*IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)*
*e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 10, Issue 3, Ver. III (May - Jun.2015), PP 38-44*
*www.iosrjournals.org*

# Non-Uniform Circular Array Synthesis Using Teaching Learning Based Optimization

VVSSS Chakravarthy[1], SVRAN Sarma[2], K Naveen Babu[1], PSR Chowdary[1], T Sudheer Kumar[3]
[1]*(Department of ECE, Raghu Institute of Technology, India)*
[2]*(Department of Basic Sciences, Vignan Institute of Information Technology, India)*
[3]*(Department of ECE, Shri Vishnu Engineering College for Women, India)*

***Abstract :*** *Teaching-Learning Based Optimization (TLBO) is a novel population based optimization algorithm that has proved to be worthy in solving many multimodal problems in production engineering. In this paper, the application of TLBO is extended to electromagnetics. Non-uniform circular array synthesis is performed using TLBO with amplitude only technique. With the objective of -15dB side love level (SLL). Along with SLL the beam-width is controlled and almost made equal to that of uniform circular array with 10% relaxation. The synthesized radiation pattern for 20, 30, 40 and 50 elements circular array are presented here along with corresponding excitation amplitude as stem plots and convergence plots for both scanned and non-scanned conditions.*

***Keywords:*** *Circular array, side lobe level, beam scanning, non-scanned beams, TLBO.*

## I. Introduction

In communication systems, an antenna is designed to radiate in or to receive from desired direction [1-4]. Any radiation in the unwanted direction must be suppressed by reducing the energy in the side lobes. Traditionally this was achieved by using a group of antennas arranged in a geometrically well-structured manner, which are generally referred to as antenna arrays. To obtain the desired radiation characteristics such as required side lobe level, beam-width etc., various numerical methods for antenna array synthesis such as Schelkunoff, Dolph-Chebyscheff and Taylor's have evolved over the course of time. These are mathematically rigorous, time consuming and could not handle multi-modal problems. Hence heuristic methods are employed to determine the excitation coefficients required to generate the desired radiation pattern. Evolutionary methods such as genetic algorithm [5,6], particle swarm optimization algorithm [7-10], ant colony optimization [11], invasive weed optimization [12], bees algorithm [13], Taguchi's algorithm [14] and flower pollination algorithm [15] were used to obtain solutions for of non-uniform linear and circular arrays synthesis problems with several single and multiple objectives.

Side lobe level (SLL) has been a prominent issue in a communication system because it effects the level of interference in the direction outside of main beam area. The reduction in interference gives the possibility of increasing the capacity of the communication system. Circular arrays have become popular in wireless communications ever since they have employed in this field due to several inherent features like beam scanning. There are three parameters predominantly used to arrive at required pattern of an array. These are amplitude and phase of the excitation, spacing between the antenna elements in the array.

In this paper, a non-uniform circular array is considered. The coefficients are generated for the amplitude of excitation using a novel evolutionary method called Teaching and Learning Based Optimization (TLBO) algorithm [16-21] to keep the side lobe level to as low as -15db while the main beam is scanned to $20^0$. The other two steering parameters were kept constant. Non-scanned beams with the lower SLL are reported earlier by the same authors for circular arrays [20] and linear arrays [21]. Initially the array factor was formulated for a non-uniform circular array followed by the elaboration of the teaching learning based optimization algorithm and its fitness function. Finally the results are presented comparing it with the pattern of a uniform circular array.

