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Study of Multilayer Perceptron Neural Network for Antenna Characteristics Analysis

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Abstract— Microstrip antenna (MSA) has gained very much importance these days because of its low cost, small size & wide frequency operation for different bands. In the paper, Microstrip antennas are studied and various parameters like resonant frequency, substrate material & width of patch are used for training and testing of Multilayer Perceptron Neural Network(MLPNN). A set of dielectric constant, width & height of Antenna are taken as input & resonant frequency is considered as an reference. Analysis of this parameters on resonant frequencies is done with the use of Multilayer Perceptron Neural Network. It is found that Multilayer Perceptron Neural Network gives the minimum error and the results of MLPNN can be used as input for design parameters of MSA which will definitely gives us the close approximation between resonant frequency & design.

Keywords— Microstirp Antenna, Resonant frequency, Substrate Material, width of patch, Multilayer Pereptron, Neural Network, design

I. Introduction to Antenna

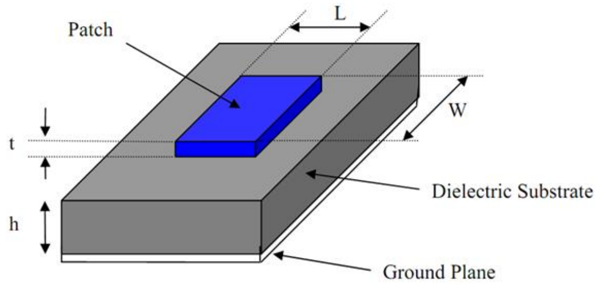

Fig 1. Basic Structur of a Microstrip Antenna

Basic structure of antenna consist of conducting patch which is a substrate covered by conducting plane known as ground plane. Substrate material has particular dielectric constant value which affects the field generated by radiating patch contributing to fringing field. More the dielectric value, more field will confined to substrate. Length by width ratio of MSA should be less than unity so as to reduce the fringing field effect to contribute for radiation.[1][3] Losses and gain are major problems in the MSA. Loss in MSA can be overcome by proper impedance matching between patch (radiating element) and feed of MSA. A little variation in matching technique causes significant effect on antenna characteristics. For better matching a 50ohm feed line is to be maintained where some of techniques are variation of gap between feed and patch, patch & ground etc. Improvement of gain can be done by using reflecting material as ground plane or printing through hole (PTH) technique etc.[5][8]

II. Introduction to MLP

The following diagram illustrates a perceptron network with three layers:

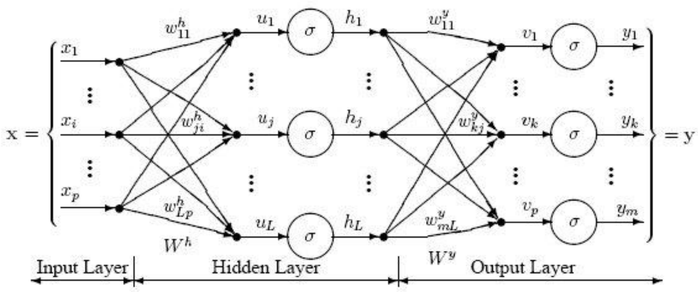

Fig 2: Representation of MLP

The multilayer perceptron neural network Model consists of three layers. First layer is input layer, the middle layer is hidden layer and the last layer is output layer, each consisting of three neurons as shown in figure. All the layers can consist of 'n' neurons. All the neurons of the input layer are connected to the middle layer neurons. The output of hidden layer neurons are connected to output layer neurons. The weights by which they are all connected are adjustable and adapt according to the inputs fed and trained.[2] Input layer consists of vector($x_1...x_p$) which is fed as an input. The value of each variable is standardized between -1 to 1. A constant input called the BIAS of value 1.0 is fed to each of the hidden layers; the bias is multiplied by a weight and added to the sum going into the neuron. At the hidden layer, the value from each input neuron is multiplied by a weight (w_{ji}), and the resulting weighted values are added together producing a combined value u_j. The weighted sum (u_j) is fed into a transfer function, σ, which outputs a value h_j. The outputs from the hidden layer are the fed to neurons of the output layer. At output layer, each value resulting from hidden layer is multiplied by weight (w_{kj}), and the resulting weighted values are added together producing a combined value v_j. The weighted sum (v_j) is fed into a transfer function, σ, which outputs a value y_k. The output of the model is 'y'. The weights between the input and hidden units determine when each hidden unit is active, and so by modifying these weights, a hidden unit can choose what it represents.[3][4][2]

