DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA USING SELF-ADAPTIVE BACTERIAL FORAGING OPTIMIZATION

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ABSTRACT

In Communication Systems, antenna plays a very important role. Antenna is the heart of wireless communication system. Microstrip patch antennas are light in weight, small in size and easy installation make these antenna very popular these days. For designing of these microstrip antennas complex calculations are required. Few years back, Bacterial foraging Optimization has been introduced. Due to poor convergence behavior of BFO for complex problems some modification in chemotactic step size has been adapted under the name of adaptive BFO. In this paper SABFO has been used for designing of rectangular microstrip patch antenna. For different set of parameters, designing of rectangular microstrip patch antenna, have been evaluated. This optimization problem has three variables resonant frequency f_r, dielectric constant ε_r and substrate thickness h. This paper also shows how SABFO is Superior to BFO.

Key Words: Bacterial foraging Optimization (BFO), Self Adaptive Bacterial foraging Optimization (SABFO) rectangular patch, microstrip patch antenna.

I. INTRODUCTION

Microstrip antennas are popular due to light in weight, small in size and easy installation with low cost. Basically Microstrip patch antenna consists of a patch which radiates on a dielectric substrate. The conducting materials like gold or copper are used to make patch and patch can be of any shape like circular, rectangular, triangular, planer, square, etc. Photolithographic technology is mostly used for making radiating patch and feed lines on substrate [9].

These antennas are used at higher or ultra higher frequencies [10]. This paper presents a method to design rectangular patch antenna where optimization problem has three variables resonant frequency f_r, dielectric constant ε_r and substrate thickness h. SABFO algorithm has been developed for obtaining optimal value of antenna parameter like length. SABFO optimizes a problem by maintaining an adaptation in chemotactic step size of bacteria and search space. This adaption in step size of individual bacteria is guided by self adaptive feedback.

II. THEORY OF MICROSTRIP PATCH ANTENNA

Microstrip patch antennas are among the most widely used types of antennas in microwave frequency range, the size of antenna is usually too large to be practical, and other types of antenna such as wire antenna dominate also called patch antennas[7]. One of the advantages of microstrip patch antenna is that it is usually low profile, in the sense that the substrate is fairly thin [8].

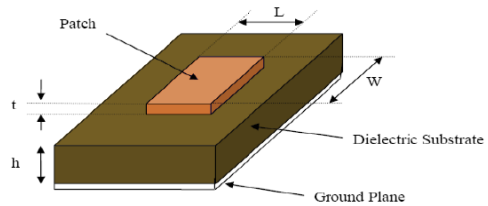


Figure 1 Structure of microstrip patch antenna

III. DESIGN OF RECTANGULAR PATCH ANTENNA

Rectangular microstrip patch antenna having a patch of width W and length L over a ground plane with a substrate of thickness h and relative dielectric constant ε_r [2], [3]and [12] .
Width W of patch:

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Here c is velocity of light and ε_r a relative dielectric constant.
Effective dielectric constant ε_{reff} of the patch:

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1 + \frac{12h}{W}\right)^{-0.5}$$

Resonant frequency f_r of rectangular microstrip antenna:

$$f_r = \frac{c}{2L_{eff}\sqrt{\varepsilon_{reff}}}$$

Increase in patch length ΔL:

$$\Delta L = 0.412\,\frac{h\,(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Effective length L_{eff} :
The resonant length of patch is not exactly equal to the physical length due to fringing field on the sides of patch.
Effective length L_{eff} of patch is longer than its physical length and is given as:

$$L = (L + 2\Delta L)$$

Actual length of Patch :

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}\sqrt{\mu_0\varepsilon_0}}} - 2\Delta L$$

IV. BACTERIAL FORAGING OPTIMIZATION

Bacterial Foraging Optimization, proposed by passion [11], which is a recently introduced soft computing technique and is inspired from the E.Coil bacteria behavior . the three basic events used to describe BFO algorithm are Chemotaxis, reproduction and elimination-dispersal. In BFO the chemotactic step size is uniform hence BFO algorithm possesses poor convergence behavior for high dimensional complex problems as search spaces increases [1].

