Comparative Analysis of Linear Antenna Arrays

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Abstract: The gain or directivity of single antenna is less. To increase the gain and directivity the solution is antenna array. It is one of the common methods for combining the radiation from a group of similar antennas in which the phenomenon of wave interference is involved. In this paper analysis of Linear Broadside, Binomial, Dolph-Tchebyscheff antenna arrays is done. And results are compared. The Binomial Array is found best among these three types of antenna arrays in terms of directivity and sidelobes.

Keywords: Directivity, Broadside Array, Binomial Array, Dolph-Tchebyscheff Array.

I. Introduction

In many applications it is necessary to design antennas with very high gain to meet the demands of long distance communication. This can be done by increasing the size of antenna. Enlarging the dimensions of single antenna often leads to more directive characteristics. Another method is increasing the dimensions of antenna without increasing the size of individual element is antenna array. The elements of an array are always identical [1]. The total field produced by antenna array at large distance from it, is the vector sum of the field produced by individual antennas of the array system. The phase depends upon the relative spacing between the elements [2].The concept of an antenna array was first introduced in military applications in the 1940s [3]. This development was significant in wireless communications as it improved the reception and transmission patterns of antennas used in these systems. In this paper three types of Linear Antenna Array (Broadside, Binomial, Dolph-Tchebyscheff antenna array) are compared by using MATLAB software.

II. Antenna Array Types

Antenna arrays can be classified according to the distribution of elements with equal and unequal excitations of currents. These are uniform linear arrays and non-uniform linear antenna arrays. Uniform linear arrays are the arrays in which the elements are fed with a current of equal magnitude with progressive phase shift along the line. The common example of Uniform linear array is broadside arrays. Broadside arrays are those in which a number of identical parallel antennas are setup along a line perpendicular to respective axes. In Broadside array individual antennas (or elements) are equally spaced along a line and each element is fed with current of equal magnitude all in same phase [2]. As uniform current is required so there is no need of special designed equations in case of these arrays.

$$E_t = E_0 + E_1 e^{j\Psi} + E_2 e^{j2\Psi} + \ldots + E_{n-1} e^{j(n-1)\Psi} \quad (1)$$

where $\Psi = \beta d \cos\phi$

and $\beta = 2\pi/\lambda$, λ is wavelength and d is spacing between elements.

Since for broadside arrays $\alpha=0$ and $\Psi=0$

So $\beta d \cos\phi = 0$

$$\phi = 90° \text{ and } 270°$$

so major lobe is having maximum radiation along perpendicular direction and 270°. Non-uniform linear arrays are those in which the elements are fed with the currents of unequal magnitude. The examples of non-uniform arrays are binomial and Dolph-Tchebyscheff arrays. Binomial arrays are considered as non-uniformly excited and equally spaced arrays. Binomial array is an array in which the amplitudes of the Antenna elements in the array are arranged according to the coefficients of the binomial series:

$$(x+a)^n = \sum_{k=0}^{n} \binom{n}{k} x^k a^{n-k} \tag{2}$$

The excitation coefficients for the binomial array are also given by Pascal's triangle as shown below in Table I in which each internal integer (leaving the side integers) is the sum of the above adjacent integers [3]:

Table I: Pascal's Triangle

No. of Sources	***Current Elements***												
1.							1						
2.						1		1					
3.					1		2		1				
4.				1		3		3		1			
5.			1		4		6		4		1		
6.		1		5		10		10		5		1	
7.	1		6		15		20		15		6		1

C.L.Dolph proposed that for a linear in-phase broadside arrays it is possible to minimize the beamwidth of main lobe for a specified side-lobe-level and vice-versa i.e. if the beam width between firstnulls is specified then the side-lobe-level is minimized [2]. Dolph-Tchebyscheff arrays are alsononuniformamplitude antenna array. So in case of Dolph-Tchebycheff arrays the non-uniform currentdistribution through elements can be calculated with the help of following polynomial equations:

$$T_0(x) = 1 \tag{3}$$

$$T_1(x) = x \tag{4}$$

$$T_2(x) = 2x^2-1 \tag{5}$$

$$T_3(x) = 4x^3-3x \tag{6}$$

So on the basis of above given methods the value of the currents are calculated and used in the below method for the calculation of radiation patterns of all the three arrays.

