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Synthesis of Circular Array Antennas Using Accelerated Particle Swarm Optimization

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ABSTRACT

In this paper, the design and synthesis of Circular Antenna Array Configuration (CAAC) is performed using the Amplitude-Spacing technique. The synthesis process uses the novel evolutionary computing tool known as Accelerated Particle Swarm Optimization (APSO). A 25 element and 50 element CAAC is designed with objectives like sidelobe level (SLL) suppression with beam-width (BW) constraints. While mitigating the inter-element spacing, the constraint on the circumference of the circle is also imposed. Analysis based on the results in terms of radiation pattern in which the SLL and BW are computed. The whole simulation is carried out in MATLAB.

Key words: Circular array antenna, SLL, BW, APSO.

1. INTRODUCTION

In many situations a single element radiating systems (SERS) are not suitable to meet the desired radiation characteristics. The desired gain and the required directivity are not possible with such SERS. The desired radiation pattern for modern wireless applications required to suite to long distance communication. In order to overcome the above discussed issues, the antenna array configuration is proposed. An antenna array configuration involves in combining several individual antenna elements. These elements are interconnected in certain electrical as well as geometrical forms [1-5]. These antenna arrays are used for several application which demand for RADAR, SONAR, radio, and advanced wireless communication systems. In the recent times, there is an incredible development in the Wireless technology. This rapid fast growth lead to the development of some latest mobile systems which offer multiple bandwidth schemes. In order to adopt this, novel techniques are to be developed. Among the latest wireless techniques, the Spatial processing appears to be the only method which paved a way to the development of cellular systems and smart antennas. Hence these techniques are often known as the emerging and enabling techniques. The antenna array configuration (AAC) is a radiating system which incorporates these techniques as working principles [1-8].

The AAC configuration also has several desirable features which the modern wireless personal and commercial communication system require. Some of them are the capability to steer the beam, shape the beam and positioning the nulls in the undesired direction as well as positioning the sidelobe level (SLL) peaks in the desired direction of the signal.

Similarly, the other desired feature being the gain and directivity. In the case of SERS, the gain, directivity and the corresponding SLL or beam-width (BW) along with the desired shape of the beam are significantly stable and cannot be altered. This is considered as the limitation with the SERS. The antenna serving for the wireless device has to be adaptive to the system and environment and should have the feature to modify the radiation characteristics according to the requirement of the application and the system. This drawback can be overcome using the AAC. In the AAC, several features like controlling the beam position as well as the null position in the radiation pattern. Similarly, it is also possible to manage and mitigate the electrical and all radiation features.

In AAC, each element is driven with a distinct electrical circuit which can control the amplitude and the phase of the current excitation. Similarly, the spacing between the elements in the array is another such parameter which has control on the radiation pattern of the AAC. Hence, these three parameters listed above are known as the steering parameters of the pattern synthesis of the AAC. These three parameters can completely control the radiation pattern of the AAC and hence play a vital role in the design process.

There are different types of AAC in accordance with the arrangement of the elements. Typically, they are classified as one dimensional, two dimensional and three dimensional. The linear AAC belongs to the 1D while the circular and planar AAC refers to the 2D. Similarly, the 3D AAC is a cylindrical or conformal array. In this paper, the circular AAC (CAAC) is designed with the objective lower SLL and BW constraint. Earlier, there are several works which have reported CAAC with similar objectives. However, in this paper, large CAAC is considered with constraint on the BW as well as the array circumference. Many evolutionary computing tools like Flower pollination algorithm, teaching learning-based optimization, genetic algorithm and particle swarm optimization are employed to synthesize the circular arrays in the past [3-11]. In this work, the famous Accelerated Particle Swarm optimization [6] is employed to solve the array design problem. Further, the work presented in this paper is organized as follows. The design problem is dealt in the Section 2 and the discussion on the algorithm and its implementation is given in Section 3. The results and discussions are presented in the Section 4 followed by Conclusions are given in Section 5.

