PSO Optimization based Dual F-Shaped Triple Band Patch Antennawith Dumbbell Comb Shaped DGS

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ABSTRACT

Particle swarm optimization (PSO) has been introduced to the electromagnetic community recently it is used for design optimization of the patch antenna. A dual F-shaped patch antenna with dumbbell comb-shaped defected ground structure (DGS) is introduced in this paper to obtain triple band resonating frequency. The proposed DGS is incorporated in the ground plane under the patch antenna to improve its performance. In this paper, PSO has been used for the optimization of resonant frequency and the area of the patch of dual F- shaped microstrip antenna. The technique develops in this paper seems to be a generalized soft computing tool to calculate parameters of microstrip patch antenna such as patch length, patch width, and resonant frequency respectively. The performance characteristics of the antenna were simulated by using CST software.

Keywords*:* Defected Ground Structure (DGS), Particle Swarm Optimization (PSO), F-shaped, microstrip patch antenna.

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INTRODUCTION

Microstrip patch antennas have been a topic of intense investigation over the last two decades, due to their several advantages and better prospects. Microstrip antennas [1-3] are low profile, lightweight, easy fabrication, and embedded. They are also can be made conformal and well suited to be integrated with microwave integrated circuits. In terms of fabrication, such a system offers simplicity, which allows for mass production and cost-effective manufacturing as well as high performance. Moreover, microstrip patch antennas can be easily designed to operate in dual-band and multi-band applications [4-6]. Thus, they are widely used in many practical applications such as WiMAX bands, medical applications, satellites, airport surveillance radars, and military systems.

There are several methods have been proposed recently, such as using a dielectric substrate of high permittivity, Defected Microstrip Structure (DMS), Defected Ground Structure (DGS) at the ground plane or a combination of them[7-9]. When DGS is introduced in a microstrip antenna, the defect geometry etched in the ground plane disturbs its current distribution. In other words, introducing DGS in a microstrip antenna can result in reducing its size concerning a given resonance frequency [10-13]. Particle Swarm Optimization (PSO) with defected ground structure is used to optimize antenna performance. The PSO serves as an effective optimizing tool for difficult multidimensional discontinuous problems for a large array of the field [14, 15]. Multiband characteristics are obtained by using a split ring resonator [16, 17],

In this paper, a dual F-shaped patch antenna has been presented with a dumbbell comb-shaped defected ground structure using particle swarm optimization. The antenna has a triple narrow band resonating frequencies at 3.2GHz, 4.276GHz, and 5GHz. Finally, the results were simulated by using CST software.

I. Particle Swarm Optimization

PSO is a kind of swarm intelligence, based on social psychological principles and provides insights into social behavior, as well as contributes to engineering applications. The particle swarm optimization algorithm [2][9][12] was first described in 1995 by Kennedy and Eberhart [6]. PSO is initialized with a group of random particles (solutions) and then searches for optimal by updating generations.

Particles move through the solutions space and are evaluated according to the same fitness criterion after each time step. In every iteration, each particle is updated by following two "best" values. The first is the best solution (fitness) it has achieved so far (the fitness value is also stored). This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value obtained so far by any particle in the population. The secondbest value is a global best and called gbest.

When a particle takes part of the population as its topological neighbors, the second best value is a local best and is called ibest. Neighborhood bests parallel exploration of the search space and reduces the susceptibility of PSO to falling into local minima, but slows down convergence speed. The following mathematical equations to modify theparticle's position:

$K_{n+1} = w * K_n + c_1$rand1 ()*($p_{best,n}\ CurrentPosition_n$)+$c_2$rand2

()*($g_{best,n} CurrentPosition_n$)Current Position [n+1] = Current Position[n] + K [n+1]

