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A Novel Approach for Analysis and Optimization of U Slot Microstrip Patch Antenna using ANN and GA

Amarpreet Kaur
M.Tech, ECE Department
LCET Katani Kalan,
Punjab, India

Simranjit Kaur
Assistant Prof, ECE Department
LCET Katani Kalan,
Punjab, India

Abstract: In this paper, coaxial probe feed microstrip patch antenna is designed using IE3D software. Slotting and optimization of antenna has been done using Artificial Neural Network (ANN) and Genetic Algorithm (GA) to improve the performance of antenna. A novel technique is used in which ANN is used as the fitness function of GA in order to obtain the minimum return losses. Optimum radius of circles of the patch antenna are obtained using ANN and GA algorithm in Matlab. Then from these values given by GA; coaxial probe feed patch antenna is designed using IE3D software and then the simulated results from IE3D software are compared with GA results obtained from MATLAB.

Keywords: Microstrip patch Antenna, Coaxial Probe Feed, Optimization, Artificial Neural Network, Genetic Algorithm.

I. INTRODUCTION

Microstrip patch antennas have been one of the most popular antennas that have drawn the attention of industries for an ultimate solution for wireless communication due to their many attractive features, such as low profile planar configuration, light weight, simple and inexpensive to manufacture [1-4]. Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate, which has a ground plane on other side. The patch is generally made of conducting material such as gold or copper [5]. Artificial Neural Networks (ANN) are the models that are inspired by animal central nervous systems; which are capable of machine learning and pattern recognition. It consists of highly interconnected processing elements known as neurons which process information by their dynamic response to external inputs. The neuro models can be used for efficient and accurate optimization and design within the range of training [6]. Optimization means to select the best element from the set of available alternatives. Genetic algorithm (GA) is one of the most effective optimization techniques that have been widely used in antenna synthesis and optimization problems. This is used to find the true or approximate solutions to optimization and search problems.

In this paper, Microstrip patch antenna is designed using Coaxial probe feed. Coaxial feeding technique is one of the most common methods used for feeding microstrip antennas. It can be placed at any desired locations in the patch of antenna and this is easy to fabricate [7]. Slotting is done in the patch of antenna. Data set is obtained from the IE3D toolbox; by changing the radius of the circles of the patch. The Feed Forward Neural Network (FFNN) has been trained using this obtained data set. This trained FFNN network has been used as an objective function for the optimization algorithm i.e. GA. After applying this genetic algorithm; it provides the optimum radius along with the optimum return loss at those values of the radius of the circle. The optimum values of the radius of circle are obtained by the optimization algorithm GA and then these are simulated using IE3D software. The antenna performance is improved by using slotting and optimization technique. Microstrip patch antenna with coaxial probe feed is designed and various parameters of antenna like return loss, gain, VSWR and resonant frequency are studied. This paper demonstrates a specific technique i.e. hybridization of ANN and GA to improve the performance of antenna.

II. METHODOLOGY

STEP 1: Design a microstrip patch antenna using co-axial probe feed. Slotting is done in the patch antenna.

STEP 2: Obtain dataset from IE3D software for training ANN: Using IE3D software, results of antenna is analyzed at different values. A data set for training ANN has been obtained. The different radius of circles (g_p, g_m) in the microstrip patch antenna have been taken as the input parameters for the training of ANN, where g_p represents the radius of outer circle and g_m represents the radius of inner circle. Return loss for the corresponding radius of the microstrip patch antenna has been taken as output.

STEP 3: Training of ANN in MATLAB: A suitable network is selected, in order to train the set of training data. Feed forward neural network (FFNN) is used as an artificial neural network. The network will learn the input output relations. FFNN are one of the popular structures among ANN. These efficient networks are widely used to solve complex problems by modelling complex input output relationships [8].

The obtained data set has been used to train the ANN. To train the network sufficient number of training samples has been used. As shown in Fig. 1; the g_p and g_m is the radius of circle and these are taken as input.

