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DESIGN OF RECTANGULAR PATCH ANTENNA USING MLP ARTIFICIAL NEURAL NETWORK

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Abstract:-This paper presents the designing of a rectangular microstrip antenna using Multi Layer Preceptron (MLP) neural network model. The model was trained for 40 set of input-output (length of patch-resonant frequency) parameters. The output error and time delay (no. of epochs) were optimized by changing the learning rate and momentum term. In case of testing the output of the present model (resonant frequency) is found in good agreement with theoretical results.

Index terms: MLP, microstrip antenna, neural network

INTRODUCTION

Present-days mobile communication systems usually require a portable wireless antenna size in order to meet the miniaturization requirements of mobile units. A conventional microstrip patch antenna which is one of the best suitable antenna for mobile communication due to its attractive features of low profile, light weight and easy fabrication. In general, it has a conducting patch printed on a grounded microwave substrate. The most commonly employed microstrip antenna is a rectangular patch antenna which shows narrow bandwidth and wide beamwidth characteristics. To overcome these problems different types of structures (regular and irregular shapes) were proposed and studied theoretically / experimentally in the processes of the development of microstrip antenna [1].

The bandwidth of the rectangular microstrip antenna is very narrow, so the resonant frequency of microstrip antenna can be accurately determinable. There are two different ways to analyze microstrip antenna namely analytical method and numerical method. Analytical methods as compared to Numerical methods are easy but only restricted to some definite shapes. On the other hand, numerical methods are complicated and require more time to solve, but are applicable to any shape. So to eradicate these problems researchers use neural models which is applicable to any shape, any complicated circuits and it also take less time with more accuracy.Various ANN models are developed for determining resonant frequencies of microstrip patches of various shapes like rectangular, triangular etc.[2-3] and [4-5]. In [6-7], several designs have been presented using ANN techniques. A comprehensive review of applications of ANN in microwave engineering and different types of methods to develop the ANN models is discussed in [7].

In this paper we optimized output error and time delay of a rectangular microstrip antenna by varying learning rate and momentum term of the MLP neural network model.

THEORY

Structure and Formulation

The geometry and various parameters of the proposed antenna are shown in Figure 1. Consider a rectangular patch of width of W and length L, both comparable to $\lambda_s/2$, over a ground plane with a substrate of thickness h and are relativity permittivity ε_r. The resonant frequency f_{mn} of the antenna can be evaluated from [8]

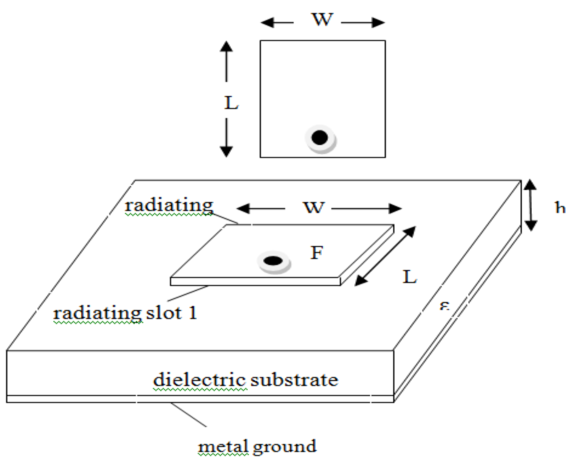

Figure 1: Rectangular microstrip antenna

$$f_{mn} = \frac{c}{2(\varepsilon_e)^{1/2}}\left\{(m/L_e)^2 + (n/W_e)^2\right\}^{1/2} \quad (1)$$

Where ε_e is the effective relative permittivity for the patch, C is the velocity of electromagnetic waves in free space, m and n take integer values, and L_e and W_e are the effective dimensions. To calculate the resonant frequency of a rectangular patch antenna driven at its fundamental TM_{10} mode, eqn. 1 is written as:

$$f_{10} = \frac{c}{2(\varepsilon_e)^{1/2} L_e} \quad (2)$$

The effective length L_e can be defined as follows:

$$L_e = L + 2\,\Delta L \quad (3)$$

The effects of the nonuniform medium and the fringing fields at each end of the patch are accounted by the effective relative permittivity ε_e and the edge extension ΔL, being the effective length to which the fields fringe at each end of the patch. The following effective–relative- permittivity expression proposed by Schneider [9] and edge extension expression proposed by Hammerstad [10] can be used in eqns. 2 and 3:

$$\varepsilon_e(w) = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 10h/W}} \quad (4)$$

$$\Delta L = 0.412\,h \frac{\{\varepsilon_e(W) + 0.300\}(W/h + 0.264)}{\{\varepsilon_e(W - 0.258)\}(W/h + 0.813)}$$

