Antenna Array :-

1

⇒ It is multiple elements of Antenna combined together to have desired radiation pattern.

In wireless communication we need to have narrow beam for large distance communication so it is possible by two ways.

1) Increase the size of Antenna

2) Using Antenna Array

In wireless communication Antenna Array is used because of added advantages.

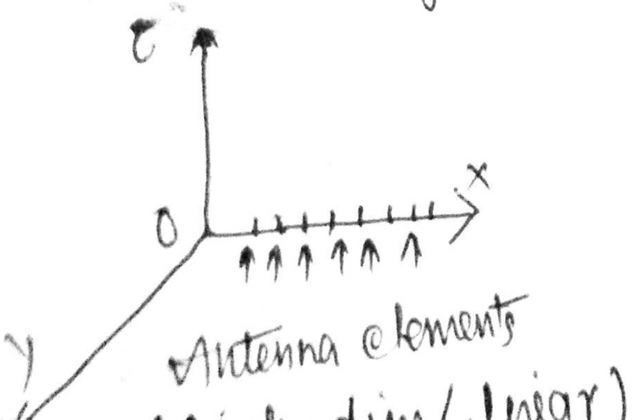
1) To increase gain of Antenna

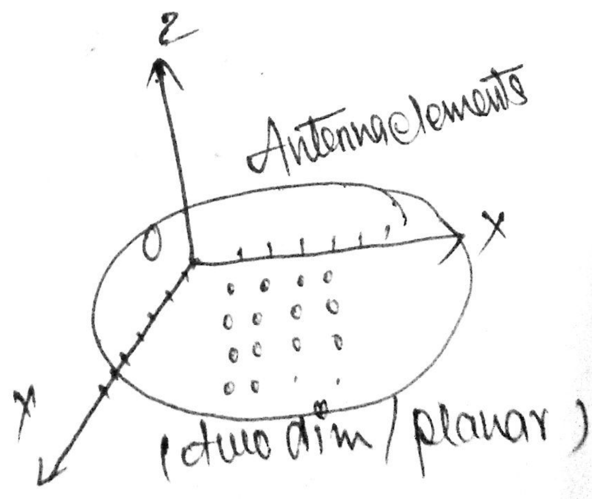
2) To have narrow beam

⇒ In Antenna Array almost similar Array are used not compulsory but we usually find because of simplicity & practically.

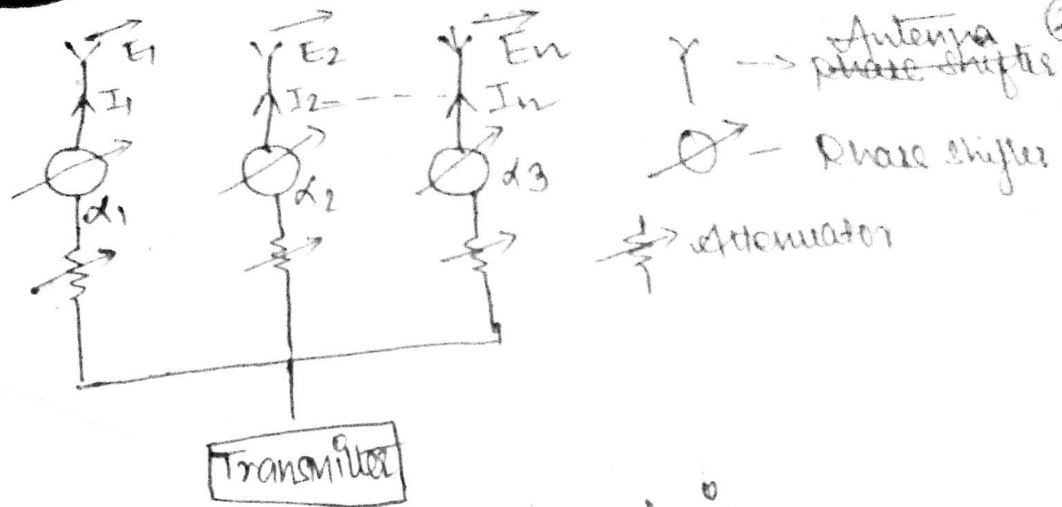
⇒ If array arranged in One ~~Array~~ Axis (x, y, z) than it is said to be One dimensional Array or linear Array.

