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Neurocomputational models for Parameter Estimation of Circular Microstrip Patch Antennas

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Abstract

Neurocomputational models eliminates the complex, lengthy and time consuming mathematical procedures for design, analysis and calculating performance parameters of Microstrip antenna. No single ANN based model has been proposed till date for calculating all parameters of circular microstrip antennas simultaneously. This paper presents a Neuro-Computational (NC) approach for estimation of all performance parameters such as Return Loss (RL), Voltage Standing Wave Ratio (VSWR), resonant frequency (f_r), Band-Width (BW), Gain(G), Directivity(D) and antenna efficiency(η) of Circular Microstrip Patch Antenna (CMPA) simultaneously. The difficulty in calculating the parameters of these antennas lies due to the involvement of a large number of physical parameters including their associated optimal values. It is indeed very difficult to formulate an exact numerical solution merely on practical observations based empirical studies. In order to circumvent this problem, an alternative solution is achieved using artificial neural network (ANN). Feed-Forward Back-Propagation Artificial Neural Network (FFBP-ANN) trained with Levenberg-Marquardt algorithm is used for estimation of different performance parameters of CMPA. The results of NC estimation are in very agreement with simulated, measured and theoretical results.

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Keywords: Gain; Neurocomputational Model; Antenna; Bandwidth; Frequency; Directivity

1. Introduction

In recent years, Microstrip Patch Antenna (MPA) has become important for antenna designer because of its advantage such as, simple configuration, low cost, ease of fabrication, mechanically strong and compatibility with

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integrated circuits [1].NC models are useful tool for microwave modeling and antenna design. Applications of ANNs in Microstrip antenna design and analysis are more than one decade old [2]. In area of microwave applications, ANNs have been design multi slot antenna [3] and CMPA [7], and analysis of circular [5-6], [4], elliptical [8] and multi-slot antenna [9]. Table1. Compares number of parameters of circular microstrip antenna estimated simultaneously using ANN more than one decade old. From Table1 It is clear that ANNs have been used for estimation of at most two parameters of CMPA simultaneously. No single NCM has been proposed till date for calculating all parameters of CMPA simultaneously. This paper suggests a feed-forward NCM for calculating all performance parameters (seven) return loss (RL), voltage standing wave ratio (VSWR), resonant frequency (f_r), bandwidth (BW), gain, directivity and antenna efficiency simultaneously. The section 2 describes the procedure to obtain a data dictionary for training and validation of NCM. Section 3 explains the development of NCM for performance parameter estimation of CMPA. Section 4 describes the result and the conclusion is presented in section 5 of this paper.

Table 1.Cpmerision of number of parameters of CMPA estimated simultaneously using ANN.

Paper no	Antenna Type	Parameter	Ann out-put
6	Circular	Resonant Frequency	Single
		Radius	Single
3	Multi-Slot Microstrip	Scattering Parameter	Single
8	elliptically	Resonant frequency and Return loss	Two
9	Multi-Slot Microstrip	Resonant frequencies	Two
7	Circular	Resonant frequency	Single
		radius	Single
5,6	Circular	Resonant frequency	Single

2. Data Dictionary

The first step in developing in NCM is collection of different parameter of CMPA. In microwave applications, there are two ways to produce the data for generating data dictionary for training and validation of NCM. These are simulations and experimentation. The selection of data producer depends on availability and application [10]. Simulation method has advantages over experimental method. In simulation method input parameter can be changed easily because in this only a mathematical change and does not involve modification in physical parameter. Experimental method has more error in producing data than simulation method due to tolerance of apparatus used in experiment [11]. In this paper IE3D software has been used for generating data dictionary. A set of forty three CMPA has been designed of which twenty eight antennas have used for training and remaining fifteen have been used for validation of NCM. Resonant frequency of CMPA can be calculated theoretically if parameter of CMPA such as radius of patch ‘a’, dielectric constant of substrate ε_r , and height of substrate (h) is known in advance. Effective radius of circular microstrip antenna can be calculated by using [1].Then by using [2] resonant frequency of antenna is calculated theoretically.

$$a_e = a\left\{1 + \frac{2h}{\pi a \varepsilon_r}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{\frac{1}{2}} \quad (1)$$

$$f_r = \frac{1.8412 v_o}{2\pi a_e \sqrt{\varepsilon_r}} \quad (2)$$

Theoretically calculated results are then compared with results obtained using NCMs. Then a set of three CMPA are fabricated on different substrates Roger 5880, Roger 5870 and glass epoxy FR4for testing NCM.