(5)

Amore accurate resonant frequency formula suggested by James et al.[11] is given by

$$f_{r1} = f_{r0} \frac{\varepsilon_r}{\sqrt{\varepsilon_e(W)\varepsilon_e(L)}} \frac{1}{(1+\Delta)} \quad (6)$$

$$\Delta = \frac{h}{L}\left[0.882 + \frac{0.164(\varepsilon_r - 1)}{\varepsilon_r^2} + \frac{(\varepsilon_r + 1)}{\varepsilon_r \pi}\left\{0.758 + Ln\left(\frac{L}{h} + 1.88\right)\right\}\right]$$

(7)

and

$$f_{r0} = \frac{c}{2L\sqrt{\varepsilon_r}} \quad (8)$$

Microstrip and Artificial Neural Network Method:

In this work an artificial neural network model in introduced for the efficient calculation of Resonant Frequency of rectangular microstrip antenna, The multilayer perceptron network is selected due to its simplest form and therefore most commonly used artificial neural network architectures have been updated for the calculation of the resonant frequency of rectangular microstrip antenna, in our paper the standard back propogation algorithm has been used for training, an multilayer perceptron consist three layers: an input layer, an output and an intermediate or hidden layer. Processing elements or neurons in the input layer only act as buffers for distributing the input signals x_i to processing elements in the hidden layer. Each neurons or processing element in the hidden layer sums up its input signals x_i after weighting them with the strengths of the respective connections w_{ji} from the input layer and computes its output y_j as a function of the sum, namely [12-14].

$Y_j = f\,(w_{ji}.\,x_i)$ (9)

Then f can be simple threshold function, a sigmoidal or hyperbolic tangent function. The output of processing elements or neurons in the output layer is computed similarly. With training our artificial neural network consist of adjusting weights of artificial neural network with the use of the standard back propagation algorithm, the result of training that is our consequent resonant Frequency of rectangular microstrip antenna, all the results that have been obtained from mathematical formula and our trained artificial neural network that is shown in Figure 2, [15-16].

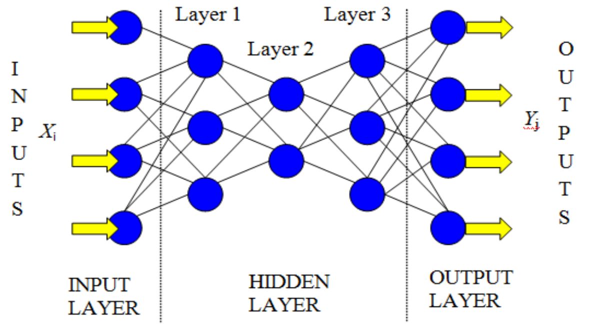

Figure 2: Generalized Structure of Multi Layer Perceptron (MLP) Neural Network Model

RESULTS AND DISCUSSION

The study was undertaken with overall objective to investigate the response of neural network to error percentage and number of epochs .The results obtained from the study has been classified into three main sections. The first section deals with the estimation of time period which varies with different number of epochs. The second section deals with the number of epochs with error percentage. The estimated number of epochs has been used to determine the error percentage of neural network. The third section shows the relationship between Patch length and resonant frequency of Microstrip Antenna.

Time Vs Epochs:

The relationship between the time taken to train the neural network and different numbers of epochs are presented in figure5. Neural Network shows when the number of epoch was 20,000 to train the model, time required was 4 second. The result revealed that the rate of increment of epoch and the rate of increment of time must be in accord. Now when the epoch is increased to 50,000 the time required was 12.5 second which is considerable in accordance with the previous result. But when neural network deals with 2, 00,000 epochs the time required is very high i.e. 390 second. This is not permissible because the rate of increment of epoch is 10 times and the rate of increment of time is 86 times which is not in accordance with rate of increment of epochs. It makes learning rate more and more time consuming so it should be cleared with the consideration of time delay as well as tendency of training of neural network.

