Hexagonal Shaped Slot Antenna Resonant Frequency Determination using ANN Approach

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Abstract − **In this paper, an artificial neural network (ANN) model, based on back propagation algorithm, is proposed for the determination of the resonant frequency of a hexagonal shaped slot antenna. The ANN model is developed to obtain the antenna resonant frequency based on the following two antenna dimensions: stub length and slot height. The results of the proposed ANN model are compared with the simulation results and percentage error is calculated. The simulation result are obtain using Ansoft's HFSS software and found to be in conformity with proposed ANN model's results.**

Keywords − **Frequency re-configurable antenna, Hexagonal slot, Stub and Artificial neural network.**

I. Introduction

In the recent years, metaheuristic techniques are found to be the most effective tool for solving complex mathematical computations. The artificial neural network (ANN) is one of them and it is considered as effective information processing system [1]. In ANN, the several functional units, usually termed as neurons, have the processing capability and they are arranged in layers. The respected weight links are used to build up the interconnection between the layers. Further, the learning power of ANN system is achieved by feeding the adequate number of training pattern to the system. The training pattern further modifies the synaptic weights associated with the interconnecting links between the neurons in various layers. Therefore, the training patterns are stored in the form of weights in the ANN. A trained network allows the reduction of the time needed for the design process of antenna.

From the related literature it can be observed that there are different examples of the ANN application in the design of different structures of antenna, such as: square patch in [2], rectangular patch structure in [3] and [4], circular patch in [5], fractal circular slot antenna in [6], slots of different shapes and sizes in [7] and [8]. In addition to this, ANN is found to be helpful to calculate the numerous output parameters of the antenna such as resonant frequency in [9], radiation pattern in [10], bandwidth in [11], input impedance in [12], etc. In proposed work, the particular dimensions of the antenna are used as input of the ANN to determine the resonant frequency as its output. Moreover, the proposed ANN model is fast and accurate as compared to existing approaches.

This paper is organized as: In section I, Introduction and literature review are presented. The considered hexagonal shaped slot antenna structure is described in Section II. The development and validation of the proposed ANN approach for the antenna resonant frequency determination are given in Section III and IV respectively. Finally, the conclusion of the proposed work is presented in Section V.

II. The Considered Hexagonal Shaped Slot Antenna Structure

Fig. 1 shows the modified structure of the antenna as described in [13]. A simplified antenna structure having one stub is used to demonstrate the application of ANN. In this design a 2 step microstrip feed line is used to excite hexagonal shape slot, which is etched from the ground plane of the antenna.

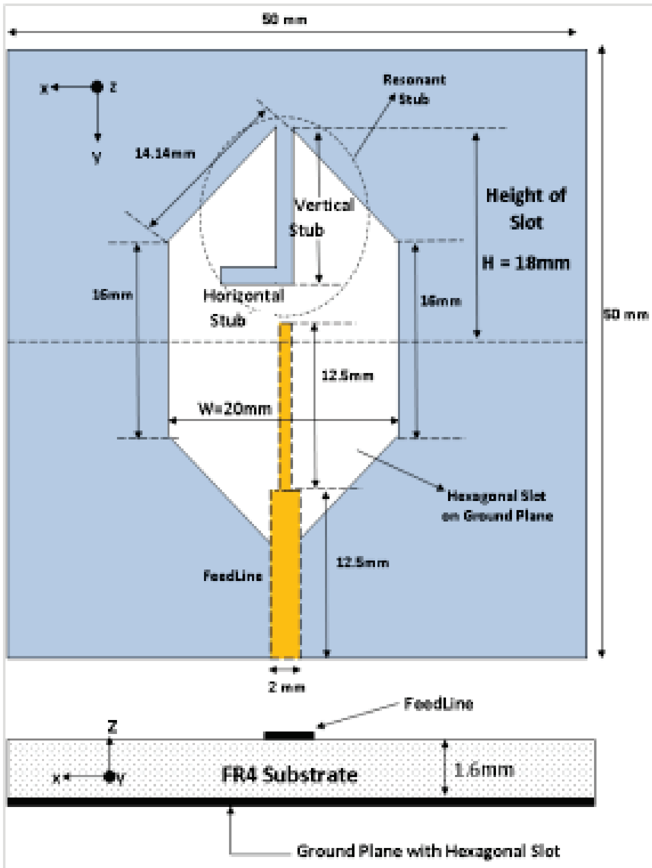

Fig. 1. Design of the hexagonal slot antenna [13].

