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Performance Test of Various Types of Antenna Arrays in Real Propagation Environment

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Abstract. The research was conducted on various types of antenna arrays namely Uniform Array, Binomial Array, Dolph-Chebyshev Array, and Taylor Array. This research is done in the real propagation environment in order to define precisely the number of antenna elements, the distance between the elements, the angle of the antenna arrays, the side lobe level and the n-bar array distribution. The testing process is done by using Matlab and the Non-Uniform Array Simulation Program. The results obtained for various types of antenna arrays are as follows: On Uniform Array produces Half Power Beam Width (HPBW) of 10.152° and directivity of 10 dB, on Binomial Array generates Half Power Beam Width (HPBW) of 20.245° and directivity of 7.47 dB, on Dolph-Chebyshev Arrayproduces Half Power Beam Width (HPBW) of 20.304° and directivity of 4.0185 dB, and on Taylor Arrayproduces Half Power Beam Width (HPBW) of 12.78° and directivity of 8.9 dB.
Keywords—Binomial Array; Dolph-Chebyshev Array; Real Propagation; Taylor Array; Uniform Array

1. Introduction

In communication world, antennas are considered as the most important component of a fully-functional communication process. An antenna is defined as a tool that is used to transmit and receive electromagnetic wave, this wave is transmitted from the transmitter to the receiver. A good antenna design will lead to the increase of the whole communication system's performance. One example is the design of an array antenna. Several antennas are arrayed according to certain geometric and electrical configuration to form an antenna array. In order to simplify the analysis, synthesis and fabrication process, the antennas are arrayed with the same type, such as array dipole, array waveguide and array microstrip.[1-3]

In this paper, antenna arrays with four different types are designed, these types are Uniform Array, Binomial Array, Dolph-Chebyshev Array, and Taylor Array. Each type has different characteristic, thus, the design between each type will vary. The simulation process is done in the real propagation environment, thus, the number of antenna elements, the distance between the elements, the angle of the antenna arrays, the side lobe level and the n-bar array distribution can be defined beforehand. From the simulation results, it can be defined that there is a relation between the number of antenna elements

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and the directivity, when the number of antenna elements increased then the electromagnetic wave that is generated will be more direct [4]. In [5], research on the characteristic of the non-uniform antennas using firefly algorithm is conducted; in [6], research regarding the integration between antenna array and solar cell multicrystal silicon is done; in [7], the multicoupling of the antenna array is researched; in [8], research of antenna array using the stepped and half bow-tie slotted is conducted; in [9], genetic algorithm is used to research the non-uniform antennas; in [10], research regarding the non-uniform antennas concentric circular is done; in [11], research regarding the non-uniform antenna array spacing which focused on the travelling rectangular design is conducted. Based on all of the above references, there is a research opportunity regarding the Half Power Beam Width (HPBW) comparison between the uniform array antennas and the non-uniform array antennas, such as Binomial array, Dolph-Chebysev array, and Taylor array. HPWB in an antenna is an angle between the mainlobe and other lobes, which can be vertical or horizontal beam.

The paper is organized as follows: in Section 2, the theory of antenna arrays in the real propagation environment is discussed, the simulation process is described in Section 3, in Section 4, the simulation results as well as its analysis are discussed, finally, the conclusion is presented in Section 5.

2. Antenna Arrays in Real Propagation Environment

As mentioned in Section I, the simulation process is done in the real propagation environment so that the value of the number of antenna elements, the distance between the elements, the angle of the antenna arrays, the side lobe level and the n-bar array distribution can be defined first and also can be changed to differentiate the results between each value.There are four antenna arrays to be designed, and they can be divided in to two types which are the Uniform Array and the Non-uniform Arrays (Binomial array, Dolph-Chebyshev Array, and Taylor Array.

2.1. Uniform Array

For the Uniform Array, there are two alignment types that are tested in this paper, they are the Broadside Array and Endfire Array.

The Broadside Array alignment has a maximum radiation angle value, ϕ, of 90^o [4]. The radiation pattern for Broadside Array alignment can be seen in Figure. 1

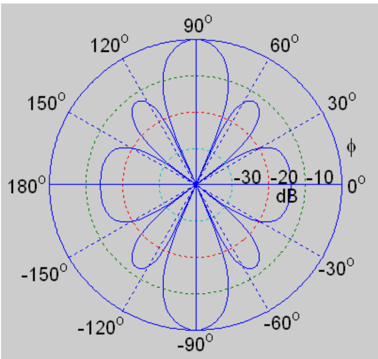

Figure1. Radiation Pattern for Broadside Array

The following equations can be used in order to calculate the value of HPBW and the value of Directivity for Broadside Array:

$$HPBW \approx 50.76 \times \frac{\lambda}{Nd} \tag{1}$$

$$D_{dB} = 10\log\left[2N\left(\frac{d}{\lambda}\right)\right] \tag{2}$$

The Endfire Array alignment has a maximum radiation angle value, ϕ, of 0^o or 180^o [4]. The radiation pattern for Endfire Array alignment can be seen in Figure. 2.

