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UNIT-3

1. Derive the field components and draw the field pattern for two point source with spacing of λ/2 and fed with current of equal n magnitude but out of phase by 180^0 ?

Ans: Arrays of two point sources with equal amplitude and opposite phase:

In this, point source 1 is out of phase or opposite phase (180°) to source 2 i.e. when there is maximum in source 1 at one particular instant, and then there is minimum in source 2 at that instant and vice-versa.

Referring to Fig.1.1 the total far field at distant point ***P*, is** given by

$$E = (-E_i e^{-\varphi j/2}) + (+E_2 e^{+\varphi i/2})$$

But $E_1 = E_2 = E_0$ (say)

Then $E = E_0\, 2j\left(\frac{e^{\frac{j\varphi}{2}} - e^{\frac{-j\varphi}{2}}}{2j}\right)$

$E = 2jE_0 \sin\varphi/2$ ……………. (1.1a)

$E = 2jE_0 \sin\left(\frac{\beta d}{2}\cos\theta\right)$ ...……. (1.1b)

Let $d = \lambda/2$ and $2E_0\, j = 1$

Enorm, = sin (π/2 COS θ) …………………….. (1.2)

Maximum directions: Maximum value of sine function is ± 1

$\sin(\pi/2 \cos\theta) = \pm 1$

$(\pi/2 \cos\theta_{max}) = \pm (2n + 1)\, n/2$ where $n = 0, 1, 2$

$(\cos\theta_{max}) = \pm 1$ if $n = 0$

$\theta_{max} = 0°$ **and 180°…………….. (1.3 a)**

Minima directions: Minimum value of a sine function is 0

$\sin(\pi/2 \cos\theta) = 0$

$\pi/2 \cos\theta_{min} = \pm n\pi$ where n = 0, 1, 2……..

$\cos\theta_{min} = 0$

Therefore θmin= 90° and -90° ……………….. (1.3b)

Half power point directions:

$\sin(\Pi/2 \cos\theta) = \pm\frac{1}{\sqrt{2}}$

$\pi/2 \cos\theta_{HPPD} = \pm (2n + 1)\, \pi/4$

$\pi/2 \cos\theta_{HPPD} = \pm \pi/4$ if $n = 0$

$\cos\theta_{HPPD} = \pm\frac{1}{2}$

$\theta_{HPPD} =$ **60°, ± 120°** ………………………… (1.3c)

From these, it is possible to draw the field pattern which is as shown in Fig.1.2

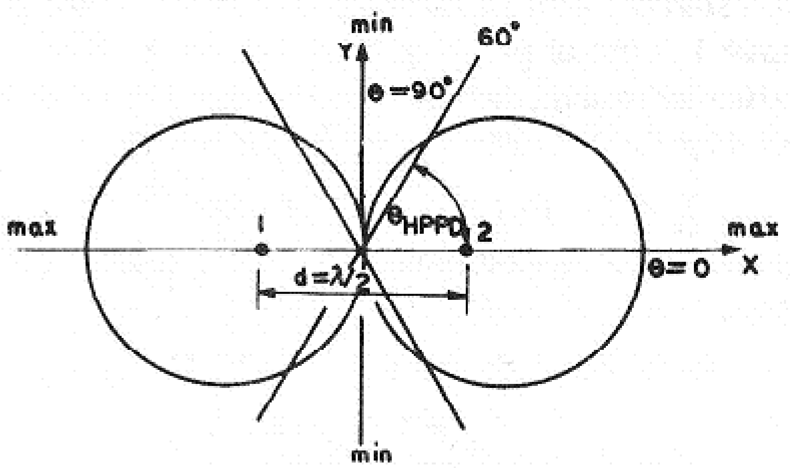


fig 1.2 Two Point sourcs with equal amplitude and opposite phase spacing λ/2

It is seen that maxima have shifted 90° along X-axis in comparison to in-phase field pattern. The figure is horizontal figure of 8 and 3-dimensional space pattern is obtained by rotating it along X-axis. Once the arrangement gives maxima along line joining the two sources and hence this is one of the simplest type of "End fire" 'Array'.

2. What is the necessity of an array? Explain the three different types of array with regard to beam pointing direction

Ans: **Antenna Array**

This is one of the common methods of combining the radiations from a group of similar antennas in which the wave-interference phenomenon is involved. The field strength can be increased in preferred directions by properly exciting group or array of antennas simultaneously, such as arrangement is known as antenna array. Array of antenna is an arrangement, of several individual antennas so spaced and phased that their individual contributions coming in one preferred direction and cancel in all other directions, which will be going to increase the directivity of the system.

The different types of arrays with regard to beam pointing direction are as follows,

1. Broadside array
2. End fire array
3. Collinear array.

1. Broadside Array

Broadside array is one of the most commonly used antenna array in practice. The array in which a number of identical parallel antennas are arranged along a line perpendicular to the line of array axis is known as broadside array, which is shown in figure (2.1). In this, the individual antennas are equally spaced along a line and each element is fed with current of equal magnitude, all in the same phase.

