Computation Of Uniform And Non-Uniform 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.

This paper discusses about the computation of uniform and non uniform antenna array parameters. The different types of antenna arrays are broadside array,end fire array ,binomial arrays and chebyshev array etc..,

In this paper analysis of Linear Broadside, Binomial, Dolph-Tchebyscheff antenna arrays is done. And results are compared.

Keywords—broadside,endfire ,binomial.array factor

I. INTRODUCTION

Antenna array is a combination of several single antenna elements in a particular fashion to improve the performance of the system is known as the array antenna. Generally, the antenna elements are arranged in linear ,circular ,planar and 3D type etc..,.

Array factor quantifies the effect of combining radiating elements in an array without the element specific radiation pattern taken into account. The overall radiation pattern of an array is determined by this array factor combined with the radiation pattern of the antenna element. The overall radiation pattern results in a certain directivity and thus gain linked through the efficiency with the directivity. Directivity and gain are equal if the efficiency is 100%.

side-lobe ratio is the Ratio of amplitude of first side lobe to major lobe.
side lobe level = 20log(side-lobe ratio).

Uniform array means, all the elements of antenna are fed with equal amplitude and phase.
Types of uniform antenna arrays:
Broadside and end fire arrays:
Array that is designed to radiate perpendicular to direction of axis of array is known as broadside array The direction of maximum radiation is always perpendicular to the line or the plane of the array according to the elements that lie on a line or a plane. A broadside array looks like a ladder. A uniform broadside array is a linear array.
Whereas, array that is designed to radiate along the direction of its axis is known as end fire array.

Non-uniform array means elements of the array are fed with different amplitudes and different phases.
Types of non-uniform amplitude linear array
Binomial and Chebyshev arrays:
A **binomial antenna array** is an array of non-uniform amplitudes in which the amplitude of the radiating sources are fed according to the

coefficients of successive terms of a **binomial** series.
Whereas, Chebyshev array is a Non-uniform amplitude array which yields and fed with the optimum source amplitude distribution for a specified Side-Lobe Level(SLL) with all side lobes of the same level.
Radiation pattern is a graphical representation of an antenna radiation field as a function of space co-ordinates

II.DESIGN OF ANTENNA ARRAYS

Design of Broadside and endfire antenna arrays:

Broad side array is a stacked collinear antenna consisting of half-wave dipoles spaced from one another by one half (λ/2) wavelengths,produces a highly directional radiation pattern that is broadside or normal to the plane of the array . Its radiation pattern is bidirectional but pattern has a broad beam width and high gain. The elements should be arranged in parallel and in the same phase when more than two elements are used in a broadside array.

The elements of a uniform broadside array contribute EM fields of equal amplitude and phase . End-fire array main lobe at = 0^o or = 180^o Broadside array main lobe at = 90^o The maximum of the array factor occurs when the array phase function is zero.

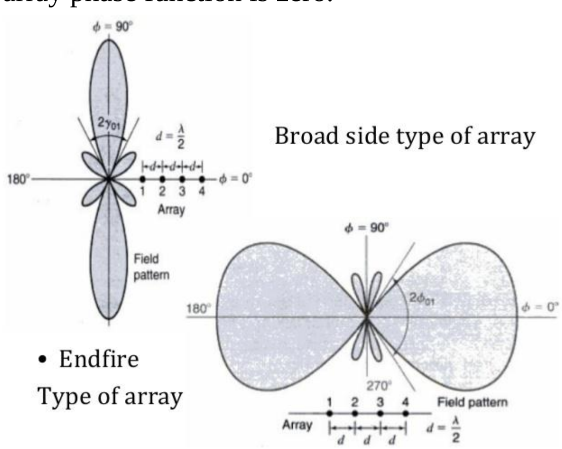


Fig1:Radiation patterns of BSA and EFA

The phasing of the uniform linear array elements may be chosen such that the main lobe of the array pattern lies along the array axis (end-fire array) or normal to the array axis (broadside array). The maximum of the array factor occurs when the array phase function is zero.

$$\Psi = \alpha + kd\cos\theta = 0 \qquad \textbf{eq-1}$$

For a broadside array, in order for the above equation to be satisfied with θ = 90 degrees, the phase angle α must be zero. In other words, all elements of the array must be driven with the same phase. With α = 0 degree, the normalized array factor reduces to

$$AF = \frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\frac{\psi}{2}} \qquad \text{-------2}$$

In general the directivity of broadside array is strongest as compared to end fire array, but the end fire produces stable unidirectional radiations. And broadside array give more symmetric pattern as the pattern is bidirectional and can be used for long distance communication as their directivity is strong. The end fire array can be used to construct directional antennas and can be used in satellite dish antenna to receive signal from fixed direction.

