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Calculation of Resonating Frequency of an Equilateral Triangular Microstrip Antenna Using Artificial Neural Network

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Abstract

This paper adopted a new method of calculation of resonating frequency of an equilateral triangular microstrip antenna using artificial neural network (ANN). The major advantage of an artificial neural network is proposed to predict the resonant frequency of an antenna as a function of its geometric parameters. The proposed neural model completely bypasses the required number of electromagnetic computation in training for design of such types of antenna. Thus resulting is an extremely fast solution and the ANN is ten times lower than that needed during antenna optimization process and resulting with high accuracy. The simulated software (Zealand IE3D version 12.0) based on method of moments has been used to generate data for training and validation set of ANN. The results of proposed ANN model are compared with the simulated results which were in very good agreement with the simulated results.

Keywords: *Artificial neural netwok, IE3D simulator, Resonant frequency, Triangular microstrip antenna.*

1 Introduction

Due to their attractive features and desirable characteristics microstrip antennas have drawn the attention of people of industries and researchers for an ultimate solution for handheld devices[1]. The present era of wireless communication has possess many desirable features such as light weight, wide band, low cost, direct integrability with microwave circuitry[2].To meet these requirements, microstrip antennas offer an optimal solution. Because of radiating elements (patches) photo etched on the dielectric substrate like circular, triangular, rectangular microstrip antenna are also referred to as patch antenna. The equilateral triangular microstrip antenna are made up of a triangular patch over a ground plane with side of triangle a, height of dielectric substrate h, dielectric constant of the dielectric material $\in r$ shown in fig 1[5].

The resonant frequency of a triangular microstrip antenna must be determined with high accuracy because the principal limitation of such antennas is their very narrow bandwidth[3].

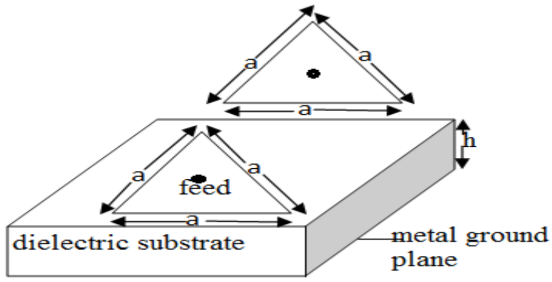


Fig 1. Triangular microstrip antenna with centre feed

Artificial neural network (ANN) has been built for various forms of microstrip antennas such as rectangular, circular and equilateral triangular patch antennas[4]. In this paper the equilateral triangular patch configuration is chosen because it has the advantage of occupying less metalized area on the substrate than other configuration. ANN can also be used for calculating different parameters of triangular microstrip antenna such as directivity, radiation efficiency, input impedance, gain, resonating frequency of triangular and rectangular microstrip antennas.

2 Design of an Equilateral Triangular Microstrip Patch Antenna

A conventional equilateral triangular patch is shown in Fig2. The initial values were chosen randomly. The values are, side of triangle (a) =19mm, substrate thickness (h) = 1.6mm, dielectric constant ($\in_r$) = 4.4mm with these values the resonant frequencies of the antenna were f_o = 8.55GHz. In this paper the position of feed point is taken as the centre of the triangular patch.

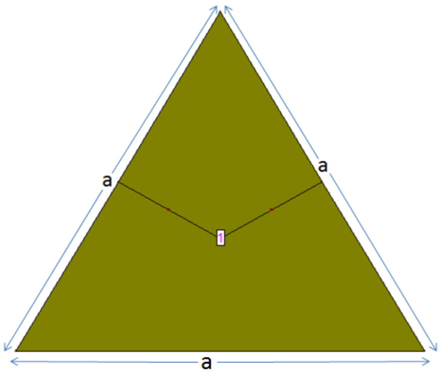


Fig 2. Proposed antenna design

3 Ann Implementation

In this paper neural network has been trained to solve the problem of accurate results of resonating frequency of equilateral triangular microstrip antenna[6-9]. In an ANN model no formula is necessary to calculate the resonant frequency of the antenna because neural network not require explicit coding of the problems. In fact they require raw data for processing. In this paper the feed forward back propogation algorithm[10] is used for training the network. This model has three layer input layer, output layer and the layer between input and output is hidden layer. In this model input is given in first forward function and after that function is transmitted to the hidden layer and the output signal is transmitted to the output layer from the hidden layer. Neurons are connected to each other by weighted connection. The reason being hidden layers of neurons for adjusting the weight between the input and output layers of the network[12]. The basic principal of back propogation of neural network is described by the fig. 3.