3. NC Model for Parameter Estimation of CMPA

NC model for parameter estimation of CMPA is shown in Fig.1. Its Neurocomputational structure is shown in Fig.2, which consists of one input, one output and one hidden layer. The number of hidden layers depends upon the complexity of the problem. The proposed Feed Forward Back Propagation NC Model has three in-puts and seven outputs as shown in Fig.1. The hidden layer of proposed NC model consist of thirty three tansigmoidal neurons with non linear activation function where as input and output layer consist of three and seven neurons respectively. In proposed NCM in input layer pure linear activation function is used. In output layer no activation function is used. Input and output layers of neurons are interconnected by different sets of weights.

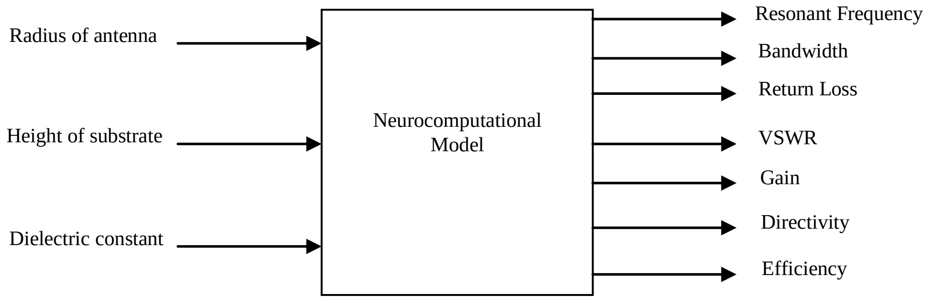


Fig.1. Neurocomputational Model for Parameter estimation of CMPA

Weights of NCM can be adjusted for the training proposed model to give the desired output. Then NC model output is compared with actual output to calculate corresponding error. This training process works until the error gets minimized than the given value. The network parameters are of proposed NCM can be optimized by using a set of input-output pairs called the 'training set', in order to fit the network targets.

4. Results and discussion

Results of proposed NCM for parameter estimation of Circular Microstrip Patch Antenna as a result of training and validation studies are given below.

4.1. Results of ANN Training

Results of proposed NCM in terms of different performance parameters such as Mean Square Error (MSE), maximum absolute value of absolute error and number of epochs taken for training are shown in Table-II. Fig.3 shows the Learning Characteristic of proposed NCM. It has been observed that only 146 epochs are needed to reduce MSE level. to a value 9.96e-007. Absolute error for estimation of different sevens parameters, versus radius of CMPA as result of training study is also shown in Fig. 4. and Fig.5. which shows that maximum error for estimating resonant frequency (f_r), bandwidth (BW), return loss (RL), voltage standing gain(G), directivity(D) and antenna efficiency(η) of CMPA are 0.0018,0.0044, 5.3515e-004, 0.0041, 0.0013, 0.001 and 0.004 respectively.