Where, K_{n+1}: Velocity of the particle at n+1th

iterationW: weighting function

K_n: Velocity of the particle at nth iteration

c_1: Acceleration factor related to gbest

c_2: Acceleration factor related to lbest

rand1 ( ): random number between 0

and 1rand2 ( ): random number

between 0 and 1gbest: gbest position

of swarm

pbest: pbest position of the particle

Current position [n+1]: position of particle at n+1th

iterationCurrent position[n]: position of particle at nth

iteration

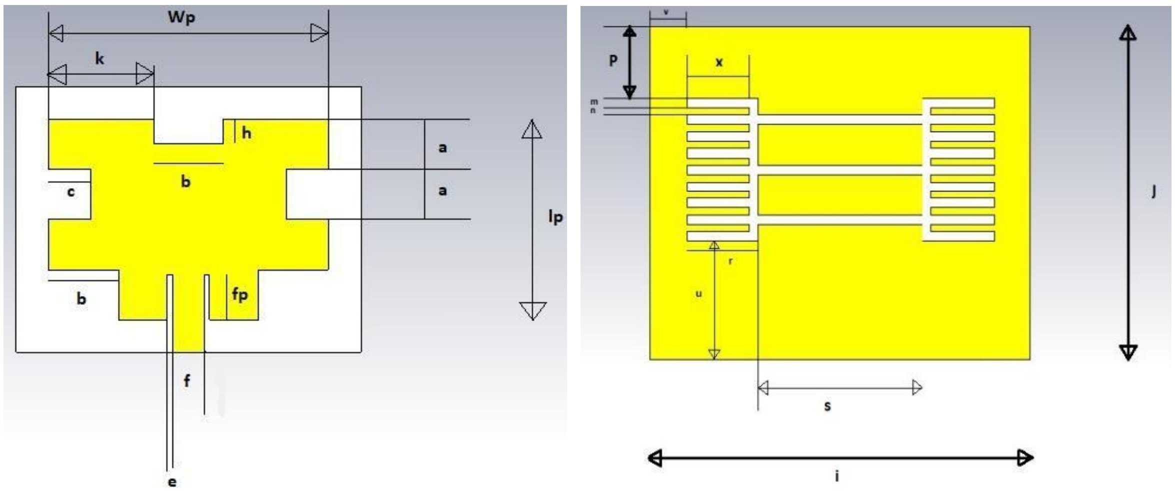
K [n+1]: particle velocity at n+1th iteration

II. Antenna Design

The antenna structure consists of a rectangular patch dimension Wp × Lp with five slots into the radiating edges and is excited using an insert feed introduced on the patch. In this design, the substrate FR4 is used due to its low cost and easy fabrication. The substrate height is 1.6mm, the dielectric constant is 4.4 and the loss tangent is

0.021. The dimensions of our antenna are optimized by using the CST Microwave studio tool.

A dual F-shaped patch with five slots on the surface of the patch is optimized by using the particle swarm optimization technique and the feed position (fP) is also optimized by using the PSO algorithm. Whereas in the ground plane the defected ground structure is introduced and the width and length of the slot are optimized using PSO. The gap between the slots m and n is also optimized by using PSO and the antenna is designed and simulated by using the CST software tool. The designed F-shaped antenna with dumbbell-shaped DGS is depicted in Fig1.



(a) (b)

Figure 1: (a) Top view (b) Bottom view of the proposed antenna

Design parameters for the F-shaped patch antenna (Ɛ r =4.4, h=1.58 mm) all the dimensions are in mm. The insert feed is used to obtain good impedance matching in the operating frequencies. The parameters to design a patch antenna aredepicted in table 1.

TABLE-1: Parameters for F-Shaped Micro Strip Patch Antenna with DGS

Parameter	Value (mm)	Parameter	Value (mm)
wp	79	n	1.5
lp	53	x	15
c	11	p	15.125
a	13.25	u	24.875
b	18.25	v	8.5
fp	12	r	17
k	17.375	s	39
f	8.2	i	90
h	6.625	j	70
m	2		

The microstrip lines with various periodic structures prohibit wave propagation in certain frequency bands, including photonic band gap (PBG), electromagnetic band gap (EBG), and defected ground structures (DGSs). Some of the commonly used DGS structures are depicted in Fig 2.

