Optimization of rectangular Microstrip antenna using Radial Basis Function Neural Network

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Abstract –

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I. INTRODUCTION

The mobile communication systems usually require a portable wireless antenna size in order to meet as requirement of mobile units. Microstrip patch antenna is one of the best suitable antennas for mobile communication due to its attractive features of low profile, light weight and easy fabrication [1]. In general, it has a conducting patch printed on a grounded microwave substrate. The most commonly used microstrip patch antenna is a rectangular patch antenna which has the problem of narrow bandwidth. To overcome these problems different types of structures (regular and irregular shapes) were proposed and studied theoretically and experimentally in the processes of the development of microstrip antenna [2].

The bandwidth of the rectangular microstrip antenna is very narrow, so the resonant frequency of microstrip antenna can be accurately determinable. There are two different ways to analyze microstrip antenna namely analytical method and numerical method. Analytical method as compared to Numerical methods are easy but only restricted to some definite shapes. On the other hand, though the numerical methods are complicated and require more time to solve, but are applicable to any shape. Therefore in order to eradicate these problems, researchers use neural models which are applicable to any shape, any complicated circuits and it also takes less time with more accuracy.

Various Artificial Neural Network (ANN) models are developed for determining resonant frequencies of microstrip patches of various shapes like rectangular, triangular etc.[3-4] and [5-6]. A comprehensive review of application of ANN in microwave engineering and different types of method to develop the ANN models is discussed [7].

II. Model architecture of microstrip antenna [8]

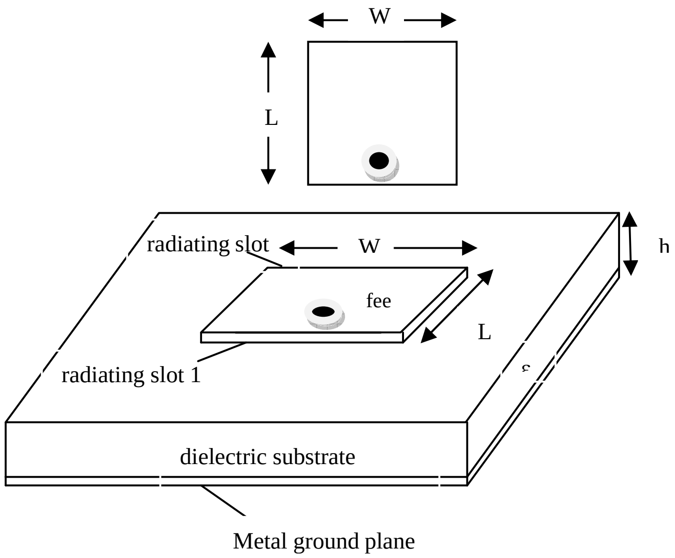


Figure 1: Rectangular microstrip antenna

Estimation of frequency

The design of a microstrip antenna begins by determining the substrate used for the antenna and then the dimensions of the patch. Due to the fringing fields along the radiating edges of the antenna there is a line extension associated with the patch, which is given by the formula [13]:

$$\frac{\Delta L}{h} = 0.412\left[\frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258}\right]\left[\frac{W/h + 0.264}{W/h + 0.813}\right] \quad (1)$$

The effective dielectric constant (ε_{eff}) due to the air dielectric boundary is given by formula [13]:

$$\varepsilon eff = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{10h}{W}\right)^{\frac{1}{2}}$$

(2)

The resonant frequency can be estimated by using the formula [12]:

$$f_r = \frac{1}{2\sqrt{\mu_0 \varepsilon_0}\left(L + 2\Delta L\right)\sqrt{\varepsilon_{eff}}} \quad (3)$$

μ_0 = permeability of free space

ε_0= permittivity of free space

ΔL = line extension

ε_{eff} = effective dielectric constant

Estimation of width and length

By choosing the substrate, the width and length of the patch can be estimated. An initial approximation for the length can be made for a half wave microstrip antenna radiated by the formula:

$L = 0.48\lambda g \sim 0.49\lambda g$ (4)

Where: $\lambda_g = \dfrac{c}{f_r \sqrt{\varepsilon_r}}$

The width (W) is usually chosen such that it lies in the ratio, L < W < 2L for good radiation characteristics, if W is too large then higher order modes will move closer to the design frequency. Radiation characteristics: A microstrip antenna is basically a broadside radiator, which has a relatively large beam width and low, gain characteristics. The formulas for the E and H plane radiation patterns are given by [13]:

III. Radial basis function (RBF) network

Feed forward neural network with a single hidden layer, radial basis activation function for hidden neurons are called radial basis function network. RBF network is applied for various microwave modeling purposes. A typical RBF network structure is given in Figure (2). The parameters c_{ij} and λ_{ij} are centers and standard deviation of radial basis activation function. In this work radial basis activation function is Gaussian [11].

