
Linearly Polarized F-Shaped Antenna with Optimized Patch Parameters Using Particle Swarm Optimization

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ABSTRACT

To show the usefulness and reliability of optimization method in electromagnetics, this manuscript employs the use of particle swarm optimization scheme to ensure minimum values (length and width) of the proposed linearly polarized antenna. An F-shaped patch antenna with partial and defective ground structure is proposed for wideband and unidirectional radiation. To achieve multiband and wide impedance width the edges of the radiating patch are transformed in to a zigzag shape. Estimated and simulated results demonstrate that the proposed antenna has a 10-db impedance bandwidth of 120% (1.4 - 4.4GHz) and 44% (5.2 - 6.3 GHz). Stable far field behavior just as the VSWR are also observed.

Keywords: Bandwidth enhancement; particle swarm optimization; imperfect ground structure; microstrip line

INTRODUCTION

Wireless communications and radar systems are among the leading technologies that have made a significant impact on the society. They have enable worldwide communication, expanding one's local community to the surrounding area to a global community. Microstrip patch antenna are regarded as one of the most widespread antennas used in modern wireless system which makes them to triggered extensive research due to their compactness, simplicity of joining with microstrip innovation, ease of fabrication, low volume, simplicity of coordination with circuit components [1]. However, they suffer a serious limitations of narrow bandwidth. This paper has made use of various techniques to enhance the bandwidth of the antenna. Consequently, PSO algorithm is utilized to minimize the design parameters for better performance. Particle swarm optimization (PSO) is an evolutionary algorithm based on swarm intelligence and is inspired by the clock of bird's movement activities. It advances a given issue by improving the hopeful arrangement in the structure space towards the ideal arrangement iteratively where every molecule is a competitor arrangement [2], [3]. The arrangement of every conceivable answer for the advancement issue is known as the inquiry space. The PSO algorithm involves three steps: generation of initial population with random position and velocity vectors for the design parameters, velocity update and eventually position update. The particle introduces a point in the hunt space that changes its situation from one move (iteration) to another dependent on speed update [4], [5], [6].

The F-shaped slot patch antenna is simply fed using microstrip line feeding method. To achieve wideband impedance matching a partial and defective ground structure and some small etching on the radiating patch are introduced. A prototype of the wideband antenna has been fabricated and tested. Both results verify that the proposed antenna exhibits a 10 -dB impedance bandwidth of 120% (1.4-4.4 GHz) and 44% (5.2-6.3 GHz). Good radiation pattern for the three bands are also observed, which makes the antenna a promising candidate to be applied in wireless communication systems.

PSO ALGORITHM

The particle swarm enhancement as present by Kennedy and Eberhart, shares numerous highlights or perspective with stochastic improvement approach, for example ant colony optimization, Genetic algorithm, differential evolution, invasive weed optimization, firefly algorithm and simulated annealing [10], [11], [12], [13], [14], [15]. The plan begins with arbitrarily picked populace and looks for ideal by refreshing peers. The potential arrangements called bit fly through the issue space by following the present ideal spot. The ease of use and few variables to set are two important characteristics of PSO unlike GA. The situation of the particle can be demonstrated scientifically as indicated by the accompanying two stage conditions as likewise appeared in figure 1.

$$V_i^{k+1} = w^k v_i^k + c_1 r_1^k, i(p_i^k - x_i^k) + c_2 r_2^k, i(g_i^k - x_i^k) \tag{1}$$

$$X_i^{k+1} = x_i^k + (v_i^{k+1} \Delta t) \tag{2}$$

Where k refers to the current iteration, i is the index of each particle, with v_i^k and x_i^k current velocities and position, respectively, w^k contains the inertia weights, p_i^k gives each particles best location, and g_i^k is the global optimum. The parameters C_1 and C_2 are two arbitrary constants which decides if a particle has an inclination towards the best position or towards the worldwide position. r_1^k , r_2^k are discretionary numbers consistently appropriated in [0,1], and Δt is the time step, typically set to solidarity.

