

# **Realization of Logarithmic Spaced Antenna Arrays for the Generation of Low Sidelobe Radiation Patterns**

B.Ramana Kumar<sup>1</sup>, Prof.P.Mallikarjuna Rao<sup>2</sup>, B.Sadasiva Rao<sup>3</sup>, Prof.G.S.N.Raju<sup>4</sup>

Research Scholar, Department of E.C.E, A.U College of Engineering (A), Visakhapatnam, Andhra Pradesh, India<sup>1</sup>

Professor, Department of E.C.E, A.U College of Engineering (A), Visakhapatnam, Andhra Pradesh, India<sup>2</sup>

GVP College of Engg for UG&PG Rushikonda Campus, Visakhapatnam, Andhra Pradesh, India<sup>3</sup>

Vice Chancellor, Centurion University, Visakhapatnam, Andhra Pradesh, India<sup>4</sup>

**ABSTRACT:** This paper presents a significant sidelobe reduction if non uniform elevational spacing of antenna elements on the logarithmic is used. Antenna elements are progressively phased with a uniform amplitude excitation. The calculation of the required element position is presented. The achieved sidelobe level reduction with unequally spaced arrays could reach even more better than with regard to the first significant sidelobe level of equally spaced arrays. By this method, arrays have the ability to produce the desired radiation pattern and could satisfy requirements for some applications like Marine RADAR, point to point communications.

**KEYWORDS:** Radiation Pattern, Logarithmic Spaced Array, Sidelobe Level Reduction and Nonuniform Distribution.

## **I. INTRODUCTION**

Since the 1990s, there has been enormous interest in multi antenna systems. As spectrum became a more and more precious resource, researchers investigated ways of improving the capacity of wireless systems without actually increasing the required spectrum. Multi antenna systems offer such a possibility [1-2]. Smart signal antenna arrays can provide an efficient way to increase the data rate in the future of wireless systems. Smart antennas work by the principle of combining antenna array with processing to optimize automatically the beam pattern in response to the received signal. Array antennas have capability of fast electronic beam steering. Also, they can be designed to offer reconfigurability, conformal characteristics, multi beam capabilities and adaptive pattern reshaping. Recently, there has been a growing interest in designing logarithmic antenna arrays. The present study was undertaken to evaluate the possible merits of a logarithmic phased-array with non uniformly spaced antenna elements in providing directive pattern with sidelobes below those for uniform arrays and complete logarithmic coverage without appreciable loss of gain. For logarithmic array, an active sector can be moved along surface and the scan angle is increased. The grating lobe phenomenon is reduced by using nonuniform antenna elements spacing.

## **II. LITERATURE REVIEW**

The use of arbitrary element position for pattern synthesis purposes was suggested by Unz [3]. King, Packard and Thomas [4] proposed the use of unequal spacing in a linear array to reduce grating lobes and computed the pattern of

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 11, November 2019

various trial sets. Sandler [5] expanded a term for each element in series. Harrington [6] presented a method for reducing sidelobe levels of linear array by using nonuniform element spacing, while retaining uniform excitation. It is shown that the side-lobes can be reduced in height to approximately  $2/N$  times the main lobe level, where  $N$  is the number of antenna elements.

Andreasen [7] computed the various possibilities of unequally-spaced arrays (linear). Ishimaru [8] presented new approach to the unequally-spaced array problem. It is based on the use of Poisson's sum formula and the introduction of a new function, the "source position function". By this method, it is possible to design unequally-spaced arrays which produce a desired radiation pattern. In the paper of Hodjat and Hovanesian [9], an iteration method based on the solution of a set of linear simultaneous equation at each iteration is proposed for calculating the distance between the elements of a symmetrical non uniformly spaced linear array antenna for sidelobe reduction. In the second part of the paper, several symmetrical non uniformly spaced planar array antennas have been designed, using the nonuniform linear array spacing.