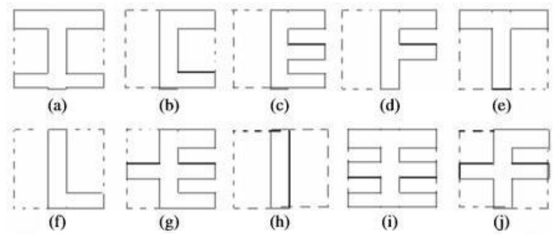
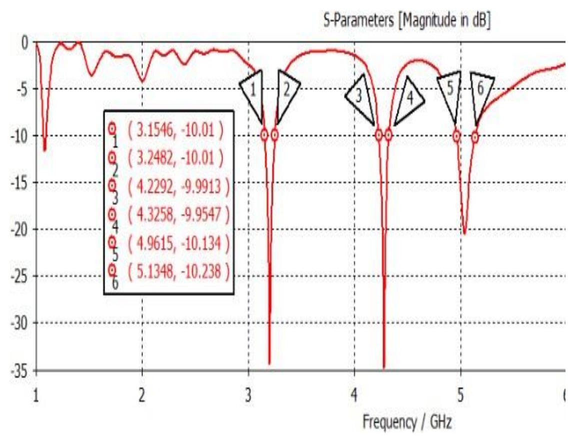


Figure 2: Different geometries of DGS [1]

The dumbbell-shaped DGS is etched on the ground plane to obtain the triple band resonance frequency of the F-shaped patch antenna. Three cells of DGS are introduced in this paper to obtain the triple band resonating frequency with narrow bandwidth using the PSO algorithm depicted in Fig1(b).

III. RESULTS AND DISCUSSIONS

The simulation of the prototype design is having three resonant frequencies i.e., 3.2GHz, 4.276GHz, and 5GHz. The resonating frequencies at 3.2GHz, 4.276GHz, and 5GHz of the S_{11} are about -34.4dB, -34.7dB, and - 20.5dB respectively. VSWR range ideally between 1-2 which has been achieved in

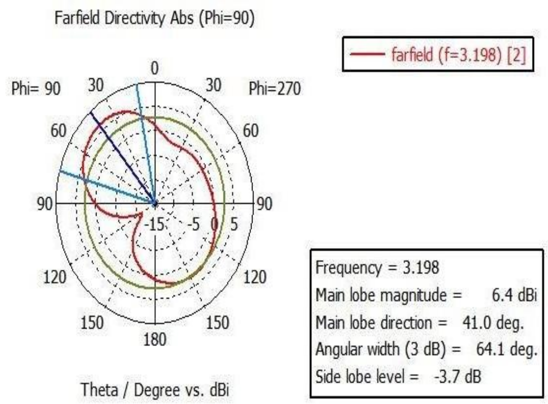


all the three operating frequencies with an impedance bandwidth of 93.6MHz, 96.6MHz, and 173.3MHz at 3.2GHz, 4.276GHz, and 5GHz respectively.The return loss graph is depicted in Fig. 3.

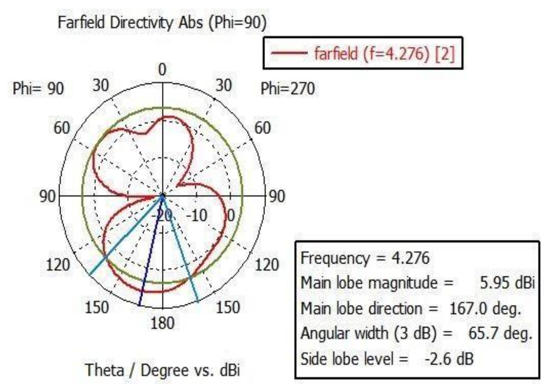
Figure 3: Return loss graph of the F-shaped antenna with dumbbell DGS using PSO

The 2-D radiation plot for the proposed antenna at 3.2GHz, 4.276GHz, and 5GHz are depicted in the Fig 4.