III. Simulations

Basically the antenna array design involves calculating the complex currents of the individual antenna elements and selecting an appropriate antenna element [7]. The array factor of *n* isotropic point sources with different excitations placed along the x axis on the x-y plane is given by [1]

$$\mathrm{AF} = \omega_0 + \omega_1 e^{j\Psi} + \omega_2 e^{2j\Psi} + \cdots + \omega_{n-1} e^{j(n-1)\Psi} \tag{7}$$

$$\Psi = \beta d \cos\phi \tag{8}$$

The ω_n are the complex currents of the elements, Ψ is the wave number, *d* is the inter-element Spacing and β is the angular variable. The frequency response of a *n* point FIR filter is given by

$$H(j\Psi) = h_0 + h_1 e^{-j\Psi} + h_2 e^{-2j\Psi} + \cdots + h_{n-1} e^{-j(n-1)\Psi} \tag{9}$$

Where h_n the impulse-response coefficients of the FIR filter and ω are is discrete angular frequency. The equations 7 and 9 are similar except of the minus sign [7]. So with the help of the equation 7 the graph should be plotted in MATLAB with the help of required codes for various elements as compared with the filter design. The plotted radiation pattern gives the value of directivity and sidelobes as given below in Fig.1 (for 6 elements):

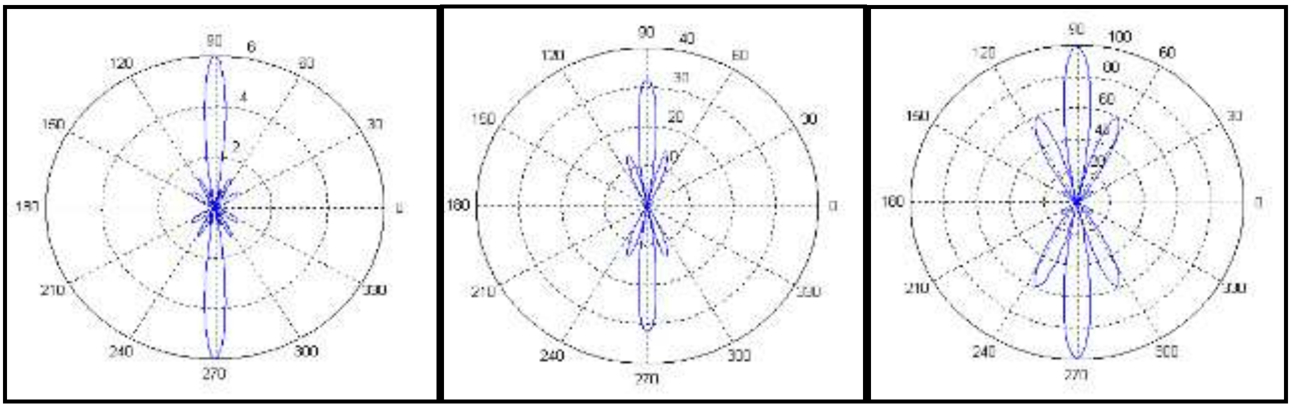


Figure 1: Directivity Plots & Side Lobe Plots for 6 elements. a) Broadside Antenna Arrays, b) Binomial Antenna Arrays,c) Dolph-Tchebyschev Antenna Arrays.

From the figure1 it becomes clear that for Broadside arrays (figure 1-a) the directivity should be 6db and maximum sidelobe level is at 1. For the case of Binomial arrays (figure1-b) the directivity should be 32db and sidelobe are at 14 db. For the Dolph-Tchebyschev array (figure 1-c) the directivity should be 100 db and sidelobe level at 60 db.

IV. RESULTS

Also the comparison among three arrays can be done by plotting the graphs for the different values of directivity and sidelobes. The array having the maximum directivity with minimum sidelobe levels can be considered as best. So for the comparison the graphs with number of elements v/s directivity are plotted for these three arrays.