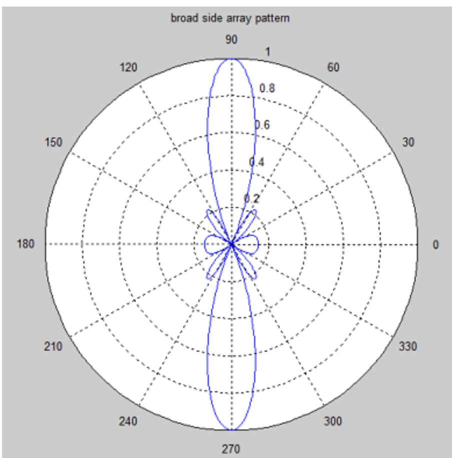
The effect of number of elements on the radiation patterns of both the arrays

In case of end fire array direction of main lobe remain unchanged, as the spacing remain unchanged throughout the results that are obtained But the minor lobes increased and main lobe little bit become narrow as thenumber of elements increases. In case of broadside array, it is clearly shown in results its directivity is more than end fire array as the main lobe is very much narrow, and also pattern is symmetrical, but the grating lobes appears with increase in number of elements. End fire array is unidirectional as spacing
is constant here, only the number of elements are varied, it may be bidirectional if the spacing is increased. The broadside array is bidirectional as it is shown in results, and produces more symmetrical pattern and can be used for long distance communication where directivity needed to be strong. End fire array provide

directional radiations and stable unidirectional radiation pattern. Thus to get more directivity size of array has to be more. It can be used in satellite dish antennas, where a very high directivity is needed, because they are to receive signals from a fixed direction.

III.RESULTS AND DISCUSSION

The optimization of directivity and number of minor lobes and main lobes for the various numbers of elements for broadside array and end fire array arrays can be done by varying the number of elements to be placed then the analysis is done. And comparison is done



between both. The radiation pattern is obtained using the MATLAB software.

Broadside array simulated Radiation Pattern:

Fig2 :Simulated radiation pattern

For N=8, d = λ/2 ,F=100Mhz

Binomial Array: The binomial array was investigated and proposed by J. S. Stone to synthesize patterns without side lobes.

As long as the d < λ/2, the first null does not exist. If d = λ/2, then null will be at □ = 00 and 1800. Thus, in the “visible” range of □, all secondary lobes are eliminated.

This array factor, being the square of an array factor with no sidelobes, will also has no sidelobes. Mathematically, the array factor above represents a 3-element equally-spaced array driven by current amplitudes with ratios of 1:2:1. In a similar fashion, equivalent arrays with more elements may be formed.

If d ≤ λ/2, the above AF does not have side lobes regardless of the number of elements N. The excitation amplitude distribution can be obtained easily by the expansion of the binome in (6.50). Making use of Pascal’s triangle, this is given by

1

1 1

1 2 1

1 3 3 1

1 4 6 4 1

1 5 10 10 5 1

The relative excitation amplitudes at each element of an (N+1) element array can be determined from this traiangle. An array with a binomial distribution of the excitation amplitudes is called a binomial array.

The excitation distribution as given by the binomial expansion gives the relative values of the amplitudes. It is immediately seen that there is too wide variation of the amplitude, which is a disadvantage of the binomial arrays. The overall efficiency of such an antenna would be low. Besides, the binomial array has a relatively wide beam. Its HPBW is the largest as compared to the uniform or the Dolph–Chebyshev array.

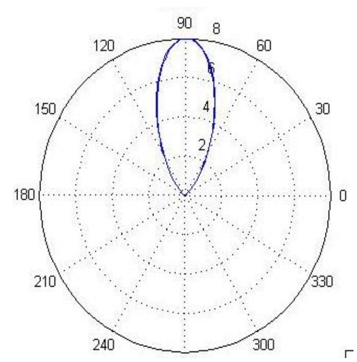


Fig3a:simulated plot of binomial array

For N=4 and d = λ/2

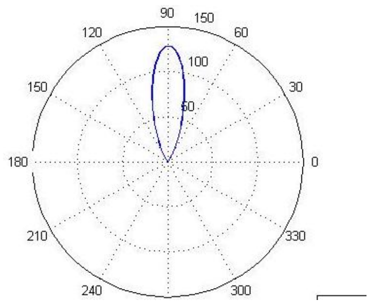


Fig3a:simulated plot of binomial array
For N=8 and d = λ/2

Chebyshev Array Antenna:

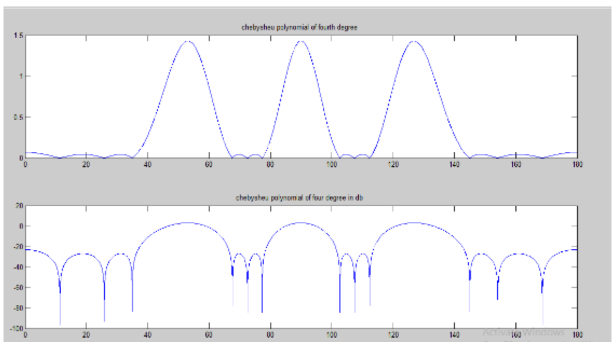


Fig4:Four element Chebyshev Polynomial array

Antennas are fed with as per Chebyshev series.Through the transformation of x=cos(u), the terms may be written as a set of polynomials.

