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MLP Neural Network Employment in the Design of Rectangular Patch Antenna

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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

I.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.

II. THEORY

A. 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]

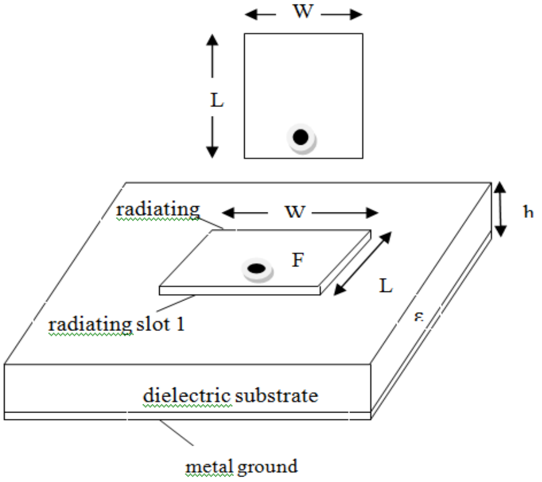

Figure 1: Rectangular microstrip antenna

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

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:

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

The effective length L_e can be defined as follows:

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

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:

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

$$\Delta L = 0.412h \frac{\{\varepsilon_e(W) + 0.300\}(W/h + 0.264)}{\{\varepsilon_e(W - 0.258)\}(W/h + 0.813)} \tag{5}$$

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

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

$$\Delta = \frac{h}{L}\left[0.882 + \frac{0.164(\varepsilon_r - 1)}{\varepsilon_r^2} + \frac{(\varepsilon_r + 1)}{\varepsilon_r \pi}\left\{0.758 + Ln\left(\frac{L}{h} + 1.88\right)\right\}\right] \tag{7}$$

and

$$f_{r0} = \frac{c}{2L\sqrt{\varepsilon_r}} \tag{8}$$

B. 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].

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

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].

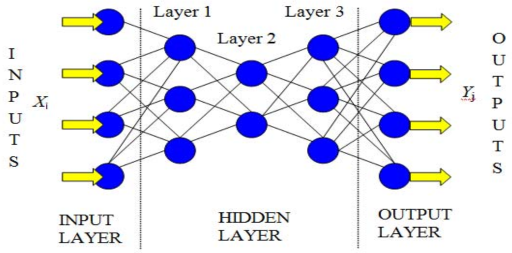

Figure 2: Generalized Structure of Multi Layer Perceptron (MLP) Neural Network Model

III.RESULTS AND DISCUSSION

In this paper two variables (Learning Rate and Momentum Term) of Multi Layer Perceptron model varied in the range of 0.2 to 1 to optimize output error and delay time (no of epochs). From Figure 3 it is observed that initially (when no of epochs are 10000) output error is minimum (approximately 3.7%) for learning rate=1. On the other hand, for lower values of learning rate it is observed that output increased up to 4.8%. We also observed that for any constant learning rate percentage output error decreases rapidly with momentum term except for learning rate α = 0.8.

Figure 4 shows relation between output frequency and patch length for 50000 epochs. In this Figure, it is observed that the results obtained by the multilayer perceptron neural network model are best optimized when learning rate=1 and momentum term is α = 0.8. The maximum output error obtained in this case is 4% which is under the tolerance limit.

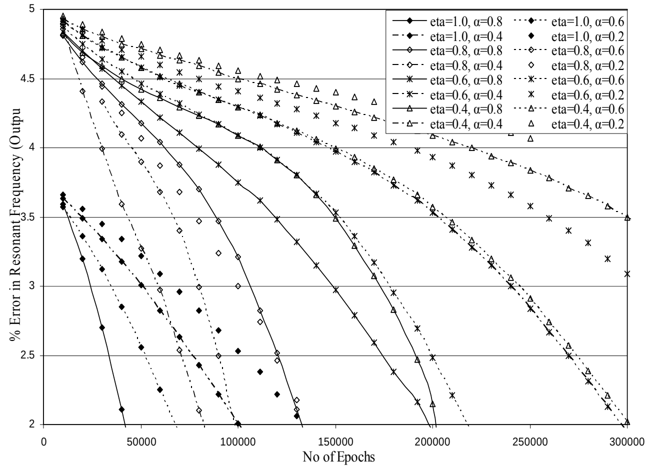

Figure 3: Variation of percentage error on resonant frequency with no. of epochs for different values of learning rate (eta) and momentum term (α).

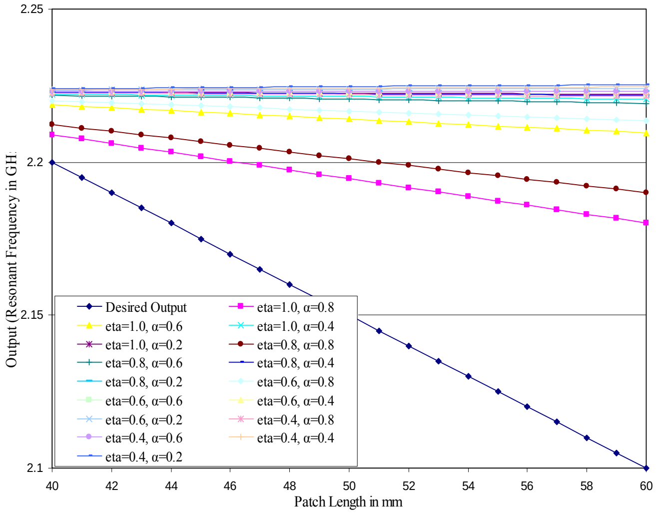

Figure 4: Variation of resonant frequency with patch length (no. of epochs=50000) for different values of learning rate (eta) and momentum term (α)

IV.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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