Chapter 2: Pattern Multiplication

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3.5 MULTIPLICATION OF PATTERN

Multiplication of pattern in general, can be stated as follows:

> "The total field pattern of an array of non-isotropic but similar sources is the multiplication of the individual source patterns 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, whereas the total phase pattern is the addition of the phase pattern of the individual sources and that of the array of isotropic point sources."

Individual source either it is in the array or isolated, it is assumed that pattern will remain same. The phase centre of the array is the reference point for total phase pattern. Let

E = total field.

$E_i(\theta, \phi)$ = field pattern of individual source

$E_a(\theta, \phi)$ = field pattern of array of isotropic point source

E_{Pi} = phase pattern of individual source

E_{Pa} = phase pattern of array of isotropic point source

Then the total field pattern of an array of non-isotropic but similar source, may be written as

$$\boxed{\underbrace{E = [E_i(\theta, \phi) \times E_a(\theta, \phi)]}_{\text{(Multiplication of field pattern)}} \times \underbrace{[E_{Pi}(\theta, \phi) + EPa(\theta, \phi)]}_{\text{(Addition of phase pattern)}}} \quad \text{...(3.18)}$$

The angle θ and ϕ respectively, represent the 'polar' and 'azimuth' angles. The principle of multiplication of pattern is true for any number of similar sources. For two dimensional cases, the resultant pattern is given by

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Let E= total field.

$E_r =$ (0,4) field pattern of individual source

E, (B) field pattern of array of isotropic point source Ey phase pattern of individual source

E-phase pattern of array of isotropic point source Then the total field pattern of an array of non-isotropic but similar source, may be written as

E= (E, (6, 0) × E, (8, 6) (Multiplication of field pattem) (0, 0) EPa (0, 0)) (Addition of phase pattern)

(3.18)

The angle and respectively, represent the 'polar' and 'azimuth' angles. The principle of multiplication of pattern is true for any number of similar sources. For two dimensional cases, the resultant pattern is given by

$$E = 2E_0 \cos \psi/2$$

$$E = 2E_1 \sin\theta \cos \psi/2$$

or

$$E = E(\theta) . \cos \psi/2 \quad ...(3.19)$$

E_0 is a function of E (θ). The total field pattern in this case, is multiplication of field pattern known as primary and cos $\psi/2$ the secondary pattern or array factor that the principle is equally applicable to 3-dimensional case also. The principle of multiplication of pattern is a speedy method, for sketching the pattern of complicated arrays, only by inspection and, therefore, the principle is useful tool in designing of antenna arrays. The width of the principle lobe and the corresponding width of array pattern are same. The number of nulls in resultant pattern determines the secondary lobe in the resultant pattern the number of nulls are the sum of nulls of individual pattern and array pattern. Let us now use the principle to solve some typical cases.

3.5.1 Radiation Pattern of 4-Isotropic Element Fed in Phase, Spaced λ/2 Apart

Figure 3.10 shows the 4-elements of isotropic (non-directive) radiators are in a linear arrays in which elements are placed at a distance of $\lambda/2$ and are fed in phase, *i.e.*, $\alpha = 0$. We can find the radiation pattern of array by two methods one of them is principle of multiplication.

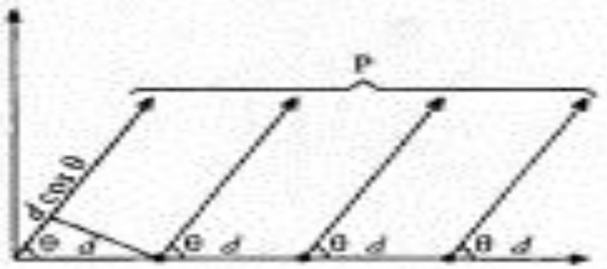


Fig. 3.10 *Linear array of 4-isotropic elements spaced λ/2 apart, fed in phase.*

The figure 3.6 (*b*) shows, the bidirectional pattern of two isotropic point sources, spaced $\lambda/2$ apart fed in phase. This radiation pattern is the figure of 8 (eight), and figure 3.11 shows, the radiation pattern of two isotropic radiation spaced $\lambda/2$ apart, fed in phase.

Now consider element 1 and 2 as one unit and is placed between the mid-way of the element and same for element 3 and 4 as another unit as shown in figure. 3.12. These two units have the same radiation pattern as figure. 3.6 (*b*) and the radiation pattern of two isotropic antenna of figure. 3.11 (*b*) spaced λ is shown in figure. 3.11.

