Analysis of a Pentagon Fractal Antenna using Artificial Neural Network

Ramandeep Kaur*, Simranjit Kaur Josan** and Balwinder Singh Dhaliwal***
*PG Student, GNDEC, Ludhiana
Email: ramandeepkaurbhamra@gmail.com
**Assistant Professor, GNDEC, Ludhiana
Email: simran_josan@yahoo.com
***Assistant Professor, GNDEC, Ludhiana
Email:bsdhaliwal@ymail.com

Abstract: The attributes of compact size, high performance and ease of fabrication has resultedin high demand of fractal antenna in wireless communication system. In this paper, a pentagon fractal patch antenna is presented. But, the analysis of a new antenna requires development of complex mathematical models and costly equipment. As conventional approaches of experiments are expensive and time consuming. Therefore, the output characteristics of pentagon antenna are calculated by Artificial Neural Network (ANN). In proposed ANN, training of network is done by using backpropagation algorithm. The agreement of ANN results and simulated results shows that this technique will be quite useful to analyse various aspects of fractal antenna.

Keywords: Artificial Neural Network, self-similar, fractal, resonant frequency, gain.

Introduction

Artificial Neural Networks (ANN) are being used as an efficient problem solving tool in various disciplines [1] due to their general purpose nature. Fractal antenna involves complex shaped geometries whose mathematical model is quite difficult to develop. Also the experimental analysis of antenna involves expensive equipment like vector network analyser, pattern recorder etc., whose availability is limited in research institutes. This brings the wide use of ANN in antenna design and analysis which is evident from recent researches [2]. The present paper describes the application of ANN for analysis of a new fractal antenna having iterated pentagon geometry. Section II discusses the study of literature of some microstrip fractal antennas and application of ANN in antenna design and analysis. Section III briefly explains the design of proposed geometry using IE3D software. Section IV describes the formation of ANN model for proposed antenna. Section V presents the results of presented work and conclusion is given in section VI.

Literature Study

Antenna technology combined with fractal geometry [3]has become an effective technique to design fractal antennas which gives high performance at desired frequency bands. In fractal antenna, the concept of self-similarity and space filling is used which increases the electrical length and reduces the physical size of antenna [4]. Some antennas involve self-similar shapes of reduced dimensions as slots in base geometry [5] while other used them at the boundaries of base geometry [6-7].
In recent years, involvement of ANN to analyse various fractal geometries has been increased which is evident from [8-11]. In [8] evaluation of resonant frequency of microstrip antennais done by employing neuro-fuzzy technique. In [9] authors made prediction of input impedance as a function of design parameters of antenna using ANN model. Comparison of simulated results and ANN results are done for resonant frequency, gain and return loss in [10]. In [11] authors evaluate the behaviour of three types of neural network models and compared them with simulated results.

Antenna Design

Benoit Mandelbrot introduced the term ‘fractal’ from the Latin word ‘fractus’ which means broken [3]. Various complex geometries have been introduced which acquire the characteristics of fractal antenna to achieve desired resonant frequency band, improved gain and low return loss values. In addition, fractal antennas provide the benefits of low cost, light weight and compatibility with integrated circuits. In present work, a pentagon shaped fractal antenna is designed using IE3D software. Using the concept of Koch, fractal shape iterations are done at boundaries such that the dimensions of successiveiterated geometry are one-third of dimensions of base geometry. Fig 1(a)-(c) show the schematic diagram of proposed antenna. Fig 1(a) illustrates the base geometry of pentagon shape. Fig 1(b) shows the first iteration where generator