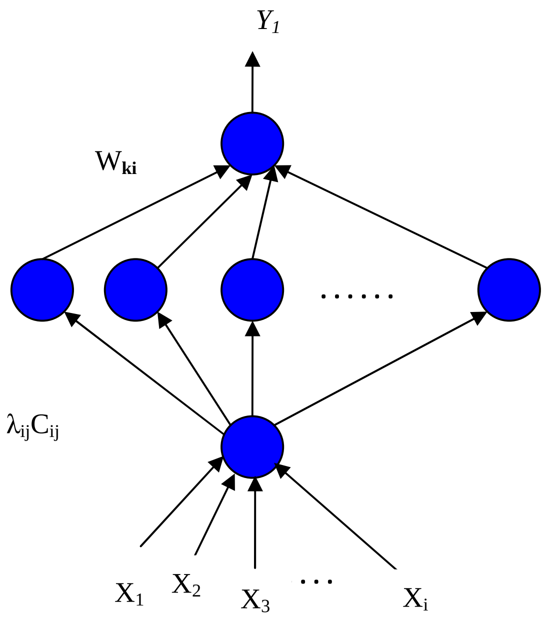


Figure 2: Architecture of Radial Basis Function

Given the inputs **x**, the total input to the *i*th hidden neuron γ_i is given by:

$$\gamma_i = \sqrt{\sum_{j=1}^{n} \left(\frac{x_j - c_{ij}}{\lambda_{ij}} \right)^2} \quad , i=1, 2\ldots\ldots\ldots\text{N} \tag{5}$$

Where N is the number of hidden neurons. The output value of the *i*th hidden neuron is $z_{ij} = \sigma(\gamma i)$, where $\sigma(\gamma)$ is a radial basis function. Finally, the outputs of the RBF network are computed from hidden neurons as:

$$y_k = \sum_{i=0}^{n} w_{ki} z_{ki} \quad ; \text{Here k=1} \tag{6}$$

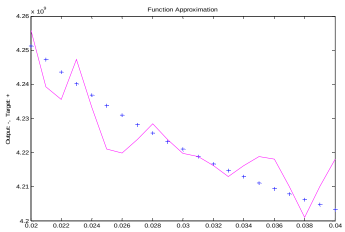
Where w_{ki} is the weight of the link between the *i*th neuron of the hidden layer and the *k*th neuron of the output layer. Training parameters *w* of the RBF network include w_{k0} , w_{ki} , c_{ij} , λ_{ij}, k = 1 ,2, . . . , m, *i* = 1 ,2, . .,N, *j* = 1,2,.,. n. [14]

IV. Result & Discussion

Variation of RBF output with Number of neurons

Here we are varying the number of neurons in the figure 3 (a), 3(b), 3(c), and 3(d) of the RBF output for given neural architecture of microstrip antenna. These figures show the variation of RBF output with number of neurons. In figure 3(a) used number of maximum neurons 5, other parameters frequency of progress display (in neurons), sum square error goal (eg) & spread constant (sc) remains constant. The error is minimized in figure 3(b) as compared with figure 3(a), where we are taking the number of maximum neurons is 10, and the input (width in mm) & target output (Resonant frequency Hz) and other parameters remain constant. When we are taking no. of maximum neurons 15, in this case the error of the respective result graph is minimized with respect to input and target output & the other parameters df=10, me=15, eg=0.002, sc=0.001 remain same as in figure 3(c). Figure 3(d) deals with the number of maximum neurons 20 & the other parameters, frequency in progress neurons, sum square error goal & the spread constant remain constant. This figure 3(d) shows the error is minimized over the figures 3(a), 3(b), and 3(c). So from the above results it is clear that when increases the no. of neurons then the variation of RBF output becomes smooth.

Resonant Frequenc



Width

Figure 3 (a): df=10, me=5, eg=0.002, sc=0.001

Resonant Frequency

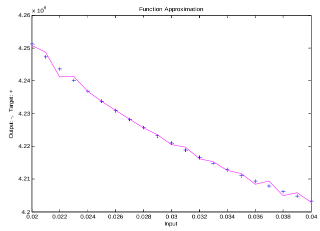


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Figure 3(c): df=10, me=15, eg=0.002, sc=0.001

Resonant Frequenc

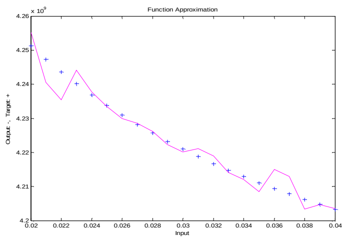

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Figure 3(b): df=10, me=10, eg=0.002, sc=0.001

Resonant Frequency

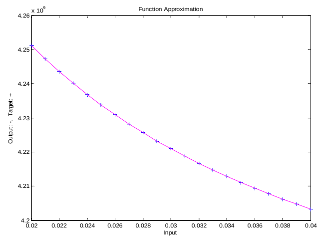

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Figure 3(d): df=10, me=20, eg=0.002, sc=0.001

Variation of RBF output with spread Constant

The figure 4(a) clearly deals with the several parameters means frequency progress (df) in neurons is 10, no. of neurons (me) 10, sum squared error goal 0.0001. This result shows the plot between the input (Width) & output (target i.e. resonant frequency). From the figure it is clear that the RBF output comes out exact for 0.029 but suddenly it is changed and remains constant for next value of input. Figure 4(b) for the spread constant 0.001 & the other parameters remain same, means without variation in the other parameters, frequency in progress in neurons, no. of maximum neurons & sum square error goal (eg). Figure 4(c) for the spread constant 0.01, and the values , frequency progress in neurons, maximum no. neurons, error goal remain constant in this case the RBF output comes out error free. Similarly figure 4(d) is also designed for the frequency in progress, number of neurons, sum square error goal & spread constant 10, 10, 0.002 & 0.1 respectively, at the value of spread constant 0.1 it will give exact RBF output. So from the above figures it is clear that if we increase the value of spread constant then RBF output for width of microstrip antenna & resonant frequency is error free, after training.