2. DESIGN PROBLEM

The AAC synthesis problem involves in designing the array for a desired radiation pattern. The desired radiation pattern constitutes low SLL and low BW. The design problem involves in determining the amplitude distribution along with the spatial distribution of the array elements. This involves in using the amplitude-spacing technique of array synthesis to design CAAC for very low SLL and BW constraint.

2.1 CAAC formulation

The geometry of the CAAC is a geometrical arrangement in which all the elements are arranged along the circumference of the circle. Several applications like radio wave-based direction finding, spatial navigation, and ground penetrating radars are few examples. In the recent past, they have become the significant part of the smart antenna. It can be resembled as a curved linear array. Unlike linear arrays, a circular array can scan horizontally for 360° with no distortions near the end-fire directions. However, they have an advantage over linear arrays in terms of phase calibration which is a difficult task in linear arrays.

The typical array with elements distributed along the circumference of the circle is as shown in Figure 1. All the elements in the CAAC are isotropic elements. The circumference of the circle is said to be ‘2πr’ while the radius of the circle is 'r'. As mentioned above, the suppression of the SLL and BW are the objectives of the design problem. The array factor (AF) plays an important role in the problem formulation of the CAAC design. Accordingly, the AF of CAAC is given as following [5].

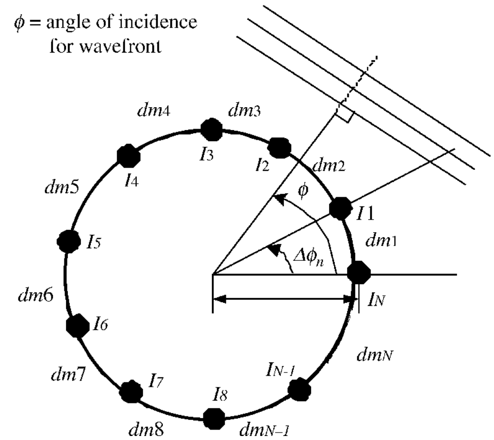


Figure 1: Geometry of CAAC

$$E(\phi) = \sum_{n=1}^{N} A_n * e^{\wedge}[j*(\beta r * cos(\phi - \phi(n)\ \ ) + \beta(n) \quad (1)$$

Here, the element index is given by ‘n’. The total number of elements in the array are N. The current amplitude of every n^{th} element is A(n). Similarly, $\beta(n)$ refers to the respective phase excitation current. While inter-element spacing is given by d_n, the 'βr' and $\emptyset_n$ are computed using the following relations.

$$\beta r = \frac{2\pi r}{\lambda} = \sum_{i=1}^{N} d(i) \quad (2)$$

$$\phi_{(n)} = \frac{2\pi}{\beta r} \sum_{i=1}^{n} d_{(i)} \quad (3)$$

2.2 Objective function

The sample radiation pattern for understanding various parameters constituting the objective of the design problem is as shown in Fig.2. The respective SLL, BW and nulls along with the different regions and nomenclature of the pattern are presented in the Figure 2. The formulation of the objective function includes all these vital parameters from the radiation pattern plot.

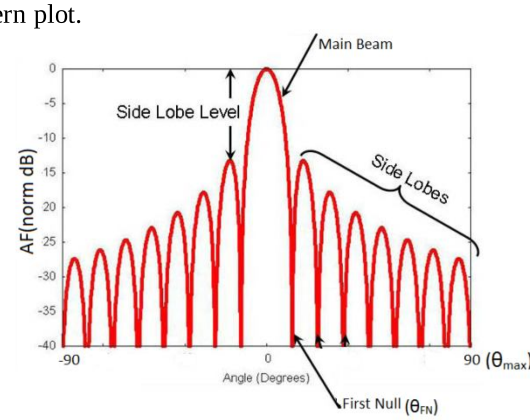


Figure 2: Sample pattern of CAAC

The fitness function is given as

$$fitness = SLL_{des} + maximum(SLL_{\theta=-90to90}) \quad (4)$$

Here, SLL_{des} refers to lowest SLL value which is required and $SLL_{\theta=(-90 \text{ to } 90)}$ is the obtained highest SLL within the range mentioned. However, in this case the SLL values with in the BW of the main beam are excluded.