Objective Function

The fitness function is generated from the two equation of width and length of rectangular patch antenna as according to the previous literature [13].

$$U = \left(\left(\frac{3 \times 10^8}{2 \times x} \right) \right) \times \sqrt{\left(\left(\frac{2}{4.4 + 1} \right) \right)} \times 1000 - F \tag{3}$$

$$V = \left(\left(\frac{3 \times 10^8}{2 \times y \times \sqrt{4.4}} \right) \right) \times 1000 - F \tag{4}$$

From (3) and (4) our fitness function will be evaluated using the Rosen Brock function test which is often used in evaluating the efficiency of optimization algorithms [14], which is given in equation 7 below.

$$\text{Value} = (u - 0.01)^2 + (v - 0.01)^2 \quad (5)$$

In equation (3) and (4) x and y stands as the width and length of the patch to be optimize. At the point when the determined resounding recurrence coordinates the ideal estimation of the equivalent the estimation of the target work winds up zero. In this manuscript inertia $w = 1.0$, correction factor $C_1 = C_2 = 2.0$, number of iterations = 50 and swarm size = 50 is used.

Optimization results

The goal of the optimization process is to minimize the important parameters of rectangular patch antenna that is width and length while keeping the arrangement recurrence f close to 2.45GHz. Figure 2 below shows the objective function vs number of iterations, figure 3 shows the optimized width of the patch and figure 4 shows the optimized length of the patch respectively. The qualities are then taken to electromagnetic solver (HFSS) for simulation, reproduction and further investigation.

ANTENNA GEOMETRY AND DESIGN

The geometry of the proposed reception apparatus is represented in figure 5. The antenna consists of three important parts: An F-shaped slot patch, a substrate and a partial ground with a defective structure at the center of the ground plane. The radiating patch dimension of 38.0363 x 29.7957 x 1.6mm which was obtained from PSO are deployed on a dielectric substrate: FR4 epoxy with a relative permittivity of $\epsilon_r = 4.3$, a loss tangent of 0.025 and 1.6mm as a thickness. The proposed antenna is placed above a metallic reflecting partial and defective ground whose size is 20 x 60mm. The recreation and investigation for the radio wire are performed by utilizing the High Frequency Structure Simulator (ANSYS HFSS). The optimized parameters of the antenna are recorded in Table I. Figure 6 shows the corresponding S_{11} and performance of the antenna without/with partial and defective ground and etching of patch edges. The F-shaped slot antenna obtains a narrow impedance bandwidth of 8% (2.4 - 2.6 GHz) for the lower band and 5.6% (3.96 - 4.1 GHz) for the upper band without the partial, defective ground and etching of patch edge. By introducing the partial, defective ground structure together with etched patch edge, it is clear that an additional higher band is produced at 5.8GHz as shown in figure 6. The bandwidth is enhanced significantly from 8% (2.4 - 2.6 GHz), 5.6GHz (3.96 - 4.1 GHz) to 120% (1.4 - 4.4 GHz) and 44% (5.2 - 6.3 GHz). At the same time, the impedance coordinating of the reception apparatus is additionally improved.

