Hexagonal Reflector based Optimized Textile Antenna for Gain Enhancement

N.R.Indira[1], Dr. A. ThenMozhi[2]
[1,2]*Associate Professor, ECE*
[1]*Sethu Institute of Technology, Virudhunagar, India,*
[2]*Kalasalingam Academy of Research and Education, Krishnsnan koil, India*

Abstract: In this article, a square patch antenna with reflector is fed by inset feed for wearable applications in the ISM band (2.45GHz) Using Jeans substrate with 3 mm thickness and dielectric constant of 1.7. In this article, design of Textile patch antenna is optimized using Oppositional Particle Swarm optimization (OPSO) algorithm to resonate at 2.45 GHz. The major advantage of proposed system is minimizing the back lobe and enhances the gain. Usually, Antenna parameters such as reflection co efficient, Voltage standing wave ratio, Gain &Directivity are measured using CST software.

Index Terms: Jeans substrate; Reflector; OPSO

I. INTRODUCTION

In Recent years, People pay more attention to develop wearable antennas. Wearable antennas are used in many field. In medical field, Wearable antennas are used to detect breast cancer [1]. In the military field, Wearable antennas are used in radar and communication system. Usually microstrip patch antennas (MSP) are preferred for developing Wearable antenna due to its easy installation and cost effectiveness [5]. Another important feature of MSP are mainly radiate perpendicular to the planar structure and also their ground plane efficiently shields the human body from Radiation [5-7]. Due to this features MSPs are preferred for designing Wearable antennas. The bandwidth and efficiency parameters of planar antennas are determined by the substrate dielectric constant and its thickness and it's optimized parameters are obtained by using OPSO Algorithm [2,4]. For improving gain and efficeicncy microstrip patch antenna is designed to resonate at 2.45 GHz dual-layer Microstrip textile patch antenna was developed by taking the design of the conventional square patch antenna, then changing it by removing symmetrical parts from the left and right sides and finally introducing a Reflector as a second layer [18].

Wearable antennas ordinary textile fabrics has been used as dielectric material. In general textile materials have low dielectric constant between 1 and 2. The low dielectric constant decreases the surface wave losses and guided the waves propagates with in the substrate[8-13]. However, less substrate permittivity can also increases the resonant frequency of the antenna and improve the gain and efficiency of the antenna [3,5]. The dielectric thickness of the substrate determines the size of the antenna, efficiency and bandwidth [5].Hence MSPs can improve their performance by using textile substrates. Wearable antennas are used in wireless system such as WLAN (2.4–2.484 GHz/5.15-5.35/5.725–5.85 GHz), WiMAX (2.5–2.69 GHz/3.3-3.8 GHz/5.25-5.85 GHz), E band application (2–3 GHz) and C-band satellite communication (3.8-4.2GHz).

II. TEXTILE ANTENNA FABRICATION

2.1 Antenna design

When patch antennas are proposed on substrate will provides changes in wavelength and hence variation in resonance frequency, depending on the distance from the body. On the other hand, antennas with reflectors (e.g. microstrip patch antennas) has less effect in resonant frequency deviation when placed on the body (from operating frequency) and impedance matching is achieved with independent of distances from the body. Fig 1 shows the general structure of the wearable patch antenna. As shown in the figure, length (L), width (W) and Depth (D) are the important variables to design a wearable patch antenna. For designing an efficient wearable patch antenna, these parameters are to be optimized.

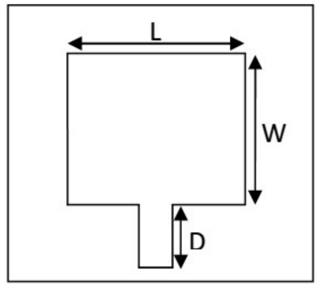

Figure1.
General Structure of wearable patch antenna

2.2 Optimized design of wearable path antenna

In this methodology, the design of microstrip patch antenna or wearable antenna is optimized to resonate at 2.45 GHz. Length (K), width (V) and depth (C) of patch those are critical factors to design a wearable antenna. These factors are optimized utilizing Oppositional Particle Swarm Optimization (OPSO) algorithm in this paper. In 1995, Eberhart and Kennedydevelop the PSO algorithm. Based on the behavior of bird flocking, PSO algorithm is developed. This is a developmental algorithm based on the population and established with a population of random solutions. In this algorithm, these initialized solutions are known as elements. Every element is initialized with its random velocity and position. Opposite based learning (OBL) strategy and PSO algorithm are combined for improving the optimization process or global optimal solution selection. The opposite solution is produced for all solutions using this approach. Ideal determination of L, W and D for structuring wearable antenna utilizing OPSO calculation is represented as pursues

