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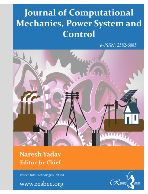


# Hybrid Particle Swarm Optimization Algorithm and Sparrow Search Algorithm for Microstrip Patch Antenna

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**Abstract:** Generally, an MPA is deployed at present in several applications as it possesses numerous advantages such as minimum volume, compatibility, minimum weight, and cost as well as easy to deploy on inflexible surfaces. Nevertheless, MPA is minimized with narrow bandwidth as well as hence, bandwidth improvement is most important for extensive banded applications. Here, the main aim is to propose a novel model that derives a non-linear objective model to help in model solution spaces of antenna restraints. Therefore, a novel enhanced optimization model called as Hybrid Particle Swarm Optimization algorithm (PSO) and Sparrow Search Algorithm (SSA) named Hybrid PSO-SSA approach is developed to tune the parameters of MPA. The most important concept of the adopted model is to increase the gain of the antenna by optimally choosing patch length, width, MPA substance thickness as well as substrate dielectric value. At last, analysis is carried out in order to examine the proposed model concerning effectuality analysis, Directivity as well as gain.

**Keywords:** Antenna, Cost , Gain, MPA, Patch Length.

***Nomenclature***

| Abbreviations | Descriptions |
|---|---|
| **GWO** | Grey Wolf Optimization |
| **MPA** | Microstrip patch antennas |
| **ABC** | Artificial Bee Colony |
| **CP** | Circularly Polarized |
| **LA** | Lion Algorithm |
| **3-D** | 3-dimensional |
| **EHO** | Elephant Herd Optimization |
| **CI** | Characteristic Impedance |

## 1. Introduction

An MPA concentrated a significant number of concentration of researchers because of its insists of its high diversity of applications in diverse fields like aircraft, radar, missiles, biomedical telemetry, satellite communications, remote sensing as well as diverse other wireless application in past few years. Nevertheless, the most important restriction of the existing MPA is narrow bandwidth which limits its applications. Because of this cause, solemn efforts were initiated between the researchers, scientists, as well as designers to enhance the patch antenna bandwidth. The enhancement of bandwidth is attained by loading diverse sizes as well as the shape of notches as well as slots on the patch or in the ground plane. There are diverse other bandwidth improvement approaches that are in addition available however this approach is easy in design as well as simple in loading as well as enhancing bandwidth without maximizing the volume of the structure. Thus, numerous numbers of studies were revealed by the researchers for wireless applications.

Nowadays communication systems and antenna arrays play a significant role to generate a communication link. In wireless communication systems, MPA is extensively exploited owing to they have a minimum profile, lightweight, minimum cost, conformal design, minimum power handling capability, and simple to incorporate and manufacture. They can be modeled in a diversity of shapes to attain improved gain as well as bandwidth. In wireless communication system designs, implementations of MPA are a highlight.



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MPA is favored for antenna design since its characteristics are appropriate for profitable wireless applications. The manufacturing of patch antenna costs is least and a wideband patch array was developed with superior uneven arms. 5G antenna is developed with a sector-disk radiating patch positioned in a circular-shaped slot. Enhancement in the shape of patch antennas has aided to attain attractive performances of antenna. Moreover, patch antennas aided several feed approaches as well as they can be adopted into arrays to enhance the gain and attain the preferred pattern needs. Because of this motivation, patch antennas encompass shown to be a well-built candidate for millimeter-wave applications. Therefore, 5G antennas were adopted by exploiting the MPA technology. For improved outcomes, microstrip array antennas designed by exploiting several approaches were used and researched for 5G applications.In general, the majority well-known models to analyze the MPA are full wave approach; transmit line as well as cavity approaches. The full-wave model is adaptable and precise as well as it treats finite as well as infinite arrays, random elements, single elements, coupling, as well as stacked elements. The transmission line scheme is easy as well as it presents improved physical imminent; nevertheless, it is minimally accurate. The cavity model presents better physical insight as well as it is extremely precise; however, it is complex in nature.