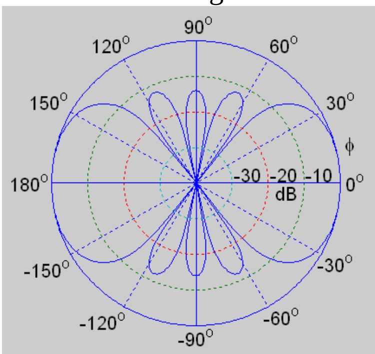

Figure2. Radiation Pattern for Endfire Array

The following equations can be used in order to calculate the value of HPBW and the value of Directivity for Endfire Array:

$$HPBW \approx \left(2\sqrt{0.886\frac{\lambda}{Nd}}\right)\times\frac{180}{\pi} \tag{3}$$

$$D_{dB} = 10\log\left[4N\left(\frac{d}{\lambda}\right)\right] \tag{4}$$

The simulation process is done in the real propagation environment so that the value of the number of antenna elements, the distance between the elements, and the angle of the antenna arrays can be defined before the simulation and also can be changed to differentiate the results between each value.

2.2. Non-Uniform Array

A non-uniform array antenna is an antenna array that has the same distance between elements but has different amplitude. The non-uniform arrays that are used in this research are Binomial Array, Dolph-Chebyshev Array, and Taylor Array.

2.2.1. Binomial Array

Binomial Array generates a really small sidelobe, even for the parameter d (distance between elements) value smaller than $\lambda/2$ the sidelobe is not visible, however Binomial Array generates a wide mainlobe.

Equations can be used in order to calculate the value of HPBW and the value of Directivity of Binomial Array are as follows:

$$HPBW \approx \frac{1.06}{\sqrt{N-1}} \tag{5}$$

$$D_{dB} = 10\log\left(1.77\sqrt{N}\right) \tag{6}$$

Due to its characteristic, in order to find an optimum result, the distance between elements should be set to $d \leq \lambda/2$.

2.2.2. Dolph-Chebyshev Array

Dolph-Chebyshev Array is more flexible than Uniform Array and Binomial Array because the sidelobe can be adjusted freely. In order to obtain an optimum result, the sidelobe should be adjusted to the uniform sidelobe.

In order to calculate the value of HPBW and the value of Directivity for Dolph-Chebyshev Array, the following equations can be used:

$HPBW = f\left(hpbw_{uniform-array}\right)$, where f is the Bordening Factor: $f = 1 + 0.632\left[\frac{2}{R}\cosh\sqrt{\left(\cosh^{-1} R\right)^2 - \pi^2}\right]^2$,

and R is the Sidelobe ratio.

$$D \approx \frac{101.5}{HPBW}$$

2.2.3. Taylor Array

Taylor Array has similar characteristic to theDolph-Chebyshev Array, its sidelobe can be adjusted to the uniform sidelobe to achieve optimum result, however, only some of the first sidelobe that can be adjusted in the Taylor Array.

In order to obtain the value of HPBW and the value of Directivity for Taylor Array, the following equations can be used:

$$\Theta_0 \simeq 2\sin^{-1}\left\{\frac{\lambda\sigma}{\pi l}\left[(\cosh^{-1} R_0)^2 - \left(\cosh^{-1}\frac{R_0}{\sqrt{2}}\right)^2\right]^{1/2}\right\}$$

$$\sigma = \frac{\overline{n}}{\sqrt{A^2 + \left(\overline{n} - \frac{1}{2}\right)^2}}$$

$$D \approx \frac{101.5}{HPBW}$$

3. Simulation Process

The whole simulation process usedwith Mathlab sofware, the flowchart for the simulation process can be seen in Figure. 3.