Jarske [10] showed that the element spacings of the optimal solution are integer multiplies of a suitable chosen basic spacing and presented two design procedures for nonuniformly spaced linear arrays. Pozar and Kaufman discussed and quantified the factors affecting the realizable sidelobe performance of microstrip arrays [11]. For the unequally spaced arrays, Jeffers presented the successive approximation method and dynamic program method [12]. Kummur and Branner presented an analytical technique for synthesis of unequally spaced arrays with linear, planar, cylindrical and spherical geometry [13]. Shihab designed a non-uniform circular antenna array using particle swarm optimization [14]. Abdolee developed a simple and fast genetic algorithm to reduce the sidelobe in non-uniformly spaced linear arrays [15]. Bevelacqua and Balanis determined optimal array geometries using the Particle Swarm Optimization (PSO) algorithm with optimal weights in order to minimize sidelobe levels in wideband arrays [16].

### III. FORMULATION FOR NONUNIFORM SPACED ANTENNA ARRAY ELEMENTS

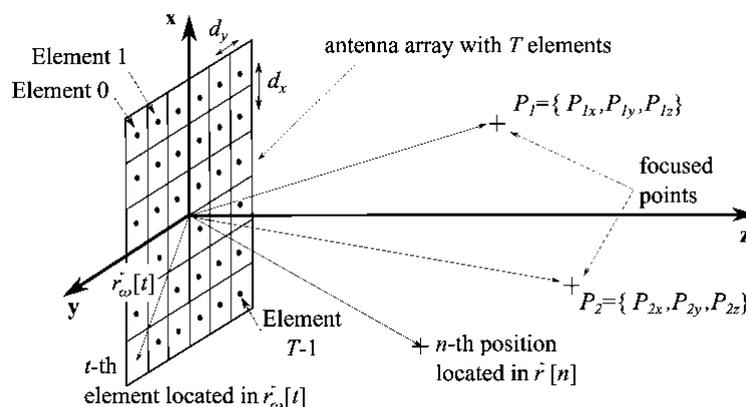


Fig.1 Design of Nonuniform Antenna Array

The main advantage of non uniformly spaced arrays presented in this research is the reduction of sidelobe levels by using nonuniform elements spacing, while retaining uniform excitation. It is possible to achieve nonuniform antenna elements spacing on the logarithmic surface by changing elevational, azimuthal or both position angles. However, when we set the direction of the main beam (maximum of radiation) defined by angles  $\theta^0$  and  $\phi^0$  on the north pole of the logarithmic surface, then we have only one option to achieve a useful nonuniform antenna spacing. In that case we are able to change only the elevational angle position of the antenna elements. Moving azimuthal angle ( $\beta_{lk}$ ) of the

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 11, November 2019

antenna elements leads significantly to unwanted degradation of E and H radiation patterns, as well as change of the main beam direction (the radiation pattern becomes asymmetric).

The change of the main lobe direction out of the pole of the logarithmic requires changes of elevational and azimuthal position of the antenna elements, which are subset of the array that radiates in the defined direction. To reach the main goal of these antenna arrays – low sidelobes, the appropriate function of the antenna elements positions must be found.

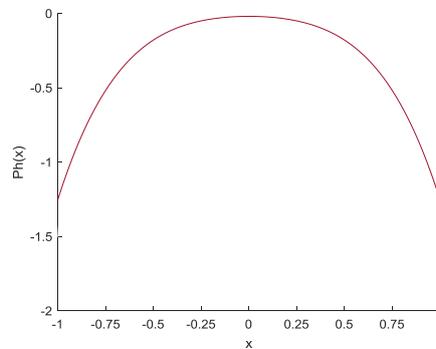


Fig.2 Phase distribution  $\varphi(x)$

The far field pattern for a continuous line sources is given by

$$E(u) = \int_{-1}^1 A(x) e^{j\left(\frac{2\pi L}{\lambda}\right)(ux + \varphi(x))} . dx [1]$$

$A(x)$ = amplitude distribution

$2L/\lambda$  = normalized array length

$2L$  =Length of array

$\lambda$  = wavelength

$U = \sin\theta$ ,  $\theta$  being the angle between broadside and direction of propagation

$x$  is the position on the array considered as  $x = -1 + \log(n)$  where  $n = 1, 2, 3, \dots, N$

The phase function used in this work for the evaluation of all radiation pattern characteristics is shown in fig.2.