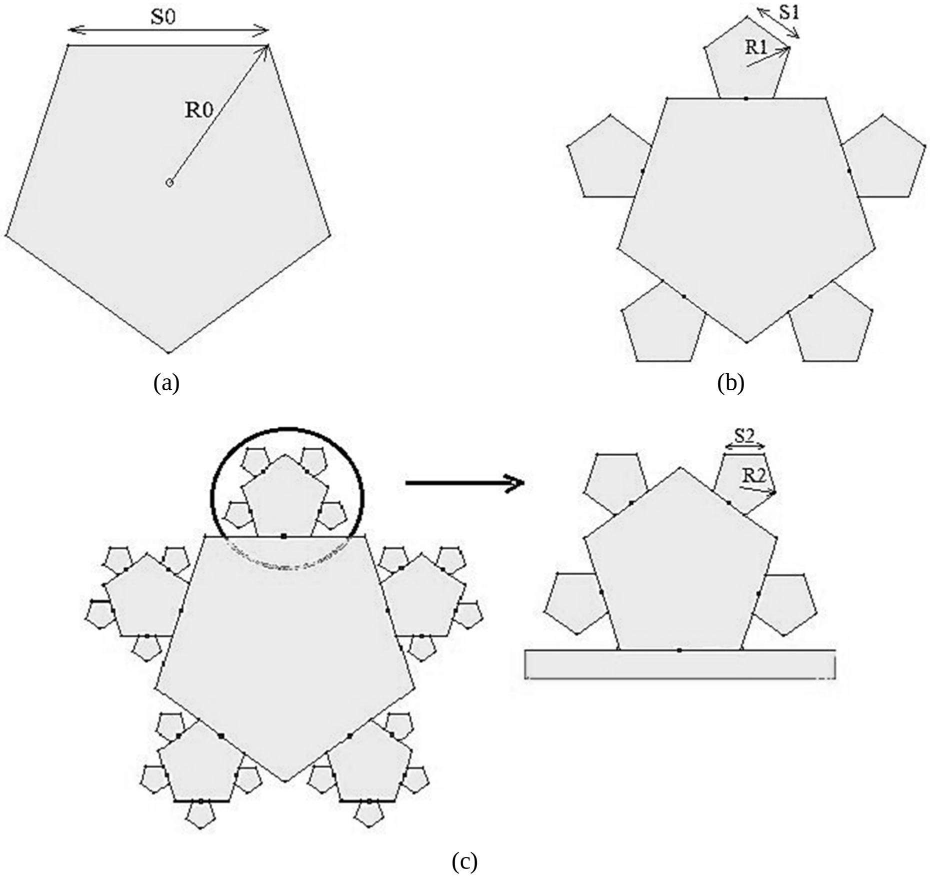

Fig 1. Schematic Diagram of (a) Base Geometry or Zeroth Iteration (b) First Iteration and (c) Second Iteration of proposed fractal antenna

is of pentagon shape with side length equivalent to one-third that of initiator.Similarly, second iteration is attained by inducing the base shape of reduced dimensions and then attachingthem to the boundaries of first iterated geometry as shown in Fig 1(c).

The proposed antenna is designed on Rogers RT Duroid substrate having relative dielectric constant ϵ_r of 2.2 and thickness ~3.175 mm. The geometry has a single controlling parameter i.e. radius of base geometry R_0 and all the other parameters are calculated from it.The detailed dimensions of proposed antenna are calculated using the following procedure:

For Base Geometry

The pentagon shaped base geometry has radius of circumscribed circle = R_0

As the relation between side length S and radius of circumcircle R of polygon is

$$R = \frac{S}{2\sin\frac{180}{n}} \quad \dots\dots\dots\dots (1)$$

Where, n = number of sides of polygon inscribed in a circle (= 5 in case of pentagon)

This implies,

$$R = \frac{S}{1.175} \quad \dots\dots\dots\dots (2)$$

Therefore, using eqn (2), side length S_0 of base geometry can be calculated as: $S_0 = R_0$ X 1.175.

For First Iteration

Side length of generator of first iteration geometry (S_1) = $S_0/3$. Therefore, by using eqn (2), radius of first iteration generator can be calculated as: $R_1 = S_1/1.175$

For Second Iteration

Side length of generator of second iteration geometry (S_2) = $S_1/3$. Therefore, by using eqn (2), radius of first iteration generator can be calculated as: $R_2 = S_2/1.175$

The antenna is fed coaxially at coordinate point (0,5.3) with centre of geometry at origin. The S-parameters or return loss characteristics which displays resonant frequency of 2.43 GHz for R_0=15.64 mm are shown in Fig 2.

Artificial Neural Network Model for Second Iteration of Proposed Geometry

The construction of proposed geometry, up to second iteration, needs high precision and is quite time consuming. To analyse the behaviour, number of copies of same geometry with different parameters are required which is again quite challenging. In addition to this, an antenna can perform efficiently when it has proper impedance matching between its feed point and source. To achieve an optimum feed point for a complex geometry is not an easy task, which involves gradual hit and trials along with long simulation runs. To overcome these issues, an ANN model is developed which enables to get results for a desired parameter of geometry within small run time.

It has been recognized during simulation that proposed geometry has single resonant frequency at its zeroth iteration and with second iteration it displays resonant frequency with higher gain and better return loss characteristics. Therefore, only resonant frequency of second iterated geometry has been considered as an output of ANN model. In proposed ANN model, the radius of base geometry has been taken as input and it generates resonant frequency as an output. The Multilayer Perceptron Neural Network (MLPNN) is used in the present work. The basic structure of proposed model is given in Fig 3 which depicts that the proposed model has three layers. The first and last layers are input layer and output layer respectively each of which has a single neuron each. Middle layer has three neurons which process the input according to sigmoid function. Each unit in every layer is connected to each other with a weight which is calculated using backpropagation algorithm.

