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Dimension Optimization of Microstrip Patch Antenna in X/Ku Band via Artificial Neural Network

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Abstract

This paper is aimed at designing the effective shape of a microstrip patch antenna for X Band (8 to 12 GHz) and Ku Band (12 GHz to 18 GHz). Artificial Neural Network is used for optimizing microstrip antenna dimensions. The Network takes the different microstrip antenna parameters as inputs and delivers its dimensions in the X/Ku Band satellite communication. The error and validity analysis of neural network results are carried out in Matlab. Finally, HFSS simulation software results for prototype microstrip antenna, which has the best antenna parameters, is compared with real value.

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Keywords: Microstrip Antenna, Artifical Neural Networks, X/Ku Band, Optimization

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1. Introduction

In recent years, wireless communication has been gradually developing and involving innovative wants in antenna technology. Wireless communication has so many applications like WLAN, WIFI, mobile phone, traffic radar, GPS, military, biomedical and aerospace area that antenna structure is vital part of these systems. Microstrip patch antennas have so useful properties which are small size, lightweight, low cost, broad bandwidth, compability to planar or non-planar surface, easy to fabricate and integrate MIC/MMK circuit. A simple microstrip patch geometry can change as a rectangular, square, triangular or circular metal patch on top of a grounded dielectric substrate (Jana, 2013). On the purpose of working in multi-band operation, compact leaf shaped microstrip patch is preferred apart from well-known geometry. In addition, it has more dominant characteristics which are low profile, low radiation loss and integration with microwave manolithic integrated circuit (Fakharian&Rezael, 2014).

X and Ku Band are separate and back-to-back in electromagnetic spectrum. According to IEEE standards, X/Ku Band are in range of 8 to 12 GHz and 12 to 18 GHz. X Band is appropriate for a fast and secure satellite communication system which is a platform between network control stations and several satellite ground terminals connected to them. X Band interval support voice, synchronous or asynchronous data transmission, video teleconferencing applications. On the other hand, Very Small Aperture Terminal (VSAT) system on the yacths and ships is suitable for Ku Band applications. For detection of ships speed or displacement, antenna beams need to be changed in Ku Band intervals.

Computer aided design (CAD) software uses various methods in order to analyze 3D microstrip patch antenna design. Numerical computing methods are Finite Elements Methods (FEM), MoM and Finite Difference Time Domain (FDTD) which consist of high computer system requirements. The relationships between microstrip patch antenna design parameters and patch dimensions have highly non-linearity. Thus, the main goal of using artificial neural network is which high level of correct patch dimensions are obtained, thanks to using restricted computer resources by means of artificial neural network.

2. Antenna Structure

Microstrip patch antenna includes very thin metallic strip placed above dielectric material and then the lowest layer is ground (Motin, Hasan & Shariful, 2012). Thickness of the metallic microstrip is very less than the wavelength ($t \ll \lambda_0$) and on top of that $0.003\lambda_0 \leq h \leq 0.05\lambda_0$ is suggested for selection of dielectric substrate's height. In order of design for well-known microstrip patch, length must be in valid interval of $\lambda_0/3 \leq L \leq \lambda_0/2$ (Huque, Hosain, Islam & Chowdhury, 2011).Various dielectrical material can be used to design microstrip patch antenna. Their dielectric constants are in the interval of $2.2 \leq \varepsilon_r \leq 12$. The microstrip patch antenna parameters depend on its dimensions and material properties. For efficient radiation pattern, well-known patch width becomes; (Motin, Hasan & Shariful, 2012).

$$W = \frac{c}{2fo}\left(\frac{2}{\varepsilon r + 1}\right)^{1/2} \tag{1}$$

The effective dielectric constant is decided using this equation;

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left(1 + \frac{12h}{W}\right)^{-1/2} \tag{2}$$

Also, length of the antenna and effective length are formulated as

$$\Delta L = 0.412h\frac{(\varepsilon reff + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon reff - 0.258)(\frac{W}{h} + 0.8)} \quad (3)$$

$$Lreff = \frac{c}{2fo(\varepsilon reff)^{1/2}} \quad (4)$$

$$L = Lreff - 2\Delta L \quad (5)$$

Modified leaf shaped planar microstrip patch antennas in Fig.1 has multilateral advantages which are high radiation performance, wider bandwidth, small size and multi-band operating frequency. Also, leaf shaped geometry is utilized to design modified tulip shaped microstrip patch antenna in this work.