## IV. RESULTS AND DISCUSSION

The far field radiation patterns are computed for an array length of  $10\lambda$ ,  $20\lambda$ ,  $30\lambda$ ,  $40\lambda$ ,  $50\lambda$ ,  $75\lambda$  and  $100\lambda$ . The results on overall radiation pattern and its characteristics are presented in table 1 for logarithmic spacing function and uniform amplitude distribution function. The radiation pattern characteristics for the same spacing function and the amplitude distribution function of raised circular is presented in table 2. The radiation pattern characteristics for the amplitude distribution function considered as tapered raised circular and the spacing function of logarithmic spacing is shown in table 3. The elemental spacing values are evaluated and considered in this work are tabulated and presented in the following tables 4 to table 6 for array length of  $10\lambda$ ,  $30\lambda$ ,  $50\lambda$  and  $100\lambda$ .

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

**Vol. 8, Issue 11, November 2019**

**Table.1** Radiation Pattern Characteristics for  $A(x) = 1$  and spacing,  $x = -1 + \log(n)$

Array Length	1 <sup>st</sup> SLL	2 <sup>nd</sup> SLL	3 <sup>rd</sup> SLL	Last SLL	BW
10λ	-35.55	-34.62	-35.69	-41.17	0.38
20λ	-35.43	-34.78	-35.73	-47.19	0.19
30λ	-35.61	-34.58	-35.77	-50.89	0.12
40λ	-35.43	-34.61	-35.68	-53.15	0.09
50λ	-35.43	-34.58	-35.68	-54.83	0.08
75λ	-35.42	-34.63	-35.69	-55.86	0.05
100λ	-35.44	-34.65	-35.69	-52.12	0.04

**Table.2** Radiation Pattern Characteristics for  $A(x) = 1 + \text{circular}$  and spacing,  $x = -1 + \log(n)$

Array Length	1 <sup>st</sup> SLL	2 <sup>nd</sup> SLL	3 <sup>rd</sup> SLL	Last SLL	BW
10λ	-40.85	-29.94	-30.87	-32.43	0.33
20λ	-40.77	-29.97	-30.87	-44.46	0.17
30λ	-40.70	-29.95	-31.04	-47.95	0.11
40λ	-40.70	-29.95	-31.06	-50.39	0.08
50λ	-40.70	-29.96	-31.07	-52.21	0.06
75λ	-40.72	-29.99	-31.13	-53.11	0.04
100λ	-40.73	-29.99	-31.15	-50.28	0.03

**Table.3** Radiation Pattern Characteristics for  $A(x) = (1 + \text{circular})^2$  and spacing function,  $x = -1 + \log(n)$

Array Length	1 <sup>st</sup> SLL	2 <sup>nd</sup> SLL	3 <sup>rd</sup> SLL	Last SLL	BW
10λ	-42.69	-37.97	-38.52	-43.46	0.39
20λ	-43.07	-38.62	-39.00	-50.12	0.19
30λ	-43.09	-38.64	-39.02	-53.37	0.13
40λ	-43.12	-38.65	-39.04	-55.76	0.09
50λ	-43.12	-38.66	-39.13	-57.44	0.07
75λ	-43.12	-38.68	-39.26	-58.40	0.05
100λ	-43.13	-38.71	-39.29	-53.65	0.04

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

**Vol. 8, Issue 11, November 2019**

**Table 4:** Inter element spacing values for the array length of 10 elements

Element number	Spacing( $\lambda$ )	Element number	Spacing( $\lambda$ )
1	-0.1000	6	-0.2218
2	-0.6990	7	-0.1549
3	-0.5229	8	-0.0969
4	-0.3979	9	-0.0458
5	-0.3010	10	0

