

Improvement of Adaptive Smart Concentric Circular Antenna Array Based Hybrid PSO GSA Optimizer

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Abstract—Unlike all recent research which used Concentric Circular Antenna Array (CCAA) based on one beam-former for each single main beam, this research presents a technique to adapt smart CCAA by using only single beam-former for multi main beams based on hybrid PSO GSA. Hybrid PSO GSA is a combining technique between Particle Swarm Optimization and Gravitational Search Algorithm which is applied in the feeding of the smart CCAA to enhance its performance. Phase excitation of the array with a large number of elements is suggested for different scenarios based on hybrid PSO GSA and other algorithms such as PSO and GSA in High Altitude Platform (HAP) application. Simulation results proved that hybrid PSO GSA achieves better performance than other optimizers for excitation of the smart CCAA in all scenarios for different parameters like normalized array factor, fitness values, convergence rate, and directivity.

Keywords—Smart antenna; CCAA; PSO GSA; HAP; and Beam-forming

I. INTRODUCTION

Smart antenna was one of the main parts in various communication systems [1-3]. Circular Antenna Array (CAA) [4,5] was considered recently in the latest research because of its ability to steer the radiation pattern more than linear antenna arrays and overcoming the broadside problem. CCAA implements different rings with different radius that are used in most wireless applications such as High Altitude Platform (HAP) and others [6-10].

Particle Swarm Optimization (PSO) in [11] was used in a MIMO system in [12]. Cooperative communication based on one and multi relay was proposed by using PSO in [13,14]. The suggested Gravitational Search Algorithm (GSA) in [15] was used for Direction of Arrival estimation in smart antenna systems and achieved better results than MUSIC and PSO in [16]. Synthesis CCAA was studied by GSA and modified PSO in [17]. GSA was used to control reconfigurable dual-beam for the CCAA and steer null toward SNOI using Linear Constraint Minimum Variance Assisted by different optimization techniques, finally GSA gave the best performance in [18, 19].

Recently, Hybrid Particle Swarm Optimization with Gravitational Search Algorithm (Hybrid PSO GSA) technique was considered as a new optimization technique that showed better performance than standard PSO and GSA in terms of computational speed and fitness values [20,21]. In [22], an algorithm based on collective animal behaviour (CAB) is used

for finding the best optimal excitation weights for linear antenna arrays, but in [4,5], hybrid PSO GSA utilizing UCA achieved better results than ULA in terms of studying the directed power in terms of normalized array factor toward the intended direction in addition to direct null to signal Not of interest (SNOI) for different scenarios.

In this paper, unlike all previous research which was based on multi beam-former for multi beams like [17-19,22,23] or small number of elements like [4-5], a novel algorithm using only one beam-former for multi beams that is based on the hybrid PSO GSA technique is utilized for optimal beam-forming using CCAA which implement a greater number of elements up to 121 elements. The main aim based on controlling the complex weights in order to maximize and minimize the beam of the radiation pattern towards the desired user (SOI) or not desired (SNOI) respectively. The paper is organized as follows. In Section II, the optimization model and problem formulation for adaptive beam-forming is suggested. In Section III, hybrid PSO GSA algorithm is proposed. Simulation results and discussions for beam-forming are discussed in Section IV. Finally, Section V explains the conclusions.

II. OPTIMIZATION PROBLEM MODEL

CCAA is suggested for Smart antenna, as shown in Figure 1. CCAA with N elements are distributed along M circles of radius r_m and each circle has N_m elements, The Array factor for CCAA can be defined from [7] as shown:

$$AF(\theta) = \sum_{m=1}^M \sum_{n=1}^{N_m} [\cos(\beta * r_m * \cos(\theta - \text{pos}_{mn}) - \alpha_{mn}) + j \sin(\beta * r_m * \cos(\theta - \text{pos}_{mn}) - \alpha_{mn})] \quad (1)$$