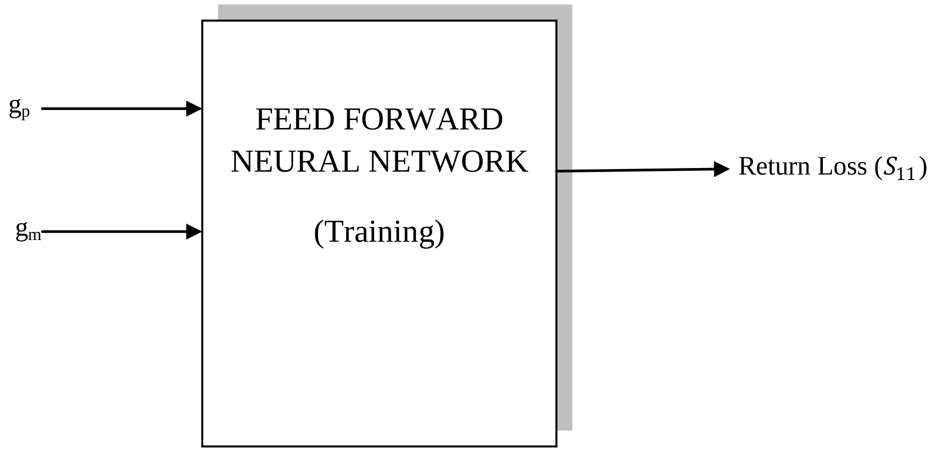

Fig. 1: Training of feed forward neural network

STEP 4: Implementation of Genetic algorithm on MATLAB: Genetic algorithm (GA) is the optimization technique that is used for optimization. GA has been implemented using MATLAB software and ANN is used as a fitness function of GA in order to calculate the design parameters of the microstrip antenna. Here, the trained FFNN is used as a fitness function. GA is used for calculation of optimized dimensions.

STEP 5: Obtain the Optimum values: After implementing the ANN and GA, optimum values are obtained. Using these optimum values, antenna is designed again on IE3D software and results are observed corresponding to these values.

STEP 6: Compare the results: Then the MATLAB results are compared with the results obtained by IE3D in order to get the minimum return loss i.e. optimal return loss. The optimum values given by GA have been compared with the results obtained from IE3D software for the same values and improvement in the antenna performance is observed.

III. ANTENNA DESIGN

The coaxial probe feed microstrip patch antenna is constructed on a substrate RT/duroid having basic parameters i.e. Dielectric constant (ε_r) = 2.2, Loss tangent (δ_d) = 0.0009 and the thickness of substrate is 3.175 mm. The antenna is composed of a rectangular patch with an etched rectangular hole in the centre of the patch. Another rectangular patch is inserted inside the hole. A circular feeding patch is inserted between these two rectangular patches; which is directly connected to the coaxial probe [9].Dimensions of the antenna are as Ws = 45 mm, Ls = 40 mm, Wp = 15 mm, Lp = 10 mm, gm = 0.2 mm, We = 11 mm, Le = 6 mm, Wm = 6.4 mm, Lm = 3.4 mm [9]. The resonance frequency of microstrip patch antenna is 5.74 GHz.

3.1 Coaxial feed Microstrip patch antenna after applying ANN and GA:

For designing this microstrip patch antenna, radiuses of both the circles has been changed and data set has been prepared by simulating it across IE3D software. Matlab software provides an option to perform an analysis between the trained network response and corresponding targets; in order to investigate the performance of the trained network.

Data set: Data sets for training ANN has been prepared by using the IE3D software. The different radiuses of the circle have been taken as the input parameters for training the artificial neural network. Here Feed forward neural network (FFNN) is used. Return loss (S11) for the corresponding radiuses of circle has been taken as the output.

Training the ANN: Data sets obtained by the IE3D software has been used for training the ANN. To train the network sufficient number of samples is used. 100 training samples have been used for this coaxial feed microstrip patch antenna. In this two variables are used as input i.e. gp and gm, which represents the radius of the outer circle and the inner circle respectively.

After training the network, FFNN has been trained by using the data sets that were prepared by using IE3D software; the Genetic algorithm is used to get the optimum values i.e. to get optimum radius for the antenna. When we are applying the GA to antenna, there is no limit to the number of constraints that the designer can set on the antenna design.

The optimization technique such as Genetic algorithm mostly relies upon the objective function, without which the optimization technique has no meaning [10]. ANN is used as a fitness function of the genetic algorithm in order to get the optimum solution. Here Feed forward neural network is used as the fitness function in GA. ANN can be used as the objective function of GA in those cases where the objective function formulation is difficult. In this paper, we use this technique to calculate the optimized radiuses of the microstrip patch antenna, since there we have no closed form mathematical formula. The measure of accuracy of the solution obtained by the GA depends directly upon the efficient training of the neural network [10].

Thus by applying GA we get the optimum value of the radius of the circle. Different values of radiuses of circle are taken and for these different radiuses of the circle, the return loss is measured. The return loss is compared and that value of the radiuses is selected at which the value of return loss is best i.e. most negative. The GA generates population of points at each iteration and the best point in the population approaches an optimal solution. The final radiuses obtained after optimization is 1.427mm and 1.333mm and the objective function value obtained is -43.03 dB approximately.

The coaxial feed microstrip patch antenna with these optimum values of the radiuses is shown in Fig. 2. Slotting is done in the inner patch; U shaped slot is cut in the patch. And using these optimum values of radiuses obtained by applying GA, coaxial feed microstrip patch antenna is designed.

