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Non-Uniform Chebyshev Excitation of a Linear Broadside Antenna Array Operating at 1.8GHz

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NONUNIFORMCHEBYSHEVEXCITATIONOFALINEARBROADSIDEANTENNAARRAYOPERATINGAT18GHZ

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Non-Uniform Chebyshev Excitation of a Linear Broadside Antenna Array Operating at 1.8GHz

Aras Saeed Mahmood [α] & Dlnya Aziz Ibrahim [σ]

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I. Introduction

Wireless communication has become an integral part for modern word. The most popular standards for mobile phones in today's word is Global System for Mobile communication (GSM). A 4x4 rectangular microstrip patch antenna with the gain about $(13.8\sim14.4)$ dBi for GSM application was presented by [1]. [2] achived the same gain range using a 2x2 microstrip patch antenna for the same application. A 13.7dBi gain for the same application was achived by [3] using a 7 dipole elements with 0.82λ spacing forming a uniform linear broadside array operating at 1.8GHz. An anaolugous binomial excitation non-uniform linear broadside dipole antenna array has been used by [4] to achieved a 12.8 dBi gain with a 10-element and 0.82λ spacing. In this study another technique for current excition known as Chebyshev excition of a non-uniform linear dipole antenna array has been studied for GSM application at 1.8GHz. Linear array antenna has a wide range of applications in radar and communication systems due to higher directivity, low side lobe and high gain when compared with other kinds of single radiating element antenna [5].

Dolph-Chebyshev arrays are typical examples of non-uniform arrays [6]. The excitation coefficients for this array relates to Tschebyscheff polynomials. A Dolph-Tschebyscheff array with no side lobes (or side lobes of $-\infty$ dB) reduces to the binomial design [7]. Tschebyscheff polynomial is defined by equation:

$$T_m(x) = \cos(m\cos^{-1}x) \quad for\ -1 \le x \le +1 \quad (1)$$

$$T_m(x) = \cos h(m\cosh^{-1}x) \quad for\ \ x < -1, x > +1 \quad (2)$$

Where T denotes the Tschebyscheff and m is the order of the polynomial. For higher terms can be had from the recursion formula:

$$T_{m+1}(x) = 2\,x\,T_m(x) - T_{m-1}(x) \qquad (3)$$

Steps to be followed while calculating Dolph-Tchebyscheff amplitude distribution are given by [8] which give Dolph- Tchebyscheff optimum distribution for a specified side lobe level.

II. Design and Simulation Results

In this work some basic radiation characteristics for a non-uniform linear dipole antenna array has been analized through the variation of the number of the elements and the spacing between them using Chebyshev method for specifing the amplitudes of the excitation currents of the elements. For a 1.8 GHz operating frequency the length (L) and the radious (R) of the array element (half wave length dipole antenna) has been calculated from [9,10] and the elements were arranged parallel to each other along the Z-axis. The results were also compaired with that of a similar uniform and binomial arrays.

a) *Effect of Number of Elements on the Performance of Dipole Array Antenna*

The first proposed study was the impact of the number of elements on the radiation charactistics for linear array chybeshiv excitation. When the spacing between the elements were fixed at (0.5λ) and the number of elements were changed from 2 to 10 elements the current excitation amplitudes for the elements has been calculated using the steps given by [8] using the major to minor lobe ratio of 20dBi. Table (1) tabulates the current excitation amplitudes for all the 10- elements.

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Table 1 : Excitation coefficients for Dolph Tschebyscheff for different number of elements