Where λ is the wavelength, the angle between adjacent elements is θ_0 , θ is the azimuth angle, $d = 0.5\lambda$ is the space between two adjacent elements, β is the phase shift constant, α_{mn} represents the complex excitation phase of the mn-th element and pos_{mn} is the angular position of the mn-th element. The studying for radiation pattern shows the phase excitation for elements in smart array must minimize the radiation power intensity at certain directions (SNOI) and maximize the main-lobes to other directions (SOI). Our cost function is modified than cost function in [13] where we maximized the total output power toward the desired signal at θ_i and minimized the total output power in the direction of the interfering signals at θ_j and this done by minimizing the fitness function in (2).

$$\text{fitness function} = -\sum_{i=1}^k a_i AF(\theta_i) + \sum_{i=1}^L b_i AF(\theta_i) \quad (2)$$

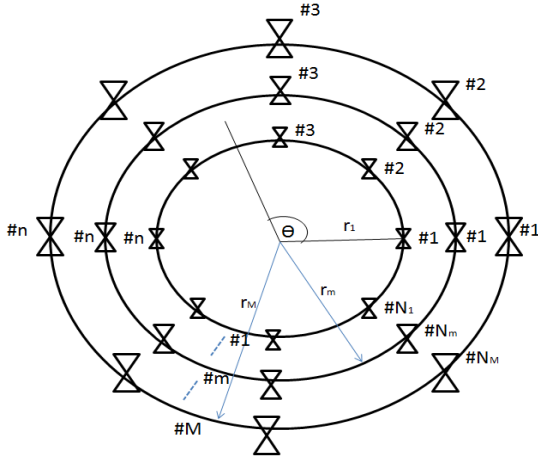


Fig. 1. Structure of the smart CCAA

In this paper, CCAA uses number of elements \$N=121\$ for huge application like High altitude Platform (HAP) as shown in [6, 23]. When PSOGSA is compared with other previous algorithms like PSO and GSA according to many factors such as normalized array factor using(1), directivity using (3) as shown in [7] and computational speed with convergence rate for normalized fitness values using (2).

$$D = 4\pi / \int_0^{2\pi} \int_0^\pi |AF_n|^2 \sin\phi \, d\phi \, d\theta \quad (3)$$

Where \$\phi\$ elevation angle which is used 900 in our work and \$\theta\$ is azimuth angle.

III. HYBRID PSOGSA OPTIMIZER

In this paper, PSO and GSA were combined with a parallel hybridized method not series method and for this reason the hybridization method was called co-evolutionary. On the other hand, the low level combines the functionality of both algorithms. It is heterogeneous because there are two different algorithms that are involved in producing final results. The main idea of hybrid PSOGSA is a combination between capability of local search by GSA and social think the ability by PSO. Velocity is updated as follows from [20,21]:

$$v_i(t+1) = \text{part 1} + \text{part 2} \quad (4)$$

Where part 1 of the GSA [15] : \$w * v_i(t) + C1 * \text{rand} * a_i(t)\$ and part 2 of the PSO [11] : \$C2 * \text{rand} * (g_{\text{best}} - x_i(t))\$ finally, velocity can be updating by

$$v_i(t+1) = w * v_i(t) + C1 * \text{rand} * a_i(t) + C2 * \text{rand} * (g_{\text{best}} - x_i(t)) \quad (5)$$

Every iteration, the positions of agents are updated as follows:

$$x_i(t+1) = x_i(t) + v_i(t+1) \quad (6)$$

Where \$g_{\text{best}}\$ is global best position from PSO, \$w\$ is a weighting factor, \$\text{rand}\$ is a random number, \$C1\$ and \$C2\$ are constant, \$v_i(t)\$ is the velocity of particle \$i\$ at iteration \$t\$ and \$a_i(t)\$ is the acceleration of agent \$i\$ at iteration \$t\$. all these parameters are taken from PSO and GSA algorithm [20, 21]. Finally Hybrid PSOGSA procedures are shown in Figure 2.

