Review On Multi-objective Optimization of Linear and Circular arrays using Evolutionary Computing Tools

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Abstract - Antenna array synthesis problem is an optimization problem with several objectives like side lobe level (SLL) suppression, Beam width (BW) control and null control. The array optimization is inherently multi-objective (MO) problem with several multiple combination of above listed objectives and constraints. Recently, the concept of MO optimization (MOO) in engineering took a significant development with the advent of evolutionary nature inspired and meta-heuristic techniques. These techniques are widely employed in antenna array synthesis and started replacing the conventional optimization techniques because of their obvious advantages of simple computational complexity and fast convergence. In this paper a brief review of such MOO schemes as applied to linear and planar antenna arrays is discussed.

Keywords: antenna arrays, multi-objective, optimization, beamwidth, sidelode level

I. INTRODUCTION

Now a days there is a rapid growth in the field of communication in which antenna place major important role. Among all which antenna arrays very important role advantages such as directivity and capable of producing desired shape of radiation.[1-6]. So antenna arrays are not preferred in electromagnetics. Generally the configuration obtained will be close to the design pattern, here the configuration involves parameters like phase, amplitude and distance [2]. This synthesis is done by obtaining the value of one or two configuration where other are kept constant. In this regard we use evolutionary computing techniques to determine these solutions. [7].The conventional techniques have tendency the stuck in the local minima and most of them are local final solution is dependent on initial solution. The main drawback in these are time consuming and cannot handle multi objective problems. So meta-heuristic algorithms have been chosen as a best solution to overcome these problems. These algorithms are genetic algorithm, particle swarm optimization, simulated annealing, differential evolution, firefly algorithms which are used for antenna design especially for multi objective Optimization in array synthesis problem [8-14]. One of the most important functions in antenna theory is array factor. It is a function of the position of elements in the array and the weight of amplitude and phase of current excitation. By varying these parameters, the array used to achieve desirable characteristics[15-17]. The technique used to enhance the dimension of the antenna is to have collection of two or more antennas having same electrical and geometrical configuration. The set of antenna elements and an antenna array and has radiation pattern described by the following factors. They are array geometry, spacing between the elements, phase of current excitation, magnitude of current excitation, original element pattern[18]. The geometry refers to the geometrical distribution of elements in the array. Basing on this arrays are classified into one dimensional, two dimensional three dimensional. Linear array is the simplest form of array in which all the elements are arranged in a straight line.2D arrays are planar arrays which are circular and rectangular and arbitrary arranged on a plane. Each array geometry has got its own advantages and disadvantages. Circular arrays are where antennas are placed in a circular ring. In order to synthesis these liner and circular arrays we use computing tools in order to get the desired output[17-33].Each and every synthesis technique has its unique importance in solving the assigned problem. So depending[on the intensity of the problem any algorithm is selected. The three parameters which are called as steering parameters are being analysed using evolutionary algorithms to get the desired pattern.

II. DESIGN PROBLEM

The synthesis problem in arrays are generally because of the dimensional properties such as spacing between the elements, amplitude and phase[2]. To get the desired radiation pattern the process of controlling the number of properties depends upon the type of the problem which is chosen assembly parameter is considered single objective what are considered it is called as multi objective problem.

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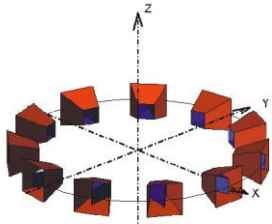
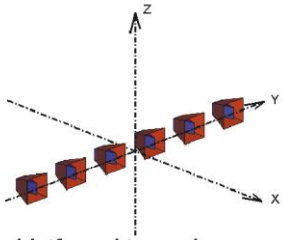
Generally in array synthesis either SLL or BW are both are controlled to produce and desired radiation.[10]. Basically these two are conflicting parameters because when SLL is



Uniform Circular Array (UCA)



Uniform Linera Array (ULA)

suppressed BW increases and when SLL increases, BW gets decreased. This is the basic problem in antenna arrays which can be reduced using conventional techniques without losing the advantages of SLL [11]. Basically this is done by modifying the steering parameters which are amplitude, phase, spacing between elements. The performance of elements in arrays can be easily analyzed. Single objective optimization can be obtained by taking a single parameter and analysis is done [19].The general drawbacks of single objective are it has high directivity and no control on sll and BW [27]. More additional equipment is required to monitor the patient main beam. Directivity need to be increased as the length of antenna is increased. These all can be overcome in multi objective optimization.

