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Calculation of Bandwidth and Gain For Improving the Performance of Planar Inverted F Antenna Using ANN

Monica Singhal[1], Garima Saini[2]
M E Scholar, Department of Electronics & Communication, National Institute of Technical Teachers Training & Research Chandigarh, U T, India[1]
Assistant Professor, Department of Electronics & Communication, National Institute of Technical Teachers Training & Research Chandigarh, U T, India[2]

Abstract: Artificial neural network is becoming popular for predicting the performance parameter of antenna due to their solution for optimization and prediction issues. Therefore, different parameters like Bandwidth and Gain for Planar Inverted F antenna using split ring resonator are observed by varying the dimensions of antenna. The PIFA is designed on FR-4 substrate with dielectric constant 4.4 and thickness of 1.58mm. The bandwidth and gain with different dimensions are computed using HFSS software and this obtained data will be given as training and testing set for the feed forward neural network with four training algorithm i.e. Bayesian Regularization, Levenberg Marquardt, Resilient Propagation and Conjugate Gradient backpropagation with Fletcher reeves Restart for proposed antenna. The predictable values of bandwidth and gain with percentage mean absolute error is 1.8×10-2 and 5.63. Results from the network are related with the data attained from HFSS simulator and determined that outcomes are in decent agreement with simulator results.

Keywords: Planar Inverted F antenna, HFSS, Artificial neural network, Levenberg Marquardt, Bayesian Regularization, Resilient Back Propagation, Conjugate Gradient backpropagation with Fletcher reeves Restart algorithms, Metamaterial.

I. INTRODUCTION

Planar Inverted F antenna (PIFA) is used as an embedded antenna for mobile phone designs. It is used in compressed hand held devices wherever space is at its superior. PIFA antenna are also used for automobile telematics. Vehicle companies use antenna that track the contours of the automobiles for grace and aerodynamic causes and for many more applications. Multiband PIFA antenna can combine antenna feeds for portable phone, satellite direction finding and car radio. It is most capable antenna type because of small size and has a low profile, thus can be mounted in the portable equipment. Both Inverted F antenna and microstrip Patch antenna have small bandwidths which require more attention, but the PIFA has adequate bandwidth to cover widespread communication bands [1]. The PIFA has quarter wavelength resonant property (it reduced the required space desirable for the wireless communication), and has respectable SAR properties. PIFA are borrowed from quarter wave half patch microstrip antenna. The shorting plate is compact in length to decrease resonance frequency. This antenna can operate at several cellular bands. On nearly all phones, grounded parasitic features are used to improve the radiation. To broaden the bandwidth the height of the shorting plate can be raised i.e increase the volume. The ground plane size also affects the Bandwidth [2]. Bandwidth is enhanced using slotting, defected ground structure, meandering, defining different shapes and size of the radiating element. Antenna performance can also be improved using different electromagnetic materials with their specific dielectric values. Metamaterials describes the idea of artificial, manmade constituents composed of minor cells comprising of minimum two unlike natural resources [3]. It has been observed that the antenna miniaturization is the best capable advantage. SRR reduces the quality factor Q of design by which bandwidth of the antenna is enhanced. To improve the antenna characteristics, these methods require a novel explanation even for minor variation in dimensions. Therefore, the responsibility for obtaining a new solution for every single slight alteration in the designing and difficulties related with substrates thickness in investigative approaches can lead to complications and increase in processing price [4].

ANN is a model operated as a natural neural network which are used for estimation of functions that are largely governed by

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large amount of inputs which are commonly unknown. They can perform many tasks such as system identification, adaptive control, function approximation and optimization. A neural network yields some features like distributed association, ability to handle imprecise data and nonlinear mapping. ANN has the capability and flexibility to learn and to generalize structures. The artificial neural network can be accomplished by calculated, measured and simulated examples. The need of training a neural network is to diminish the fault among the reference and the authentic results obtained by ANN [5]-[8]. The neural network calculates the outcomes very rapidly for every single minor deviation in the structure. For attaining the preferred level of performance of the antenna parameters like bandwidth and gain, the antenna designers need to predict the antenna dimensions. For the designing purpose, innovative and simple neural network is created for synthesis proposed in this letter.