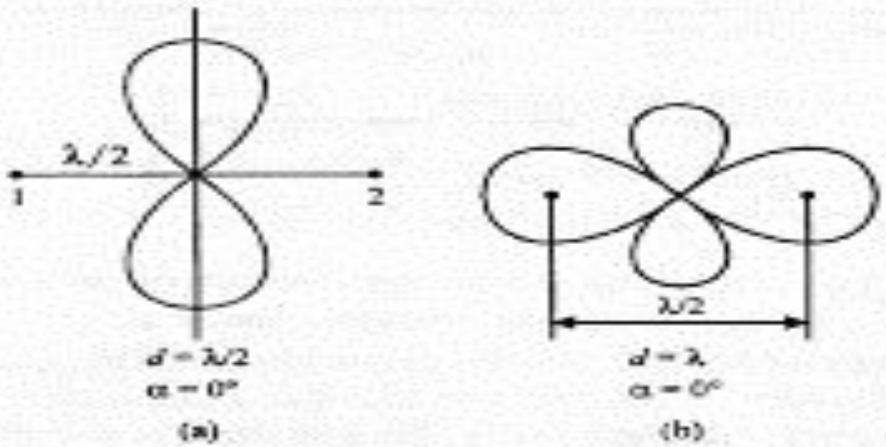


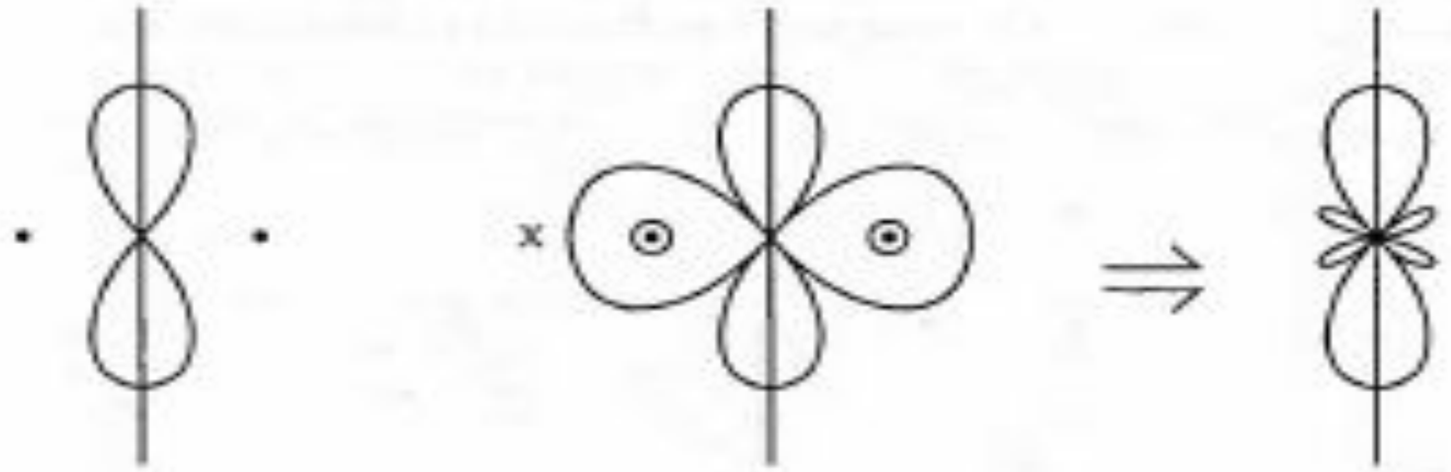
Fig. 3.11

(a) (b)

Fig. 3.12 *(a) 4-isotropic element spaced l/2 apart* *(b) 2-unit array, where one unit spaced*

Hence 4 elements spaced $\lambda/2$ have been replaced by two unit spaced λ, so problem now convert into the determination of radiation pattern of two antennas spaced λ apart. Now by the multiplication of pattern, the resultant radiation pattern of 4 elements is obtained by multiplying the radiation pattern of individual element figure. 3.6 (*b*) and array of two unit spaced λ as shown in figures 3.11 is shown in figure. 3.13.

The radiation pattern of figure 3.11 must be modified when the array is replaced by non-isotropic antenna (*i.e.*, directional antenna) in place of isotropic antennas (non-directional antennas).



Individual (i.e. unit pattern) due to two individual element

Group pattern due to array of two isotropic point source

Resultant pattern of 4 isotropic elements

Fig. 3.13 *Resultant radiation pattern of 4-isotropic elements by pattern multiplication.*

3.5.2 Radiation Pattern of 8-Isotropic Elements Fed In-Phase, Spaced $\lambda/2$ Apart

The multiplication of pattern principle can be applied to broad side linear arrays of 8-isotropic element as shown in figure 3.14. In this case 4-isotropic elements are assumed to be one unit and spaced 2λ apart. The radiation pattern of isotropic element is shown in figure 3.13 and radiation of two isotropic antennas spaced 2λ apart fed in phase can be calculated as follows:

