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Dimension Forecast in Microstrip Antenna for C/X/Ku Band by Artificial Neural Network

Umut Özkaya[1*+] and Levent Seyfi[1]

[1]*Department of Electrical and Electronics Engineering/Konya Technical University, Konya, Turkey*

[*]*Corresponding author: uozkaya@selcuk.edu.tr*

[+]*Speaker: uozkaya@selcuk.edu.tr*

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Abstract – In this study, it is aimed to design C pattern array microstrip antenna for C Band (4 to 8 GHz), X Band (8 to 12 GHz) and Ku Band (12 GHz to 18 GHz). The proposed geometry was fed by coaxial probe. Optimum antenna was designed with Artificial Neural Network (ANN). Inputs of the network are return loses and operating frequencies in C/X/Ku band. On the other hand, there are six outputs such as 2-D feed points and other design dimensions. The simulated and forecasted return losses, radiation pattern and gain results are compared with each other. All simulation results were obtained with High Frequency Structure Simulator (HFSS) software. Also, training and test process of ANN was implemented in MATLAB software. Additionally, these simulation and predicted results were analyzed comparatively. In particular, results of antenna design based on ANN is so closed to real design. This technique can be used in microstrip antenna manufacturing.

Keywords – *Microstrip Antenna, Artifical Neural Networks, C/X/Ku Band, Triple Band, Optimization.*

I. Introduction

In today's technology, many different microstrip antenna applications require novel antenna design. It has been a big problem in the development of new microstrip antenna structures due to their disadvantages which are narrow band and low gain. Any changes in simulation software account taking more time and even forcing computer resources. The methods of artificial intelligence have yielded very satisfactory results in the search for alternative methods to overcome this narrow strait. Initially, training of designed model in these methods consumes much more time. Once network training is completed, desired results are reached very quickly in accordance with input parameters. Some of the most commonly used artificial intelligence methods in microstrip antenna design are summarized in below.

Suganthi et al. designed microstrip patch antenna for GSM applications. In this study, return loss, VSWR and radiation pattern were analyzed with HFSS program. The antenna size is determined as 30x50x1.8 mm [1]. Kaur and Khanna offered a coaxial fed single layer microstrip antenna design for 5.2 GHz WLAN application. CST Microwave Studio, a commercial application based on the FDTD method, analyzes radiation characteristic with impedance compatibility of proposed structure. In the proposed WLAN 5.2 GHz frequency band, it has been shown that maximum bandwidth for coaxial fed antenna structure is obtained as 219.2 MHz (5.14-5.36 GHz) at the threshold of -10 dB reflection coefficient [2]. Majumder designed rectangular microstrip antenna between 2.0 GHz and 2.5 GHz. The antenna is designed by using FR-4 material of 1.6 mm thickness with a dielectric constant of approximately 4.4. Input Impedance in simulation software, return loss and current density were evaluated [3]. Koçer analyzed resonance frequency of rectangular and circular shape microstrip antenna with experimental and theoretical way in the literature. It was determined that properties of coaxial probe and probe height value had significant effects on resonance frequency of antenna; however, it was stated that height of air gap defined in simulation software did not cause a significant change on simulation results. In addition, width and length values of dielectric material have been shown to have no effect on resonance frequency. The effects of modified parameters on resonance frequency were determined by examining simulation results. When position of coaxial probe were changed, results of input and radiation resistances are examined by analyzing effects on resonance frequency graph [4]. Türker et al. proposed general design procedure for rectangular microstrip antenna by using artificial neural networks. Neural network method was used for microstrip antenna design in this study [5]. Singh et al. worked on double-band coaxial probe feed microstrip antenna design by using ANN method, Feed forward network was trained by using bandwidth values obtained with IE3D program and then antenna design was implemented. Obtained bandwidth values for C-shaped microstrip antenna are analyzed. ANN has some advantages which are simplicity and accuracy evaluation. It is stated that the results of the analysis can be obtained very quickly with ANN [6]. Zheng et al. used support vector machine (SVM) that provides fast and accurate results in antenna design. After a suitable training process, it was determined that SVM is compatible with antenna design [7]. Kumar and Rai used ANN to obtain resonance frequency of microstrip antenna experimentally [8]. Xu proved that Support Vector Machine is very efficient method in solving real-time antenna diagnostics problems [9]. Kayabasi and Akdagli calculated resonance frequency of microstrip antenna in UHF band with ANN and SVM. In MoM-based IE3D program, 144 resonance frequencies were performed for various size and electrical parameters [10]. Garg et al. increased potential parameters of microstrip antenna and analyzed double bandwidth of proposed antenna. With proposed antenna model, design result was obtained at 2.478 GHz and 2.919 GHz resonance frequencies. The obtained values and the measured values of the antenna were found to be very close [11].