II. Design and Simulation of Planar Inverted F Antenna

A. *Antenna Design*

The view of proposed Planar Inverted F antenna is displayed in Fig.1, in terms of ground plane, substrate, patch, shorting plate and SRR respectively. The size of the antenna is 30mm×32mm×6mm with patch of dimensions 7mm×15mm×1.58mm and ground of magnitudes 30mm×32 mm. For allocation of maximum power starting from source to antenna, the feed should have 50Ω characteristic impedance [9]. A Feed point is 5 mm away from the shorting plate. The proposed antenna is embedded with SRR rings in which total four slots are introduced. The radius of the inner ring is r_1, r_2 and radius of outer ring is r_3, r_4. The center of rings is identical. There is small gap d provided between the rings. There is single slot present on each ring at opposite side. The size of the slot is g=0.6 mm. The thickness of rings is w=0.5 mm. The radius of rings are r_1=0.5mm, r_2=1mm, r_3=1.5mm and r_4=2mm. The antenna is simulated by HFSS software using FR-4 substrate of thickness 1.58mm with permittivity of 4.4.

W=5mm L_1

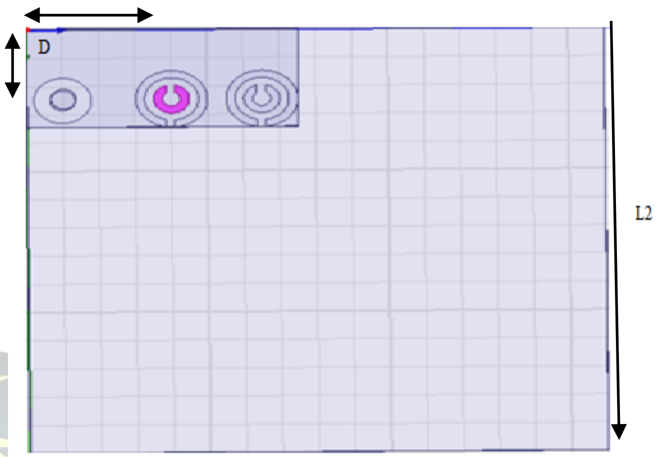

Fig. 1 Front view of proposed PIFA.

B. *Parametric Study Using HFSS software for Optimization*

The influence of patch length and width over bandwidth and resonant frequency are estimated by parametric study as displayed in fig.2. This investigation is achieved by changing one constraint at a time while keeping all other dimensions constant.

i] Consequence of Patch length: The Patch length has a little effect on antenna performance as revealed in Fig. 2 (a). The PIFA is simulated for several value of Patch length staring from 7 to 14 mm in step of 1mm. From the simulation results, it is observed that when L_1 increases from 7mm to 10mm, simulated resonant frequency decreases from 3.37 GHz to 2.99 GHz. Antenna shows good result for L_1=7mm.

ii] Influence of patch width: The Patch width has more effect on the antenna performance as revealed in Fig. 2 (b). The PIFA is simulated for the range of 12 to 18 mm in step of 1mm for patch width. It is detected that resonant frequency shift to lower band and show better matching at L_2=15mm.

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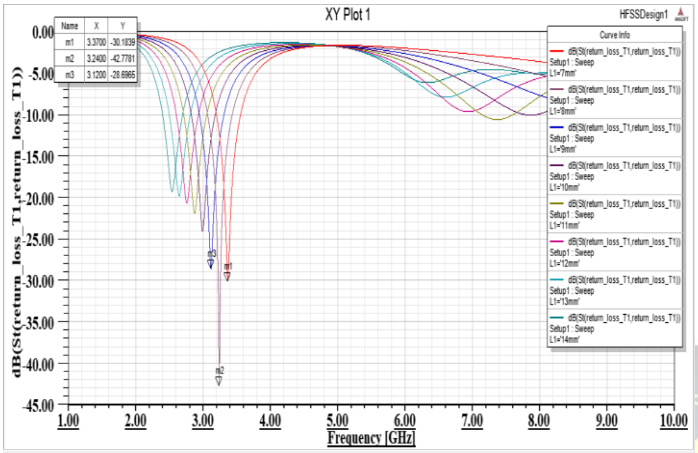