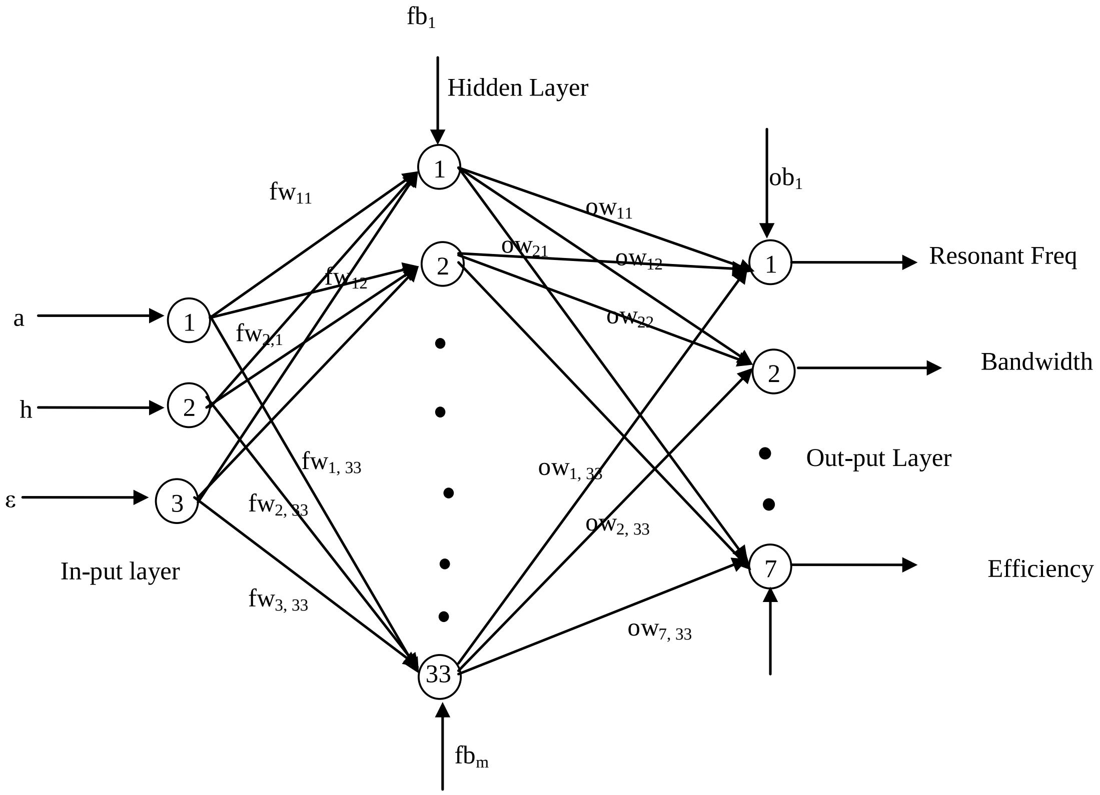


Fig.2. Proposed Neurocomputational Model

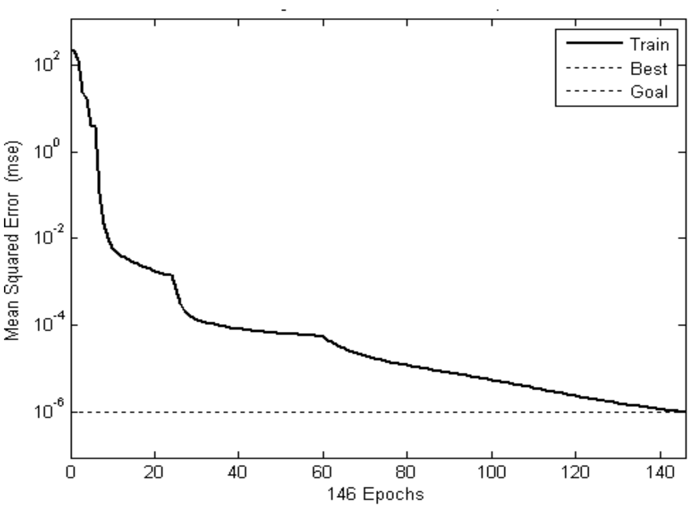


Fig.3. Learning Characteristics of Neurocomputational Model

Table 2 Results of Proposed NCM for training data

Epochs	MSE	Absolute error for estimation of						
		Resonant Freq.	Bandwidth	Return Loss	VSWR	Gain	Directivity	Effi.
146	9.96e-007	0.0018	0.0044	5.3515e-004	0.0041	0.0013	0.001	0.004

