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Finding Optimum Gain and Return Loss of a Circular Microstrip Patch Antenna Using KBNN at 3.7 GHz

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Abstract: Antennas are key components of any wireless communication system. Patch antennas are widely used as they offer low-profile designs for a wide range of wireless applications. The design of circular patch antenna is presented in this paper and the simulated results are compared with the general well-known results of antenna's performance incorporating its radiation property, gain, port characteristics and s-parameters. The optimum gain was observed at the substrate thickness of 0.35mm and here the return loss (S11) is -22dB but return loss is still good at radius of patch 21.5mm with increasing gain. Modelling was done using backpropagation algorithm (KBNN) and simulations were done using HFSS.

Keywords: Knowledge Based Neural Networks (KBNN), Patch Antenna, HFSS.

INTRODUCTION

Microstrip antennas are similar to parallel plate capacitors. Both have parallel plates of metal layer and a sandwiched dielectric substrate between them. But in microstrip antenna, one of these metal plates is infinitely extended than the other, to form the ground plane; whereas the smaller metal plate is described as radiating patch. The size of the patch is often proportional to frequency of the propagating signal; this class of antenna is classified as resonant antennas [1]. This contributes to the basic shortcoming of the microstrip antennas related with its narrow bandwidth, usually only a few percent of the resonance frequency. So far, several shapes of microstrip patches, such as rectangular, circular, triangular, semi-circular, sectoral and annular etc., are successfully used as radiating antenna elements employed in various communication and control devices. There are many methods of analysis of microstrip antennas. The most popular methods are based on the transmission line model, cavity model and full-wave analysis. Full wave models are very versatile and can provide accurate results but they are the most complex models and usually give less physical insight.

Microstrip patch antennas can be excited by different methods. Generally, the methods could be categorized as contact method and non-contact method. In the contact method, the power is fed directly to the patch. In the noncontact method the power is transferred through coupling between the microstrip line and the patch. The four most popular feed techniques used are the microstrip line, coaxial probe, aperture coupling and proximity coupling [3]. Here probe feed technique is used.

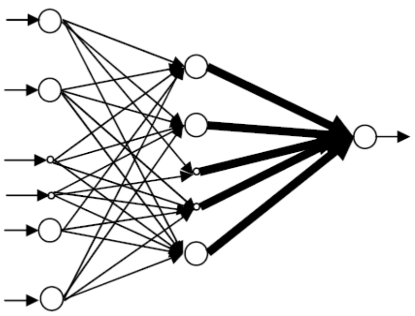

Fig.1. KBNN architecture

Recently a simple Knowledge Based Neural Network (KBNN) has been proposed in [2] to efficiently train neural networks with limited data (Fig. 1). It uses back propagation

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algorithm for training. Details of training steps can be found in [2]. In this paper, equations are proposed which acts as knowledge of KBNN algorithm to calculate gain and return loss of circular microstrip patch antenna. Fig.1 shows the KBNN architecture which contains one input layer one hidden layer and one output layer. As we are using supervised learning here input layer is assigned with some parameters like substrate thickness and radius of patch etc. Output layer gives the gain and return loss, to test whether it is correct or not we have used 1000 samples to train the Neural Network and 600 samples to test the network performance.

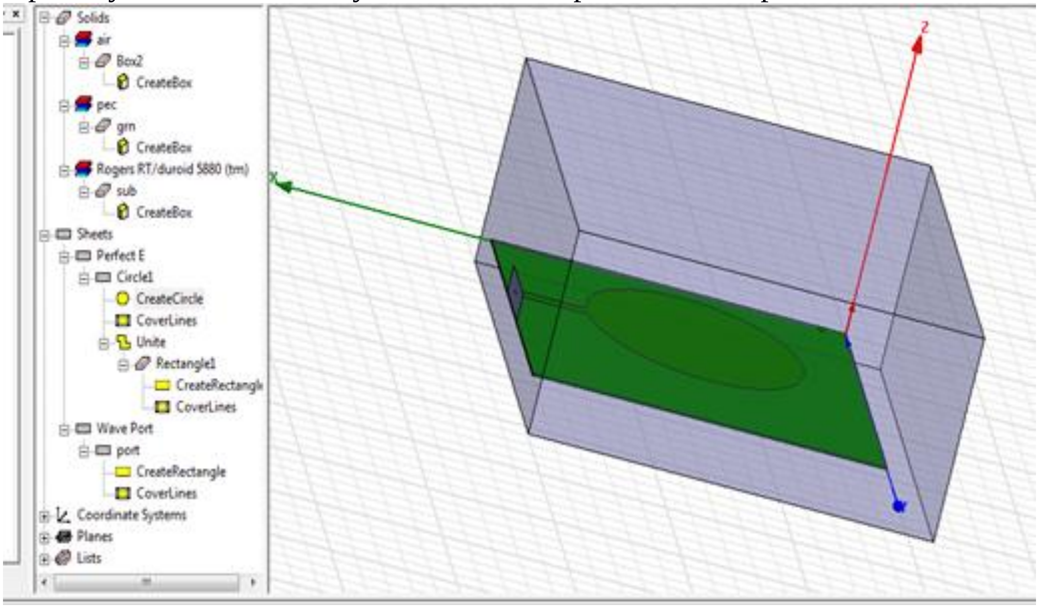

Fig.2. Circular microstrip patch antenna

Fig. 2 shows schematic of co-axially fed circular microstrip patch antenna. An approximate expression for the gain of the configuration according to transmission line theory can be written as [3],

$$Gain = 4\pi \frac{radiationintensity}{totalinput(accepted)power} = 4\pi \frac{U(\theta,\emptyset)}{P}$$