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Fig. 2 shows a vertical stub (VS) which is placed on the upper part of the hexagonal slot where length is extended by a horizontal stub (HS). When the antenna is excited by the two step feedline, the vertical stub acts like a radiating stub due to the current induced in it. The horizontal stub length L can be varied to resonate the structure at different frequencies.

The important geometrical parameter in antenna structure is the height of the hexagonal slot H, which can be varied to achieve the different resonant frequency. With this variation, the overall length of the stub also varies which in turn enables the antenna to resonate at different frequency. Fig. 3 shows the return loss plot of the antenna when H=17, 18, 19 and 20. Here, the length (L) of a horizontal stub is varied from 1 mm to 8 mm in a step of 0.5 mm.

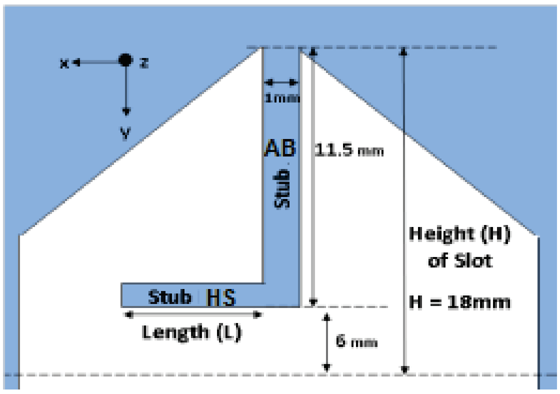

Fig. 2. Diagram representing dimensions of slot height (H) and stub length (L).

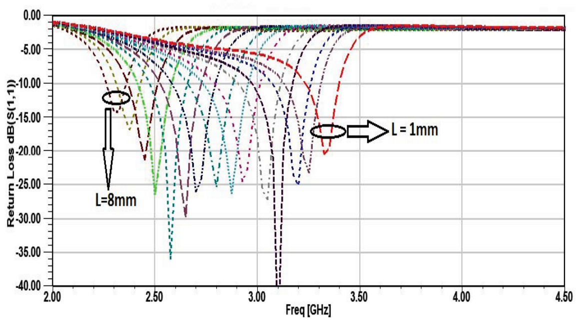

Fig. 3 (a). Determination of return loss using Ansoft HFSS for H=20mm (L varies from 1mm to 8mm).

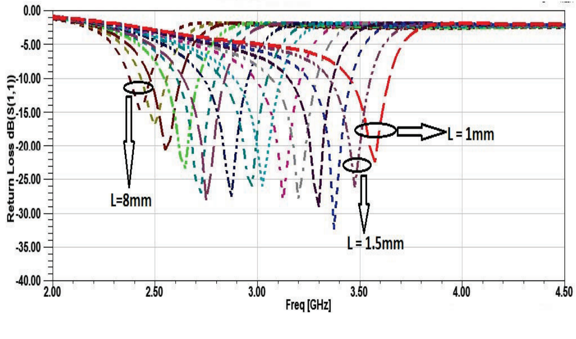

Fig. 3 (b) Determination of return loss using Ansoft HFSS for H=19mm (L varies from 1mm to 8mm).