(a)

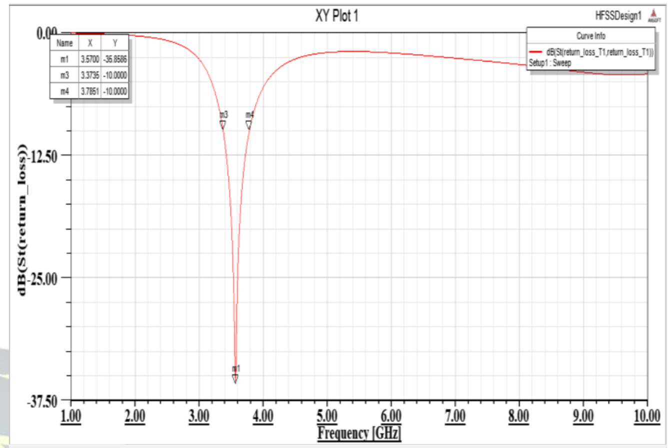
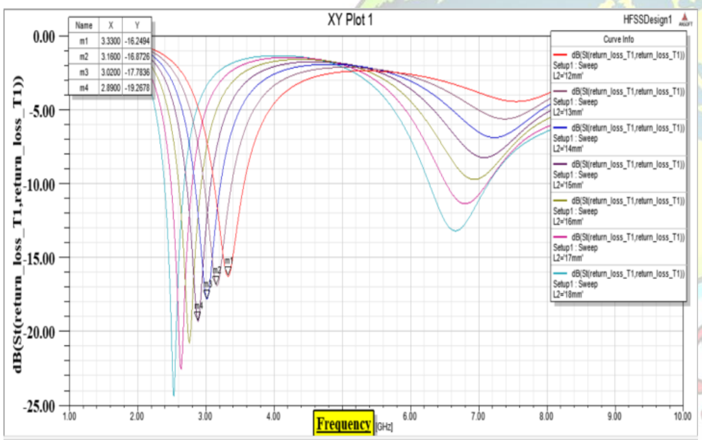


Fig. 3 (a) shows the return loss vs. frequency curve



(b)

Fig. 2 (a) Simulated return loss by varying L_1.
(b) Simulated return loss by varying L_2

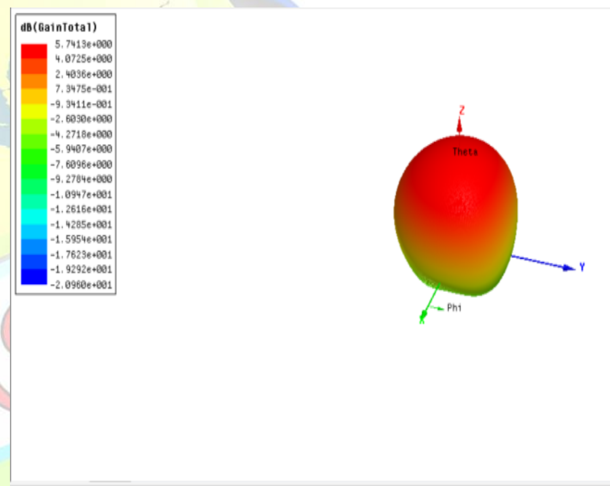


Fig. 3 (b) Gain plot for parametric PIFA

C. Parametric Antenna Simulation

After Parametric analysis the L_1=7mm and L_2=15mm and PIFA resonates at 3.57GHz. Fig. 3 (a) shows the return loss vs. frequency curve and Fig. 3 (b) shows the gain plot for the proposed PIFA antenna. Overall 660 samples for bandwidth and gain are generated by varying the patch length, patch width, shorting plate height, SRR height above the ground and the resonant frequency. For training and for testing of proposed neural network the produced samples are used.