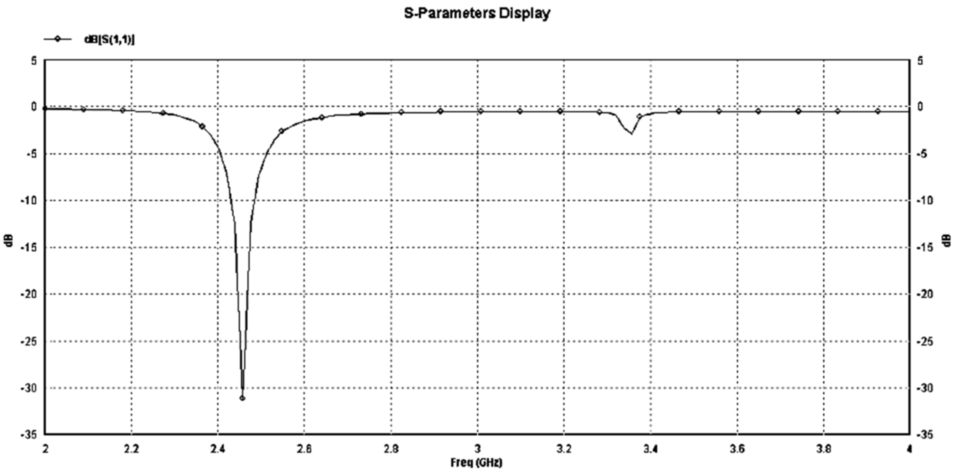

Fig 2. Return Loss characteristics for R_0 = 15.64 mm

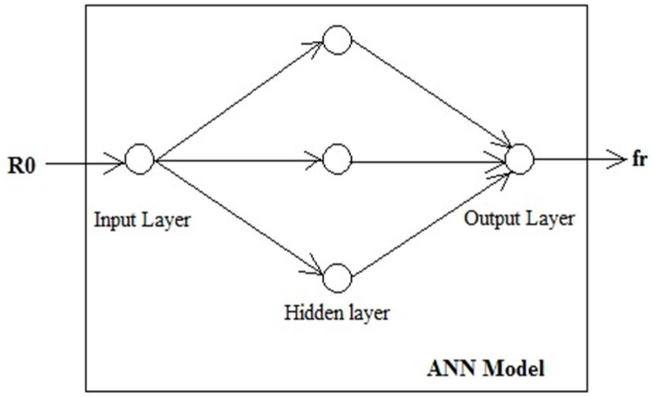

Fig 3. MLPNN Model

Results and Discussions

Table 1.Comparison of simulated and ANN results for resonant frequency

Sr. No.	RadiusR0 (mm)	Simulated Results *fr* (GHz)	ANN Results *fr* (GHz)	% Error
1	7.50	4.9732	5.0677	1.900
2	8.82	4.2103	4.2247	0.342
3	10.68	3.5319	3.6145	2.338
4	12.24	3.1008	3.1435	1.377
5	13.75	2.7700	2.7127	2.068
6	15.64	2.4589	2.4834	0.996
7	17.42	2.2020	2.2186	0.753
8	18.00	2.1460	2.1175	1.095
Average % Error =		1.358		

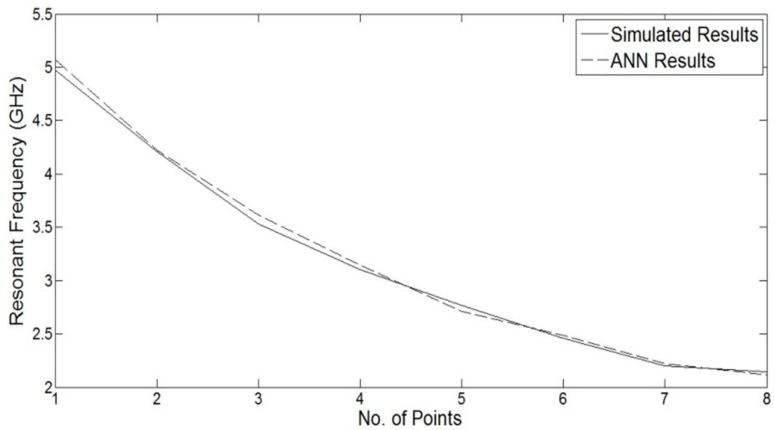

Fig 4. Graphical representation of simulated and ANN results for resonant frequencies for eight test inputs

The MLPNN need large number of data to train the network. The data set for the proposed antenna is obtained by IE3D software. Twenty geometries of proposed antenna with different values of radius have been simulated and their respective resonant frequencies are obtained which are used to train the ANN model at 0.05 learning rate. After training, ANN is validated by some test values of input so as to compare its output with the simulated results as shown in Table 1. Eight values of input radius are tested to get an estimation of accuracy provided by ANN. The precision of accuracy depends on the amount of training data. The comparison of simulated and ANN results is also shown graphically in Fig 4. It depicts that ANN results provide good estimated result for a given value of input, that is, radius of base geometry.

Conclusion

A new pentagon fractal antenna is proposed in this paper. The main characteristics of proposed antenna are that it has high gain and better impedance matching. An ANN model to find the value of resonant frequency for desired values of parameter of proposed antenna is prepared which is trained with backpropagation algorithm. The results obtained shows good agreement with the simulated results. The model provides an easy approach to analyse the frequency of operation of proposed antenna design with given parameter.

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