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Design and Development of An Antenna Model using Artificial Intelligence

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Abstract - This paper presents a Neural Network model for the design of Micro-strip Antenna for Ultra wideband (UWB) applications which can be operated in a desired frequency range between 2 GHz to 20 GHz. Artificial neural network based on back -propagation (BP) and radial basis network (RBN) algorithms have been used in designing rectangular patch antenna highlighting the difference between them and the results extracted from these methods are then matched with the results obtained by Computer Simulation Technology (CST) simulation software and are found to be in good agreement. These two algorithms prove to be very advantageous as they can be used to design any rectangular patch monopole antenna of a particular resonant frequency and bandwidth without any lengthy iterative processes.
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Keyword - *Microstrip Antenna, backpropagation method, radial basis method, neural network.*

1. Introduction

Ultra wideband (UWB) frequency spectrum consists of ultra-short pulses in frequency domain. Main purpose of working with UWB is achieving high data rate communication in compliance with the standards of wireless communications.UWB are preferred to obtain data rates of the order of hundreds of megabits per second .

On the other side the drawback of using planar UWB is that they are calculated based on lengthy trial and error method that involves rigorously complex full wave electromagnetic simulation. It is preferred to design antenna using simple design formulae that provide a good approximation to the final design. This paper focuses on this issue and proposes two new techniques in soft computation to calculate the design parameters.In this paper two different techniques based on Artificial Neural Network (ANN) are implemented to design a rectangular patch antenna. The first method is based on back-propagation method, while the other on radial basis functions. Back-propagation algorithm has various applications. It can be used for both fitting and pattern recognition problems. It can also be used for prediction problem with the addition of a tapped delay line. The theory of radial basis function networks is based on the concept of function approximation [1].The output of the network is a linear combination of radial basis functions of the inputs and neuron parameters.

Radial basis function networks have numerous applications, including approximation, time, classification, and system control. These were first formulated in a 1988 paper by Broomhead and Lowe.

Because of various attractive features of the neural network, these two techniques have been used in this paper to model the relationship between the parameters of the rectangular planar antenna and the measured resonant frequency results. Then the results obtained from the two techniques are compared and the differences are discussed in details.

Monopole antenna in its simplest configuration consists of a radiating patch of one side of dielectric substrate and has a ground on the other side of the substrate. Patch which is made up of copper or gold can be designed in any shape. General shapes like square, rectangular and circular structures [2] are generally used for ease of performance and analysis [3]. Among numerous regular shapes, rectangular and square monopole are generally preferred because of simple geometry and less degradation of their radiation pattern within their impedance bandwidth [4], [5].

The paper is organized as follows. Section 2 describes the design of antenna. Section 3 presents the models based on artificial intelligence to calculate design papers of antenna. Section 4 reports on experimental results and section 5 concludes the findings of the paper.

2. Antenna Design

In the design of antenna system, the most important design parameter are usually the number of elements, spacing between the elements, excitation, half power bandwidth, directivity and side lobe level. In design procedure some parameters are specified and others are determined [6].

The rectangular planar antenna offers a large bandwidth and they are mostly used for wireless communication application.

The Fig-1 below shows a simple structure of rectangular planar antenna.

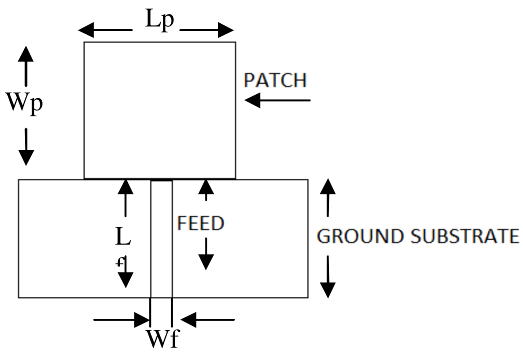

Fig-1: Design of rectangular patch antenna

The substrate has the thickness of 1.6 mm and relative permittivity of 4.4. The patch i.e. rectangular plate has the side of Lp and width of W_p .The feed which is rectangular in shape has length of 20 mm and width of 4 mm which is on the same side of substrate. Conducting ground plane which is rectangular in shape is in the other side of substrate. Ground plane has the length of 40 mm and width of 20mm. By varying the length of the patch i.e. Lp and width of the patch i.e. Wp, we obtained different resonating frequency fr [7] .The data obtain from this structure is used to prepare two different models based on back propagation algorithm and radial basis network.

