Antenna Design Prediction Using Deep Learning

Objective To Predict the Parameters and dimensions of antenna using Deep Learning.

Abstract

The microstrip patch antenna can also be designed using an artificial neural network (ANN) modeling technique where size of the antenna is major limitation especially in mobile and wireless applications. Analysis and synthesis problems for designing of microstrip patch antennas were discussed using the artificial neural network technique. An analysis problem refers to calculation of resonant frequency of microstrip patch antenna whereas a synthesis problem refers to calculation of dimensions of patch antenna. Sequential training model of artificial neural network is used to train the network for minimization of error and computation time. Therefore, the geometric dimensions of patch are obtained with high accuracy in less computation time as compared to simulation software.

Introduction

There has been a tremendous development in the field of patch antenna during the last two decade . It is the result of the overwhelming research and this technology has been quickly absorbed for consumption. A few previous research works done in this field are discussed in this section. The length of an antenna is inversely proportional to the resonant frequency of patch, that is, an antenna operating at higher frequency is smaller in size than compared to the antenna operating at lower frequency. So, to decrease the antenna dimensions required for operating the antenna at lower frequency, the electrical length of the patch should be enlarged at lower frequency. In the mentioned article, 70% size reduction of the proposed microstrip patch design is reported. an innovative technique is proposed for calculating the resonant frequency of circular microstrip patch antennas using artificial neural for computer-aided design (CAD) applications. This technique is applicable for a wide range of substrate thicknesses and permittivity for the computer-aided design (CAD) applications of microstrip antennas. .], single-fed broadband square patch antenna was constructed for ultra high frequency (UHF) radio frequency identification (RFID) applications using meandered probe feeding techniques for good impedance matching. The purpose of the antenna was to optimize and modify antenna.. Two parallel L-shaped antennas were used to obtain better bandwidth. The bandwidth of the antenna was 6.41 GHz ranging from 3.51 to 9.65 GHz. Return-Loss of the proposed antenna is −28 dB at 3.51 GHz and −25 dB at 9.65 GHz. E-shaped antenna was constructed for wireless communications, and its applications using U-slot patch was introduced under patch antenna to increase and optimize bandwidth of the proposed antenna. The systematic study of antenna was enhanced gain, return loss, bandwidth, and radiation pattern.. The proposed design was used for broadband applications. Four spring resonators form an ultra-wideband frequency. Low percentage error and high precision in less time are obtained by using a knowledge-based hybrid neural network (KBHNN) model for designing of microstrip antennas (proximity coupled), which is used for various WiMAX, WiFi, and WLAN applications. Figure 1 illustrates a simple rectangular microstrip patch antenna of substrate height h, dielectric constants εr, εy, width W, and length L.

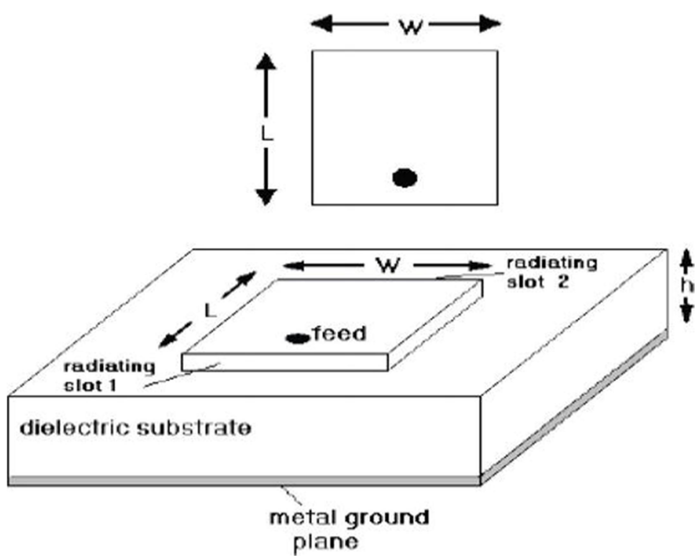

Figure-1: Basic layout of rectangular patch antenna.

Synthesis is defined as to obtain dimensions (W, L) of microstrip antenna while providing the resonant frequency (fr), height of the dielectric substrate (h), and dielectric constants at the input of the ANN model (Figure 2). Dimensions of patch are computed using the designed equations of the microstrip patch antennas. For the analysis problem of patch antenna, resonant frequency (fr) or both upper and lower cutoff frequencies are obtained at the output of ANN model while providing the dimensions of patch and other parameters as the inputs of ANN model, as shown in Figure 3. This model is very significant for antenna researchers to determine the dimensions and other parameters of microstrip antenna.

