Analysis of Elliptical Microstrip Patch Antenna using Neural Network Ensemble

Simranjit Kaur Josan* and Balwinder Singh Dhaliwal**
*Assistant Professor, GNDEC, Ludhiana
simran_josan@yahoo.com
** Assistant Professor, GNDEC, Ludhiana
bs_dhaliwal@gndec.ac.in

Abstract: Artificial Neural Network Ensemble (NNE) approach has been used in the recent past as objective functions in various optimization problems. In this paper, an NNE has been used to calculate the optimized resonant frequencies (even and odd mode) for an elliptical microstrip patch antenna. Length of major axis is given as an input to the NNE for the given eccentricity, thickness and dielectric constant of the substrate. At the output of each network, error is calculated by comparing the obtained output with the desired output. The successful application of NNE is depicted in the results obtained proving it to be one of the trending optimization approach.

Keywords: Elliptical Microstrip Patch Antenna, Neural Network Ensemble, Resonant Frequency.

Introduction

Micro-strip patch antennas are very versatile in terms of resonant frequency, impedance, polarization owing to the characteristics like low profile, conformable to planar and non-planar surfaces, compatibility with the integrated circuit technology, mechanically robust when mounted on rigid surfaces [1]. The possibilities of examination of various parameters of microstrip antennas have made the research area very vast. Numerous types and shapes of antennas are available for exploration [1]. In this paper the elliptical patch antenna is under consideration due to its greater potentials for low-profile antenna applications. An elliptical microstrip antenna resonates dual frequencies i.e. even and odd mode frequencies [2, 3]. Elliptical geometry is the least analysed shape because of the association of complex functions in its analysis [2]. Previously, the analysis process involved the tedious methods like Variational method, Hammerstad formula, Mathieu's and modified Mathieu's function [2, 4].

Design Approaches for Elliptical Antenna

Fig. 1 shows the elliptical geometry under consideration for the patch antenna, where, ‘a’ and ‘b’ are the lengths of semi-major and semi-minor axis of the ellipse respectively, ‘ε_r’is the permitivity of dielectric constant and ‘d’ is the thicknes of the substrate.

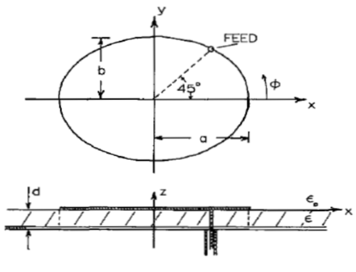

Fig. 1 Elliptical Microstrip Patch Antenna

Calculating resonant frequency from the given dimensions is called the analysis process. Various approaches like Variational method, Hammerstad formula, Mathieu's and modified Mathieu's function have been used to analyze the elliptical patch. Also to obtain circular polarization, methods like the Pentagon method, Corner fed rectangle method, Variations methods have been used [4].

The following equations given by [2] are used for analyzing elliptical patch antenna to find the resonant frequencies (f_e, f_o):

$$a_{eff} = a\left[1 + \frac{2h}{\pi\varepsilon_{ra}}\left\{\ln\left(\frac{a}{2h}\right) + (1.41\varepsilon_r + 1.77) + \frac{h}{a}(0.268\varepsilon_r + 1.65)\right\}\right]^{\frac{1}{2}} \quad (1)$$

$$q_{11}^{e} = -0.0049e + 3.7888e^2 - 0.727e^3 + 2.314e^4 \quad (2)$$

$$q_{11}^{o} = -0.0063e + 3.8316e^2 - 1.1351e^3 + 5.2229e^4 \quad (3)$$

$$f_{11}^{e,o} = \frac{15}{\pi e a_{eff}} \sqrt{\frac{q_{11}^{e,o}}{\varepsilon_r}} \quad (4)$$

Where

a - Semi-major axis
h - Height of dielectric substrate
ε_r - Permittivity of dielectric substrate
a_{eff} - Effective semi-major axis
e - Eccentricity of elliptical patch
$f_{11}^{e,o}$ - Dual-Resonance frequency
$q_{11}^{e,o}$ - Approximated Mathieu function of the dominant $TM_{11}^{e,o}$ mode.