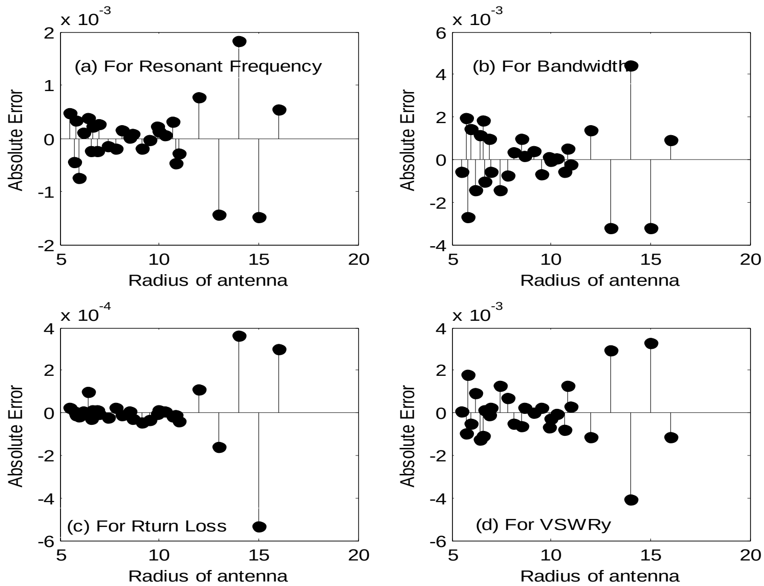


Fig.4. Absolute Error for estimating the value of (a) resonant frequency (b) bandwidth (c) Return loss (d) VSWR of CMPA using NCM as a result of training study

4.2. Results of Validation Study

In order to test the NCM remaining 15 antennas are used for validation of developed 3-33-7 structure for estimating different seven parameters of CMPA. The maximum value of error for estimating resonant frequency (f_r), bandwidth (BW), return loss (RL), voltage standing gain(G), directivity(D) and antenna efficiency(η) of CMPA as a result of validation study are 0.1333, 0.04257, 1.5601 , 0.1066, 0.3353, 0.1088and 0.0476respectively. Accomplishment of such low value of these errors proves that the NCM model is an exact model for all parameter estimation of CMPA. Graphical Comparison of NCM results for different parameters with simulated and theoretical results are shown in fig.6, fig.7 and fig.8 respectively.

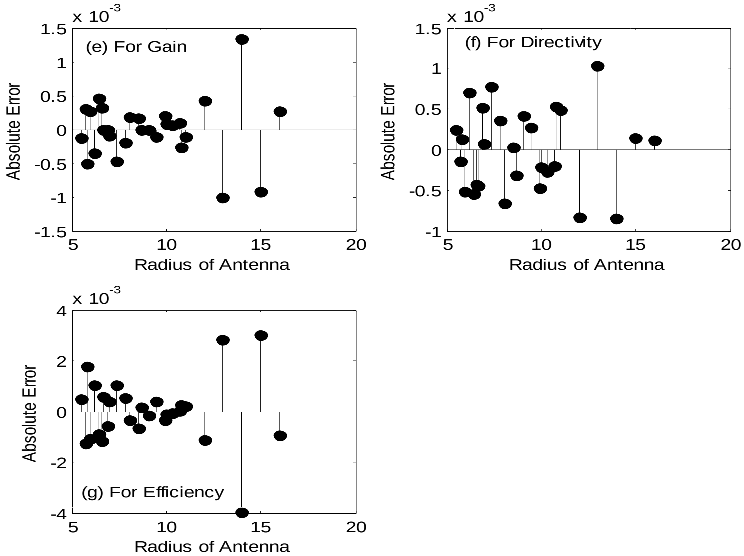


Fig.5. Absolute Error for estimating the value of (e) Gain (f) Directivity (g) Efficiency of CMPA using NCM as a result of training study