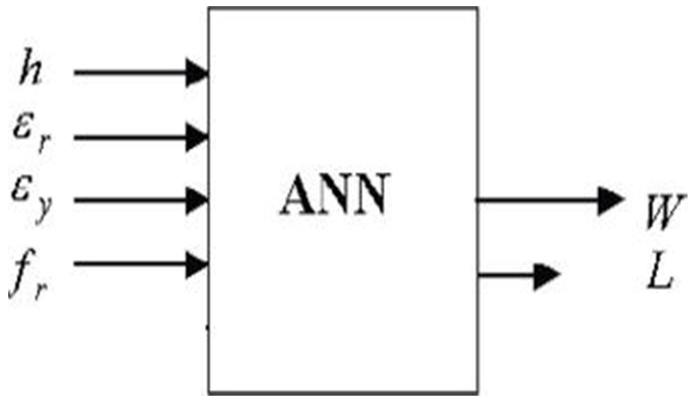

Figure-2: The synthesis of microstrip patch using ANN model

The range of dielectric constants should be taken between 2.2 and 12 but the dielectric substrate should be thicker and the dielectric constant should be less for obtaining high efficiency and wide bandwidth. The effective thickness (*he*) and effective dielectric constant ($\varepsilon_{\text{reff}}$) are calculated using Eqs. (1) and (2), where *h* is thickness and εg is the geometric mean of dielectric constant.

$$h_e = \sqrt{\frac{\varepsilon_r}{\varepsilon_g}}\, h \qquad \text{E1}$$

$$\varepsilon_{eff} = \frac{\varepsilon_g + 1}{2} + \frac{\varepsilon_g - 1}{2}\left[1 + 12\frac{h_e}{W}\right]^{-\frac{1}{2}} \qquad \text{E2}$$

If the velocity of light is denoted by *C*, the width of antenna is calculated using Eq. (3).

$$W = \frac{C}{2f_o}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad \text{E3}$$

Eqs. (4) and (5) represents the real length of the patch (L).

$$L = L_{eff} - 2\Delta L \qquad \text{E4}$$

$$L = \frac{1}{2f_{r}\sqrt{\varepsilon_{eff}}\sqrt{\mu_0\varepsilon_0}} - 2\Delta L \qquad \text{E5}$$

The fringing property of patch gives rise to the extended electric length, which is illustrated by Eq. (6)

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{w}{h}+0.813\right)} \qquad \text{E6}$$

ANN architecture for microstrip antenna

There are many algorithms of ANN which is used to train the neural network [12]. In this work, Feed dorward training algorithm was applied to train the neural network and to build the ANN models for patch antenna

These models are called feedforward because information flows through the function being evaluated from **x**, through the intermediate computations used to define f, and finally to the output y. There are no feedback connections in which outputs of the model are fed back into itself. When feedforward neural networks are extended to include feedback connections, they are called **recurrent neural networks**(we will see in later segment)**.**

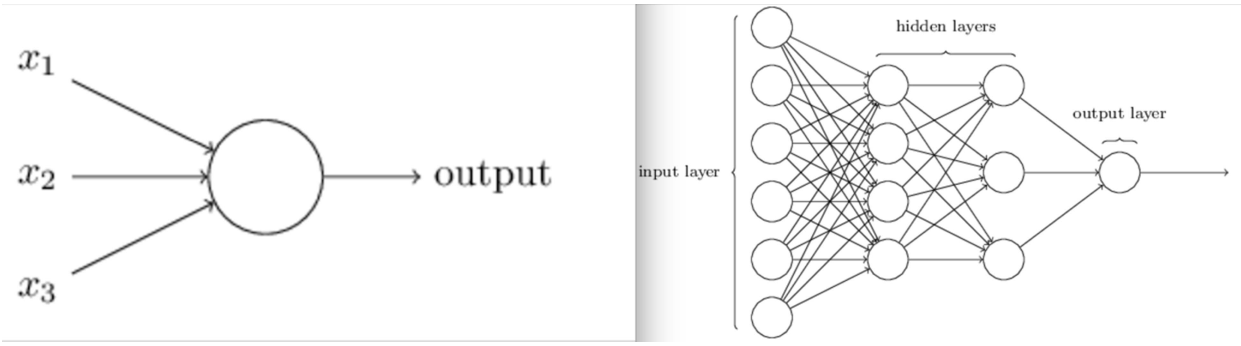

Fig 3. The left image is of perceptron layer and right layer is the image of Multilayer neural network.

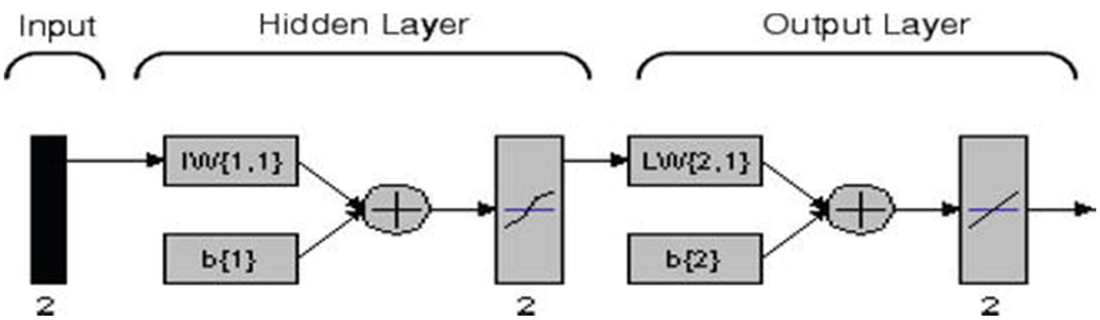

Fig-4Neural network architecture for microstrip patch antenna.