[Chebyshev polynomials-Tn(x)].

$\cos 0u=1=T0(x)$

$\cos 1u=x=T1(x)$

$\cos 2u=2x^2-1=T2(x)$

$\cos 3u=4x^3-3x=T3(x)$

$\cos 4u=8x^4-8x^2+1=T4(x)$

$\cos 5u=16x^5-20x^3+5x=T5(x)$

$\cos 6u=32x^6-48x^4+18x^2-1=T6(x)$

$\cos 7u=64x^7-112x^5+56x^3-7x=T7(x)$

$\cos 8u=128x^8-256x^6+160x^4-32x^2+1=T8(x)$

$\cos 9u=256x^9-576x^7+432x^5-120x^3+9x=T9(x)$

Using properties of the Chebyshev polynomials, we may design arrays with specific side lobe characteristics. Namely, we may design arrays with all side lobes at some prescribed level.

Properties of Chebyshev Polynomials

1. Even ordered Chebyshev Polynomials are even functions.

2. Odd ordered Chebyshev Polynomials are odd functions.

3.The magnitude of any Chebyshev Polynomial is unity or less in the range of -1<=x<=1.

4.Tn(1)=1 for all Chebyshev Polynomials .

5.The important property of the Chebyshev Polynomial is that if the ratio R is specified the beam width to the first null is minimized.

if the beam width is specified , the ratio R is maximized(side-lobe level minimized). The order of the Chebyshev Polynomials should be one less than the total number of elements in the array(p-1).

Chebyshev Array Design Procedure

1.Select the appropriate AF(array factor) for the total number of elements(p).

$$(AF)_p=\sum_{n=1}^{M} a_n \cos[(2n-1)u] \quad p=2M \text{ (even)} \qquad \text{eq-3}$$

$$(AF)_p=\sum_{n=1}^{M} a_n \cos[2(n-1)u] \quad p=2M+1 \text{(odd)} \qquad \text{eq-4}$$

2.Replace each cos(mu) term in the array factor by its expansion in terms of powers of cos(u).

3.For the required main lobe to side lobe ratio (R_0) ,find x_0 such that

$$R_0=T_{p-1}(x_0) = \cosh[(p-1)\cosh^{-1} x_0] \qquad \text{eq -5}$$

$$x_0=\cosh[(\cosh^{-1} R_0)/(p-1)] \qquad \text{eq-6}$$

4.plot the array factor of different values .

Table-1 BSA

s.no	N	No of Side lobes	SLL	Beam width	D(dB)
1	2	0	0	~180	3.01
2	4	4	-13.5	57.3	6.02
3	8	12	-13.5	28	9.030

Table 2-EFA

s.no	N	No of Side lobes	SLL	Beam width	D(dB)
1	2	0	0	180	6.02
2	4	4	-13.5	114.6	12.04

3	8	12	-13.5	81.022	18.06

Table-3:Binomial array

s.no	N	No of Side lobes	SLL	Beam width	D(dB)
1	2	0	-∞	180	3.01
2	4	0	-∞	68.14	5.5
3	8	0	-∞	44.61	6.98

Table 4:Chebyshev array results

s.no	N	No of Side lobes	SLL(dB)	Beam width	D(dB)
1	2	0	-30	180	3.01
2	4	4	-30	61.8	6.99
3	8	12	-30	30.21	9.97

From fig2,SLL and Beamwidth,Directivity of BSAare calculated and tabulated in table-1.

From fig3, SLL and Beamwidth,Directivity of Binomial array are calculated and tabulated in table-3.

From fig4, SLL and Beamwidth,Directivity of Chebyshev array are calculated and tabulated in table-4.

In table-2,Antenna parameters of EFA are tabulated.

IV.Conclusion

In this paper three types of Linear Antenna Array (Broadside, Binomial, Dolph-Tchebyscheff antenna array) are compared by using MATLAB software.

It was observed that as the number of elements increased number of side lobes are also increased. And the first side lobe level of N element uniform antenna array is -13.5dB and it was observed that it is independent of number of elements.

Binomial antenna array with N number of elements is designed and analysed.

And it was also observed that number of side lobes are nil and beam width is more compared to uniform antenna array. Directivity is less than uniform antenna array.

Chebyshev antenna array is designed at a frequency of 100MHz and side lobe ratio of 30 is analysed.It was observed that SLL of all the side lobes is equal.And it was observed chebyshev antenna array is giving the better results.The Directivity of Endfire antenna array is twice that of BSA.

V.References

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