The main aspire of this work is to put forward a novel approach named a Hybrid PSO-SSA algorithm to fine the parameters of MPA like patch length, width, and dielectric substrate value as well as substrate thickness for antenna gain augmentation.

## 2. Related Works

In 2019, Ki-Baek Kim *et al.,* [1] worked on a planar antenna to put back multifaceted arrangements of numerous rat races as well as 90° hybrids exploited in conservative objective detection antennas to receive the radar signals. The developed antenna possesses two MPA arrays with double feeding to radiate symmetric polarizations. At port 1, the sum (Σ) pattern with circular polarization was developed via a series feeding. In all linear polarizations, the concurrent feeding of port 2 radiates a different (Δ) pattern. Therefore, the adopted antenna was compressed, planar, as well as possesses an easy comparator circuit. In 2018, Chaoqun Zhang *et al.,* [2], worked on a zeroth-order mode circular MPA, comprising of 2 axial symmetrical semi-circulars as well as pins that were in necessary 2 compounds right/left handed meta-material unit-cells. Enhancing equal magnetic current densities beside perimeter of developed antenna, a patch-like radiation pattern was attained for 0zeroth order mode. Also, the dissimilarity of resonant frequency affected by positions of pins was examined. The dispersion illustration showed phase differences in one period, therefore examining the subsistence of zeroth order mode. In 2019, Muhammad Fahad Farooqui and Ahmed Kishk [3], developed a tunable CP MPA that was proposed by exploiting 3-D printing. CP was attained using a new approach of developing an L-shaped slot in a square patch antenna. In addition, by loading 4 edges of patch with shunt varactors, antenna frequency can be tuned when preserving the radiation of CP. In order to manufacture 3-D printing was exploited that set up the vertical incorporation of varactors amid the patch as well as ground that was not been exhibited earlier. Such a combination reduces the communication of varactors by means of the radiating properties of the antenna as well as outcomes in minimized parasitics. In 2020, Zabed Iqbal *et al.,* [4], worked on a single-layer, dual-mode MPA with self-nulling patterns. Antenna comprises a circular MPA, enclosed by exploiting a shorted concentric ring patch, stimulating TM11 as well as TM21 modes, correspondingly. By concurrently exhilarating these 2 modes, adaptive radiation patterns with self-scanning as well as nulling abilities were comprehended. Four symmetrical arc splits to obtain the mode purity enthused by surface current distribution of TM21 mode, and 2 horizontal slits were positioned in ring patch. The circular patch was loaded by 3 vertical slits for the neatness principle. A prototype of the adopted antenna was fictitious as well as examined. In 2019, Wen Tao Li *et al.,* [5], developed a bandwidth-improved, minimum cost, dense, inkjet-printed multilayer MPA for incorporation into supple and conformal devices. Antenna comprises 2 layers of patches, by means of initial layer inkjet-printed directly on a 0.125-mm Kapton polyimide substrate. A Minkowski fractal geometry patch was used as second layer inkjet-printed over SU-8 polymer to attain preferred efficiency and high-quality impedance match. The prototype was fabricated as well as examined for impedance as well as radiation characteristics.

## 3. Microstrip Patch Antenna Modeling

Generally, Patch antennas comprise a controlling patch as well as a ground plane. A dielectric media called the substrate is available in the middle of design that exhibits precise value called dielectric constant. Generally, patch sizes are referred to as lesser than substrate as well as ground. “A resonance frequency and dielectric medium are selected on basis of an MPA size when modeling an MPA”.