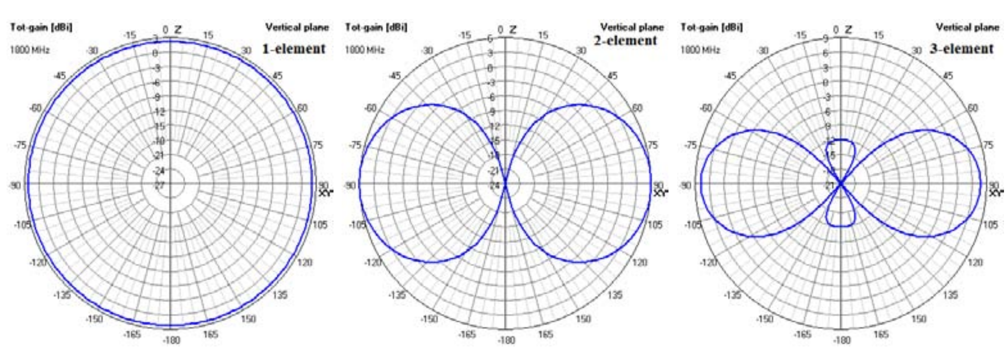
No. of Elements										
N=1	1									
N=2	1	1								
N=3	1	1.636	1							
N=4	1	1.736	1.736	1						
N=5	1	1.607	1.929	1.607	1					
N=6	1	1.439	1.855	1.855	1.439	1				
N=7	1	1.276	1.683	1.837	1.683	1.276	1			
N=8	1	1.139	1.507	1.72	1.72	1.507	1.139	1		
N=9	1	1.023	1.355	1.596	1.662	1.596	1.355	1.023	1	
N=10	1	0.926	1.212	1.436	1.558	1.558	1.436	1.212	0.926	1

The design simulation and optimization processes were carried out with the aid of the 4NEC2 simulator (antenna design procedure using 4NEC2 were mentioned in [11]) after equating the phase of the elements current to zero for broadside array. Table (2) tabulates some of the outputs of the 4NEC2 simulator for this section.

Table 2 : Gain, HPBW, SLL max and No. of SLLversus the number of elements

No. of elements	Gain (dBi)	HPBW (vertical plane) degree	HPBW (horizontal Plane) degree	SLL max. (dBi)	No. of SLL
1	2.14	360	80	-∞	0
2	5.97	60	80	-∞	0
3	7.72	40	80	-12.1	2
4	9.03	28	80	-10.9	4
5	10.07	24	80	-9.28	6
6	10.92	20	80	-8.84	8
7	11.62	16	80	-7.54	10
8	12.23	12	80	-7.4	12
9	12.75	12	80	-6.53	14
10	13.22	12	80	-6.37	16

The above data (Table 2) was translated to Fig. (1) through the pattern representation where the horizontal HPBW remained unchanged while the vertical one decreased with the elements up to 8 elements then kept constant. The number of side lobes, max. SLL and the gain all increase with the number of elements. Fig. (1) shows all these variations.