⇒ If Array is Arranged in plane (xy, yz, zx) than it is said two-dim Array or planar Array.





example



⟹ Electric field by diffrent element is

$\vec{E_1} = E_1 e^{j\varphi_1}$ $\quad \vec{E_2} = E_2 e^{j\varphi_2}$

$\vec{E_n} = E_n e^{j\varphi_n}$

$\alpha_1, \alpha_2, \alpha_3$ are phase differen of diffrent elements

$I_1 = I_1 e^{j\alpha_1}$, $\quad I_2 = I_2 e^{j\alpha_2}$ $\quad I_n = I_n e^{j\alpha_n}$

So total Electric field is given by

$$E_t = \vec{E_1} + \vec{E_2} + \cdots \vec{E_n}$$

$$= E_1 e^{j\varphi_1} + E_2 e^{j\varphi_2} + \cdots + E_n e^{j\varphi_n}$$

where $\boxed{\varphi = \beta d + \alpha}$ $\qquad \beta = \boxed{\frac{2\pi}{\lambda}}$

$$\varphi = \frac{2\pi}{\lambda} d + \alpha$$

α = Initial phase

d = Spacing between elements

λ = wavelength

Types of Arrays

- End-fire Array
- Log-periodic Array
- Collinear Array
- Broad Side Array
- Yagi-Uda Array
- Parasitic Array
- Supra-turnstile Array
- Turnstile Array (crossed dipoles)

Broad Side Array :-

- Array having number of elements of equal size, equally spaced along a straight lines or axis, forming collinear points. The frequency range for this is around 30MHz to 3GHz which belongs to VHF & UHF bands.
- An Arrangement of Array in which principal direction of radiation is ⊥r to the array axis and also the plane containing Array elements. The radiation pattern of board side Array is bi-directional and right angle to the plane.

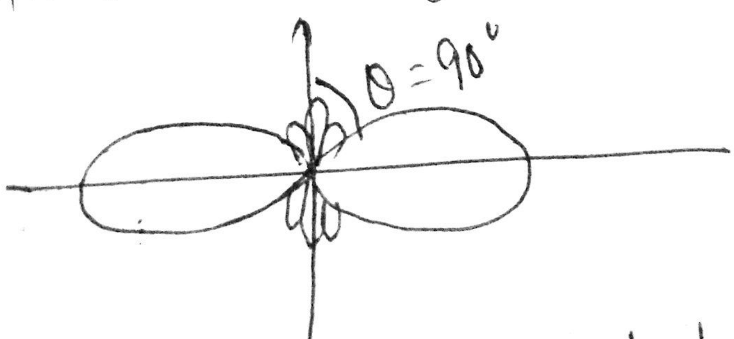


Fig: radiation pattern of board side Array.

End-Fire Array :-

Physcial Arrangement of End-fire Array is same as that of Board-Side Array.

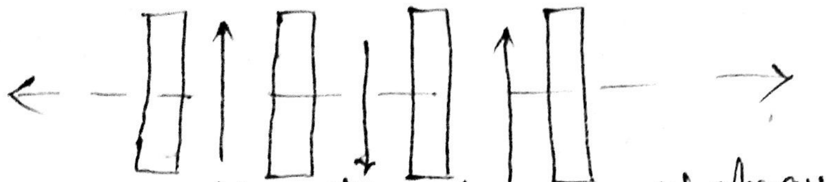
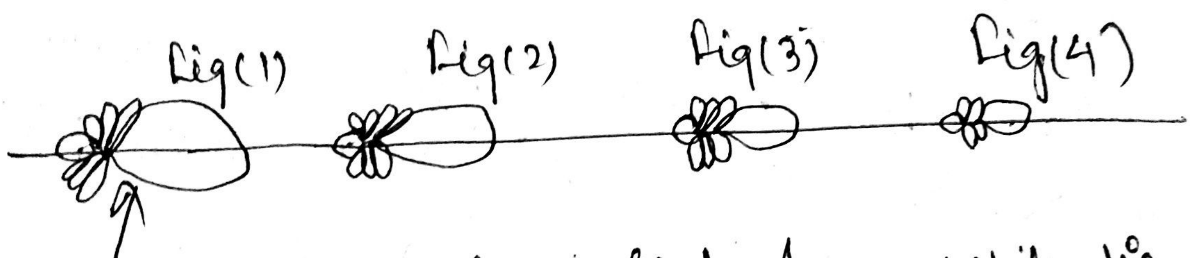


fig: top of view of Array.

fig: Side view of Array

Radiation pattern of end-fire Array is uni-directional. A major lobe occurs at one end, where max^m radiation is present.



fig(1) is radiation pattern for a single Array, while fig 2, 3 & 4 represents radiation pattern of Multiple Array.

Antenna Array :-

Antenna Array is a radiating system which consist of Individual radiators and elements.
Antenna radiates Individually while in Array radiation of each elements sum up to form radiation beam, which have high gain, high directivity and better performance with minimum losses.