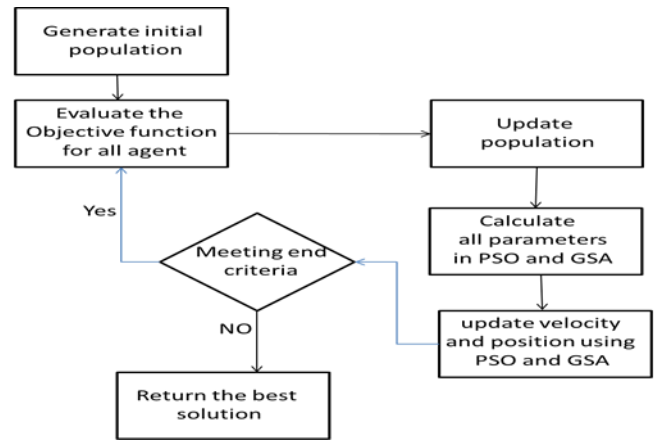


Fig. 2. Flow chart of procedures for hybrid PSOGSA optimizer

As shown in Figure 2, the first step is responsible for all agents are randomly initialized. Each agent is considered as a candidate solution. As can be seen in the second step, after initialization, evaluate the fitness function based on equation (2). At the third and fourth step, gravitational force, gravitational constant, resultant forces among agents are calculated, and the accelerations of particles are defined from [20, 21]. In each iteration, the best solution so far (\$g_{\text{best}}\$) must be updated. After calculating the accelerations and with updating the best solution so far, the velocities and the positions of all agents can be updated from [20, 21] at the fifth step. Finally, after the agents are updated. The process of updating velocities and positions will be stopped by meeting an end criterion.

IV. SIMULATION AND DISCUSSION RESULTS

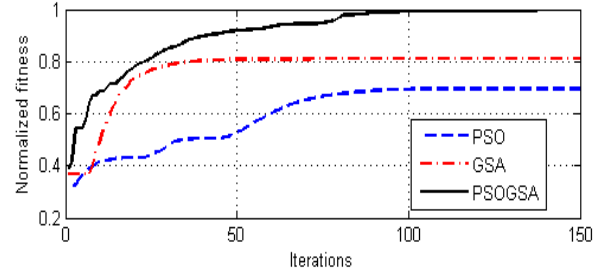
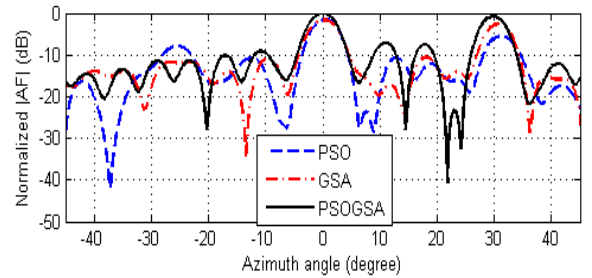


Fig. 3. The first scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSOGSA, PSO and GSA based on CCAA topology

MATLAB package is used for evaluating the above analysis. In this section, ability of adaptive beam-forming based on hybrid PSO-GSA technique using CCAA is studied. All algorithms are employed with a population size of 30 and 150 iterations which represent a small number of iterations. Figures 3,4,5,6, and 7 show comparison of PSO-GSA with GSA and PSO using CCAA topology for many scenarios in terms of radiation pattern, convergence curve and computation time, in order to compute directivity. The work implemented 121 elements in all scenarios for HAP application.