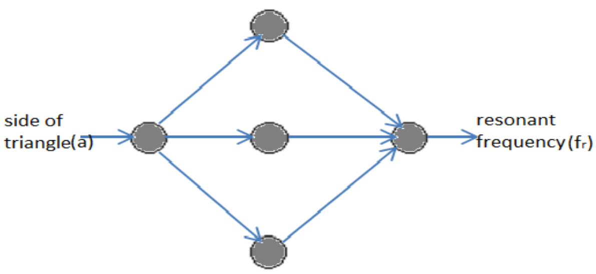


Fig 3. Network Structure

3.1 Ann model

The ANN black box is shown in fig 4 in which input a is applied at input neurons while fo are obtained from output neuron. In this ANN box various input variable to ANN are height of the substrate (h), dielectric constant of dielectric material (∈r) and patch dimensions of equilateral triangular microstrip antennas which is the side (a) of the triangle. Resonant frequency of the triangular antenna is obtained as the output of ANN for a chosen dielectric substrate and patch dimensions at the input side. In ANN model feed forward network contains one Input as side of triangle, and output layer consist of 1 neuron as resonant frequency of antenna while hidden layer consist of 3 neuron. In hidden layer function is sigmoid and in output layer function is linear. The ANN can be divided into two types- the forward and the feedback by the direction of the signal transmission [13]. The training of neural network performs in 10000 epochs. With the help of IE3D software we obtained the different resonant frequency for different dimensions.

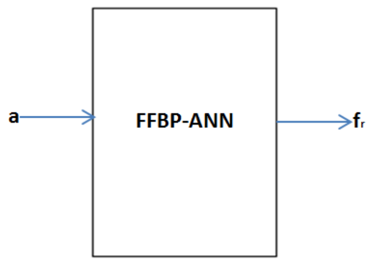


Fig 4: ANN model

Table I. Neural network parameters

S.NO.	Parameters	Values
1	Number of input neuron	1
2	Number of output neuron	1
3	Number of hidden neuron	3
4	Training Algorithm	Backpropogation
5	Number of epochs	10000
6	Learning rate	0.01

3.2 Data Generation

In this paper resonant frequency of the equilateral triangular microstrip antenna is obtained as a function of input variable which is side of the triangle (a) and resonant frequency (fr) of antenna is obtained from the output for each side of length of equilateral triangular microstrip antenna. All initial weights and biases are initialized randomly. The proposed technique used feed forward back propagation artificial neural network (FFBP-ANN) with one hidden layer and trained by levenberg-marquardt back propagation learning algorithm is used to analyze resonant frequency for design of triangular microstrip patch antennas with reasonable accuracy[14]. The parameters taken in this paper is given in table 1. In our work Nearly 90 data set were prepared by this method, out of this data set nearly 75 data set was used for training and rest of the data set was used for testing, which are in given in table 2.

Table 2: Results of ann and compare with the ie3d results

ϵ_r =4.4 and h=1.6mm

Side of triangle (a) in mm	Resonant frequency fr(IE3D) in GHz	Resonant frequency fr(ANN) in GHz
19	8.550	8.5501
20	8.07	8.067
20.784	7.773	7.7727
22	7.395	7.39
22.516	7.173	7.173
23	7.069	7.082
24	6.793	6.8
24.24	6.692	6.6917
25	6.551	6.449
25.980	6.272	6.2732
26	6.31	6.31
26.5	6.239	6.2392
27	6.103	6.104
28	5.88	5.783
29	5.682	5.6826
30	5.426	5.4251
31	5.298	5.289
31.17	5.244	5.244
32.90	5.0139	5.0032
33	4.98	4.951
34	4.846	4.849
34.64	4.763	4.7713
35	4.662	4.6676
36	4.582	4.583
36.37	4.529	4.527
38.105	4.345	4.3445
38.5	4.303	4.305
39	4.247	4.252
39.83	4.094	4.0952
40	4.15	4.151
40.5	4.094	4.094
41	4.05	4.03
41.56	3.994	3.9961

42	3.941	3.9421
43.3	3.793	3.7899
44	3.788	3.78
45	3.681	3.6743
46	3.622	3.6287
48	3.454	3.4554
49	3.398	3.3982
50	3.300	3.3054
51	3.231	3.23
51.961	3.208	3.2056
52	3.186	3.1861
53	3.142	3.143
54	3.052	3.0542
55	3.0185	3.0275
56	2.921	2.9209
57	2.896	2.8965
58	2.852	2.8496
59	2.807	2.807
61	2.715	2.714
62	2.689	2.68
63	2.649	2.65
64	2.591	2.5899
65	2.557	2.557
66	2.523	2.5559
67	2.491	2.4912
68	2.443	2.4435
69	2.423	2.422