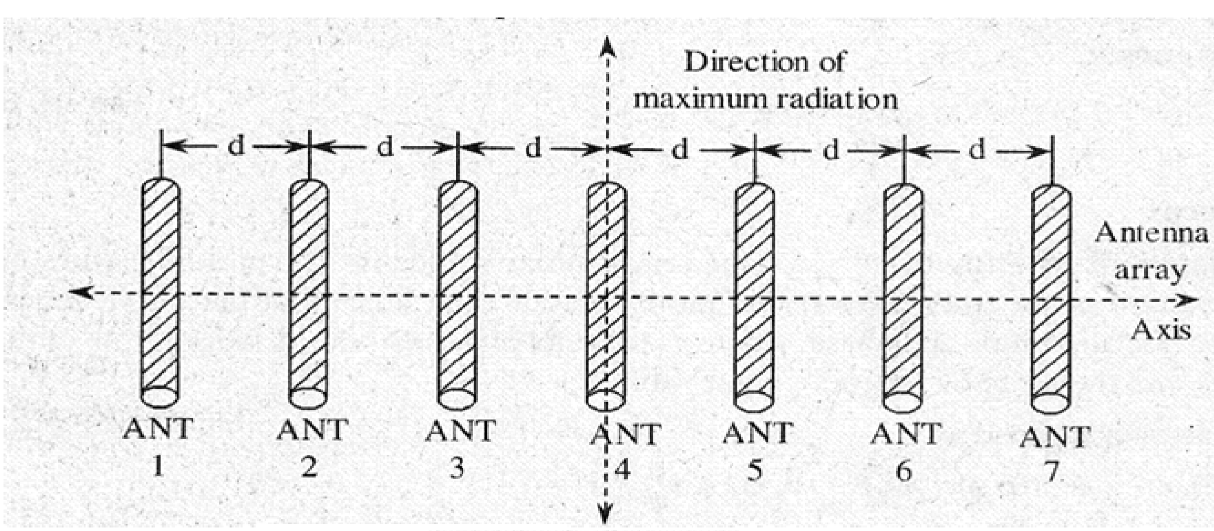


fig 2.1 Board side array

The radiation pattern of broadside array is bidirectional, which radiates equally well in either direction of maximum radiation.

2. **End Fire Array**

The array in which a number of identical antennas are spaced equally along a line and individual elements are fed with currents of unequal phases (i.e., with a phase shift of 180°) is known as end fire array .This array is similar to that of broadside array except that individual elements are fed in with, a phase shift of 180 .In this, the direction of radiation is coincides with the direction of the array axis, which is shown in figure (2.2)

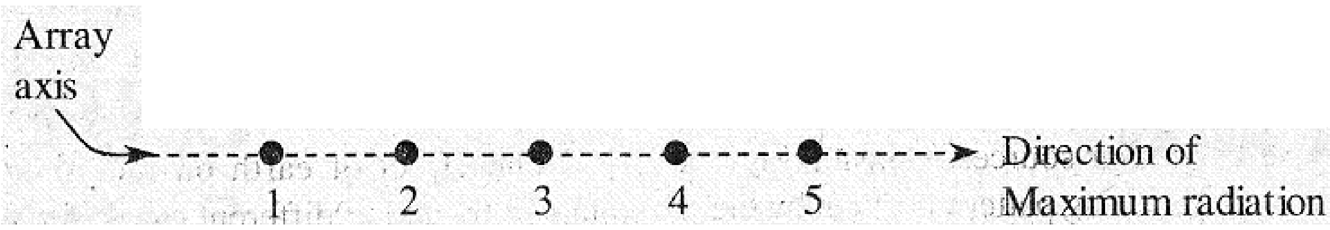


fig 2.2 End fire array

The radiation pattern of end fire array is unidirectional. But, the end fire array may be bidirectional also. One such example is a two element array, fed with equal current, 180° out of phase.

3. **Collinear Array**

The array in which antennas are arranged end to end in a single line is known as collinear array. Figure (2.3), shows the arrangement of collinear array, in which one antenna is stacked over another antenna. Similar to that of broadside array, the individual elements of the collinear array are fed with equal in phase currents. A collinear array is a broadside radiator, in which the direction of maximum radiation is perpendicular to the line of antenna. The collinear array is sometimes called as broadcast or Omni directional arrays because its radiation pattern has circular symmetry with its main to be everywhere perpendicular to the principal axis.

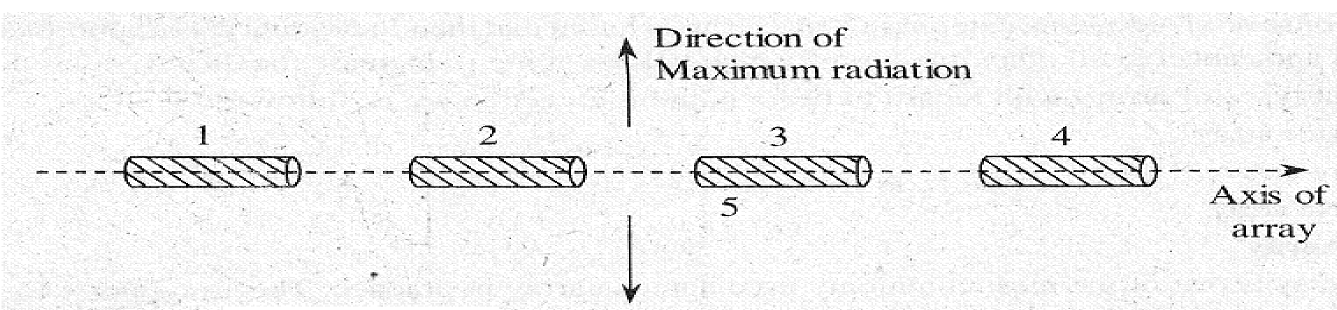


fig 2.3 Collinear array

3. Explain the principal of pattern multiplication .What is the effect of earth of radiation pattern of antennas?

Ans: Multiplication of Patterns ,

The total field pattern of an array of non-isotropic but similar sources is the multiplication of the individual source pattern and the pattern of an array of isotropic point sources each located at the phase centre of individual source and having the relative amplitude and phase, where as the total phase patterns is the addition of the phase pattern of the individual sources and the array of isotropic point sources. Total field by an array is defined as

$E = \{ E_0(\theta,\varphi) \times E_i(\theta,\varphi)\} \times \{ E_{pi}(\theta,\varphi)+ E_{pa}(\theta,\varphi) \}$

= (Multiplication of field patterns) (Addition of phase patterns)

Where

E - Total field

$E0(\theta,\varphi)$ = Field pattern of individual source

$Ei(\theta,\varphi)$ = Field pattern of array of isotropic point source

$Epi(\theta,\varphi)$= Phase pattern of individual source

$Epa(\theta,\varphi)$= Phase pattern of array of isotropic point sources.

Hence, θ and φ are polar and azimuth angles respectively.

