Bended Dipole Antenna Parameter Estimation by Using Artificial Neural Network

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Abstract This paper investigates the feasibility of using artificial neural networks (ANN) to establish the design parameters of the bended dipole antenna. The feed-forward backpropagation based on the Scaled Conjugate Gradient (SCG) algorithm was applied to develop the ANN model. The proposed ANN model includes two hidden layers, and each hidden layer contains ten neurons. A total of 66 datasets were used for training, testing, and validating the proposed ANN model to identify bending positions and angles of a dipole antenna with a working frequency range of 1.6–2.2 GHz. Simulation and experimental validations were conducted to test the proposed method. Both simulation and experimental results showed that the proposed method has the potential to provide dipole antenna design parameters in a fast and cost-effectively manner.

Keywords Dipole antenna · Artificial neural networks · Antenna parameters · Resonance frequency

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1 Introduction

With the rapid development of information technology, breakthroughs have been made in many fields that eliminate human factors, resulting in time and cost advantages. In recent years, several artificial neural networks (ANN) have been applied to improve antenna design [1–4]. An ANN model was applied to design a circular microstrip patch antenna [1]. ANN was used to develop an elliptical microstrip patch antenna with high gain and impedance matching [2]. ANN model was applied to create an antenna in the X-Ku band [3]. Using the Levenberg Marquardt algorithm, the ANN model was applied to establish a flexible wideband antenna with an error rate of 6% for WLAN, 5G, and WiMAX applications [4].

The ANN model was trained with different notch antenna data, taking the antenna dimensions and frequency as input and outputs. The notch antenna frequency was calculated correctly without simulation [5]. Different ANN algorithms were tested and compared for developing high-accuracy antenna parameters [6]. The reduction of mutual interaction between antenna cells in a MIMO antenna was investigated with the help of ANN modeling [7]. The ANN-based hybrid fractal antenna was developed for biomedical applications [8, 9]. ANN techniques have been investigated for designing metamaterial antennas [10–13].

This study investigates the feasibility of ANN in dipole antenna to establish antenna design parameters. The proposed ANN model includes two hidden layers, each containing ten neurons. The feedforward backpropagation based on the scaled conjugate gradient (SCG) algorithm is applied to develop the ANN model. The ANN-based dipole antenna has a working frequency range of 1.6–2.2 GHz. Both simulation and experimental validations were conducted to test the proposed ANN-based dipole antenna.

2 Dipole Antenna Design

This study investigates a dipole antenna with a target operating frequency range of 1.6 and 2.2 GHz. Finite integration technique-based microwave simulation program is selected for antenna design and simulation. The dipole antenna has 35 mm in length and 1 mm in thickness. Figure 1a shows the proposed dipole antenna with a target bending configuration, and Fig. 1b shows the radiation pattern with the proposed antenna. The parameters of antenna gain, return loss (S11), and resonance frequencies with different configurations have been investigated to establish length position (L) and angle (θ) using COMSOL tool. The length positions are changed from 5 to 30 mm, angles are shifted from 0° to 90° with 150 intervals. A total of 42 configurations have been investigated. Frequency, S11, and gain values corresponding to bending positions and angles were applied for ANN training using MATLAB tool.

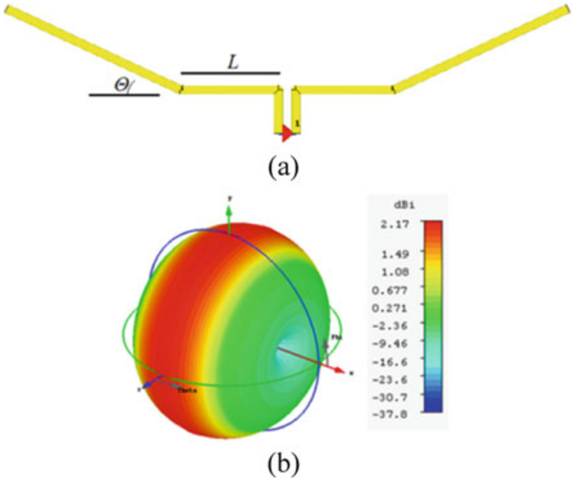

Fig. 1 **a** Dipole antenna, **b** simulated radiation pattern

3 Artificial Neural Network Modelling

The SCG algorithm is used for developing ANN structure because SCG offers minor errors. The ANN model consists of two hidden layers, and each hidden layer contains two neurons. Figure 2 shows the structure of the proposed ANN model. Table 1 lists example input and out parameters of the ANN network. The bending length position and angle are the output parameters of the proposed dipole antenna. In this study, the authors select 63.6, 18.2, and 18.2% of 66 datasets for training, testing, and validating the ANN-based antenna using MATLAB tool.