III. SINGLE OBJECTIVE OPTIMIZATION

Certain analysis is done on single objective optimization and problems encountered in single objective are given below. Basing on the technique proposed in[5,6] generating sharpest beam by concentrating it in one direction and by placing a vertical rod which is placed behind the antenna acting as a reflector due to current induced in which lags behind the electromagnetic field where the current induced leads the EMF in vertical rod which is slightly less than the antenna that acts as a director. When placed in front of it.it is experimentally demonstrated that directive radio wave produced by the antenna aided with single reflector and several directors. The number of directors would add to the directive characteristics of the proposed antenna.

Radiation pattern with minimized SLL and optimum BW are obtained using the technique proposed in [7]. In this technique a broadside array was considered with elements fed in phase and symmetrical arranged about the centre of the array.A mathematical technique based on Chebyshev polynomial was well explored for better control over the pattern [29]. The properties of the Chebyshev polynomial used to calculate and distribution on all the elements of that equally spaced array to keep all the sidelobes at the same level with first null positioned at the desired angle. Calculating optimum current distribution of the linear in phase, symmetric array has certain limitations with beamwidth and its computational complexity but still appeared to be the best for those in array synthesis

Desired beam shaping technique is proposed in [8] in which the synthesis process is accomplished by proper field distribution on the aperture. This technique involves in sampling the specified pattern at discrete locations called sample and writing the composing function for each sample then tries to approximately attain its desired shape at the sample point by proper current distribution [24]. Later the finite summation of all and sample point would produce the specified pattern. This technique is elegant and simple but has no control on side lobe levels in the un scanned region of the pattern.

The novel concepts of including the time as an additional degree of freedom in design of antennas in presented in [31]. The use of time as fourth dimension improved performance of the antenna. This technique was later coined as ‘Time modulation’ and it uses several time delay circuits and operates with different combination of excitation coefficients on time scale [29]. This reduces the impractical excitation coefficient magnitudes and can even operate with uniform and constant distribution of coefficients with time tapping.

IV. MULTI OBJECTIVE OPTIMISATION

Optimization handling more than one objective is called as multiobjective optimization. When compared to single objective, multi-objective have many advantages. By applying these multi optimization techniques to antenna arrays consisting of the three steering parameters the analysis can be done. The complexity becomes more severe when the objectives considered are mutually conflicting [23]. The simplest form is a classical method of transforming a multiobjective problem into single objective using either weighted objective technique or method of distance functions.

It is proposed in [10] genetic algorithm with adaptive searching area ,the Injection of simulated annealing and immune operator etc is to improve the effectiveness. Performance is of the linear arrays is analyzed while synthesizing using improved GA [18]. Both the amplitude coefficients and the position of elements are considered as steering parameter, that are defined using the algorithm in the synthesis process with the objective of reducing relative sidelobe levels.

[11] proposed a hybrid optimization method which uses an adaptive GA and non linear programming optimize circular array [14].The proposed method successful in suppressing the SLL as well as generating radiation patterns with desired null positions. From the results it can be inferred that the proposed algorithm works more effectively in solving such problems better than standard GA.

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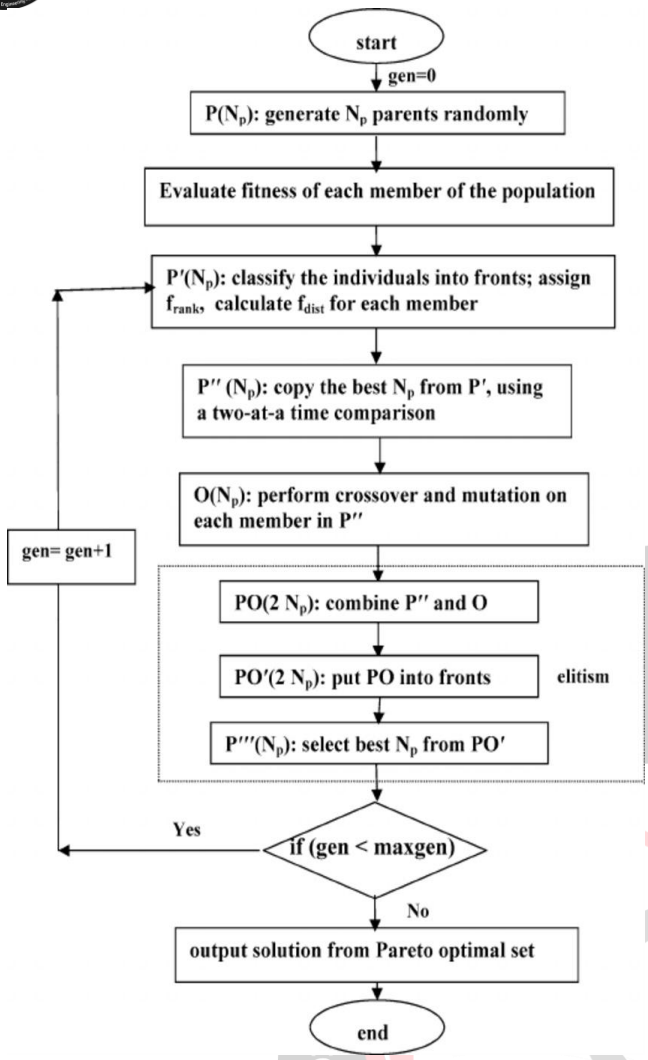