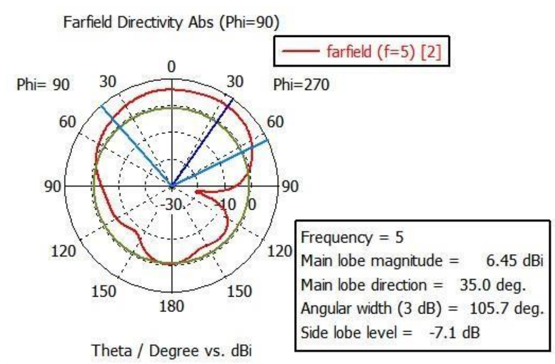
It is observed that the radiation patterns are having omnidirectional radiation in the E-plane.



(a)



(b)



(c)

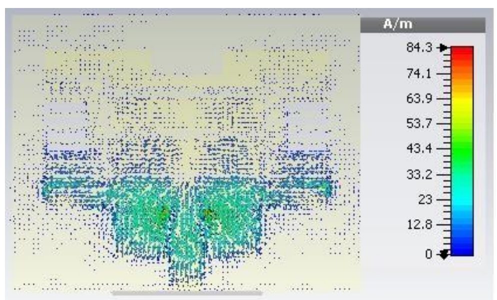
Figure 4: 2-D radiation plot for (a) 3.2GHz (b) 4.276GHz (c) 5GHz frequency

The radiation plot at 3.2GHz, and 4.27GHz depicts the dipole pattern with a 3dB beam width of 64.1deg, 65.7deg respectively and at 5GHz it is a slight omnidirectional pattern with a 3dB beamwidth of 105.7dB with reduced back loop radiation. The evaluation parameters of the designed antenna are depicted in table 2 for different resonating frequencies.

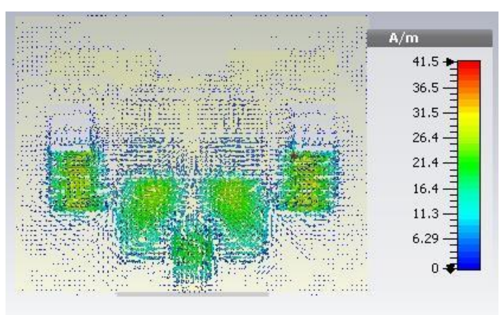
Table 2: S_{11}, impedance, VSWR, and directivity at different frequencies of the proposed antenna.

Frequency(GHz)	S11 (dB)	Z11 (Ω)	VSWR	Directivity(dBi)
3.2	-34.4	50.6	1.03	6.4dB
4.276	-34.7	48.7	1.03	5.95dB
5	-20.5	50.2	1.20	6.45dB

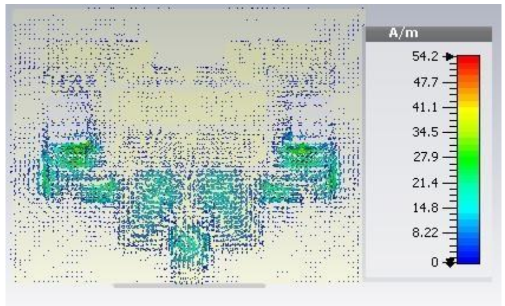
The surface current distributions obtained from CST simulation on both patch and ground plane for optimized antenna were studied. The current was more concentrated along the DGS on the ground plane of the patch antenna. The defects in the ground structure disturb the current distribution. The current distribution at triple band frequenciesat 3.2GHz, 4.275GHz, and 5GHz are shown in Fig5.



(a)



(b)



(c)

Figure 5: Surface current distribution at (a) 3.2GHz (b) 4.276GHz (c) 5GHz of the designed antenna.

V. CONCLUSION

The design and optimization of a dual F-shaped patch antenna with a dumbbell-shaped defected ground structure have been presented and discussed. This design is obtained by combining PSO, an evolutionary optimization method, with DGS to obtain a triple band resonating frequency at 3.2GHz, 4.276GHz, and 5GHz. The designed antenna is having S11 much less than -15dB with directivity greater than 5dBi at all three resonating frequencies which makes the antenna useful for radio location, aeronautical, and radio navigation applications**.** For future simulation processes, other DGS shapes can be implemented to reduce the antenna size and improve bandwidth obtained by improved optimization algorithms.

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