The principle of multiplication of pattern is best suited for any number of similar sources. Considering a two dimensional case, the resulting pattern is given by the equation,

$E = 2\, E_0 \cos\varphi /2$

$E = 2\, E_1 \sin\theta \cos\varphi /2.$

$E = E\,(\theta) \cos\varphi /2$

It can be seen that E0 is a function of E (θ). In the above equation the total field pattern is equal to the product of primary pattern E (θ) and a secondary pattern cosφ/2.

Effect of Earth on the Radiation Pattern

The effect of earth on the radiation pattern can be obtained by using an image principle. In image principle, earth is considered as an image antenna of same length and current as shown in the figure (3.1).

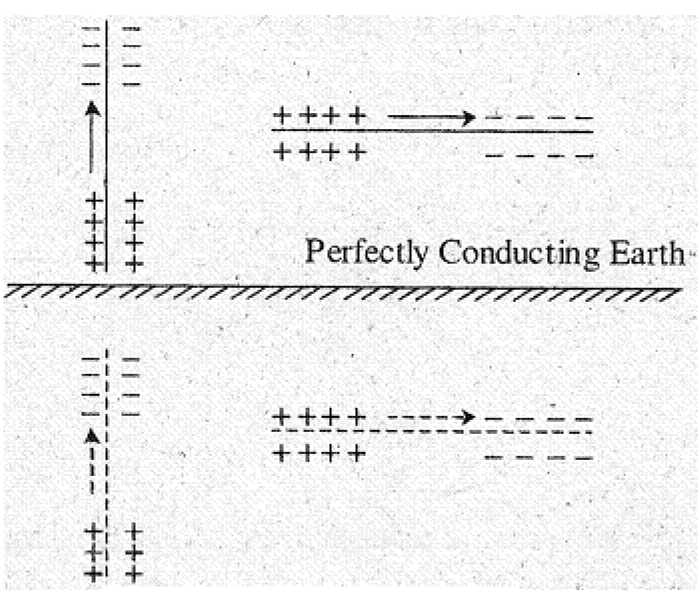


fig 3.1 Earth as Image Antenna

For vertical antenna, currents in actual and image antennas are equal and have same direction, whereas opposite direction for horizontal antenna. The resultant field is obtained by the addition of field of an image antenna to that of an actual antenna. The shape of the vertical pattern is affected more than the horizontal pattern

Effect of Earth on the Radiation Pattern of Vertical Antenna

The ground-effect factor of a perfectly conducting earth is given as,

$$2\cos\left[\frac{2\Pi h}{\lambda}\sin\varphi_0\right]$$

Where,

h = Height of the center of antenna above earth

φ = Elevation angle above horizontal.

But, for the case of finite conducting of earth, the above given expression is valid for large angles of φ0. Whereas, for low angles of φ_0, less than 15° known as "Pseudo-Brewster angle", the phase of the reflection factor is nearer to 180° than it is to 0° and the use of above equation would lead to erroneous result.

The effect of earth on radiation pattern can be explained by taking different cases of conductivities (σ). The function 'n' is defined as,