Additionally, dielectric substrates with a minimum dielectric constant are needed to enhance performance of the antenna, in which effectiveness is enhanced with superior bandwidths as well as radiation [11]. The notable constraints when modeling the MPA are stated as follows:

**Width computation:** The width assessment of MPA is stated in eq. (1), in which, $\alpha_d$ represents dielectric substrate value, $d^f$ represents the resonant frequency, as well as $L$ represents light speed. The $d^f$ formulation is stated in eq. (2) wherein $\varepsilon^{re}$ represents the powerful refractive index as well as $P$ represents patch length [6].

$$W = \frac{L}{\alpha d^f}\sqrt{\frac{2}{\alpha_d + 1}} \tag{1}$$

$$d^f = \frac{L}{2P\sqrt{\alpha^{de}}} \tag{2}$$

**Assessment of height:** Eq. (3) is exploited to calculate the height $(H)$ of MPA in which $T$ refers substrate thickness [6].

$$H = \frac{T}{1000 \times 2.54} \tag{3}$$

**Assessment of ERI:** On the basis of eq. (4) the constraint, $\varepsilon^{re}$ is computed, in which $H$ signifies substrate's height.

$$\alpha^{de} = \frac{\alpha_d + 1}{2} + \frac{\alpha_d + 1}{2}\left[1 + 12\frac{H}{W}\right]^{-1/2}, \frac{W}{H} > 1 \tag{4}$$

**Assessment of normalized length:** On the basis of eq. (5), the MPA's normalized length $(\Delta P)$ is calculated.

$$\frac{\Delta P}{H} = 0.412\frac{\left(\alpha^{de} + 0.3\right)\left(\frac{W}{H} + 0.264\right)}{\left(\alpha^{de} - 0.258\right)\left(\frac{W}{H} + 0.8\right)} \tag{5}$$

**Assessment of Length**: As per eq. (6), $(P)$ indicates the MPA length is computed.

$$P = \frac{L}{2d^f\sqrt{\alpha^{de}}} - 2\Delta P \tag{6}$$

**Computation of CI:** Eq. (7) illustrates transition element CI, in which, $Y_i$ exhibits patch impedance as well as it is computed [6].

$$Y_I = \sqrt{50 + Z_i} \tag{7}$$

$$Y_i = 90\frac{\alpha_d^2}{\alpha_d - 1}\left(\frac{P}{W}\right)^2 \tag{8}$$

**Computation of Gain:** The proportion of antenna intensity to input power comprises MPA gain. Eq. (9) explains MPA gain, wherein $R_I$ exhibits radiation intensity as well as $I$ exhibits the input antenna power [6].

$$M_A = 4\pi\left(\frac{R_I}{I}\right) \tag{9}$$

# 4. Optimized MPA Modeling Using The Proposed Model

## 4.1 Objective Model

Eq. (10) defines the proposed model as attempt to augment the antenna gain. For that reason, design parameters like $W$, $P$, , $T$ and $\alpha_d$ of MPA [11] are optimally tuned using the Hybrid PSO-SSA algorithm.

$$M_A^* = \underset{(P,W,T,\alpha_d)}{\arg\max}\left(M_A\right) \tag{10}$$

## 4.2 Developed Hybrid PSO-SSA algorithm [10]

In the SSA algorithm, the sparrows are partitioned into followers as well as explorers for the process of foraging for food. Generally, explorers possess superior energy reserves and are in charge to find the food in population and present the foraging areas as well as directions for whole sparrow population, when followers utilize explorers to attain food. In PSO approach, the optimal solution is realized and searched on the basis of the common collaboration and information shared amid the particles in the group.

Initialize all parameters. Substituting $b$ into eq. (9) to attain fitness value, as well as update individual optimal value as well as global optimal value, where, $f$ represents the fitness value, $b$ represents the initialization of control parameters.

$$f = \left| b - \frac{n\left(1 - e^{-bt_n}\right)}{nt_n e^{-bt_n} + \left(1 - e^{-bt_n}\right)\sum_{i=1}^{n} t_i} \right| \tag{11}$$

Ascertain if the approach stop condition is attained, specifically, the number of iterations is lesser than or equivalent to M and the global best fitness value, accurateness is higher than or equivalent. On the basis of eq. (12) and (13), the speed and position of each paper are updated. In eq. (12), $w$ represents the inertia weight, $c_1$ and $c_2$ represents the learning factor, $rand_1$ and $rand_2$ represents random numbers, $x_{id}^{t}$ position of i^th^ particle.