## II. Array Factor Formulation

The geometry of non-uniform circular array is shown in fig.1. The figure shows isotropic radiators placed in the form of a circle having a radius ‘r’. The array factor of this geometry is,

$$AF(\phi) = \sum_{n=1}^{N} I_n \exp\left(j\left(kr\cos(\phi - \phi_n) + \beta_n\right)\right) \tag{1}$$

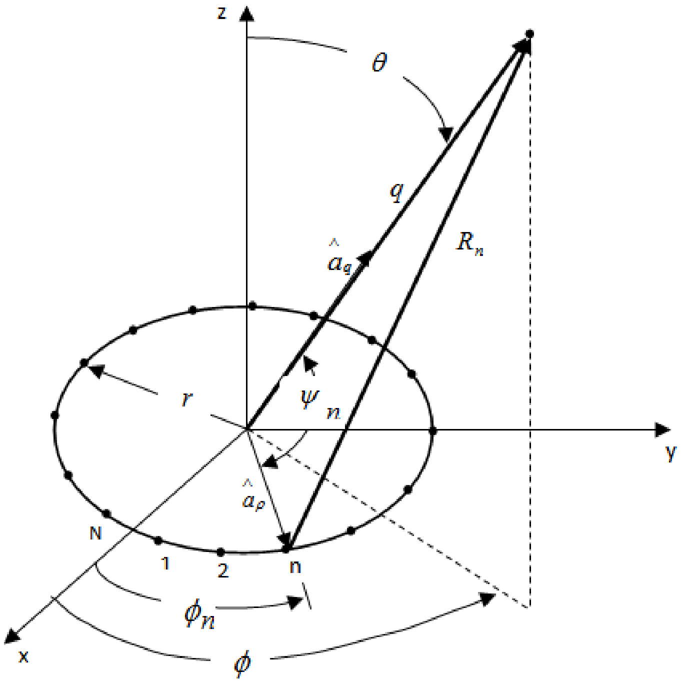



**Fig.1.**Geometry of N Element Non-Uniform Circular Array

where,
n is element number
$I_n$ is current excitation of the $n^{th}$ element
N is number of elements in the array
$\beta_n$ is the phase of excitation of the $n^{th}$ element

$$kr = \frac{2\pi r}{\lambda} = \sum_{i=1}^{N} d_i \tag{2}$$

$$\phi_n = \frac{2\pi}{kr} \sum_{i=1}^{n} d_i \tag{3}$$

## III. Fitness Evaluation

The fitness is evaluated using the following expression.

$$f = \min\left(\max\left(AF_{dB(-90\ to\ 90)}\right)\right) \tag{4}$$

Where, $AF_{dB(-90to+90)}$ refers to the array factor values excluding the main beam. The expression inside gives the maximum of $AF_{dB}$ values. The term min refers to minimization problem. In brief, optimization problem involves in achieving lower SLL by minimizing the maximum SLL in the region of the radiation pattern not covered by the principal beam.

## IV. TLBO Algorithm

TLBO algorithm is a novel meta-heuristic optimization algorithm based on the exchange of knowledge which happens possibly in two different ways in a class room environment viz., between the teacher and the student and learner and fellow learner [16-19]. This process in divided into Teaching phase and Student phase. Each student is treated as an array and the corresponding subjects in the class are array elements. The best student is in the class is treated as the array with best fitness function. The algorithm is applied to synthesize the non-uniform circular antenna array to obtain the desired SLL.

The algorithm is classified into initialization, teaching phase, learning phase and termination criterion. In the first phase, the population is generated with specified lower and higher boundary. During the teaching phase the mean of each of the subjects for all generations is calculated and presented as $M^g$. in the minimization problem the learner with the least mean is considered as teacher for that iteration. All the learners now takes a shift towards the teacher with the following expression [16,17]:

$$X_{new}{}^{g} = X^{g} + rand * \left( X_{teacher}^{g} - tf * M^{g} \right) \tag{5}$$

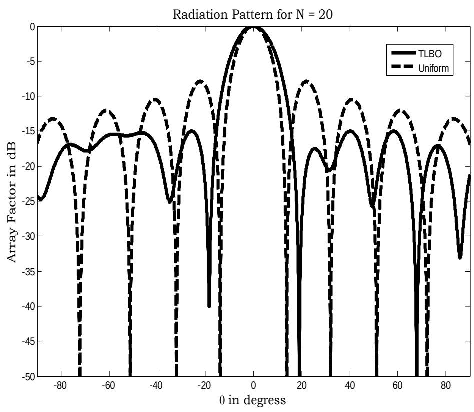
where, X is the learner, g is generation, tf is teaching factor ranging from 1 to 2.
In the learning phase the learner's knowledge is updated using the flowing equation:

$$X_{new}^{g} = \begin{cases} X_i^g + rand * \left( X_i^g - X_r^g \right) & fitness\left(X_i^g\right) \langle fitness\left(X_r^g\right) \\ X_i^g + rand * \left( X_r^g - X_i^g \right) & Otherwise \end{cases} \tag{6}$$