Table 2 compares the ANN output parameters with desired parameters. The average error of frequency, S11, and gain are 2.76, 13.75, and 3.505%. The results show that the proposed ANN could establish design parameters (bending length position, and angle) of the dipole antenna.

Figure 3 shows the simulated S parameters of the proposed antenna with different bending length positions and angles. Figure 4 displays the simulated radiation pattern of dipole antenna with different configurations. The proposed ANN model examines antenna configurations covering bending length positions and angles.

4 Experimental Validation

The proposed dipole antenna is constructed using copper strips, and various experimental validations are conducted to validate the proposed antenna. The Agilent VNA, with a frequency of up to 43.5 GHz, is used to measure complex S11 characteristics. The measurement calibrations are performed using open, short, and 50 Ω loaded

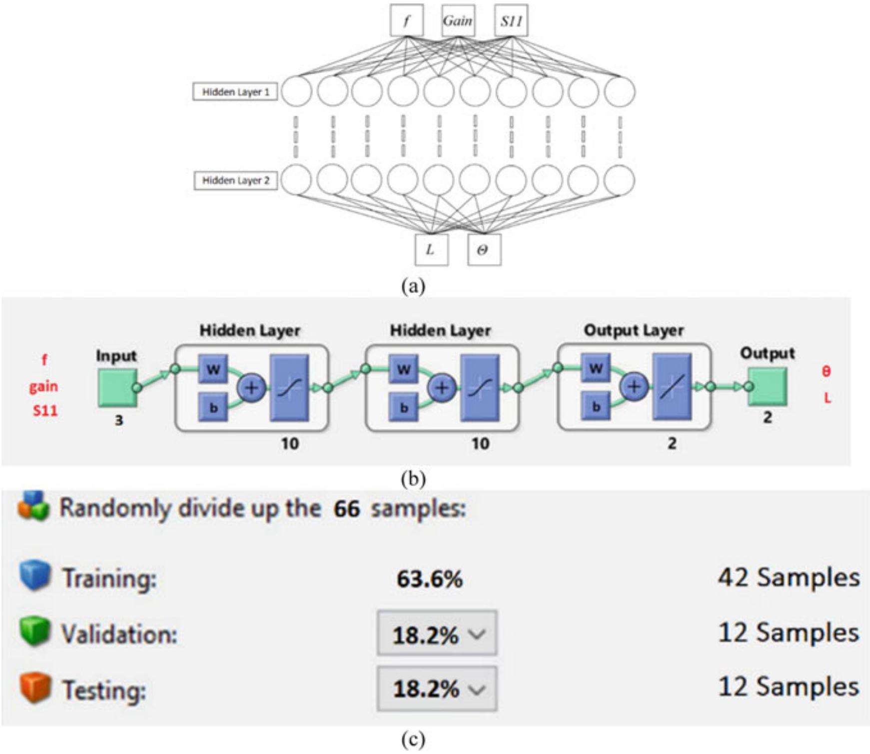

Fig. 2 **a** ANN structure, **b** ANN hidden layer model, **c** training performance

Table 1 Example input and output parameters of ANN model

Desired frequency	Desired gain	Desired $S11$	ANN L	ANN θ
1.9	2.1	− 18	12.1	15.7
1.82	1.9	− 22.5	12.6	50.9
1.75	2.15	− 18.5	9.6	15.05
1.87	1.6	− 15.5	8	53.4
1.69	2.05	− 26	7.5	34.2
1.72	1.95	− 24	8.3	32.7
1.92	2.1	− 20.2	12.5	20.7
1.86	2.11	− 25	11.9	17.3
2	2	− 24	24.8	61.6
2.2	1.75	− 24	15.5	88.3
1.95	2.11	− 19	25.9	35.5
1.95	1.95	− 17.5	26.8	53.3

Table 2 ANN output parameters with error rates

Desired frequency	ANN frequency	Frequency error %	Desired S11	ANNS11	S11 error %	Desired gain	ANN gain	Gain error %
1.9	1.92	1.05	− 18	− 19.7	9.72	2.1	2.13	1.42
1.82	1.85	1.64	− 22.5	− 26.9	19.5	1.9	1.84	3.15
1.75	1.89	8	− 18.5	− 20.1	8.64	2.15	2.11	1.86
1.87	1.82	2.67	− 15.5	− 15.7	1.29	1.6	1.72	7.5
1.69	1.79	5.91	− 26	− 33.5	28.8	2.05	1.96	4.39
1.72	1.81	5.23	− 24	27.6	15	1.95	1.99	2.05
1.92	1.92	0	− 20.2	− 19.6	2.97	2.1	2.1	0
1.86	1.91	2.68	− 25	− 19.9	20.4	2.11	2.11	0
2	1.99	0.5	− 24	− 20.9	12.7	2	2.06	3
2.2	2.09	5	− 24	− 15.4	35.8	1.75	1.6	8.57
1.95	1.95	0	− 19	− 18.7	1.57	2.11	2.14	1.42
1.95	1.96	0.51	− 17.5	− 19	8.57	1.95	2.12	8.71
Average error %		2.76			13.75			3.51