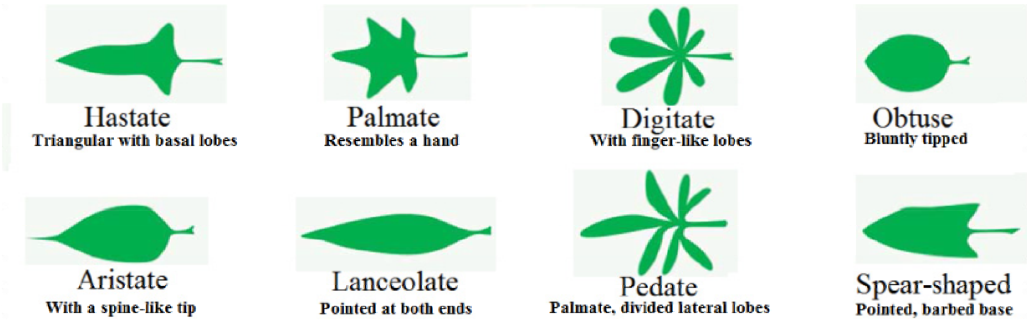


Fig. 1. Modified leaf shaped planar microstrip patch antennas

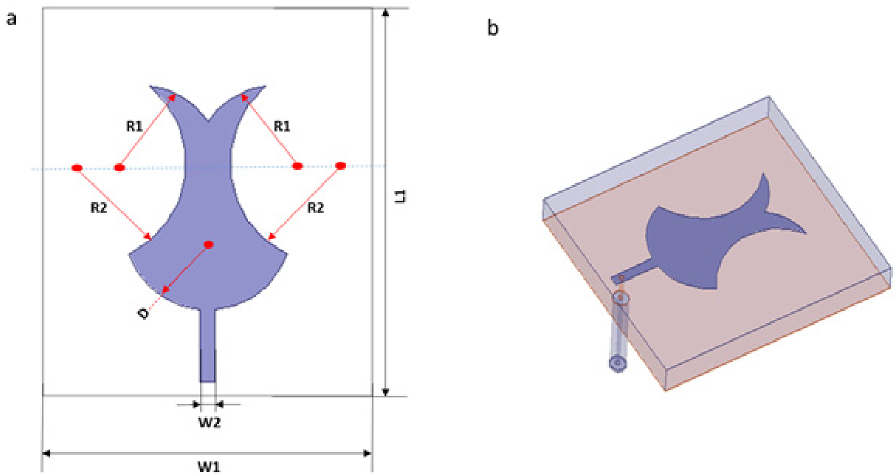


Fig. 2. (a) Top view; (b) Three dimension view of modified tulip shaped microstrip antenna

The antenna has a tulip-shaped structure fed by CPW 50Ω microstrip line with coaxial probe. The dimensions of the antenna used for Ansoft HFSS three-dimensional full-wave electromagnetic field software simulation program are in mm range. The patch and CPW fed are printed on the standard FR4 substrate with a dielectric constant ε_r=4.4 with thickness 1.588 mm and loss tangent of 0.02 in Fig.2. The FR4 dielectric substrate's width (W1) is 16 mm and length (L1) is 25 mm.

3. ANN Implementation

Artificial Neural Network (ANN) is a decision mechanism between the dimensions of antenna and its return loss and resonance frequency. In Fig. 3, the input parameters to network diagram are low, high resonance frequencies and their return losses, on the other side; output parameters are the patch dimensions (D,R1,R2,W2). Backpropagation algorithm is used to classify or optimize as a ANN technique. For generating of training and test data, obtaining optimum antenna parameters and dimensions are dependency on each others. Simulations are performed on these data by HFSS simulator software and also resonance frequencies and their return losses are taken down (Jain, Sinha&Patnaik, 2009). While data generation, input data sets are discarded for the operating frequency in X/Ku band. 119 data set is prepared for this algorithm. Nearly 100 data is used for training and other is used as test data.