$$n = \frac{x}{\epsilon_r}$$

Where, $x=\sigma/\omega\epsilon_v$

σ = conductivity of the earth in mho/meter

ϵ_r=15, Relative dielectric of the earth.\

The vertical radiation pattern of a vertical dipole is a shown in the fig 3.2

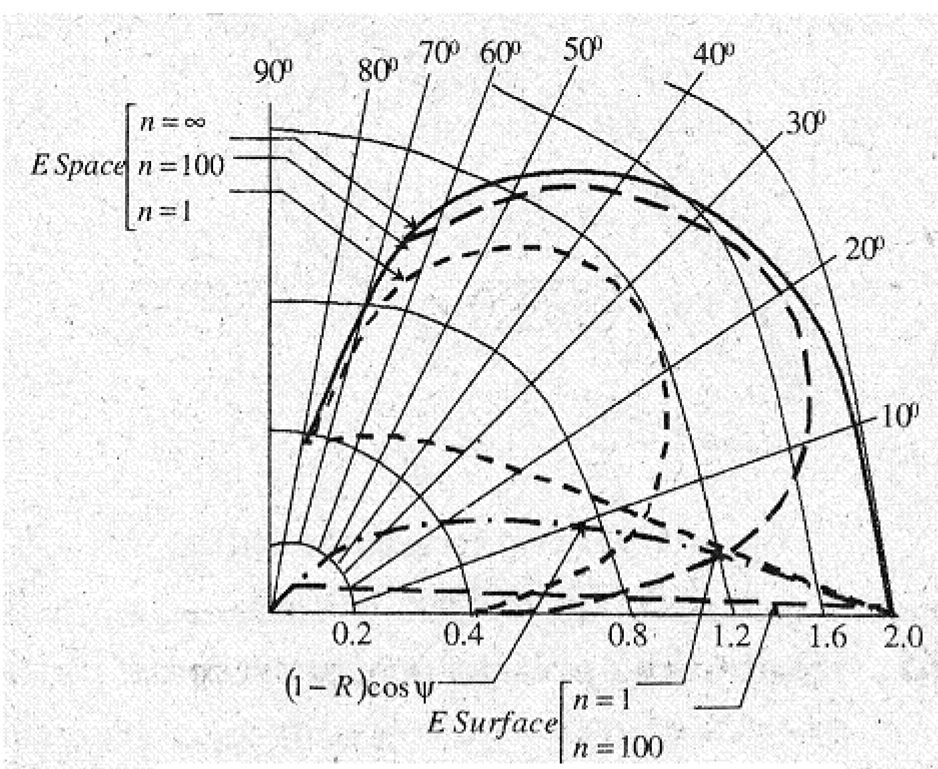


fig 3.2 Effect on Earth vertical pattern of vertical dipole

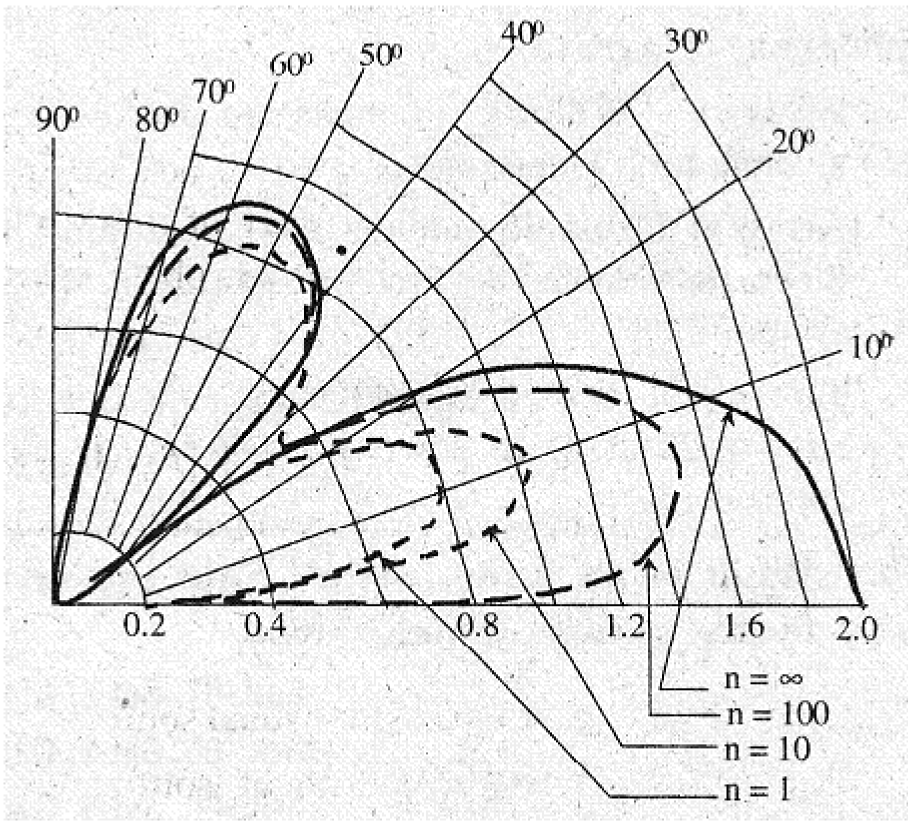


fig 3.3 Vertical pattern of a vertical dipole placed at a certain height above the earth

Effect of Earth on the Radiation Pattern of Horizontal Antenna

The effect of ground is obtained by multiplying free-space pattern and ground factor, i.e.

$2\cos\left[\frac{2\Pi h}{\lambda}\sin\varphi_0\right]$

The first maxima in this pattern occurs at,

$\sin\varphi_0 = \lambda/4h \quad (h > \lambda/4)$

The effect of earth on the vertical pattern perpendicular to the axis of dipole is as shown in figure3.4.

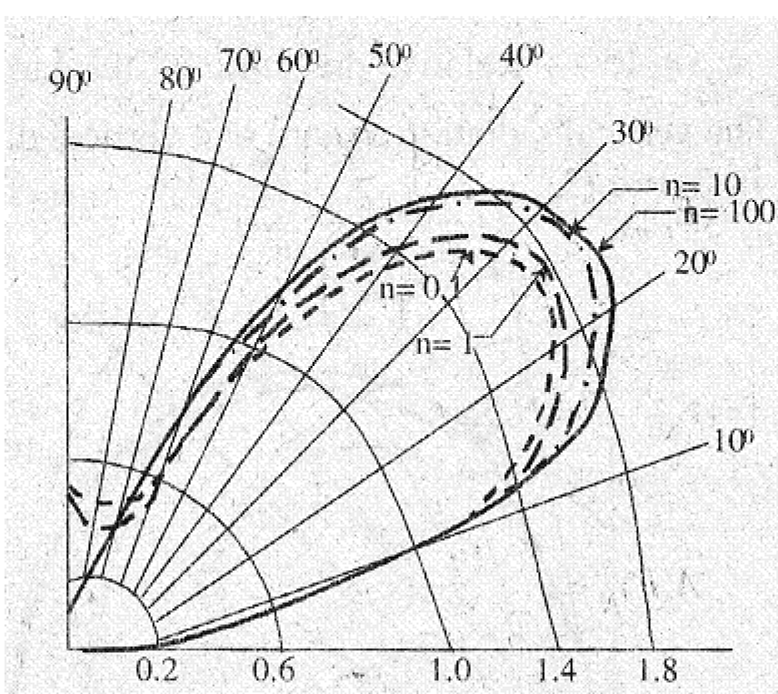


fig 3.4 Effect of the earth on vertical pattern of horizontal antenna

4. Explain about radiation pattern of 4-isotropic and 8-isotropic elements fed in phase, spaced λ/2 apart?

Ans: Radiation Pattern of 4-isotropic elements fed in phase, spaced λ/2 apart:

Let the 4--elements of isotropic (or non-directive) radiators are in a linear arrays (Fig. 4.1) in elements are placed at a distance of λ/2 and are fed in phase, i.e. $\alpha = 0$. One of the method to get the radiation pattern of the array is to add the fields of individual four elements at a distance point P vectorially but instead an alternative method, using the principle of multiplicity of pattern, will be shown to get the same