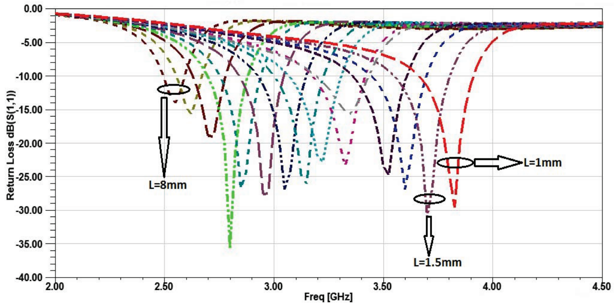

Fig. 3 (c) Determination of return loss using Ansoft HFSS for H=18mm (L varies from 1mm to 8mm).

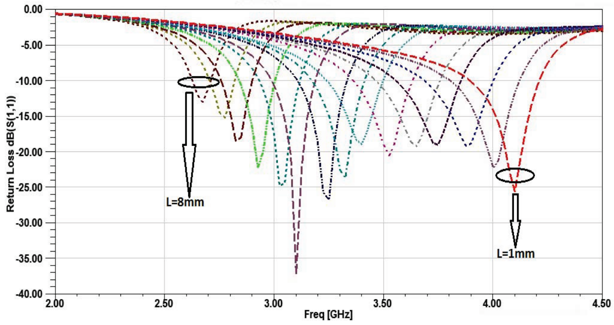

Fig. 3 (d) Determination of return loss using Ansoft HFSS for H=17mm (L varies from 1mm to 8mm).

III. Development of the Proposed ANN Approach for the Antenna Resonant Frequency Determination

In this paper, proposed ANN have two input parameters i.e., length (L) of the horizontal stub (HS) and height (H) of the hexagonal shape slot. These parameters are used by the ANN as inputs to determine the resonant frequency of the antenna.

Fig. 4 shows ANN model of a 2-60-1 structure with two inputs as stub length (L) and slot height (H) for the generation of the resonant frequency.

In this model, hidden layer has 60 neurons. The weights represented by $W_{a1,1}$, $W_{a1,2}\ldots W_{a2,60}$ have connections between input layer and hidden layer whereas, the weights represented by $W_{b1,1}$, $W_{b2,1}$, $\ldots W_{b60,1}$ are associated with the connections between the hidden layer and the output layer. Both hidden layer and output layer are also fed with a bias of unit value along-with the associated weight. The value of these weights is adjustable and this process of weight adjustment is part of the training process. When ANN is fed with the training data, the output is calculated with activation function f_1 and f_2 at the hidden layer and the output layer, respectively. The function f_1 and f_2 used in this network are the binary sigmoidal functions.

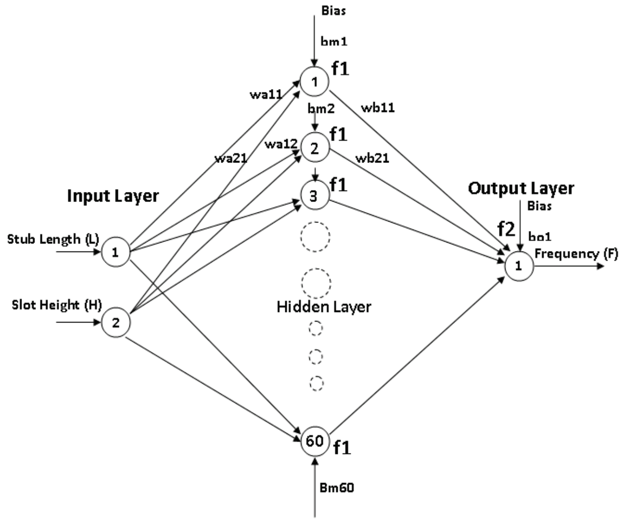

Fig. 4. ANN based model for antenna structure.