The proposed PIFA antenna resonates at 3.57 GHz frequency with bandwidth of 411.6 MHz and gain is 5.7414dB.

III. Artificial Neural Network

An artificial neural network is an immensely comparable extended processor that has a common tendency for storing practical information and creating it accessible for usage. It look like the mind in two respects: information is attained by a net over a learning procedure, and neuron linking assets are identified as synaptic loads that can be used to store the observed knowledge. It has been observed that in dynamic era, artificial neural network has exceptional contributions and important advancement in the field of wireless

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communication [11]. Few known samples of problem can be used to attain the information during training of neural network system. The network is established to practice the learned information efficiently in resolving "unknown" otherwise "untrained" illustrations of difficulties. Multilayered perceptron feed forward neural networks contain an input level, a hidden level (or an amount of hidden levels) and output level. Every individual layer in network has exclusively diverse role. 3 phases are used for Feed forward neural network training [12]-[15]. Initially, the training examples are created, then the essential arrangement of hidden level is chosen and finally, in last step, various training algorithm are used to improve the weights and biases. The trained neural network system is verified on a random group of examples which are not contained within the training sets. The analysis procedures for the artificial neural network system is generated in the MATLAB. The weights of the neural networks are calculated by training the system using Back propagation. In this present work, four training algorithm (Levenberg Marquardt, Bayesian Regularization, Resilient Back Propagation and Conjugate Gradient backpropagation with Fletcher reeves Restart algorithms) architecture shown in Fig. 4.

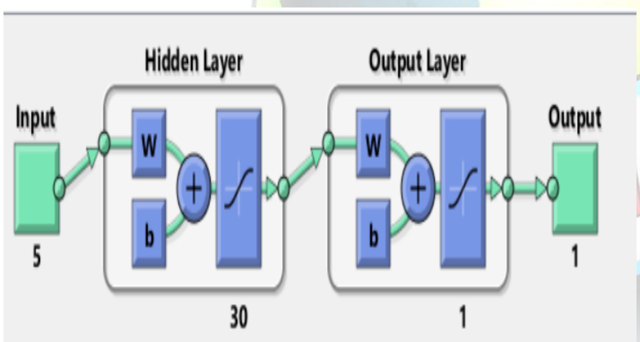

Fig. 4 3 layer Feed forward neural network

A. Data generation for training and testing purpose

The artificial neural network is trained using a group of values (identified as per training examples) yields very fast results. However, generating these models and then distributing them into testing set and training set is an inspiring assignment for a complex structure. Using HFSS software, 660 samples for antenna characteristics are produced by varying the Patch length, Patch width, height of shorting plate, SRR above the ground plane and resonant frequency as displayed in Fig. 1. The random sample used for generating the values is displayed in Table 1. Various performance characteristics like bandwidth as well as gain are detected by changing the antenna parameters. Therefore, 2-dimensional performance matrix was attained by changing 5 dimension simulation matrix. For artificial neural network, a forward strategy will help in calculating the 1-dimensional performance parameters (bandwidth/gain) for the given 5-dimensional simulation parameters [9].

Table 1. Sampling of Samples

Parameters	Specified range
Patch Length	7mm $\leq L_1 \leq$ 8mm
Patch width	15mm $\leq L_2 \leq$ 16mm
Height of shorting plate	5mm $\leq h \leq$ 7mm
SRR above ground	d= 1.58mm, 3.42mm, 4.42mm,5.52mm
Resonant frequency	3.17GHz $\leq f_r \leq$ 3.58GHz

B. Proposed Organization of Artificial Neural Network and Various Training Algorithms

An Artificial neural network for predicting the Bandwidth and gain is displayed in Fig. 5.