3. ACCELERATED PSO ALGORITHM

3.1 APSO structure

The Particle swarm optimization algorithm is a population-based nature inspired algorithm. The algorithm structure follows the manner of the flock of birds which are in search of food. The typical strategy of searching for food involves in mutual and collective approach in which the individual contribution is also considered. The typical strategy is formulated as

$$v_{ij}(t+1) = wv_{ij}(t) + c_1\text{rand}_1(t)\left(p_{gj}(t) - x_{ij}(t)\right) + c_2\text{rand}_2(t)\left(p_g(t) - x_{ij}(t)\right)$$

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1), \quad (5)$$

Here x refers to an individual position and ‘p’ refers to the personal best and suffix ‘g’ refers to the global component. The velocity ‘v’ is updated over every iteration ‘t’. The ‘rand’ is a random number generated. Similarly, the position of the individual also updated. In the equation for the velocity updating, the first term is the inertial term while the second term involving the global component ‘g’ is global search while the local search is addressed by the last part of the equation.

In PSO, both the local and global search are given equal preference and weightage. However, it is evident from simulations that the search capability yields better results while the global search in progress. Considering this, a new version of PSO known as APSO is introduced in which only the global search is preferred ignoring or giving least weightage to the local search [5,6].

3.2. Implementation

The population initially generated randomly and is given as [5]

$$pop = [p_1(k), p_2(k) \dots\dots\dots p_M(k)] \quad (6)$$

where *'k'* is the iteration number and

$$\begin{bmatrix} p_1 \\ p_2 \\ . \\ . \\ p_M \end{bmatrix} = \begin{bmatrix} A_1^1, AI_1^2, \dots\dots, A_1^N \\ A_2^1, A_2^2, \dots\dots, A_2^N \\ \dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots \\ A_M^1, A_M^2, \dots\dots, A_M^N \end{bmatrix}$$

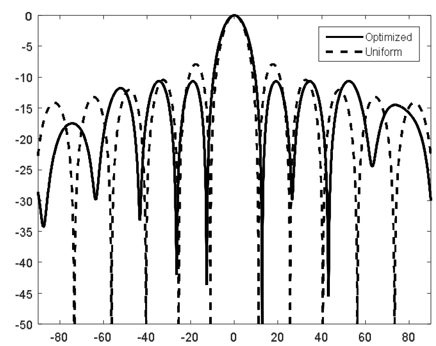
(7)

where *'A'* is current excitation coefficients. If inter-element spacing is also considered, then the matrix will have position parameter also as (A_M^i, d_M^i).

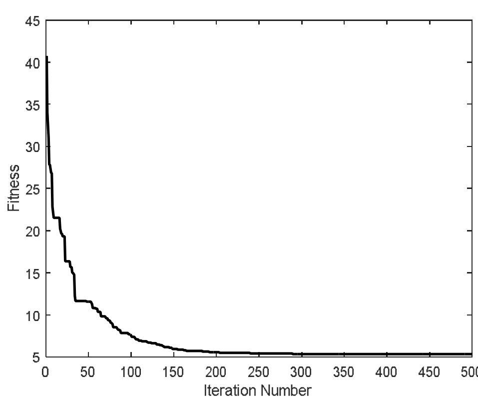
4. RESULTS AND DISCUSSIONS

Results pertaining to the implementation of the APSO and optimization for the CAAC for suppressed SLL and constrained BW are presented in this Section. The simulation experiment is carried out on two CAACs which have 25 and 50 elements respectively. The radiation patterns of CAAC with 25 elements and reduced SLL is as shown in Figure 3(a). The corresponding convergence plot is given in Figure 3(b). Similarly, the radiation pattern and the respective convergence plots of a 50 element CAAC is presented in Fig.4(a) and Fig.4(b). In both the cases, the radiation pattern plots have both the uniform distribution plot overlapped by the non-uniform distribution as determined by the APSO. It is evident from these plots that the uniform pattern for 25 and 50 element CAAC have a SLL as high as -7.5dB. Similarly, the corresponding BW for 25 element and 50 elements uniform CAAC are 23^0 and 11.2^0 respectively.