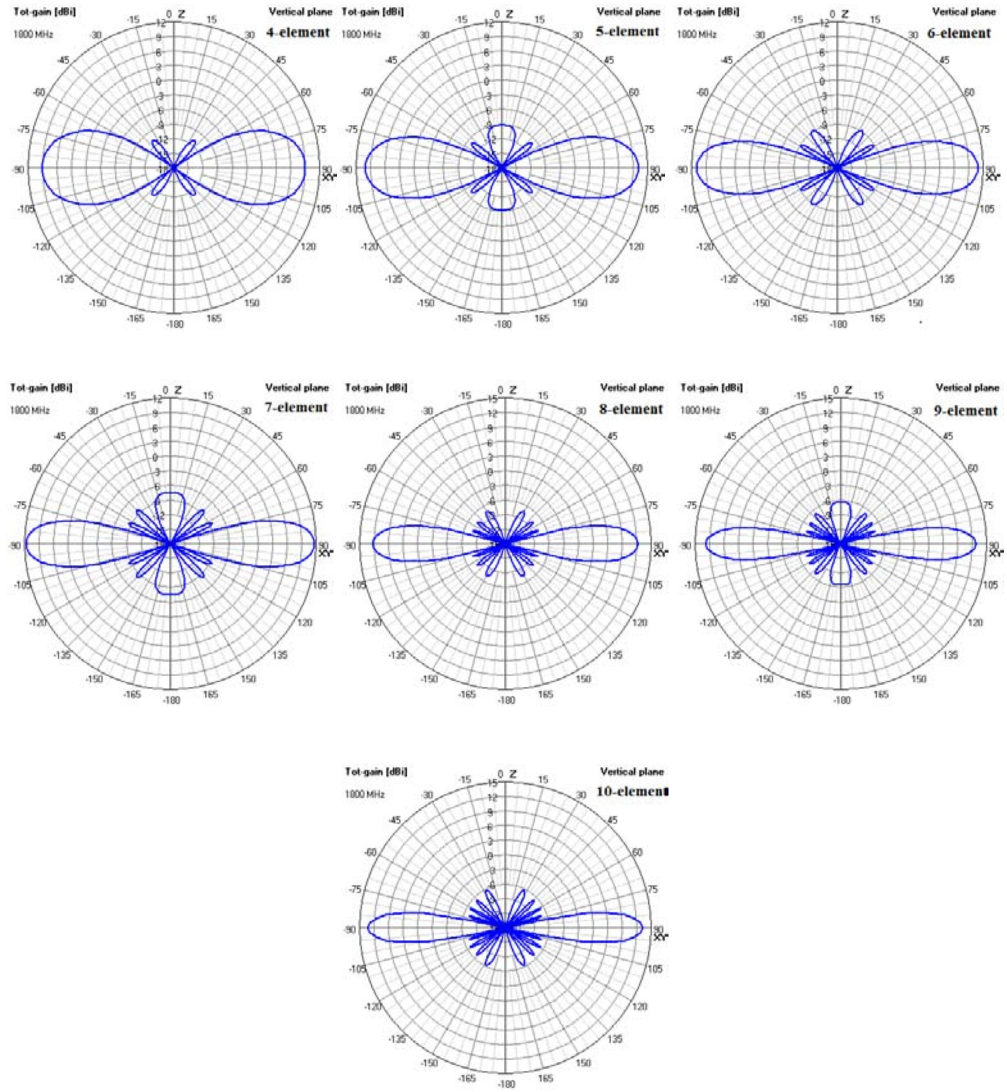


Figure 1 : Radiation pattern in vertical plane vs. the number of the elements

b) Effect of Element Spacing on the Performance of the Dipole Antenna Array

The second part is to investigate the impact of the variation of the spacing of a chebyshev excitation linear dipole array with 10 elements has been calculate using the steps of [8] to calculate the excitation current amplitudes. Table (3) contains some of the outputs of the utilized software (4NEC2); it shows a smooth and a systematic increase of both the gain, max.SLL and the number of side lobes respectively with the spacing up to 0.9λ while the HPBW in vertical plane decreases with the spacing and that for horizontal plane remained constant.

Table 3 : Gain, HPBW, SLL max and No. of SLL versus the spacing for 10 element array

Elements spacing(λ)	Gain (dBi)	HPBW (vertical Plane) degree	HPBW (horizontal Plane) degree	max. SLL (dBi)	No. of SLL
0.1	5.89	60	80	-∞	0
0.2	9.33	28	80	-10.8	4
0.3	11.1	20	80	-8.75	8
0.4	12.31	12	80	-7.52	12
0.5	13.22	12	80	-6.37	16
0.6	13.96	8	80	-5.93	20

0.7	14.58	8	80	-5.37	24
0.8	15.12	8	80	-4.97	28
0.9	15.58	4	80	-0.15	34
1	11.30	4	76	-8.45	28

Figure 2 : Illustrates the radiation patterns for a 10 element array at different spacing starting from 0.1λ to one λ