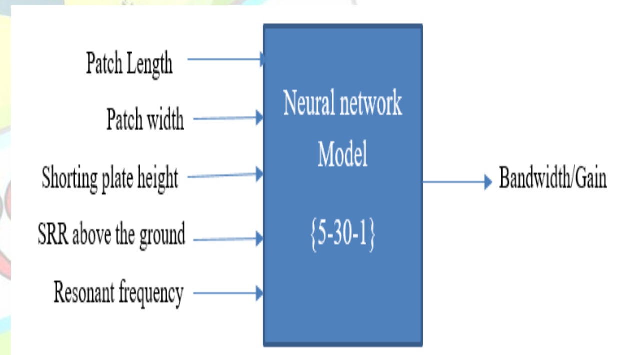

Fig. 5 Multilayered Perceptron Neural Network

Training of artificial neural network is performed by altering the biases and weights for input example to obtain preferred answer. This modification is approved by means of various training procedure. By changing the amount of hidden level as well as hidden layer neurons the training performance is detected. After numerous trials, the operational configuration of network is optimized as 5-30-1 to show the finest performance. This one proves that here 5 neurons at input level, 30 hidden level neurons and 1 neurons for output level. Moreover, the performance of ANN is detected using four different algorithms: Bayesian regulation (BR), Conjugate gradient with Fletcher Peeves (CGF), Levenberg–Marquardt (LM) and Resilient Propagation (RP) respectively [16]. The samples produced in HFSS software are applied to MATLAB for training purpose.

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The final result of the network is then designed with these response configuration. The average square error among the expected and the predicted results is calculated while biases and weight updating occur consequently. The apprising procedure is approved subsequently by offering group of input values till the designed precision of neural network is expected for 561 training examples. Neural network training is completed by using some primary constraints: Maximum number of epochs=1000, learning rate=0.63 and momentum coefficient=0.001 [17]. The testing process is carried out on the remaining 99 values. Therefore, all the primary biases and weights are exchanged with their equivalent optimized results. The network then calculates the "bandwidth" and "gain" separately within a few second for any random set of patch length, patch width, shorting plate height, SRR above the ground plane and resonant frequency within the indicated range revealed earlier.

IV. Result and Discussion

The mean absolute error (MAE) in predicting the bandwidth and gain both for testing set and training set of the neural network is revealed in Table 2 and Table 3 along with the time taken in training of the network for each algorithm.

Table 2. ANN Performance of Bandwidth

Algo.	MAE during training	MAE during testing
LM	9.7907×10^{-4}	1.84×10^{-3}
BR	8.6356×10^{-5}	1.8×10^{-4}
RP	1.1×10^{-3}	3.9×10^{-4}
CGF	2.6068×10^{-4}	2.40×10^{-4}

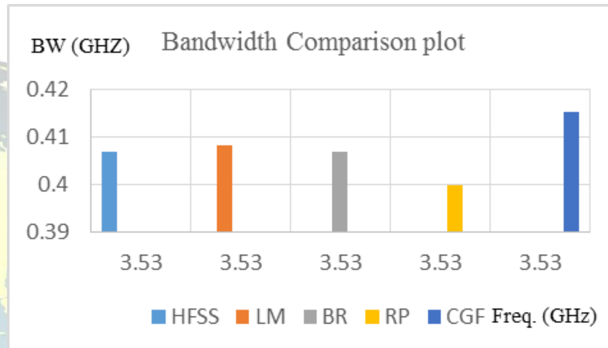
Table 3. ANN Performance of Gain

Algo.	MAE during training	MAE during testing
LM	2.5×10^{-3}	8.67×10^{-2}
BR	2.4×10^{-3}	5.63×10^{-2}
RP	4.38×10^{-2}	4.276×10^{-1}
CGF	1.38×10^{-2}	4.893×10^{-1}

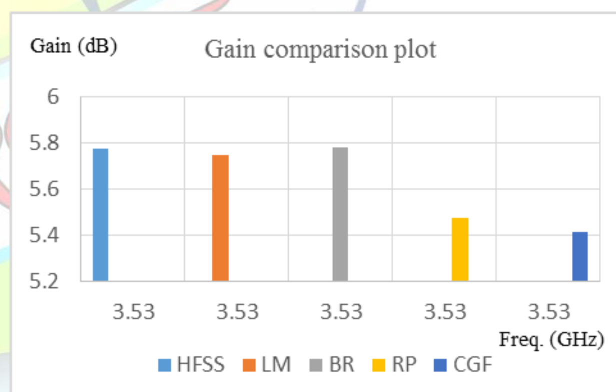
The Bayesian Regularization algorithm is verified to be the accurate training procedure for the suggested network as it yields the minimum error together for validation and testing of neural network.