This paper is organized as four sections. Section I is introduction part which includes general information and state of arts. In Section II, materials and methods used in this study are mentioned. The result and discussion part are listed in Section III. Finally, there is a conclusion part Section IV.

II. Materials and Method

A. Microstrip Antenna Theory

The radiation pattern of microstrip antennas is towards ground plane from ends of patch on upper surface. The quality of radiation characteristic depends on thickness of medium and a low dielectric constant value. If it is desired to obtain good quality radiation characteristics, material quality, thickness and dielectric constant of material should be taken into consideration.

The physical structure of the microstrip antenna consists of a dielectric material between two conductors. There is a ground plane bottom of antenna and a patch conductive part at the top on dielectric surface. Fig. 1 shows a conventional microstrip antenna structure.

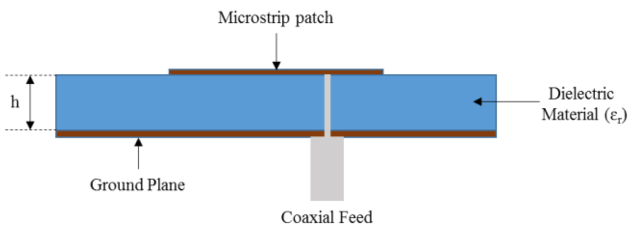

Fig. 1 Microstrip Antenna Structure

Basic analysis methods are used in microstrip antenna design. These methods are transmission line model, cavity model and full wave model. Transmission Line Model is a numerical analysis method which uses analogy between field theory and circuit theory to solve electromagnetic problems. Although relatively easy, its accuracy is less than other methods. Cavity model has a more complex structure despite its accuracy. Full wave, finite difference, finite element and moment method are some method to analysis. Although it is the most accurate method, it has some mathematical complexity and memory requirement.

When microstrip antenna design is performed, selected electrical and physical parameters are calculated through the formulas in transmission line model described below.

W of microstrip antenna is obtained using Eq. 1 as follows.

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

Where W shows width of patch, c is speed of light, resonance frequency is f_r and ε_r is dielectric constant. If $W/h \geq 1$, effective dielectric constant (ε_{ref}) is expressed by Eq. 2.

$$\varepsilon_{ref} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + \frac{12h}{W}}}\right] \quad (2)$$

The effective length (L_{eff}) is expressed by Eq. 3.

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_r}} \quad (3)$$

ΔL is calculated by Eq. 4.

$$\Delta L = 0.412h.\frac{(\varepsilon_r + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_r - 0.258)(\frac{W}{h} + 0.8)} \quad (4)$$

Patch length L is formulized by Eq. 5 as follows:

$$L = L_{eff} - 2\Delta L \quad (5)$$

B. Artificial Intelligence Methods

Rapid growth in technological developments has opened door to acquisition of high capacity equipment. In particular, high-speed processors and memory have brought about a rapid development in the areas of computers and robots. In the light of these developments, artificial intelligence field has been adopted as a very serious field of study for many researchers and scientists. Therefore, various activities, learning and evaluation processes of a computer, computer-based device or robot can do similar to intelligent operation.

Artificial intelligence method was investigated to solve complex mathematical equations of electromagnetic antenna design and non-linear analysis due to loss of time or long duration of processing. The electrical and physical parameters of microstrip antenna were developed to establish relationships with ANN models. Artificial intelligence methods are effective and high in accuracy for nonlinear electromagnetic problems has been obtained.