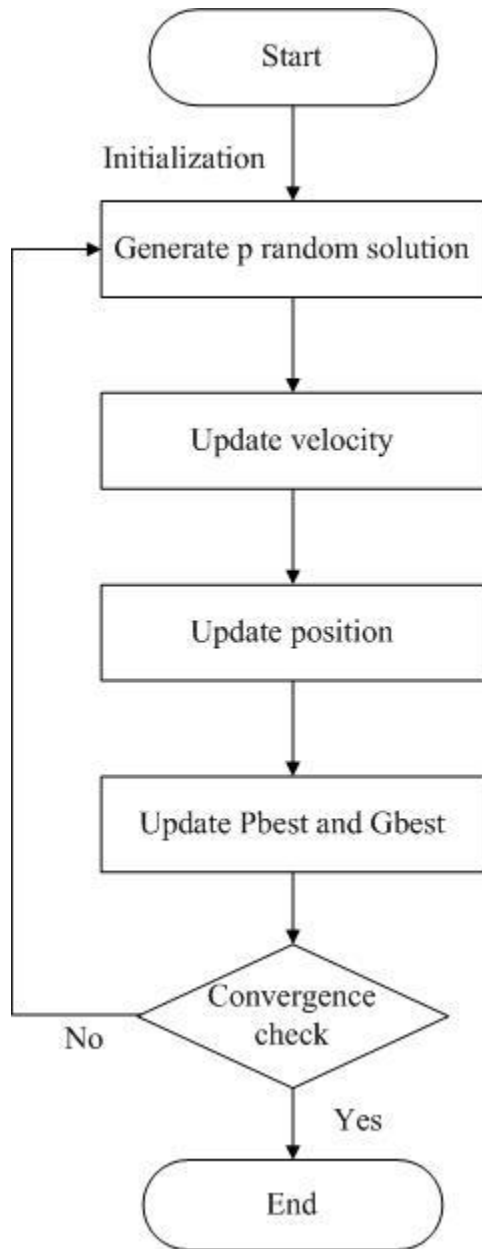


Figure 1: Flowchart of the PSO algorithm.

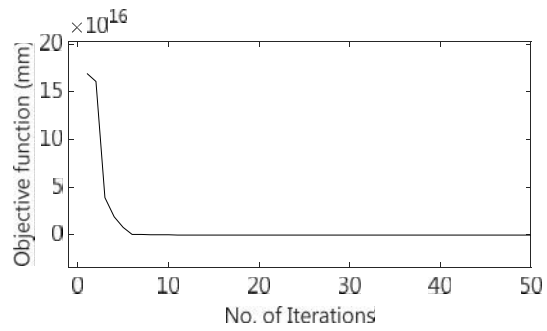


Figure 2: Objective function vs iteration.

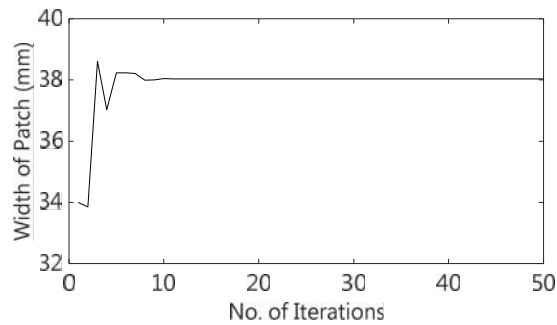


Figure 3: Minimized width of the patch

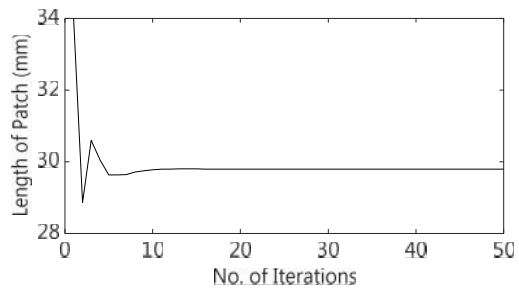


Figure 4: Minimized length of the patch.

RESULTS AND DISCUSSION

A model of the F-molded antenna dependent on the parameters indicated in Table I is constructed and tested to verify the performance. A system analyzer is utilized to gauge S-parameter of the manufactured radio wire just as the simulated. The simulated and measured S₁₁ is appeared in figure 7. The voltage standing wave proportion for both the simulated and measured is appeared in figure 8. The radiation performance for the three bands are presented in figure 9, 10 and 11. The constructed photo is depicted in figure 15. The discrepancy between the simulated and measured S₁₁ at the higher frequency band is most likely due to cutting of some strips on the radiating patch and some soldering effect just as the fabrication tolerance. The result demonstrates

that the proposed antenna (F-shaped slot antenna) with partial and defective ground structure achieves bandwidth of 120% (1.4 - 4.4 GHz) for the lower bands and 44% (5.2 - 6.3 GHz) for the higher band, for $S_{11} < -10\text{dB}$. The VSWR is in understanding to the variety of S_{11} versus recurrence just as to the imperative of the plan procedure, in which the incentive to be lower than 2 and more noteworthy than 1.