**Table 5:** Inter element spacing values for the array length of 30 elements

Element number	Spacing( $\lambda$ )	Element number	Spacing( $\lambda$ )	Element number	Spacing( $\lambda$ )
1	-0.1000	11	0.0414	21	0.3222
2	-0.6990	12	0.0792	22	0.3424
3	-0.5229	13	0.1139	23	0.3617
4	-0.3979	14	0.1461	24	0.3820
5	-0.3010	15	0.1761	25	0.3979
6	-0.2218	16	0.2041	26	0.4150
7	-0.1549	17	0.2304	27	0.4314
8	-0.0969	18	0.2553	28	0.4472
9	-0.0458	19	0.2788	29	0.4624
10	0	20	0.3010	30	0.4771

**Table 6:** Inter element spacing values for the array length of 50 elements

Element number	Spacing( $\lambda$ )						
1	-0.1000	15	0.1761	29	0.4624	42	0.6232
2	-0.6990	16	0.2041	30	0.4771	43	0.6335
3	-0.5229	17	0.2304	31	0.4771	44	0.6435
4	-0.3979	18	0.2553	32	0.4914	45	0.6532
5	-0.3010	19	0.2788	33	0.5051	46	0.6628
6	-0.2218	20	0.3010	34	0.5185	47	0.6721
7	-0.1549	21	0.3222	35	0.5315	48	0.6812
8	-0.0969	22	0.3424	36	0.5441	49	0.6902
9	-0.0458	23	0.3617		0.5563	50	0.6990

## International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

**Vol. 8, Issue 11, November 2019**

10	0	24	0.3820	37	0.5682		
11	0.0414	25	0.3979	38	0.5798		
12	0.0792	26	0.4150	39	0.5911		
13	0.1139	27	0.4314	40	0.6021		
14	0.1461	28	0.4472	41	0.6128		

**Table 7:** Inter element spacing values for the array length of 100 elements

Element number	Spacing( $\lambda$ )						
1	-0.1000	26	0.4150	51	0.7076	76	0.8808
2	-0.6990	27	0.4314	52	0.7160	77	0.8865
3	-0.5229	28	0.4472	53	0.7243	78	0.8921
4	-0.3979	29	0.4624	54	0.7324	79	0.8976
5	-0.3010	30	0.4771	55	0.7404	80	0.9031
6	-0.2218	31	0.4914	56	0.7482	81	0.9085
7	-0.1549	32	0.5051	57	0.7559	82	0.9138
8	-0.0969	33	0.5185	58	0.7634	83	0.9191
9	-0.0458	34	0.5315	59	0.7709	84	0.9243
10	0	35	0.5441	60	0.7782	85	0.9294
11	0.0414	36	0.5563	61	0.7853	86	0.9345
12	0.0792	37	0.5682	62	0.7924	87	0.9395
13	0.1139	38	0.5798	63	0.7993	88	0.9445
14	0.1461	39	0.5911	64	0.8062	89	0.9494
15	0.1761	40	0.6021	65	0.8129	90	0.9542
16	0.2041	41	0.6128	66	0.8195	91	0.9590
17	0.2304	42	0.6232	67	0.8261	92	0.9638
18	0.2553	43	0.6335	68	0.8325	93	0.9685
19	0.2788	44	0.6435	69	0.8388	94	0.9731
20	0.3010	45	0.6532	70	0.8451	95	0.777
21	0.3222	46	0.6628	71	0.8513	96	0.9823
22	0.3424	47	0.6721	72	0.8573	97	0.9868
23	0.3617	48	0.6812	73	0.8633	98	0.9912
24	0.3820	49	0.6902	74	0.8692	99	0.9956
25	0.3979	50	0.6990	75	0.8751	100	1.0000

# International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: [www.ijirset.com](http://www.ijirset.com)

Vol. 8, Issue 11, November 2019

## V. CONCLUSION

This research work presents spacing schemes for reducing sidelobe levels which could be easily calculated by computers. The amount of reduction in sidelobe level is quite significant. All antenna elements are fed equally and are progressively phased so that the radiation field from all antenna elements could form appropriate main beam or radiation pattern. If arrays are arranged in this way, they have the ability to produce desired radiation patterns and could satisfy requirements for some directive applications like Marine RADAR, point to point communication systems and low noise EMI applications.