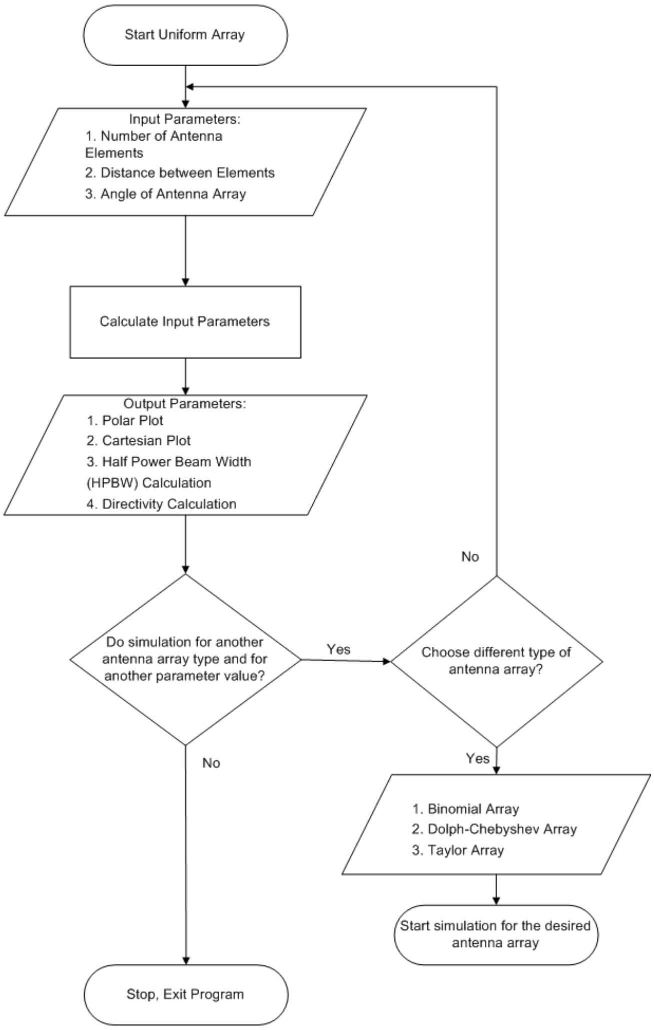

Figure3. Simulation Process Flowchart

The initial process of the simulation is by starting the simulation for the Uniform Array. As this process is done in the real propagation environment, the next step is, the value of the parameters such as number of antenna elements, distance between elements and the angle of the antenna array is defined. The third and the fourth step calculate the input value to get the Polar and Cartesian plot and also calculate the value of HPBW and directivity.

Once the simulation for the Uniform Array is done, the next simulation can be run. For the next simulation, another type of antenna array can be selected and the value of the input parameters can be changed as well.

The input parameters that can be changed are number of antenna elements (N), distance between elements (d), and angle of antenna array (ϕ).

4. Result and Analysis

This Section presents the results from the simulation process as well as the analysis for all of the results.

4.1. Uniform Array

For the Uniform Array, there are two alignment types that are tested in this research namely the Broadside Array and Endfire Array.

For Broadside Array alignment, the parameters that are defined first are: $N = 5$, $d = 1/2\lambda$, and $\phi = 90^o$. The result of this simulation can be seen in Figure. 4.

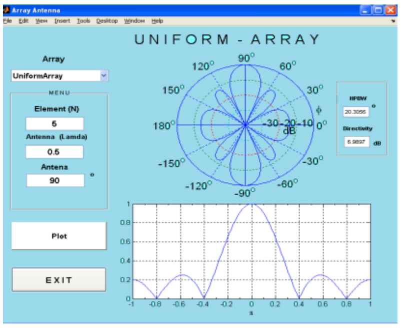

Figure4. Broadside Array Simulation Result for$N = 5$

For the next simulation, the parameters are changed as follows: $N = 10$, $d = 1/2\lambda$, and $\phi = 90^o$. The result can be seen in Figure. 5.

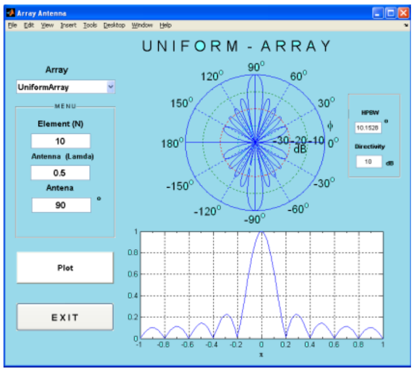

Figure5. Broadside Array Simulation Result for $N = 10$

It can be seen from the above simulations, for Broadside Array, the more the number of the elements, the larger the Directivity value but the sidelobe (value of HPBW) became smaller.

For Broadside Array alignment, the parameters that are defined first are: $N = 5$, $d = 1/2\lambda$, and $\phi = 0^o$ and 180^o. The result of this simulation can be seen in Figure. 6.