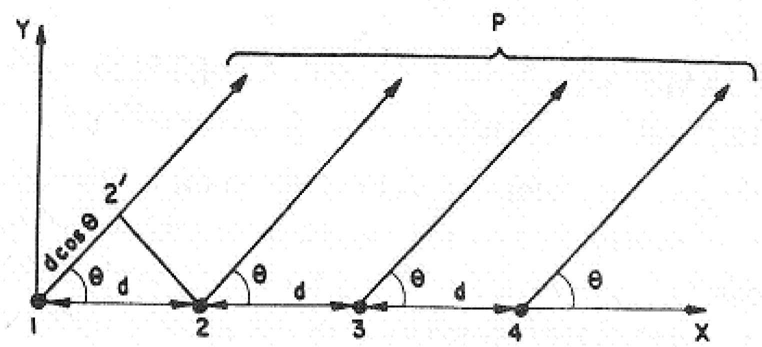


fig 4.1 Linear array of 4-isotrpic elements spaced λ/2 apart,fed in phase

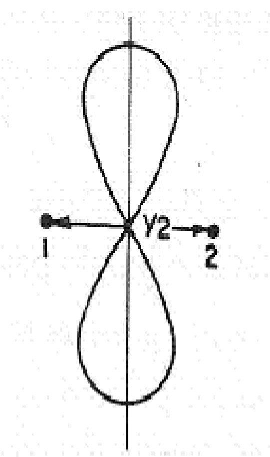


fig 4.2(a) d=λ/2 ,α=0

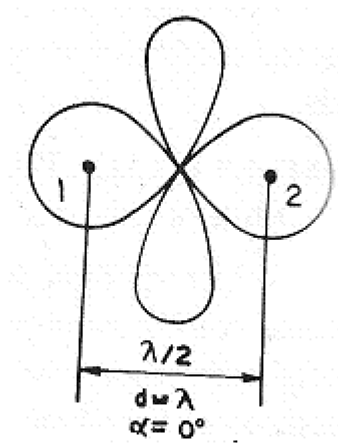


fig 4.2(b)

The radiation pattern of two isotropic radiation spaced λ apart, fed in phase is known to be as shown in Fig. 4.2

Now elements (1) and (2) are considered as one unit and is considered to be placed between the midway of the elements and so also the elements (3) and (4) as another unit assumed to be placed between the two elements as shown in fig 4.2.

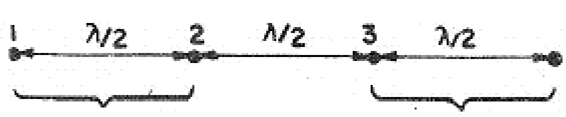


fig 4.3(a) 4-isotropic elements spaced λ/2

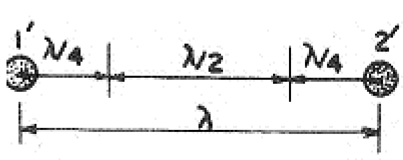


fig 4.3(b) 2-unit array ,where one unitmspaced at λ/2

Thus 4 elements spaced λ/2 have been replaced by two units spaced λ and by doing so, the problem of determining radiation of 4 elements has reduced to find out the radiation pattern of two antennas spaced λ apart

Then according to multiplicity of pattern. The resultant radiation pattern of 4 elements is obtained by multiplying the radiation pattern of individual element Fig 4.3 (b) and array of two units spaced λ.

In place of isotropic (non-directional) if the array is replaced by an non-isotropic (i.e. directional) antennas, then the radiation pattern Fig. 4.2 must be accordingly modified.

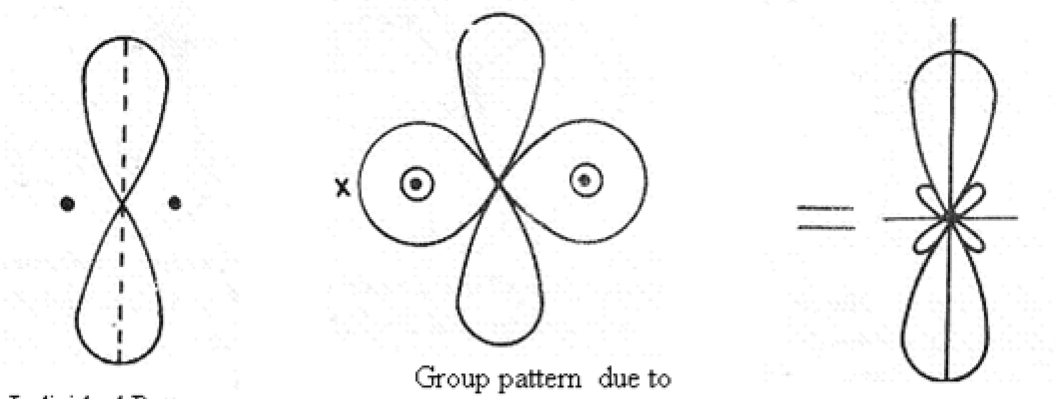


fig 4.4 Resultant radiation pattern of 4-isotropic elements by pattern multiplication

Radiation pattern of 8-isotropic elements fed in phase, spaced λ/2 apart. As above the principle can be applied to broad-side linear array of 8-isotropic elements also as shown in Fig. 4.5 In this case 4-isotropic elements are assumed to be one unit and then to find the radiation pattern of two such units paced a distance 2λ apart. The radiation pattern of isotropic element is just seen in Fig. 4.4

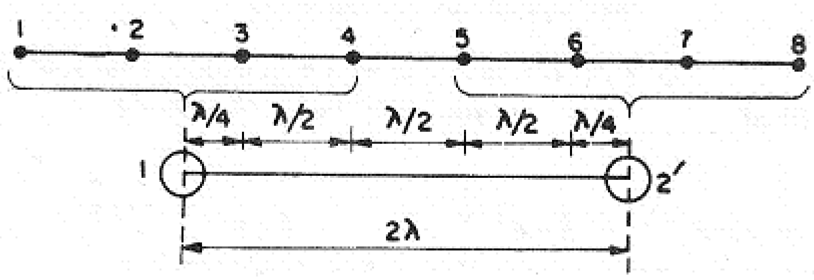


fig 4.5 (a)Linear array of 8 isotropic elements spaced λ/2.
(b) equivalent two units array spaced 2λ