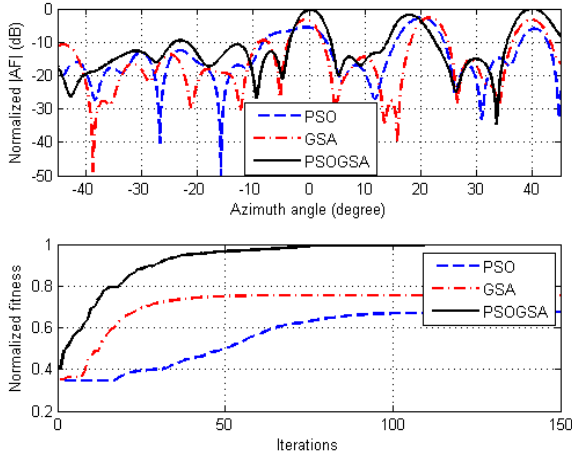


Fig. 4. The second scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSO-GSA, PSO and GSA based on CCAA topology

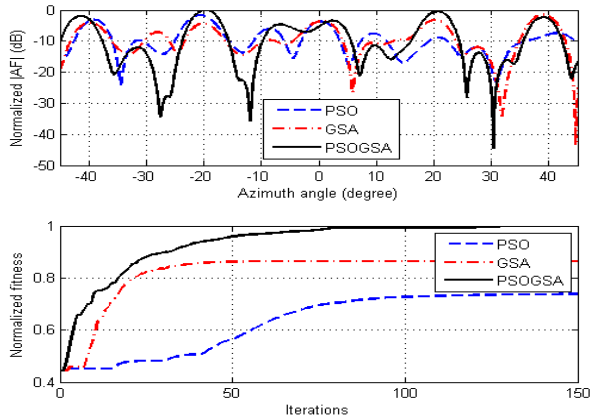


Fig. 5. The third scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSO-GSA, PSO and GSA based on CCAA topology

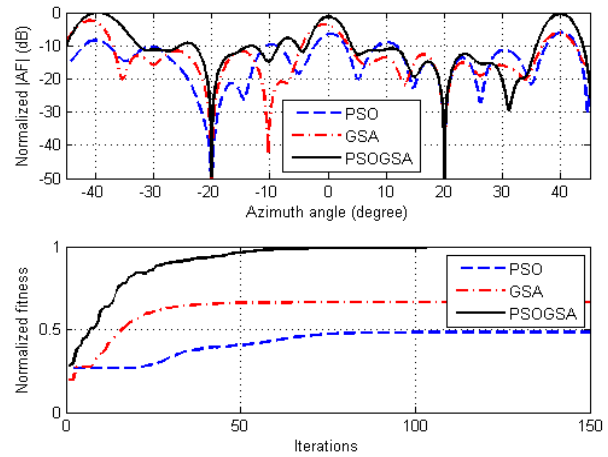


Fig. 6. The fourth scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSO-GSA, PSO and GSA based on CCAA topology

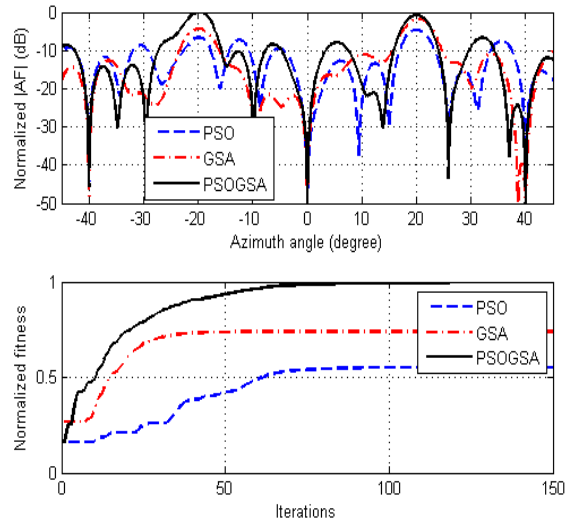


Fig. 7. The fifth scenario for normalized array factor versus azimuth angle and fitness functions versus iteration using Hybrid PSO-GSA, PSO and GSA based on CCAA topology

All scenarios can be discussed in Tables 1 and 2. Table 1 indicates that hybrid PSO-GSA in general outperforms PSO and GSA. The hybrid PSO-GSA is better than PSO and GSA in all scenarios by range from -2.8 to -6.65 and from -1.4 to -3.85 respectively in terms of averages normalized array factor in dB.