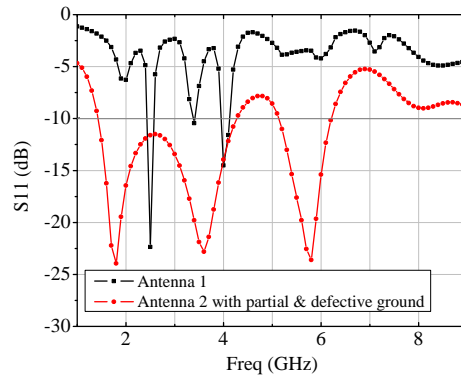
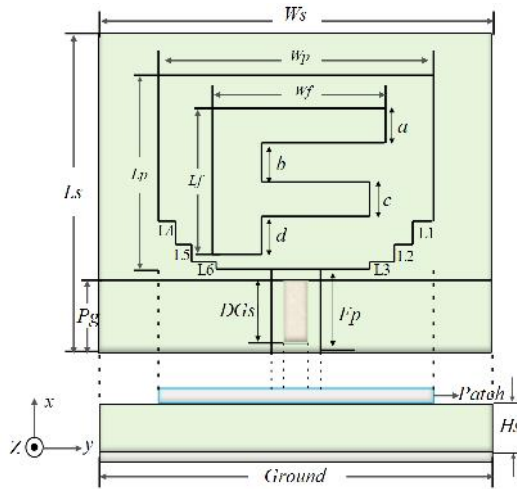


Figure 5: Geometry of F-slot patch antenna **Figure 6:** S_{11} with/without partial and DGS.

The design exhibits symmetry unidirectional radiation in both the E and H planes. Figure 12, 13 and 14 are the surface current distribution of the antenna at 1.8GHz, 3.6GHz and 5.8GHz respectively. Most of the current concentrate among the edges of the radiating patch, edge of the slot and microstrip line.

Table I: Design parameters of linearly polarized patch antenna

Parameters	Values (mm)	Parameters	Values (mm)	Parameters	Values (mm)
L_s	60	W_F	20	L_1	6.5
W_s	60	a	6	L_4	6.5
H_s	1.6	b	6	$L_2 = L_5$	3.25
L_p	29.7957	c	6	$L_3 = L_6$	2
W_p	38.0363	d	6	P_g	20
L_f	23	F_p	22.5	DG_s	14

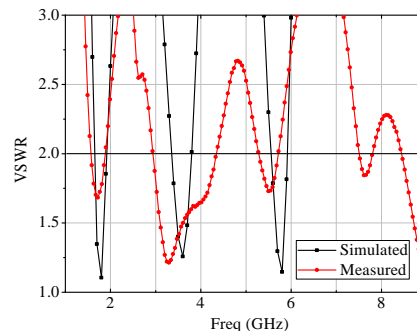
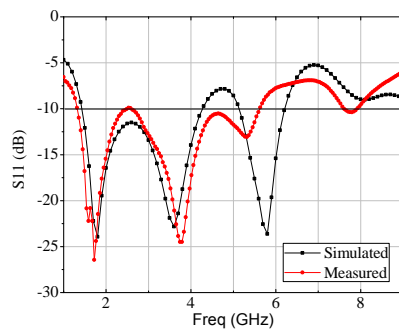


Figure 7: S_{11} of linearly polarized antenna. **Figure 8:** VSWR of linearly polarized antenna.