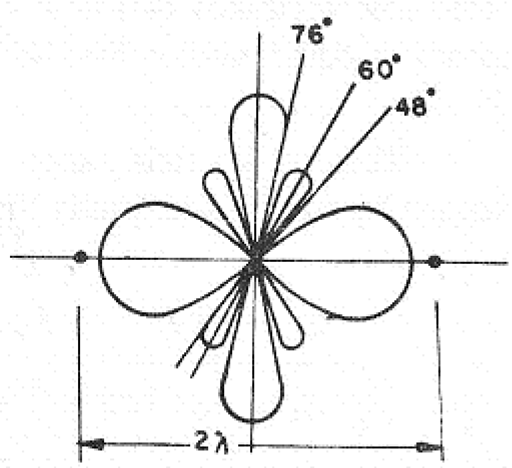
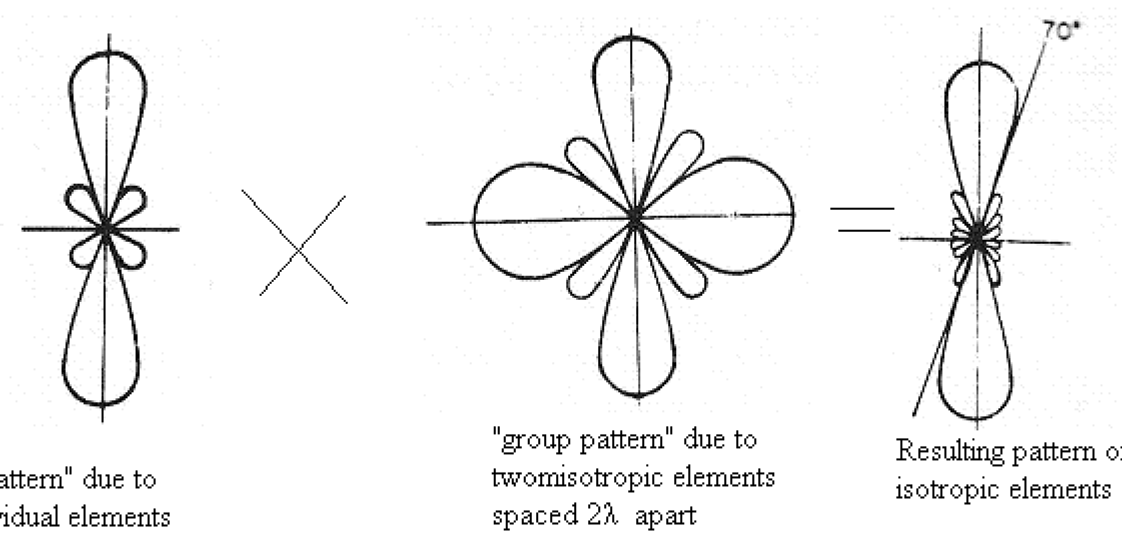


fig 4.6 Radiation Pattern of isotropic radiators spaced 2λ

Thus the radiation pattern of 8 isotropic elements is obtained by multiplying the unit pattern of 4 individual elements as already obtained in Fig. 4.4 and Group pattern of two isotropic radiators spaced 2λ is as shown in Fig. 4.6 and hence the resultant (Fig. 4.7).



4.7 Resulatant radiation pattern of 8 isotropic elements by pattern multiplication.

5. What is uniform linear array? Discuss the application of linear array? and also explain the advantages and disadvantage of linear array?

Ans: In general single element antennas having non uniform radiation pattern are used in several broadcast services. But this type of radiation pattern is not useful in point-to-point communication and services that require to radiate most of the energy in one particular direction i.e., there are applications where we need high directive antennas. This type of radiation pattern is achieved by a mechanism called antenna array. An antenna array consists of identical antenna elements with identical orientation distributed in space. The individual antennas radiate and their radiation is coherently added in space to form the antenna beam.

In a linear array, the individual antennas of the array are equally spaced along a straight line. This individual antennas of an array are also known as elements. A linear array is said to be uniform linear array, if each element in the array is.fed with a current of equal magnitude with progressive phase shift (phase shift between adjacent antenna elements).

Application of Linear Array

1. Adaptive linear arrays are used extensively in wireless communication to reduce interference between desired users and interfering signals.

2. Many linear arrays spaced parallel on the common plane create a planar array antenna. These are used in mobile radar equipment.

3. The linear array is most often used to generate-a fan beam and is useful where broad coverage in one plane and narrow beam width in the orthogonal plane are desired.

4. Linear arrays can be made extremely compact and .are therefore very attractive for shipboard applications.

The advantages and disadvantages of linear arrays are as follows.

Advantages

1. Increases the overall gain. .

2. Provide diversity receptions.

3. Cancel out interference from a particular set of directions.

4."Steer" the array so that it is more sensitive in a particular direction.

5. Determines the direction of arrival of the incoming signals.

6. It maximize the Signal to Interference plus Noise ratio

Disadvantages

1. Ray deflection only in a single plane possible.

2. Complicated arrangement and more electronically controlled phase shifter needed. ;

3. Field view is restricted.

4. Considerable minor lobes are formed.

5. Large power loss due to current flowing in all elements.

6. Overall efficiency decreases.

7. Costly to implement.

6. What is the optimum spacing in parasitic array? why?

Ans: The simplest case of a parasitic array is one driven element and one parasitic element and this may be considered as two element array. A parasitic array consists of one or more driven element and a number of parasitic elements. Hence in parasitic arrays there are one or more parasitic elements and at least one driven element to introduce power in the array.

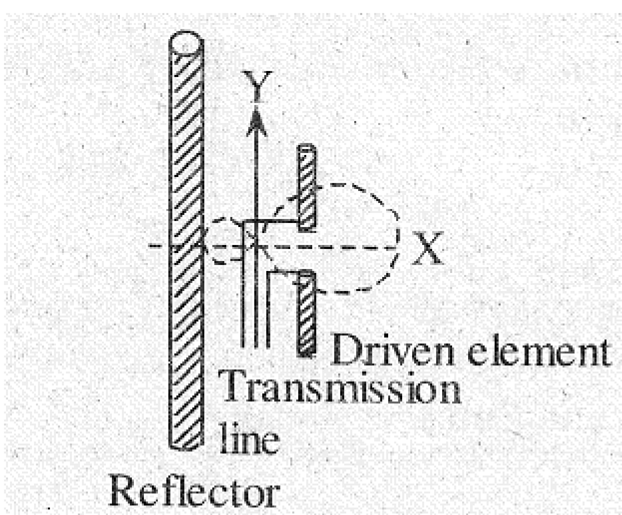


fig 6.1 Parasitic Element Lengthened

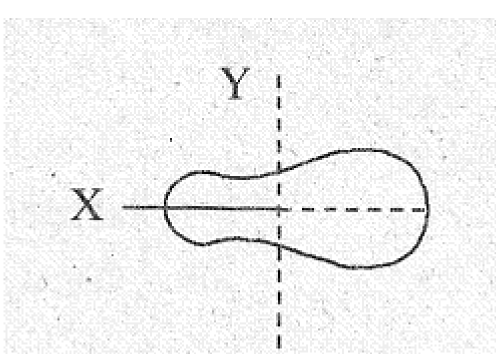


fig 6.2 ardiation Pattern(Cross section)