Proposed NNE Analysis Approach

The simple ANN model approach has been used in the past. In this paper, the resonant even and odd mode frequencies are determined by using NNE approach.The ANN ensembles use a number of ANN models (trained for the same input-output relation) in parallel whose outputs are combined eventually [5]. ANN ensemble has proved to be a better approach for modeling the behavior of different networks. The ANN ensembles are preferred over single ANN models because the later have limitations such as generalization of diverse individual networks, which is not unique and performance is not satisfactory in many cases [6]. Fig. 2 shows the proposed ANN ensemble model.

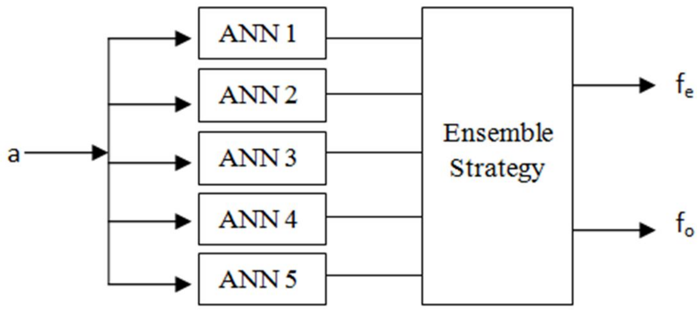

Fig. 2 Proposed NNE model

The above model depicts the NNE consisting of five ANN's. Each ANN individually is given 'a' i.e. the length of the semi major axis of the ellipse as an input for the given eccentricity, dielectric constant and height of the substrate. The proposed NNE model predicts the even mode frequency f_e and odd mode frequency f_o for the given value of 'a'.
Table 1 shows the details of ANN models used in the ensemble. All the five networks considered are multilayer feedforward networks and the number of hidden neurons is varied randomly. The training function considered is *trainlm.*

Table 1: Structure of ANN models used in the proposed NNE

S.No.	Network Name	Network Type	Hidden neurons	Other Parameters
1.	ANN 1	ANN	10	Training function = *trainlm*, learning rate = 0.05
2.	ANN 2	ANN	14	Training function = *trainlm*, learning rate = 0.1
3.	ANN 3	ANN	15	Training function = *trainlm*, learning rate = 0.15
4.	ANN 4	ANN	11	Training function = *trainlm*, learning rate = 0.15
5.	ANN 5	ANN	12	Training function = *trainlm*, learning rate = 0.15

Results and Discussion

Data set of 20 values for 'a' is being generated for which even and odd mode frequencies are calculated using equations (1-4). Five ANN models are created with varying learning rates and number of neurons in the hidden layer. The networks are then trained and tested, thereafter; output in the form of resonant frequency is calculated. Absolute error is calculated between the desired output and the simulated output for each ANN. NNE is formed by combining these networks and finding the average of the five networks. Absolute error of the ensemble network is calculated at the end by calculating the difference in ensemble output and the desired output.

Table 2: Performance comparison (error in even and odd mode frequencies in GHz) of ANN ensemble with individual ANN networks

S. No.	**Input (cm)**	**Desired output (GHz)**		**ANN 1 Output (GHz)**		**ANN 2 Output (GHz)**		**ANN 3 Output (GHz)**		**ANN 4 Output (GHz)**		**ANN 5 Output (GHz)**		**NNE Output (GHz)**	
	a	f_e	f_o	err_ f_e	err_ f_o	err_ f_e	err_ f_o	err_ f_e	err_ f_o	err_ f_e	err_ f_o	err_ f_e	err_ f_o	err_ f_e	err_ f_o
1.	1.6616	3.0538	3.0888	0.0518	0.0524	0.1031	0.1042	0.1110	0.1123	0.0768	0.0778	0.0632	0.0640	0.0045	0.0044
2.	1.9848	2.6060	2.6349	0.0240	0.0252	0.0265	0.0259	0.0097	0.0107	0.0460	0.0474	0.0136	0.0129	0.0079	0.0089
3.	2.5505	2.0734	2.0972	0.0063	0.0063	0.0163	0.0164	0.0113	0.0115	0.0096	0.0100	0.0122	0.0124	0.0017	0.0018
4.	3.5202	1.5376	1.5552	0.0065	0.0066	0.0047	0.0047	0.0037	0.0038	0.0062	0.0063	0.0052	0.0053	0.0034	0.0034
5.	5.4192	1.0223	1.0340	0.0044	0.0044	0.0051	0.0052	0.0051	0.0052	0.0058	0.0059	0.0046	0.0047	0.0009	0.0009
Average Error				**0.0186**	**0.0190**	**0.0311**	**0.0313**	**0.0282**	**0.0287**	**0.0289**	**0.0295**	**0.0198**	**0.0199**	**0.0037**	**0.0039**