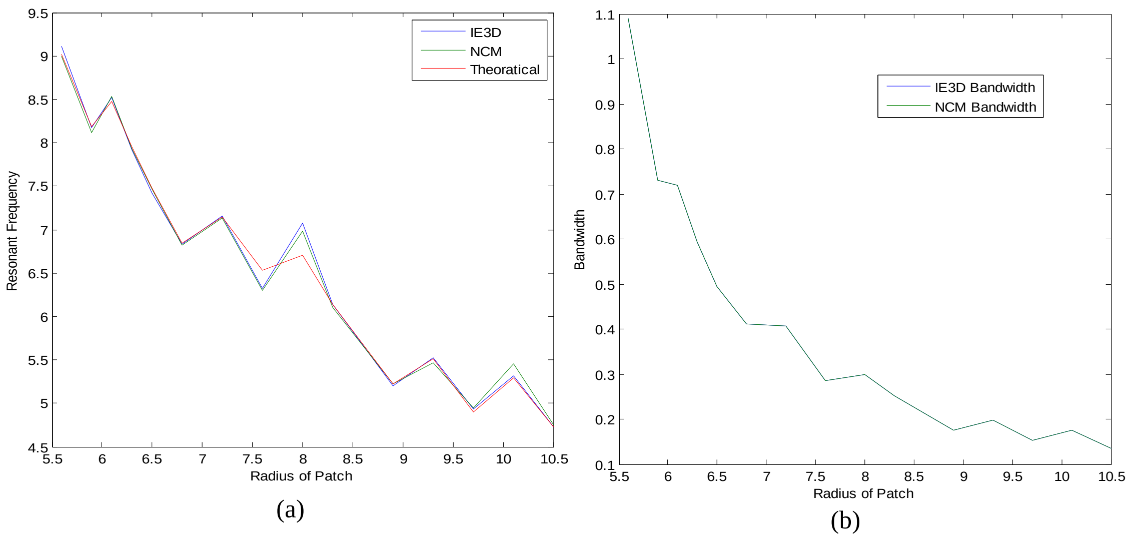
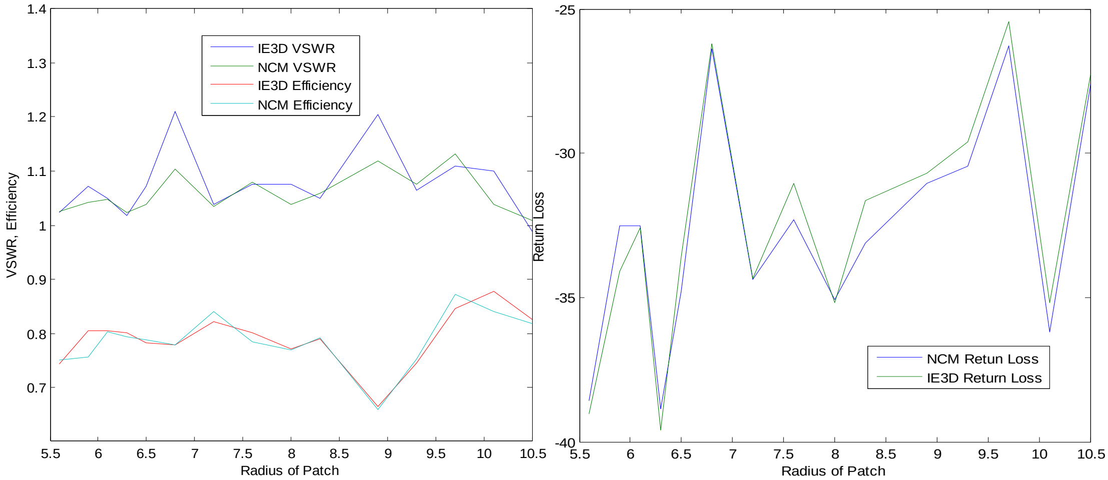


Fig.6 (a) Comparison of NCM results for (a) resonant frequencies and (b) bandwidth with simulated and theoretical results



(a) (b)

Fig.7. Comparison of NCM results for (a) VSWR and Efficiency (b) return loss with simulated results

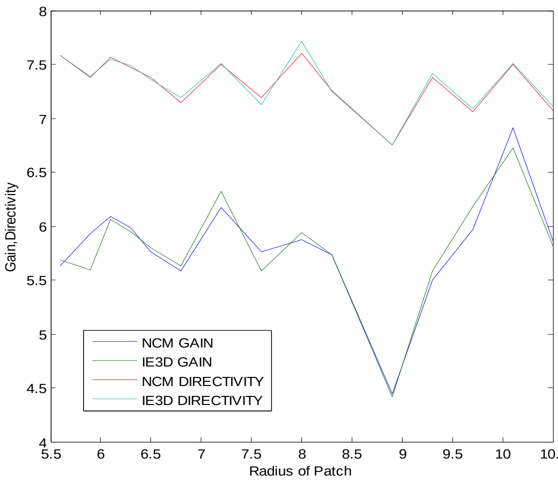


Fig.8 Comparison of NCM results for Gain and Directivity with simulated results

5. Conclusion

In this paper neurocomputational(NC) approach is applied for estimation of all performance parameters such as return loss (RL), voltage standing wave ratio (VSWR), resonant frequency (f_r), bandwidth (BW), gain(G), directivity(D) and antenna efficiency(η) of Circular Microstrip Patch Antenna simultaneously. Back-Propagation Artificial Neural Network trained with Levenberg-Marquardt algorithm is applied for estimation of different performance parameters of Circular Microstrip Antenna. Proposed ANN model has good accuracy and validity for wide range of input parameters of CMPA. This ANN model takes very small computation times and is suitable for wide range of applications.

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