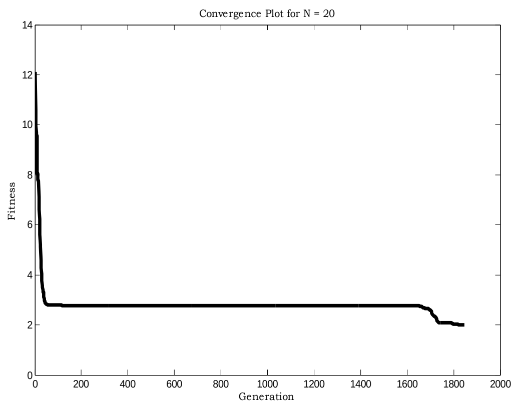
where, 'i' refers to considered learner and 'r' to another randomly selected learner. The program will be terminated if the desired criterion is obtained. The criterion can be number of generations or the desired value of the fitness.

## V. Results And Discussions

The simulation was carried out for N=20, 30, 40 and 50 elements. The resultant plots without steering the main beam and with main beam steered to $20^0$ are shown below:

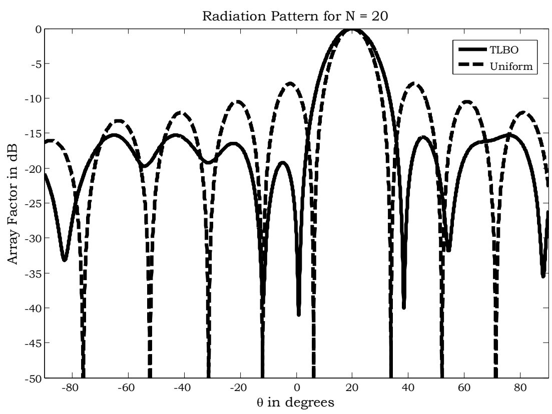



**(a)** Radiation Pattern

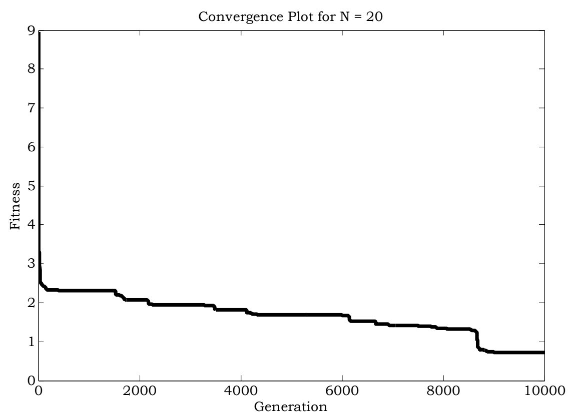



**(b)** Convergence Plot

**(i)** Plots without beam-steering




**(c)** Radiation Pattern

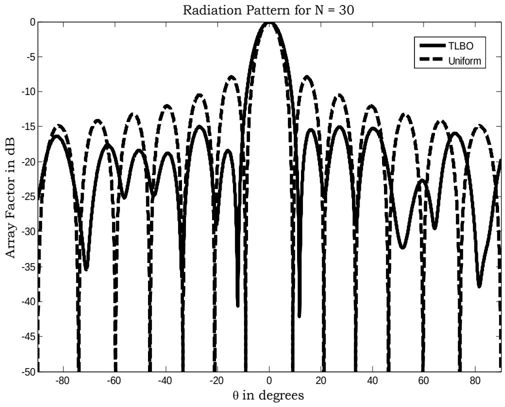


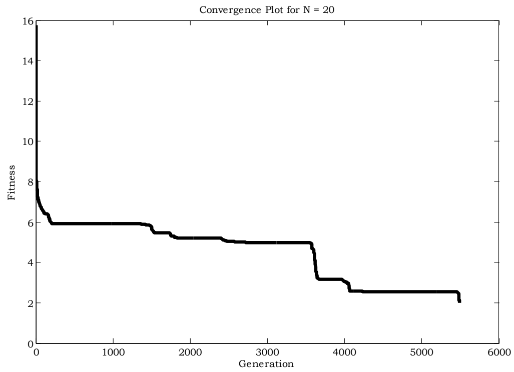

**(d)** Convergence Plot

**(ii)** Plots with main beam steered to $20^0$

**Fig.2** Plots for non-uniform circular array of 20 Elements

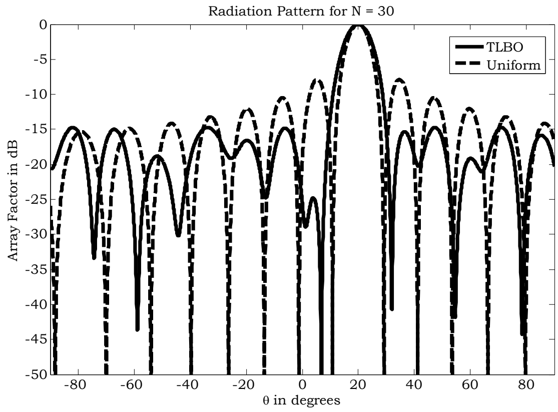
The above figures (a) and (c) shows the radiation pattern without and with beam-steering for a 20 element non-uniform circular array respectively. In both the cases the side lobe level is maintained at -15 dB. The beam-width is also maintained consistently with uniform circular array with 10% relaxation. As it is evident from figures (b) and (d) the plots converge after 1900 and 10000 generations respectively