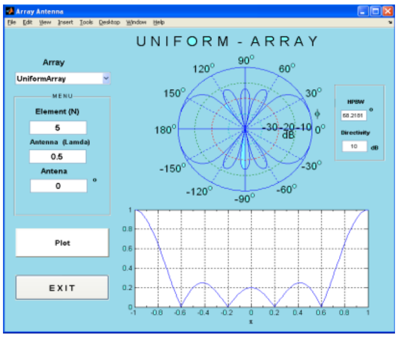

Figure6. The Endfire ArraySimulation Resultfor N = 5

For the next simulation, the parameters are changed as similar to the second simulation of Broadside Array: N = 10, d = 1/2λ, and ϕ = 90^o. The result can be seen in Figure. 7.

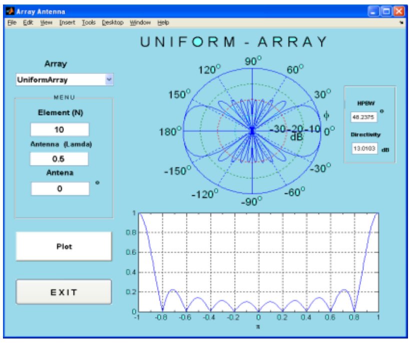

Figure7. The Endfire Array Simulation Resultfor N = 10

From the above simulations, it can be concluded that the larger the number of the elements, the smaller the HPBW value and the larger the Directivity Value.

4.2. Binomial Array

For Binomial Array, the parameters that are defined first are the following: N = 5, d = 1/2λ, and ϕ = 90^o. The result of this simulation can be seen in Figure. 8.

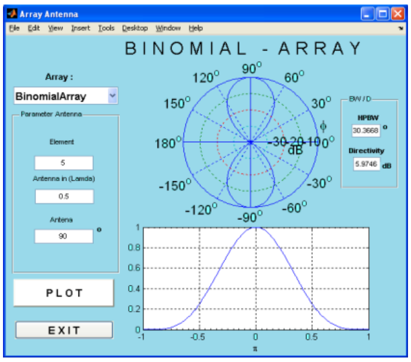

Figure8. The Binomial ArraySimulation Resultfor$N$ = 5

For the next simulation, the parameters are changed as follows: N = 10, d = 1/2λ, and ϕ = 90^o. The result can be seen in Figure. 9.

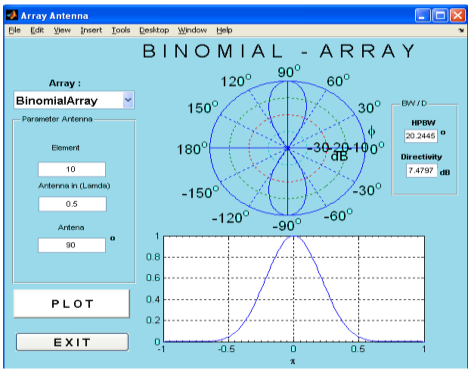

Figure9. Binomial ArraySimulation Resultfor$N$ = 10.

From the above simulations, it can be concluded that Binomial Array has the same characteristic as the Uniform Array, which is the larger the number of the elements, the smaller the HPBW value and the larger the Directivity Value.

4.3. Dolph-Chebyshev

For Dolph-Chebyshev Array, the sidelobe is adjusted first to get an optimum result. The parameters are as follows: $N = 5$, $d = 1/2\lambda$, and sidelobe, R = 26 dB and R = 30 dB. For R = 26 dB, the result can be seen in Figure 10.

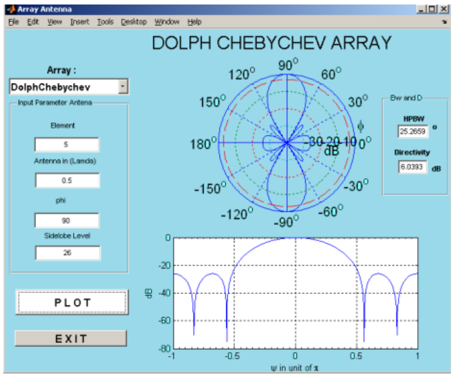

Figure10. Dolph-Chebyshev Array Simulation Result for$R$ = 26 dB

For R = 30 dB, the result can be seen in Figure. 11.