3. Development of Models Based on Artificial Intelligence

In this paper, the length and width of the patch of a rectangular antenna is calculated based on artificial intelligence while other parameters like length and width of ground plane and feed are kept constant. Two techniques of artificial intelligence have been applied to compute the same design parameters of rectangular patch antenna. Three hundred and twenty one sets of data were collected from CST for developing the antenna models.

2.1 Development of Radial Basis Model

A radial basis function network is an artificial neural network that uses radial basis functions as activation functions. The output of the network is a linear combination of radial basis functions of the inputs and neuron parameters. The main objective of Radial-basis is to determine the optimum values of the equivalent antenna parameters by using input-output data sets. The parameter optimization is done in such a way that error between the target and the actual output is minimized.

2.2 Development of Back propagation Model

The model is developed using feed forward back propagation algorithm which has a special property of backward propagation of error. This model utilizes the optimization method such as gradient descent. The model calculates the gradient of a loss function with respect to all the weights in the network. The optimization method uses the gradient to update the weights in order to update the minimize the loss function.

A typical neural network structure is shown in the **Fig-2**.

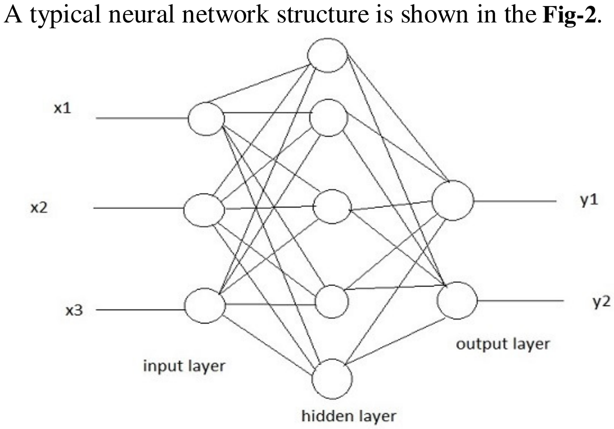

Fig-2: A Neural Network structure

2.3 Training of The Artificial Models

The networks are trained with BP and RBN one at a time. Both the models are trained with 321 sets of data collected from CST where length and width of the rectangular patch is kept in the input layer while resonant frequency in output layer. The input and output set of data are collected with the help of a simulating software i.e. CST. While training both the models, the performance goal is set to be 10^{-5} and epochs are set to be 1000. The training time for

321 input output data in case of back-propagation took 90 seconds whereas for radial basis network it took only 10 seconds. The models are trained to give dimensions of radiating element i.e. Lp and Wp for a desired frequency ranging from 2GHz to 20GHz, keeping all other parameters constant at a fixed position. The trained neural network provides special approximations which are used for neural computation for obtaining all the required designing parameters of an antenna for a desired frequency. When both the networks are ready after training, they are tested with 10 sets of resonant frequencies ranging between 2 GHz and 20 GHz which does not belong within the training data. The 10 sets of values of the design parameters (i.e. Lp and Wp) for the patch so obtained from the two models are then used by CST software to give corresponding 10 resonant frequencies each for the two models.

4. Results and Discussions

For the sake of simplicity, the model is trained to give two output designing parameters [Lp and Wp] for any desired operating frequency ranging between 2 GHz and 20 GHz, while all other designing parameters (Lg, Wg, Lf and Wf) are predetermined as given below:

1. The length of the ground plane, Lg = 40mm
2. The width of the ground plane, Wg = 20mm
3. The length of the micro-strip feed line, L_f = 4mm
4. The width of the micro-strip feed line, W_f = 20mm

The values of resonant frequencies simulated from the output design parameters given by the two models are compared with the testing resonant frequencies to calculate the error percentage using the following formula:

% Error = (Simulated Value–ANN Value)/Simulated value * 100 [9]

A comparison between the outputs of the two models is presented in TABLE- 1. The error percentage is noted down in TABLE -2 for Back-propagation and for Radial basis.