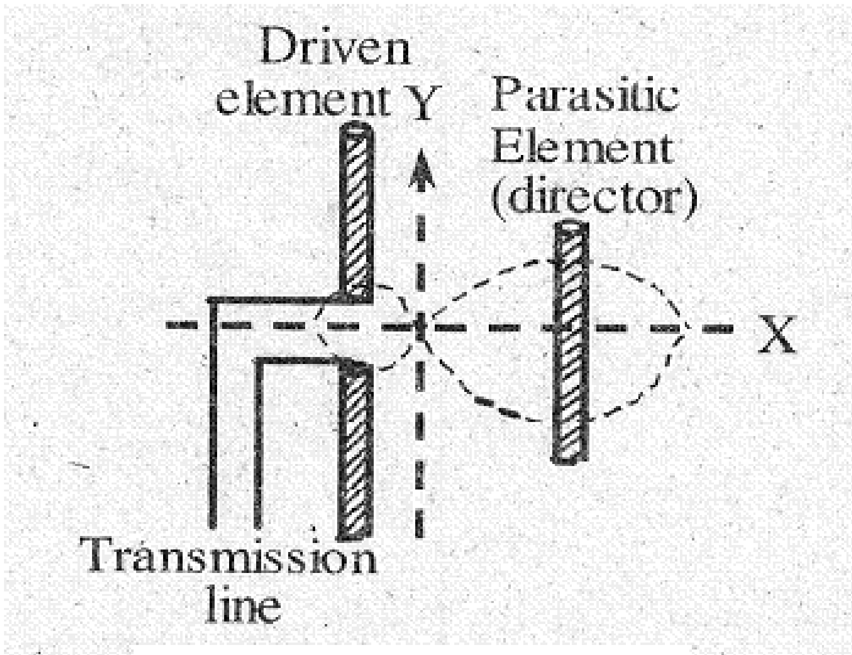


fig 6.3 Parasitic Element Shortend

A parasitic array with linear half-wave dipole as elements is normally called as "Yagi-Uda" or simply "Yagi" antenna after the name of inventor S.Uda (Japanese) and H. Yagi (English).

The amplitude and phase of the current introduced in a parasitic element depends on its tuning and the spacing between parasitic element and driven element to which it is coupled. A variation in the distance between driven element and parasitic element changes the relative phases and this proves to be very convenient. It helps in making the radiation pattern unidirectional. A distance of $\lambda/4$ and phase difference of $\Pi/2$ radian (or 90°), for example, provides a unidirectional pattern.

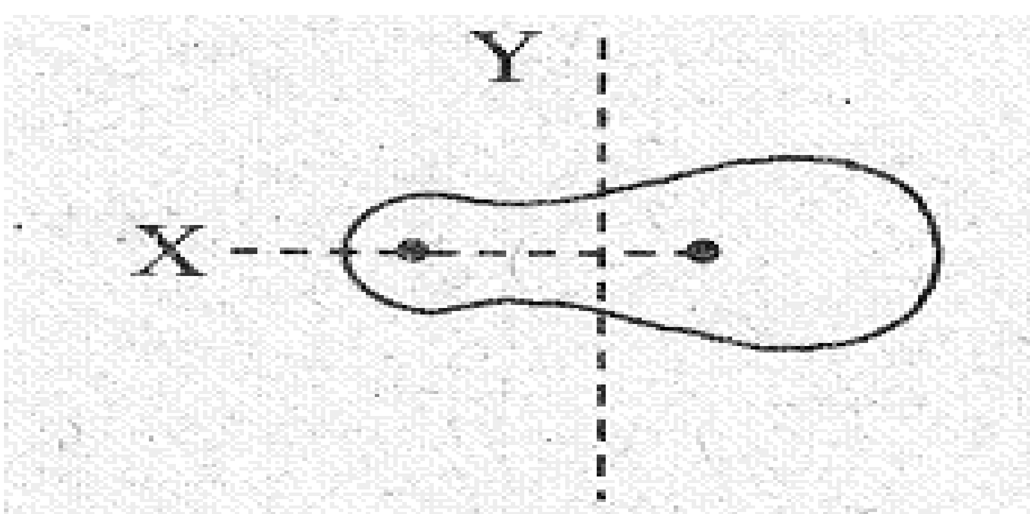


fig 6.4 Cross sectional Pattern

7. What is linear array? Compare Broad side array and End fire array?
Ans :

Linear arrays: The arrays in which the individual antennas (called as elements) are equally spaced along a straight line are called as linear arrays. Thus, linear antenna array is a system of equally spaced elements.