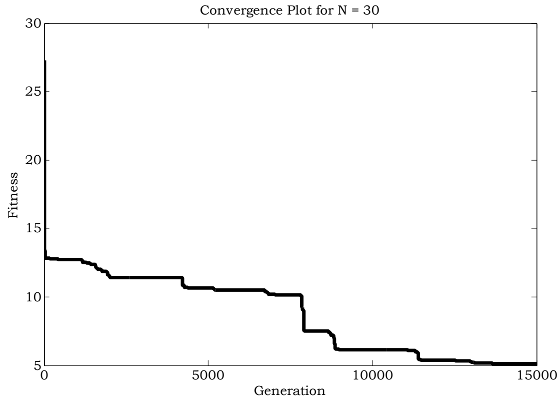



(a) Radiation Pattern (b) Convergence Plot

(i) Plots without beam-steering



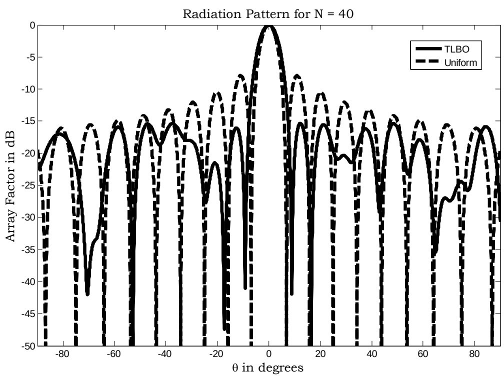



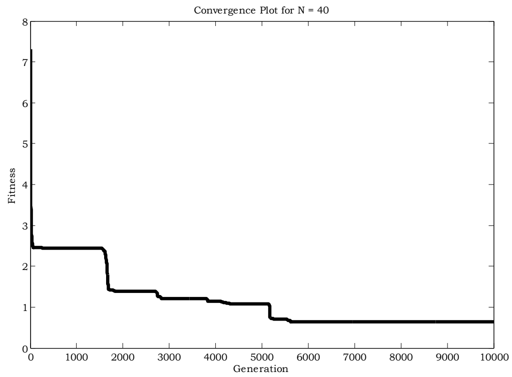

**(c)** Radiation Pattern **(d)** Convergence Plot

**(ii)** Plots with main beam steered to $20^0$

**Fig.3** Plots for non-uniform circular array of 30 Elements

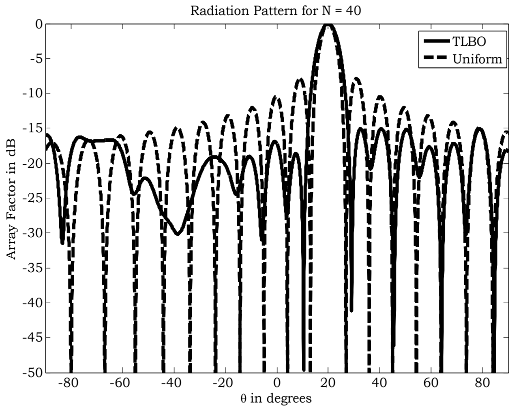
The above figures (a) and (c) shows the radiation pattern without and with beam-steering for a 30 element non-uniform circular array respectively. In both the cases the side lobe level is maintained at -15 dB. The beam-width is also maintained consistently with uniform circular array with 10% relaxation. As it is evident from figures (b) and (d) the plots converge after 5500 and 15000 generations respectively.

