Analysis of Hybrid Fractal Antenna using Artificial Neural Network

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Abstract: In high performance weather radar, surface ship radar, and communication satellite applications, low profile antennas having small size and less weight are required. The fractal geometry can be used for antenna miniaturization. In this paper a hybrid fractal antenna which is based upon fractal geometries is presented. For analyzing the behaviour of antenna artificial neural network (ANN) tools are used. The output results from the ANN exhibits close approximation with the simulated results of IE3D software.

Keywords: Hybrid fractal antenna, Artificial neural network, Resonant frequency.

Introduction

Fractal antennas are based upon the self-similarity and space filling properties of fractal geometry. The primary goal of fractal antenna design is to design a small size and multiband antenna with good performance [1]. In addition to this, the fractal's iterative methodology also provides discontinuities at the boundaries of antennas, which results in higher efficiency [2]. This paper explains an ANN model used for the analysis of hybrid fractal antenna. A hybrid fractal antenna is generally created from the combination of two different fractal geometries or a fractal and non fractal geometries of antennas [3].The proposed ANN model is created to obtain the resonant frequency (f_r) of the hybrid antenna with length (L) and width (W) as input variables. The proposed ANN model is simple, easy to apply, and is very useful for determining the resonant frequency of antenna. The ANN model provides an efficient, time saving method to find resonant frequency for different dimensions of patch antenna [4]. In the next section, some recent antenna geometries with their ANN analysis have been discussed. A brief explanation of antenna design is discussed in Section-III. Section-IV explains the ANN model for antenna, the results and discussion is presented in Section-V. At the end, the conclusion of paper is explained in Section-VI.

Literature Review

ANNs are one of the most intelligent techniques that can be used to solve many engineering and mathematical problems. Recently, ANN models have achieved popularity for analyzing and designing of antennas [5-10]. Singh introduced a method to calculate the resonant frequency of rectangular microstrip patch antenna using Feed Forward Back Propagation Algorithm, Resilient Back-propagation, Levenberg-Marquardt and Radial Basis functions (RBF) of ANN. The comparison of these algorithms shows that RBF algorithm is best suitable for calculating the resonant frequency of antenna [5]. Gehani et al. designed an antenna by using ANN with adaptive neuro-fuzzy inference system [6]. The ANN tool was also used by Rai et al. for designing of microstrip antenna [7].The analysis and the design of X-band reflectarray using ANN model was proposed in [8]. ANN was used for dual band frequency estimation of coaxial fed fractal patch antenna proposed by Arora and Dhaliwal [9]. Santos et al. explained the use of ANN for analyzing and designing of several shapes of microstrip antennas [10].

The fractal concept was introduced by Mandelbrot that describes different complex shapes based upon self-similarity and space filling properties [11]. In the present scenario, a large number of fractal geometries have been explored for antenna design. Fadzil et al. proposed a Sierpinski carpet fractal antenna with capability of suppressing frequency harmonics in the range of 2 GHz to 5 GHz [12]. A Koch fractal antenna was introduced by Chitra and Nagarajan which operates in the frequency range of 2-30 GHz for different iterations [13]. By using the combination of Koch and Sierpinski carpet, a fractal antenna for UWB applications was developed by Behera et al. [14], in which the sierpinski carpet is slotted into triangular patch and the Koch iterations were performed for decreasing the size of antenna.