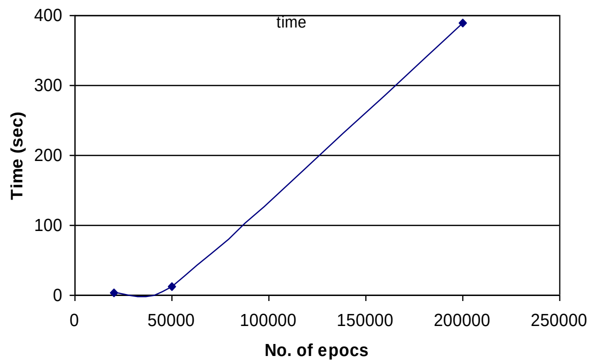

Figure: 5 Variation of percentage of time with no. of epochs.

Number Of Epochs Vs Percentage Error:

Figure 6 shows the error percentage with different number of epoch to train neural network. In this project the percentage error which is permissible is 1%, above this error the system would not be considered good. It is obtained when the epoch was 20,000 the error found was .45%, for 50000 epochs error found was .37% and for 2, 00,000 epochs the error found was 0.21%. It is observed that with more epoch, error % decreases but very eventually the rate of decrement of error with increment epoch are not in judgment. The number of epochs when increased to 2.5 times, the error decreased was not even half and

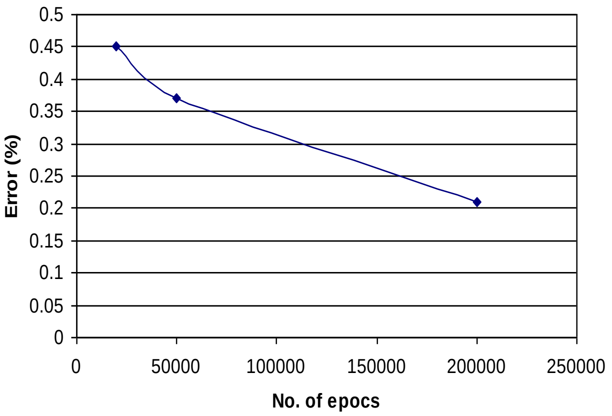

Figure: 6 Variation of percentage of error with no. of epochs.

when the epoch was increased to 10 times the error should be reduced to 8 to 10 times (permissible) and it also consumes much time to be trained. So consumption of more time and epoch do not produce reciprocated change in error %. So the consideration of best epoch is first and foremost for the betterment of neural network.

RESONANT FREQUENCY WITH PATCH LENGTH

The relationship between the resonant frequency and patch length are presented in figure 7. The top most line in the graph is the desired value. The result revealed that when the no. of epochs increase the graph shifts towards desired value.

Compute review of three graphs shown in figure 5 to 3 reveals that 20000 epochs give the time delay of 4 sec, 50000 epochs gives the time delay of 12.5 sec but for 200000 the time delay goes to 390 sec. Similarly the error also does not reciprocate in the same fashion. For 20000 it is 0.45%, for 50000 it is 0.35% and for 200000 the error is 0.21%.

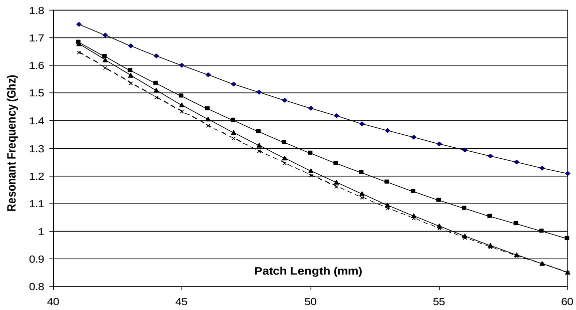

Figure: 6 Variation of Resonant frequencies with patch length.

Finally it is observed that for 200000 epochs the error is not showing the steep fall desired although the time taken is more and more. The only advantage gained is that with more epochs the resultant line approaches more towards the desired value line.

CONCLUSION

We have presented a multilayer perceptron based neural network model to optimize the design parameters of a rectangular microstrip antenna with better accuracy and less delay time.

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