Prediction of Resonant Frequency of Spiralled Swastika Slotted Antenna using ANN-BFO for WLAN Applications

Saroop Singh*, Chahat Jain**, Nancy Gupta***, and Gurjot Walia**
*PG Student, GNDEC, Ludhiana
Saroopsingh65@gmail.com
** Assistant Professor, GNDEC, Ludhiana
Chahatjain26@gmail.com
*** Assistant Professor, CTIEMT, Jalandhar
Nancy.gupta24@gmail.com

Abstract: In today's life, wireless communication has become an essential part of life. So to achieve efficient wireless communications, efficient radiators are required. The antenna is crucial component for wireless communication which must be of small size and less weight as per recent trends. In this paper, a spiralled swastika slotted antenna along with ANN model is proposed for parameters estimation, the ANN model uses 'traingd' function based training model named Gradient-Descent back propagation BPNN model algorithm. The tool in Zealand software namely IE3D is used to simulate and design a coaxial fed Micro-strip patch antenna resonating in the vicinity of 3-6GHz. This band is used for unlicensed WPAN (Wireless Personal Area Network) Bluetooth applications. ANN (Artificial Neural Network) tool is used to calculate the corresponding resonance of antenna which is further optimized with BFO (Bacterial Foraging Optimization) algorithm. ANN shows the close approximation results as compared to the results simulated in IE3D software. The ANN-BFO algorithm assists in locating appropriate feed locations so as to resonate the designed antenna structure at desired resonant frequency. Thus, the paper presents the accurate prediction of resonant frequency of antenna by using ANN-BFO algorithm.

Keywords: Microstrip patch antenna, Spiral Swastika Slot, Bacterial foraging optimization, resonant frequency, Artificial Neural Network.

Introduction

Wireless communication has grown at a very rapid pace across the world over the last two decades. This provides greater flexibility in communication infrastructure. Wireless communication has become an essential part of life of human beings [1]. With development of communication equipment like mobiles, laptops, antennas of low profile and compact size are needed. For long distance communication the use of wired technology has been impossible. The research for transmission over long distances and new concept of wireless communication came due to drawback of wired technology. The EM (electromagnetic wave) is used for the communication field which replaced wired technology to wireless technology. Smart cities need to be equipped with highly effective communication systems and patch antennas have huge potential to minimize spatial problems and thus providing a highly efficient communication system. In the last two decades a revolutionary growth has been undergoing in the field of wireless communication like 2G-cellular communication, 3G-bluetooth, LAN etc [5]. The modern telecommunication systems prefer antennas which have wider bandwidth and smaller dimensions. The concept of new design of antennas has been introduced with the evolution of antenna theory. So day by day as the demand for wireless technology has increased, new category of antennas is designed by the antenna designers by which the structure of antenna have been miniaturized and fit into the ever shrinking devices and applicable to various wireless standards across the world. Patch antenna is a low profile antenna that has some attractive properties such as robustness, small in size and offers relatively high gain and photolithographic technique is being used to fabricate. In communication systems, the patch antennas are extensively used and thus are found in wide range of applications in the field of aeronautics and missile [3]. Generally a patch antenna is designed to operate at a particular frequency and the operational frequency is decided by the antenna specifications. Patch antennas are easily fabricated by using printed technology and this also helps in reducing manufacturing cost. The miniaturization of antenna and enhancement of bandwidth is obtained by adjusting the cut slot in the ground plane and the patch. So to increase the gain, radiation pattern, bandwidth, return loss, impedance matching and antenna efficiency different slot techniques are used. For a wireless telecommunication device that support high mobility, a lightweight and small size antenna is likely to be preferred which easily fit into the device. The compact patch antenna is one of the most suitable applications for this purpose. There are various shapes of patch antenna such as square, rectangle, pentagonal, triangle, elliptic, ring etc [7].