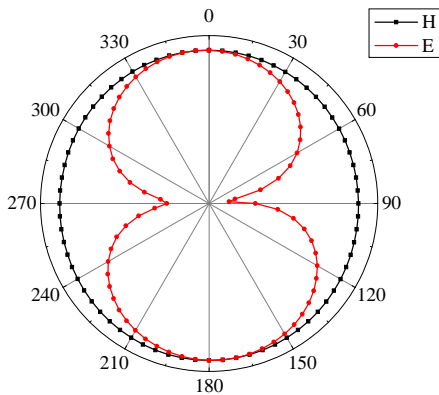


Figure 9: Radiation pattern at 1.8GHz.

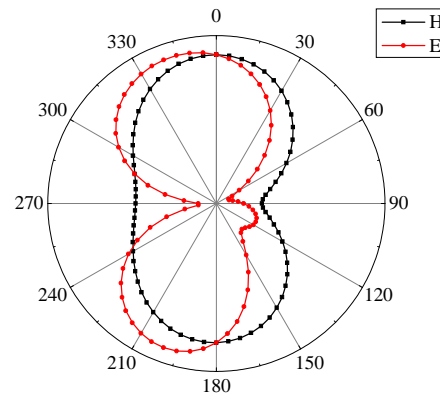


Figure 10: Radiation pattern at 3.6GHz.

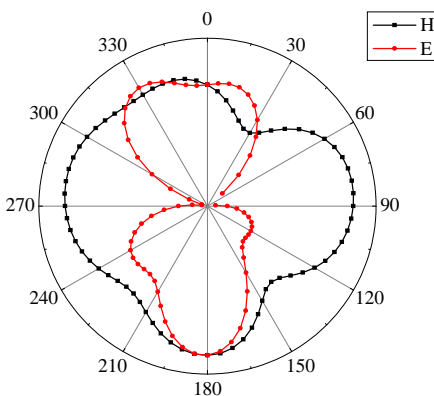


Figure 11: Radiation pattern at 5.8GHz.

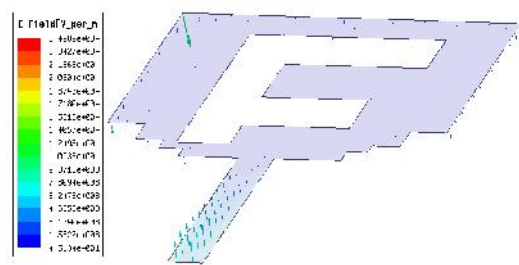


Figure 12: Current distribution at 1.8GHz.

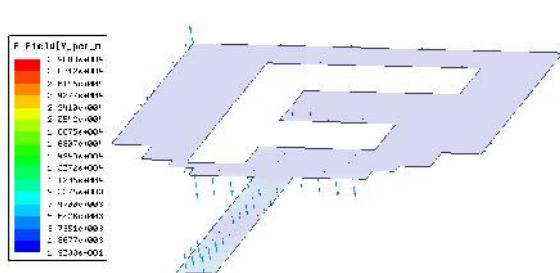


Figure 13: Current distribution at 3.6GHz.

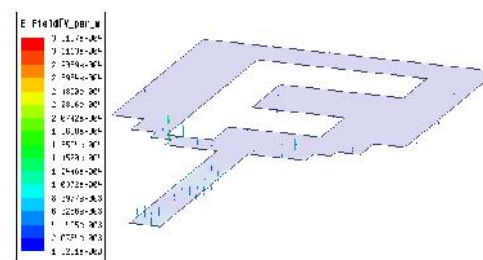


Figure 14: Current distribution at 5.8GHz.

COMPARISON OF RELATED ANTENNAS DESIGN USING PSO

To better illustrate the advantages of the design, comparisons with different performances include bandwidth, type of antenna, gain and dimensions between the design and related antenna design utilizing particle swarm enhancement are recorded in table 11. Contrasted and these reception apparatuses, the proposed radio wire has a few favorable circumstances in some angle.