Resonant Frequenc

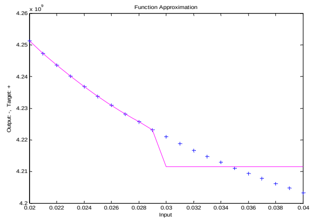

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Figure 4(a): df=10,me=10,eg=0.002,sc=0.0001

Resonant Frequency

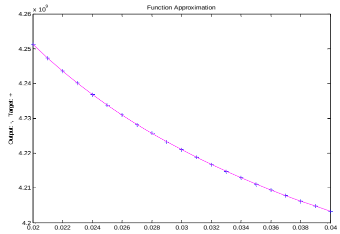

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Figure 4(c): df=10, me=10, eg=0.002, sc=0.01

Resonant Frequenc

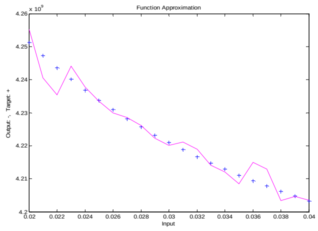

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Figure 4(b): df=10,me=10,eg=0.002,sc=0.001

Resonant Frequency

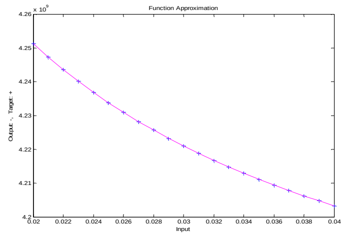

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Figure 4(d): df=10,me=10,eg=0.002,sc=0.1

Conclusion

In this paper, the star line (blue color) in the figure shown is the conventional result of resonant frequency vs. width of the rectangular microstrip antenna and solid line shown is the trained result of the RBF neural network. The conventional result has been produced by the many researchers. In this work the error has been minimized in different figures and obtained the good result when it is trained with RBF neural network. The application of these approaches is used for designing the microstrip antennas with optimized speed.

References

[1] G. A. Deschamps., "Microstrip microwave antennas," Third USAF Symposium on Antennas,1953.

[2] A.T Adams, "An introduction to the method of moments," Syracuse Univ., Report TR-73- 217, Vol.1, 1974.

[3] R. Baititi., "First and second order methods for learning between steepest descent and Newlons method." Neural Computation 4, 141-166, 1992.

[4] T. Bose, and Nisha Gupta, "Neural Network Model for Aperture Coupled Microstrip Antenna." Microwave Review, pp. 21-24, 2008.

[5] K.R. Carver, "Practical analytical technique for the microstrip antenna." Proc. Workshop on Printed Circuit Antenna Technology. New Mexico State University, Las Cruces, 7.1-7.20., Oct. 1979.

[6] K.R. Carver, J.W, Mink, "Microstrip antenna technology." IEEE Trans. Antennas Propagat. 29, 2-24, 1981.

[7] W.C. Chew, Liu, "Resonance frequency of a rectangular microstrip patch." IEEE Trans. Antennas Propagat. 36, 1045-1056, 1988.

[8] E.Chang, S.A Long, W.F. Richards, "An experimental investigation of electrically thick rectangular microstrip antennas." IEEE Trans. Antennas Propagat. 34 767-772, 1986.

[9] J.P. Damiano, A. Papiernik., "A simple and accurate model for the resonant frequency and the input impedance of printed antennas." Int. J. of Microwave Millimeter-wave Computer-Aided Engineering 3, 350-361, 1993.

[10] R.W. Deamley, A.R.F. Bard, "A comparison of modes to determine the resonant frequencies of a rectangular microstrip antenna." IEEE Trans. Antennas Propagat. 37114-118, 1989.

[11] S. Devi, D. C. Panda and S S Pattnaik, "A Novel Method of using Artificial Neural Networks to Calculate Input Impedance of Circular Microstrip Antenna". Symposium Antennas and Propagation Society International, vol 3, pp 462-465, June 16-21, 2002.

[12] A.Balanis, "Antenna Theory Analysis and Design." Second Edition. United States of America. John Wiley & Sons, 1997.

[13] P. Bhartia, K. V. S. Rao, and R. S. Tomar, "Millimeter-Wave Microstrip and Printed Circuit Antennas." Artech House, Norwood, MA, 1991.

[14] K. Guney, "A new edge extension expression for the resonant frequency of recungular microstrip antennas with thin and thick substrates." Communications Technology and Electronics 49, pp.49-53, 2004.