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Optimization of Ultra wide Band Communication TCA and AVA by using PSO and IGWO-FU Algorithm

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ABSTRACT:

Recently, with the faster pace of development on the sophisticated detection and stealth technology, an extensive attention is being paid to the reduction of Radar Cross Section (RCS) as it emerge in security and commercial application. Communication based applications have greater influence depends upon design architecture and performance of an antenna. This paper proposed FSS to triumph over varying values as considering design parameters. Here, Frequency Selective Surface (FSS) is optimized with a technique said to be Particle Swarm Optimization (PSO), used for tightly coupled array (PSO-UTC-FSS). This paper intends to design an Optimized Vivaldi antenna to enhance the gain performance. More particularly, optimization algorithms play a vital role in fine-tuning of parameter, and hence this paper intends to propose a new Improved Grey Wolf Optimization Algorithm with Fitness based Update evaluation (IGWO-FU), which is the enhanced version of traditional GWO. Using above concepts, losses are minimized and hence it improves radiation efficiency, gain measurement, bandwidth ratio etc. Finally, the performance of proposed IGWO-FU model is compared over other traditional algorithms with respect to gain, VSWR, directivity, charge and current distribution, return loss as well.

Key words: PSO, UTC, FSS, Antipodal Vivaldi Antenna, IGWO-FU.

1. INTRODUCTION:

Recently, FSS advance in antenna designing parameters play a major task in controlling interaction profile of the electromagnetic waves [1-2]. Owing to occurrence of resonance in FSS, reflection loss can be reduced. Usage of Tightly Coupled Arrays (TCAs) is most suitable choice for these applications provides wider bandwidth to achieve low profile and easier integration.

Of these, superstrate surface is the simplest approach used to perk up the performances of antenna includes bandwidth, broad side gain and directivity. But occurrence of any insignificant variations in superstrate surface affects the antenna performances [3-4]. Hence, dimension measurement must be carefully switched during designing processes. Combination of two calculating methods requires more time for replication and hard to extract results. Due to changes in frequency ranges for different applications, signal interference and radiation emission are very less compared to other methodologies. To overcome above disadvantages new technique called PSO-UTC-FSS is introduced to reduce interference and losses in bandwidth and frequency values [5].

In the recent era, the communication industry is grooming up massively with newer evolutionary techniques in wireless arena. The key component of wireless communication system is the antenna. An UWB antenna is a renowned type of antenna, which can fulfil the real-life applications demands like low power consumption, high data rates, simple hardware configuration [6-8]

Vivaldi antennas are one of the best choices for wide impedance bandwidth, planar configuration and low profile [9] [10]. A Vivaldi antenna generally comprises of end-fire radiation characteristics along with two variants, namely “coplanar and antipodal

configuration". The AVA is highly utilized in stealth applications due to its radiation characteristics as well as attractive impedance [11]. A key factor to be considered for stealth application is its radar signature. Several techniques are reported in the literature to enhance the RCS performance of Vivaldi Antennas, which includes either semiconductor technology or PCT [12] [13]. Few other researchers have utilized the polarization converters, partial reflecting surfaces and artificial magnetic conductors in the design to improve the radar signature of the antenna. However, these antennas design techniques are limited in beam width and enlargement in overall antenna size; there is necessity to have an apt technique for AVA.

2. PROBLEM STATEMENT:

The major contribution of this research work is depicted below:

Design of resistive surfaces affected by various frequency selection factors are,

- Bandwidth 10 GHz
 - Radiation Efficiency 75%
 - Gain 0.8 decibel
 - Frequency 10 GHz
 - Thickness 1mm
- The major intention of this research work is to design and Optimized Vivaldi antenna to enhance the gain performance.
 - To achieve the optimized Vivaldi antenna design, the key parameters, which serves as the milestone of the antenna, viz. the Taper Length (l_t), Aperture Width (w_{ap}), Opening Rate, Slot Line Width (w_s), Cavity Diameter (d), Cavity to Taper Spacing (s), Ground Plane Length (l) and Ground Plane Width (w), respectively are fine-tuned.
 - As a novelty, the fine-tuning of the antenna parameters are achieved with a novel optimization algorithm referred as IGWO-FU, which is the conceptual improvement of GWO.
 - Finally, the performance of proposed IGWO-FU model is compared over other traditional algorithms with respect to gain, VSWR, directivity, charge and current distribution, return loss as well.