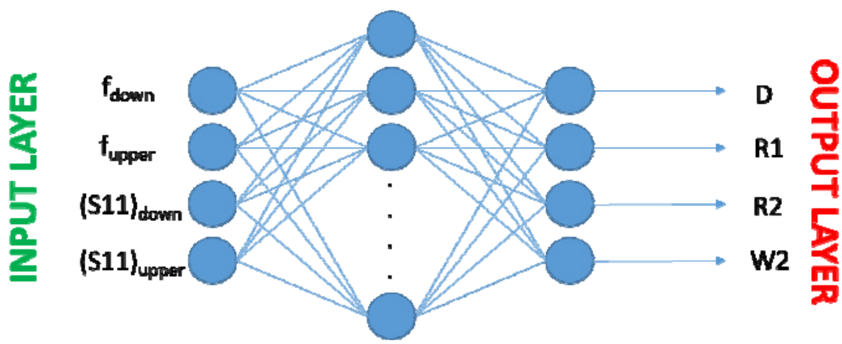


Fig. 3. ANN Model

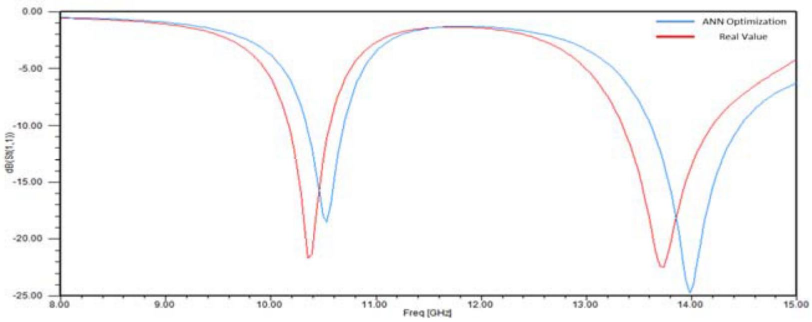
Backpropagation mode is a type of multilayer perceptron network and more effective in nonlinear function mapping problems. The neural network parameters are indicated in Table 1. Number of input and outputs neurons are equal to 4. Besides, number of hidden neurons and epochs are selected 10 and 2000 respectively. Learning rate is choosen as 0.01. In addition, there are fixed antenna dielectric properties and dimension value which are L1=25 mm, W1=16 mm, h=1.588 mm and ε_r=4.4.

Table 1. Neural Network Parameters

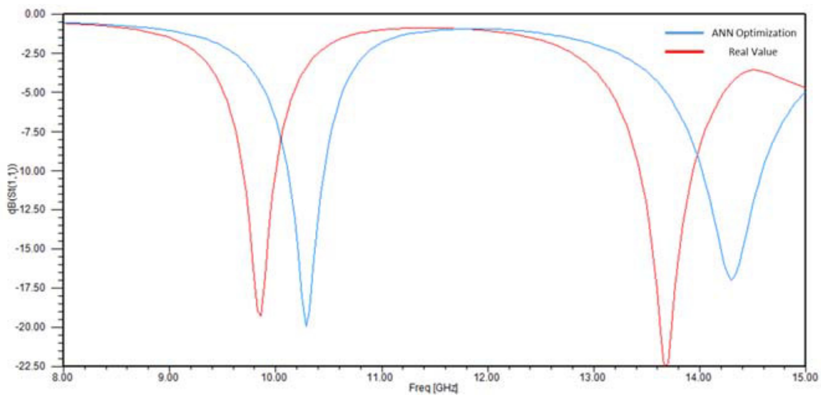
S.N	Parameter	Values
1	Number of Input Neurons	4
2	Number of Output Neurons	4
3	Number of Hidden Neurons	12
4	Training Algorithm	Backpropagation
5	The Number of Epochs	2000
6	Learning Rate	0.01

4. Results and Discussion

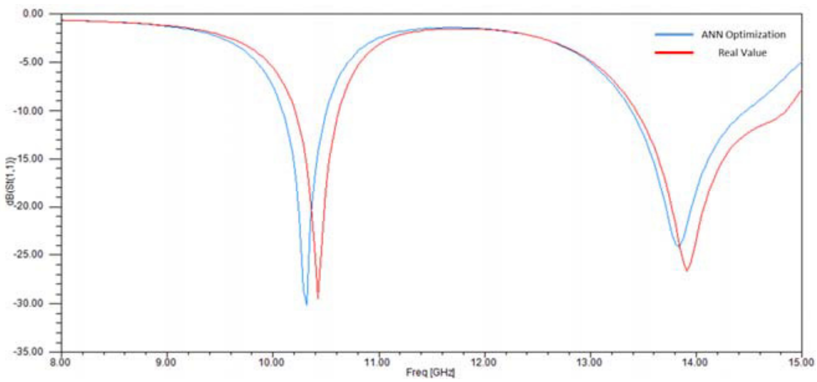
Backpropagation neural network test results are implemented by Ansoft HFSS electromagnetic software program and compared with real test data results. Both of these results are shown in a graph as Fig. 4. Then, approximation of optimization for the patch dimensions can be observed from these figures easily.