III. TRAINING MULTILAYER PERCEPTRON NETWORKS

The main purpose of training the neural network is to find the set of weights which will approximate the output of the neural network very close to the target values. Hence its very important to decide how many hidden layers are required, how many neurons are to be used in each layer etc. In most of the neural networks, only a single hidden layer is used. Two or more hidden layers are used for modeling the data with discontinuities. Using two or more hidden layers have no prominent effect on the results instead they increase the risk of converging to local minima. The next issue is to decide how many neurons are needed in hidden layer of the network. If inadequate neurons are used, it might not completely train the network and might not yield satisfactory results. If too many neurons are used, the time required for training may be too long and the model may begin producing noise at some stage.[6][7]

IV. ANN FOR ANTENNA

In this paper, the artificial neural network is trained for microstrip patch for studying the different characteristics of antenna like like height of the substrate h_1, h_2, and superstrate h_3 , h_4, and their dielectric constant ε_{r1} , ε_{r2} , ε_{r3} and ε_{r4} and resonant frequency using analysis ANN model as shown in Fig. 2.The feed forward network has been utilized to calculate the resonant frequency of the patch by inputting radius of patch, substrate, superstrate dielectric constant and height. This is defined as synthesis Multilayer Perceptron Neural Network model. The desired resonant frequency is taken as desired output. Resonant frequency is calculated by inputting the values of dielectric constants, height of the substrate and desired resonant frequency. The output of the neural network is resonant frequency which is compared to the desired frequency and the error is computed. The error is fed back to the neural network and again the outputs are computed until the errors become negligible and the output resonant frequency gets closer to the required resonant frequency. As soon as the error becomes minimum, the weights of Multilayer Perceptron Neural Network gets fixed and the network is set for testing.[12][13][14][4][3]

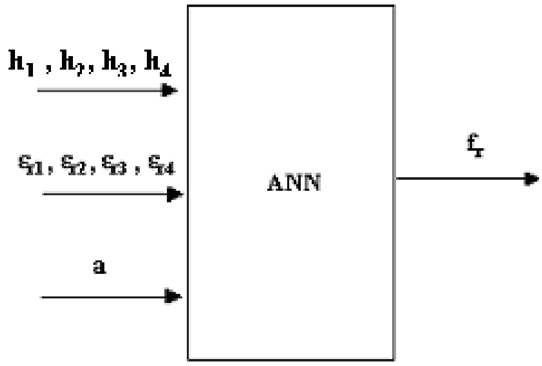

Fig3: ANN for MSA

V. EXPERIMENT AND RESULTS

The Multilayer Perceptron Neural Network(MLPNN) and many other neural networks is implemented using an algorithm called backpropagation. With backpropagation, the input data is given to the neural network, the output is calculated and then the output is compared to the desired output. If the desired output and the output of neural network don't match, an error is computed.