According to the IEEE standards, "gain does not include losses arising from impedance mismatches (reflection losses) and polarization mismatches (losses)" [7].

Now each individual weight in the output layer in Fig.1 is replaced by

$$w_{k1} = w_{kj} + e^{-w_{k1}}\left(\frac{0.6773}{w_{k2}\sqrt{w_{k3}(1+w_{k4})^{-w_{k5}}}}\right)$$

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Similarly weights for other output neurons are set like (3) i.e. each hidden weight contain now additional four weights. Each weight in (3) is updated by gradient descent method which is straight forward. In order to implement the problem a 2X20X2 feed forward neural network [6] is considered. The two input neurons are thickness of the substrate and radius of circular patch. Gain and return loss being the output of the network. Data are collected according to DoE [4]. Training data is collected using HFSS.

RESULTS AND DISCUSSIONS:

From table-I it can be observed that when the thickness of the substrate is decreasing (till some value), gain is increasing and return loss is also decreasing but after reaching some value both are decreasing, this is because of spurious radiations associated with the patch antenna. From table-II it can be observed the same effect, here when radius of patch is decreasing (till some value) gain and return loss magnitude are increasing and after some value gain is decreasing. The authors got good results for gain and return loss at a radius of 21.5mm and thickness of the substrate of 0.35mm. Another point the authors have observed is when thickness is decreasing return loss is varying and this can be observed from table-I.

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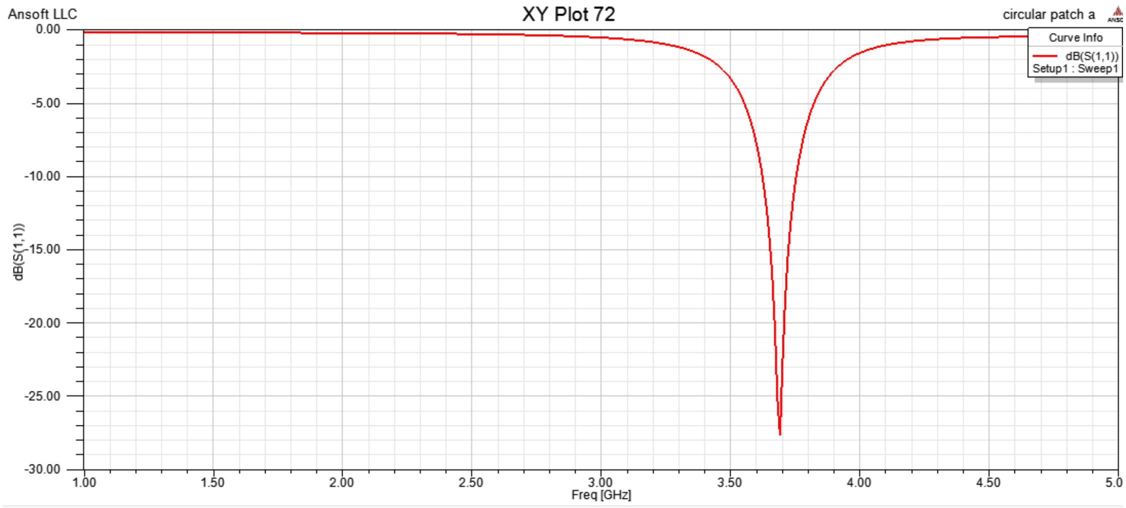
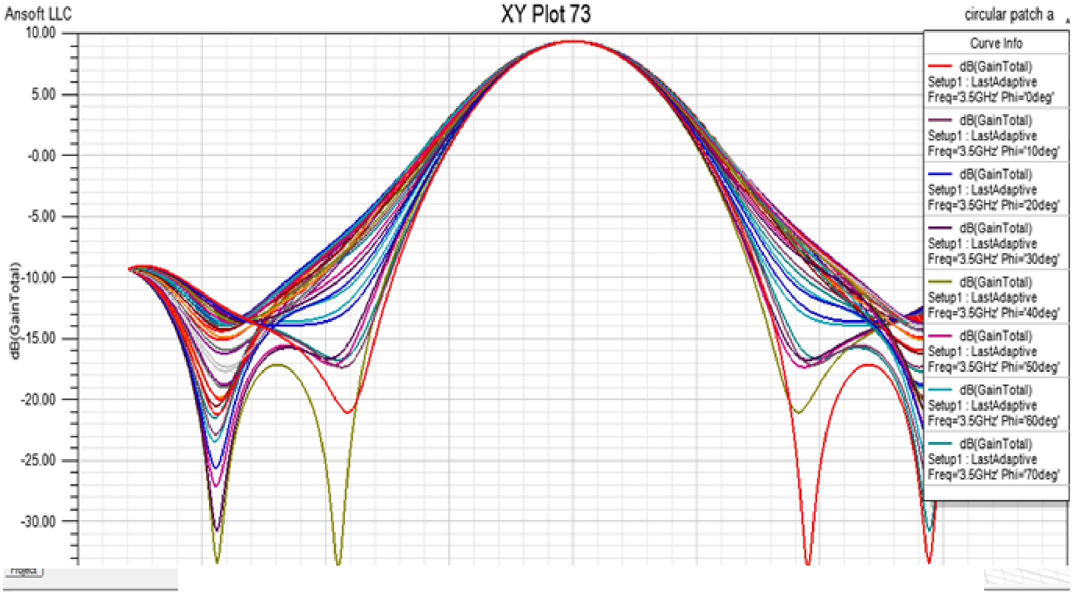