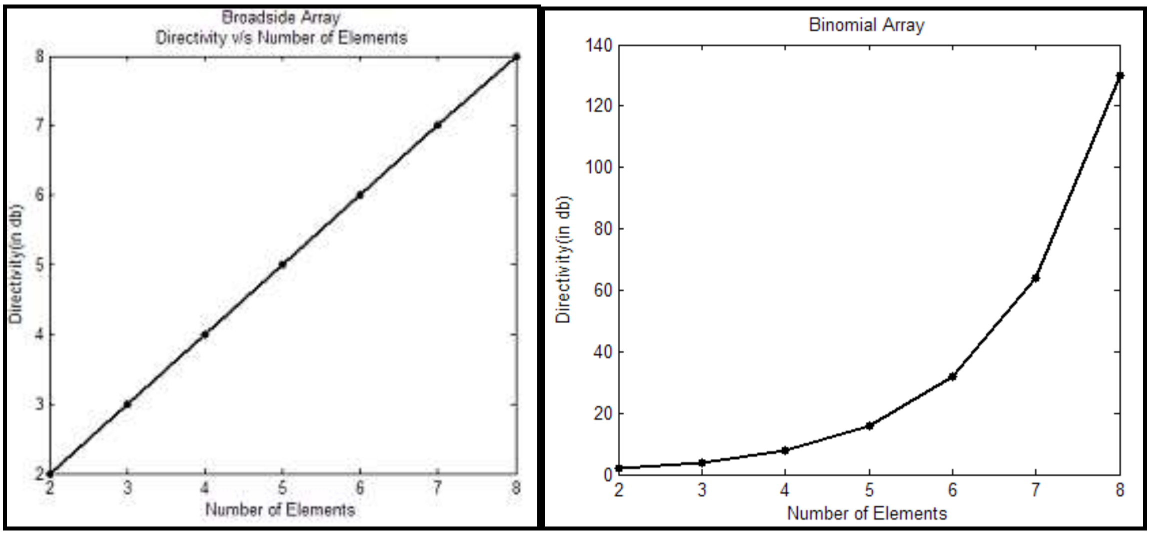
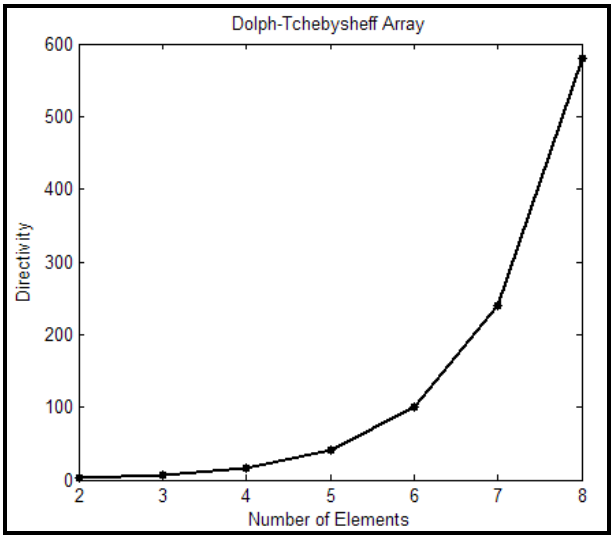


Figure 2: Directivity v/s Number of Elements Plots. a) Broadside Antenna Arrays, b) Binomial Antenna Arrays,



c) Dolph-Tchebyschev Antenna Arrays.

From figure 2-a it is clear that directivity in case of broadside array increases linearly with the increase in number of elements in an array. The directivity of Binomial array shown in figure 2-b and Dolph-Tchebyschev array as shown in figure 2-c increases exponentially with the increase in number of elements. It is observed that the increase in directivity of Dolph-Tchebyscheff array is more as compared to that of Binomial and Broadside arrays.

Also as second parameter for the comparison is side lobe level. In the similar manner the graphs are plotted. From figure 3-a, 3-b and 3-c, it is clear that the side lobe for Broadside arrays is less as compared to that of other two Binomial and Dolph-Tchebyscheff arrays. But the directivity for Broadside arrays is very less as compared to that of these arrays.