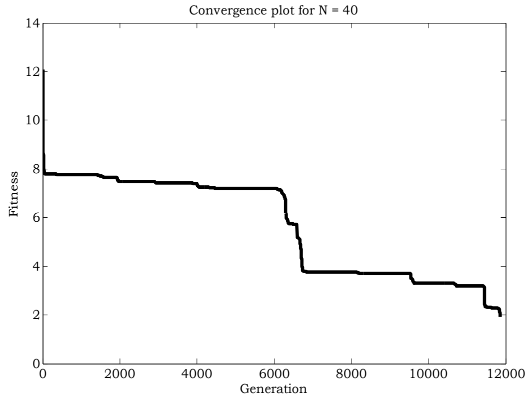



**(a)** Radiation Pattern **(b)** Convergence Plot

**(i)** Plots without beam-steering



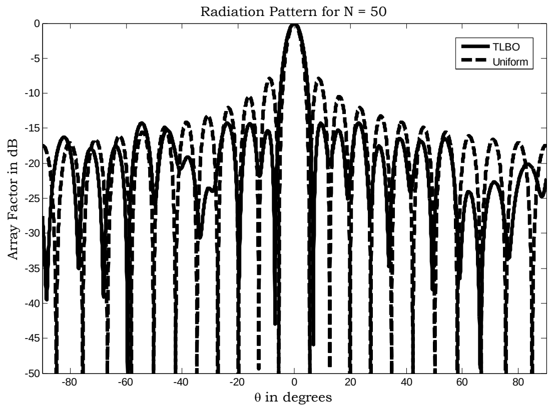



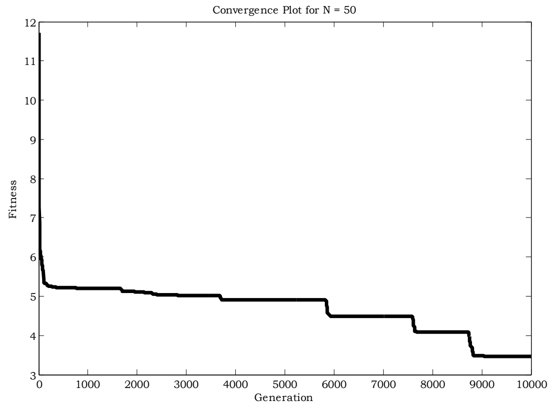

(c) Radiation Pattern (d) Convergence Plot

(ii) Plots with main beam steered to $20^0$

**Fig.4** Plots for non-uniform circular array of 40 Elements

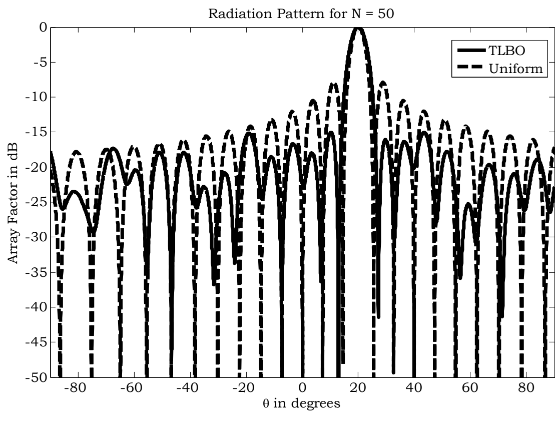
As is evident from figures (a) and (c) the side lobe level is maintained below -15 dB even while the main beam is steered for a 40 element array as well.

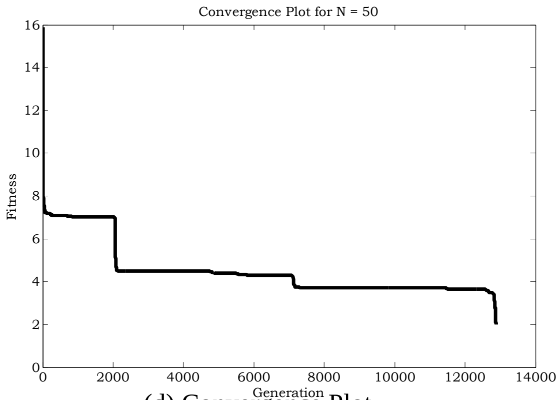



(a) Radiation Pattern (b) Convergence Plot

(i) Plots without beam-steering




(c) Radiation Pattern (d) Convergence Plot

(ii) Plots with main beam steered to $20^0$

**Fig.5** Plots of non-uniform circular array having 50 Elements

In figures (a) and figures (c), of all the plots shown above, the radiation pattern of non-uniform circular array are plotted and compared with that of uniform circular array. It is obvious from the plots that the side lobe level is reduced by 7 dB by using non-uniform amplitude distribution. The excitation coefficients for the sizes of the non-uniform circular array considered above are tabulated in Table 1.