C. Artificial Neural Network

Artificial Neural Network (ANN) is an artificial intelligence method inspired by neural network of living things. Especially, this method is widely used in microstrip antenna applications. It is an effective method for estimating parameters of microstrip antennas.

ANN method is mainly considered as input, hidden and output layer. The information comes first to input layer and processed in hidden layers. Hidden layers provide training to the network according to input information. The trained network provides this result to output layer by making estimates against new data coming from input.

ANN method has some advantages and disadvantages. It’s advantages are use in non-linear applications, lack of programming requirements, availability for any application and applicability without any problems. In contrast to these advantages, it needs for training process and high processing time for large neural network applications.

Activation functions used in ANN layers are one of main parameters in network. There are various activation functions in the literature. These are tangent-sigmoid, log-sigmoid and purelin. Tangent-sigmoid transfer function (tansig) is a neural network activation function. This transfer function is used to calculate output layer from network input. The dynamic interval of tansig function is in [-1 1], which is also referred to hyperbolic tangent function. Log-Sigmoid transfer function (logsig) is another activation function. The dynamic change interval of logsig function is in [0 1]. In Purelin transfer function, change in neuron inputs is a kind of activation function that changes linearly at neuron output. The dynamic range of function is in [-1 1].

D. Proposed Antenna Design and Method

The proposed antenna design has a microstrip patch geometry located in different positions with C-shapes. In the antenna design, which is based on C patch shape, patch geometries with 120^0 angle difference are placed on FR4 ($\varepsilon_r=4.4$) dielectric material. Dimensions of dielectric material are 18.5x18.5 mm. In addition, dielectric substrate has a height of h = 1.566 mm. The antenna feed is provided by coaxial probe. A circular ring is attached to patch to deflect radiation pattern. The outer and inner radius of C patch shape are defined as R_1 and R_2. The feed position is expressed as (x, y) on a 2-D plane. The outer and inner radius of circular ring located in the centre of patch is expressed as R_3 and R_4. Fig. 2 shows the antenna geometry.

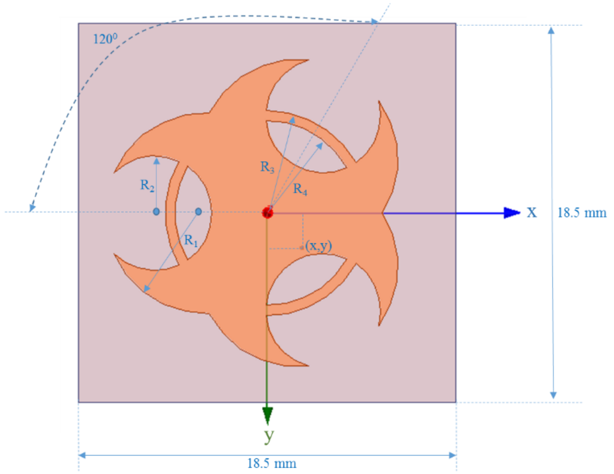

Fig. 2 Microstrip Antenna Structure

ANN method was used as proposed method. The dimension parameters were changed to obtain 61 data. 40 number of these data were used in training process and remaining data were used for testing. Resonance frequencies (f_c, f_x, f_{Ku}) and the return losses ($S11_c$, $S11_x$, $S11_{Ku}$) of each band were given as input to designed network structure. There are 6 neurons in input layer of the network. There are a total of 20 hidden layers in the network. There are 6 neurons in the output layer. Logsig and purelin were used as activation function in the designed network. Learning rate was determined as 2, momentum coefficient was 0.7 and the number of iterations was 1000. In the network structure given in Fig. 3, antenna dimensions were obtained in accordance with desired resonance frequencies and return losses.