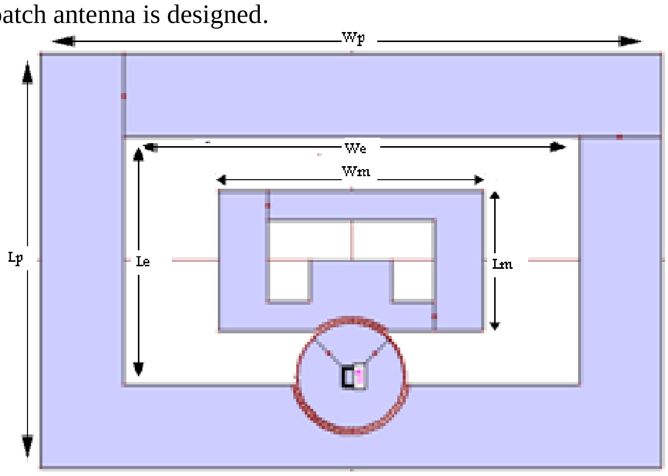

Fig. 2: Coaxial probe feed microstrip patch antenna with optimum radius

IV. RESULTS AND DISCUSSION

The result obtained by simulation using IE3D toolbox of Zeland software; after applying ANN and GA algorithm. These results obtained after applying ANN and GA are in good agreement with the results obtained from Zeland IE3D software. Therefore this provides a noval approach for getting the optimal radiuses of the circle for the coaxial feed microstrip patch antennas, which provides the minimum value of return loss.

Thus using the optimization technique GA, optimum radiuses are obtained for the antenna. The FFNN and GA algorithm has been implemented successfully to obtain the optimum value of radius of circle. The optimum final points obtained by optimization technique GA are shown in Table 1 and the objective function value obtained is -43.03 approximately. By using these dimensions of the radius of circles we have designed the coaxial probe feed microstrip patch antenna using Zeland IE3D software and the value of return loss obtained after simulation is -43 dB. This value of return loss matches with the results provided by the genetic algorithm. Thus the results of coaxial feed microstrip patch antenna obtained after applying the slotting and optimization technique i.e. ANN and GA are better than the results of antenna before applying ANN and GA.

Table 1: Values of radius of circle provided by GA

Outer circle (gp)	1.427
Inner circle (gm)	1.333

Return Loss

The scattering parameter S11for the designed antenna is calculated and value of return loss obtained before applying GA is -28 dB, which shown in Fig.3 and value of return loss obtained after applying GA for the designed antenna is -43 dB, shown in Fig.4.

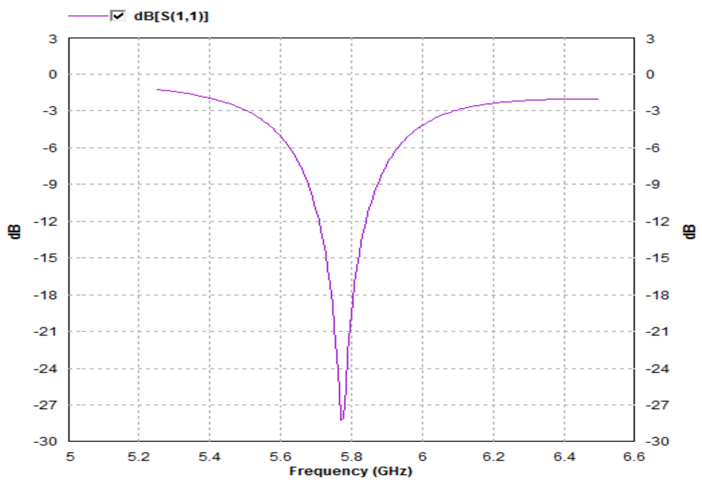

Fig. 3: Return loss obtained before applying GA

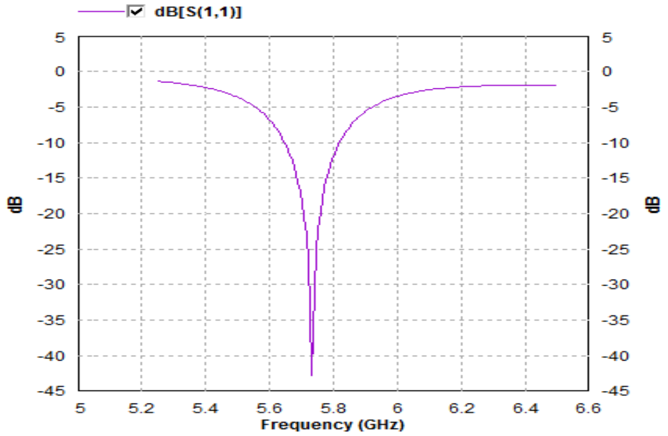

Fig. 4: Return loss obtained after applying GA

Gain

Gain of an antenna is the key performance figure that combines antennas directivity and electrical efficiency. The gain plot of coaxial probe feed microstrip patch antenna is shown in Fig. 5. The measured gain of antenna is 6.5 dB.