2.2.1 Initialization:

With a c dimensional vector, the candidate solutions or particles are initialized. Arbitrary estimations of K, V and C are considered as the candidate solutions in this methodology. It tends to be initialized as pursues,

$$W_j(s) = \{w_1, w_2, \ldots, w_c\} \quad (1)$$

Where, wc denotes the position of the solution in the cth dimensional vector and it can be represented as

$$w_c = \{K, V, C\}_c \quad (2)$$

2.2.2 Oppositional solution:

Utilizing OBL technique, the oppositional solutions are evaluated for the initial solution wc. The calculation of oppositional solutions of wc are performed using equation (3):

$$w_c' = z_j + a_j - w_c \quad (3)$$

Here, in the cth dimensional search space, oppositional solution is denoted by wc. At time s, the lower limit of solution wc is represented by zj and the upper limit of solution wc is represented by aj.

2.2.3 Fitness:

Using equation (4), the fitness value is calculated for every solution after initialization of the candidate solutions.

$$Fit_j = Max\left[v_1 * Gain + v_2 * \frac{1}{Ter\min al\, impedance}\right] \quad (4)$$

Where, v_1 and v_2 are the weight parameters in the range [0, 1], terminal impedance is calculated as follows,

$$Terminal\,impedance = Q * \cos^2\left(\frac{\pi C}{V}\right) \quad (5)$$

Where, Q denotes the resonance input resistance. According to the equation (4), the solution with maximum fitness values is considered as the optimal solution i.e., the selected K, V and C are considered as the optimal solution. Otherwise the solutions are updated as described in the following phase.

2.2.4 Updation:

Based on the position and velocity vector, the solution is updated after the estimation of the solution. Every solution is updated using (6) and (7) until determining the optimal solution. The global best values represented by F_{best} and the local or personal best values represented by O_{best} are estimated in all the iterations.

$$u_{j+1} = V_{in} * U_j + \left(O_{best_j} - W_j\right) b_1 q_1 + \left(F_{best_j} - W_j\right) b_2 q_2 \quad (6)$$

$$W_{j+1} = W_j + U_{j+1} \quad (7)$$

Here, the position and velocity of the hth particle in cth dimensional space at iteration j is denoted by Wj and Uj. The acceleration coefficients which are of the value of 2 are presented by b1 and b2. The random variables that are in the range [0,1] are represented as q1 and q2. The inertia weight which is utilized for controlling the search process is denoted by Vin. On increasing the iteration, the weight value decreases. This is calculated using equation (8).

$$V_{in} = V_{max} - \frac{V_{max} - V_{min}}{s_{max}} \times s \quad (8)$$

Here, the maximum inertia weight and minimum inertia weight are denoted by Vmax and Vmin respectively. The maximum number of iterations is denoted by smax. The best position of the particle j is denoted by $O_{best\,j}$ and the best position of the group at iteration s is denoted by $F_{best\,j}$. The particle is considered as new $O_{best\,j+1}$ when the fitness of the jth particle W_{j+1} is greater than the previous $O_{best\,j}$. Else, the particle W_j is considered as new $O_{best\,j}$. Also, the particle is assumed as new $F_{best\,j+1}$ when the fitness of the hth particle W_{j+1} is greater than the fitness of previous $F_{best\,j}$. In other cases, the particle Wj is assumed as new $F_{best\,j+1}$.

$$O_{best_{j+1}} = \begin{cases} W_j & if\ E(W_{j+1}) \geq E\left(O_{best_j}\right) \\ W_{j+1} & otherwise \end{cases} \quad (9)$$

$$F_{best\ j+1} = \begin{cases} W_j(s) & if\ E(W_{j+1}) \geq E\left(F_{best\ j}\right) \\ W_{j+1} & otherwise \end{cases} \quad (10)$$

2.2.5 Termination:

Till finding the optimal solutions or variables from the initialized solutions and opposite solutions, the above phases are carried on. The algorithm will be terminated only when the optimal solution is achieved.

III. HEXAGONAL REFLECTOR

In Wearable antennas, front to back ratio is a very important factor .Hence the proposed design uses reflector layer which uses thirty six repeated Hex shaped structures is placed 5 mm behind the first layer which is shown in figure 2& 3. The proposed antenna is fed with Microstrip transmission line by SMA connector as shown in figure 4.