**Table 1: Amplitude distribution for non-scanned and scanned beams**

| S.No | Number of Elements | Amplitude coefficients without Beam scanning | Amplitude coefficients with Beam scanning ($20^0$) |
|---|---|---|---|
| 1 | 20 | 0.99887 0.39963 0.25807 0.51404 0.31376<br>0.15784 0.01000 0.12706 0.42894 0.16340<br>0.55307 0.53109 0.23445 0.03295 0.13247<br>0.17522 0.05017 0.27300 0.44578 0.24161 | 0.48302 0.58274 0.65326 0.06680 0.33814<br>0.09420 0.12040 0.22002 0.25096 0.27596<br>0.53185 0.90125 0.33578 0.55301 0.01028<br>0.60786 0.07332 0.11553 0.22953 0.33421 |
| 2 | 30 | 0.59518 0.41890 0.42279 0.24161 0.24185<br>0.40210 0.03291 0.01399 0.16903 0.29305<br>0.15150 0.28982 0.18305 0.44031 0.74780<br>0.30610 0.54546 0.29218 0.11367 0.06665<br>0.08031 0.43144 0.34637 0.10481 0.19880<br>0.19504 0.52639 0.49467 0.11814 0.95539 | 0.15595 0.20247 0.12306 0.02868 0.19924<br>0.03218 0.08625 0.07028 0.01201 0.06227<br>0.03291 0.10504 0.07812 0.06492 0.10860<br>0.17364 0.07991 0.19824 0.29498 0.07164<br>0.03555 0.07257 0.03983 0.05520 0.07366<br>0.06462 0.03993 0.03872 0.02722 0.05548 |
| 3 | 40 | 0.64067 0.76952 0.69126 0.13673 0.52632<br>0.48691 0.09877 0.27575 0.03409 0.03819<br>0.55009 0.01000 0.34868 0.07318 0.13483<br>0.26571 0.39519 0.65351 0.39117 0.63488<br>0.27555 0.45659 0.72464 0.43303 0.20735<br>0.01175 0.15885 0.19189 0.06702 0.11686<br>0.24899 0.02694 0.57324 0.19424 0.37058<br>0.38721 0.40950 0.65085 1.00000 0.19946 | 0.59218 0.44869 0.57375 0.60308 0.25032<br>0.23286 0.17171 0.04818 0.05364 0.37777<br>0.05188 0.16567 0.09223 0.42654 0.11095<br>0.03841 0.54389 0.25614 0.62593 0.76522<br>0.51171 0.59347 0.80309 0.44418 0.39216<br>0.71987 0.41901 0.08146 0.35873 0.11769<br>0.24993 0.01562 0.08853 0.12222 0.07807<br>0.18186 0.25073 0.42319 0.17460 0.20565 |
| 4 | 50 | 0.90792 0.62133 0.22757 0.49018 0.36449<br>0.28283 0.14071 0.34417 0.29222 0.38332<br>0.21530 0.52455 0.47622 0.12033 0.09200<br>0.13557 0.72302 0.53800 0.01000 0.40289<br>0.73890 0.20181 0.87449 0.36330 0.93152<br>0.63849 0.66351 0.46902 0.86279 0.24310<br>0.77243 0.21307 0.14805 0.03081 0.10077<br>0.29064 0.18872 0.36722 0.34743 0.15887<br>0.33854 0.43397 0.02634 0.31201 0.06549<br>0.20791 0.87053 0.68613 0.79435 