Artificial Neural Network

Artificial neural network (ANN) is one of the mathematical models that can be used like a human brain. ANN can be treated as one of the most intelligent techniques that can be used to solve many problems in the field of engineering and mathematics [2]. In many applications where ANNs have become very common like in a broad domains including medical, industrial and financial applications. Due to their learning ability, neural networks are one of very promising techniques that can be used for antenna applications, specifically for antenna designing and analysis. To simulate the features and behaviors of the antenna arrays the artificial neural network (ANN) is a powerful computational model that has been successfully used [6]. Neuron is the basic unit in structure of ANN [4]. A number of inputs and single output is considered in a single neuron, by which the weighted sum of all inputs is produced and a function is being evaluated known as squashing function at that weighted sum. To form a layer, a number of neurons are stacked over one another. To make a simple neural network number of different layers can be placed one after the other. By adjusting the weights in accordance to the algorithm chosen, the ANN learns the input. For enhancement of the learning capability of an ANN, in hidden layer the numbers of neurons can be increased. Fig 1 shows the basic model of Artificial Neural Network (ANN) [6].

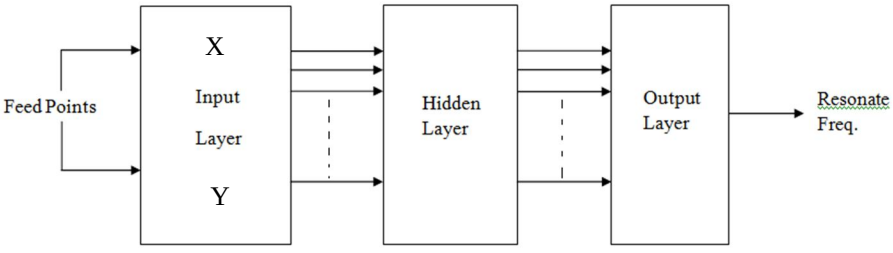

Fig. 1 Basic ANN Model

Fig. 2 shows the steps to be followed to design or train the artificial neural network (ANN)

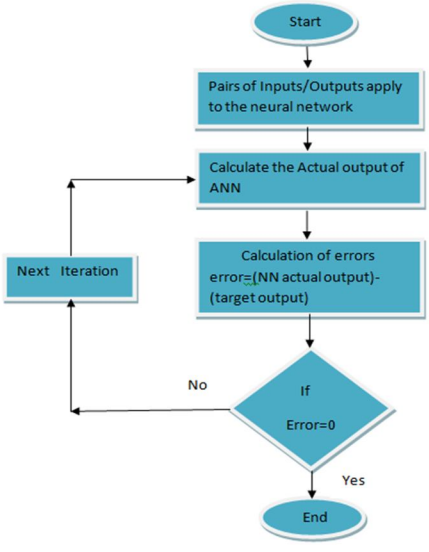

Fig. 2 Flowchart for ANN

BFO (Bacterial Foraging Optimization)

Bacterial foraging optimization algorithm (BFOA) is being widely used as a global optimization algorithm in the field of distributed optimization and control. The social foraging behavior of *Escherichia coli* inspires BFO algorithm and this strategy of foraging can be used as mathematical technique for optimization [12]. Specifically, the chemotaxis behavior of bacteria to explore nutrient food in the search space forms the basic searching strategy in BFO. The chemical gradient is used to perceive the direction of food (nutrient) for movement of bacteria. Similarly, individual bacteria perceive towards each

other by using attracting and repelling chemicals that they secrete, forming swarming behavior. For movement, they use locomotion mechanisms such as chaotical movement (tumbling and spinning) and a directed manner usually referred as swimming. Bacterial cells use perception of food and other cells for movement, and stochastic tumbling and swimming like movement to re-locate. The cells usually search a food source or may repel each other depending on the interactions.
In this algorithm, the cells are allowed to move stochastically and collectively swarm towards optima under the information process strategy. Three processes on a population of simulated cells are used to achieve this: 1) 'Chemotaxis' where the cells cost is rerated by the proximity to other cells and cells move along the manipulated cost surface one at a time, 2) 'Reproduction' where only those cells are used to contribute to the next generation that performed well over their lifetime, and 3) 'Elimination-dispersal' where cells are discarded followed by insertion of new generated random samples with a low probability [12]. Table 1 shows the Initialized parameters required for BFO implementation.