It is possible to infer from these plots that the optimized patterns in both the plots have SLL much less than that of uniform CAAC while the BW is almost kept constant. The corresponding amplitude coefficients and positions of the elements on the circle are listed in Table 1.

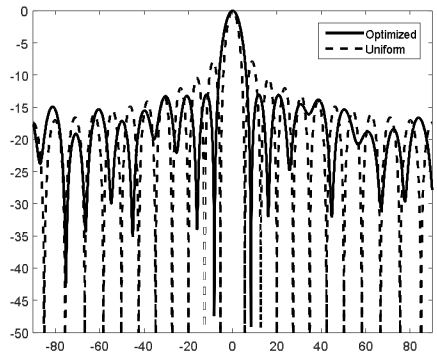


(a)

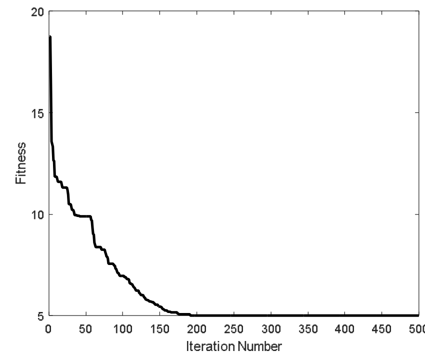


(b)

Figure 3: (a) Radiation pattern and (b) convergence plot of 25 element CAAC



(a)



(b)

Figure 4: (a) Radiation pattern and (b) convergence plot of 50 element CAAC

Table 1: Non-uniform optimized amplitude and spacing distribution using APSO

Number of Elements	Amplitude Distribution					Position of the elements (in λ)					SLL (in dB)	CAAC circumference (in λ)
25	0.50841	0.15774	0.44011	0.68197	0.096075	0.49957	0.49692	0.49871	0.49663	0.29162	-10.7	11.11
	0.40936	0.86965	0.32451	0.39881	0.13817	0.49996	0.48637	0.48216	0.4926	0.49891		
	0.6634	0.99511	0.31615	0.031595	0.086611	0.49935	0.48816	0.40734	0.47599	0.21584		
	0.4929	0.3404	0.92712	0.85116	0.17704	0.49303	0.48118	0.38906	0.49996	0.41101		
	0.32765	0.077729	0.27068	0.47077	0.99999	0.49337	0.30098	0.45096	0.37162	0.39738		
50	0.62051	0.97753	0.83731	0.55123	0.56491	0.25506	0.35152	0.46719	0.48828	0.48967	-13.1	19.40
	0.47189	0.015838	0.29054	0.084708	0.78032	0.3354	0.37849	0.49953	0.30496	0.4946		
	0.42999	0.44598	0.98343	0.10922	0.60196	0.47024	0.10104	0.4018	0.48962	0.44422		
	0.022958	0.83839	0.3331	0.56771	0.72185	0.43173	0.49649	0.16301	0.49801	0.27105		
	0.80096	0.68439	0.71101	0.80189	0.36579	0.49018	0.46768	0.44823	0.090767	0.48197		
	0.82358	0.74858	0.30467	0.84773	0.34355	0.14825	0.49489	0.15954	0.35506	0.33173		
	0.93876	0.016691	0.63373	0.91999	0.69718	0.2725	0.31625	0.49691	0.49747	0.49146		
	0.16478	0.36605	0.37223	0.55417	0.35696	0.48605	0.23756	0.48338	0.48808	0.42871		
	0.83692	0.35688	0.12264	0.017219	0.75095	0.48685	0.48409	0.48753	0.49803	0.38673		
	0.13697	0.92981	0.50836	0.84189	0.32096	0.20469	0.10982	0.49544	0.3581	0.39305		

5. CONCLUSION

The aperture size and the amplitude distribution of the CAAC are optimized for suppressed SLL with optimal BW using APSO. The APSO is successfully applied to the CAAC optimization in terms of SLL and BW along with the reduced aperture crossection. From the Table 1 the corresponding aperture circumference of 25 element CAAC is 11.1λ when compared with the uniform CAAC which used to be 12.5λ. Similarly, the in the case of 50 element of CAAC, the non-uniform optimized geometry has a circumference of 19.40λ which has to be 25λ in uniform CAAC. This reduction in SLL and aperture circumference are achieved successfully using the APSO.