Advantages :-

⇒ The signal strength increases
⇒ High directivity
⇒ High gain
⇒ Better performance
⇒ Low power wastage.

Disadvantages :-

⇒ Huge external space is required
⇒ Resistive losses increases.

Applications :-

⇒ Used in Satellite Communication.
⇒ Used in Wireless Communication
⇒ Used in Military Radar Commn.

⇒ Antenna Array is the mechanism by which we can realise complex radiation pattern without altering the antenna Impedance.
Antenna Array problem can we divided into 2 part

1) Array Analysis :- Here we investigate radiation pattern for given Array.
2) Array Synthesis :- Here we design the Array configuration to achieve desired

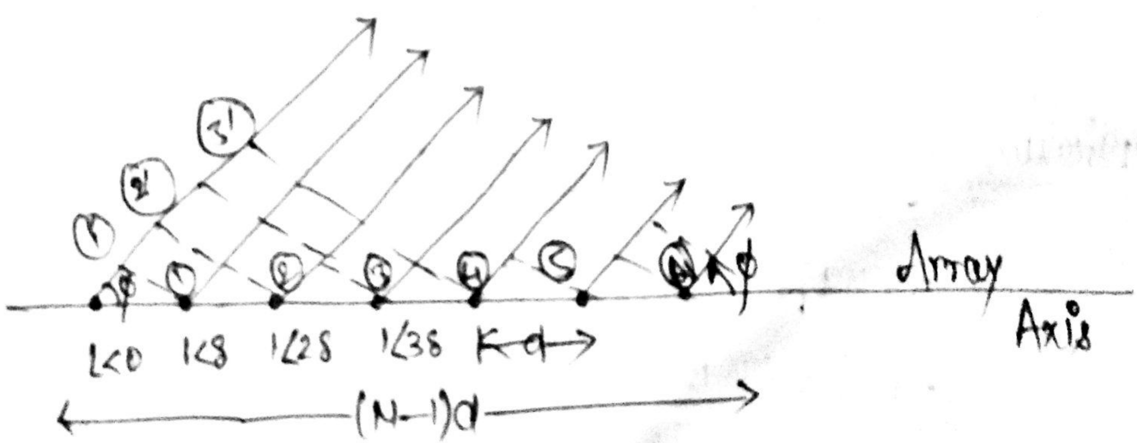
Analysis of Uniformly Spaced Array :

⑥

=) An Antenna Array consist of Identical Antenna distributed in Space. The Individual Antenna radiator and their radiation pattern is Coherently Added in Space.

For a linear Array antenna are placed along a line called Axis of Array. The Antenna array have Arbitary Spacing between them and excited with different Complex Currents. However here we first Anlyase the Uniform Array.

In a uniform Array the Antenna are equi-spaced and are excited with Uniform Current with constant progressive phase shift.



Let the Array have N elements

Inter element Spacing :(d) Spacing between array on two adjacent elements of Array.

Phase Shift :- (δ) : This is phase shift between two adjacent elements of Array.

The phase have two components
1) phase due to phase of excitation current (δ)
2) phase due to propagation $\beta d\cos\phi$.

Total phase difference ψ between two components is

$$\psi = \beta d\cos\phi + \delta$$

Without loosing generality we assume that electric field due to individual antenna have unit amplitude at the observation point.

Then total field at observation point is

$$E = e^{j0} + e^{j\psi} + e^{j2\psi} + \cdots + e^{j(N-1)\psi}$$

$$E = \{1 + e^{j\psi} + e^{j2\psi} + \cdots + e^{j(N-1)\psi}$$

The R.H.S of eq^n is geometric series.

$$\boxed{E = \frac{1 - e^{jN\psi}}{1 - e^{j\psi}}}$$

$N =$
$\psi = \beta d\cos\phi + \delta$.
$\beta = \frac{2\pi}{\lambda}$ $d =$

After algebraic manipulation we get the electric field ($\phi = 0$)

The max^m field therefore is N.