Table 1 Initialized parameters for BFO implementation

Input parameters for BFO algorithm	Parameter values
p, search space dimensions	2
S, number of bacteria	26
N_c, number of chemotactic steps	50
N_{re}, number of reproduction steps	4
N_{ed}, number of elimination-dispersal events	3
N_s, maximum number of swim steps	4
P_{ed}, propability of elimination and dispersal	0.25
Upper bound on search space	11 mm for both x and y feed locations
Lower bound on search space	-11 mm for both x and y feed locations
$d_{attract}$= $d_{repellent}$, depth of attractant and repellent signals	5
$w_{attract}$, width of attractant signals	0.02
$w_{repellent}$, width of repellent signals	0.1

Also, the flowchart shows the steps which are followed to perform the Bacterial Foraging Optimization (BFO) in Fig.3 [10].

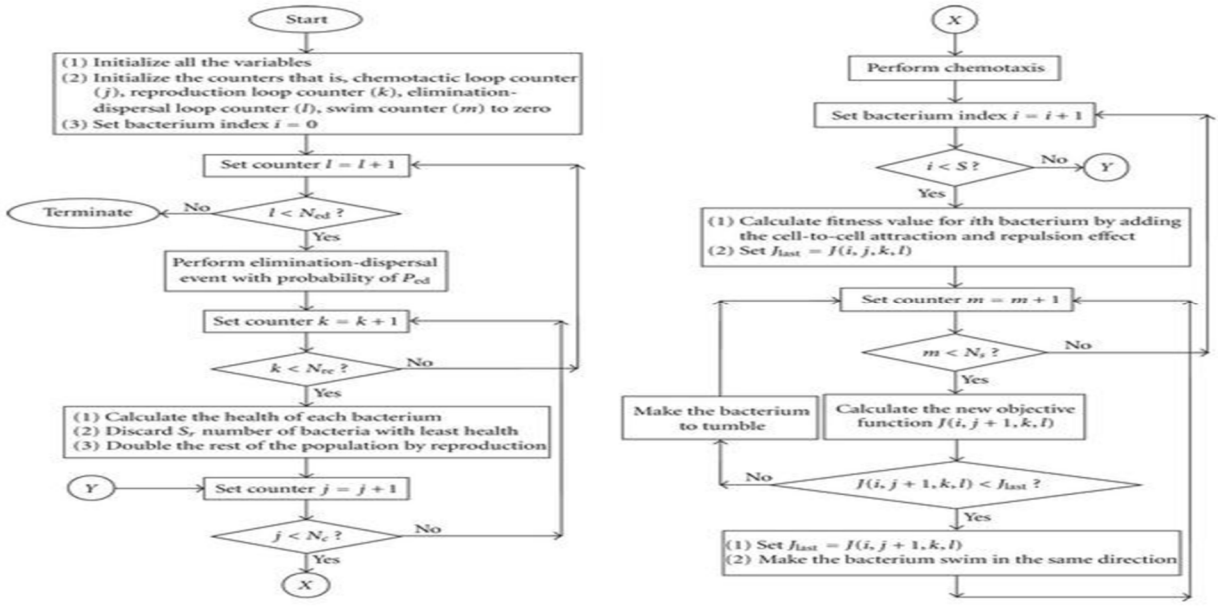

Fig. 3 Flowchart of BFO Algorithm [10]

Work Methodology

In IE3D Software, the designing of spiraled swastika slot patch antenna is simulated. IE3D Software is the tool where the designing and stimulation of the proposed antenna is done. Artificial Neural network (ANN) along with BFO algorithm is

used to find the optimum feed location of the proposed antenna as there are hundreds or thousands of possible feed points on a patch antenna and it is relatively difficult to evaluate performance at every feed point of an antenna manually using hit and trail approach. Thus instead of finding it manually, BFO algorithm is effective alternative to automate the process and locate optimum feed points to achieve desired antenna resonance within 80 training samples. Firstly, ANN with back propagation training algorithm is used as function approximation tool to learn from 80 training samples collected by simulating designed antenna for different feed points. After successful training and testing, the trained ANN model is used as objective function for implemented BFO algorithm in MATLAB, thus obtaining optimum feed locations so that designed antenna may resonate at 5.4 GHz (suitable for WLAN applications).

Simple Planar Antenna Design

In this section, designing of spiraled swastika slotted is discussed. A rectangular geometry of Ls=22 and Ws=22 is created and on which spiral swastika slot is created. The antenna is designed using dielectric material having ε_r of 4.4 and thickness of 1.5mm. The proposed antenna is designed and simulated in IE3D software. This antenna is designed for WLAN applications. The proposed geometry of antenna is shown in Fig. 4.