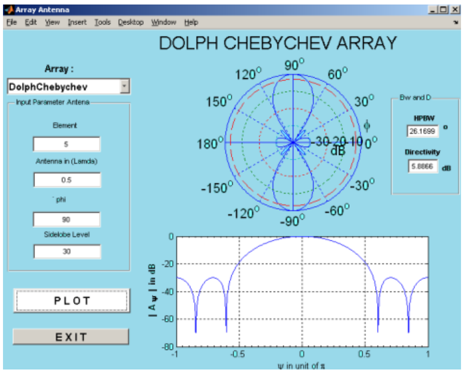

Figure11.Dolph-Chebyshev Array Simulation Result for R = 30 dB

From the above simulations, it can be concluded that with the same value of number of elements, the larger the value of the sidelobe will result to the larger the value of the HPBW and the smaller the value of the Directivity.

4.4. Dolph-Chebyshev

It has been mentioned in Section II that Taylor Array has similar characteristic to the Dolph-Chebyshev Array, its sidelobe can be adjusted as desired. Thus, for Taylor Array, it is the number of the element that is changed, the sidelobe value remains unchanged.

For the first simulation, the parameters are the following: N = 10, d = 1/2λ, and R = 25 dB. The result is presented in Figure 12.

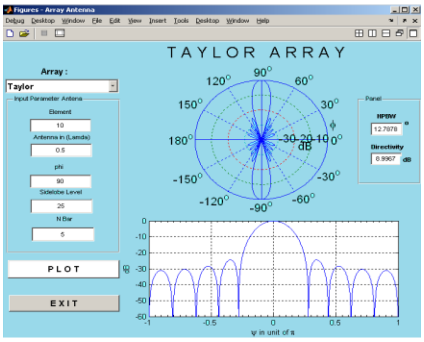

Figure12. The Taylor Array Simulation Result for$N$ = 10

For the second simulation, the parameter that is changed is only the number of elements, it is changed to N = 15. The result can be seen in Figure 13.

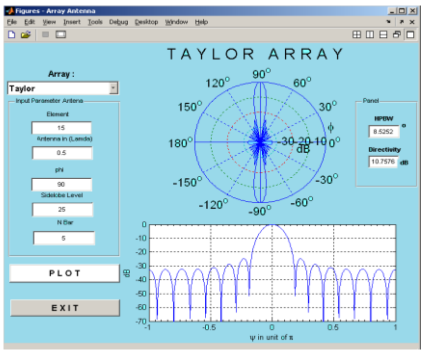

Figure13. The Taylor Array Simulation Result for N = 15

It can be concluded from the above simulations that the larger the number of the elements, the larger the Directivity value and the smaller the HPBW value.

The simulation results for all types of array and for all scenarios can be seen in Table1.

TABLE 1.SIMULATION RESULTS

Array Type	Output Value	
	Half Power Beam Width (HPBW)	***Directivity***
Uniform Array – Broadside Array Alignment (N=5, d=1/2λ)	20.5036	6.9897 dB
Uniform Array – Broadside Array Alignment (N=10, d=1/2λ)	10.152^o	10 dB
Uniform Array – Endfire Array Alignment (N=5, d=1/2λ)	68.2181^o	10 dB
Uniform Array – Endfire Array Alignment (N=10, d=1/2λ)	48.2375^o	13.01 dB
Binomial Array (N=5, d=1/2λ)	30.367^o	5.97 dB
Binomial Array (N=10, d=1/2λ)	20.245^o	7.47 dB
Dolph-Chebyshev Array (N=5, d=1/2λ, R = 26 dB)	25.2581^o	6.041 dB
Dolph-Chebyshev Array (N=5, d=1/2λ, R = 30 dB)	26.1699^o	5.8666 dB
Taylor Array (N=10, d=1/2λ)	12.78^o	8.9 dB
Taylor Array (N=15, d=1/2λ)	8.5252^o	10.7576 dB

5. Conclusion

There are two alignments for the Uniform Array, it can be concluded thatfor Broadside Array, the more the number of the elements, the larger the directivity value, but the sidelobe (value of HPBW) became smaller, meanwhile for the Endfire Array, it can be concluded that the larger the number of the elements, the smaller the HPBW value and the larger the Directivity Value.From the simulation results, it can be concluded that theBinomial Array has the same characteristic as the Uniform Array, which is the larger the number of the elements, the smaller the HPBW value and the larger the Directivity value.Fromthe Dolph-Chebyshev Array simulations it can be concluded that with the same value of number of the elements, the larger the value of the sidelobe will result to the larger the value of the HPBW and the smaller the value of the Directivity. The last simulation for the Taylor Array, itcan be concluded that the larger the number of the elements, the larger the Directivity value and the smaller the HPBW value.

6. References

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