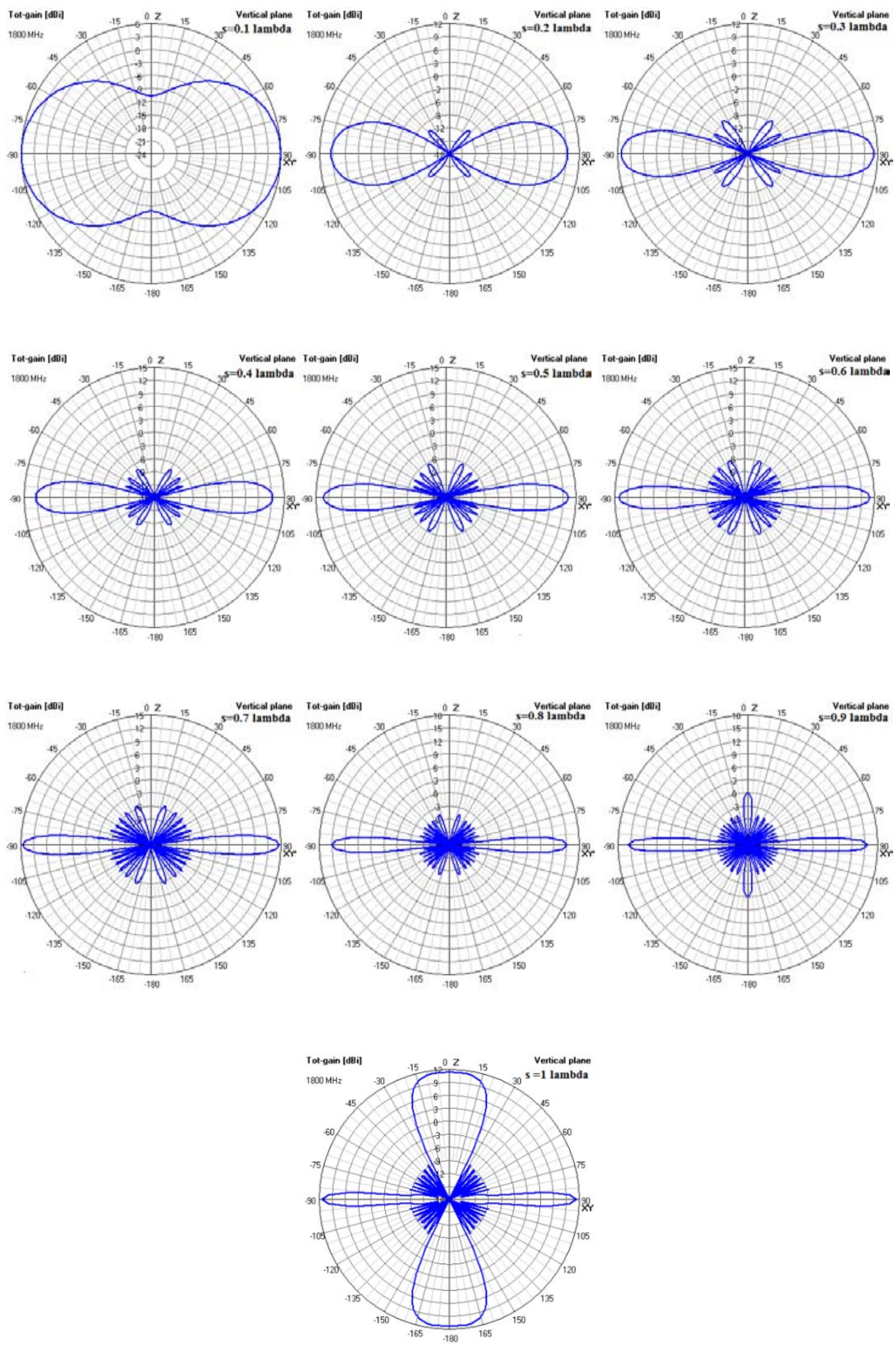


Figure 2 : Radiation pattern for a 10 elements array at different spacing

c) Optimization for Best Spacing for the Dipole Antenna Array

At the third part of this analysis, both the number of the elements and the spacing between them were varied to see their impacts on the same radiation characteristics as before . The spacing is varied up to 2λ at steps of 0.02λ for each number of the elements from 2 to 10 elements separately. Table (4) tabulates the outputs for the specified parameters at the best spacing for maximum gain only.