V. SELF-ADAPTIVE BACTERIAL FORAGING OPTIMIZATION

In this algorithm the run length of individual bacteria has changed itself based upon the feedback by its own. The bacterium has change its run length as well as it position for batter results[6].
A balance between these two state can be achieved by using feed from current search of individual bacterium whether the run length of individual bacterium increase or decrease to that particular search area. The variation of run length is on fitness function improvement means best results found or not in that particular direction.
Criterion -1:If the bacterium found best results (minimum fitness function) then run length of this bacterium has been modified to smaller than present run length. Hence find best and accurate result.
Criterion -2 :If bacterium did not find best results (unchanged fitness) for number Ku (user defined) of consecutive generations, then run length of this bacterium has been modified to larger than present run length. As reproduction elimination and dispersal events increased the convergence increased hence better results [4],[5].

VI. SABFO BASED OPTIMIZATION OF PATCH LENGTH

The length of patch of rectangular microstrip antenna as an optimization problem and defined as follows: ε_{reff} is effective dielectric constant of the patch and L_{eff} is effective length of patch of rectangular patch antenna, the optimum value Leff of such that the frequency of antenna becomes resonance frequency. So the objective function z is:

$$z = \text{abs}\left(f - \frac{c}{2L_{eff}\sqrt{\varepsilon_{reff}}}\right)$$

The objective is to minimize z, such that effective length Leff of patch of the rectangular microstrip antenna is calculated.

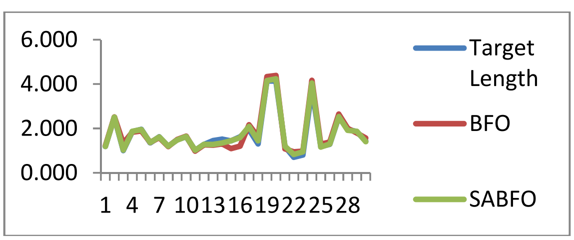
VII. RESULTS AND DISCUSSION

To illustrate the effectiveness of proposed technique SABFO over BFO for calculating the length of patch of rectangular microstrip patch antenna. Both BFO and SABFO are initialized using same number of bacterium, chemotactic steps, reproduction events and Elimination and dispersal events. Now considering a set of input parameters like Resonant frequency f_r, a substrate of thickness h and relative dielectric constant ε_r. It is observed that the value of length measured by SABFO is more close to the target value as compare to BFO. SABFO shows less convergence error but take more time for convergence than BFO.

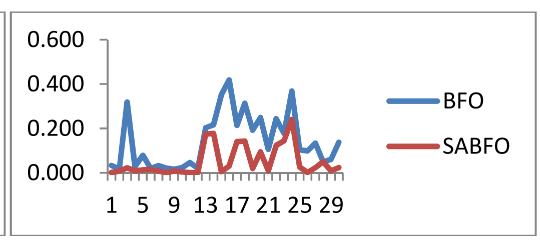
Table1. Comparison of SABFO & BFO (a) target Length (b) error in Length (c) Convergence time (d) Convergence Error.

S.No.	fr(hz)	P	h (cm)	Target value	Measured Length		Error in Measured Length by		Conergence time(in sec) by		Convergence error by	
				Length	BFO	SABFO	BFO	SABFO	BFO	SABFO	BFO	SABFO
1	8.450	2.22	0.017	1.185	1.218	1.187	0.033	0.001	7.944	10.904	0.037	0.015
2	3.970	2.22	0.017	2.500	2.517	2.507	0.017	0.007	7.933	8.087	0.007	0.004
3	4.600	10.2	0.127	1.000	1.319	1.022	0.319	0.022	7.729	7.907	0.018	0.017
4	5.060	2.33	0.157	1.860	1.832	1.869	0.028	0.009	7.899	7.942	0.006	0.006
5	4.805	2.33	0.157	1.960	1.882	1.947	0.078	0.013	7.734	7.915	0.009	0.005
6	6.560	2.55	0.163	1.350	1.369	1.365	0.019	0.015	7.700	7.894	0.024	0.009
7	5.600	2.55	0.163	1.621	1.589	1.613	0.032	0.008	7.780	7.968	0.012	0.006
8	7.050	2.55	0.242	1.200	1.179	1.200	0.021	0.000	7.833	8.085	0.009	0.010
9	5.800	2.55	0.252	1.485	1.501	1.477	0.016	0.008	7.769	7.978	0.014	0.007
10	5.270	2.50	0.300	1.630	1.653	1.634	0.023	0.004	7.732	7.946	0.013	0.008
11	7.990	2.50	0.300	1.018	0.972	1.018	0.046	0.000	7.847	7.915	0.016	0.017
12	6.570	2.50	0.300	1.280	1.260	1.281	0.020	0.001	7.881	7.879	0.010	0.012