3. LITERATURE SURVEY

Author [Citation]	Methodology	Features	Challenges
Shouyuan Shi et al [14]	Tightly coupled array antenna with ultra wide band technique is used.	<ul style="list-style-type: none"> • Improves the operational bandwidth 	<ul style="list-style-type: none"> • Gain reduced and widens the beam bandwidth due to the variation in scan angle

Gabriele Minatti et al [15]	A Synthesis method is used to control the parameters of meta surface antenna.	<ul style="list-style-type: none"> • Improve polarisation • Improved phase performance 	<ul style="list-style-type: none"> • For large bandwidth, overall process rarely requires a feedback
L. Peng et al [16],	The curved EZR-MZR technique is used to design antenna.	<ul style="list-style-type: none"> • Uniform amplitude • High design efficiency 	<ul style="list-style-type: none"> • To design circular polarized antenna with good features need careful dimension and position.
Yizhe Zhao et al [17]	A new antenna array based on liquid crystal technology is used.	<ul style="list-style-type: none"> • Control resonance frequency • Low cost 	<ul style="list-style-type: none"> • Variation in permittivity would change the wavelength guide.
Bichai Wang et al [18]	New spectrum and energy efficient technique is used.	<ul style="list-style-type: none"> • High efficiency • Low complexity 	<ul style="list-style-type: none"> • RF chain used with more number leads energy consumption and hardware cost is high.
Muniyasamy <i>et al.</i> [19]	BALUN taper based AVA	<ul style="list-style-type: none"> ✓ Reduction in size. ✓ Extended bandwidth. 	Surface area of antenna need to be reduced .
Chamaani <i>et al.</i> [20]	MOPSO based linear array AVA	<ul style="list-style-type: none"> ✓ Low BW. ✓ Low time-domain SLL. ✓ Explores the tradeoff between the BW and SLL 	Threshold level of isolation is not specified correlated energy and peak power patterns are highly sensitive to noise
Chamaani <i>et al.</i> [21]	MOPSO based AVA	<ul style="list-style-type: none"> ✓ Provides optimum trade-off 	High fabrication cost high complexity

		<p>between solutions in a 3D Pareto front.</p> <p>✓ Good impedance matching</p>	
Boujemaa <i>et al.</i> [22]	Metamaterials based AVA	<p>✓ Higher radiation performances</p> <p>✓ Improves antenna directivity</p>	Low BW High bandwidth limiting transition
Dardeer <i>et al.</i> [23]	Elliptical curve shaped AVA with NIM	<p>✓ Achieved high input impedance bandwidth</p> <p>✓ Increase in antenna array gain</p>	Requires directional UWB antenna
Nath <i>et al.</i> [24]	High Gain Vivaldi antenna	<p>✓ In bore sight, the low frequency gain is increased</p>	High cross polarization
Dvorsky <i>et al.</i> [25]	Portable miniaturized AVA	<p>✓ Fractional bandwidth</p> <p>✓ Stable radiation patterns</p>	Low peak gain High Cost
Kumar <i>et al.</i> [26]	Leaf Shaped AVA based on GA	<p>✓ Low cross-polarization level</p>	Low gain factor

		✓ Reduction in volumetric size	
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4. METHODOLOGY

4.1 PSO-UTC-FSS:

PSO methodology requires only solitary stage manoeuvre for iteration. It does not need progression of exchange from dual to authentic values of parameters involved in optimization procedure. PSO algorithm maintains intangible ease of non-specific algorithm while being much easier to execute and relate to design exertions with both distinct and constant design parameters. Parallel calculations have great collision on PSO in deceiving an amount of time required to improve performance.

Fig.1: Individual cell of resistive FSS with tightly coupled Bowtie array

Above fig. 1revealed figure represents a tightly coupled bowtie array with a resistive FSS and a corresponding superstrate is introduced with them [27]. An efficient low profile [28] ultra wideband firmly coupled array utilizing FSS along with superstrate contains intrusion of the ground plane and array's bandwidth [29]. Victims in an array element can be minimized by suitable designing of superstrate [30]. It achieves low profile index about 0.055λ with a bandwidth ratio of 21:1and the proficient radiation of about 73% athwart band.

Presence of ground plane limits the bandwidth of array whose terminals are coupled together by a capacitance [31]. Appropriate concern must take while a resistive element is utilized. The fig. 2 shows the overlapping of superstrate [32], FSS and optimal efficiency reduces the thickness to $\lambda/4$ times than the existing one. Corresponding increase of the resistance value probably minimizes the width ratio at an appropriate range [33].