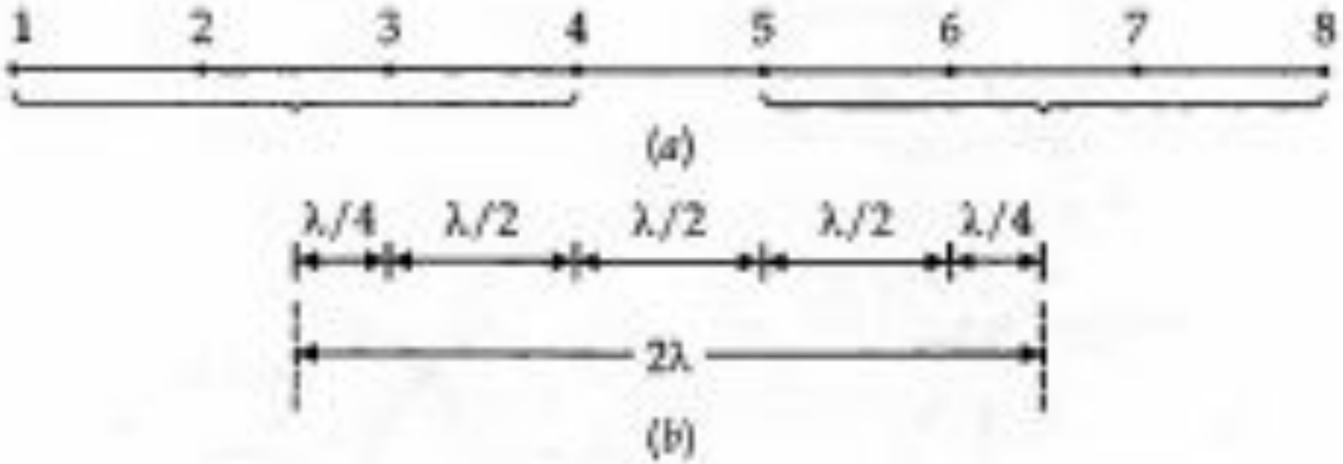


Fig. 3.14 (a) *Linear arrays of 8-isotropic elements spaced $\lambda/2$ apart*

(b) Equivalent two units array spaced 2λ.

Thus the radiation pattern of 8-isotropic element is obtained by multiplying the unit pattern of 4 individual elements as already obtain in figure 3.13 and group pattern of two isotropic radiator spaced 2λ is as shown in figure. 3.15 and hence the resultant is shown in the figure. 3.16.

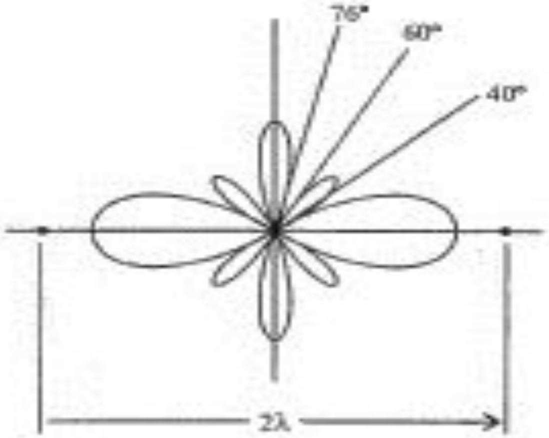


Fig. 3.15 *Radiations pattern of isotropic radiators spaced 2λ.*

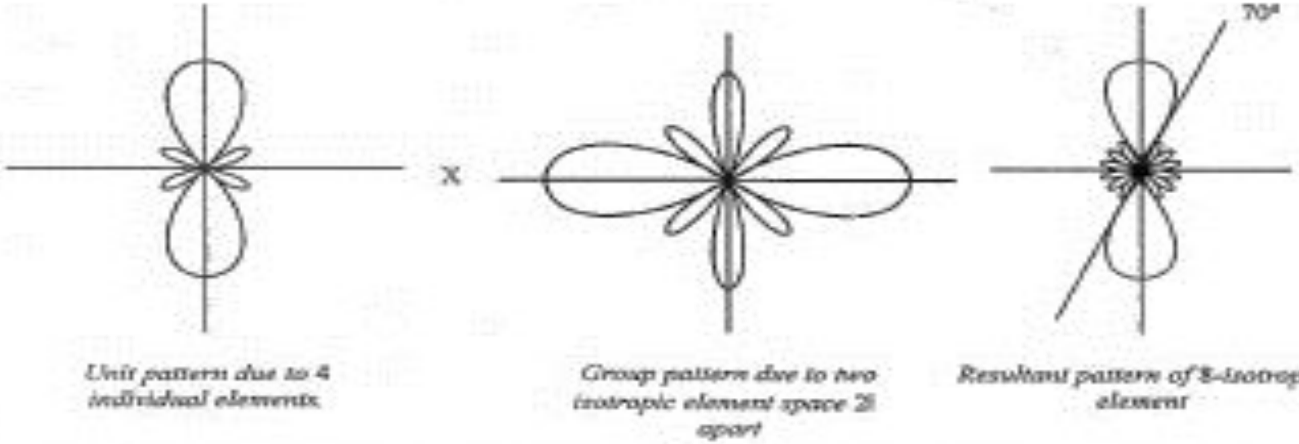


Fig. 3.16 *Resultant radiation pattern of 8-isotropic elements by pattern multiplication.*

The important features of resultant pattern are as follows:

(i) The width of the principal lobe (between nulls) is the same as the width of the corresponding lobe of the group pattern.

(ii) The sum of the nulls in the unit and group pattern gives the number of nulls in the resultant pattern assuming none of the nulls are coincident.

(iii) The number of secondary lobes in the resultant pattern can be determined from the number of nulls in the resultant pattern.

THANK YOU