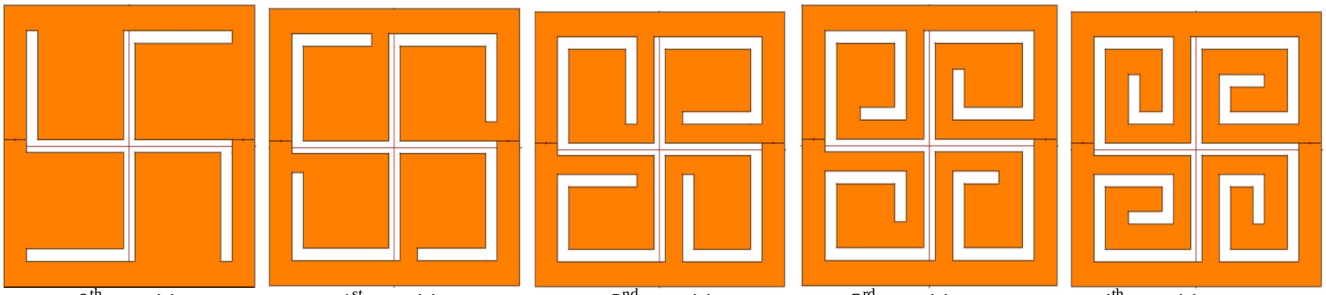

Fig. 4 Proposed geometry of an antenna

In this geometry the basic shape is a swastika slotted antenna is used and number of iterations of slots are performed up to the 4^{th} level to get a final geometry of spiraled swastika slotted antenna. The purpose of these iterations of slots is to get better results of S-parameters, VSWR so that the antenna can resonate in the desired frequency with minimum return loss. The slots in the rectangular geometry have width of 1mm each.

Results and Disscussions

ANN is mathematical model which is used to train the data and give best possible results by adjusting the weights. So ANN (Artificial Neural Network) is a powerful tool that is used to get best possible solution from given set of data. For training the ANN, feed forward back propagation algorithm is used. For training of ANN model, training function named as 'traingd' is used for adjusting the biasing values and weights. This function is named as gradient descent back propagation algorithm. BFO (Bacterial Foraging Optimization) is applied after training of ANN network. By applying BFO algorithm the optimum feed locations is discovered on which the antenna is resonating, Fig.5 shows the S-parameters of SSSA. The optimum feed location which is finding by using BFO is X (9.0477) and Y (5.7664) on which minimum loss of antenna is achieved. The data set which is given to ANN is a set of different feed points of an antenna with different resonating frequencies of antenna. Simulation output is taken from IE3D software tool, which is specially used for antenna designing and simulation. So for training an ANN different feed points is given as input considering X and Y as shown in the Fig. 1. ANN helps to find the frequency which is calculated in IE3D Software by using feed points as input of ANN. The data is given to ANN for its training at different values of feed points of an antenna. Table 2 shows the comparison of ANN output and the antenna simulation outputs, that shows the difference between the ANN output and the output which is taken from IE3D simulation software tool.

S-Parameters (S_{11})

S-parameters is defined as which shows the relationship between input and output ports in an electrical system. So the way of expressing mismatch between power fed to the antenna and power returned by the antenna is called as S-parameters of antenna or Return loss of antenna and it is measured in the units of dB (decibels). Fig.5 shows the S-parameters of SSSA (Spiralled Swastika Slotted Antenna).