Proposed the method in [12] of PSO for the design of linear and circular arrays to generate a radiation pattern with desired properties .The parameters of antenna elements that provide the goal radiation pattern are optimized using PSO [4]. Results shows that the design of antenna arrays using the PSO method provides considerable enhancements compared with the uniform array and the synthesis obtained from other optimization techniques.

A detailed review of the research and development in phased array antennas is given in [32] by L. Stark. Literature on formulation and optimization of the phased arrays with single and multiple degrees of freedom has been discussed, R.S. Elliot [33] suggested a design method for the creation of line sources which are capable of yielding antenna patterns consisting of a narrow main beam along with low sidelobes, with the sidelobe levels on either sides of the main beam being different (asymmetric pattern).

V. PERFORMANCE ANALYSIS

Basing on the study done on SOO and MOO oriented analysis it is clear that MO is vast advantageous than SO.Moreover the performance that has to be obtained either by SO or MO should be more accurate and perfect for better result.

VI. COMPARATIVE ANALYSIS OF EXISTING AND PROPOSED MODEL

The basic parameters which is used in attaining the performance of an antenna are phase, distance and amplitude which are called steering parameters. Weather it maybe either a SO optimization or a MO optimization, the general objective which are considered are SLL,BW and null control. The analysis done clearly states about the existing problems which are carried out while analyzing the three objectives which is solved in the proposed model because of the conventional optimization technique.

VII. CONCLUSION

The brief review on the application of evolutionary computing tools and techniques for antenna array optimization is presented. The discussion elevated the multi-objective nature of the array synthesis and need to handle the problem in its original form. Both the linear and circular arrays are dealt in the review. The review also discussed several limitation and drawbacks on the earlier technique of transforming the MOO problem to weighted single objective problem. Thereby, the significance of the MOO is highlighted. So the MOO problem can be obtained by using the evolutionary computing tools for linear and circular array in order to get the benefits of simple computational complexity and fast convergence.

REFERENCES

[1] C.A.Balanis:Antenna theory:Analysis and design,John Wiley and Sons,Hoboken,NJ,USA,2005.

[2] LHaupt,Antennaarrays:acomputationalapproach,Wilkey New York,2010.

[3] Kennedy,J.;Eberhat,R.,"ParticleswarmOptimisation",Neural Networks,1995.Proceedings.,IEEE International Conference on Vol.4, no.,pp.1942,1948 vol.4,Nov/Dec 1995.

[4] GoldbergD."GeneticAlgorithminSearch,Optimisation,and Machine Learning.

[5] H.Yagi and S.Uda,"Projector of the sharpest beam of electric waves", Proceedings of Imperical Academy(Tokyo) Vol.2,pp.49-52,February 1926 .

[6] Yagi,H.,"Beam Transmission of Ultra Short Waves",Radio Engineers,Proceedings Of the Institute of,vol.16,no.6,pp715-70,June,1928.DOI:10.1109 /JRPROC.1928.221464.

[7] Dolph,c.l.,"A Current Distribution for Broadside Arrays Which Optimises the relationship between Beamwidth and sll",Proceedings of the IRE,vol.34,no.6,pp.335-348,June1946

[8] Goldberg,D."GeneticAlgorithmsinSearch,Optimisation,and Machine Learning."(1989).

[9] A.Chatterjee,G.K.MahantiandP.R.S.Mahapatra,"Optimum ring spacing and inter element distance for side

 DOI : 10.18231/2454-9150.2018.0263

lobe reduction of a uniform concentric ring array antenna using differential evolution algorithm",Communication Systems(ICCS),2010 IEEE International Conference on,pp.254-258,17-19,November 2010.

[10] Yu-Bo Tian;Jian Qian,"Improve the performance of a linear by changing the spaces among array elements in terms of genetic algorithm ,"Antennas and propagation ,IEEE Transactions on ,vol.53,no.7,pp.2226-2230,July 2005,DOI:10.1109/TAP.2005.850739

[11] A.A.Noaman,AK.S.Abdallah,R.S.Ali,"Optimal side lobes reduction and synthesis of circular array antennas using hybrid adaptive genetic algorithms,"Microwave Radar and wireless communication (MIKON) 18th International conference on, pp. 1-4 , 14-16 june 2010

[12] M.M. Khodier, M. Al – Aqueel, "Linear and circular array optimization : A study using Particle swarm intelligence", Progress in Electromagnetics Research B, Vol. 15, pp. 347-373, 2009

[13] 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 Indian CSI volume 2. Springer International Publishing, 2015.