0.15358 | 0.18263 0.22499 0.36861 0.44848 0.27281<br>0.29385 0.15210 0.30748 0.31313 0.18843<br>0.01050 0.16650 0.15030 0.04802 0.16277<br>0.09473 0.14521 0.10977 0.05435 0.02987<br>0.06483 0.14682 0.11161 0.20323 0.27789<br>0.13567 0.31271 0.21375 0.13602 0.22442<br>0.36722 0.32789 0.22441 0.15175 0.17386<br>0.06055 0.07194 0.03687 0.23440 0.02319<br>0.08191 0.27199 0.03827 0.05135 0.13643<br>0.10240 0.20273 0.09185 0.22548 0.28261 |

## VI. Conclusion

The circular array synthesis is formulated as an optimization problem with control over the two conflicting parameters known as SLL and BW. The BW is maintained at magnitude of that of the uniform circular array with SLL much less than the uniform case. TLBO algorithm is successfully applied to determine the coefficients required to obtain desired side lobe level of -15 dB and simultaneously scanning the main beam to desired direction in radiation pattern of non-uniform circular arrays. The table gives the amplitude distribution for both scanned and non-scanned cases.

## References


[1]. C.A Balanis, Antenna Theory: Analysis and Design, 2nd ed. Singapore, John Wiley and Sons (Asia), 2003.

[2]. P. S. R. Chowdary, A. Mallikarjuna Prasad, P. Mallikarjuna Rao, and Jaume Anguera, " Simulation of Radiation Characteristics of Sierpinski Fractal Geometry for Multiband Applications," International Journal of Information and Electronics Engineering vol. 3, no. 6, pp. 618-621, 2013.

[3]. Chowdary, P. Satish Rama, et al. "Design and Performance Study of Sierpinski Fractal Based Patch Antennas for Multiband and Miniaturization Characteristics." Wireless Personal Communications: 1-18.

[4]. Chowdary, P. Satish Rama, A. Mallikarjuna Prasad, and P. Mallikarjuna Rao. "Multi Resonant Structures on Microstrip Patch for Broadband Characteristics."Proceedings of the 3rd International Conference on Frontiers of Intelligent Computing: Theory and Applications (FICTA) 2014. Springer International Publishing, 2015.

[5]. A. Marco Panduro, et al, "Design of non-uniform circular antenna arrays for side lobe level reduction using the method of genetic algoritms", AEU-International Journal of Electronics and Communications, vol.60, No. 10, pp. 171-186, 2009.