1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Figure.2. Unit cells of reflector surface

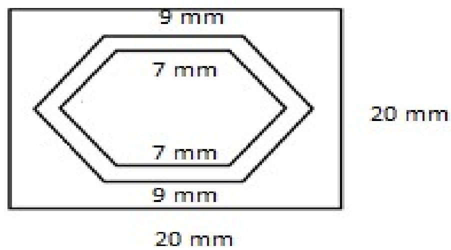

Figure 3. Single Unit cell of the reflector

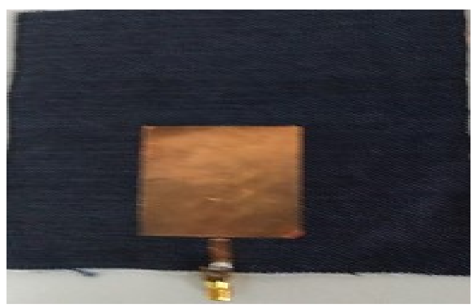

Figure 4. Prototype of jeans patch antenna

Side view of Wearable antenna with reflector is shown in Fig 5. The jeans substrate with permittivity of 1 and permeability of 1.6 is coated with annealed copper of .07 mm thickness is placed in both antenna and reflector.

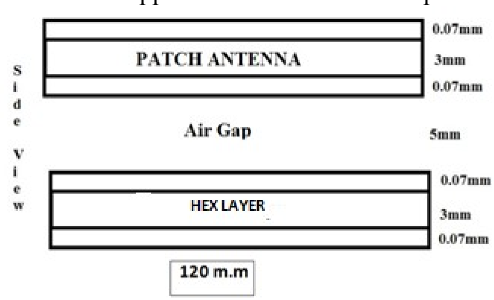

Figure 5. Side view of Wearable antenna with hexagonal Reflector

IV. Simulation results

The antenna parameters were studied by simulating the proposed antenna using Computer Simulation Technology software. The design was done by two main stages. The first stage has design of wearable antenna using jeans substrate. Using the OPSO algorithm designing variables of the antenna are optimized to resonate at 2.45 GHz and the obtained values are L=40mm, W=45mm and D=5mm. Fig 6 shows the optimized design of Wearable Patch antenna.

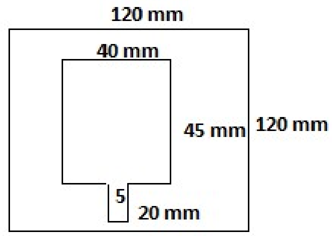

Figure 6. Structure of Optimized Wearable Patch antenna

The Back Radiation of the Jeans patch antenna is reduced by introducing Reflector which is placed behind the wearable antenna, hence gain and directivity is improved.

4.1 Return Loss

Return loss is one of the antenna parameter, to indicate how well the device or the transmission line is matched with the antenna. A match is good if the return loss will be high. It is generally indicated as a ratio in decibels (dB). The return loss of the jeans antenna with out and with reflector is -20.35 dB and -11.57 dB respectively which is shown in fig 7.

Measured result of without reflector is -19 dB which is nearer value to the simulated value.

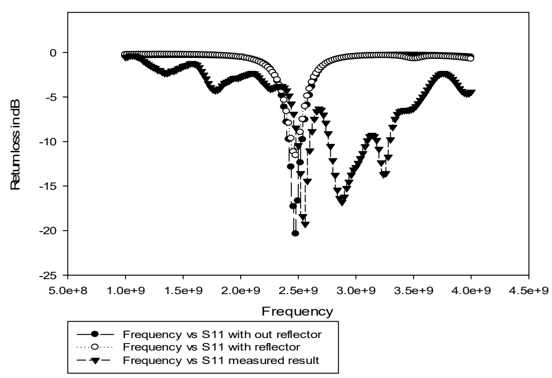

Figure 7.The simulated and measured results of return loss of the proposed antenna with and without reflector

4.2 VSWR

VSWR is important parameter used to describe the power reflected from an antenna. If VSWR value is minimum then it indicates the antenna is matched to the transmission line. Minimum value of VSWR is 1.

The VSWR of the jeans antenna with and without reflector is 1.21 and 1.72 respectively which is shown in figure 1. Measured result of VSWR is 1.214 for without reflector which is exact value of simulated value. Measured value of VSWR is shown in figure 8.

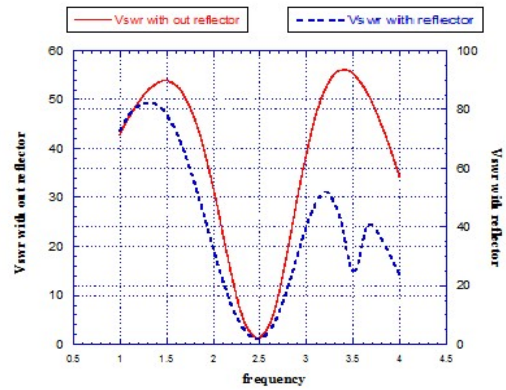

Figure 8. VSWR of the Wearable antenna with and without reflector

4.3 Gain

In a transmitting antenna, the gain is defined as how much of input power is converted in to Radio power in a particular direction. Gain of the receiving antenna is decided by how much of electromagnetic waves are converted into electrical signal in a particular direction.