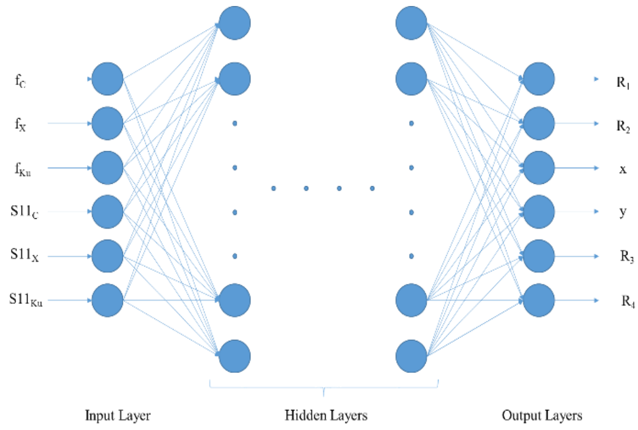

Fig. 3 Proposed Method

III. Results And Discussion

Artificial neural networks have been used to estimate antenna dimensions. Three of test data were given real and estimation graphs. The real antenna dimensions in Fig. 4 are R_1 = 4.9 mm, R_2 = 2.5 mm, $x = y$ = 2.1 mm, R_3 = 5.3 mm, and R_4 = 4.8 mm. Estimated dimensions are R_1 = 4.71 mm, R_2 = 2.52 mm, x = 2.07 mm, y = 2.14 mm, R_3 = 5.17 mm and R_4 = 5.02 mm. The antenna characteristics obtained for real values of antenna dimensions are f_c = 5.29 GHz, f_x = 10.28 GHz, f_{Ku} = 15.42 GHz, $S11_c$ = -19.51 dB, $S11_x$ = -13.23 dB and $S11_{Ku}$ = -11.52 dB. The antenna characteristics obtained for estimated antenna dimensions are f_c = 5.26 GHz, f_x = 10.76 GHz, f_{Ku} = 17.43 GHz, $S11_c$ = -13.94 dB, $S11_x$ = -10.06 dB and $S11_{Ku}$ = -8.83 dB. The real antenna dimensions in Fig. 5 are R_1 = 4.8 mm, R_2 = 2.4 mm, $x = y$ = 2 mm, R_3 = 5.3 mm and R_4 = 4.8 mm. Estimated dimensions are R_1 = 4.68 mm, R_2 = 2.52 mm, x = 1.86 mm, y = 2 mm, R_3 = 5.20 mm, and R_4 = 4.88 mm. The antenna characteristic obtained for real values of antenna dimensions is f_c = 5.45 GHz, f_x = 10.44 GHz, f_{Ku} = 15.74 GHz, $S11_c$ = -17.03 dB, $S11_x$ = -12.40 dB and $S11_{Ku}$ = -11.68 dB. The antenna characteristics obtained for estimated antenna dimensions are f_c = 5.61 GHz, f_x = 10.84 GHz, f_{Ku} = 16.23 GHz, $S11_c$ = -17.67 dB, $S11_x$ = -11.60 dB and $S11_{Ku}$ = -7.52 dB. The real antenna dimensions in Fig. 6 are R_1 = 4.7 mm, R_2 = 2.4 mm, $x = y$ = 2.2 mm, R_3 = 5.3 mm and R_4 = 4.5 mm. Estimated dimensions are R_1 = 4.62 mm, R_2 = 2.54 mm, x = 1.9 mm, y = 2.01 mm, R_3 = 5.23 mm and R_4 = 4.82 mm. The antenna characteristics obtained for the actual values of the antenna dimensions are f_c = 5.61 GHz, f_x = 10.68 GHz, f_{Ku} = 16.15 GHz, $S11_c$ = -24.12 dB, $S11_x$ = -9.07 dB and $S11_{Ku}$ = -10.75 dB. The antenna characteristics obtained for the estimated antenna dimensions are f_c = 5.77 GHz, f_x = 11 GHz, f_{Ku} = 15.02 GHz, $S11_c$ = -24.79 dB, $S11_x$ = -11.61 dB and $S11_{Ku}$ = -7.90 dB.