The expression gives the variation of field as a function of direction ϕ and hence the radiation pattern of antenna array

The Radiation pattern generally normalized with respect to value N to get "Array factor" as

$$\boxed{A.F = \frac{1}{N} \frac{\sin\left(\frac{N\psi}{2}\right)}{\sin(\psi/2)}}$$

$\psi = \beta d\cos\phi$
N

Typical Radiation pattern is

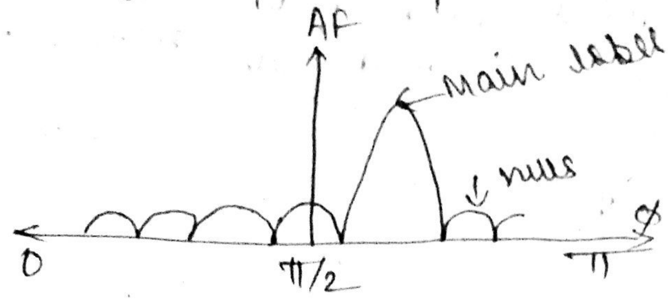


Fig: Radiation pattern in Cartesian plot.

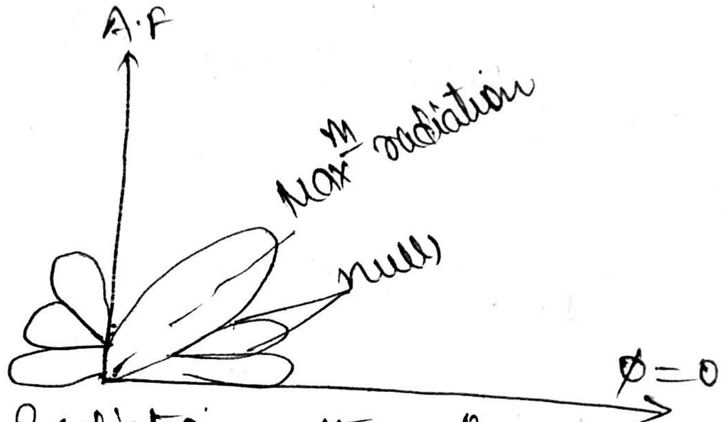


Fig: Radiation pattern in polar plot.

⇒ The range of angle ϕ is from 0 to π and 3d radiation pattern is the fig of revolution of ~~Array~~.

Direction of Max^m Radiation :- (ψ)

⇒ The direction of max^m radiation is also known as direction of main beam (

⇒ max^m radiation is obtained when $\psi = 0$

$$\psi = \beta d \cos\phi_{max} + \delta = 0$$

$$\Rightarrow \cos\phi_{max} = \frac{-\delta}{\beta d} = \left(\cos^{-1}\left(\frac{\delta}{\beta d}\right)\right) = \left(\frac{\delta\lambda}{2\pi d}\right)$$

$$\boxed{\psi = \beta d\,(\cos\phi - \cos\phi_{max})}$$

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

hence

$$\boxed{\psi = \beta d\,(\cos\phi - \cos\phi_{max})}$$

hence from above we conclude that

1) It is independent of number of elements of Array.

2) Direction of main beam can change from 0 to π by changing the progressive phase shift. δ from $-\beta d$ to βd.

✡ HALF POWER BEAM WIDTH (HPBW)

For large Array HPBW is taken half of BWFN.

$$\psi_{B.S} = \frac{\lambda}{dN} = \frac{\lambda}{\text{length of Array}}$$

$$\psi_{E.F} = \sqrt{\frac{2\lambda}{dN}} = \sqrt{\frac{2\lambda}{\text{Length of Array}}}$$

✡ DIRECTIVITY :-

The directivity of Antenna Array is given by

$$D = \frac{4\pi}{\iint |AF|^2 d\Omega}$$

$$\boxed{D_{B.S} = \frac{2dN}{\lambda}} \qquad \boxed{D_{EF} = \frac{8dN}{\lambda}}$$

GRATING LOBE :-

Grating lobe is the beam similar to main lobe but in undesired direction.

A grating lobe appears when

$$\boxed{\psi = 2m\pi}$$

⇒ For broadcast Array grating lobe Appears when $d \geq \lambda$

⇒ For End-fire Array when $d \geq \lambda/2$.

To avoid grating lobe radiation pattern of the Array ~~Elemen~~ inter element spacing should be $< \lambda/2$.

Radiation pattern :-

Radiation pattern of Array is known as Primary radiation pattern.

$$\boxed{\text{Radiation pattern} = \text{Primary Pattern} \times \text{A.F}}$$

Fourier transform Method :-

This Method can be used to determine given a complete description of desired pattern, the excitation distribution of a discrete source Antenna System.

The desired excitation will yield exactly or approximately, the desired antenna pattern.