The training patterns are captured using Ansoft's HFSS simulation software, version 14.0 [14] with different values of the height of hexagonal slot (H) and length of the horizontal stub (L). The values of H lies between 17 mm to 20 mm whereas, the values of L lies between 1 mm to 8 mm. The return loss plot corresponding to H and L are represented in Fig 3(a) to (d). Here, 60 training patterns are formed which consists of H, L, and resonant frequency and later used to train the ANN. From the long list of these training patterns, only four of these 60 training patterns are listed in Table I. This is for indicative purpose; however for actual training all 60 patterns are used.

TABLE I
SIMULATED RESONANT FREQUENCY RANGE FOR DIFFERENT VALUES OF STUB LENGTH "L" AND SLOT HEIGHT "H"

S.No.	Input		Output
	Length of stub (L) in mm	Height of slot (H) in mm	Frequency (GHz)
1.	1.0	17	4.11
2.	1.5	17	4.01
3.	2.0	17	3.89
4.	…..	…..	…..
60.	8.0	20	2.31

In order to train a network, the generated output is compared with the desired output and error is calculated. The error propagates backward as per back propagation algorithm and it is used to adjust the weights at input and output layers. This process of generation of error and the adjustment of weights is repeated multiple times, and with multiple training patterns until the error is below the predetermined threshold value. The learning characteristics of the network are summarized in Table II. It is evident that it took 453 numbers of epochs to bring the level of percentage error to 0.002 and mean square error (MSE) of 9.0e-6.

TABLE II
SUMMARY OF TRAINING

Algorithm used	No. of training patterns	No. of epochs	Mean square error	Error in calculation of frequency	
				%	Absolute (GHz)
Back propagation	60	453	9.0e-6	0.002	0.0000051

IV. VALIDATION OF THE PROPOSED ANN APPROACH FOR ANTENNA RESONANT FREQUENCY DETERMINATION

A trained ANN is used to generate the resonant frequency. Here, the network was fed with 60 values of L and H as the input of ANN model for the validation. In this work, the tested samples are same as the training sample, as given in Table I. However, these sets may be different under different conditions. Further, the generated resonant frequency from the ANN model is compared with the simulated resonant frequency which is obtained from Ansoft HFSS software when same value of H and L are taken. Also, percentage error is calculated based on the difference in values of the ANN output and the HFSS software output. Table III lists the number of samples falling within percentage error range of 0-0.5%, 0.5%-1%, 1%-1.5%, 1.5%- 2% and 2%-2.5%. Fig 5 represents the percentage error for 60 random inputs, which were used to validate the ANN, and here it can be noticed that maximum percentage error is 2.3%.

TABLE III
RESULTS-PERCENTAGE ERROR

S.No.	Percentage error	Number of samples
1	0.0%-0.5%	16
2	0.5%-1.0%	10
3	1.0%-1.5%	17
4	1.5%-2.0%	9
5	2.0%-2.5%	8
Total Number Sample Tested		60

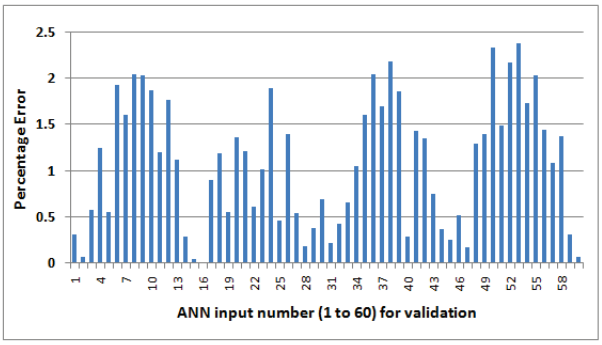

Fig. 5. Percentage error for 60 random inputs for verification of ANN.

V. CONCLUSION

This paper presented an ANN model for the determination of the resonant frequency of the proposed antenna. In this model, two dimensions of antenna are considered namely: stub length and slot height for the determination of antenna parameter. The results obtained by using the ANN are in conformity with the simulated results from Ansoft's HFSS software, which proves the validity of the proposed ANN approach. Moreover, the developed ANN model is fast and accurate as compared to the existing approached in the related literature.

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