(a) Real: D=5.4mm, R1=5mm, R2=6.5mm, W2=1mm
ANN Output: D=5.4433mm, R1=4.927mm, R2=6.7712mm, W2=0.9129mm

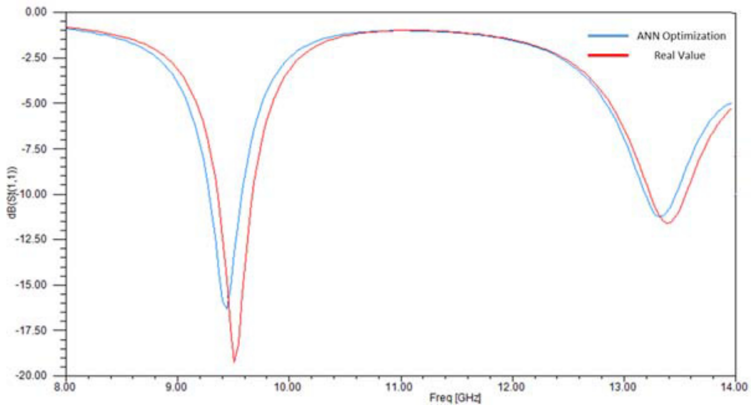


(b) Real Value: D=4.9mm, R1=5.7mm, R2=7.1mm, W2=0.8mm
ANN Output: D=5.0473mm, R1=5.4319mm, R2=7.3089mm, W2=0.9006mm

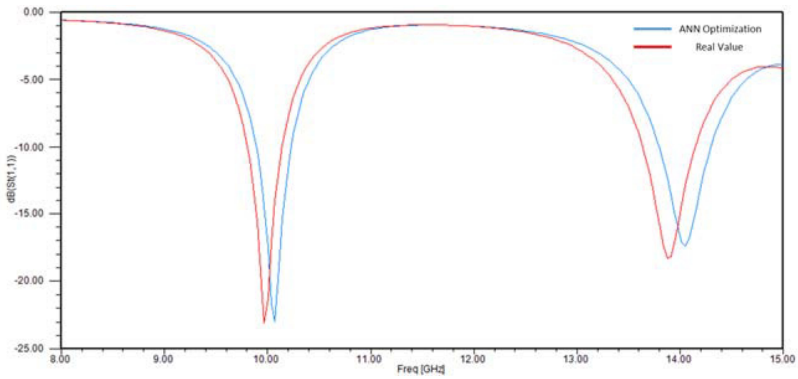


(c) Real Value: D=5.8mm, R1=5mm, R2=7.1mm, W2=1.45mm

ANN Output: D=5.6618mm, R1=5.0884mm, R2=6.9554mm, W2=1.3612mm



(d) Real: D=5.2mm, R1=6mm, R2=7.5mm, W2=1.3mm
ANN Output: D=5.1334mm, R1=6.1739mm, R2=7.6809mm, W2=1.3889mm



(d) Real: D=4.8mm, R1=5.7mm, R2=7.2mm, W2=0.9mm
ANN Output: D=4.7761mm, R1=5.5739mm, R2=7.3077mm, W2=0.9061mm

Fig. 4 Real and ANN response for Test Data

5. Conclusion

Trained backpropagation neural network to determine tulip-shaped microstrip patch antenna's dimensions was designed. The main goal of using the neural network model is to construct an antenna design of simulator for X/Ku band in tulip-shaped geometry. Additionally, it tries to minimize resonance frequencies and return losses' errors. On the otherhand, tulip-shaped multi-band microstrip patch antenna has small size low cost for satellite communication. This developed network can offer to design multi-band microstrip antenna in accordance with user's setting resonance frequencies and their return losses.

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