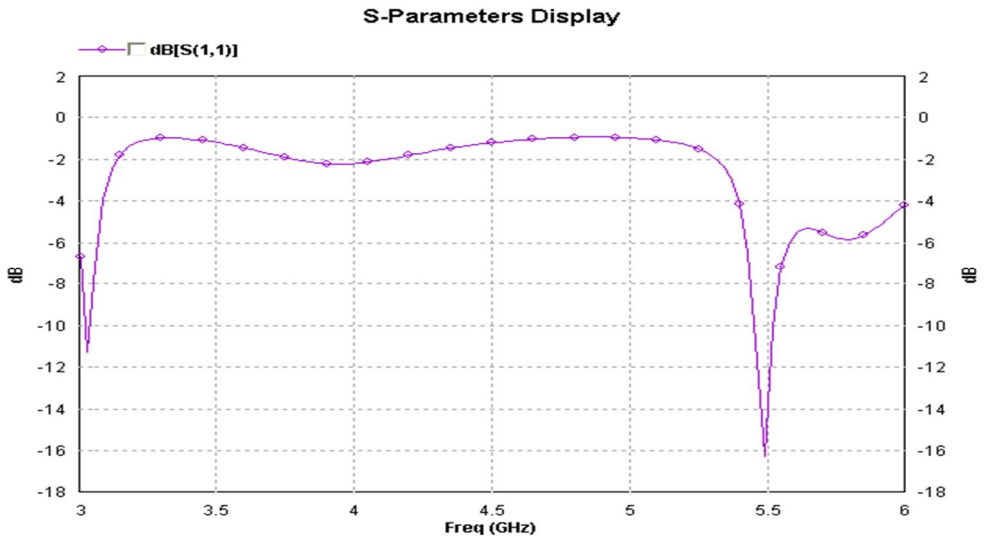

Fig.5 S-parameters of SSSA

Table 2 Analysis of ANN and antenna data set

S. No.	X (Direction)	Y (Direction)	Resonating frequency from Antenna simulation(*fr*)	Resonating frequency from ANN(*fr*)	Error Approx.
1.	0.72	0.92	5.459	5.551	0.092
2.	0.9	1	5.459	5.549	0.09
3.	1.17	1.2	5.451	5.546	0.095
4.	1.32	1.35	5.451	5.451	0
5.	1.45	1.8	5.453	5.482	0.029
6.	1.72	1.15	5.452	5.552	0.1
7.	1.82	1.82	5.453	5.535	0.082
8	3	1.8	5.442	5.455	0.013
9	5.22	6.15	5.365	5.538	0.173
10	3.6	1.72	5.537	5.552	0.015
11	3.8	1.52	5.569	5.548	-0.021
12	4	1.72	5.524	5.552	0.028
13	4.3	0.95	5.556	5.473	-0.083
14	-3.8	1.5	5.453	5.521	0.068
15	-9.15	1.23	5.481	5.552	0.071

Fig. 5 shows the ANN performance plot after training network.

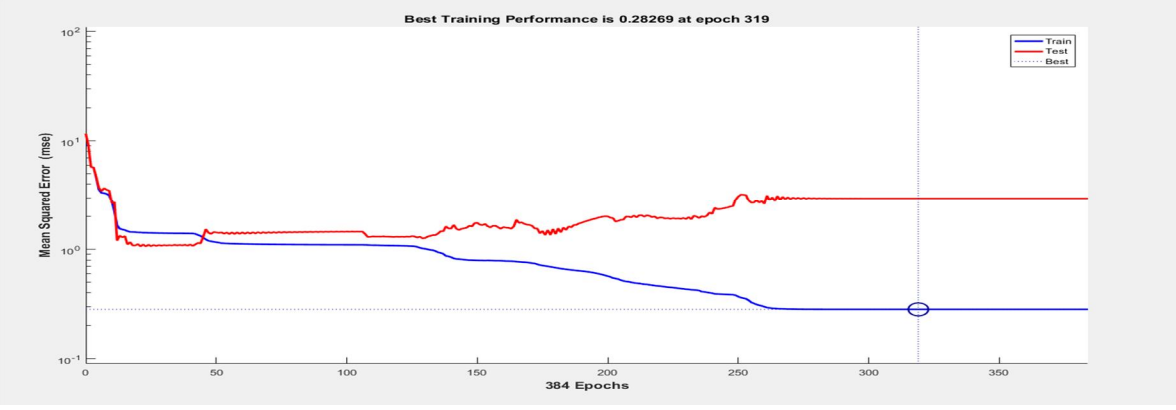

Fig.6 performance plot of ANN

Conclusion

In this paper the simulated results and the ANN results along with BFO algorithm are analyzed which exhibit that gives better response than simulated results. The ANN model is used to analyze the resonating frequency of the patch antenna. Because to analyze the resonance frequency of an antenna manually is time consuming process. The results which are obtained from ANN are compared with the simulated results and it is observed that ANN gives better results and faster response due to its fast adaptive properties, the time required for the simulation is also less due to their attractive properties. From this paper it concluded that the ANN technique gives better and satisfactory response than other experimental trends.

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