## REFERENCES

1. Slavko Rupcic, Vanja Mandric, Drago Zagar, "Reduction of Sidelobes by Nonuniform Elements Spacing of a Spherical Antenna Array", Radio Engineering, Vol.20, No.1, 2011, pp.299-306.
2. Molisch, A.-F. Wireless Communication. John Wiley & Sons, LTD, IEEE Communication Society, 2005.
3. Unz, H. Linear arrays with arbitrarily distributed elements. IRE Transactions on Antennas and Propagation, March 1960, vol. AP8, p. 222 – 223.
4. King, D. D., Packard, R. F., Thomas, R. K. Unequally spaced, broad-band antenna arrays. IRE Transactions on Antennas and Propagation, July 1960, vol. AP-8, p. 380 – 385.
5. Sandler, S. S. Some equivalence between equally and nonequally spaced arrays. IRE Transactions on Antennas and Propagation, March 1961, vol. AP-9, p. 496-500.
6. Harrington, R.-F. Sidelobe reduction by nonuniform element spacing. IRE Transactions on Antennas and Propagation, March 1961, p. 187 – 192.
7. Andreasen, M. G. Linear arrays with variable interelement spacing. IRE Transactions on Antennas and Propagation, March 1962, vol. AP-10, p. 137 – 143.
8. Ishimaru, A. Theory of unequally-spaced arrays. IRE Transactions on Antennas and Propagation, November 1962, vol. AP-8, p. 691 – 702.
9. Hodjat, F., Hovanessian, A. A. Nonuniformly spaced linear and planar array antennas for sidelobe reduction. IEEE Transactions on Antennas and Propagation, March 1978, vol. AP26, no. 2, p. 198 – 204.
10. Jarske, P., Saramaki, T., Mitra, S. K., Neuyo, Y. On properties and design of nonuniformly spaced linear arrays. IEEE Transactions on Acoustics, Speech and Signal Processing, March 1988, vol. 36, no. 3, p. 372 – 380.
11. Pozar, D. M., Kaufman, B. Design considerations for low sidelobe microstrip arrays. IEEE Transactions on Antennas and Propagation, August 1990, vol. 38, no. 8, p. 1176 – 1185.
12. Jeffers, J. L., Boucher, S. G. Optimum unequally spaced arrays and their amplitude shading. In Proceedings of Ultrasonics Symposium, November 1995, vol. 2, p. 965 - 969.
13. Kummar, B. P., Branner, G. R. Generalized analytical technique for the synthesis of unequally spaced arrays with linear, planar, cylindrical or spherical geometry. IEEE Transactions on Antennas and Propagation, February 2005, vol. 53, no. 2, p. 621-634.
14. Shihab, M., Najjar, Y., Dib, N., Khodier, M. Design of non-uniform circular antenna array using Particle Swarm Optimization. Journal of Electrical Engineering, 2008, vol. 59, no. 4, p. 216 – 220.
15. Abdolee, R., Vakilian, V., Rahman, T. A. Elements space and amplitude perturbation using Genetic Algorithm for antenna sidelobe cancellation. Signal Processing: An International Journal (SPIJ), March/April 2008, vol. 2, no. 2, p. 10 – 16.
16. Bevelaqua, P. J., Balanis, C. A. Geometry and weight optimization for minimizing sidelobes in wideband planar arrays. IEEE Transactions on Antennas and Propagation, April 2009, vol. 57, no. 4, p. 1285 – 1289.