Hybrid Fractal Antenna Design

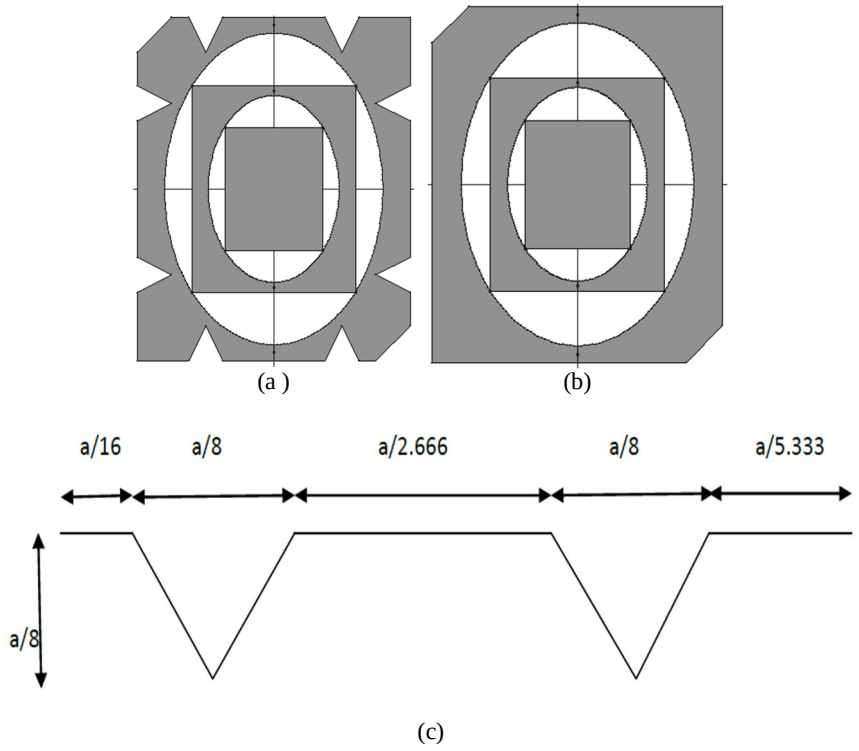

Figure1. (a) Tapered rectangular pre-fractal antenna [15] (b) Proposed Hybrid fractal antenna (c) Koch Curve

In hybrid structure, antenna is designed using different combination of fractal geometries which decreases the area and fabrication cost of antenna. By using different fractal configurations such as Koch, Sierpinski, Minkowski, Hilbert,Cantor sets and fractal tree antennas with fractal or non fractal geometries provide an atmosphere for designing of hybrid fractal antenna.

In the proposed work, a hybrid fractal antenna has been designed by modifying the tapered rectangular pre-fractal antenna proposed by [15]. The modification has been done by adding Koch curves at the boundaries of the reference antenna as shown in Fig. 1.The proposed antenna is designed on the RT duroid substrate with thickness 'h' = 3.175 mm and 'ϵ_r' = 2.2. The Koch curves have same dimensions which have been used for tapering of diagonally opposite corners of the antenna. In Fig.1(c), the positions of added Koch curve are mentioned where 'a' denotes either length or width of the antenna for horizontal and vertical boundaries. The comparison of different parameters of the reference rectangular pre-fractal antenna and proposed hybrid fractal antenna is given in the table 1. It is clear from the comparison that the resonant frequencies 2.43 GHz and 3.71 GHz in case of tapered rectangular pre-fractal antenna are shifted to 2.35 GHz and 3.60 GHz in hybrid fractal antenna. The small changes are also observed in gain and bandwidth of hybrid fractal antenna.

The designed hybrid fractal antenna resonates at the frequency 2.35 GHz and it has overall dimensions of 'L' =32 mm and 'W' = 39 mm resulting in an area of 1248mm^2; however the simple rectangular antenna for same frequency requires the dimensions of 'L' = 43.03 mm and 'W' = 50.46 mm with an area of 2171.29mm^2. So the proposed antenna has an area of 57.48 % of the required area at 2.35 GHz, resulting in a size reduction of 42.52 %.

Table 1. Comparison of rectangular pre-fractal antenna and hybrid fractal antenna

Tapered Rectangular Pre-Fractal Antenna				Proposed Hybrid fractal antenna			
f_r(GHz)	S_{11} (dB)	BW (MHz)	Gain (dBi)	f_r(GHz)	S_{11}(dB)	BW (MHz)	Gain (dBi)
2.43	-19.8	160	5.17	2.35	-22.61	130	4.58
3.71	-15.3	70	1.72	3.60	-23.14	70	2.04