Fig.2: Top view of unit cell

Algorithm 1: Proposed PSO Algorithm	
Initialise the PSO Parameter	
The parameters Generate swarm	
	Evaluate the fitness of particles
	Record best fitness particles V_n , X_n , w , p , c and g
	Record best fitness particles X_n
	Evaluate the global best particles
	Analyse the swarm meets the criteria
	If yes
	End
	If else
	Update velocity particle
	Update position particle
	Update the global particles
	Return swarm criteria

Fig.3: Flowchart of proposed PSO algorithm

4.2 Proposed Algorithm for Optimal Parameter Tuning

A. Objective Function

As said before, the selected antenna parameters are optimally tuned by a new IGWO-FU algorithm, and the input fed to the proposed algorithm is illustrated in Fig .The foremost objective of this research work is to maximize the antenna gain (G_a) of compact AVA with optimized parameters. The mathematical expression of the defined objective function (Obj) is given in Eq. (1).

$$Obj = \text{Max}(G_a) \quad (1)$$

Fig 4. Solution Encoding

B. Proposed IGWO-FU Algorithm

Step 1: On the basis of the fitness (Fit), the position of the search agents is sorted. For illustration, if the count of search agents=10 ($i=1,2,3,...,10$) and if the highest fitness position (X_{i_α}) is recorded by 5th search agent, and the lowest fitness position (X_{i_δ}) is recorded by 2nd search agent. The other search agents occupy the position between the highest and the lowest fitness. Fig. 3 shows the sorted solution on the basis of fitness.

Fig 5. Illustration of fitness based position update

Step 2: Subsequently, the solution (exist in 1st position of sorted list, i.e, $\bar{X}_{i_\alpha}$) is updated by using the mathematical formula expressed.

Step 3: The worst solution (last position in sorted list i.e, $\bar{X}_{i_\delta}$) is updated randomly by choosing an arbitrary number (Ra_2) in between the upper (UB) and the lower bound (LB) of the solutions.

Algorithm 1: Proposed IGWO-FU Algorithm	
Population initialization $\bar{X}_i(t); t = 1, 2, \dots, n$	
The parameters $\bar{b}, \bar{M}, \bar{K}$ and $\bar{r}$ is initialized	
Evaluate the fitness of entire search agents	
Set $\bar{X}_{i_\alpha} = 1^{\text{st}}$ best solution	
Set $\bar{X}_{i_\beta} = 2^{\text{nd}}$ best solution	
Set $\bar{X}_{i_\delta} = \text{Worst solution}$	
While ($t < t_{\max}$)	
For every wolf	
Calculate fitness (Fit) for all search agents	
Sort (Fit)	
Update $\bar{X}_{i_\alpha}$ of the current search agent using Eq. (17)	
Update $\bar{X}_{i_\beta}$ using Eq. (16)	
Update $\bar{X}_{i_\delta}$ of the current search agent using Eq. (18)	
The parameters $\bar{b}, \bar{M}, \bar{K}$ are updated	
Update $\bar{X}_{i_\alpha}, \bar{X}_{i_\beta}$ and $\bar{X}_{i_\delta}$	
$t = t + 1$	
$t = t + 1$	
Return $\bar{X}_{i_\alpha}$

Fig 6. Flow chart of the proposed IGWO-FU model

RESULT AND DISCUSSION

Below diagrams represents proposed antenna design model. Simulation output provides frequency in GHZ.

Fig.7 : Proposed HFSS model for bowtie antenna

Graph fig 5 and 6, below shows S-parameter plot beside frequency. Ultra wideband antenna works at a large frequency range of 0 to 10 GHz. Bandwidth of antenna was about 10GHz. S-parameter value of antenna ranges from -580 decibel to -560 decibel. Method behind HFSS is the Software Limited Component Analysis. The Fig 7 & 8 shows the Radiation emission and radiation pattern of the respective antenna. The output results of the following figures indicate that the obtained frequency bandwidth, radiation losses of the antenna.

Fig.8: Output graph of the proposed model

Fig.9: Output graph for Rectangular plot

Fig.10: Output graph for polar plot of Radiation Emission

A. Antenna Design

The optimized proposed AVA model evolved from the reference antenna after undergoing various modifications. The geometry of the reference antenna (Simple Vivaldi antenna) is illustrated in Fig. 11.

