{aperture efficiency.}$$

$$\boxed{L \simeq \frac{A^2}{8\delta H}}$$

$$\boxed{\theta_H = 2\tan^{-1}\frac{A}{2L}}$$

optimal horn

(It takes care of how much flare angle is to be chosen for given horn length in order that we get maximum directivity.) → optimal design.

optimal horn is that when flare angle is too small, aperture area for specified length $\int$ becomes small, thus at the mouth of horn, uniform phase is resulted which increases directivity and decrease in beam width.

12 (ii) Given $a_E = 4\lambda$, $a_H = 7\lambda$

$\delta_E = 0.25\lambda$, $\delta_H = 0.375\lambda$

$G_1 = 17\,dB$.

~~Approximate as~~

$\cancel{G_{1(dB)} = 17\,dB}$

$\cancel{D \; G_1 = 10^{\ldots}}$

$G_1 = 10^{1.7} = 50.118$

design eqns

$$L = \frac{a_E^2}{8\delta_E} = \frac{a_H^2}{8\delta_H} \Rightarrow \frac{a_E^2}{8\delta_E} = \frac{(4\lambda)^2}{8(0.25\lambda)} = 8\lambda$$

$$\theta_E = 2\tan^{-1}\left(\frac{a_E}{2L}\right) = 2\tan^{-1}\left(\frac{4\lambda}{2\times 8\lambda}\right) = 28.072^\circ$$

$$\theta_H = 2\tan^{-1}\left(\frac{a_H}{2L}\right) = 2\tan^{-1}\left(\frac{7\lambda}{2\times 8\lambda}\right) = 47.258^\circ$$

~~and~~ ~~D~~.

and HPBW of H plane $= \dfrac{67^\circ}{(a_H/\lambda)}$ degrees

$$= \frac{67^\circ}{(7\lambda/\lambda)} = 9.571^\circ$$

HPBW of E plane $= \dfrac{56^\circ}{(a_E/\lambda)} = \dfrac{56^\circ}{(4\lambda/\lambda)} = 14^\circ$