$$v_{id}^{(t+1)} = wv_{id}^{t} + c_1 rand_1(\,)\left(P_{bid}^{t} - x_{id}^{t}\right) + c_2 rand_2(\,)\left(g_{bid}^{t} - x_{id}^{t}\right) \tag{12}$$

$$x_{id}^{t+1} = x_{id}^{t} + v_{id}^{t+1} \tag{13}$$

Update the individual as well as global optimal values, substitute $b$ into the fitness function eq. (11) to attain fitness value of each paper, sort by fitness value, as well as update worst individual. On the basis of eq. (14), the position of the explorer is updated, wherein, $X_{i,j}^{t}$ indicates $i^{th}$ sparrow position information, $t$ indicates the current iteration number, $X_{worst}$ indicates worst position, $X_p$ indicates optimal position.

$$X_{i,j}^{t+1} = \begin{cases} X_{i,j}^{t} \cdot \exp\left(\dfrac{X_{worst} - X_{i,j}^{t}}{i^2}\right), \text{if } i > n/2 \\ X_P^{t+1} + \left|X_{i,j}^{t} - X_p^{t+1}\right| \cdot A^{+} \cdot L, \text{ otherwise} \end{cases} \tag{14}$$

On the basis of eq. (15), the position of followers is updated.

$$X_{i,j}^{t+1} = \begin{cases} Q \cdot \exp(\,) \,|\, X_{i,j}^{t} - X_{best}^{t} \,|, if\ f_i < f_g \\ X_{i,j}^{t} + K \cdot \left(\dfrac{|\, X_{i,j}^{t} - X_{best}^{t} \,|}{(f_i - f_w)}\right), if\ f_i = f_g \end{cases} \tag{15}$$

On the basis of eq. (6), the sparrow position that is aware of danger is updated, wherein $\beta$ indicates the step controller.

$$X_{i,j}^{t+1} = \begin{cases} X_{best}^{t} + \beta \cdot |\, X_{i,j}^{t} - X_{best}^{t} \,|, \text{if } f_i < f_g \\ X_{i,j}^{t} + K \cdot \left(\dfrac{|\, X_{i,j}^{t} - X_{best}^{t} \,|}{(f_i - f_w)}\right), \text{if } f_i = f_g \end{cases} \tag{16}$$

Update the individual optimal as well as global optimal, Substitute $b$ into fitness function Eq. (17) to attain ppaper fitness value.

$$f_{it} = \frac{\sqrt{\sum_{i=1}^{n}\left[m(t_i) - m^0(t_i)\right]^2}}{n} \tag{17}$$

Ascertain if the approach stop circumstance is attained, specifically, the number of iterations is lesser than or equivalent to M, if it is fulfilled.

## 5. Result and Discussion

In this section, experimental analysis of adopted model over the existing models was demonstrated as well as the outcomes were attained. Here, population size was allocated as 10 and the iteration count was represented as 100. Moreover, the performance evaluation was performed regarding the gain, CI directivity, as well as efficiency.

Fig 1 indicates the performance analysis of developed model over the existing models regarding CI and efficiency. Fig 2 exhibits the performance analysis of developed model over the existing models concerning

Directivity and Gain. As a result, the entire analysis of the developed model over the existing models for varied design constraints is exhibited. From the overall analysis, it is apparent that the developed Hybrid PSO-SSA model has attained enhanced performance when comparing with the conventional models.

## 6. Conclusion

The most important aspire of this work is to develop a new antenna model by using the optimization named Hybrid PSO-SSA algorithm. For that reason, the parameters of MPA like patch length, width; substrate thickness as well as dielectric substrate value were optimized using the proposed model called Hybrid PSO-SSA algorithm in order to attain the maximum gain. Moreover, the performance analysis was performed with the revealed effectuality of the proposed model. Furthermore, the proposed approach was revealed to attain superior directivity values from the analysis. Therefore, it assures the superiority of the proposed model using the precious analysis.