[6]. A. Marco Panduro, et al, "Design of non-uniform circular antenna arrays for side lobe level reduction using the method of genetic algorithms", AEU-International Journal of Electronics and Communications, vol.60, No. 10, pp. 171-186, 2009.

[7]. Liang, J. J., A. K. Qin, P. N. Suganthan, and S. Baskar, "Comprehensive learning particle swarm optimizer for global optimization of multimodal functions," IEEE Trans. on Evol. Compt., Vol. 10, 281–295, 2006.

[8]. Najjar, Mohammad Shihab—Yahya, and Nihad Dib—Majid Khodier. "Design of non–uniform circular antenna arrays using particle swarm optimization." *Journal of electrical engineering* 59.4 (2008): 216-220.

[9]. Khodier, Majid M., and Mohammad Al-Aqeel. "Linear and circular array optimization: A study using particle swarm intelligence." *Progress In Electromagnetics Research B* 15 (2009): 347-373.

[10]. VVSSS Chakravarthy, P. Mallikarjuna Rao, "Circular Array Antenna Optimization with Scanned and Unscanned Beams using Novel Particle Swarm Optimization". Indian Journal of Applied Research, Vol. 5, Issue. 4, April, 2015, ISSN-2249-555K.

[11]. Hosseini S. A. and Z. Atlasbaf, "Optimization of side lobe level and fixing quasi-nulls in both of the sum and difference patterns by using continuous ant colony optimization (ACO) method," Progress In Electromagnetics Research, Vol. 79, 321–337, 2008.

[12]. Mallahzadeh, A. R., H. Oraizi, and Z. Davoodi-Rad, "Application of the invasive weed optimization technique for antenna configurations," Progress In Electromagnetics Research, Vol. 79, 137–150, 2008.

[13]. Guney, K. and M. Onay, "Amplitude-only pattern nulling of linear antenna arrays with the use of bees algorithm," Progress In Electromagnetics Research, Vol. 70, 21–36, 2007.

[14]. Dib, N. I., S. K. Goudos, and H. Muhsen, "Application of Taguchi's optimization method and self-adaptive differential evolution to the synthesis of linear antenna arrays," Progress In Electromagnetics Research, Vol. 102, 159–180, 2010.

[15]. VVSSS Chakravarthy, P. Mallikarjuna Rao, "On the Convergence Characteristics of Flower Pollinations Algorithm for Circular Array Synthesis", Proceedings of IEEE sponsored 2nd International Conference on Electronics and Communication Systems (ICECS-2015).

[16]. Rao, R.V., Savsani, V.J., Vakharia, D.P. "Teaching-Learning Based Optimization: A Novel Method for Constrined Mechanical Design Optimization Problems. Computer-Aided Design" 43(3), 303-315 (2011).

[17]. Rao, R.V. & Savsani, V.J. (2012). Mechanical Design Optimization using Advanced Optimization Techniques, Springer Verlag, London.

[18]. Dib, N., Sharaqa, A, "Synthesis of Thinned Concentric Circular Antenna Arrays using Teaching-Learning Based Optimization. International Journal of RF & Micowave Comp. Aided Engg.24, 443-450 (2014), doi:10.1002/mmce.20784"

[19]. Dib, N.: Synthesis of Thinned Planar Antenna Arrays using Teaching-Learning Based Optimization. International Journal of Microwaves and Wireless Technologies available on CJO (2014), doi:10.1017/S1759078714000798.

[20]. Chakravarthy, V. V. S. S. S., and P. Mallikarjuna Rao. "Implementation of TLBO for Circular Array Synthesis," IJATIR, Vol.7, Issue 3 (2015).

[21]. Chakravarthy, V.V.S.S.S, et al, "Linear Array Optimization using Teaching Learning Based Optimization." Emerging ICT for Bridging the Future- Proceedings of the 49th Annual Convention of the Computer Society of India, CSI Vol.2. Springer International Publishing, 2015.