Synthesis of microstrip patch antenna using artificial neural network

Synthesis is defined as to obtain the dimensions of microstrip patch (W, L) as targets while providing the cutoff frequencies (f_1, f_2), thickness and dielectric constants of the dielectric material as the input parameters of ANN model. Around 25–30 samples are collected for ANN training which is obtained by varying the dimensions of microstrip patch antenna using electromagnetic simulation software as illustrated in Table 1. It is used for the synthesis of patch antenna. The neural network is trained by using back-propagation algorithm. The ANN training graph results for the synthesis of microstrip patch antenna is shown in Figure 5 which shows that 100 epochs are required for ANN training and error get reduced from 10^2 to nearly 10^{-2}.

Table-1

Inputs (lower and upper cutoff frequency in GHz)		Targets (dimensions of patch in mm)	
f_1	f_2	W	L
4.94	5.04	17.7	13.34
4.86	4.95	17.7	13.55
4.82	4.91	17.7	13.65
4.8	4.89	17.7	13.85
4.77	4.85	17.7	14.05
4.73	4.81	17.7	14.15
4.71	4.79	17.7	14.25
4.69	4.76	17.7	14.35
4.66	4.73	17.7	14.45
4.78	4.87	18.3	13.85
4.65	4.73	18.3	14.35
4.61	4.7	18.8	14.35
4.49	4.55	18.8	14.85
4.47	4.55	19.3	14.85
4.37	4.41	19.3	15.35
4.35	4.41	19.8	15.35
4.31	4.37	20.3	15.85
4.29	4.35	20.3	16.35
4.27	4.33	20.8	16.35
4.26	4.33	20.8	16.85
4.21	4.27	21.3	16.85
4.16	4.21	21.3	17.35
4.14	4.19	21.8	17.35
4.02	4.04	21.8	17.85
3.99	4.01	22.3	17.85
3.92	3.93	22.3	18.35

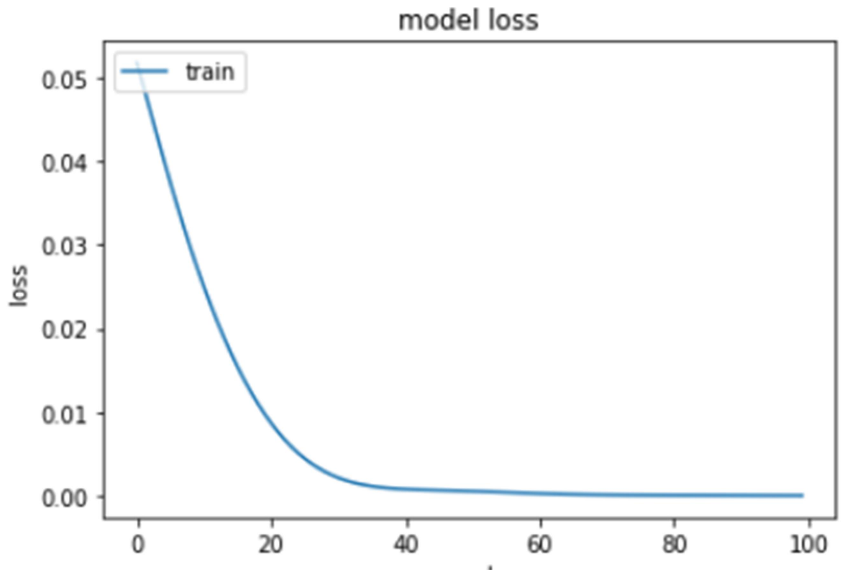

Fig-5:Loss

Conclusion

In this work, the rectangular microstrip patch antenna is designed using the artificial neural network modeling procedure. Here synthesis refers to forward side and analysis refers to reverse side of the problem. Therefore in synthesis problem, the geometric dimensions such as length and the width of antenna are obtained with more accuracy in less time as compared to simulation software while providing resonant frequency, thickness, and dielectric constant at the input side of the ANN model. In the analysis problem of patch antenna, resonant frequency or both upper and lower cutoff frequencies of patch antenna are obtained at the output side of the ANN model while providing the dimensions of patch (W, L) and other parameters at the input side of the ANN model with much accuracy in less time.

Now the future work in this work includes trying more topologies to obtain more compact patch antennas, filters, and many other microwave/RF modeling design using artificial neural network for different band of applications such as ultra-wideband (UWB), Global System for Mobile communications (GSM)