TABLE- 1: The inputs and outputs of the two techniques

SL NO.	INPUTS Fr(Ghz)	BACKPROPAGATION		RADIAL BASIS	
		L_p(mm)	**W_p(mm)**	**L_p(mm)**	**W_p(mm)**
1.	5.77	19.8726	30.0268	16.7417	32.8706
2.	5.8	19.658	29.9892	16.9048	32.5097
3.	6.2	17.2711	30.1599	18.523	28.8003
4.	9	30.353	49.8113	25.9605	25.3842
5.	10	30.201	33.2283	29.5464	22.937
6.	10.5	27.5888	31.5918	30.269	21.8999
7.	11	27.6193	22.5186	29.9546	21.4697
8.	11.5	27.9834	14.1366	28.6089	21.8745
9.	12	26.0833	21.9459	26.4702	23.1445
10.	12.5	24.4062	30.5359	23.9604	25.0927
11.	13	22.9207	29.9949	21.6519	27.3545
12.	13.5	21.8367	30.0264	20.0806	29.4389
13.	14	17.8534	31.2595	19.688	30.8437

TABLE- 2: Error % calculated for both the models

SL NO.	**INPUT FREQUENCY(F_r)**	**OUTPUT FREQUENCY(F_R) GIVEN BY CST (Hz)**		**ERROR %**	
		BACKPROPAGATION	**RADIAL BASIS**	**BACKPROPAGATION**	**RADIAL BASIS**
1.	5.77	5.77	5.996	0	3.769179
2.	5.8	5.798	6.086	-0.03449	4.69931
3.	6.2	6.23	5.978	0.481541	-3.71362
4.	9	10.064	12.044	10.57234	25.274
5.	10	10.082	10.118	0.813331	1.166238

6.	10.5	10.424	10.064	-0.72909	-4.33227
7.	11	11.684	10.082	5.85416	-9.10534
8.	11.5	11.648	11.54	1.270604	0.34662
9.	12	11.99	11.882	-0.0834	-0.9931
10.	12.5	12.53	12.83	0.239425	2.572097
11.	13	13.016	13.574	0.122926	4.228672
12.	13.5	13.502	14.200	0.014813	4.92957
13.	14	14.474	14.438	3.274838	3.033661

Based on data in Sl. No.12 of Table 2. a rectangular patch antenna is fabricated with a patch length of 21.8367 and width of 30.0264 mm on FR4 sheet of dielectric constant of 4.4.The fabricated model is then tested using network analyzer as shown in Figure:3. Analyzing the results of the fabricated model, the resonant frequency comes out to be 12.67 GHz whereas the according to the artificial model the resonant frequency comes out to be 13.5GHz.The results of the fabricated model, is approximately matching with the results of the simulated model with error less than 5% proving the model to be accurate enough to give the values of the design parameters.

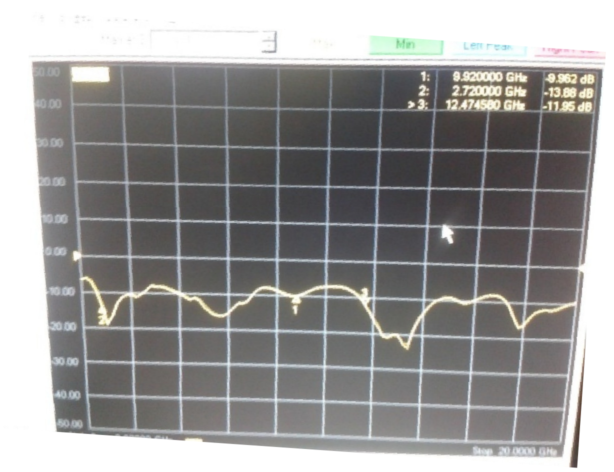

Fig-3: Results given by Network Analyzer

The models are tested for 10 random frequencies. Those input frequencies are compared with the resonant frequencies obtained from CST software for the corresponding output parameters given by the network. The comparison between the results obtained from CST software and that of ANFIS model is tabulated in TABLE: 2. The above mentioned characteristics of the monopole antenna obtained from both the models are found to be acceptable within the error limit. But in case of model based on back-propagation, error percentage is much less as compared to the error percentage in case of Radial-basis network. Thus this back-propagation model can be very well used for design of monopole antenna using FR4 sheet having a dielectric constant of 4.4. RBF is much better than BP in terms of time consumed for training the network as BP takes approximately takes 90 seconds whereas RBN takes only 10 seconds.

5. Conclusion

The networks that were trained give all the design parameters of the monopole antenna for any desired resonant frequency. So they are very useful. After proper training, they completely bypass repeated use of complex iterative processes for new design presented to it. Fabrication of this type of antenna can easily be done using a single metal plate, resulting into a low construction cost [10]. Impedance bandwidth of very wide of about 20GHz (2GHz-20GHz) has been obtained with this antenna. Out of the two models, the BP model is much better than the RBF model as it reduces the error performance.

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