Table 2 depicts the performance comparison of individual ANN's and the NNE in terms of output resonant frequencies. The absolute error is calculated in even and odd mode frequencies (err_ f_e, err_ f_o) obtained through individual ANN's and NNE. Table 2 also shows that the average absolute error obtained is relatively very less in case of NNE for both outputs. Hence, NNE approach is better than using the individual ANN models. Fig. 3 shows the comparison graph for individual ANN's and NNE. It is clear from the graph that error fluctuation is less in case of NNE.

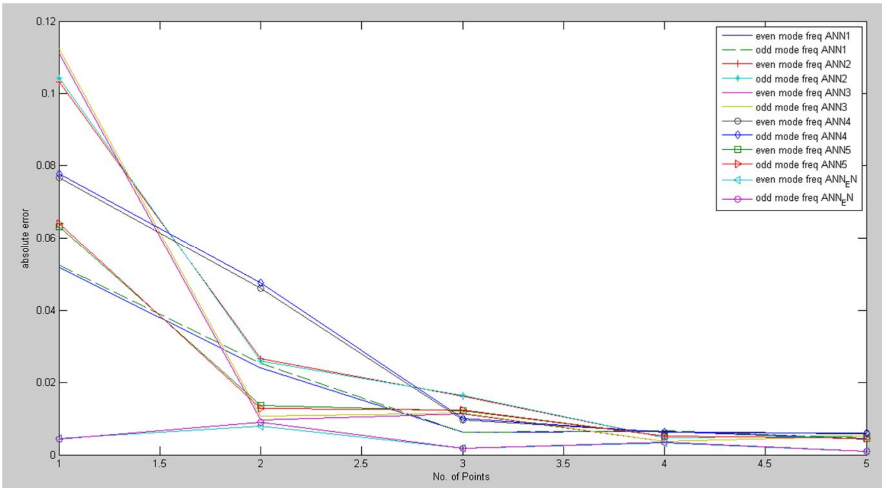

Fig. 3 Comparison graph obtained for individual ANN's and NNE

Conclusion

The proposed technique is more accurate and requires lesser simulation time. The present paper proposes an application of NNE approach to analyze the resonant behavior of elliptical microstrip patch antenna. The proposed NNE has the length of semi-major axis as input and predicts the corresponding even mode resonant frequency, f_e and odd mode resonant frequency, f_o. The average absolute error is very less in case of NNE for both outputs. Also, the error fluctuation is small for NNE outputs. Hence, the proposed NNE approach is an accurate and efficient approach.

References

[1] C. A. Balanis, " Antenna Theory", John Wiley & Sons, Inc., 1997.

[2] Aggarwal , D. Vakula and N.V.S.N. Sarna, " Design of elliptical micro strip patch antenna using ANN ", PIERS proceedings China, September 2011, pp. 264-268.

[3] S.A. Long, L.C. Shen, D.H. Shaubert, F.G. Farrar "An experimental study of circular polarized elliptical printed patch antenna", IEEE transaction on antennas and propagation, Vol. 29, No.1, 1981, pp. 95-99.
[4] P. Mythili , A. Das "Simple approach to determine resonant frequencies of micro strip antennas", IEE Proceedings microwave antenna propagation Vol. 145, No.2, April 1998, pp 159-162.
[5] Granitto PM, Verdes PF, Navone HD, Ceccatto HA, "Aggregation algorithms for neural network ensemble construction ", Proc Brazilian Symp Neural Netw, 178-183.
[6] S. Yang and A. Browne, "Neural network ensembles: combining multiple models for enhanced performance using a multistage approach", Expert Syst., Vol. 21, No. 5, Nov. 2004, pp. 279- 288.