The gain tends to increase extensively due to the reflector. The gain of the jeans antenna is 7.35 dBi and antenna with reflector is 8.5 dBi by decreasing the back lobe level as shown in figure 9.

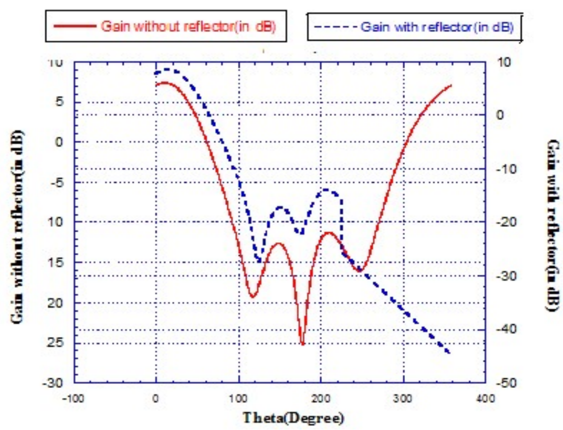

Figure 9. Gain of the Wearable antenna with and without reflector

4.4 Directivity

Directivity is a parameter of an antenna system which measures the amount of radiation in a specified direction.

Far field directivity of the jeans antenna is shown in fig 10. Directivity without and with reflector is 8.5 and 8.81dBi. Due to reflector, radiation from the jeans patch antenna move towards the main lobe direction. As the result, the main lobe radiation is enhanced up to .31 dBi. Fig 11shows the Measured value of S11 and VSWR. Table 1 shows the Comparison of the proposed work with various references using Jeans substrate.

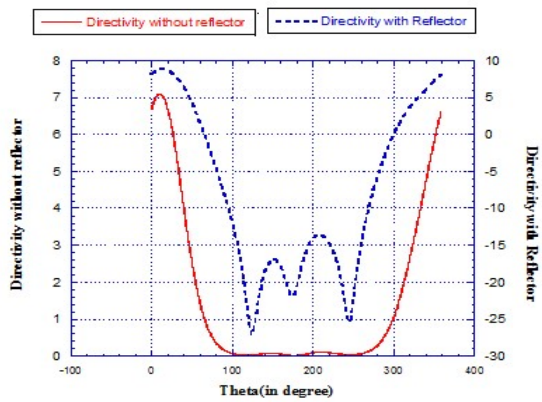

Figure 10.The Directivity of the Wearable antenna with and without reflector

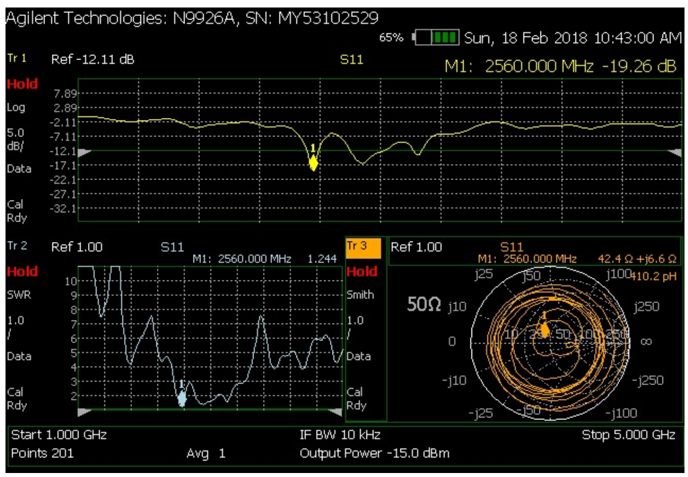

Figure 11. Measured value of S11 and VSWR

V. Conclusion

A low profile, Uni directional jeans antenna with reflector has been designed. By presenting the OPSO algorithm, the optimized variables have been selected for designing wearable patch antenna. In the table proposed work is compared with various reference works using jeans substrate without reflector. From the comparison table we conclude that, the proposed work has highest gain and directivity. Thus the novel design provides good method to decrease back lobe reduction and enhancement in gain.

Table 1 Comparison of the proposed work with various references using Jeans substrate

	ANTENNA PARAMETERS				
	fr	S11	VSWR	GAIN	DIR
Reference paper(15)	1.3 2.5	-8.5 -10	1.9 2.2	-----	----
Reference paper(16)	2.4	-23.64	----	------	-----
Reference paper(17)	2.45	-32.57	----	7.2	-----

Proposed work	(with out ref)	2.45	-20.35	1.212	7.35	8.5
	(with ref)		-11.57 (dB)	1.71	8.5 (dB)	8.81 (dBi)

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