Table 4 : HPBW, Gain, max. SLL, no. of SLL for the max. gain at different no. of elements

No. of element	Element spacing (λ)	Gain (dBi)	HPBW (vertical plane) (degree)	HPBW (horizontal plane) (degree)	max. SLL (dBi)	No. of SLL
2	0.66	7	44	80	0.73	2
3	0.72	9.20	28	80	0.23	6
4	0.75	10.8	20	80	-3.1	10
5	0.8	12.1	16	80	-2.04	14
6	0.84	13.1	12	80	0.26	18
7	0.86	13.9	10	80	-0.12	22
8	0.86	14.5	8	80	-5.63	26
9	0.88	15.1	8	80	-5.12	30
10	0.9	15.6	6	80	-0.15	34

The variation of the gain with the spacing up to 2λ for different number of array elements is shown in the Figure 3 below.

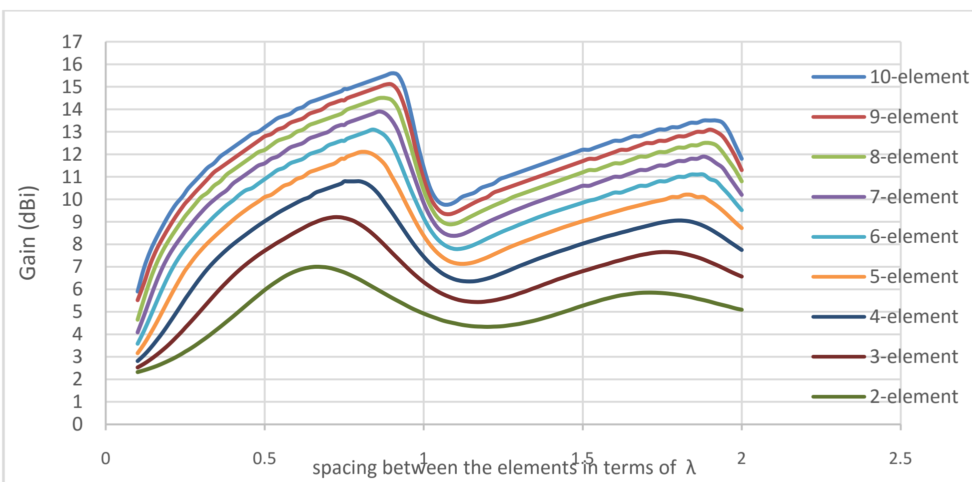


Figure 3 : Gain vs. the spacing for different number of elements

The above data (table 4), clearly shows the maximum gain of the different number of elements produced at different spacing between them; the level of side lobe is changing from one to another and the number of side lobes increases when the number of elements increases; for increasing one element, four side lobes add to the radiation pattern. The same results are sumarized in Fig. (4) throught the radiation pattern of each array with the specifications of Table (4).