During simulation in HFSS software, about 11 sampling point is used for every simulating structure and overall 660 such arrangements are simulated. The computation period in HFSS software is influenced by the complexity introduced in the design. For the planned PIFA, it is figured out 30 min per structure. By using Artificial neural network the computation time is fairly reduced.

Fig. 6 (a) and (b) shows the comparison between simulated and predicted Bandwidth and Gain parameter for proposed PIFA. From the plot it is clear that the performance parameter is better optimized using Bayesian regularization algorithm for the Patch dimension L_1=7.1mm and L_2=15.1mm. Bayesian Regularization algorithm is chosen as best algorithm as it provide minimum MSE and MAE performance parameter.



(a)



(b)

Fig. 6 Comparison plot for (a) Bandwidth. (b) Gain

The bandwidth of 407 MHz is obtained using HFSS software and the predicted value of ANN bandwidth is 407.012 MHz whereas the gain of 5.7775 dB is obtained using HFSS and predicted gain value from neural network is 5.78006 dB. It is observed that there is a decent agreement among the HFSS results and the values obtained using ANN (Bayesian Regularization).

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V. Conclusion

The work presented in the paper is regarding the application of the artificial neural network to optimize the antenna characteristics. By varying the size of ground plane, height of the patch and the width of the shorting plate, the bandwidth of the Planar Inverted F antenna can be adjusted and optimized. The split ring resonator height variation above the ground plane have a great effect on the gain performance. To model antenna parameters high frequency structure simulator is used which provide good results but on the other hand take too much time from the design perspective and provide computation complexity. So to model this non linearity between the parameters an ANN is utilized, which shows good performance in terms of time taken and not much complex in terms of computation complexity. Simulated antenna resonates at the operating frequency of 3.57 GHz with -10 dB bandwidth range from 3.3735 - 3.7851 GHz. The parametric antenna has a gain of 5.7314 dB.

Using HFSS 660 samples of parameters are calculated for Bandwidth and gain. Then, a precise, simple and fast Artificial neural network modeling system has been suggested to predict the “Patch Length” and “Patch width” instantaneously in order to attain desired bandwidth and gain of Planar inverted F antenna. In ANN model, 561 samples are taken into consideration to train the neural network and 33 samples are used to test the network. Results are estimated with different training algorithm. It is found that Bayesian Regularization algorithm leads to best approximate results in just few seconds after training process by providing minimum MAE% and MSE%. The PIFA antenna is designed for patch dimensions 7mm×15mm but using ANN the optimized results are obtained for the patch dimensions 7.1mm×15.1mm. In ANN, the step size of 0.1mm between the antenna dimensions can show results in few seconds but during parametric analysis in HFSS, the step size of 0.1mm will take vast amount of time to show the results. Therefore, ANN technique can be used for any step size. From the ANN technique it is observed that, PIFA resonates at 3.53 GHz with bandwidth of 407 MHz and gain of 5.7775 dB. A precise good convergence among HFSS results and simulated outcomes from ANN has been attained, which maintain the EFFECTIVENESS of proposed work.

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Biography

Monica Singhal received Bathlors degree in Electronics and communication from Bharat Institute of technology, Meerut. She is persuing M.E from National Institute of Technical Teachers Training and Research, Chandigarh, India. Her current research interest is in Antenna Design and Soft Computing.

Garima Saini received Bachelor's degree in Electronics and Communication from Kurukshtera University, Kurukshtera. She has completed her M.Tech in Electronics and Commincation from P.T.U, Jalandhar. She is an Assistant Professor in the department of Electronics and Communication in National Institute of Technical Teachers Training and Research, Chandigarh. Her research interest is Antenna design and soft computing.