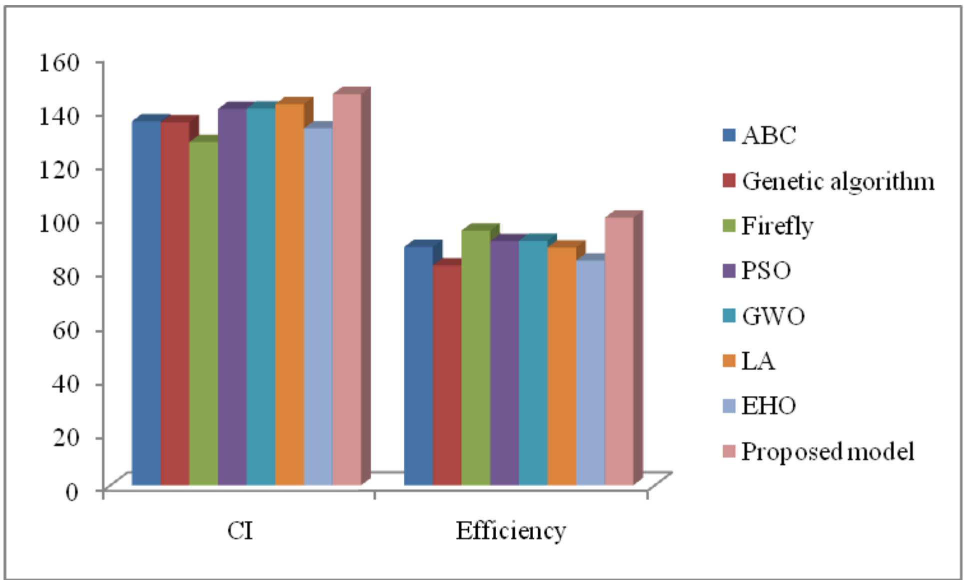


***Fig.1.*** *Performance analysis of the adopted and traditional approaches regarding CI and efficiency*

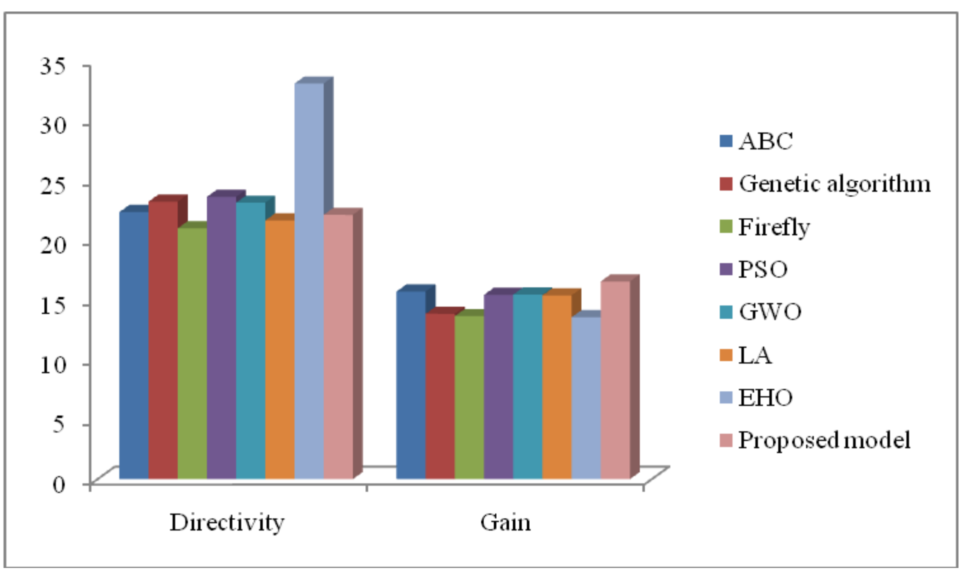


***Fig.2.*** *Performance analysis of the adopted and traditional approaches regarding Directivity and Gain*

## Compliance with Ethical Standards

**Conflicts of interest:** Authors declared that they have no conflict of interest.

**Human participants:** The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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