4 Result and Discussion

The most important feature of neural model is their generalization capability so the neural network is able to calculate the input – output relationship for dependent parameters with independent parameters such as side of triangular patch, thickness of dielectric substrate and relative permittivity of substrate. In our work it can be seen from table 3 that without changing other parameters of patch resonant frequency is decreasing by increasing the side of triangle. The error comes out by this method is very minimum. The percentage error is calculated by the formula given in equation 1 [15].

$$\%Error = \frac{Simulated Value - ANN\ Value}{Simulated\ Value} \cdot 100 \quad (1)$$

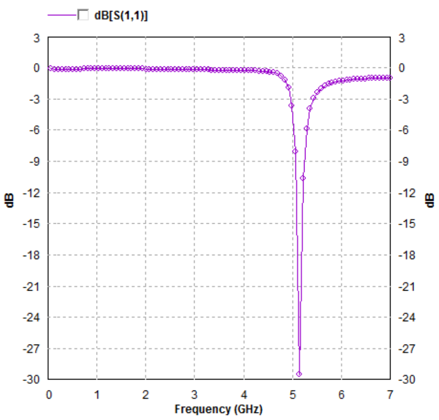
In the training process of neural network the weight of layers continuously adjust the process of learning for the input signal being transmitted on each layer. The procedure continues till the output error of the network is reduced to our desired level. The response of the network was tested with same typical experimental results and is shown in fig. 5.

Table 3: Results in IE3D and in ANN on non-trained data

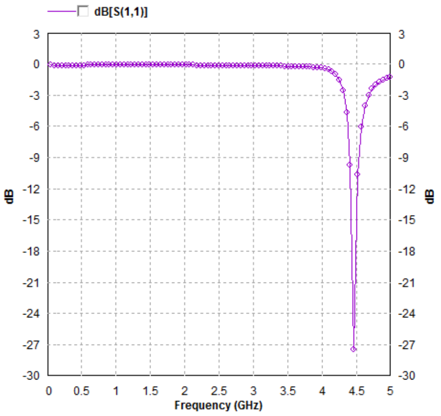
side of equilateral triangle (a) in mm	Resonant frequency obtained (GHz) in IE3D	Resonant frequency obtained (GHz) in ANN	% Error
32	5.147	5.159	0.233
37	4.48	4.4632	0.376
47	3.53	3.5261	0.110
79	2.106	2.1119	0.28

5 Conclusion

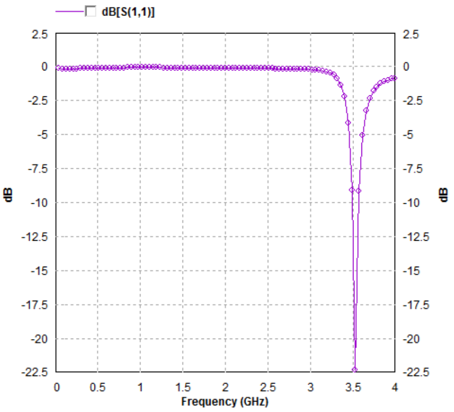
A trained neural network is more flexible to locate the resonant frequency of an equilateral triangular microstrip antenna. It is based on the neural architecture of the human brain. Artificial neural network are one of the popular technique for solving engineering problems. It provides linear and non-linear modeling without the requirement of preliminary assumption as to the relation between input and output. There is also a fast technique to evaluate the resonant frequency of microstrip antenna using ANN. The results obtained are satisfactory and show the interest of the application of neural networks. Application of ANN for the calculation of resonant frequency of an equilateral triangular microstrip antenna seems to be a simple, inexpensive and accurate method having a very good agreement with the simulated results.



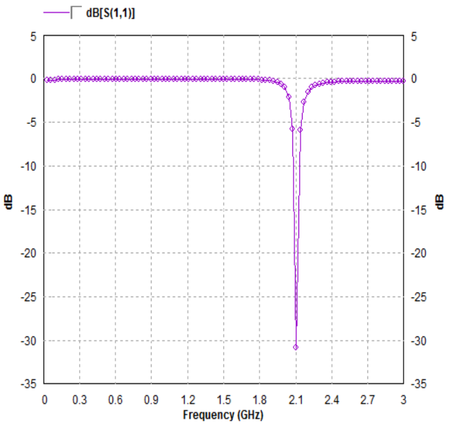
(a) Return loss v/s frequency graph with triangular side a=32mm



(b) Return loss v/s frequency graph with triangular side a=37mm



(c) Return loss v/s frequency graph with triangular side a=47mm



(d) Return loss v/s frequency graph with triangular side a=79mm

Fig5: Experimental S11 plots for test data set

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