Fig 11. Illustration of geometry of Simple vivaldi antenna

The proposed optimization assisted antipodal Vivaldi antenna for UWB communication using was implemented in MATLAB and the results acquired are noted. The proposed

IGWO-FU model is evaluated over the traditional models like ABC [34], DE [35], ABC-DE and PSO [36] in terms of gain, Return loss and VSWR by varying the frequency of the tilt angle.

Fig 12: 3D pattern of Vivaldi antenna at the rotating angle of (a) 0°(b) 30°(c) 45°(d) 90°

“Directivity (D) is the quantitative measure of an antenna’s ability to concentrate radiated power per unit solid angle in a certain direction and it is highly dependent on the three-dimensional pattern of an antenna”. The directivity of antenna is expressed mathematically in Eq.in which $R_{specific}$ and $R_{reference}$ is the radiation intensity of the given antenna and the radiation intensity of the reference antenna, respectively.

$$D = \frac{R_{specific}}{R_{reference}}$$

Fig 13. Polar plot exhibiting the directivity of optimized antenna for traditional and proposed IGWO-FU at (a) tilt angle= 0° (b) tilt angle= 30°, (c) tilt angle= 45° and (d) tilt angle= 90°.

Table I: Optimal Values of the S-Parameter of modified AVA with IGWO-FU

Algorithm	S-parameter
ABC[27]	0.72637-0.31242i
DE[28]	0.71902-0.29712i
ABC-DE[29]	0.71413-0.34004i
PSO[30]	0.71562-0.31998i
IGWO-FU	0.71844-0.32769i

CONCLUSION:

Proposed methodology eliminates an interference of array's bandwidth and ground plane. This paper presents combined evaluation of Frequency Selection Surface (FSS) along with

PSO which has several advantages like increased reliability, efficiency and ease of implementation.

The current research has achieved the objective of designing an Optimized Vivaldi antenna to enhance the gain performance. The optimized Vivaldi antenna was designed by fine-tuning the antenna parameters like taper length l_t , aperture width w_{ap} , Slot Line width w_s , cavity diameter d , Cavity to taper spacing s , Ground Plane length l and ground plane width w , respectively. As a major contribution, these antennas were tuned in an optimal way by introducing IGWO-FU, which was the enhanced version of traditional GWO. Finally, the performance of proposed IGWO-FU model was compared over other traditional algorithms with respect to gain, VSWR, directivity, charge and current distribution, return loss as well. Moreover, at the frequency value $= 7e^9$, the IGWO-FU is 52%, 8%, 40% and 4% superior to the traditional models like ABC, DE, ABC-DE and PSO, respectively at tilt angle of 45° in terms of VSWR. at tilt angle of 0°, The IGWO-FU in terms of gain is 30%, 5.2%, 7.3% and 15.7% better than the traditional models like DE, ABC-DE, ABC and PSO, respectively at frequency $= 7e^9$. Thus, from the evaluation, it is obvious that the proposed IGWO-FU model has achieved the improved gain performance of the optimized AVA.

DECLARATION

I K Nishanth Rao, declare that the Submitted Research Paper is my original work and no part of it has been published anywhere else in the past. I take full responsibility, that if in future, the paper is found invalid according to basic rules, the last decision will be of the Authorities concerned. Any form of plagiarism will lead to disqualification of the paper.

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Figures

Figure 1

Individual cell of resistive FSS with tightly coupled Bowtie array

Figure 2

Top view of unit cell

Figure 3

Flowchart of proposed PSO algorithm

Figure 4

Solution Encoding

Figure 5

Illustration of fitness based position update

Figure 6

Flow chart of the proposed IGWO-FU model

Proposed HFSS model for bowtie antenna

Figure 8

Output graph of the proposed model

Figure 9

Output graph for Rectangular plot

Figure 10

Output graph for polar plot of Radiation Emission

Figure 11

Illustration of geometry of Simple vivaldi antenna

Figure 12

3D pattern of Vivaldi antenna at the rotating angle of (a) 0°(b) 30° (c) 45°(d) 90°

Figure 13

Polar plot exhibiting the directivity of optimized antenna for traditional and proposed IGWO-FU at (a) tilt angle= 0° (b) tilt angle= 30° , (c) tilt angle= 45° and (d) tilt angle= 90° .