Broad side array	End fire array

1. The array is said to be broad side array, if the direction of maximum radiation is perpendicular to the array axis.	1. The array is said to be end fire array, if maximum radiation is along the array axis.
2. In broad side, phase difference $\alpha = 0$	2. In end fire, phase difference between adjacent element is $\alpha= -\beta d$
3.General equation for pattern maxima is $(\theta_{max})_{minor}=\cos^{-1}\left\{\frac{1}{\beta d}\left[\mp\frac{(2N+1)\Pi}{n}-\alpha\right]\right\}$	3. General expression for pattern maxima is, $(\theta_{max})_{minor}=\cos^{-1}\left[\mp\frac{(2N+1)\Pi}{\beta dn}+1\right]$
4.general Expression for pattern minima is, $(\theta_{min})_{major}=\cos^{-1}\left\{\mp\frac{N\lambda}{nd}\right\}$	4.Genaral expression for pattern minima is, $\theta_{min}=2\sin^{-1}\left[\mp\sqrt{\frac{N\lambda}{2nd}}\right]$
5.Half power beam width is given by, HPBW= $\frac{57.3}{\left[\frac{L}{\lambda}\right]}$ degree	5.Halfpower beam width is given by, HPBW=$57.3\sqrt{\frac{2}{\left[\frac{L}{\lambda}\right]}}$ degree
6.Directivity of broad side array is , $D=2\left[\frac{L}{\lambda}\right]$ L=Length of array	6.Directivity of end fire array is, $D= 4\left[\frac{L}{\lambda}\right]$ L=Length of array
7.Beam width between first nulls is, BWFN=$\frac{114.6}{\left[\frac{L}{\lambda}\right]}$ degree	7.Beam width between first nulls is BWFN=$114.6\sqrt{\frac{2}{\frac{L}{\lambda}}}$ degree
8. In broad side array, all elements are equally spaced along the array axis and fed with current of equal magnitude and same phase.	8. In End fire array, all elements are equally spaced along the array axis and fed with current of equal magnitude but their phases are different.
9. Radiation pattern of broad side array is bidirectional	9. Radiation pattern of broad side array is Unidirectional
10.In broad side array, $\varphi =\beta d\cos\theta+\alpha$ (since $\alpha=0$) Therefore $\varphi =\beta d\cos\theta$	10.In end fire array, $\varphi =\beta d\cos\theta+\alpha$ (since $\alpha=-\beta d$) Therefore $\varphi =\beta d(\cos\theta-1)$

8. What are the various difference between binomial and linear arrays?
Ans:

Binomial Array	Linear Array
1. The binomial array is one in which all the elements are fed with currents of non-uniform amplitude.	1. In antenna array if the individual antennas are equal spaced in a straight line, then it is said to be linear array.
2. Elements are fed with unequal amplitude.	2. If elements are fed with equal amplitude, it is called as uniform linear array.
3. We use Pascal triangle to select the coefficient or amplitudes of elements.	3. We do not use Pascal triangle,
4. Principle of multiplication of pattern is used for derivation of pattern.	4. Principle of multiplication of pattern is used for derivation of pattern.
5. Secondary lobes does not appear in the radiation pattern.	5.Secondary lobes appear in the radiation pattern
6. HPBW increases and directivity decreases.	6. HPBW is less compared to binomial array.
For Example: *For 5 element array with $\lambda/2$ spacing HPBW = 31°*	**For Example:** For 5 "element array with $\lambda/2$ spacing HPBW=23^0.
7. Design is complex for large array due to large amplitude ratio.	7. Design is simple for large array due to uniform amplitude

9. Explain the concept of scanning arrays and What the requirement of tapering of arrays is

Ans: In broad side (or) end fire array, the maximum radiation occurs in a specific direction. In broad side array, the direction of radiation pattern is perpendicular to the array axis whereas in end fire array radiation pattern is normal, to the array axis.

It is possible to change the orientation of maximum radiation in any direction with the help of scanning (or) phased arrays

Let,

θ_0=Orientation angle

Therefore Phase difference (α) can be calculated by,

$$y = (\beta d\cos\theta + \alpha)_{\theta=\theta 0}$$

$$0 = \beta d\cos\theta + \alpha$$

$$\alpha = -\beta d\cos\theta_0$$

From above equation, the phase difference is directly proportional to the orientation angle. By maintaining the proper phase difference between the elements, desired radiation can be obtained in any direction

\ The basic principle of scanning and phased array is to get the maximum radiation in any direction

Tapering of Arrays:

The bidirectional patterns of antennas contain minor lobes in addition to major lobes. These minor lobes not only waste the amount of power but cause interference thus they are undesirable. The interference is severe in case of radar applications where it may cause improper detection of the target object.

Tapering is a technique in which currents or amplitudes are fed non-uniformly in the sources of a linear array. If the centre source is made to radiate more strongly than the end sources, the level of minor lobes are reduced.

Minor lobes are the lobes other than major lobes in the radiation pattern and the minor lobes adjacent to major lobes are called side lobes. By tapering of arrays from centre to end according to some prescription reduces the side lobe level. If the tapering amplitudes follow coefficients of binomial series or Tchebyscheff polynomial, then accordingly the arrays are known as binomial arrays or dolph Tchebyscheff arrays respectively.

NOTE:

This technique is primarily intended for broadside arrays and also applicable to end fire arrays because the side lobe ratio in case of broadside arrays is approximately 20 or 13 dB.

10. Explain the advantages and disadvantages of binomial array? and also Explain the procedure for measuring the radiation pattern of half wave dipole?

Ans:

Advantages of Binomial Array

1. The binomial array is one in which all the elements are fed with current of non uniform amplitude such that it reduces minor lobes.

2. Hence, we use Pascal triangle to select the coefficient or amplitudes of elements.

3. Hence, we use Pascal triangle to select the coefficient or amplitudes of elements.

4. Secondary lobes do not appear in the radiation pattern.

Disadvantages of Binomial Array.

1. HPBW increases and hence the directivity decreases.

2. Large amplitude ratio is required for a design of a large array

Procedure for Measuring the Radiation Pattern of a Half Wave Dipole

1. Initially, the primary half wave dipole i.e., dipole antenna under test must be kept stationary where as the secondary half wave dipole i.e., dipole antenna with known radiation pattern is transported around along a circular path at a constant distance.

2. If the secondary half wave dipole antenna is directional, then it is kept aimed at primary half wave dipole antenna so that only primary half wave dipole antenna pattern will affect the result.

3. Basically, primary half wave dipole antenna may be a transmitting antenna (not a compulsion).

4. The field strength readings and direction of the secondary half wave dipole antenna with respect to primary half wave dipole antenna are recorded along the circle at different points.

5. Finally, using the readings of field strengths at a number of points the plot of radiation pattern of primary half wave dipole antenna is made either in rectangular form or in polar form.