13	6.070	2.55	0.450	1.450	1.247	1.276	0.203	0.174	7.787	7.986	0.010	0.008
14	5.820	2.55	0.476	1.520	1.304	1.343	0.216	0.177	7.875	8.089	0.013	0.004
15	6.380	2.55	0.476	1.440	1.089	1.445	0.351	0.005	7.781	7.288	0.013	0.081
16	5.990	2.55	0.550	1.620	1.201	1.590	0.419	0.031	7.756	7.953	0.009	0.003
17	4.240	2.33	0.318	1.950	2.164	2.090	0.214	0.140	7.717	7.862	0.006	0.000
18	5.840	2.33	0.318	1.300	1.613	1.443	0.313	0.143	7.946	7.805	0.009	0.009
19	2.228	2.50	0.152	4.140	4.332	4.160	0.192	0.020	7.742	7.964	0.001	0.002
20	2.181	2.50	0.152	4.140	4.389	4.234	0.249	0.094	7.761	7.936	0.001	0.001
21	7.730	2.55	0.073	1.183	1.077	1.193	0.106	0.010	7.734	7.931	0.025	0.001
22	9.140	2.33	0.318	0.700	0.944	0.823	0.244	0.123	7.765	8.044	0.038	0.037
23	8.270	2.33	0.318	0.800	0.977	0.944	0.177	0.144	7.765	8.019	0.121	0.026
24	2.310	2.33	0.318	3.800	4.169	4.040	0.369	0.240	7.969	7.969	0.002	0.002
25	8.450	2.22	0.017	1.184	1.288	1.159	0.104	0.025	7.844	7.993	0.036	0.029
26	7.740	2.22	0.017	1.290	1.388	1.291	0.098	0.001	7.805	8.119	0.023	0.001
27	3.970	2.22	0.079	2.510	2.644	2.533	0.134	0.023	7.807	7.979	0.002	0.001
28	4.805	2.33	0.016	1.961	2.010	1.911	0.048	0.050	7.797	7.948	0.018	0.001
29	5.060	2.33	0.016	1.860	1.800	1.869	0.060	0.009	7.788	7.943	0.006	0.003
30	6.200	2.55	0.020	1.429	1.567	1.406	0.138	0.024	7.784	8.559	0.042	0.004



(a)



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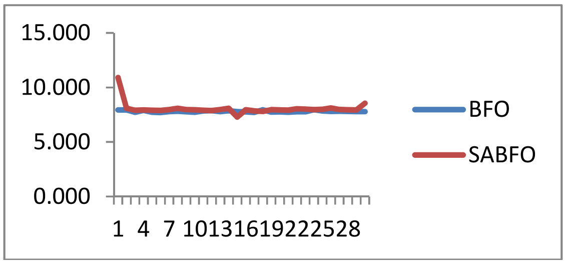

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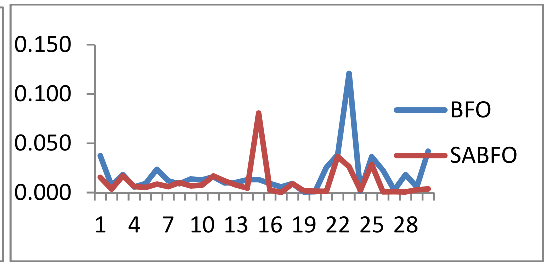

(d)

Figure 2 Comparison of SABFO & BFO (a) target Length (b) error in Length (c) Convergence time (d) Convergence Error.

VIII CONCLUSION

In this study, for given values resonant frequency and substrate, calculation of the optimum rectangular microstrip antenna dimension (Length) is time consuming process. However, Convergence time is more in SABFO but convergence error is less than BFO.

It can be concluded from the table that the optimum length of rectangular microstrip antenna for SABFO is much closer to formulated length. This shows that the optimum length of rectangular microstrip antenna is computed more accurately by using SABFO as compare to BFO.

Hence, application of SABFO for this purpose seems to be an accurate and simple method This might helps to facilitating improved antenna design, specially for small microstrip antenna a where length and width of patch are to be adjusted simultaneously in order to achieve the required resonant frequency.

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