Though the antenna in the work Min-chi chang and Wei-chung weng [4], have higher gain however, their antenna has larger dimension and a smaller bandwidth than the proposed antenna. The antenna in the work by Anthony and Trevor [5], have smaller dimension and higher gain than the proposed antenna but the thickness is larger and the bandwidth is relatively smaller than the proposed antenna. The work of Yogesh Choukiker, and Behera [6], though the dimension is smaller and the gain is above 5dBic but the bandwidth is narrower than the proposed antenna. The work of Goudos, and Tsiflikiotis et al [3], has triple bands and high gain but the bandwidth is also smaller than the proposed antenna. The comparison lead to the conclusion that the proposed antenna has a wide bandwidth and gain.

Table II: Comparison of various antennas design using PSO

Ref.	Type of Antenna	Frequency Band	Bandwidth	Peak Gain	Dimensions
3	Evolutionary design of dual band E-shaped patch Antenna for 5G mobile communications	25GHz	5.8%	6.71	6.8mm × 4.96mm × 3.0mm
		29.2GHz	6.4%	4.55	
		37GHz	20.8%	1.72	
4	A Broadband circularly polarized polygon slot antenna design by particle swarm optimization	2.45GHz	17.6%	3.69	66mm × 66mm × 1.6mm
5	Particle swarm optimization of microstrip antennas for wireless communication systems	5.25GHz	19%	5.7	50mm × 50mm × 3.175mm
		5.78GHz		7.6	
6	Optimization of dual band microstrip antenna using PSO	2.4GHz	1.25%	6.67	49mm × 39.6226mm × 1.58mm
		3.08GHz	0.8%		
This work		1.4-4.4GHz & 5.2-6.3GHz	120% & 44%	2.30 & 1.46	60mm × 60mm × 1.6mm

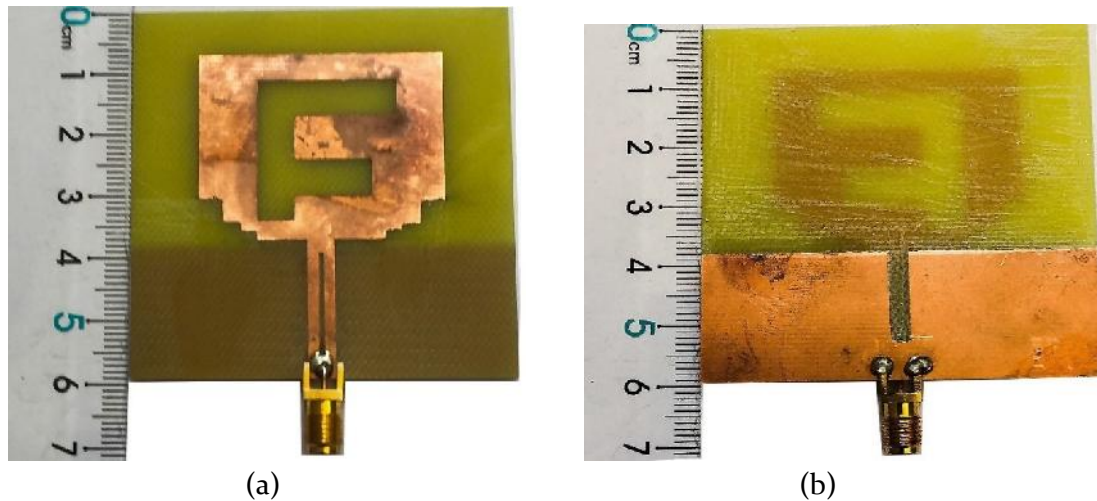


Figure 15. Photograph of the linearly polarized antenna; top view (a), bottom view (b).

CONCLUSION

In this article, particle swarm optimization method has been utilized for optimization of patch dimensions (width and length). A wideband F-formed opening patch receiving wire with fractional and deficient ground structure is proposed. By cutting the edges of the patch and introducing a partial and defective ground the bandwidth of the antenna is significantly increased, which give an impedance bandwidth of 120% ranging from 1.4 to 4.4 GHz for the lower bands and 44% ranging from 5.2 to 6.3GHz for the higher band. Consequently, the proposed antenna achieved a multiband frequency. These are very useful frequencies that can be used for wireless communication applications.

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