[14] Chakravarthy, V.V.S.S.S., et al. "Non-Uniform circulalar Array synthesis using Teaching learning Based Optimization. "IOSR Journal of Electronics and communication Engineering (IOSR - JECE), Vol. 10,Issue 3, May (2015).

[15] Chakravarthy. V.V.S.S.S., P. Mallikarjuna Rao; "Synthesis of circular Array Antenna for Sidelobe level and Aperture Size control using follow pollination Algorithm, "International journal of Antenna & Propagation (IJAP), Hindawi Publications , ISSN : 1018 – 4864 (Print), ISSn : 1572 – 9451 (electronic) (Accepted)

[16] Chakravarthy, V.V.S.S.S., and P. Mallikarjuna Rao "Implementation of TLBO for circular Array synthesis" International Journal adv. Tech and innovative research (IJATIR), Vol.7Issue.4, April(2015)

[17] Chakravarthy . V.V.S.S.S., P. Mallikarjuna Rao, "Circular array antenna optimization with scanned and unscanned beams using novel partical swarm optimization, "Indian journal of applied research (IJAR), Vol.5, Issue 4, 2015. 2249 – 555X

[18] Chakravarthy . V.V.S.S.S., and P. Mallikarjuna Rao. "On the convergence characteristics of flower pollination algorithm for circular array synthesis." Electronics and communication system (ICECS), 2015 2nd IEEE international conference on.

[19] Chakravarthy.V.V.S.S.S., P. Mallikarjuna Rao; "Amplitude – only Null positioning in circuits Arrays using genetic Algorithm" IEEE international conference on electrical, computer and communication technology (ICECCT - 2015), Vol 3, pp 1118 – 1122, 5-7 March., 2015 SVS college of ENgg, Coimbatore, TN

[20] Randy L Haupt, Antenna RRays : A comutatioan approach, Wiley new York, 2010

[21] Tsoulos, G.V. (ed.) Adaptice antennas for wireless communications, IEEE press, Piscataway, NJ, 2001.

[22] T. Heath, R. Kerr, and G. Hopkins, "Two – dimensional, nonlinear oscillator array antenna." In Aerospace conference, 2005 IEEE, march 2005,pp. 1104 – 1115

[23] Goldberg, D. "Genetic Algorithms in search, optimization, and Machine Learning."(1989).

[24] Hansen, W.W.; Woodyard, J.R., "A new principaple in directional Antenna Design." Radio Engineers, Proceedings of the institute of, Vol. 26, n0.3, pp. 333-345, March 1938, Doi: 10.1109/JRPROC. 1938.228128

[25] Dolph, C.L., "A current distribution for Broadside arrays which optimizes the relationship between beam width and side-lobe level", Proceedings of the IRE, Vol.34, no.6,pp.335- 348, june 1946

[26] Yaru, N., "A note on super – gain antenna arrays, "Proceedings of the IRE, vol.39, no.9, pp.1085, sept. 1951.

[27] Harrington, R.F., "Sidelobe reduction by nonuniform element spacing," Antennas and propagation, IRE Transactions on, vol.9, no.2, pp. 187-192, March 1961, DOI: 10.1109/TAP. 1961. 1144961

[28] Goto, naohisa' Cheng, D., "Sidelobe – reduction techniques for phased arrays using digital phase shifters, "Antennas and propagation, IEEE transactions on, vol.18, no.6, pp.769 – 773, nov 1970, DOI : 10.1109/TAP. 1970 . 1139797

[29] D.K. Cheng and P.D. Raymond, "Optimisation of array directivity by phase adjustments, "Electronic letters, vol.7,no. 18,pp.552-554, September 1971

[30] RS Elliott, "Array Pattern synthesis", IEEE antennas and propagation News letter, PP. 5-9, October 1985.

[31] Shanks, H.E. and Bickmore, R.W, "Four- Dimensional Electromagnetic Radiators", canad, J. Phys., vol. 37, pp 263 March, 1959, DOI = 10.1139/ p59-031

[32] D.K. Cheng and P.D. Raymond, "Optimisation of array directivity by phase adjustments, "Electronic letters, vol.7, No. 18 pp, 552-554, September 1971

[33] Stark, L., "Microwave theory of phased- array antennas &# 8212; A review."Proceedings of the IEEE, Vol. 62,no.12,pp. 1661 – 1701, dec. 1974,

 DOI : 10.18231/2454-9150.2018.0263