ANN Model for Hybrid Fractal Antenna

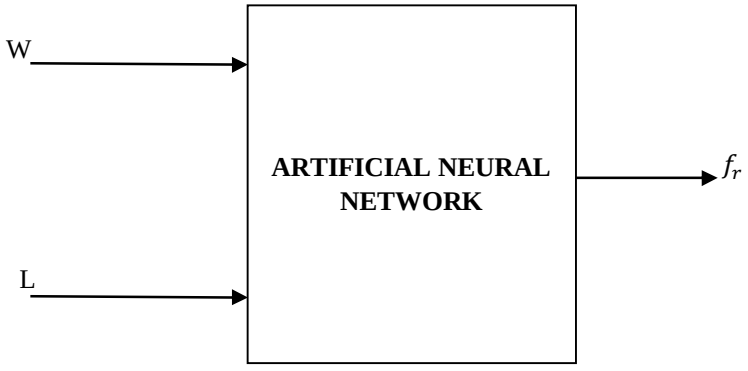

Figure 2. ANN Model

The antennas operation is strictly based upon the corresponding resonance of the antennas i.e. resonant frequency of the antenna. For the proposed hybrid fractal antenna to calculate the resonant frequency using IE3D simulator is a time consuming task. For more complex fractal geometries this problem becomes more complex. In this paper an ANN model is proposed to tackle this problem. The proposed ANN model takes the length (L) and the width (W) as inputs and predicts resonant frequency at output. The block diagram of ANN model is shown in Fig. 2. The multilayer perceptron network model having multiple layers of neurons connected in feed forward manner is used.

Results and Discussion

The proposed ANN model is trained using backpropagation algorithm. The network function '*traingd'* is used for training of ANN. This function is used for updating weight and biasing values as per gradient descent backpropagation algorithm. The network has two input neurons, three neurons in hidden layer and an output neuron. The data set which contains different values of 'L' and 'W' of antenna and corresponding resonant frequencies were generated with the help of IE3D software tool. The ANN was trained using this data set, and the ANN is tested for different unknown values of 'L' and 'W' of antenna. The ANN output is compared with simulation results obtained by IE3D software tool as shown in table 2. The graphical comparison of simulated and ANN output is also shown in Fig. 3 which depicts that there is good matching of ANN results with the desired simulation results.

Table 2.Performance analysis of ANN for test data set

S. No.	L (in mm)	W (in mm)	Simulation Result (f_r)	ANN Output (f_r)	% Error
1.	33.2	40.5	2.254	2.231	1.020
2.	33.6	41	2.202	2.201	0.045
3.	34	41.48	2.150	2.173	1.069
4.	34.5	42.09	2.145	2.139	0.279
5.	35.5	43.31	2.092	2.082	0.478
6.	36	43.92	2.018	2.059	2.031
7.	36.5	44.53	1.990	2.040	2.512
					Average % Error = 1.062

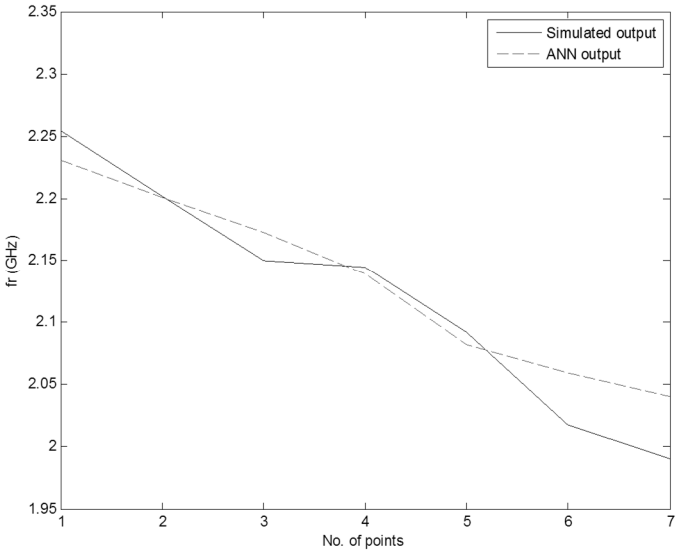

Figure 3. Performance comparison of Simulated and ANN result

Conclusion

A new hybrid fractal antenna is proposed by modifying the boundaries of the reference antenna. The proposed antenna has better miniaturization than the reference antenna. The ANN output is compared with the simulated value of the resonant frequency. The average percentage error obtained from comparison is 1.062 which shows ANN performance has good agreement with simulated output. The proposed ANN model provides a faster way to find the resonant frequency of proposed hybrid antenna geometry for given values of dimensions.

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