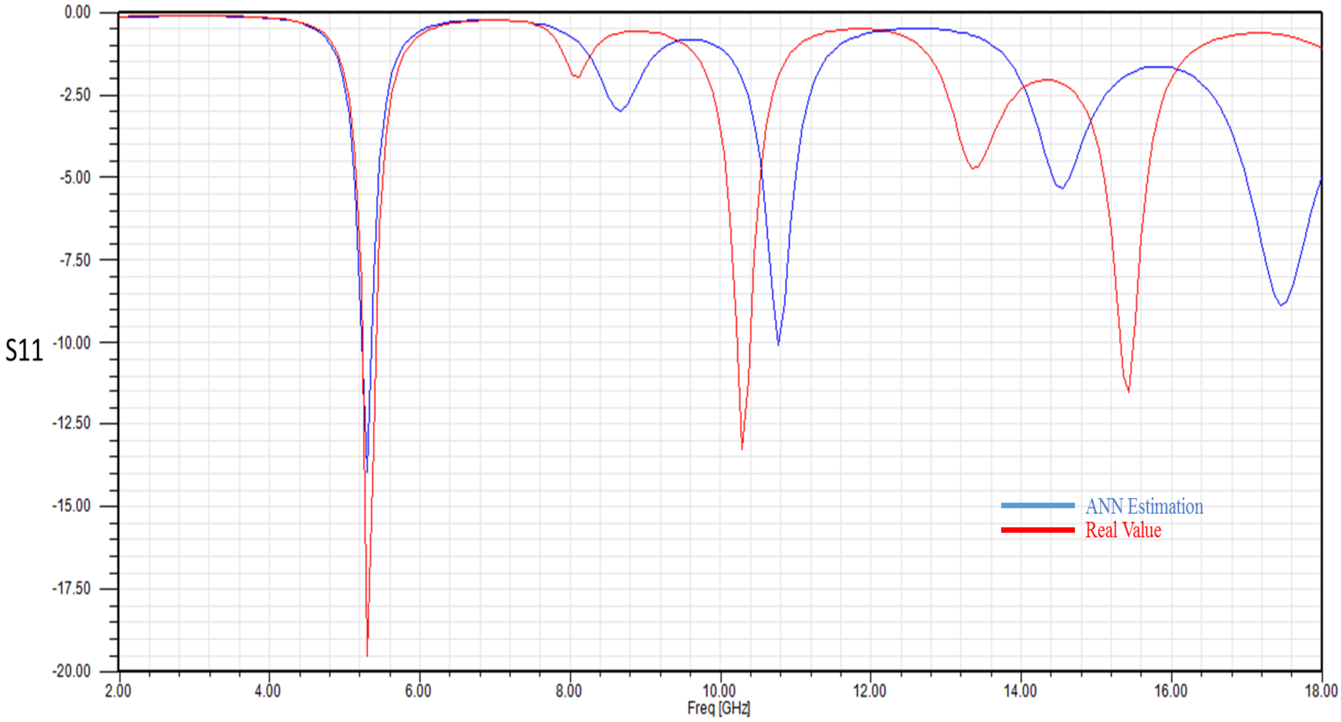

Fig. 4 Real Value and ANN Estimation Results for First Sample

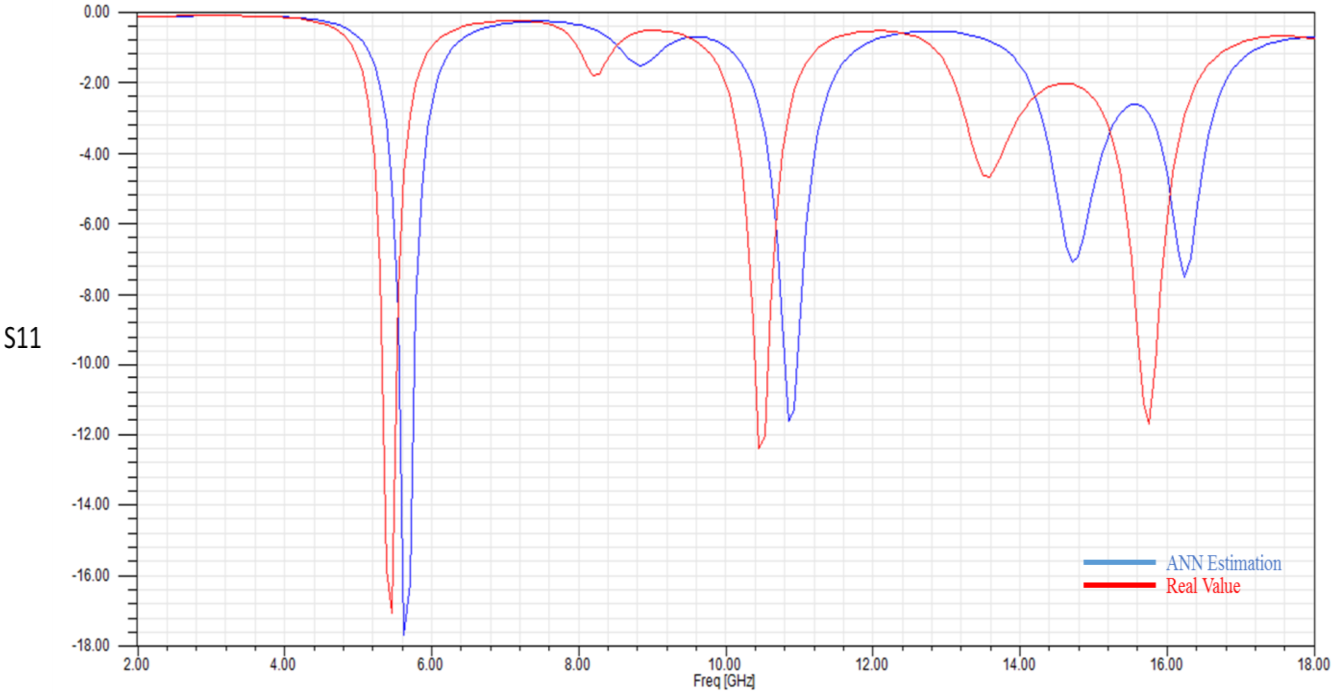

Fig. 5 Real Value and ANN Estimation Results for Second Sample

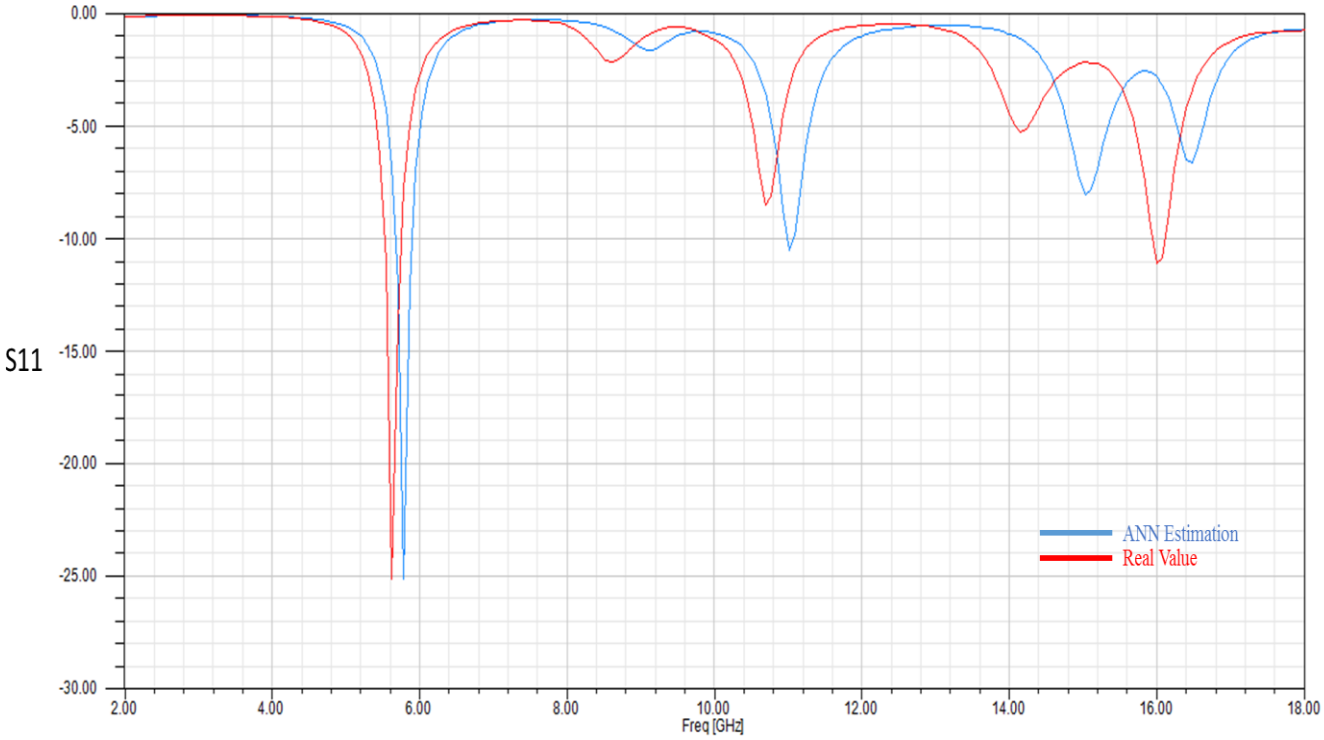

Fig.6 Real Value and ANN Estimation Results for Third Sample

IV. CONCLUSION

According to obtained results in this study, desired antenna dimensions in proposed antenna geometry could be approached with a very low error rate. It is seen that even if level of forecasting error is in µm level due to fact that decrease in antenna dimensions increases significantly as antenna resonance frequency increases and has more effects on antenna characteristics. It is concluded that ANN method is more successful in estimating dimensions of proposed antenna geometry, and it is suggested that ANN model with fast and good performance can be recommended for such antenna design studies.

REFERENCES

[1] Suganthi, T., Robinson, S., Kanimolhi, G., Nagamoorthy, T. 2014. Design and Analysis of Rectangular Microstrip Patch Antenna for GSM Application. IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1