Line - Source :-

For a continuous line source distribution of length l the normalized space factor can be written as

$$SF(\theta) = \int_{-l/2}^{l/2} I(z') e^{j(k\cos\theta - k_z)z'} dz' \quad —— (1)$$

$$= \int_{-l/2}^{l/2} I(z') e^{j\xi z'} dz' \quad —— (2)$$

$$\xi = k\cos\theta - k_z \Rightarrow \theta = \cos^{-1}\left(\frac{\xi + k_z}{k}\right) \quad —— (3)$$

where k_z is the ~~excitati~~ excitation phase constant of source

For a normalized uniform current distribution of the form $I(z') = I_0/l$

reduces to

$$SF(\theta) = I_0 \frac{\sin\left[\frac{kl}{2}\left(\cos\theta - \frac{k_z}{k}\right)\right]}{\frac{kl}{2}\left(\cos\theta - \frac{k_z}{k}\right)} \quad —— (4)$$

The observation angle θ of eqn (2) will have real values (visible region) provided that

$$-(k+k_z) \leq \xi \leq (k-k_z)$$

Since the current distribution of eqn (3) extends on

$$+\sum_{m=1}^{M} a_m e^{j[(2m-1)/2]\psi} \quad (4)$$

where $\psi = kd\cos\theta + \beta$

For odd number of elements $(N = 2M+1)$ the elements are placed at

$$z_m' = md, \quad m = 0, \pm 1, \pm 2, \ldots \pm M \quad (5)$$

For even number $(N = 2M)$ at

$$z_m' = \begin{cases} \dfrac{2m-1}{2}d, & 1 \le m \le M \\[2ex] \dfrac{2m+1}{2}d, & -M \le m \le -1 \end{cases} \quad (6)$$

An odd number of elements must be utilized to synthesize a desired pattern whose average value all over angles is not equal to zero.

The $m=0$ term of eqn (3) is analogous to the d.c term in fourier series expansion of function whose average value is not zero.

In general Array factor of Antenna is periodic function of ψ and it must repeat for every 2π radians.

In order for array factor to satisfy the periodicity requirements for real values θ, d must be relaxed $d < \lambda/2$ which can be customarily done by Fourier Series Analysis.

at yield approximate pattern $SF(\theta)_a$. The approximate pattern is used to represent with certain error. (3)

Thus desired pattern

$$\boxed{SF(\theta)_d \approx SF(\theta)_a = \int_{-l/2}^{l/2} I_a(z') e^{j\xi' z'} dz'}$$

For all values of ξ, the synthesized approximate pattern $SF(\theta)_a$ yields the least mean square error or deviation from the desired pattern $SF(\theta)_d$.

But the criteria is not satisfied if the value is restricted only in the visible region.

LINEAR ARRAY :-

The Array factor of an N-element linear array of equally spaced elements and non-uniform excitation is given by

$$A.F = \sum_{n=1}^{N} a_n e^{j(n-1)(kd\cos\theta+\beta)} \quad \text{—— (1)}$$

$$= \sum_{n=1}^{N} a_n e^{j(n-1)\psi} \quad \text{—— (2)}$$

If the reference point is taken at physical centre of the array than array factor can be written as

Odd Number of Elements $(N = 2M+1)$

$$\boxed{AF(\theta) = AF(\psi) = \sum_{m=-M}^{M} a_m e^{jm\psi}} \quad \text{—— (3)}$$

Even Number of Elements

$$AF(\theta) = AF(\psi) = \sum_{m=-M}^{-1} a_m e^{j[(2m+1)/2\,\psi]}$$

If $AF(\psi)$ represents the desired Array factor the excitation coefficients of array can be obtained by Fourier formula. (5)

Odd no of elements $(N = 2M+1)$

$$\boxed{a_m = \frac{1}{T}\int_{-T/2}^{T/2} AF(\psi)\, e^{-jm\psi}\, d\psi = \frac{1}{2\pi}\int_{-\pi}^{\pi} AF(\psi)\, e^{-jm\psi}\, d\psi \qquad -M \le m \le M .} \tag{7}$$

Even numbers of elements $(N = 2M)$

$$a_m = \begin{cases} \dfrac{1}{2\pi}\displaystyle\int_{-\pi}^{\pi} AF(\psi)\, e^{-j[(2m+1)/2]\psi}\, d\psi = \dfrac{1}{T}\displaystyle\int_{-T/2}^{T/2} AF(\psi)\, e^{-j[(2m+1)/2]\psi}\, d\psi & -M \le m \le -1 \quad (8) \\[2ex] \dfrac{1}{T}\displaystyle\int_{-T/2}^{T/2} AF(\psi)\, e^{-j[(2m-1)/2]\psi}\, d\psi = \dfrac{1}{2\pi}\displaystyle\int_{-\pi}^{\pi} AF(\psi)\, e^{-j[(2m-1)/2]\psi}\, d\psi & 1 \le m \le M \quad (9) \end{cases}$$