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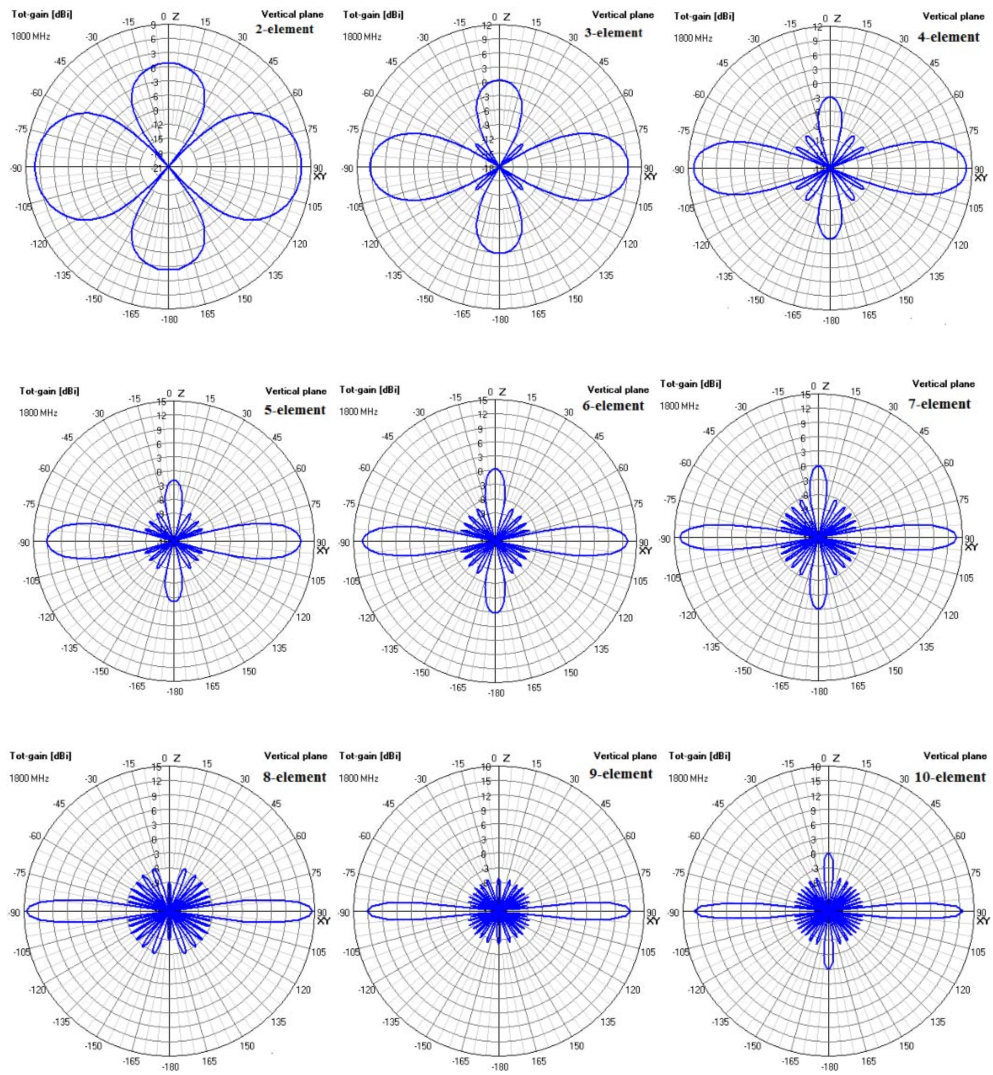

Figure 4 : Radiation patterns for different number of elements and spacing at maximum gain (best spacing)

III. Comparison between Different Types of Excitations Arrays

For the half wavelength dipole antenna array operating at 1.8GHz the radiation characteristics of the chebyshev excitations have been compaired with the same correspounding uniform array of ref.[12] and the binomial excitation of ref. [research 2]. Table (5) tabulates the variation of these characteristics with the number of the elements having 0.5λ spacing between them.

Table 5 : Variation of the Gain, HPBW, max. SLL and No. of SLL of different excition arrays with the number of elements

Number of Elements	uniform Array ref.3				Binomial Array ref.4				Chebyshev Array			
	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL
1	2.14	80	-∞	0	2.14	80	-∞	0	2.14	80	-∞	0
2	5.97	60	-∞	0	5.97	60	-∞	0	5.97	60	-∞	0
3	7.80	36	-1.3	2	7.41	44	-∞	0	7.72	40	-12.1	2
4	9.2	28	-1.97	4	8.29	36	-∞	0	9.03	28	-10.9	4
5	10.2	20	-1.82	6	8.92	32	-∞	0	10.07	24	-9.28	6

6	11.06	16	-1.36	8	9.42	28	-∞	0	10.92	20	-8.84	8
7	11.74	16	-0.89	10	9.82	24	-∞	0	11.62	16	-7.54	10
8	12.35	12	-0.61	12	10.2	24	-∞	0	12.23	12	-7.4	12
9	12.88	12	-0.07	14	10.4	20	-∞	0	12.75	12	-6.53	14
10	13.36	8	0.29	16	10.7	20	-∞	0	13.22	12	-6.37	16

From the above table (5) it is clear that for all the arrays as with different elements both uniform and cebyshev excitations give almost the same gain and it is more than that of the binomial arrays. Ingeneral uniform array gives more directive beam (narrow HPBW) while binomial arrays give wider major lobes.