Ansoft LLC
XY Plot 72
circular patch a
Curve Info
dB(S(1,1))
Setup1 : Sweep1
dB(S(1,1))
Freq [GHz]


Ansoft LLC
XY Plot 73
circular patch a
Curve Info
dB(GainTotal)
Setup1 : LastAdaptive
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Freq='3.5GHz' Phi='10deg'
Freq='3.5GHz' Phi='20deg'
Freq='3.5GHz' Phi='30deg'
Freq='3.5GHz' Phi='40deg'
Freq='3.5GHz' Phi='50deg'
Freq='3.5GHz' Phi='60deg'
Freq='3.5GHz' Phi='70deg'
dB(GainTotal)

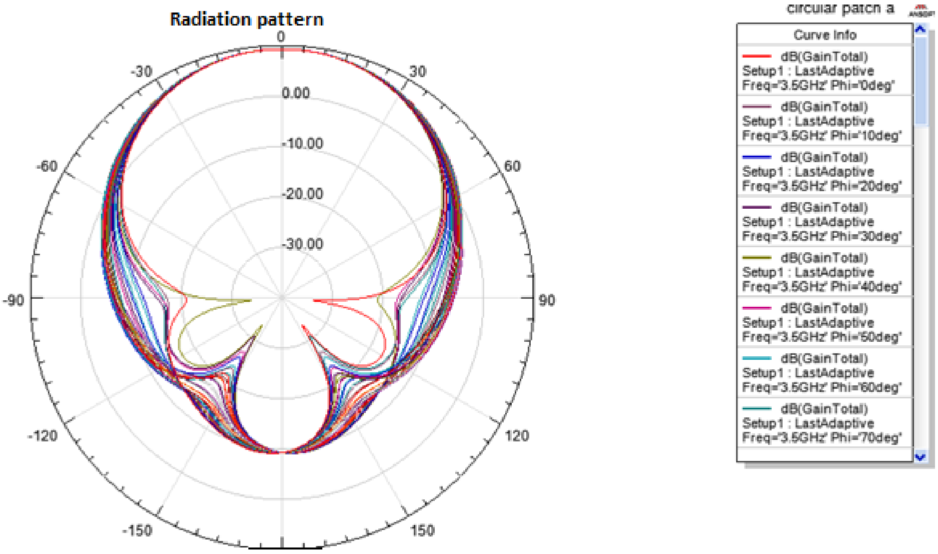
Radiation pattern
circular patch a
Curve Info
dB(GainTotal)
Setup1 : LastAdaptive
Freq='3.5GHz' Phi='0deg'
Freq='3.5GHz' Phi='10deg'
Freq='3.5GHz' Phi='20deg'
Freq='3.5GHz' Phi='30deg'
Freq='3.5GHz' Phi='40deg'
Freq='3.5GHz' Phi='50deg'
Freq='3.5GHz' Phi='60deg'
Freq='3.5GHz' Phi='70deg'

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TABLE-I

Thickness of substrate (in mm)	Gain (in dB)	Return loss (in dB)
3	4.1	-13
2	4.3	-14
1	7.6	-19
0.86	9.7	-22
0.5	8.4	-28
0.35	9.8	-22

TABLE-II

Radius (in mm)	Gain (in dB)	Return loss (in dB)
19	6.2	-14
19.5	6.8	-13.5
21	7.3	-19
21.5	9.85	-27
22	8	-25
23	8.5	-22

CONCLUSION

Optimum gain and return loss of the circular patch antenna were analysed using KBNN at 3.5GHz and the simulated results are compared with the general well-known results of antenna's performance incorporating its radiation property, gain, port characteristics and s-parameters. The optimum gain was observed at the substrate thickness of 0.35mm and here the return loss (S11) is -22dB but return loss is still good(-27dB) at radius of patch 21.5mm with increasing gain.

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