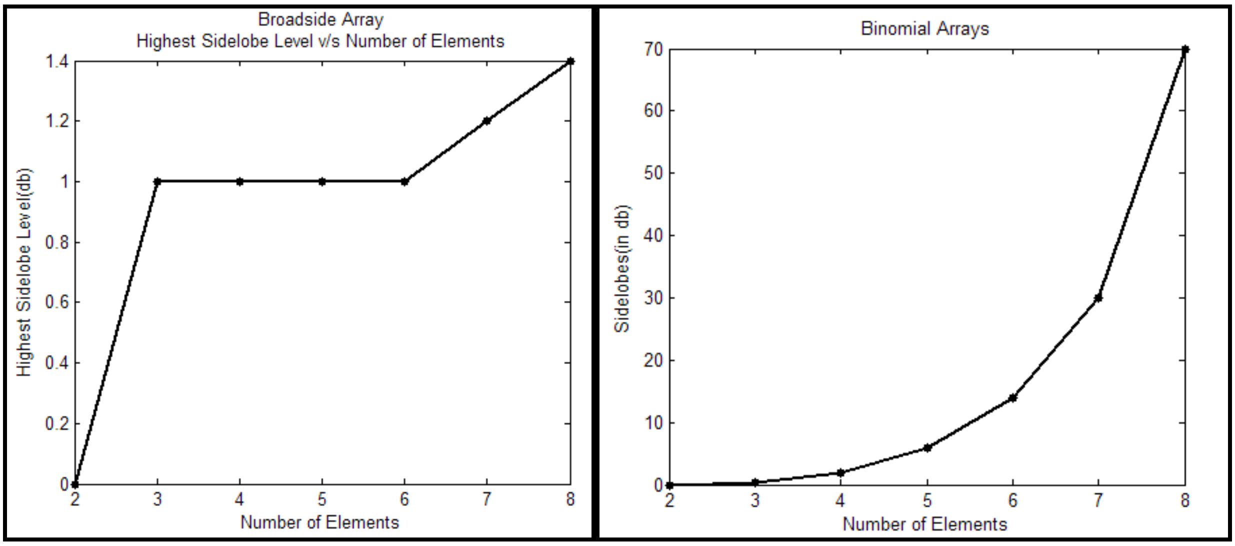
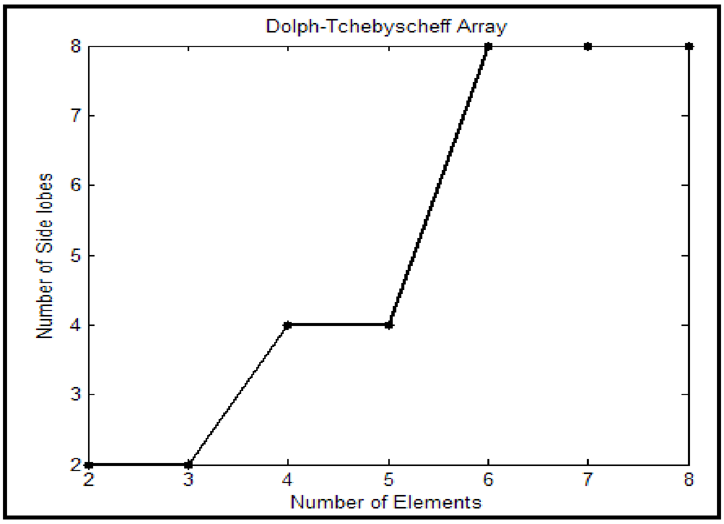


Figure 3: Side Lobe v/s Number of Elements Plots. a) Broadside Antenna Arrays, b) Binomial Antenna Arrays,



c) Dolph Tchebyschev Antenna Arrays.

V. CONCLUSION

It is concluded that the binomial arrays are considered to be best from the other two arrays. The binomial array is having high directivity as compared to that of broadside arrays whereas binomial array is having lower side lobe level as compared to that of Dolph-Tchebyscheff arrays.

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