At 0.5λ spacing the binomial array has not any side lobes while both uniform and chebyshev arrays have the same number of side lobes for any element numbers but with different intensities such that the intensity of the side lobes for the uniform array excitations is higher than that of the chebyshev.

The same comparison has been made for a 10 element arrays with different spacing and the results has been shown in the table (6) below.

Table 6 : Comparison between uniform,binomial and chebyshev 10 element array at different spacing

Elements spacing (λ)	Uniform Array ref.3				Binomial Array ref.4				Chebyshev Array			
	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL
0.1	6.56	54	-17.5	2	2.72	0	-∞	0	5.89	60	-∞	0
0.2	9.48	24	-3.33	4	6.21	52	-∞	0	9.33	28	-10.8	4
0.3	11.21	18	-1.9	8	8.32	32	-∞	0	11.1	20	-8.75	8
0.4	12.43	12	-0.52	12	9.69	24	-∞	0	12.31	12	-7.52	12
0.5	13.36	8	0.29	16	10.7	20	-∞	0	13.22	12	-6.37	16
0.6	14.11	8	1.14	20	11.2	16	-∞	0	13.96	8	-5.93	20
0.7	14.71	8	1.74	24	12.2	16	-∞	0	14.58	8	-5.37	24
0.8	15.17	4	2.19	28	12.7	12	-3.17	2	15.12	8	-4.97	28
0.9	15.34	4	2.26	32	11.9	12	8.23	2	15.58	4	-0.15	34
1	11.43	4	-1.77	32	9.08	10	-∞	0	11.30	4	-8.45	28

At 1.8GHz operating frequency it is clear that the optimum separation for uniform and chebyshev excitations is 0.9λ which gives the best gain, but for binomial array it was 0.8λ

The same comparison has been made for different of element arrays with different spacing and the results has been shown in the table (7) below.

Table 7 : Comparison between uniform,binomial and chebyshev 10 element array at different spacing

No. of element	Uniform Array ref.3					Binomial Array ref.4					Chebyshev Arrat				
	Elements spacing (λ)	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL	Elements spacing (λ)	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL	Elements spacing (λ)	Gain (dBi)	HPBW (ver. plane)	SLL max. (dBi)	No. of SLL
2	0.66	7	44	0.73	2	0.66	7	44	0.73	2	0.66	7	44	0.73	2
3	0.75	9.35	24	0.11	6	0.72	8.81	30	1.15	2	0.72	9.20	28	0.23	6
4	0.8	10.9	16	-0.61	10	0.74	9.88	24	0.31	2	0.75	10.8	20	-3.1	10
5	0.82	12	12	-0.22	14	0.74	10.6	20	-2.07	2	0.8	12.1	16	-2.04	14
6	0.86	13	10	0.33	18	0.75	11.2	18	-3.31	2	0.84	13.1	12	0.26	18
7	0.88	13.8	8	0.87	22	0.78	11.7	16	-1.33	2	0.86	13.9	10	-0.12	22

8	0.9	14.4	8	2.93	26	0.78	12.1	14	-3.17	2	0.86	14.5	8	-5.63	26
9	0.9	14.9	6	1.82	30	0.8	12.4	12	-1.68	2	0.88	15.1	8	-5.12	30
10	0.92	15.4	4	4.19	34	0.82	12.8	12	0.13	2	0.9	15.6	6	-0.15	34

From the above table it is shown that the optimum separation for three method are difference for example in 10-element for chebyshev arrays was (d=0.9λ), which gave the best radiation properties while for binomial arrays the optimum space dimension was (d=0.8λ), uniform array with space between elements (d=0.92λ) had best radiation properties. The sequence of high gain and good HPBW starts from uniform excitation to chebyshev then binomial arrays.