cases in free space. Figure 5a, b show the experimental measurement setups corresponding to the configurations shown in Fig. 3. Figure 5c displays measured return loss (S11) parameters of the proposed antenna with different bending angles. The measured antenna performance results are close to the simulation results. The results show that the proposed ANN model can potentially establish design parameters of dipole antenna, especially in bending position and angle.

5 Conclusions

In this study, bending length positions and angles of dipole antenna were investigated using the ANN model. The SCG algorithm was used to develop the ANN model containing two hidden layers, each consisting of ten neurons. The proposed ANN model was applied to establish dipole antenna design parameters, especially the bending length and angle values. Both simulation and experimental results showed that the proposed ANN model has the potential to become a helpful tool in designing antennas in a cost-effective and fast manner.

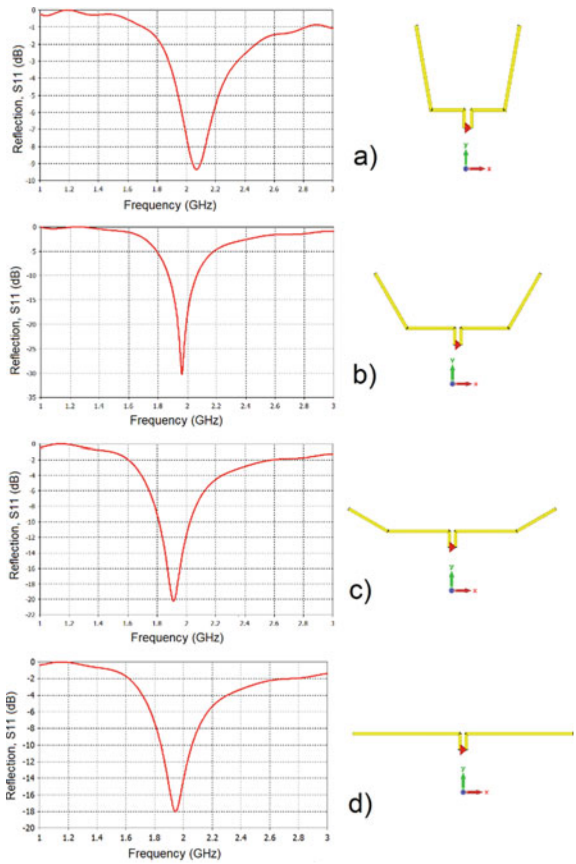

Fig. 3 S parameters of dipole antenna using different configurations

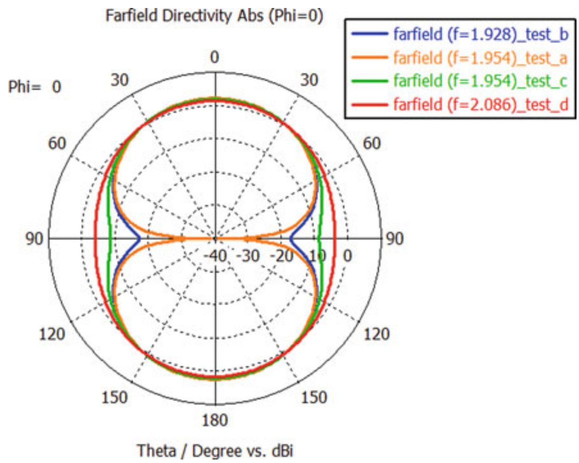

Fig. 4 Radiation pattern of dipole antenna with different configurations

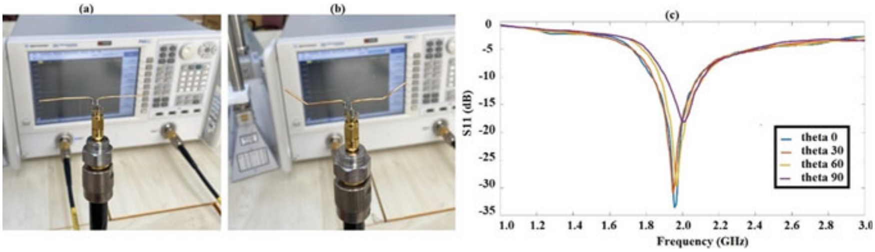

Fig. 5 **a**, **b** Experimental measurement setups, **c** measured S11 parameters

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