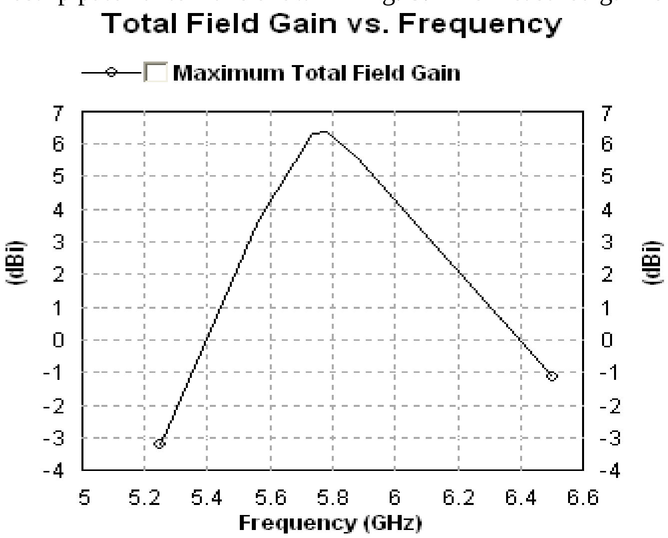

Fig. 5 : Gain plot of coaxial probe feed microstrip patch antenna

VSWR

VSWR is a measure of how well an antenna is matched to the feed line it connects to. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. The VSWR plot for coaxial probe feed microstrip patch antenna is shown in Fig. 6. Ideally, value of VSWR must lie in the range of 1 to 2. The value for VSWR is 1.035.

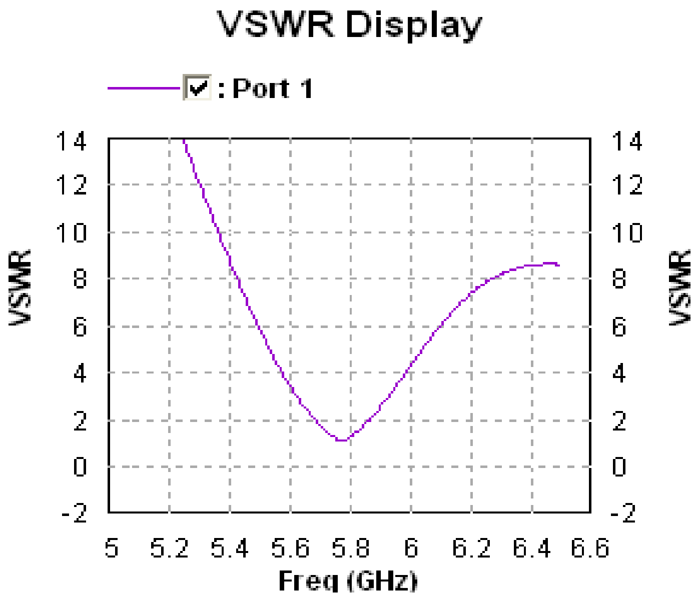

Fig. 6: VSWR plot of coaxial probe feed microstrip patch antenna

The comparison between the different parameters of antenna before applying the genetic algorithm and after applying genetic algorithm is shown in the table 2.

Table 2: Different antenna parameters before and after applying GA

Parameters	Before applying GA	After applying GA
Return Loss	-28 dB	-43dB
Gain	4.7	6.5
VSWR	1.191	1.035
Impedance	50 Ω	50 Ω

V. CONCLUSION

The design of coaxial feed microstrip patch antenna has been completed using Zeland IE3D software. In this a novel technique of artificial neural network (ANN) as a fitness function of a genetic algorithm (GA) is used in order to calculate the optimized radiuses of circle of the coaxial feed microstrip patch antenna. GA is used to solve problems in many applications due to its parallel architecture and probabilistic and deterministic nature. Optimization technique such as GA relies upon the objective function without which the optimization is not possible. Here feed Forward Neural Network (FFNN) is used as fitness function in GA and the accuracy of the results obtained by GA depends upon the efficient training of the neural networks. In case where there is no accurate theoretical formulation, ANN can be used as an objective function for the optimization purposes. The results obtained after applying slotting and the optimization technique GA are in very good agreement with the results obtained before applying ANN and GA i.e. the results obtained by using the IE3D software.

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