IV. Conclusions

1. At 0.5λ spacing the sequence of high gain and good HPBW starts from uniform excitation to chebyshev then binomial arrays.
2. Binomial arrays have very low side lobes compared with chebyshev and uniform excitation arrays because the excitation coefficients in binomial arrays are very large especially in long arrays which cause great different in level between major lobe and side lobe in radiation properties. Moreover there is no SLL level for 10-element when space from (0.1λ until 0.7λ) after this point produce SLL, but in practical it's difficult to produce signals with great difference between the excitation coefficient. For 10-elements binomial array the different between center coefficient $(a_0 = 126)$ and last excitation coefficient $(a_5 = 1)$ is too much, while in chebyshev arrays for same number of elements, the center coefficient $a_0 = 1.5579)$ and the last coefficient $(a_5 = 1)$, in practical its easy generate signals with variation in amplitude between the center and the edge.
3. When the spacing between the elements was λ, all the three different excitations produce both broadside and end fire radiation patterns together.
4. For a fixed element spacing at 0.5λ the number of side lobes for both uniform and chebyshev excitations increase equally by two lobes per each number increment of elements but with different intensities such that the intensity of the side lobes for the uniform array excitations is higher than that of the chebyshev while the binomial array has not any side lobes.
5. When the spacing between the elements increases from 0.1λ to 0.8λ at fixed fix number of 10 element, both the uniform and chebyshev arrays have the same rate of increase of side lobes with the sequence of high gain from uniform excitation to chebyshev then binomial arrays.
6. For any number of elements up to 10 and the best spacing for high gain of each one both uniform and chebyshev arrays have almost the gain which was higher than that of the binomial array.
7. For the same upper condition both uniform and chebyshev arrays have the same rate of increase of side lobes which was four lopes per each number of elements while the binomial one has a fixed number of two side lobes.

References Références Referencias

1. Roshni.S. Babu and P. Sampath (2012)" Design of 4X4 Rectangular Microstrip Phased Array Antenna for GSM Application", International Journal of Latest Research in Science and Technology, Vol.1, Issue 4, Page No.403-407.
2. Satya Prakash Sinha, Mukesh Kumar and Jolis Gupta (2015) "Design Of 2x2 Shaped Rectangular Microstrip Array Antenna for GSM Application", International Journal of Scientific & Engineering Research, Volume 6, Issue 5.
3. Aras Saeed and Dlnya Aziz (2016) "Analysis of a Uniform Linear Broadside Dipole Antenna Array Operating at 1.8 GHz for Use in GSM Application" *Journal of Zankoy Sulaimani,* Vol. 18, No. 2.
4. Aras Saeed and Dlnya Aziz (2016) " Study of the Binomial Excitation of a Linear Broadside 10-Element Dipole Antenna Array " International Journal of Electronics Communication and Computer Engineering, Volume 7, Issue 3.
5. Yi Huang, Kevin Boyle (2008), Antennas from Theory to Practice, John Wiley & Sons Ltd.
6. L. Sarika, P. Nandini, S. Bharathi, Y. Dhana Lakshmi, Sameena Suresh (2014), "Side lobe Reduction in a Uniform Linear Array Antenna Using Windowing Techniques" ,International Journal of Research in Engineering and Technology, Vol. 03, Issue 04.
7. C. A. Balanis (2005), Antenna Theory Analysis and Design, Second Edition: John Wiley and Sons, Inc., New York.
8. Subbarao, M. Venkata; Khasim, N. Sayedu; Thati, Jagadeesh and Sastry, M. H. H. (2013) "Tapering of Antenna Array for Efficient Radiation Pattern", *E-Journal of Science & Technology*, Vol. 8 Issue 2, p37.
9. Singh P., Sharma A., Uniyal N., Kala R.(2012)"Half-Wave Dipole Antenna for GSM Applications" *International Journal of Advanced Computer* Research, Volume-2 Number-4 Issue-6.
10. Mohammad Tareq, Dewan Ashraf Alam, Mazidul Islam and Razin Ahmad (2014) "Simple Half Wave

Dipole Antenna Analysis for Wireless Applications by CST Microwave Studio", International *Journal of Computer Applications,*Vol. 94, No.7.

11. Dwija Reddy Aloori (2010) "Simulation of near Field Generated by S-band Rectangular Horn Antenna Array for Hyperthermia Therapy Applications Using 4NEC2 Software", *M.Sc. thesis,* California state university, Sacramento.

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