The error is given by,

Error e(r)= Desired output d(r)-Actual Output a(r)

This error is then fed back (backpropagated) to the neural network and used to adjust the weights such that the error decreases with each iteration and the neural model gets closer and closer to producing the desired output. Lavenberg Maquirt Backpropagation algorithm have been successfully used for pattern recognition and nonlinear mapping. The BP is a supervised learning method, and is an implementation of the Delta Rule; in this algorithm are calculated desired outputs for any given input. One iteration of this algorithm can be written $\mathbf{x}_{k+1} = \mathbf{x}_k - \alpha_k \mathbf{g}_k$ where $\mathbf{x}_k$ is a vector of current weights and biases, $\mathbf{g}_k$ is the current gradient,and α_k is the learning rate.[7][8]

The radiation/working of MSA is based on three parameters like resonant frequency, substrate material and width of the patch. The mechanism of radiation gives us analysis of parameters like S11, VSWR etc. A set of inputs are required for deciding the resonant frequency of MSA. The input reference is decided as resonant frequency for which different sets of dielectric constant materials height of substrate & width of patch can be evaluated. So, having one resonant frequency, analysis of patch antenna can be done. These parameters are given by Artificial neural network where set of dielectric constant, width & height are inputs & resonant frequency is reference for inputs. ANN (MLP) gives the minimum error. Results of MLP & ANN can be used as input for design parameters of MSA which definitely gives us the close approximation between resonant frequency & design.[12][17][18]

After initializing the network, we train it use the scaled conjugate gradients algorithm for 10 cycles.

Cycle 1 Error 3.990395 Scale 1.000000e+000
Cycle 2 Error 2.055408 Scale 5.000000e-001
Cycle 3 Error 1.911751 Scale 2.500000e-001
Cycle 4 Error 1.845149 Scale 1.250000e-001
Cycle 5 Error 1.842506 Scale 6.250000e-002
Cycle 6 Error 1.812509 Scale 3.125000e-002
Cycle 7 Error 1.804854 Scale 1.562500e-002
Cycle 8 Error 1.794609 Scale 7.812500e-003
Cycle 9 Error 1.780693 Scale 3.906250e-003
Cycle 10 Error 1.778742 Scale 1.953125e-003

Now we plot the data, underlying function, and network outputs on a single graph to compare the results.

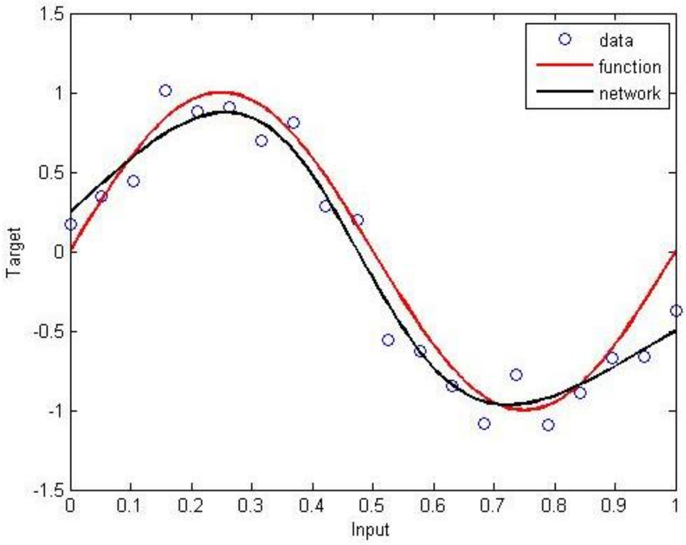

Fig4: Data representation of Function & Network

VI. Conclusion

This paper represents the different aspect for design consideration of MSA. A approximation is considered here with relation between MSA & Artificial Neural Network which can be used for design for MSA resulting into analysis of parameters of it. For more promising results, the network is trained and tested with Lavenberg – Marquardt Backpropogation training algorithm for modelling, simulation and optimization. Levenberg – Marquart (LM) algorithm has been used to train the Multi- Layer Perceptron Neural Networks (MLPNNs). Set of dielectric constant, height and width of the path are taken as input. Resonant frequency of 4.6 GHz is taken as the reference frequency. The outputs are computed and compared. The frequency at which error obtained is miminum is the set as the reference frequency and other parameters for Microstrip Antenna Design are calculated. Momentum learning rule and Tanh transfer function are used for MLPNN which give the optimal results . For generalization, the network is trained and tested rigorously with different methods. The results are compared and analysis is studied.

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