[2] Kaur, J., Khanna, R. 2013. Co-axial Fed Rectangular Microstrip Patch Antenna for 5.2 GHz WLAN Application. Universal Journal of Electrical and Electronic Engineering, 1(3):94-98.

[3] Majumder, A., 2013. Rectangular Microstrip Patch Antenna Using Coaxial Probe Feeding Technique to Operate in S-Band. International Journal of Engineering Trends and Technology, Vol. 4, Issue 4.

[4] Koçer, D. 2009. Daire ve Dikdörtgen Geometrik Yapılı Mikroşerit Antenlerin Simülasyonun ve Rezonans Frekanslarının Yapay Sinir Ağları ile Belirlenmesi. Yüksek Lisans, Selçuk Üniversitesi Fen Bilimleri Enstitüsü, Konya.

[5] Türker, N., Güneş¸ F., Yıldırım, T. 2006. Artificial Neural Design of Microstrip Antennas. Turk J Elec Engin, Vol.14, No.3, TÜBİTAK.

[6] Singh, V.K., Ali, Z., Ayub, S. 2013. Dual Band Microstrip Antenna Design Using Artificial Neural Network. International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 3, Issue 1.

[7] Zheng, Z., Chen, X., Huang, K., 2010. Application of Support Vector Machines to the Antenna Design. Master Thesis, School of Electronics and Information Engineering, Sichuan University, China.

[8] Kumar, A., Rai, A. 2014. Resonant Frequency of Microstrip Antenna using Artificial Neural Network. International Journal of Engineering Research & Technology (IJERT), Vol. 3, Issue 2.

[9] Xu, N. 2011. Applications of Support Vector Machines in Electromagnetic Problems. PhD Dissertation, The University of New Mexico, Albuquerque, New Mexico, Page(s):121.

[10] Kayabaşı, A. 2015. Kompakt Mikroşerit Antenlerin Rezonans Frekansının Yapay Sinir Ağları ve Bulanık Mantık Sistemine Dayalı Uyarlanır Ağ Kullanarak Hesaplanması. Doktora Tezi, Mersin Üniversitesi Fen Bilimleri Enstitüsü, Mersin.

[11] Garg, B., Verma, R.D., Samadhiya, A. 2012. Design of Rectangular Microstrip Patch Antenna Incorporated with Innovative Metamaterial Structure for Dual band operation and Amelioration in Patch Antenna Parameters with Negative µ and ε. International Journal of Engineering and Technology, 1 (3), Pages: 205-216.