TABLE I. THE CORRESPONDING AVERAGE NORMALIZED |AF| VALUES AT THE SOI AND SNOI DIRECTIONS FOR DIFFERENT SCENARIOS BASED ON CCAA TOPOLOGY

| Scenarios | Desired Angles | Interferer Angles | Average Normalized array factor (dB) | | | | | |
|-----------|--------------------------|-------------------|--------------------------------------|-------|-------|-------|--------|-------|
| | | | PSO | | GSA | | PSOGSA | |
| | | | Major | Null | Major | Null | Major | Null |
| 1 | [0 30] | ---- | -3.8 | ----- | -2.2 | ----- | -0.35 | ----- |
| 2 | [0 20 40] | ---- | -4.7 | ----- | -3.5 | ----- | -1.2 | ----- |
| 3 | [-40 - 20 0 20 40] | ---- | -5 | ----- | -3.6 | ----- | -2.2 | ----- |
| 4 | [-40 0 40] | [-20 20] | -7 | >-40 | -4.2 | >-40 | -0.35 | >-40 |
| 5 | [-20 20] | [-40 0 40] | -5.5 | >-40 | -3 | >-40 | -0.35 | >-40 |

On the other hand, from table 2, simulation results have shown tremendous improvement over the previous work done using standard PSO and GSA in terms of directivity and convergence speed for normalized fitness values. PSOGSA is better than PSO and GSA by 25%–50% and 15%–30%, respectively in terms of convergence percentage at the end of iteration. It was shown that PSOGSA achieved improvement over GSA and PSO by 1%–70% nearly in terms of directivity. The only disadvantage in PSOGSA is computational time. Still, all algorithms have the ability to produce null toward SNOI by more than -40 dB at scenario #4 and #5.

TABLE II. THE CORRESPONDING NORMALIZED CONVERGENCE PERCENTAGE AT THE END OF ITERATIONS, THE DIRECTIVITY VALUE AT THE MAX SOI DIRECTIONS AND COMPUTATIONAL TIME FOR DIFFERENT SCENARIOS BASED ON CCAA TOPOLOGY

| Scenarios | Normalized Convergence percentage (nearly) % | | | Directivity (dimensionless) | | | computational time in sec using Lenovo core i7 4702MQ RAM 8 G | | |
|-----------|--|-----|---------|-----------------------------|------|---------|---|-----|---------|
| | PSO | GSA | PSO GSA | PSO | GSA | PSO GSA | PSO | GSA | PSO GSA |
| 1 | 70 | 80 | 100 | 15.63 | 16.4 | 17.4 | 1 | 0.5 | 1.5 |
| 2 | 65 | 75 | 100 | 9.680 | 11.7 | 12.5 | 1 | 0.5 | 1.3 |
| 3 | 75 | 85 | 100 | 7.975 | 9.40 | 9.52 | 1.7 | 0.9 | 2 |
| 4 | 50 | 70 | 100 | 8.008 | 10.7 | 10.8 | 1.7 | 0.9 | 2.1 |
| 5 | 55 | 75 | 100 | 5.665 | 14.4 | 14.9 | 1.6 | 0.8 | 1.9 |

V. CONCLUSION

In this paper, a hybrid PSOGSA technique is implemented only on one beam-former for multi-beams smart antenna systems based on CCAA to improve the capability of smart beam-former in wireless communication systems. It is clear from our optimization model using CCAA, simulation results have shown tremendous improvement over the previous work done using standard PSO and GSA in terms of normalized array factor by range from -2.8 to -6.65 and from -1.4 to -3.85 respectively, directivity by range from 1% to 70%, and convergence speed for normalized fitness values by range from 25% to 50% dB and from 15% to 30%, respectively. However,

simulation results and discussions proved the ability of our technique to deal with a big set of simultaneously incident and interfere angles. It was found that hybrid PSOGSA based on CCAA is the best powerful optimizer for smart beam-forming applications and better than GSA and PSO on average for several scenarios.

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