REFERENCES

1 Marconi. **On methods whereby the radiation of electric waves may be mainly confined to certain directions, and whereby the receptivity of a receiver may be restricted to electric waves emanating from certain directions**. Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 77, no. 518, pp. 413–421, 1906. https://doi.org/10.1098/rspa.1906.0036

2 K. D. Cheng. **Optimization techniques for antenna arrays.** Proceedings of the IEEE, vol. 59, no. 12, pp. 1664–1674, 1971. https://doi.org/10.1109/PROC.1971.8523

3 Chakravarthy, V.V.S.S. Sameer; Mallikarjuna Rao, P., **Amplitude-only null positioning in circular arrays using genetic algorithm.** International conference on *Electrical, Computer and Communication Technologies (ICECCT), 2015 IEEE International Conference on*, vol., no., pp.1-5, 5-7 March 2015 doi: 10.1109/ICECCT.2015.7226120

4 Chakravarthy, V.V.S.S.S., Sarma, S.V.R.A.N, Babu K.N., Chowdary, P.S.R., & Kumar, S.T. **Non-uniform circular array synthesis using teaching learning-based optimization. Journal of Electronics and Communication Engineering**, doi: 10.6084/m9.figshare.1452770.

5 V. S. S. S. Chakravarthy Vedula, S. R. Chowdary Paladuga, and M. Rao Prithvi. **Synthesis of Circular Array Antenna for Sidelobe Level and Aperture Size Control Using Flower Pollination Algorithm**. International Journal of Antennas and Propagation, vol. 2015, Article ID 819712, 9 pages, 2015. https://doi.org/10.1155/2015/819712.

6 Yang XS., Deb S., Fong S. **Accelerated Particle Swarm Optimization and Support Vector Machine for**

Business Optimization and Applications. In: Fong S. (eds) Networked Digital Technologies. NDT 2011. Communications in Computer and Information Science, vol 136. Springer, Berlin, Heidelberg https://doi.org/10.1007/978-3-642-22185-9_6

7 Chakravarthy V.V.S.S.S., Babu K.N., Suresh S., Devi P.C., Rao P.M. **Linear Array Optimization Using Teaching Learning Based Optimization**. In: Satapathy S., Govardhan A., Raju K., Mandal J. (eds) Emerging ICT for Bridging the Future - Proceedings of the 49th Annual Convention of the Computer Society of India CSI Volume 2. Advances in Intelligent Systems and Computing, vol 338. Springer, Cham

8 D. Mandal, S. P. Ghoshal, and A. K. Bhattacharjee, **Application of evolutionary optimization techniques for finding the optimal set of concentric circular antenna array**. Expert Systems with Applications, vol. 38, no. 4, pp. 2942–2950, 2011. https://doi.org/10.1016/j.eswa.2010.08.082

9 Reyna, M. A. Panduro, D. H. Covarrubias, and A. Mendez**. Design of steerable concentric rings array for low side lobe level**. Scientia Iranica, vol. 19, no. 3, pp. 727–732, 2012. https://doi.org/10.1016/j.scient.2011.08.028

10 Chakravarthy, V.V.S.S.S., Chowdary, P.S.R., Panda, G. et al, **On the Linear Antenna Array Synthesis Techniques for Sum and Difference Patterns Using Flower Pollination Algorithm**, Arab J Sci Eng (2018) 43: 3965. https://doi.org/10.1007/s13369-017-2750-5

11 V. V. S. S. S. Chakravarthy, P. S. R. Chowdary, Suresh Chandra Satapathy, Jaume Anguera, Aurora Andújar, *Socio-cultural Inspired Metaheuristics*, vol. 828, pp. 267, 2019. https://doi.org/10.1007/978-981-13-6569-0_13